Apr 16, 2008
8:27:40pm

THE BENEFITS OF SPACEBORNE LIDAR DATA FOR ATMOSPHERIC COMPOSITION PREDICTION

Angela Benedetti

n collaboration with: James Campbell (NRL), Pete Colarco (NAS
ke Jones (EMCWF), Anne Caroline Lange (Uni Koln), Jeff Reid (N
Juli Rubin (NRL), and Thomas Sekiyama (MRI)

CALIPSO-CloudSat Ten Year Progress and Path-Forward
Maison des Océans, Paris **June 10, 2016**

FIRST OF ALL

- Congratulations to CALIPSO and CloudSat on their 10th anniversary of operations!

- Both instruments have been game changers in the cloud and aerosol panorama

- Success stories made also of patient work to improve the products and/or offer new products tailored-made to the needs of the user community

- Set a great paradigm for future active sensing missions

So, THANK YOU CALIPSO and CloudSat!!!!!!!

OUTLINE

- Motivation
- Aerosol forecast evaluation with lidar data
- Overview of lidar data assimilation efforts
- Current challenges and future perspectives

Atmospheric composition is a pivotal element between human activities and the Earth Environment

emissions

mitigation

aerosol

ozone PM

greenhou

NOx se gases

air quality

climate chan

ozone hole

numerical weat

prediction

exposure

adaptation

impacts

Why?

Atmospheric composition and its changes affect our health

Copernicus

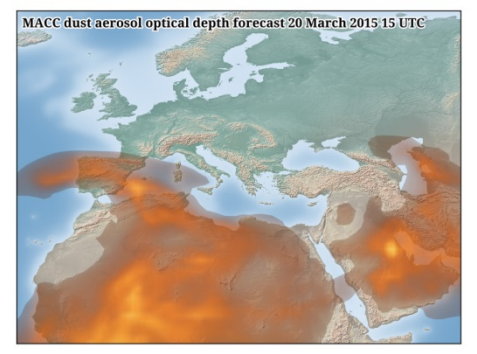
ECMWF

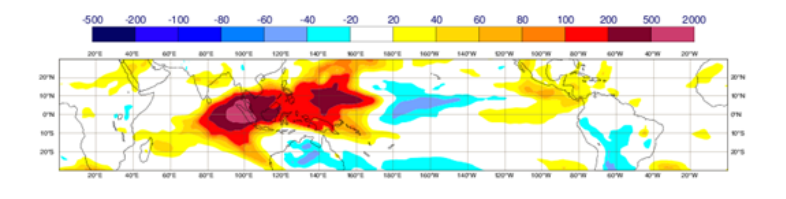
MOTIVATION

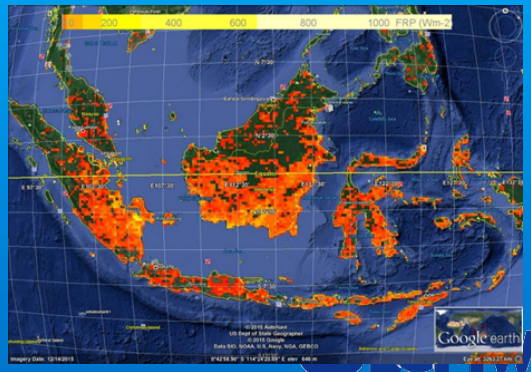
- Atmospheric composition prediction has developed greatly over the last 10 year

- Several operational centres run aerosol forecasts and analysis on a daily basis (ECMWF/Copernicus Atmosphere Monitoring Service, NASA, NCEP, NRL, JMA, BSC).

- Societal applications vary from air quality forecasts and solar energy management to health and severe event preparedness (dust storms, volcanic ash, biomass burning)





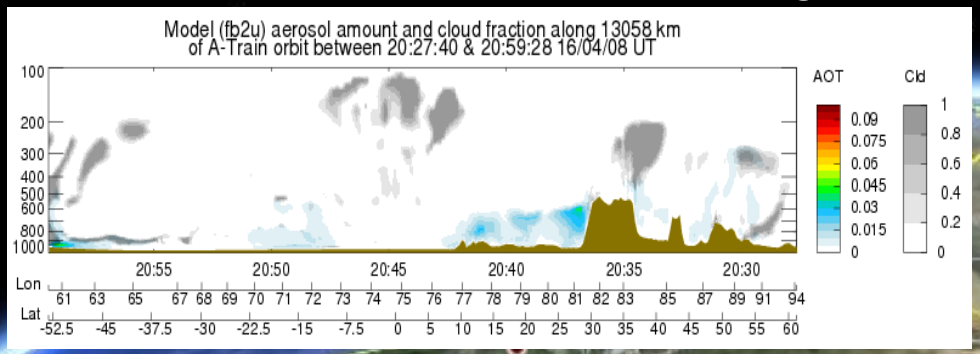


AEROSOL FORECAST VERIFICATION USING LIDAR DATA

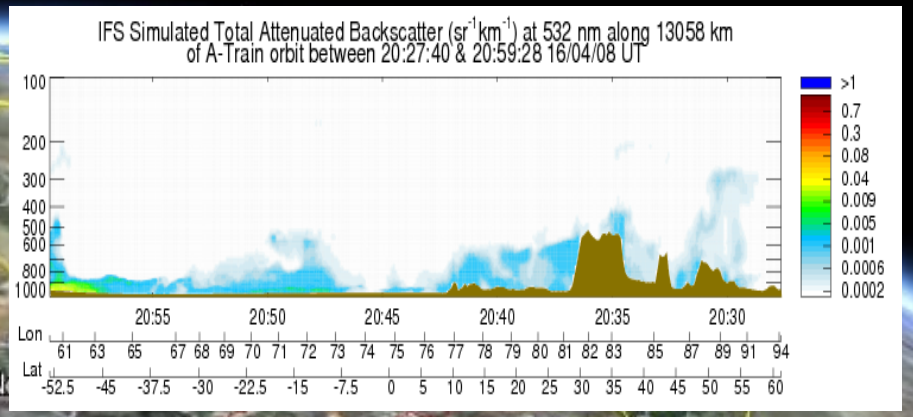
ECMWF

COMPARISONS OF MACC/ECMWF MODEL RUNS WITH LIDAR OBSERVATIONS FROM CALIOP

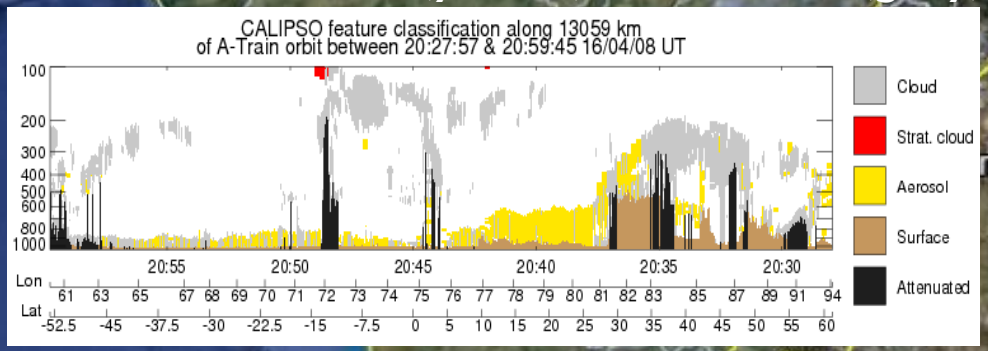
Model aerosol (color) and clouds (grey)



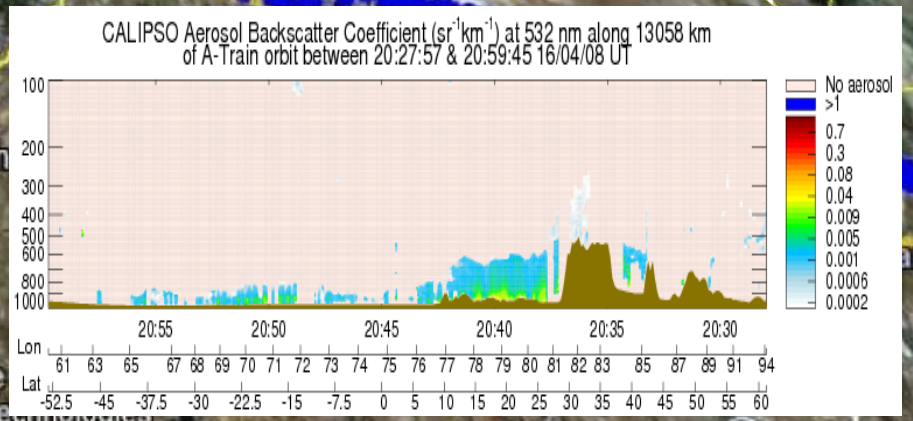
Model aerosol backscatter (sr-1 km-1)



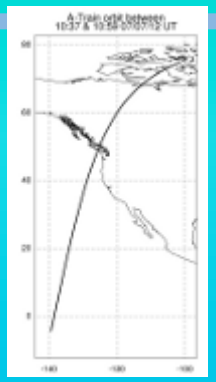
Observed aerosol (yellow) and clouds (grey)



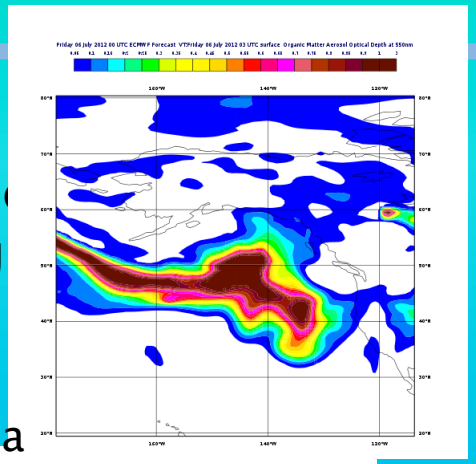
Observed aerosol backscatter (sr-1 k



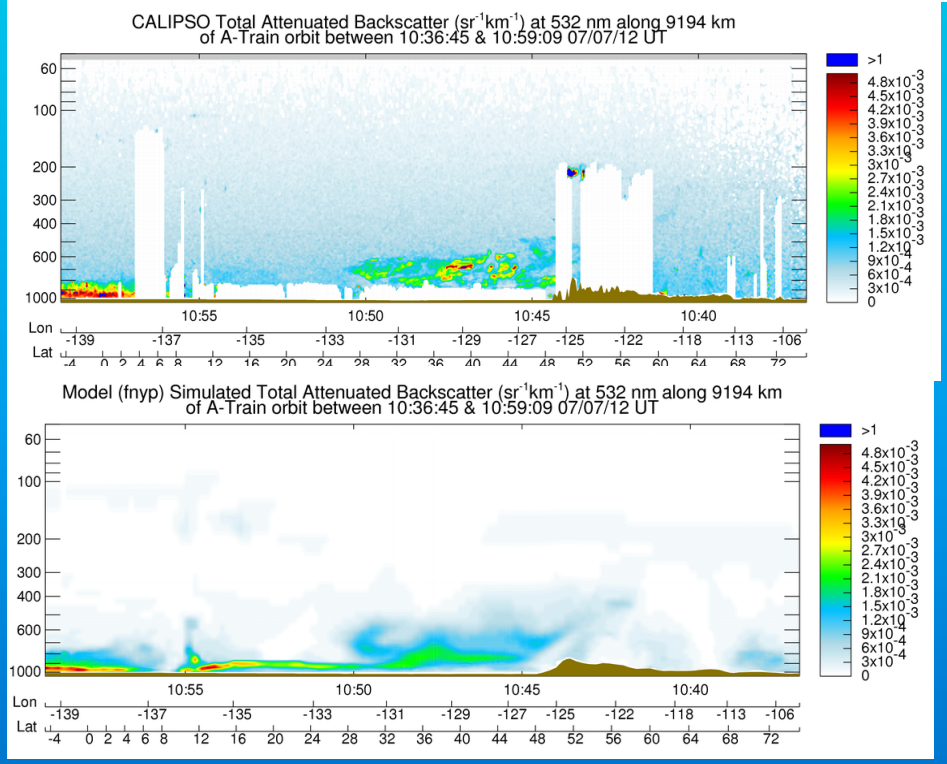
Siberian Smoke in Seattle July 2012

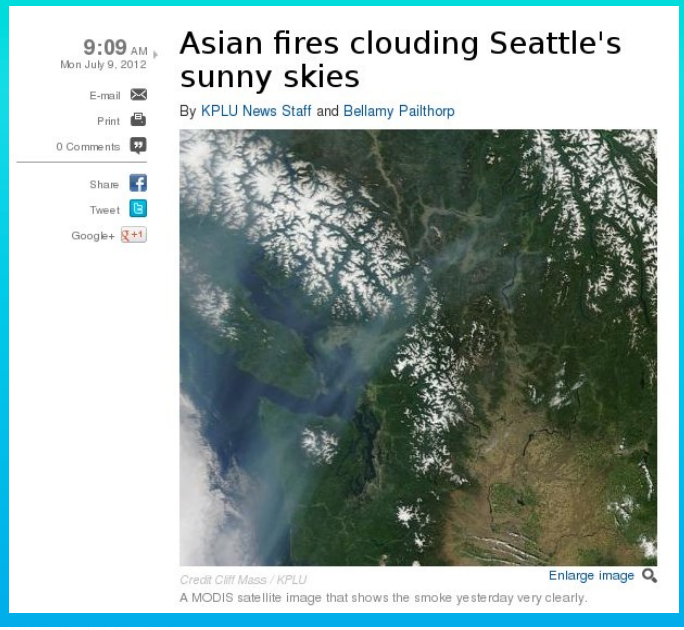


Modelled smoke plume approaching Seattle



Verification with CALIPSO data





9:09 AM
Mon July 9, 2012

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Print
0 Comments
Share
Tweet
Google+

Asian fires clouding Seattle's sunny skies

By KPLU News Staff and Bellamy Pailthorp

Credit Cliff Mass / KPLU

Enlarge image

A MODIS satellite image that shows the smoke yesterday very clearly.

Updated Jul 9, 2012 - 3:11 pm

Wildfires in Asia to blame for hazy sunsets

By Tim Haeck
97.3 KIRO FM Reporter

Comments (2) | Print | E-mail | +1 0 | Tweet 1

Haze at sunrise at Mount Pilchuck. (Photo courtesy Josh Thayer-Facebook)

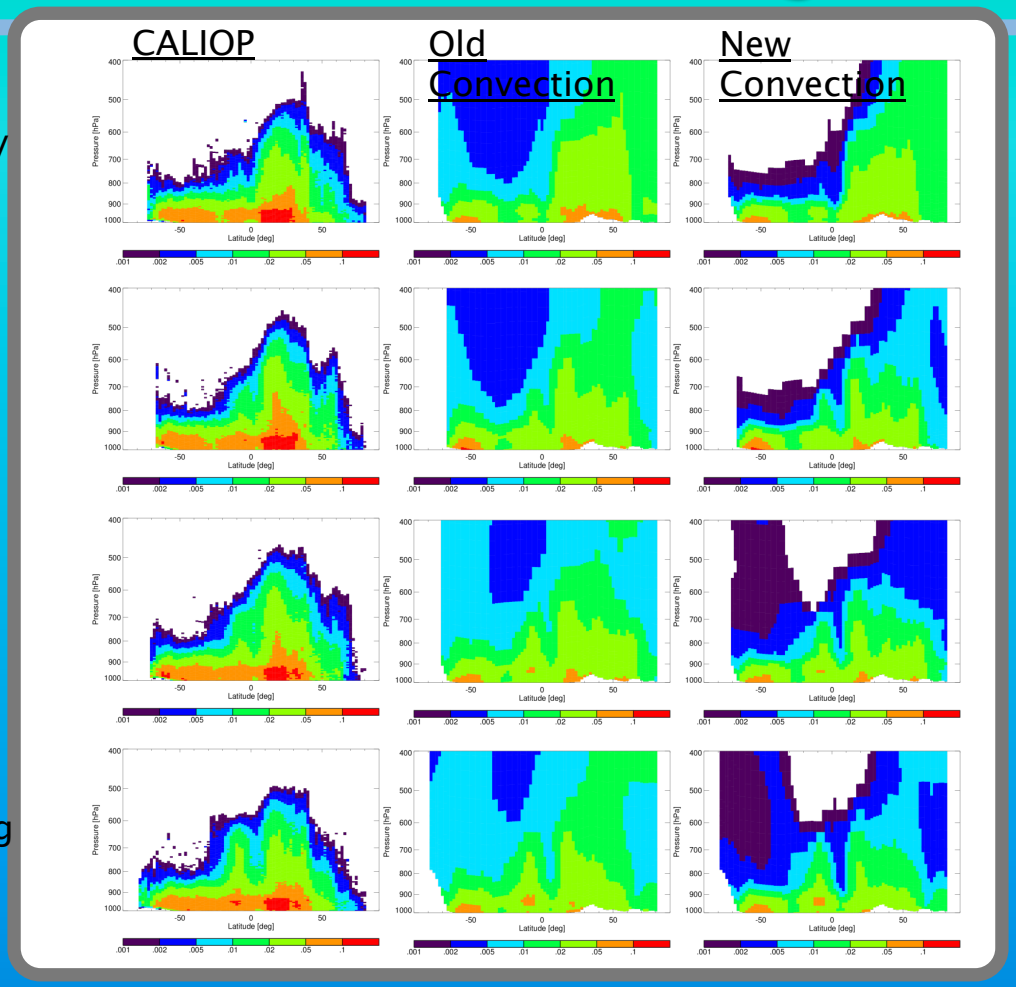
You might have noticed a haze in the skies of Western Washington, particularly at sunset the last several days.

At first, Cliff Mass, University of Washington Professor of Atmospheric Sciences, thought it was smoke from massive wildfires in Colorado circulating in the upper atmosphere and into our area.

"And then finally, when I did a little investigation, it became clear it was from Asia. It was from major fires over Asia and that smoke went all the way across the Pacific into us," said Mass.

ECMWF

Model evaluation with lidar data: Update to Convection Algorithms

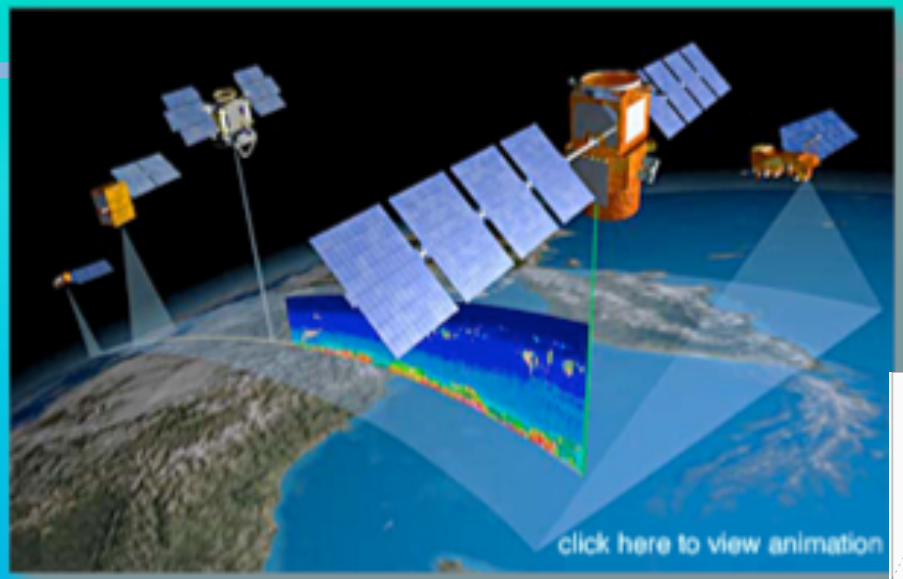


- Comparison of offline and online instances of GOCART revealed discrepancies in implementation traced to online convective scavenging

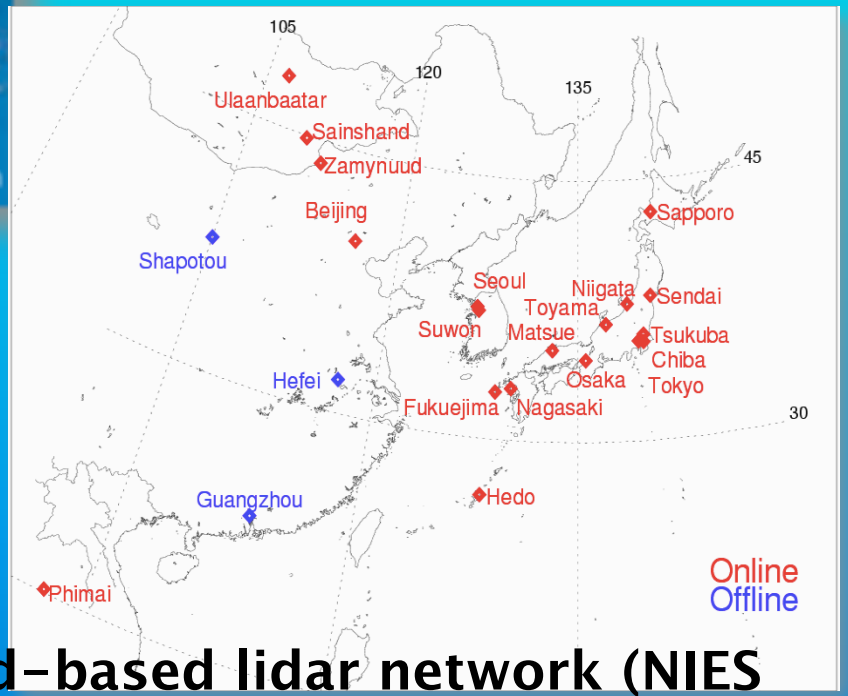
Credits: Pete Colarco, NASA

LIDAR ASSIMILATION ACTIVITIES

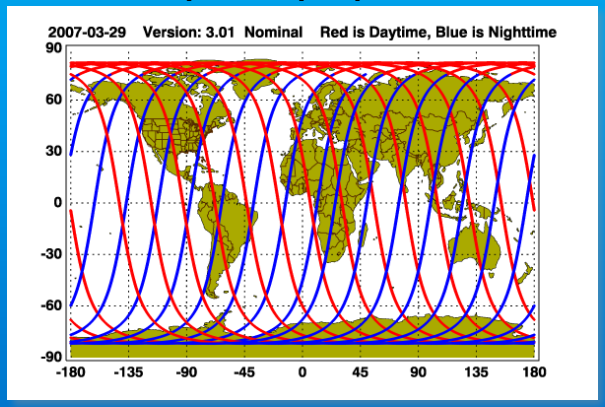
Assimilation of CALIPSO Data



Satellite Lidar observation (CALIPSO/CALIOP): NASA launched the polar-orbit satellite in 2006.



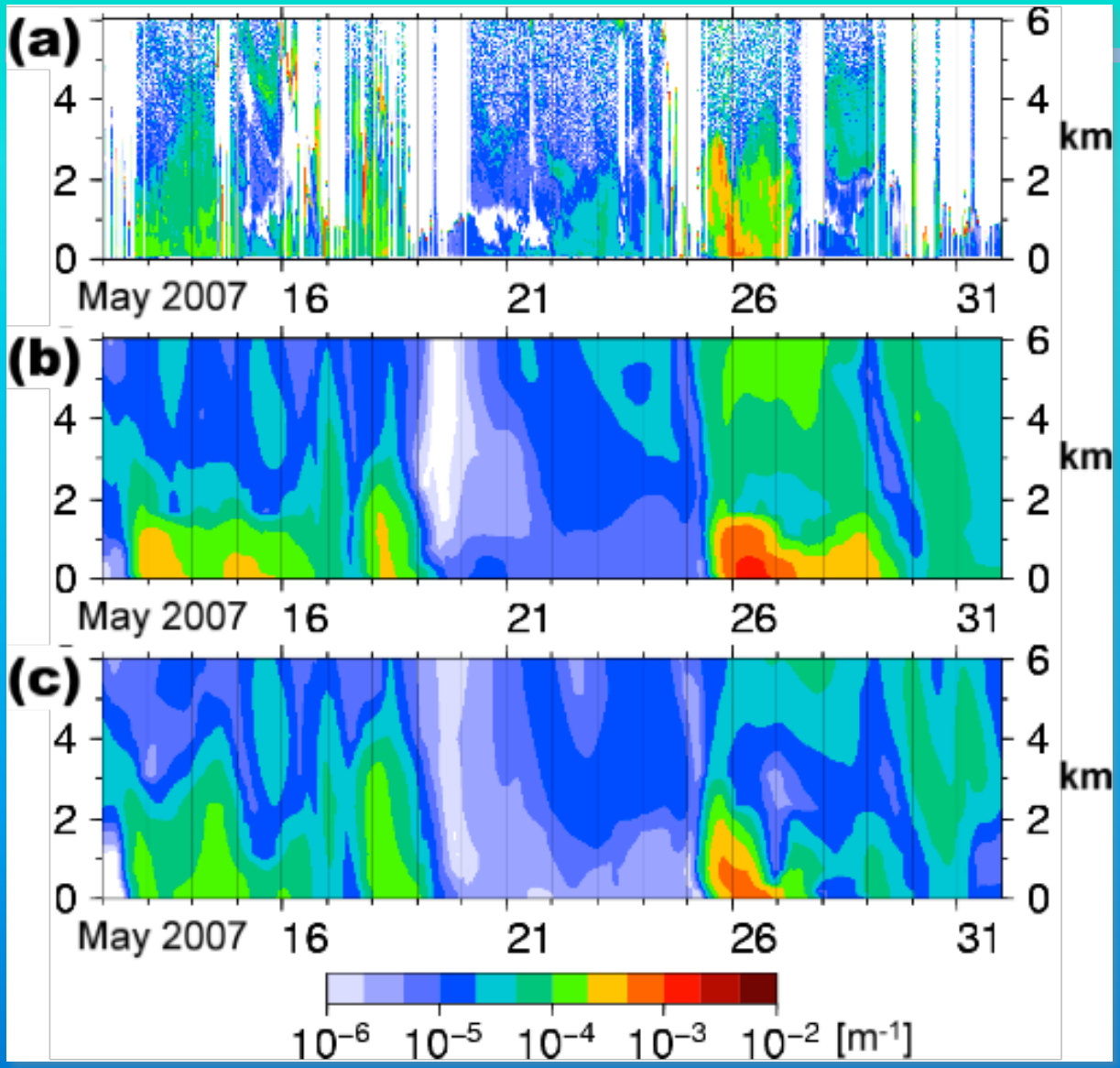
- The CALIPSO orbit has an about 1000 km longitudinal interval per day at mid-latitudes.
- Data density: very sparse horizontally, but



Ground-based lidar network (NIES AD-Net): NIES Japan is operating more than 20 lidar stations in East Asia.

Credits: Thomas Sekiyama, MRI

Assimilation of CALIPSO Data



Comparison of 532nm extinction coefficients for **dust aerosol.**

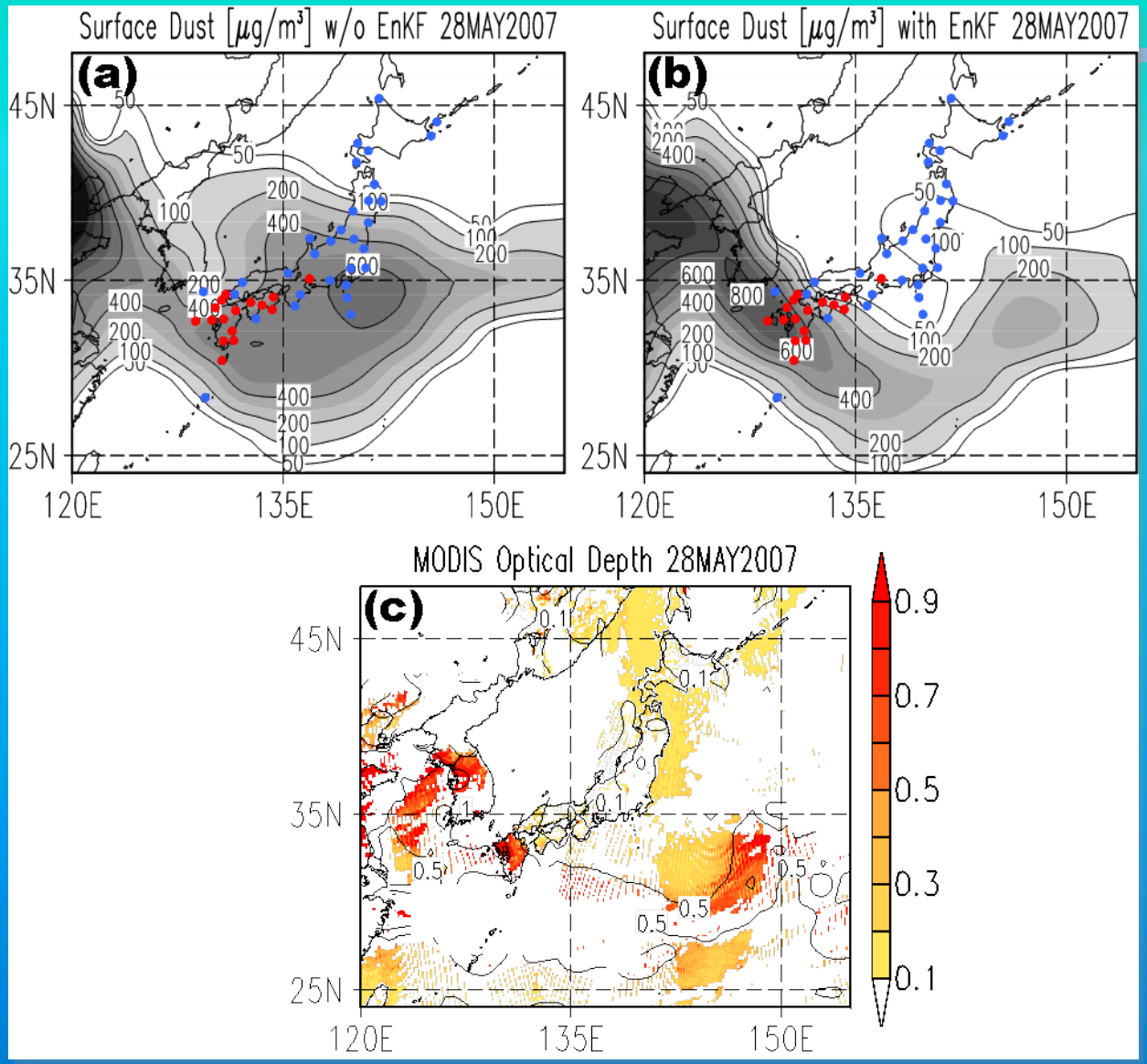
(a) Independent ground-based lidar observations at Matsue, Japan;

(b) free model-run results without data assimilation;

(c) CALIPSO **data assimilation results** using EnKF

Sekiyama et al., ACP (2010)

Assimilation of CALIPSO Data



The contours and gray shades are **surface dust concentrations**.

(a) Free model-run result without data assimilation.

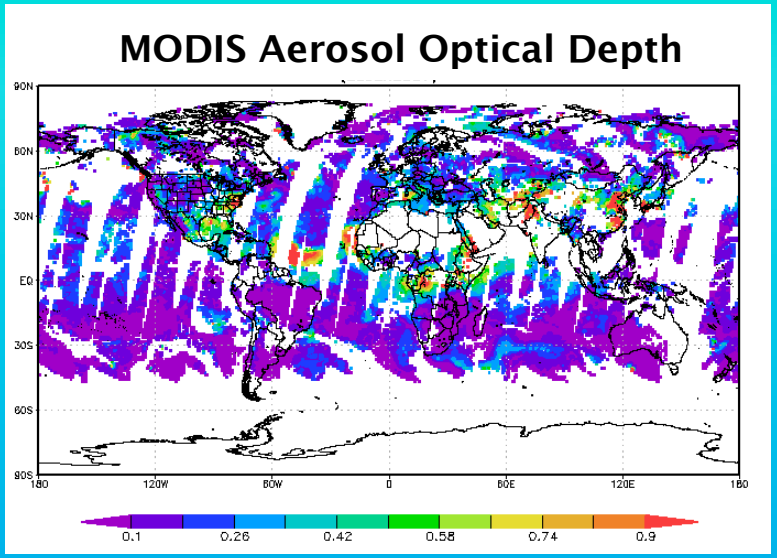
(b) CALIPSO data assimilation result.

Red and blue circles are weather stations. The Red ones observed aeolian dust on the day. Blue ones did not observe any dust events.

(c) MODIS AOT on the same day.

Sekiyama et al., ACP (2010)

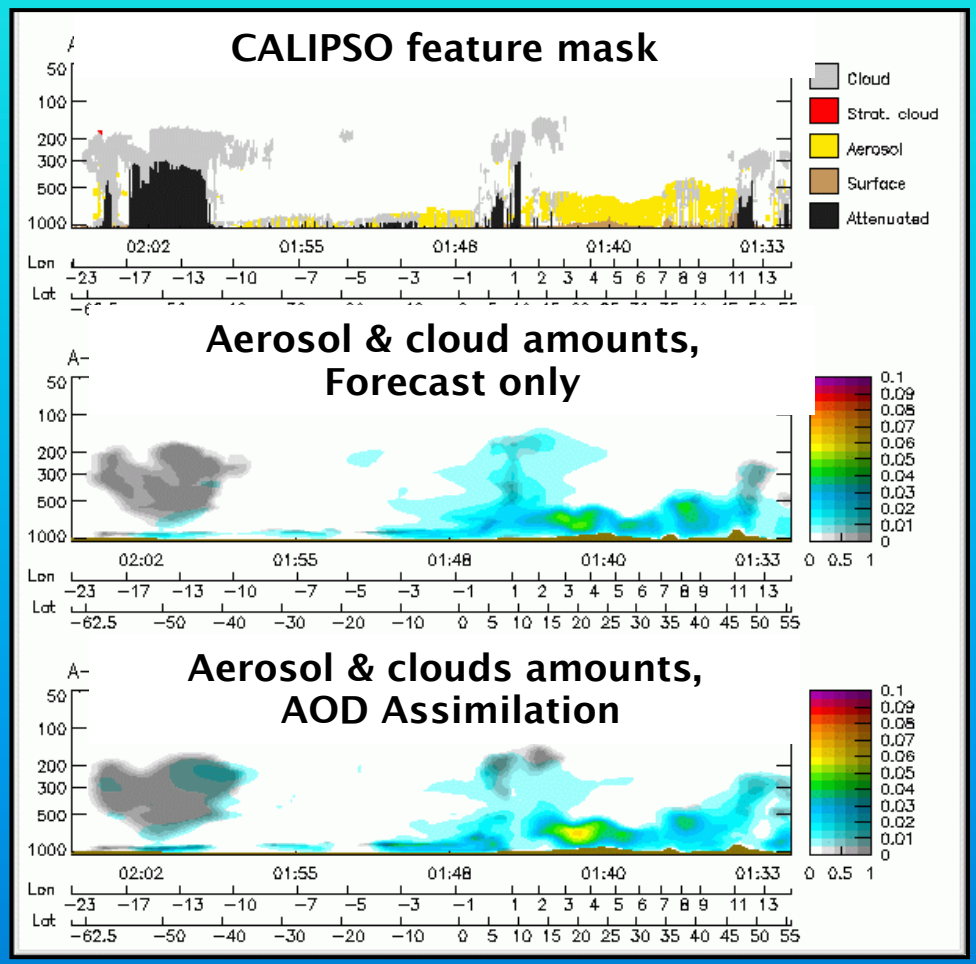
Rationale for lidar assimilation (1)



- The assimilation is driven by AOD which is a column-integrated quantity

- Assimilation of AOD modifies the aerosol mass but not its vertical distribution

- Profile data are needed (lidars from satellite for assimilation and ground-based for verification)



Credits: Luke Jones and Jean-Jacques Morcrette

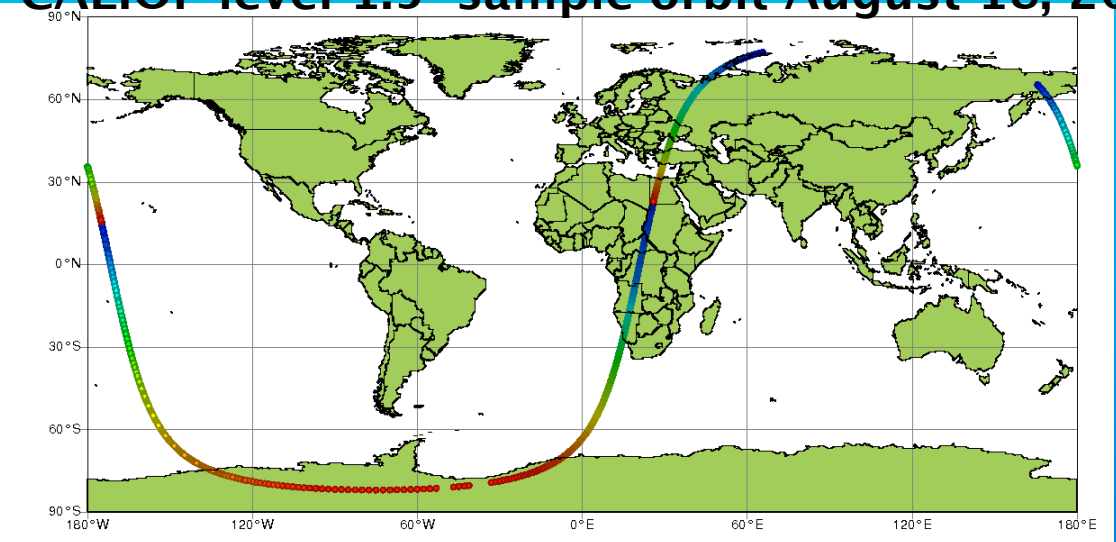
ECMWF

Expedited CALIOP data for 4D-Var assimilation

- Mean and Median Attenuated aerosol backscatter at 532 nm
-Standard deviation
-cloud-cleared at 1km resolution
-averaged at 20 km horizontal resolution
-60m vertical resolution
-Feature mask
-Some indication of aerosol typing

This product has been custom-made for NRT (expedited) provision and assimilation at operational centres.

CALIOP level 1.5 sample orbit August 18, 2010

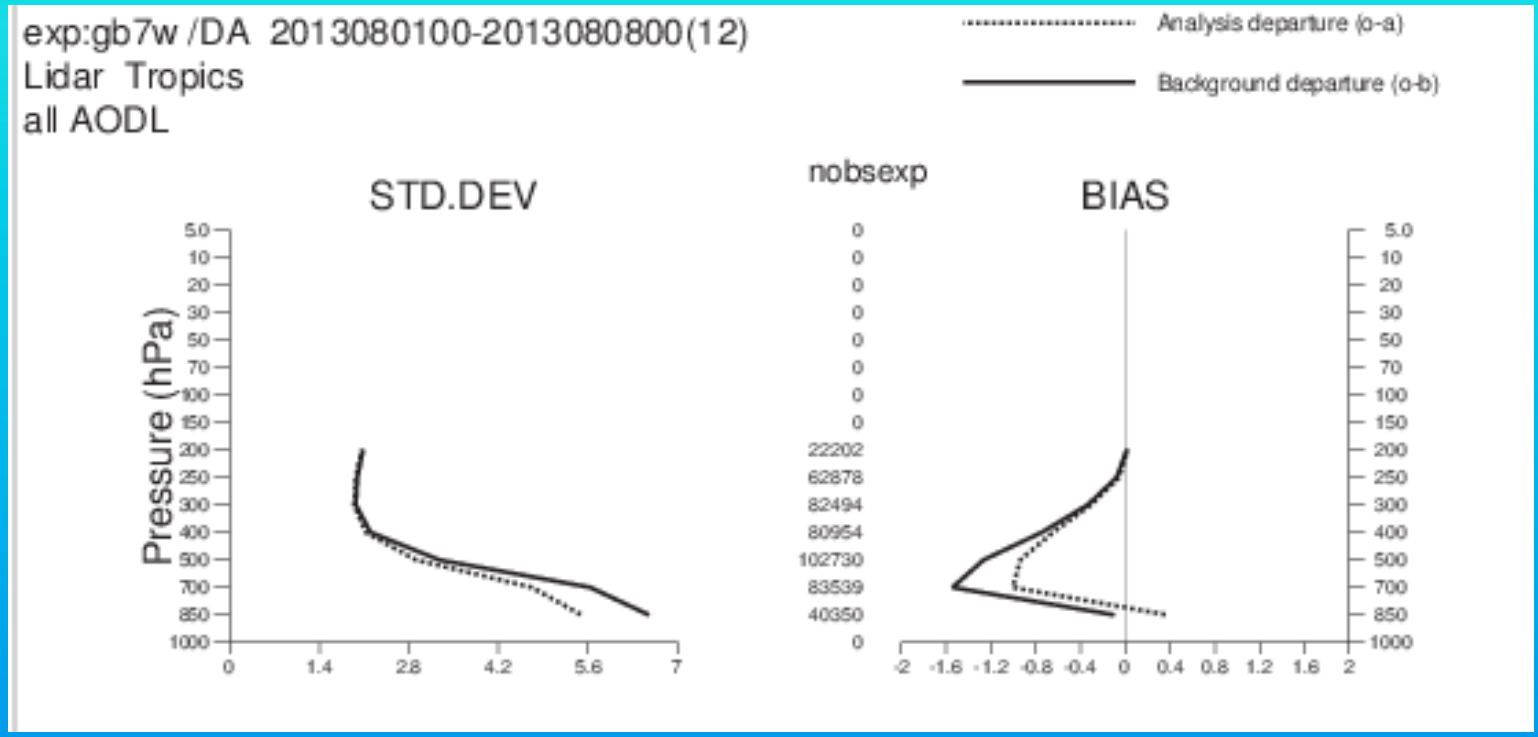


- Thinned to 900 profiles (originally 1800)
- 345 vertical levels
- ~200000 backscatter observations actively assimilated over the 4DVAR 12-hour window

Acknowledgements:
NASA LarC CALIPSOTeam (Dave Winker, Chip Trepte, Jason Tackett)

ECMWF

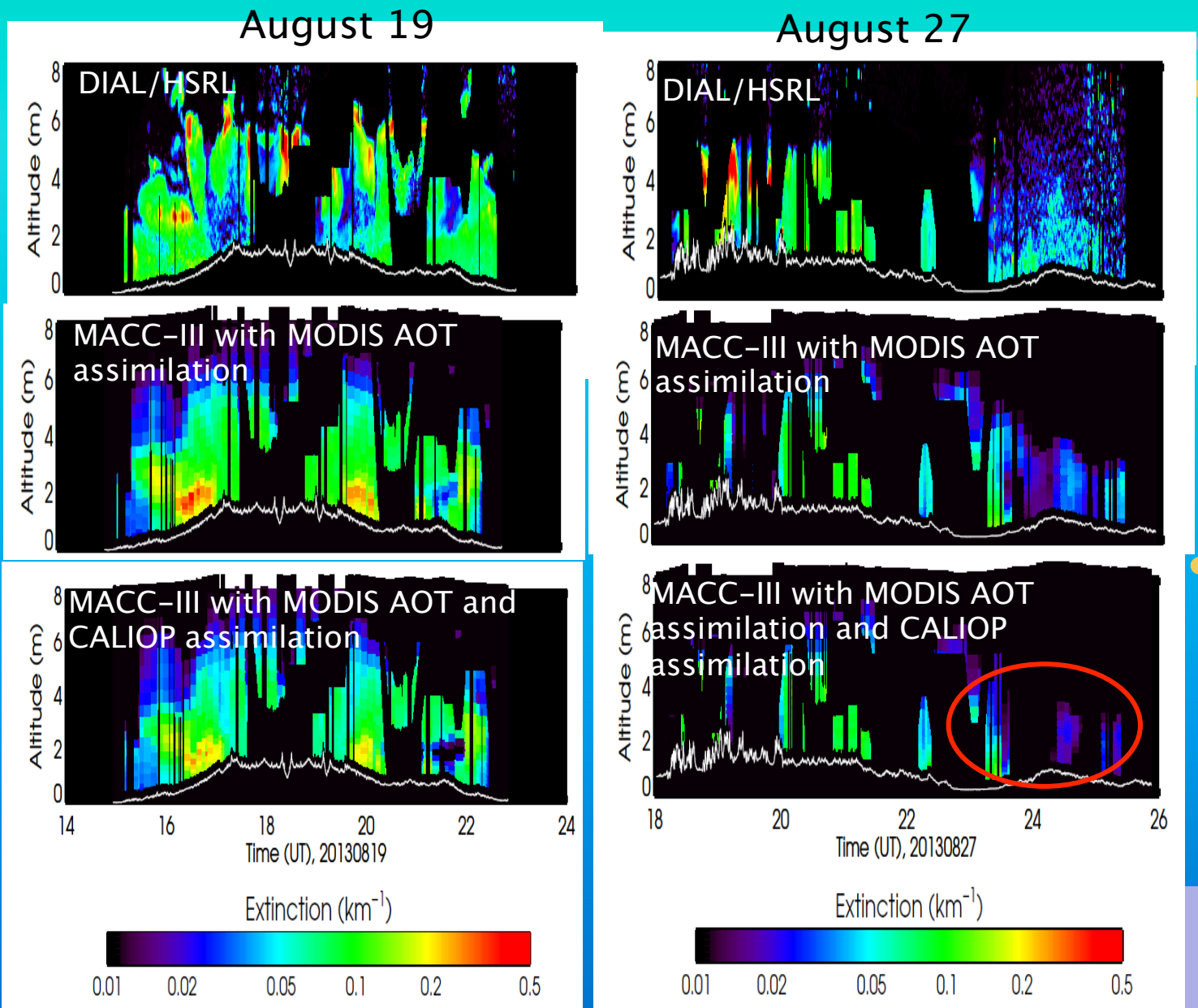
Assimilation experiments with lidar data



Lidar backscatter x 1e7 (sr m)-1

- Data: all operational data plus MODIS AOD and CALIOP Level 1.5 backscatter
- Both CALIPSO and MODIS are bias-corrected online using the varBC approach. Bias estimate is based on first guess departures (difference between model first guess and observations)

Evaluation of CALIOP profile assimilation using HSRL data



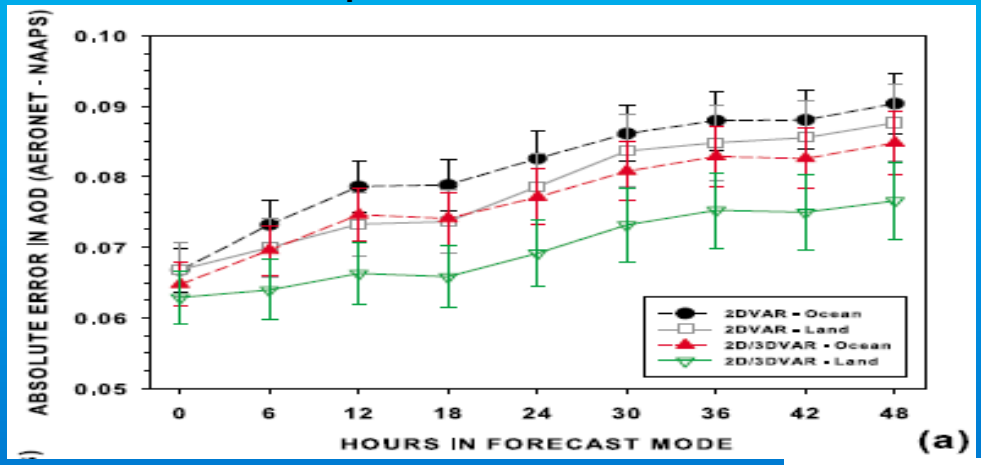
- Assimilation of CALIOP profiles slightly reduces extinction profiles in some locations; largest extinction values remain near surface
- Depending on location, these reductions can improve or worsen agreement with HSRL

Credits: Sharon Burton and Rich Ferrare, NASA Langley

Rationale for lidar assimilation (2)

Navy Application

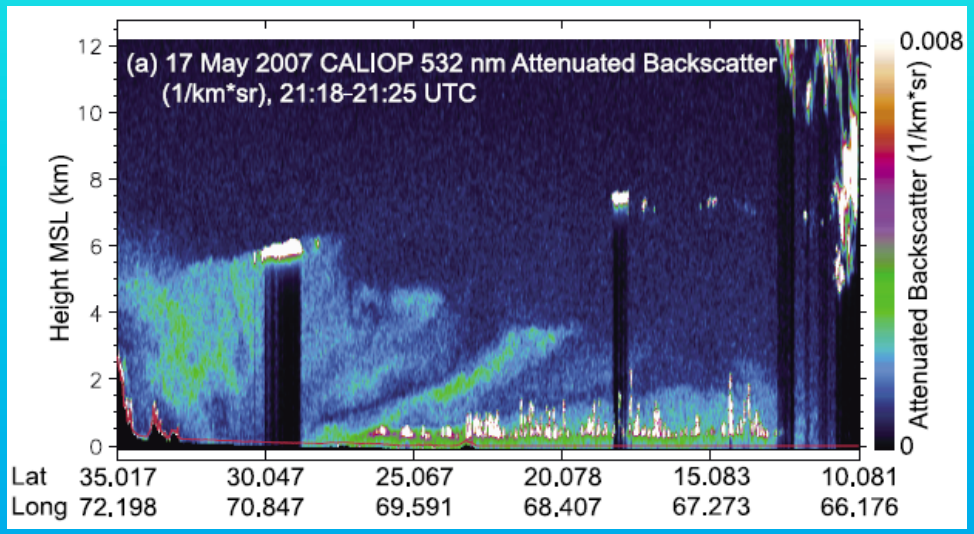
- 10–15% improvement in NAAPS AOD forecast accuracies out to 48 hr using CALIOP *(Zhang et al., GRL*, 2012)
- Assimilating satellite lidar data causes redistribution of aerosol particle extinction within NAAPS. This *directly* impacts:
  1. Visibility assessment
  2. Forecasts downwind
  3. Depiction of boundary layer
  4. Diabatic heating rates/radiative transfer calculations
  5. Radiance assimilation/atmospheric correction



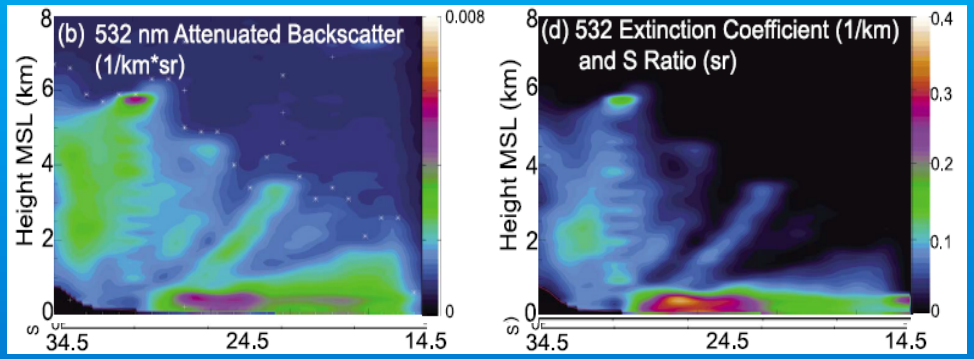
Credits: James Campbell, NRL

Applying CALIOP Vertical Aerosol Profile to Constrain Transport Models

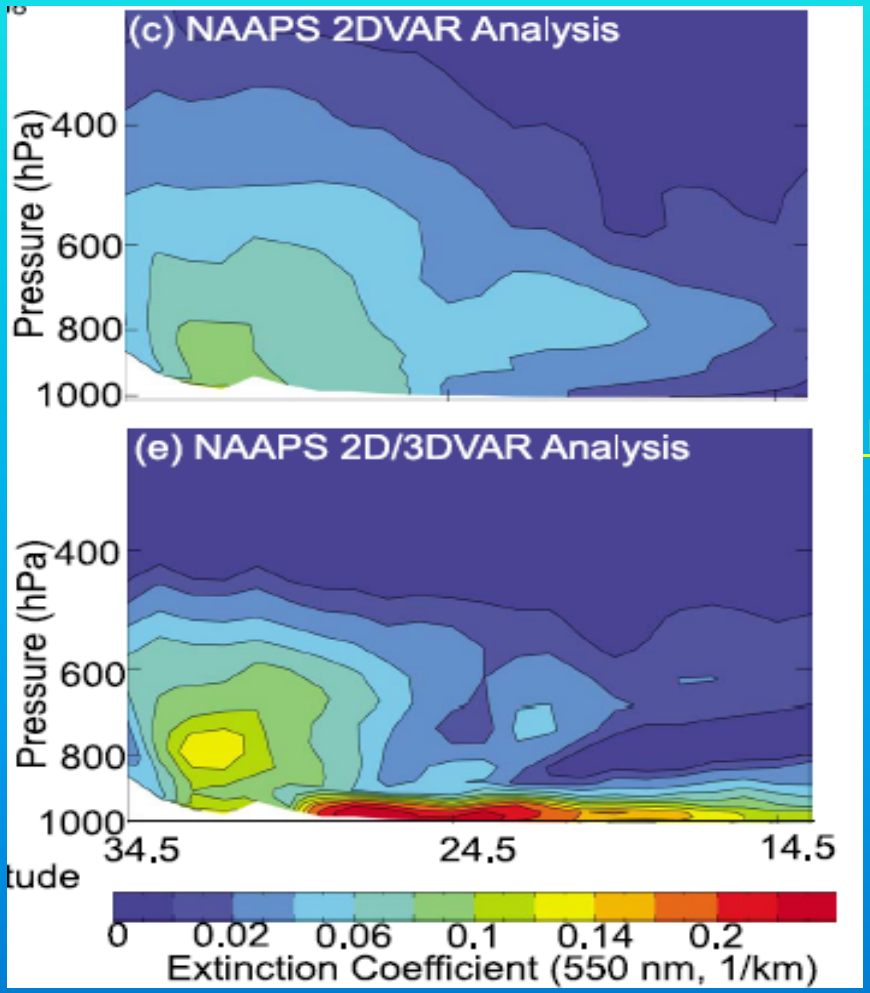
1. Collect Level 1 Signals



2. Process for QA Level 2 Product



3. Assimilate and Innovate



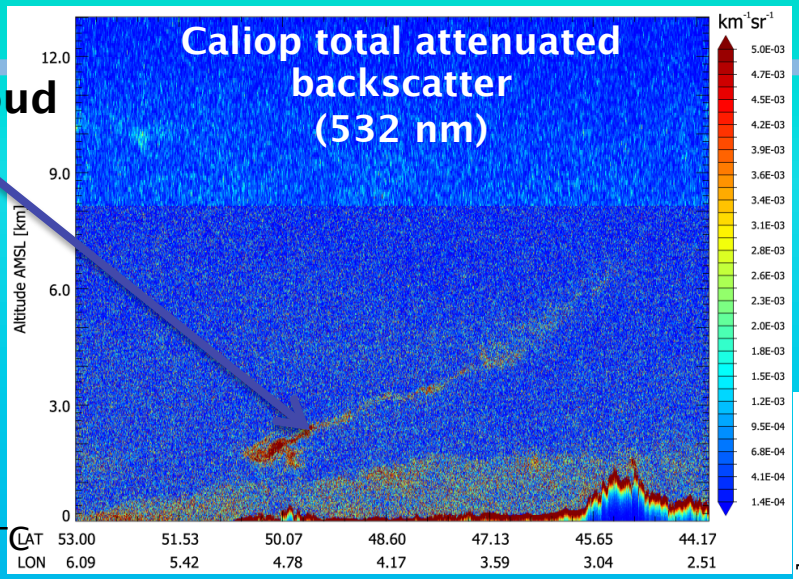
Zhang et al. (2012) – GRL DOI: 10.1029/2011GL0477

Volcanic Ash Assimilation

Observation:

Eyjafjalla ash cloud
17 April 2010

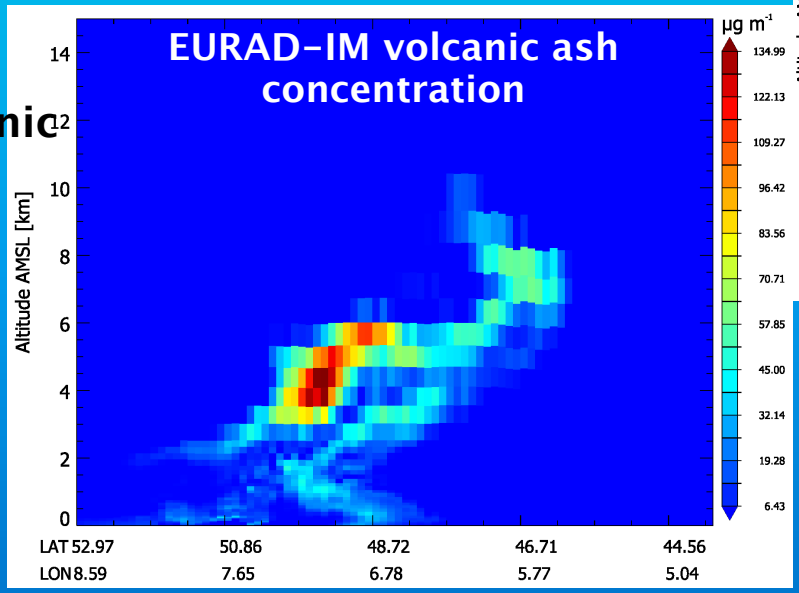
CALIPSO flight path
02:01:24 – 02:14:53 UTC



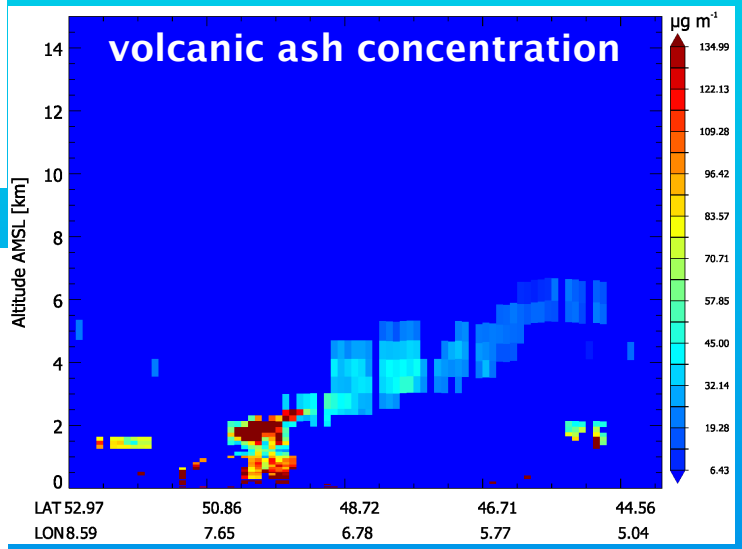
Background:

EURAD-IM volcanic ash forecast
17 April 2010
02:00 UTC

same location as CALIPSO track



Analysis:



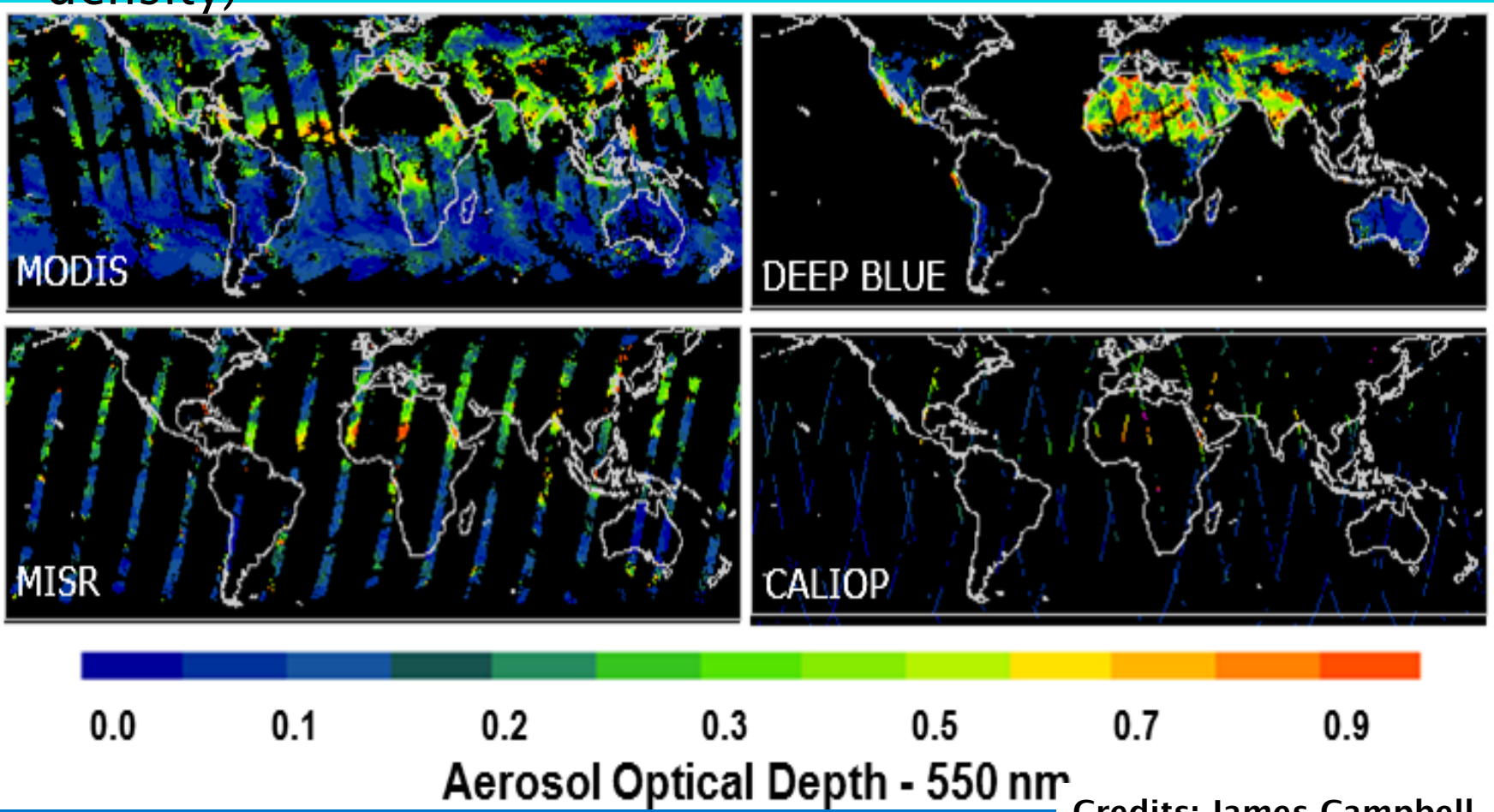
observation error 10^{-3} km^{-1} sr^{-1} + 0.05 · P_{obs}
background error 1.0 km^{-1} sr^{-1}

Credits: Anne Caroline Lange

CURRENT CHALLENGES

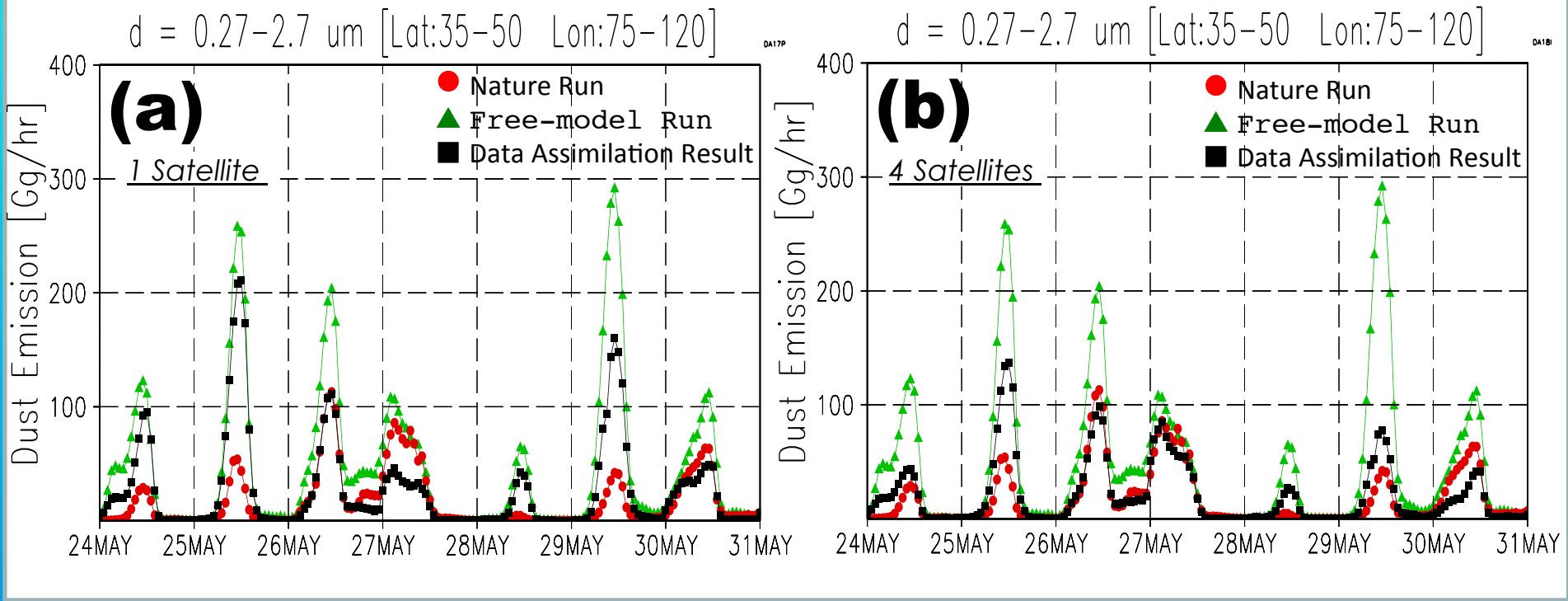
Challenge 1: coverage

- A significant part of the disconnect among different datasets comes down to apparent scale (i.e., observation density)



Credits: James Campbell, NRL

Sensitivity study of the frequency of CALIPSO observation with OSSE studies



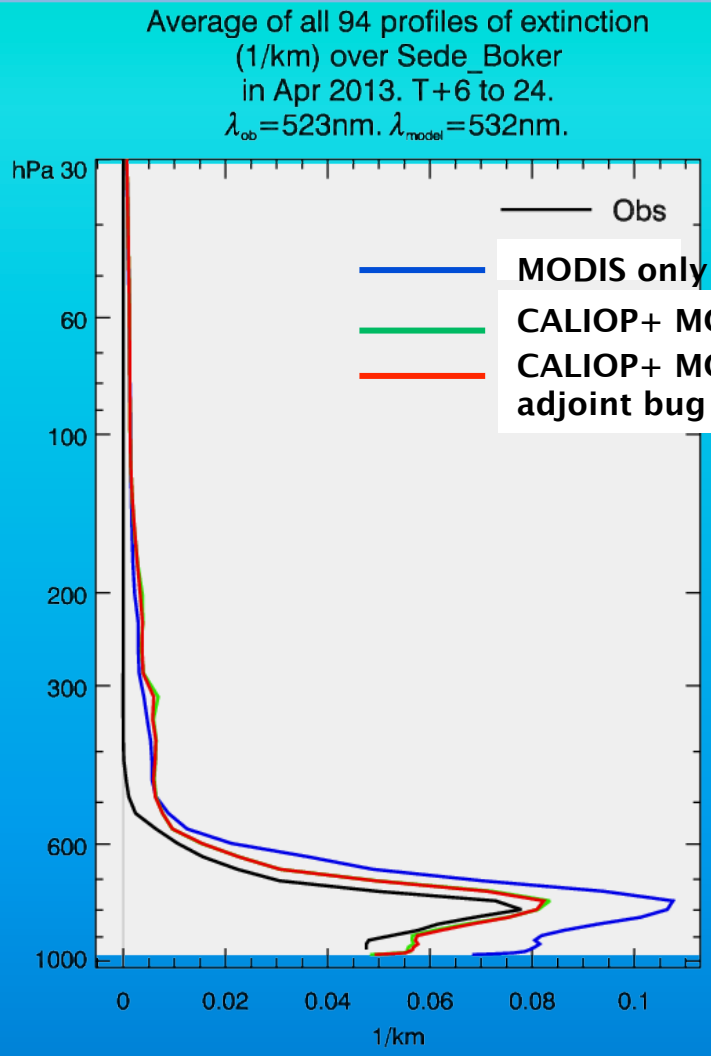
Total dust emission : 1 satellite

Total dust emission : 4 satellite

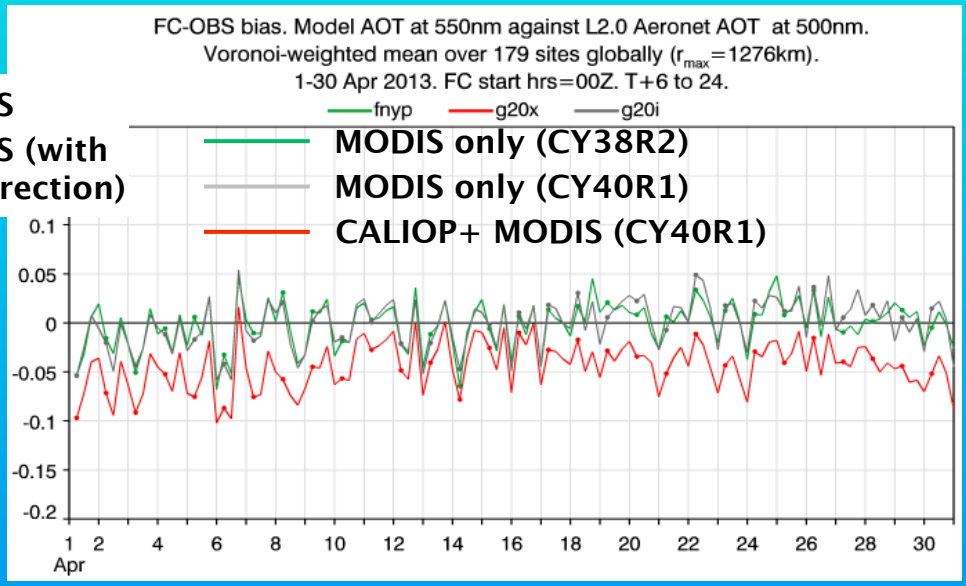
The data assimilation results become better with 4 CALIPSO satellites into different orbits.

Credits: Thomas Sekiyama, M

Challenge 2: biases



- Good impact of CALIPSO data from CALIOP instrument on vertical profiles at Sede Boker, but…



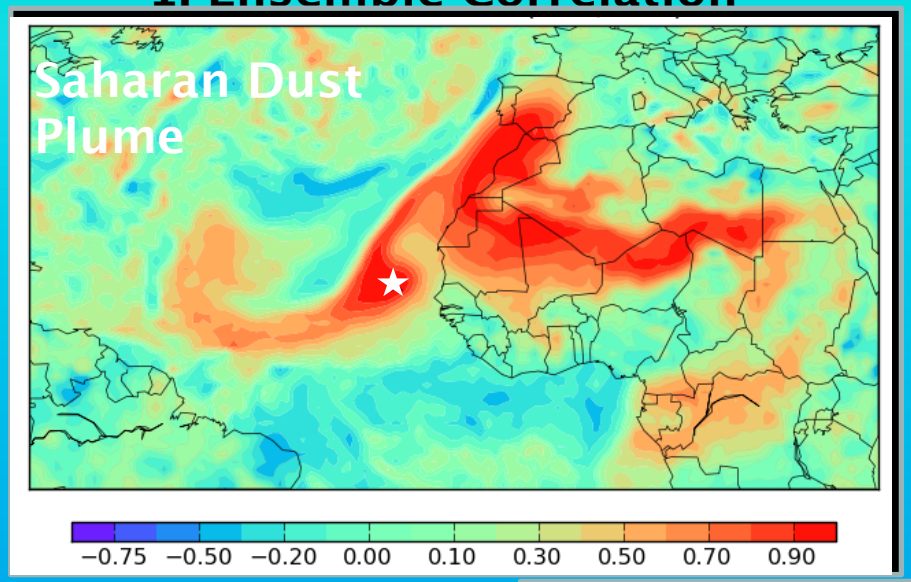
…AERONET verification shows that globally lidar assimilation underperforms with respect to MODIS only analysis!

- This is due to model biases (optical properties?) and possible discrepancies between the two dataset

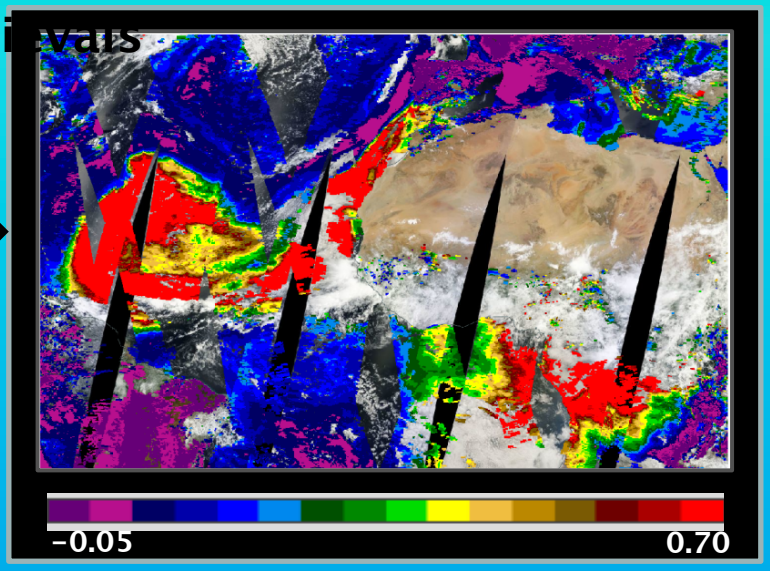
(**) Lidar data are courtesy of Arnon Karnieli. Special thanks to Simone Lolli, Judd Welton and the MPLNET team. Graphics by Luke Jones.

Challenge 3: model skills

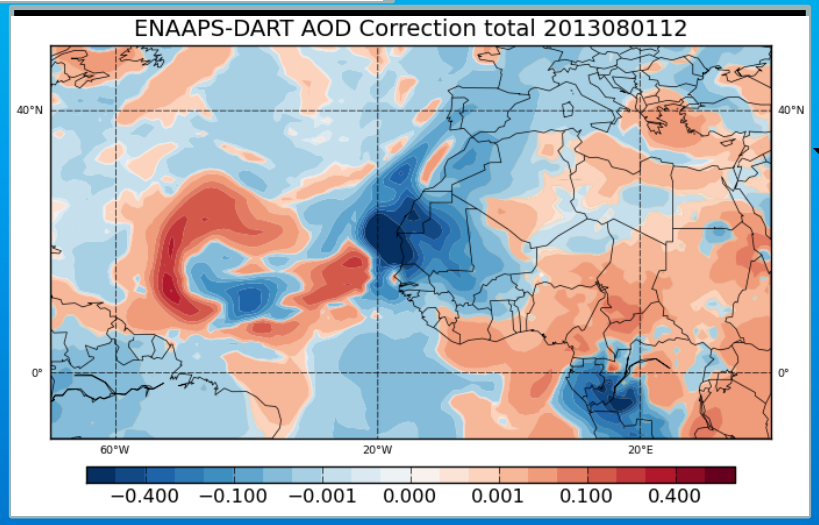
1. Ensemble Correlation



2. Combined with MODIS AOD Retrievals



3. To produce flow dependent corrections in the horizontal.

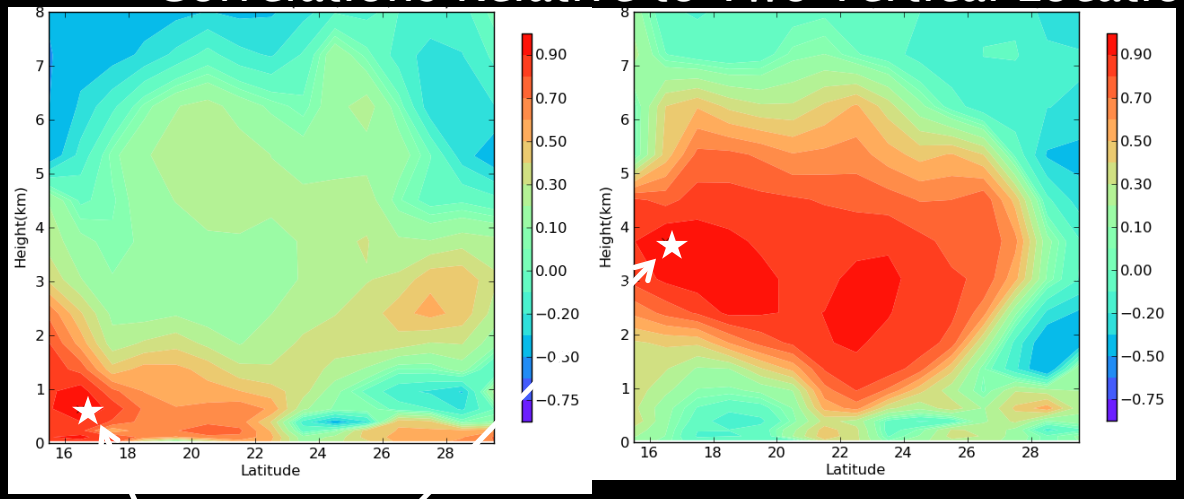


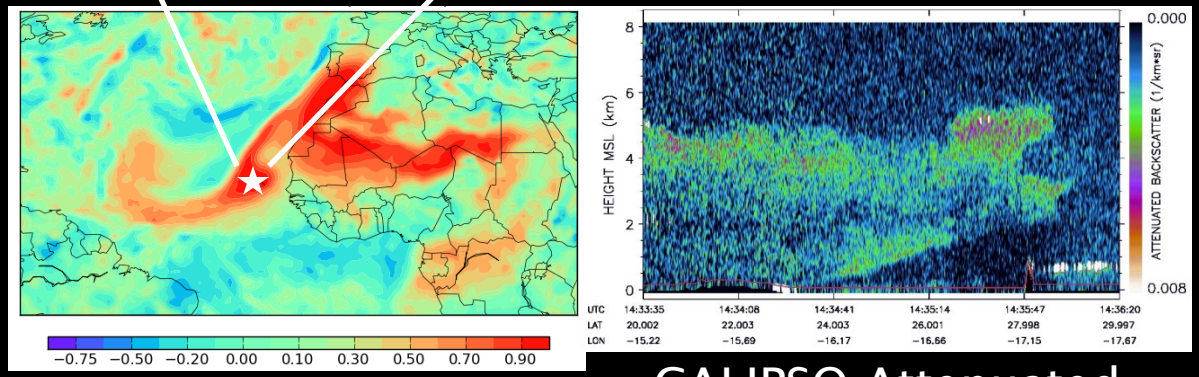
With ensemble data assimilation methods,
we can capture the correlation fields in the horizontal but…

Rubin et al. 2015

..capturing realistic correlations in the vertical for global forecasts is a bigger challenge.

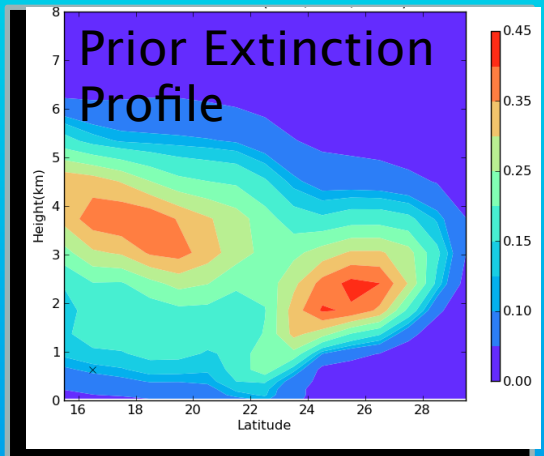
Correlations Relative to Two Vertical Locations

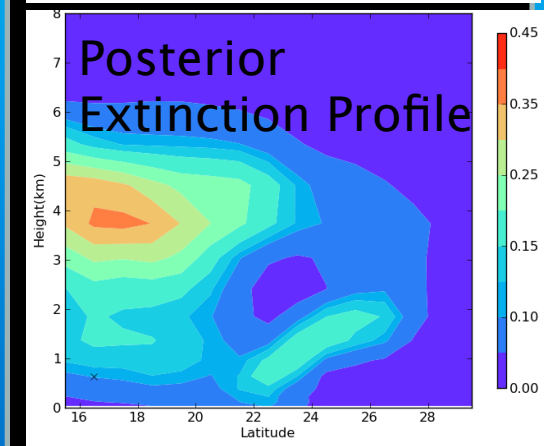




CALIPSO Attenuated Backscatter

Get a separation of surface and upper atmosphere, but difficult to capture finer features in the vertical.





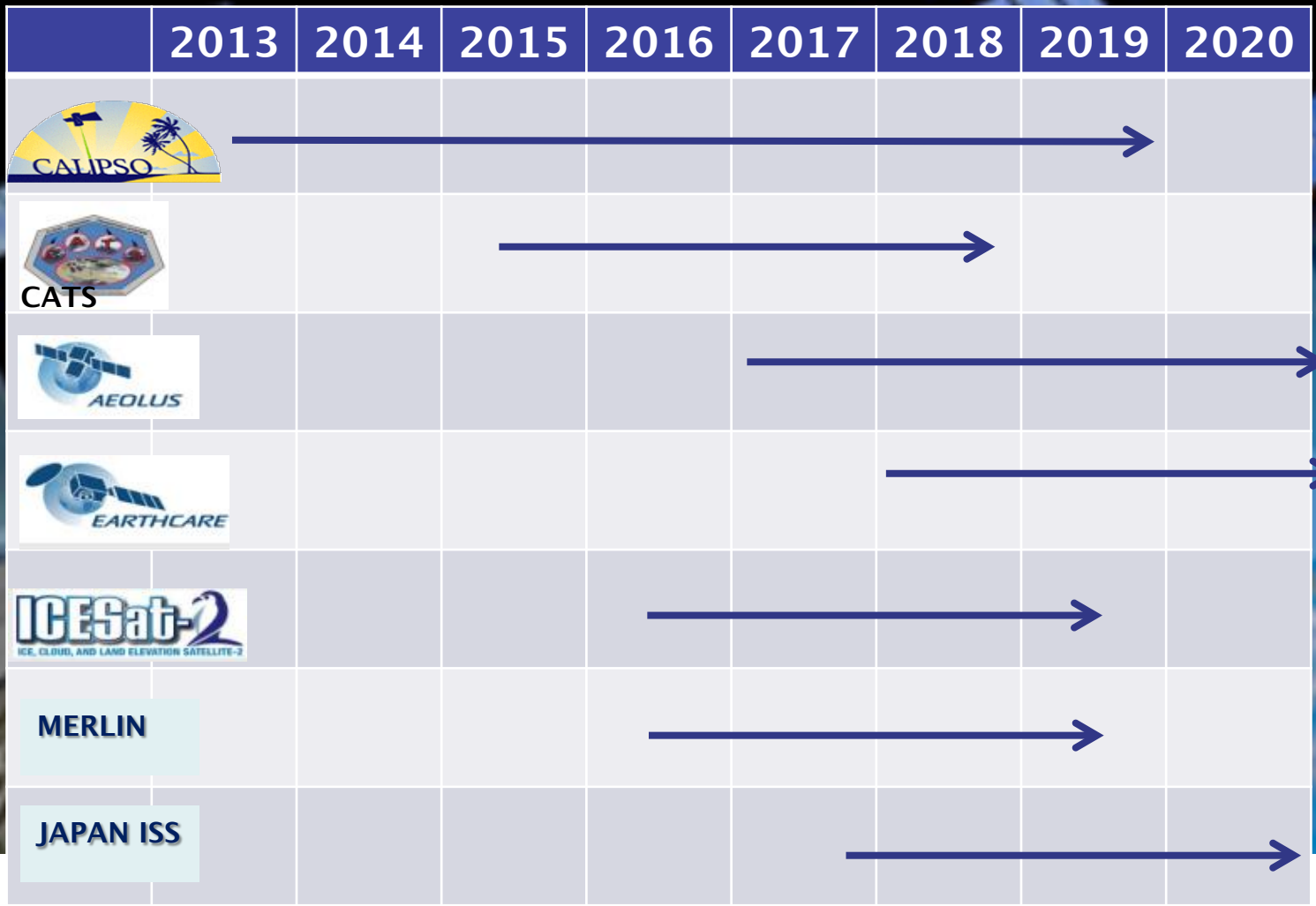
Rubin et al. 2015

*correlations calculated using ensemble extinction

Summary/Perspectives

- Lidar assimilation for aerosol prediction is an active area of research at many forecasting centres and research institutes
- Much progress has been facilitated by CALIPSO data availability
- Systems used range from variational to ensemble methods
- Variables assimilated are extinction, backscatter or lidar raw signal
- Applications range from aerosol global forecasts, to volcanic ashes detection and regional air quality.
- Much progress has been made in the last few years, but challenges still lie ahead due to:
  - observation coverage
  - obs/model biases
  - model skills
- Collaboration with data provider is paramount (fostered by collaborations such as the International Cooperative for Aerosol Prediction)
- NRT data delivery from all lidar mission is paramount (best effort is fine)
- Research projects funded by space agencies are very useful (ESA project on Aeolus Aerosol data assimilation, A3S, for example)
- Community is getting ready to use lidar data to improve aerosol prediction

Future Lidar Missions



Outlook

- Spaceborne lidars expected beyond 2020
- Possibility of having up to 3–4 overlapping lidar missions.
- There are vastly different expected capabilities and efficacies, full exploitation requires further research & collaboration with data providers
- Important to provide input on product design and operational use, advocating < 6 hr latency