Real-time Air Quality Modeling System aerosol and ozone assimilation and forecasting experiments during the NOAA ARCPAC field mission

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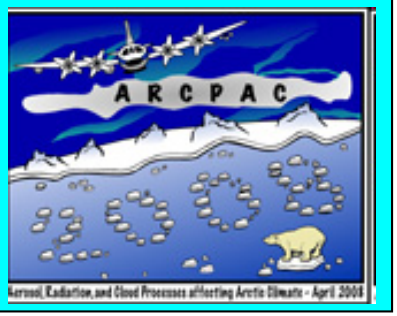
During April 2008, as part of the International Polar Year (IPY), NOAA's Climate Forcing and Air Quality Programs engaged in an airborne field measurement campaign in the Alaskan Arctic.

The Aerosol, Radiation, and Cloud Processes affecting Arctic Climate (ARCPAC) field mission focused on direct measurements of properties and processes designed to address non-greenhouse-gas atmospheric climate forcing.



•The Real-time Air Quality Modeling System (RAQMS) chemical and aerosol forecasts, initialized with real-time satellite measurements (e.g. MLS stratospheric ozone profiles, OMI total column ozone, Terra and Aqua MODIS aerosol optical depth) were used for daily flight planning activities during ARCPAC.

•This talk presents results from post mission studies focused on evaluation of the RAQMS large-scale ozone and aerosol analyses based on comparisons with satellite, ground based, and airborne observations.

Model Description

1. **Online global chemical and aerosol assimilation/ forecasting system**

2. **UW-Madison hybrid θ–η coordinate model (UW-Hybrid) dynamical core**

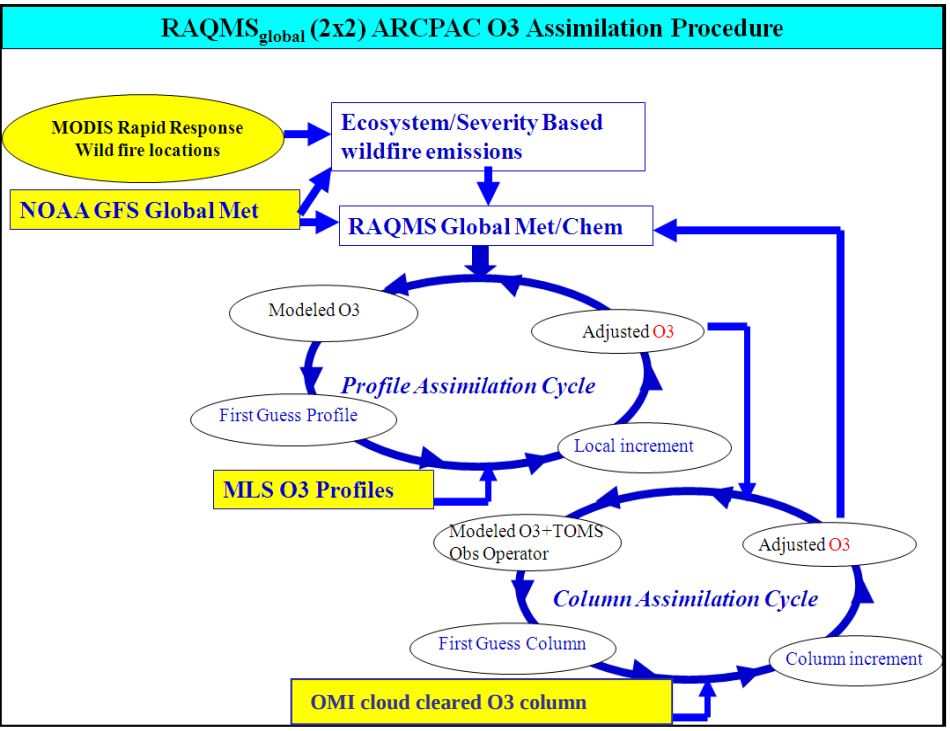
3. **Unified stratosphere/troposphere chemical prediction scheme (LaRC-Combo) developed at NASA LaRC**

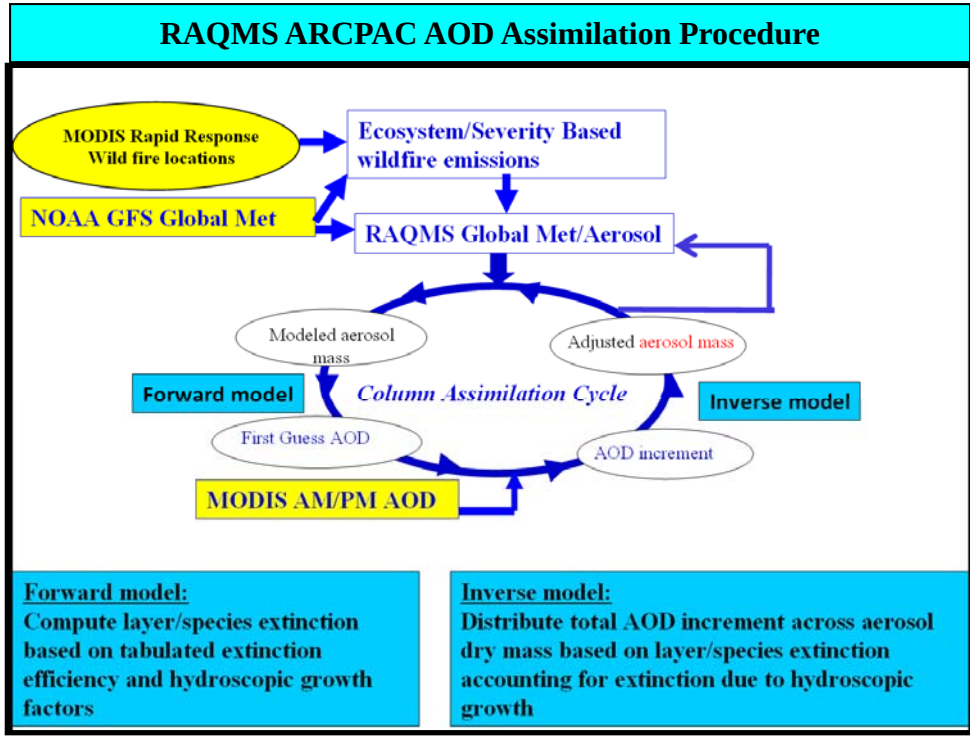
4. **Aerosol prediction scheme (GOCART) developed by Mian Chin (NASA GSFC).**

5. **Statistical Digital Filter (OI) assimilation system developed by James Stobie (NASA/GFSC)**

RAQMS has been used to support airborne field missions [Pierce et al, 2003, 2007, 2008], develop capabilities for assimilating satellite trace gas and aerosol retrievals [Pierce et al., 2007, 2008, Fishman et al., 2008, Sunita et al., 2008] and assess the impact of global chemical analyses on regional air quality predictions [Song et al., 2008, Tang et al., 2008]

RAQMS ARCPAC O3/AOD Assimilation Procedure



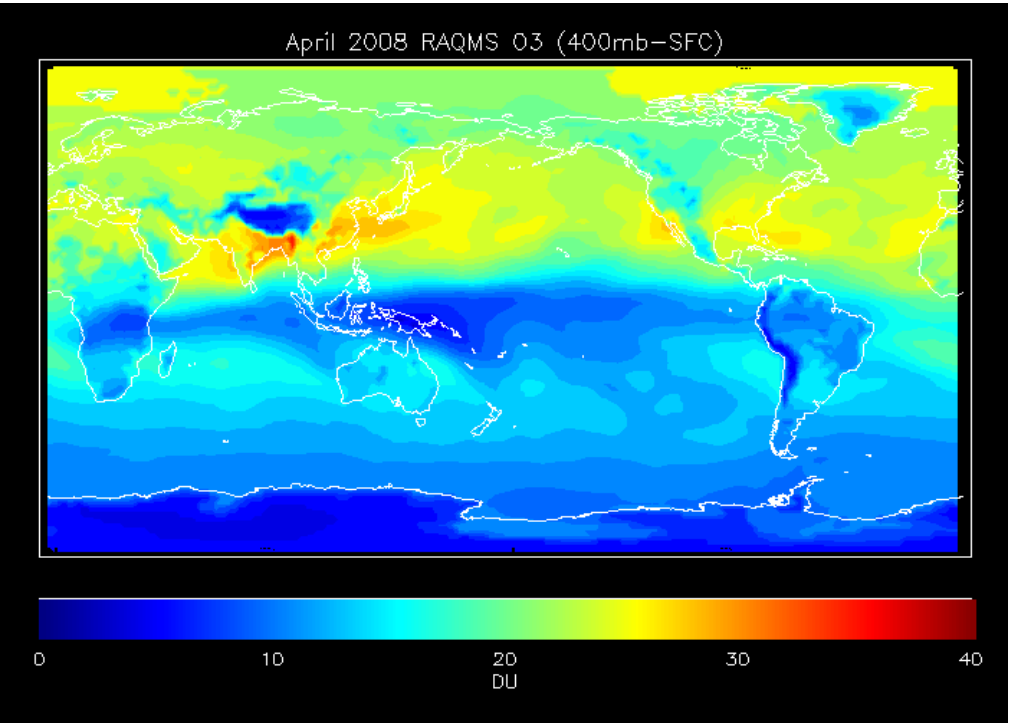


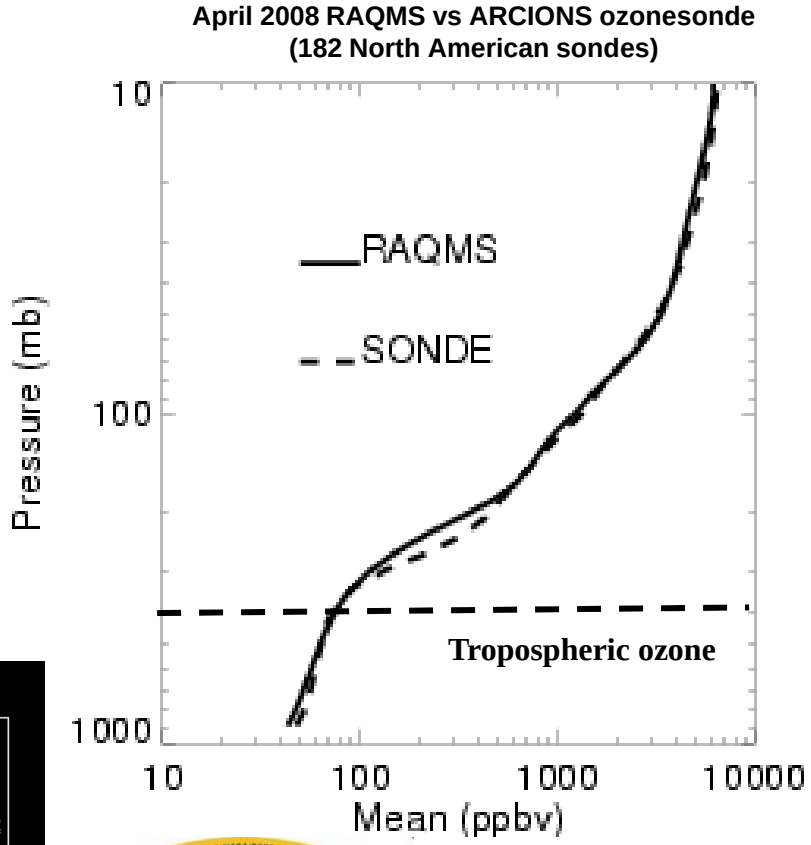
Real-time Demonstration of:

- **Assimilation of Microwave Limb Sounder (MLS) stratospheric ozone profiles**
- **Assimilation of Ozone Monitoring Instrument (OMI) total ozone column**
- **Assimilation of MODIS Aerosol Optical Depth (AOD)**
- **Incorporation of MODIS based biomass burning emissions**

Risk-mitigation for Operational assimilation of OMPS and VIIRs on NPOESS

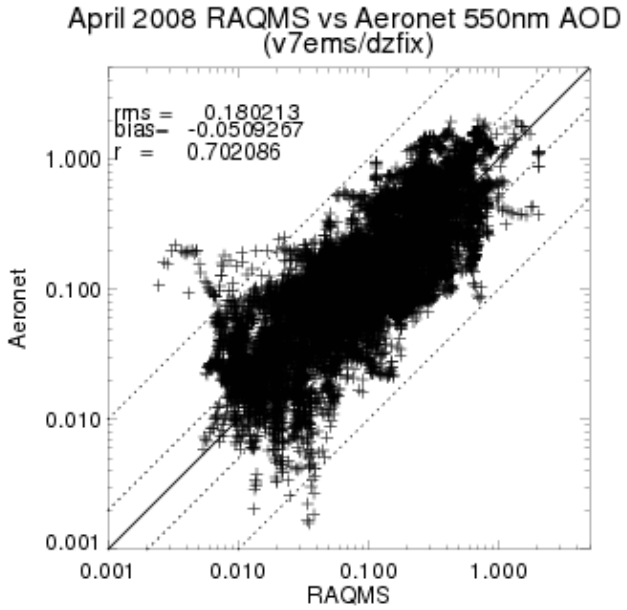
RAQMS Ozonesonde Validation April 2008

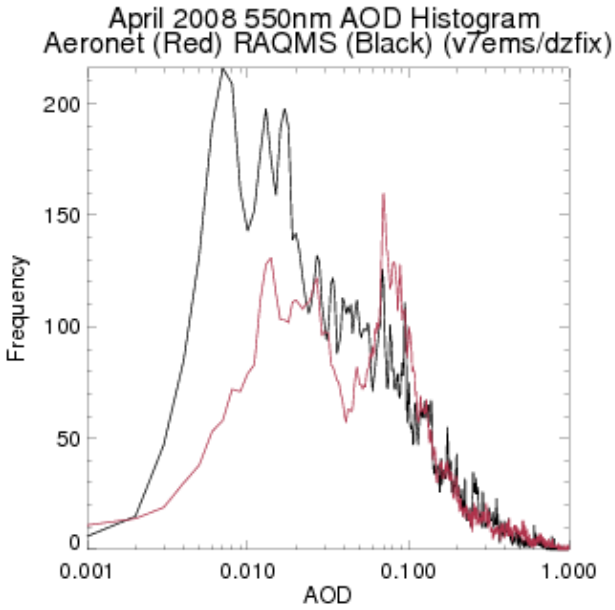


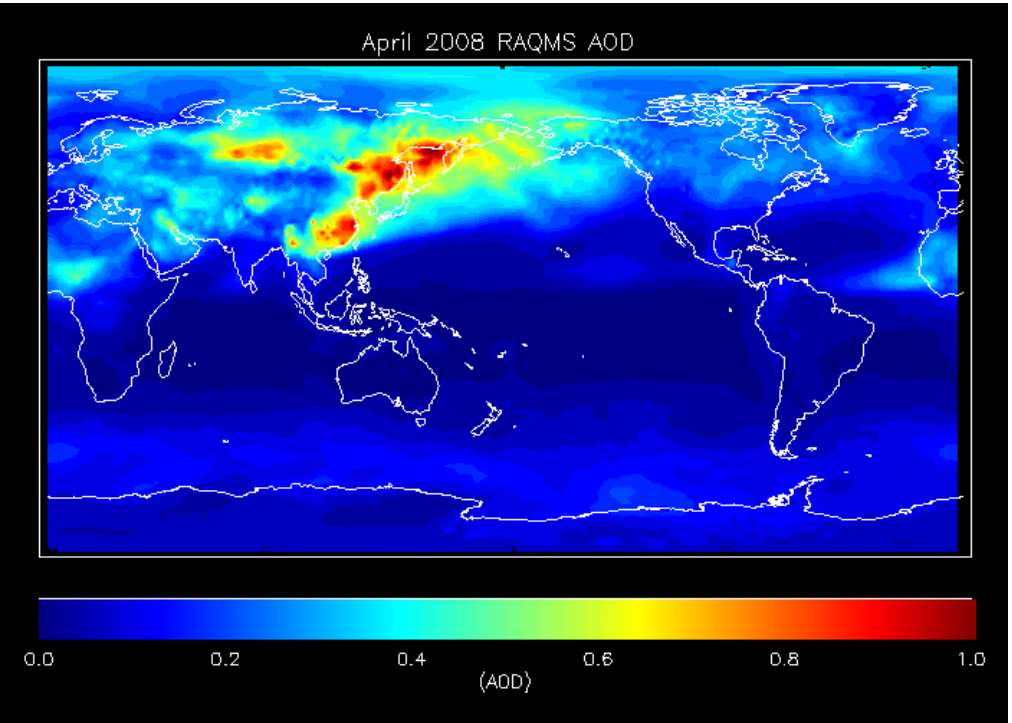


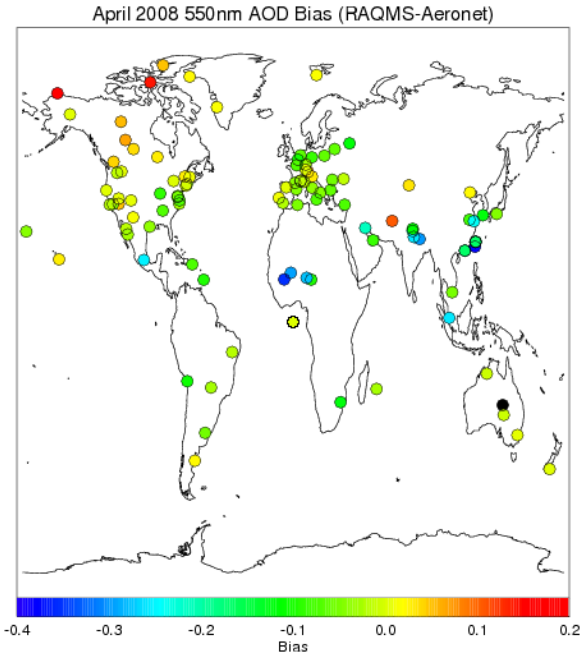
1-Alert, NU, CAN
2-Eureka, NU, CAN
3-Summit, GL
4-Resolute, NU, CAN
5-Barrow, AK, US
6-Whitehorse, YT, CAN
7-Yellowknife NWT, CAN
8-Churchill, MB, CAN
9-Stonyplain, AL, CAN
10-Kelowna, BC, CAN
11-Bratts Lake, SK, CAN
12-Trinidad Head, CA, US
13-Boulder, CO, US
14-Goose Bay, ND, CAN
15-Sable Island, NS, CAN
16-Yarmouth, NS, CAN
17-Egbert, ON, CAN
18-Narragansett, RI, US
19-Huntsville, AL, US

RAQMS Aeronet Validation April 2008

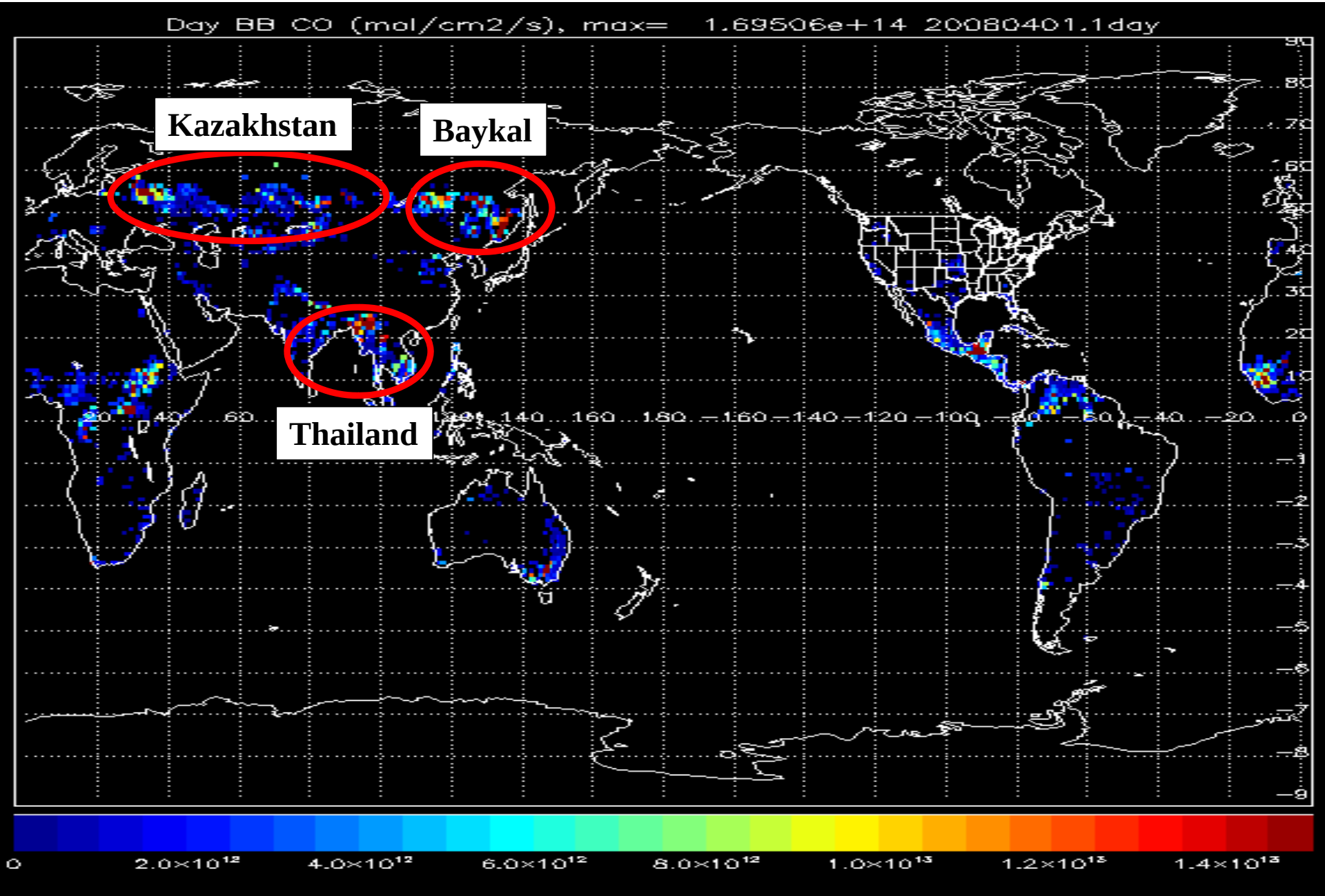


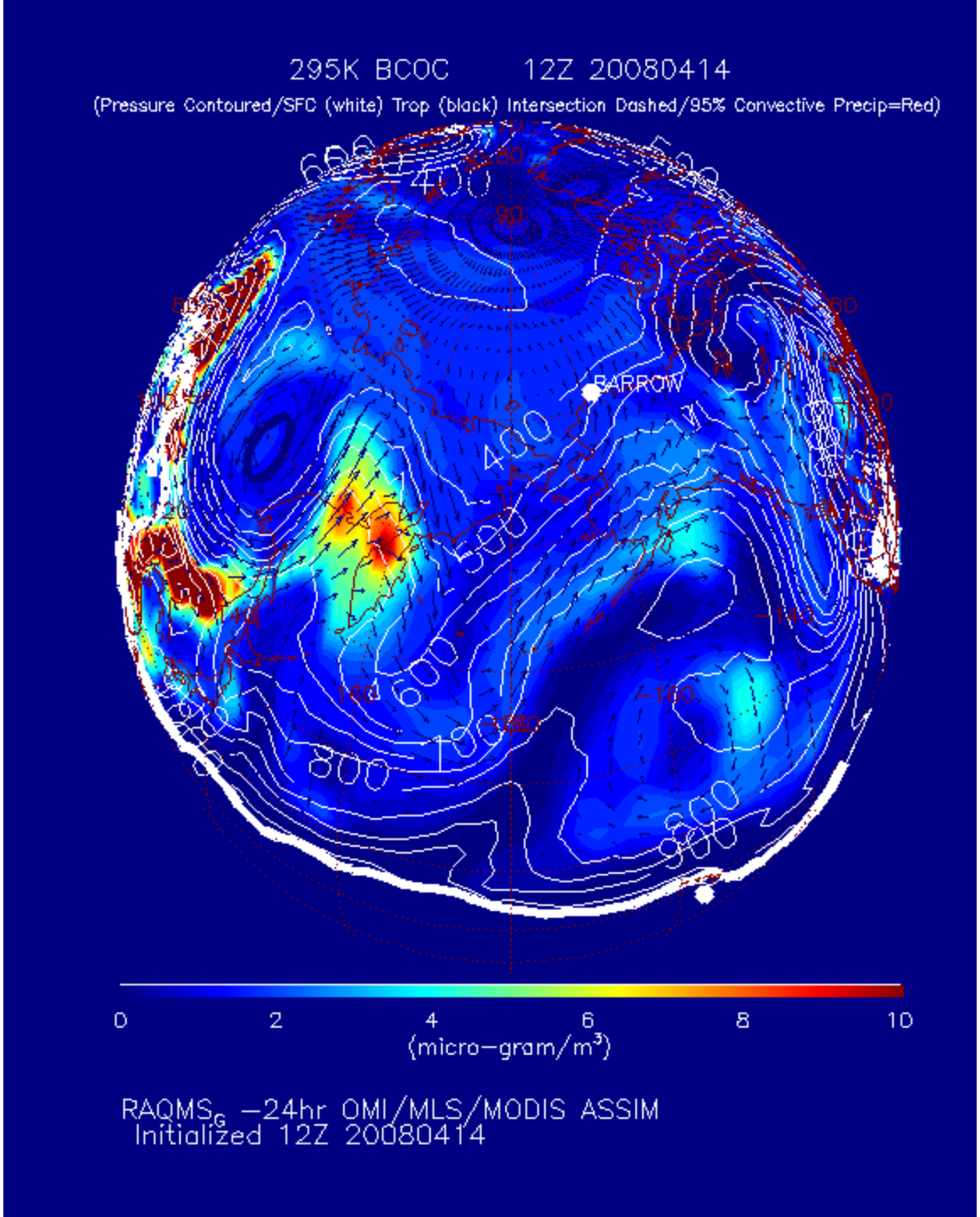




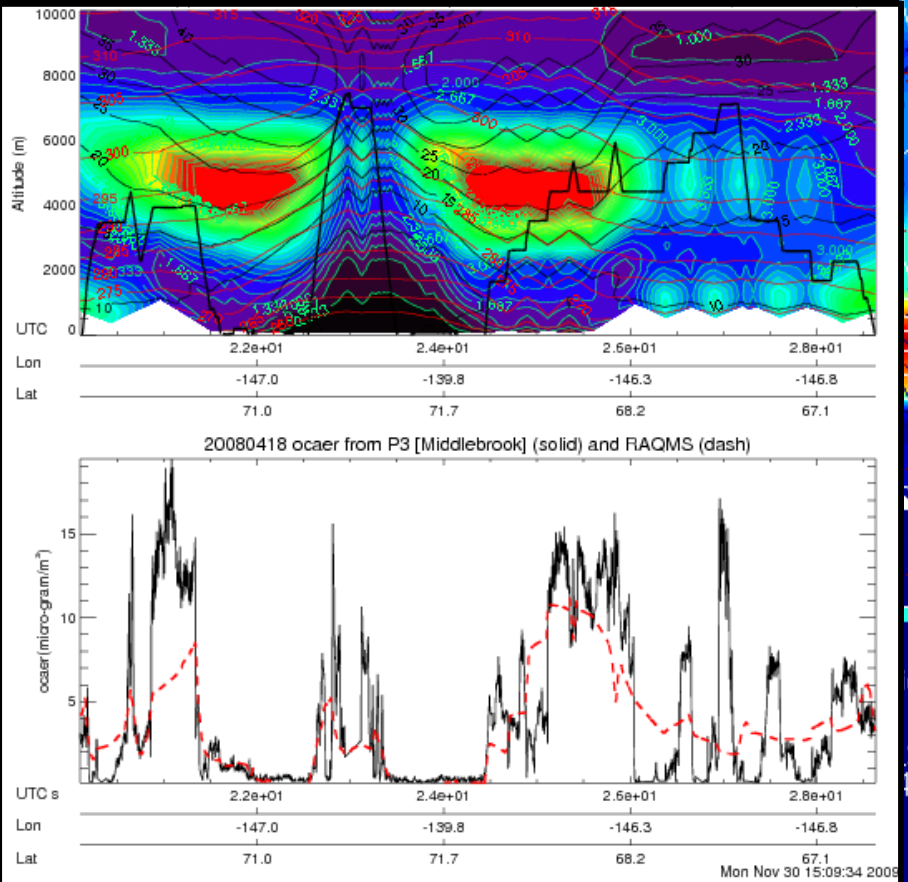


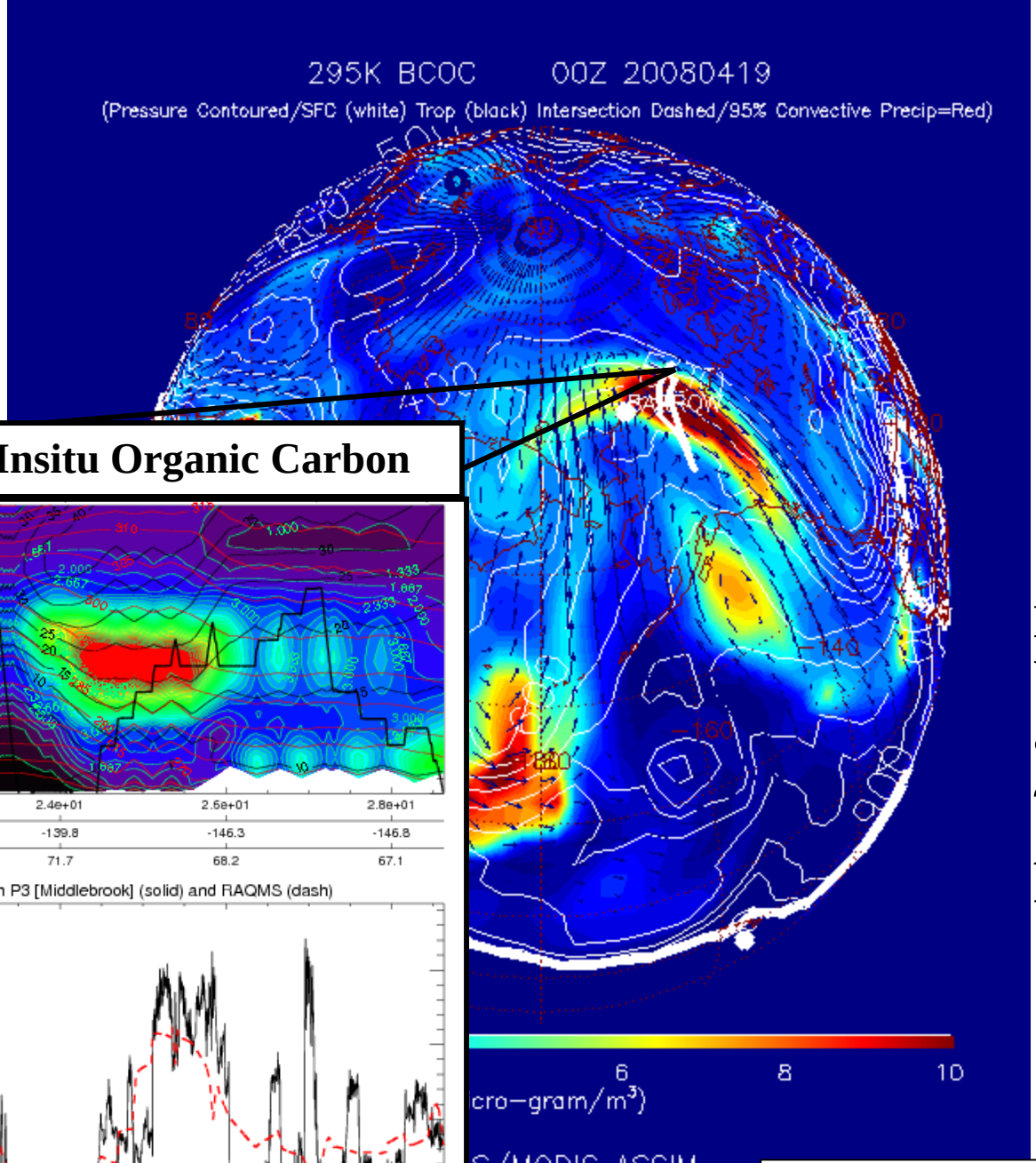
April 2008 Biomass Burning CO Emissions




295K BCOC 12Z 20080414
(Pressure Contoured/SFC (white) Trop (black) Intersection Dashed/95% Convective Precip=Red)
BARROW
400
500
600
700
800
900
0
2
4
6
8
10
(micro-gram/m3)
RAQMS6 -24hr OMI/MLS/MODIS ASSIM
Initialized 12Z 20080414

RAQMS vs P3 Insitu Organic Carbon

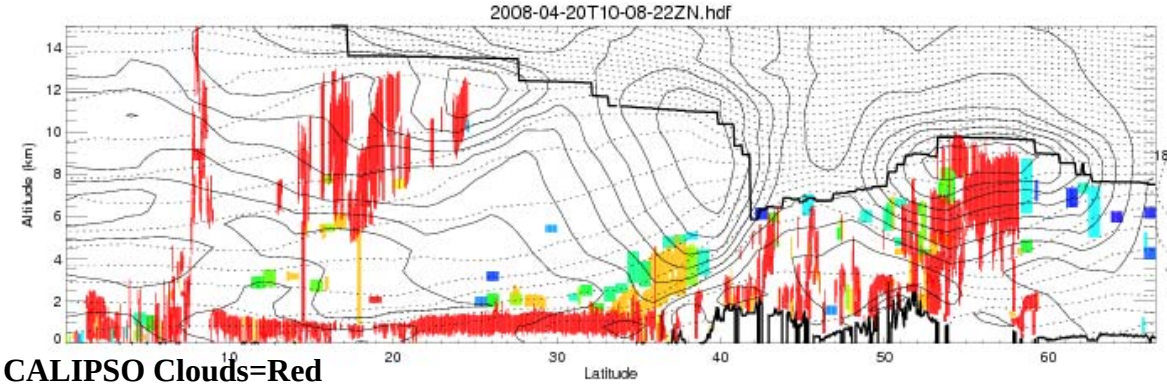


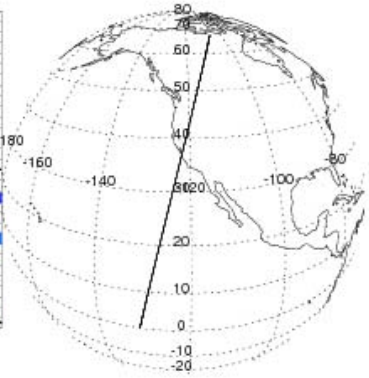


Biomass burning aerosols at ~5km (295K) in Arctic upper troposphere

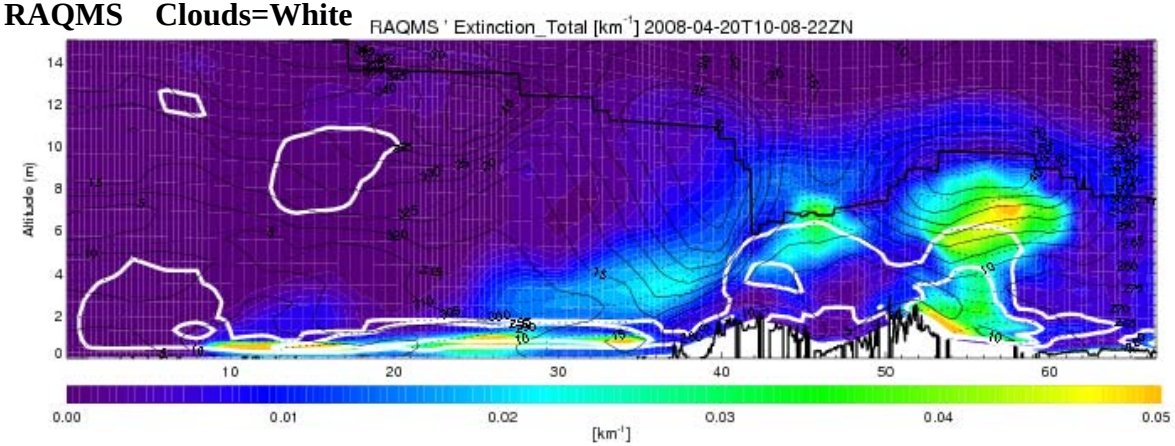
Insitu OC provided by Ann Middlebrook (NOAA/ESRL)

CALIPSO vs RAQMS Extinction: April 20, 2008



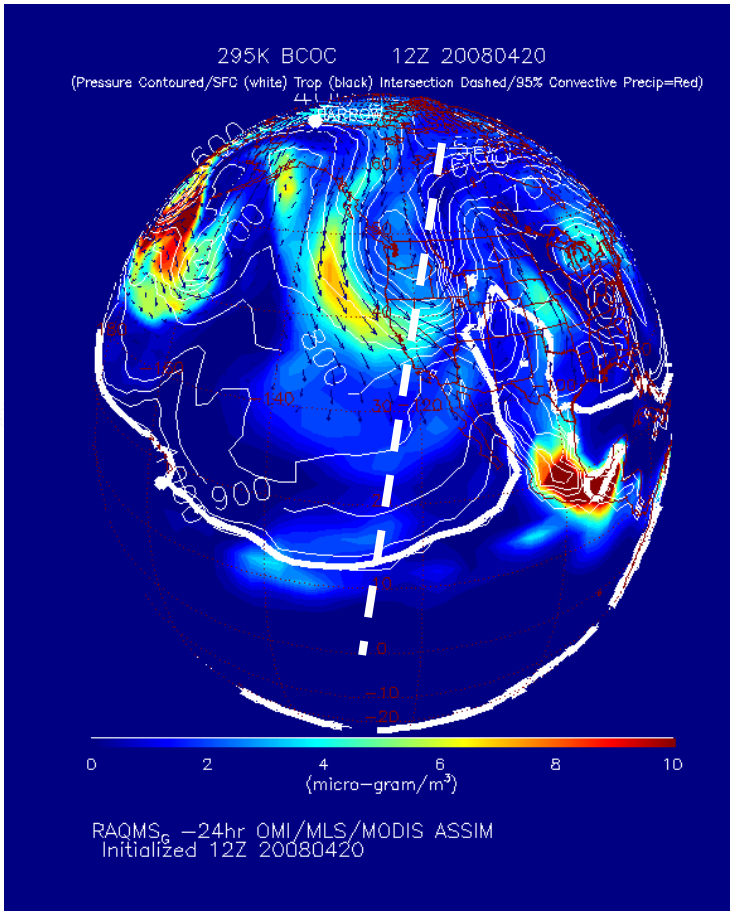


CALIPSO Clouds=Red
RAQMS Clouds=White

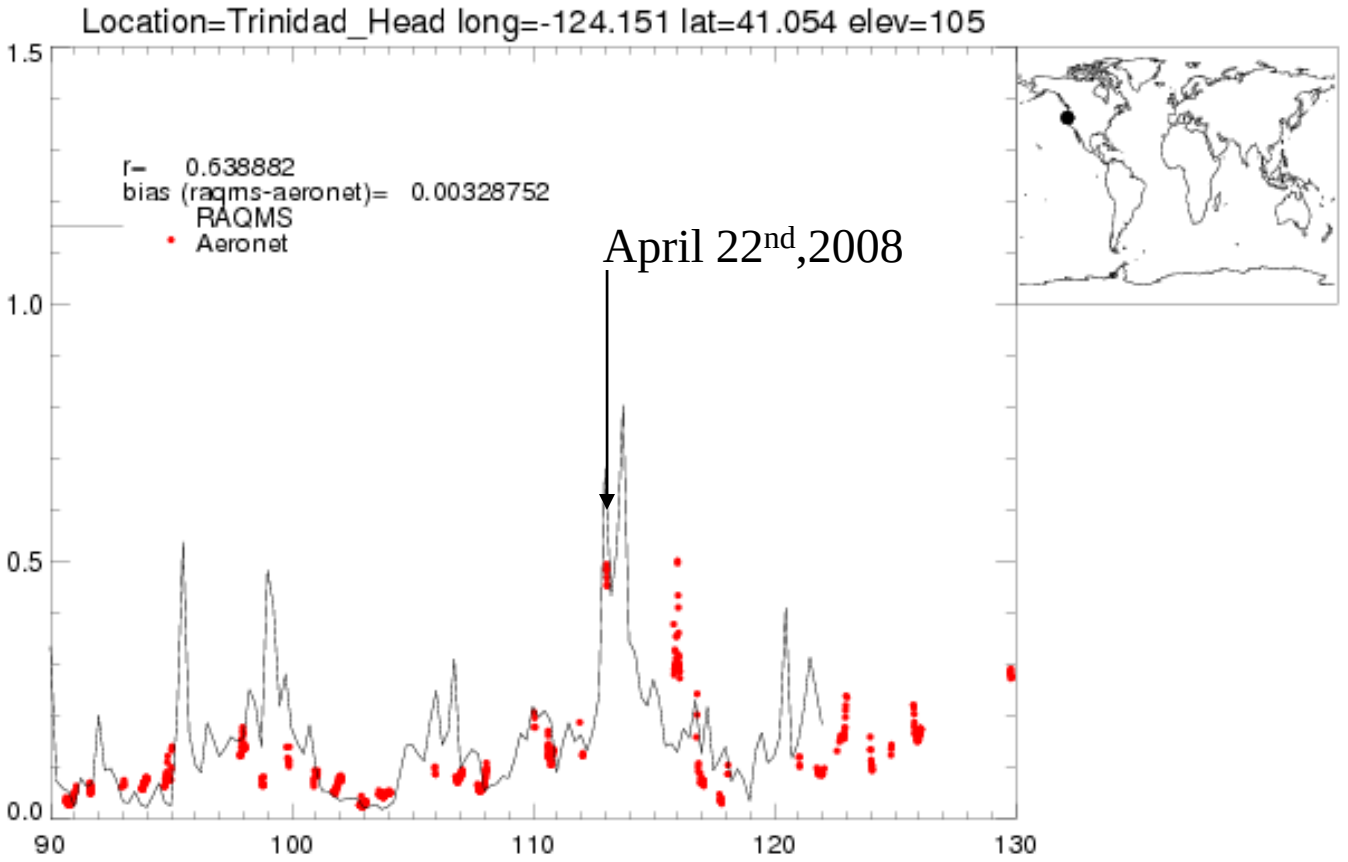


Biomass burning aerosols at ~2-4km (295K) in Mid-latitude lower troposphere

RAQMS analysis underestimates total extinction associated with biomass burning plume relative to CALIPSO



Trinidad Aeronet vs RAQMS AOD: April 2008



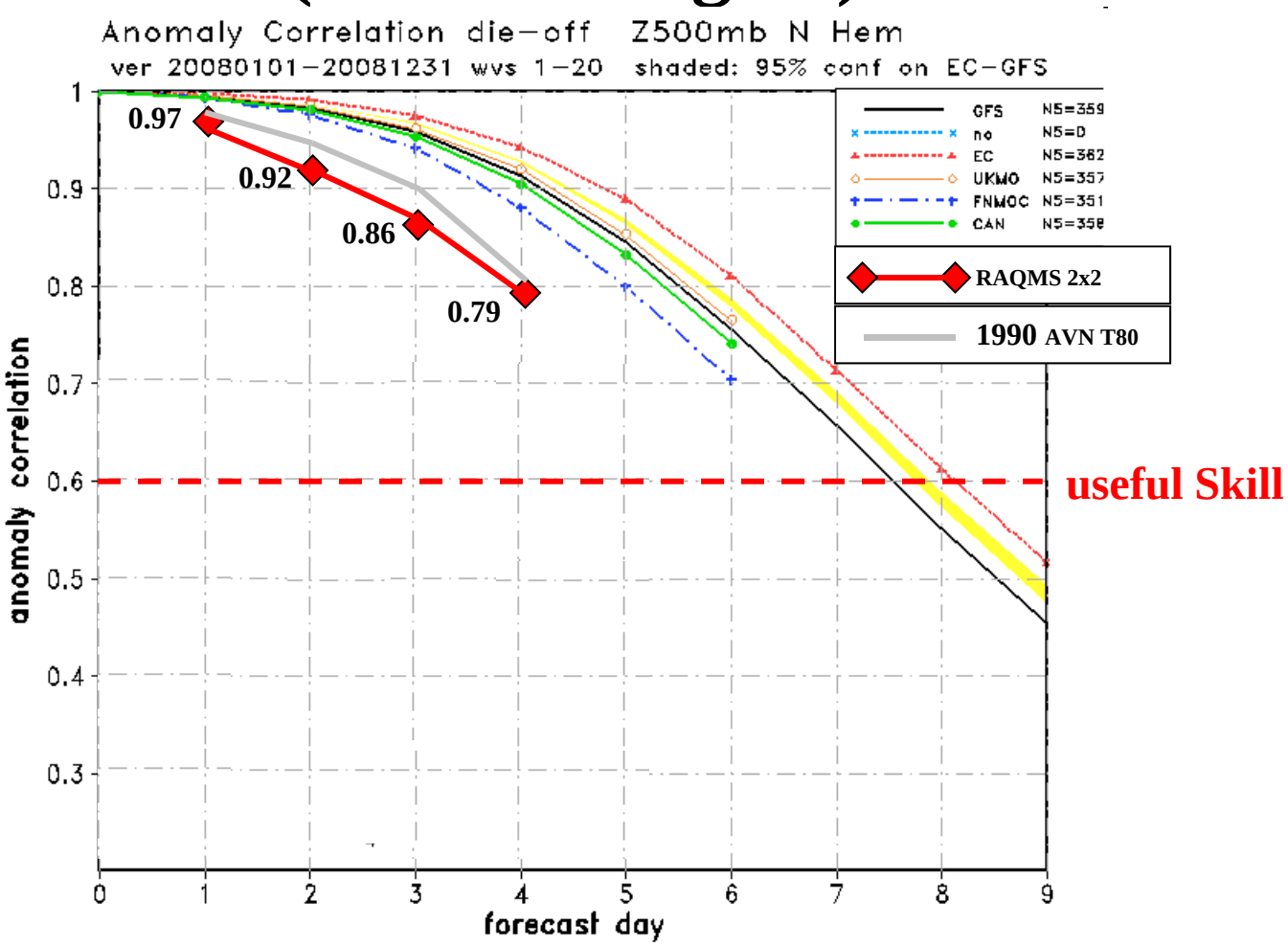
Biomass burning aerosols observed at Trinidad Head on April 22, 2008

RAQMS analysis overestimates AOD associated with biomass burning plume relative to Aeronet

Assessment of Global Forecast Skill

- Anomaly Correlations (AC)
  - April Monthly mean removed
  - Spectrally truncated to wavenumber 20

2008 RAQMS (2x2) Global Forecast Skill (500mb Heights)



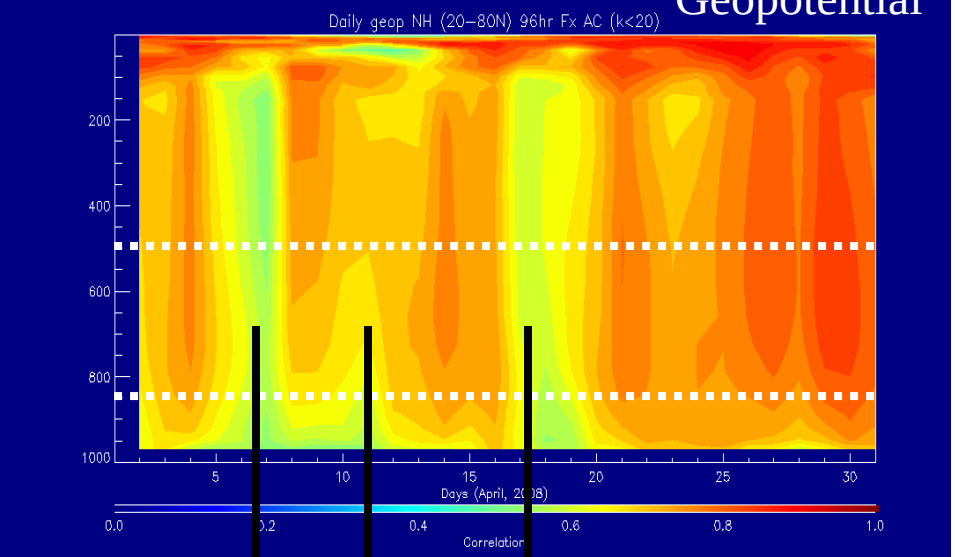
NH (20-80N) Anomaly Correlation (AC) between analysis and forecast 500mb heights (Different physics, RAQMS 2x2 vs GFS T382)

The RAQMS 2x2 NH Z500mb AC score is comparable to the 1990 AVN (T80~1.5 degrees)

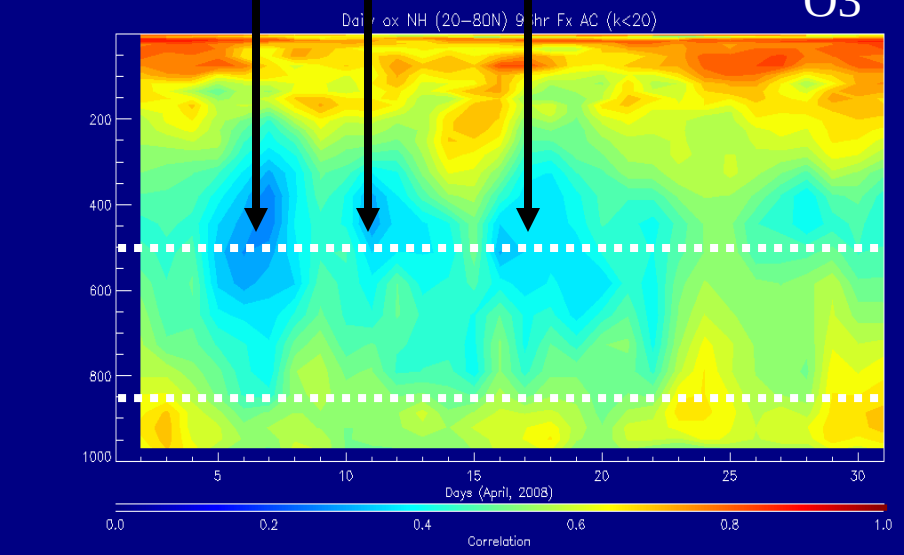
UW-Hybrid (0.7x0.7) NH Z500mb AC score is comparable to 2005 GFS (T256 ~0.5degrees)

2008 RAQMS (2x2) Global Forecast Skill (96hr NH Geopotential, O3 & Aerosol Extinction)

Geopotential



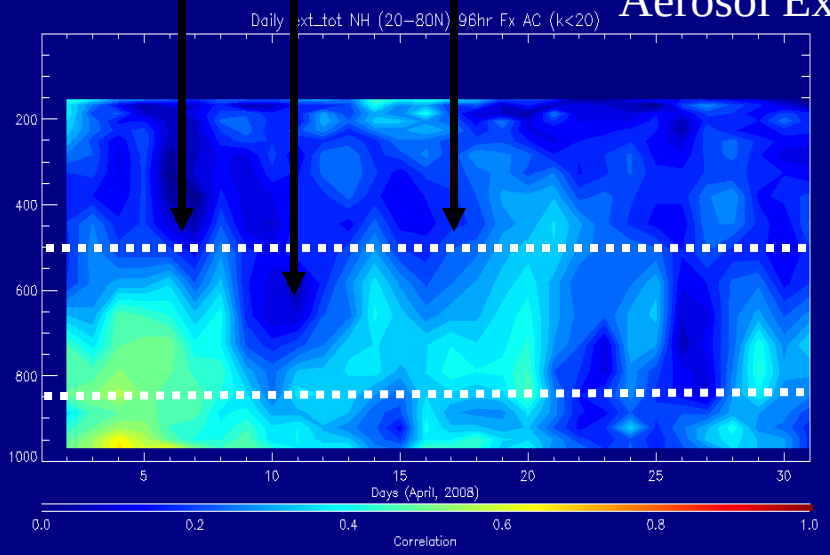
O3



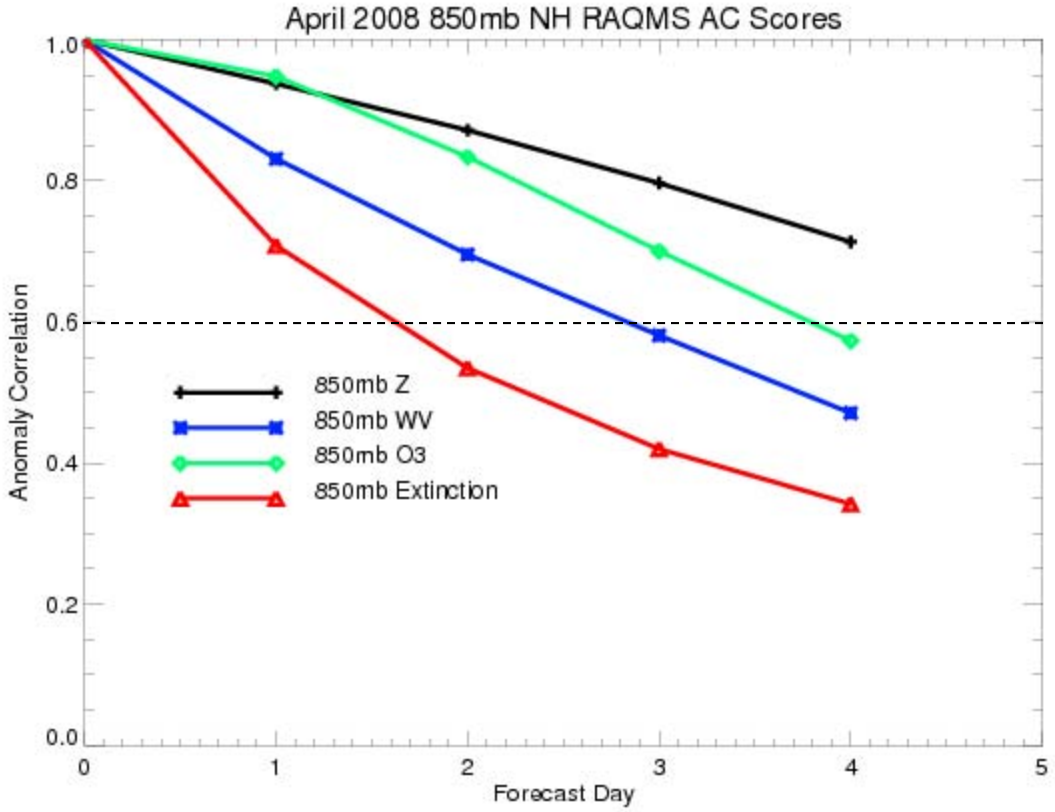
Mid-troposphere O3 and aerosol AC closely linked to Dynamical AC

Not true in lower troposphere

Aerosol Ext



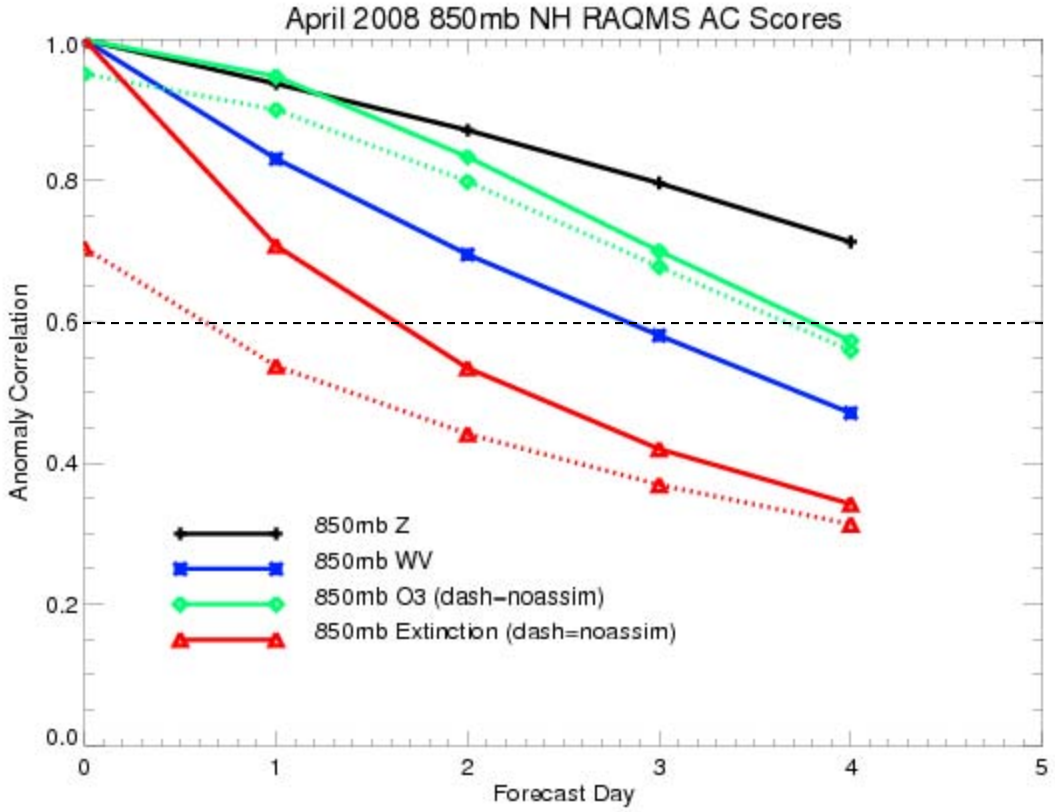
RAQMS (2.0x2.0) Global O3/Aerosol Forecast Skill
(850mb with MODIS and OMI assimilation)



Skill Threshold

- **850mb ozone forecasts have useful skill past 3 days (significantly better than water vapor)**
- **850mb extinction forecasts have useful skill for ~1.5 days**

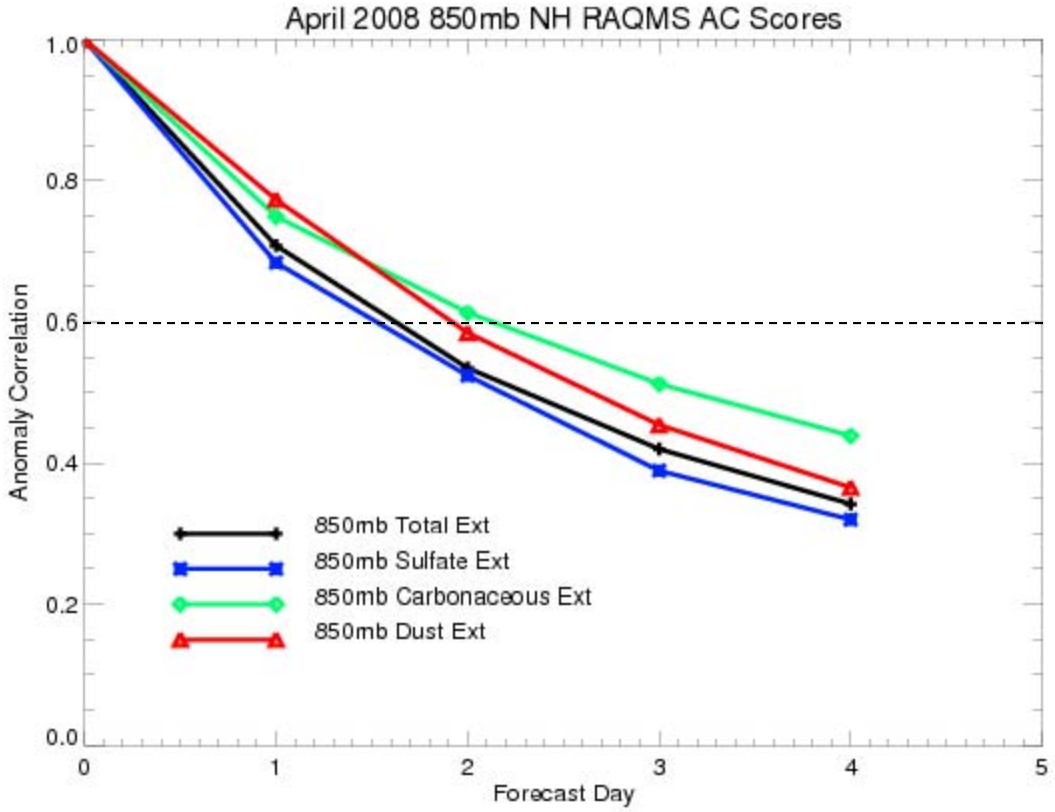
RAQMS (2.0x2.0) Global O3/Aerosol Forecast Skill (850mb with and without MODIS and OMI assimilation)



Skill Threshold

- **Assimilation of OMI O3 column has a positive impact on 850mb Ozone**
- **Assimilation of MODIS AOD has a large positive impact on 850mb extinction**

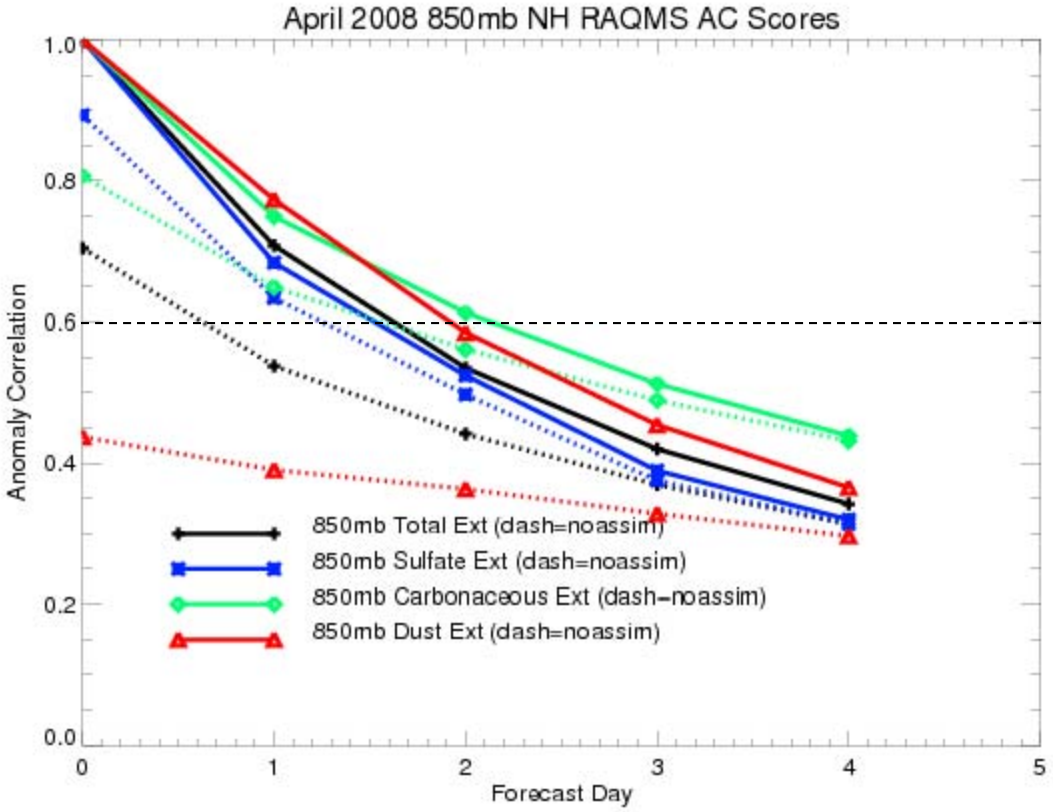
RAQMS (2.0x2.0) Global Aerosol Forecast Skill
(850mb with MODIS and OMI assimilation)



Skill Threshold

•**Reduced Sulfate aerosol forecast skill determines Total aerosol forecast skill**

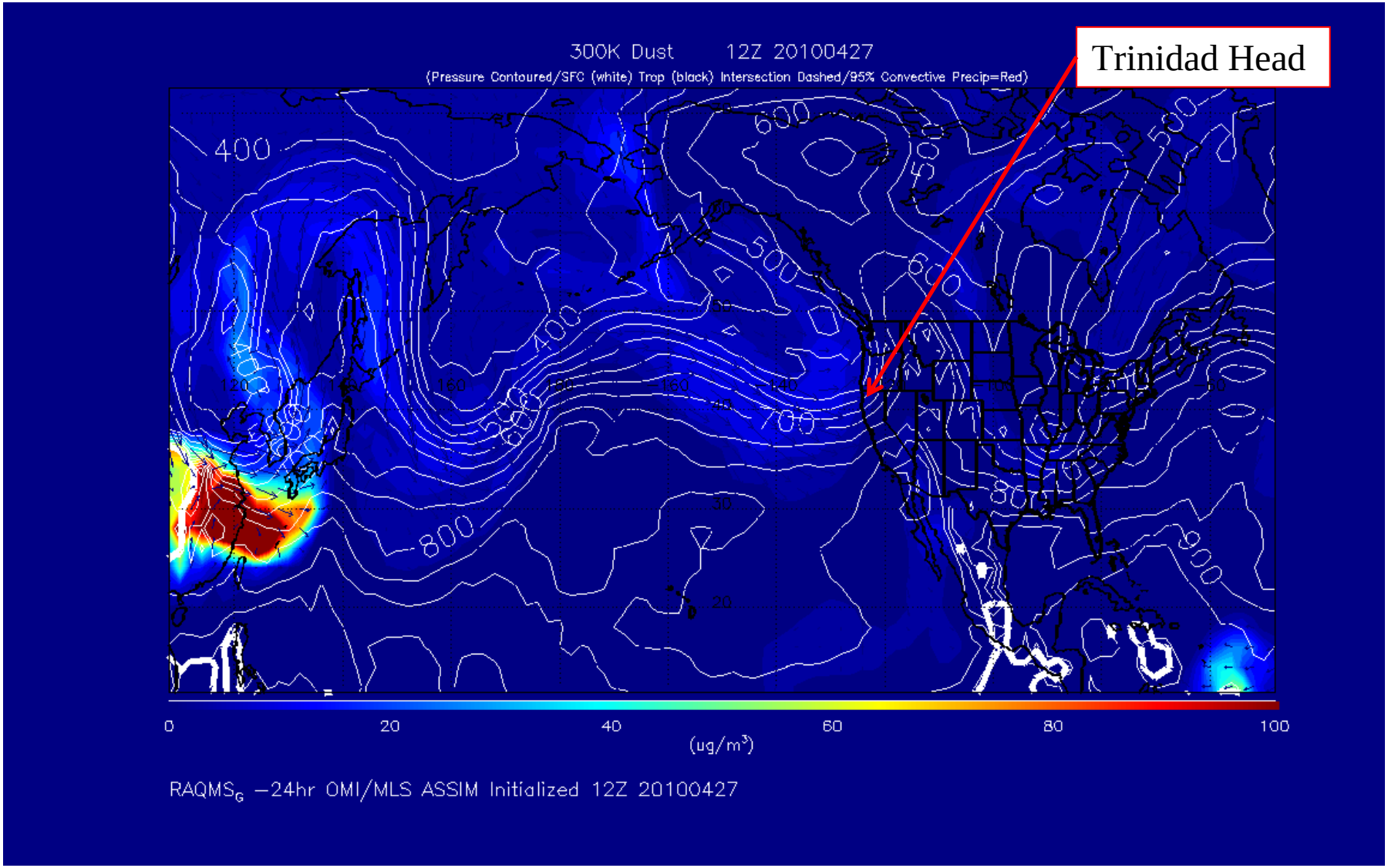
RAQMS (2.0x2.0) Global O3/Aerosol Forecast Skill
(850mb with and without MODIS and OMI assimilation)

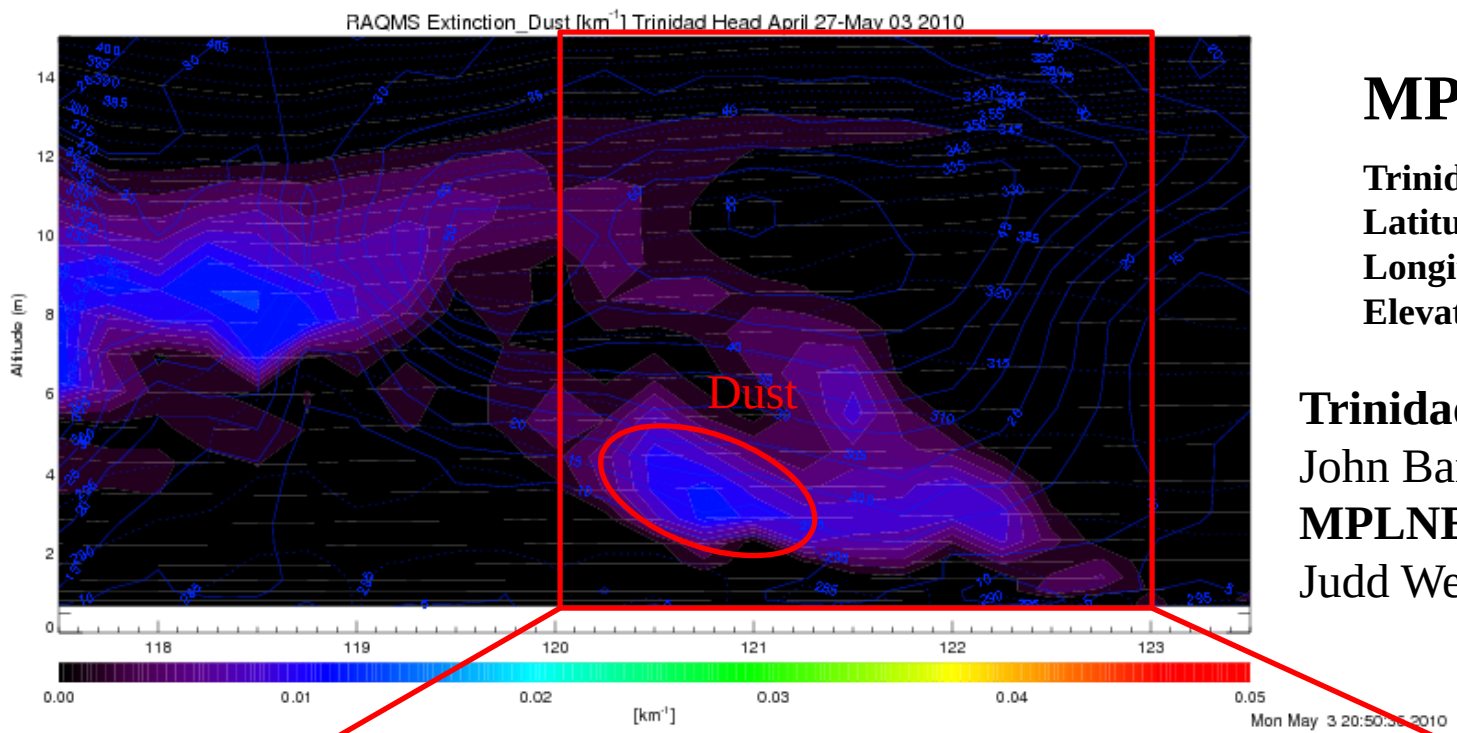


Skill Threshold

•**Carbonaceous and Dust extinctions are most significantly impacted by AOD assimilation**

RAQMS 300K Dust Forecast 12Z April 28-12Z May 03, 2010

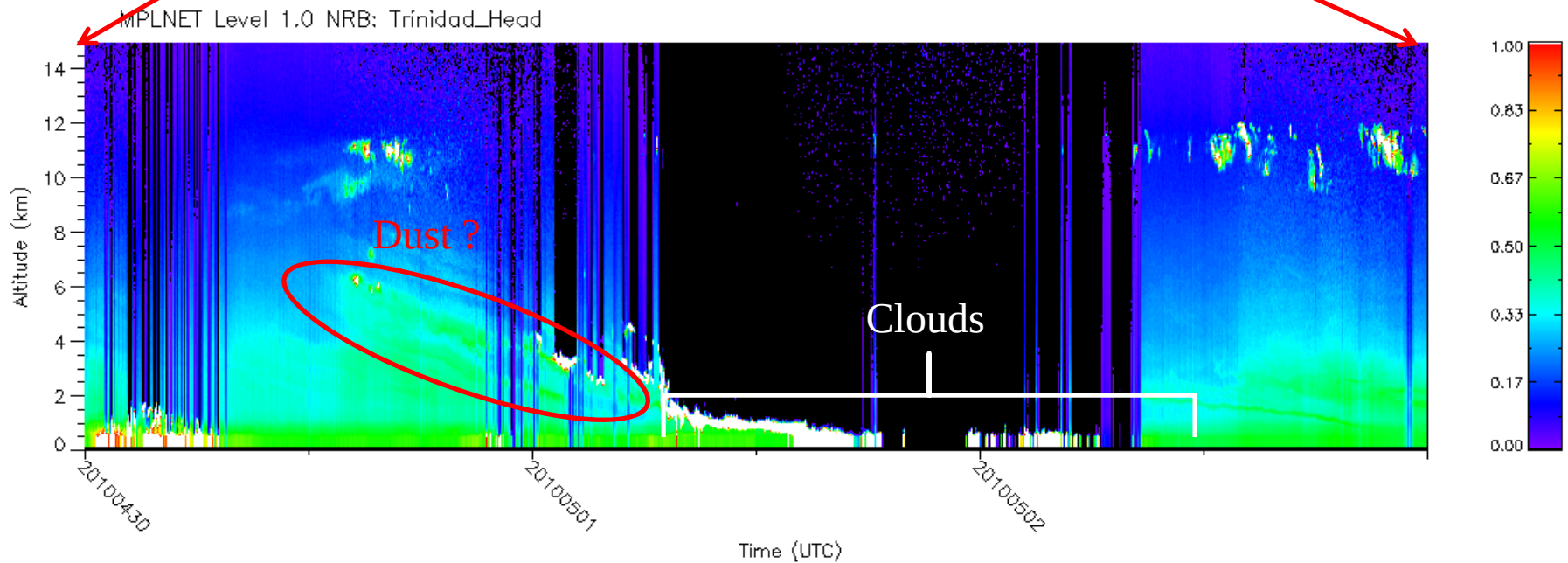




MPLNET Lidar

Trinidad_Head
Latitude: 41.05400
Longitude: -124.15100
Elevation: 0.1070 km

Trinidad Head PI:
John Barnes (NOAA/ESRL)
MPLNET PI:
Judd Welton (NASA/GSFC)



Conclusions

Ozone

•Assimilation of MLS (stratospheric) and OMI (total column) ozone results in good (<10% except in lower stratosphere) agreement with ARCIONS ozonesonde

•Global ozone forecasts have useful skill past 3 days at 850mb

Aerosol

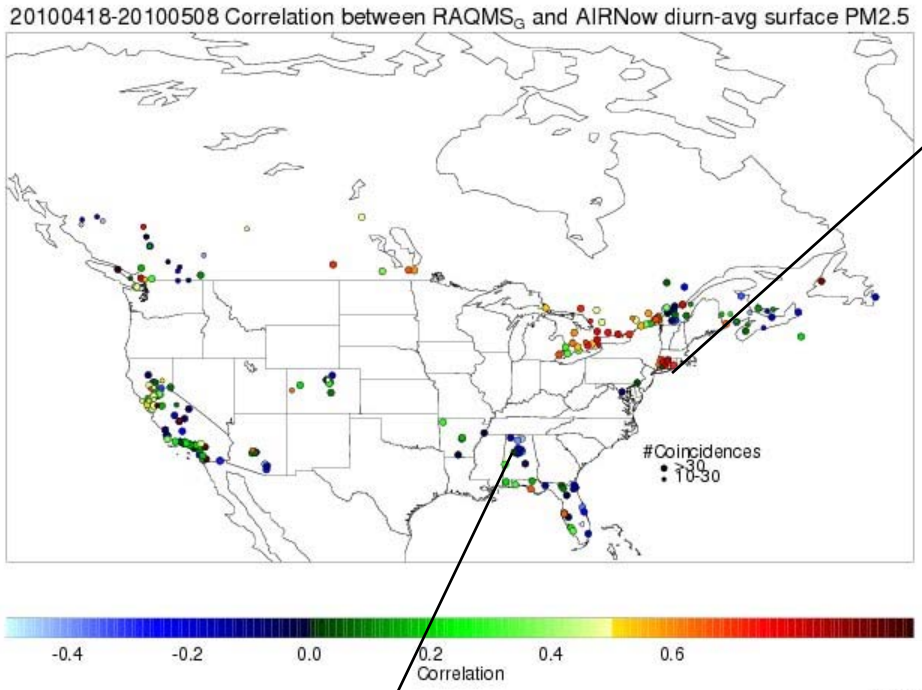
•Assimilation of MODIS aerosol optical depth results in good (r=0.7, bias=-0.05) agreement with Aeronet

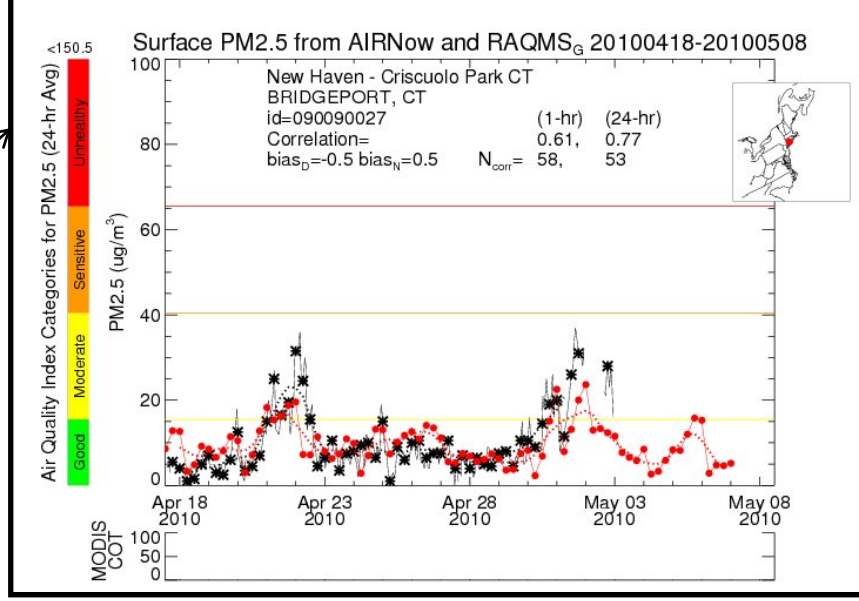
•Global extinction forecasts have useful skill for 1.5days at 850mb

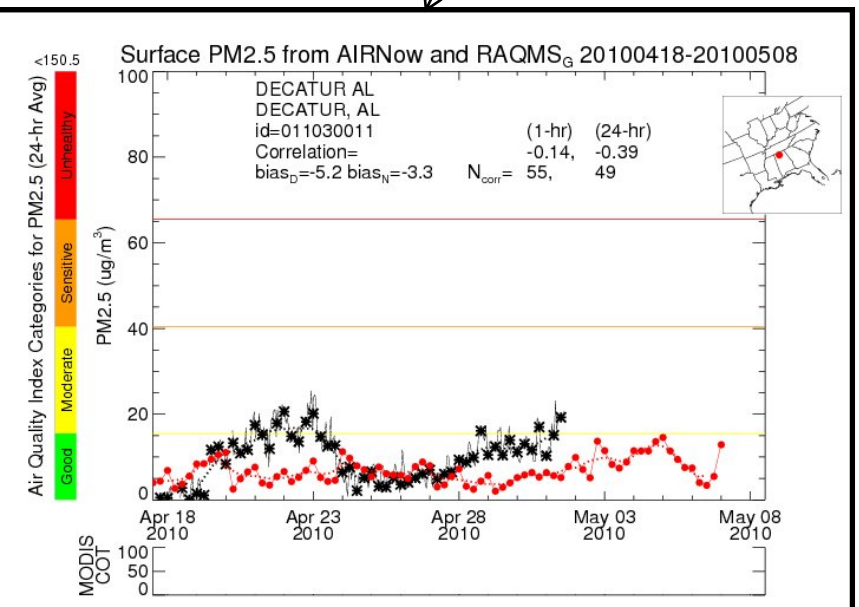
- •Reduced Sulfate aerosol forecast skill determines total aerosol forecast skill
- •Carbonaceous and Dust extinctions are most significantly impacted by AOD assimilation

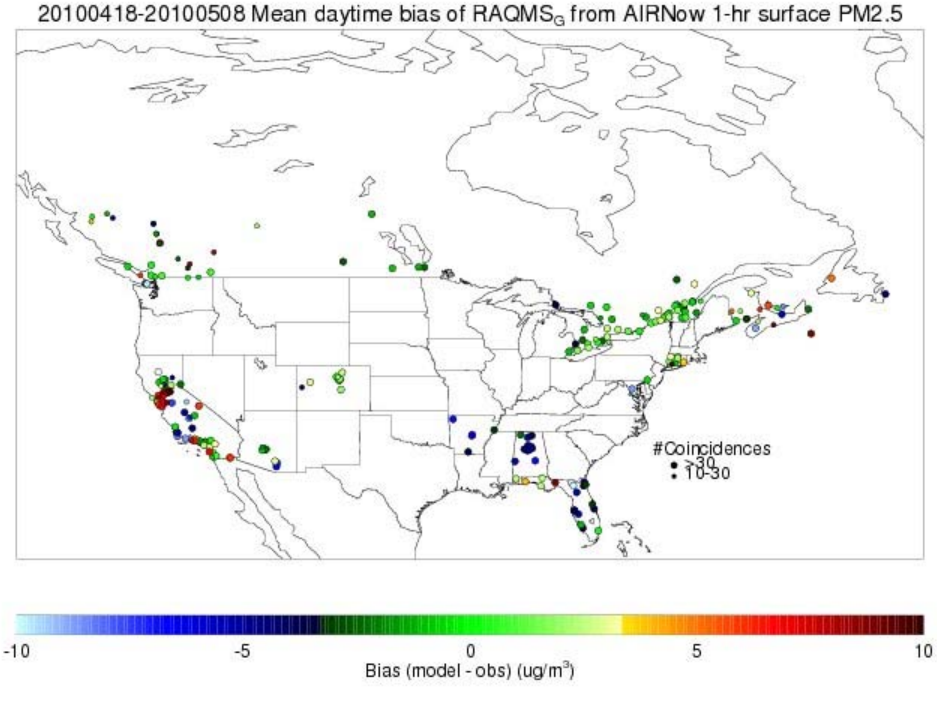
Extra Slides

Surface PM2.5 Statistics

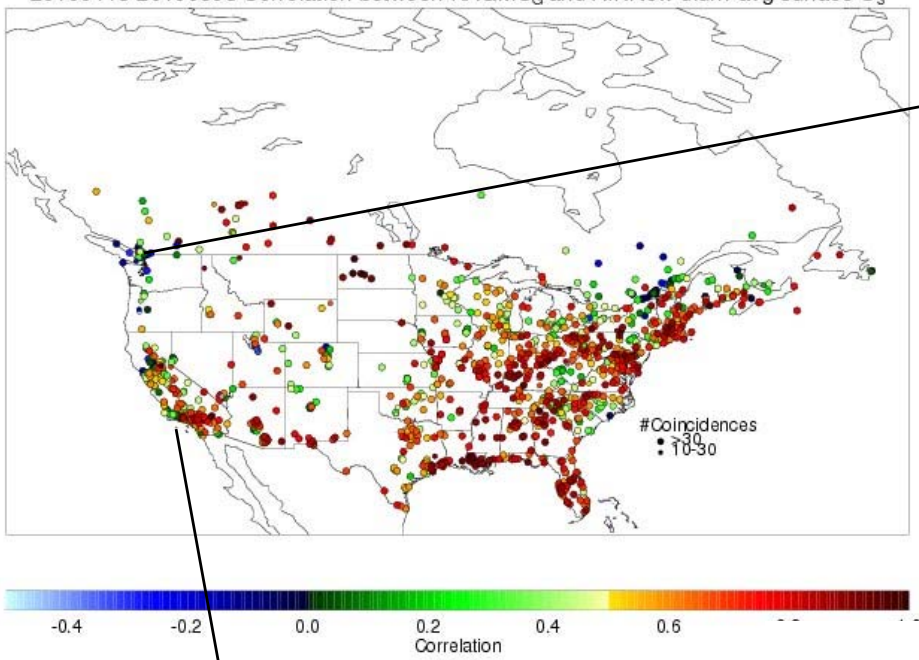


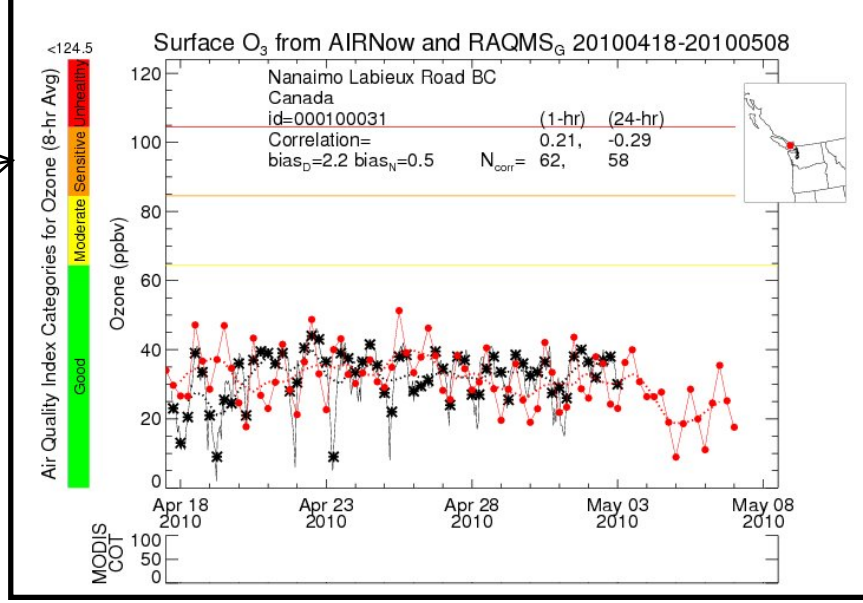


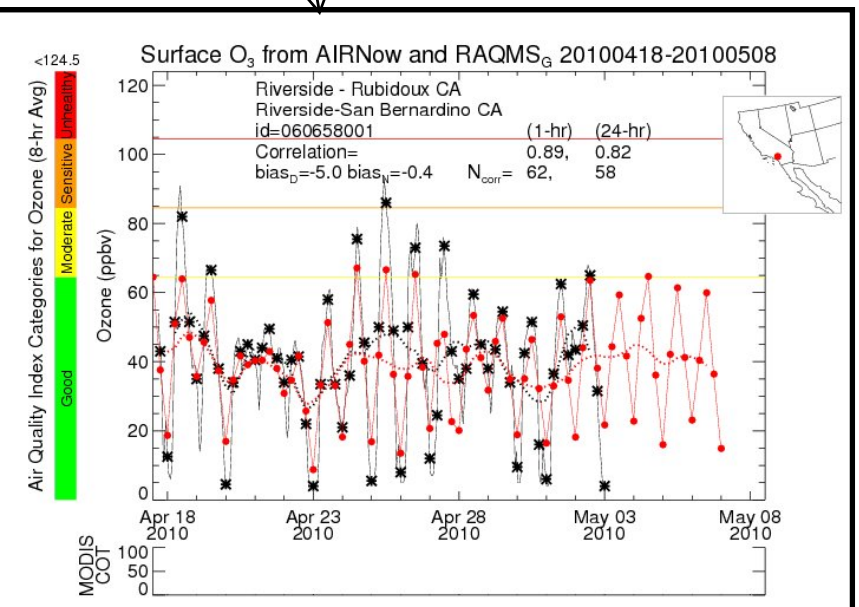


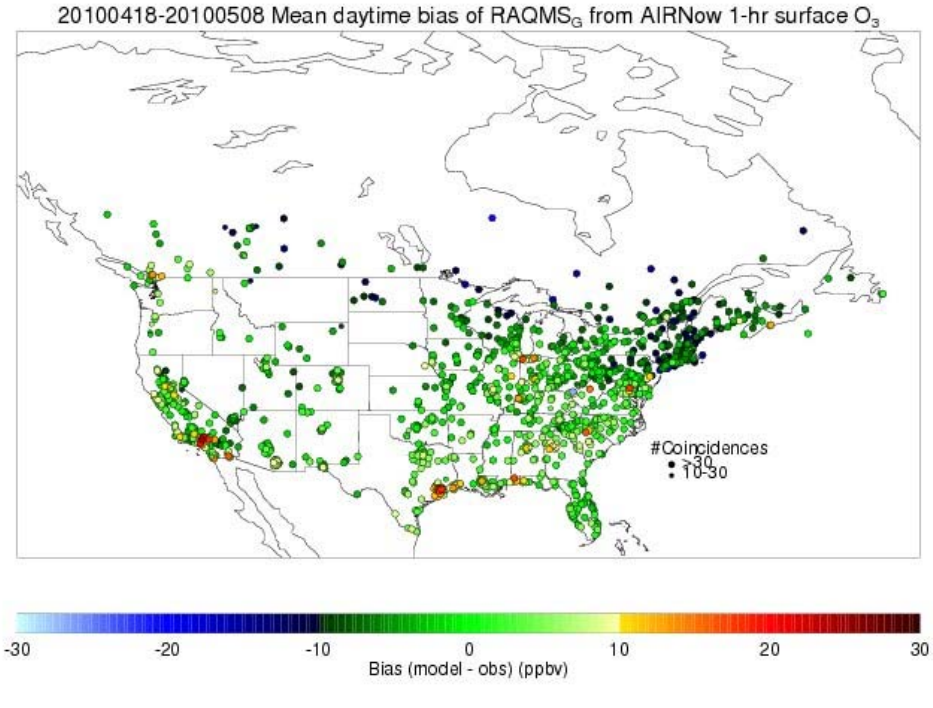


Surface O3 Statistics

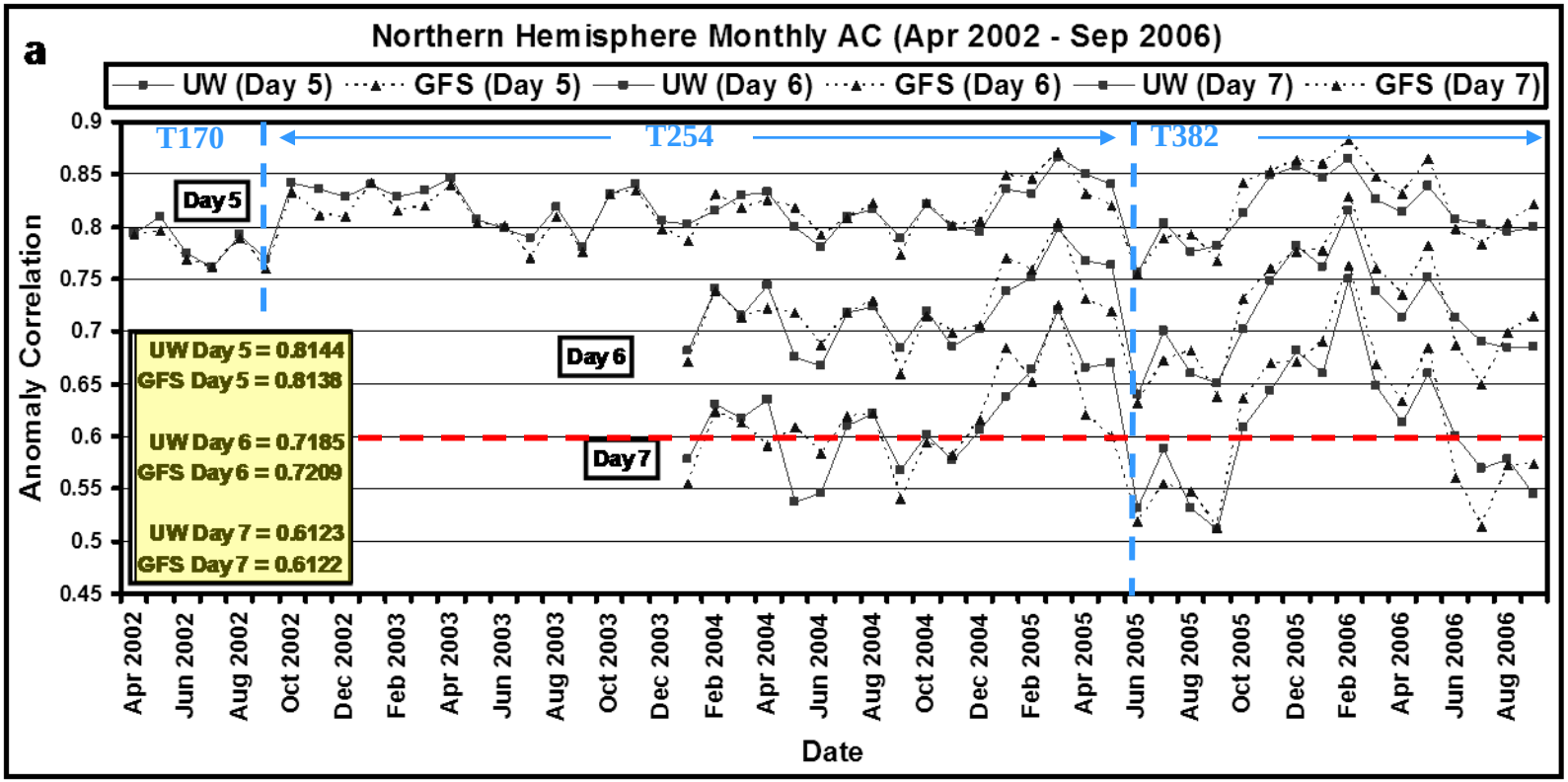








UW-Hybrid (0.7x0.7) Global Forecast Skill (500mb heights)



useful Skill

NH (20-80N) Anomaly Correlation (AC) between analysis and forecast 500mb heights (Identical physics, planetary wave numbers 1-20)

UW θ–η model: 0.7 degree (~T170), 37 layers (L37)

From Zapotocny et al., 2007, "Daily Numerical Weather Prediction with the Global University of Wisconsin Hybrid θ–η Model", unpublished manuscript