平成１９年度

科学技術総合研究委託費

委託業務成果報告書

＜アジア科学技術の戦略的推進＞

＜東南アジア地域の気象災害軽減国際共同研究＞

国立大学法人京都大学

## Ⅰ．業務実績

### １．基礎実験・システム開発（京都大学担当分）

① メソモデルを用いた熱帯域気象のダウンスケール予報実験

- メソモデルを用いた、インドシナ領域におけるダウンスケール予報実験、および全球モデル解析値との比較評価
- メソモデルにおける、急峻地形対応および大気海洋結合の為のモデル要素の開発

② 最新データ同化システムの試験開発と機動的観測データのインパクト評価実験

- 大気海洋結合モデルにおける4次元同化システムの開発・改良、およびインド洋域における検証
- メソモデルにおける4次元データ同化システムを用いたGPS掩蔽データの同化実験および、そのインパクト評価 (気象研究所との協力)

③ 観測・予報データ統合データベースの構築と気象災害対策判断支援システムの試作

- 気象庁数値天気予報データおよび解析値の取得およびアーカイブの開始
- 当該データのデータベース・解析・可視化システムの試作

④ 国際研究集会の開催と国際的技術協力の推進

- 平成20年3月3-5日に京都市において国際研究集会の開催
- バンドン工科大学(インドネシア)および南洋理工大学(シンガポール)における、気象庁メソモデルの講習会(2008/2)、およびデータベース・解析・可視化ツールの講習会(2008/3)の開催
- ニュースレターの発行・配布　(2回; 2007/12, 2008/3)

## II. 業務説明

(日本気象学会機関紙「天気」への投稿済原稿からの転記)

### １．はじめに

経済活動高度化や地球温暖化で異常気象災害の増加が懸念される現在,社会的経済的に影響の大きい顕著現象の予測による気象災害の低減は政策的必要性が高い研究課題である（余田ほか 2008）.最近では,2008 年 5 月にミャンマーをサイクロンが襲い,7 万人を超える犠牲者が出たことが大きく報道された.高精度・高分解能な数値天気予報の情報は,危機管理や水資源管理を通して,集中豪雨,台風,熱帯擾乱に伴う水害,暴風雨災害などの軽減に資するものである.また,エネルギー,航空,交通,農業,経済,衛生などの応用気象分野でも,確率予報を含む数値天気予報情報の高度利用により,社会的経済的な管理対応能力の向上を図ることができる.パソコンなど一般的な計算機の性能が格段に向上し,インターネットが普及して気象データの取得が容易になりつつある現在,東南アジア地域でも,それぞれ独自にメソモデルを用いた数値天気予報の研究や日常業務を始めようという機運が盛り上がりつつある.

このような状況のなかで,2007 年度科学技術振興調整費の「アジア科学技術協力の戦略的推進：自然災害への対応に資する防災科学技術分野の研究開発」課題枠において,我々は「東南アジア地域の気象災害軽減国際共同研究」を提案し,それが認められた.京都大学，気象研究所，インドネシア国立バンドン工科大学が中心となり，東南アジア各国の若手研究者と協同して，気象災害の軽減に向けた３年間の国際共同研究を展開する内容である（第１図）．提案の詳細と活動の現状はこの共同研究のホームページで公開している（http://www-mete.kugi.kyoto-u.ac.jp/project/MEXT/）.高分解能の領域気象モデルを用いた熱帯域気象のダウンスケール予報実験と機動的観測データのインパクト評価実験を行うとともに，データ同化システムの高度化，統合データベースの構築，確率予報情報の高度利用による気象災害軽減のための判断支援システムの試作を行う．また,国際研究集会を定期的に開催して，不断に最新技術情報を交換できる「東南アジア地域気象災害軽減国際共同研究推進ネットワーク」を構築する．高温多湿な熱帯域特有の現象に関する新知見・予報モデル化技術は,梅雨期や台風時の我が国の減災にも寄与するものである.また,気候予測モデルの精緻化にも直結し,地球温暖化局面での東南アジア地域の環境予測にも寄与しうるものである.

この小文では,2008 年３月に開催した第１回国際ワークショップの概要を報告すると共に,京都大学,気象研究所の取組みを紹介する.技術力のある気象庁とアジア研究展開で実績のある京都大学とが連携して本研究課題を実施することにより,アジア科学技術協力を戦略的に強力に推進していく.国際的な研究者ネットワークの構築と共同研究の推進は３年間に限られたものでなく,より長い期間を通じて展開していく予定である.

多くの方々の御理解とご支援をお願いしたい.

## 2．第1回国際ワークショップ

本研究プロジェクトの第1回国際ワークショップ「東南アジアにおける気象災害の防止と軽減」が2008年3月3日から5日に京都市パレスサイドホテルにて開催された．東アジア・東南アジア・南アジアの12カ国から58人が集まり，アジア域の気象災害をテーマとして研究成果の発表がなされるとともに，相互の情報交換を通じて共通の課題への取り組みや相補的な協力関係の構築について議論がなされた．集合写真を第2図に示す.

最初に小林（科学技術振興機構）の開催挨拶と研究代表者である余田（京大）による研究計画の概観的な講演がなされ，その後テーマ別セッションで計42件の招待講演があった．各セッションのテーマは，高解像度数値天気予報，顕著現象のシミュレーションと予測，衛星観測の利用とデータ同化，計算結果の統計/予測可能性/判断支援，基盤研究ツールとしての高解像度モデルであった(第1表).

アジア各国の参加者からは，東南アジアを主としたアジア太平洋地域やインドを解析対象地域として，実験的な数値天気予報あるいは気象擾乱の数値シミュレーションといった研究成果について多数の講演があった．また衛星データなどの観測値を同化した高精度の数値予報の取り組みや災害警報システムに関する話題提供も目立った．日本側からは，東南アジア域の数値予報・シミュレーションの現状や非静力学モデルを利用したメソ擾乱の解析，アジアの気象災害を解析する新しい研究手法（衛星観測やデータ処理,数値解析手法など）についての報告がなされた.

1日目午後後半には「チュートリアル／デモ」としてモデルや解析の実践的な面について解説・情報交換するセッションが設けられた．このセッションでは，林（気象研）により気象庁・気象研究所非静力学モデルNHMについての解説がなされ，西澤（京大）によりデータ処理の統合環境について意思決定のための支援システムという意図のもとに解説がなされた．それぞれの講演では十分な時間を確保して情報の共有・交換が図られた．このような試みはまさに本研究プロジェクトの趣旨に合致した活動であり，第1回のワークショップにふさわしい場であったと思う.

日本にはNHMや名古屋大学地球水循環研究センター雲解像モデルCReSSといった国産の高性能な非静力学モデルが存在し，これらのモデルは温暖湿潤な気候帯である日本において十分な研究実績あるいは現業予報での実績を積み重ねている．したがって，東南アジア地域を対象とした気象予報には世界的にも最も適用性が高いモデルと言え，今後の展開が期待される．こういった観点から，本ワークショップのように十分な時間をかけてアジア各国の研究者と日本の研究者とが情報交換する場は大変貴重であると思う．本ワークショップは，これまで構築してきた個別の人的コネクションをベースにしつつより広範なネットワークとして発展させるべく，参加者同士の交流が活発に図られたように思う．なごやかな雰囲気ながらも今後の展開に対しての意欲も強く感じた．本ワークショップが，今後の協力関係をより深めるための信頼醸成の場として位置づけられるのは間違いないであろう．次回は2009年3月にインドネシア国立バンドン工科大学で，3回目は2010年3月に別府市にある立命館アジア太平洋大学で開催する予定であることが紹介されてワークショップが締めくくられた.

## 3．京都大学の取組み

近年,メソモデルを用いた熱帯域における気象予報に関する研究が増えつつあり,熱帯気象・気候予測のための領域モデルに関する国際ワークショップも開催されるようになってきた(余田ほか 2006).しかし,従来,メソモデルの主なターゲットは中緯度域であったため,熱帯域におけるメソモデルの利用に関しては,経験がまだまだ浅く,解決されていない問題点も多い.このような中で,京都大学では,気象研究所やアジア各国の研究者と協力し,メソモデルを用いた熱帯気象の基礎実験を行っている.

急峻地形対応や大気海洋結合といったメソモデルの要素開発を行うとともに,メソモデルを用いた熱帯低気圧やスコールラインなどに伴う暴風雨などの小規模スケール現象の予報・感度実験や,インドシナ領域のダウンスケール予報実験,メソスケール大気海洋結合モデルを用いた小規模スケール大気海洋相互作用の実験などを行い,熱帯域におけるメソモデルの利用の為の基礎的研究を行っている.また,気象研究所との共同研究でメソモデル用データ同化システムの開発を行い,インド洋域における検証実験や,地上集中観測,衛星観測(マイクロ波,GPS 等)などの非現業型の機動的観測データの同化インパクト評価実験を行うなど,メソモデルの高度利用の為の研究も行っている.

また,京都大学では,観測・予報データの統合的なデータベースの構築を行っている.気象庁・気象研究所と

日本気象学会の気象研究コンソーシアム(後述)を通じて取得した気象庁天気予報・解析データや,京都大学生存圏研究所や京都大学21世紀ＣＯＥプログラム「活地球圏の変動解明」(http://kagi.coe21.kyoto-u.ac.jp/jp/index.html)との協力により取得したNCEP/NCAR再解析データなどの各種データをアーカイブし,それらのデータに統一的にアクセスする為のシステムを構築している.また,気象予報データから気象災害軽減の為の判断をする際の,支援システムの試験開発を行う.これらデータベースおよび判断支援システムは,地球流体電脳倶楽部が開発している" Gfdnavi" (http://www.gfd-dennou.org/arch/davis/gfdnavi/)をベースに開発を行っている.

国際的技術協力の推進の取組みとして,年1回の国際ワークショップの開催の他,年2回ニュースレターの発行および配布を行っている.また,2008年3月に,インドネシア国立バンドン工科大学およびシンガポール南洋理工大学において,データの解析および高度利用法に関するチュートリアルセミナーを開催するなど,国際的技術協力を進めている.

## ４．気象研究所の取組み

気象モデルは,数値天気予報情報と研究の両方にとって不可欠なインフラであり,現業予報センターと気象研究コミュニティで,さまざまなモデルが開発・利用されている.欧米では積極的に公開しているものがあり,日本を含むアジア諸国においても米国製のメソモデルが広く利用されている.モデルは顕著現象の解析などに有効なツールであるが,余田(2007)も触れているように,その利用を通じて外国への技術的な依存が進む心配がある.　現業気象予報の進歩が研究技術開発に立脚したものである以上,気象機関と研究コミュニティの連携は,技術基盤の裾を拡げ根を張ったものにするために大変重要である.

これまで気象庁では,国内向けには,2001年に「数値予報研究開発プラットフォーム」(http://pfi.kishou.go.jp/)を設置し,気象庁モデルの利用希望者に向けたオンラインサービスを開始するとともに,2007年からは日本気象学会との包括的な共同研究契約に基づく「気象研究コンソーシアム」(http://www.mri-jma.go.jp/Project/cons/index.html)を結成して,気象庁の数値解析予報システムで現業的に計算されている解析・予報データの提供を開始している（事務局は気象研究所）.その一方で,国外向けには,韓国・香港など国外の気象機関に対する技術支援はあったものの,モデル利用を通じた国外研究者との連携は殆ど行われていなかった.その原因として,英語マニュアルの整備など技術的なユーザーサポート体制の問題が大きかった.気象庁では,平成18年度末のモデル技術開発推進本部において,気象庁モデルの外国における利用希望に対してより前向きに対処するとともに,利用のための手続きを簡素化し,気象研究所が主体となって研究推進のための技術的支援を行う方針を確認した.

第1図に示したように,気象研究所は「東南アジア地域の気象災害軽減国際共同研究」においては,国内参画機関として「実用モデル開発・応用実験」を担当している.本研究で,データサーバーの強化とポスドク雇用を行い,NHMやデータ同化システムの熱帯域への適用実験を進めるとともに,各種データ（気象庁再解析(JRA25)データ,気象業務支援センター配信の気象庁全球予報値,気象研究コンソーシアムデータなど）からNHMを実行するツールと英文チュートリアルの整備に着手している.これらの活動については,気象研究所ホームページ(http://www.mri-jma.go.jp/Project/Kashinhi_seasia/Jap/MRI_kashinhi.htm)に情報掲載を開始しており,国外研究者が気象庁数値予報モデルを利用するための英文モデル貸与申請書のサンプルもアップしている.

上記に関連して,インドネシア国立バンドン工科大学とシンガポール南洋理工大学との技術協力を開始した.2008年2月には,予報研究部から2名が現地を訪問し,国際共同研究の遂行のための打ち合わせと現地ワークステーションでのNHMの動作確認を行った.訪問の様子は,本研究のニュースレター第2号(http://www-mete.kugi.kyoto-u.ac.jp/project/MEXT/newsletters.html)に掲載されている.

参考文献

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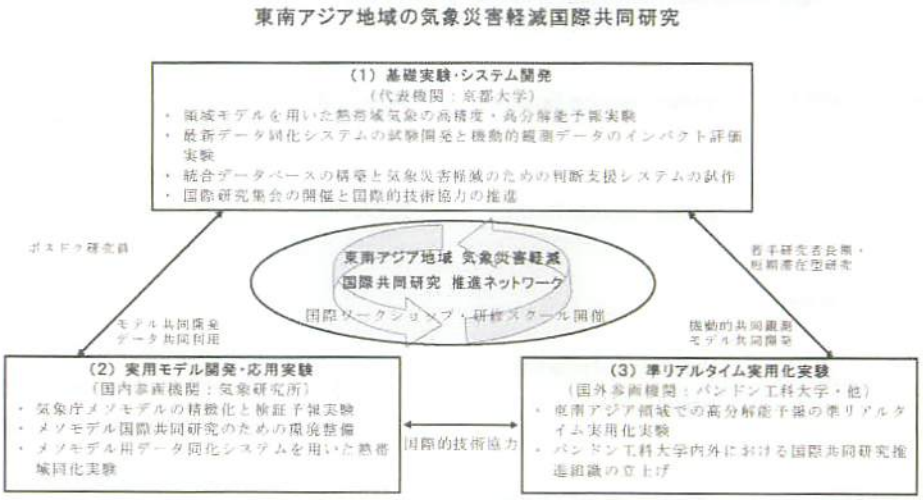
余田成男・中澤哲夫・山口宗彦・竹内義明・木本昌秀・榎本剛・岩崎俊樹・向川均・松枝未遠・茂木耕作・三好建正・新野宏・斉藤和雄・瀬古弘・小司禎教, 2008: 日本における顕著現象の予測可能性研究. 天気, 55, 117-126.

| | | |
|---|---|---|
| 2008年<br>3月3日<br>（月） | 午前 | オープニング<br>高解像度数値天気予報 |
| | 午後 | 高解像度数値天気予報（続き）<br>チュートリアルとデモ |
| 3月4日<br>（火） | 午前 | 顕著現象のシミュレーションと予測 |
| | 午後 | 衛星観測の利用とデータ同化 |
| 3月5日<br>（水） | 午前 | 計算結果の統計/予測可能性/判断支援 |

第1表　第1回国際ワークショップ「東南アジアにおける気象災害の防止と軽減」プログラム




第1図　「東南アジア地域の気象災害軽減国際共同研究」研究体制

第2図　「東南アジアにおける気象災害の防止と軽減」第1回国際ワークショップ集合写真

## Ⅲ. 第１回国際ワークショップ「東南アジアにおける気象災害の防止と軽減」プログラム

### The First International Workshop on Prevention and Mitigation of Meteorological Disasters in Southeast Asia

### March 3 (Mon)

| | | | | | |
|---|---|---|---|---|---|
| 9:00 | 9:10 | Opening | | | |
| 9:10 | 9:30 | Shigeo YODEN | Department of Geophysics, Kyoto University | JAPAN | International Research for Prevention and Mitigation of Meteorological Disasters in Southeast Asia |
| | | **Session I: High-resolution numerical weather predictions** | | | **(chair: S. Yoden)** |
| 9:30 | 9:50 | Emmy SUPARKA | Institut Teknologi Bandung | INDONESIA | Reduction of Geohazard Risks for Sustainable Development in Indonesia |
| 9:50 | 10:30 | Tri Wahyu HADI | Institut Teknologi Bandung | INDONESIA | Mesoscale NWP Model Intercomparisons for the Maritime Continent: Preliminary Results and Future Plan |
| | | (coffee break) | | | |
| 11:00 | 11:20 | Kazuo SAITO | Meteorological Research Institute, JMA | JAPAN | Contribution of MRI to the International Research for Prevention and Mitigation of Meteorological Disasters in Southeast Asia |
| 11:20 | 11:40 | Tabito HARA | Japan Meteorological Agency | JAPAN | Operational Mesoscale NWP at the Japan Meteorological Agency |
| 11:40 | 12:20 | Md. Nazrul ISLAM | SAARC Meteorological Research Centre | BANGLADESH | Use of Regional Climate Model to Study Extreme Weather Events in and around Bangladesh |
| | | (lunch break) | | | |
| 13:30 | 13:50 | KIEU Thi Xin | Vietnam National University of Hanoi | VIETNAM | Numerical Weather Prediction with High Resolution Regional Model-HRM in Vietnam. Impact of Convection Parameterization on Heavy Rainfall Forecast of HRM, Verification and Problems for Very Low Latitudes |
| 13:50 | 14:30 | Mezak Arnold RATAG | Indonesia National Meteorology and Geophysical Agency (BMG) | INDONESIA | Development of High Resolution Models and its Applications for Weather and Climate Risk Reduction in Indonesia (tentative) |
| 14:30 | 14:50 | Palikone THALONGSENGCHANH | Department of Geophysics, Kyoto University | JAPAN/LAO, PDR | A Down-Scale Experiment on Numerical Weather Prediction in Indochina Region (Lao PDR) |
| 14:50 | 15:30 | Krushna Chandra GOUDA | CSIR Centre for Mathematical Modelling and Computer Simulation | INDIA | Comparison of Two Strategies for Simulation of Extreme Rainfall Events |
| | | (coffee break) | | | |

## Session II: Tutorials and demonstrations (chair: S. Yoden)

| | | | | | |
|---|---|---|---|---|---|
| 16:00 | 16:40 | Shugo HAYASHI | Meteorological Research Institute, JMA | JAPAN | Basic Usage of the NHM for Numerical Weather Experiments |
| 16:40 | 17:20 | Seiya NISHIZAWA | Department of Geophysics, Kyoto University | JAPAN | Experimental Development of a Unified Data Base and Decision Support System for Prevention and Mitigation of Meteorological Disasters |

40 min. talk = 30 min. presentations + 10 min. questions/discussions
20 min. talk = 15 min. presentations + 5 min. questions/discussions

## March 4 (Tue)

## Session III: High-impact weather and its simulation/prediction (chair: K. Saito)

| | | | | | |
|---|---|---|---|---|---|
| 9:00 | 9:20 | Vinliam BOUNLOM | Hydrological Division, Department of Meteorology and Hydrology | LAO, PDR | Country Report on Hydro-Meteorological Disasters in Lao PDR For the Year 2006 |
| 9:20 | 9:40 | Long SARAVUTH | Ministry of Water Resources and Meteorology | CAMBODIA | Flash Flood in Preas Vihear Province (tentative) |
| 9:40 | 10:20 | Fredolin TANGANG | National University of Malaysia | MALAYSIA | On the Roles of the Northeast Cold Surge, the Borneo Vortex, the MJO and the IOD during the Worst 2006/2007 Flood in Southern Peninsular Malaysia |
| 10:20 | 10:40 | Taiichi HAYASHI | DPRI, Kyoto University | JAPAN | Disaster by the Severe Cyclone "Sidr" in the Coastal Region of Bangladesh in November, 2007 |
| | | (coffee break) | | | |
| 11:10 | 11:30 | Hiromu SEKO | Meteorological Research Institute, JMA | JAPAN | Numerical Simulation of Heavy Rainfall Events in South/Southeast Asia Using NHM |
| 11:30 | 11:50 | Rosbintarti Kartika LESTARI | Nanyang Technological University | SIMGAPORE | Preliminary Study on the Precipitation of Maritime Southeast Asia |
| 11:50 | 12:10 | Kazuhisa TSUBOKI | Nagoya University | JAPAN | Simulation Experiments of Typhoons and Tornadoes Using the Cloud Resolving Model |
| 12:10 | 12:30 | Toshiki IWASAKI | Tohoku University | JAPAN | Influences of Cloud Microphysical Processes on Structure and Development of Tropical Cyclone |
| 12:30 | 12:50 | Mitsuru UENO | Meteorological Research Institute, JMA | JAPAN | Recent Advancements in the Understanding of Typhoon Inner-Core Structures and its Implication for Typhoon Vortex Initialization |
| | | (lunch break) | | | |

## Session IV: Satellite observations, their applications and data assimilation (chair: T.-Y. Koh)

| | | | | | |
|---|---|---|---|---|---|
| 14:00 | 14:40 | Toshitaka TSUDA | RISH, Kyoto University | JAPAN | Utilization of GPS Radio Occultation Data for the Studies of Atmosphere Dynamics |
| 14:40 | 15:00 | Yoshinori SHOJI | Meteorological Research Institute, JMA | JAPAN | An Experiment of Near Real-time Precipitable Water Vapor Retrieval Using Ground-Based GPS stations in South East Asia |
| 15:00 | 15:40 | Perapol BEGKHUNTOD | RFMMC, Mekong River Commission | CAMBODIA | Satellite-Based Rainfall Estimation and Hydro-Meteorological Networks for Flood Forecasting in the Mekong River Basin |
| | | (coffee break) | | | |
| 16:10 | 16:30 | Hirohiko ISHIKAWA | DPRI, Kyoto University | JAPAN | Satellite Monitoring of Hazardous Weather in Asia |
| 16:30 | 16:50 | Masaru KUNII | Meteorological Research Institute, JMA | JAPAN | Meso-Scale Data Assimilation Experiment in Low Latitudes |
| 16:50 | 17:10 | Le DUC | Vietnam National University of Hanoi | VIETNAM | Development of a Data Assimilation System with HRM Model and 3DVAR Technique |
| 17:10 | 17:30 | Takeshi ENOMOTO | Japan Agency for Marine-Earth Science and Technology | JAPAN | ALERA:AFES-LETKF Experimental Ensemble Reanalysis |
| 17:30 | 18:10 | Vijapuapu S. PRASAD | National Center for Medium Range Weather Forecasting | INDIA | Assimilation of Direct Satellite Radiance Data at NCMRWF |
| 18:30 | 20:30 | (banquet) | | | |

40 min. talk = 30 min. presentations + 10 min. questions/discussions
20 min. talk = 15 min. presentations + 5 min. questions/discussions

## March 5 (Wed)

## Session V: Model output statistics, predictability, and decision supports (chair: T. Satomura)

| | | | | | |
|---|---|---|---|---|---|
| 9:00 | 9:20 | Tieh Yong KOH | Nanyang Technological University | SIMGAPORE | Statistical Verification of COAMPS Model over SCSMEX Period |
| 9:20 | 9:40 | Hongwen KANG | APEC Climate Center | KOREA | Multi-Model Output Statistical Downscaling Prediction of Precipitation in the Philippines and Thailand |
| 9:40 | 10:00 | Edwin S. T. LAI | Hong Kong Observatory | P. R. CHINA | Use of NWP and EPS Products in Support of Location-Specific Forecasts |
| 10:00 | 10:20 | Hitoshi MUKOUGAWA | DPRI, Kyoto University | JAPAN | Predictability of Tropical Circulation Examined by Breeding of Growing Mode(BGM) Method for JMA Ensemble Prediction System |
| | | (coffee break) | | | |

| | | | | | |
|---|---|---|---|---|---|
| 10:50 | 11:10 | Syozo YAMANE | Chiba Institute of Science | JAPAN | Properties of Ensemble Perturbations Evolving in an Atmospheric General Circulation Model |
| 11:10 | 11:30 | Prawit JAMPANYA | Thai Meteorological Department | THAILAND | The Meteorological Natural Disasters Warning System of Thailand |
| 11:30 | 11:50 | SANGA-NGOIE Kazadi | Ritsumeikan Asia Pacific University | JAPAN | Our Endangered Costal Ecosystems - an Eco-climatic and Risk Analysis Using GIS and Remote Sensing - |
| 11:50 | 12:10 | Kamol PROMASAKHA NA SAKOLNAKHON | Thai Meteorological Department | THAILAND | Integration NWP Data and Applied Geographic Information System(GIS) Management for Landslide at Amphure Pai, Mae Hong Son |
| 12:10 | 12:30 | Takeshi HORINOUCHI | RISH, Kyoto University | JAPAN | Database and Data-Analysis Infrastructure for Atmospheric Studies |

**(lunch break)**

## Session VI: High-resolution model as a fundamental research tool (chair: T.W. Hadi)

| | | | | | |
|---|---|---|---|---|---|
| 14:00 | 14:20 | Takehiko SATOMURA | Department of Geophysics, Kyoto University | JAPAN | Development of Ultra-High Resolution Numerical Model |
| 14:20 | 14:40 | Nurjanna Joko TRILAKSONO | Institut Teknologi Bandung | INDONESIA | Study of Diurnal Patterns of Convection in Sumatra Island Using Weather Research and Forecasting-Advanced Research WRF (WRF-ARW) Model |
| 14:40 | 15:00 | Shigenori OTSUKA | Department of Geophysics, Kyoto University | JAPAN | Numerical Experiments on Vertically Fine Structures of Water Vapor in the Tropics |
| 15:00 | 15:20 | Yoichi ISHIKAWA | Department of Geophysics, Kyoto University | JAPAN | Dependency of the Tropical Convective Clouds on the Sea Surface Temperature Simulated by a High-Resolution Coupled Model |
| 15:20 | 15:40 | Tetsuya TAKEMI | DPRI, Kyoto University | JAPAN | Environmental Stability Control of the Precipitation Structure and Intensity within Mesoscale Convective Systems |

**(coffee break)**

## Session VII: Future research and collaborations

| | | | |
|---|---|---|---|
| 16:10 | 16:50 | all participants | Open Discussions |
| 16:50 | 17:00 | **Closing** | |

40 min. talk = 30 min. presentations + 10 min. questions/discussions
20 min. talk = 15 min. presentations + 5 min. questions/discussions

## 1. International Research for Prevention and Mitigation of Meteorological Disasters in Southeast Asia

Shigeo YODEN
Department of Geophysics. Kyoto University

Risk of high-impact weather in Southeast Asia is potentially increasing because of the economical development and urbanization. Global warming and climate change might become another factor for the increase of the risk. It would be a good timing for us to start an international research project for prevention and mitigation of meteorological disasters in Southeast Asia, because the research environment is rapidly changing by the growth of computer powers and the improvement of internet infrastructures. Regional meso-scale models can be run with personal computers for downscale numerical weather predictions (NWPs). Data transfer via internet is getting fast enough to perform near-real time NWPs. Utilization of probability information obtained by ensemble NWPs is a challenge for the development of decision support tools. Assessments of the impact of new observational data on the improvement of NWPs with advanced data assimilation schemes are also important subject in these days.

Thus, we have just started "International Research for Prevention and Mitigation of Meteorological Disasters in Southeast Asia" under the Ministry of Education. Culture. Sports. Science and Technology (MEXT) Special Coordination Funds for Promoting Science and Technology, supported for FY 2007-2009 under Asia S & T Strategic Cooperation Program (http://www-mete.kugi.kyoto-u.ac.jp/project/MEXT/).

Three main affiliations of this international research project are Kyoto University, Meteorological Research Institute (MRI) of Japan Meteorological Agency (JMA), and Institut Technologi Bandung (ITB) in Indonesia. Fundamental research and system development will be done at Kyoto University. while operational model development will be done at MRI/JMA. Real-time experiment will be done at ITB and other institutes outside Japan. Our main purpose is to establish "International Scientist-Network for Prevention and Mitigation of Meteorological Disasters in Southeast Asia" through research and development of downscaling NWP systems.

## 2. Reduction of Geohazard Risks for Sustainable Development in Indonesia

Emmy Suparka
Vice Rector for Research. Innovation. and Partnership
Institut Teknologi Bandung, Indonesia

Being situated in the earth's convergent region. Indonesia is rich of natural resources as well as prone to natural disasters of all kind. Since the great Sumatran earth quake and tsunami that occurred in December 2004. Indonesia has relentlessly suffered from natural disasters that are occurring in different parts of the country with increasing frequency. These disasters are causing loss of many lives. endangering the economic and political stability. and threatening the sustainability of the national development. Because of its vast territory and big population, reducing the risk of geohazard in Indonesia is important in stabilizing both regional and global economy.

This paper presents a brief survey of current organizational infrastructures related to disaster prevention and mitigation in Indonesia and their effectivity in reducing the geohazard risks, based on recent cases. It reveals that some problems related to low preparedness in both technical and management aspects of geohazard-risk mitigation have caused great losses in a series of natural disaster events. Thus. there is an urgent need to enhance national capacity building in infrastructure. technology. and human resources to alleviate the problems. In this context, Institut Teknologi Bandung (ITB) has played an important roles because it is the only university in Indonesia that develops research and study program in earth sciences and technology including geology, geophysics.

oceanography, and atmospheric science (meteorology). There are several different research groups at ITB having research interests from basic science to management system related to geohazard mitigation. Therefore, ITB has been involved in several programs related to capacity building in natural disaster mitigation under the support of national as well as international organizations. Since 2005, ITB has allocated its own research funding to enhance its contribution in the national capacity building of science and technology including those related to natural disasters.

Among proposals that are annually submitted through the office of Vice Rector for Research, Innovation, and Partnership of ITB, topics in water-related natural disaster like flood, drought, and land-slide quite competetively gain support from both internal and external funding agencies. Significant amount of funding has also come to support research related the global climate change issues in recent year. Numerical Weather Prediction (NWP) is, however, one field of research that still needs promotion in the form of industrial application to attract financial supports. Through a continuous collaboration with Kyoto University, especially with Prof. Yoden and colleagues, we hope that we can invite our industrial partners to take part in the efforts to foster a strong research group in NWP whose development is now still at an embryonic stage at ITB.

## 3. Mesoscale NWP Model Intercomparison for the Maritime Continent: Preliminary Results and Future Plan

Tri Wahyu HADI
Atmospheric Sciences Research Group
Institut Teknologi Bandung

We have set up a simple near real-time numerical prediction system with an effective prediction range up to 36-hour lead time by downscaling the NCEP-GFS global model output using MM5 Mesoscale NWP model developed by Pennsylvania State University/NCAR. Although thorough verification has not been carried out, some case studies show that there are propective capabilities of the mesoscale model in predicting complex mesoscale cloud convection in the Maritime Continent of Indonesia; despite no local data were ingested into the model. In order to develop the prototype system into operationally usable model, we anticipate two problems inherent in modern NWP application i.e. *local data assimilation* to improve model accuracy and *ensemble prediction* to estimate model uncertainty. We are planning to carry out some research on these topics under the collaborative "International Research for Prevention and Mitigation of Meteorological Disasters in Southeast Asia".

As a preliminary work, we are now performing a simple mesoscale NWP model intercomparison using MM5 and WRF (another mesoscale NWP model developed at NCAR) in order to understand the differences in model behavior when applied in the tropical/equatorial region. In this experiment, we downscale the GFS output of 1 degree resolution into 30 km and 10 km regional model resolutions. Results from analysis of the regional model output show that WRF tend to produce smaller scale cloud convection, compared to MM5. We further investigated the differences by performing a higher resoluton simulation of cloud convection related to the Jakarta flood event of January/February 2002. It is found that the two models produced quite different mechanisms for strong convective cloud generation. The cloud convection in MM5 was somewhat dominated by cold pool advection, while WRF seemed to produce gravity-wave induced convection. It is also found that WRF is more sensitive to cumulus parameterization. These result may indicate that WRF requires more parameter tuning for tropical application.

As a future plan, we are going to include JMA Non-Hydrostatic mesoscale model in our intercomparison under the aforementioned collaborative research program. We have also invited more partners from Indonesia to join in our near real-time NWP experiments. Under collaboration with PT Berau Coal, a coal mining company operating in Berau area, East Kalimantan, we are planning to install six Automatic Weather Station (AWS) that will provide local data to ingest into our model in the near future. Another collaboration with researchers from the National

Coordinating Agency for Suvey and Mapping, we are also planning to include GPS derived near real-time PWV data into our data analysis system. The GPS network has been developed under the Indonesian Tsunami Early Warning System (INATEWS) project and currently there are about 13 GPS stations installed in West Java area. We expect that under the leadership of Kyoto University there will be more enhanced collaboration for research in NWP application in Southeast Asia.

## 4. Contribution of MRI to the International Research for Prevention and Mitigation of Meteorological Disasters in Southeast Asia

Kazuo SAITO
Meteorological Research Institute

In the research project 'International Research for Prevention and Mitigation of Meteorological Disasters in Southeast Asia', the Meteorological Research Institute (MRI) takes charge of the second theme, 'Development of a mesoscale model and application'. This subject consists of three parts; 1) Development of a mesoscale model for tropical weather prediction. 2) Promotion of international collaborative studies with a mesoscale model, and 3) Data assimilation experiment in tropical areas.

The contents of each subject are as follows.

1) Development of a mesoscale model for weather prediction in Southeast Asia:

To apply the JMA nonhydrostatic model (NHM) to the disasters prevention in Southeast Asia, optimize its physical processes for tropical whether condition. Develop a mesoscale ensemble prediction technique available for forecasts of severe weather events such as the heavy rainfall.

2) Promotion of international collaborative studies with a mesoscale model:

Prepare an English document of NHM and hold training seminars. Share technical information on tropical NWP with researchers in Southeast Asia through the international collaborations.

3) Data assimilation experiment in tropical areas:

Develop a variational mesoscale data assimilation system in tropics and apply it to forecast experiments. Improve the initial condition of mesoscale models for the typhoon prediction.

In the presentation, brief history and current status of NHM and activities at MRI relevant to above topics will be introduced. A WWRP underway project, the Beijing Olympic 2008 Forecast Demonstration / Research and Development Project (B08FDP/RDP), will also be introduced, including the verification results for the 2007 preliminary intercomparisons of mesoscale ensemble prediction systems over the domain of east China.

## 5. Operational mesoscale NWP at the Japan Meteorological Agency

Tabito Hara
Numerical Prediction Division
Japan Meteorological Agency

Almost every year, people and properties are lost in heavy rain cases caused by precipitation system such as Baiu stationary front appeared in rainy season around June and July, typhoon, and convective storm in hot days. It is very important for the national meteorological agency to issue information for disaster prevention and help people to protect their lives and properties. Higher resolution numerical weather prediction (NWP) can be a powerful means to support forecasters issuing the information.

Japan Meteorological Agency (JMA) has been operating Meso Scale Model (MSM), aiming to provide forecasts of phenomena such as heavy rain and strong wind around Japan. Table 1 shows the brief history of MSM. MSM was started to operate in March 2001 with the hydrostatic spectrum model, having 10-km horizontal grid

spaces and 40 vertical layers and delivering 18-hour forecasts every 6 hours. This hydrostatic model was the higher resolution version of 20-km Regional Spectrum Model (RSM) of JMA, and MSM incorporated the forecasts of RSM as lateral boundary condition.

The non-hydrostatic model (JMA-NHM, hereafter NHM) was employed as the NWP model of MSM instead of the former hydrostatic one in September 2004. The differences between hydrostatic and non-hydrostatic models are not only dynamical frame, but also physical processes such as the cloud microphysics, cumulus convection and turbulence process. The new MSM can more precisely predict relatively heavy precipitation than the former one due to improvement on physical process, especially the introduction of cloud microphysics and Kain-Fritsch scheme(K-F) as cumulus convective parameterization. Although resolution was not changed in this replacement of models, the introduction of non-hydrostatic model paved the way to have resolution of MSM higher.

Table 1: History of operational Meso Scale Model (MSM)

| | |
|---|---|
| Mar. 2001 | Start of MSM operations |
| Mar. 2002 | Introduction of Meso 4DVAR |
| Sep. 2004 | Replacement of NWP model by NHM |
| Mar. 2006 | Enhancement of resolution and frequency installed some improvements |
| May. 2007 | Extension of forecast period(15 hous to 33 hous) installed many improvements |
| Nov. 2007 | Replacement of boundary condition |

The renewal of the supercomputer system at JMA in March 2006 made it possible to en hance resolution of MSM and have the update of forecasts more frequently. The horizontal grid spaces were increased twice from 10km to 5km and 50 vertical layers were adopted instead of 40 ones. The latest forecast was delivered every 3 hours (8 times a day). At the same time, some physical processes were improved such as the adjustment of parameters for K-F and turbulence process, and the introduction of updated radiation scheme in which radiation from cloud was more suitably realized. With this improvement, although predicted coverage of precipitation was not changed very much, its intensity could be more accurately represented, and more diurnal changes of surface temperature and wind velocity were secured.

The latest MSM has been in operation from May 2007. It provides 33-hour forecast 4 times among 8 times daily operations. This extension of forecast period makes it possible to deliver longer term information for disaster prevention up to 24 hours ahead. Simultaneously with the forecast period extension, many considerable improvements for dynamical and physical processes were installed, such as the introduction of hybrid terrain-following vertical coordinate, the implementation of the trigger function depending on relative humidity in K-F scheme, the improvement of clear sky radiation process and the introduction of the improved Mellor-Yamada Level 3 (MYNN3) scheme to the turbulence process. It can give more accurate forecasts, especially for precipitation, vertical profiles of temperature, and surface temperature and wind.

Furthermore, in November 2007, RSM was replaced as the model providing boundary condition by Global Spectrum Model (GSM) of 20-km horizontal grid spaces corresponding to employment of 20-km GSM as the operational model for short-term forecasts instead of RSM. Frequency of updating forecasts was increased to 4 times a day while RSM was operated only twice. More frequently updated GSM forecast can provide more accurate boundary conditions for MSM because of its shorter forecast period and the latest observations assimilated through the analysis system.

Table 2 shows the specification of the current MSM.

To show the progress of MSM in recent years and the performance of the current MSM, the predictions[1] with 10-km MSM, the former 5-km MSM and the latest (current) 5-km MSM for the heavy rain case in July 2004 at Niigata and Fukushima region are displayed in Fig.1. In this case, the line-shaped heavy precipitation band along Baiu stationary front hit around Niigata and Fukushima area and was staying for a long time, killing 15 people and flooding more than 12.000 houses above floor. 5km-MSM more suitably represents the sharpness of the precipitation band than 10km-MSM. Comparing the former and the latest 5-km MSM, precipitation intensity with

the latest one is more appropriately predicted than former one, although the position of rainband differs a little from the corresponding observation. This improvement is attributed to updated physical processes, especially MYNN3.

In a NWP system, analysis system also plays an important role. Regarding the analysis system, initial conditions for the current MSM are prepared with 4DVAR system based on the hydrostatic model, in which observations from Doppler radars, wind profilers and satellite data are assimilated in addition to conventional observations. The analysis system based on NHM (JNoVA 4DVAR) is under final tests for the operational use and will be installed into the operational system in a near future.

In this talk, brief review of MSM history and the current MSM specification will be given to have the operational meso scale model at JMA well understood, and more examples of prediction with MSM will be presented.

Table 2: Specifications of the current MSM.

| | |
|---|---|
| Number of grids | 721 × 577 × 50 |
| Time step | 24sec |
| Short time step | 6sec |
| Initial time | 00,03,06,09,12,15,18,21UTC |
| Forecast period | 15 hours (00,06,12,18UTC)<br>33 hours (03,09,15,21UTC) |
| Initial conditions | Meso 4DVAR with 60hour assimilation window |
| Data cutoff<br>Boundary conditions | 50 min<br>20-km GSM (RSM until Nov. 2007) |
| Vertical coodinates | Hybrid terrain-following |
| Model top | 21801m |
| Prognostic variables | $U, V, W, P, \theta, q_v, q_c, q_i, q_r, q_s, q_g$, TKE, $\theta'^2, q_v'^2, \theta'q_v'$<br>4-layer ground temperatures, efficiency of evaporation on surface |
| Horizontal discretization | Arakawa C |
| Gravity waves | Time splitting |
| Sound waves | HE-VI (Horizontal split and explicit, vertically implicit) |
| Cloud microphysics | 3-ice bulk method |
| Convective parameterization | Modified Kain-Fritsch (with perturbation depending on relative humidity) |
| Coud in the radiation process | Diagnosed with partial condensation scheme |
| Turbulent process | Improved Mellor-Yamada Level 3 (MYNN) |

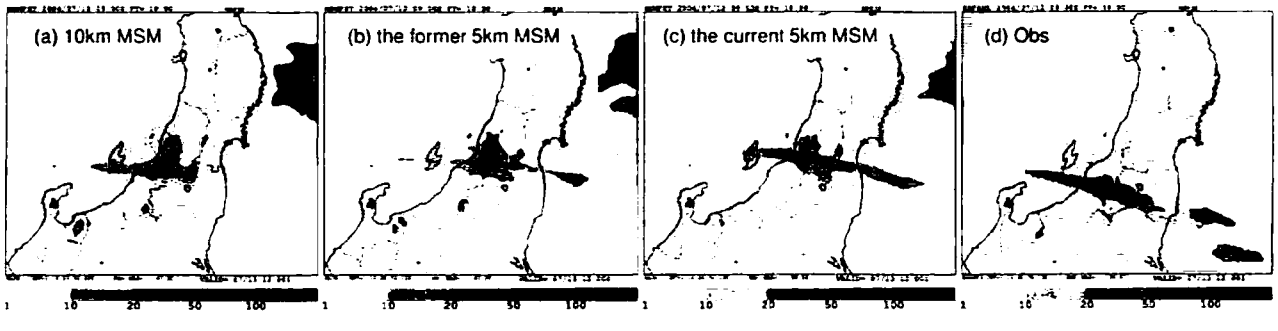



Figure 1: Forecasts of 3-h accumulated precipitation with (a) 10km MSM, (b) the former 5km MSM. (c) the latest 5km MSM, and (d) corresponding observation. The initial time is 09UTC in 12 July 2004 and 18-hour forecasts are displayed.

[1]These are not the operational results, but are obtained with the models equivalent to the operational ones at these time. In addition, initial condition and boundary conditions of them are the same each other. Consequently, the difference between them are only their models.

## 6. Use of Regional Climate Model to Study Extreme Weather Events in and around Bangladesh

Md. Nazrul Islam[1*], Ahsan Uddin Ahmed[2], Taiichi Hayashi[3], Toru Terao[4] and Fumie Murata[5]
[1]Synoptic Division, SAARC Meteorological Research Centre, Dhaka, Bangladesh
[2]Centre for Global Change, Shymoli, Dhaka, Bangladesh
[3]DPRI, Kyoto University, Uji, Japan
[4]Kagawa University, Takamatsu, Japan
[5]Kochi University, Kochi, Japan

Bangladesh is one of the topmost sufferer countries by natural hazards especially extreme weather events occurred in almost every year, such as severe cyclone and serious flood. The detection of extreme weather events occurred during last couple of decades is very important for the fixation of indices and also for the calibration of Regional Climate Model (RCM) outputs. Then the model outputs may be very useful for the projection of extreme weather events, which are very essential for stakeholders of a nation like agricultural dependent country Bangladesh. In this connection, we collected observed daily data of rainfall, maximum and minimum temperature of the Bangladesh Meteorological Department including 31 stations throughout the country during 1951 to 2006. Outputs for the same parameters from the RCM named RegCM during the baseline period 1961-1990 are appropriate for model calibration. Indices for rainfall, maximum and minimum temperatures are determined at each station. From the model generated future scenarios, probability of the frequency of extreme weather events like spell of heavy rainfall, cold wave and hot wave are obtained for 2041. Detail will be discussed in the workshop.

*on leave from the Department of Physics, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh

## 7. Numerical Weather Prediction with High Resolution Regional Model -HRM in Vietnam. Impact of Convection Parameterization on Heavy Rainfall Forecast of HRM, Verification and Problems for Very Low Latitudes

Kieu Thi Xin
Vietnam National University of Hanoi

The early involvement of Meteorological Department of Vietnam National University (VNU) of Hanoi and Meteorological Institute of University of Munich (MIM) and the later co-operation between DWD and Hydrometeorological Service (HMS) of Vietnam ( 2001) formed the basis of a rapid build-up of the first local NWP by HRM in Vietnam . A task sharing between VNU and HMS is implemented where VNU takes care of developing, testing and evaluating new components like using new convective parameterization schemes or verification of data assimilation, and HMS incorporates them in the operational suite.

The vital moisture from Indian monsoonal westernization in convergence with TCs -ITCZ of West Pacific Ocean causes heavy rainfall leading to severe flooding for the Indochinese Peninsula (IP) and adjacent countries makes it extremely important to improve rain forecast, may be by a Regional Numerical Weather Prediction Model nested in a Global Model. The heavy rainfall over Southeast Asia (SEA) region caused mostly by convection makes it extremely important to choose and improve an appropriate convection parameterization scheme for this tropical region.

The Improved High Resolution Regional Model (HRM) originated from DWD nested in the GME is used for weather forecast in Vietnam with concentration on typhoon forecasting and quantitative precipitation forecast (QPF) by 1) Increasing model resolution to horizontal resolution of 14 km and 31 vertical levels (H14-31) ; 2) Implemnting three new convective parameterization schemes: Extended Tiedtke scheme (ETK), Heise scheme (HS) based on low level moisture convergence and atmospheric instability hyppothesis, and Bettes-Miller-Janijc

scheme (BMJ) based on adjusting temperature and moisture structures of model to observational temperature and moisture structures in the tropics. together with the original Tiiedtke(1989) scheme in HRM to choose the best for SEA region; and 3) Assimilating local observations with 3DVAR ( by Le Duc report).

This report concentrates on the role of convective parameterization in simulation of heavy rainfall with HRM. First of all we found that the higher the model resolution is, the suitability of convective parameterization scheme based on low level moisture convergence such as TK scheme decreases. The verification of model rainfall forecast for three rain seasons (2003-2005) over the area of ( 97.E – 117.E X 5.N – 25.N) show that H14-31 using Tiedtke scheme often underestimates rainfall of high thresholds and overestimates rainfall of low thresholds while H14-31/ BMJ scheme provided better rainfall forecast both in the location and the amount. The improvement is averagely of 15%-25% in comparision with the forecast of the original HRM of DWD.

The verification of the 1. day rainfall forecast of H14-31/BMJ by CRA method for the Northeast subregion of Vietnam provided with errors decomposition as: displacement error of 46.1 %, volume error of 7,8 % and pattern error of 46,1 % based on 633 CRAs during those 3 rain seasons. Those errors may be comparable with corresponding errors of (501) % (50.3) % and (451) % of LAPS for Australian region. The bootstrap methode is apllied to test the statistical significance of verification scores and confirmed the stability and confidence of our model forecasts too. But for the south area of latitudes lower 10-12 degrees, HRM provides with forecast of much lower quality, specially underestimates rainfall, all verification scores expose much lower skill of HRM in comparision with one for the northeast subregion of Vietnam. It seems to be the weakness of the regional modell of self for very low and equatorial latitudes , what we need to investigate and improve for the future.

## 8. Development of High Resolution Models and its Applications for Weather and Climate Risk Reduction in Indonesia

Mezak Arnold RATAG
Indonesia National Meteorology and Geophysical Agency (BMG)

## 9. A Down-Scale Experiment on Numerical Weather Prediction in Indochina Region (Lao PDR)

Palikone THALONGSENGCHANH, Shigenori OTSUKA, and Shigeo YODEN
Department of Geophysics, Kyoto University

The main objective of this paper is to evaluate a performance of a Down-Scale Experiment on Numerical Weather Prediction in Indochina Region with a Meso-scale Model during the wet southwest monsoon period.

We performed a downscaling hindcast experiment in Indochina region (Lao PDR) with a fine-mesh meso-scale regional model under the assumption of the "perfect forecast" produced by global numerical weather prediction model, by using the Fifth-Generation NCAR/Penn State meso-scale model (MM5), which is a non-hydrostatic regional model nested to a global dataset. The model domain covers the Indochina Region including the South China Sea (85°E – 125°E in longitudes and Equator – 30°N in latitudes) on a Mercator projection. The computational domain has 230 x 170 grids with the grid distance of about 20 km. The model has set up 23 vertical levels from the surface to 100 hPa with no uniform vertical resolutions. We used a cumulus parameterization scheme "Kain-Fritsch 2"and micro physics "Mixed-Phase" with rain cloud water, ice, and snow. Both longwave and shortwave radiation are calculated, including longwave radiation from clouds. We used NCEP Final Analyses (FNL) for initial and boundary conditions.

The experiment was done for June, July, August and September of the years 2003, 2004, 2005 and 2006 in the wet Southwest Monsoon period. We performed 5-day runs with 1-day overlapping to obtain long term data, discarding initial 1-day of each run. Validations of a downscaling hindcast are done with 17 main surface stations data of temperature and accumulated rainfall in Lao PDR. We obtained an improvement of

biases in temperature, possibly due to the well-resolved terrain in the model. Correlation values of daily average and max surface temperature between model and observation, and FNL and observation are shown in figure (a, b) for all 17 surface stations, for each month (June, July, August and September). This shows that the improvement in correlation is limited.

In future we should do operational real-time forecasts in Indochina region every hour or so for mitigation and prevention of meteorological disasters by high-impact meso-scale weather of heavy rainfall or tropical cyclones (TC) during the Asian monsoon season.

## 10. Comparison of Two Strategies for Simulation of Extreme Rainfall Events

K C Gouda, S Himesh and P Goswami
CSIR Centre for Mathematical Modelling and Computer Simulation

Extreme rainfall events (ERE) are among the most high-impact weather events; the impact of ERE is only likely to increase with growing urbanization and industrialization. It is evident that even a short-range successful forecast could be of considerable help in managing such a disaster. Forecasting of such extreme events, with accuracy to make such forecasts useful in policy decision is, of course, still a major scientific challenge. Nevertheless, recent improvements and developments in atmospheric modelling, data coverage and computing make such forecasts attemptable.

The most widely used tool for dynamical forecasting of meso-scale events is the so called limited area models (LAM) or meso-scale models: three dimensional models of the atmosphere defined over a domain much smaller than the global domain. While a LAM can afford very high resolution over a domain of interest, not yet feasible in GCM, it requires artificial lateral boundary conditions which have to be supplied externally and which can greatly limit its performance. Besides, LAM cannot incorporate the effects of larger (than domain) scale circulations in the model dynamics except through the lateral boundary conditions. There are reasons to believe, however, that a global model would provide a better platform for tropical cyclone simulation and forecasting, especially to address issues like growing demand for longer lead (AMS, 2000) and interaction with large scale circulation; there is growing evidence that the large scale circulation features have considerable effect on the smaller scale circulation (Tanguay, Bartello and Gauthier, 1995).

For the meso-scale simulation, we use a version of MM5 with three nests, with resolution of 10 Km for the inner domain. For the global simulation, we use a GCM with stretched coordinate (variable resolution with zoom). The variable resolution, prescribed as a continuous variation (stretching) in the resolution with respect to a point (zoom), allows relatively higher resolution over a chosen domain in a continuous and dynamically consistent manner. The variable-resolution, however, offers more than high resolution: in a complex system like a GCM there is no clear separation between numerics, dynamics and physics and a change in the grid can affect a change of strength and distribution of convergence, and hence precipitation.

We compare and contrast multi-lead hindcasts of three heavy rainfall events with leads of 96, 48 and 24 hours with the two configurations. The three events selected represent different geographical locations (Mumbai, Bangalore and Chennai) over India and different seasons (background states). Most of the forecasts showed heavy, concentrated rainfall over and around event locations; however, there are complementary aspects of the two sets of forecasts. Possibilities of a synthesis of the two methodologies are discussed.

## 11. Basic usage of the NHM for numerical weather experiments

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## 1. Introduction

In Japan, the Meteorological Agency (JMA) has been running an operational mesoscale model (MSM) since Mar. 2001, and replaced the model dynamics from hydrostatic to nonhydrostatic in Sep. 2004. The nonhydrostatic MSM is based on a nonhydrostatic model (NHM, Saito et al., 2006, 2007) developed by a collaborative work between the Numerical Prediction of the JMA and the Meteorological Research Institute (MRI). The NHM has been widely used in the Japanese meteorological community as a research too, while use in foreign countries was relatively limited compared to US community mesoscale models such as MM5 and WRF, due to the lack of the English tutorial.

In this paper we describe basic usage of the NHM. Figure 1 shows the flowchart to run the NHM and relevant data sets.

## 2. Requirements for running the NHM

### 2.1. Hardware

The NHM has been successfully installed to a number of UNIX-based machines from PCs to parallel super computers as listed in Table 1. The physical memory size depends on the domain size of the experiment design. Approximately, 100 x 100 x 40 grids in x-y-z need 1.0GBytes physical memory on a single processor run.

### 2.2. Software

Most of the NHM source codes are written in Fortran90 (C is partially used). Fortran compiler is needed for compiling the NHM. We have tested the NHM on several Fortran compilers. g95-fortran, Intel-Fortran (non-commercial), PGI-Fortran, and others (see Table 1) and have confirmed no problems.

In case the NHM is executed on a shared memory system, any external libraries are not required. If a distributed memory system is selected, the NHM needs a MPI library for inter-node communication. In some preprocesses to use the JMA operational NWP datasets, the NHN employs an exclusive library called NuSDaS (Numerical Prediction Standard Data-set System), which is included in the NHM source codes. Some external constant files, e.g., topography dataset (GTOPO30) and vegetation dataset (GLCC), may be needed to conduct a forecast experiment, and they can be downloaded from the USGS website. Compiling the NHM source codes is not difficult, because configuration files for several systems are prepared as the NHM standard shell scripts.

## 3. Preparation for running the NHM

### 3.1. Initial and boundary conditions

Since the NHM is an operational model, forecast and analysis data of JMA in the NuSDaS format can be used for initial and boundary conditions. Additionally, forecast and analysis data by NCEP-GFS, JRA25 (JMA-25yr-reanalysis) and JMA global model data supplied by the Japan Meteorological Business Support Center (JMBSC) data are available as shown in Table 2. These data can be downloaded easily using prepared shell scripts.

### 3.2. Convert GPV data to the NuSDaS format

The preprocessing systems for the NHM support in this paper use the NuSDaS format. Downloaded datasets have to be converted to the NuSDaS format, if original ones are in the GRIB (GRIB2) format. Shell scripts for conversion are included in the NHM libraries.

## 4. Running the NHM

When the GPV data in the NuSDaS format are prepared, it is time to run the NHMA sample shell script for a forecast experiment is in the directory "Nhm/Ss/RF40km" with recommended namelist parameters. Shell scripts to prepare a topography file and initial and boundary files are also in the same directory.

## 5. Post-Process (visualization) for the NHM

The NuSDaS format data are easily visualized through the web browser by using a prepared software 'webpandah' (Fig. 2).

## 6. Result samples of the NHM (comparing the WRF-ARW)

Figure 3 shows an example result of the NHM run around Japan using NCEP GFS forecast data. The grid

number is 150 x 150 x 40 in x-y-z and the horizontal resolution is 20km. Elapse time was about 2hours for 36hr forecast (dt=75sec, 1728steps) using 4 cores of the Xeon 2.0GHz. The 24-hour accumulated precipitation at 2007-Jul-06 12UTC is shown from initial time at Jul-05 00UTC. For reference, a result by the WRF-ARW model using same initial and boundary conditions is also indicated. Comparing the radar observation, basically the both models well reproduced the distributions of the observed precipitation, while the NHM seems to predict the rainfall more precisely around the central part of the main island of Japan.

Figure 4 shows the results of them around Indonesia at the same day. In this case, we haven't yet compared the results with radar observations, though the WRF-ARW seems to overestimate the precipitation. NHM (as well as WRF) has been mainly applied to the mid-latitude so far, and more tests should be done for the simulations in low-latitude.

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## 12. Experimental development of a unified data base and decision support system for prevention and mitigation of meteorological disasters

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In recent years, weekly and monthly weather forecasts are performed by numerical ensemble simulations. These data have information of not only magnitude of physical variables but also their probability. However the information of the probability is not use enough. We could potentially obtain much useful information from the dataset, which is helpful for making decision for prevention and mitigation of meteorological disasters.

We are trying to develop a unified data base and decision support system for prevention and mitigation of meteorological disasters by making use of such ensemble dataset. We are archiving dataset of global analysis and all ensemble members of weekly and monthly weather forecast done by Japan Meteorological Agency (JMA) provided through consortium for meteorological research [1]. Searching data from keywords, area and time, applying mathematical functions, and making plots can interactively be done with graphical user interface in this system, which is developed based on the "Gfdnavi" [2] developed by GFD-Dennou Club [3]. We can easily make not only plot of ensemble mean and spread but also other several plots, such as box-plot, line-plot and histogram of the ensemble members, and so on, which could give us more information contained in the dataset.

Collaborating with data base system of Research Institute for Sustainable Humanosphere Kyoto University (RISH) [4], datasets provided by Japan Meteorological business support center (JMBSC) [5] and ECMWF 40 Year Re-analysis dataset (ERA40) [6] are plan to be available uniformly in this system.

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## 13. Country Report on Hydro-Meteorological Disasters in Lao PDR For the Year 2006

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The topography of Lao People's Democratic Republic is closely related to the geology with watershed highlands of granites. The slopes of the mountains generate the runoff draining down rapidly from upstream to low lands or to the Mekong River during heavy rainfall season. Mekong River flows through the Lao territory along a length of 1865 km. . In Lao PDR , Agriculture is the principal economic sector, contributing 55 % and covers a wide range of activities from subsistence production to agriculture related industries. About 80 % of the population is engaged in agriculture mostly in the plain valley broadly defined to include livestock, crops, fisheries and forestry. Forest covers 47 % of the land and the fertile flood plain embraces about 30 % along the Mekong River.

During the last 40 years (1966-2005), 28 notable flood occurred with different magnitudes, duration and an average frequency once in approximate1.4 year. Of these 28 historic flood only 6 were large flood (1966, 1971, 1978, 1955, 1996, 2000 and 2002), giving and average frequency of once in every 5.7 years.

In year 2005 floods of the Mekong River and its tributaries were mainly caused by storm rainfall in catchments in the upstream of the Mekong River and local heavy rainfall, resulting from strong southwest monsoon with Inter-Tropical Convergence Zone (ITCZ) and typhoon originating in south of China Sea during the months of August to September.

The most affected provinces by flash flood and river flood in year 2005 are: Oudomxay, Bolikhamxay, Khammuane , Savannakhet, Saravane and Champasack. The water levels along the River Mekong, especially from Bolikhamxay to Champasack provinces, rose over the flood warning stage during the end of August 2005. As a result many districts along Mekong River and downstream of its tributaries were flooded, causing damages to national infrastructures, agriculture production, and human settlements, and resulted in losses to livestock and human lives.

In flood season year 2006 has been seen as a year without flood along the Mekong River, due the onset of monsoon took place with weak intensity and no any Typhoon best track over Lao P.D.R and the rainfall distribution over the upstream of lower Mekong country's basin was recorded negative anomaly on the beginning rainy season (May-June).

Mostly the flash flood occurred in the ends of rainy season at main tributatries of Mekong River, caused by low atmospheric pressure with southwest monsoon heavy rainfall and Typhoon best track over Lao PDR.

The most affecting provinces by flash flood in year 2006 are: Luangnamtha (from Namtha river) and Attapeu provinces (from Xekong and Xekhaman rivers) .The exceeding of water levels from danger stage was 2.70 meters recorded at hydrological station Hongleuai (Namtha river) on 01:00 pm of 07 August 2006. For Xekong River at Veunkhen station the maximum flood peak was observed 17.92 meters at 02 am of 02 October 2006 and higher than warning stage 1.42 meters. As a result many districts along the river were flooded, causing damages to national infrastructures, agriculture production, and human settlements, and results in losses to livestock and human lives.

The main function of Meteorology and Hydrology of Lao PDR is flood management and to disseminate of the weather forecasts, flood forecasts and issue warnings to public and to ministries concerned.

The National Disaster Management Office (NDMO) (Ministry of Labour and Social Welfare) is an agency responsible to the victims of the flood, with the support of the United Nation Development Program (UNDP). It started in 1997 for the formulation of the government policy on Disaster Management.

In August 1999 Lao PDR established an Inter-Ministerial National Disaster Committee (NDMC). The NDMO has served as the secretariat of the NDMC and has a function to coordinate procedures with Disaster Management organizations and government institutions, other agencies and stakeholders such as: the United Nations (UN), and international nongovernmental organizations (NGOs).Natural Disaster prevention and mitigation is one of measures that contribute to the poverty alleviation strategy of the Lao P.D.R government.

This paper is the review last few year up to now of hydro-meteorological disaster, operational flood

forecasting along the Mekong River and Warning system in Lao PDR during the rainy season (from July to August).

## 14. Flash Flood in Preas Vihear Province

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## 15. On the roles of the northeast cold surge, the Borneo vortex, the MJO and the IOD during the worst 2006/2007 flood in southern Peninsular Malaysia

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The flood that occurred in southern Peninsular Malaysia during mid-December 2006 to late January 2007 in southern Peninsular Malaysia was the worst occurrence in a century. Exacerbated by the conditions on the ground (e.g. poor drainage) in most areas, the duration of the flood extended over a month. The number of people evacuated exceeded 200,000 with 16 reported deaths. The initial estimate of economic losses due to the flood was reported to be around US1.5 billion dollars. The 2006/2007 flood was caused by extreme precipitation events which occurred in three episodes: namely, 17 – 20 December 2006, 24 – 28 December 2006 and 11 – 16 January 2007. Two major factors contributed to the occurrence of the extreme precipitation episodes i.e. strong northeast cold surges and the Madden-Julian Oscillation (MJO) event. The interaction between these two large-scale factors in conjunction with topographic effects contributed to the extreme events. During the first episode, a very strong cold surge occurred from the north. Combined with strong easterly winds from the western Pacific, the northeasterly winds over the southern South China Sea became anomalously strong and followed an almost straight trajectory to southern Peninsular Malaysia and Sumatra. The blocking effect of the elevated terrain over Sumatra caused low-level moisture convergence and enhanced deep convection over Peninsular Malaysia and Sumatra leading to the flood. The lack of counter-clockwise turning of the northeasterly winds was due to a strong easterly over and north of Java, which also inhibited the formation of the Borneo vortex. Strong easterly winds over the western Pacific, Java and north and north-east of Australia during the period were associated with the Rossby wave-type responses to the MJO activity over the Indian Ocean. The MJO disturbance travelled eastward but weakened considerably when it was over the western Maritime Continent.

During the second episode, the twin-cyclones associated with the MJO were located just west of Sumatra. The scenario during the second episode was similar to that of the first. A direct penetration of strong northeasterly winds over the region of elevated terrain in Sumatra and southern Peninsular Malaysia caused enhanced deep convection that led to the second extreme precipitation event. However, the presence of strong westerly jets over the equator in between the twin-cyclones eventually promoted the counter-clockwise turning of the northeasterly winds and the formation of the Borneo vortex. The synoptic-scale circulation associated with the vortex helped to intercept low-level moisture from the regions of Sumatra and southern Peninsular Malaysia to western Borneo. For a period of about two weeks after the second episode, southern Peninsular Malaysia did not accumulate a

significant amount of rainfall despite strong northeasterly winds over the southern South China Sea during the period. This was due to a greater tendency for the counter-clockwise turning of the northeasterly winds and formation of the synoptic-scale Borneo vortex due to the presence of strong westerlies over and north of Java as the MJO passed over the Maritime Continent. However, during the third episode. remnants of MJO disturbances were roughly located at the eastern edge of the Maritime Continent. During this period, the MJO-related westerly over and north of Java had weakened and this allowed for a direct penetration of northeasterly winds to the region of elevated terrains over Sumatra and Peninsular Malaysia.

The anomalous conditions during the extreme episodes could also be related to the abrupt termination of the 2006 IOD. The anomalously cool sea surface temperature (SSTA) in southeastern Indian Ocean associated with this event was at its peak in September-October-November 2006. However, the negative anomaly was abruptly eroded in December 2006. In fact, during this period the entire equatorial Indian Ocean and regional seas surrounding the Maritime Continent were warmer than usual. Associated with this change was the eastward propagation of the precipitation anomalies. However. convection over the Indian Ocean had a secondary role in the extreme precipitation episodes over Sumatra and Peninsular Malaysia.

## 16. Disaster by the severe cyclone "Sidr" in the Coastal region of Bangladesh in November, 2007

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Bangladesh was damaged seriously by the cyclone "Sidr" in the middle of November. 2007. which is one of the severest cyclones in the last two decades years. The total number of died and missing persons was more than four thousands, and the damaged persons about nine million. reported from the of Disaster Management Bureau of Bangladesh government on December 29. 2007.

We visited Bangladesh for the field research of the damage conditions and the collection of meteorological data for clarify the structure of this cyclone. The cyclone occurred in the middle of the Bay of Bengal on the November 11th, moved northward and landed at the southwestern coast of Bangladesh. The Bangladesh Meteorological Department (BMD) reported the minimum pressure of 944hPa of the cyclone and the peak gust of 69ms$^{-1}$ at the time of landing on the coast of Bangladesh. The height of the storm surge and the high wave were more than 5 to 6m above the sea level and the peak water level was higher than the altitude of the embankment. The most of the houses were destroyed completely near the coast of the Bay of Bengal and the river.

The numerical forecasting system has not been introduced to BMD and is now preparing. We expect the appropriate warning system will be introduced and the damage will decrease near future on the basis of this kind of workshop.

## 17. Numerical simulation of heavy rainfall events in South/Southeast Asia using NHM

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Numerical simulations of the strong wind and heavy rainfall events have been conducted to confirm the usefulness of NHM for the prediction of weather phenomena in the tropical region. Preliminary results on these events will be presented.

First event is the strong wind on 29 November 2006 over the Java Sea. A ferryboat was wrecked by the strong wind and high waves, and more than 500 people were claimed. Sea surface wind speed and rainfall intensity when the ferryboat was in distress were observed by AMSR-E (Fig. 1). The wind and rainfall intensity near the accident scene exceeded 20 m/s and 30 mm/hour, respectively (http://www.eorc.jaxa.jp/imgdata/topics2007/tp07024.html). The strong wind event was simulated by NHM with the grid interval of 5 km. The JMA global analysis data were employed for the initial and boundary conditions. A low pressure system developed south of the Java Island, and then westerly flow intensified by this low pressure system expanded eastward over the Java Sea (Fig. 2). Strong wind region moved to the north of Bali by 16 UTC 29, and then the wind speed at the height of 20 m reached the maximum speed of 27 m/s. A convective region is seen in the Java Sea, while this cluster seems not to much affect the simulated strong wind because it was located far from the strong wind region.

Second event is the heavy rainfall occurred at Mumbai on 26 July 2005 (Bohra et al. 2005). Rainfall more than 900 mm/day was observed at Santa Cruz, a suburb of Mumbai (Fig. 3). Although this heavy rainfall occurred at the localized area of 20-30 km, rainfall system that produced the intense rainfall lasted for more than 6 hours. This heavy rainfall was also simulated by NHM with the grid interval of 5 km using the JMA global analysis data. Localized intense rainfall was reproduced near Mumbai while relatively weak rains (less than 10 mm/hour) were generated along the southern coastal line (Fig. 4). Because the heavy rainfall was developed at the coastal line near Mumbai, the topographic effect seems to be essential for its generation. As the convection of the heavy rainfall was developing, the surface pressure near the convection decreased. This drop of the surface pressure intensified the convergence, and maintained the heavy rainfall. As for the horizontal flow around the heavy rainfall, the zonal wind reverses its direction as the height increases, while the latitudinal wind is relatively weak. These airflows around the heavy rainfall were favorable to stay the heavy rainfall near the Mumbai.

## 18. Preliminary Study on the Precipitation of Maritime Southeast Asia

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Improving the quality of weather and climate prediction over maritime Southeast Asia region is important to mitigate the disaster's effect over there. In order to improve the weather and climate prediction, the basic understanding of the mechanisms affecting weather and climate in maritime Southeast Asia is important to be studied. Contributing in the climate study, we have confirmed the impacts of the land surface temperature, sea surface temperature (SST) and the Asian monsoon on the precipitation pattern over maritime Southeast Asia during the boreal summer.

We did sensitivity experiments on the land surface temperature and the SST using Global Circulation Model, GCM. Our result showed that the land surface temperature affects the strengthening of the Asian summer monsoon and then smoothly shifts the heavy precipitation from southern to northern hemispheres in early summer. Another result of the sensitivity experiment on SST showed that the SST induces suddenly jump of heavy precipitation between both hemispheres in early summer. Both land surface temperature and SST may have an impact on the activity of the Asian summer monsoon and consequently affect the amount of precipitation over maritime Southeast Asia during the boreal summer. Focusing the result on Borneo, the monsoon over South China Sea plays an important role in the precipitation migration over Borneo and then influences the precipitation amount over Borneo during the boreal summer. Our work confirmed that global variation in land surface temperature and SST affect precipitation over maritime Southeast Asian during the boreal summer.

The maritime Southeast Asia sits within the warmest SST and its climate is dominated by intense convection by heavy precipitation. Besides, the topography of maritime Southeast Asia is very complex with seas and islands interspersed together. We suggest that the impact of the islands and variation of SST in this own region contribute to the climate change over there. In order to cover the complexity of topography, we prefer using high resolution regional model to study the impact of the islands and SST. We expect that the result will be useful for other work

in climate prediction and help to mitigate the disaster's effect in maritime Southeast Asia.

## 19. Simulation experiments of typhoons and tornadoes using the cloud resolving model

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High-impact weather systems occasionally cause huge disasters to human society owing to heavy rainfall and/or violent wind. A typhoon is one of the most significant high-impact weather systems and occasionally accompanies tornadoes in Japan. Since both tornadoes and waterspouts are called "tatsumaki" without distinction in Japan, we will use the term in the present study. High-resolution simulations within a large domain are necessary for quantitatively accurate prediction of a typhoon and prevention/reduction of disasters. For a simulation of tatsumaki, the resolution is extremely high. In the present study, we used a cloud resolving model named the Cloud Resolving Storm Simulator (CReSS) to make simulation experiments of a typhoon and associated tatsumaki. The purpose of the present research is to clarify structures of clouds in typhoon rainbands and the relationship between tatsumaki and the typhoon by high-resolution simulations using the CReSS model

Even through a typhoon center is located in the far distance, a disaster due to a strong wind is occasionally caused by a "tatsumaki". When Typhoon 0613 (T0613) moved northward off the west of Kyushu, a severe disaster was caused by an intense tatsumaki along the east coast of Kyushu. The tatsumaki occurred when typhoon rainbands moved northward along the east coast. Two simulations with different horizontal resolutions were performed using CReSS Ver.2 in the present study. The experiment with a horizontal resolution of 500m successfully simulated not only the overall structure and movement of T0613 but also a detailed structure of the typhoon rainbands. The other experiment with a resolution of 75 m simulated that a tatsumaki forms in convective clouds. Using the results of the simulations, we defined two indices. One is a supercell index (SCI) which is defined as a product of vorticity and vertical velocity at a height of 2-3 km. If SCI is larger than 0.1 within a convective cloud, we consider that the cloud is a supercell. The other index is tatsumaki index (TI) which is defined as a product of vorticity and pressure perturbation near the surface. We use the index TI to find a tatsumaki in the simulation result. Using these indices, we examined the two simulation results. The result shows that the outermost rainband was composed of suprecells which involve a meso-cyclone. Tatsumakis form within the supercells. On the basis of the result, we will discuss the relationships between rainbands, convective clouds and tatsumakis.

## 20. Influences of Cloud Microphysical Processes on Structure and Development of Tropical Cyclone

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Typhoon is one of the most hazardous phenomena in Japan and the mitigation of its damage is of great concern to the society. Many efforts have been made to improve predictive skill of Numerical Weather Prediction (NWP) of typhoon. In the coming year, with increasing computational resources, the global NWP model will be used for typhoon forecast. The global models, however, considerably underestimate intensities of typhoon. In the future, we are expected to use high resolution cloud resolving models for detailed forecasts on intensity and fine structure of typhoon. Cloud resolving models should properly parameterize complicated cloud microphysical processes. In this respect, it is interesting how microphysical processes influence on intensity and structure of tropical cyclone.

Now, we are conducting the preliminary study on impacts of cloud microphysics on an idealized typhoon simulation, where an axially symmetric typhoon is simulated in a constant Coriolis parameter plane. The

sensitivity study suggests that the ice phase processes significantly delay the development of typhoon. The melting cooling statically stabilizes the atmosphere and suppresses the development of tropical cyclone. The melting cooling suppresses the radial transport of absolute angular momentum in the low and middle troposphere. The ice phase processes, thus, reduces size of tropical cyclone.

Another important cloud microphysical process is the evaporation from rain drop. The evaporation decreases static stability and suppresses the development of tropical cyclone as well as melting cooling. It suppresses the secondary circulation but it does not have a large impact on size of tropical cyclone. Probably the inflow within the boundary layer does not effectively transport the absolute angular momentum inward because of the surface frictional loss. Furthermore, it is shown that the evaporation plays an important role in the formation of rainband. The evaporation from rain drop significantly enhances downdrafts, forms cold pools, induces updrafts near its frontal edge and generates line-shaped deep convections.

Some of cloud microphysical processes considerably affect development and structure of tropical cyclone in different way. Thus, the parameterization scheme for cloud microphysical processes is very important in accurately simulating tropical cyclones.

## 21. Recent Advancements in the Understanding of Typhoon Inner-Core Structures and its Implication for Typhoon Vortex Initialization

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Tropical cyclone (TC) vortex initialization is one of the most crucial aspects of meso-scale TC modeling. The meso-scale model used for the prediction of typhoon intensity and/or wind and rainfall distributions associated with typhoon is required to be initialized with a realistic inner-core structure. For example, a comparative numerical study conducted by Bender et al. (1993) has demonstrated that it is essential to start with TC vortex of realistic intensity for accurate TC intensity forecasts. However the detailed inner-core structure is not captured by the conventional observational network. In addition, the traditional TC vortex initialization based on some bogussing technique only provides a rough structure of typhoon, though it is enough to locate the center of initial typhoon at the observed storm position

Recent observational and numerical studies with high resolution models suggest that vortex Rossby-waves are frequently formed and developed in the inner-core of intense tropical cyclones and play a vital role in structure and intensity changes of the storms. Some theoretical studies shows that the structure and behavior of vortex Rossby-waves depend on the inner-core structure such as the radial gradient of potential vorticity, suggesting a significant impact of the inner-core vortex structure on typhoon forecasts. In addition, recent observational and modeling studies suggest that TC exhibits significant wavenumber-one asymmetries in its inner-core structure (including those in wind distribution in the TC boundary layer) especially under vertically sheared environments. Some theoretical works suggest that the asymmetries depend not only on the environment but also on the vortex strength, reaffirming the importance of TC inner-core structure in the model.

One of noteworthy features of the JMA typhoon bogussing method is that an analytical function is utilized with some arbitrary parameters to determine the structure of the synthetic TC vortex. The structure depends on the sea level pressure profile as well as the parameters. In the present study it is attempted that the parameters are tweaked so as to best fit the observations within the typhoon area including inner-core region and information on eyewall radius (or radius of maximum wind) is utilized in the specification of sea level pressure profile on a trial basis.

## 22. Utilization of GPS Radio Occultation Data for the Studies of Atmosphere Dynamics

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GPS radio occultation (RO) has recently been attracting close attention as a means of global environment monitoring and improvement of numerical weather prediction (NWP) models. Recent CHAMP and COSMIC satellite missions are successfully providing a large amount of data-sets of temperature and humidity profiles below 35-40 km and about 10 km, respectively. The GPS RO data is characterized by a good height resolution, comparable to ground-based measurements, which are particularly valuable in the tropics and polar region where routine radiosonde observations are sparse.

We are promoting a research project in Japan in 2005-2008 as a part of GEOSS under a support by MEXT to improve prediction accuracy of NWP models by making use of GPS RO data. We also study with the GPS RO data the behavior of temperature and humidity variations in the tropics in the Asian monsoon region. Three subjects are undertaken in the project: (1) development of retrieval algorithms for GPS RO data, (2) assimilation of GPS RO data into a meso-scale weather prediction model and (3) validation and scientific application of GPS RO data, The project has been conducted under a close collaboration between National Institute of Information and Communications Technology (NICT), Meteorological Research Institute (MRI) and Kyoto University, which are mainly studying the subjects (1), (2) and (3), respectively.

This paper is concerned with an overview of this project with a focus on recent topics, such as retrieval of a high resolution stratospheric temperature profiles, characteristics of the temperature perturbations in polar and tropical regions, and assimilation of GPS RO data into MWP models.

## 23. An Experiment of Near Real-time Preciptable Water Vapor Retrieval Using Ground-based GPS Stations in South East Asia

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Meteorological Research Institute (MRI),

In this topic, we introduce preliminary results of a near real-time preciptable water vapor (PWV) retrieval experiment using ground-based Global Positioning System (GPS) stations in south east Asia.

Global Navigation Satellite Systems (GNSS) as typified by GPS provides sources of continuous and global data which can be used to retrieve water vapor information in the atmosphere, and is expected to improve numerical weather prediction (NWP). Particularly, in Japan, a very dense continuous ground-based GPS network named GEONET (GPS Earth Observation Network) allows us to analyze meso scale water vapor variation.

For the last few years, the Numerical Prediction Division (NPD) of the Japan Meteorological Agency (JMA) and the Meteorological Research Institute (MRI) have been constructing data assimilation (DA) systems of GPS remote sensing data. A near real-time analysis (NRT) system of the GEONET has been developing at MRI and DA experiments of NRT retrieved PWV with JMA meso-scale NWP model (MSM) show positive impacts of GPS data on precipitation forecast.

The International GNSS Service (IGS) operates several continuous ground-based GPS stations in south-east Asia. Observation data of these stations are available to the public through the internet. We are developing near real-time analysis procedure of those GPS stations by applying procedure of our GEONET NRT analysis. Retrieved water vapor information will be used to DA experiment in south east Asia.

## 24. Satellite-Based Rainfall Estimation and Hydro-meteorological Networks for Flood Forecasting in the Mekong River Basin

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The evolution of precipitation estimates derived from cloud top temperatures of cloud images from meteorological satellites and merged with daily observed rain gauge readings have been the main input in flood forecast systems in the MRC since 2001. Satellite-based precipitation algorithms, developed in the1990's by various groups of scientists involved in microwave and remote sensing, both from ground-based observations and remote sensing from satellites and spacecraft, are the main sources of rainfall data. This is due to the scarcity of hydro-meteorological networks, long delays of data transmission, and an absence of data sharing in many trans-boundary river basins. The knowledge of merged satellite- and surface-based rainfall estimation (RFE) was initially developed over Africa by the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC). NOAA/CPC generated RFE 3-times per day and transferred daily to the RFMMC via ftp have been used as the main rainfall input over the sub-basin in the Streamflow Synthesis and Reservoir Regulation (SSARR) model. The Flood Forecasting and River Monitoring Systems by SSARR have over the years been improved to provide timely and accurate river forecasts to member countries in order to reduce the vulnerability of floods and droughts in wet and dry seasons respectively. The MRC currently operates 19 telemetry stations in the four riparian countries, Cambodia, Lao PDR, Thailand and Viet Nam including two stations in China so-called 'Appropriate Hydrological Network Improvement Project (AHNIP) sponsored by the Australian Agency for International Development (AusAID)' and also in the process of preparation of the Mekong Hydrological Cycle Observing System (Mekong-HYCOS) sponsored by French Development Agency (AFD), as a regional component of the global World HYCOS (WHYCOS) of the World Meteorological Organization (WMO). These two projects of the MRC aim to strengthen both the technical and also institutional capacity for real-time hydro-meteorological data monitoring in the Mekong basin. In the future, AHNIP and Mekong-HYCOS will be combined to be a single MRC network with a total number of approximately 50 hydro-meteorological stations. The RFE brings value-added information to rain gauge interpolations as a near real time rainfall data set. An early warning system and preparedness plan are vital tools in reducing loss of life and socio-economic impacts of floods. Improvement of flood forecasting operation requires continuous efforts in data collection, transmission and processing.

This paper illustrates an integrated approach using RFE and hydro-meteorological networks for flood mitigation and management in the Mekong basin.

## 25. Satellite monitoring of hazardous weather in Asia

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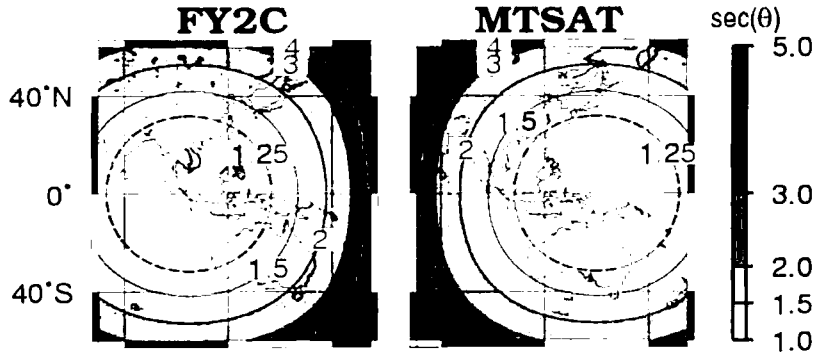
It is well recognized that the Japanese geostationary meteorological satellites, GMS/MTSAT or *'Himawari'* series, drastically improved the prediction of typhoons. The satellite resides at 140E over the equator and provides us with a comprehensive view of cloud activity over the western pacific every hour. Although the seen of GMS well cover the western Pacific area, the South East China and India is at the western merge of the GMS view. Since the Asian countries are affected by Asian summer monsoon and are suffered by severe weather associated to monsoon, it is highly required to monitor monsoon activity. In order to do this, the data observed from the Chinese geostationary meteorological satellite, Feng-Yun 2 series which resides at 105 E over the Singapore, is very useful.

The first Chinese operational meteorological satellite, Feng-Yun 2C is officially in operation on early May in 2005 after an experimental satellite Feng-Yun 2B. The observed data are transmitted in the HiRID format. The Disaster Prevention Research Institute started to receive the data since the area of Fenf-Yun 2B. The precision of the data is compared with that of GMS/MTSAT observation, and it is confirmed that the data are really consistent with GMS/MTSAT observation.

If the FY-2C images are combined with GMS/MTSAT data, typhoons which hit south east China are consistently tracked from Pacific area to the Vietnam, the cyclone which landed on Bangladesh is firstly identified by FY-2C and the extra-tropical transition and the succeeding influence to China and Japan are well monitored by

GMS/MTSAT. In Equatorial regions. the MJO is continuously monitored from Indian Ocean through Pacific Ocean in the combined images. The DPRI is now showing some images in south Asia in the web-site




## 26. Meso-scale Data Assimilation Experiment in Low Latitudes

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It is important to prepare accurate initial fields for the forecast of typhoons with numerical models, and the resolution of the models is critical to predicted typhoon intensity. However we are usually forced to use the coarse-meshed initial fields produced by global model analysis in low latitudes, where tropical cyclones originate and develop. In this study, to prepare high-resolution initial fields for the simulation of tropical cyclones, the 4-dimensional variational data assimilation (4D-Var) system for the JMA hydrostatic meso-scale model (MSM) is modified so as to permit its use in low latitudes.

The meso 4D-Var system was developed for meso-scale numerical weather forecasts in and around Japan and put into operation in March 2002. The control variables of the system are unbalanced wind, virtual temperature, surface pressure, and specific humidity in grid space. The unbalanced wind is calculated by subtracting the wind components balanced by pressure gradient force from the full wind, so the analysis increments satisfy the geostrophic constraint. For routine use, these balanced components are calculated using a regression coefficient prepared beforehand and the coefficient value is used for the whole domain. Because the analysis domain is expaned to include low-latitudes in the current study, it is conceivable that geostrophic balance argument is not valid partly in the domain. To solve this problem, the degree of geostrophic balance is investigated from a statistical point of view and the coefficient is calculated at various latitudes of the analysis domain. In addition to this, the coefficient of the penalty term which is introduced to suppress gravity wave noise in the cost function is optimized for the new domain.

Assimilated observational data include radiosonde, pilot balloon, wind profiler, aircraft, ship, buoy, and analysis precipitation around Japan area. The satellite data such as SSM/I, TMI, AMSR-E are also assimilated as retrieved one-hour precipitation amount and total precipitable water. In the study, GPS radio occultation data obtained by CHAMP and COSMIC is assimilated additionally.

To investigate the effectiveness of the assimilation system and the influence of GPS occultation refractivity both on the assimilated fields and subsequent model forecasts, the system is applied to the case of Typhoon USAGI in July 2007. The assimilation period of the experimental meso 4D-Var is 24-hour and typhoon bogus data is not assimilated. When the global analysis is used for the initial field, the typhoon is not formed in the forecast model. By contrast, when the global analysis is replaced by the meso 4D-Var analysis in the experiment, the generation of the typhoon is successfully simulated. With GPS refractivity assimilated, the simulated typhoon intensity is closer to the best-track data. The result shows that the assimilation system performs well in low latitudes and GPS radio occultation data is beneficial for typhoon forecasts.

## 27. Development of a data assimilation system with HRM model and 3DVAR technique

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The High resolution Regional Model (HRM), which was originally developed by German Weather Service (Deutsch WetterDienst - DWD) and known as the name EM/DM, has been run in Vietnam National Center for HydroMeteorological Forecast (NCHMF) and Vietnam National University of Hanoi (VNU) for both operation and research purposes since 2002. HRM was nested in DWD global model GME with 3 hours boundary update frequency. For initial conditions, HRM interpolated GME analyses.

To obtain a reliable NWP system as guidance for short-range weather forecast, a data assimilation system was implemented in 2006 with HRM as the prognostic component. Other components include: a quality control system with simple checks (physical, climatological, consistence), a 3DVAR program which is adapted from DWD (based on the 3DVAR program for GME), and a digital filter initialization (DFI) procedure which is a module in HRM. The feature of variational quality control in the 3DVAR program is also used in quality control. Boundary conditions for HRM still come from GME.

The system was tested with conventional data (SYNOP, SHIP, TEMP, PILOT, AMDAR) for two years 2005 and 2006 (for these years, satellite data were not available because NCHMF did not store this kind of data). The system was run in 6-hours analysis-forecast cycle and its analyses were used as initial conditions for HRM forecast up to 48 hours. Verification scores shown that data assimilation only impact on the first 12 hours forecast. However, the impact is especially significant in storm movement and storm intensity forecast.

In the next two years 2007 and 2008, the system will be changed in some features. The initialization component has been switched to the increment digital filter initialization (IDFI). The satellite data (AMV from METEOSAT and MTSAT, SCATT from QuikSCAT and ASCAT) has been incorporated into the observation database and assimilated in the system. For ATOVS data, the system will be tested firstly with a 1DVAR program, which is also adapted from DWD before assimilating directly radiance observation with the 3DVAR program.

## 28. ALERA: AFES-LETKF experimental ensemble reanalysis

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ALERA (Miyoshi et al. 2007) is an estimate of global atmospheric state produced from observational and simulation data (reanalysis). It is a product of a collaboration among Japan Meteorological Agency (JAMSTEC), Japan Agency for Marine-Earth Science and Technology (JMA) and Chiba Institute of Science (CIS). Although the period of this experimental product is limited to about a year and a half from May 2005, it is produced using an advanced ensemble data assimilation technique on the Earth Simulator (ES), one of the largest vector-parallel supercomputer system for earth sciences. Since there are multiple estimates of atmosphere at the same instant, the best estimate is given by the ensemble average. Flow-dependent uncertainty is also provided in terms of the ensemble spread (standard deviation). Conventional reanalysis data sets lack information on its uncertainty.

Local ensemble transform Kalman filter (LETKF) is used to assimilate global atmospheric observational data. Unlike four dimensional variational method (4DVar), ensemble Kalman filter (EnKF) does not require tangent

linear and adjoint models. Thus linearization of complicated physics schemes such as the cumulus convection scheme are unnecessary. The forward non linear model plays the key role in the quality of analysis. LETKF has outstanding computational performance over other EnKF methods on parallel computers.

In order to estimate the future atmospheric state. AFES (Atmospheric General Circulation Model (AGCM) for the Earth Simulator) is used with horizontal resolution of about 80 km and 48 vertical levels. Its dynamical core employs the primitive equations and uses Eulerian advection. AFES has all the physical schemes usually found in AGCM: radiation, grid condensation, cumulus convection (Emanuel scheme), vertical diffusion, simple surface and land processes. AFES is written in Fortran 90 and highly optimized for ES.

ALERA is available online from the Earth Simulator Center (http://www3.es.jamstec.go.jp/alera/). Not only ensemble mean and spread but all 40 members are available at pressure levels. Full ensemble data can be used as an initial perturbations for ensemble hindcast experiments using a global or a limited area model.

**References:**

Miyoshi, T., S. Yamane, and T. Enomoto, 2007: The AFES-LETKF Experimental Ensemble Reanalysis: ALERA. , SOLA, Vol. 3, pp.45-48. Available online from http://www.jstage.jst.go.jp/article/sola/3/0/3_45/_article

## 29. Assimilation of direct satellite Radiance data at NCMRWF

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Assimilation of satellite radiance directly into NWP models is a difficult problem. It requires accurate variational schemes. With the development of such variational analysis schemes , the incorporation of radiances directly in an analysis and assimilation system became practical in an operational environment. These variational analysis systems requires a very accurate background field ( a short range forecast) and all types of observations ( surface temperatures. Upper air data, radiances from different satellites etc). Analysis system blend these information and extend the influences of the data in both the horizontal and vertical directions.

National Center for Medium Range Weather Forecasting (NCMRWF) operationally running a Global Data Assimilation System (GDAS) since 1995. The GDAS is a six hourly intermittent system basically providing initial condition to the numerical prediction model. It has all three components a) data reception and pre-processing b) data analysis based on spectral statistical interpolation (SSI) and d) the NWP model. The NWP model basically provides the short range forecast as a background field to the analysis scheme. The system is adopted from NCEP, USA, and modified according to requirements. The system has a capability to assimilate NOAA NESDIS level 1B data sets and NCMRWF started assimilating this data from the middle of current calender year.

NCMRWF receives global meteorological observations from various observing systems through Regional Telecommunication Hub, (RTH). New Delhi. As soon as data received, it gets decoded to retrieve the meteorological information in it. NCMRWF also receives bulk data sets such as satellite radiances directly from data providers via FTP access. It includes NESDIS level 1B data sets from NOAA16, NOAA-18 and METOP-2 also. Level 1B is a predefined format in which NOAA digital data is supplied to users and other organizations in the world, who supply the data, follow the same format. It is a packed format and all the band data exists in a 10 bit format. The data product, in addition to video data, contains ancillary information like Earth Location Points (ELPs), solar zenith angle and calibration. All the commercially available Image Analysis Packages have the facility to read data in Level-1B format. The raw counts in the level 1b files are transformed using the calibration coefficients in the data file to antenna temperatures and then to brightness temperatures (for AMSU-A data) using the algorithm of Mo (1999). Then, the geometrical and channel brightness temperature data is extracted from orbital data is then binned in 6 hour periods (+/-3hrs) of the analysis time for use in the assimilation system.

his paper describes methodology for using level 1B data within analysis schemults from the experiment carried out to test the impact of the data in terms of quality of analysis and subsequent forecasts. The experiment is carried out by running the model at T254 resolution for the month of April 2007 using level 1B radiances from NOAA-16 and 18 satellites. This is compared with a corresponding current semi-operational analysis system without the radiance data. Figure 1 shows typical global distribution of the data for a single cycle along with the number of observations that used in that cycle. The results are very encouraging it shows over all improvement in the forecast skill with the use of radiance datasets (fig 2). The results will be presented in detail in the workshop.

## 30. Statistical Verification of COAMPS model over SCSMEX period

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This is a two-month statistical verification of operational-type forecasts over Southeast Asia for the field observation period in May – June 1998 of South China Sea Monsoon Experiment (SCSMEX). The period was chosen because there are more radiosonde observations available for verification. Twice daily 6h-, 12h-, 18h- and 24h-forecasts on 54km- and 18km-grids have been compared with radiosonde measurements for the scalar variables: temperature and dew point depression. The results are reported in this talk.

## 31. Multi-Model Output Statistical Downscaling Prediction of Precipitation in the Philippines and Thailand

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Multi-model outputs statistical downscaling prediction of precipitation for the stations over the northern Philippines and the Bangkok region are carried out in this research. In order to choose the predictor and its range for downscaling, we used observation data other than model data to make correlation analysis and SVD analysis. The analyses based on the observed data can reveal real atmospheric dynamic linkage between precipitation and the large-scale circulation, and provide robust physical basis for the choice of predictor and its range. For the Philippines and Thailand, Z500 and SLP are selected as predictors, respectively. However, downscaling prediction of precipitation should be specified by predicted large-scale circulation information. Current GCM generally suffers from the systematic bias due to some shift of spatial pattern in prediction. In order to avoid the model bias, a movable window is set to scan over the range to select the most sensible large-scale circulation area for downscaling. The downscaling is carried out at each station for each model in a cross-validation manner. Then two MME predictions are made: one is average of downscaled precipitation from the 6 models: another is that of raw model predicted precipitation. The downscaled MME and raw model MME predictions are verified against observed station precipitation, separately. Downscaled MME achieve apparently better prediction skill than the original one. The results suggest that the predicted large-scale circulation by current GCMs have the potential in predicting station-scale precipitation by means of statistical downscaling method. In this way, we may make operational forecasts with timely collected GCM outputs for some regions, especially for some important cities such as Manila and Bangkok where a large amount of people live. However, statistical downscaling in this study has also limitation for some stations, where precipitation is governed mainly by local complicated terrain other than large-scale process. Further research is needed to use multi-predictor to make downscaling prediction for these stations.

## 32. Use of NWP and EPS Products in support of Location-specific Forecasts

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With NWP models now firmly established as a major forecasting tool, and the increasing use of EPS-based probabilistic information in support of decision-making by forecasters as well as other special users, the challenges in downscaling the model forecasts, normally applicable for a grid area commensurable with the model resolution, to a meaningful location-specific product are by no means trivial. As global models continue to develop along the trend of increasingly high resolution, the ability to optimize the use of the large volume of numerical data and to extract the critical information most wanted by users will ultimately determine how much value can be added to the forecasting and warning services. Through a review of the post-processing techniques used currently at the Hong Kong Observatory (HKO), the importance of transferring such knowledge and skill to other parts of the world where NWP capacity remains limited will be discussed.

The HKO Operational Regional Spectral Model (ORSM), adapted from JMA, has been in operation since 1999. It is configured with a 20-km resolution inner domain and a 60-km resolution outer domain to provide 42-hour and 72-hour forecasts respectively. The 20-km model, one-way nested within the 60-km model, is run in a 3-hour analysis-forecast cycle. The 60-km model has a 6-hour analysis-forecast cycle with boundary data provided by JMA's Global Spectral Model forecasts. In support of location-specific temperature forecasts, the ORSM grid point outputs are calibrated against observation data at specific sites through Kalman filter or linear regression processes. Such calibration is able to reduce the model biases due to factors such as topographical influences and other localized effects. For instance, it has been found that calibration of temperature forecasts at 3-hourly interval can adequately correct biases observed in the diurnal trends. A time-lagged ensemble approach is also applied to the ORSM output to estimate the spread and distribution of temperature and precipitation forecasts, and a composite display in the form of meteograms updated every 3 hours is generated for reference by forecasters. Alerts on the potential threat of heavy rain and thunderstorms are visually displayed through the use of a Combined Rainstorm Warning Panel.

For the meteorological community, ORSM tropical cyclone (TC) forecast guidance has been disseminated to WMO Members through the Global Telecommunication System since 2005. The guidance is issued and updated twice a day based on 00 and 12 UTC model runs whenever a TC is located within the HKO area of responsibility (10-30°N, 105-125°E). Under a RAII pilot project, ORSM also generates city-specific NWP products in the form of forecast time series of selected weather parameters for specified cities. With JMA and KMA also playing the role of NWP product provider, websites have been set up for participating Members to access the respective products through the Internet. As at February 2008, forecast time series for a total of 160 cities are routinely generated at the HKO website for reference and use by the project's participants. To facilitate the recipients to adapt the model outputs for their own specific applications, a software program in the form of a spreadsheet has been developed for users to carry out post-processing and verification of the numerical forecasts.

It has been shown that super-ensemble of global models run at major NWP centres such as ECMWF, JMA, UKMO and NCEP can also provide useful objective forecast guidance. TC consensus track forecasts, based on the equally-weighted average of TC forecast positions derived from global model output routinely received at HKO, have been computed for forecasters' reference on an operational basis in the past few years. Verification statistics indicate that the multi-model consensus tracks generally out-perform the individual models. The super-ensemble technique can be similarly applied to combine the surface temperature forecasts from various models by assigning appropriate weighting to each model member. Again, the technique is found to be superior as the forecasts so derived are found to be in general more accurate than the direct model output (DMO) from individual models.

More recently, Ensemble Prediction Systems (EPS) run at major NWP centres such as ECMWF and JMA have injected probabilistic information into the formulation of location-specific forecasts. For example, a method based on logistic regression has been developed to calibrate the probability of precipitation derived from the EPS. The method has proved to be particularly effective for improving the reliability of the probability forecasts and

reducing the over-forecast bias as evident in the DMO point forecasts. An index-based approach has also been studied to detect extreme events such as heavy rain by comparing the EPS forecast probability distribution against the model climate. Time series of accumulated TC strike probability at specific points, as derived from the JMA EPS TC data, allow decision makers to critically assess the timing of TC passage with respect to the location of interest.

Since 2004, HKO has been operating on a trial basis a Non-hydrostatic Model (NHM) adapted from JMA. The HKO NHM is run at a 5-km horizontal resolution, with 45 levels in the vertical, and over a domain measuring about 600 x 600 $km^2$. It is updated on an hourly basis to provide 12-hour numerical guidance in support of operational forecasting and warning of fast-developing high-impact weather phenomena such as rainstorms. Initial and boundary conditions are obtained from the ORSM, while the cloud-hydrometeor amounts as analyzed by LAPS (Local Analysis and Prediction System first developed by GSD/NOAA) are also utilized for initializing the NHM. Positive impacts are seen in the quantitative precipitation forecasts (QPF), likely to be attributable to the more advanced treatments of cloud and moisture processes in the NHM. NHM QPF guidance is also blended with the HKO nowcasting system QPF output to provide very-short-range guidance on the chance of precipitation in the next six hours.

Yet despite the significant advances seen in the development of NWP models and related technology, the notion of all meteorological centres running their own NWP models remains a distant target. Even if it is achievable, it is doubtful whether it makes any economical sense for all countries to invest heavily in computing resources for such purposes when equally good, if not better, location-specific forecast information can be derived from global models through the use of well set-out post-processing techniques. This in turns means that if major NWP centres can provide numerical data at the full resolution from their sophisticated models for subscribed users, smaller centres can then feed off those data in setting up their own specific applications. The problem then becomes a matter of capacity-building in the cultivation and use of post-processing skills, likely to be a more surmountable challenge for meteorological services in the developing and least-developed countries.

Already, we are seeing movement in that direction through the RA II pilot project on NWP city-specific forecasts. Further extension of the project in both scope and depth would certainly lead to more wide-ranging and far-reaching benefits for NMHSs lacking the essential computational resources to benefit from the ever-improving NWP technology. There are several possibilities in taking the project forward to the next phase. Firstly, we can explore the feasibility of issuing objective guidance messages to alert NMHSs of potential hazardous weather conditions based on pre-determined criteria and NWP outputs, using colour highlights, visual icons or other forms of graphical display. These can be generated through the adoption of warning thresholds for different weather elements, specified by participating Members and pre-set with respect to local climatology and other risk assessment considerations relating to specific weather hazards. Secondly, the merits of developing some kind of multi-model or time-lagged super-ensemble based on the output generated by the contributing NWP product providers can also be examined. The objectives here are to establish a more robust consensus forecast methodology for deterministic applications, as well as to inject probabilistic information into the forecasts for more effective decision-making processes. The deliverable can be in the form of a portable and easy-to-use software that ingests the relevant numerical data in a readily digestible format and carries out the computation to generate the ensemble output. Finally, especially to facilitate a user-friendly implementation of the aforementioned possibilities, the creation of a centralized portal for easy access and navigation among the products originating from various NWP sources may also become necessary.

For NMHSs with some NWP capacity to operate or experiment with limited area models in support of their own short-range forecasting systems or other specialized applications, consideration should be given to the provision of quality analyzed fields from global models run by the major NWP centres. As the data assimilation systems become increasingly complex and computationally intensive, this will help to ensure that the initial conditions are adequately represented in the simulation process. As such, a short-cut in this direction is likely to bring benefits in promoting a wider use of NWP techniques. The initiative can be implemented as a bilateral collaborative effort between major NWP centres and participating NMHSs, with the latter in return committing to the provision of local observations to ensure and enhance the quality of the analyzed fields. A positive feedback will create a win-win situation in which the major NWP centres have the assurance of ready access to reliable sources of local

observations to complement the synoptic observations and remote sensing information such as satellite data; whereas the NMHSs, through the active use and innovative application of NWP techniques, will actually have visible forecast deliverables to justify the input of resources into the development and maintenance of local observation networks.

## 33. Predictability of Tropical Circulation Examined by Breeding of Growing Mode (BGM) Method for JMA Ensemble Prediction System

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The tropical intraseasonal oscillation (Madden-Julian Oscillation: MJO), which has a period of 30-60 days and is associated with eastward propagating anomalous convective activity around the globe, dominates the tropical atmospheric circulation in the troposphere. In this study, we examine the predictability of the MJO using the operational 1-month ensemble prediction system of the Japan Meteorological Agency (JMA). For this purpose, we obtain initial perturbations, which are appropriate to assess the predictability of the atmospheric circulation in the tropics, by modifying the Breeding of Growing Mode (BGM) method of the JMA 1-month ensemble prediction system during 10 years from April 1996 to February 2006. The predictability of the atmospheric circulation is evaluated by the growth rate of the obtained first bred vector, corresponding to the most unstable mode.

First, it is found that the average growth rate of the first bred vector is around 0.1 $day^{-1}$ corresponding to an e-folding time of 10 days. Thus, the tropical circulation is unstable to the initial perturbations, consistent with Chikamoto et al. (2007). Second, the dependence of the first bred vector on the amplitude and the phase of the MJO is examined. As a result, we find that the growth rate of the first bred vector is almost independent of the amplitude of the MJO consistent with the result of Boer (1995) while it significantly depends on the phase of the MJO as shown by Jones et al. (2000) and Waliser et al. (2003): the growth rate of the first bred vector becomes significantly smaller when the active convective region associated with the MJO resides over the Indian Ocean and the western Pacific. Thus, our result indicates that the predictability of the tropical circulation significantly depends on the phase of the MJO. Third, a clear seasonal dependence of the obtained first bred vector is revealed: the growth rate for the boreal summer is significantly larger than that for the boreal winter: zonal wavenumber 1 components propagating eastward dominate the first bred vector during the boreal winter as shown by Chikamoto et al. (2007) while in the boreal summer standing wave components become distinct in the horizontal structure of the perturbation.

## 34. Properties of Ensemble Perturbations Evolving in an Atmospheric General Circulation Model

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The properties of atmospheric perturbations evolving in the flow fields have been investigated by conducting a preliminary numerical experiment of breeding of growing modes (BGM; Toth and Kalnay, 1997) with an atmospheric general circulation model (AGCM), known as AFES (AGCM for the Earth Simulator: Ohfuchi et al. 2004) at a relatively high-resolution of T159/L48. The control run of the BGM experiment is a three month hindcast integration of AFES under the observed sea surface temperature and sea ice distribution from 1 January 2006 with a certain initial condition, and the growing modes are bred around the control run for one month from 1 March. Twelve BGM experiments are performed by changing the value of two BGM parameters; one is the time interval of breeding cycle, which is set to 6 hours, 12 hours, or 24 hours, and the other is the rescaling size of

growing mode at breeding cycle, which is set to 0.5 $ms^{-1}$, 1 $ms^{-1}$, 2 $ms^{-1}$, or 4 $ms^{-1}$ evaluated in the total energy norm.

The exponential growth rate of the first growing mode, namely the first Lyapunov exponent, estimated from the BGM experiments shows a tendency to increase with smaller rescaling size and shorter time interval of breeding cycle, which signifies the non-linearity of the perturbation growth in the BGM experiments. The growing mode with the largest growth rate of 0.8 $day^{-1}$ that is obtained in the case of 6 hour breeding cycle and 0.5 $ms^{-1}$ rescaling size has a large moist energy in the tropical lower troposphere which is considered to be related to the convective instability with cloud formation. The growing mode with smaller growth rate of 3 $day^{-1}$ that is obtained in the case of 6 hour breeding cycle and 4 $ms^{-1}$ rescaling size has a large kinetic and thermal energy in the extra-tropical upper troposphere which is considered to be related to the baroclinic instability. These results imply that the rapidly growing local mode, such as convective instability, has a limitation on how much energy it stores, and that it is to be saturated in the perturbation bred with a larger energy, resulting in the dominance of larger scale instability mode that is less unstable but can store more energy.

## 35. The Meteorological Natural Disasters Warning System of Thailand

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In present, it clearly has been happening that the situation of climate change has been strongly affected to human life and properties of the people in Southeast Asia. Therefore, Thailand where is also located in these disaster prone areas needs to establish the meteorological natural disasters warning system throughout country to relief and mitigate the damage of people in our risky areas. This natural disasters warning system is consisted of the seismic and tsunami early warning network firstly, which has been finished the installations of its 15 automatic seismic stations in the year 2006 with twenty five more automatic stations are under implementation and the whole project will be completed in 2008. TMD is confident that our seismic network will play the instrumental role in the early warning of not only Thailand but also the Tsunami vulnerable countries.

Secondly, the multi-hazard warning tower, as a result of the tragedies due to the 26 December 2004 Tsunami Event, which brought lots of damages and claimed more than 70.000 lives of people living in the coastal areas of the Indian Ocean. Consequently, 76 warning towers have been constructed primarily in 6 provinces directly affected by the Tsunami. However, to be able to cost-effectively use and cover all types of natural disasters, including torrential rain, flash floods, and landslide etc. apart from Tsunami and earthquake, TMD has constructed 48 more warning towers in the disasters prone areas of the country. Totally there are 124 multi-hazard warning towers in Natural Disasters Warning System of Thailand. In the future, 268 warning towers will be put in our network to cover the whole areas at risk of the country.

Thirdly, the tidal gauges network, to support Tsunami warning system, 9 tidal gauges have been set up in the Andaman Sea of the Southern part of Thailand. To enhance the capability of Tsunami Warning System and to be able to obtain more tidal information, additional 9 tidal gauges will be completely set up by the end of 2008. With the coverage of the tidal gauges, TMD assures that the tidal wave monitoring will be the beneficial information of our National Tsunami Warning System.

Fourthly, the DART Buoy, the government of Thailand in the cooperation with the government of the United State (NOAA/USAID) deployed its first DART buoy on 1 December 2007 to detect the Tsunami Wave/ information in the Indian Ocean. The location of the DART is at Lat. 9.0 $^{0}$N. Lon. 89.0$^{0}$E. The information will be analyzed at the NOAA before dissemination via internet to countries located in the Indian Ocean Region.

Fifthly, the Tele-metering Network, TMD has implemented tele-metering system project for flood forecasting and warning in the 12 selected river basins out of 25 river basins in Thailand since 1999. The project has been designed to install 161 automatic observing stations comprising 125 automatic rainfall stations and 36 hydrometeorological stations in the 12 selected basins. All stations transmit every 15 minutes the observing data directly to TMD headquarters in Bangkok mostly by GPRS, some by leased line, satellite and radio system. And

also, the on–going project is to replace volunteer rainfall stations in northern Thailand with 110 tele-metering stations. It is expected to complete its installation by 2007. Data from the stations will be incorporated into the existing tele-metering network to do flood monitoring and warning in the critical flood-risk areas. In addition, the future plan is to replace the 820 remaining volunteer rainfall stations over Thailand by tele-metering stations by the end of 2008. Totally 930 stations will be replaced with automatic stations over the country.

Lastly, the radar network is to closely monitor rainfall pattern, cloud movement, and its intensity to cover the remote areas of the country. 3 more C-band Doppler radars have been added to the TMD's Radar Network, raising its total number of radars to 23, apart from 2 portable radars and 1 mobile radar that will be operating at the request of local authority in the vulnerable area. With the potential of the disasters supporting systems mentioned above. TMD assures that our implemented networks will strengthen the national disaster warning of the country completely.

## 36. Our Endangered Coastal Ecosystems: - an Eco-climatic and Risk Analysis using GIS and Remote Sensing -

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Coastal ecosystems are those tremendously diversified and extremely active ecosystems spanning over the global *coastal zone*. This coastal zone is itself a fuzzy concept meant to define the portion of the earth that encompasses the *coastal ocean* (the shallow area of the global ocean where land, ocean and atmosphere physically, biologically and biogeochemically interact) and the portion of lands adjacent to the coast (*backshore*), including the intertidal zone (*foreshore*). Notwithstanding its relatively modest surface area (about $26 \times 10^6$ km$^2$ in total), the coastal zone is known to play a very important role in the global flow of matter and energy: (i) a highly determinant role in the biogeochemical cycles of all the land-derived materials entering the sea through surface runoff or groundwater flow, (ii) most of the geochemical and biological activities in the biosphere happen here via coastal metabolism: 15% of the oceanic primary production, 80% of organic matter burial, 90% of sedimentary mineralization, etc.... (iii) an overall economic value estimated at 40% of the world's ecosystem service value and natural capital, and (iv) an ever increasing part of human population (up to 40% nowadays) living within 100 km distance from the coast, bringing in deep changes to the shape and contents of the ecosystem itself as a whole. Estuaries, intertidal flats, mangroves forests, lagoons and salt ponds, seagrass, rocks and sand beaches, coral reefs, the continental shelf as well as our scenic shoreline cities, ports and resort beaches are all parts of this rich ecosystem.

However, coastal ecosystems are enduring nowadays deep, and most often irreversible, sudden or progressive, changes due to both natural and human activities-related causes. Floods and inundations due to typhoons, heavy rains or tsunamis, sea level rise due to the global warming, land claiming and waterfronts developments, extreme coastal urbanization, land and sea water pollution due to human activities, or any combination of these elements, are among the main risks the coastal ecosystems, and therefore the people depending on them, are facing now, on both the local, regional and global scales.

In our work, GIS and remote-sensing are used as tools for assessing the risks to this ecosystem, based on climatic and ecological change analysis. From these findings, ways and means for mitigation and prevention are devised for proposal to the stakeholders (decision makers and local population). We think that using downscaled NWP output data will help us to better predict future climatic changes that will be used as new inputs for more appropriate mitigation and prevention scenarios. Some case studies using Mie Prefecture data (satellite-derived land use land cover maps, DEM data, air photos, and other statistical and climatic data) will be presented and discussed.

## 37. Integration Data and Applied Geographic Information System (GIS) Management for Landslide at Amphure Pai, Mae Hong Son

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Natural disasters as tropical cyclone, earth quake, flash flood, flood, droughts and landslide are dangerous for life, property and economics of Thailand in every year. Landslide is one of the natural disaster that makes the most destroy. Besides, parameters that cause land slide are heavy rain and the change of landuse every year due to the forest area has been changed to agriculture filed. Therefore, landslide occurred from characteristic of geology, meteorology and landuse. The technique used weighted factors index by fix parameters that consider factors. The first is climate factor as accumulated rain. The second is physical factor as slope topography, characteristic landuse, characteristic mineral and soil. Results showed higher resolution of risk area map through villages that composed of five category risk area as follows: very strong risk area, strong risk area, moderate risk area, weak risk area and very weak risk area. The technology applied geographic information system (GIS) used to landslide management. The technique can respond to the faster events of landslide, and it can fixed area of landslide with plot Amphure Pai, Mae Hong Son through villages in output of risk area map. Therefore, it can used to preparing and reduce of life and property from landslide.

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## 38. Database and data-analysis infrastructure for atmospheric studies

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Research Institute for Sustainable Humanosphere
Kyoto University

In this talk, I will first overview topics related to software infrastructure for the analysis and visualization of numerical atmospheric data. A particular emphasis will be made on open-source libraries in the object-oriented programming language Ruby. Object-oriented languages are suitable to create flexible, multi-purpose, and reusable libraries to handle atmospheric data of a wide variety (in terms of formats and dimensionality) in a consolidated way. Therefore, if properly done, we can create infrastructure for science communities. Recently, a number of atmospheric scientists have been working with Ruby, and their products are being accumulated on the GFD Dennou-Club servers for open access.

I will second talk on the ongoing effort to develop a web-based database and visualization/analysis tool named Gfdnavi. It is based on the Ruby libraries mentioned above, relational databases, and the web development framework Ruby on Rails. With Gfdnavi, one can create database of his/her data and analyze/visualize them with web browsers. It is also suitable to share data and the knowledge obtained from the data among research groups and/or further to run public-access data servers. Gfdnavi will be used in this international cooperative research project (to be presented by S. Nishizawa).

# 39. Development of Ultra-High Resolution Numerical Model

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## 1. Introduction

One of the problems of high-resolution simulations is the representation of topography. The commonly used terrain following representation of topography induces large truncation errors over steep slopes. Here, we propose an modified version of "shaved cell" method where small cells are combined to upper cells to keep the volume of cells larger than a half of regular shaped cells. Flux form equations are well suited to the finite volume method in the view of conservation characteristics. Quasi-flux form fully compressible dynamical equations are employed. The combination of the shaved cell method and the quasi-flux form equation is expected to achieve high-resolution and highly-precise simulations over complex terrain. Here, the results of two-dimensional numerical simulations of flow over a bell-shaped mountain and a semi-circular mountain by the developed model will be presented.

## 2. Result

Results of two-dimensional numerical simulations of flow over a bell-shaped mountain and a semi-circular mountain are presented. The constant horizontal velocity, $U = 10$ m s$^{-1}$, is imposed initially in the whole domain. The maximum surface height of the bell-shaped mountain is 100 m and the half width is 5 km. The horizontal resolution is 1 km and the vertical resolution is 50 m. Figures 1a and 1b show vertical velocity fields over the bell-shaped mountain calculated by the model using the modified shaved cell method and by the terrain following model, respectively. The vertical velocity calculated by the model agrees well with that by the terrain following model. The momentum flux in the model normalized by that in the linear theory is shown in Figure 1c. It is nearly unity and thus it agrees well with that of the linear theoretical value.

The radius of the semi-circular mountain is 1 km. Figures 2a and 2b show vertical velocity fields in case of the semi-circular mountain calculated by the model using the modified shaved cell method and the model using the terrain following coordinate, respectively. The modified shaved cell model reproduce more smooth mountain waves than that reproduced by the terrain following model. Therefore it is concluded that the dynamics and the topography representation of the method proposed in this study are appropriate and sufficiently accurate for simulations of flow over complex terrain.

## 3. Summary

The modified shaved cell method for the $z$-coordinate topographic representation was proposed and implemented in the non-hydrostatic atmospheric model to achieve high-resolution and highly-precise simulations over topography. The solutions of flow over the bell-shaped mountain and the semi-circular mountain show that the method reproduces smooth and accurate mountain waves over gentle and also steep slopes. Since the $z$-coordinate representations do not suffer from truncation errors due to the steepness of slopes, they suit to high-resolution simulations where steep slopes may appear in models.

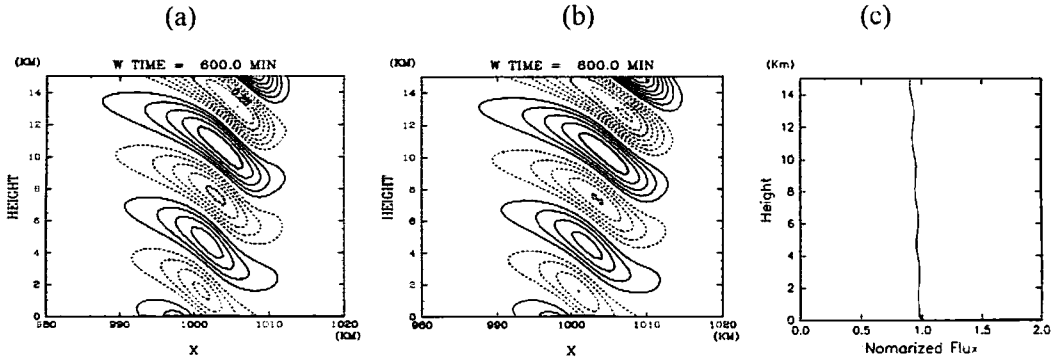


Figure 1. Vertical velocity and momentum flux over the bell-shaped mountain after 600 minutes integration. (a) Vertical velocity reproduced by the vertically combined shaved cell model, (b) vertical velocity in the terrain following model, and (c) normalized momentum flux by the vertically combined shaved cell model. The contour

interval in (a) and (b) is 0.05 m $s^{-1}$. Solid and dashed lines indicate positive and negative values. respectively

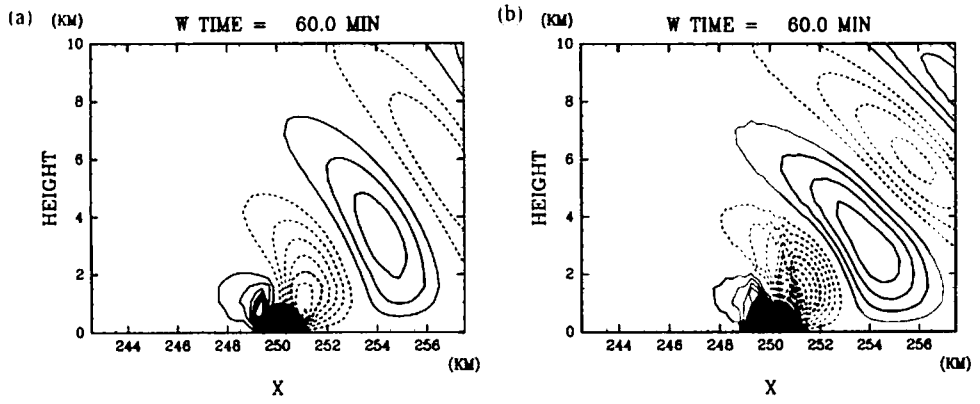


Figure 2. Vertical velocity over the semi-circular mountain after 100 minutes integration by (a) the vertically combined shaved cell model, and (b) the terrain following model. The contour interval is 1 m $s^{-1}$. Solid and dashed lines indicate positive and negative values. respectively.

## 40. Study of Diurnal Patterns of Convection in Sumatra Island Using Weather Research and Forecasting-Advanced Research WRF (WRF-ARW) Model

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Institut Teknologi Bandung

The diurnal patterns of convection over Sumatra Island have been investigated from geostationary satellite data (GMS 5, GOES 9 and MT-SAT) at infrared channel (IR1) and numerical weather prediction model simulations. The Weather Research and Forecasting-Advanced Research WRF (WRF-ARW) developed and maintained by the Mesoscale and Microscale Meteorology Division of NCAR, which consist of Euler non-hydrostatic and fully compressible set of equation. has been used in the numerical simulation. Both initial and boundary condition for the simulations are taken from Global Tropospheric Analysis data operated by NCEP.

From the satellite data, four periods of different convection scales over Sumatra Island has been identified based on Outgoing Longwave Radiation (OLR) data. Cloud top temperature composites (derived from IR1 images) from 2002-2006 suggest that there are temporal and spatial shifts for each convection scale, particularly for the phase of convection peak over land. The spatial shifts seem to indicate the important role of small islands along the western part of Sumatra Island. Moreover, the detailed daily convective activities over Sumatra Island show stronger random pattern.

The numerical model simulations have been used to investigate diurnal patterns of convection for several days in November 2006 during the period of large-scale convection. The model output consistency test has been carried out to choose the best combination of parameterizations in this study. From several experiments, it is found that a combination involving WSM6 microphysics and MRF planetary boundary layer parameterization give the best result. Using this combination, the model successfully simulated diurnal convection peak over the land, which was indicated by correlation coefficient of cloud top temperature over 0.6. However, the peak phase over the sea has not been yet well simulated. Further investigation show that the local data (radiosonde) availability affects the model performance. These results indicate that the model is capable to take effects of complex topography of Sumatra Island into account but further study is needed to overcome the weakness of the model in simulating the convective phase in the sea.

## 41. Numerical experiments on vertically fine structures of water vapor in the tropics

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We performed numerical experiments on vertically fine structures of water vapor in the tropics. In the tropics, water vapor is one of the most important materials to determine climatological structure of the atmosphere through cumulus convections and radiative heating. Upper air soundings often tell us vertically fine structures of water vapor distribution, with those vertical scales ranging from several meters to several kilometers. But time-spatial distribution of vertically fine structures is not well-understood. especially over the tropical eastern Pacific.

We performed numerical experiments to reproduce thin and moist layers in the tropical mid-troposphere to describe time-spatial variation. We used NCAR/PSU mesoscale model (MM5). NCEP Final Analyses (FNL) is used for initial and boundary conditions. We performed 3-day integrations with 1-day overlapping to make 2-year dataset from January 2005 to December 2006. discarding the initial 1-day of each run.

The occurrence ratio of the layers in the model is shown in fig. 1. Annual cycle is the most prominent, due to the seasonal cycle of the intertropical convergence zone in the eastern Pacific region. In boreal winter. thin and moist layers are abundant. especially between 5 and 12 km in altitude. On the other hand. the occurrence ratio of the thin and moist layers is at its minimum in boreal summer. having local maxima at 5 km and 10 km in altitude.

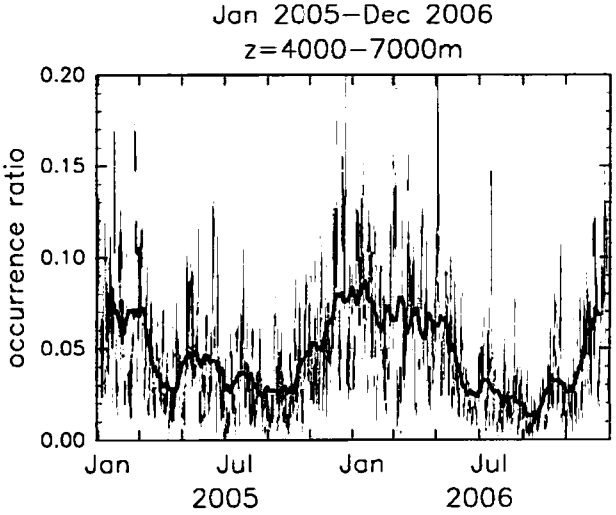


Fig. 1: The occurrence ratio of the moist layers between 4 and 7 km in altitude for two years, obtained in the model. The thick line shows 30-day running mean.

## 42. Dependency of the Tropical Convective Clouds on the Sea Surface Temperature Simulated by a High-Resolution Coupled Model

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The western tropical Pacific is a hot ocean where sea surface temperature (SST) is over 29 degree and often called as warm water pool (WWP). In the WWP region, vigorous convective clouds lead by the evaporation bring strong coupling between atmosphere and ocean. It is well known that the activities of the tropical convective clouds are depends on the SST, that is. the convective activities rise up in the region where SST is over 29 degree (Hirst, 1986). The mechanism of a suddenly increase of the convective activities is still unclear, although it is suggested to be associated with the nonlinearity of the saturated vapor pressure to the temperature.

In this study. the dependency of the convective activity on SST is examined using a regional high-resolution atmosphere-ocean coupled model (Ishikawa and Satomura, 2008) developed in Kyoto University. This model consists of a 3-dimensional non-hydrostatic cloud resolving model (Satomura, 1989) and upper ocean model (Ishikawa et al.. 2007). The horizontal resolution of the model is 1km for both atmospheric part and ocean part and

size of the model region is 500km x 100km. The number of the vertical levels for atmospheric part is 58 with the resolution of 50m in surface. The vertical resolution of the ocean is 0.5m for upper 100m. The vertical profiles derived from TOGA-COARE observation by Keifu-Maru are used for atmospheric initial condition. To examine the SST dependency of the activities of the convective clouds. 4 experiments are carried out, in which uniform temperature over 100m are changed from 27 degree to 30 degree as the initial condition of the ocean.

The result of the experiments shows distinct difference between the case over 29 degree and under 28 degree in the activity of the convective clouds due to the difference in the evaporation, as shown in Fig. 1. The distinctive feature of SST variability is that the SST difference increase through the experiment (Fig 2), that is, regional mean SST decrease about 1 degree at the end of the 5 day experiment in the low SST cases. although it does not decrease so much (0.1 degree / 5day) in high SST cases. Although these features might be curious at a glance, they can be explained considering the ocean mixed layer processes. In these processes, salinity field plays critical roles to form a thin mixed layer (about 5 m) associated with precipitations in the low SST cases. The thin mixed layer restricts the heat contents and SST decreases fast. On the other hand, in the high SST case, the amount of evaporation is large enough to prevent the formation of thin mixed layer and SST does not decrease so much.

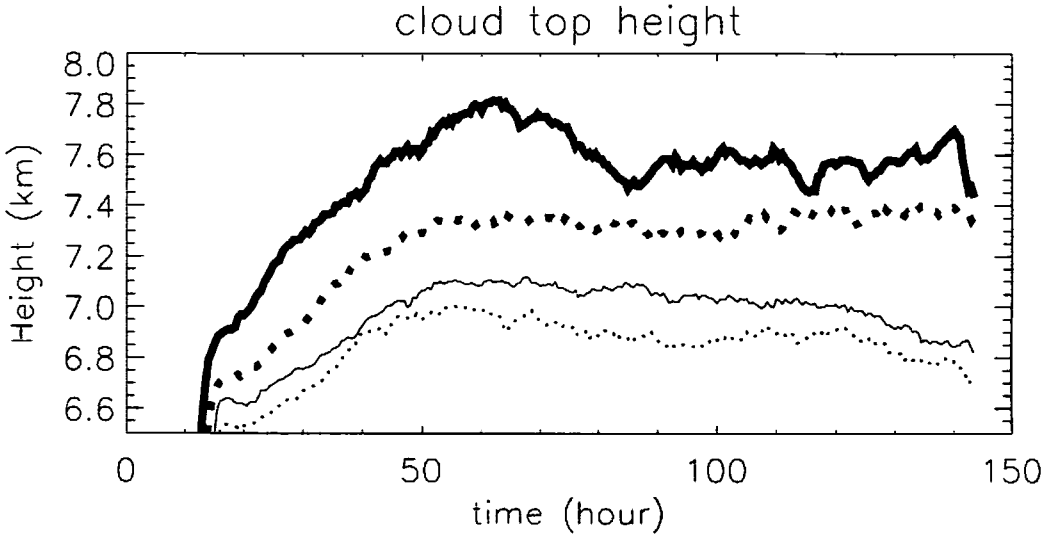


Figure 1: 25 hour running mean of the highest cloud top height. Thin dot line, thin solid line, thick dot line, thick solid line is for 27, 28, 29, 30 degree case.

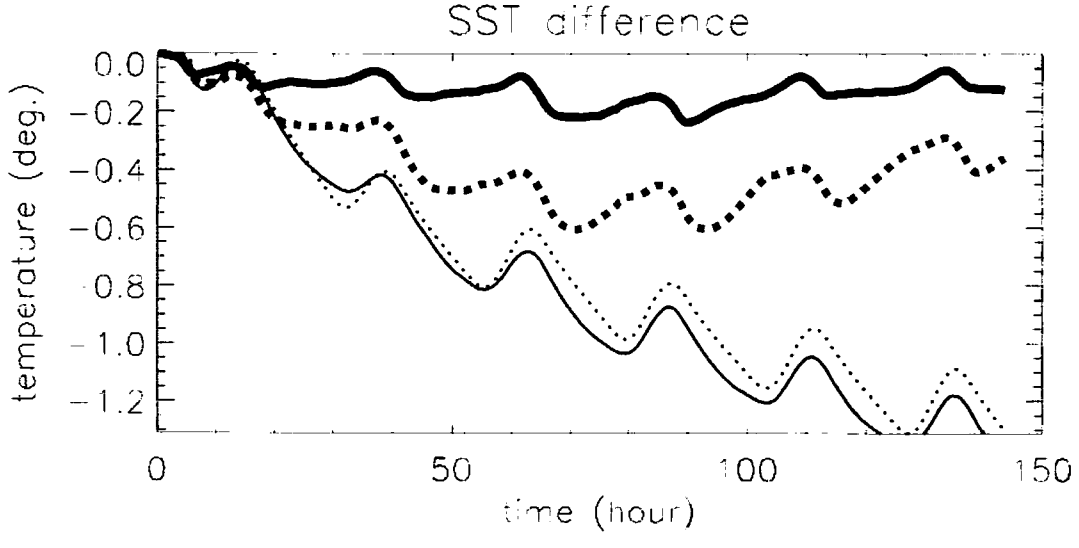


Figure 2: Same as Fig.1, but for SST difference from each intial condition averaged over the model domain.

# 43. Environmental Stability Control of the Precipitation Structure and Intensity within Mesoscale Convective Systems

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The environment for the development and evolution of precipitating convective systems is diverse for their existence under various climatic conditions ranging from the Tropics to the midlatitude regions and further to the arid and semi-arid regions. Understanding the precipitation structure and intensity associated with the mesoscale convective systems is vital from a diagnosing and forecasting point of view, since such precipitating systems occasionally spawn severe winds, heavy rainfall, and flush flooding that damage human lives and social infrastructure. Especially in the monsoon Asian regions, severe precipitation events frequently occur and in some instances lead to devastating disasters each year.

In addition, the meteorological environments in future global-warming climates will affect the behavior of mesoscale convective systems and hence the precipitation structure and intensity. Projection of future precipitation features is of great concern not only from a scientific point of view but also from a social and political standpoint.

One of key parameters that would clearly characterize the various climates on Earth and the future global-warming conditions is temperature, that is, static stability or temperature lapse rate. In order to understand the fundamental dynamics and mechanisms of precipitation behavior under various temperature environments, the present study investigates numerically the effects of environmental temperature lapse rate on the precipitation structure and intensity within mesoscale convective systems. We conduct systematically a large number of idealized simulations of the precipitating systems that develop under low-level shear conditions using the Advanced Research Weather Research and Forecasting (WRF-ARW) model that has been developed primarily by National Center for Atmospheric Research (NCAR) through collaborative efforts among the United States research community (Skamarock et al. 2005). The numerical experiments are setup in horizontally uniform base states with no Coriolis force, no surface friction, no land-surface physics, and no radiation, which capture the basic environmental characteristics for mesoscale convective systems. The temperature lapse rates are controlled by changing the tropopause temperature but maintaining the surface temperature. In order to conduct convection-resolving simulations, the horizontal grid spacing is set to 500 m. The total number of the numerical experiments is 26 by changing the temperature and shear profiles.

Changing the temperature lapse rate with convective available potential energy (CAPE) being unchanged, we showed that the environmental stability in a convectively unstable layer well delineates the intensity of the simulated precipitating systems. A less stable stability (i.e., cold environment) is favorable for generating stronger precipitating systems. The amount of CAPE does not account for the difference in the precipitation intensity in different temperature environments. An environment with a less static stability leads to the development of stronger cold pool, which will strongly controls the scale and strength of convective updrafts, the intensity of tropospheric overturning, and thus the precipitation structure and intensity. It was found that the lapse rate has a contrasting impact on accumulated precipitation and instantaneous precipitation intensity: a more stable environment (i.e., warm condition) is favorable for producing larger intensity of precipitation.

It has long been argued that CAPE can be a parameter that diagnoses the development and strength of convective storms and systems. The present sensitivity analysis clearly indicates that the amount of CAPE can only be a good measure for diagnosing the intensity of precipitating convective systems so long as the environmental lapse rate is identical.

The present study strongly suggests that the first thing we should do in order to diagnose the organization and strength of precipitating convective systems is to examine the environmental temperature lapse rate, that is, the static stability, in a convectively unstable layer. Then other parameters such as CAPE, precipitable water, moisture content in the low levels and in the middle levels as well, and other standard stability indices are to be consulted. Since the temperature lapse rate in a specific region generally depends on the climatological and geographical features of the region, the intensity of the convective systems that develop in a region of interest is critically

influenced by its climate. In comparing the features of convective systems in various climate regions, one should take into account the climatological features of the temperature environment. The static stability is a controlling parameter in determining the precipitation structure and intensity within the mesoscale convective systems. The present results should give insights into the characteristics of the convective precipitation under future climates.

This study is based on the recent publications of the present author (Takemi 2007a, b).

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## VI. 学会等における口頭・ポスター発表

| 発表した成果（発表題目、口頭・ポスター発表の別） | 発表者氏名 | 発表した場所（学会等名） | 発表した時期 | 国内・外の別 |
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