Navy Aerosol System Science and Development for Operations

http://www.nrlmry.navy.mil/aerosol/

10th ICAP Working Group
UKMO, Exeter, UK
June 6-8, 2018

Send comments
Jeffrey S. Reid, US Naval Research Laboratory
jeffrey.reid@nrlmry.navy.mil

Overview

- Overview of peoples and systems
- Systems update
- Major projects: MURI, C-FOG, CAMP^{2}Ex, & PISTON
- Recent results in the literature from the last year

Navy Sponsored Aerosol Development for Operations Community

NRL Monterey (Marine Meteorology)

Anthony Bucholtz: Radiation, tactical decision aids
Chris Camacho: Software engineering
James Campbell: Cirrus, lidar studies
Josh Cossuth: Remote sensing systems
Edward Hyer: Satellite data, biomass burning , transitions
Kathleen Kaku (CSRA): Air quality, chemistry
Arunas Kuciauskas: Dust systems
Ming Liu: Inline NAVGEM aerosol
Mayra Oyola (ASEE) Dust radiation
David Peterson: Fire meteorology, biomass burning
Elizabeth Reid: Deployments and analysis
Jeffrey Reid: Applied meteorology & aerosol
Benjamin Ruston: Dust Infrared impacts on DA
Mindy Surratt: Remote sensing
Annette Walker: Mesoscale aerosol & dust sources
Doug Westphal: Emeritus
Peng Xian: ICAP-MEE, NAAPS reanalysis

NRL Washington DC (Remote Sensing)

Maggie Anguelova: Microwave retrievals
Juli Rubin: Ensemble systems
Ivan Savelyev: Sea Salt production

Key ONR Programs

HAALE: Littoral zone aerosol prediction S. Miller (CSU, PI), S. Albers (CIRA), R. Holz (SSEC), S. Kreidenweis(CSU), S. van den Heever(CSU), J. Wang(UI), J. Zhang (UND), and M. Zupanasky (CIRA)
C-FOG: Fog prediction: J. Fernando (U. NotreDame) et al.
PISTON: Maritime Continent intraseasonal oscillations

Plus Joint with NASA CAMP^{2}Ex

Current Research & Development areas

Basic Research

Aerosol clim., lifecyle, & meteorology
Aerosol microphys/chem/optics
Aerosol observability/predictability
Aerosol Radiation
Arctic radiation & cloud
Biomass burning emissions
Cirrus radiation
Fire meteorology
Marine Boundary Layer/Wave Physics

Aerosol Product Lines

DA grade satellite products
Dust source database
FAROP
FLAMBE
Lidar aerosol climatology
Performance Surfaces

Global Modeling

NAAPS Operational
NAAPS Reanalysis
NAAPS Ensemble
ICAP MME
Fused Products
+
NAVDAS-AOD
DART

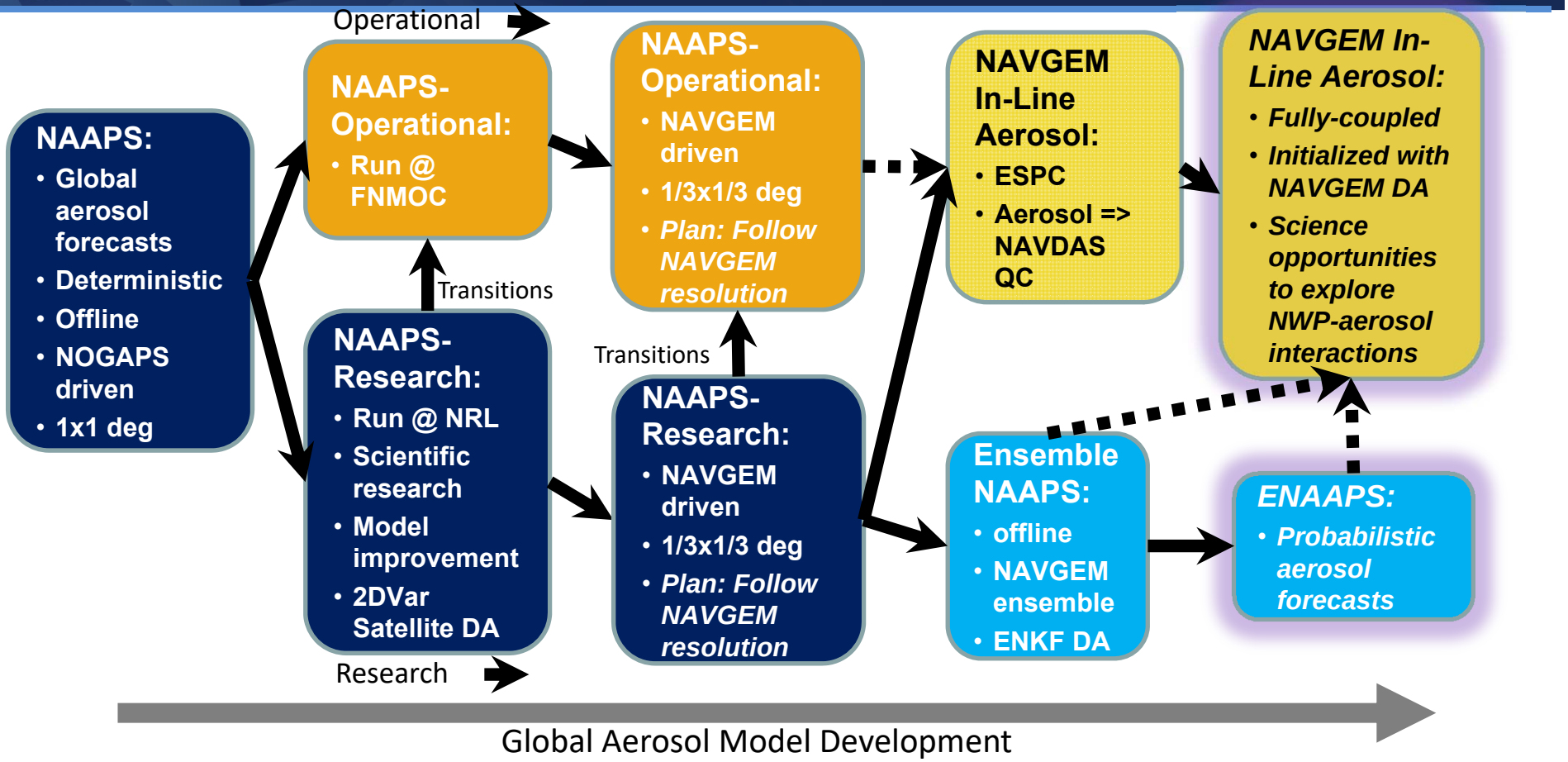
Interdisciplinary

Applied meteorology
NWP
Oceanography, ocean color, SST
Tactical decision aids

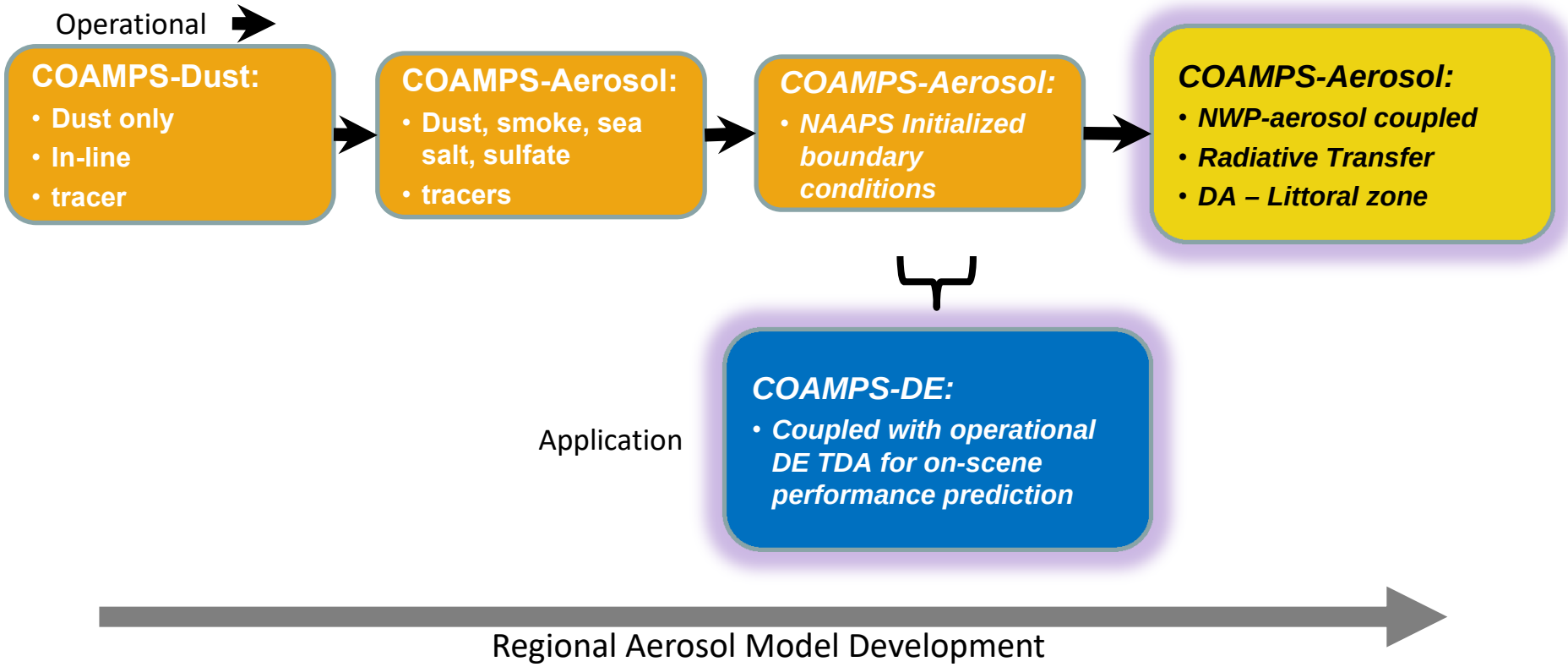
Mesoscale

COAMPS Dust
COAMPS Scaler

Navy Global Aerosol Modeling Family Tree

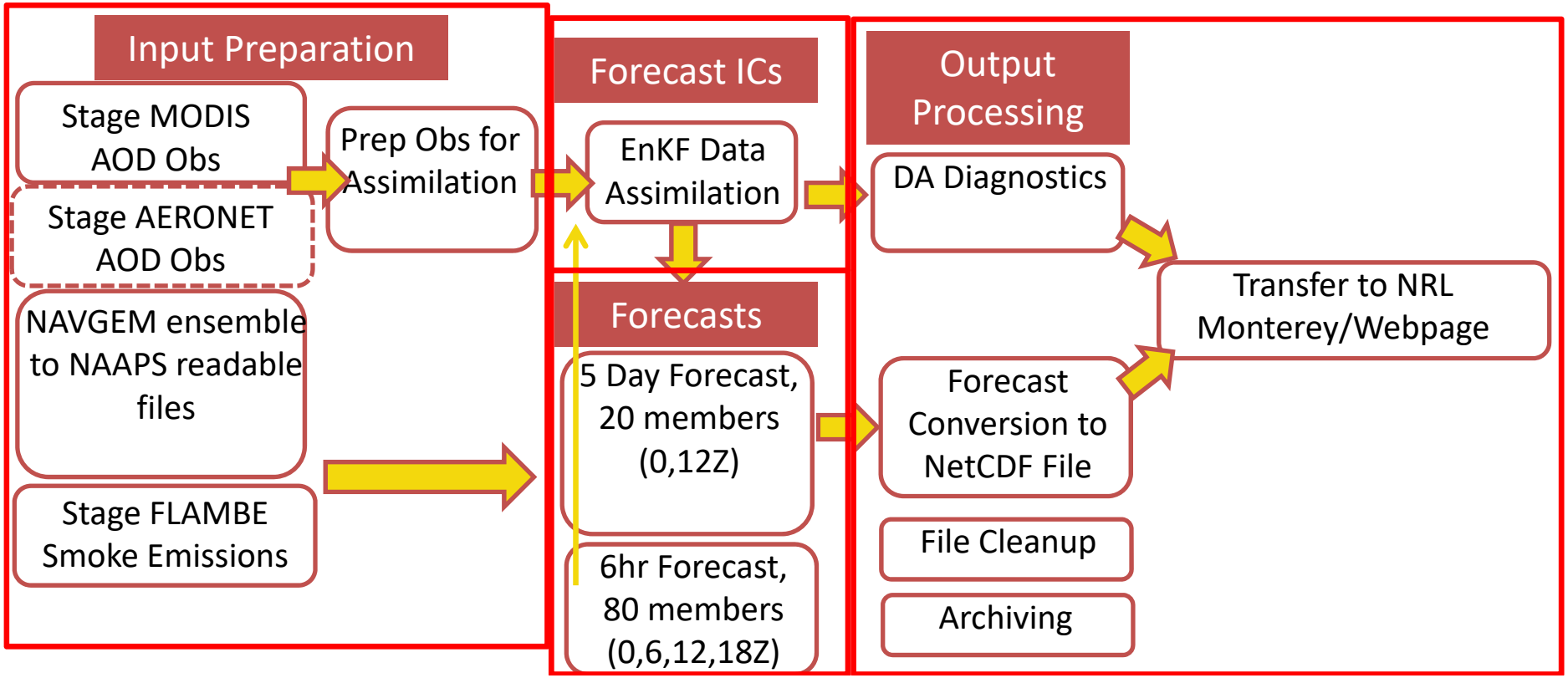


Navy Mesoscale Aerosol Modeling Family Tree



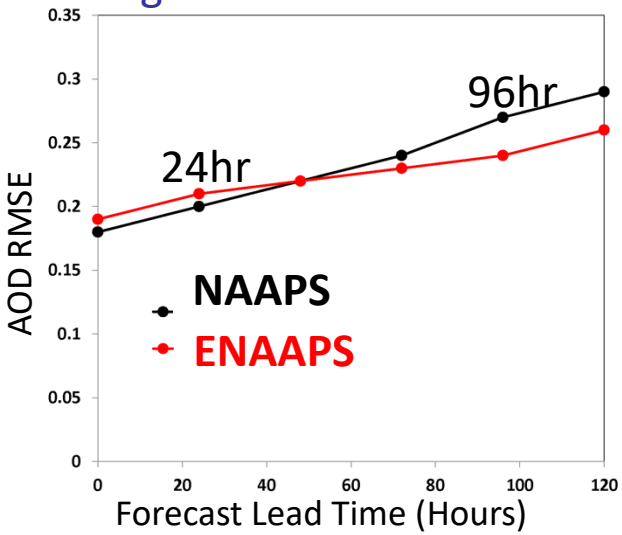
ENAAPS Semi-operational at Navy DSRC

- ENAAPS was tested and converted to a NRT system at DSRC (Conrad) in FY17.
- New scripts developed to break system into smaller tasks for Cylc implementation.



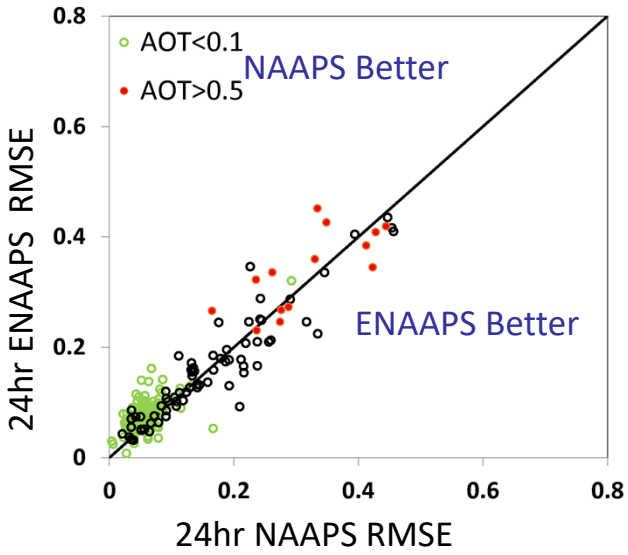
ENAAPS Ensemble Mean Verification

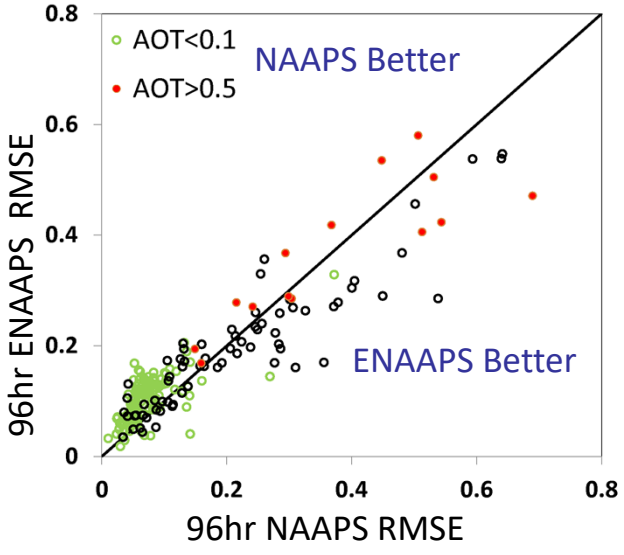
Global Forecast Evaluation against AERONET AOD:



December 2017-April 2018

Evaluation at Individual AERONET sites:



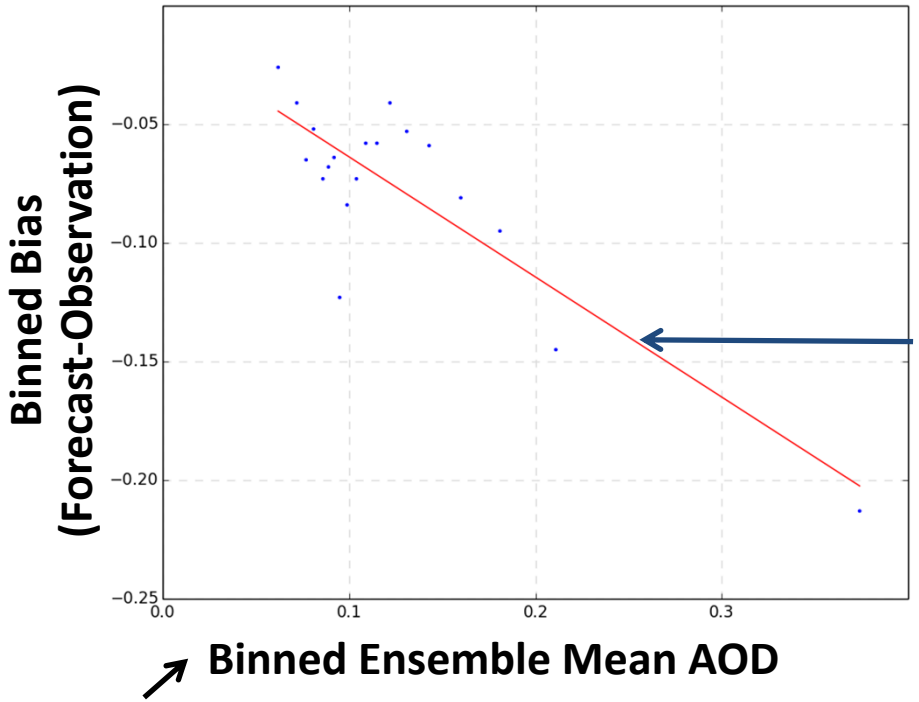


1. NAAPS/ENAAPS performance ~ the same out to 48 hours.
2. ENAAPS performance better after 48 hours.
3. ENAAPS has positive bias issues at background aerosol levels **(AOD<0.1)**.
4. Additional bias issues at some sites impacted by high AOD aerosol events **(AOD>0.5).**

ENAAPS: Bias Correction

Method is based on 6.4 National Unified Operational Prediction Capability (NUOPC)) (J. Peak, D. Hodyss)

Observations are from MODIS or any gridded AOD product (U. Wisc, Holz).



Method uses archived ENAAPS forecasts (1 week shown).

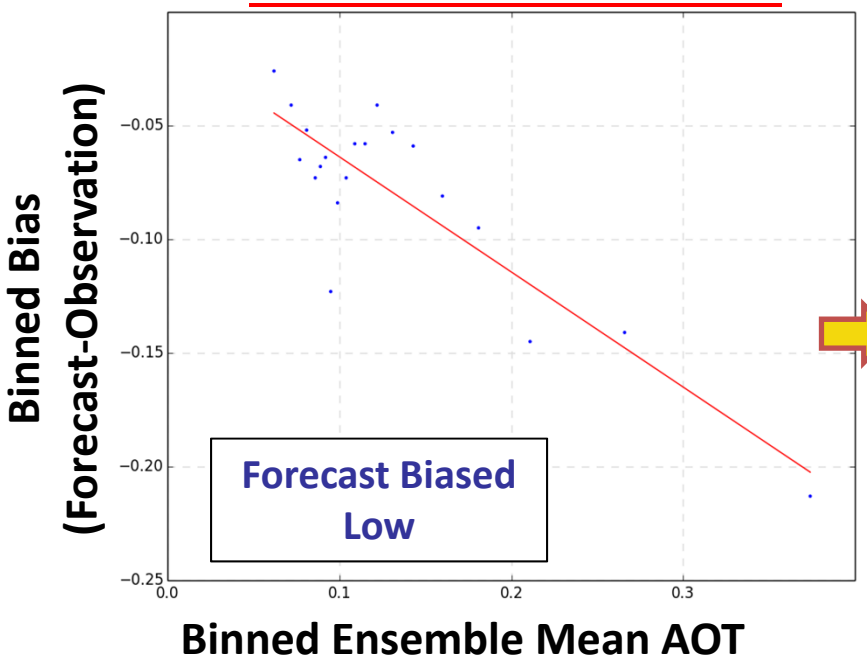
The regression line is used to map AOD forecast to bias correction.

Forecast bins are defined so that they are equally populated and the bias is calculated in each.

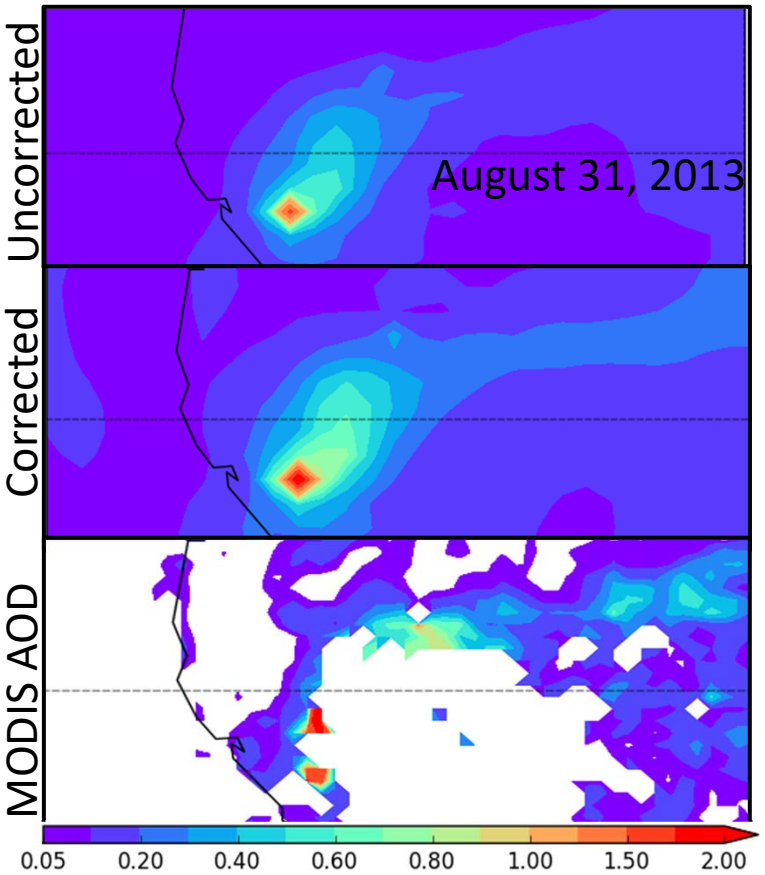
ENAAPS: Bias Correction

Correction applied by region and as a function of forecast lead time.

Western United States:
Smoke from Extensive Fires



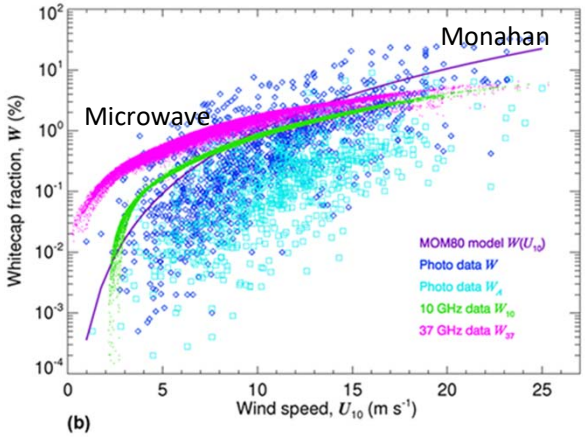
24hr Forecast Correction
August 23-August 30, 2013



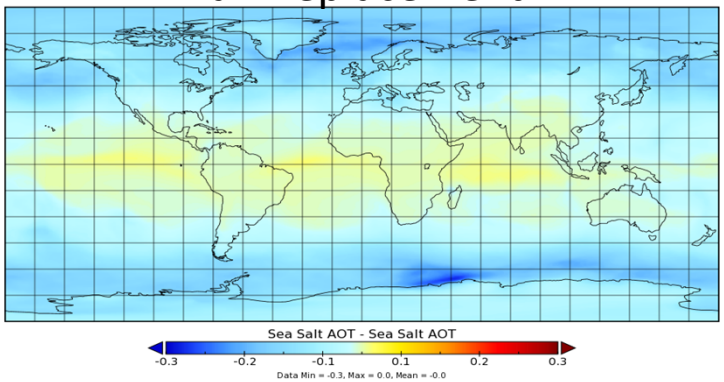
Using bias correction, smoke transport is better captured in ENAAPS forecast.

Sea Salt Development

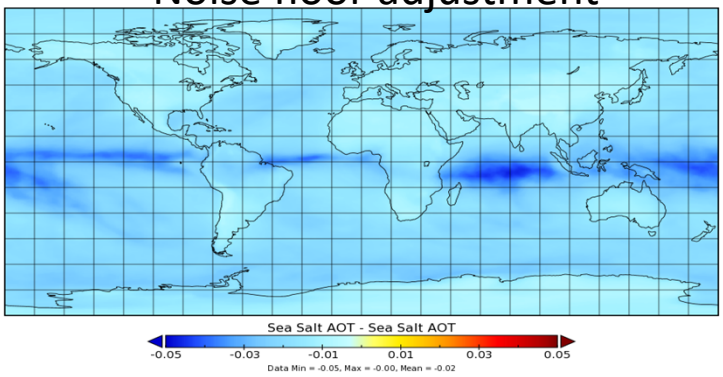
- Time for a Sea Salt Tune up In NAAPS.
- NAAPS tend to over predict AOD in the mid latitudes
- Replacing Monahan Whitecap fraction with Microwave derived whitecap fraction from Anguelova et al. NRL DC
- Significant improvement if we account for a microwave noise floor.
- Ongoing work on vertical distribution & deposition



Raw replacement



Noise floor adjustment



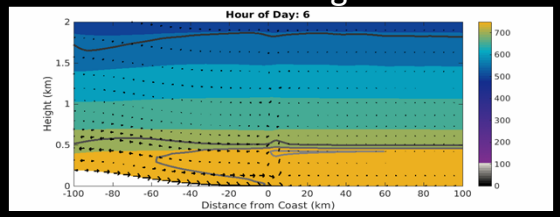
MURI: Holistic Analysis of Aerosol in Littoral Environments-HAALE

Interested? Steven.Miller@colostate.edu

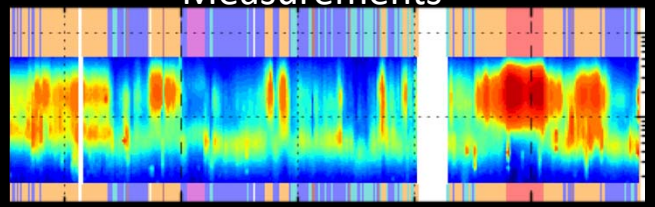
Colorado State University · Wisconsin · University of North Dakota · The University of Iowa

What are the fundamental environmental factors that govern the spatial distribution and optical properties of littoral zone aerosols at the sub-km scale?

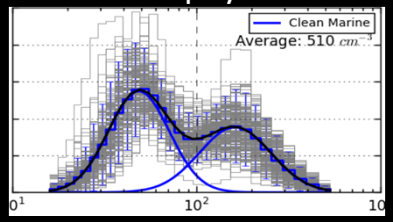
Modeling



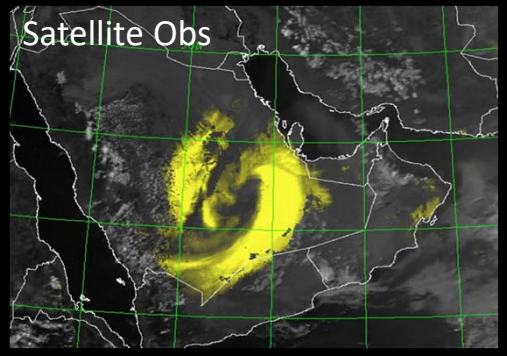
Measurements

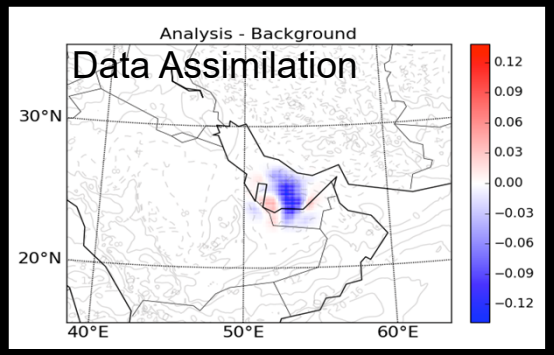


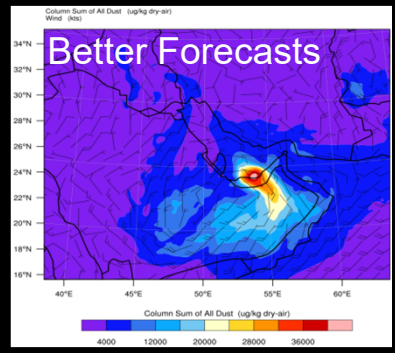
Microphysics



How can we best leverage emergent satellite observing systems and derived products via advanced D/A techniques to optimally inform a high-resolution forecast model's initial aerosol field?







Toward Improving Coastal Fog Prediction C-FOG

Interested? Contact Joe Fernando (hfernand@nd.edu)

Science Questions

- How does warmer moist air advecting over closer ocean lead to (cold) marine of via competing factors of shear instabilities, turbulent mixing, and stable stratification?
- What mechanisms (convective instabilities, stratus/cumulus clouds, entrainment etc.) trigger (warm) marine fog when colder air advects over warmer ocean surface?

Approach

- A comprehensive atmosphere-ocean field campaign (September-November 2018) in eastern Canada.
- Studies on coastal fog physics/governing parameters
- Analytical studies on fog physics/governing parameters
- Cascading simulations: Mesoscale (NWP), Large eddy & direct numerical simulations

Principal Investigators

- Clive Dornan (Scripts)
- Joseph Fernando (U Notre Dame, PI)
- Ismail Gultepe (Environment Canada)
- Eric Pardyjak (U. Utah)
- Qing Wang (NPS)

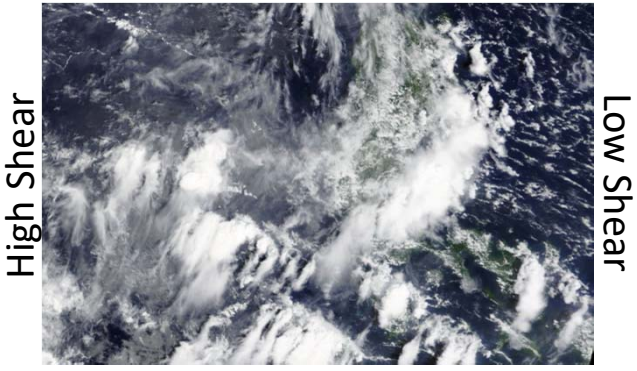
Principal Collaborators

- Chris Hocut (ARL)
- Andrew Heymsfield (NCAR)

Cloud, Aerosol, Monsoon Processes Philippines (CAMP^{2}Ex)

Aircraft maintenance pushed us to summer 2019. Interested? jeffrey.reid@nrlmry.navy.mil

- NASA, Manila Observatory, NRL will conduct an airborne P3 and Lear 35 campaign out of Subic Bay Philippines September, 2019.
- Research will focus on these questions
  - Do aerosol particles influence warm/mixed phase precipitation in tropical environments?
  - Do aerosol induced changes in clouds and precipitation feedback into aerosol lifecycle?
  - How does the aerosol and cloud influence on radiation co-vary and interact?
- Manila Observatory is taking a lead on how land use change effects clouds and if this change is a confounder for perceived aerosol impacts.
- ~100 scientist, including ~20 Philippine scientist will conduct ~16 8-hour P3 and 8 5-hour Lear 35 flights to measure the cloud and pollution environment around the Philippines.



Selected Instruments

NASA P-3B

- Aerosol in-situ microphysics:
  - Black carbon
  - Cloud condensation nuclei
  - Composition
  - Light scattering
  - Size distribution
- Aerosol profiles (lidar)
- Cloud cover/properties
  - Cloud cameras
  - Cloud in-situ microphysics
  - Droplet/ice particle size
  - Polarimeter
  - Precipitation
- Cloud/precip remote sensing
  - 94 GHz radar
  - 18-27 GHz radar
  - Microwave radiometer
- Tracer Gases (CO_2, CO, SO_2, NOx)
- Radiative balance: Hyperspec., Solar, & IR flux
- State variables (temperature, wind humidity):
  - In-situ & profile
  - Sea surface temperature


NASA P-3B

SPEC Lear Jet 35

Aerosol Size

Cloud in-situ microphysics

droplet/ice particle size

precipitation


SPEC

CAMP²Ex WeatHEr and CompoSition Monitoring: CHECSM

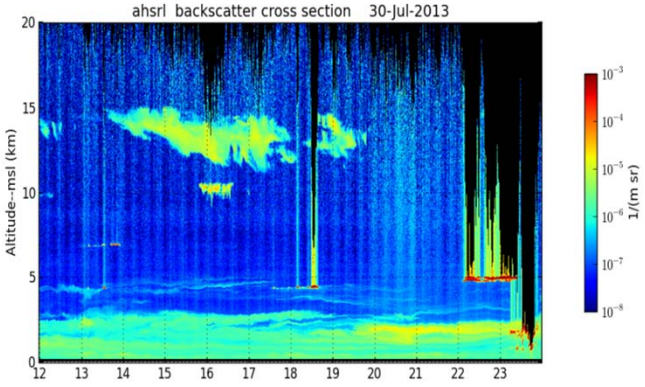
Making lemonade: Mission push gives us some time to exercise the latest data streams-Models, Terra/Aqua/SNPP, CALIPSO/CloudSat and GPM

Manila deployments for radiation, aerosol, chemistry and SSEC HSRL.

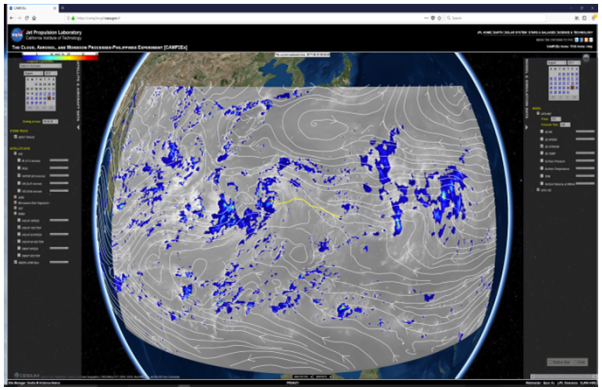
Strong synergy with PISTON modeling and Thompson observations.

Do all of the data streams really make sense?????

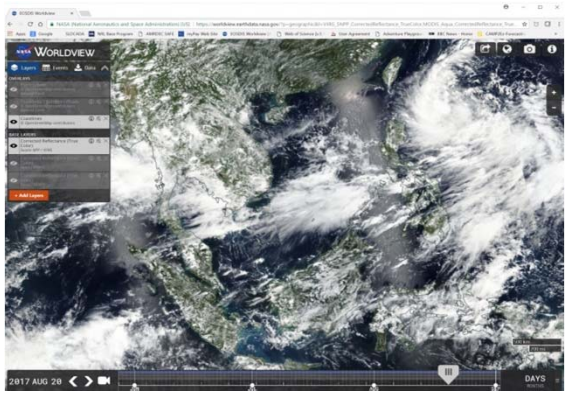
Metro Manila Obs



JPL Model/Sat Viewing and Download



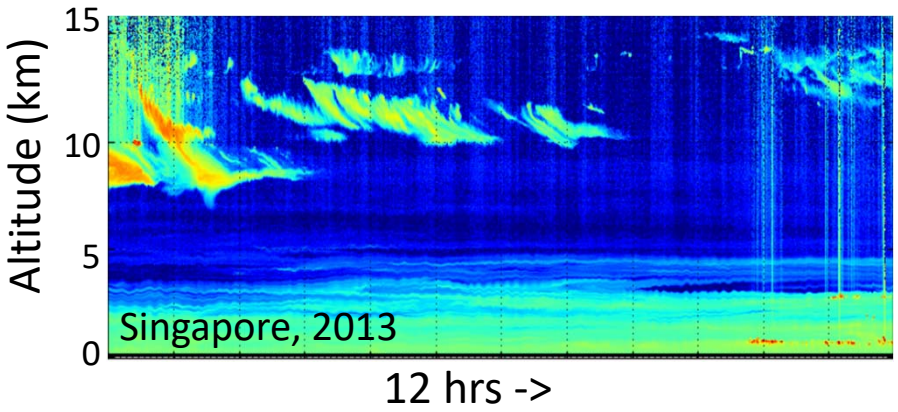
AHI in Worldview Portal

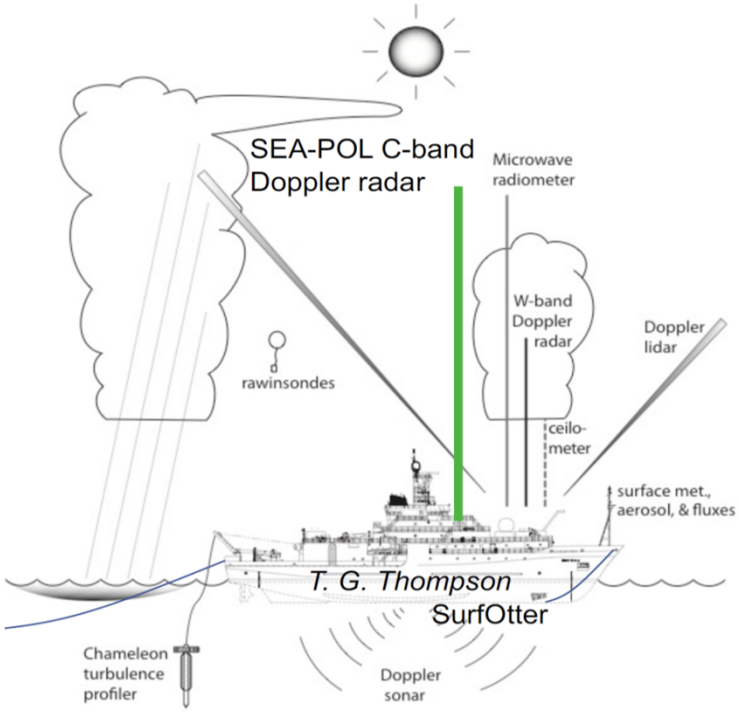


PISTON: Propagation of Intra-seasonal Oscillations

Joint sponsored CALIPSO/ONR deployment of SSEC HSRL to the Thompson

- PISTON is an ONR DRI to assess SE Asian of intraseasonal weather phenomenon across the Maritime Continent, such as the MJO.
- Included is the R/V Thompson cruise mid Aug-Mid Oct, 2018, off of Luzon to examine diurnal cycle in association with BSISO originally with some overlap with CAMP2Ex.
- Included are Air/Sea Flux, C-POL & W radar, and wind lidar.
- For the aerosol community, SSEC HSRL is slated for deployment providing the first solid lidar data in the region.
- Will exercise COAMPS aerosol .





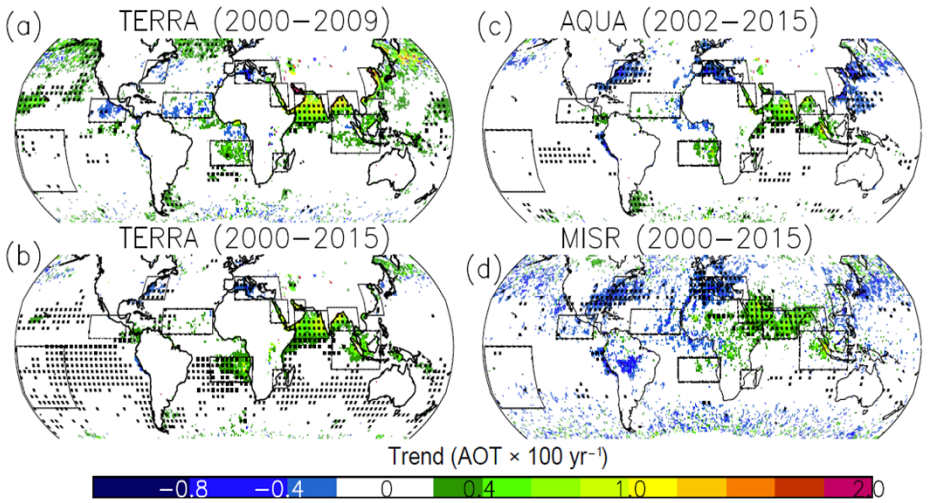
Interested? Atmos measurements-jeffrey.reid@nrlmry.navy.mil
Meteorology Models- sue.chen@nrlmry.navy.mil
Oceanography-moum@coas.oregonstate.edu

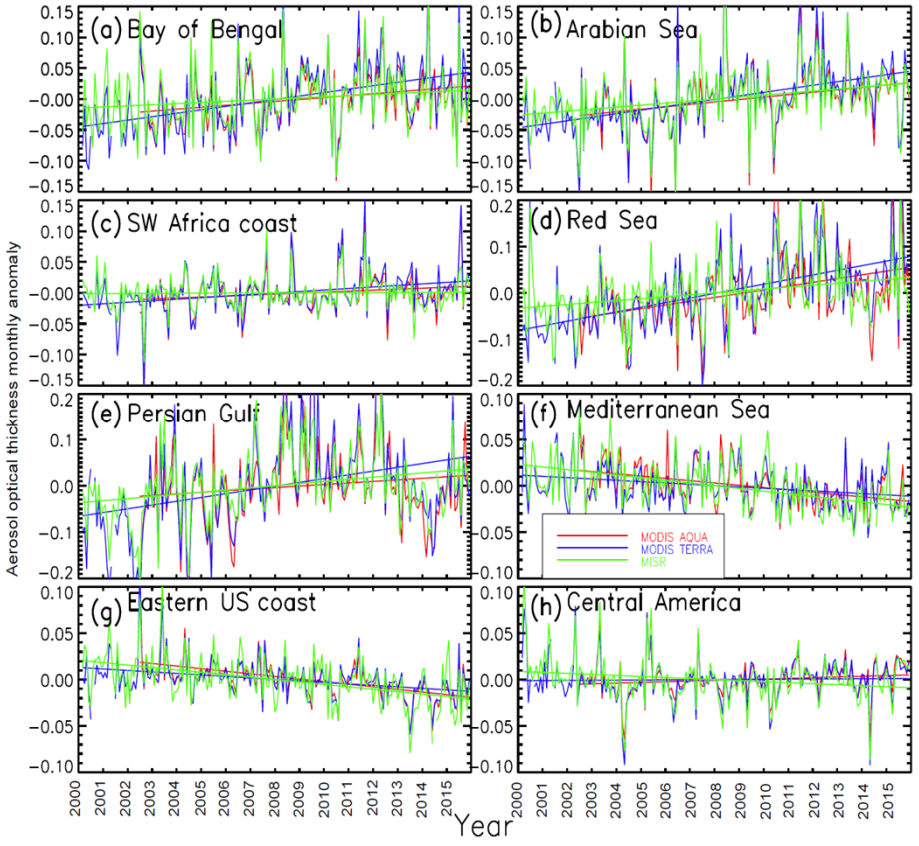
Global Trends in AOD and Forcing

Alfaro-Contreras, R., J. Zhang, J. S. Reid, and S. Christopher (2017). A study of 15-year aerosol optical thickness and direct shortwave aerosol radiative effect trends using MODIS, MISR, CALIOP and CERES, *Atmos. Chem. Phys.*, 17, 13849-13868, https://doi.org/10.5194/acp-17-13849-2017

Big news:

- China loadings and fluxes reducing since 2008.
- Steady improvement on East US Coast and Mediterranean.
- S. Asia, Persian Gulf and Red Sea flattening out.
- Slight downward trend in CERES calibration?

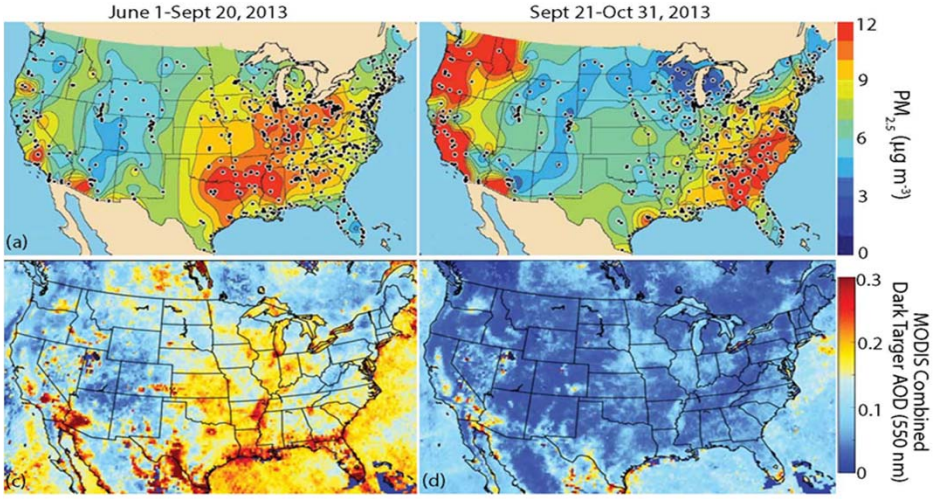


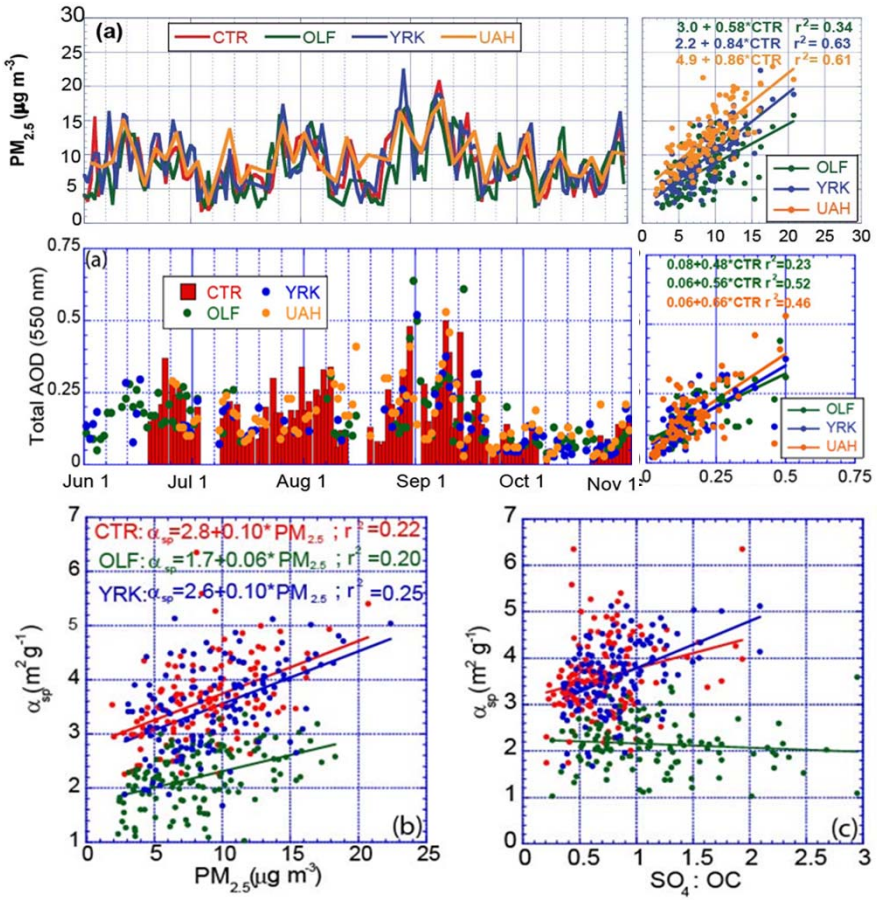


SEAC^{4}RS surface station baseline analysis

Kaku, K. C., J.S. Reid, J. L. Hand, E. S. Edgerton, B. N Holben, J. Zhang and R. E. Holz (2018), Assessing the challenges of surface-level aerosol mass estimates from remote sensing during the SEAC^{4}RS and SEARCH campaigns: Baseline surface observations and remote sensing in the Southeastern United States, J. Geophys. Res, In revision.

- Examined baseline aerosol chemistry and optical properties for the SE US for SEAC^{4}RS.
- PM2.5 was better correlated between stations than AERONET AOD. For satellite it went downhill.
- The mass scattering efficiency was uncorrelated to OC:SO4, but was moderately correlated with PM2.5.
- But over the past decade a third of the AOD reduction in the region was due to a reduction in mass scattering efficiency.

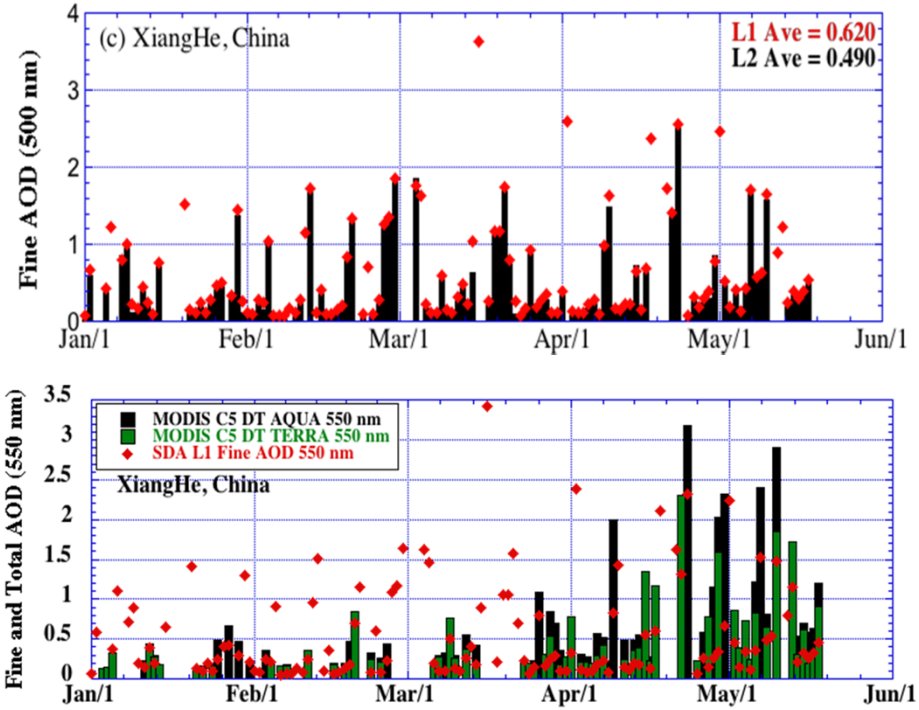


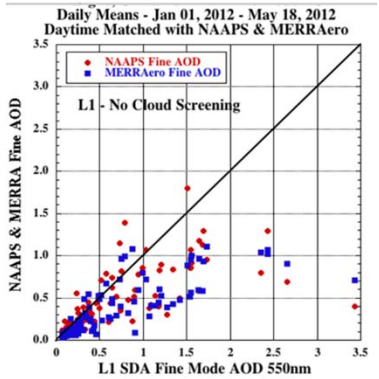


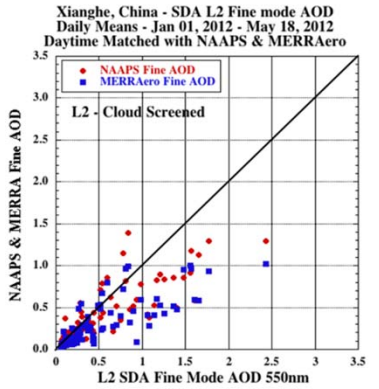
Aerosol covariance with clouds and fog.

Eck, T. F., B. N. Holben, J. S. Reid, P. Xian, D. M. Giles, et al., (2018), Observations of the interaction and transport of fine mode aerosols with cloud and/or fog in northeast Asia from Aerosol Robotic Network (AERONET) and satellite remote sensing, J. Geophys. Res, in press doi: 10.1029/2018JD02831

- Used the SDA method to extract fine mode AOD in periods of moderate cloud and haze that normally are rejected in cloud screening.
- L2 AERONET and MODIS miss these events, leading to sampling bias.
- MERRA and NAAPS reanalyses under-predict in general, but especially the most sevre events.







MURI: AOD retrieval over global coastal turbid water

50+% population lives in the coast.

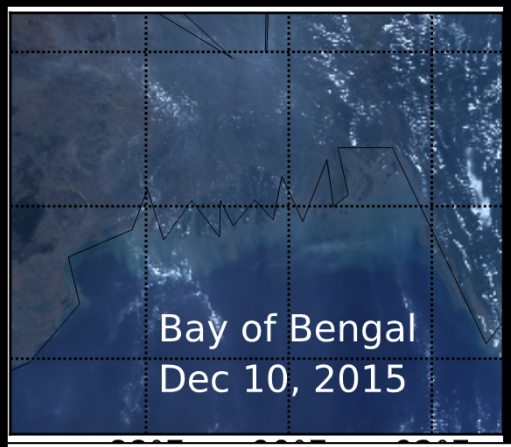
Coastal water can be very turbid as a result of runoffs from land (and coastal pollution).

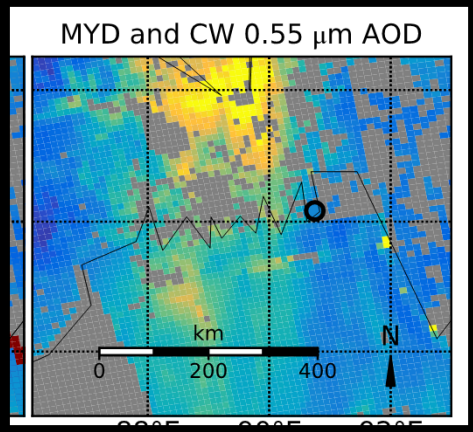
Ocean color algorithm doesn't provide any retrieval for AOD > 0.3

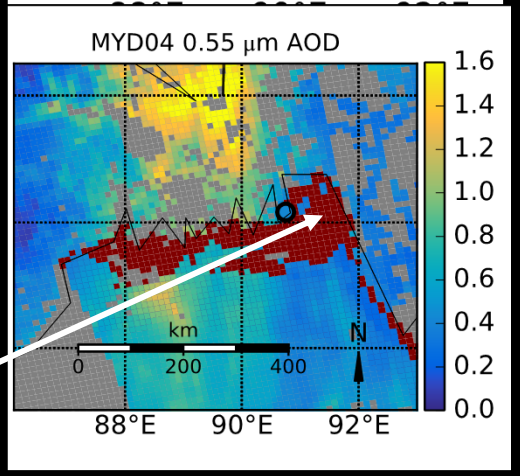
MODIS algorithm doesn't do any retrieval of AOD over the turbid water.

~20% of time AOD is not retrieved simply because water is turbid.

No retrieval



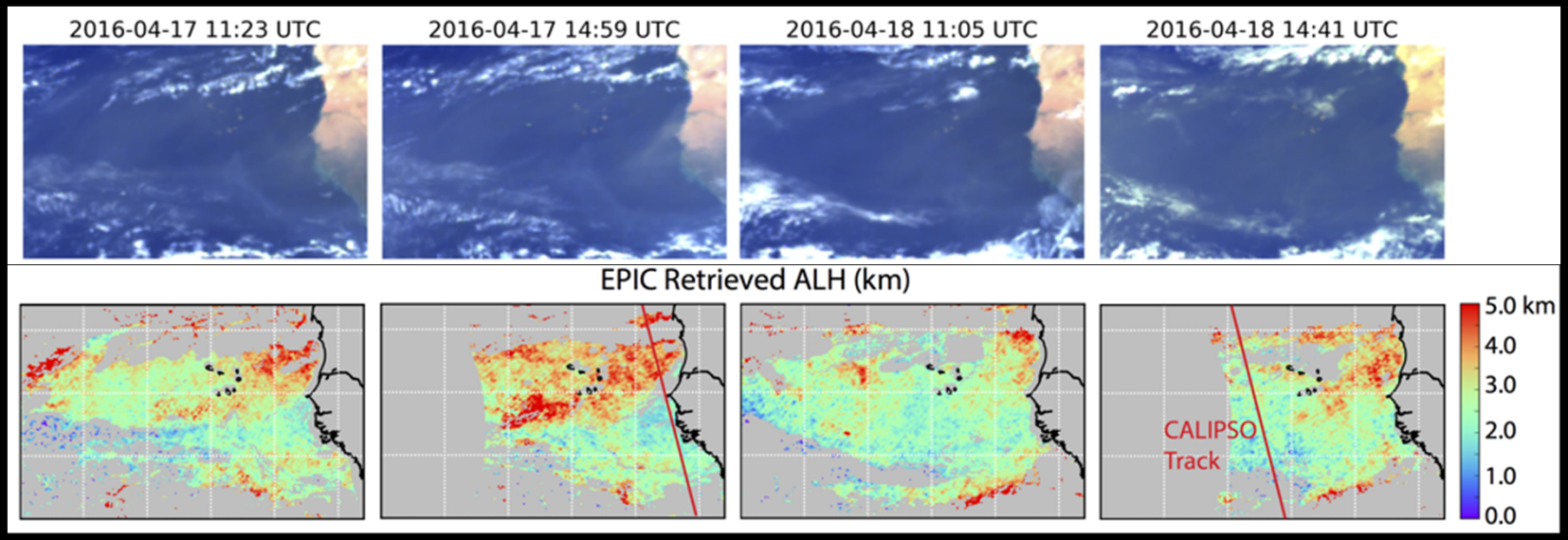


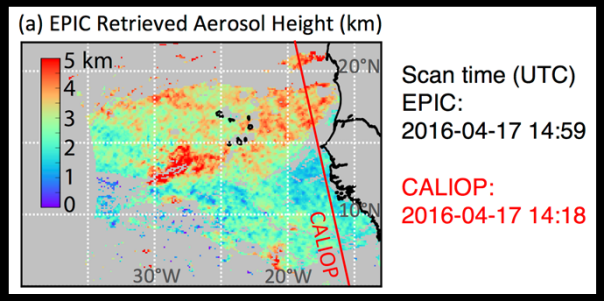


Retrieval is performed in the near infrared using nearest neighbor aerosol model. Yields ~18% more AOD data in the coastal water regions.

Wang, Y., J. Wang, R. Levy, X. Xu, J. Reid, MODIS retrieval of aerosol optical depth over turbid coastal water, *Remote Sensing*, 9, 595, 2017.

MURI: Retrieval of dust plume height from EPIC's O2 A and B bands over ocean every hour for sunlit surfaces

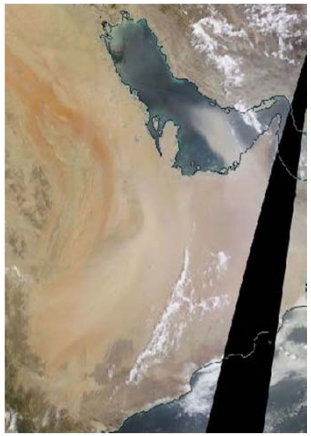




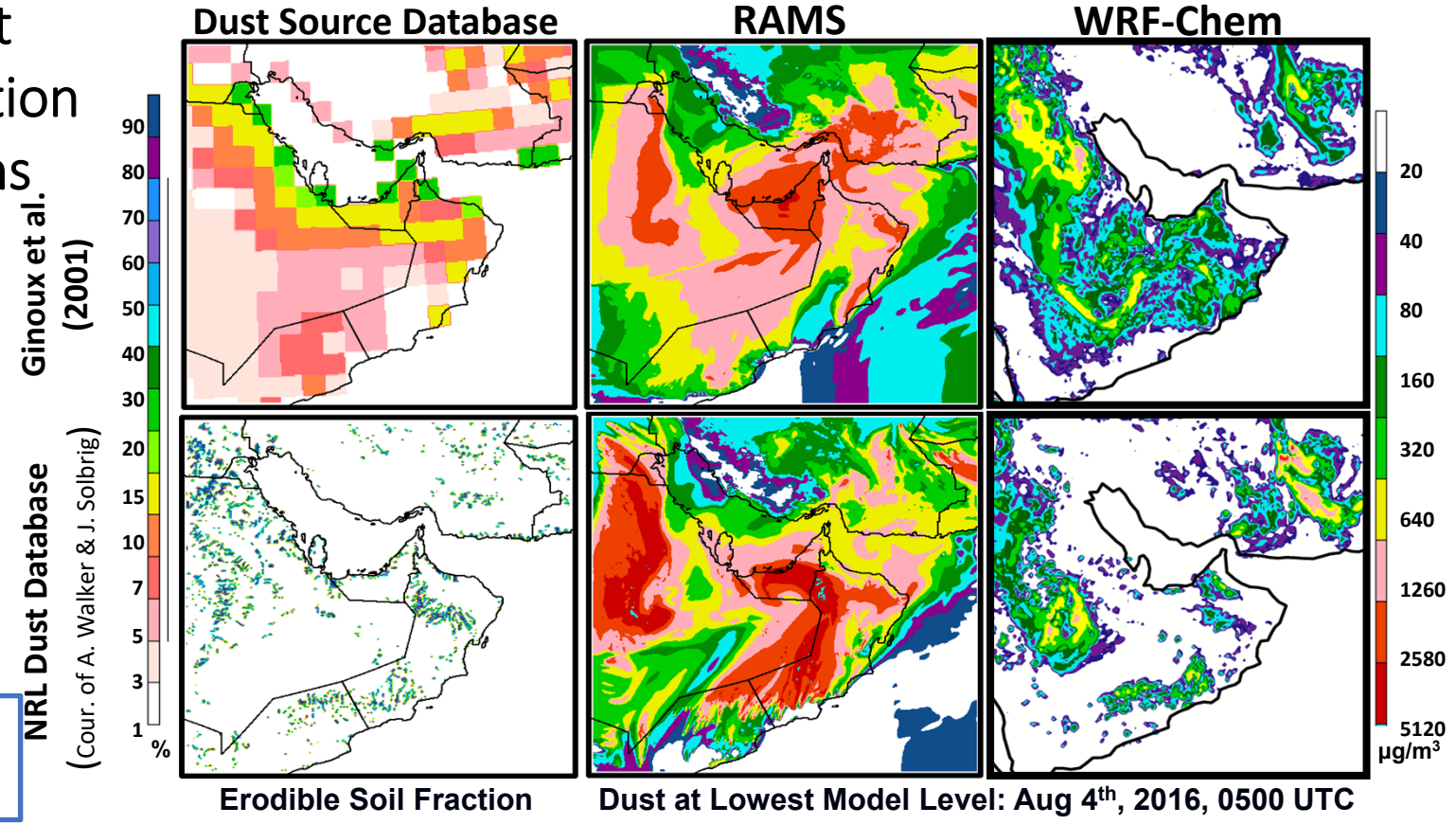
The results are validated with CALIOPSO and MODIS

Xu, X. et al., Passive remote sensing of altitude and optical depth of dust plumes using the oxygen A and B bands: First results from EPIC/DSCOVR at Lagrange-1 point, Geophys. Res. Lett., 44, 7544-7554, 2017.

MURI: Dust Parameterization Comparisons



Saleeby, Bukowski, van den Heever, Walker and Solbrig, 2018

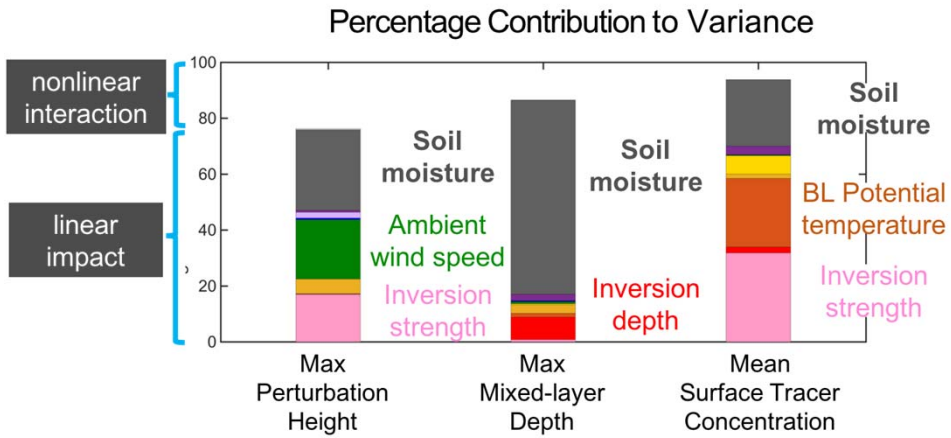


The higher resolution dust source database results in more fine-scale dust features in both RAMS and WRF-Chem. **But there is more uncertainty in the dust forecast due to the choice of model than due to the selection of an emissions database**

MURI: Factors Impacting Coastal Aerosol Distribution within Sea-Breeze Regime

Park, van den Heever and Igel 2018

- What are the **governing environmental factors** responsible for the vertical redistribution of aerosol?
  - Factors, such as **soil saturation fraction**, that alter **surface sensible heat flux and/or vertical mixing** are responsible for vertical redistribution of tracer ahead of sea breeze front (i.e. inland region where people reside)



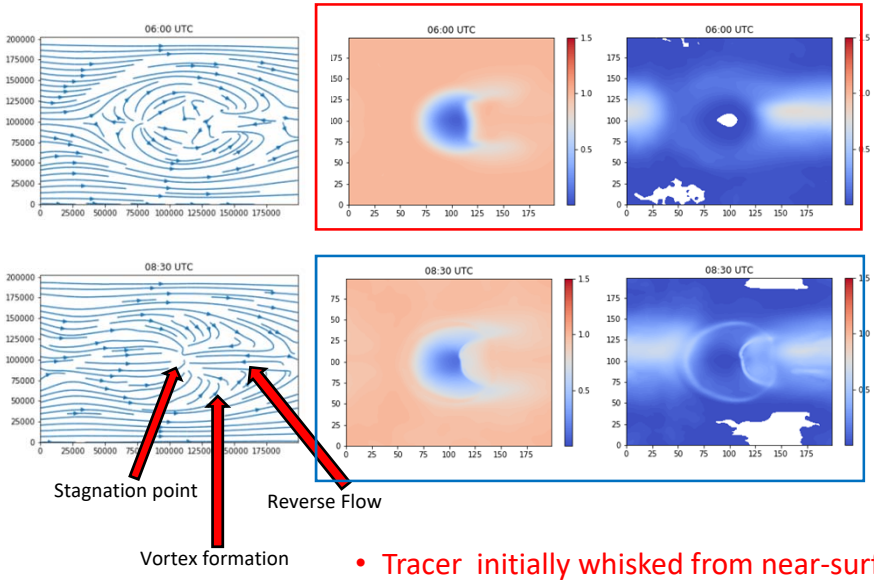
- This study provides **guides for potential ways to improve numerical weather prediction of sea breezes and spatio-temporal distribution of aerosol**.
  - Large-scale winds are already well simulated in forecast models
  - **Better representation of land surface properties** such as soil moisture may lead to improvements in forecast of aerosol transport

MURI: Tracer Transport on Mountainous Islands: 2 flow regimes

Kawecki and van den Heever 2018

High Relative Humidity and Zonal Wind

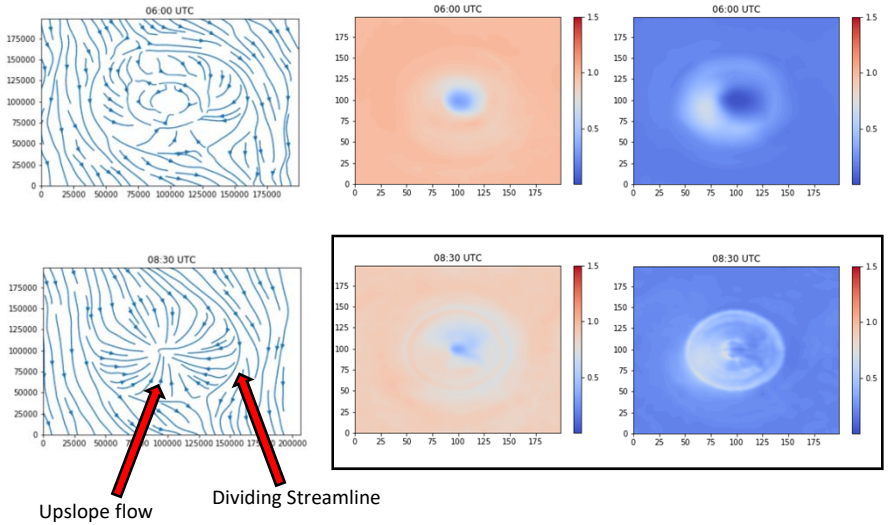
Surface Streamlines | Tracer at 0-500 m AGL | Tracer at 500 -1000 m AGL



- Tracer initially whisked from near-surface of island and lofted in the wake
- Tracers then lofted as a function of convergence

Low Relative Humidity and Zonal Wind

Surface Streamlines | Tracer at 0-500 m AGL | Tracer at 500 -1000 m AGL



- With weak U-wind, convergence is more associated with seabreeze and mountain circulations, which lofts tracers

Tracer (aerosol) transport is dependent on synoptic regime and island orography. Classifying the tracer behavior in idealized regimes can aid in forecasting aerosol fields near and on mountainous islands.

Wrapping up.

- Motoring along on model development, inline NAAPS into NAVGEM well underway, ENAAPS cycling at DSRC.
- NRL is leveraging ONR/OSD base research programs to help guide future applied science development.
- The NASA CAMP^{2}Ex big show got pushed to 2019, but we are making good use of the time with a virtual campaign w/ PISTON and enhanced measurements in Metro Manila.
- Lots of basic research coming out of Navy and partner programs on fundamental aerosol science, in particular on physics relative to associated regional meteorology.