



Recent development using the Navy Aerosol Analysis and Prediction System

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ICAP
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- NAAPS components and status
- A small science experiment: Orders of interaction between aerosol properties and (even the simplest) DA
- Final thoughts: The post-MODIS era is (still) coming

Navy Aerosol Analysis and Prediction System

The Navy forecasts global aerosol transport to support tactical operations and decision-making

- 1. Can you tell us when this is coming?*
- 2. How long until we can see again?*

- *Global forecasts 4x/day*
- *1/3-degree spatial resolution*
- *35 vertical levels from surface to 100hPa*
- ***Operational NAAPS uses NAVGEM 2.1, unchanged from previous ICAP***

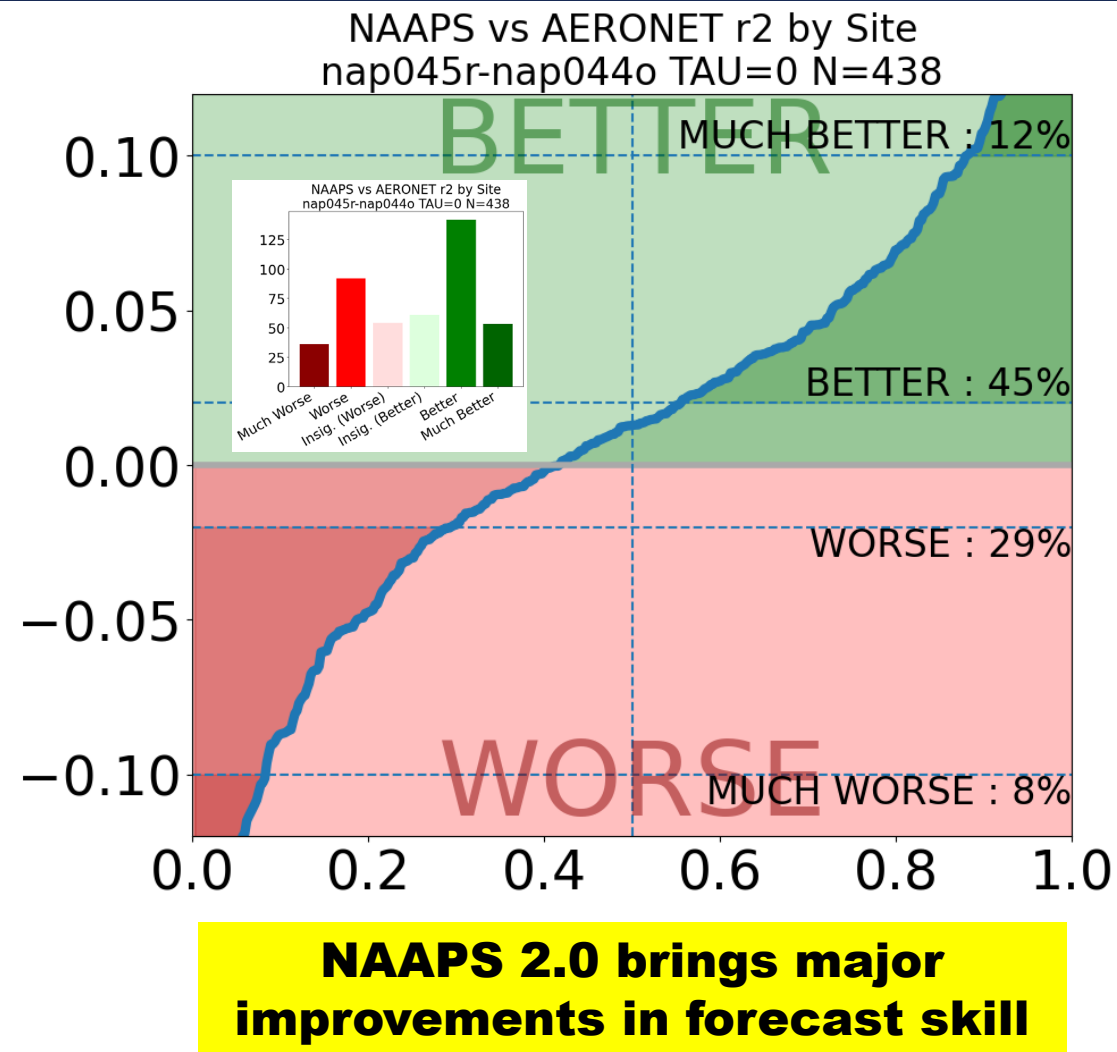


NAAPS Uniqueness

- Offline forced aerosol particle model
 - SO₂->SO₄ is the only chemistry in NAAPS
 - Entire system runs on a single compute node
 - Reads met fields from (mostly) CF-compliant NetCDF files
 - Testing using Navy NEPTUNE weather model in progress
- 2DVar AOD data assimilation
 - Computes increment at full horizontal resolution
 - Uses climatology to add mass when background AOD is low
 - Runs in seconds, can fully prototype in a python notebook

NAAPS Component Status

- NAAPS 2.0 is still pending completion of testing for operations
- Key differences:
 - **NAAPS horizontal resolution: 0.25 degree vs 1/3 degree**
 - Totally refactored NAVDAS-AOD DA
 - Improved interpolation of background
 - Rebuilt vertical/speciation climatology
 - Completely rewritten optical post-processor (FAROP)
 - Fixes numerous bugs that affect the operational products
- Near-term transitions: end of the MODIS era
 - AOD QAQC obs preprocessor (NASA MODIS L2 AOD → NRL/UND L3 AOD) being replaced with new L3 product from NASA SIPs
 - Smoke source model being completely replaced— initial FLAMBE2 will be VIIRS-only

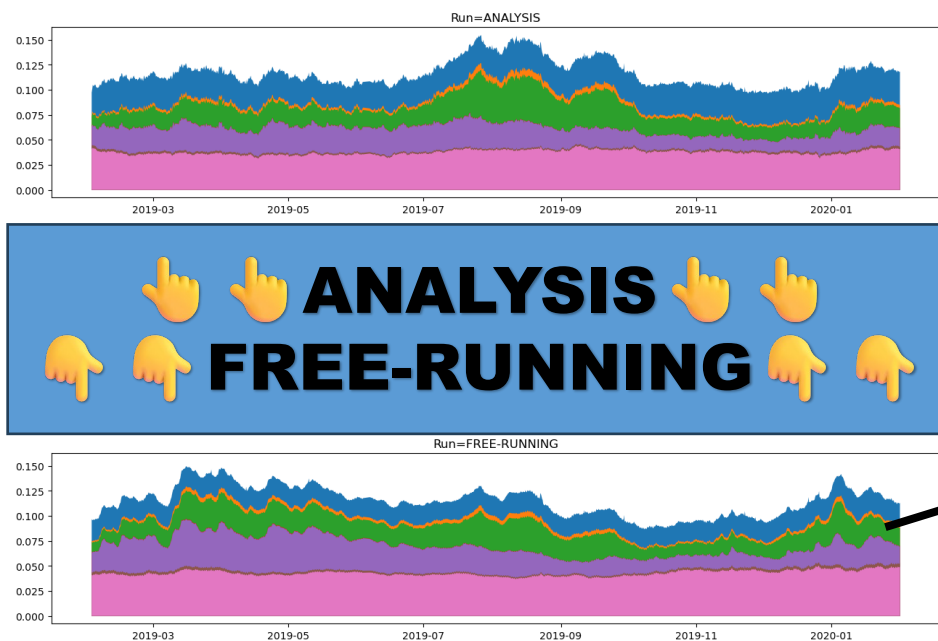


Experiment: Assimilation of AOD550 and its effects on SSA

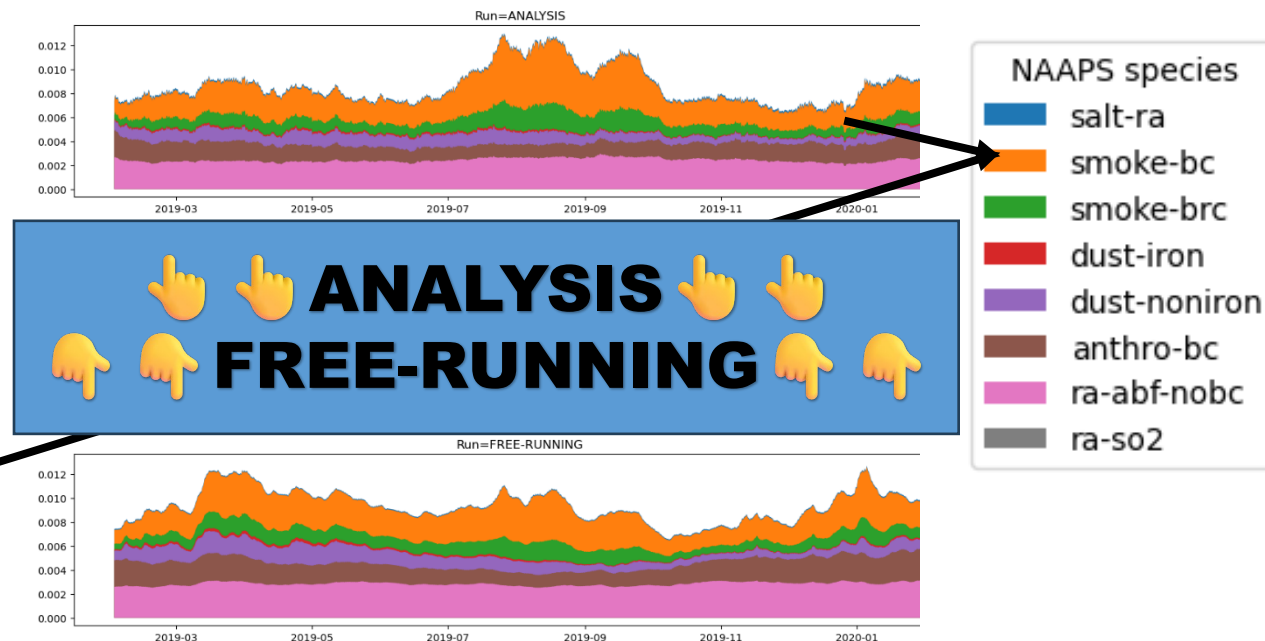
- Test configuration (NAAPS-RA v2 early prototype):
 - 5 tracers from operational NAAPS split into 8 tracers
 - Gaseous SO₂ : same as OPS
 - Undergoes conversion to SO₄
 - Anthropogenic and Biogenic Fine Mode (ABF) particles: split
 - ABF-NOBC : OPS ABF excluding anthropogenic black carbon
 - Anthro-BC : black carbon emissions, gridded monthly inventory
 - Dust: split
 - Dust-non-iron / Dust-iron : new sources for NAAPS-RA
 - Smoke: split
 - Smoke-abs: 7% black carbon by mass
 - Smoke-nonabs: the remaining 93%
 - Salt: unchanged (NAAPS2.0 uses ENAAPS parameterization)
 - Running 50 levels (49 layers) using L100 NAVGEM-RA
 - 12 month runs from 20190201-20200201
 - Free-running NAAPS started at 20190101 (1 month spinup)
 - Cycling run: initialized from free run starting at 20190201

This configuration allows improved diagnostics of absorption

AOT550 time series

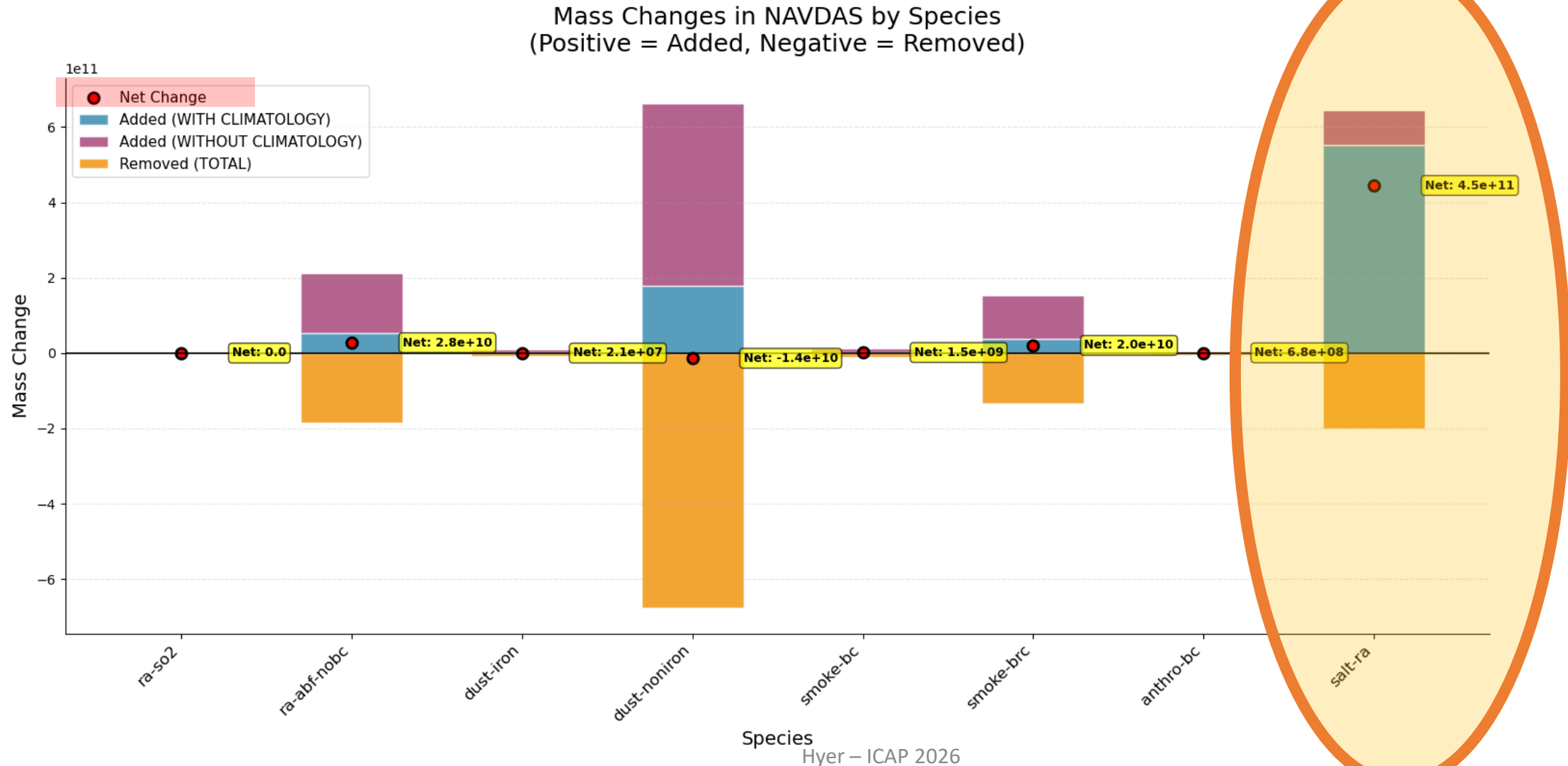


AAOT550 time series



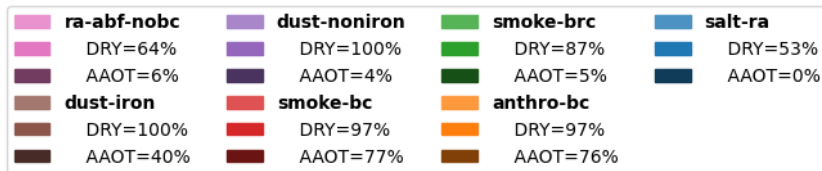
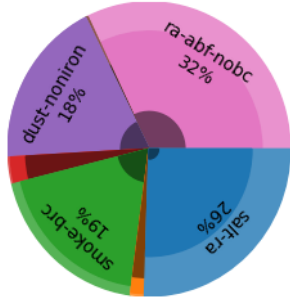
- **BC component of smoke** is largest contributor to global AAOT
- **Anthro. BC** is nominal in AOT, large contributor to AAOT
- **Iron-rich dust** is very dark but very small mass fraction– low impact on global AAOT
- DA is correcting some substantial seasonal biases in dust and other tracers

First-order effect: Mass change

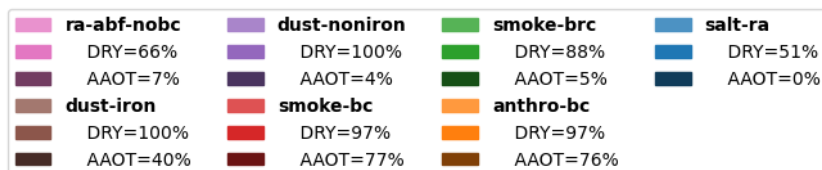
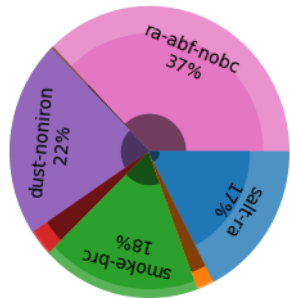


Breakdown by species and component highlights first-order effect

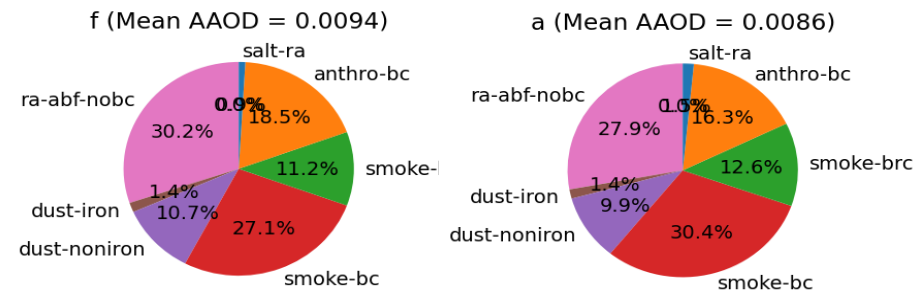
ANALYSIS MEAN AOT=0.12



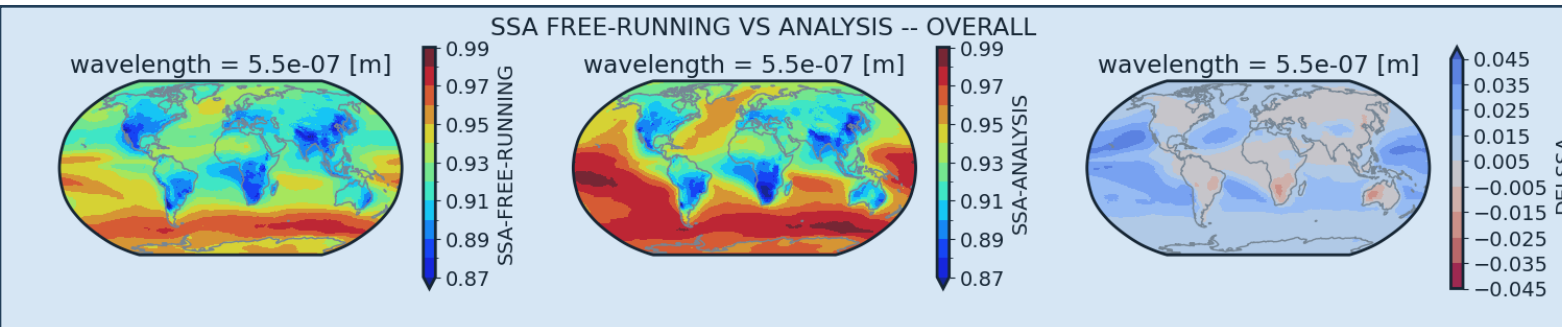
FREE-RUNNING MEAN AOT=0.11



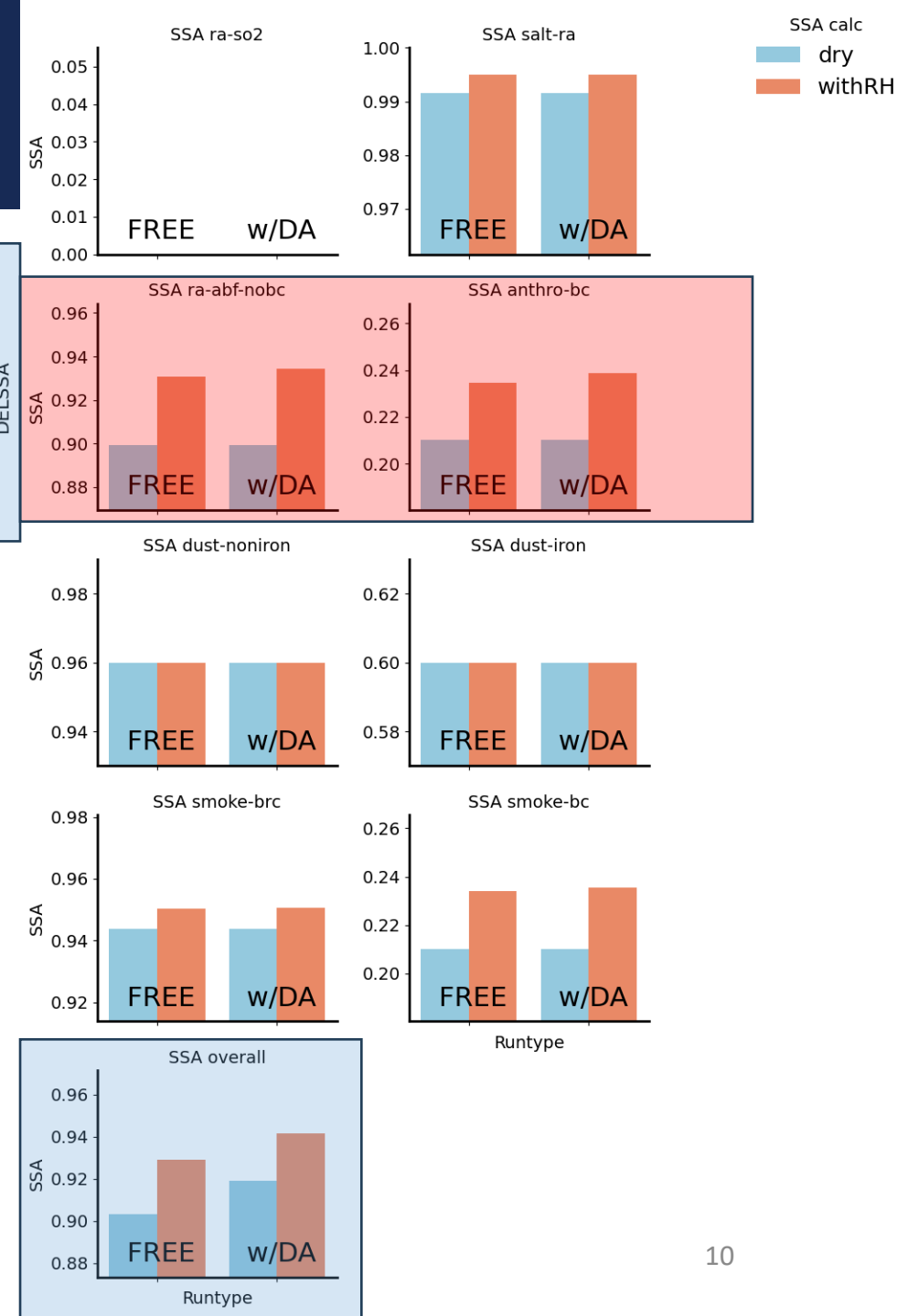
- Three components:
 - Absorption (inner ring)
 - Dry extinction (absorption + scattering, no fRH) (middle ring)
 - Total extinction (dry + fRH) (outer ring)
- Above: cycling analysis, Below: free-running
- Items of note:
 - Bulk changes in speciation in cycling run:
 - DA adds sea salt mass,
 - slightly increases smoke AOD, and
 - reduces dust
 - sea salt AOD is >50% from fRH effects
- Below, breakdown of AAOT only (left=free, right=analysis)
 - Contribution of smoke to AAOT goes up in cycling run
 - Salt is negligible in AAOT



DA alters global SSA – *and tracer-specific SSA*

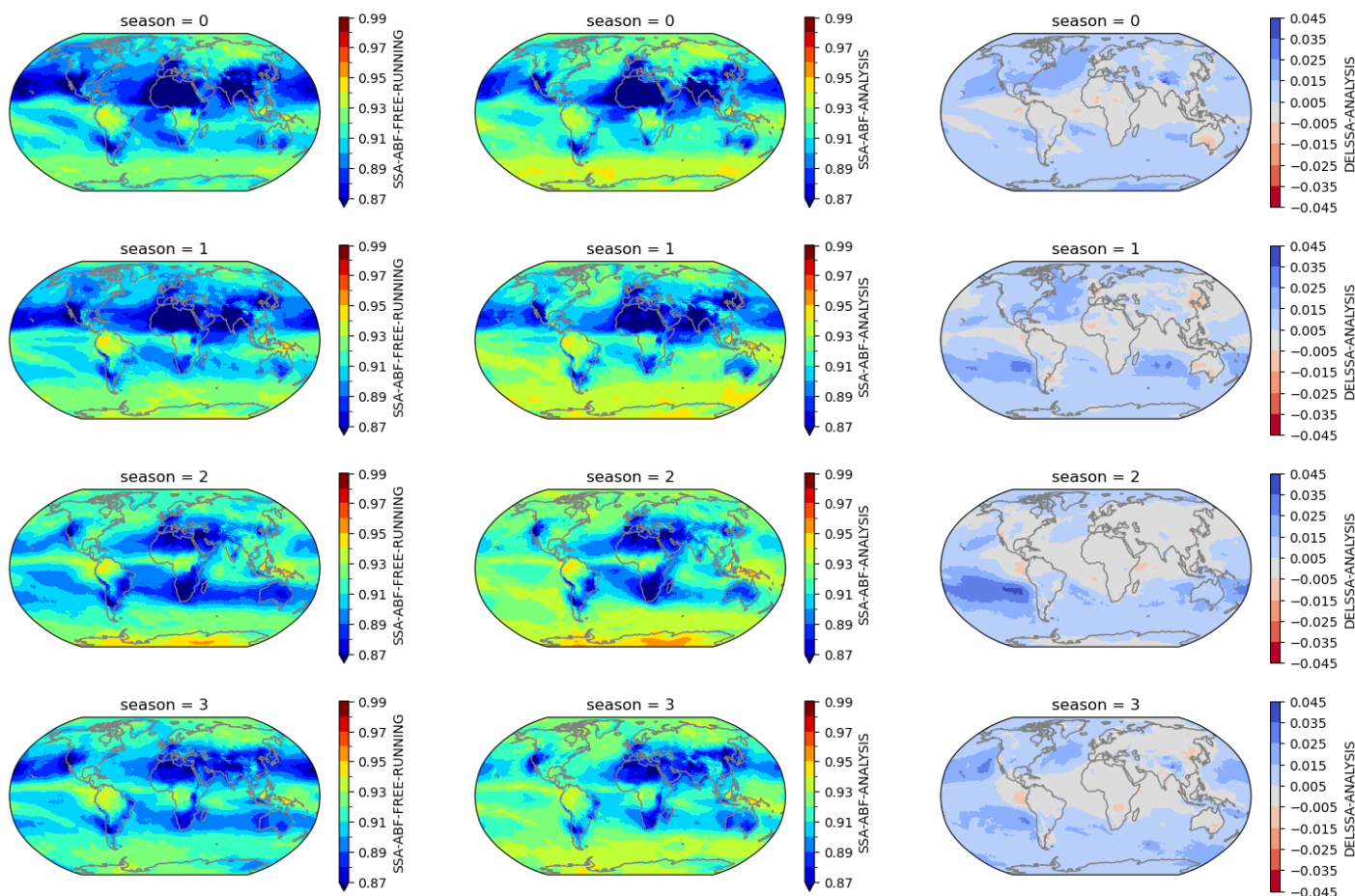


- (above and bottom right)
 - DA run is ~ 0.02 brighter than free run
 - Largely attributable to added salt
 - Blue on difference map = brighter
 - Strong brightening over ocean offsets darkening over land
- (right) SSA per tracer shows perturbation by DA
 - “**Dry**” SSA reflects only the composition change
 - Single-tracer values unaffected by DA
 - “**withRH**” SSA reflects the additional influence of RH
 - If increments are + correlated with RH, aerosols will get brighter
 - If – correlated, aerosols get darker



SSA of NAAPS ABF: Mass Increment perturbs %BC

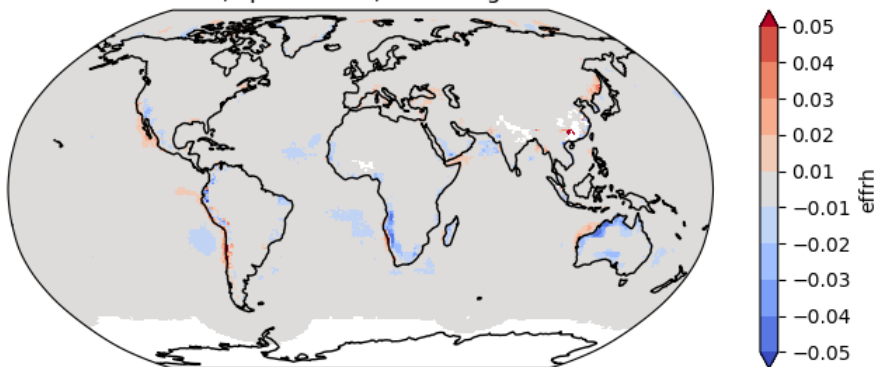
SSA of NAAPS ABF tracer (both components)
Free-running (left) vs analysis (center)



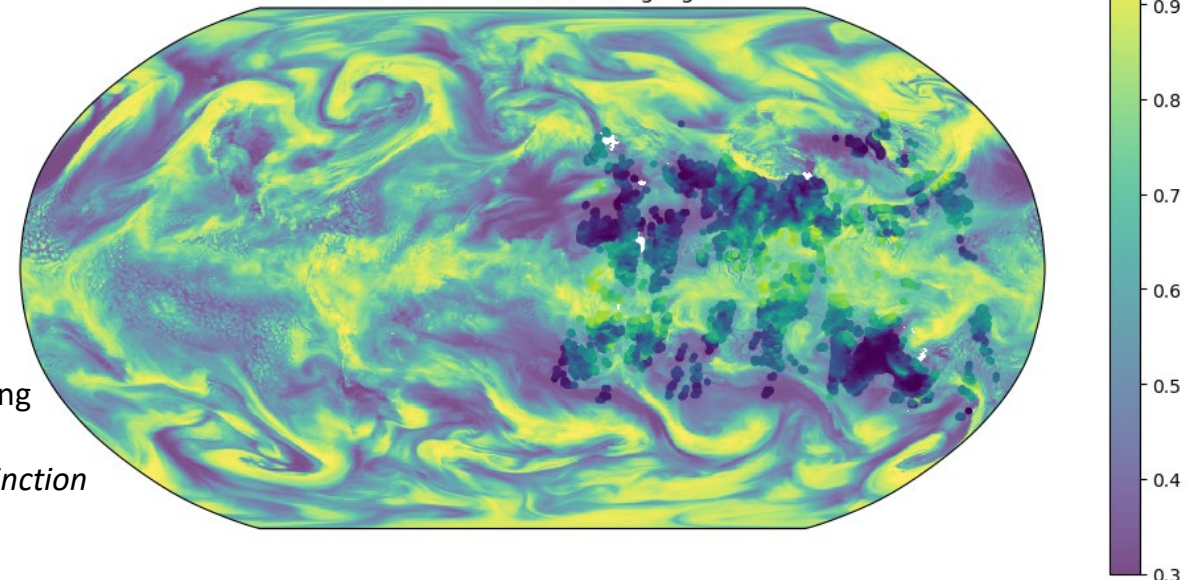
- Blue = brighter (SSA increase)
- Rows are season: DJF MAM JJA SON
- ABF-NOBC has greater sensitivity to RH vs BC, so...
- ... since the mass increment is scaled to extinction, the *increment in dry conditions has greater %BC vs humid conditions*
 - If the increment is positively correlated to RH (adding mass in humid conditions), we add relatively more NOBC and increase SSA
 - If negatively correlated (adding aerosol in relatively dry conditions), we should add relatively more BC and lower SSA
 - We see on the maps that both of these things can occur depending on location/season
- ***If, for example,*** the meteorology had a dry bias over land and a negative source bias, that combination will yield a darker aerosol near sources

Why does climatology make analyzed aerosols brighter?

case = case4, sp = salt-ra, wavelength = 5.5e-0...

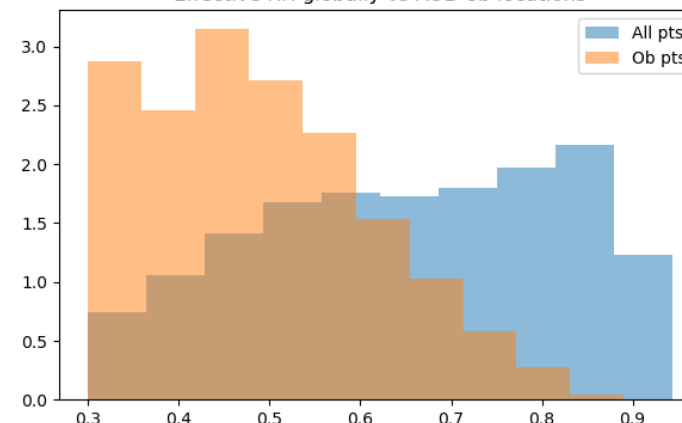


Effective RH-- ob locations highlighted



- NAVDAS-AOD Climatology is used to get the speciation and vertical distribution for adding aerosol mass in cases where the background (prior) is low (<0.1 AOD)
- Climatology is used to partition *extinction* and thus it is based on the partitioning of *extinction* (as opposed to mass)
 - Climatology is based on a no-DA “free” run
 - Extinction based on analyzed RH
 - **temporally aggregated to 1 month and spatially aggregated to 5x5 degrees**
- The locations with valid AOD are cloud-free, and have a very **systematically** different RH from randomly selected locations (map and histogram, right)
- The effects of aggregation can be clearly seen on the map:
 - Mountaintops: actual conditions of ob (*with + increment*) drier than climo
 - Desert SW USA: actual conditions of ob wetter than climo
 - Ocean areas: actual conditions of ob wetter or occasionally drier, it varies!
- On net the use of climatology results in a brightening of NAAPS aerosol (increase of SSA)
- **The aerosol mass added via climo is thus “out of sync” with the local RH— extra information would need to be included in the climo to eliminate this effect**

Effective RH globally vs AOD ob locations



Perturbation of SSA by single-wavelength AOD assimilation: summary

- DA results in brightening of NAAPS aerosols
 - First-order effect is change in composition:
 - +salt
 - -dust
 - -ABF
 - Second-order effect via correlation with RH
 - More mass in high-RH => brightening
 - More mass in low-RH => darkening
 - Compounded if we consider smaller fRH of BC vs OC/sulfate
 - Additional effect associated with DA climatology
 - Net effect is small but both SSA and balance of hygroscopic and non-hygroscopic species can be changed
- Important points:
 - Even assimilation of a single wavelength AOD has important impacts on aerosol composition
 - SSA is not static vs DA
 - Point results, Spatial and temporal averages show different facets of how DA affects modeled aerosol properties
 - Sampling bias of AOD observations propagates through the system!

Final thoughts: Aerosol prediction post-MODIS

- Operational NAAPS still has MODIS dependence:
 - AOD data assimilation
 - FLAMBE smoke source
 - Hopefully we're the last ICAP model in that situation!
- VIIRS is a more capable sensor in multiple respects
 - Can detect much smaller fires
 - Much less loss of resolution at high scan angles
 - Actual global daily coverage, rather than "nearly"
- Many other capable sensors are now available
- Turning this into better forecasts is our R&D challenge

Acknowledgements

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THANK YOU!



**U.S. NAVAL
RESEARCH
LABORATORY**