出國報告（出國類別：研究）

研習空氣品質模式預報與模擬

服務機關：行政院環境保護署
姓名職稱：游智淵技士
派赴國家：美國
出國期間：100 年 8 月 14 日至 8 月 20 日
報告日期：100 年 11 月 15 日

摘要

前往美國海洋大氣總署(National Oceanic and Atmospheric Administration, NOAA)研習空氣品質模式預報與經驗交流，研習重點包括：汲取美國空氣品質預報作業技術及經驗，過程中，NOAA 也提供更多即時衛星觀測及模式模擬數據，供本署預報作業之參考。本次研習與國家環境預測中心(National Centers for Environmental Prediction, NCEP)人員分享本署沙塵預報作業，其對本署沙塵預報作業有很高之評價，NOAA 尚未有因應沙塵之標準作業程序，也希望與本署做進一步交流。本次研習對本署空氣品質預報作業有三項助益，一是未來環資部可考慮由氣象預報單位，統籌辦理氣象及空氣品質預報；二是將參考 NCEP 之預報驗證經驗，嘗試於本署預報作業增列驗證程序，期使預報能更加準確；三是已與 NCEP 人員建立交流窗口，可透過網路獲得衛星觀測及模擬數據，作為本署空氣品質預報之參考。

目錄

壹、 目的及背景說明

我國環保署目前每天執行空氣品質預報，全年無休公布預報資訊供民眾參考。為精進本署空氣品質預報作業，需借鏡國外預報經驗及作法，以提升預報能力。由於美國海洋大氣總署(National Oceanic and Atmospheric Administration, NOAA)在空氣品質預報有多年經驗，爰派員赴 NOAA 研習及交流空氣品質預報技術。

NOAA 主要關注地球的大氣和海洋變化，提供對災害天氣的預警，提供海圖和空圖，管理對海洋和沿海資源的利用和保護，研究如何改善對環境的了解和防護。美國區域性氣象及空氣品質預報，主要由 NOAA 進行，涉及團隊包括大氣資源研究室(Air Resources Library, ARL)、國家環境預測中心(National Centers for Environmental Prediction, NCEP)等，分別負責模式之研發改良、模式測試驗證與預報系統維護執行等。NOAA 於數年前才開始接手空氣品質預報模式業務，故與其他單位仍有業務重疊之處，仍待統整，此點與國內相似，惟其預報分組相當完整且即時互相交換及討論，此項為我國目前較欠缺之處。國內現行預報作業，分由氣象局執行氣象預報、環保署執行空氣品質預報，環保署限於人力不足，在空氣品質預報發展上，有相當限制。

鑑於 NOAA 在海洋、大氣、空氣品質等預報及監測上有長程發展及經驗，更具備全球最先進技術，本次研習目的及重點包括汲取美國空氣品質預報作業技術及經驗，過程爭也不斷將我國目前預報作法及面臨之瓶頸與 NCEP 人員討論及學習，期能藉此研習，擴展及精進我國空氣品質預報，提供民眾更適時預報資訊。

貳、 研習過程

本次前往美國海洋大氣總署(NOAA)研習空氣品質模式預報與經驗交流（行程如表 1），研習重點包括：汲取美國空氣品質預報作業技術及經驗，過程中，NOAA 也提供更多即時衛星觀測及模式模擬數據，供本署預報作業之參考。本次研習與 NCEP 人員分享本署沙塵預報作業，其對本署沙塵預報作業有很高之評價，NOAA 尚未有因應沙塵之標準作業程序，也希望與本署做進一步交流。出

國行程如表 1 所示。

一、8 月 14 日由台北前往美國華盛頓特區(NOAA) ：

8 月 14 日下午抵達美國，美國海關安檢相當謹慎， 直至晚上才到達美國華盛頓特區。先與接待人員見面討論接下來研習及交流議程，第一天先了解 NOAA 空氣品質預報基本運作及流程，再與 NCEP（如圖 1）各預報小組成員進行三天討論（議程詳附錄一）。

二、空氣品質預報需整合及分工

NOAA 主要提供空氣品質預報數據，供各單位發布預報及管制之依據，其 NCEP 負責預報操作及管理，並即時回饋給美國環保署(EPA)、模式研發單位(ARL)及各州政府（圖 2）；我國則是由本署一手包辦，很難落實中央與地方分工合作精神。未來環資部可考慮由氣象預報單位，統籌辦理氣象及空氣品質預報，應能更有效提升預報準確度。第一天的參訪主要是了解美國空氣品質預報的運作（接觸人員如圖 3 及附錄二），如附錄二所示，其預報有一小組成員約 8 人，分為操作、前處理驗證、模式模擬及後處理驗證四項。因美國幅員廣大，必須先模擬全球尺度的空氣品質，再將其模擬結果做為區域性空氣品質模式的輸入資料，進而模擬美國各區域空氣品質，我國則是用區域性的空氣品質模式預報空氣品質。而 NOAA 也針對不同污染物使用不同模式，包含沙塵、臭氧、細懸浮微粒及區域性氣膠等模式；美國雖由 NOAA 主司空氣品質預報，但僅提供預報數據給各個州政府，各州政府再參考 NOAA 預報結果發布預報，NOAA 較不涉及業務導向工作，主要是專注於研究及技術的提升，以提供預報資訊給業務單位於適當時間發布預報。NOAA 也同時與美國環境保護署(EPA)及各州政府保持密切聯繫，當預報誤差較大時，能互相檢討以改善未來預報能力，在此我注意到 NOAA 每天都會做「預報驗證」(Verification)，預報幾次就做幾次驗證，每驗證結果都做為下次預報參考，這是我與各預報人員討論及分享一天後最大的收穫及發現。NOAA 在預報上能分工負責確實且能

相互檢討，以改進或提升預報結果，這也是我第一天先行了解整體預報架構及作法。

三、我國預報作法與美國討論及交流

NOAA 空氣品質預報負責人 Jeff McQueen 對中國大陸沙塵事件很感興趣。第三天除了分享空氣品質預報作法，同時也介紹我國沙塵預警作業，簡單來說我國對沙塵暴分成預警及因應兩部分，有模式模擬及監測資料提供應變，而 NOAA 目前並未有相關緊急應變程序，這主要在於我國每年受沙塵影響程度及次數均較美國高。NOAA 預報團隊也分別介紹其預報作法及經驗，整體確認及預報輸出流程需在 6 小時內完成，每天運作 4 次，大部份過程皆已自動化處理，視需要才需預報人員進行人工修正，每天空氣品質預報數據公布 2 次（圖 4），提供州政府等單位做該區域之 AQI 預報（相關參考資料如附錄三）。預報過程包含評估排放源資料是否正確、改良後模式測試、氣象模擬資料驗證、與觀測資料同化及模擬結果與監測資料驗證等步驟。排放源資料由 EPA 提供 NOAA 預報團隊，該團隊再檢核其資料正確性，若有不合理情形則請 EPA 補充或重新提供，此資料為造成預報不確定性之最大因素，我國的預報面臨最大的問題也是在此；接著進行模式測試，測試的目的在於輸入資料及模式程式碼若有更新，必須確保該模式處於正常，不因任何更新何影響模式之預報能力及結果，測試可藉由過去的案例進行模擬，若結果與模式更新前之模擬結果相同，表示模式未因任何修改而影響其預報能力，表示模擬結果無誤（排放源資料的改變會影響模式模擬過程）；接著再與觀測資料同化即可輸出預報之模擬值，最後經驗證後進入下一次的預報。「預報驗證」為每次預報程序中扮演最關鍵角色，若驗證發現預報不確定性高則需立即檢討及改善，否則無法進入下一階段預報（每天執行 4 次預報，公布 2 次），驗證程序主要是以觀測資料驗證模式模擬數據之正確性，包含時間及空間數據的確認。以上程序皆以程式自動化處理，必要時則由人工進行修正。

四、與 NOAA 預報組員討論預報經驗及改善作法

NOAA 預報組員提出維持及提升預報準確度最重要在於「驗證」作業，每

次發現預報失準時應有改進方式及時程，以提供下次預報之基礎。另外 NOAA 預報團隊也提供適合台灣之即時衛星觀測（如圖 5 所示）及模式模擬數據（如圖 6 所示）供我國預報參考（網址: http://www.emc.ncep.noaa.gov/mmb/hchuang/web/html/realtime.fcst.reg.html）。

五、歸納本次研習心得及後續交流方式

這次研習除了學習及分享空氣品質預報作業外，也獲得 NOAA 之觀測及模擬（亞洲區域）數據，其中更是建立彼此後續討論及交流方式(E-MAIL)，空氣品質預報負責人 Jeff McQueen 也期望未來能進一步與我國交流。（照片如圖 7）

參、 心得與建議事項

一、未來環資部可考慮由氣象預報單位，統籌辦理氣象及空氣品質預報。

二、 NCEP 預報流程包括資料來源確認、模擬數據驗證及即時預報檢討等，其預報數據先經系統及客觀評估，且須通過驗證程序才能發布，數據發布後立即做分析及修正，提供下次預報參考。其中即時預報檢討及修正為預報準確率提升之關鍵。

三、 本次研習與 NCEP 人員建立交流窗口，可透過網路(http://www.emc.ncep.noaa.gov/mmb/hchuang/web/html/realtime.fcst.reg.html)獲得衛星觀測及模擬數據，作為本署空氣品質預報之參考。

表 1 出國行程表

8 月 14 日	台北前往美國華盛頓特區(NOAA)
8 月 15 日	了解 NOAA/NCEP 空氣品質預報作業流程
8 月 16 日	台灣空氣品質及沙塵預報作業簡介，與 NOAA/NCEP 預報人員相互討論
8 月 17 日	NOAA/NCEP 分享預報經驗，並提供適合台灣之即時衛星觀測及模式模擬數據
8 月 18 日	與 NOAA/NCEP 分享研習心得及經驗
8 月 19 日-8 月 20 日	美國華盛頓特區(NOAA)返回台灣

圖 1　NOAA 之 NCEP

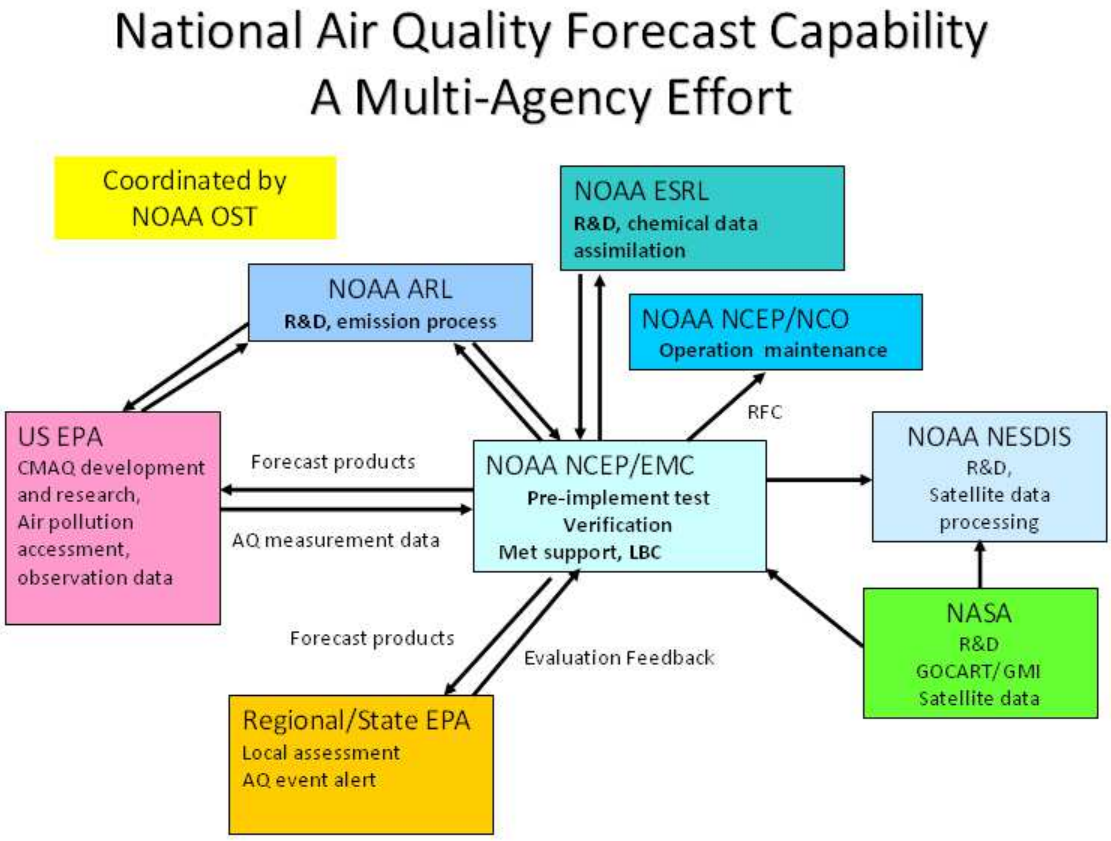


圖 2　NOAA 預報與其他單位分工情形

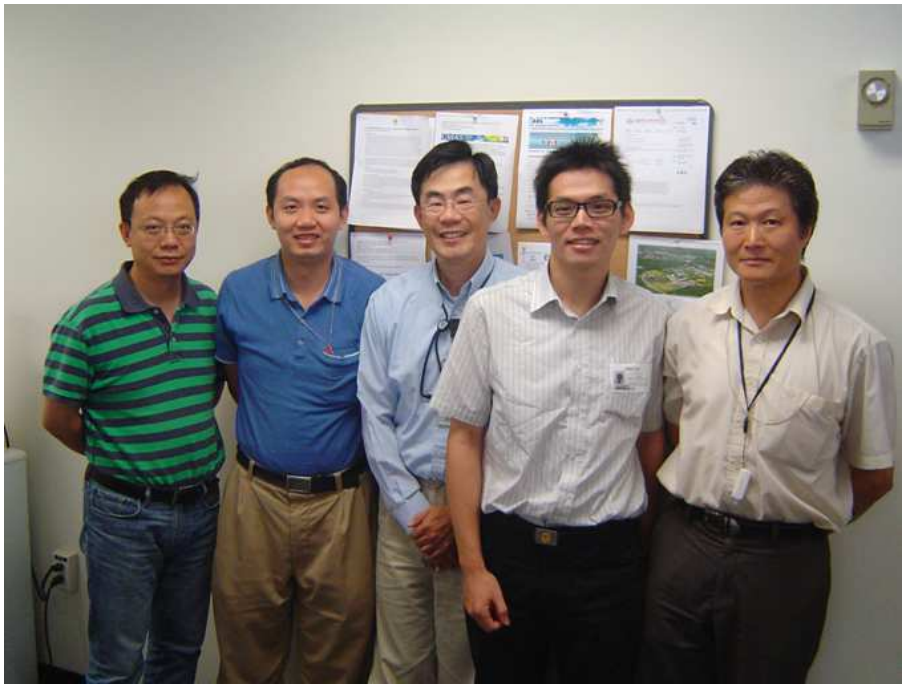


圖 3　與預報小組合影

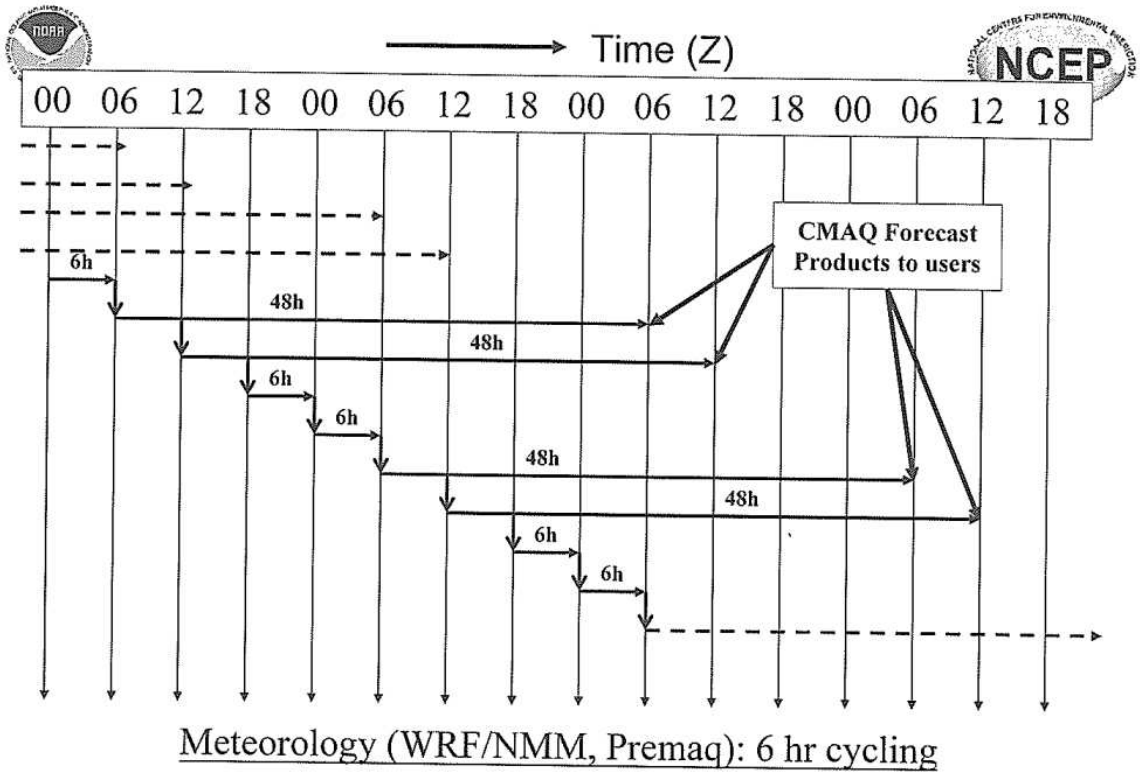


圖 4　NOAA 空氣品質預報公布

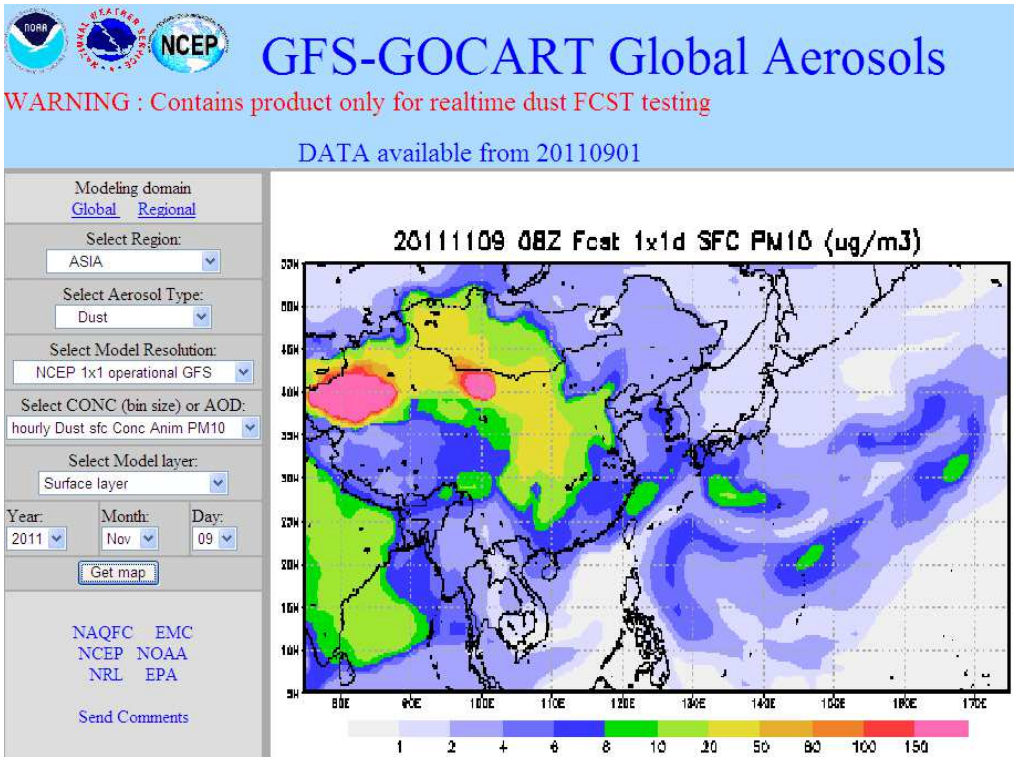


圖 5　Global Forecast System (GFS)模擬亞洲區域沙塵之 PM_{10} 濃度

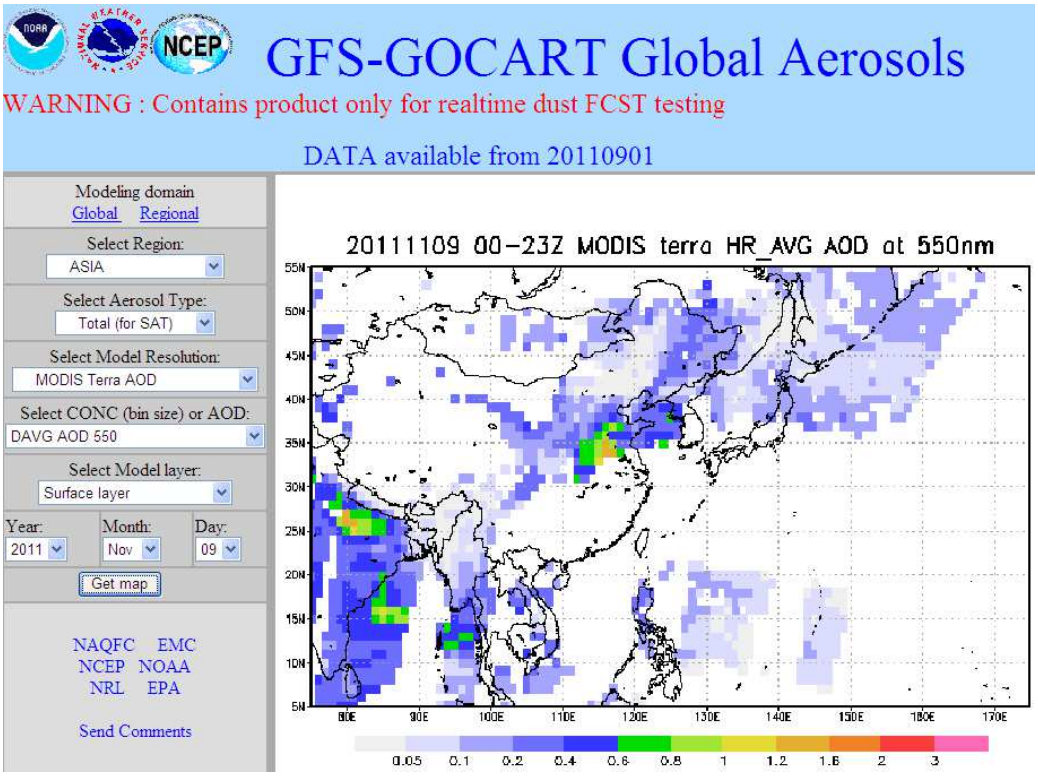


圖 6 衛星觀測亞洲 Aerosol Optical Depth (AOD)

圖 7 與 NOAA 空氣品質預報負責人合影

附錄一、Agenda for Mr. Jhih-Yuan You (Taiwan EPA), August 16-18, 2011

Agenda for Mr. Jhih-Yuan You (Taiwan EPA), August 16-18, 2011

Contact: Ho-Chun Huang (WWB 100), 301-763-8000 x7249

August 16, 2011 Tuesday

9:00AM - 09:45AM	The status of AQ Forecasting programs at Taiwan EPA (Jhih-Yuan You; Taiwan EPA; WWB 209)
09:45AM - 10:30AM	AQ Forecasting programs at NOAA/NWS/NCEP/EMC (Jeff McQueen; AQ group leader; WWB 209)
11:00AM - 12:00PM	Sit–in on weekly AQ teleconference with NWS/OST and ARL (McQueen's cubical)
1:30PM - 2:00PM	Meeting with Bill Lapenta (EMC acting director, EMC director office)
3:00PM - 3:30PM	Pre-operational testing (Youhua Tang; WWB 307)
3:30PM - 4:00PM	Operational implementation processes and post-processing (Jianping Huang; WWB 307)
4:00PM - 4:30PM	Verification (Marina Tsidulko; WWB 307)
4:30PM - 5:00PM	Gas and aerosol data assimilation (Ho-Chun Huang; WWB 307)

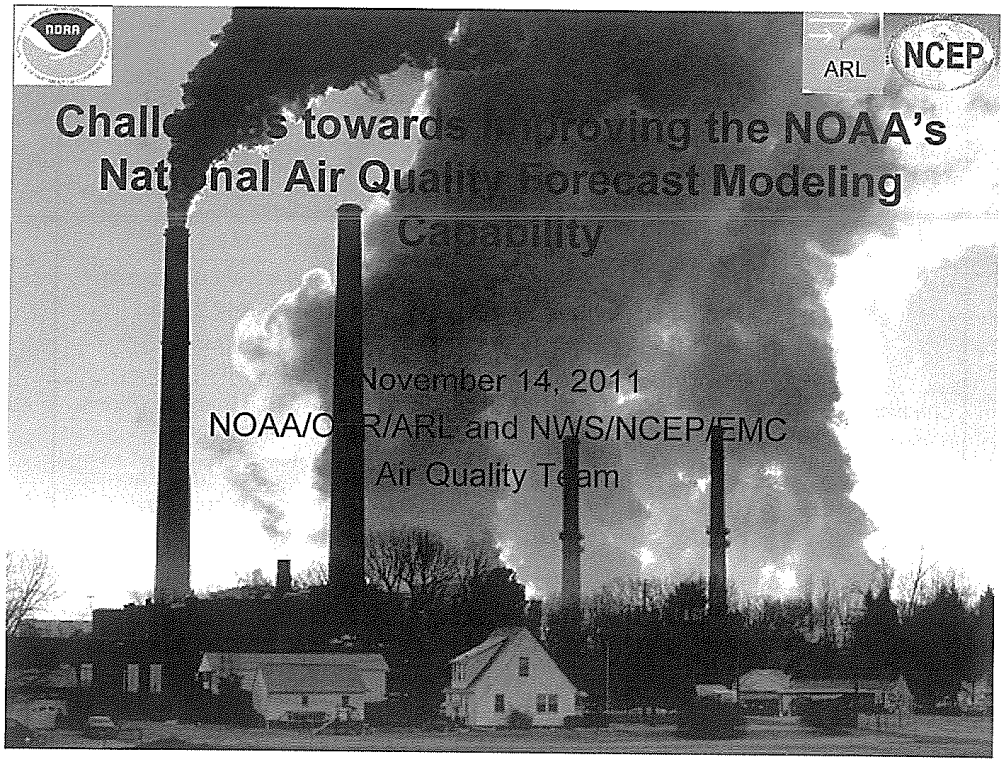
August 17, 2011 Wednesday

9:00AM - 10:30AM	Briefing and discussion on NEMS Global Aerosol Modeling (Sarah Lu; teleconference, x7249)
10:30AM - 11:30AM	Discussion with Youhua Tang (Tang's cubical)
1:00PM - 2:00PM	Discussion with Jianping Huang (Huang's cubical)
2:30PM - 3:30PM	Discussion with Marina Tsidulko (Tsidulko's cubical)

August 18, 2011 Thursday

9:00AM - 10:00AM	Discussion with Ho-Chun Huang (Huang's cubical)
10:30AM - 11:30PM	Discussion with Jeff McQueen (McQueen's cubical)
12:00PM - 1:00 PM	Emissions for operational model (Daniel Tong, ARL; Huang's cubical)
1:00PM - 2:00PM	Sit-in on EMC Mesoscale Modeling Branch meeting (WWB 209)
3:00PM - 4:00PM	Summary & feedback on the visit (Jhih-Yuan You; Taiwan EPA; WWB 209)

附錄二、AQ Forecasting programs at NOAA/NWS/NCEP/EMC



NCEP AQ Project Overview

• Marina Tsidulko	- PBL & Chemistry Verification - High Res. Met modeling
• Youhua Tang	- Regional AQ modeling smoke, dust development and testing - Transition research AQ modeling to NCEP - AQ Lateral Boundary Condition Studies
• *Jianping Huang*	- National AQF System Design & Operational Implementation - Improved Met-Chem coupling - Hysplit Smoke & CMAQ AOD verification W/ NESDIS
• Sarah Lu	- NEMS Global Aerosol Capability online aerosol development
• Ho-Chun Huang	- Air Pollution data assimilation
• Jeff McQueen	- AQF System Evaluation - Dispersion & PBL analysis support
• Geoff Manikin	- Hysplit Smoke testing & implementation
• Caterina Tassone • Binbin Zhou	- Real-time 2.5 km Boundary Layer Analysis – Dispersion/ensemble modeling for homeland security

NCEP Air Quality Modeling Systems

Model	*Region*	*Purpose*
NAM-HYSPLIT G. Manikin	**CONUS ~20 km** **Alaska, Hawaii**	**Daily smoke & dust forecasts** **(06 UTC, 48 h)**
NAM-CMAQ J. Huang, Y. Tang, M. Tsidulko	**CONUS 12 km** **Alaska, Hawaii**	**ozone & PM2.5 forecasts** **2x/day (06,12 Z, 48h)** **Smoke/dust under development**
Chemical Data Assimilation H. Huang, ESRL, NESDIS	**Global MODIS AOD** **Regional AIRNOW PM**	**Improve initial conditions for NGAC and CMAQ**
NEMS GFS Aerosol Capability (NGAC) S. Lu, A. DaSilva(GSFC)	**On-line interactive global aerosols (1x1 degree)**	**Next-gen global w/ aerosol impacts on radiation,** **00 Z, 96 h**
NEMS-NMMB Air Quality Z. Janjic, C. Perez, NASA/GISS O. Joba, BSC	**On-line interactive global/regional aerosols & ozone**	**Next-gen regional AQ w/ aerosol impacts on radiation**

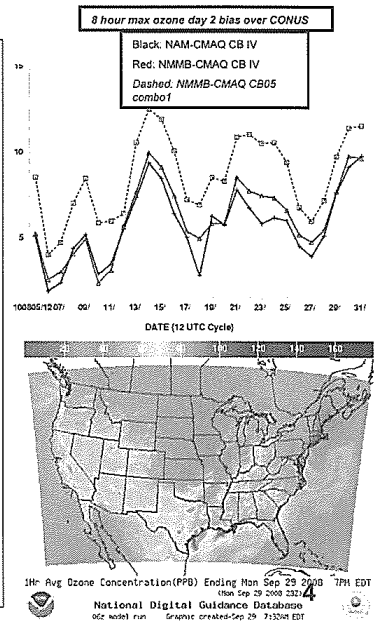
NAM-CMAQ NAQFC Current Configuration
Ozone and PM2.5 Predictions
http://www.weather.gov/aq

Emissions:
- **EPA CEM anthropogenic inventories**
- **2005 base year projected to current year w/ EGU**
- **BEIS V3 Biogenic Emissions**

Met Model:
- **North American Model (NAM)**
- **Non-hydrostatic Multi-scale Model (NMM→NMMB)**
- **12 km 60 Levels**

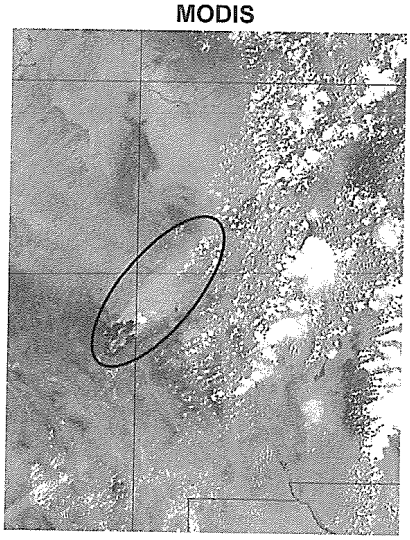
AQ Model:
- **EPA Community Model For Air Quality**
  - **CMAQ V4.6: 12 km/L22 CONUS Domain**
  - **Operational: CB04 gas-phase**
  - ***Exper/Dev: CB05 gas-phase/ Aero-4 aerosols***

Access
- **Output available on National Digital Guidance Database**
  - **48 hour forecasts from 06/12 UTC Cycles**
- **PM graphics, GRIB files from EMC**



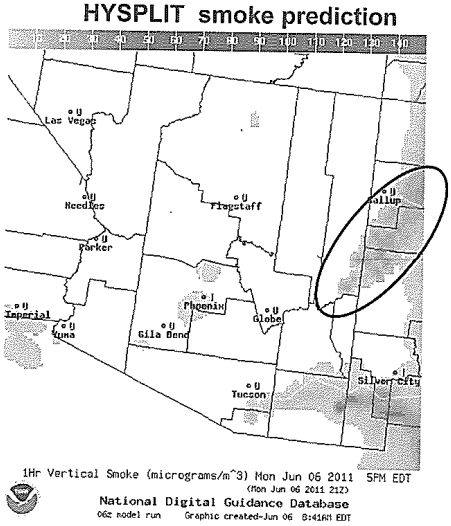
HYSPLIT Smoke Model

MODIS



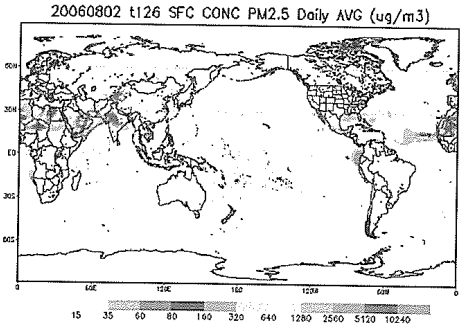
Wallow North fire, Arizona :
2011/157 - 06/06 at 20:40 UTC
Aqua 1km pixel size

HYSPLIT smoke prediction

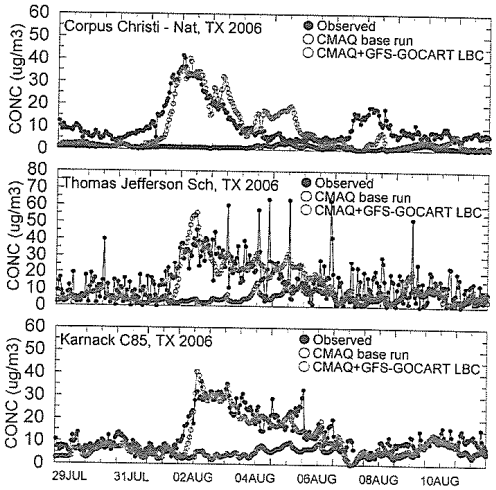


Vertical column smoke at 21 Z on 06/06

CMAQ Lateral Boundary Conditions Tests NGAC: Trans-Atlantic dust Transport (Sarah Lu, Y. Tang, Ho-Chun Huang)



- During Texas Air Quality Study 2006, the model inter-comparison team found all 7 regional air quality models missed some high-PM events, due to trans-Atlantic Saharan dust storms.
- These events are re-visited here, using dynamic lateral aerosol boundary conditions provided from dust-only off-line GFS-GOCART.



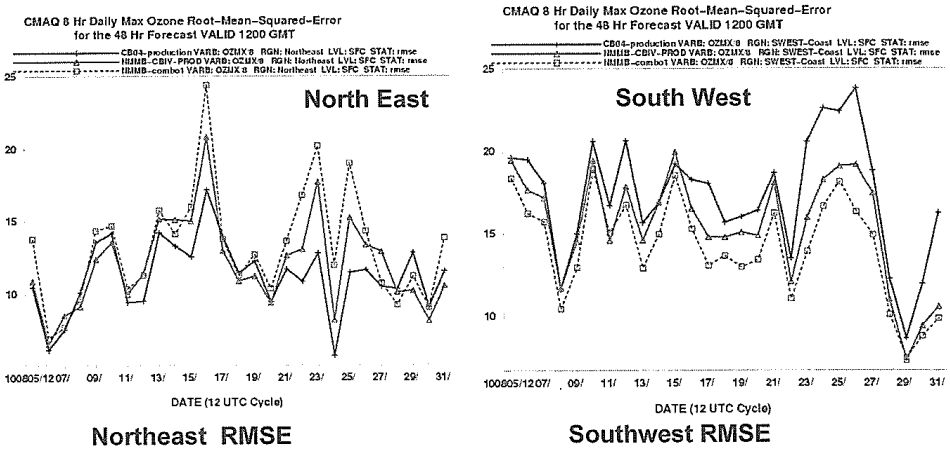
Youhua Tang and Ho-Chun Huang (EMC)

NAM-CMAQ Coupling (Youhua Tang, Jianping Huang)

Run	*NAM*	CMAQ-Ops (CONUS) & CMAQ-Exp/Dev (CONUS PM)
Domain	*Rotated Lat-Lon E grid*	*Interp to Lambert-Conf. C grid*
Vertical Coordinate	*NMM Hybrid (60L)*	*Common NMM Hybrid coord (22L)*
Radiation/ Photolysis	*Lacis-Hansen Bulk*	*NAM Surface clear-sky Radiation for Photolysis Scaling*
PBL	*Mellor-Yamada-Janjic (MYJ) local TKE*	*Asymmetric Convective Mixing -2 (1st Order closure for daytime PBL)*
Clouds Aqueous	*Ferrier cloud water, graupel/ice*	*NAM cloud water, graupel/ice*
Convective Cloud Mixing	*Betts-Miller-Janjic Mass Adjustment*	*Asymmetric Convective Model (ACM) mixing*
Land Surface ** PM	*NOAH LSM*	*Canopy resistance from NOAH LSM*

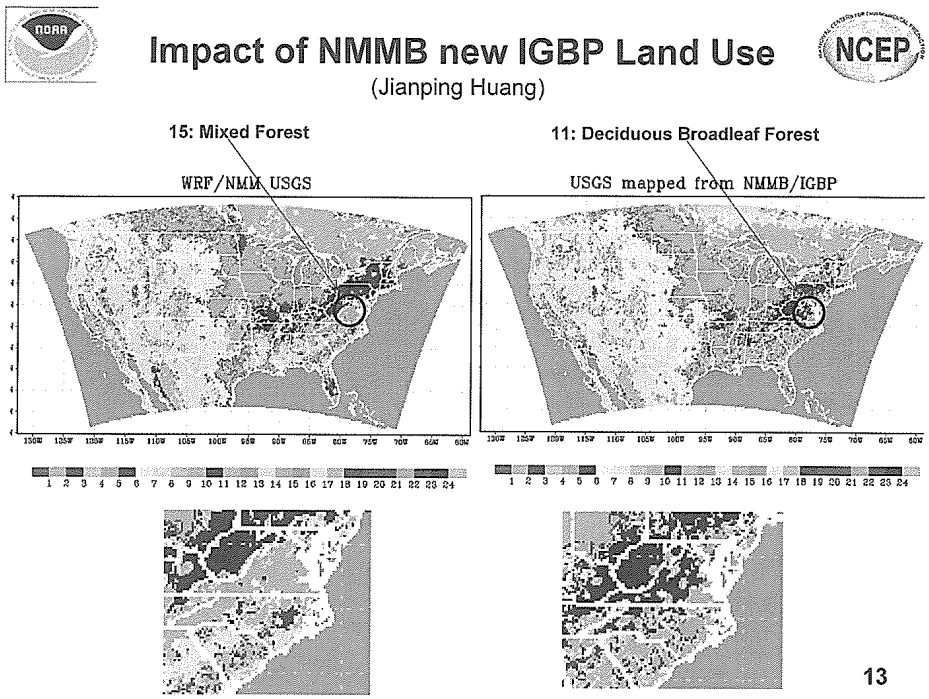
Daily RMSE : Sub-regions 8h-max O_3

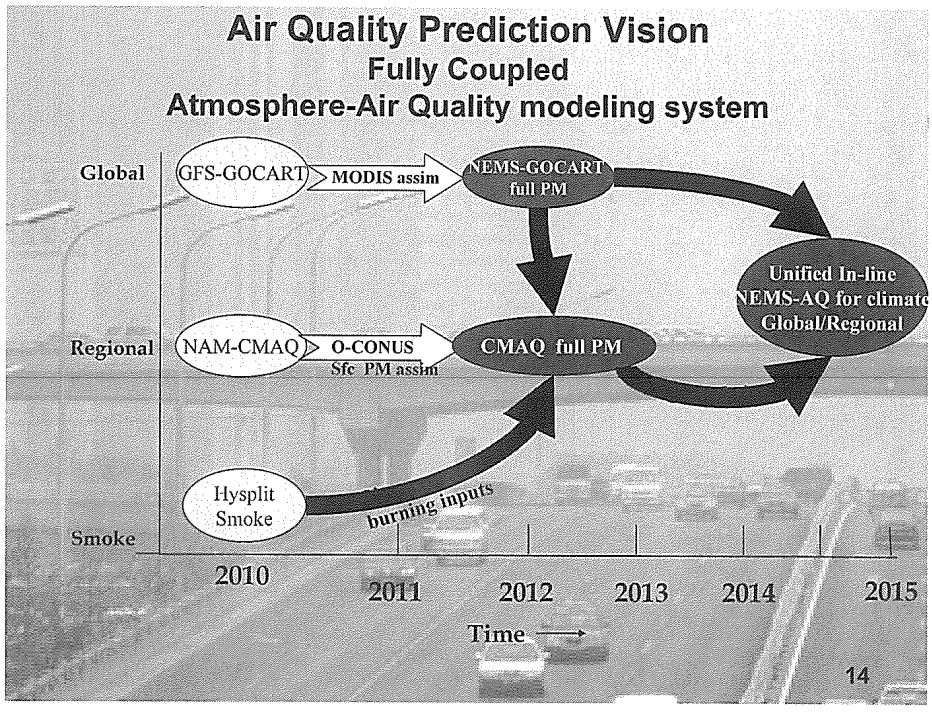
Black: NAM-CMAQ CB IV
Red: NMMB-CMAQ CB IV
Dashed: NMMB-CMAQ CB05 combo1



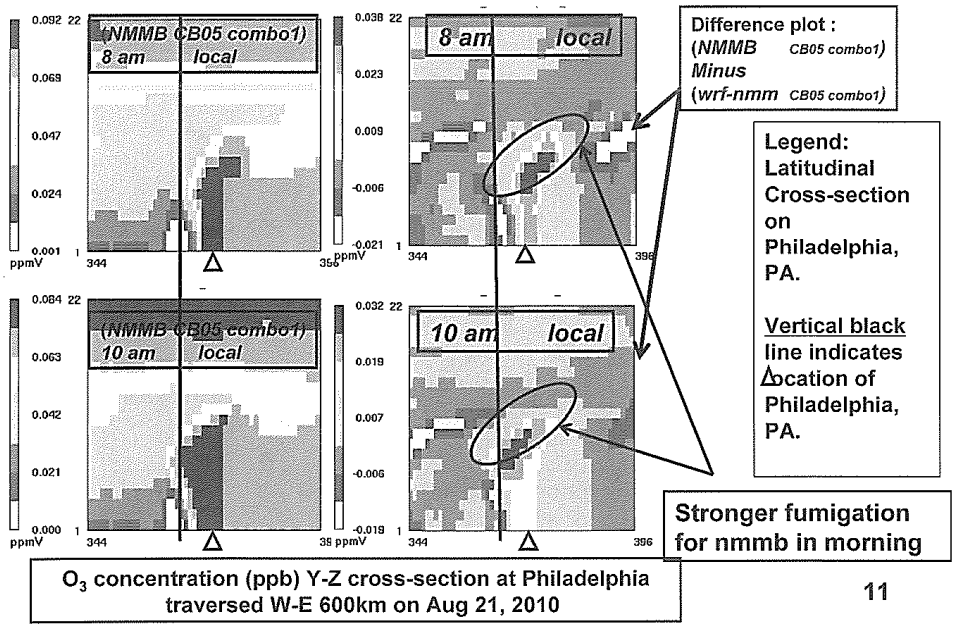
Northeast RMSE **Southwest RMSE**

- NMMB-CBIV worse than Production over North East
- NMMB-CBIV & CB05 better than Production over South West





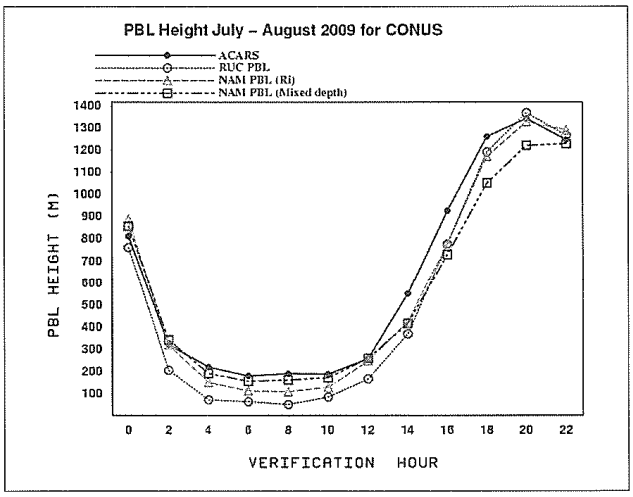
Contributions to early morning O3 spike: Fumigation (Jianping Huang, EMC)



O_3 concentration (ppb) Y-Z cross-section at Philadelphia traversed W-E 600km on Aug 21, 2010

11

Model PBL verification: averaged over CONUS domain (M. Tsidulko, C. Tassone

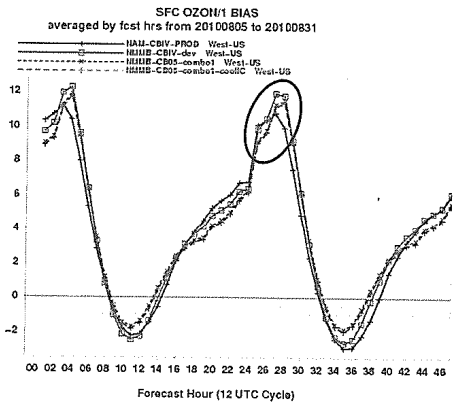


Diurnal cycle of ACARS PBL depth estimates NAM and RUC forecasts for Continental US area. Averaged for July – August 2009.

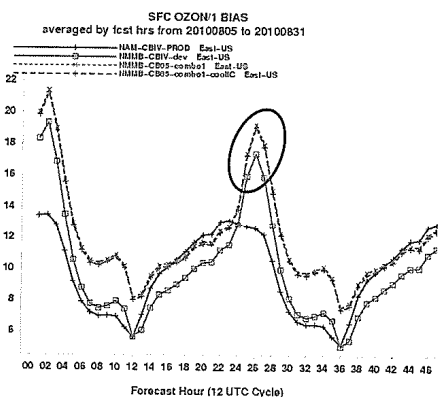
12

Diurnal Cycle 1 hr O3 BIAS (ppb)
August 2010 West vs East

Western US

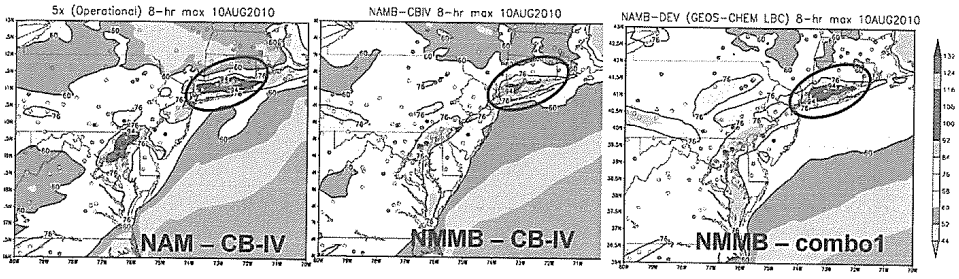


Eastern US



- Early morning error spike for only NMMB runs in East
- Early morning error spike for all runs in West
  Deeper PBLH in NMMB mixes down residual pollutant air mass

NMMB Impact on CMAQ
Day 2 Ozone 8h daily maximum
August 10, 2010 Case (M. Tsidulko)

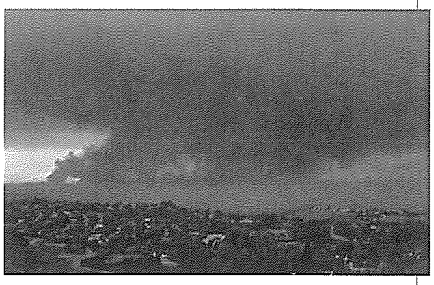


- NMMB CB-IV runs:
  - Improved along Long Island Sound
  - Underpredicted Max O3 over Baltimore-Washington areas
- NMMB CB05 combo1 run: (improved Vd, PBL limits, chem lbcs)
  - Overestimates in low ozone regions (e.g.: Upstate NY, Mass)

RECOMMENDATIONS

- **AQ models**
  - Improved Met-Chemistry coupling
  - Global models for lateral boundary conditions
  - Urban vs rural model performance

- **Utilize additional boundary layer measurements**
  - WVSS moisture aboard aircraft
  - U.S. /Canada boundary layer profilers
  - Lidar networks (NASA MPLNET...)
  - Co-location with met measurements



- **Evaluate use of satellite data for forecast evaluation & assimilation**
  - MODIS AOD
  - CALIPSO aerosol backscatter
  - OMI, TES ozone profiles
  - EARLINET lidars

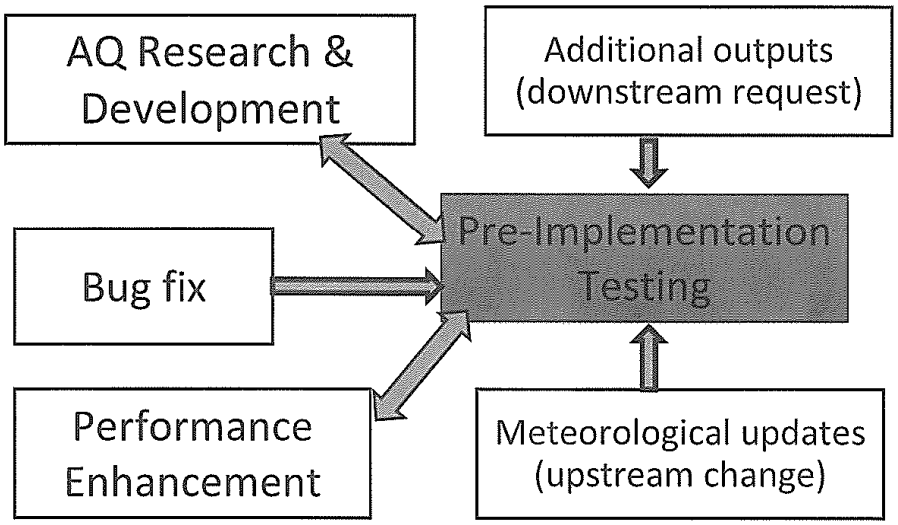
- **Create a suite of cases for AQ model evaluation**
  - Urban plume cases
  - Orographic influences
  - Other sources: smoke, dust, volcanic ash...
- **Field experimental data portal** (Discover AQ, CALNEX 2010, TEXAQS)

附錄三、AQ Forecasting programs(Pre-operational testing、Operational implementation processes and post-processing、Verification、Gas and aerosol data assimilation、Briefing and discussion on NEMS Global Aerosol Modeling)

Various updates that we need test before the implementation

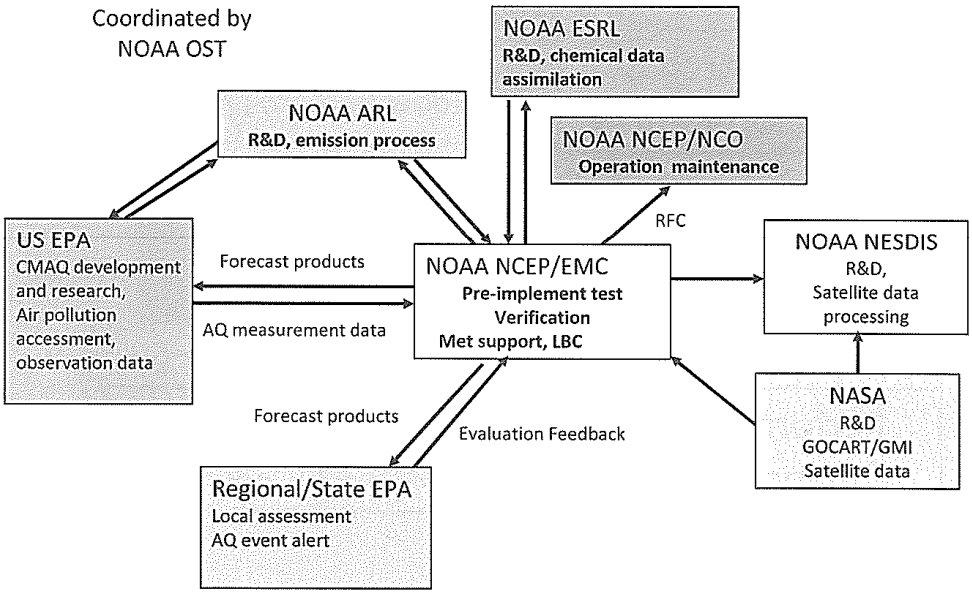
- Emissions: point, area, mobile, biogenic etc
- Chemical mechanism: CB04 andCB05
- Meteorology drivers: WRF-NMM and NMM-B
- Different vertical and horizontal resolutions
- Adjustment on lateral boundary condition or initial condition (using data assimilation)
- Other adjustment on physical schemes/parameters (PBL, dry deposition)
- Additional products

Updates from different requests



Introduction to Air Quality Pre-Implementation Testing Procedure

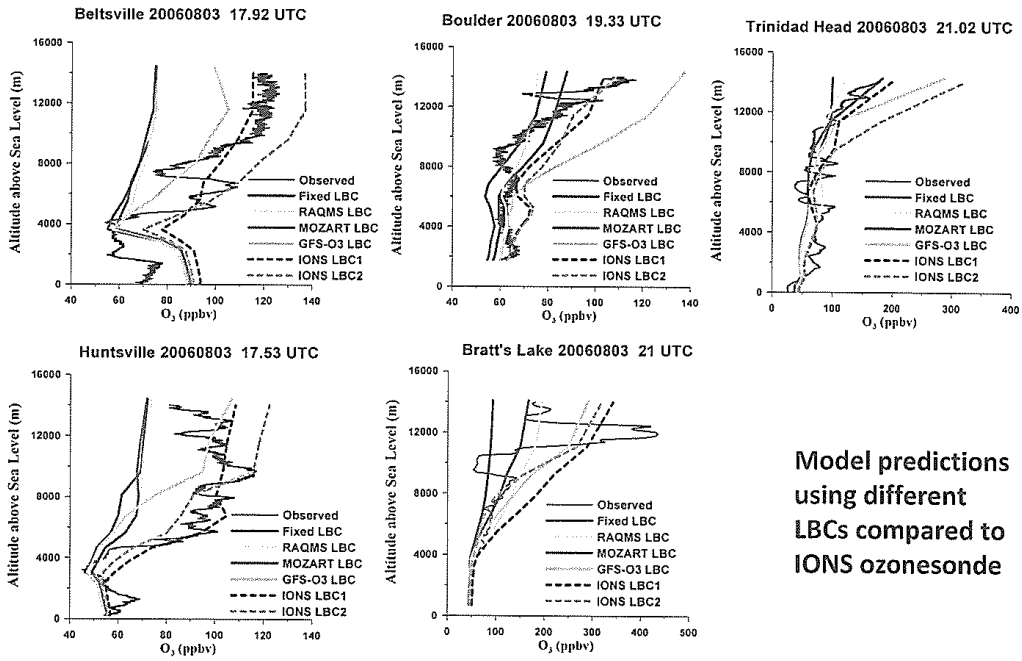
National Air Quality Forecast Capability
A Multi-Agency Effort



Type of the Tests

- Testing for retrospective period. It is typical for some certain events, such as high-ozone episode, biomass burning event, dust intrusion case and field experiments.

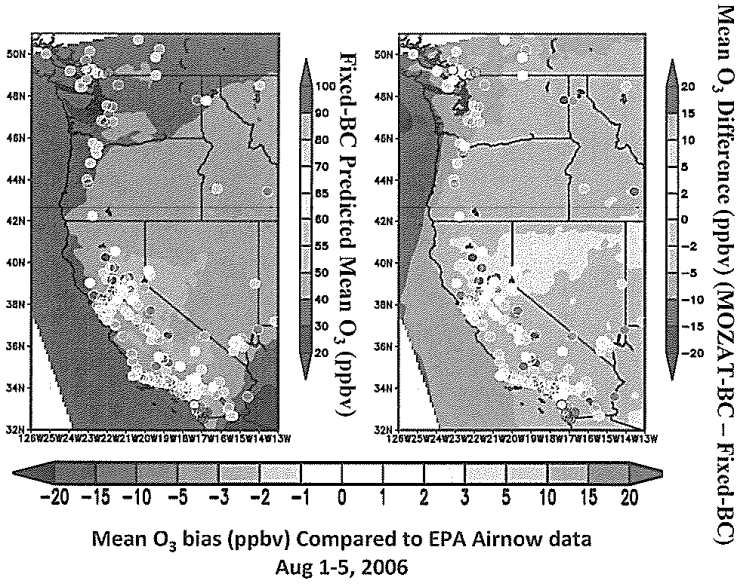
- Real-time testing. It is usually happened when the change is near to the actual implementation.



Model predictions using different LBCs compared to IONS ozonesonde

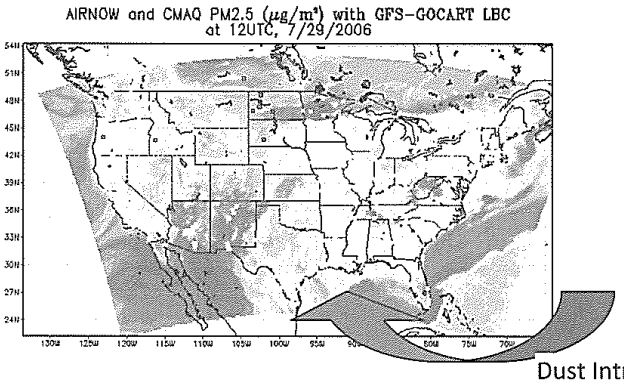
Impact on ozone prediction due to the regional model coupling with global models via lateral boundary condition.

	All Stations	West of -115°W
Fixed LBC	S=0.887 R=0.714 MB=8.0 ppbv	S=0.804 R=0.691 MB=4.7 ppbv
RAQMS LBC	S=0.911 R=0.718 MB=10.0 ppbv	S=0.914 R=0.703 MB=7.1 ppbv
MOZART LBC	S=0.941 R=0.716 MB=8.2 ppbv	S=0.872 R=0.730 MB=2.2 ppbv
GFS O_3 LBC	S=0.935 R=0.714 MB=9.2 ppbv	S=0.820 R=0.697 MB=4.8 ppbv
IONS LBC1	S=0.947 R=0.718 MB=12.4 ppbv	S=0.912 R=0.692 MB=10.4 ppbv



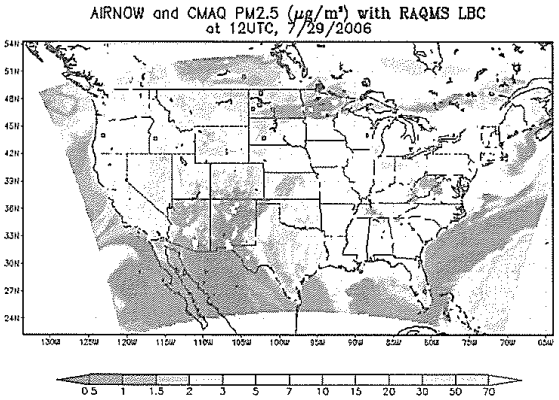
Mean O_3 bias (ppbv) Compared to EPA Airnow data
Aug 1-5, 2006

GFS-GOCART LBC

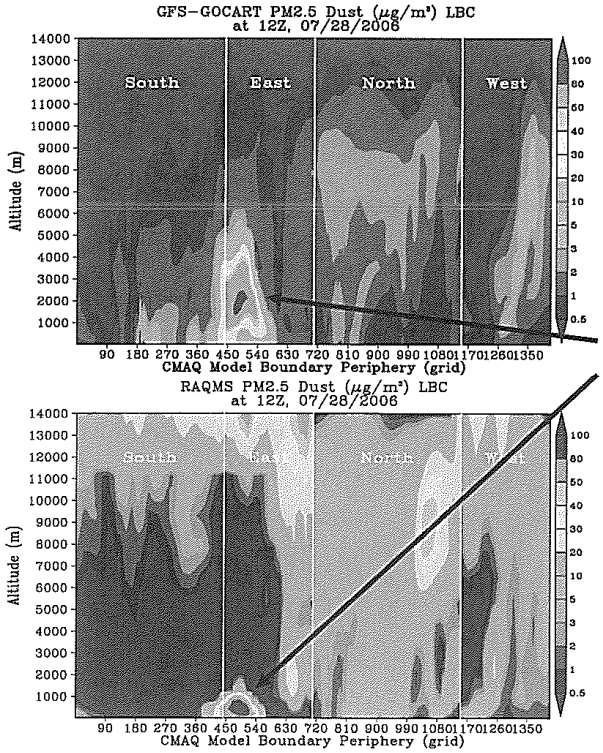


Dust Intrusion Path

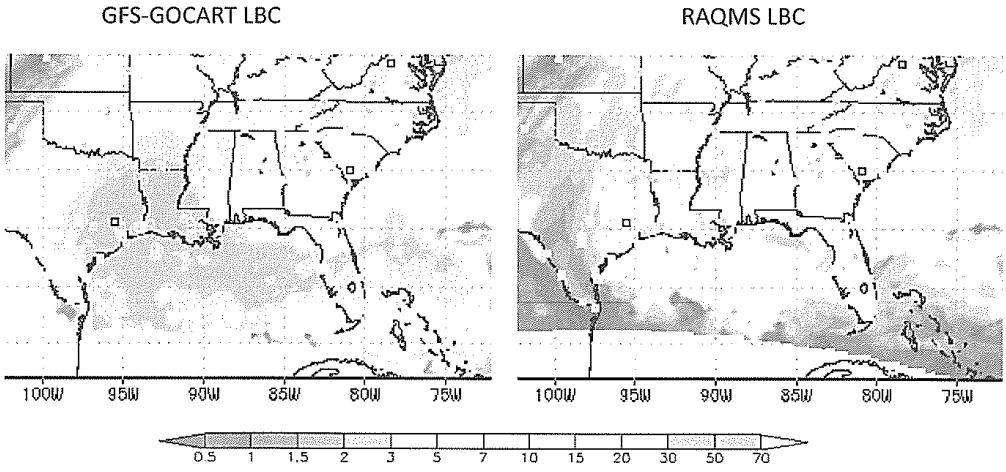
RAQMS LBC



Saraha Dust Intrusion events during summer 2006 (TexAQS 2006)



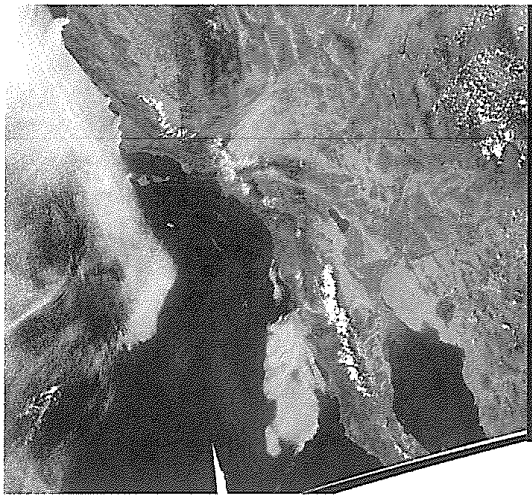
GFS-GOCART and RAQMS exhibit differences in altitude and concentration of dust along the eastern lateral boundary of CMAQ that causes differences in PM prediction over Texas



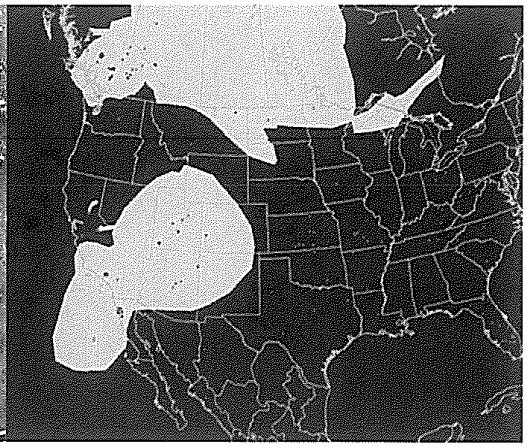
CMAQ surface PM2.5 (μg/m^3) Compared to AIRNOW
at 18Z, 08/02/2006

California fires on 08/30/2009

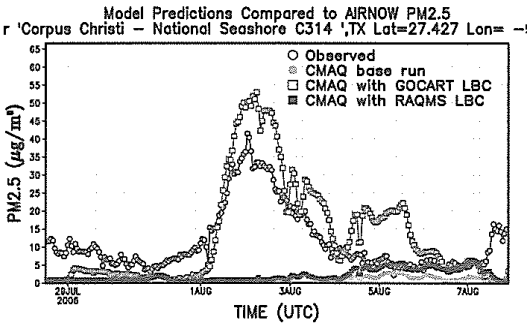
MODIS/Aqua Image

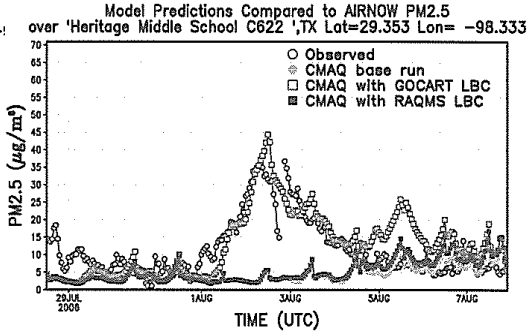


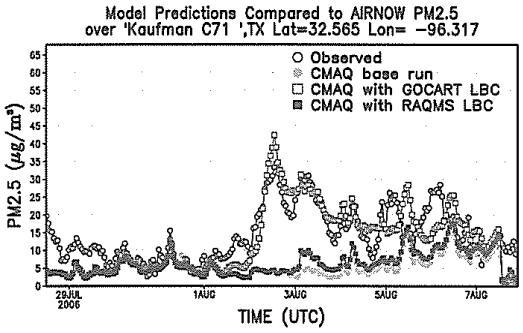
NOAA/NESDIS HMS data

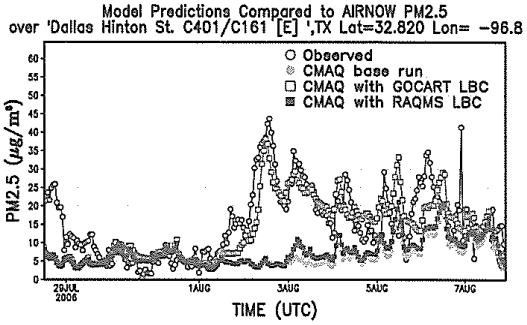


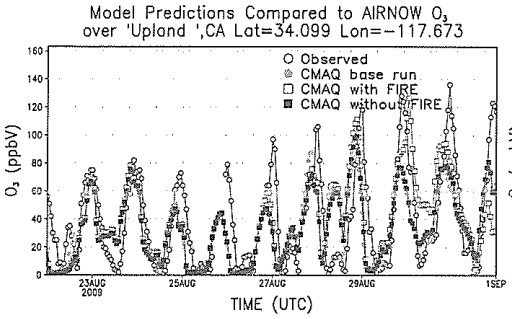
Comparison for surface stations over Texas

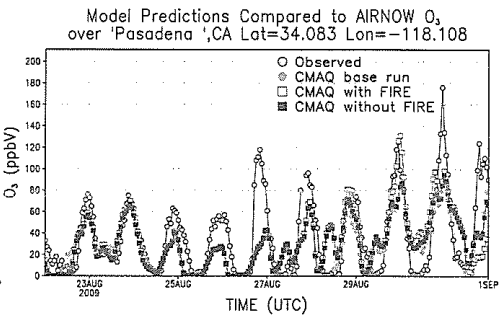


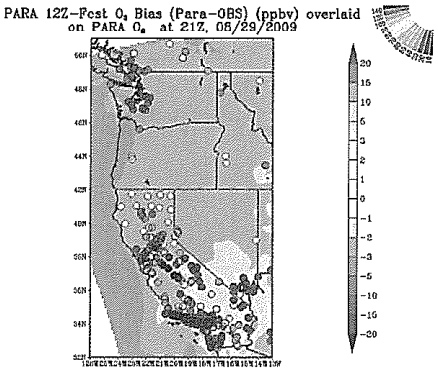


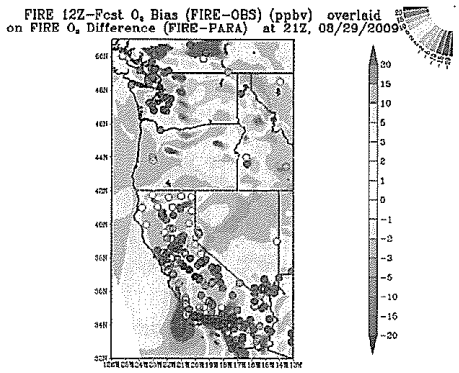


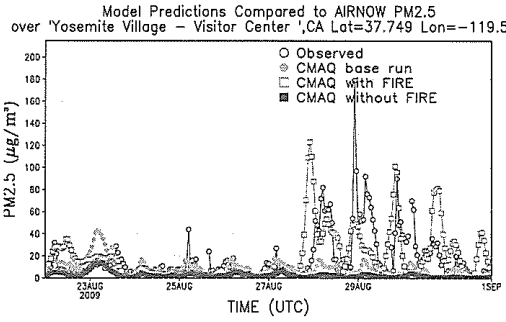


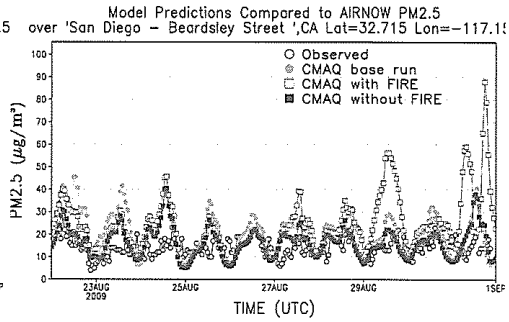


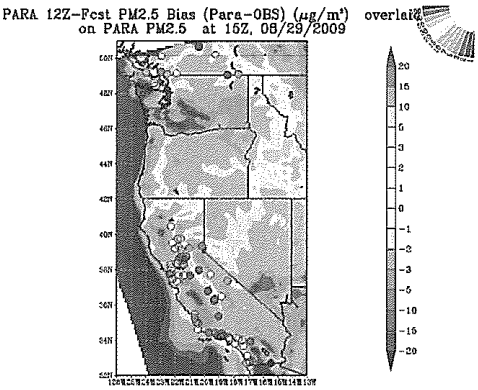


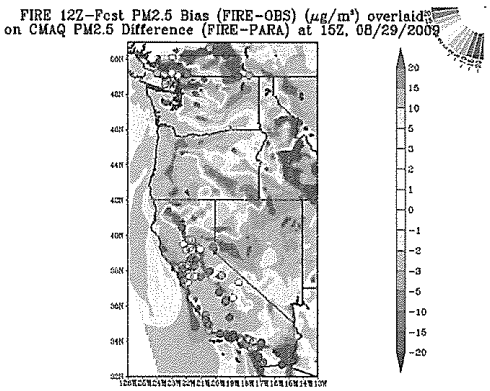












Other tests we made in past 2 years

- Hawaii/Alaska air quality prediction
- NMM-B implementation
- CB05/CB04 comparison
- Test the updates on point sources and area emissions
- Adjustment on dry deposition velocity
- BlueSky wildfire emission testing
- Dust lateral boundary condition from Inline GOCART
- Adjust PM2.5 initial condition using GSI

Summary

- All changes/updates need to be tested before the implementation to prove that they can yield better prediction.
- These changes could be due to various requests, including model upgrade, our project team, upstream changes, downstream users, or NCO request.
- Most changes have side effects, and we need find a way to minimize those side effects. Otherwise we have to abandon these changes or defer their implementation until finding a better solution.

Real-time testing and operational implementation of National Air Quality Forecasting Capability

Jianping Huang

August 16, 2011

Tasks

- Set up real-time testing of National Air Quality Forecasting Capability (NAQFC) (EMC)
- Prepare Request For Change (RFC) for operational implementation
- Work with NCO on implementation
- Check and post-process forecasting results

NAQFC

- **Part I: Pregen**

  - reads the Met model (e.g., NMMB) outputs and interpolates the met fields into the CMAQ domains (e.g., CONUS, HK and AK)

- **Part II: PREMAQ**

  - does vertical coupling and biogenic emission calculation and provides met and emission inputs to CMAQ

- **Part III: CMAQ**

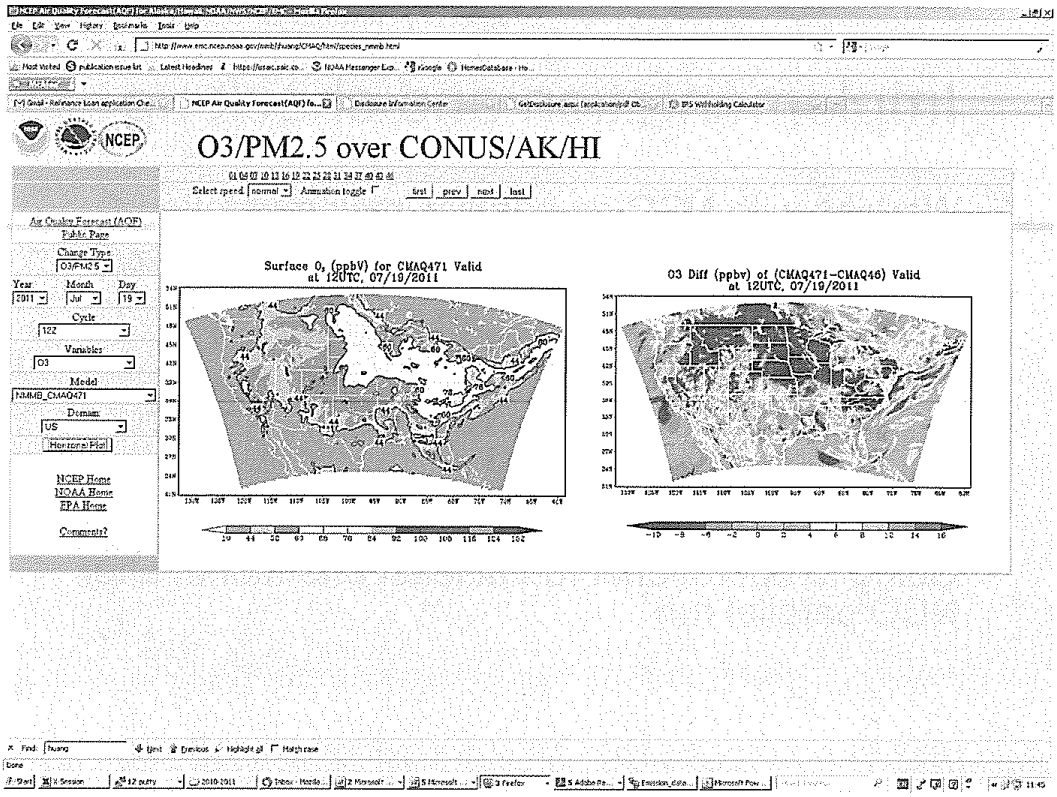
  - provides chemical species forecasts (e.g., O_3 and $PM_{2.5}$) (hourly, surface and upper levels)

- **Part IV: Posts**

  - Post1: provides 1-hr and 8-hr averaged surface ozone, day 1 and day 2 daily 1-hr and 8-hr max surface ozone forecast
  - Post2: provides grib format output fields at upper levels
  - Post3: provides AOD products in grib format

Real-time resting of NAQFC

- Interact with ARL to receive and test the latest version of PreMAQ and CMAQ codes (with Youhua)
- Check all source codes, scripts, fixed and parameter files, emission and related files, and set up real-time testing of NAQFC
- Run the system on developmental machine once per day at 12z at the first stage and then 4 cycles per day before submitting RFCs
- Work on posts and provide all product files including 1-hr and 8-hr average surface O_3, daily max 1-hr and 8-hr surface O_3, surface $PM_{2,5}$ and AOD files, grib1 and grib2 format data files
- Present real-time results on our website



Prepare RFC

- Clean-up and prepare all run jobs, scripts, source, codes, check all input files such as fixed, parameter files, utilities, and emission related files according to NCO's requirements
- Write up RFC
  - description of change (what)
  - benefits of change (why)
  - user impact statement (who)
  - risks (what could go wrong?)
  - computer resource estimates
  - implementation instructions
- All RFCs must be completed at least one month before NCO implementation except for emergency situation.

Implementation and check up

- Working with NCO on parallel implementation
  - NCO parallel runs 4 cycles per day (00z, 06z, 12z, 18z) where 00z and 18z provide 6 hrs forecasts and 06z and 12z provide 48 hrs forecasts

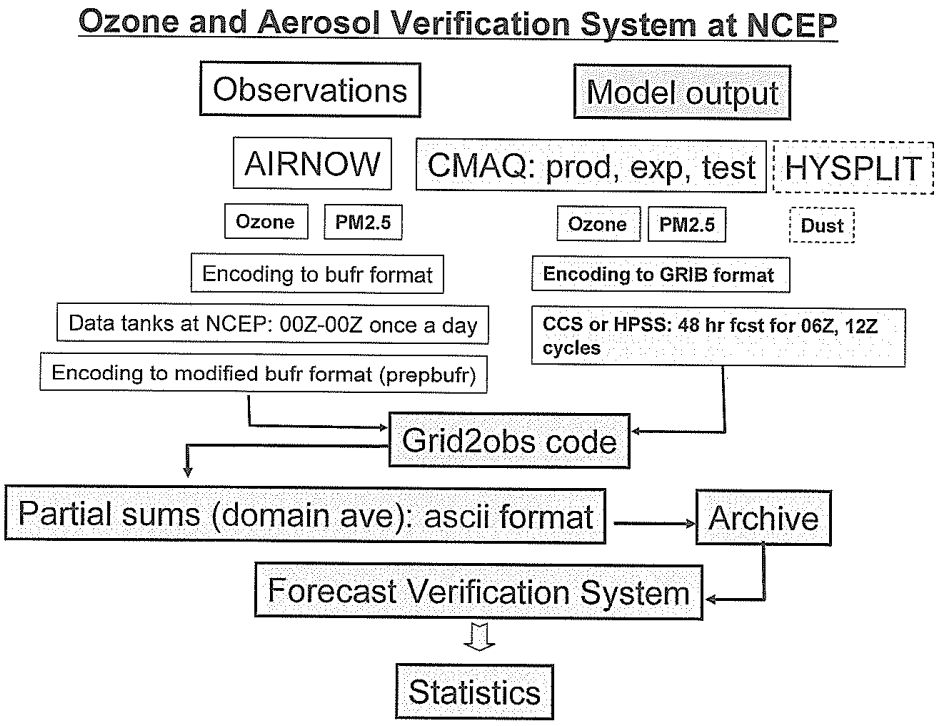
- Checking all output files

- Going to operational run at least one month after NCO parallel run

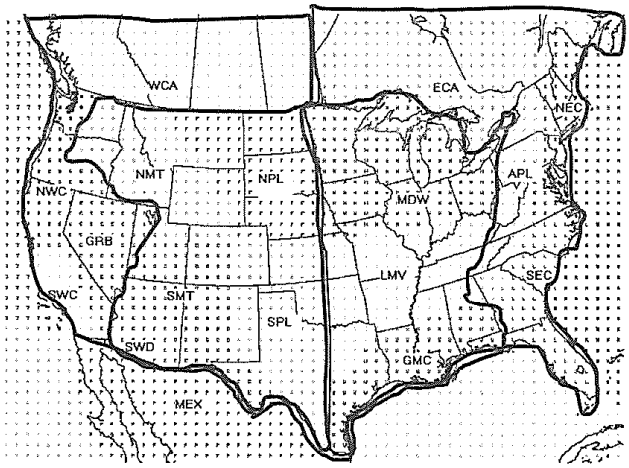
AQ verification at NCEP

NCEP team

August 16, 2011

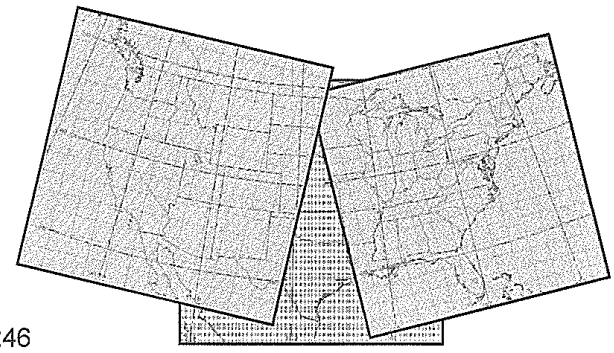


Verification Sub-domains



- **Eastern US: NEC, APL, SEC, GMC, MDW, LMV, ECA**
- **Western US: NPL, SPL, NMT, SMT, GRB, SWD, NWC, SWC, WCA**
- **Central US: GMC, MDW, LMV, NPL, SPL, NMT, SMT, SWD**

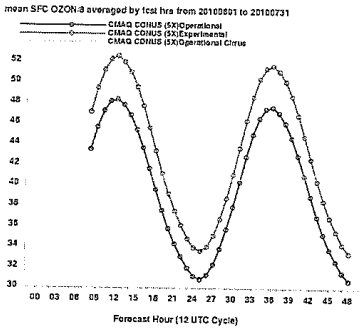
VERIFICATION DOMAINS

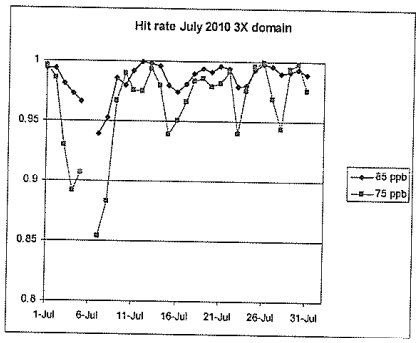


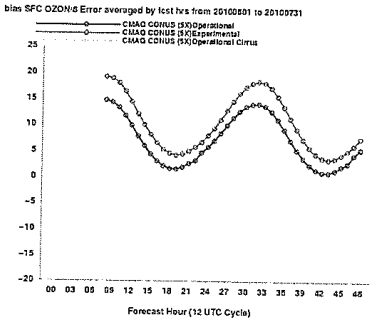
G246
Western US

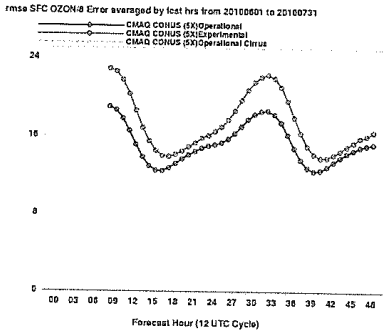
G247
Central US

G245
Eastern US







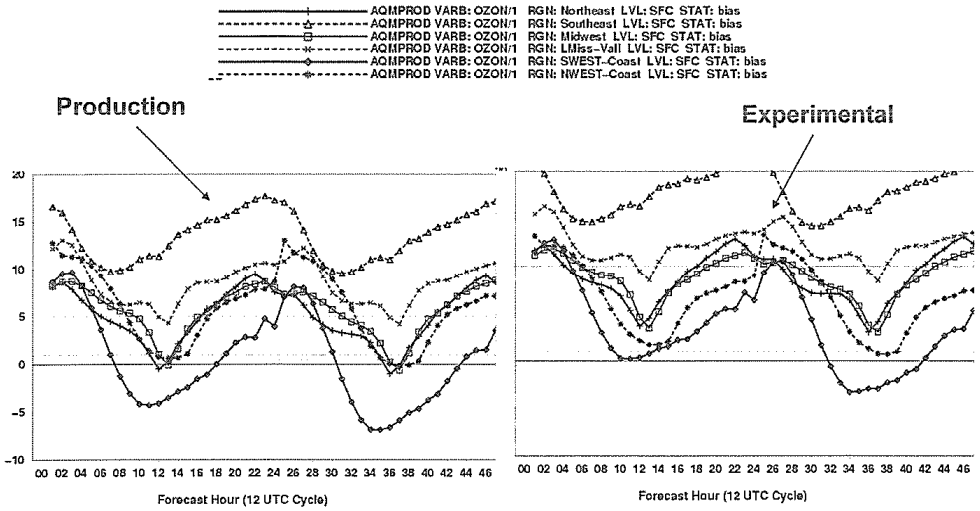


1-hr Max: 5x/full domain	1-Jul	2-Jul	3-Jul	4-Jul	5-Jul	6-Jul	7-Jul	8-Jul	9-Jul	10-Jul
Reporting stations	1228	1205	1207	1206	1240	N/A	1221	1208	1221	1252
Forecast,Observed	0	0	0	1	0	N/A	0	0	0	0
Forecast,Not Observed	0	0	0	0	0	N/A	1	6	0	0
Not Forecast,Observed	0	1	0	0	1	N/A	0	0	0	3
Not Forecast,Not Observed	1228	1204	1207	1205	1239	N/A	1220	1202	1221	1249
Hits	1	0.999	1	1	0.999	N/A	0.999	0.995	1	0.998
Threat Score	N/A	0	N/A	1	0	N/A	0	0	N/A	0
POD	N/A	0	N/A	1	0	N/A	N/A	N/A	N/A	0
FAR	N/A	N/A	N/A	0	N/A	N/A	1	1	N/A	N/A

75 ppb standard:

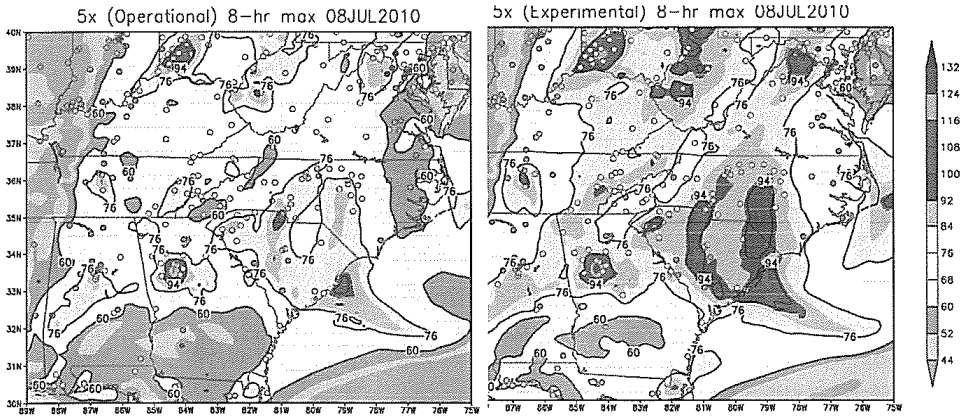
8-hr Max: 5x/full domain	1-Jul	2-Jul	3-Jul	4-Jul	5-Jul	6-Jul	7-Jul	8-Jul	9-Jul	10-Jul
Reporting stations	1244	1210	1208	1218	1246	N/A	1248	1221	1242	1254
Forecast,Observed	0	1	8	19	38	N/A	90	58	13	3
Forecast,Not Observed	16	6	34	65	80	N/A	112	77	34	23
Not Forecast,Observed	17	20	38	43	23	N/A	38	61	27	34
Not Forecast,Not Observed	1211	1183	1128	1091	1105	N/A	1008	1025	1168	1194
Hits	0.973	0.979	0.94	0.911	0.917	N/A	0.88	0.887	0.951	0.955
Threat Score	-0.007	0.033	0.082	0.12	0.238	N/A	0.316	0.245	0.159	0.038
POD	0	0.048	0.174	0.306	0.623	N/A	0.703	0.487	0.325	0.081
FAR	1	0.857	0.81	0.774	0.678	N/A	0.554	0.57	0.723	0.885

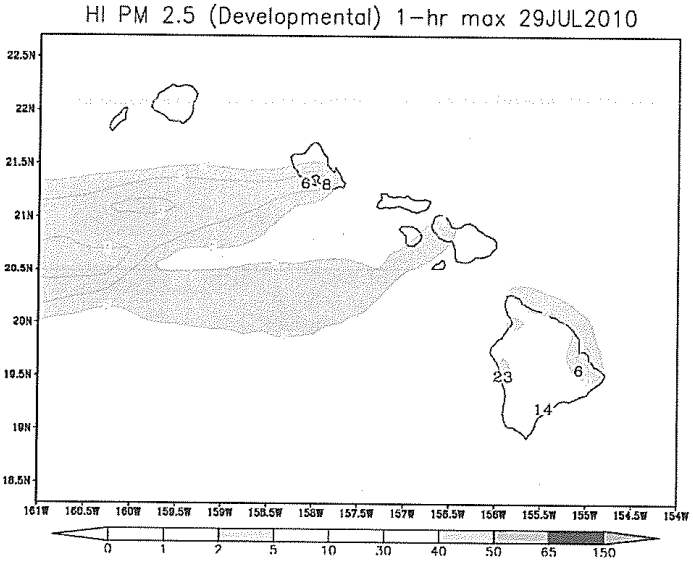
NCEP Air Quality Forecast 2010 Verification
(1 hr avg ozone bias)

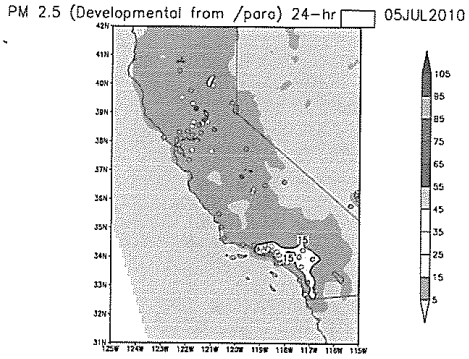


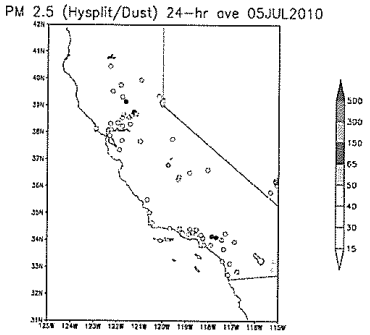
Almost the same for NW and Mid West
Higher for NE, SE and Low Miss Valley (increase positive bias)
Higher for SW (improve negative bias)

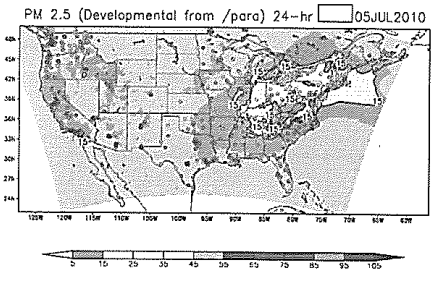
NCEP Air Quality Forecast
8 hr Day 2 Daily Max ozone
July 8, 2010 SE U.S.

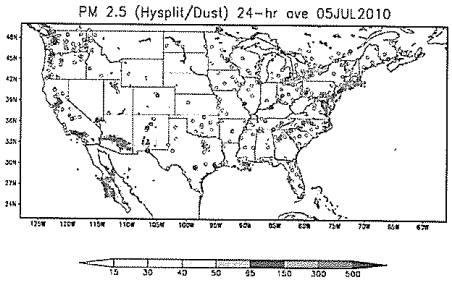




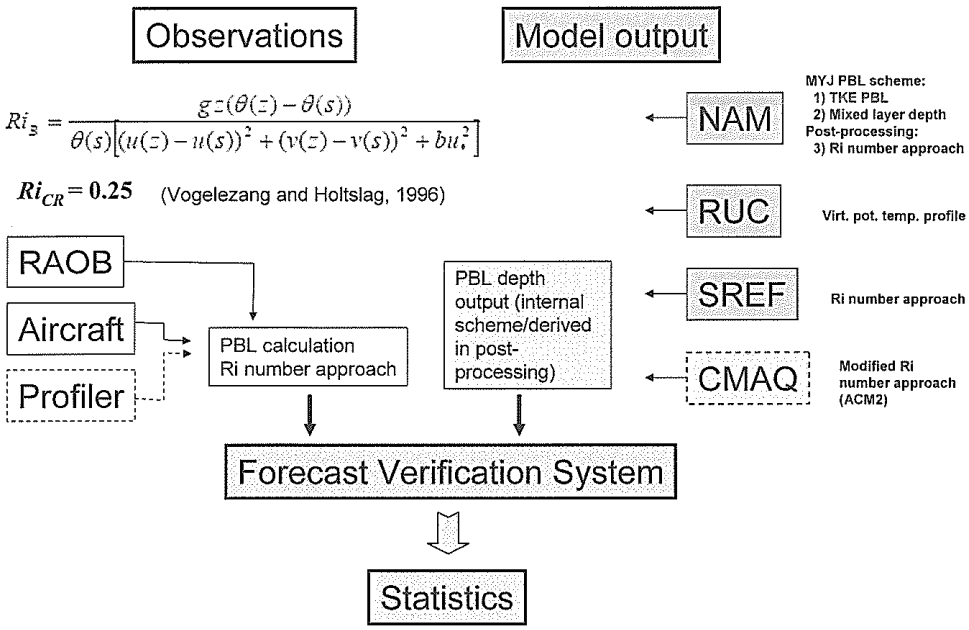




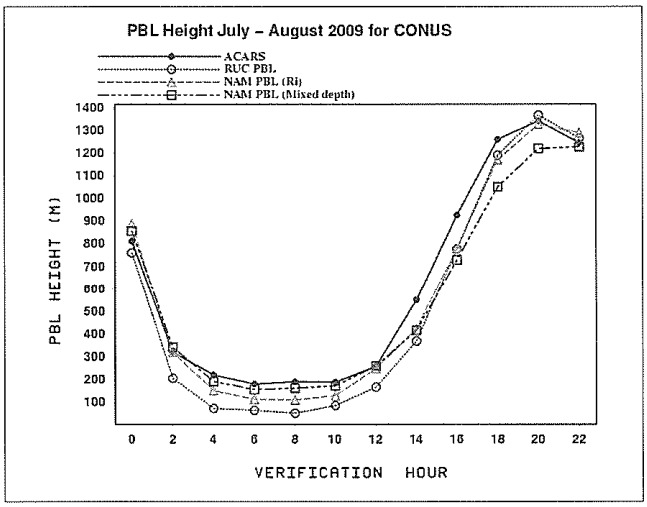




PBL Verification System at NCEP



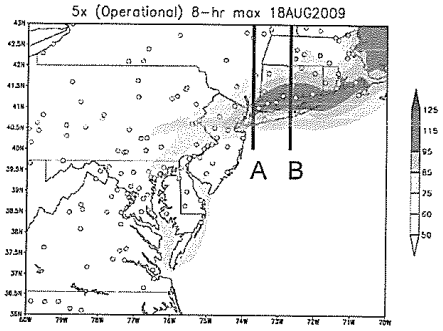
Model PBL verification: averaged over CONUS domain

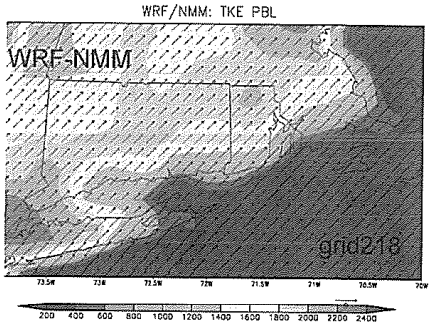


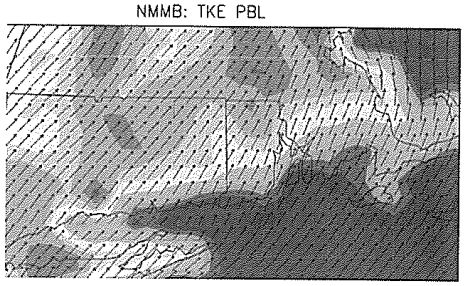
Diurnal cycle of ACARS PBL depth estimates NAM and RUC forecasts for Continental US area. Averaged for July – August 2009.

Case studies: WRF-NMM vs NMMB

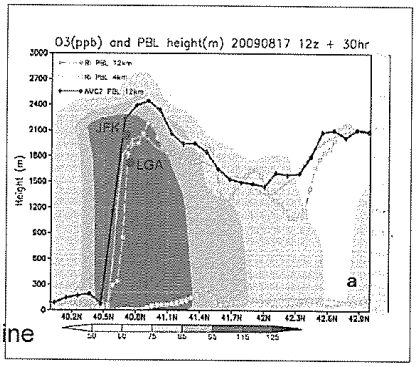
17-18 Aug 2009 CT ozone overprediction



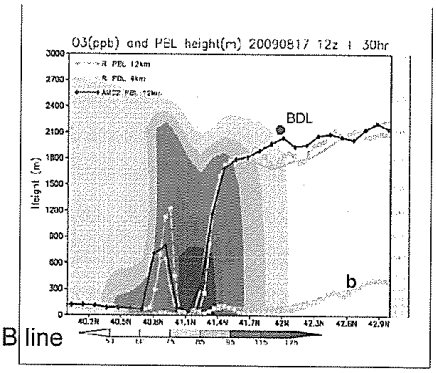




- Main direction of winds is SE, potentially bringing pollutants from the NYC area
- PBL is collapsing over the sea forcing the pollutant to stay near surface, which could be one of potential reasons of large ozone over-prediction in this case



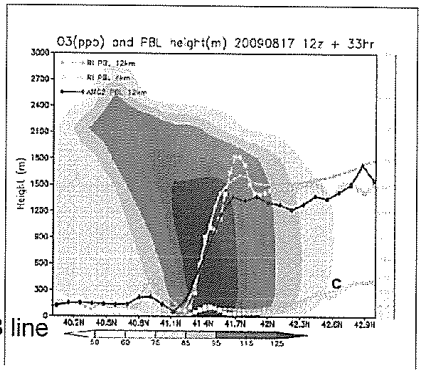
A line



B line

Ozone concentrations (ppb) predicted in NCEP Air Quality Forecast system (correspondent σ-levels are shown on right axis) and PBL height from different model simulations (green and black lines). Grey lines indicate surface. Blue circles indicate PBL estimations from ACARS data at airports.

Over Long Island, high-resolution (4km) NAM run has 400-500 m higher PBL than 12 km NAM PBL and 12 km ACM2 PBL (currently used in CMAQ). Potentially this may help pollutants to stay higher while travelling over water and reduce surface concentrations in Connecticut.



B line

NCEP GSI aerosol DA

Ho-Chun Huang

August 16 2011

NCEP Global Aerosol Models

Aerosol Module

•NASA Goddard Global Ozone Chemistry Aerosol Radiation and Transport Model (GOCART; dust, sea salt, sulfate, and BC/OC)

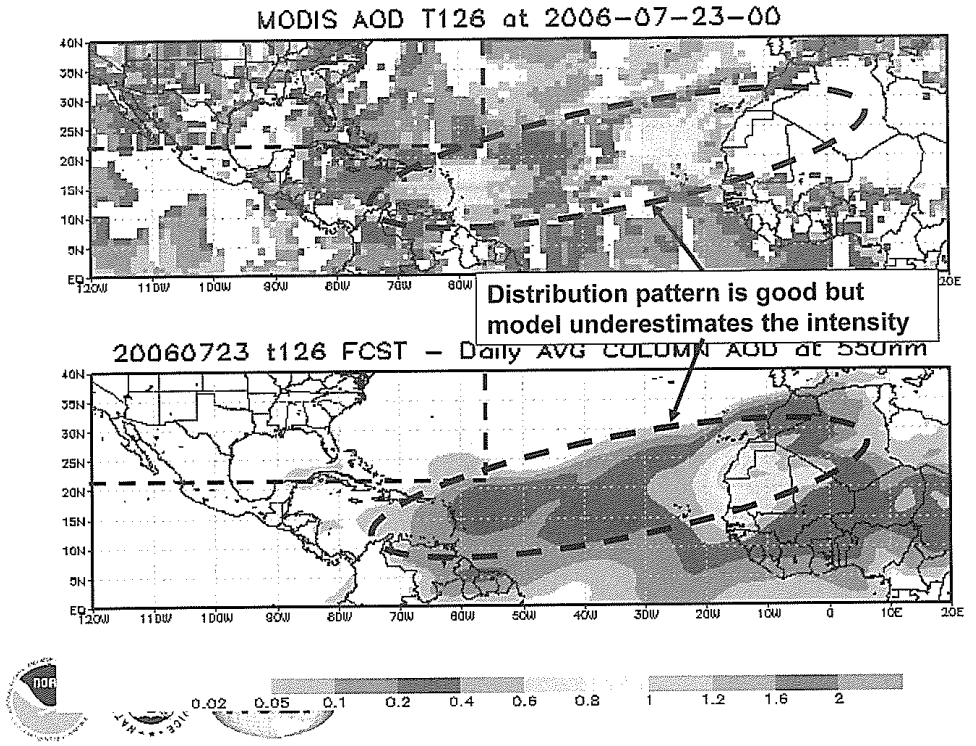
Meteorology Module

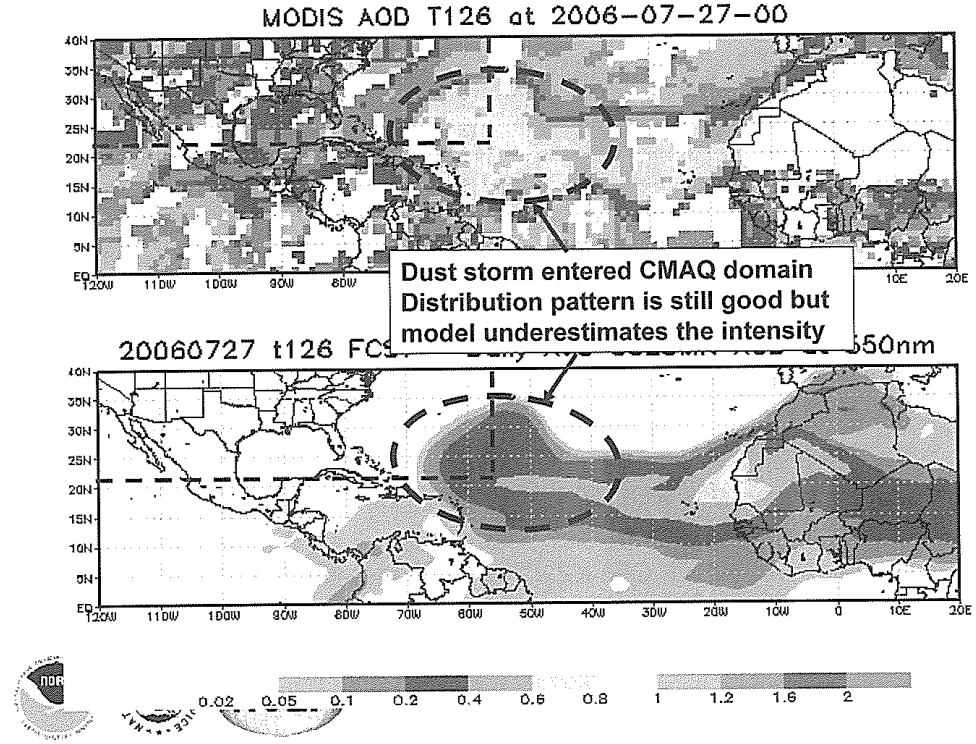
•NCEP/EMC Global Forecast System (GFS) - offline

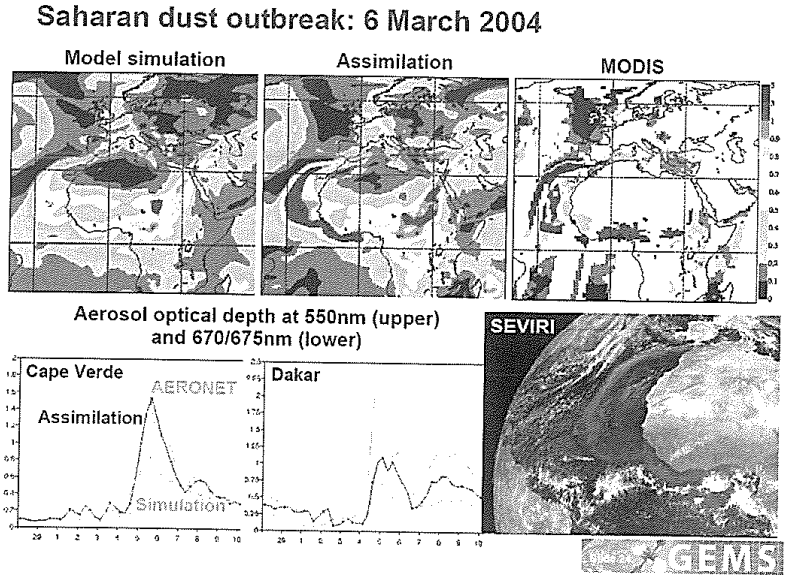
•NOAA Environmental Modeling System with GFS component (NEMS/GFS) - inline

•Off-line dust-only GFS-GOCART is driven by operational GFS for real-time testing since December 2009.

•On-line dust-only NEMS/GFS-GOCART is in real-time testing since June 2011 (Sarah Lu)



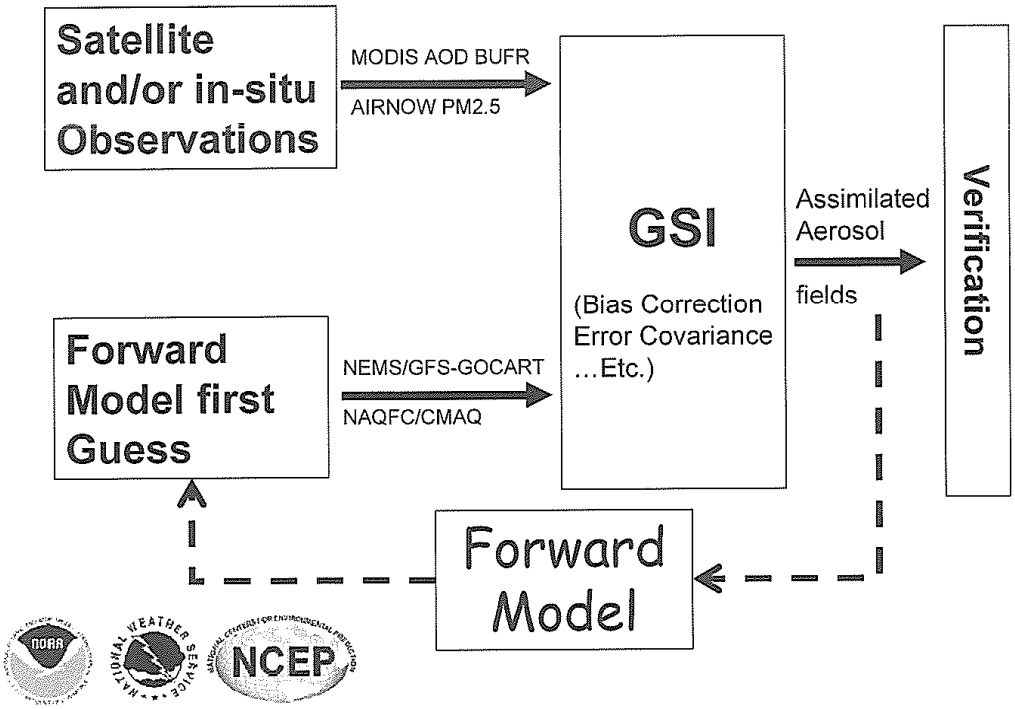


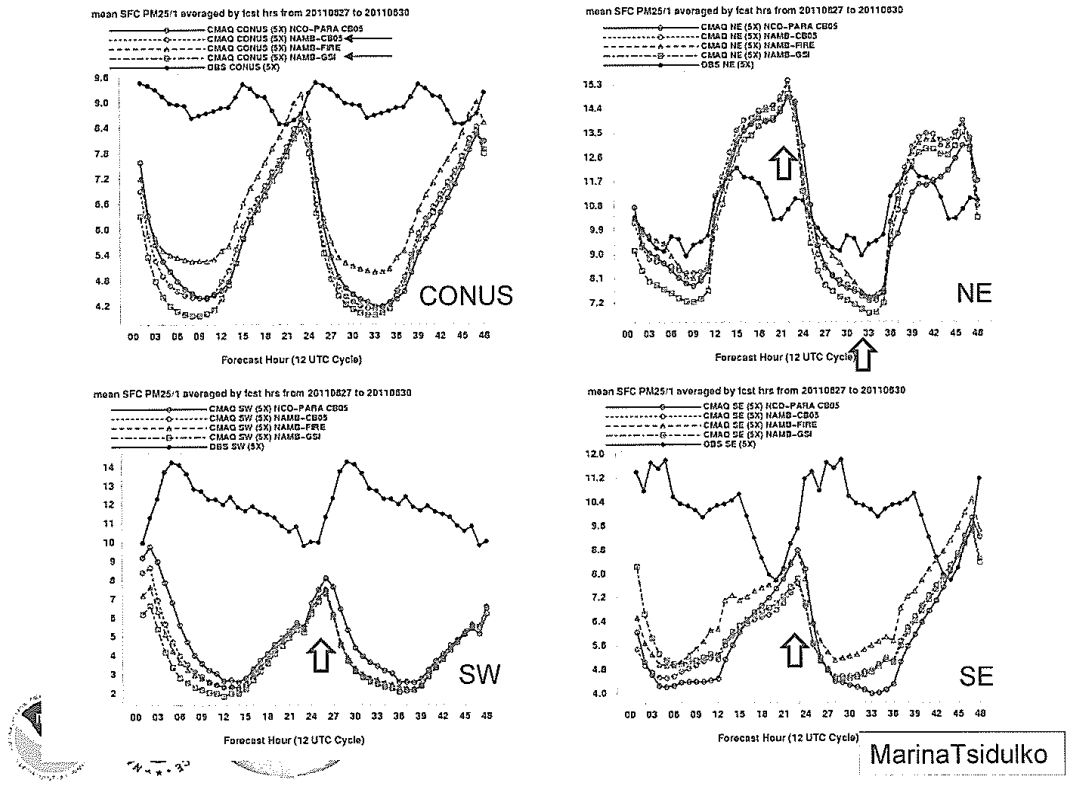


From Martin Schultz GEMS presentation November 14 2008

NCEP Aerosol Data Assimilation

- The Gridpoint Statistical Interpolation (GSI; Wu et al., 2002) is the analysis component of NCEP Global Data Assimilation Systems.
- Global
  - MODIS L1.5 AOD (Aqua and Terra)
  - NEMS/GFS-GOCART model output
- Regional
  - US EPA AIRNOW PM2.5 Concentration
  - NCEP/NAQFC experimental PM2.5 model run
- Verification
  - AERONET AOD
  - CLIPSO onboard lidar profile





The project list of global/regional gases and aerosol DA using GSI

Organization	Personnel	Spatial scale	First guess	Observations	Sponsor Agency	Utilities development
NCEP EMC	Ho-Chun Huang John Derber	Global	GFS-GOCART	MODIS TC AOD	In house	general CRTM optical property for GOCART
NCEP EMC	Haixia Liu John Derber	Global	GFS	SBUV, OMI TC, MLS (BUFR)	In house	
NESIDS	Qiang Zhao Shobha Kondragunta	CONUS	CMAQ/CB05	GOES TC AOD*	In house	general CRTM optical property for CMAQ
ARL	Tainfeng Tsai Pius Lee	CONUS	CMAQ/CB05	MODIS TC AOD	In house	general NEMSIO convertor for CMAQ IC species
				AIRNOW PM		
				AIRNOW Ozone		
GSD	Mariusz Pagowski George Grell	CONUS	CMAQ/CB05	AIRNOW PM	NWS/AQ	AIRNOW PrepBUFR read
			WRF-CHEM##		AFWA	
NESDIS	Allen Lenzen Brad Pierce	CONUS	CMAQ/CBxx	GOES TC Ozone*	JSDI	
NCAR	Zhiquan Liu	CONUS	WRF-CHEM ##	MODIS TC AOD*	AFWA	MODIS BUFR utilities

Non-NCEP model

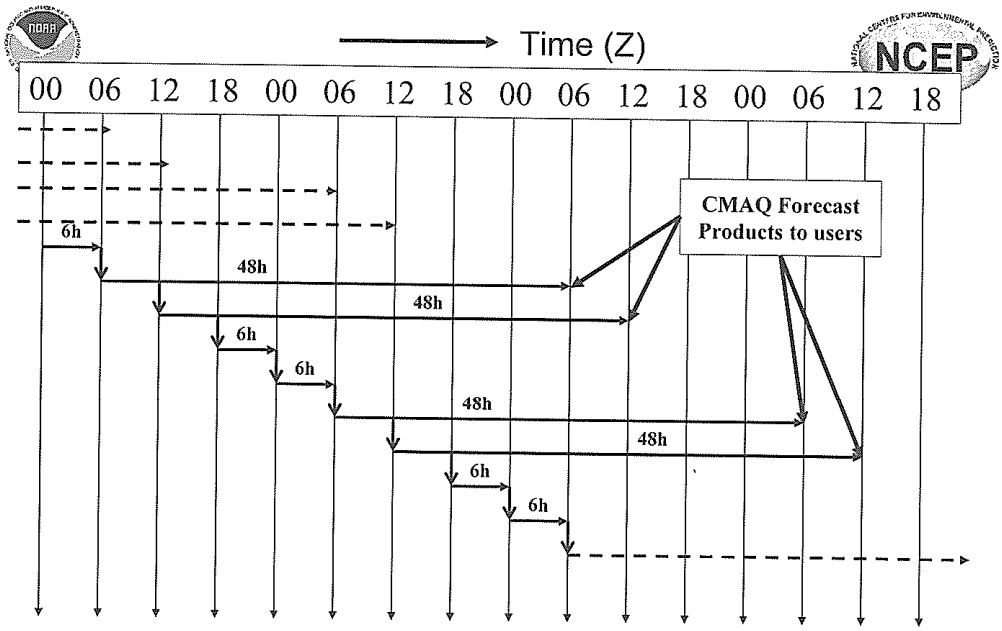
TC: Total Column

SFC: in-situ surface data

NEMS GFS Aerosol Component

An interactive atmosphere-aerosol system

Sarah Lu



Meteorology (WRF/NMM, Premaq): 6 hr cycling

NGAC Overview

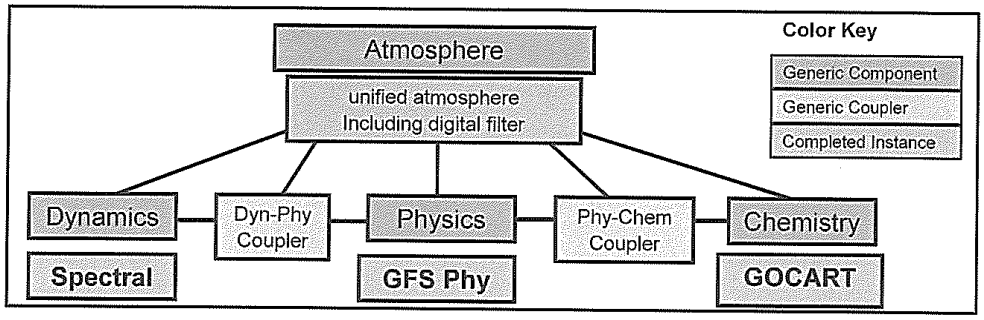
Team efforts toward building global aerosol forecast capability at NCEP

Mark Iredell (NEMS team lead)
Sarah Lu (aerosol modeling)
Shrinivas Moorthi (physics)
Yu-Tai Hou (radiation-aerosol)
Henry Juang (dynamics)
Jun Wang (I/O)
Hui-Ya Chuang (post)
Weiyu Yang (ESMF infrstructure)
Ho-Chun Huang (data assimilation)
Downstream applications (Jeff McQueen, Youhua Tang, Xu Li)

GSFC collaborators (Arlindo da Silva and Mian Chin)

Developing an interactive atmosphere-aerosol forecast system

- **In-line chemistry advantage**
  - Consistent: no spatial-temporal interpolation, same physics parameterization
  - Efficient: lower overall CPU costs and easier data management
  - Allows for feedback to meteorology
- **NEMS GFS Aerosol Component**
  - NEMS GFS and GOCART are interactively connected using ESMF coupler components
  - The NEMS/GFS has the capability to forecast dust, sulfate, sea salt, and carbonaceous aerosols

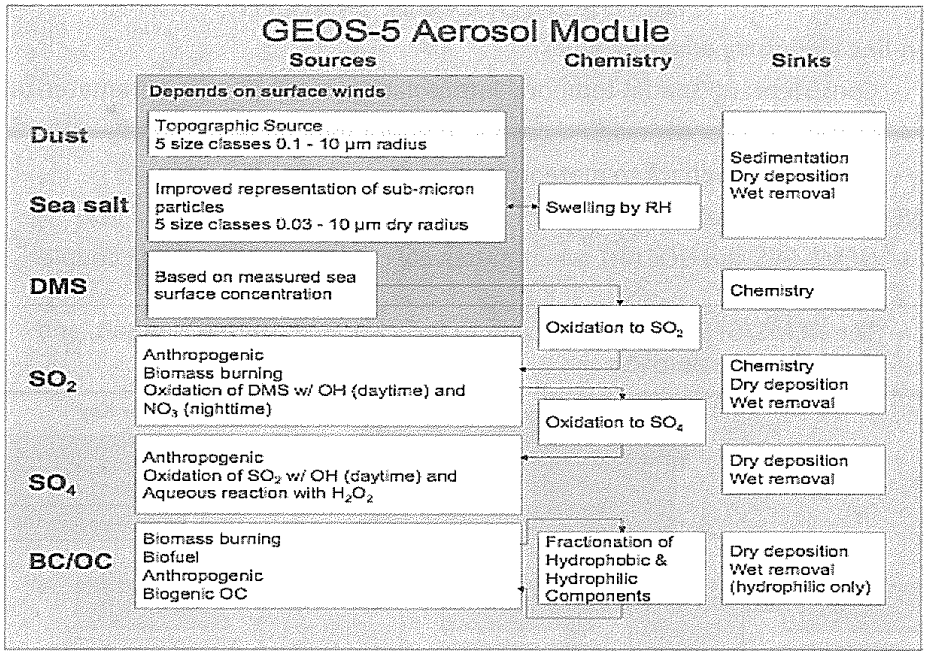


Off-line system versus in-line system

The outcomes of GOCART aerosol fields:

		Off-line System	In-line System
dust/smoke	Provide dynamic dust/smoke LBCs for regional AQ forecasts	YES	YES
volcanic ash	Provide global volcanic particulates transport tracking capability and LBCs for regional AQ	YES	YES
full package	Radiation feedback in GFS	NO	YES
	Atmospheric correction in SST retrievals	NO	YES
	Aerosol effects in GSI/CRTM	NO	YES
	Aerosol data assimilation	NO	YES
	Aerosol-cloud interaction in GFS/CFS	NO	YES

Goddard Chemistry Aerosol Radiation and Transport Model (GOCART)

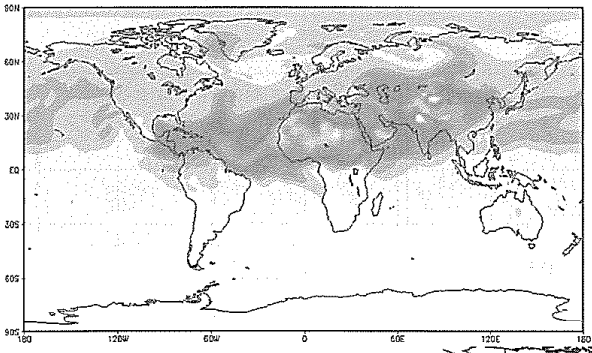


From Arlindo da Silva (GSFC)

AOD comparison (GEOS5 versus NGAC)

NGAC

24–hr fcst, initialized on 00Z 2011–06–14



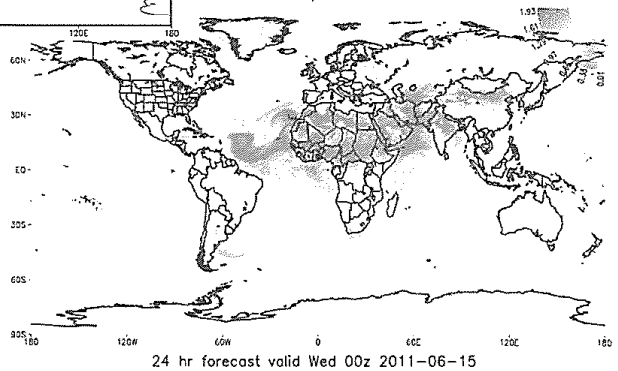
Same color scheme is used

Different AGCM; same GOCART

- Dust loading near source regions are comparable
- Need to examine (and possibly adjust) removal processes in NGAC

GEOS5

Dust Aerosol Optical Thickness



24 hr forecast valid Wed 00z 2011–06–15

Current Status and Performance

Dust Source Function

Function of surface topographic depression, surface wetness, and surface wind speed (Ginoux et al. 2001)

$$Source\ Flux_p = \begin{cases} S\, s_p\, u_{10}^2 \left(u_{10} - u_t\right) & u_{10} > u_t \\ 0 & otherwise \end{cases}$$

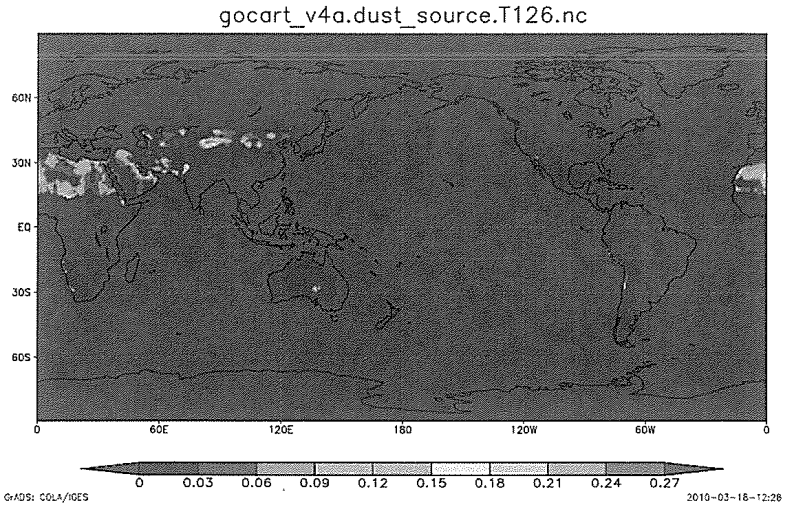
S : Source function s_p: fraction of clay and silt size
u_{10}: wind speed at 10 m u_t: threshold wind velocity

$$u_t = \begin{cases} A\sqrt{\dfrac{\rho_p - \rho_a}{\rho_a} g \Phi_p \left(1.2 + 0.2 \log_{10} w_t\right)} & if\ w_t < 0.2 \\ \infty & otherwise \end{cases}$$

A : constant=6.5 w_t: surface wetness
Φ_p : particle diameter ρ_p, ρ_a : particle and air density

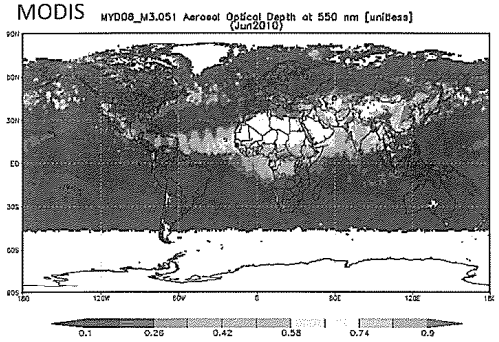
Courtesy of Ho-Chun Huang

Use dust source map mapped to T126



Monthly averaged Aerosol Optical Depth (AOD, column-integrated aerosol extinction coefficient)

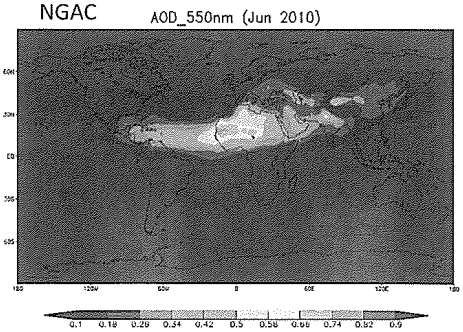
MODIS



MODIS Data: Giovanni online data system, developed and maintained by the NASA DISC

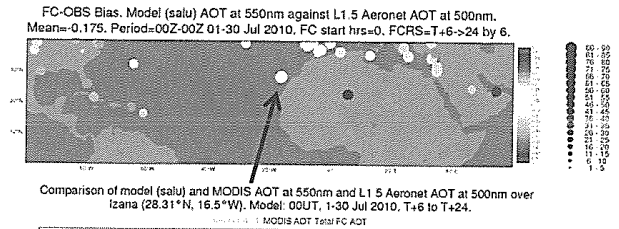
Monthly average of 550nm AOD for June 2010 from MODIS onboard Aqua (left) and dust-only NGAC simulations (right)

NGAC

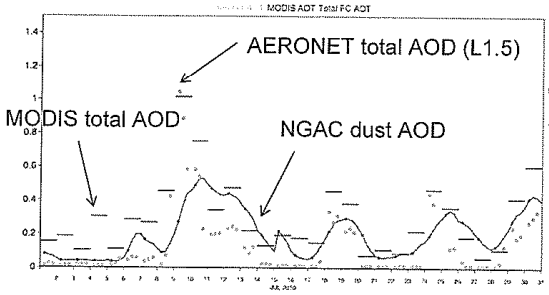


Retro NGAC experiment:
- T126 L64
- June-Aug, 2010 with one-month spin-up
- Meteorological fields are replaced by oper T574 GDAS every 24 hour

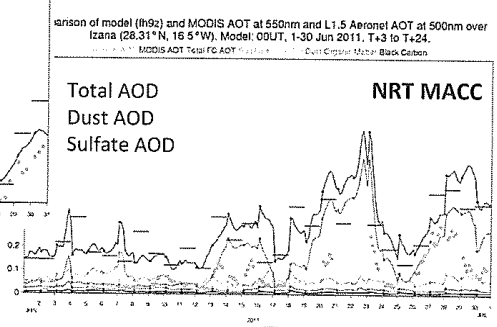
AOD from NGAC forecasts versus in situ observations (AERONET) and satellite measurements (MODIS) at Izana



Good agreement between model and observations near the source region



This is a dust-dominated site



We thank Philippe Goloub for the efforts in establishing and maintaining Izana site.

Coutersy of Luke Jones of ECMWF

ECMWF macc GMES INFO

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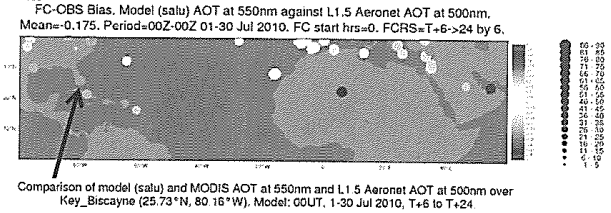
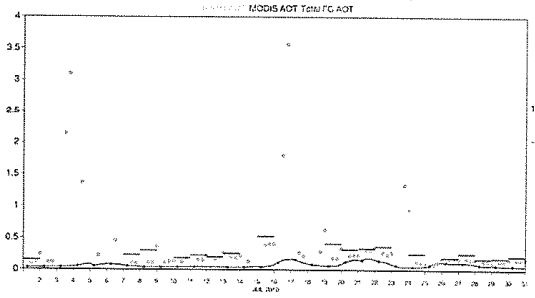
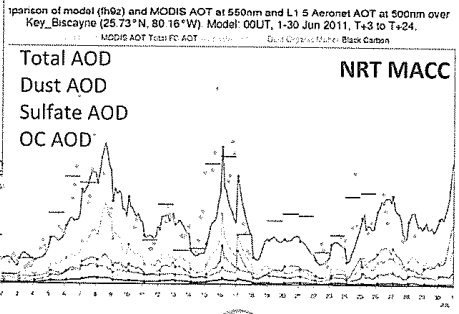
AOD from NGAC forecasts versus in situ observations (AERONET) and satellite measurements (MODIS) at Key Biscayne



It is challenging to evalute dust-only NGAC over the areas affected by other aerosol species



This site is influenced by sulfate, OC, and dust aerosols



We thank Kenneth Voss for the efforts in establishing and maintaining Key Biscayne site.

Coutersy of Luke Jones of ECMWF

ECMWF macc GMES INFO

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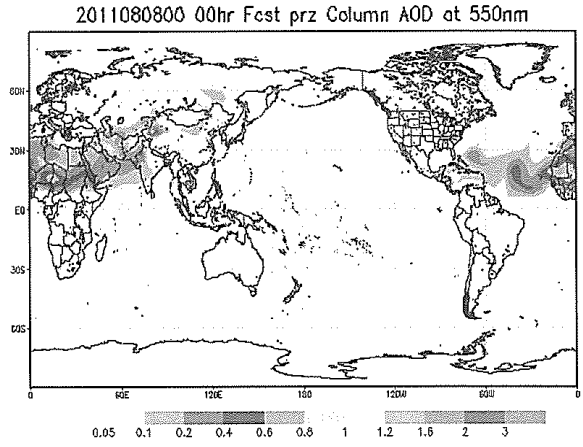
NRT Dust Forecasting

NRT NGAC configuration

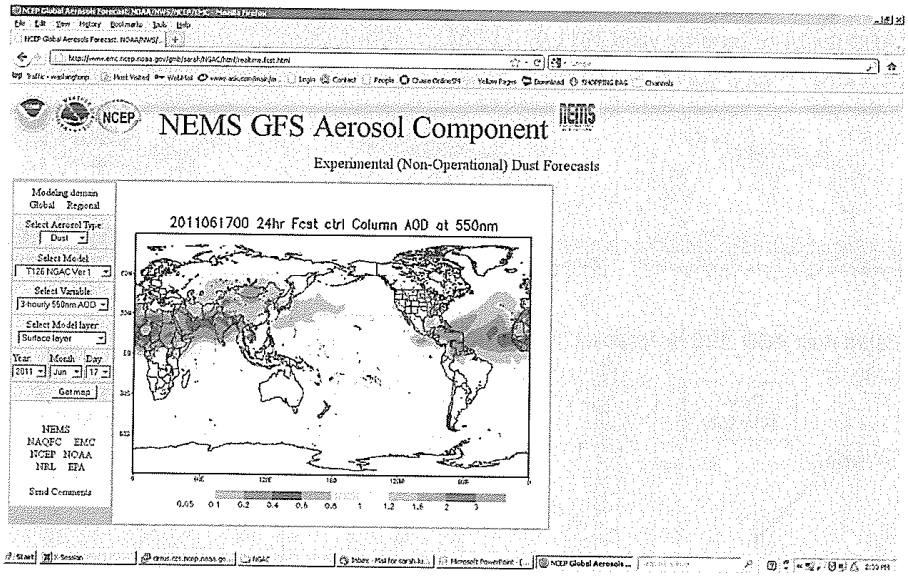
Experimental (non-operational)

- EMC parallel on NCEP's CCS (dev)
- Executable compiled from NEMS code repository
- 120-hr dust-only forecast once per day (00Z)
- ICs: Aerosols from previous day forecast and meteorology from operational GDAS
- 3-hourly products: 3d distribution of dust aerosols (5 bins from 0.1 – 10 μm)



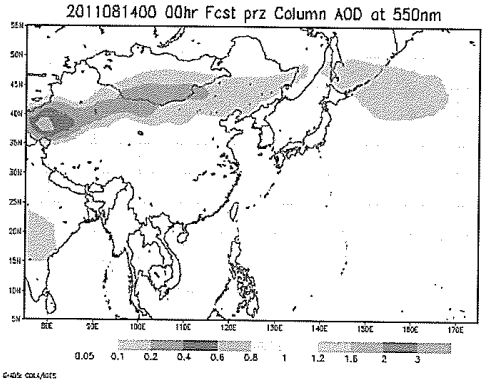
- Automatic output archive, post-processing and web update since June 11, 2011
- Same physics and dynamics as operational GFS with the following exceptions:
  - Lower resolution (T126 L64)
  - Use RAS with convective transport and tracer scavenging
  - Turn off aerosol-radiation feedback

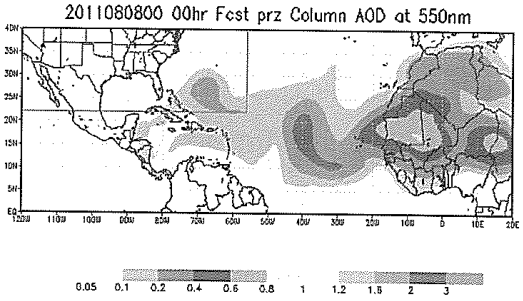
Web page for NRT NGAC dust forecasts



http://www.emc.ncep.noaa.gov/gmb/sarah/NGAC/html/realtime.fcst.html

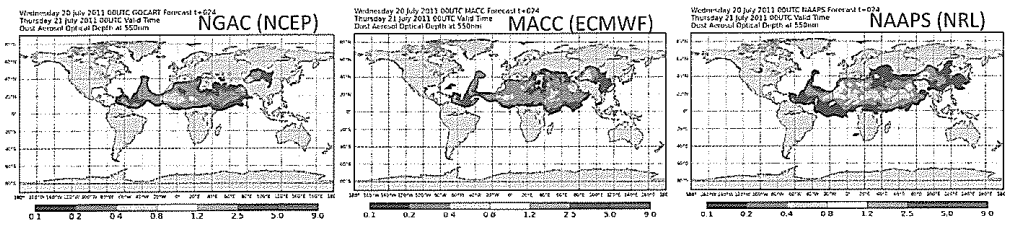
NRT NGAC dust forecasts (regional)



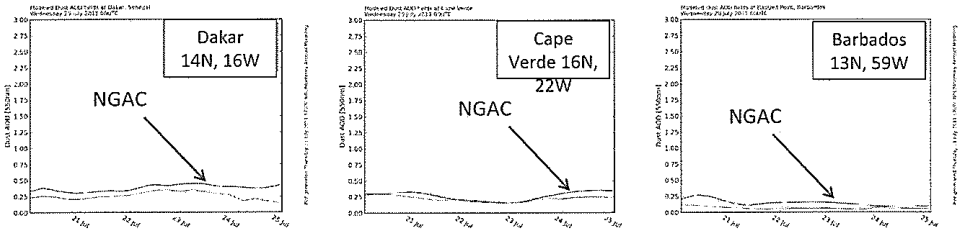


International Cooperative for Aerosol Prediction (ICAP)

Dust AOD for 24-hr forecast valid 2011-07-21 00Z



Modeled dust AOD, 120-hr forecast, initialized from 2011-07-20 00Z



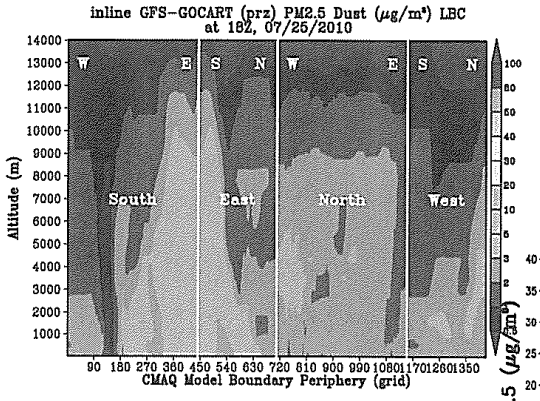
Courtesy of Walter Sessions (NRL)

Plans toward FY12 implementation

- Use NCEP unified post for post-processing
- Set up aerosol verification system
  - Satellite: MODIS AOD, CALIPSO backscatter
  - Ground-based: AERONET AOD, backscatter from lidar network (MPLNET, EARLINET, SKYNET)
- Refine and optimize the NGAC (revisit removal, emission..etc)
- Code delivery to NCO by Dec 2011
- Operational implementation targeted for Mar 2012

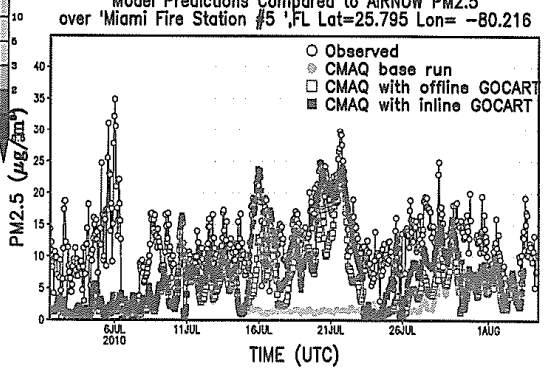
Beyond Dust forecasting

Aerosol Lateral Boundary Conditions:
Trans-Atlantic dust transport



- Left panel: Dust influx at CMAQ boundaries from NGAC simulations
- Right panel: Baseline CMAQ simulation with static LBCs versus experimental CMAQ simulations with dynamic LBCs from NGAC and off-line GFS-GOCART

Verification with AIRNOW surface PM observations shows great enhancement using dynamic LBCs from GOCART

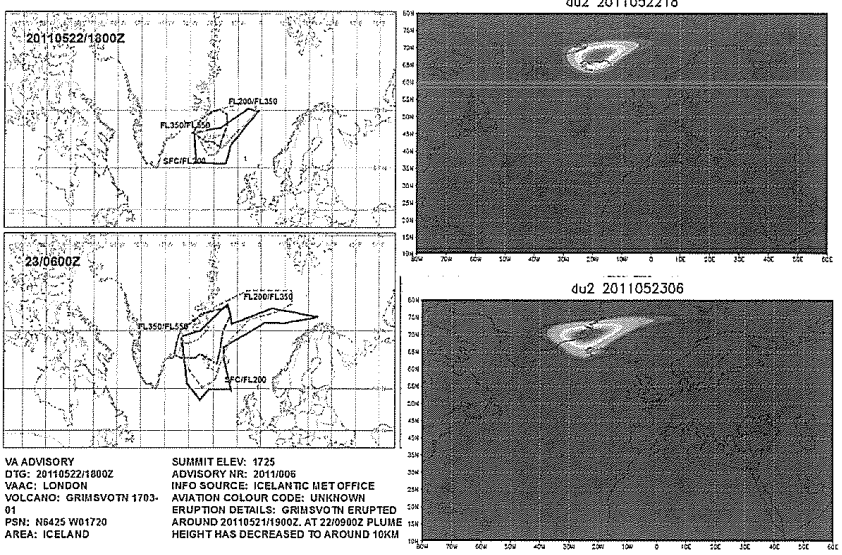


Youhua Tang and Ho-Chun Huang (EMC AQ team)

Grimsvotn eruption (21 May 2011)

Left panel: Ash forecast from London VAAC

Right panel: NGAC ash forecast at level 32 (corresponding to FL200/FL350 [green dash] on the



NGAC dust module has been modified to forecast volcanic ashes.

Results from the prototype ash system are qualitative, as the focus is on plume transport pattern.

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Outcomes of the aerosol component

- Prototype system for NEMS-CHEM
- Enable NCEP to produce global short-range chemical weather forecasts
- Provide lateral aerosol boundary conditions for regional air quality forecast system
- Create aerosol information needed for atmospheric correction in satellite retrievals
- Provide a first step toward an aerosol data assimilation capability at NCEP
- Allow NCEP to explore aerosol-chemistry-climate interaction in the climate system

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附錄四、Summary & feedback on the visit

Summary

- The AQ forecasting at NOAA/NCEP is an objective and systematic system. At present time, Taiwan lacks objective and systematic AQ forecasting.
- For a successful AQ forecasting, it needs a lot of effort in different areas (model development, emissions, pre-operational testing, implementation, and verification). I am glad that I learn from you on this trip for information of those critical components.
- Among those, I feel an objective verification is very important in air quality forecasting for Taiwan EPA. Taiwan EPA needs to build verification first.
- Taiwan EPA and NOAA should have a collaboration in future on AQ forecasting, but we need to build a similar AQ forecasting system in Taiwan.