AEROSOL LIDAR ACTIVITIES AT ECMWF: STATUS AND PLANS

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ECMWF

In collaboration with: Marijana Crepulja, Martin Suttie,
Mohamed Daouhi and Luke Jones
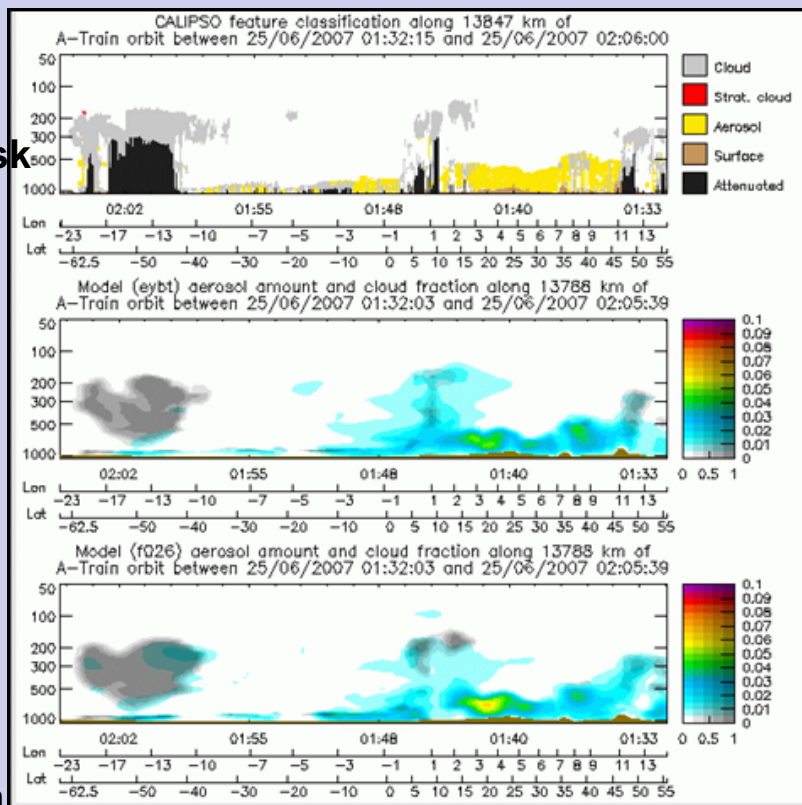
Scientific motivation

- ECMWF/CAMS provides daily aerosol forecasts up to day 4 since 2008
- MODIS Aerosol Optical Depths (AODs) are assimilated routinely
- No profiling observation is currently used – large uncertainty on aerosol vertical structure which is determined by the model

CALIPSO Feature mask

Model forecast

AOD assimilation

CALIPSO backscatter

Model backscatter

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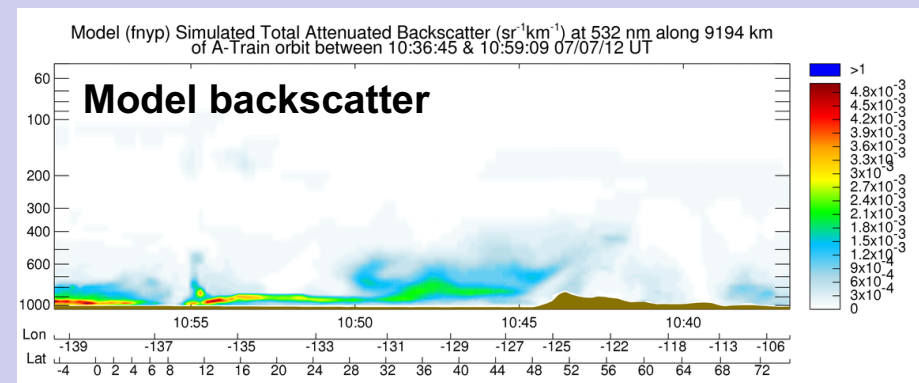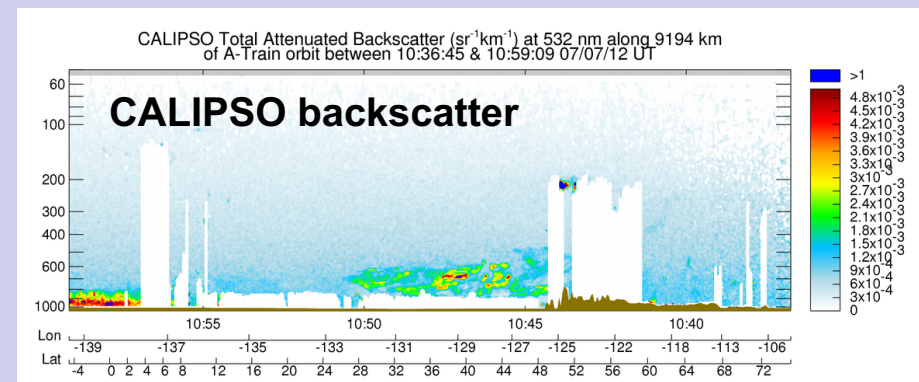
Historical perspective

- Since the first ICAP meeting in 2010, there has been an effort from the CALIPSO team to provide NRT aerosol backscatter data for assimilation. From an email of David Winker dated 02/08/2010:

> Angela et al.,
>
> Based on conversations at the meeting in Monterey and since, we've put together a preliminary product catalog for the Level 1.5 NRT product. Our initial assumption is that size is not an issue and as defined here the product comes in at about 500 MB per day. This is defined as a tropospheric product. We're thinking the profiles would cover the range 0 - 20 km, but we detect little aerosol above 10 km and virtually none above 15 km.

- Operational centres including ECMWF have been looking at using the CALIPSO data for assimilation since 2011 with various degree of success and facing several challenges (mainly connected to model skill)

- Following the CALIPSO example, Aeolus and EarthCARE will provide near-real-time (NRT) aerosol products from the ALADIN and ATLID lidars when in orbit. Data will be delivered to operational centres with interest in aerosol prediction and forecasting

- Strong interest in pursuing assimilation of aerosol profiling data

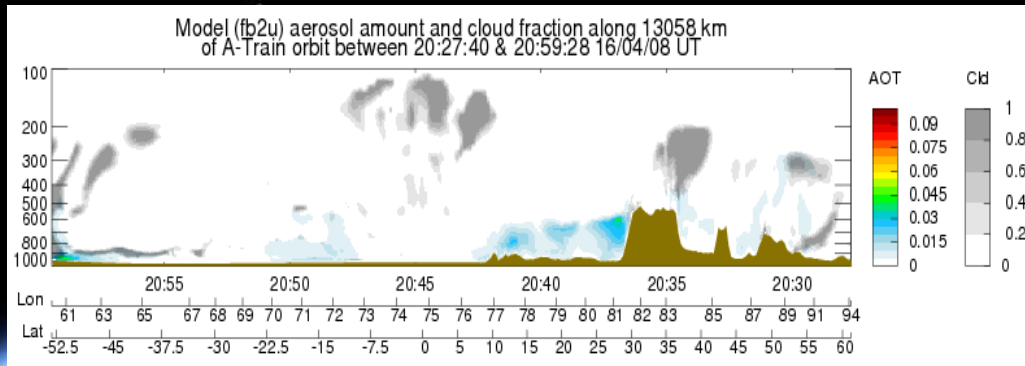**ECMWF**

Historical perspective & Current status

- Observation operator for lidar data was developed for inclusion in 4D-VAR under the ESA-funded project QuARL in 2010 (thanks to Jean-Jacques Morcrette, Olaf Stiller and Marta Janiskova)

- Initial assimilation tests at ECMWF using CALIPSO data were started in 2011 (single orbit)

- Several model changes (cycles) occurred over the years which helped with fitting better the observations

- CALIPSO assimilation improvements (i.e. activated variational bias correction)

- Evaluation of CALIPSO assimilation with HSRL and ground-based lidars

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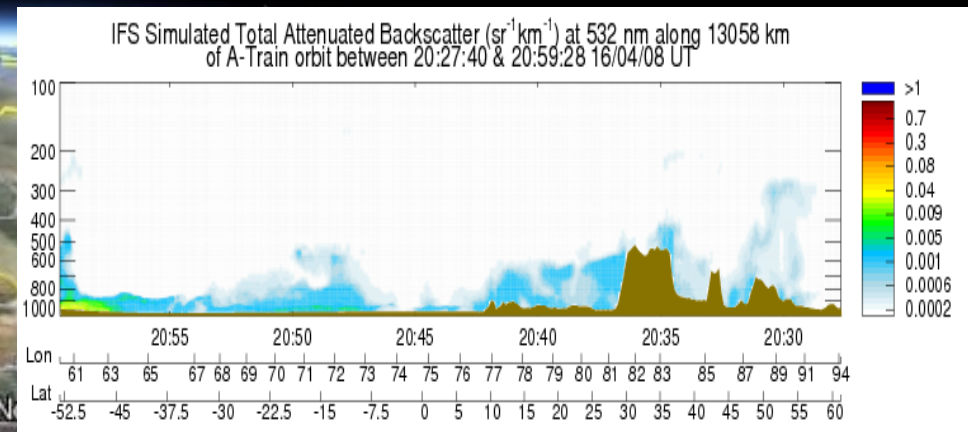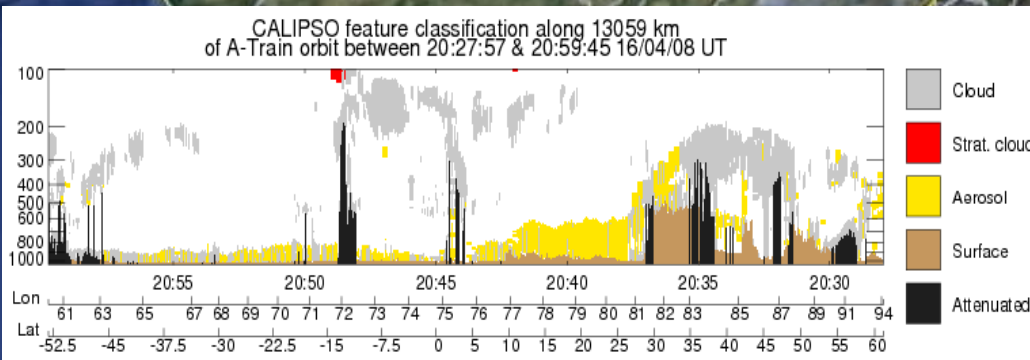# Examples: Comparisons of MACC/ECMWF model runs with lidar observations from CALIOP sensor on CALIPSO

Apr 16, 2008
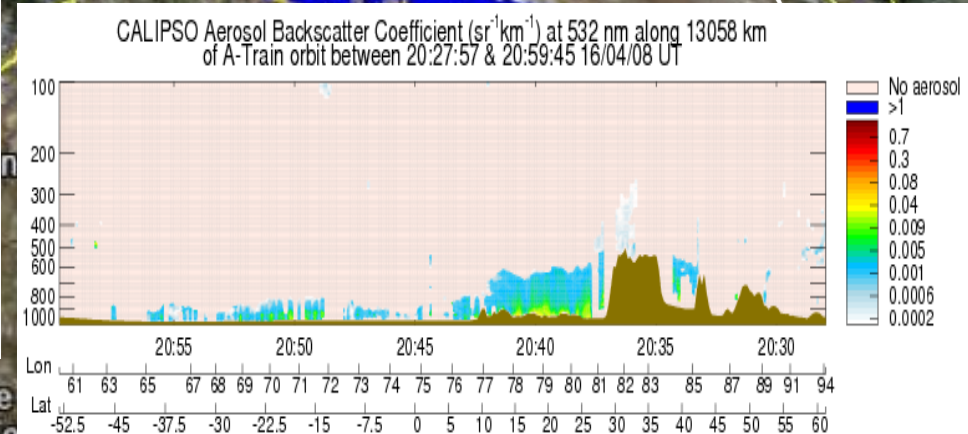
Model aerosol (color) and clouds (grey)

Model (fb2u) aerosol amount and cloud fraction along 13058 km of A-Train orbit between 20:27:40 & 20:59:28 16/04/08 UT

Model aerosol backscatter (sr-1 km-1)

IFS Simulated Total Attenuated Backscatter (sr^{-1}km^{-1}) at 532 nm along 13058 km of A-Train orbit between 20:27:40 & 20:59:28 16/04/08 UT

Observed aerosol (yellow) and clouds (grey)

CALIPSO feature classification along 13059 km of A-Train orbit between 20:27:57 & 20:59:45 16/04/08 UT

Cloud
Strat. cloud
Aerosol
Surface
Attenuated

Observed aerosol backscatter (sr-1 km-1)

CALIPSO Aerosol Backscatter Coefficient (sr^{-1}km^{-1}) at 532 nm along 13058 km of A-Train orbit between 20:27:57 & 20:59:45 16/04/08 UT

No aerosol

India

Kyrgyzstan Bishkek
Бишкек

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TI ©2010 Google
US Dept of State Geographer

Google

28°40'22.89" N   77°45'13.75" E   Dhaka   Bhuta elev 215 m   Eye alt 2186.46 km

NRT 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**
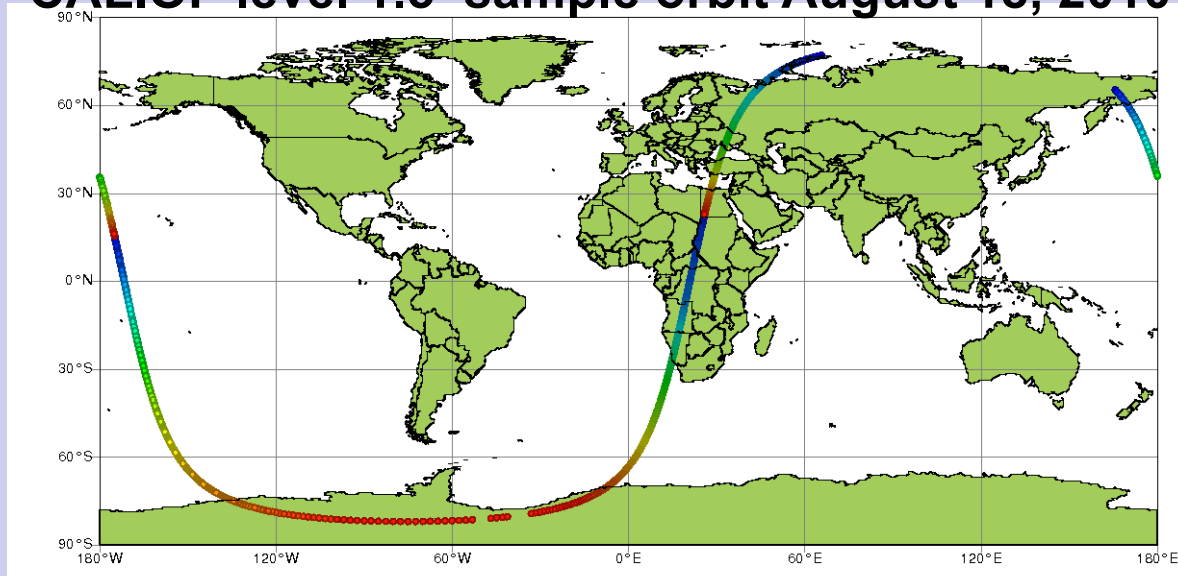
- Thinned to 900 profiles, 40 km effective resolution (originally 1800)

- 67 vertical levels, 300m resolution (originally 345)

- ~200000 backscatter observations actively assimilated over the 4DVAR 12-hour window

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OBSERVATION STATISTICS

CY40R2 (NRT cycle)

Lidar backscatter x 1e7 (sr m)-1

800-850hPa

Lidar backscatter x 1e7 (sr m)-1
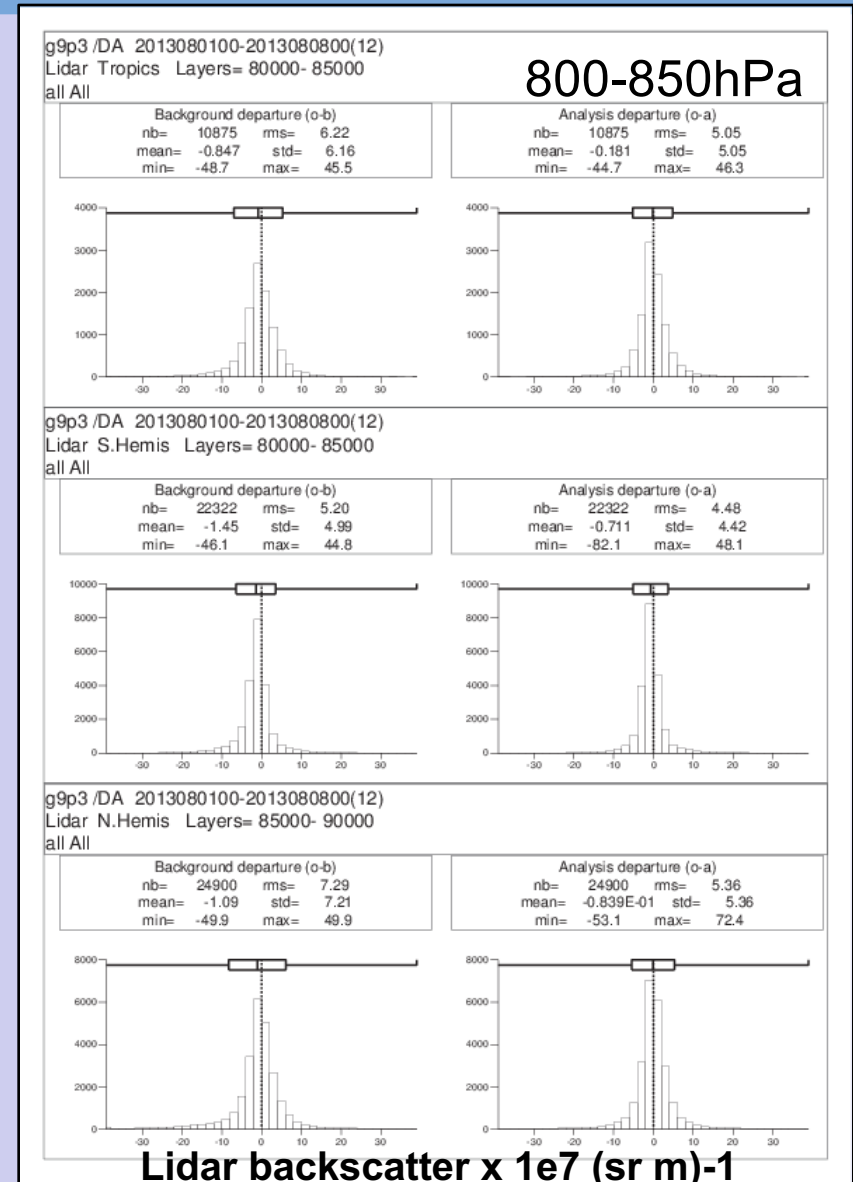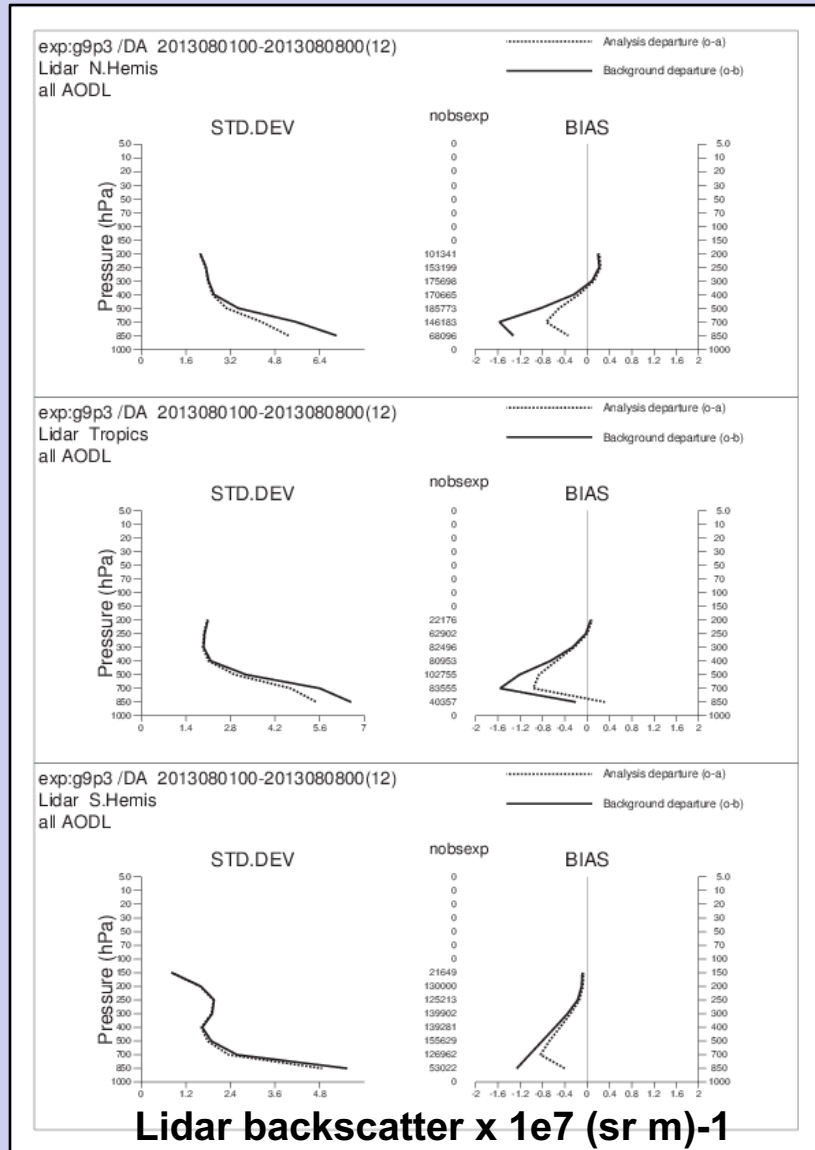
Data: all operational data plus MODIS AOD and CALIOP Level 1.5 backscatter

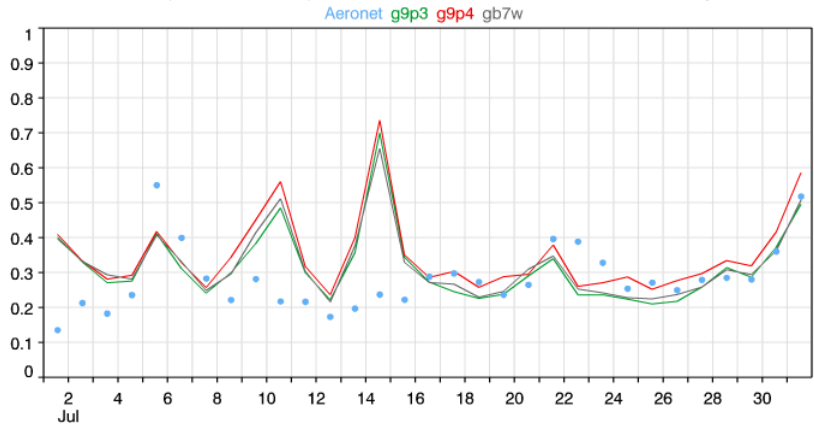CCECMWF

Verification of lidar assimilation experiments

AERONET and MPLNET verification shows good performance of lidar assimilation locally or at least not worse than the MODIS Dark Target-only run…

Comparison of g9p3, g9p4 & gb7w AOT at 550nm and L2.0 Aeronet AOT at 500nm over Tamanrasset_INM (22.79°N, 5.53°E). Model: 00UT, 1-31 Jul 2013, T+3 to T+24. Daily means.
Aeronet g9p3 g9p4 gb7w
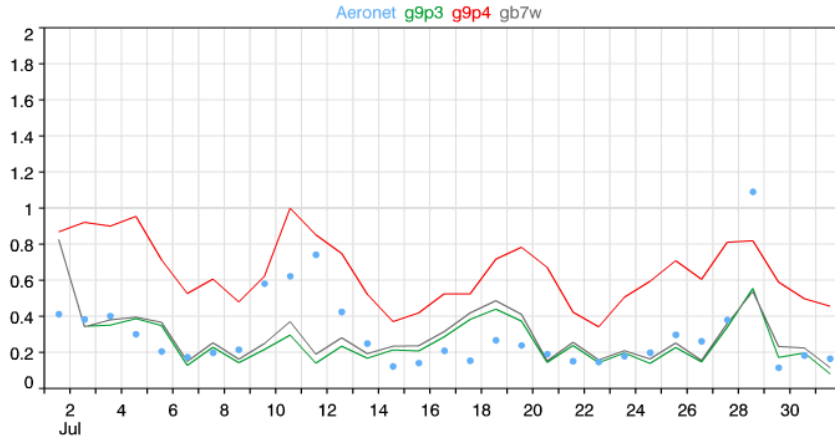
MODIS only
CALIOP+ MODIS
CALIOP + MODIS (both bias corrected)

Comparison of g9p3, g9p4 & gb7w AOT at 550nm and L2.0 Aeronet AOT at 500nm over Dushanbe (38.55°N, 68.86°E). Model: 00UT, 1-31 Jul 2013, T+3 to T+24. Daily means.
Aeronet g9p3 g9p4 gb7w

Average of all 94 profiles of extinction (1/km) over Sede_Boker in Apr 2013. T+6 to 24.
λ_{ob}=523nm. λ_{model}=532nm.

Obs
MODIS only
CALIOP+ MODIS
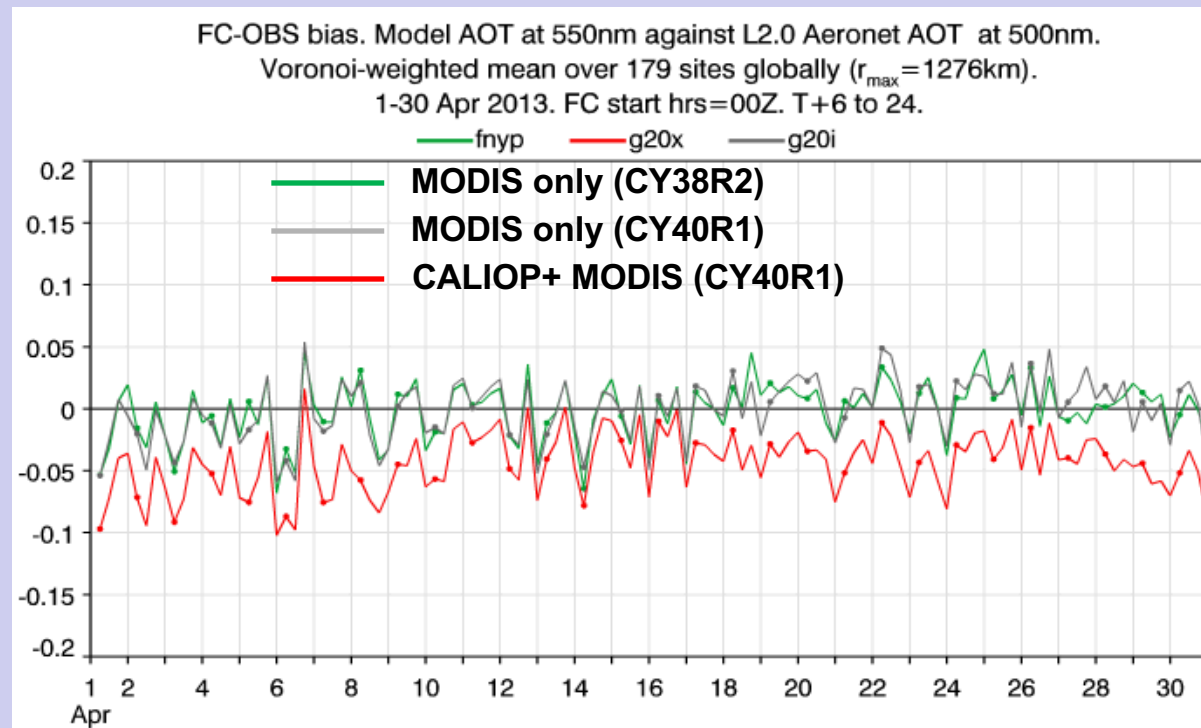**CALIOP+ MODIS (with adjoint bug correction)**
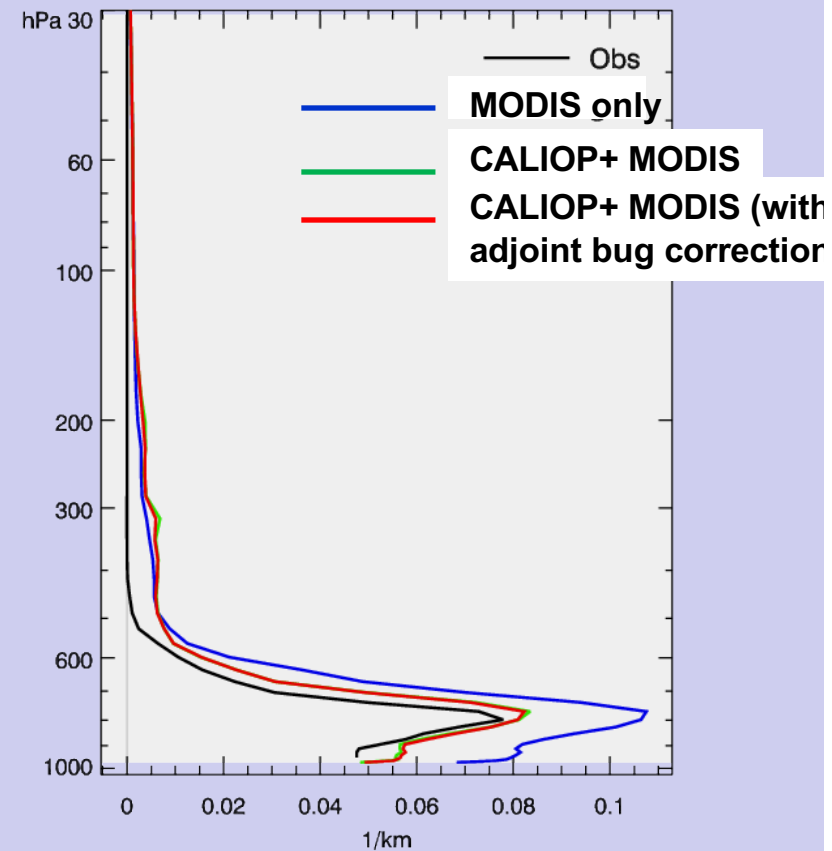
Lidar data are courtesy of Arnon Karnieli. Special thanks to AERONET and MPLNET teams. Graphics by Luke Jones.
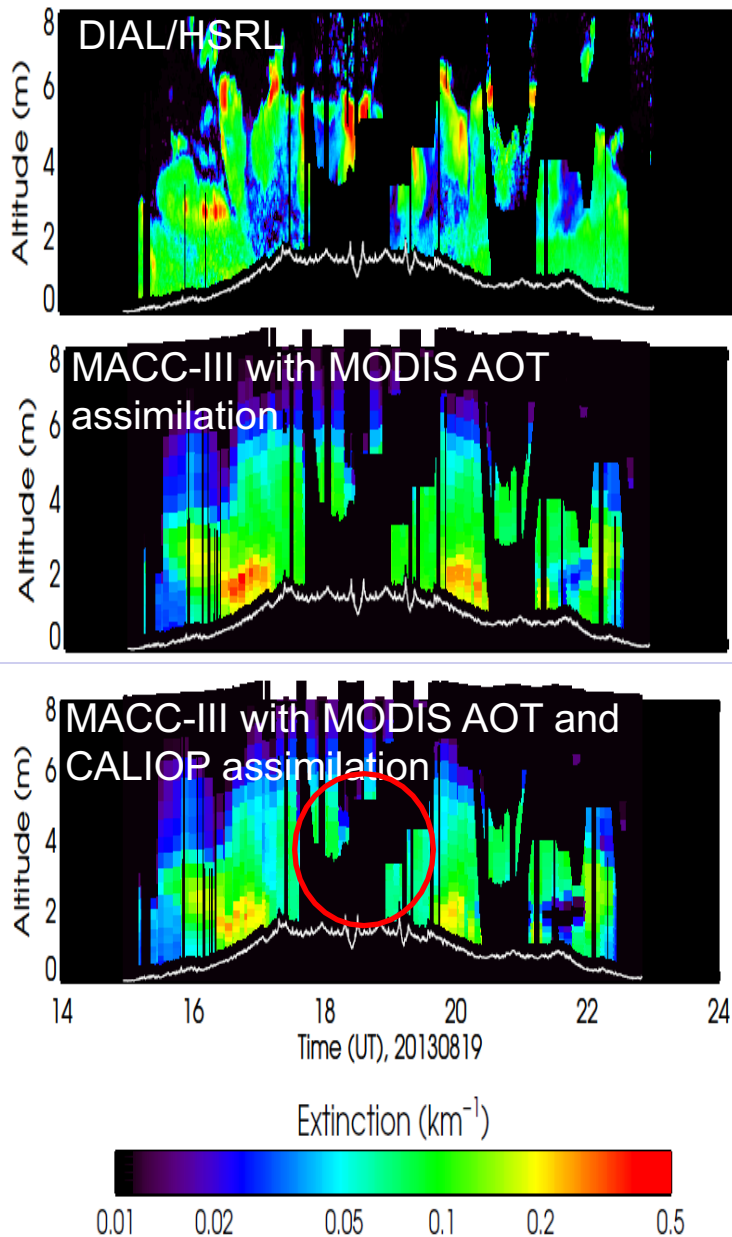
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Verification of lidar assimilation experiments (2)

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

- This is due to model biases (optical properties are the main suspect) and possible discrepancies/biases between the MODIS and CALIOP

FC-OBS bias. Model AOT at 550nm against L2.0 Aeronet AOT at 500nm. Voronoi-weighted mean over 179 sites globally (r_{max}=1276km). 1-30 Apr 2013. FC start hrs=00Z. T+6 to 24.
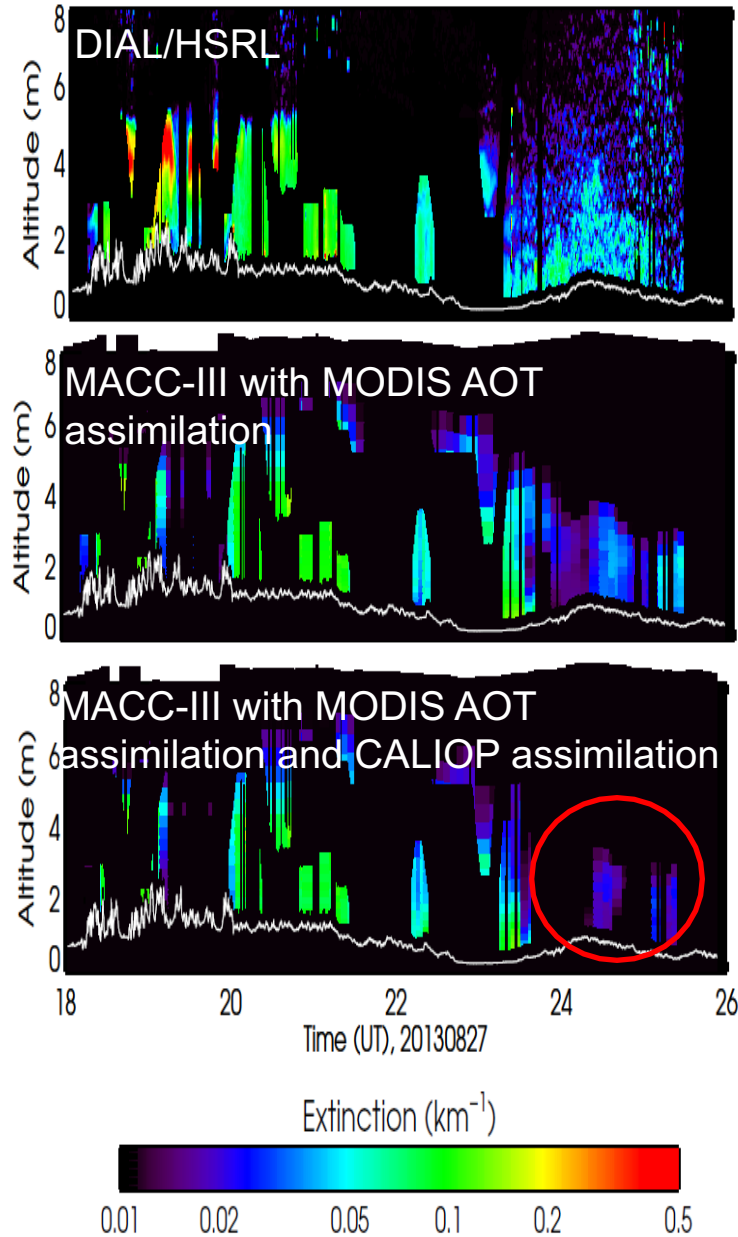
# Verification of lidar assimilation experiments (3)

August 19

August 27

- 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
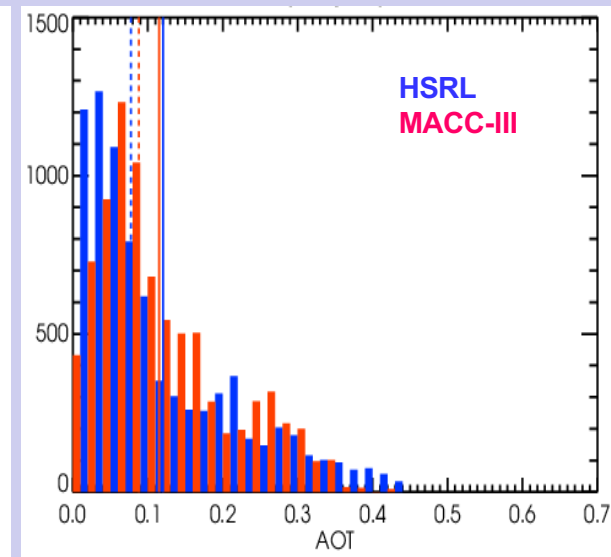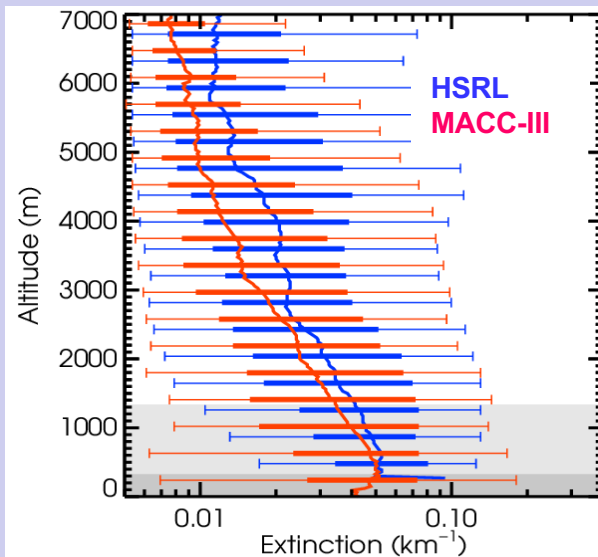
Credits: Sharon Burton and Rich Ferrare (NASA LARC)

Comparison of Median Profiles with and without CALIOP assimilation

MODIS assimilation only
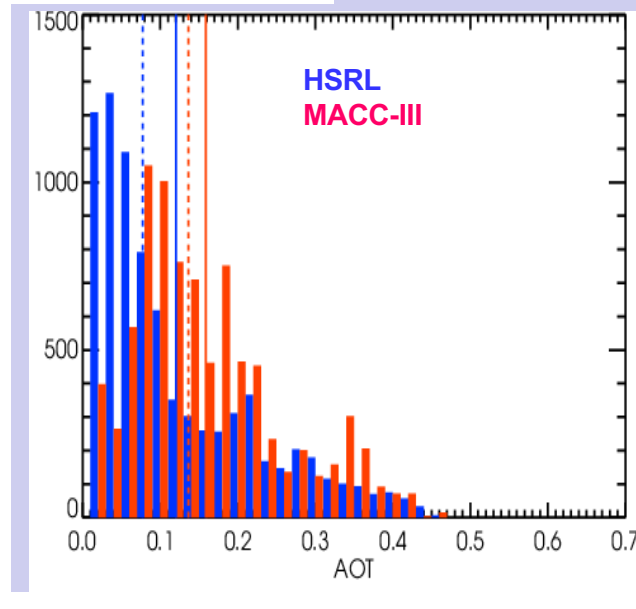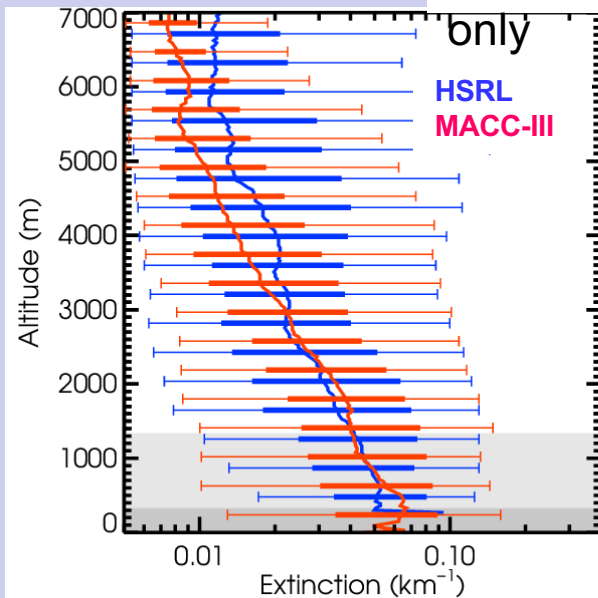
MODIS and CALIOP assimilation

- Median profiles in good agreement with MODIS AOT assimilation
- Adding CALIOP:
  - produces relatively minor effects on median profiles
  - tends to lower the AOT with respect to runs that assimilate only MODIS AOT – slightly better agreement with HSRL

Credits: Sharon Burton and Rich Ferrare (NASA LARC)
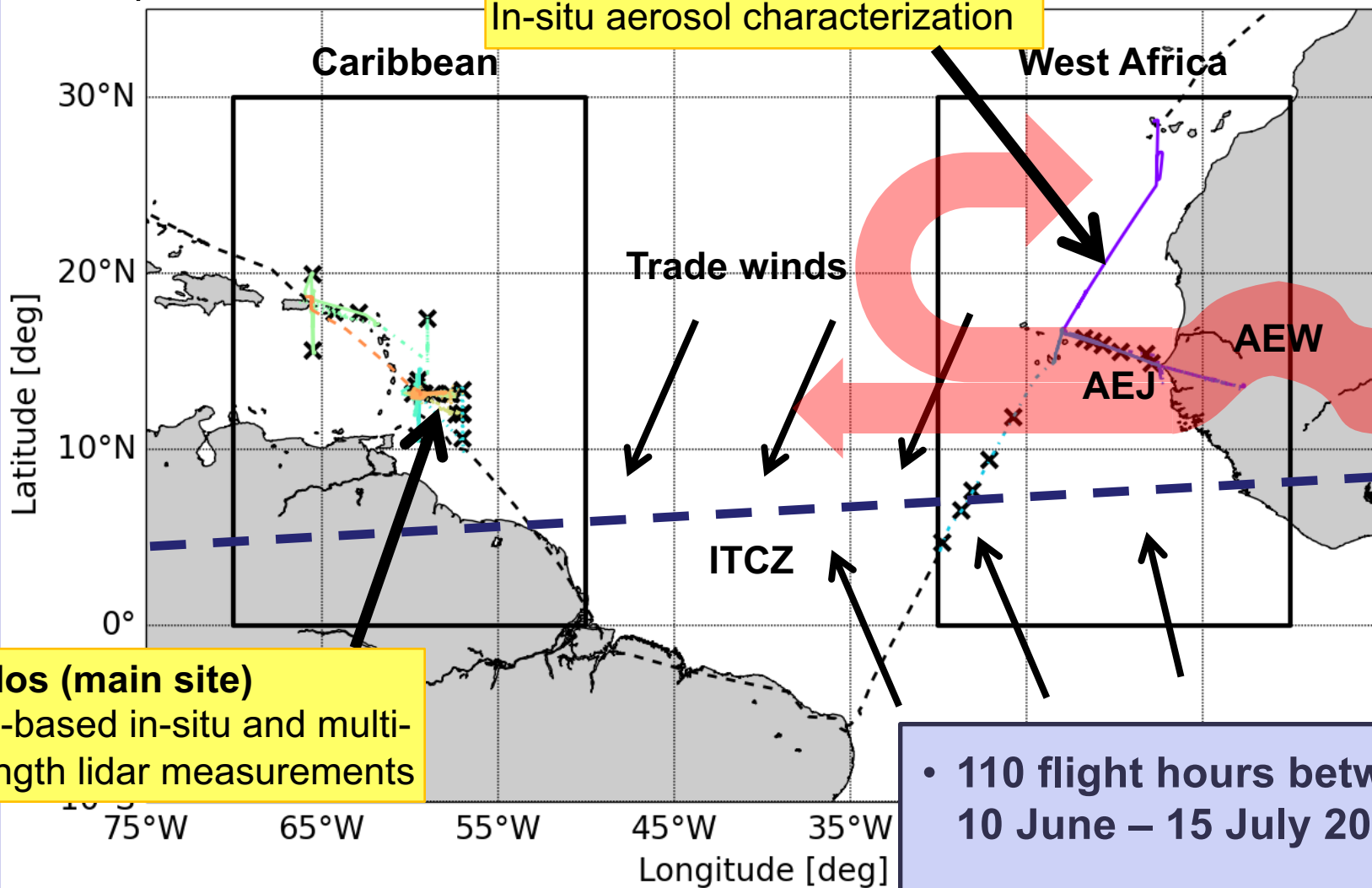
Other lidar-related activities

SALTRACE experiment, 2013

DLR Falcon 20
Doppler wind lidar @ 2µm
Dropsondes
In-situ aerosol characterization

Caribbean

West Africa

Trade winds

AEW

AEJ

ITCZ

Barbados (main site)
Ground-based in-situ and multi-wavelength lidar measurements

- 110 flight hours between 10 June – 15 July 2013

- 5 large dust outbreaks

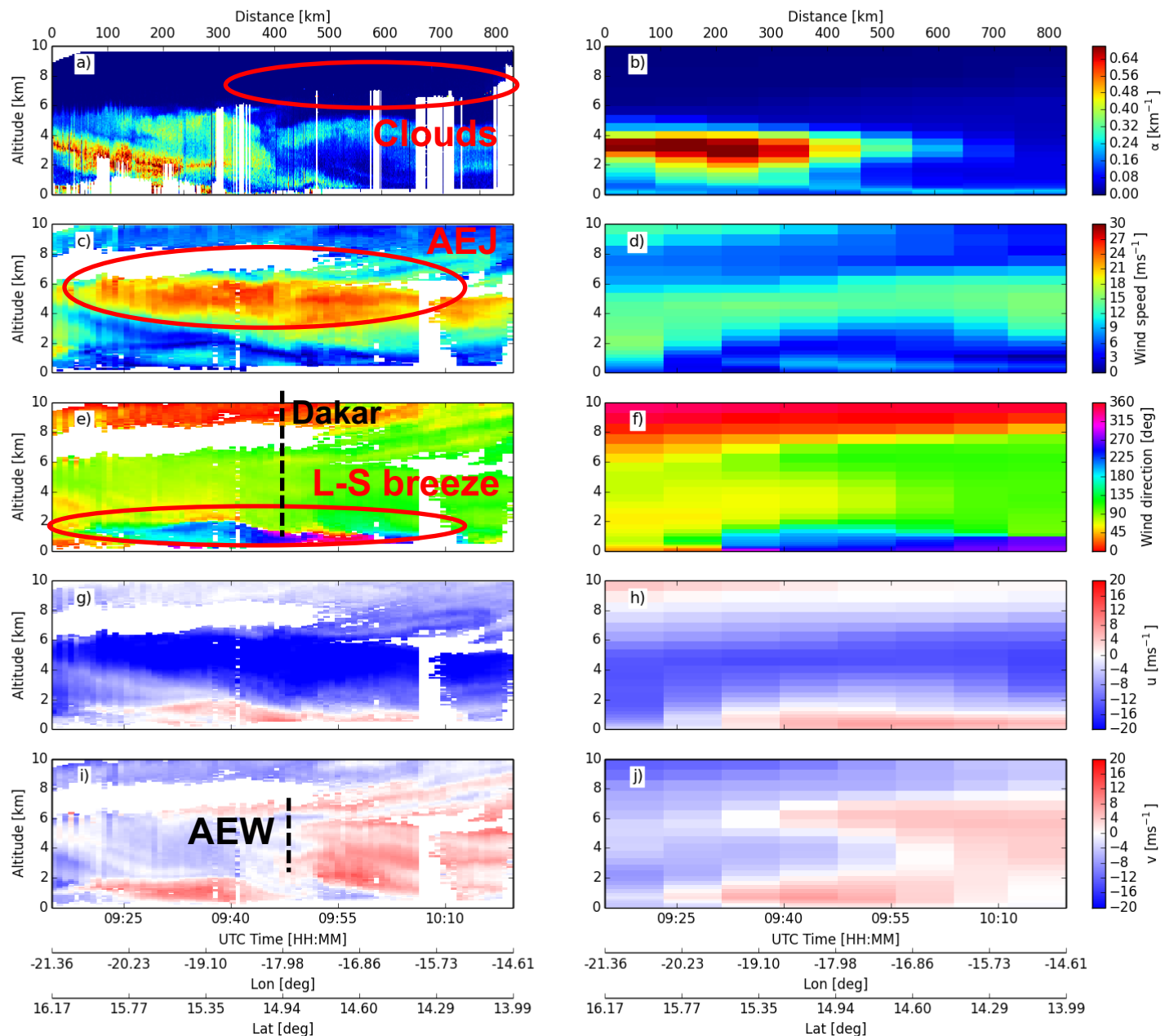**Credits: Fernando Chouza and Oliver Reitebuch (DLR)**

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MACC model validation – The African Easterly Jet

Good qualitative dust spatial distribution agreement

AEJ intenstiy is strongly underestimated by MACC

Land-sea breeze over Dakara is in good agreement

AEW trough position is well reproduced

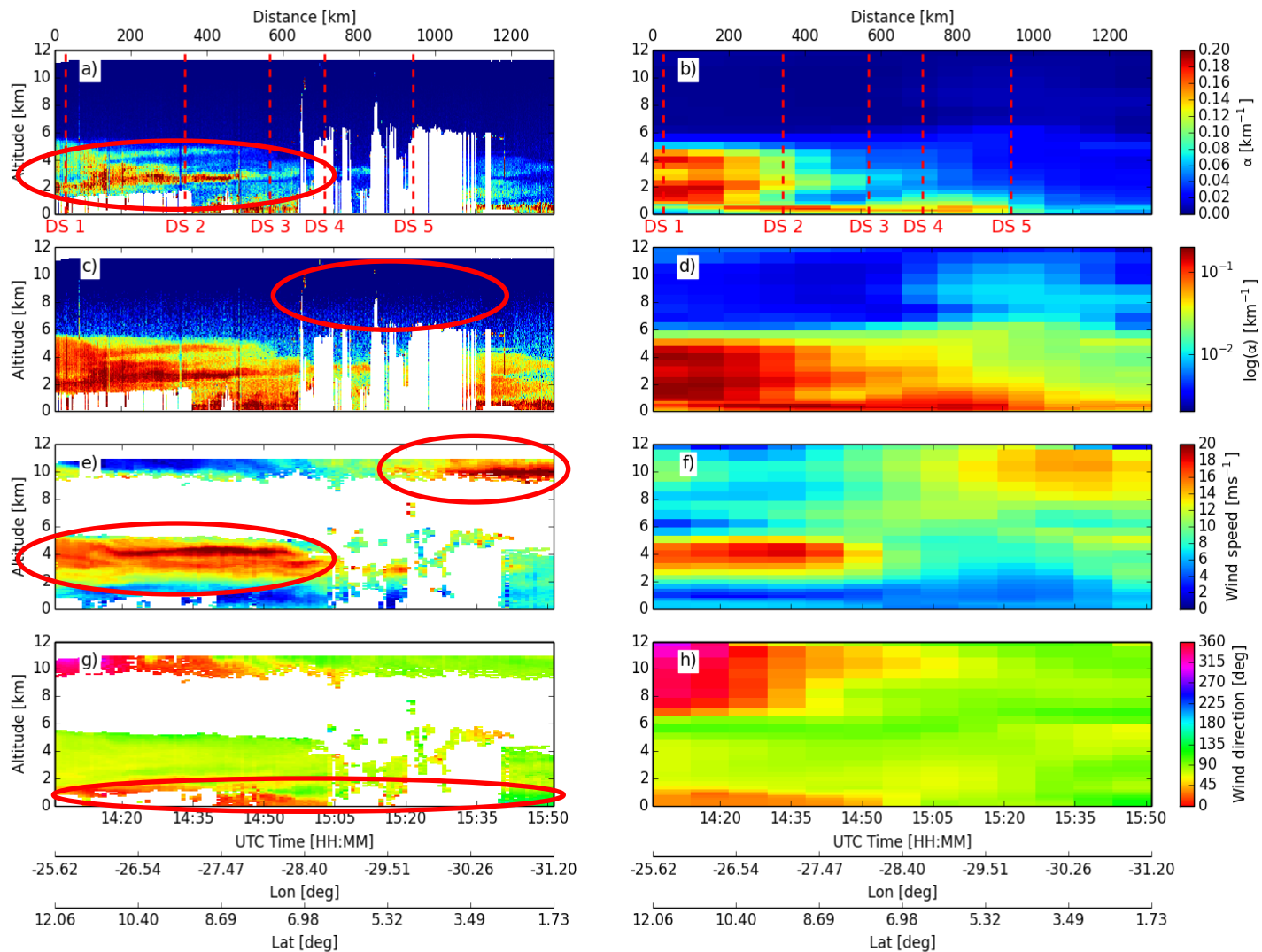**Credits: Fernando Chouza and Oliver Reitebuch (DLR)**

MACC model validation – The ITCZ

Good qualitative dust spatial distribution agreement. ABL too low.

Overestimation of the dust above the SAL

AEJ and TEJ position is well reproduced, but the speed underestimated-

Good estimation of the trade winds

Credits: Fernando Chouza and Oliver Reitebuch (DLR)

ECMWF

MACC model validation – Long-range transported dust

Good qualitative dust spatial distribution agreement. ABL extinction is strongly underestimated.

Good wind speed and direction agreement

Credits: Fernando Chouza and Oliver Reitebuch (DLR)

ECMWF
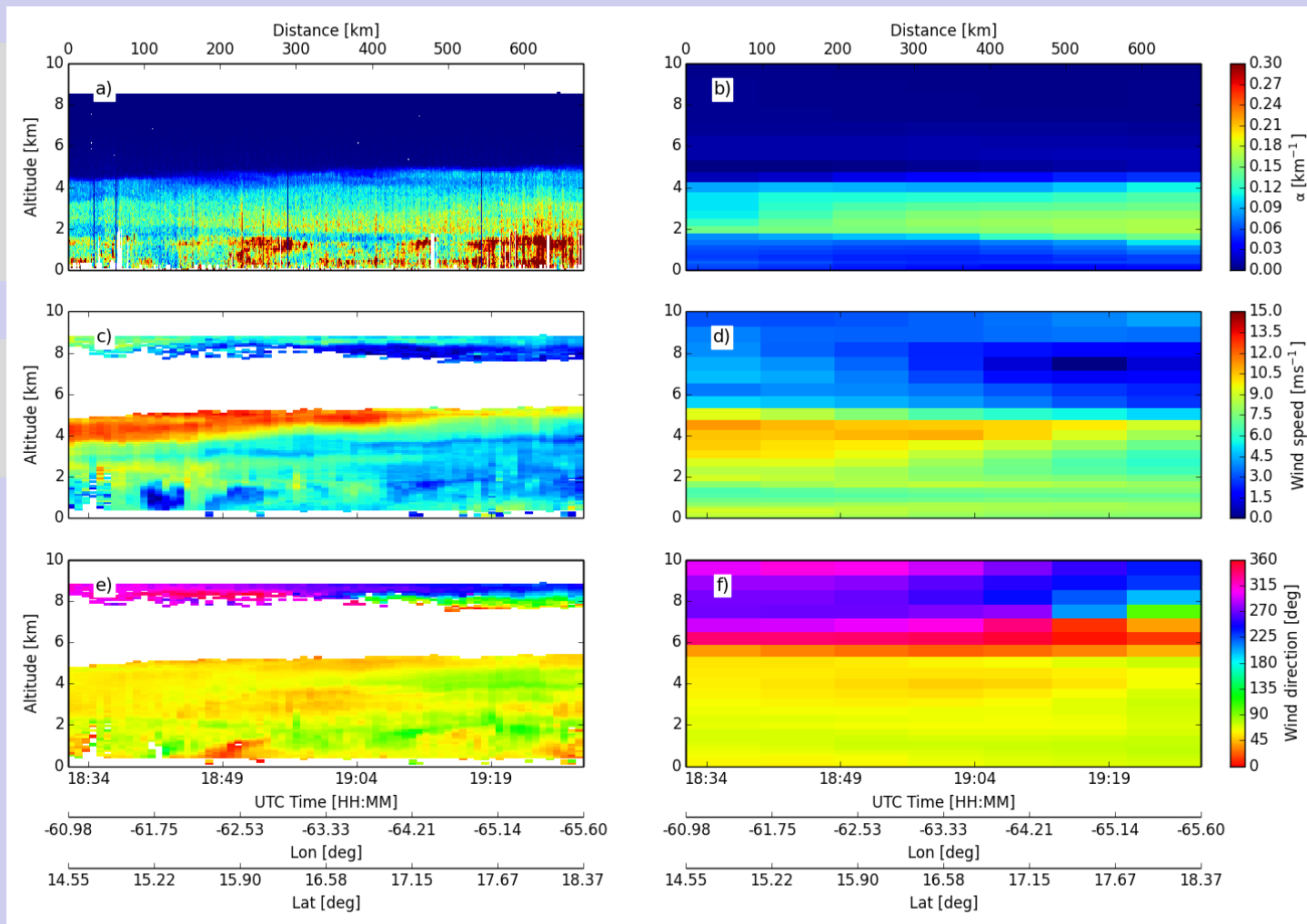
FUTURE PLANS

- Resume lidar assimilation tests with CALIOP data within the framework of ESA-funded activities such as the Aeolus/EarthCARE Aerosol Assimilation Study (A3S)

- Test assimilation of ground-based lidar data within the framework of the EU-funded project ACTRIS-2

- Collaborate with BSC (WMO SDS-WAS) on the validation of the model extinction profiles using lidar data

- Collaborate with European projects TOPROF and E-PROFILE for the use of ceilometers data for model evaluation and assimilation

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A3S objectives

1. Assess the developments necessary to prepare the ECMWF Composition-Integrated Forecast System (C-IFS)'s 4D-Var system for assimilation of ADM-AEOLUS/EarthCARE aerosol profiles

2. Generate/select suitable demonstration lidar observational datasets as a proxy for AEOLUS/EarthCARE data

3. Develop and test the aerosol assimilation scheme to prepare for assimilation of ADM-AEOLUS/EarthCARE aerosol profiles

4. Perform feasibility studies of the profile assimilation using the demonstration datasets

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ACTRIS-2 objectives

1. …