Aerosols and Ozone: Air Quality, Climate Change

1. **Aerosol and Ozone Proxy Data Assimilation (GOES-R Algorithm Working Group)**
2. **ABI Proxy Data Studies (GOES-R Risk Reduction)**
3. **Air quality modeling and aerosol assimilation during the ARCPAC field mission (NOAA Climate Forcing and Air Quality Program)**

Brad Pierce NOAA/NESDIS/STAR/CIMSS

Todd Schaack (UW/SSEC)

Allen Lenzen (UW/SSEC)

From Shobha Kondragunta (NOAA/STAR)

NOAA Air Quality Program

NESDIS

- Algorithm development for satellite-derived air quality products
- Data assimilation studies
- Provision of near real time data to NWS and EPA

NWS

- Global and regional model development
- Air quality forecasting guidance

→
- EPA AIRNOW
- NCEP website

Oceanic & Atmos. Res.

- Model development
- Field campaigns
- Process studies using in situ and satellite data
- Transition research models to NWS/NCEP operations

[Satellite imagery and *in situ* data sources]

→ **State and local governments responsible for issuing air quality forecasts**

GOES-R Aerosol and Ozone Proxy Data Assimilation
GOES-R Algorithm Working Group (AWG)

- Augment the current GOES-R AWG WRF Advanced Baseline Imager (ABI) proxy data capabilities with proxy data sets for aerosols and ozone over the continental US.

- Output from coupled WRF-CHEM [Grell et al., 2005] regional chemical model and RAQMS global chemical/aerosol analyses [Pierce et al., 2007] are used to construct simulated radiances using the NOAA Community Radiative Transfer Model (CRTM) [Han et al., 2006].

- Supports the development of algorithms supporting retrievals of aerosol properties (optical depth, aerosol type, effective radius, fine vs. coarse mode fraction), total column ozone, and detection of dust, smoke and SO2.

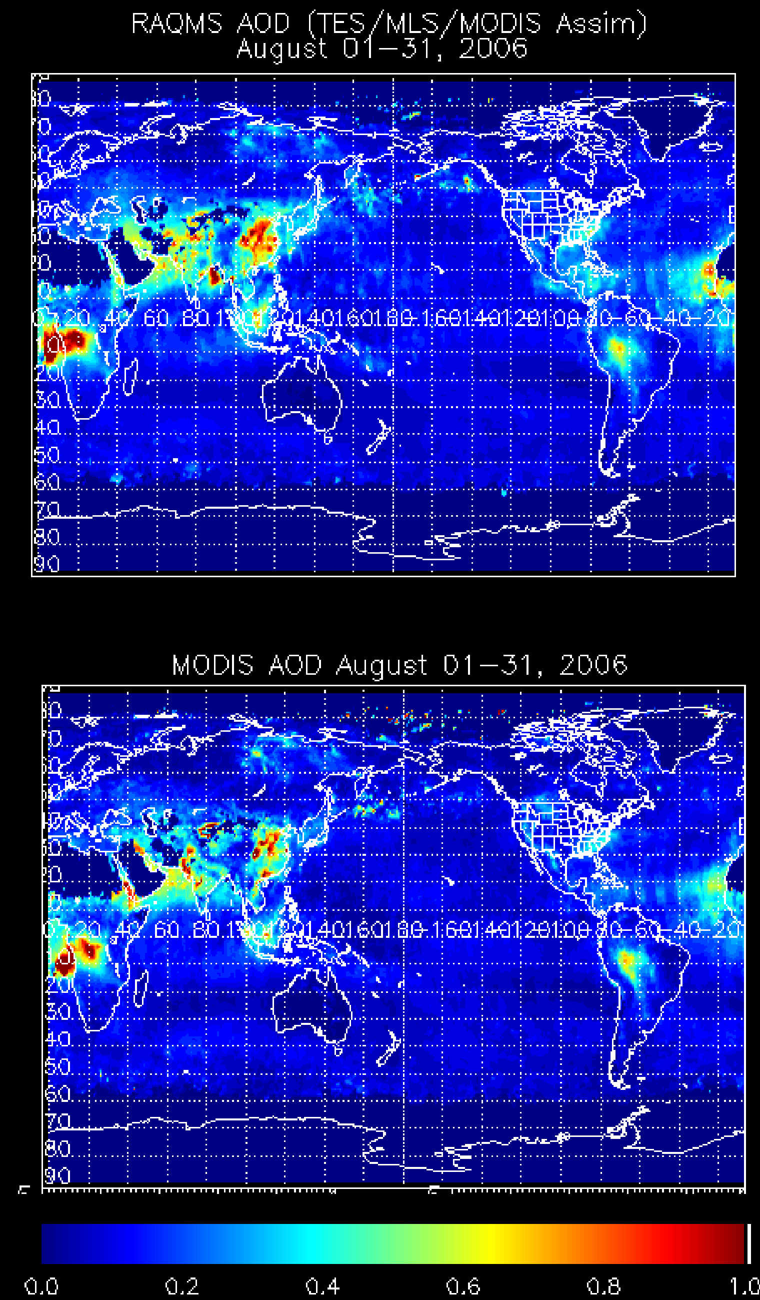
This work is conducted in close collaboration with the existing GOES-R WRF proxy data simulation team at CIMSS (Lead, Allen Huang, CIMSS) and with the ABI aerosol retrieval and GOES-R aerosol assimilation activities under the GOES-R Air Quality and Aerosols AWG (Lead, Shobha Kondragunta, NOAA/NESDIS).

During the first year of this project we completed a 30hr high resolution (4km horizontal resolution) aerosol/ozone proxy data set over the continental US (CONUS)

Real-time Air Quality Modeling System (RAQMS)

1) Online global chemical and aerosol assimilation/forecasting system
2) Sigma-theta hybrid coordinate dynamical core (UW-Madison)
3) Unified stratosphere/troposphere chemical prediction scheme developed at (NASA LaRC)
4) Aerosol prediction scheme (GOCART) developed by Mian Chin (NASA GSFC).
5) Statistical Digital Filter assimilation system developed by James Stobie (NASA/GFSC)

RAQMS has been used to support airborne field missions, develop capabilities for assimilating satellite trace gas and aerosol retrievals, and assess the impact of global chemical analyses on regional air quality predictions.



Weather Research and Forecasting Chemistry and Aerosol Model (WRF-Chem)

Georg Grell, Steven E. Peckham,
Stuart A. McKeen
(NOAA/ESRL)

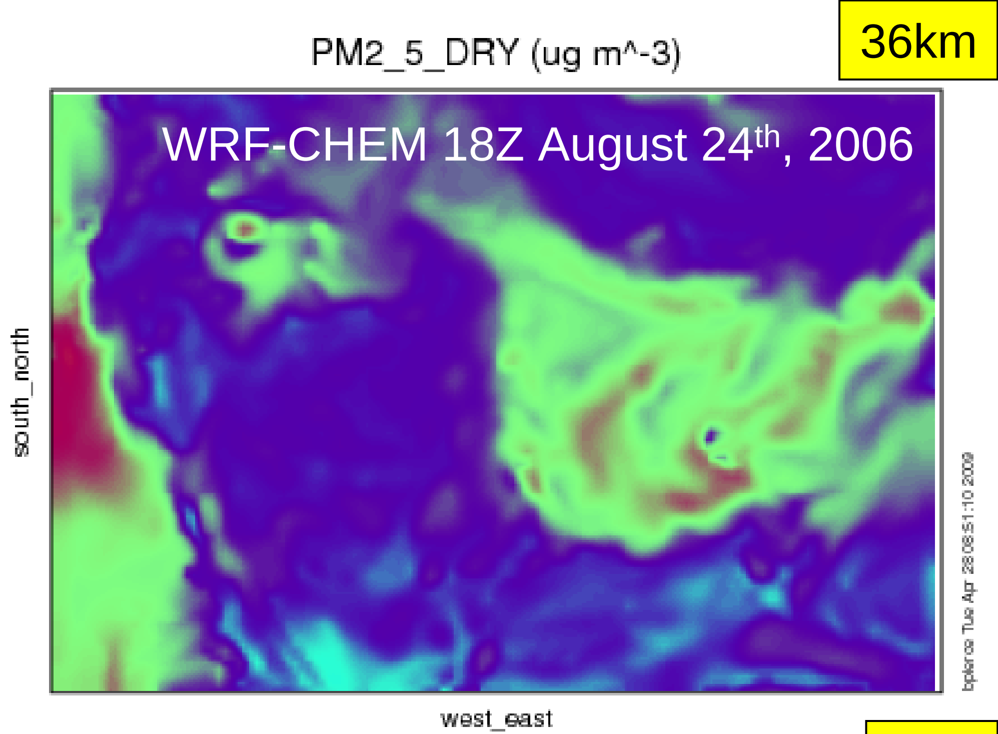
•Online, completely embedded within WRF

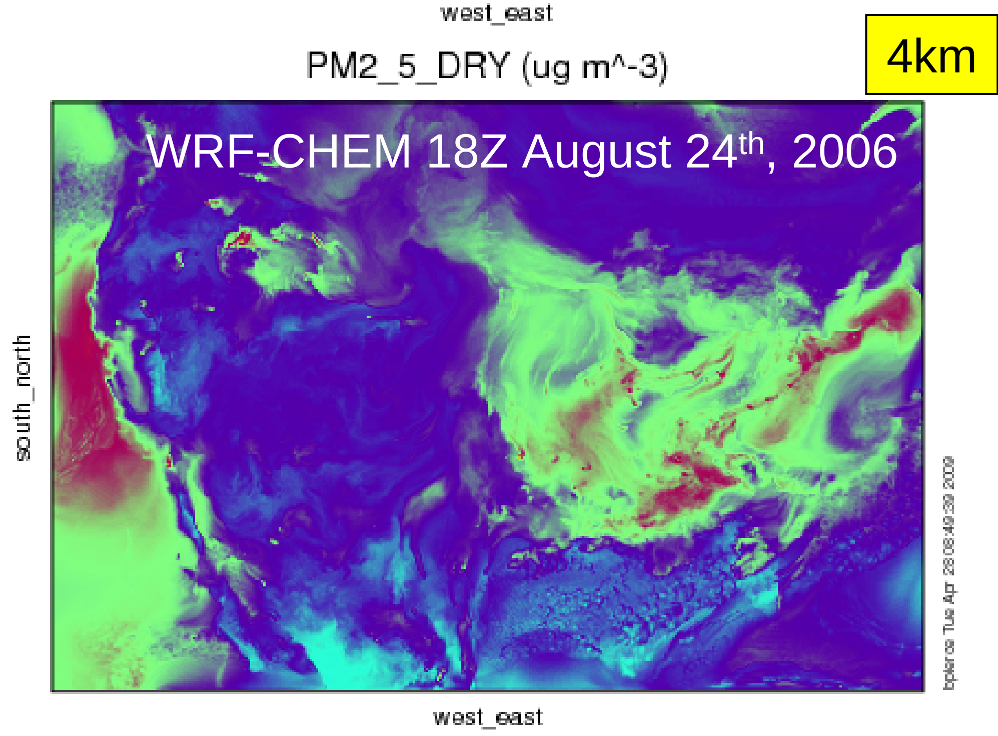
• Consistent: all transport done by meteorological model.

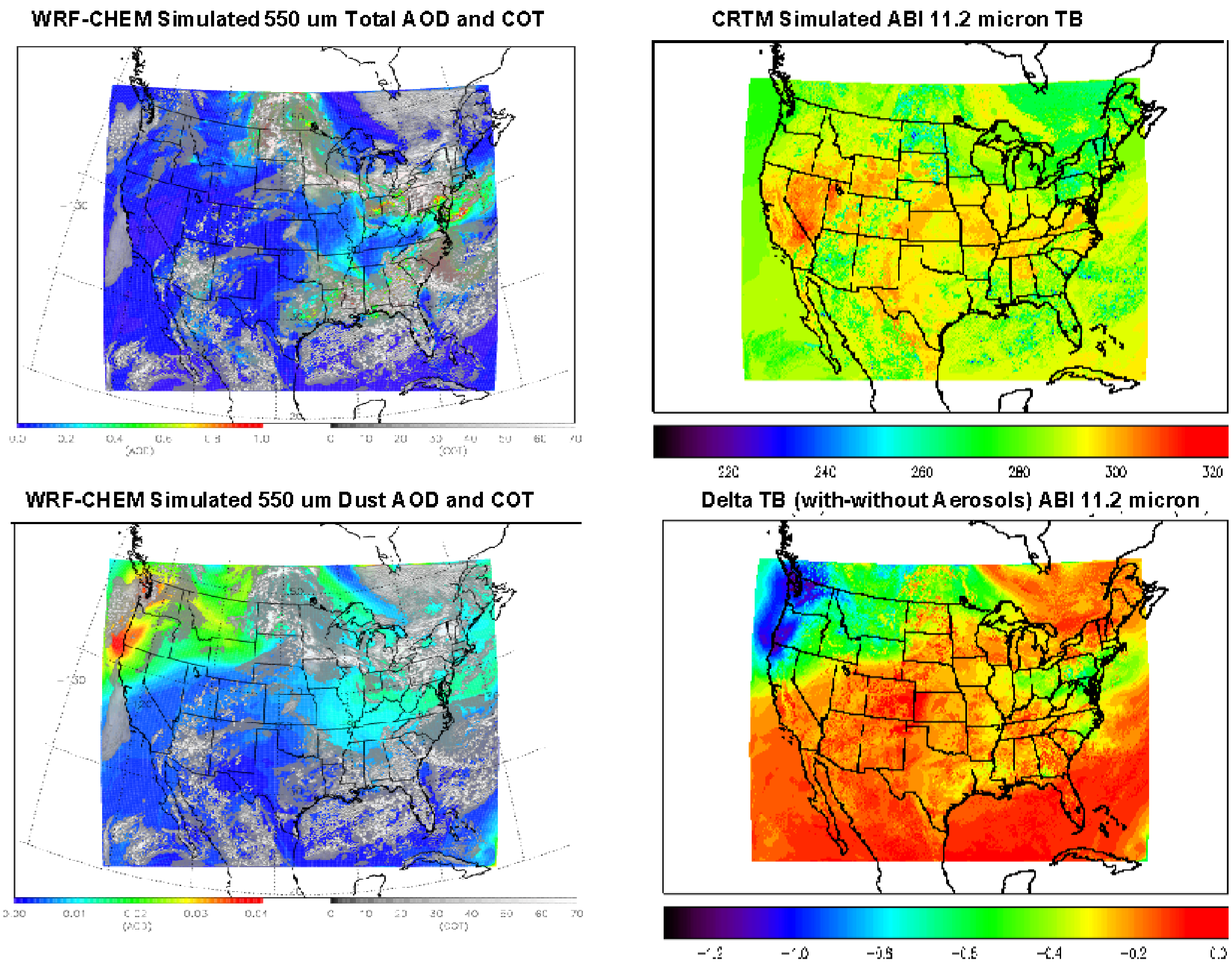
• Easy handling (Data management)

• Very modular approach: Wide range of complexity for chemical and aerosol mechanisms

High resolution (4km) nested RAQMS/ WRF-CHEM simulations performed on National Center for Supercomputing Applications (NCSA) Supercomputers







WRF-CHEM simulated 550 nanometer total Aerosol Optical Depth (AOD) and Cloud Optical Thickness (COT) (upper left), Dust AOD (lower left, note change in color scale), CRTM simulated 11.2 micron Brightness Temperatures (TB) (upper right), and TB differences (with-without aerosols) for 18Z August 24th, 2006.

ABI Proxy Data Studies
(GOES-R Risk Reduction)

•Boundary conditions (BC) from global ozone analyses have been shown to improve regional air quality (AQ) predictions [Tang et al., 2007].

•However, these studies also point out that uncertainties in the global model BCs can have significant impacts on the regional AQ predictions.

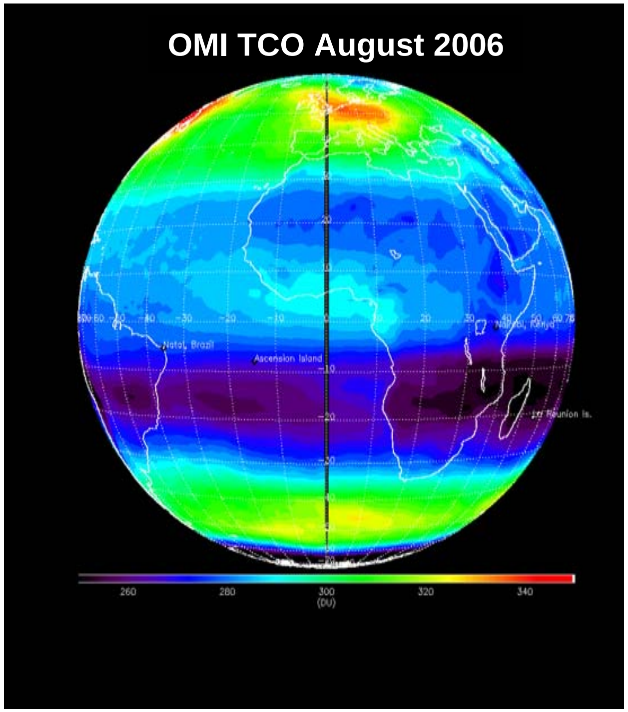
•One way to reduce the impact of these uncertainties is through regional assimilation of high frequency, high spatial resolution geostationary measurements, which is the objective of this project.

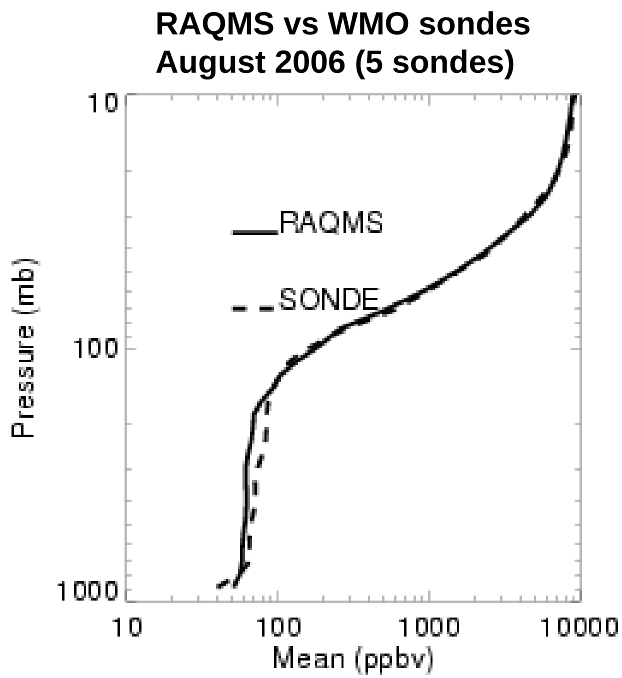
This project uses Coupled RAQMS/WRF-CHEM LEO/GEO ozone analyses to evaluate the impacts of GOES-R Advanced Baseline Imager (ABI) like Total Column Ozone (TCO) retrievals on air quality forecasts.

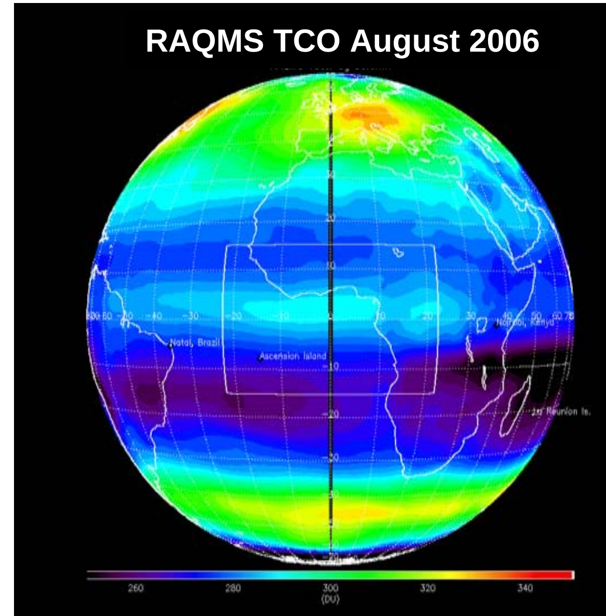
Spinning Enhanced Visible and Infrared Imager (SEVIRI) measurements are used as ABI proxy data.

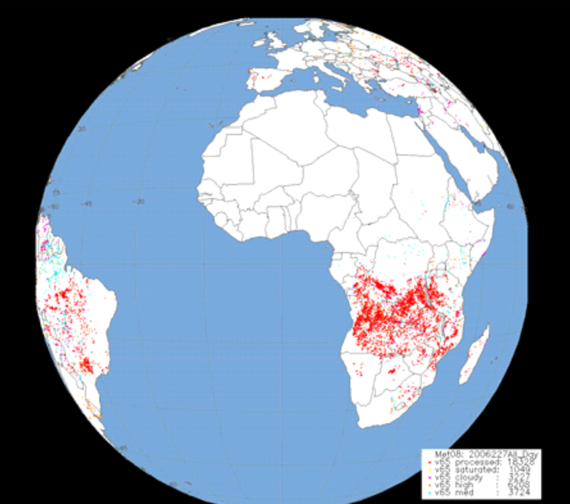
RAQMS Global Scale MLS Ozone Analysis: August 2006

Linking global RAQMS ozone analyses with ozone predictions from the WRF-CHEM regional model provides a first guess for SEVIRI TCO assimilation studies.



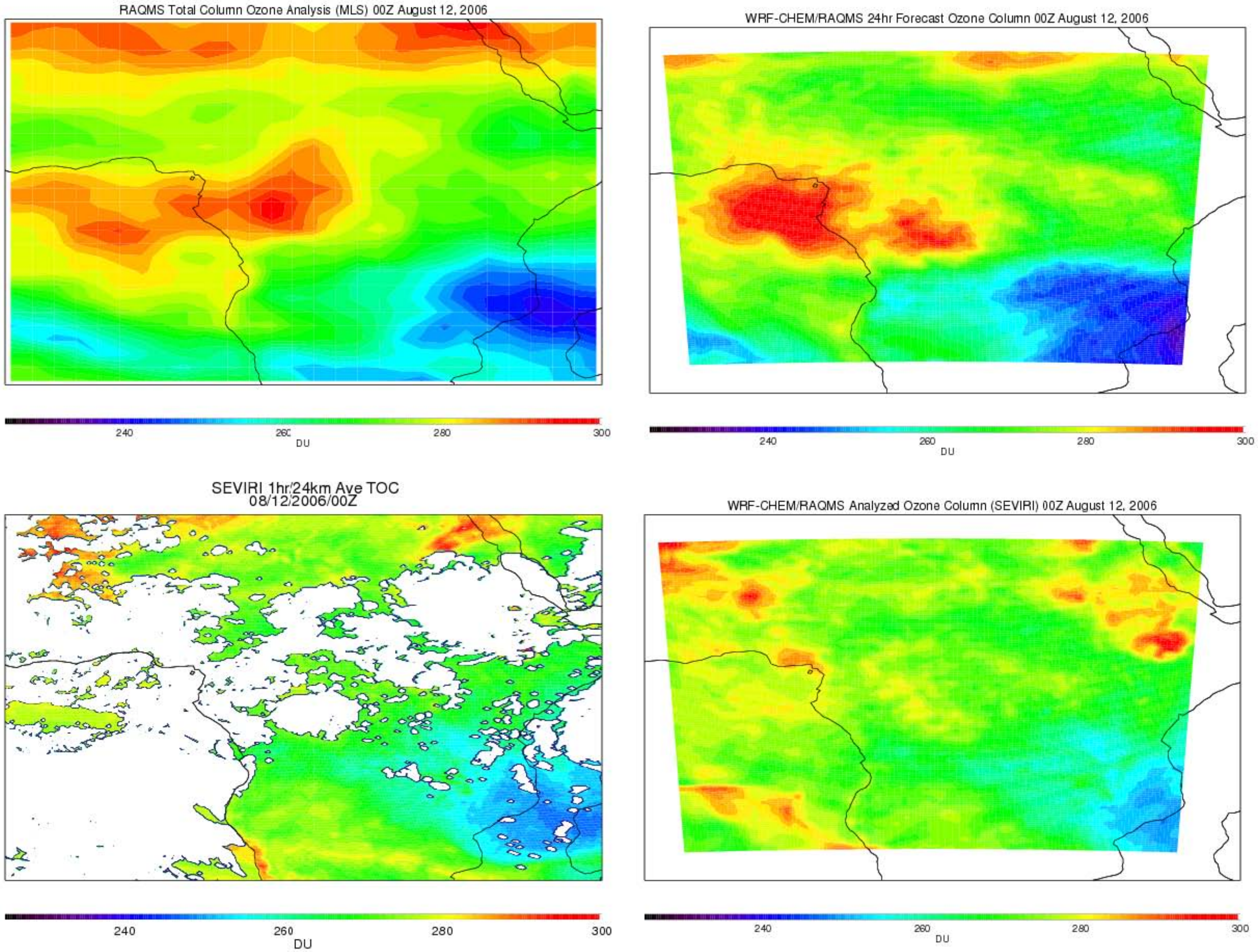






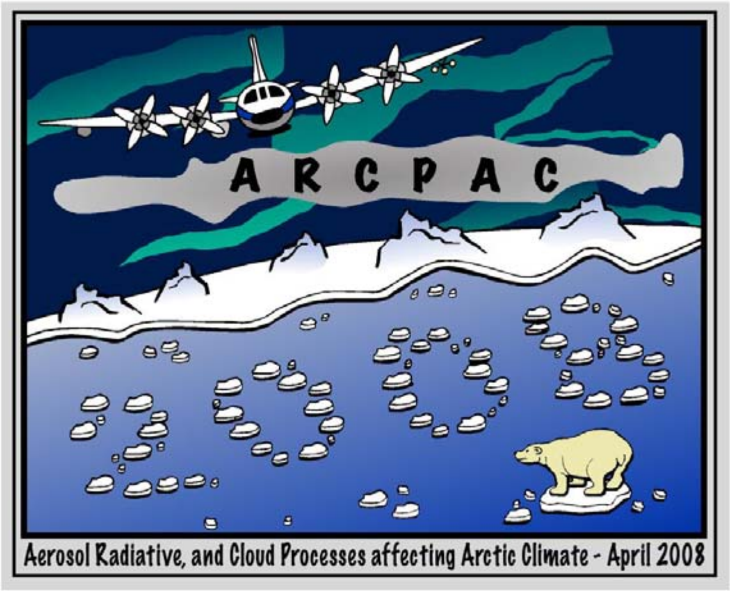
August 2006 OMI V8 Total Column Ozone (TCO) retrieval (upper left), RAQMS TCO Analysis (upper right), and RAQMS/WMO ozonesonde comparison (upper middle).
TCO enhancement over central Africa is associated with tropospheric ozone column enhancements due to biomass burning (right).

RAQMS/WRF-CHEM Regional 36km SEVIRI Ozone Analysis: August 12, 2006



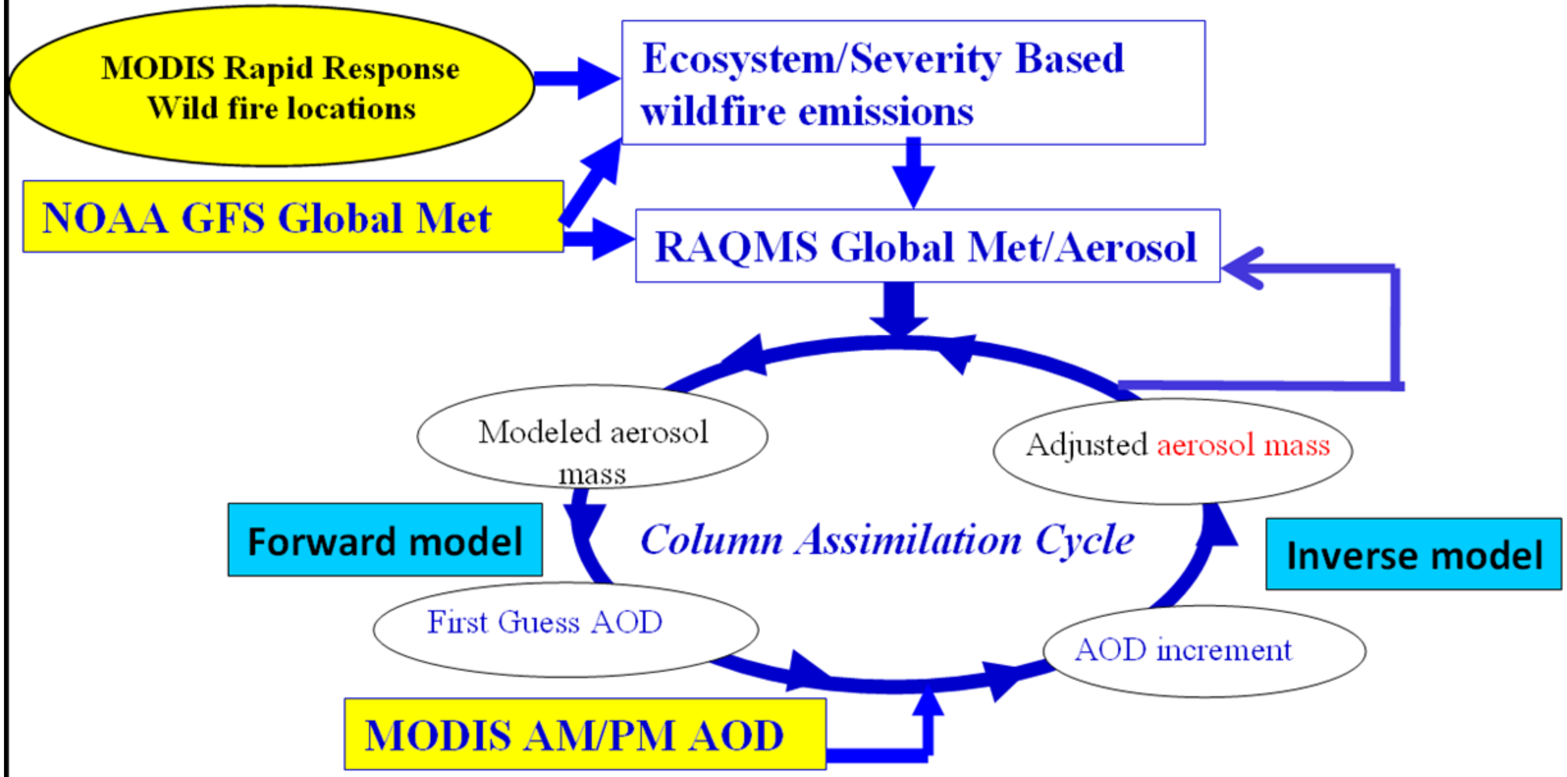
Total Ozone Column (TOC) from RAQMS MLS Analysis (upper left), WRF-CHEM/RAQMS 24hr Forecast (upper right), processed SEVIRI (lower left), and WRF-CHEM/RAQMS SEVIRI Analysis (lower right) valid at 00Z August 12th, 2006.

Air quality modeling and aerosol assimilation during the ARCPAC field mission



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 (Fairbanks AK) focused on direct measurements of properties and processes associated with non-greenhouse-gas atmospheric climate forcing

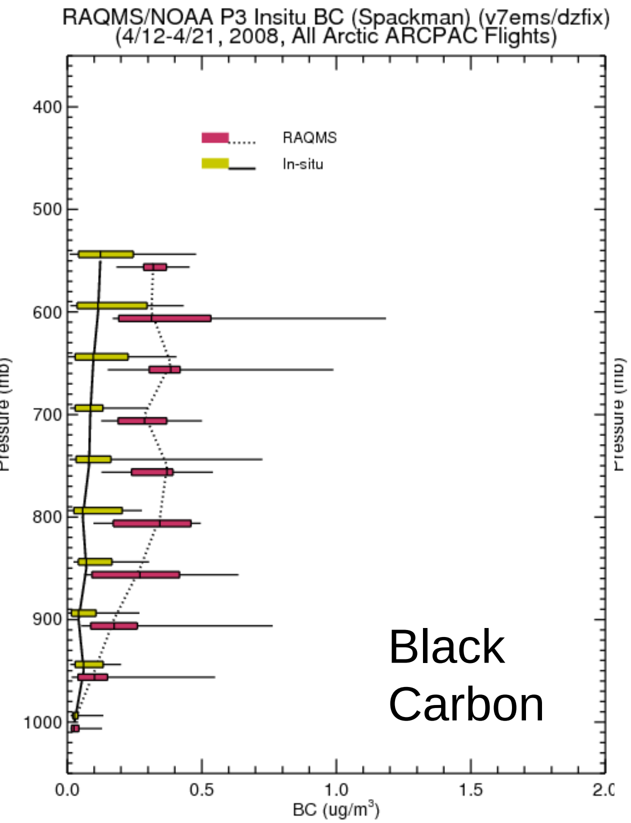
RAQMS ARCPAC AOD Assimilation Procedure

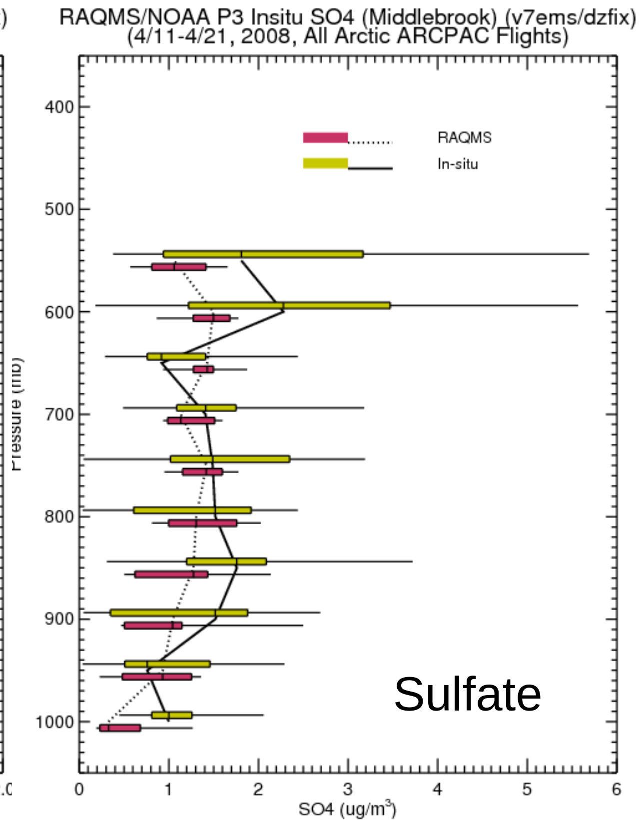


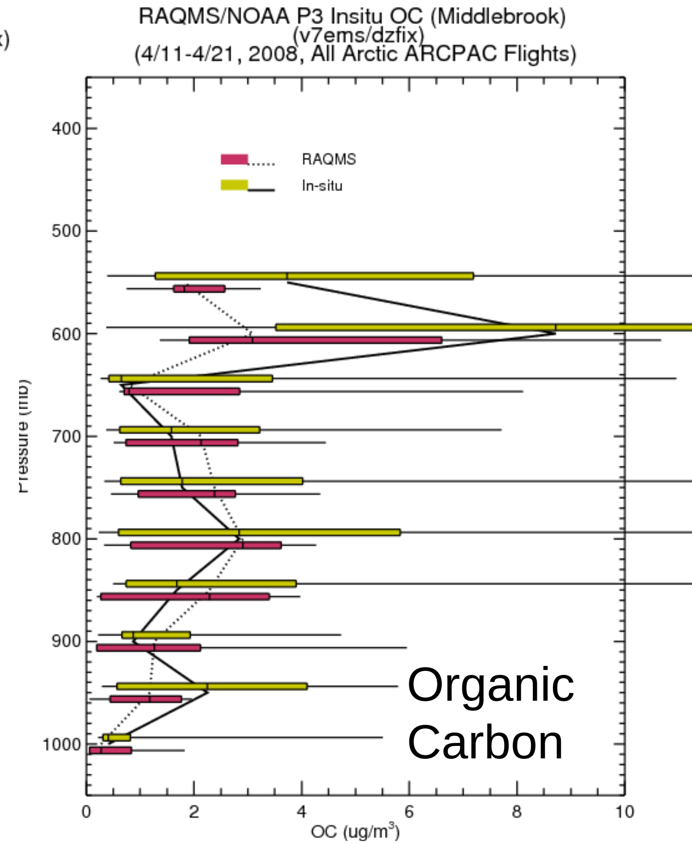
Forward model:
Compute layer/species extinction based on tabulated extinction efficiency and hydroscopic growth factors

Inverse model:
Distribute total AOD increment across aerosol dry mass based on layer/species extinction accounting for extinction due to hydroscopic growth

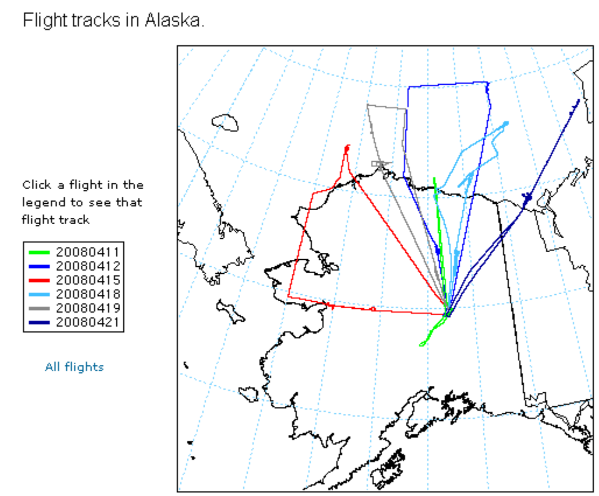
- ***Applied to SO4, Dust, BC, OC (not Sea Salt)***







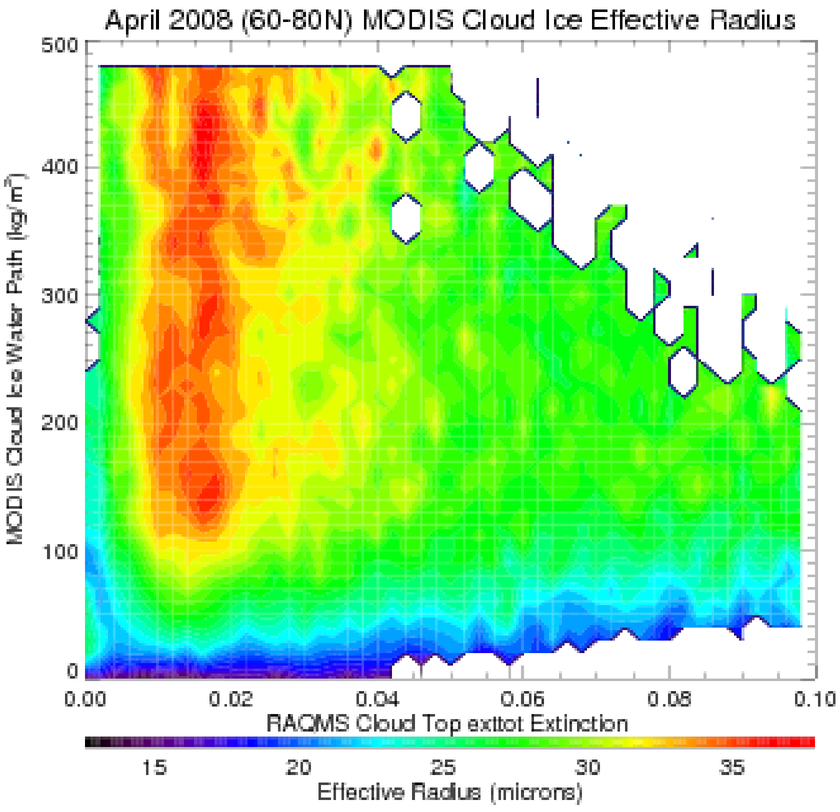
WP-3D Flight Track Map

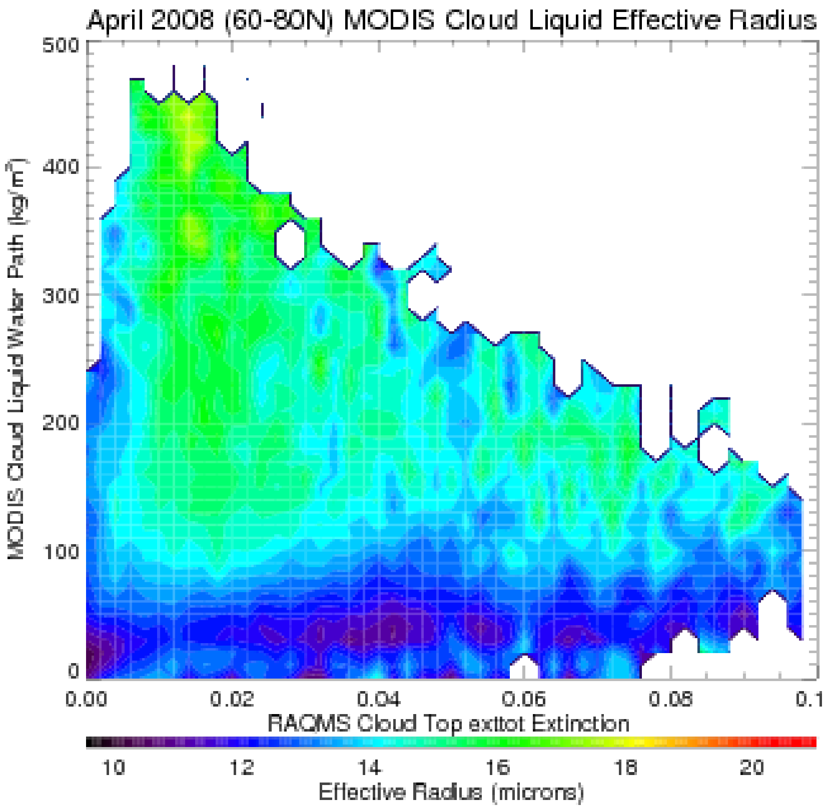


MODIS aerosol optical depth (AOD) assimilation results in good agreement with P3 insitu SO4 and Organic Carbon (OC) measurements but overestimates Black Carbon (BC) mass.

Arctic aerosol indirect effects during ARCPAC

Use RAQMS analyzed aerosol extinction to sort MODIS Ice/Liquid Effective Radius as a function of Cloud Ice/Liquid Water Content to investigate Arctic first indirect effect





Evidence for First (Twomey) indirect Effect: Aerosol loading increases cloud droplet number concentration resulting in a decrease in average cloud droplet size (effective radius) for a fixed liquid water content (LWC).

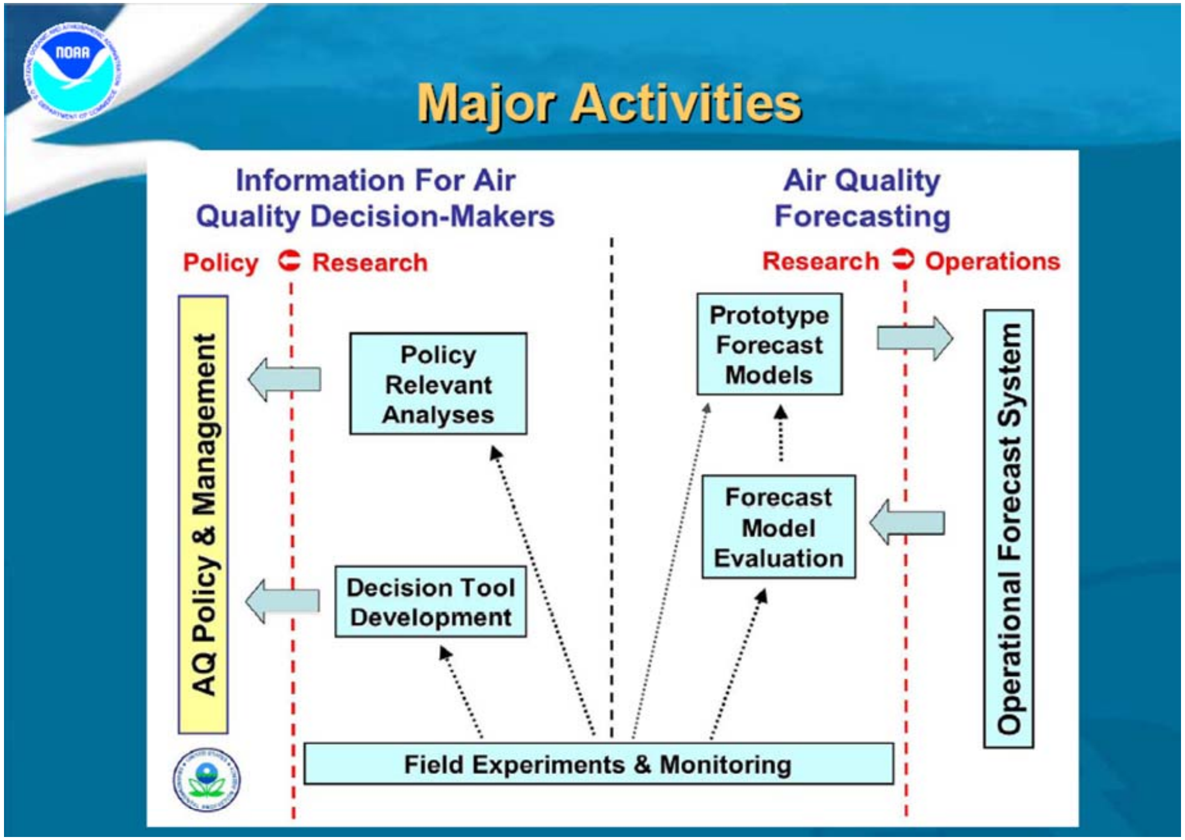
Impacts of aerosols on Arctic radiative forcing during ARCPAC

Shortwave effects: Decreased droplet size due to aerosol loading leads to ***increased cloud albedo*** and additional reflection of shortwave radiation to space and leads to ***surface cooling***.

Longwave effects: Decreased droplet size due to aerosol loading ***increases the longwave emissivity*** of optically thin clouds, which leads to increased emitted longwave radiation [Curry and Ebert, 1992, Curry 1993] and ***surface longwave heating***.

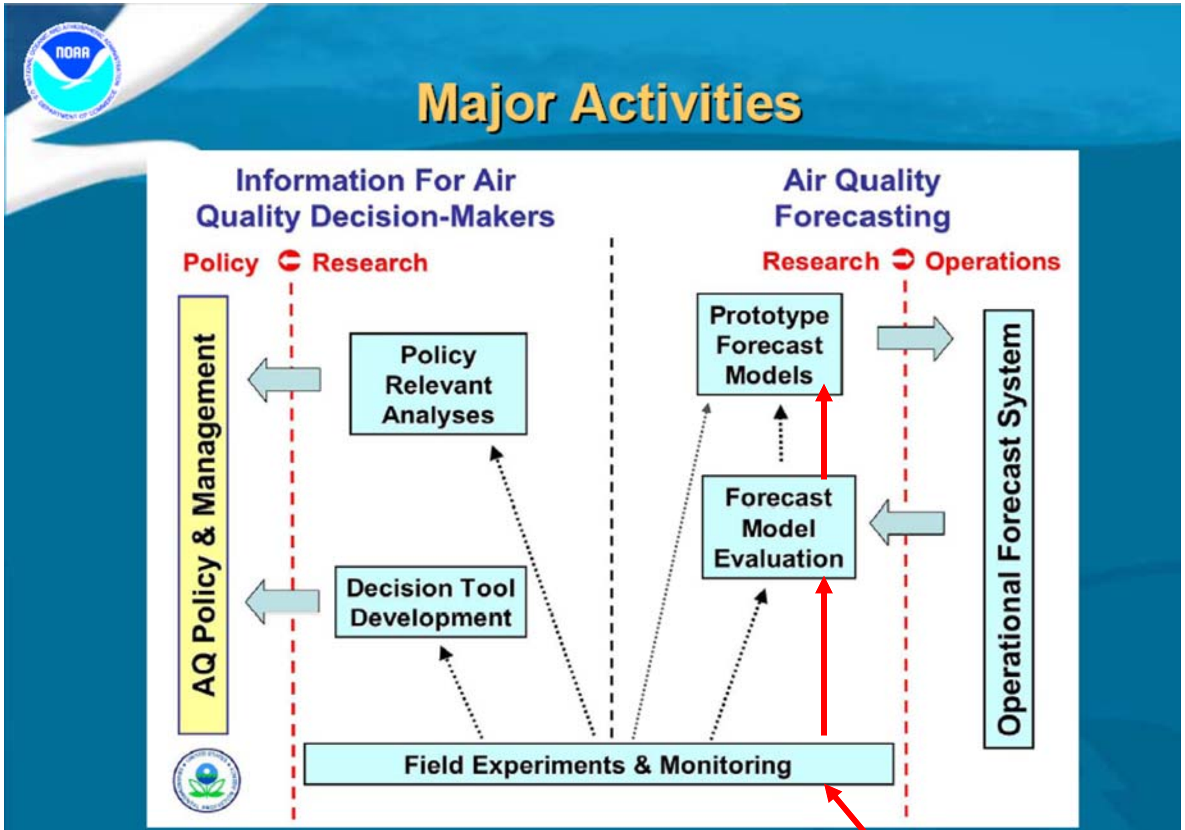
Observational studies have shown that the longwave aerosol indirect effect can lead to significant (3.4 Wm^{-2}) positive radiative forcing in the Arctic [Lubin and Vogelmann, 2006].

NOAA Air Quality Research Program (from Steve Fine, NOAA/OAR)



The NOAA AQ research program has traditionally focused on field experiments, where regional forecast model development and evaluation is driven by comparisons with in-situ composition measurements from airborne platforms and surface monitoring stations.

NOAA Air Quality Research Program (from Steve Fine, NOAA/OAR)



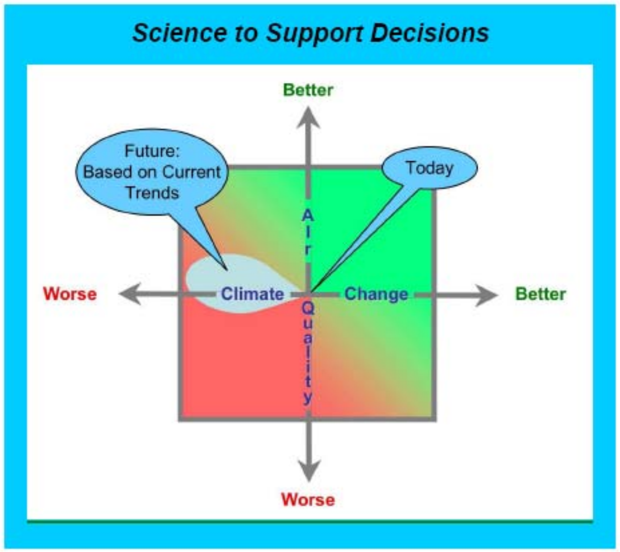
NESDIS/STAR participation in airborne AQ field studies brings satellite trace gas and aerosol measurements into NOAA AQ Research Program

STAR Center for Satellite Applications and Research
formerly ORA — Office of Research and Applications

The NOAA AQ research p[illegible] experiments, where regional forecast model development and evaluation is driven by comparisons with in-situ composition measurements from airborne platforms and surface monitoring stations.

Next Airborne Mission: CalNEX 2010

2010 CalNex
White Paper



Research at the Nexus of Air Quality and Climate Change

The California Air Resources Board (CARB), the National Oceanic and Atmospheric Administration (NOAA) and the California Energy Commission (CEC) are planning a joint field study (CalNex) over California and the eastern Pacific coastal region in 2010.

Current trends indicate slowing improvement in air quality in the U.S., along with accelerating increases in greenhouse gas

The goal of the CalNex 2010 program is to study the nexus of the air quality and climate change problems, and trade-offs between these two inter-related issues.