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Geostationary AOD in the NAAPS Aerosol Model

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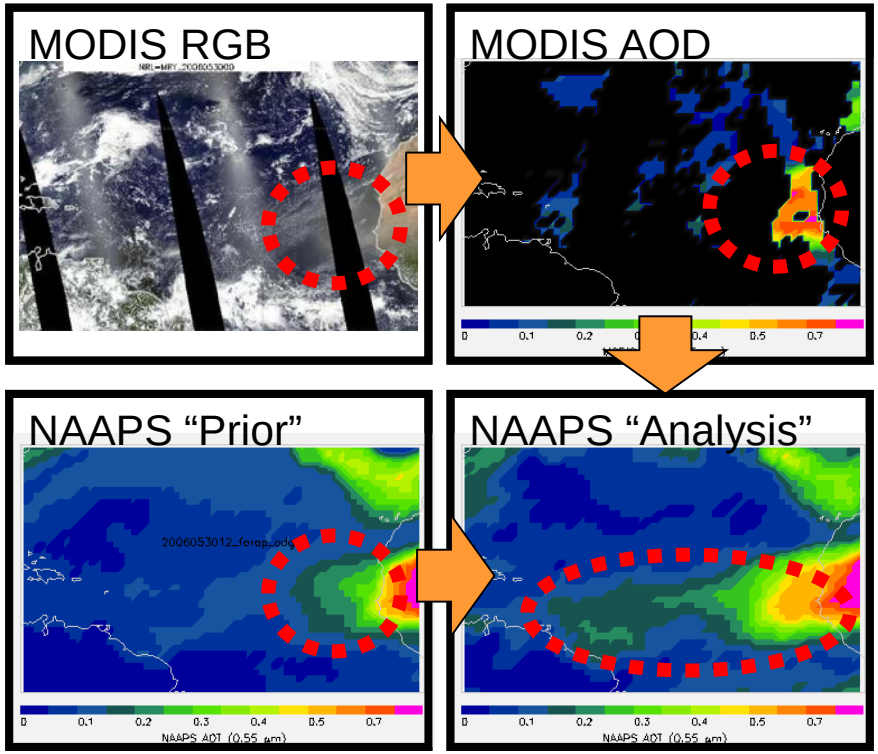
In This Talk

- Context: modeling of sub-daily variation in atmospheric conditions
- Aerosol Products from the Geostationary Ocean Color Imager
- Daily and Sub-Daily variation in aerosol data and models
- Effects of geostationary AOD assimilation
- Outlook and next steps

Time and Space Scales of Aerosol

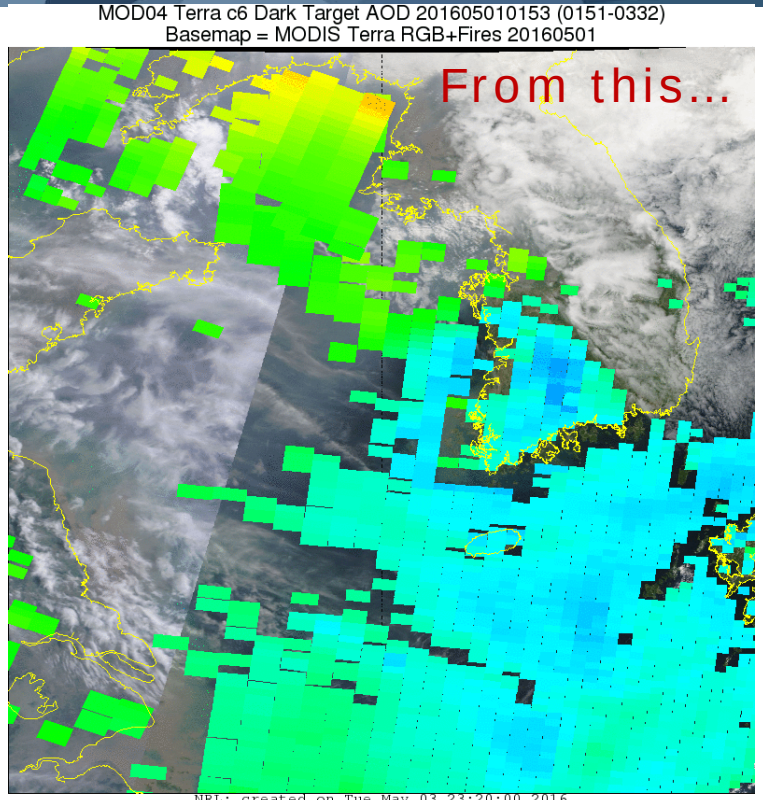
- Time and Space Scales tightly interact
- Drivers of sub-daily variation cannot be resolved at coarse spatial resolution
  - Topographically forced flows
  - Land/sea breezes
  - Boundary layer dynamics
- At higher spatial resolution, it becomes possible to resolve these processes
- Data assimilation may be able to help

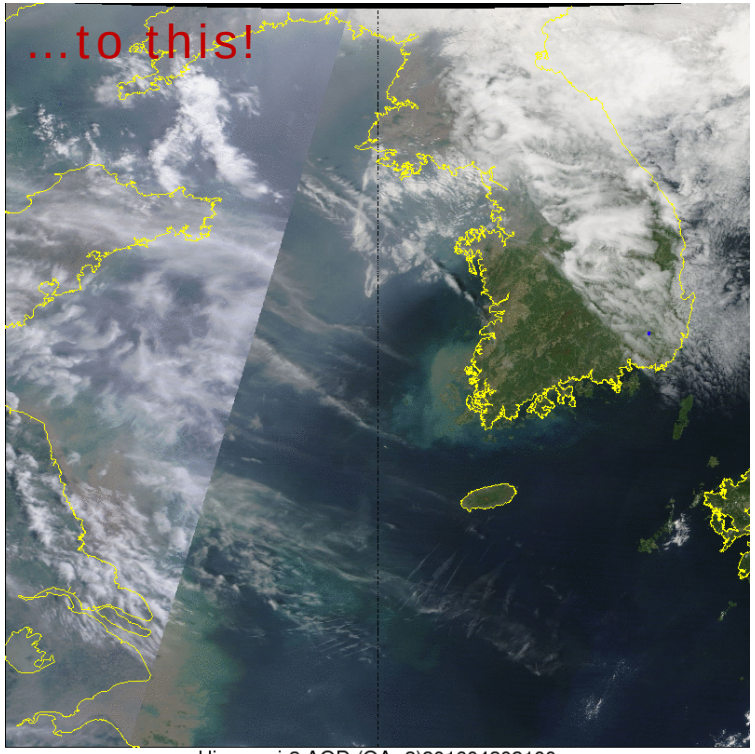
Data Assimilation for Aerosols



- Data Assimilation: Combine short model forecast with observations
- Used to generate initial conditions for forecast
- NAAPS uses a variational assimilation in AOD space
  - Speciation and vertical profile are carried forward from forecast…
  - …except where prior is low and significant mass is added, then climatology is used

Geostationary: A New View





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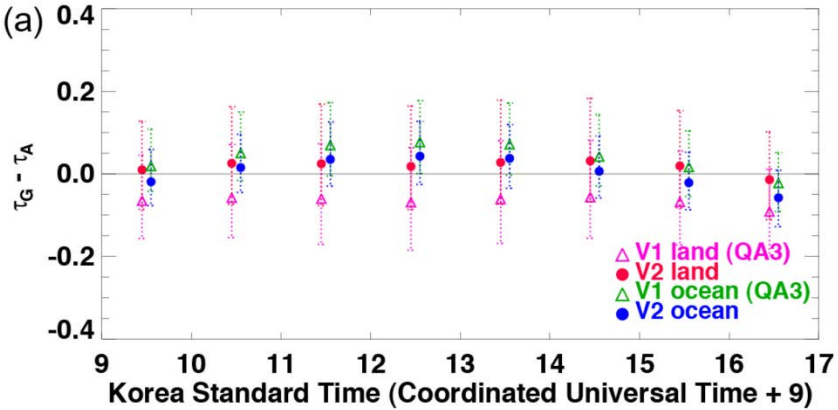
Datasets Used

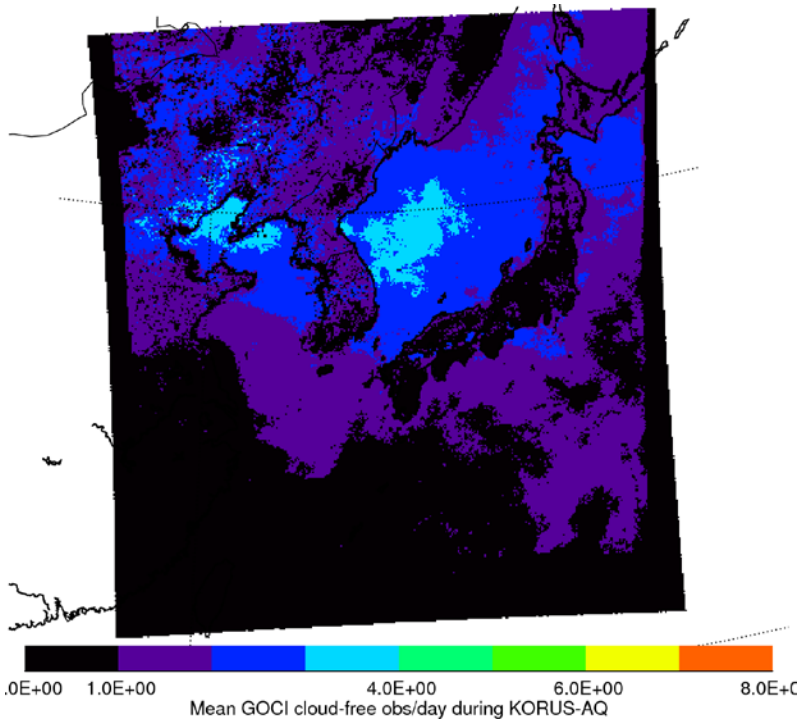
- 20160501 – 20160618 (KORUS-AQ flight period)
- AERONET: Version 3 L1.5
    - 550nm AOD calc. via spectral decomposition (SDA)
    - 42 stations
    - 19,195 triplet measurements paired to GOCI
        - Used as basis for model pairs as well
    - “Sunny subset” 179 sites/days with valid AERONET at 9+12+15 local time used for subdaily variance estimation

Yonsei University Aerosol Product

- Geostationary Ocean Color Imager in Korean COMS-1 satellite
  - 500m resolution
  - 6VIS+2NIR bands
  - 400-865nm
  - 8x/day, hourly ~0030Z-0730Z
- Sensitivity to water-leaving radiance == sensitivity to fine scattering particles
- Yonsei University YAER_V2 retrieval
  - **(Choi et al. AMT 2017)**
  - 6km spatial resolution
  - Excellent performance vs AERONET
  - Specifically, diurnal artifact is small (bias vs AERONET <0.05)

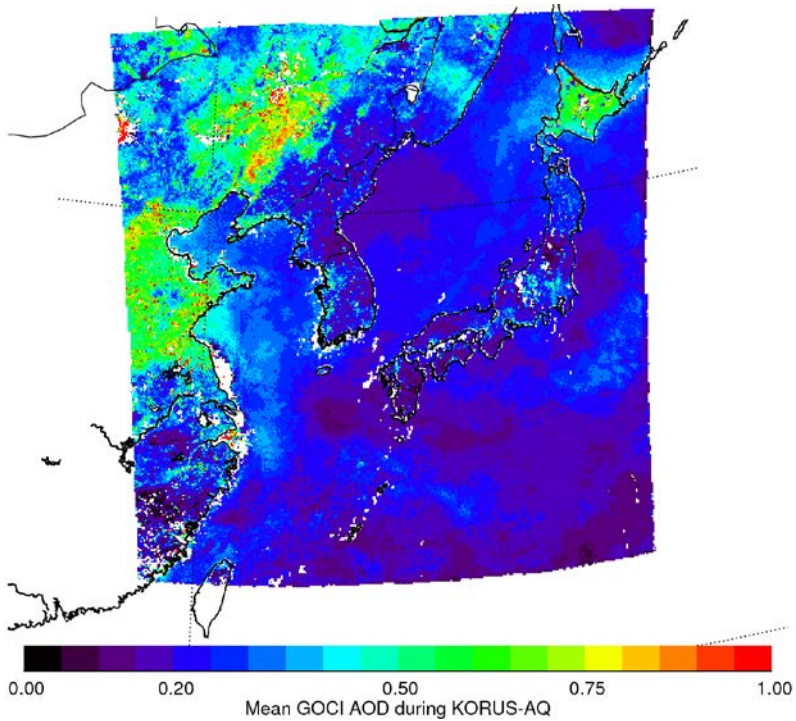


GOCI AOD: Looks per day



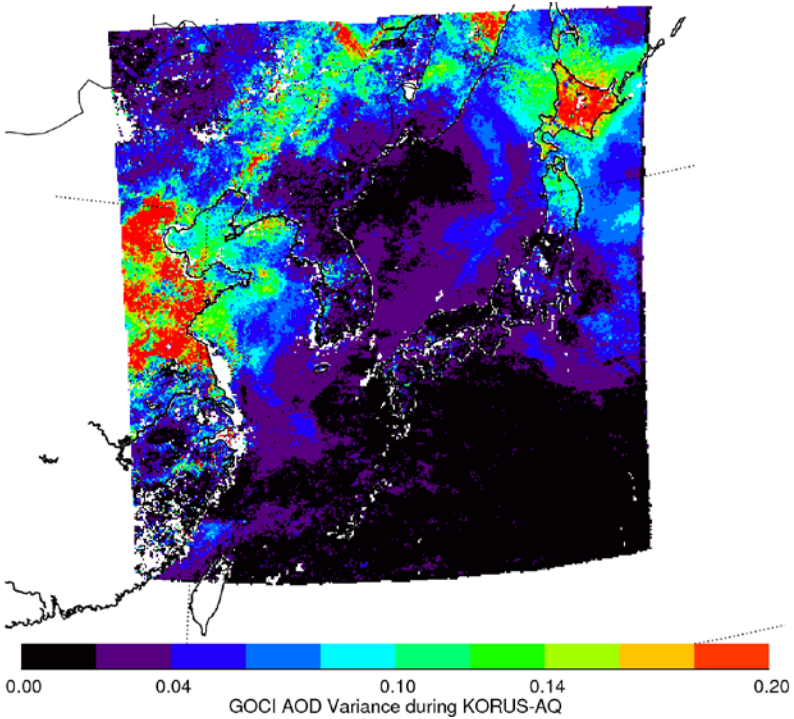
- Lots of cloud
- More cloud over land
  - Also more conservative cloud filtering over land
  - Still 60+ looks over most of Korea during KORUS-AQ
- Open water areas near Korea average > 2 looks per day, 100+ looks during KORUS-AQ

GOCI AOD: Mean AOD



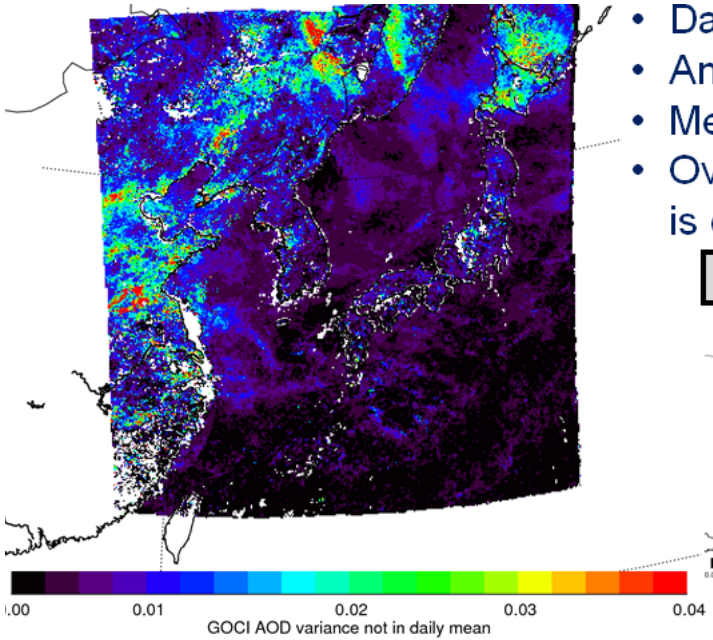
- Regional pollution in China
- Urban areas in China, Korea, Japan
- Clean ocean areas
  - Not including Yellow Sea
- Hokkaido had one well-observed high-AOD event and lots of clouds otherwise (limited sampling)

GOCI AOD: Total Variance



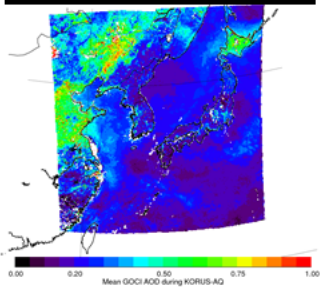
- Variance high in regional pollution in China
- Transboundary pollution is strongest signal in variance over Korea
- Very low variance in East Sea

GOCI AOD: Subdaily Variance

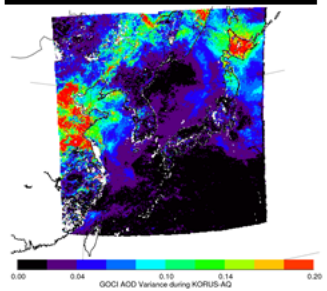


- Daily mean subtracted at each point
- Anthropogenic features stand out
- Meteorological features also notable
- Over whole domain, 90% of variance is captured by the daily mean AOD

Mean AOD



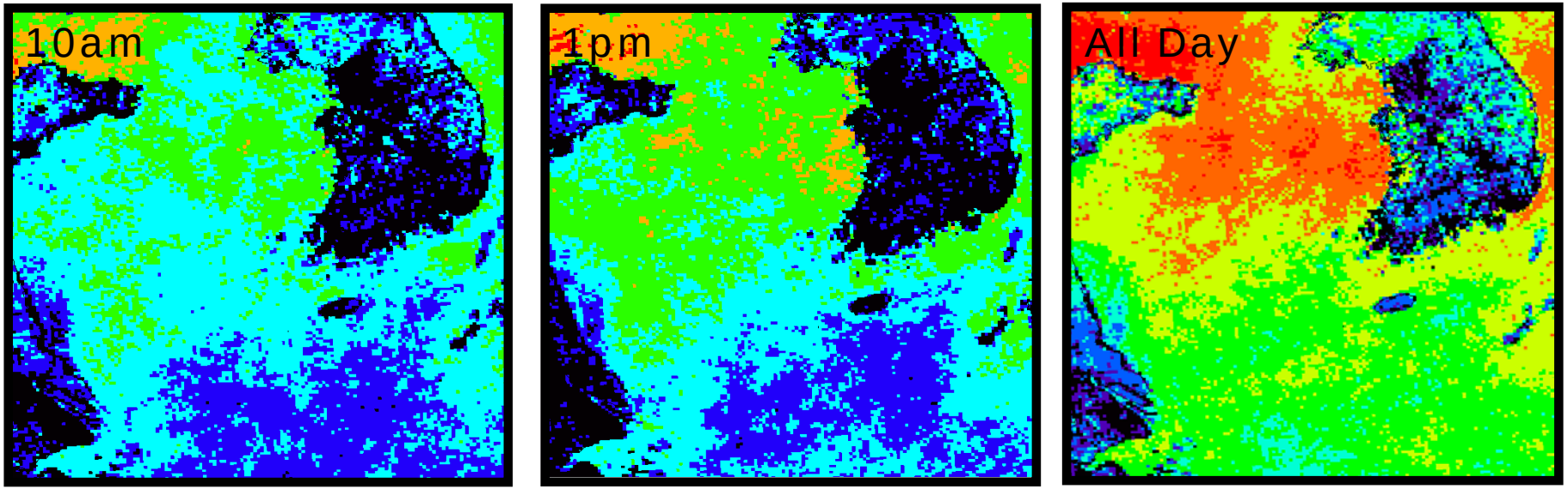
AOD Variance



Daily mean AOD accounts for 80+% of total variance in satellite observed AOD for most areas in this region during KORUS-AQ
***BUT* subdaily variance suppressed by missing data**

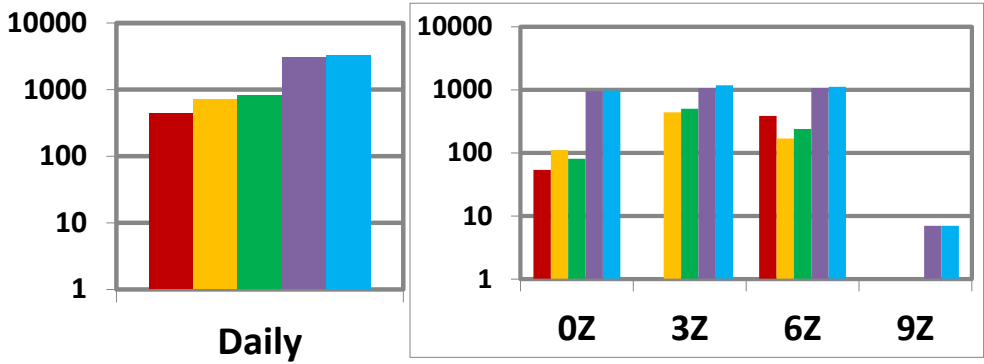
GOCI Data Impact: Many More Cloud-Free Looks!

- May-June-July 2016



GOCI AOD: Data Volume for Assimilation

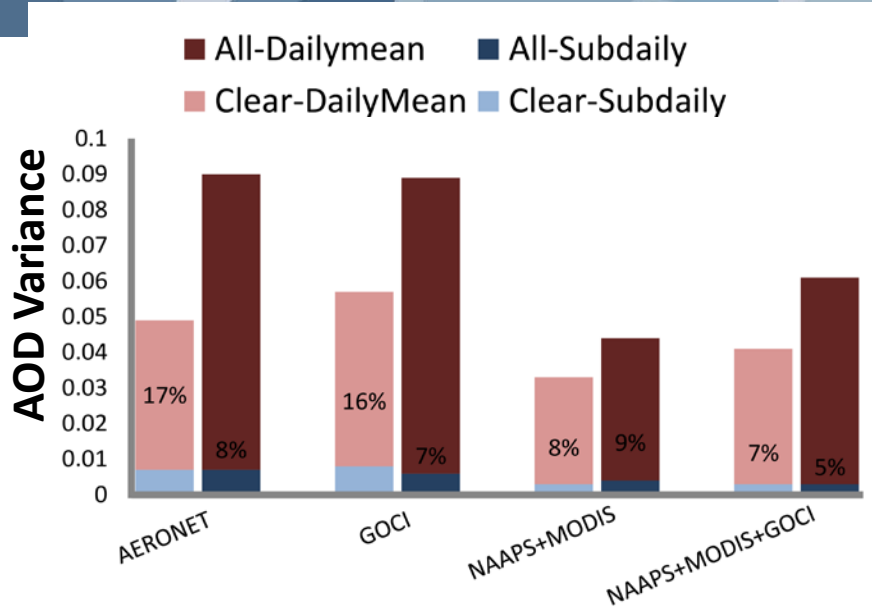
- MODISc56h
- MODISc5-3h
- MODISc6-3h
- GOCI
- MODIS+GOCI



- Multiple sensors/retrievals combined: MODIS algorithms DT Ocean > DT Land > DB; MODIS = (Terra+Aqua)[weighted]; MODIS > GOCI
- Over KORUS-AQ domain, 99% coverage is between 0-6UTC
- C6 includes Deep Blue, C5 is Dark Target only
- GOCI has 3x observations of MODIS after spatial and temporal averaging

AOD Variance in obs+models

- AERONET observations over East Asia during Sping 2016
- GOCI (Yonsei v2 AOD) and NAAPS sampled to match
- Variance partitioned into daily-mean and sub-daily "anomaly" for each site
- "Clear" excludes partially cloudy days



1. **Subdaily variation is a 10-20% residual in this region**
2. **Satellite observations show similar variance to AERONET**
3. **NAAPS has smaller variance overall, much less subdaily variance (more with GOCI)**

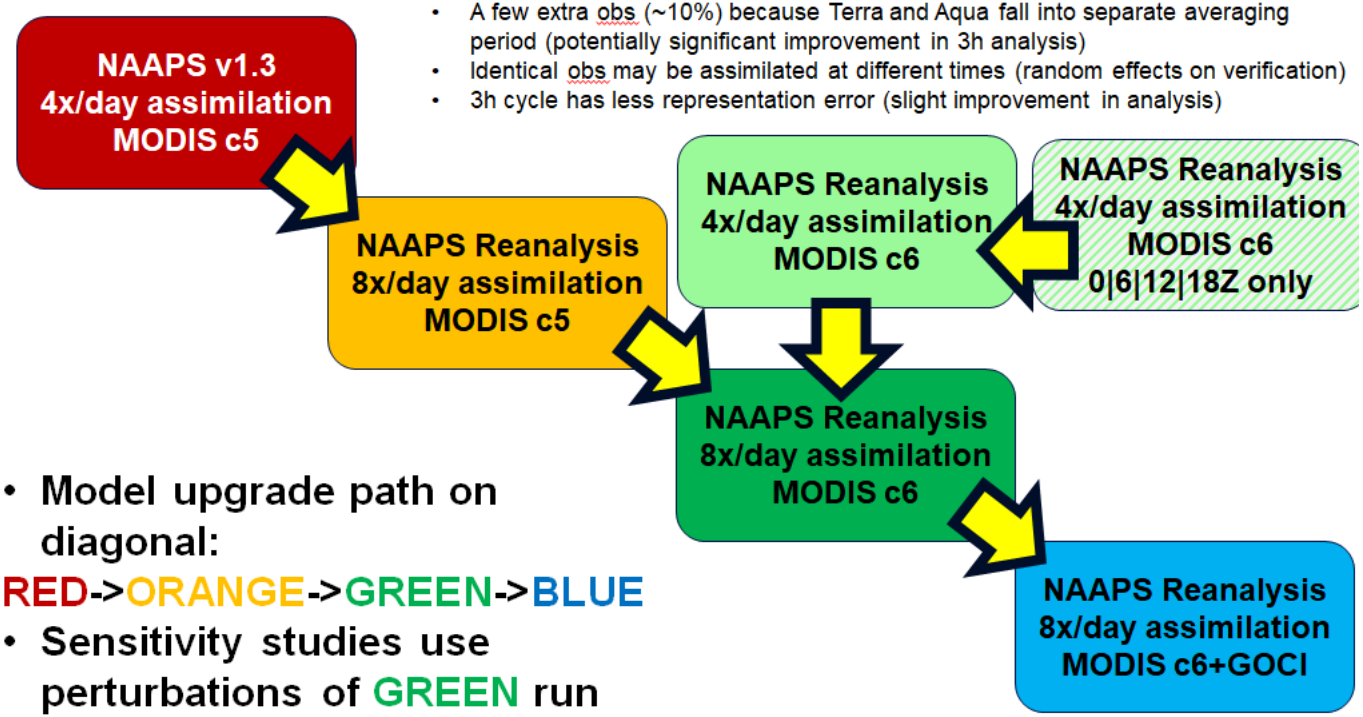
NAAPS configuration for KORUS

20160501 – 20160612 (KORUS-AQ flight period)

- All runs at 1/3 degree
- All runs write output every 3 hours
- Meteorology = NAVGEM analysis
- Smoke, Dust, Sea Salt, Anthropogenic aerosols
  - Lifting, advection, sedimentation, wet deposition, dry deposition
  - Reanalysis version (Lynch et al. (2016)): Tuned Smoke, Dust, Anthropogenic/Biogenic Fine Mode (ABF) primary and secondary particles
- 2-D variation assimilation (NAVDAS-AOD)
  - Observations binned to 0.5 degree before assimilation
  - Analysis calculated in AOD observation space
  - Increments calculated via SOAR autoregression

NAAPS experiment series

- 3h assimilation cycle has three effects (vs 6h)
  - A few extra obs (~10%) because Terra and Aqua fall into separate averaging period (potentially significant improvement in 3h analysis)
  - Identical obs may be assimilated at different times (random effects on verification)
  - 3h cycle has less representation error (slight improvement in analysis)



- Model upgrade path on diagonal:
  RED->ORANGE->GREEN->BLUE
- Sensitivity studies use perturbations of GREEN run

8x/day vs 3x/day assimilation

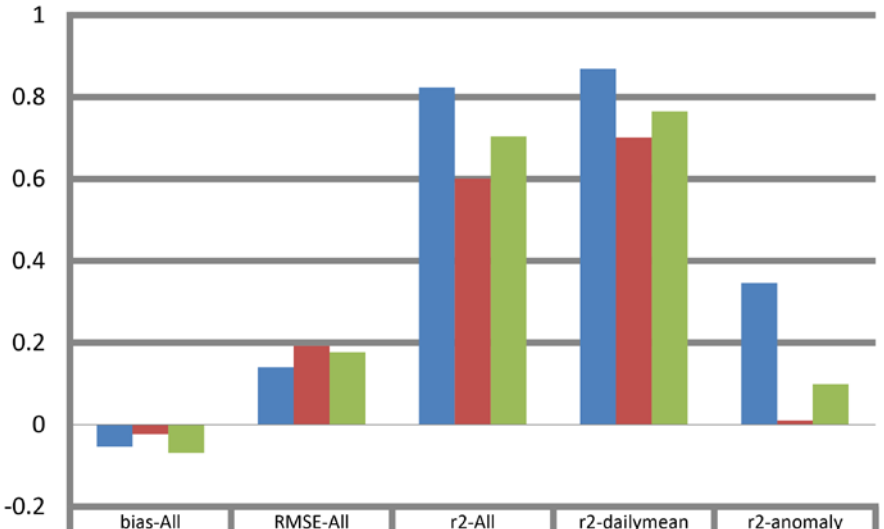
- 8x/day-3h assimilation cycle has three effects (vs 4x/day-6h)
  - A few extra obs (~10%) because Terra and Aqua fall into separate averaging period
    - potentially significant improvement in 3h analysis
  - Identical obs may be assimilated at different times
    - random +/- effects on verification, basically noise
  - 3h cycle has less representation error
    - Not 4DVAR, so OB.TIME is (+/-90 minutes vs +/-180 minutes)
    - slight improvement in analysis

- Representation error effect on analysis is likely very small because information is spread over >200km by NAVDAS-AOD
  - A point innovation results in an increment over a 125,000km2 area
  - If the associated feature is moving at 10ms-1, and the time offset is 90 minutes, the increment area will still overlap 65% of the 'matched' increment area. At 180 minutes, the increment areas still overlap by 28%.

Assimilation Results: Analysis

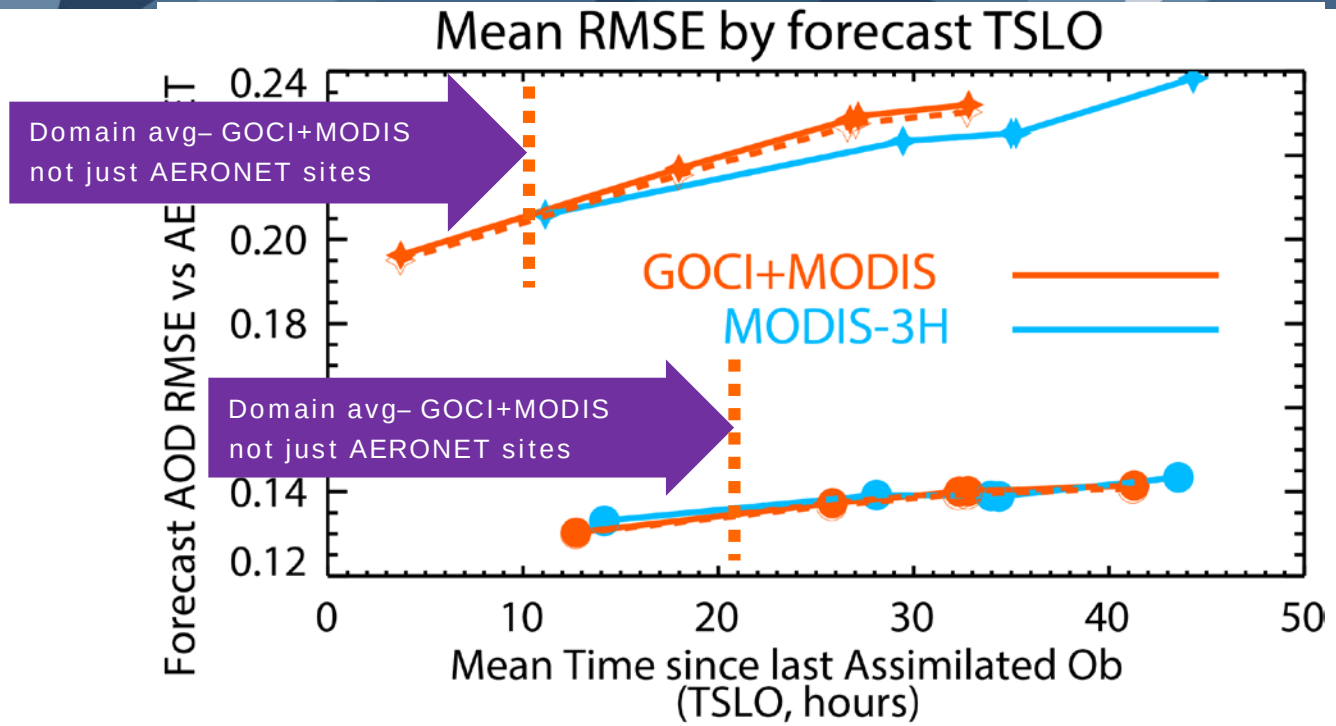
- Two NAAPS Simulations
  - **MODIS-only**
  - **MODIS+GOCI**
- Also tested **GOCI vs AERONET** for comparison

1. **NAAPS-MODIS+GOCI bridges half the gap between NAAPS-MODIS-only and GOCI raw data**
2. **NAAPS-MODIS-only captures none of the subdaily anomaly from the AERONET data**
3. **GOCI AOD is biased against AERONET in this sample; if this bias could be removed, it would match AERONET extremely well.**



	bias-All	RMSE-All	r2-All	r2-dailymean	r2-anomaly
GOCI	-0.054	0.14	0.823	0.869	0.346
NAAPS+MODIS	-0.023	0.192	0.601	0.701	0.01
NAAPS+MODIS+GOCI	-0.069	0.177	0.704	0.765	0.099

Assimilation Results: Forecast



- **Reforecast experiment: no NWP error growth, no FLAMBE error growth**
- **Forecast error in this simulation is source+sink error only**
- **East Asia domain has larger aerosol loading => higher RMSE**

The clear-sky bias effect of validating using AERONET gives a "bonus" in RMSE equivalent to ~3 hours forecast integration

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Outlook: What's Next?

- GOES-16!
- GOES-17!
- Himawari-8!
- Himawari-9!
- KOMPSAT-2 AKI!

- How much of the day can we quantitatively observe?
- Investigation of diurnal processes and interactions of DA and models in the presence of these effects

Acknowledgements

- NRL APES Group
- Dr. Jhoon Kim and group at Yonsei University
- NASA AERONET team

THANK YOU!

AMS Meeting in Phoenix in January has a special session on "Nighttime Environmental Monitoring"

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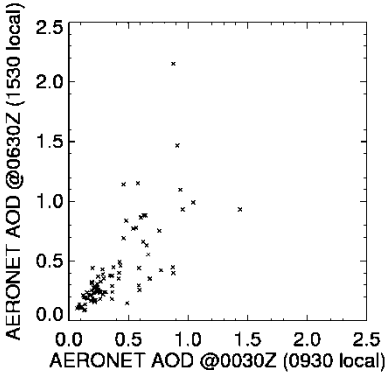
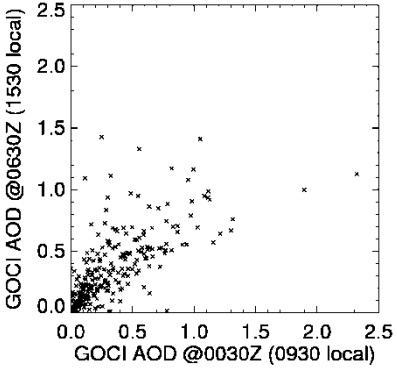
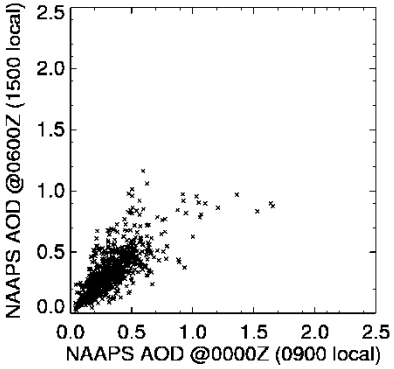
Extra Slides

AOD Variability in obs+models







AERONET	
Both AM+PM	70%
Only AM or PM	30%
Correlation (R^2)	0.54
$\Delta(AM - PM) > 0.2\bar{\tau}$	61%

GOCI	
Both AM+PM	70%
Only AM or PM	30%
Correlation (R^2)	0.46
$\Delta(AM - PM) > 0.2\bar{\tau}$	75%

NAAPS Analysis	
Both AM+PM	100%
Only AM or PM	0
Correlation (R^2)	0.54
$\Delta(AM - PM) > 0.2\bar{\tau}$	54%