METHODS OF NAAPS EVALUATION

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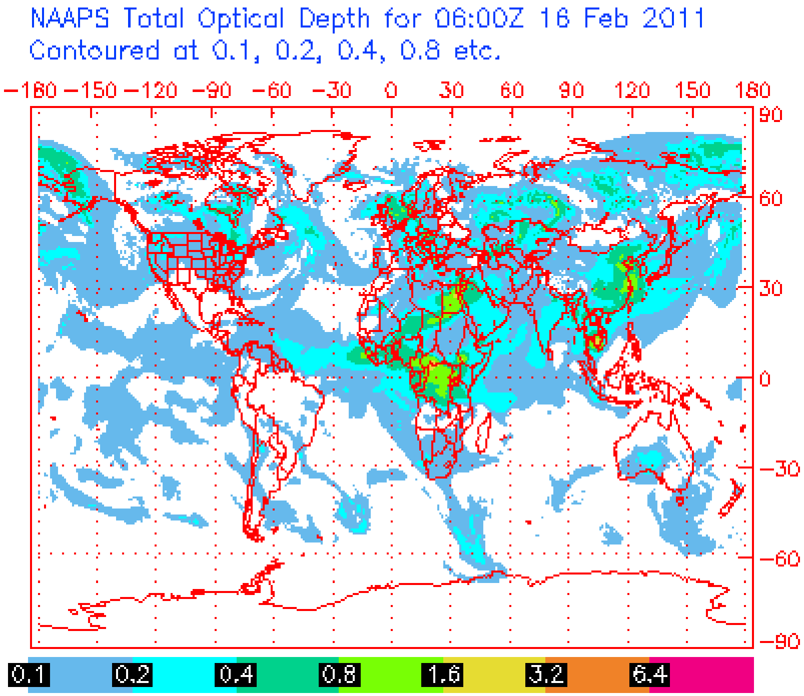
ICAP, 12 May 2011

Background

Navy Aerosol Analysis and Prediction System - NAAPS

- Global Aerosol Mass Transport Model
- 1° x 1°
- Produces Forecasts of:
  - Smoke
  - Dust
  - Sulfate
  - Sea Salt
  - SO_2
- Uses output from NOGAPS
  - U.S. Navy Operational Global Analysis and Prediction System
- Assimilation of Satellite and LIDAR
  - NAVDAS-AOD



NAAPS Total Optical Depth from the NRL Marine Meteorology Division Website

Goals and Outline

- Create a convenient method for assessing model performance
- Accomplish by comparing model forecasts with analyses (OWN analysis)
  - Analysis versus previous forecasts at same valid time
  - Can use single model (herein) or multi-model analyses
  - Data assimilation in analysis is imperative for comparing with forecasts
- Evaluation of NAAPS with AERONET
- Effect of LIDAR data assimilation

NAAPS OWN Analysis Code

- Code in IDL and Perl, will change to Python for convenience
- Calculate absolute differences between NAAPS analysis and forecast files at each model grid point
- Mean Absolute Error:
  - Sum all of the absolute differences in corresponding forecast groups
  - Divide by total number of differences in each forecast group
- Root Mean Square Error:
  - Sum the square of all of the absolute differences in corresponding forecast groups
  - Divide by the total number of differences in each forecast group
  - Take the square root

NAAPS OWN Analysis Code

- Forecast Group:
  - 6 hour forecasts – Analyses
  - 12 hour forecasts – Analyses … etc.

070100	070106	070112	070118	070200	070206	070212	070218	070300
A_1	F6_1	F12_1	F18_1	F24_1	F30_1	F36_1	F42_1	F48_1
	A_2	F6_2	F12_2	F18_2	F24_2	F30_2	F36_2	F42_2
		A_3	F6_3	F12_3	F18_3	F24_3	F30_3	F36_3
			A_4	F6_4	F12_4	F18_4	F24_4	F30_4
				A_5	F6_5	F12_5	F18_5	F24_5

NAAPS OWN Analysis Code

- Other features of OWN analysis
  - Choose any range of dates to analyze
  - Specify range of AOD values to be included
  - Options for: Over Land only, Over Ocean only, and Over Land and Ocean
- First Step: Use AERONET data to compare with NAAPS
  - Test comparison method concept
  - Expect increase in mean absolute error with increasing forecast time (48 hour forecast error > 6 hour forecast error)

AERONET Comparison

- Assume AERONET AOD is truth
- Method of comparison similar to OWN analysis
  - Calculate absolute differences between NAAPS and appropriate AERONET data
  - AERONET observation must be within ± 30 minutes of NAAPS valid time

070100	070106	070112	070118	070200	070206	070212	070218	070300
A_1	F6_1	F12_1	F18_1	F24_1	F30_1	F36_1	F42_1	F48_1
	A_2	F6_2	F12_2	F18_2	F24_2	F30_2	F36_2	F42_2
		A_3	F6_3	F12_3	F18_3	F24_3	F30_3	F36_3
			A_4	F6_4	F12_4	F18_4	F24_4	F30_4
				A_5	F6_5	F12_5	F18_5	F24_5

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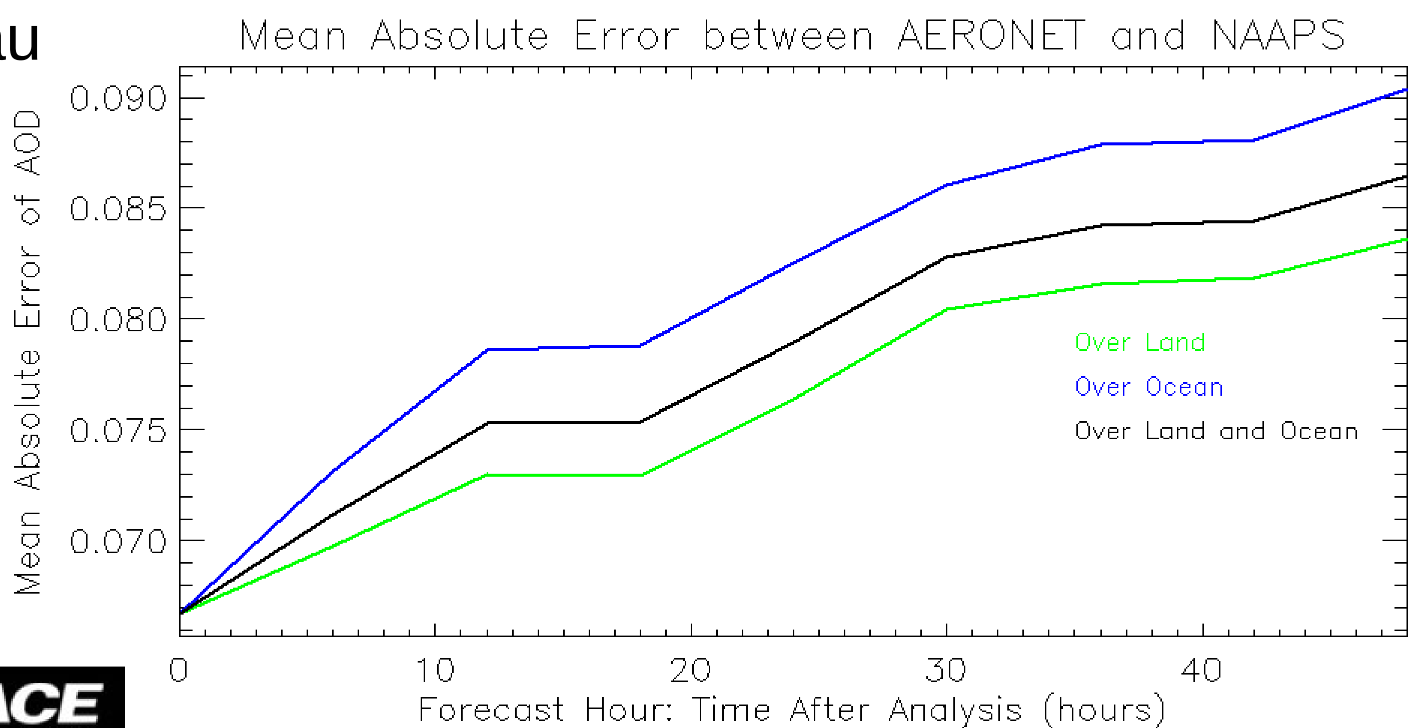
AERONET Comparison

01 June 2007 00z through 31 July 2007 18z

- Global mean absolute error should increase with each forecast
- 18 and 12 hour forecast error nearly the same
- Error plateau repeated at 42 and 36 hour forecasts



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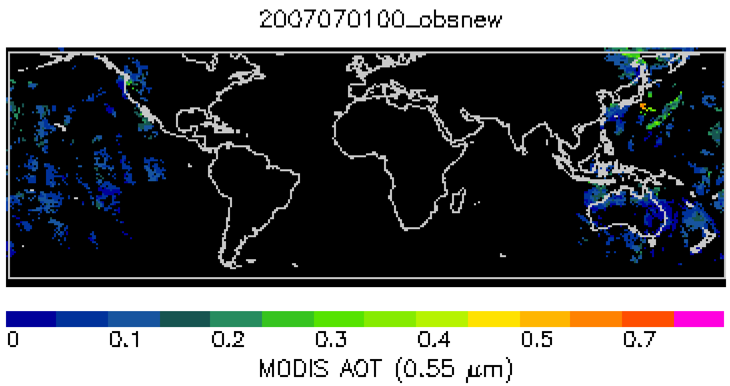
AERONET Comparison

- Determine cause of 18 and 42 hour forecast plateaus of mean absolute error before continuing with the OWN analysis
  - Plateau phenomenon appears to be a cycle of 24 hours (affected the 18 hour and 42 hour forecasts)
  - AERONET sites used for NAAPS model evaluation
    - AERONET data availability: Day time only
    - 24 hour cycle
  - Satellite data are assimilated into NAAPS
    - Satellite data availability: Day time only
    - 24 hour cycle

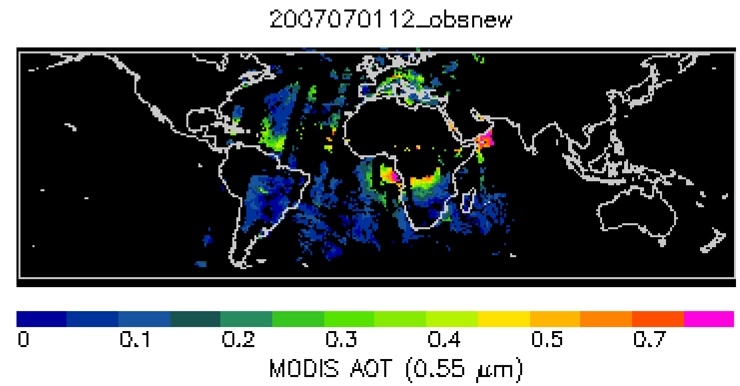
AERONET Comparison

- Investigation into role the of AERONET and satellite observations is warranted
- Sample MODIS satellite observations from 01 July 2007:

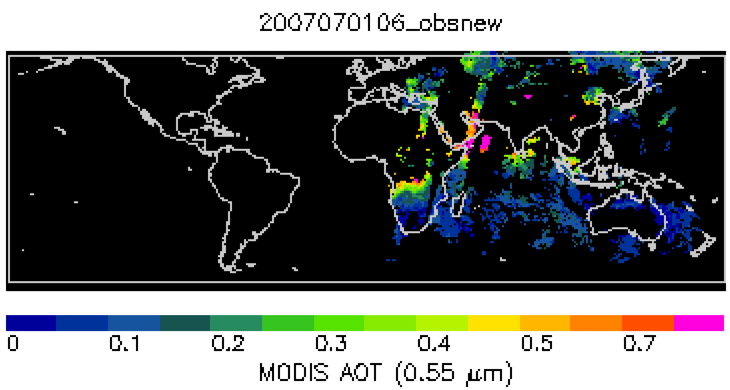
00 Z



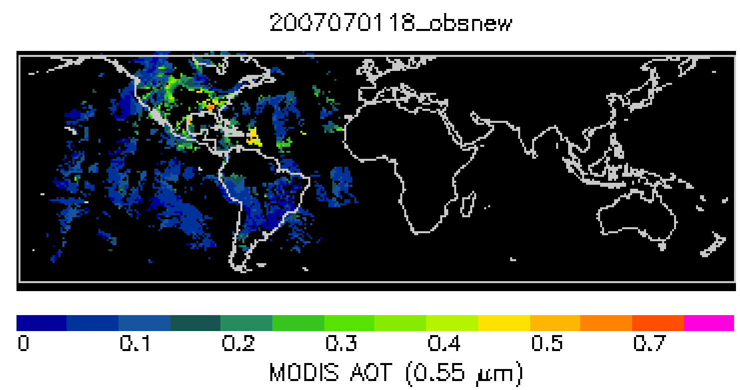
12 Z



06 Z



18 Z



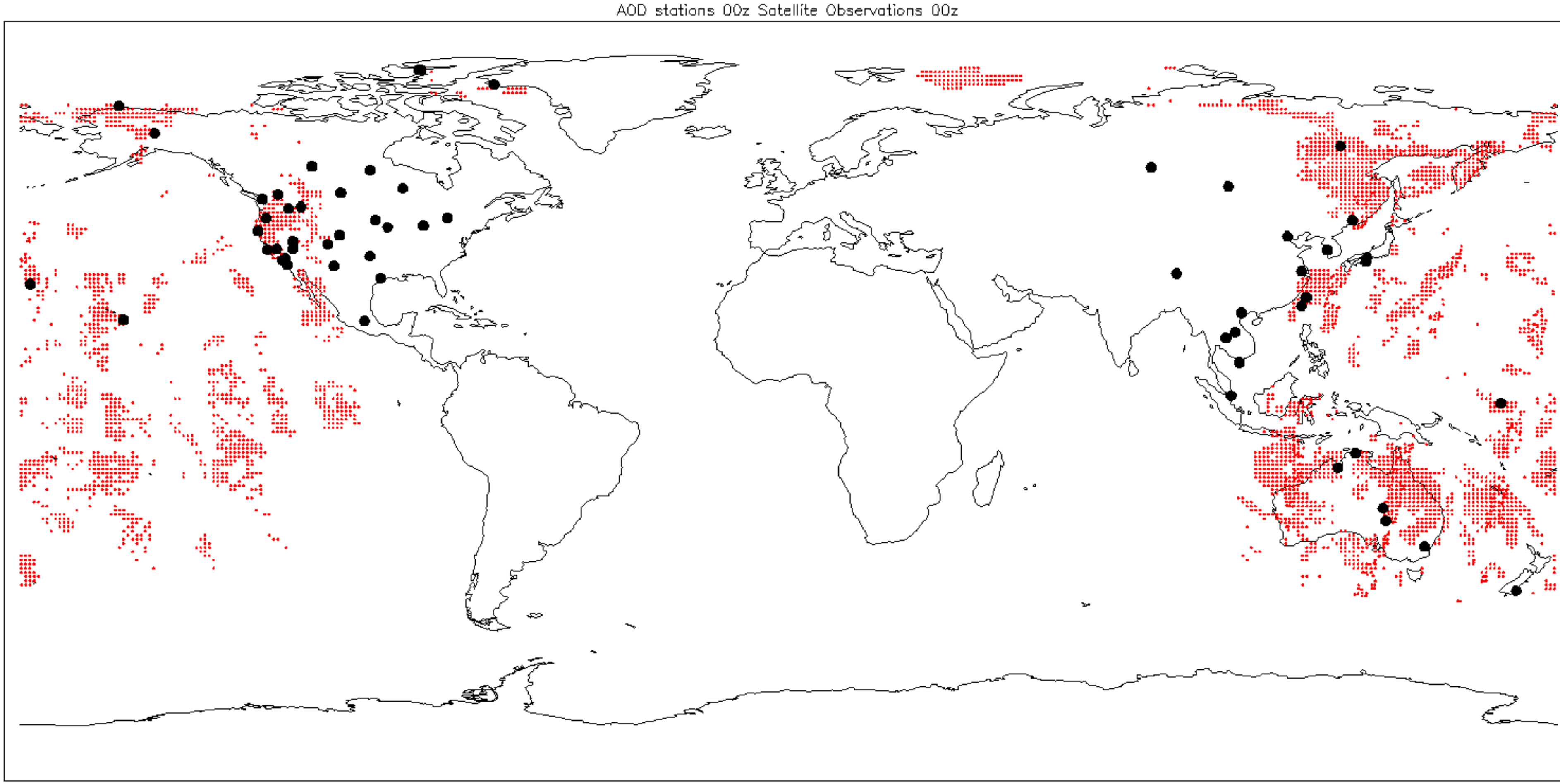
AERONET Comparison

Analysis 00z AERONET 00z Satellite Obs	6 Hour Forecast 06z AERONET 00z Satellite Obs	12 Hour Forecast 12z AERONET 00z Satellite Obs	18 Hour Forecast 18z AERONET 00z Satellite Obs
Analysis 06z AERONET 06z Satellite Obs	6 Hour Forecast 12z AERONET 06z Satellite Obs	12 Hour Forecast 18z AERONET 06z Satellite Obs	18 Hour Forecast 00z AERONET 06z Satellite Obs
Analysis 12z AERONET 12z Satellite Obs	6 Hour Forecast 18z AERONET 12z Satellite Obs	12 Hour Forecast 00z AERONET 12z Satellite Obs	18 Hour Forecast 06z AERONET 12z Satellite Obs
Analysis 18z AERONET 18z Satellite Obs	6 Hour Forecast 00z AERONET 18z Satellite Obs	12 Hour Forecast 06z AERONET 18z Satellite Obs	18 Hour Forecast 12z AERONET 18z Satellite Obs

AERONET Comparison

- View by Column: 1st Column
- Analyses
- Black Dots: AERONET stations used for model evaluation.
- Red Specks: Location of most recently assimilated satellite data.

Analyses



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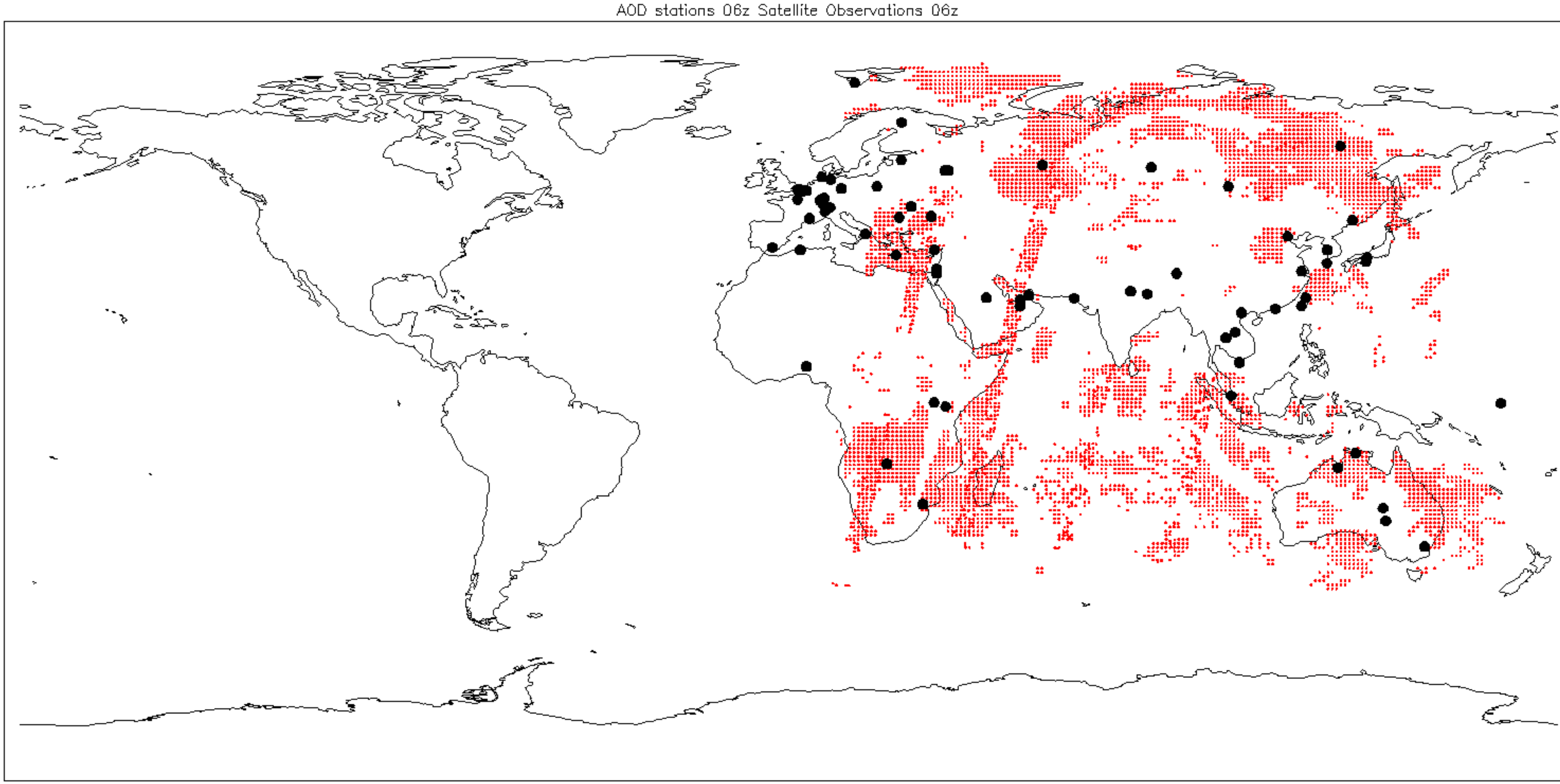
Analyses



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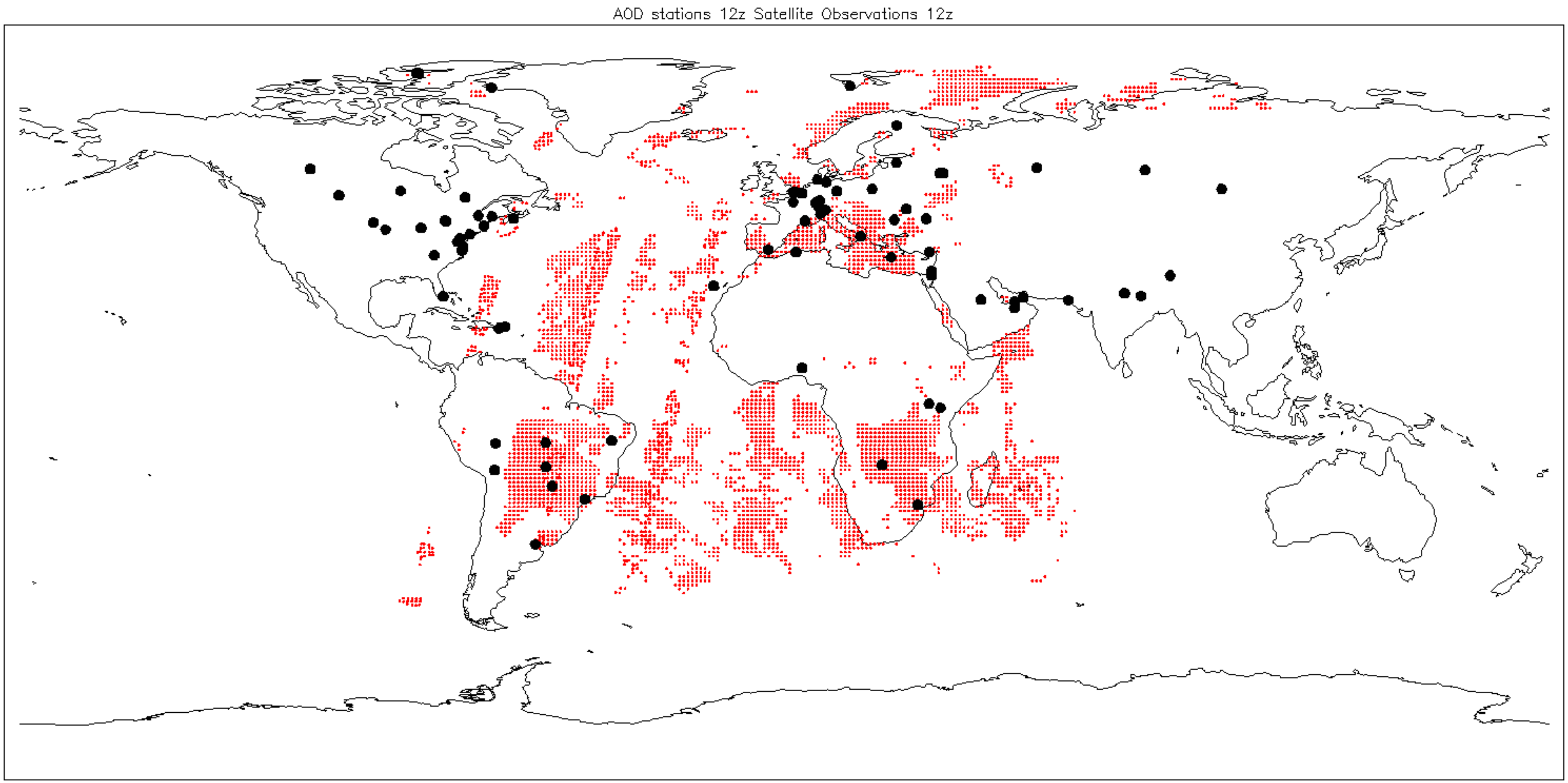
Analyses



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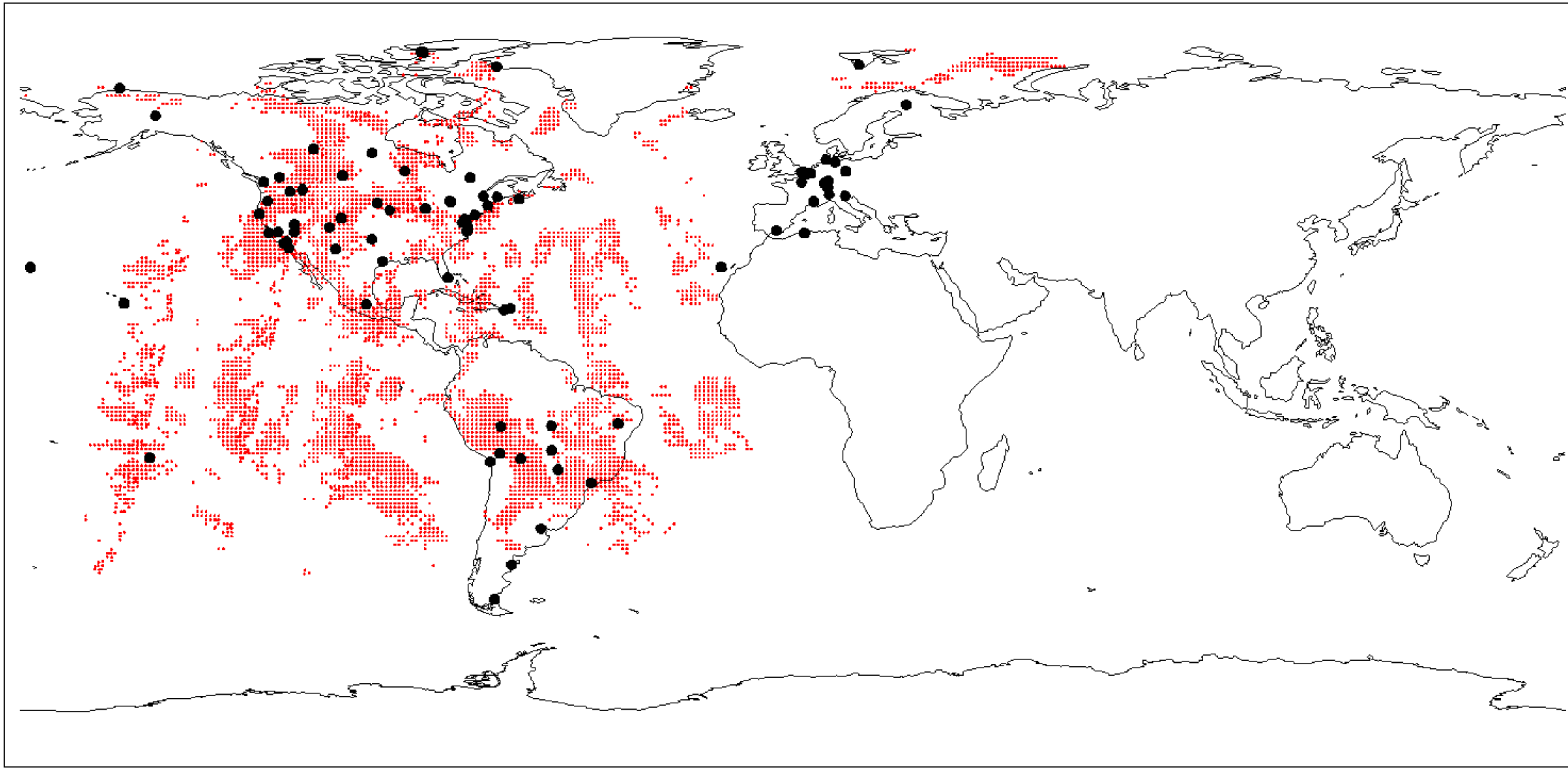
Analyses

AOD stations 18z Satellite Observations 18z



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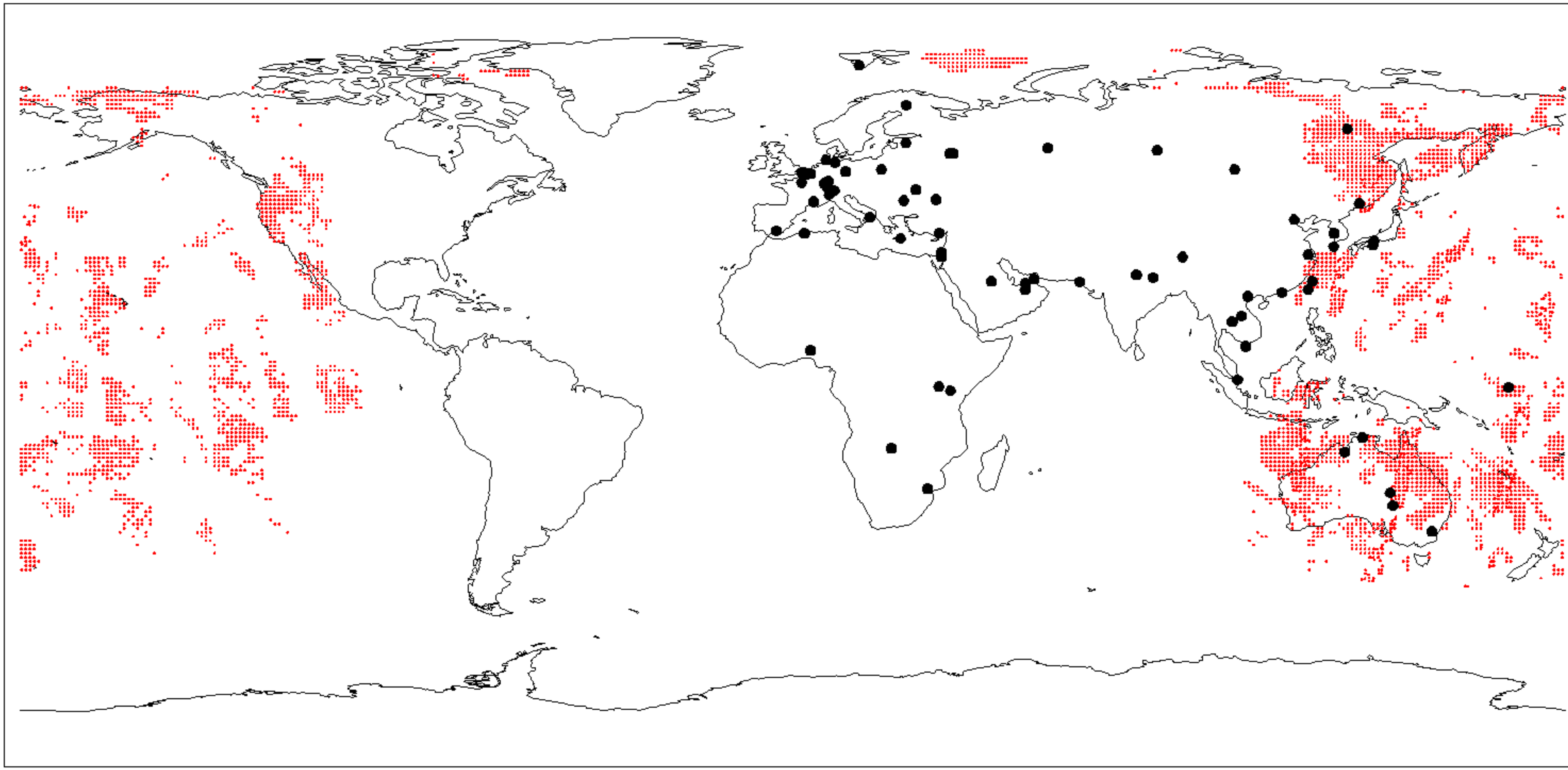
AERONET Comparison

- View by Column: 2nd Column
- 6 Hour Forecasts
- Black Dots: AERONET stations used for model evaluation.
- Red Specks: Location of most recently assimilated satellite data.

6 Hour Forecasts

AOD stations 06z Satellite Observations 00z



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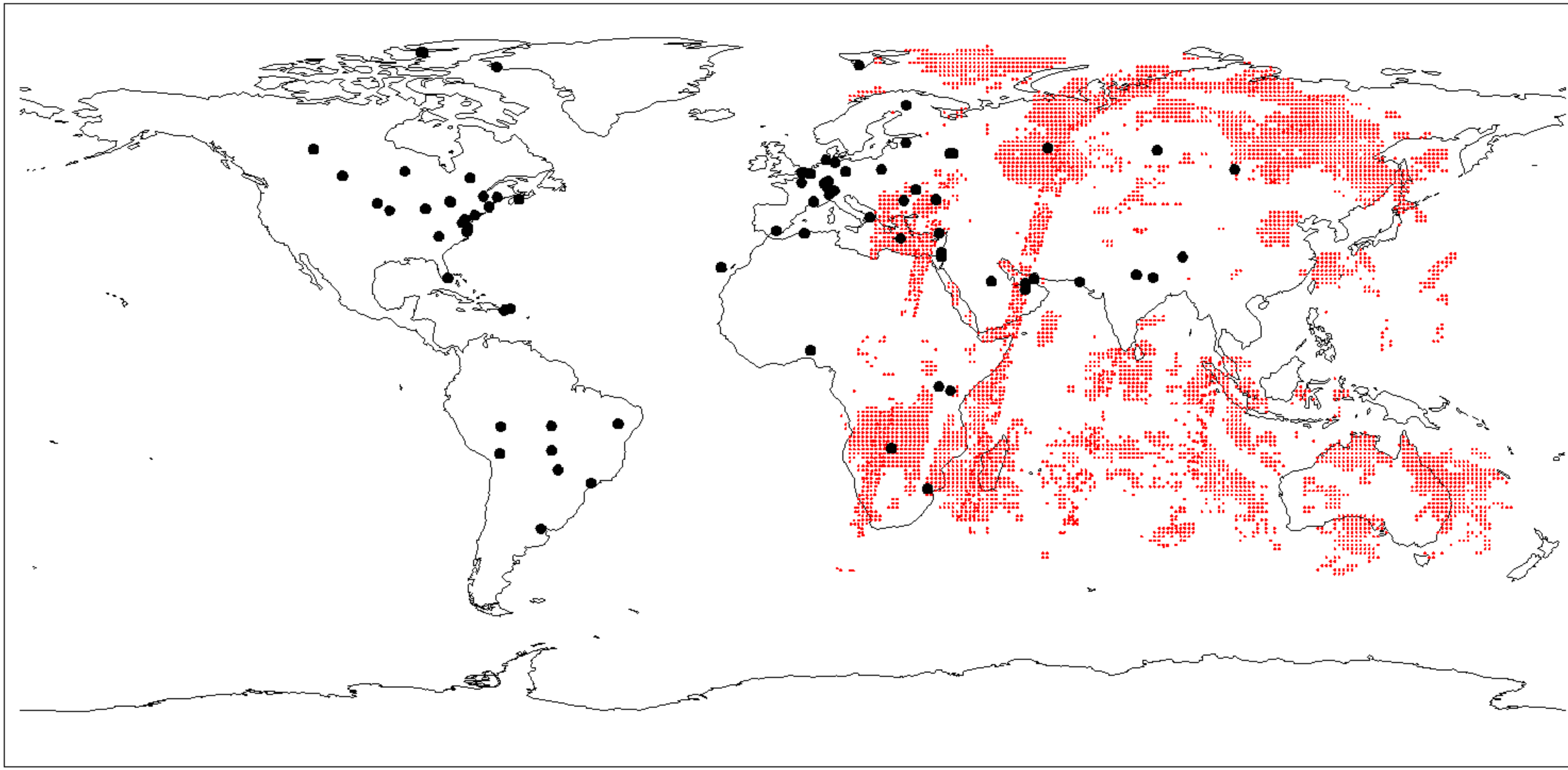
6 Hour Forecasts

AOD stations 12z Satellite Observations 06z



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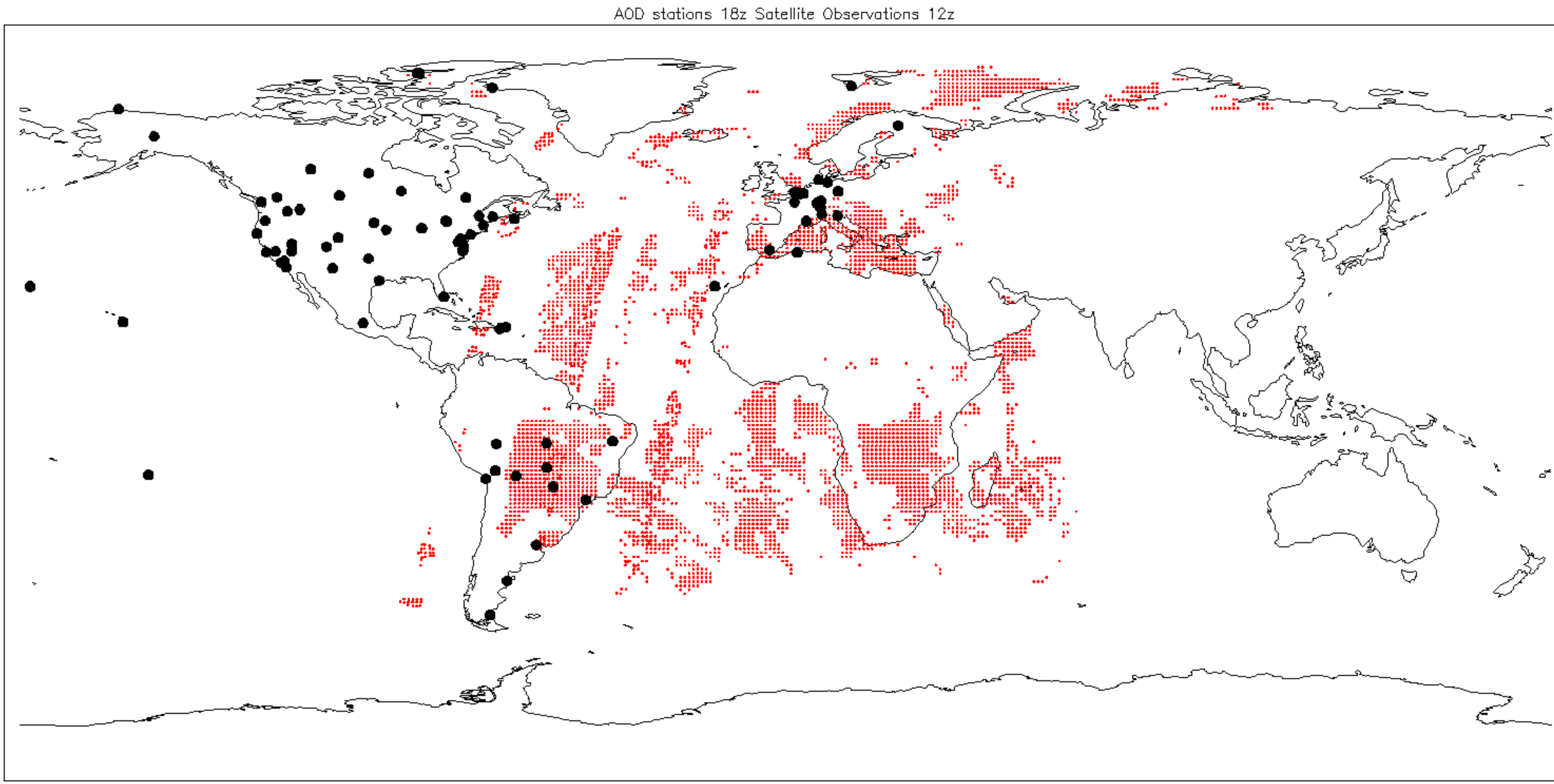
6 Hour Forecasts



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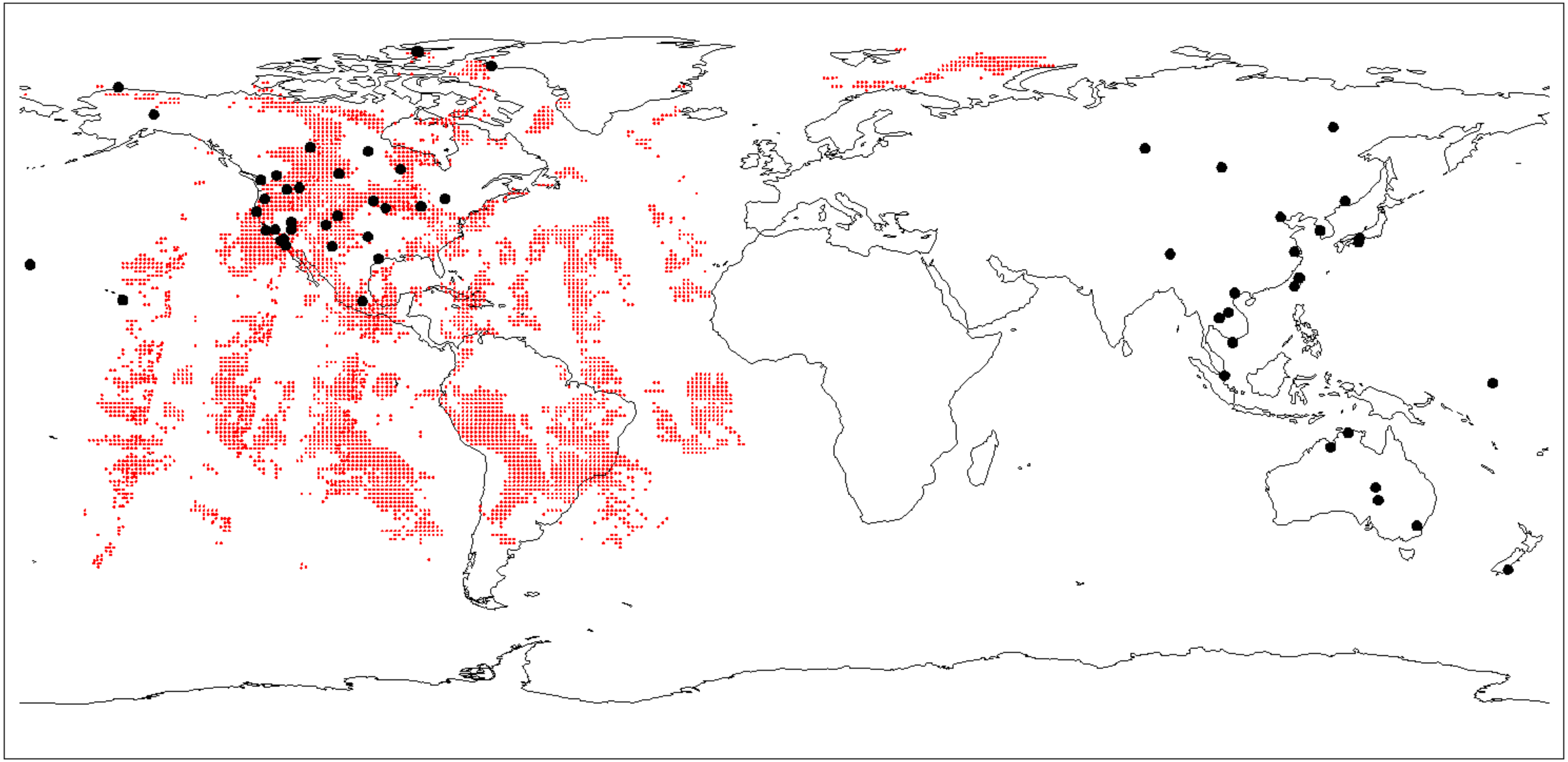
6 Hour Forecasts

AOD stations 00z Satellite Observations 18z



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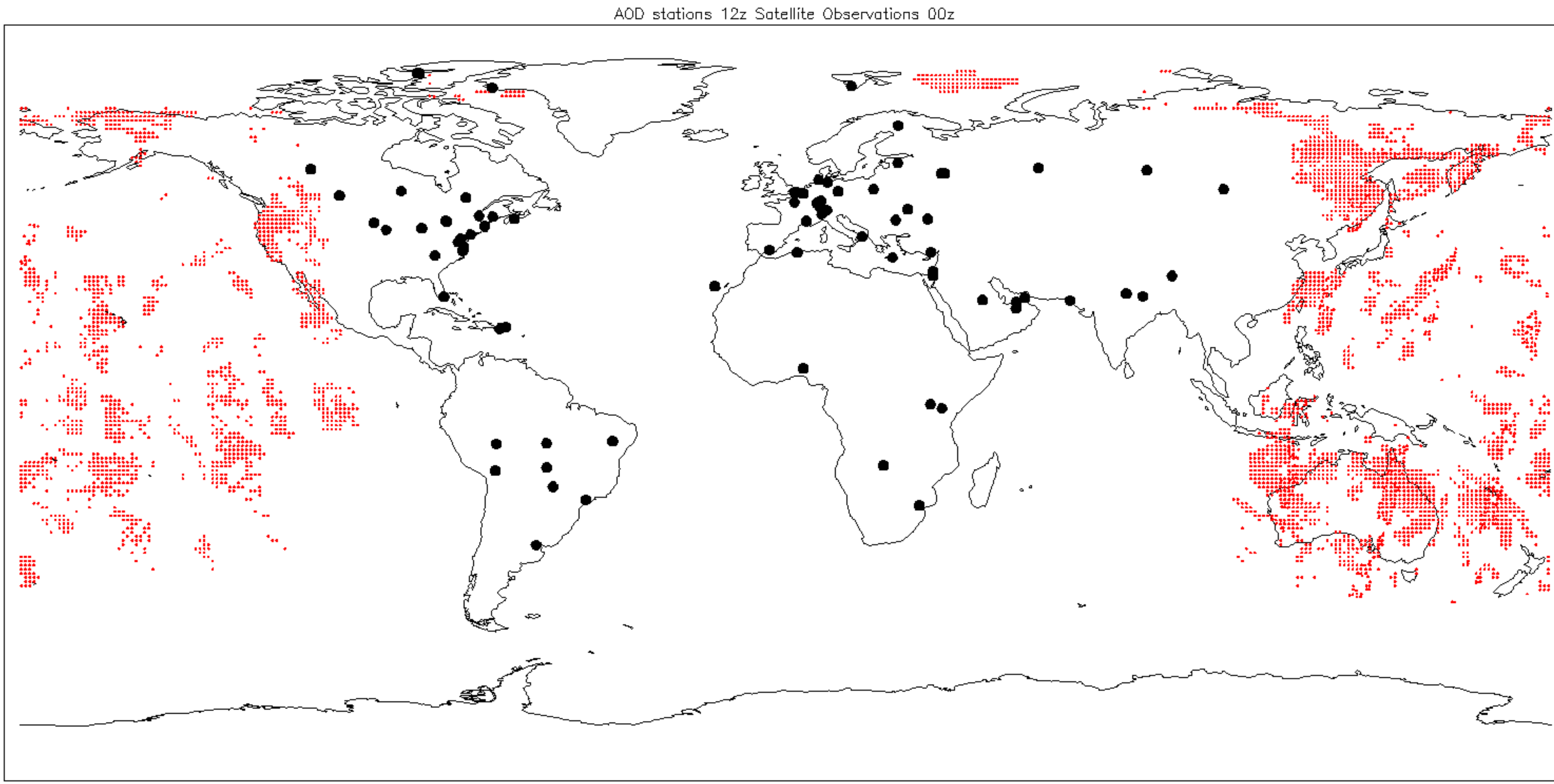
AERONET Comparison

- View by Column 3rd Column
- 12 Hour Forecasts
- Black Dots: AERONET stations used for model evaluation.
- Red Specks: Location of most recently assimilated satellite data.

12 Hour Forecasts



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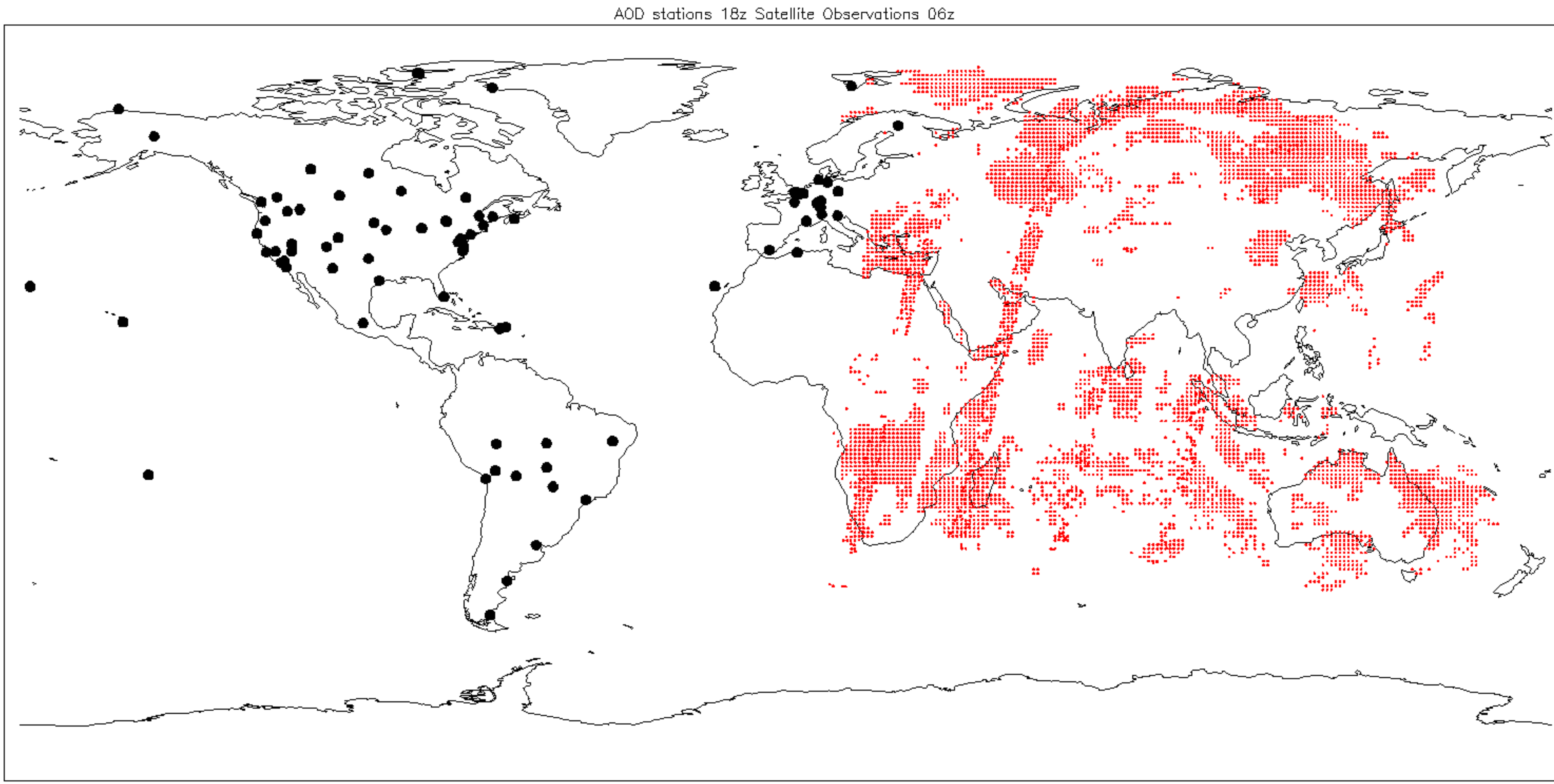
12 Hour Forecasts



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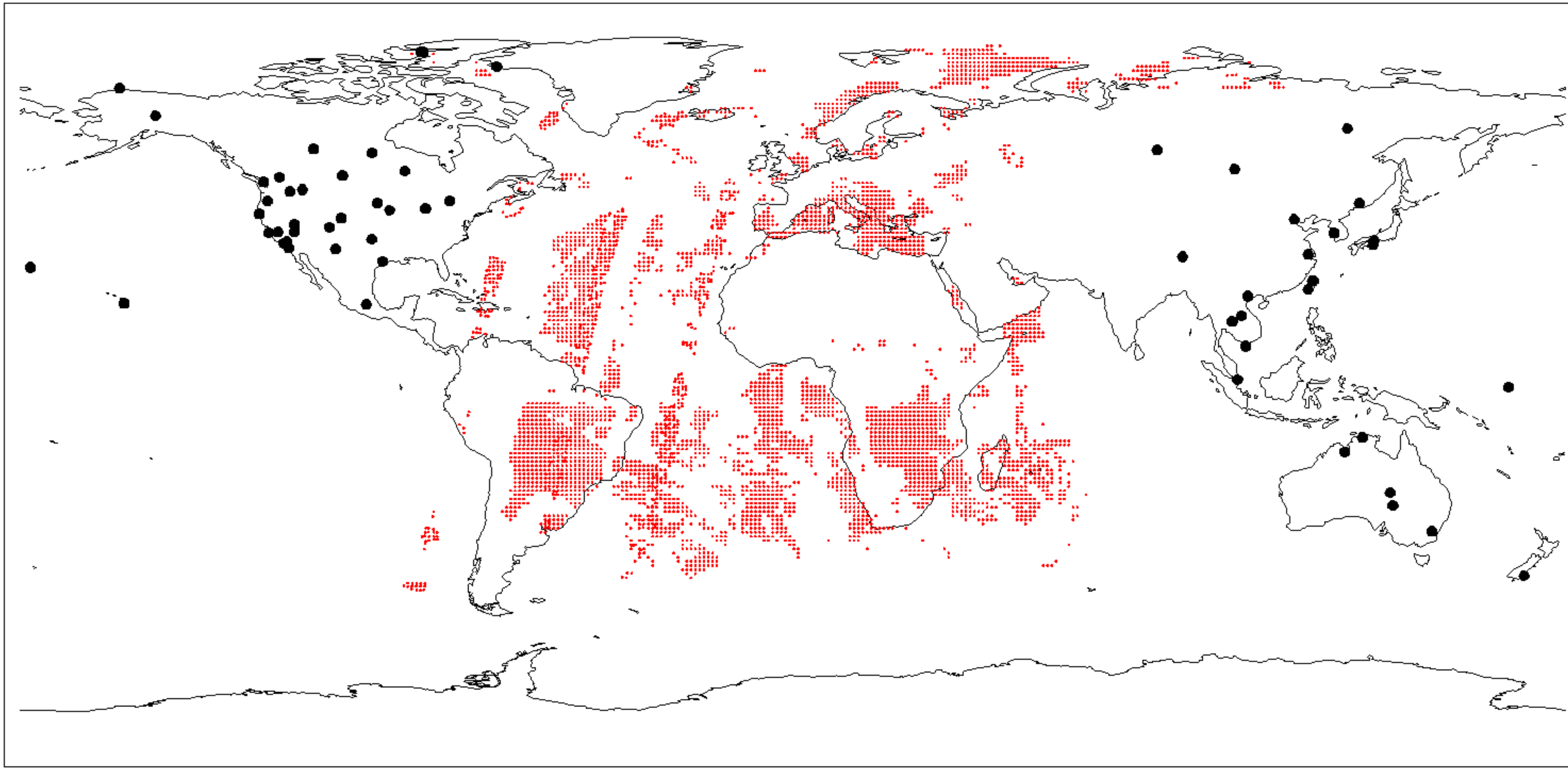
12 Hour Forecasts

AOD stations 00z Satellite Observations 12z



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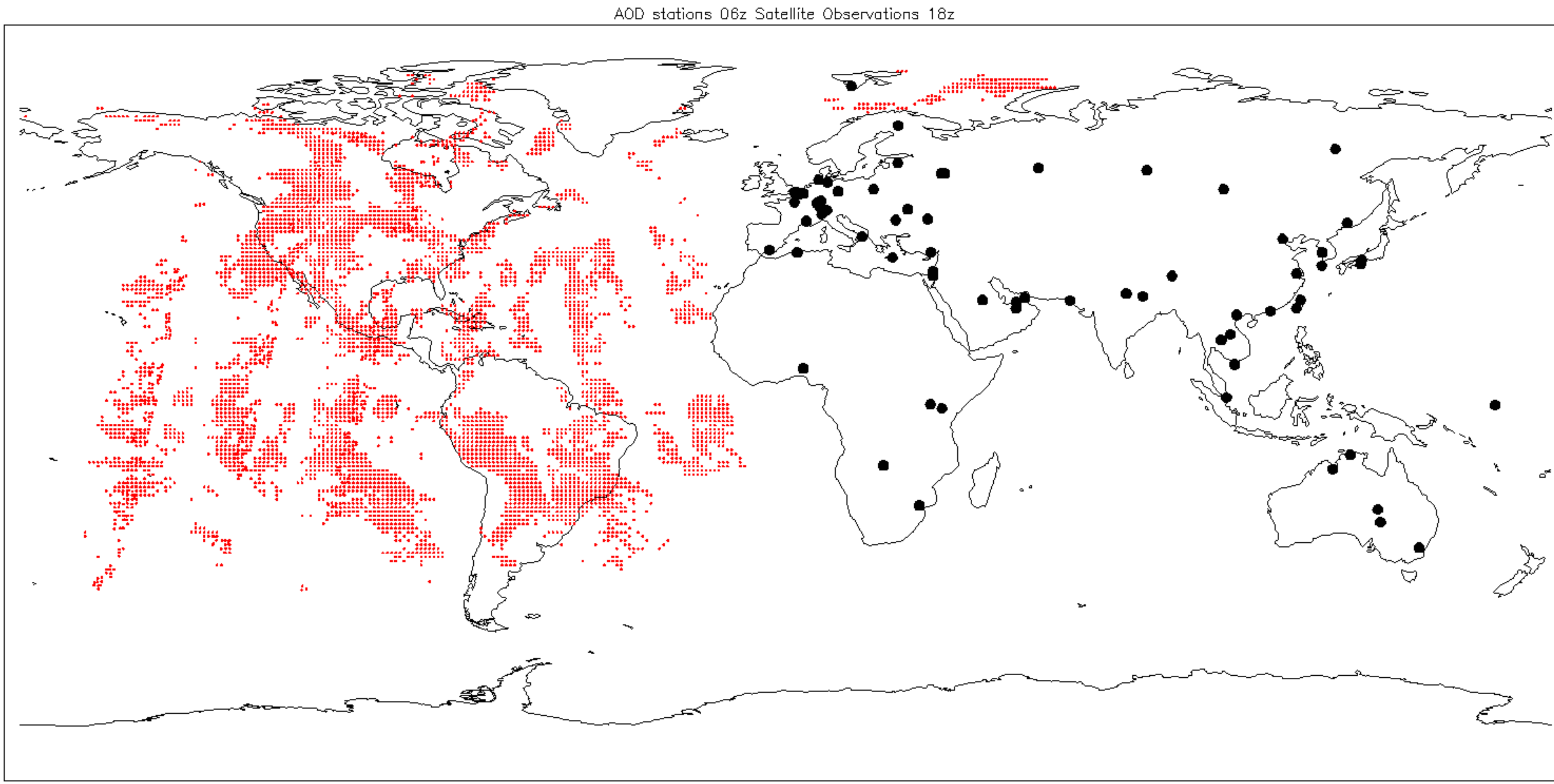
12 Hour Forecasts



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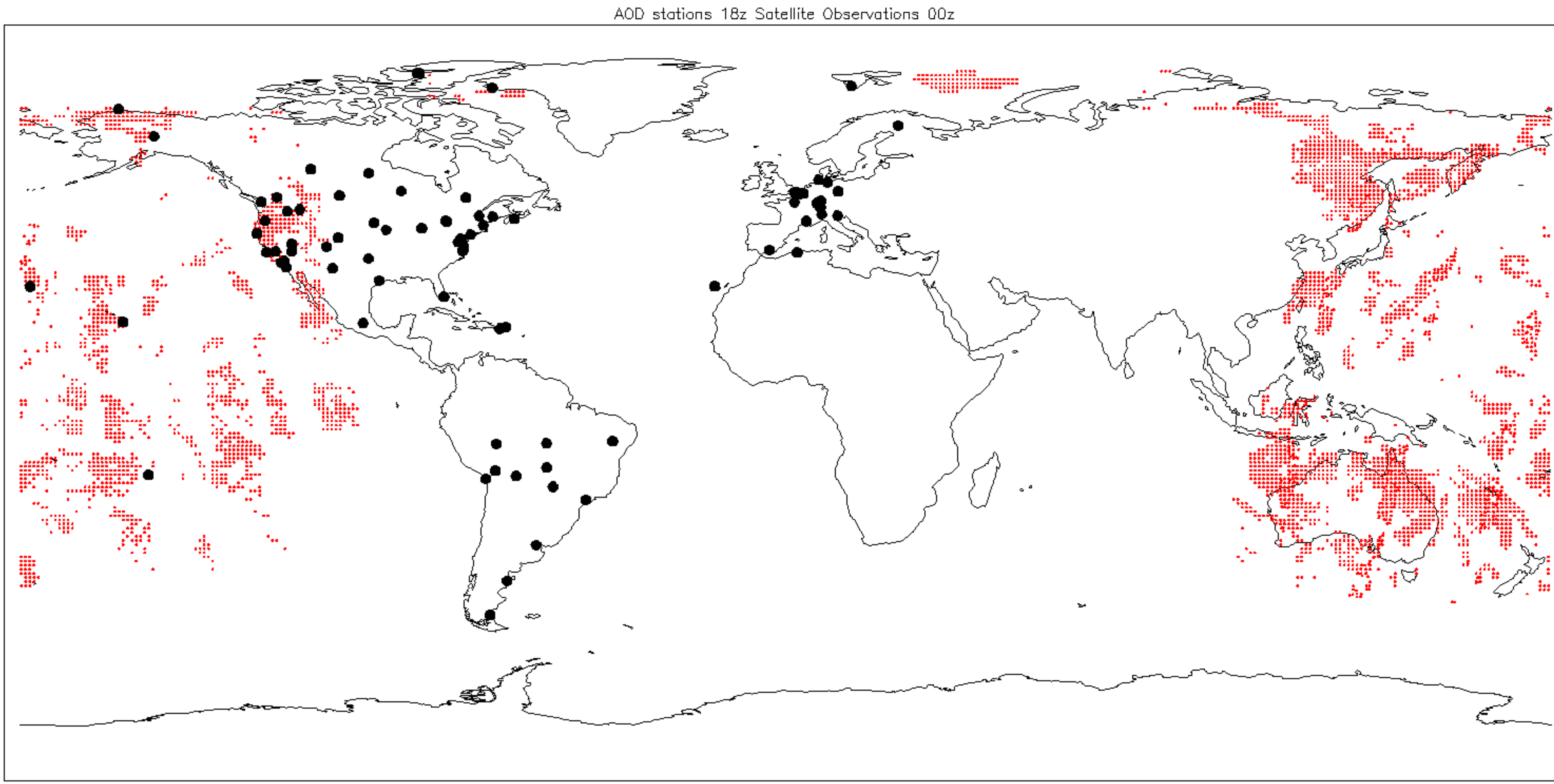
AERONET Comparison

- View by Column: 4th Column
- 18 Hour Forecasts
- Black Dots: AERONET stations used for model evaluation.
- Red Specks: Location of most recently assimilated satellite data.

18 Hour Forecasts



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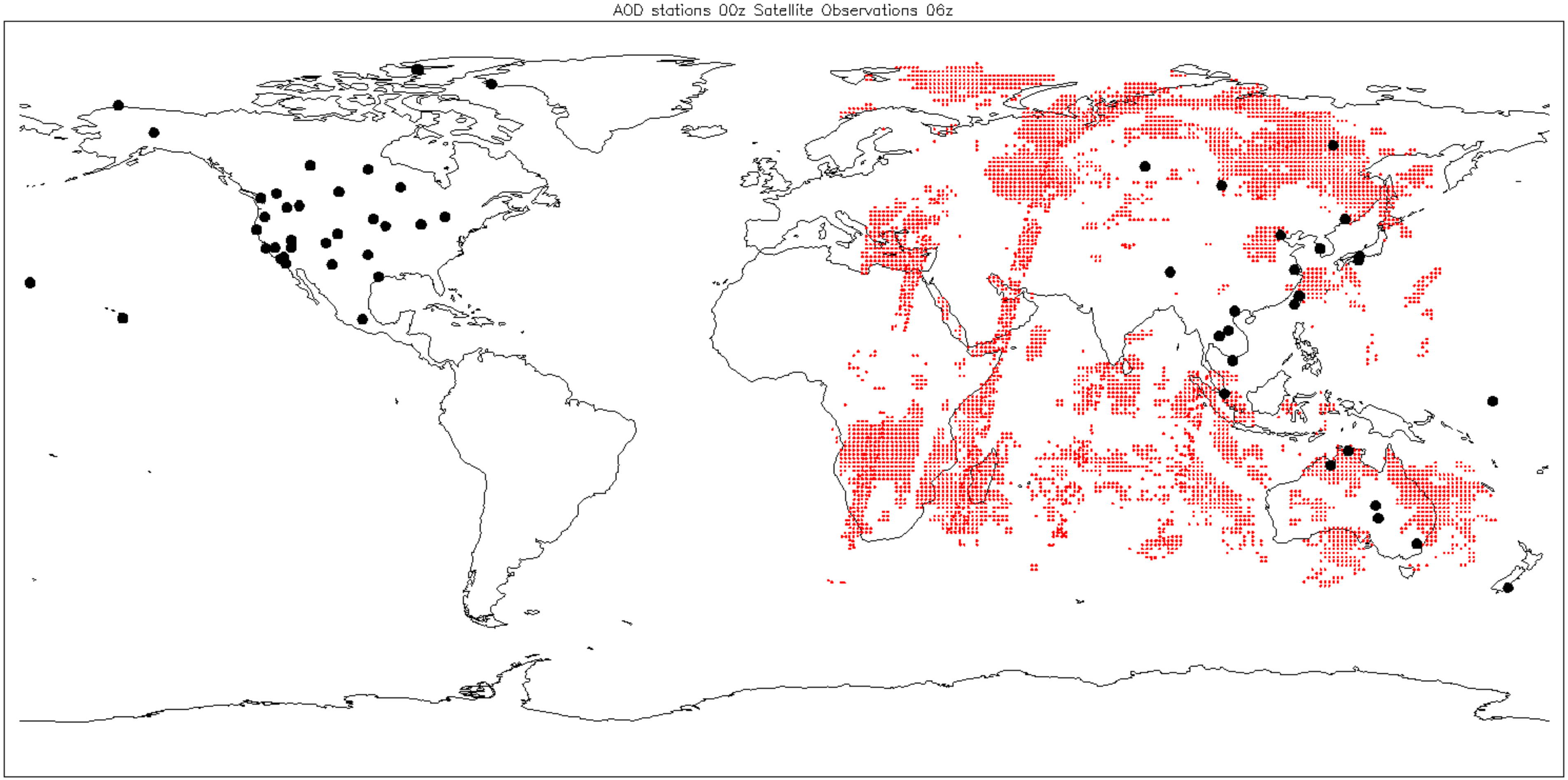
18 Hour Forecasts



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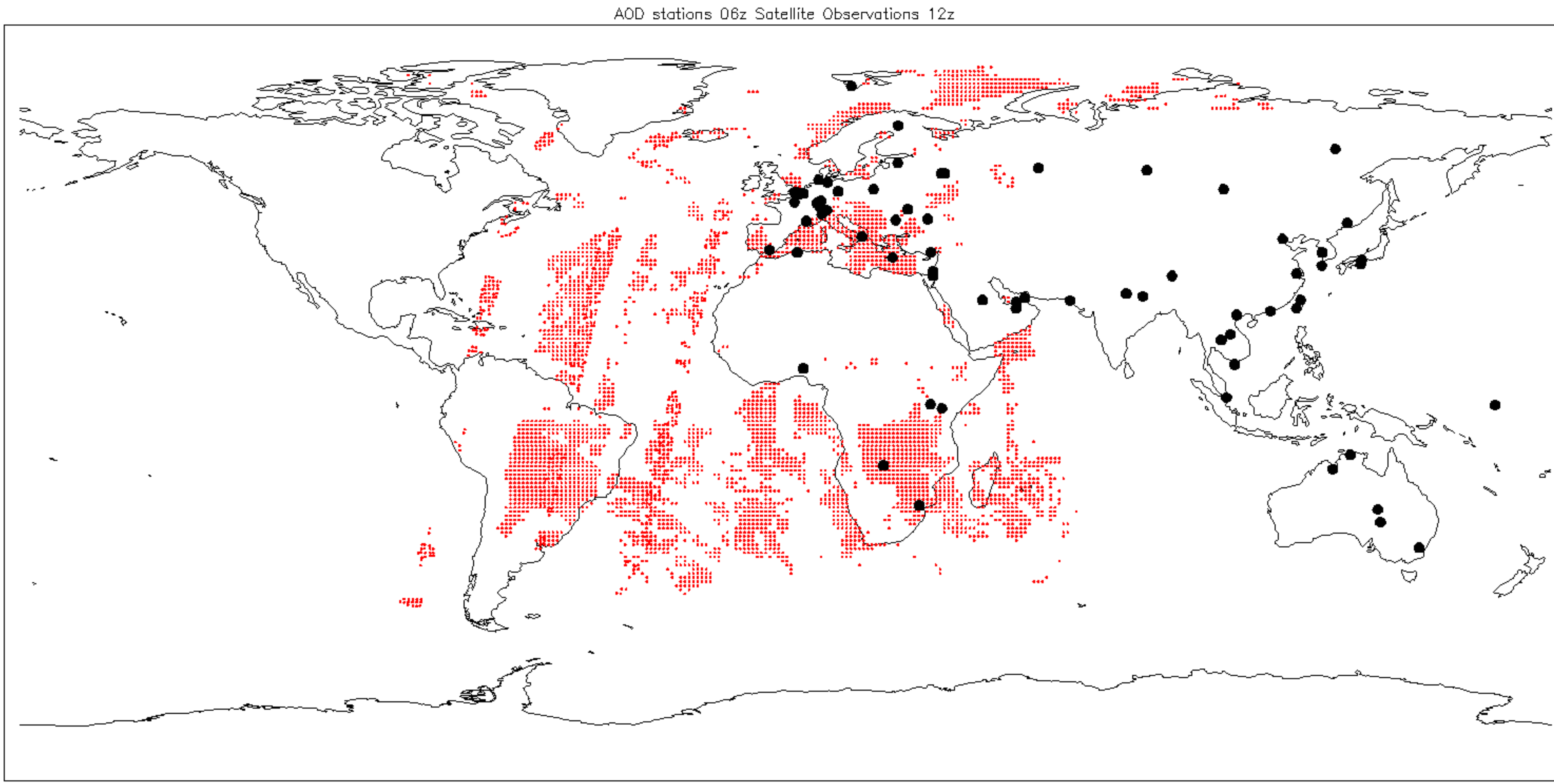
18 Hour Forecasts



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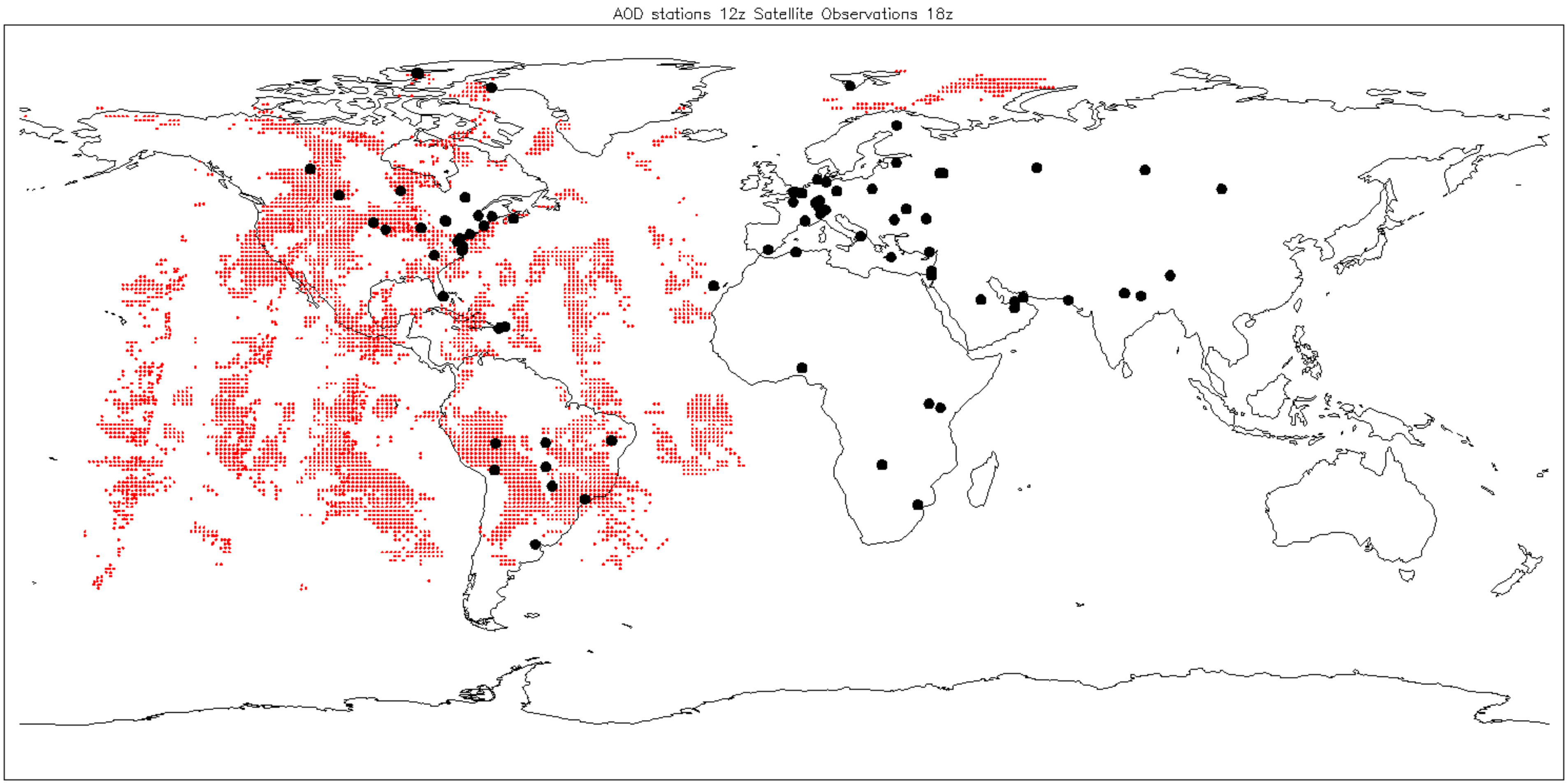
18 Hour Forecasts



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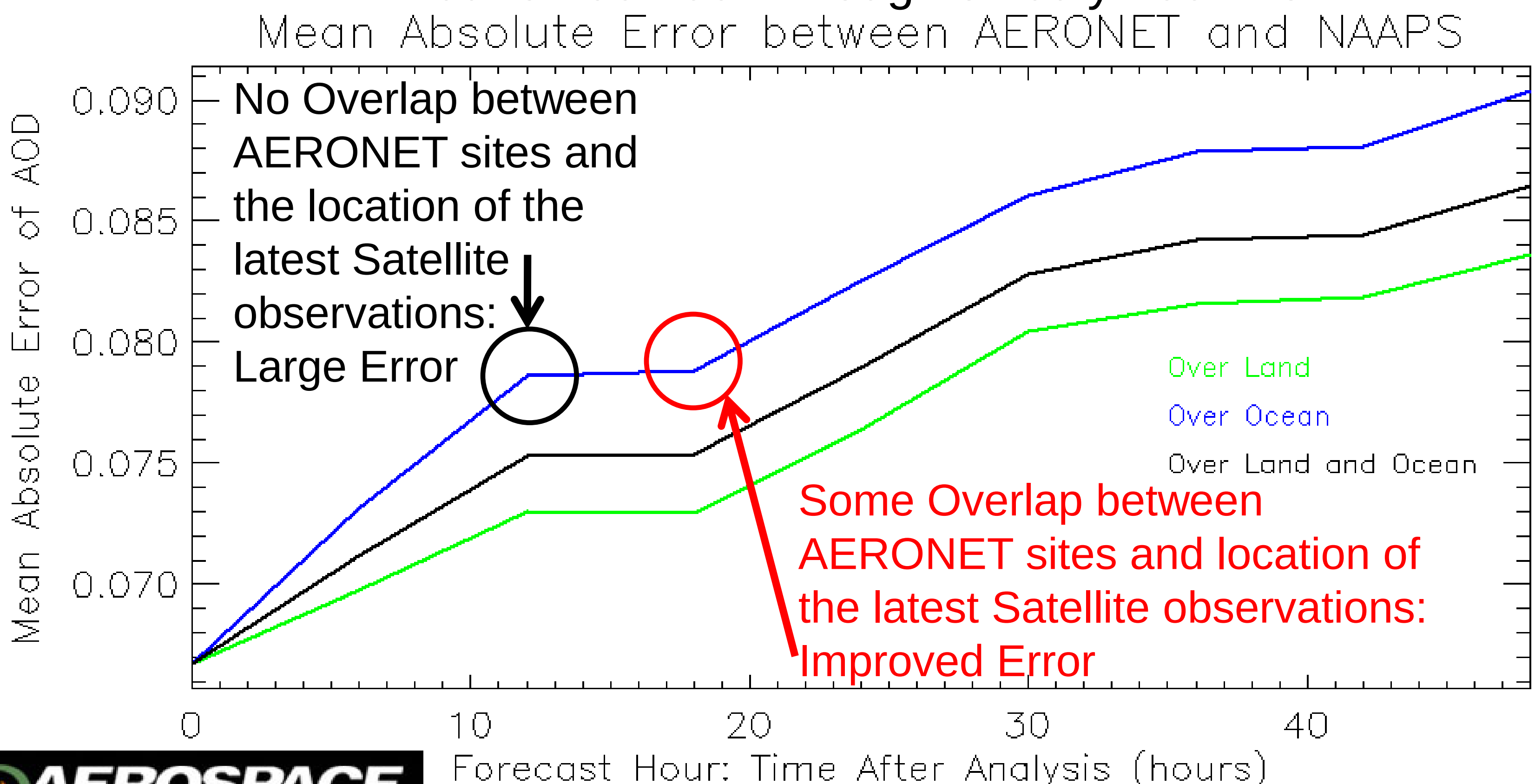
AERONET Comparison

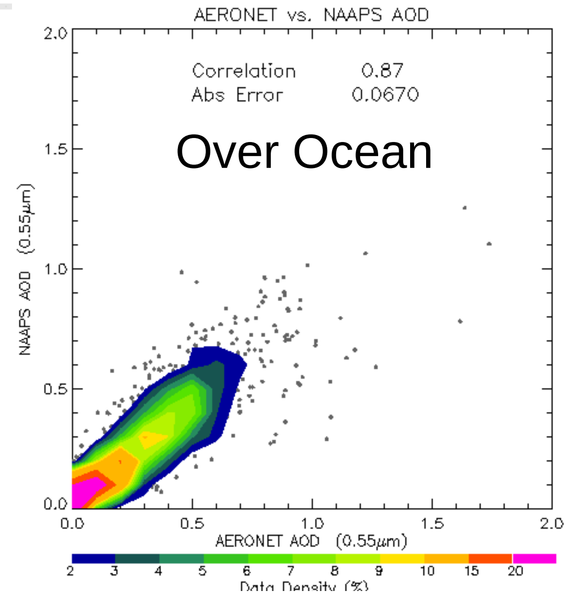
- Method of evaluating NAAPS is the cause of the mean absolute error plateau at the 18 hour forecast

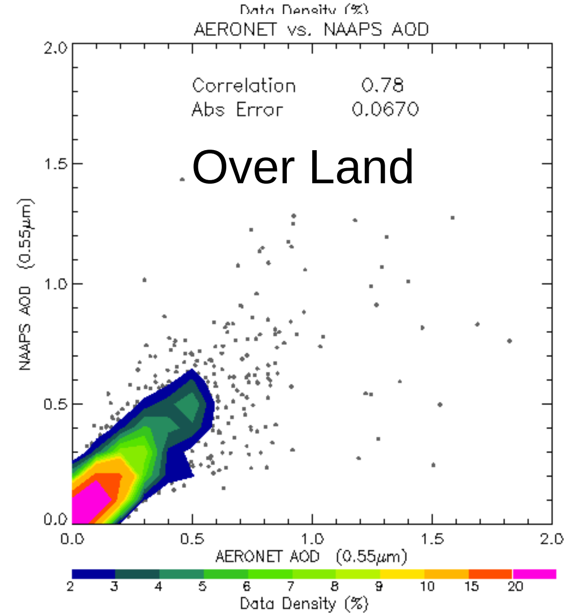
1 June 2007 00z through 31 July 2007 18z



NAAPS OWN Analysis

- Now we understand the NAAPS AERONET comparison results
- Continue with the OWN analysis
- Mean absolute error obtained with OWN analysis is relative to the error in the analysis
  - This is why data assimilation is imperative for the OWN analysis

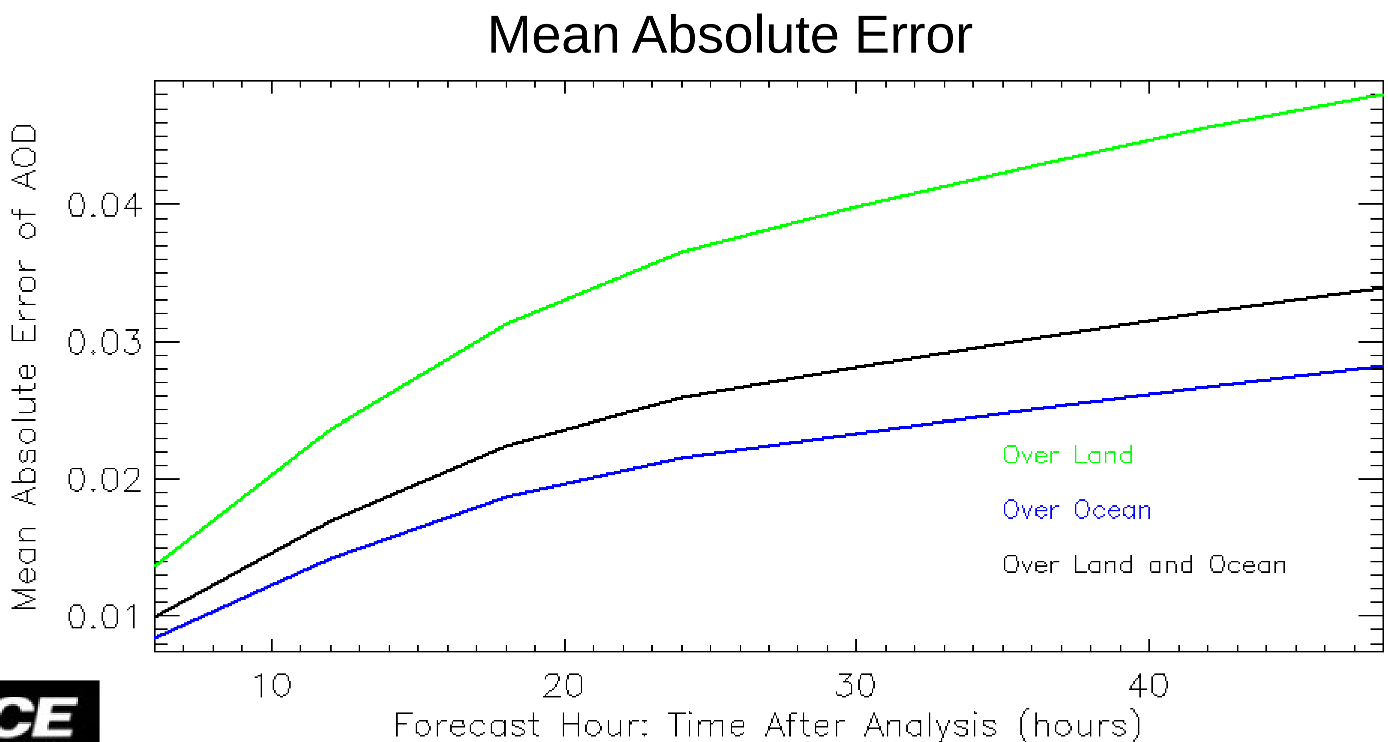




Comparison of NAAPS analyses with AERONET from 01 June 2007 00z to 31 July 2007 18z

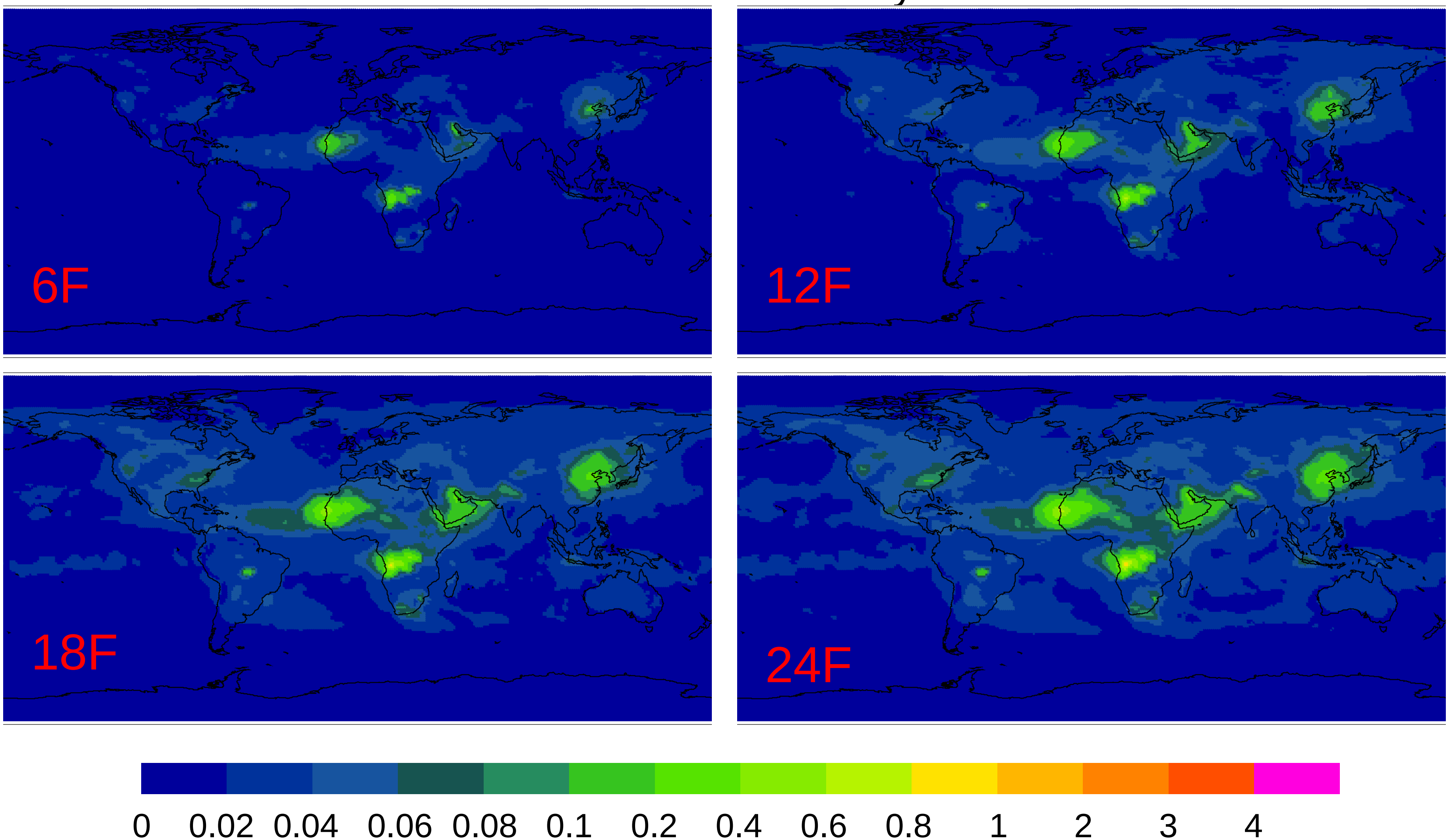
NAAPS OWN Analysis

- Case: 1 June 2007 00z to 31 July 2007 18z
- Mean absolute error increases, as expected
- Can also examine these results graphically
- Visualize regions of error in the model



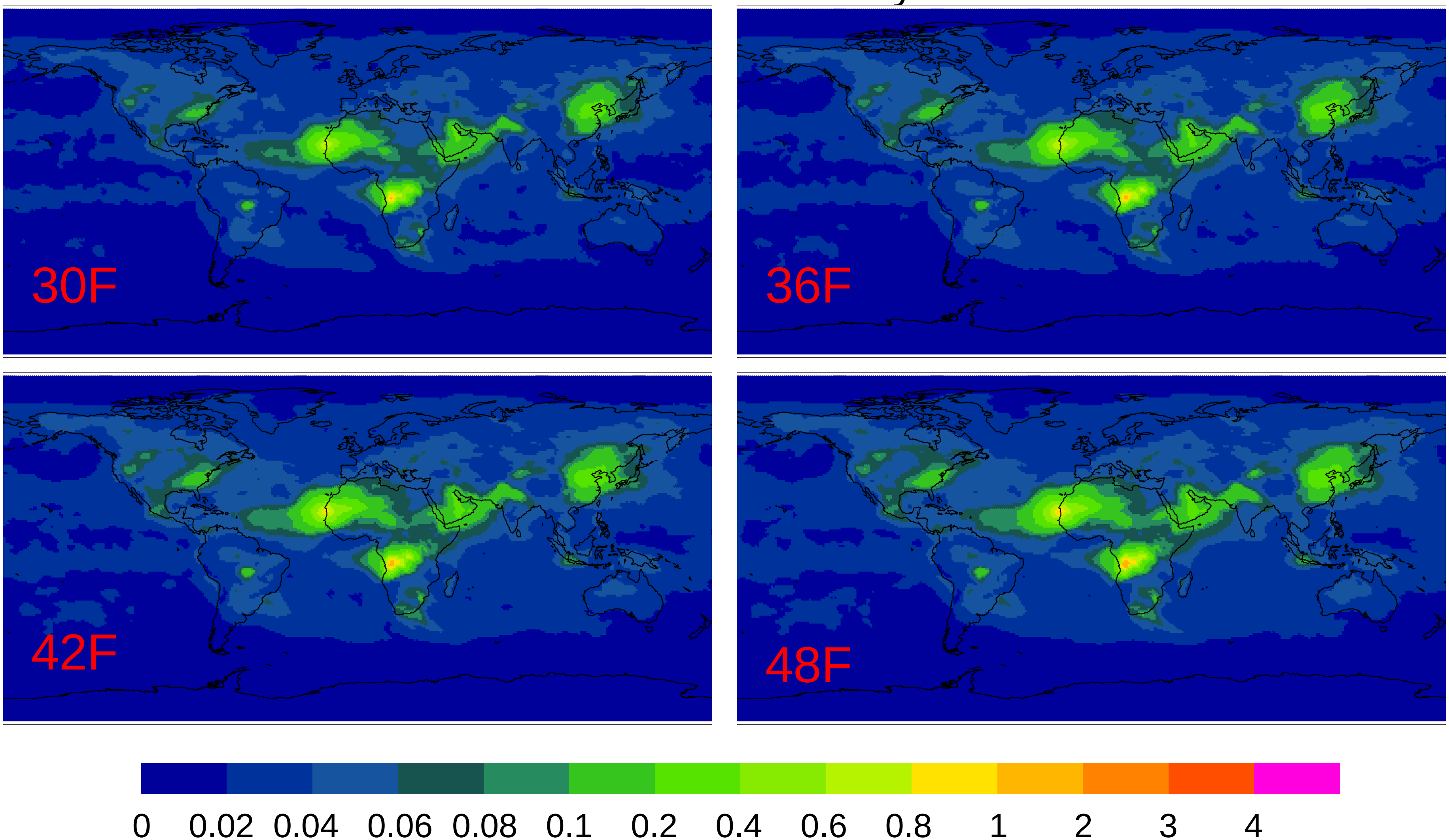
NAAPS OWN Analysis

Mean Absolute Difference in AOD from Analysis
01 June 2007 00z to 31 July 2007 18z



NAAPS OWN Analysis

Mean Absolute Difference in AOD from Analysis
01 June 2007 00z to 31 July 2007 18z

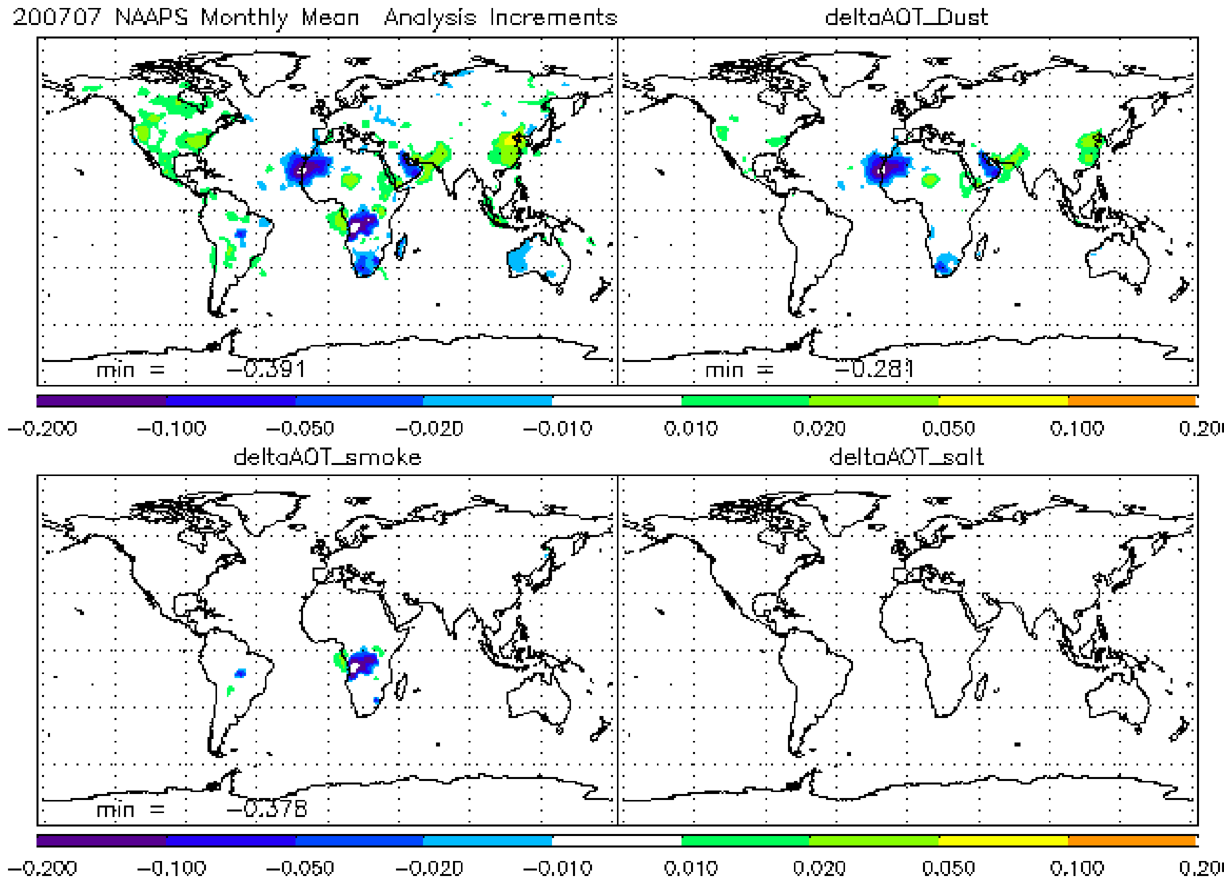


NAAPS OWN Analysis

- OWN analysis shows that error increases with each forecast
- Additionally, there is a relatively large amount of error in major source regions
  – e.g., Africa and East Asia
- Average analysis increments also reveal the source region problem

Average Analysis Increments

- Average analysis increments reveal relatively large error near major source regions
- The OWN analysis has the benefit of examining the regional growth of error uncertainty



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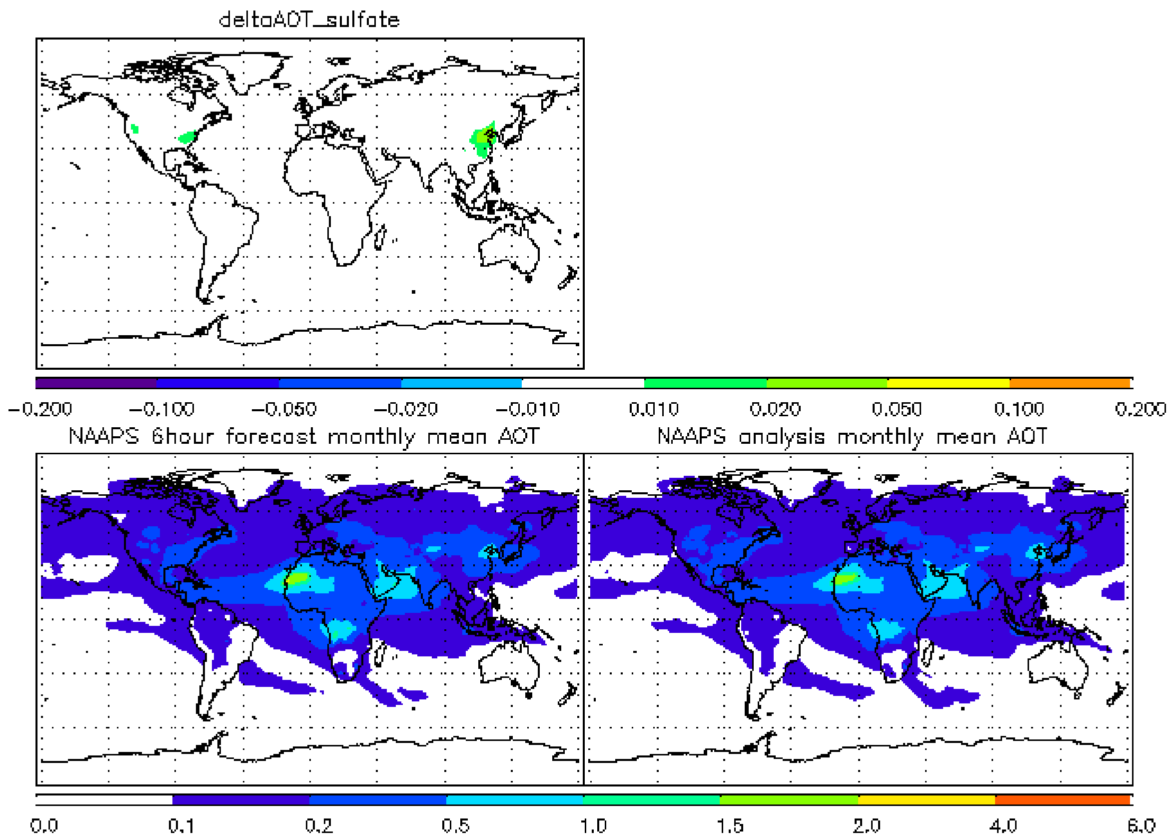
Average Analysis Increments

- Average analysis increments reveal relatively large error near major source regions

- The OWN analysis has the benefit of examining the regional growth of error uncertainty



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Assimilating CALIOP Data

- Satellite data assimilation limits error in NAAPS analyses
- Vertical distribution of aerosols is not obtained with satellite data
- Errors in analysis lead to forecast errors
- Using LIDAR data can provide distribution profiles
  - e.g., **CALIOP**
  - **C**loud **A**erosol-**LI**dar with **O**rthogonal **P**olarization
  - On board the **C**loud-**A**erosol **L**idar and **I**nfrared **P**athfinder **S**atellite **O**bservation (**CALIPSO**) satellite

Assimilating CALIOP Data

- First Step: Obtain 0.532 μm attenuated backscatter (km^{-1} sr^{-1})
  - CALIOP Level 1B product

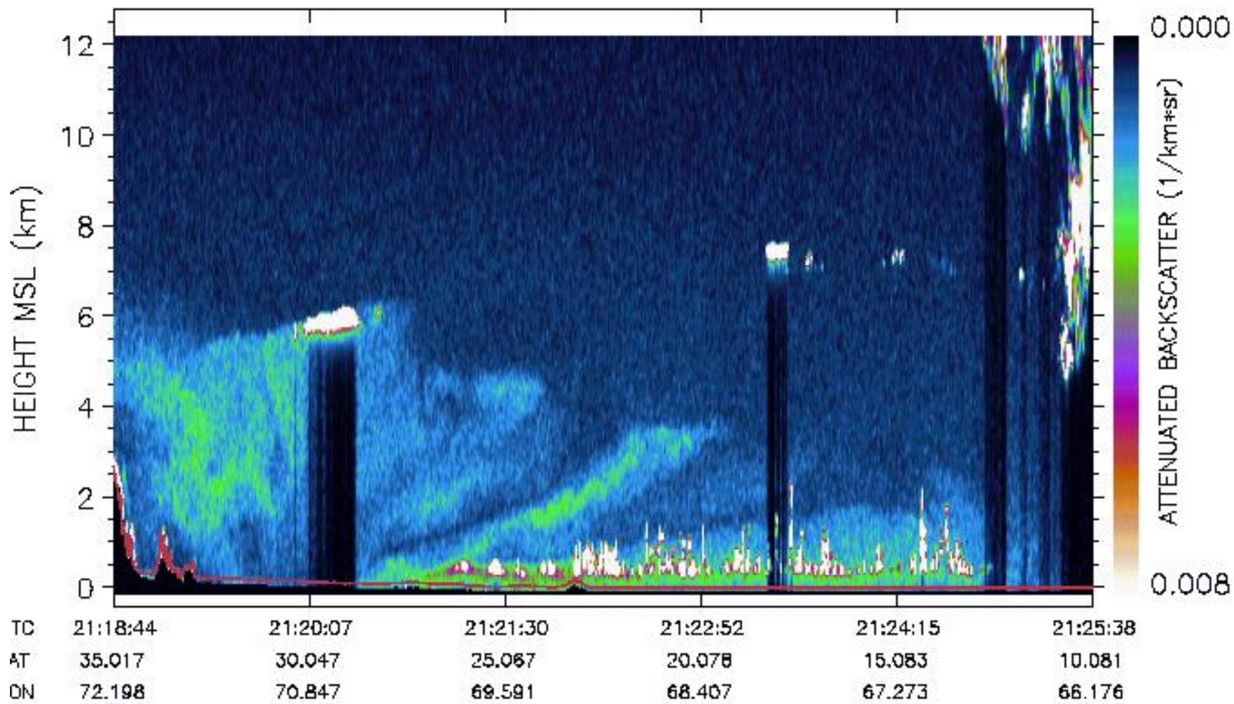

Image from: Zhang et al. (2011)

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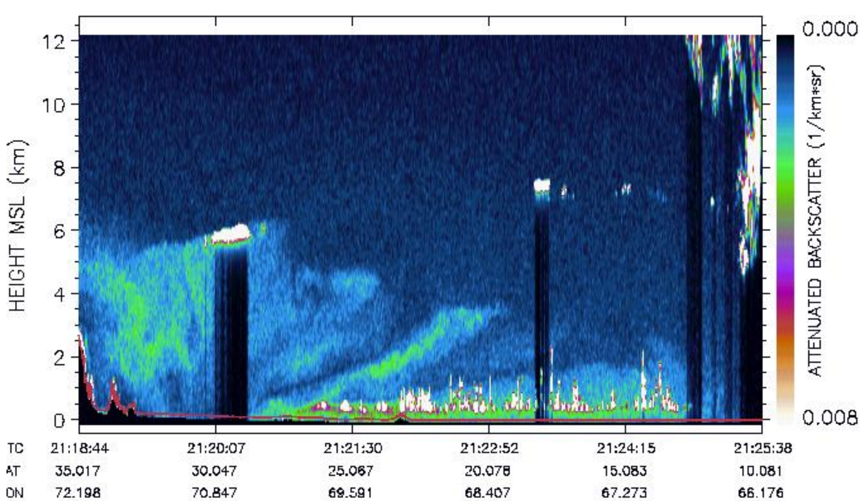
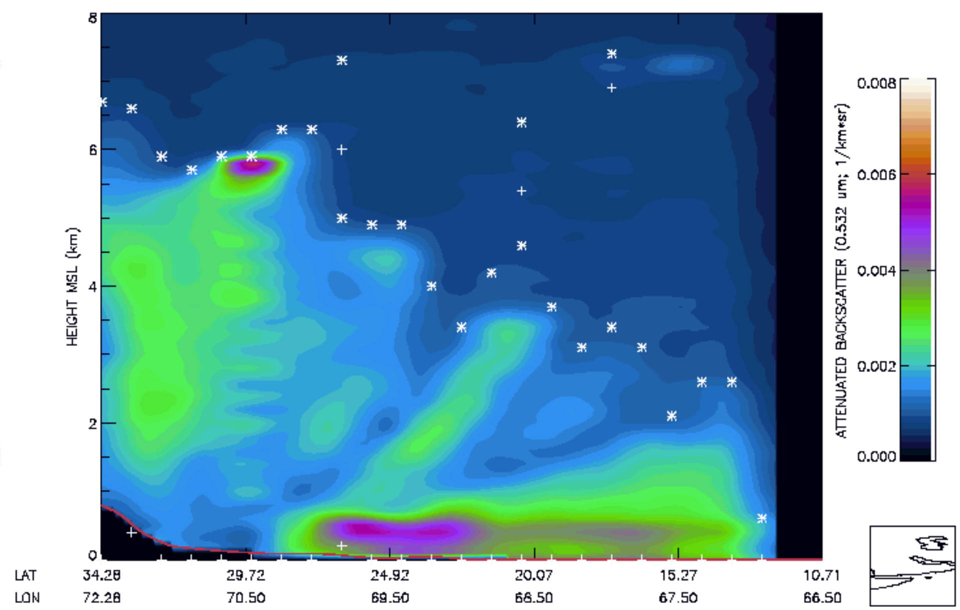
Assimilating CALIOP Data

- Second Step: Cloud Screen and Average
  - NASA-generated Level 2 0.333 km CALIOP cloud detection product
  - 1° along-track averages (to fit with NAAPS resolution)





Images from: Zhang et al. (2011)

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Assimilating CALIOP Data

- Third Step: Convert from attenuated backscatter to extinction coefficient
  - Use the backward Fernald Solution
  - 2D-Var NAAPS analysis AOT is used to estimate total transmission
  - Approximately mass neutral

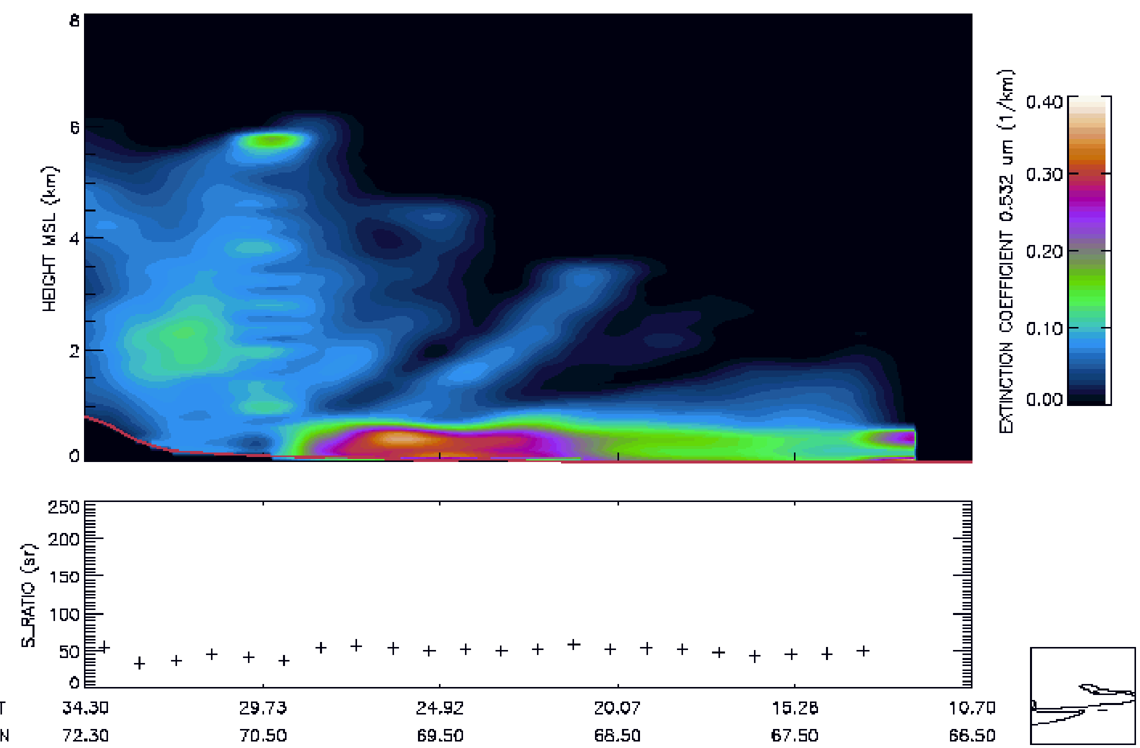
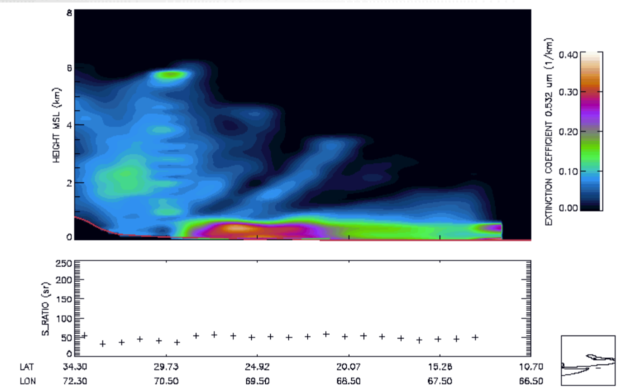


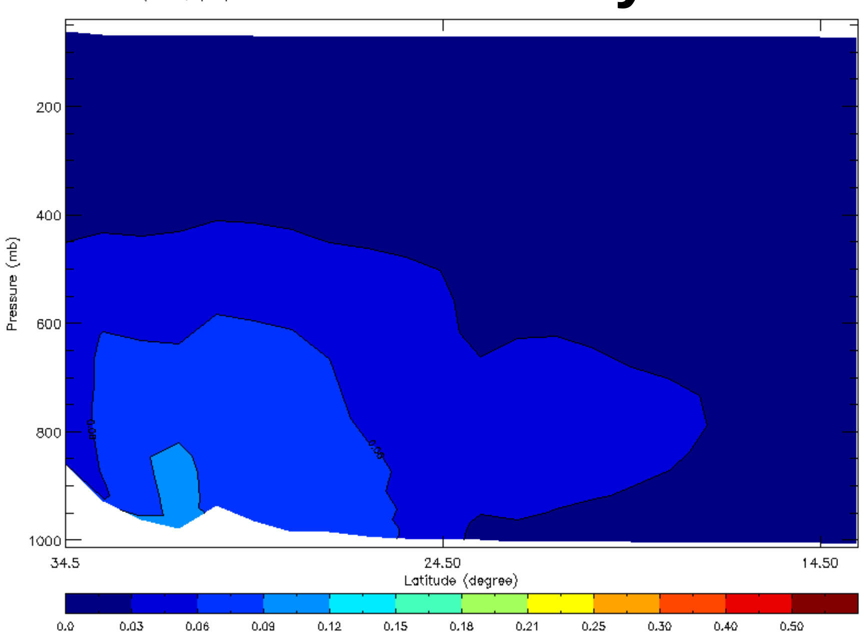
Image from: Zhang et al. (2011)

Assimilating CALIOP Data

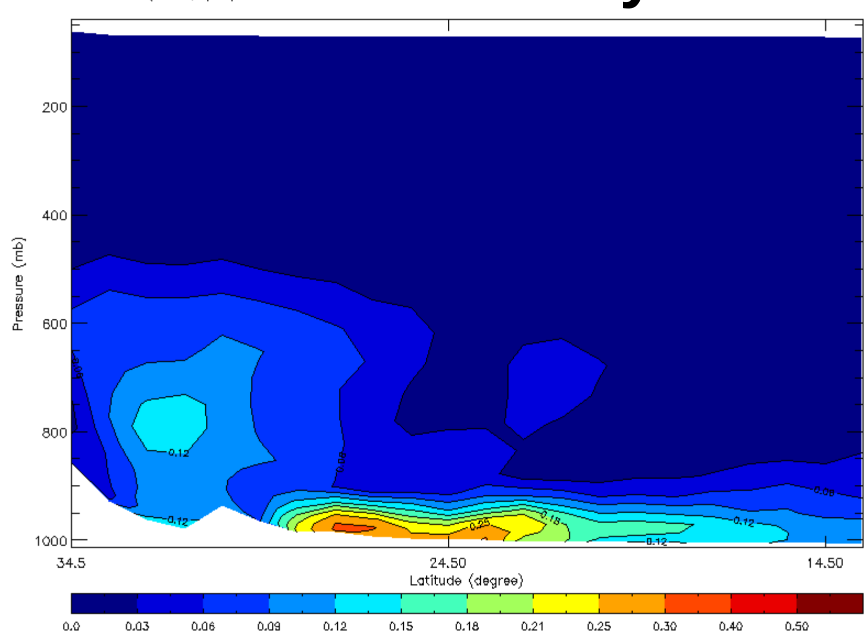
- Fourth Step: Assimilate
- Vertical distribution of AOD is significantly altered



2D-Var Analysis



3D-Var Analysis



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Images from: Zhang et al. (2011)

Assimilating CALIOP Data

- Effect of CALIOP assimilation on NAAPS
  - AERONET Comparison
- CALIOP helped improve NAAPS performance
- Next step: perform OWN analysis in regions close to the LIDAR path

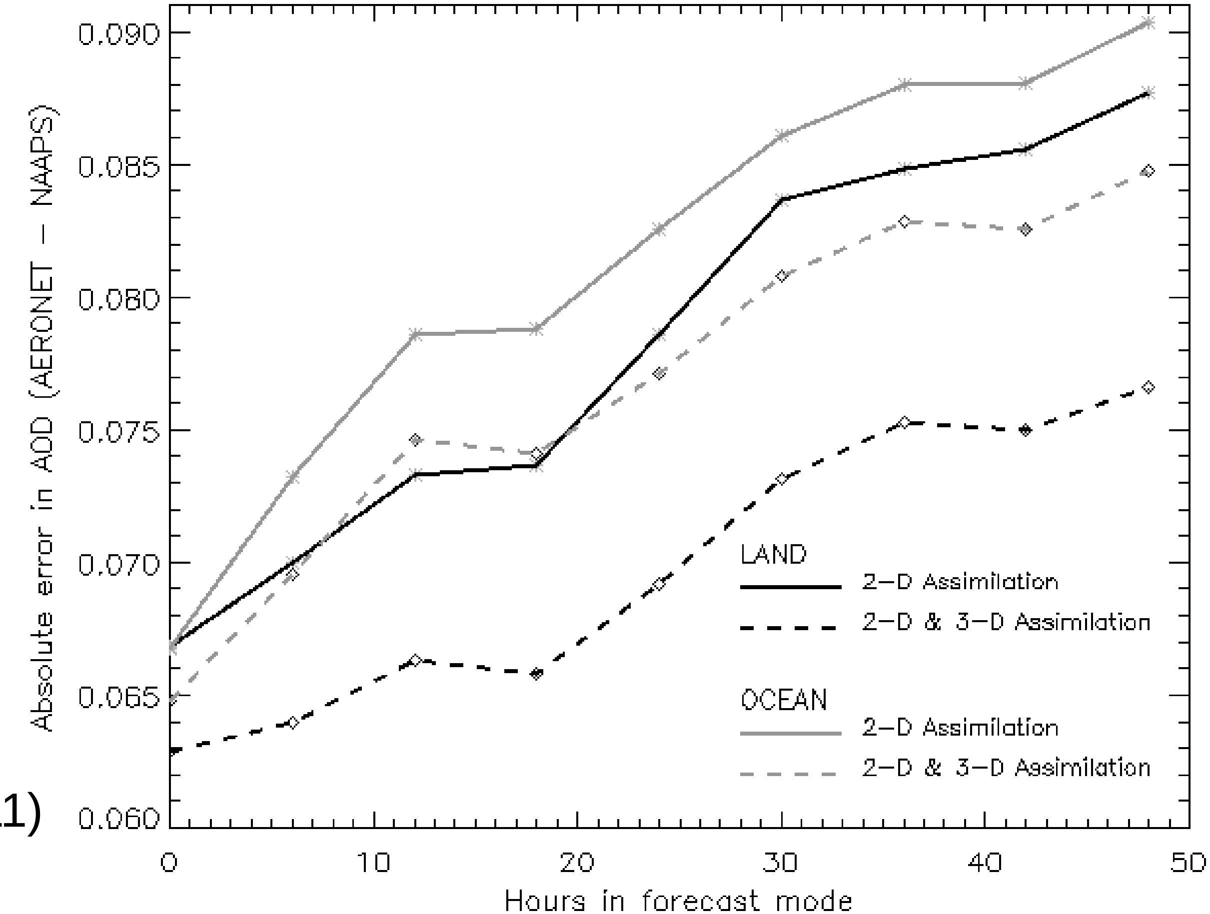

Image from: Zhang et al. (2011)

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Summary

- Generated OWN analysis method of evaluation
  - Goal: conveniently check model performance
- Tested OWN analysis idea with AERONET data
  - Anomalous behavior in mean absolute error of AOD
  - Error plateaus: 12-18 hour and 36-42 hour forecasts
  - Caused by selective evaluation: the locations of the AERONET stations relative to the locations of the most recently assimilated satellite data
- OWN analysis for 01 June 00z to 31 July 18z 2007
  - Increase in mean absolute error with forecasts
  - Relatively large error in major source regions of aerosols

Summary

- Data assimilation limits error in analyses
- Satellite data assimilation
  - No information about the vertical distribution of aerosols
  - Lack of this information leads to more error
- LIDAR data assimilation
  - Does provide vertical distribution information
  - Can help make analyses more accurate
- Next Step: Perform OWN analysis only in regions near the LIDAR path

Selected References

- Campbell, J. R., J. S. Reid, D. L. Westphal, J. Zhang, E. J. Hyer, and E. J. Welton, 2010: CALIOP aerosol subset processing for global aerosol transport model data assimilation. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, **3**, 203-214.
- http://aeronet.gsfc.nasa.gov
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- Zhang, J., J. R. Campbell, J. S. Reid, D. L. Westphal, N. L. Baker, W. F. Campbell, and E. J. Hyer, 2011: Evaluating the impact of assimilating CALIOP-derived aerosol extinction profiles on a global mass transport model. *Geophys. Res. Lett.*