Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System

SUNYA: Sarah Lu, Sheng-Po Chen
NESDIS/STAR: Quanhua Liu
NCEP/EMC: Robert Grumbine, Andrew Collard, Jun Wang,
               Partha Bhattacharjee, Bert Katz

Outline

- Introduction
- Dual resolution weather-aerosol system at NCEP
- R2O project on "Investigation of aerosol effects on weather forecast"
  - Overview
  - Proposed work and deliverables
  - Status update

Global aerosol modeling at NWP centers

- Aerosol modeling, traditionally serving regional air quality and climate communities, has seen rapid development at several operational NWP centers over the last few years

- Why include aerosols in the predictive systems ?

  - Improve weather forecasts and climate predictions by taking into account of aerosol effects on radiation and clouds

  - Improve the handling of satellite observations by properly accounting for aerosol effects during the assimilation procedure

  - Provide aerosol (lateral and upper) boundary conditions for regional air quality predictions

  - Produce quality aerosol information that address societal needs and stakeholder requirements

- Aerosol prediction systems are built upon modeling/assimilation methodologies already in place for the meteorological systems.
  - NRL: NAAPS, driven by NOGAPS
  - ECMWF: IFS coupled with LMD
  - GMAO: GEOS-5 coupled with GOCART
  - NCEP: NEMS GFS coupled with GOCART
- Near-real-time smoke emissions from satellites are used. For instance,
  - NRL: FLAMBE (Fire Locating and Modeling of Burning Emissions), fire counts from MODIS and GOES
  - ECMWF: GFAS (Global Fire Assimilation System), FRP from MODIS
  - GMAO: GFED (Quick Fire Emission Dataset), FRP from MODIS
  - NCEP: GBBEPx (Blended Global Biomass Burning Emissions Product – eXtended), FRP from MODIS and geostationary satellites
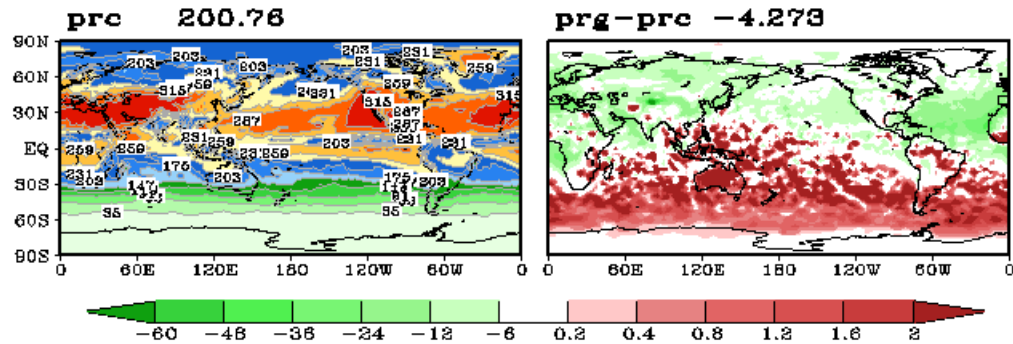
Aerosol-Radiation Feedback:
Impact of Aerosols on Weather Forecasts

- ☐ T126 L64 GFS/GSI experiments for the 2006 summer period

- ☐ PRC uses the OPAC climatology (as in the operational applications)

- ☐ PRG carries aerosols as passive tracers, using the GEOS4-GOCART 6-hr dataset

- ☐ PRG only impacts the model results via its direct effect on the radiative forcing of the atmosphere

- ☐ Comparisons between forecasts and observations indicate:

  - ◻ Warm biases are reduced by 10% in lower atmosphere

  - ◻ Positive surface SW flux biases are reduced (verified against SURFRAD)

  - ◻ Neutral impact on North American precipitation (verified against rain gauge observations)

  - ◻ Storm track errors are reduced (Note small sampling sizes, Alberto and Ernesto only)
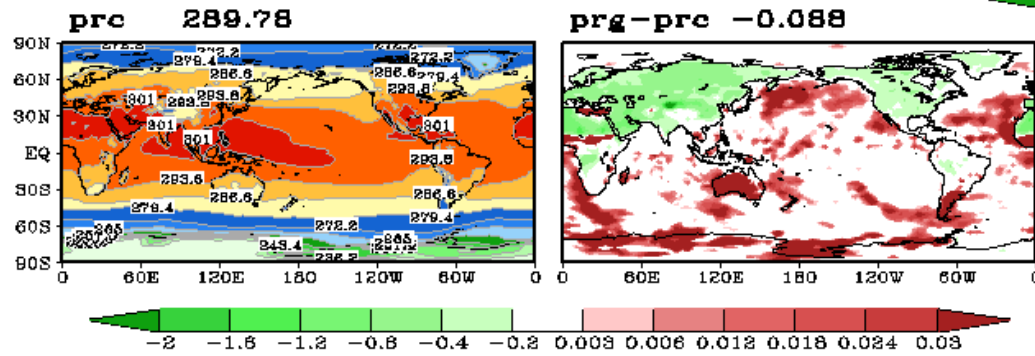
Aerosol-Radiation Feedback:
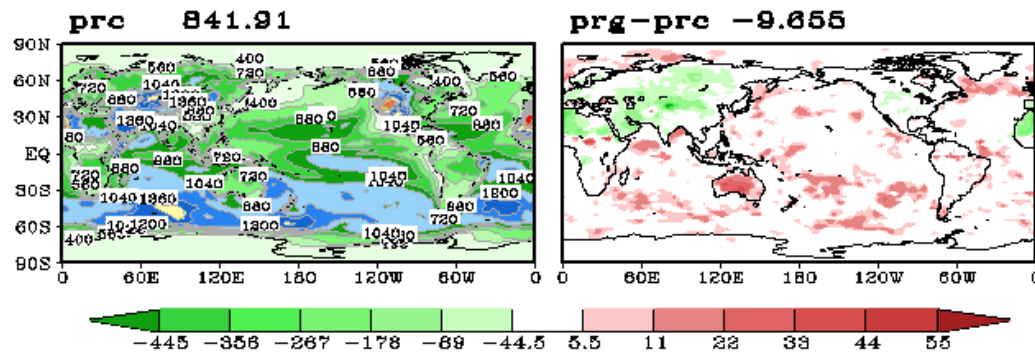# Impact of Aerosols on Weather Forecasts

Surface downward SW fluxes are reduced
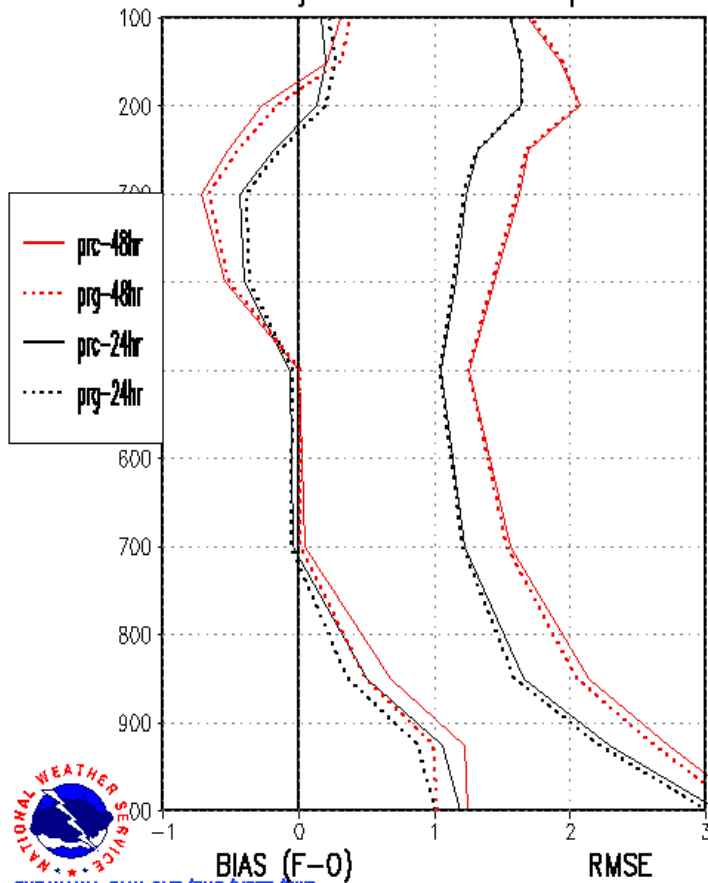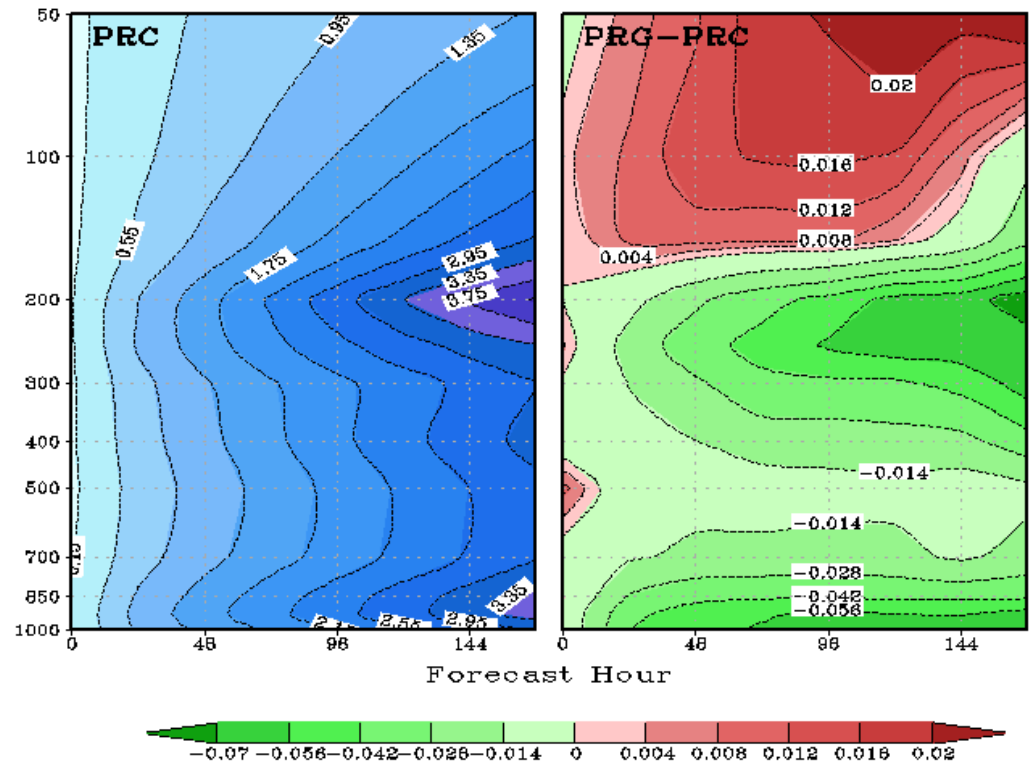
Cooler near surface tempeature

Suppressed PBL depth

Aerosol-Radiation Feedback:
Impact of Aerosols on Weather Forecasts

North America Temp Fits to RAOBS
00z04jun2006 – 00z07sep2006

RMS: 20060604-20060907 Mean for T G2/NHX 00Z

Verification against analyses and observations indicates a positive impact in temperature forecasts due to realistic time-varying treatment of aerosols.

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NEMS GFS Aerosol Component

- NCEP's global in-line aerosol forecast system
- Build upon NOAA Environmental Modeling System (NEMS), a common modeling framework using Earth System Modeling Framework (ESMF)
- Provide 5-day dust-only forecast since 2012
- Model Configuration:

  - Resolution: T126 L64
  - AGCM: NEMS GFS
  - Aerosol: GOCART

**Earth System Modeling Framework**

ATM and AER in NEMS
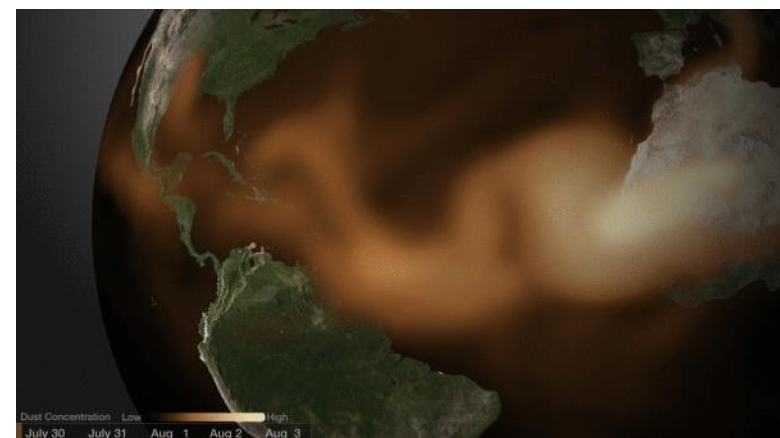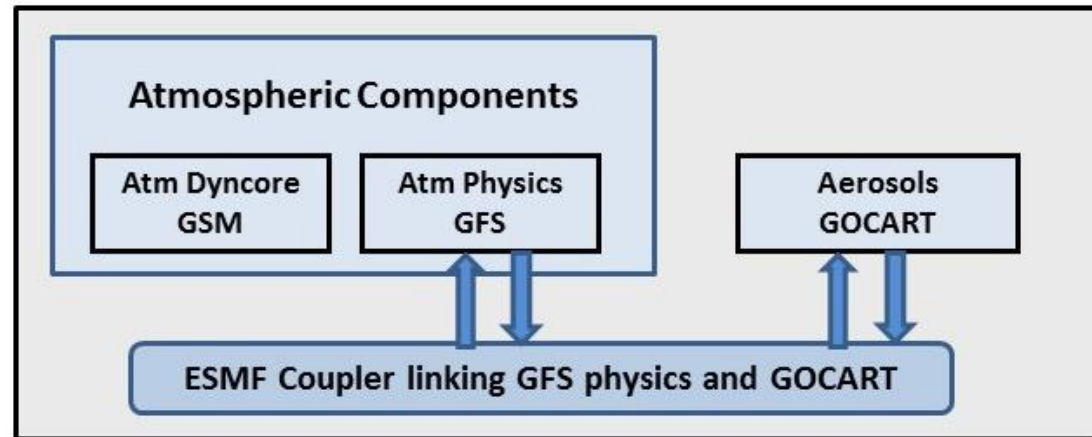
NASA/GSFC GOCART Module

In-line chemistry advantage

- Consistency: no spatial-temporal interpolation and same physics parameterization

- Efficiency: lower overall CPU costs and easier data management
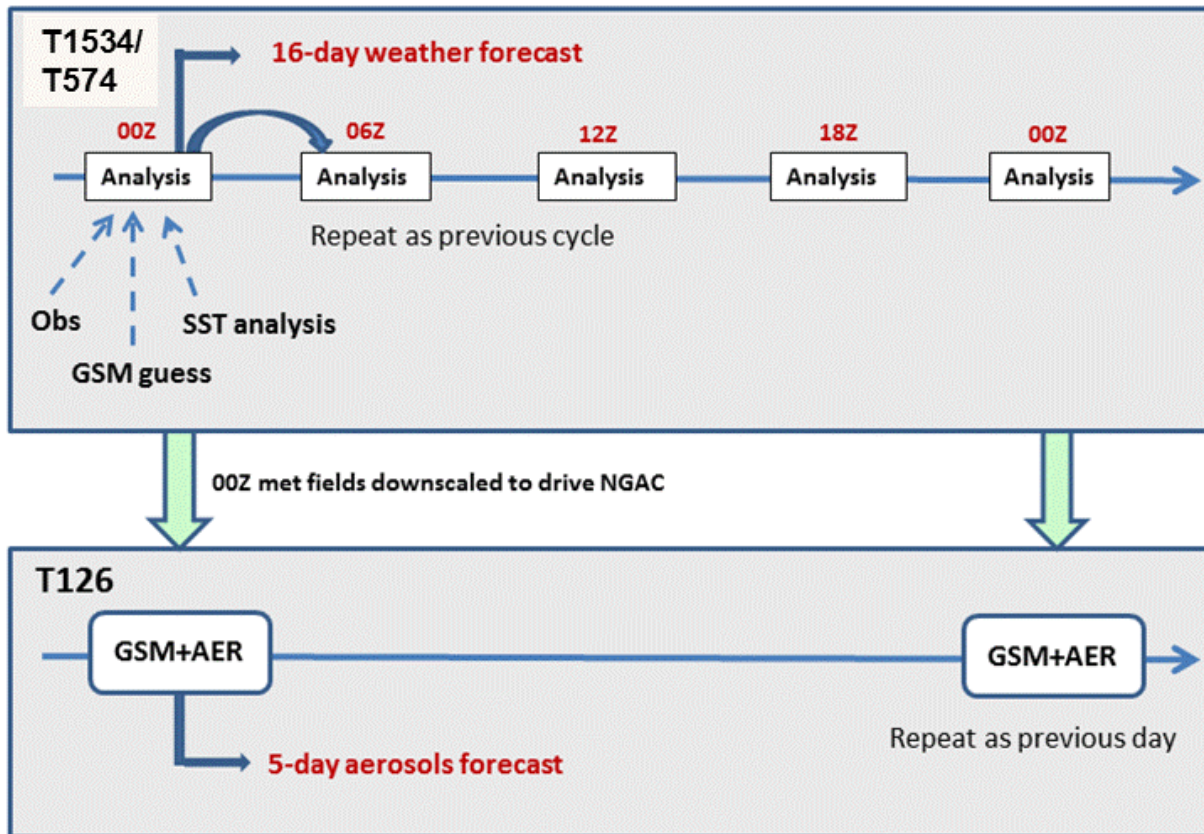
- Interaction: Allows for feedback to meteorology

GOCART diagram provided by Peter Colarco (GSFC)

GEOS-5 on-line GOCART Aerosol Module
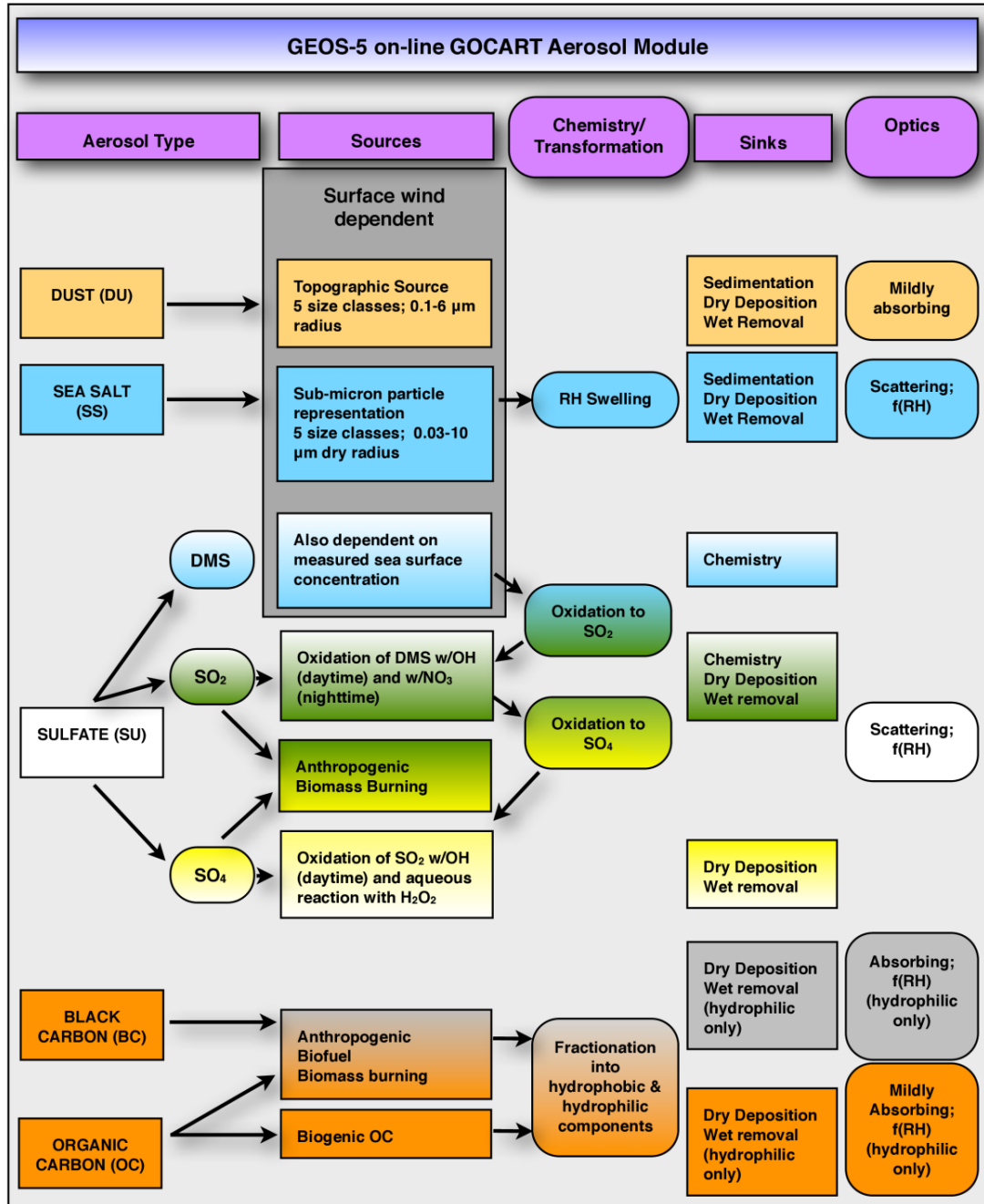
Dual resolution weather-aerosol system

Operational: One-way coupling

GFS for weather

GFS: OPAC climatology
GSI: Background aerosols
RTG_SST[#]: No aerosol correction

NGAC* for aerosols

Initial conditions:
ATM: downscaled from GDAS
AER: cycled from NGA runs

#: Real-time Global Sea Surface Temperature
*: NGAC is one version of GSM (in NEMS framework; with the prognostic aerosol option)

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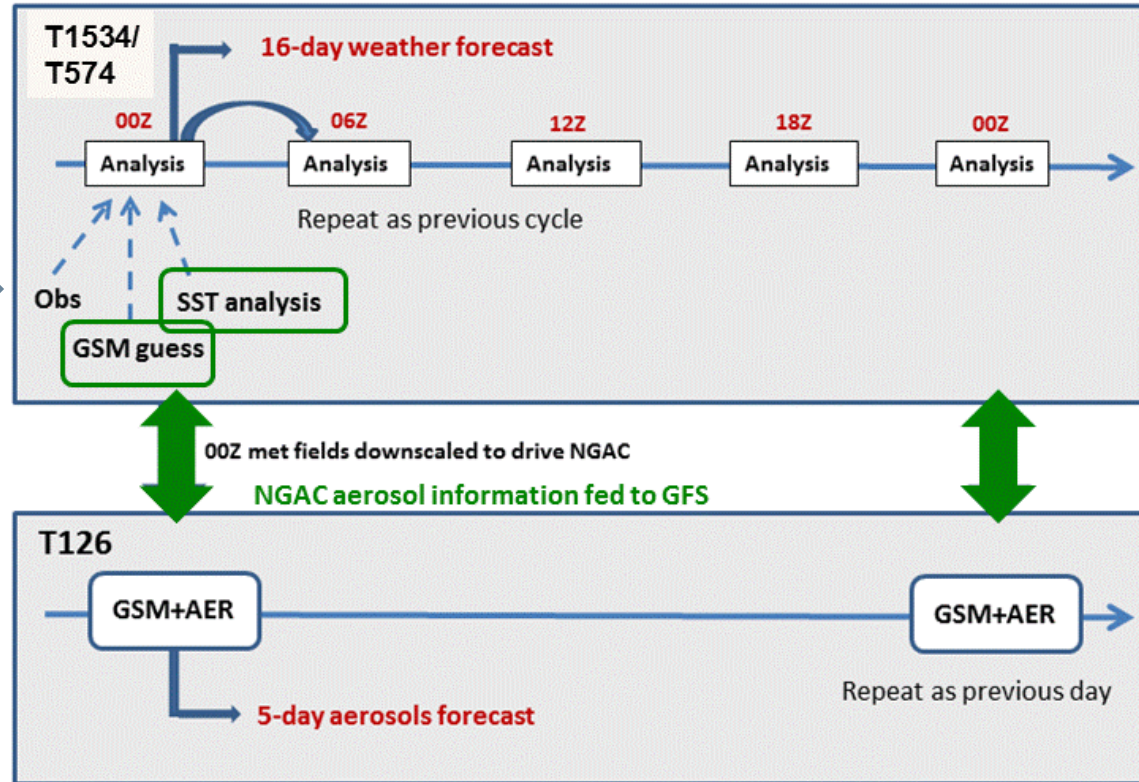# R2O project: Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System

- **Objective**:
  - Investigate how much complexity is needed to accurately represent the aerosol processes and effectively account for aerosol effects
- SUNYA-NCEP-STAR collaborative effort to explore the optimal (accurate and yet affordable) aerosol configuration for pre-operational testing at NCEP
- **Tactical approach**:
  - Producing an improved estimates of the temporal and spatial distributions of atmospheric aerosols
  - Using aerosol fields in conjunction with the forecast model (GSM), the analysis system (EnKF-GSI hybrid), and SST analysis (RTG_SST) to assess the atmospheric response to aerosols
  - Incorporate flexible aerosol configuration in pre-operational testing at NCEP to foster Research-to-Operation (R2O) and Operational-to-Research (O2R)

R2O project: Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System

Operational: One-way coupling
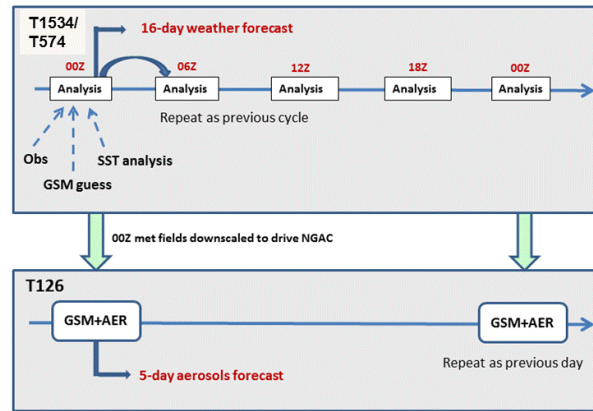
Proposed: Two-way loose coupling

Aerosol fields from low-resolution NGAC run are fed to high-resolution GFS run.

This allows aerosol radiative effects in GSM, physical retrievals in RTG_SST, and aerosol attenuation in EnKF-GSI hybrid to be determined from low-resolution NGAC simulations.

Use NGAC as the forward model in GDAS, which effectively fold the dual resolution system into a single fully-integrated system (tight coupling).

R2O project: Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System

Synergistic Activities

☐ Leverage on-going NEMS development: This project is closely aligned with, and complementary to, on-going NEMS and NGGPS development

☐ Unified framework fostering both R2O and O2R: This project facilitates R2O transition (by performing extensive testing and evaluation of NWP impact of aerosols under quasi-operational environment) as well as foster O2R transition (by making the parallel NWP system available to the research community)

☐ Version Control: Code changes made to GSM, GSI, RTG_SST, and GFS parallel scripts will be committed to code repository (SVN)

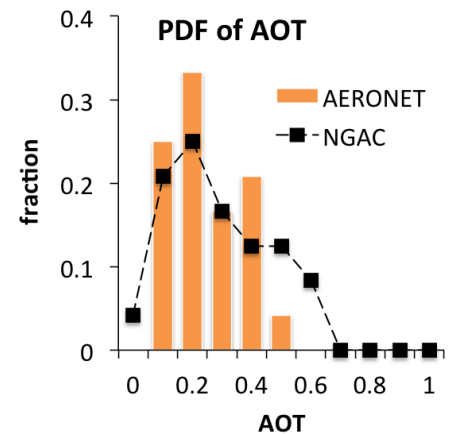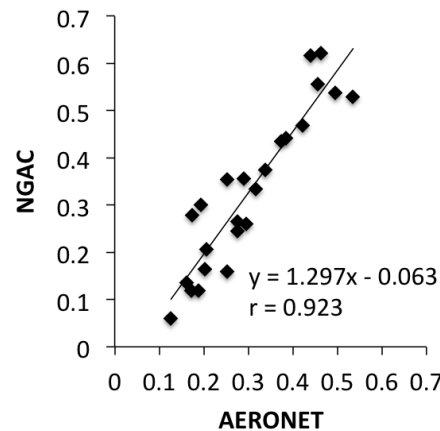# R2O project: Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System

Proposed work plan

- Year-1:

    - Modify GSM radiation and GSI/CRTM code for loose/tight coupling

    - Upgrade GFS parallel scripts for loose/tight coupling

    - Evaluate RTG_SST analysis system with the aerosol option incorporated

    - Select cases with scenarios of interest (dust outbreak, biomass burning events, and hurricane activities)

- Year-2:

    - Conduct baseline GFS experiments for selected periods

    - Conduct parallel GFS experiments with the loose and tight coupling configuration

    - Diagnose the results from baseline versus parallel experiments
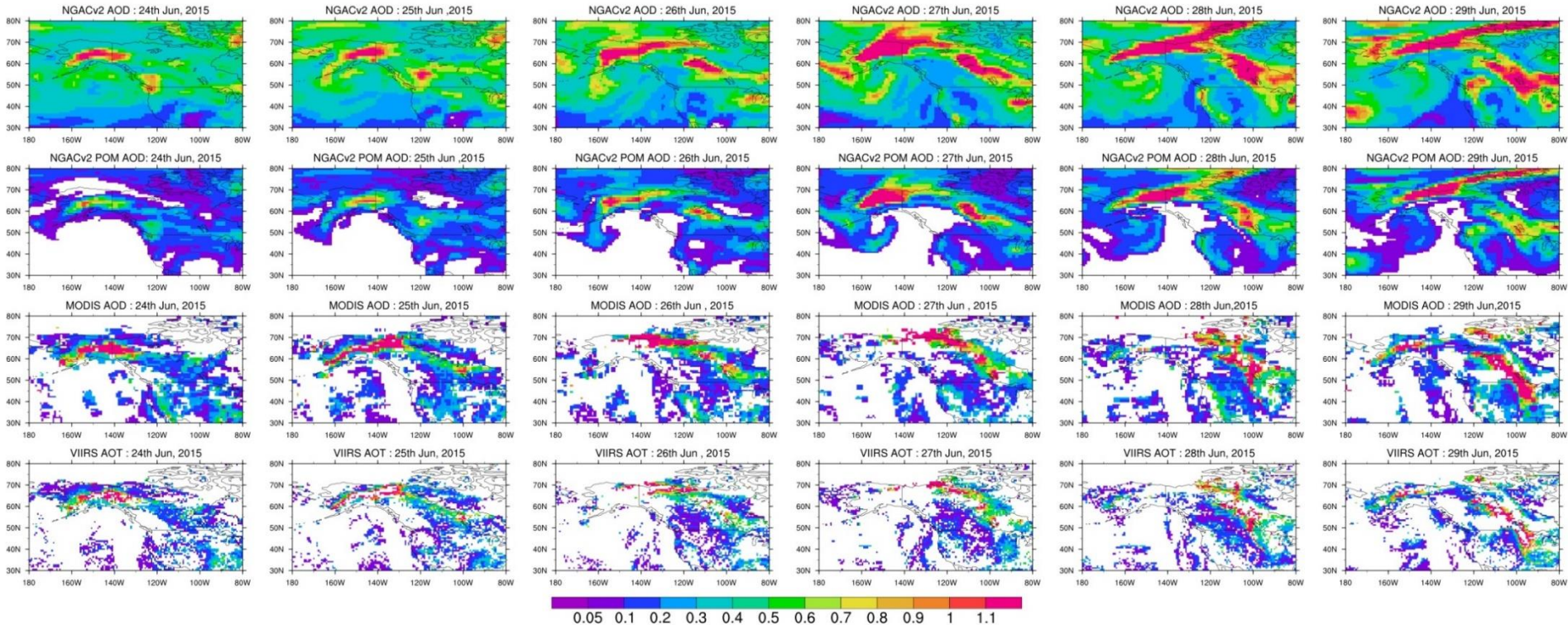
    - Benchmark report

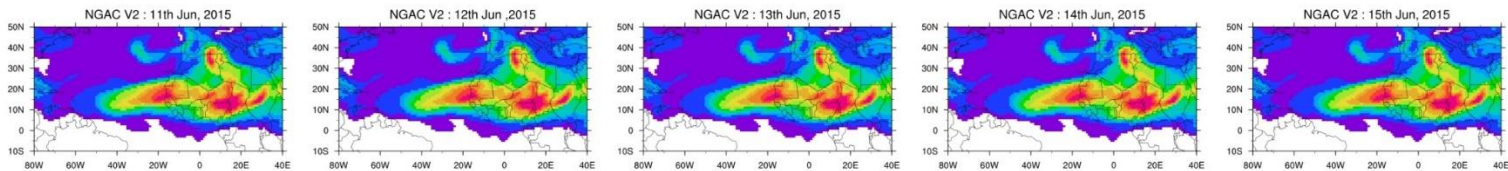# 2013-2014 NGAC evaluation using in situ AERONET observations
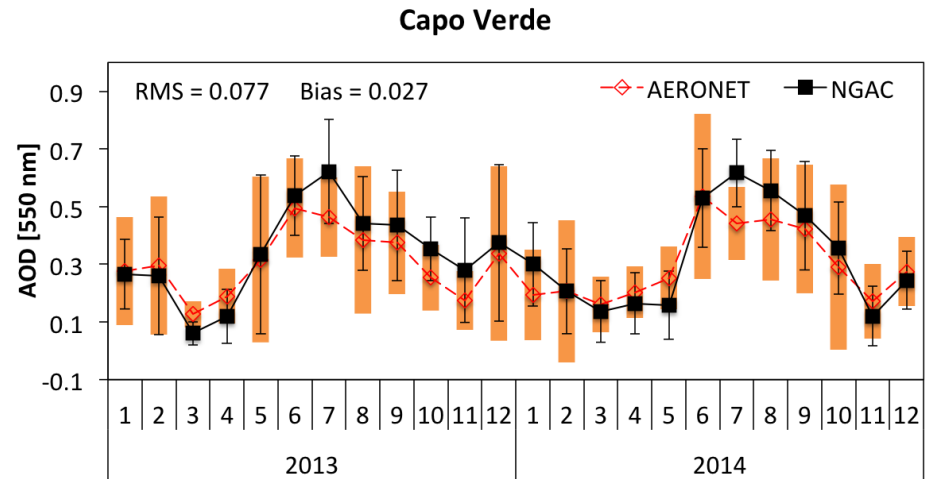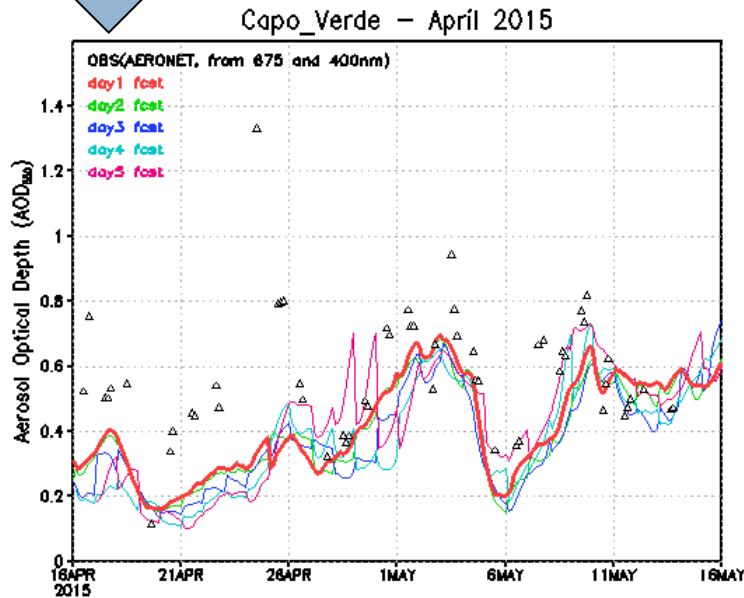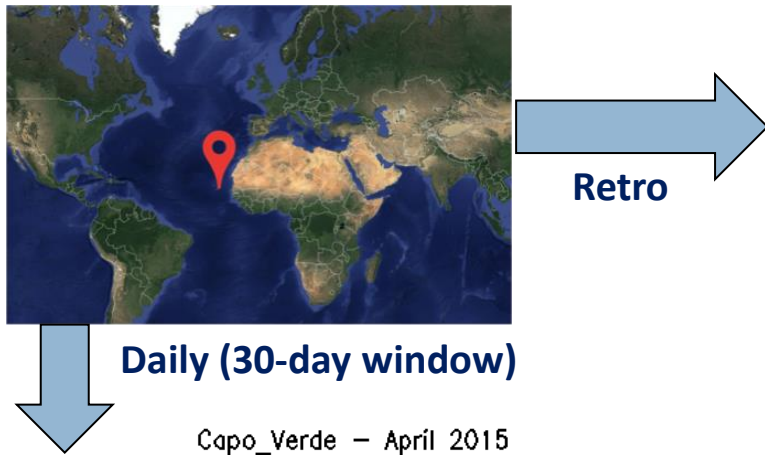
Alaska fires (June 2015)

Identify selected cases
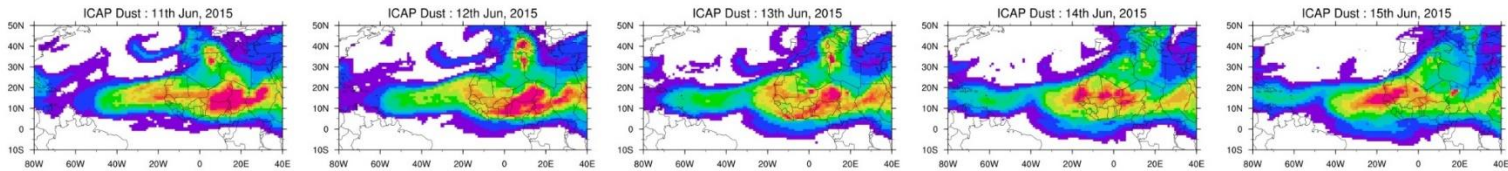
Evaluate spatial and temporal distributions of aerosols.
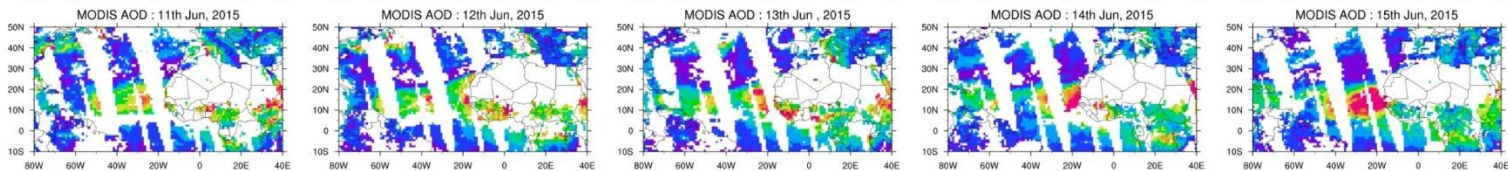
Long range dust transport (June 2015)
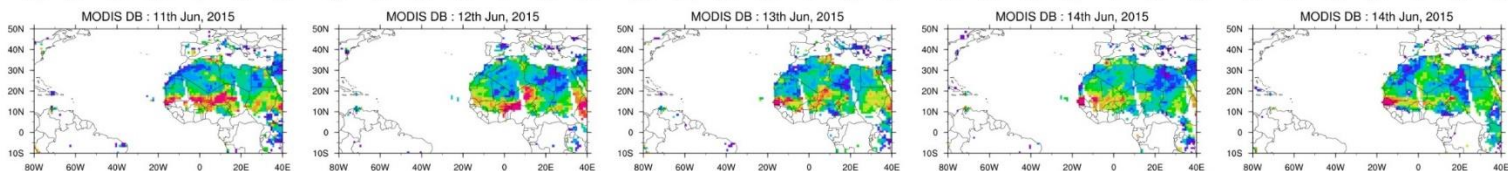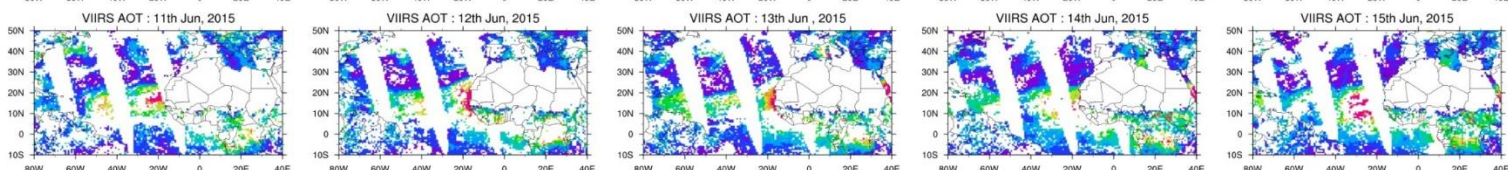

NGAC

ICAP MME

MODIS

MODIS DB

VIIRS

June 18, Joseph Prospero (U Miami) report 1.34 AOD at Barbodos AERONET site

June 23, Judd Welton (GSFC) reported a dust layer near the surface layer at GSFC MPLnet site

R2O project: Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System

Overarching goals:

☐ Resources versus complexity

 ◻ How much complexity is needed to accurately represent the aerosol processes and effectively account for aerosol effects?

 ◻ What is the optimal strategy to best use the available computer resources?

Project status update:

☐ GSM radiation code development in progress

☐ NCEP's NGAC is evaluated using in situ and satellite observations

☐ Cases of interest are identified

☐ New hire has been identified and the paper work is in progress

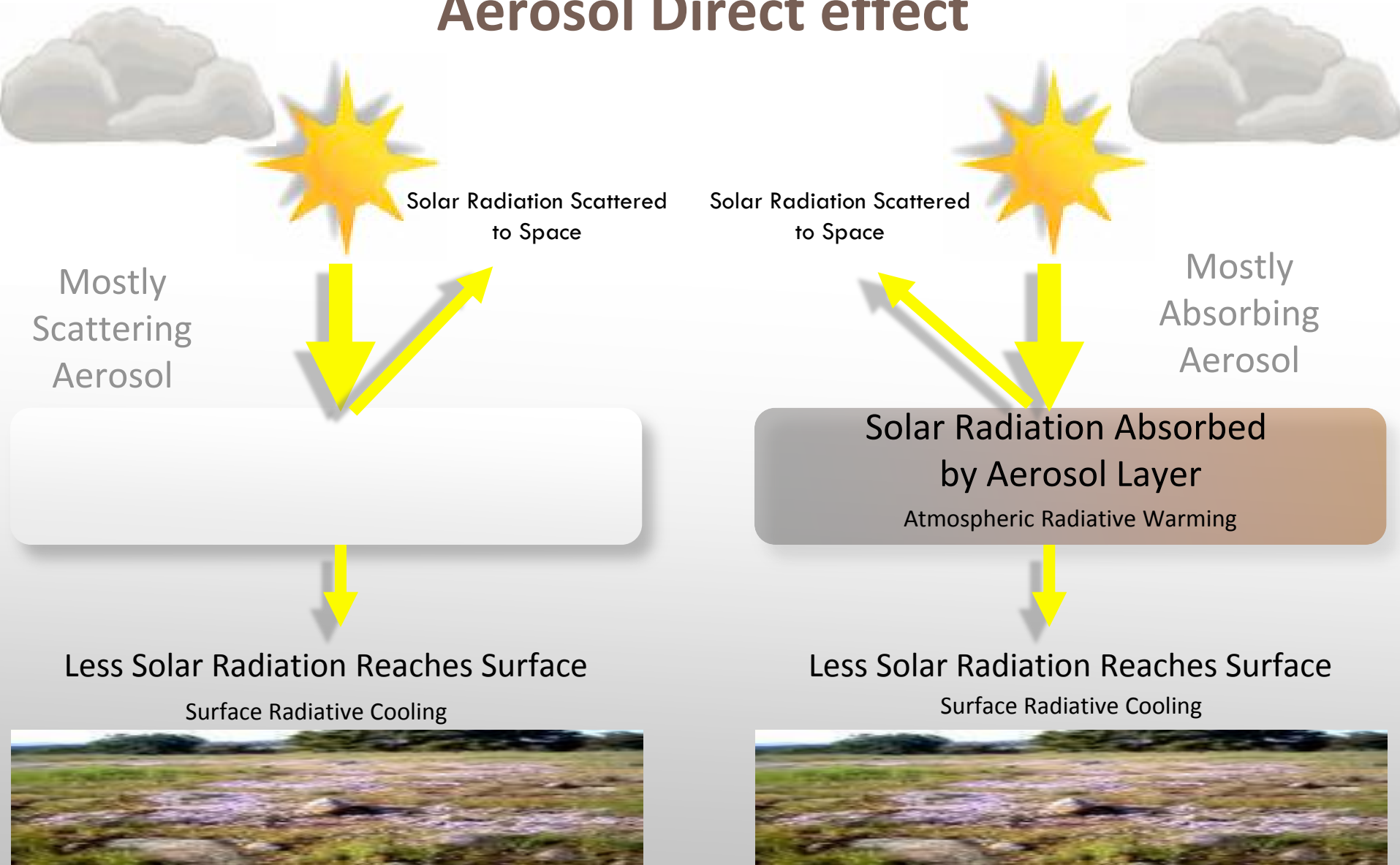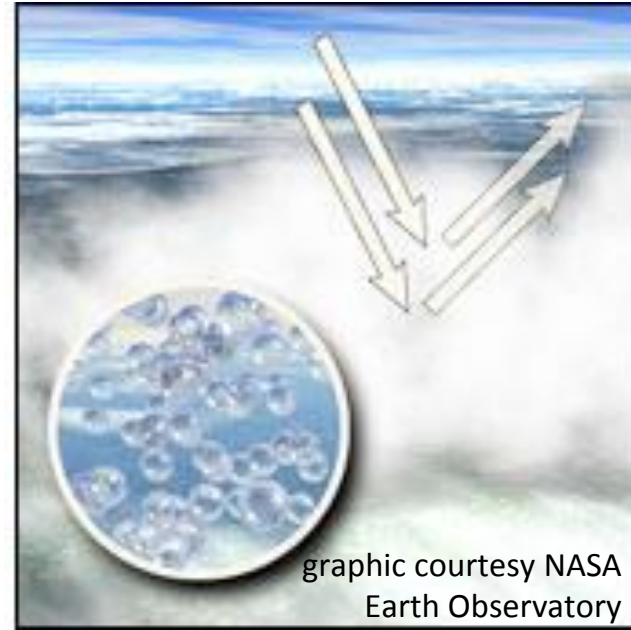☐ HPC account request will be submitted shortly

Back up slides

Thank You
Questions or comments?

Aerosol Direct effect

Solar Radiation Scattered to Space

Solar Radiation Scattered to Space

Mostly Scattering Aerosol

Mostly Absorbing Aerosol

Solar Radiation Absorbed by Aerosol Layer

Atmospheric Radiative Warming

Less Solar Radiation Reaches Surface

Surface Radiative Cooling

Less Solar Radiation Reaches Surface

Surface Radiative Cooling

Animation by C. A. Randles

Aerosol InDirect Effect

graphic courtesy NASA Earth Observatory

graphic courtesy NASA Earth Observatory
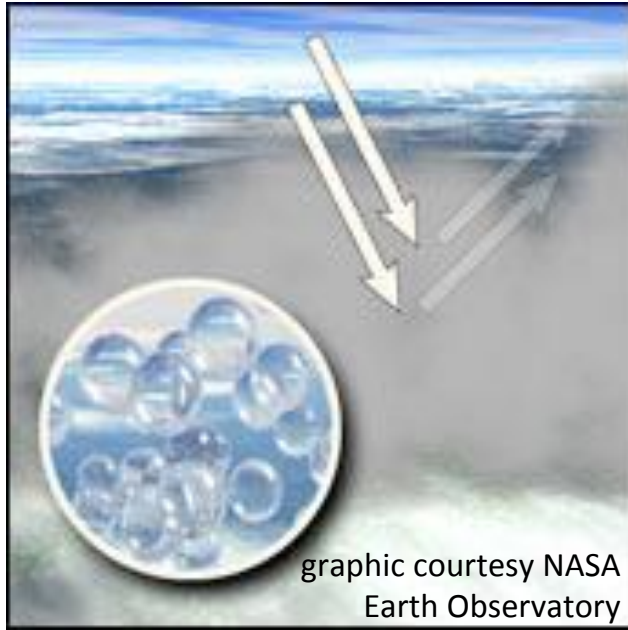
Larger cloud droplets, less reflective cloud.

Twomey Effect

Smaller cloud droplets, more reflective cloud.

Less Aerosols   Increased Cooling by Clouds   More Aerosols

Larger cloud droplets, droplets rain out easier, clouds dissipate quicker.

Albrecht Effect

Smaller cloud droplets, droplets rain out less, longer-lived clouds.

Animation by C. A. Randles