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Recent development using the Navy Aerosol Analysis and Prediction System

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In This Talk

- 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***

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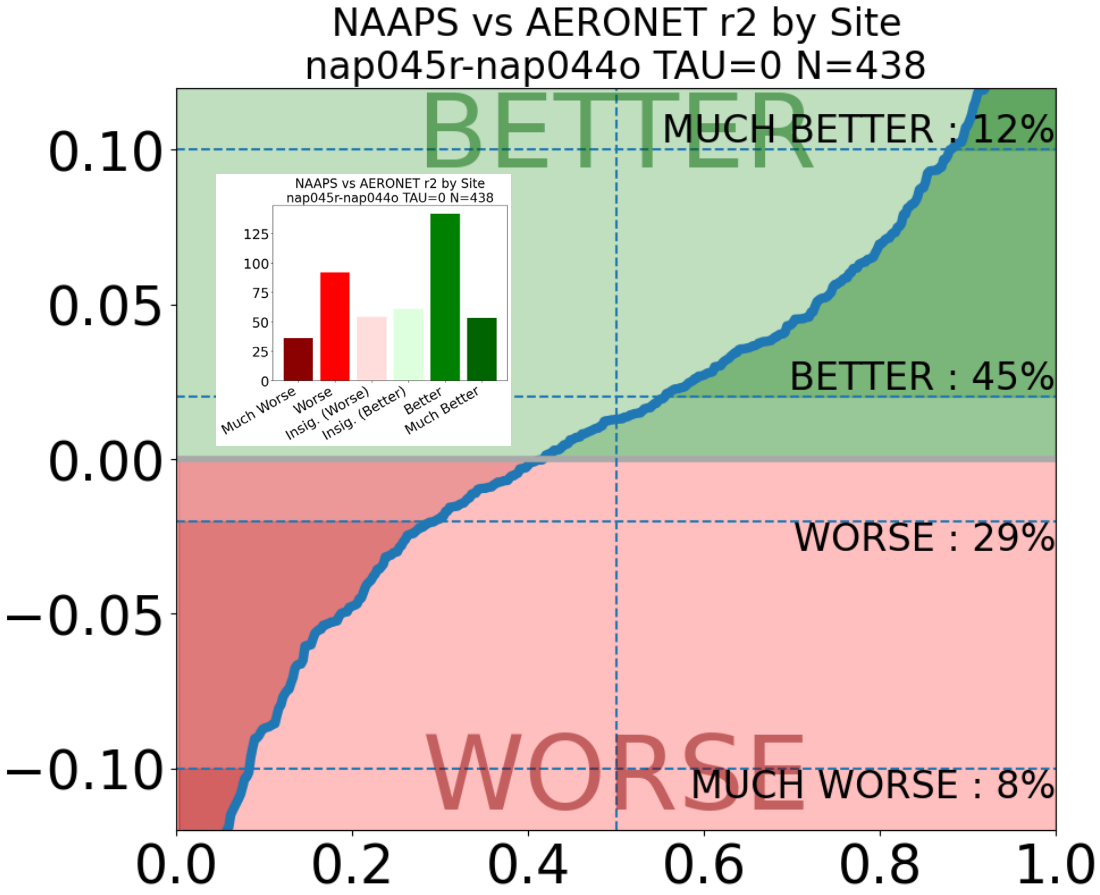
NAAPS Uniqueness

- 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



NAAPS 2.0 brings major improvements in forecast skill

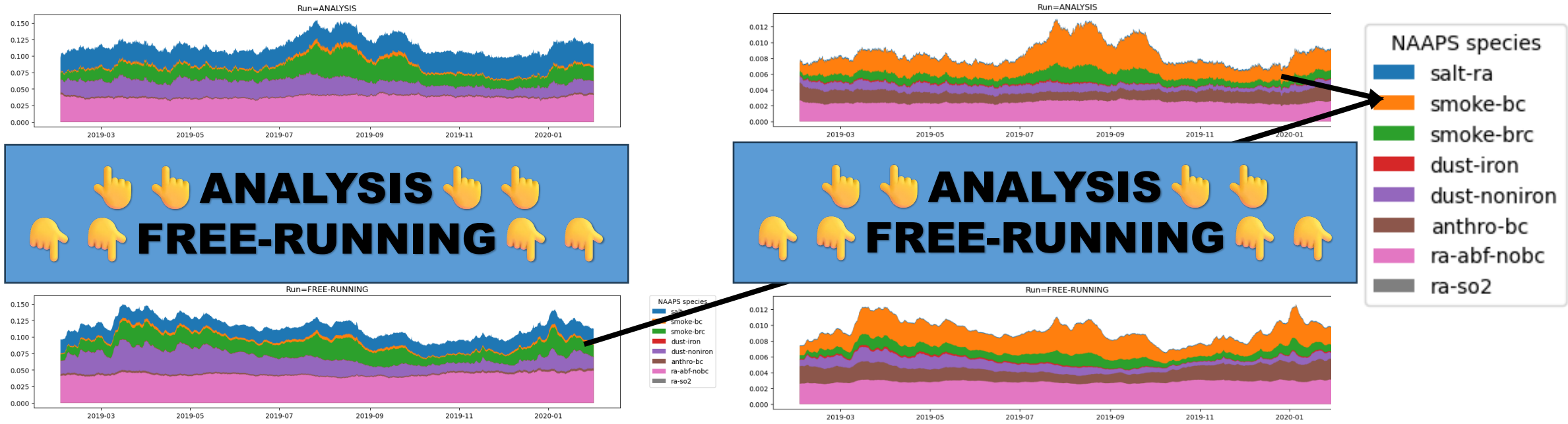
Experiment: Assimilation of AOD550 and its effects on SSA

- 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

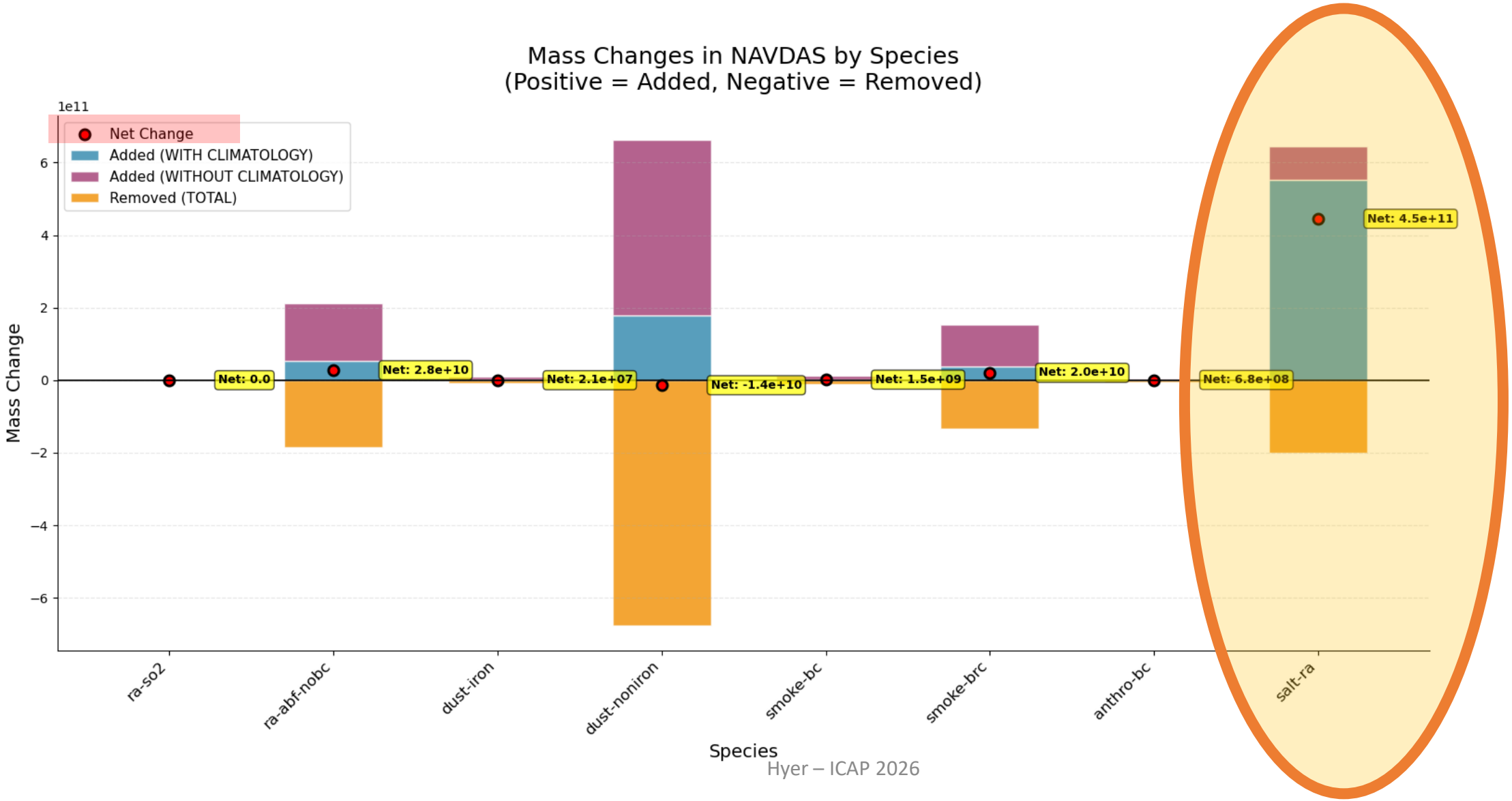
AOT550 time series

AAOT550 time series

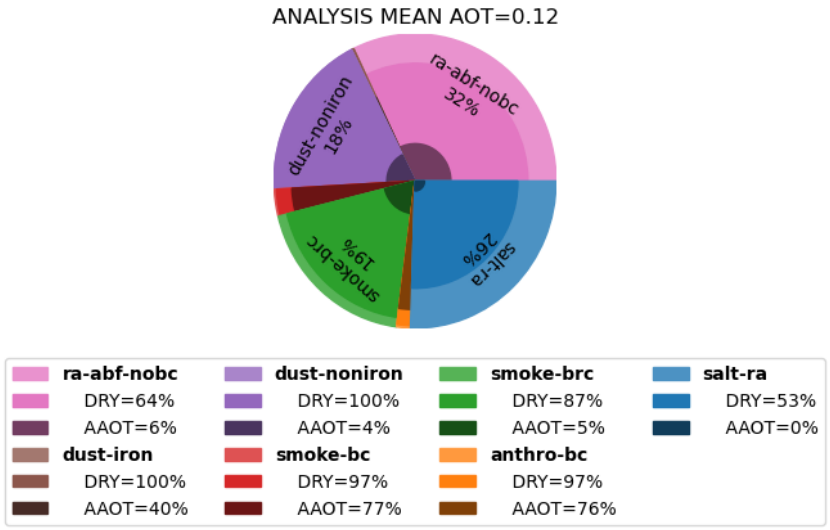


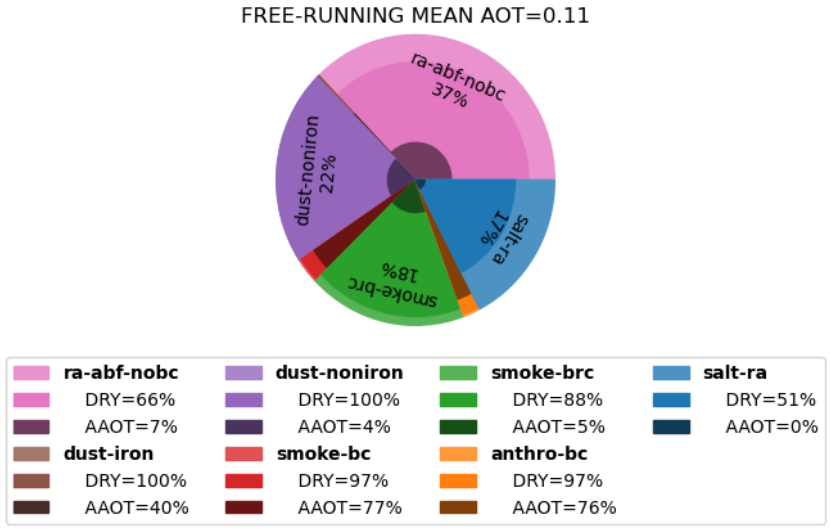
- **BC component of smoke** is largest contributor to global AAOT
- **Anthro. BC** is nominal in AOT, large contributor to AAOT
- **Iron-rich dust** is very dark but very small mass fraction– low impact on global AAOT
- DA is correcting some substantial seasonal biases in dust and other tracers

First-order effect: Mass change

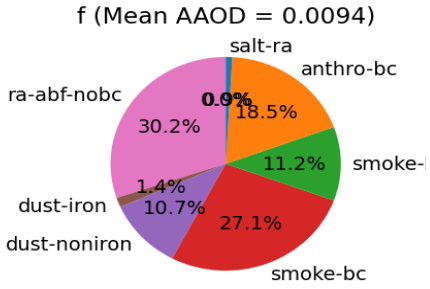


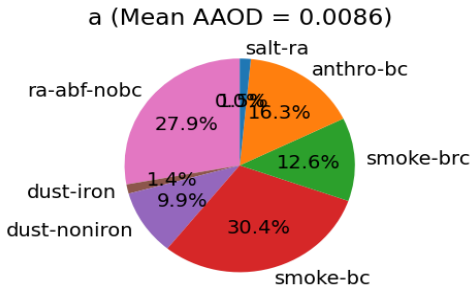
Breakdown by species and component highlights first-order effect



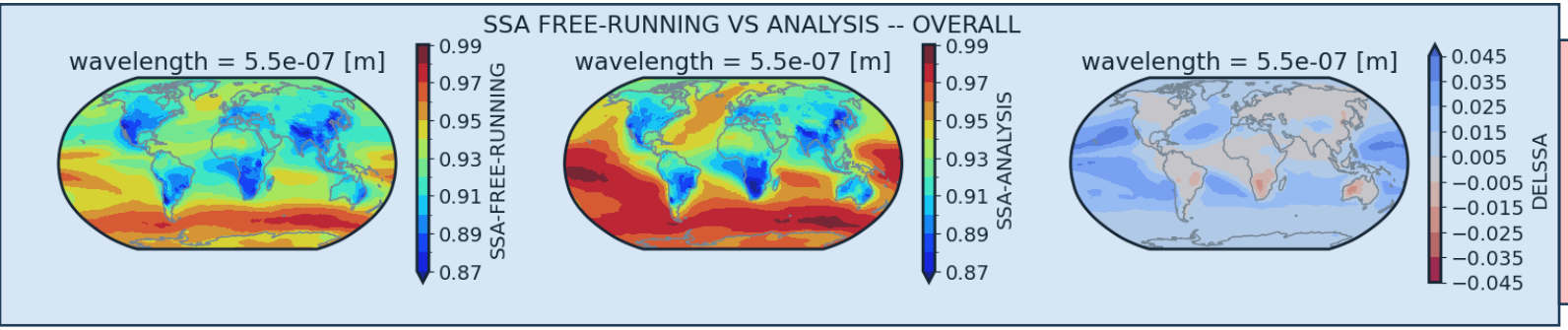


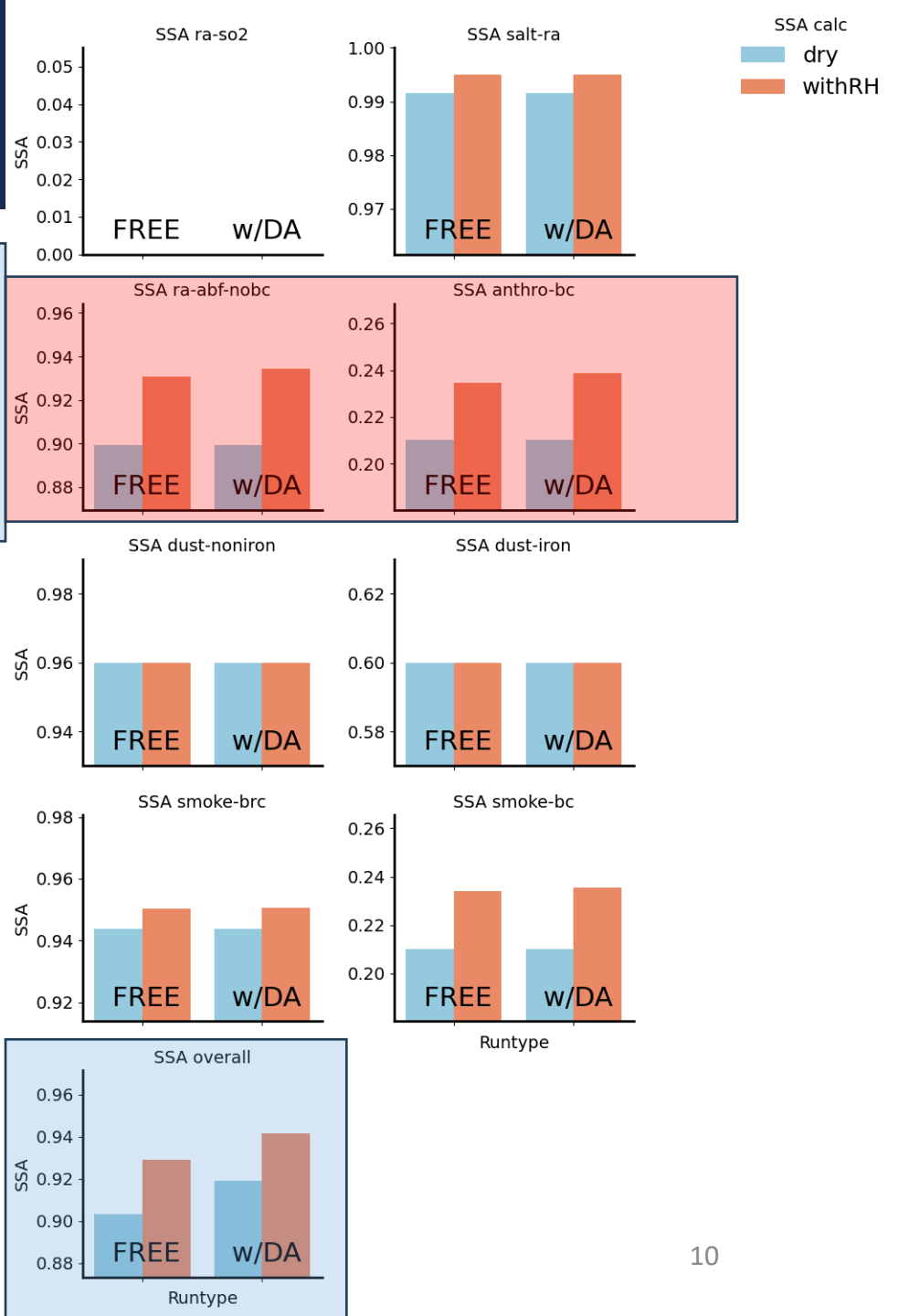
- Three components:
  - Absorption (inner ring)
  - Dry extinction (absorption + scattering, no fRH) (middle ring)
  - Total extinction (dry + fRH) (outer ring)
- Above: cycling analysis, Below: free-running
- Items of note:
  - Bulk changes in speciation in cycling run:
    - DA adds sea salt mass,
    - 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*

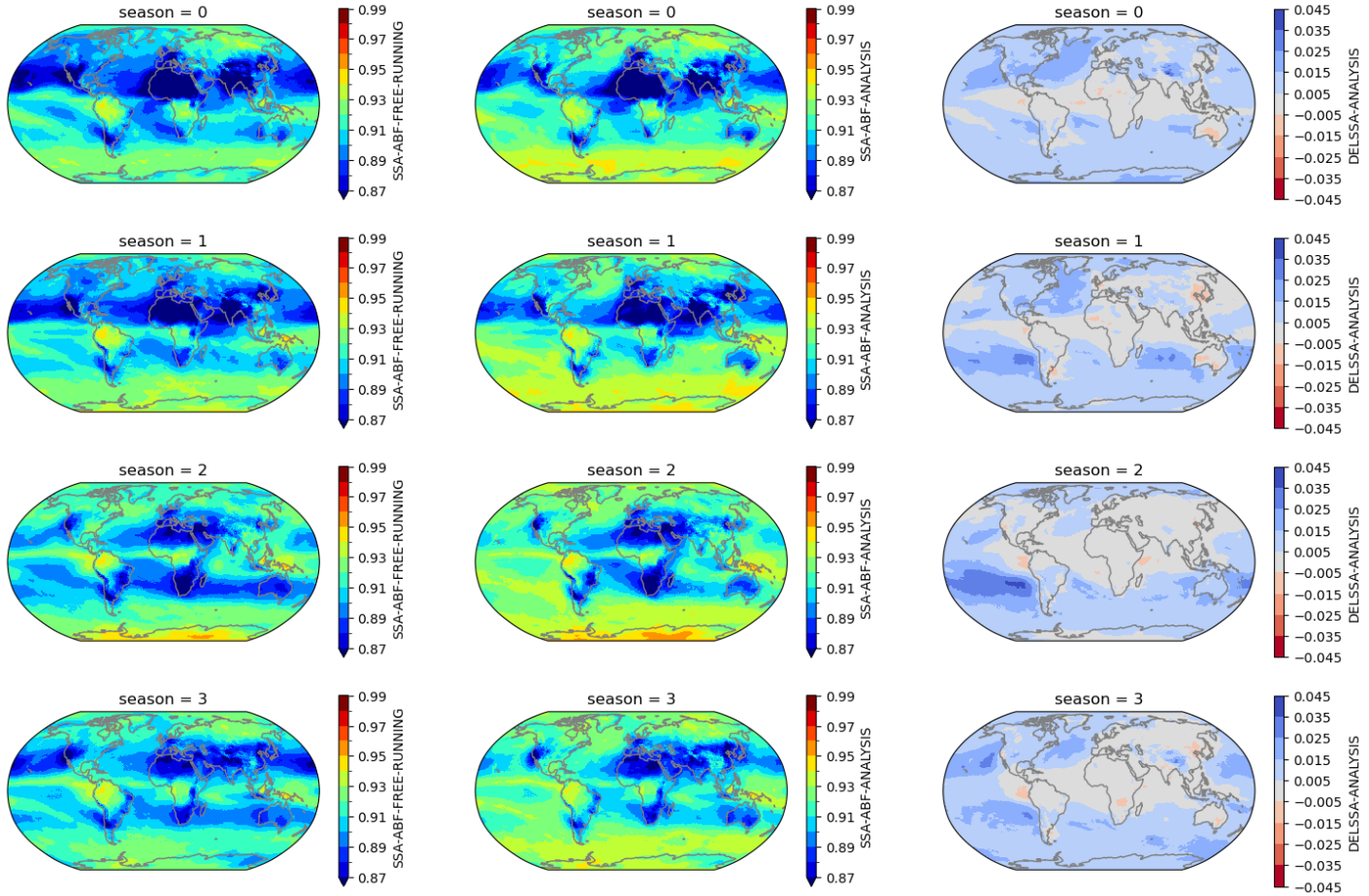




- (above and bottom right)
  - DA run is ~0.02 brighter than free run
    - Largely attributable to added salt
  - Blue on difference map = brighter
  - Strong brightening over ocean offsets darkening over land
- (right) SSA per tracer shows perturbation by DA
  - "**Dry**" SSA reflects only the composition 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

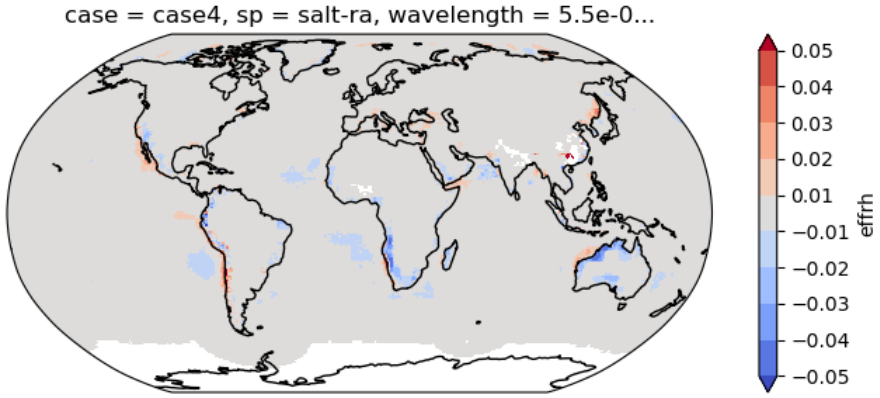
SSA of NAAPS ABF: Mass Increment perturbs %BC

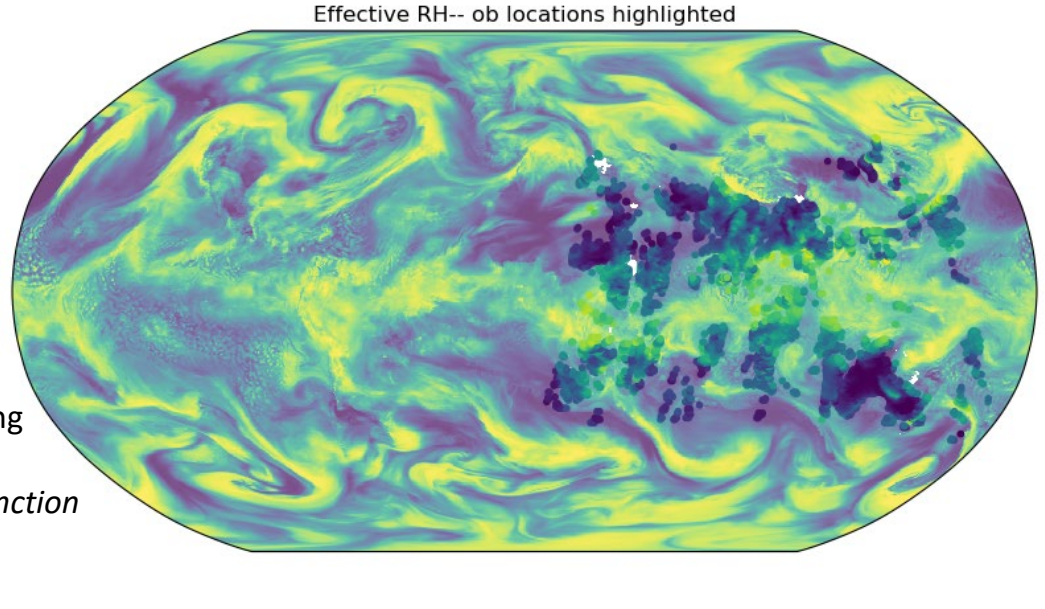
SSA of NAAPS ABF tracer (both components)
Free-running (left) vs analysis (center)



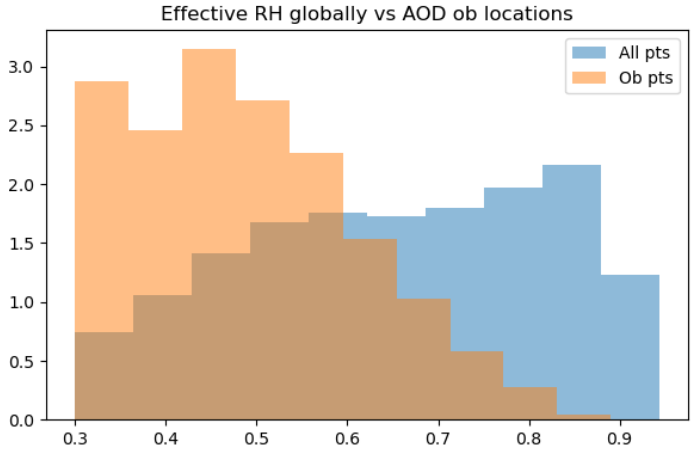
- Blue = brighter (SSA increase)
- Rows are season: DJF MAM JJA SON
- ABF-NOBC has greater sensitivity to RH vs BC, so…
- … since the mass increment is scaled to extinction, the *increment in dry conditions has greater %BC vs humid conditions*
  - If the increment is positively correlated to RH (adding 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?





- 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***



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-hygrosopic 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!

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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

- NRL Team
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- Patient Audience!

THANK YOU!