Could MERRA-2 3-D tables be useful for the determination of water and aerosols levels ?

Paris calibration workshop - October 2018

Atmospheric transparency at LSST : What we can expect

Parameter Variability	Impact on transmission	Achievable precision
Δ O3 ~ 20 Dobsons overnight	8% variation 4 mmag/airmass @ 6000 Å O3 peak Buton et al. 2012	σ_{O3} ~ 6 Dobsons From MERRA-2
Δ PWV ~ 1 mm hourly	ΔTtrans ~3% @ 900 nm	σ_{PWV} ~ 0.3 mm T. Li et Al. 2014
Δ AOD ~ 0.05 overnight	ΔAOD 0.01→ ΔTatmo~1% @ 500nm	σ_{AOD} ~ 0.02 From MERRA-2

MERRA-2 modeling system

Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2)

Undertaken by NASA's Global Modeling and Assimilation Office (GMAO)

Two primary objectives:

1) Place observations from NASA's Earth Observing System (EOS) satellites into a climate context

2) Update MERRA system to include the most recent satellite data.

Produced using :

- ➡ GEOS-5 atmospheric model and data assimilation system
- ➡ the three-dimensional variational data analysis (3DVAR) and Gridpoint Statistical Interpolation (GSI) meteorological analysis scheme

Assimilation of satellite radiances are performed using radiative transfer calculations (Community Radiative Transfer Model (CRTM, Han et al. 2006, Chen et al. 2008)).

incremental analysis update procedure every 6 h

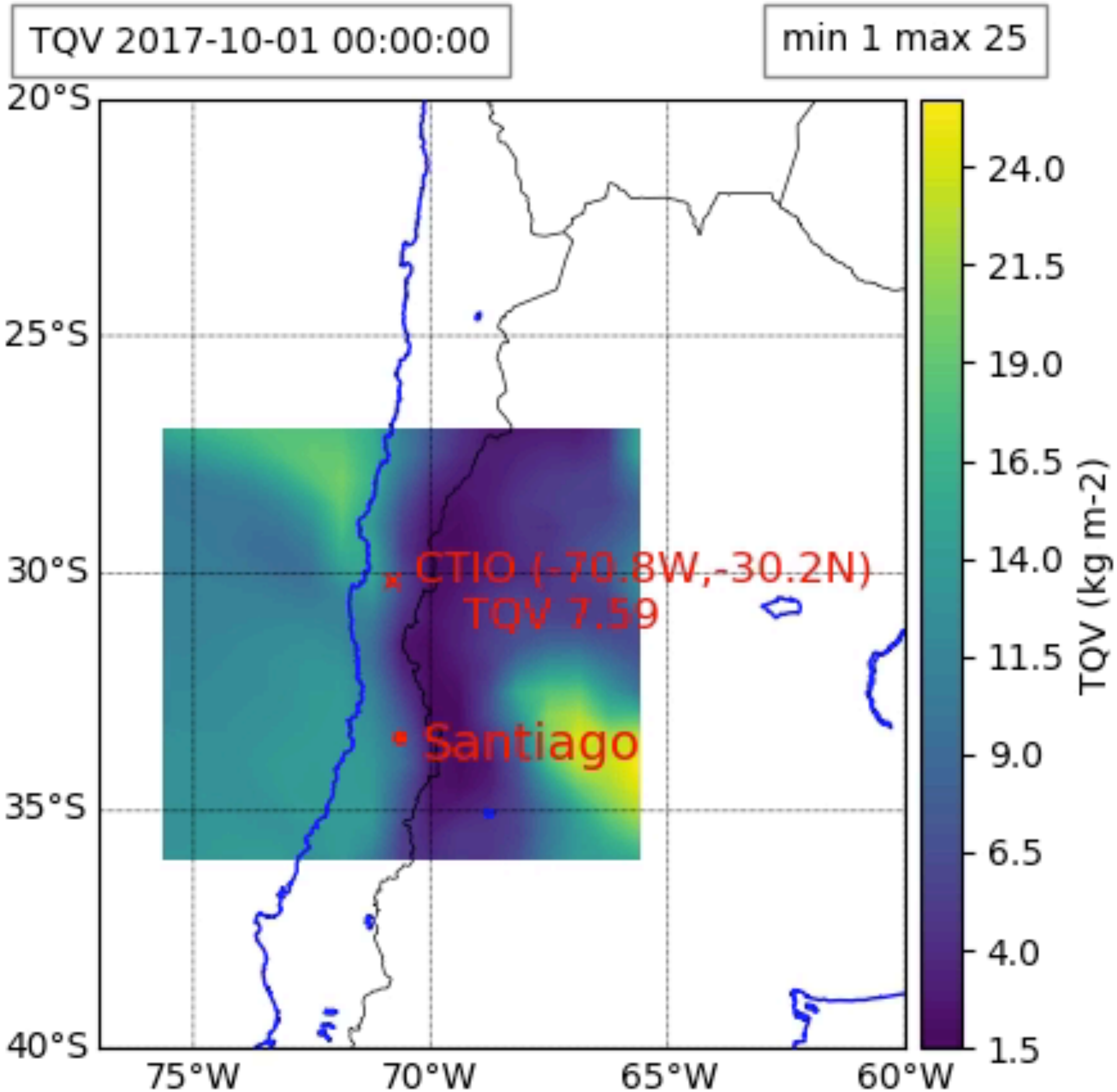
Resolution on a cubed-sphere grid ~50 km
with 72 layers from the surface to 0.01 hPa

https://gmao.gsfc.nasa.gov/pubs/docs/Randles887.pdf

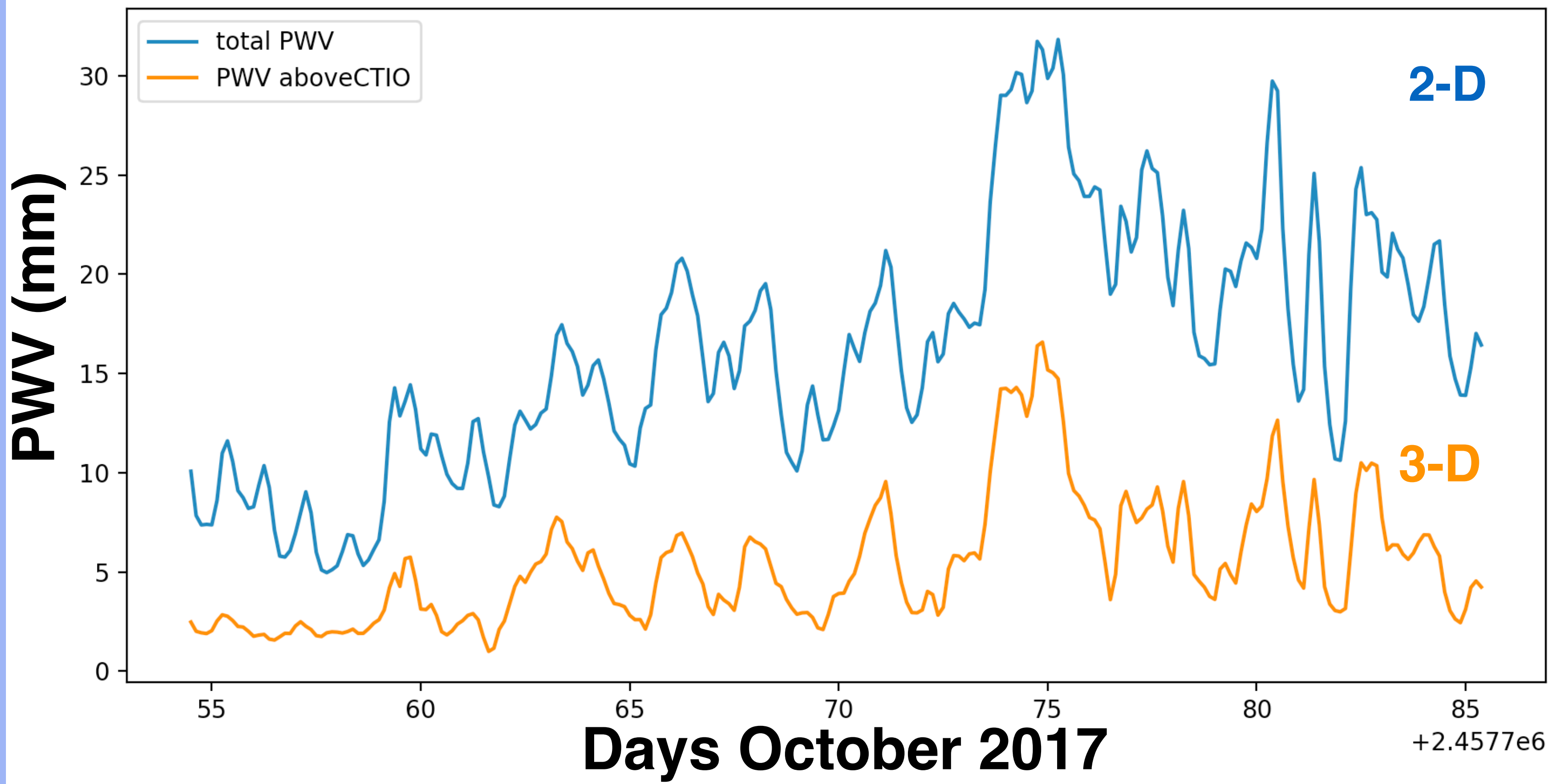
https://journals.ametsoc.org/doi/pdf/10.1175/JCLI-D-16-0609.1

https://confluence.lsstcorp.org/display/DM/Merra-2+Movies+October+2017

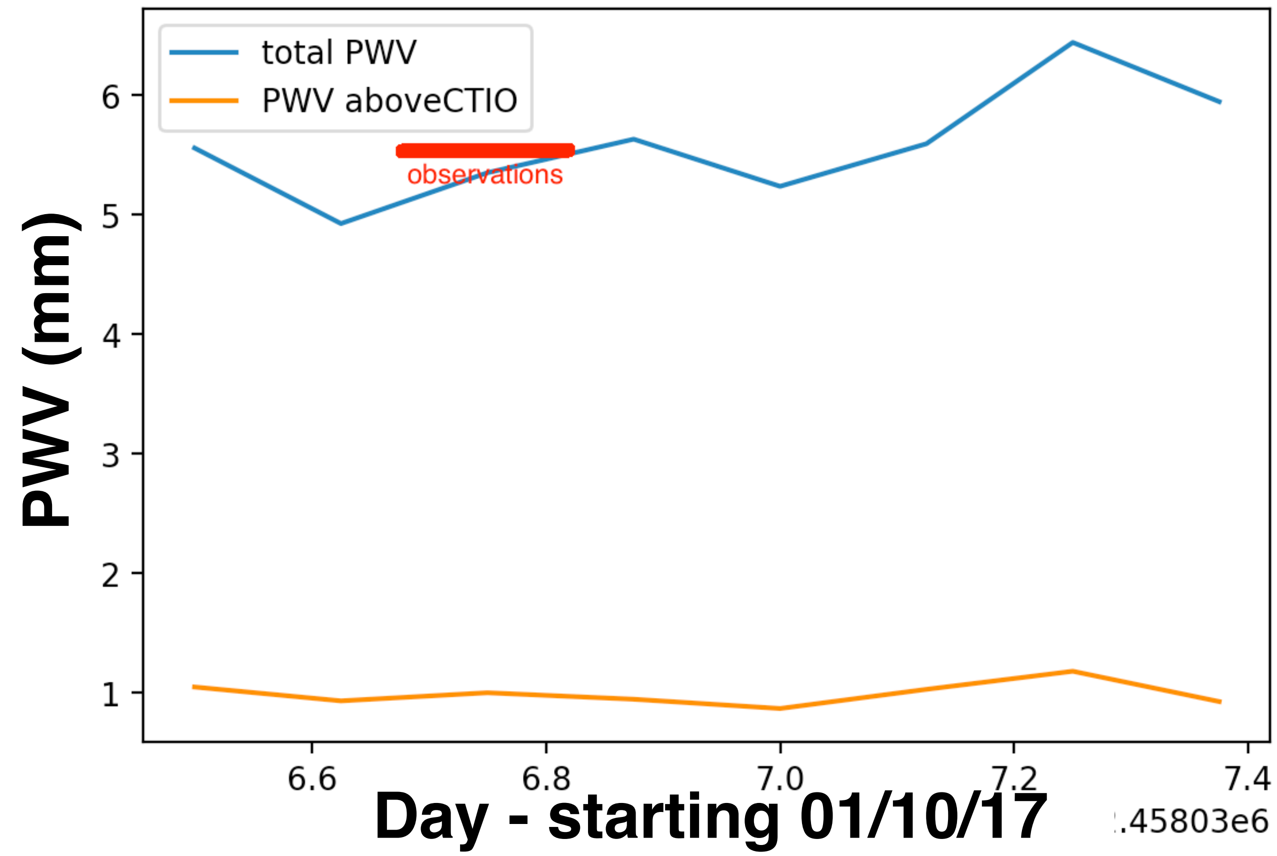
PWV 2-D table



MERRA-2 PWV : Would it be reliable to interpolate from 3D tables ?



specific humidity interpolation at CTIO lat-lon,
Then integrated from 2200m to top of the atmosphere



It can be tested using a weather balloon
in conjunction with a weather forecast algorithm

https://arxiv.org/pdf/1804.05200.pdf

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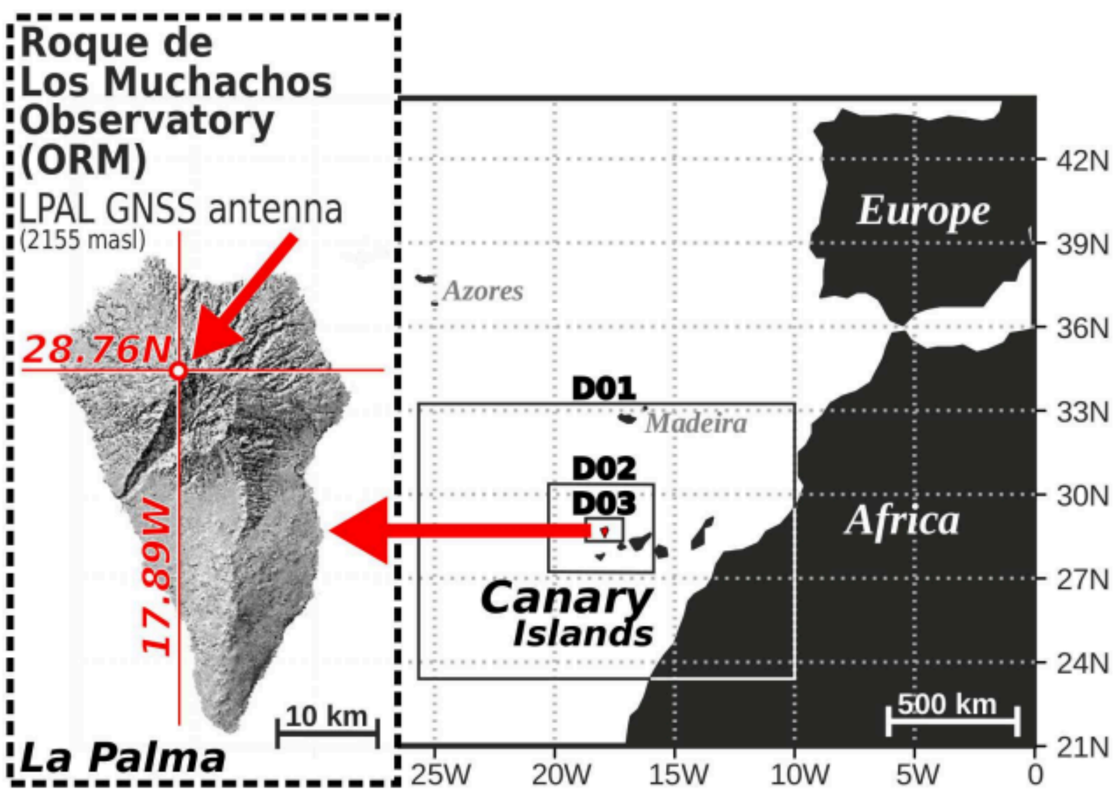
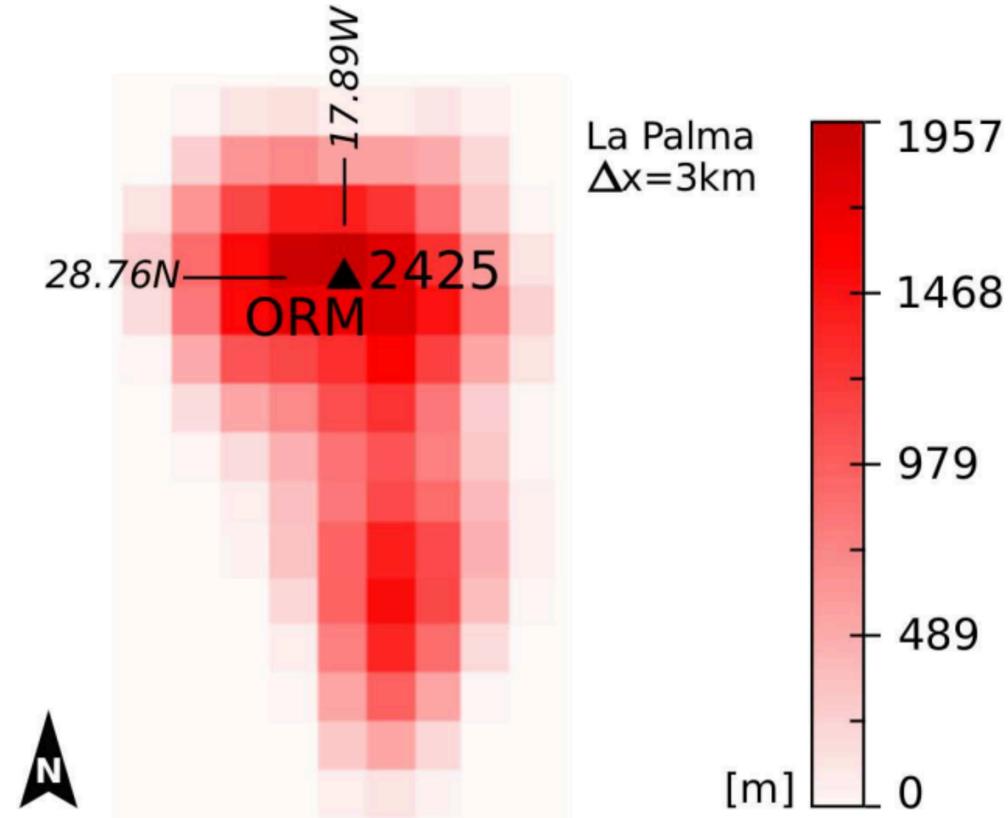
PWV from the Weather Research and Forecasting (WRF) model has been validated against GPS.



Roque de los Muchachos Observatory (ORM)
Canary Islands



Mesoscale weather forecast algorithm
In the context of steep orography
(horizontal resolution = 3km)

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https://arxiv.org/pdf/1804.05200.pdf

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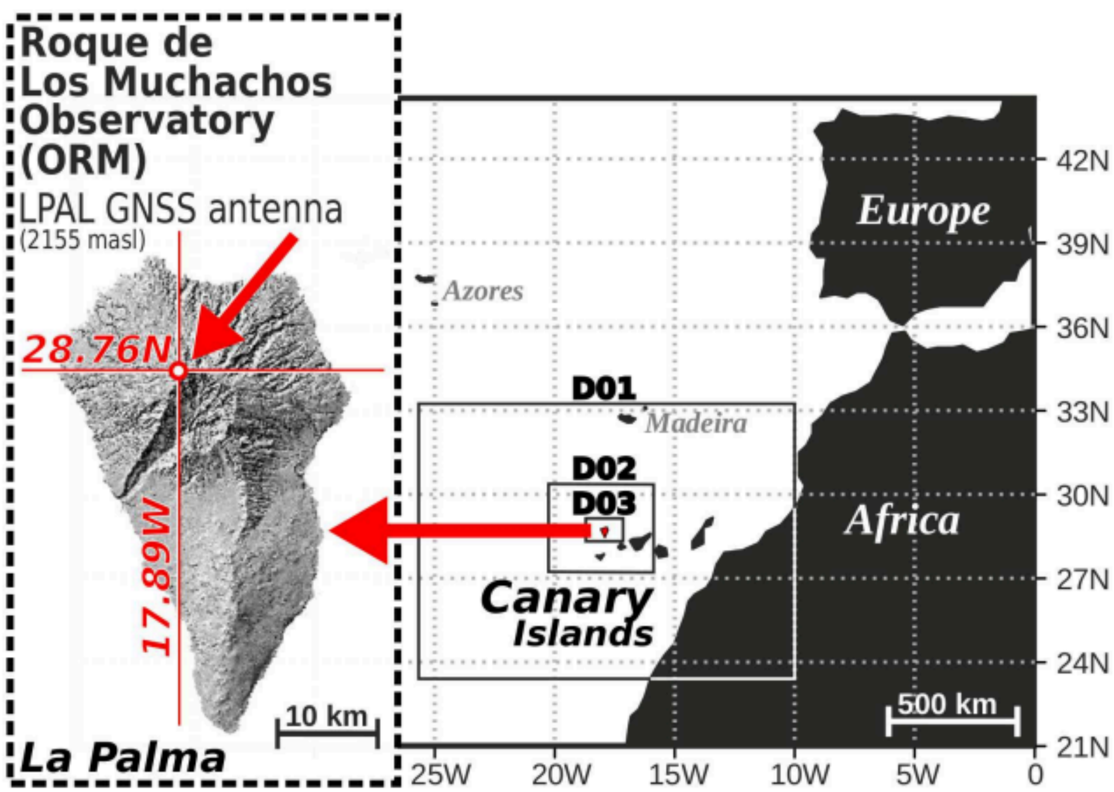

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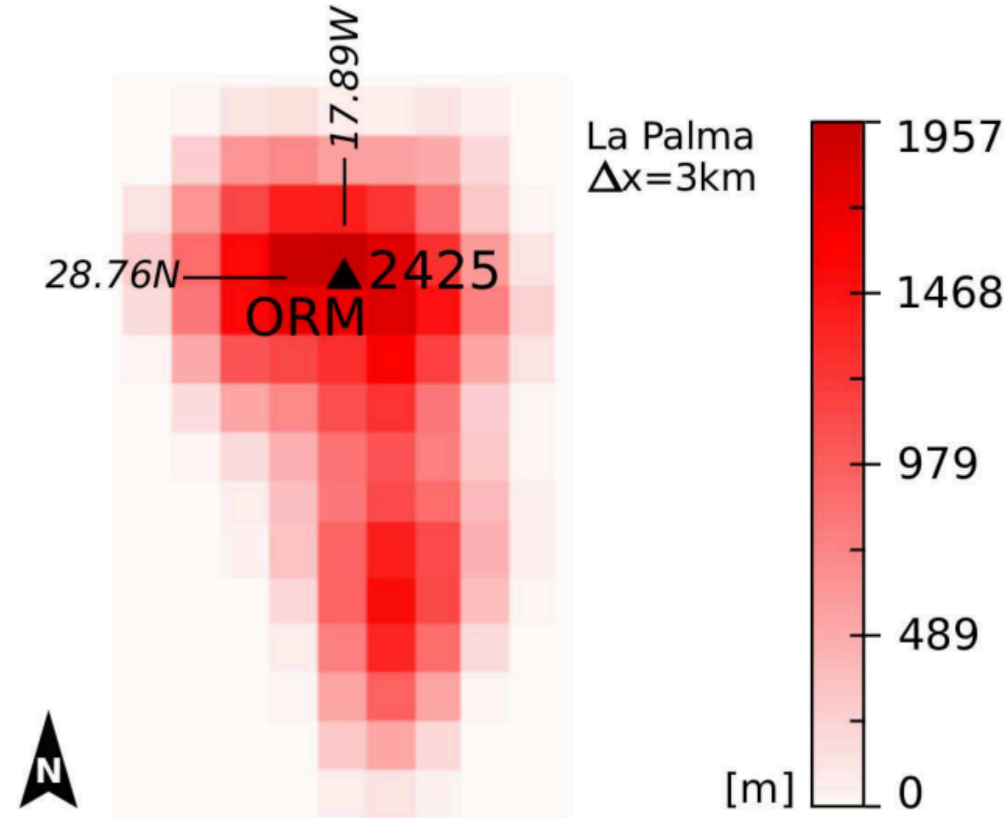


Mesoscale weather forecast algorithm
In the context of steep orography
(horizontal resolution = 3km)

WRF : non-hydrostatic mesoscale meteorological model (Skamarock & Klemp 2008).
high horizontal and vertical resolution so that it can best represent the subgrid processes
Initial conditions for : temperature, relative humidity and wind velocity in 32 vertical levels.

It can be tested using a weather balloon in conjunction with a weather forecast algorithm

https://arxiv.org/pdf/1804.05200.pdf

From 2016 January 11 to 2016 March 4,

WRF was run every 24 h for ~2 months, with an horizon of 24 hours (hourly forecasts).

—> 1296 hourly forecast points.

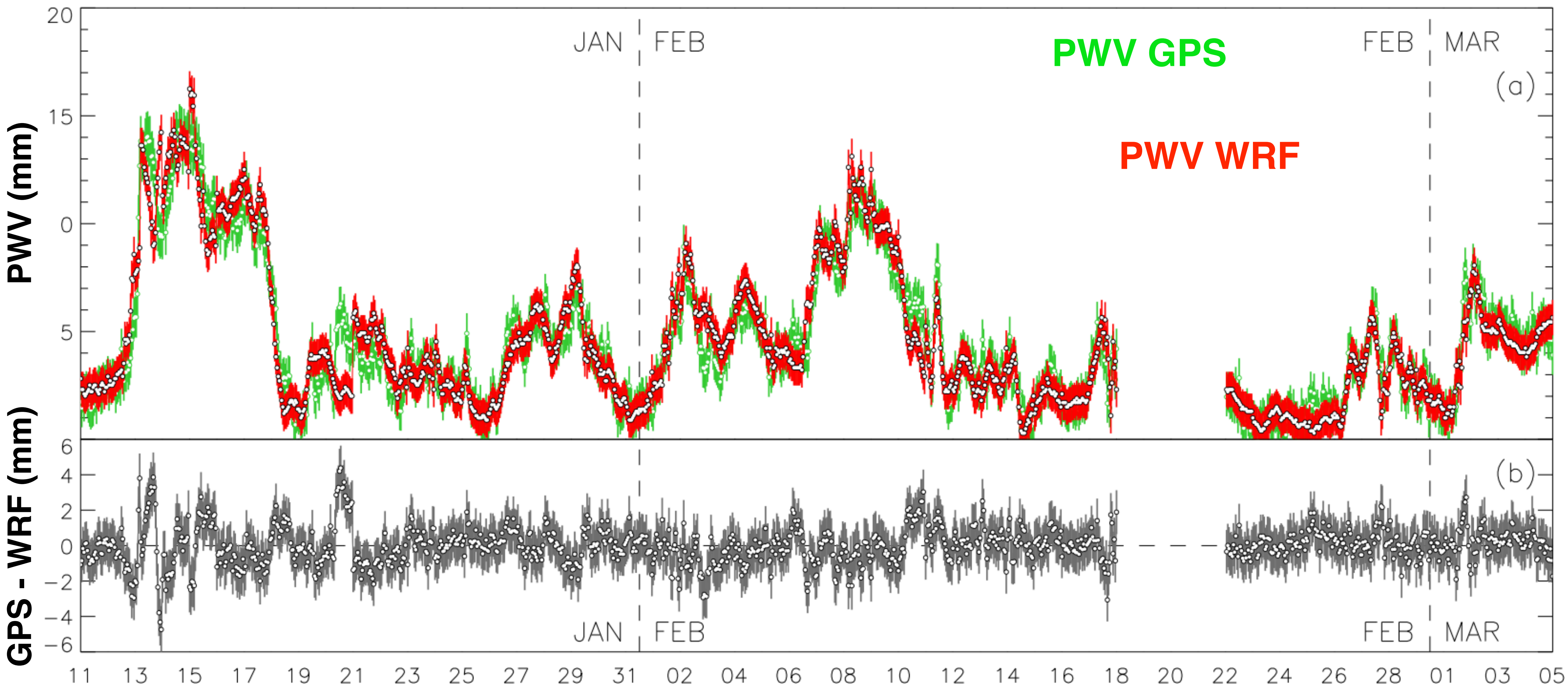
Validation from different approaches:

— Performance as a function of the forecast range, time horizon accuracy (24- and 48-hour),

— Performance as a function of the PWV value,

—> Excellent agreement between the model forecasts and observations.

PWV below 6 mm for ≈ 76 % of the period.



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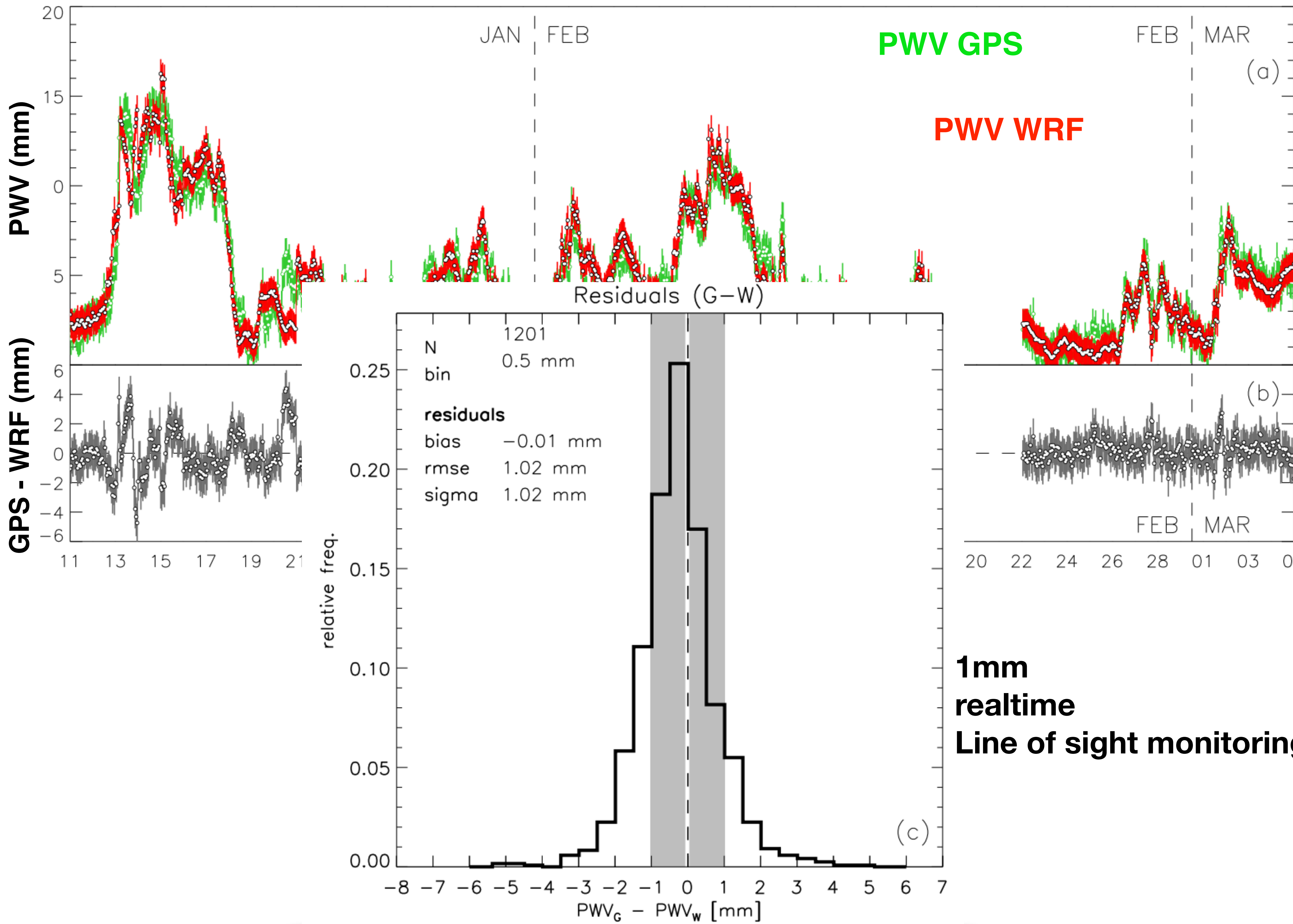

1mm
realtime
Line of sight monitoring

Testing Merra-2 PWV tables interpolation

—> An initial Weather balloons measurement of the local vertical atmospheric profile propagated overnight using MWFA.

—> Evaluate photometric residuals after atmospheric variability correction with :

- PWV from MERRA-2
- PWV from A.T.
- PWV from MWFA

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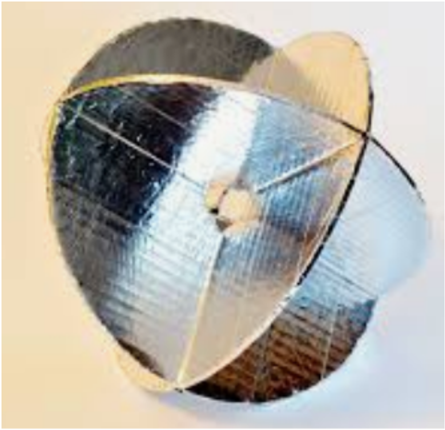
GPS
$149.65

Wireless Weather Station
$54.99

Weather Balloon Payload Parachute
$40.00

Weather Balloon 1kg payload
$89.00

Radar Reflector



$1.00

Testing Merra-2 PWV tables interpolati

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Just a Weather Balloon T-Shirt
$21.99 USD

GPS
$149.65

Wireless Weather Station
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Weather Balloon 1kg payload
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Weather Balloon Payload Parachute
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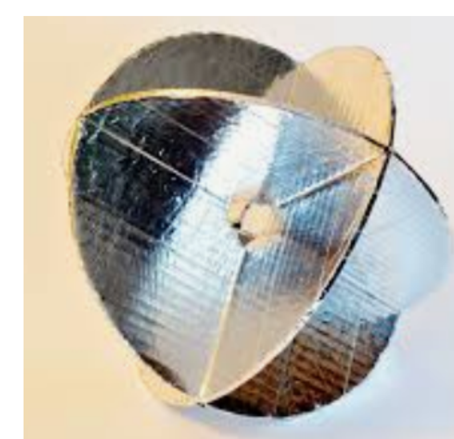
Radar Reflector



$1.00

MERRA-2 on aerosols

Aerosol Optical Depth (AOD) obtained from :

- MODIS (Terra and Aqua satellites radiances)
- NOAA Polar Operational Environmental Satellites (POES),
- NASA Earth Observing System (EOS), series of polar-orbiting and low inclination satellites.
- AERONET (land station network).

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Simulated with a radiatively coupled version of the Goddard Chemistry, Aerosol, Radiation, and Transport model (GOCART). It treats the sources, sinks, and chemistry of 15 externally mixed aerosol mass mixing ratio tracers (kg kg-1):

- Dust (five noninteracting size bins), DUINC
- Sea salt (five noninteracting size bins), SSINC
- Hydrophobic and hydrophilic black and organic carbon (four tracers), BCINC & OCINC
- And sulfate (SO_4). SUINC

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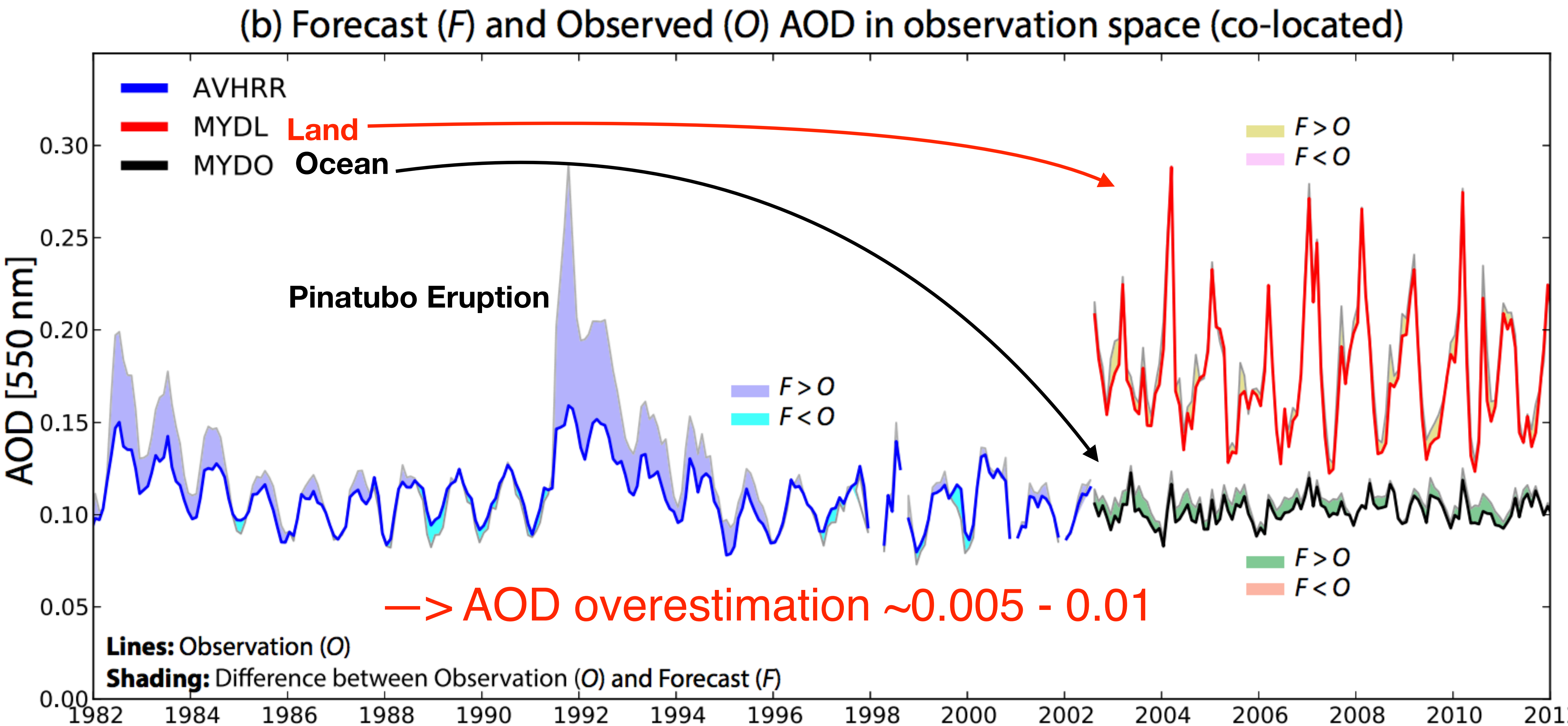
- And sulfate (SO4). SUINC

Assimilated into the GEOS-5, every 3h., the outputs are :

- three-dimensional profiles of aerosol mass mixing ratio for synoptic times on the native 72 eta-coordinate levels,
- and two-dimensional surface level or column-integrated aerosol diagnostics (e.g. wet deposition rate, surface mass concentration)
- AOD at 550nm.

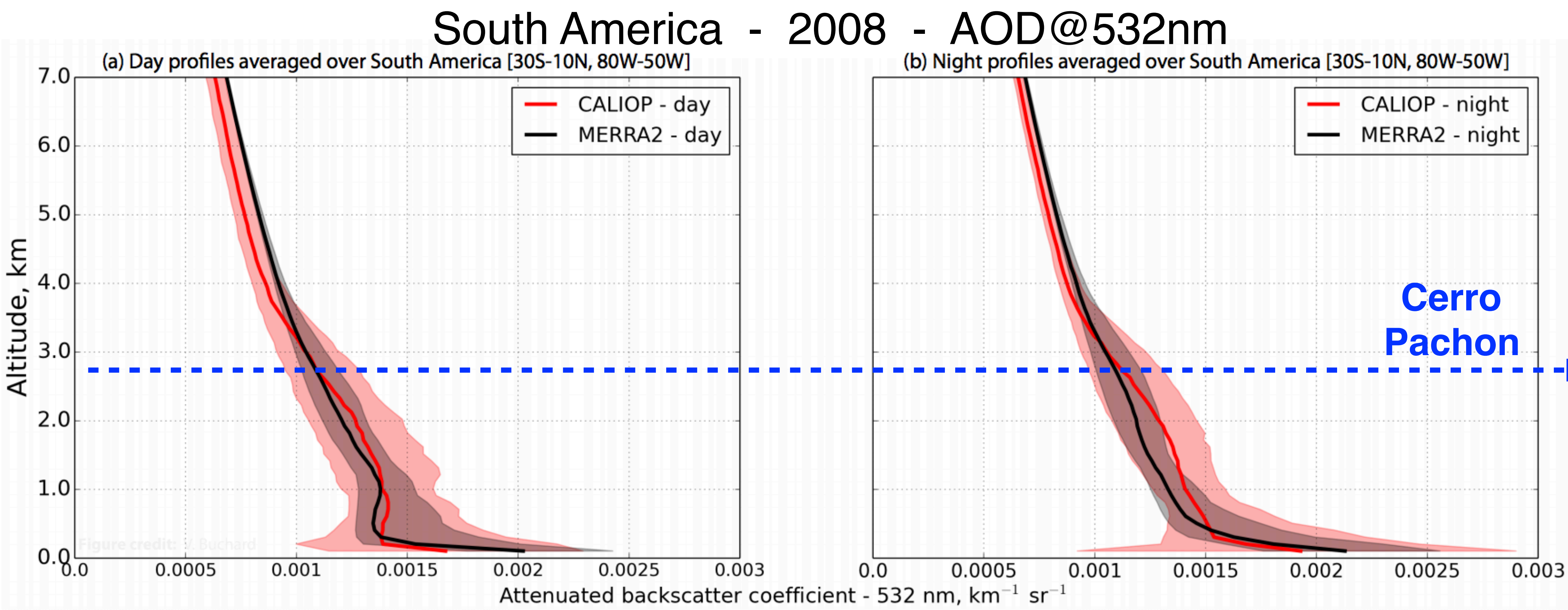
MERRA-2 on aerosols : an assessment



« Merra-2 overestimated the volcanic plume height, injecting sulfur dioxide gas higher in to the stratosphere. This has implications for transport and lifetime of the subsequently formed stratospheric sulfate aerosol […] »

« We reiterate that it is challenging to independently validate the MERRA-2 aerosol products because most of the global, readily available space-borne and ground-based observations are included in the assimilation. »

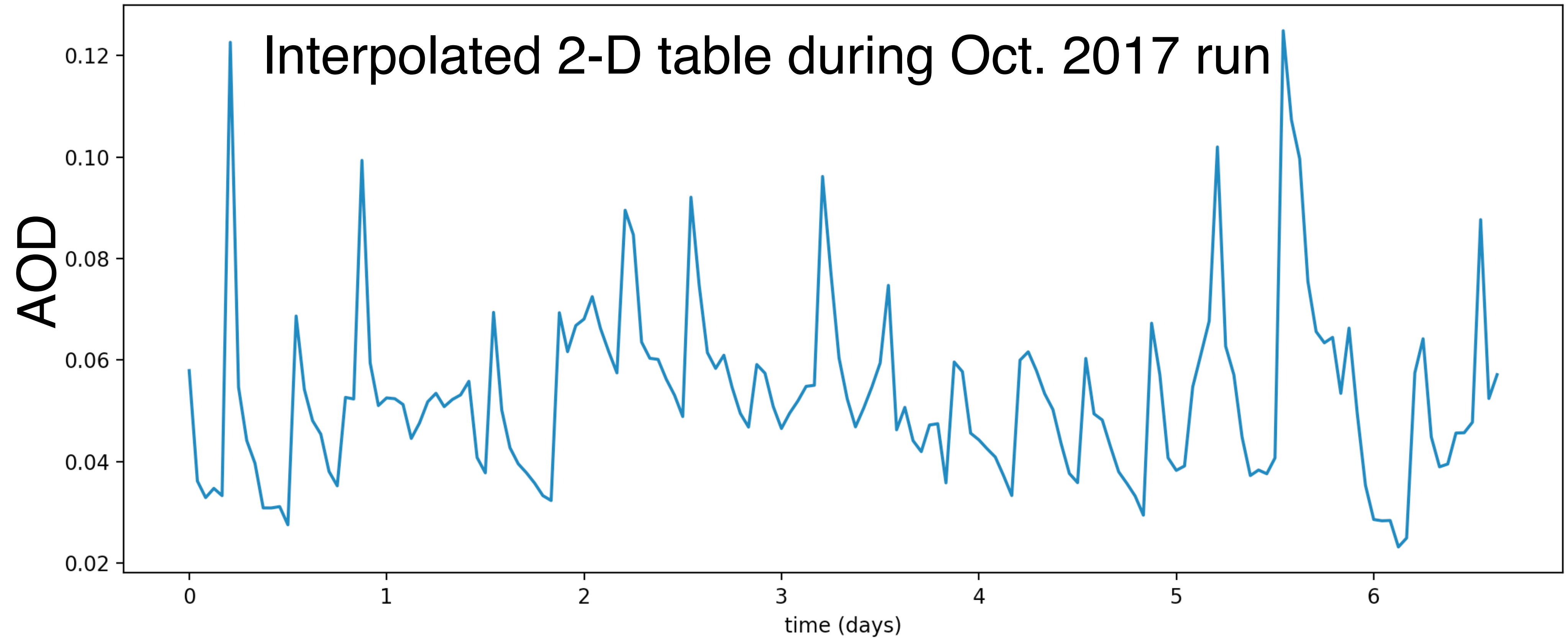
MERRA-2 aerosols South America: 3-D profiles



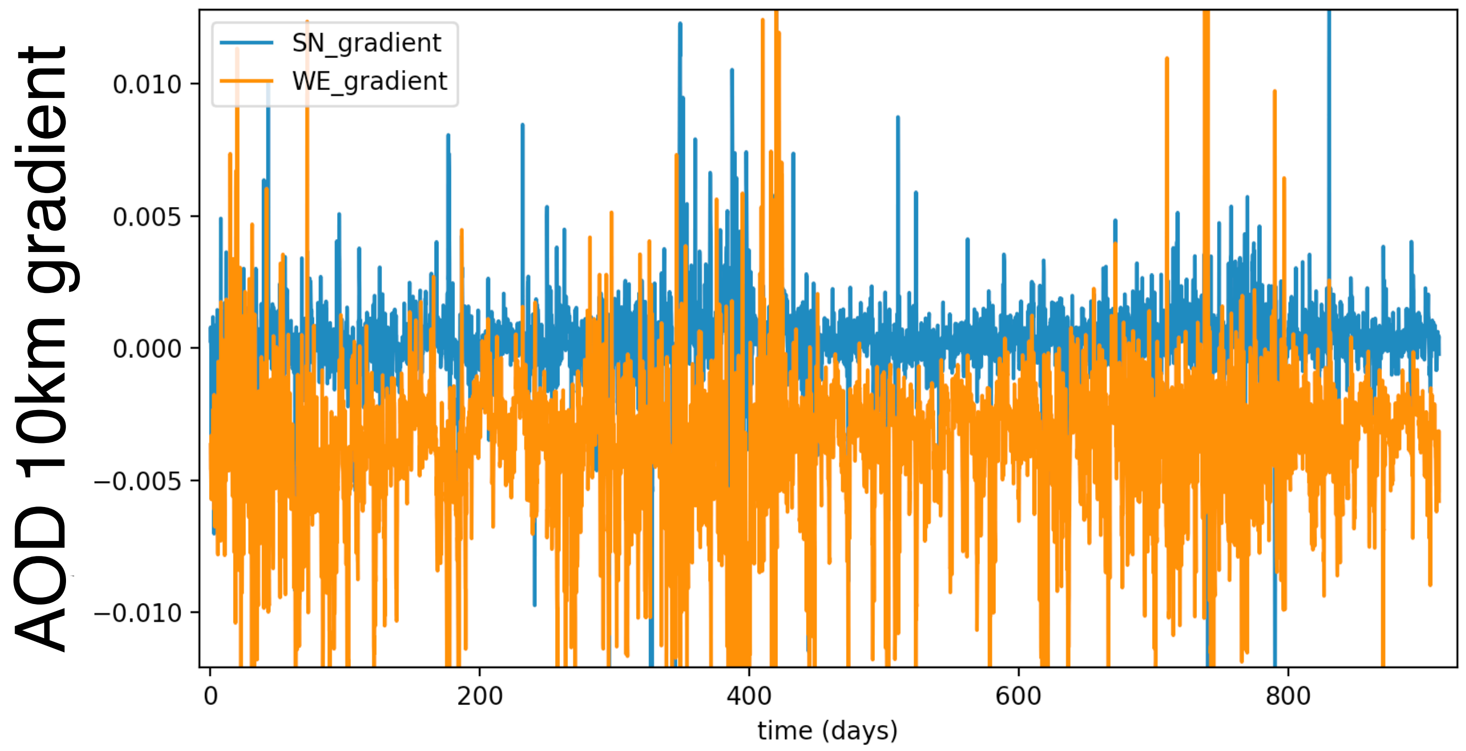
https://gmao.gsfc.nasa.gov/pubs/docs/Randles887.pdf

Large contribution from altitude below 2km

MERRA-2 AOD @ LSST site

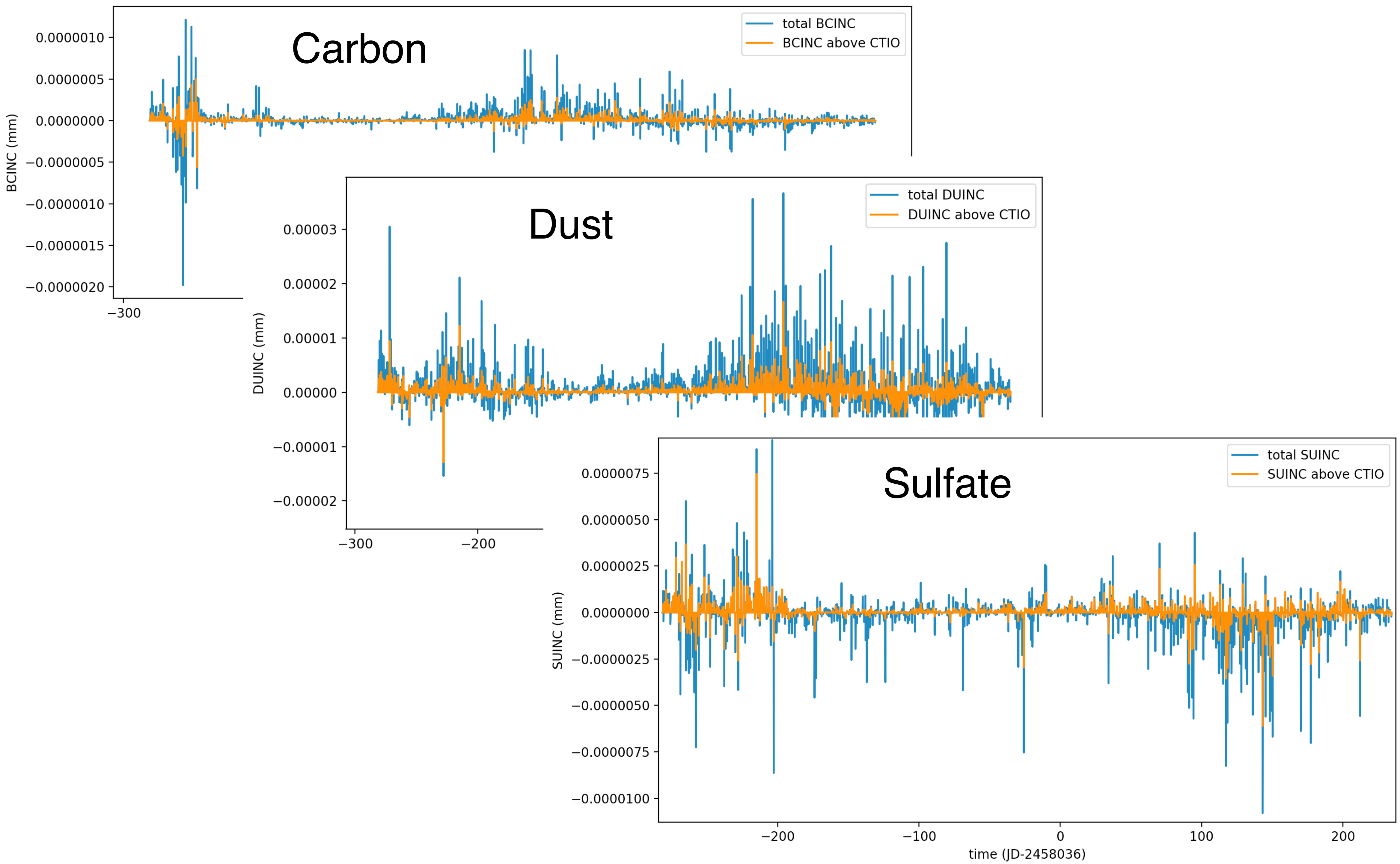


AOD~0.05

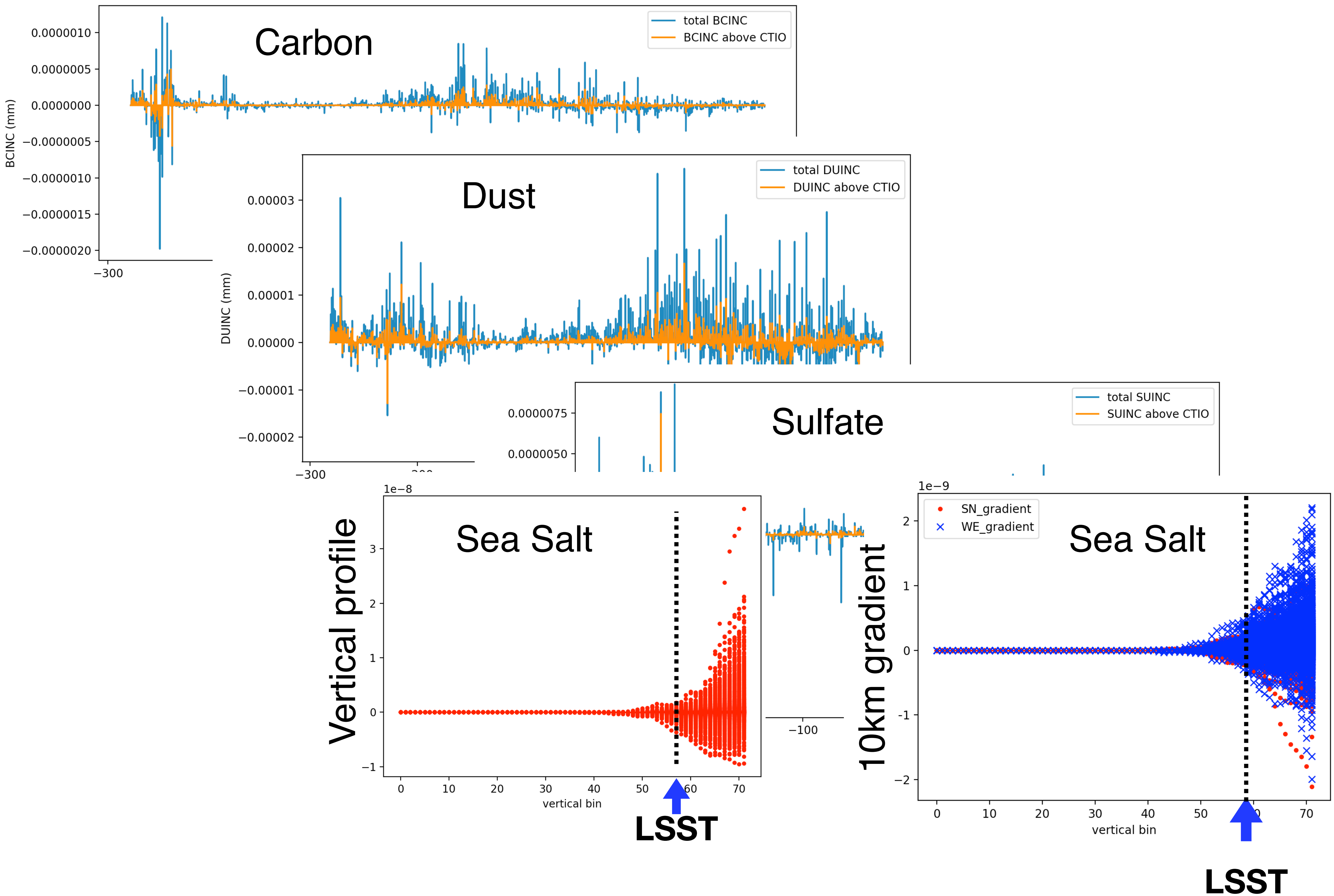


Steady ~0.003
East → West
Gradient

MERRA-2 3-D Aerosols components above LSST



MERRA-2 3-D Aerosols components above LSST



Could we use MERRA-2 tables on aerosols ?

Could we replicate the aerosol study at OHP where we would benefit from
On-site meteorological monitoring?

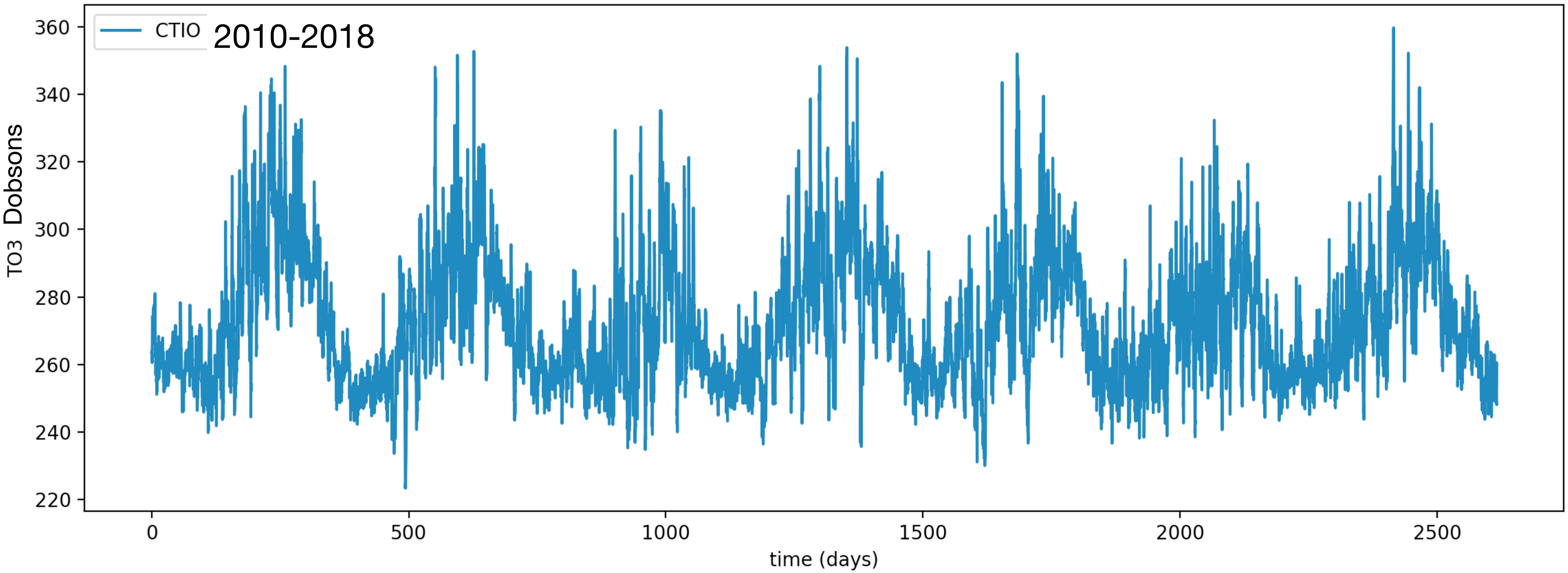
—> OHP geophysics station is monitoring profiles of :
Ozone, PWV, temperature, clouds, aerosols and wind from Lidar, radar and balloons.

http://www.obs-hp.fr/geo/geo_ohp.shtml

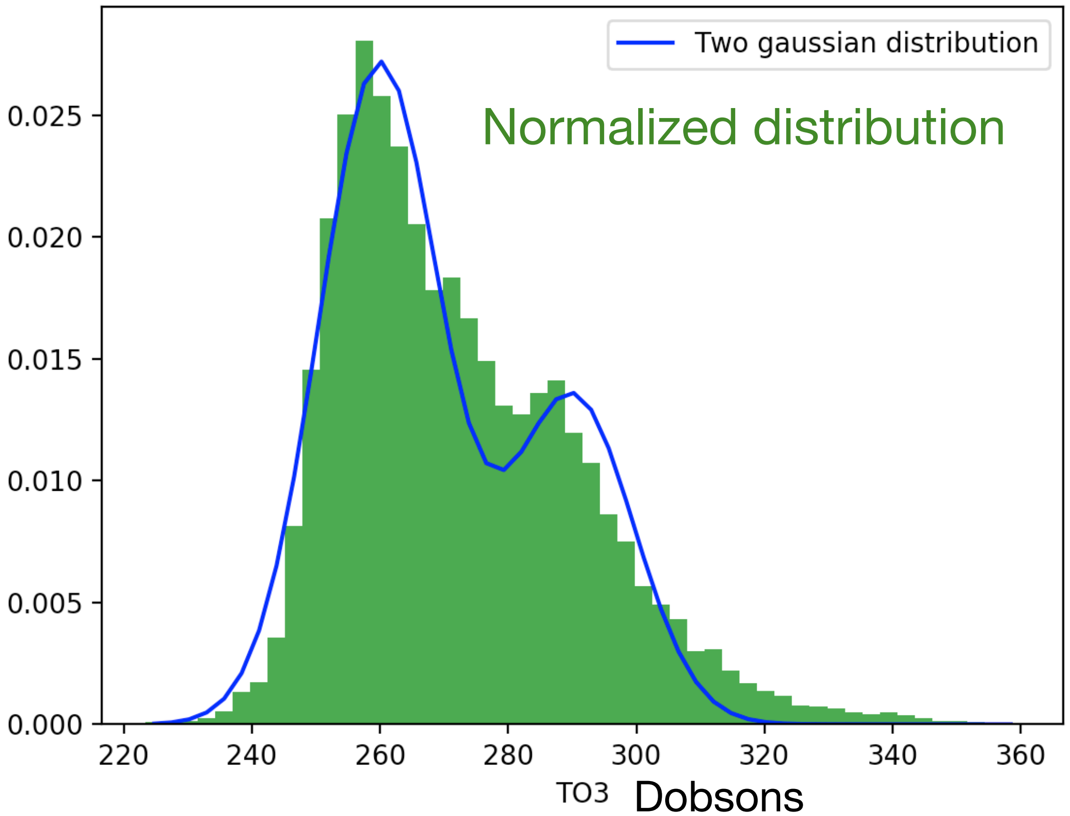
The End

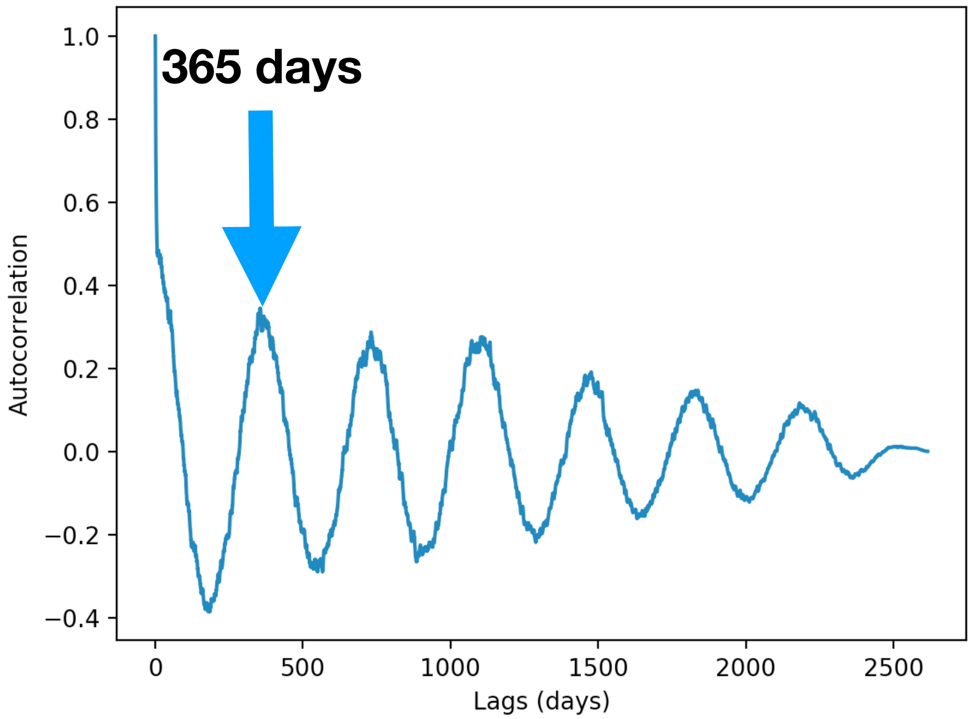
What about clouds?

Clouds - Extinction from cumulus and stratus do exhibit a small trend in wavelength. But even for such strong extinction of 5 mag/airmass the change in transmission from 3200 Å to 10000 Å is below 3%. Cirrus with less than 1 mag of extinction is the most common cloud environment that still allows useful observing, Buton et al. 2012



Annual variation (~50 Ds) with lower levels during summers





https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2013JD020914

McPeters et al. [2008] discuss validation of the OMI daily total ozone by comparing OMI with Brewer and Dobson ground-based measurements and also with aircraft total ozone for four campaign missions.

The Brewer and Dobson measurements indicated about +0.4% offset for OMI total ozone (OMI being higher), while the aircraft measurements indicated -0.2% offset with an RMS difference of 3%. Assuming average OMI total ozone of 300 DU, these numbers indicate a small offset of ~1 DU and RMS difference of 9 DU.

Also : Lower stratosphere model assimilation
Is more accurate than for the upper troposphere

*** Ozone Monitoring Instrument onboard satellite**

The global structure of upper troposphere- lower stratosphere ozone in GEOS-5 : A multiyear assimilation of EOS Aura data

https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2014JD022493

The meteorological analysis in GEOS-5 is performed four times daily, using 6 h model forecasts (backgrounds) and observations within a ±3 h window of the analysis time.

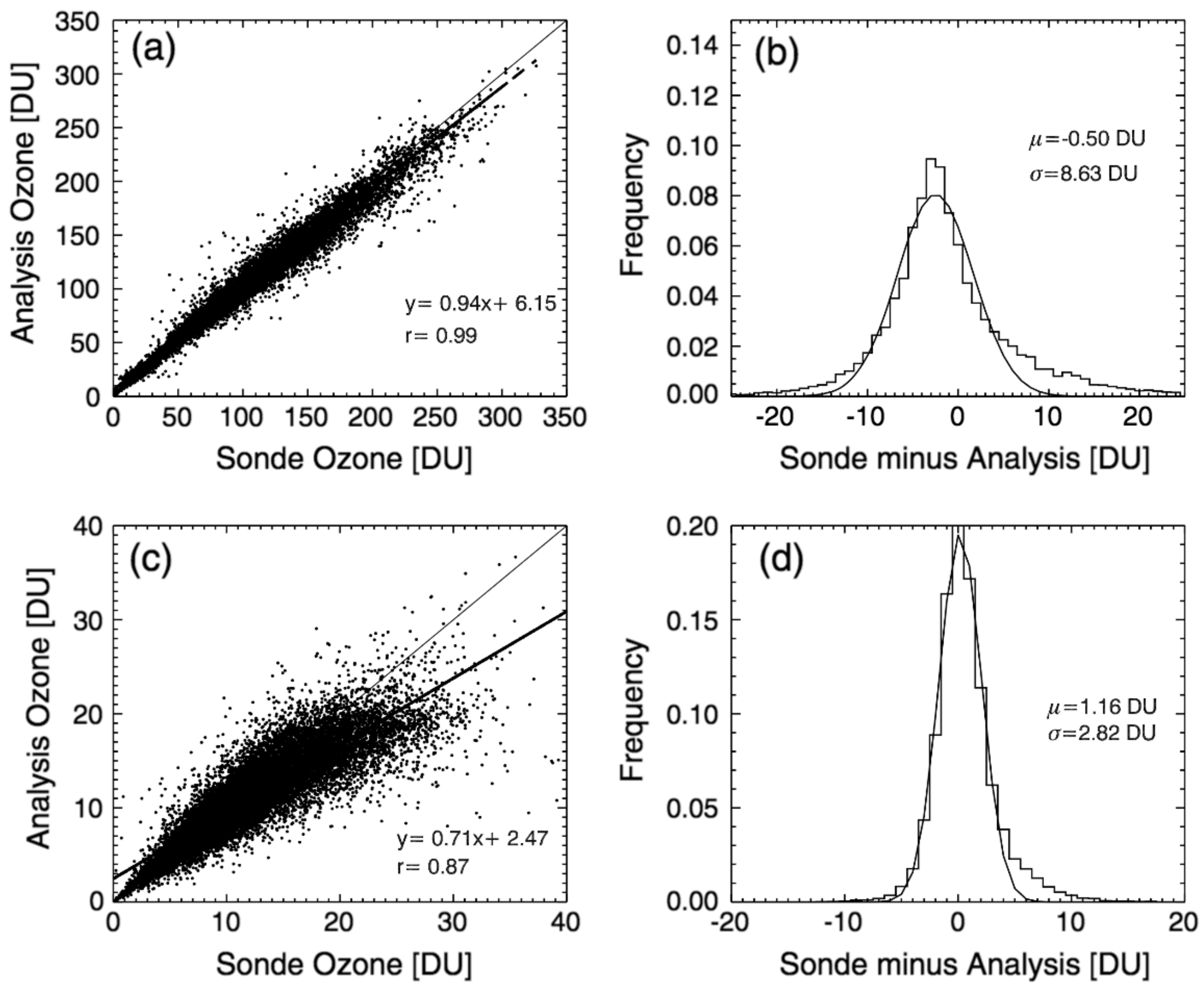


Figure 10. Comparisons of the analyzed UTLS ozone with the collocated ozonesonde observations. (a) Scatterplot of the lower stratospheric partial column, integrated between the tropopause and 50 hPa. The thick black line represents a linear fit to the data plotted. (b) The binned distribution of the sonde-minus-analysis differences (stepped line) along with a Gaussian fit to this distribution (smooth curve). (c and d) The equivalent plots for the upper tropospheric layer (500 hPa to the tropopause). This comparison includes about 16,000 sonde observations, with no sorting by their spatial or seasonal locations.

Table 2. Statistical Description of the Sonde-Minus-Analysis of the LS (the Dynamical Tropopause to 50 hPa) Ozone Column Separated Into Latitude Bands[a]

	Bias (DU) (analysis-sondes)	Standard Deviation (DU)	Relative Bias (%)	Correlation	Slope	Number of Sondes
All sondes	0.50	8.63	0.54	0.99	0.94	18,377
60°N–90°N	−2.08	12.30	−1.75	0.97	0.87	2,548
30°N–60°N	0.43	8.54	0.42	0.98	0.91	9,784
30°S–30°N	1.94	2.77	8.85	0.97	0.92	3,736

[a]All available sondes between 2005 and 2012 were used. Relative biases are computed with respect to ozonesonde data.

Table 3. Statistical Description of the Sonde-Minus-Analysis of the UT (500 hPa to the Dynamical Tropopause) Ozone Column Separated Into Latitude Bands[a]

	Bias (DU)	Standard Deviation (DU)	Relative Bias (%)	Correlation	Slope	Number of Sondes
All sondes	1.16	2.82	9.26	0.87	0.71	18,588
60°N–90°N	0.88	1.70	9.88	0.88	0.79	2,553
30°N–60°N	1.02	2.59	7.87	0.85	0.78	9,892
30°S–30°N	2.45	3.83	14.30	0.75	0.44	3,834

[a]All available sondes between 2005 and 2012 were used. Note that the number of sondes here is greater than that in Table 2. This is because there is a small number of soundings that do not reach the 50 hPa pressure surface but that do reach the tropopause.

Conclusion

The Ozone value from MERRA-2 is correct on large space (continental) and time (monthes) scales. Consistency with observation at a given day and location is lacking, except for a few events such as Russian wildfires (+5 Dobsons) and Beijing Olympics.

In Chile, Ozone is driven by El Nino.
As a first implementation, I suggest that we fit the annual variation and retrieve one value per-day.

https://tel.archives-ouvertes.fr/tel-00855585/document

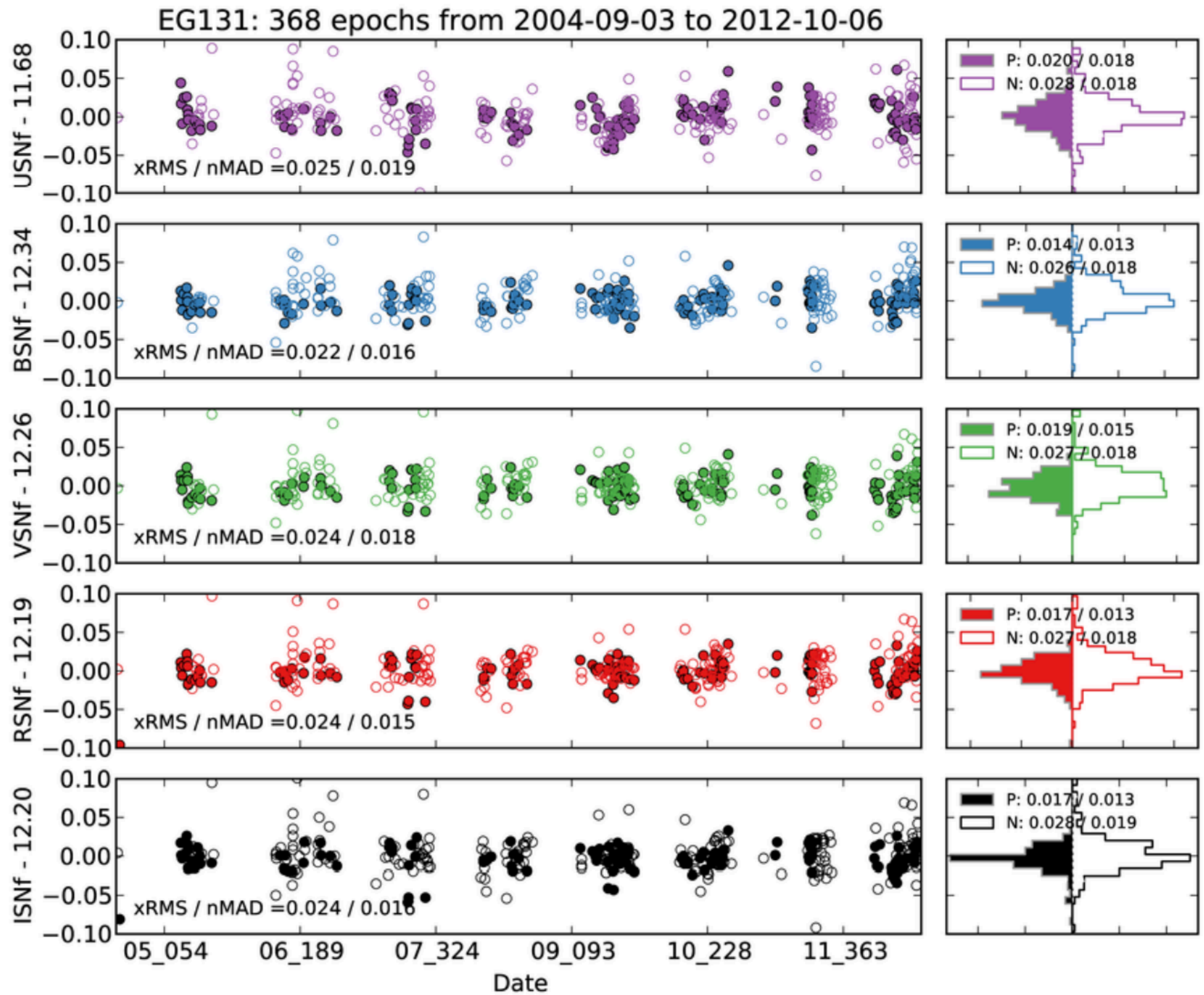
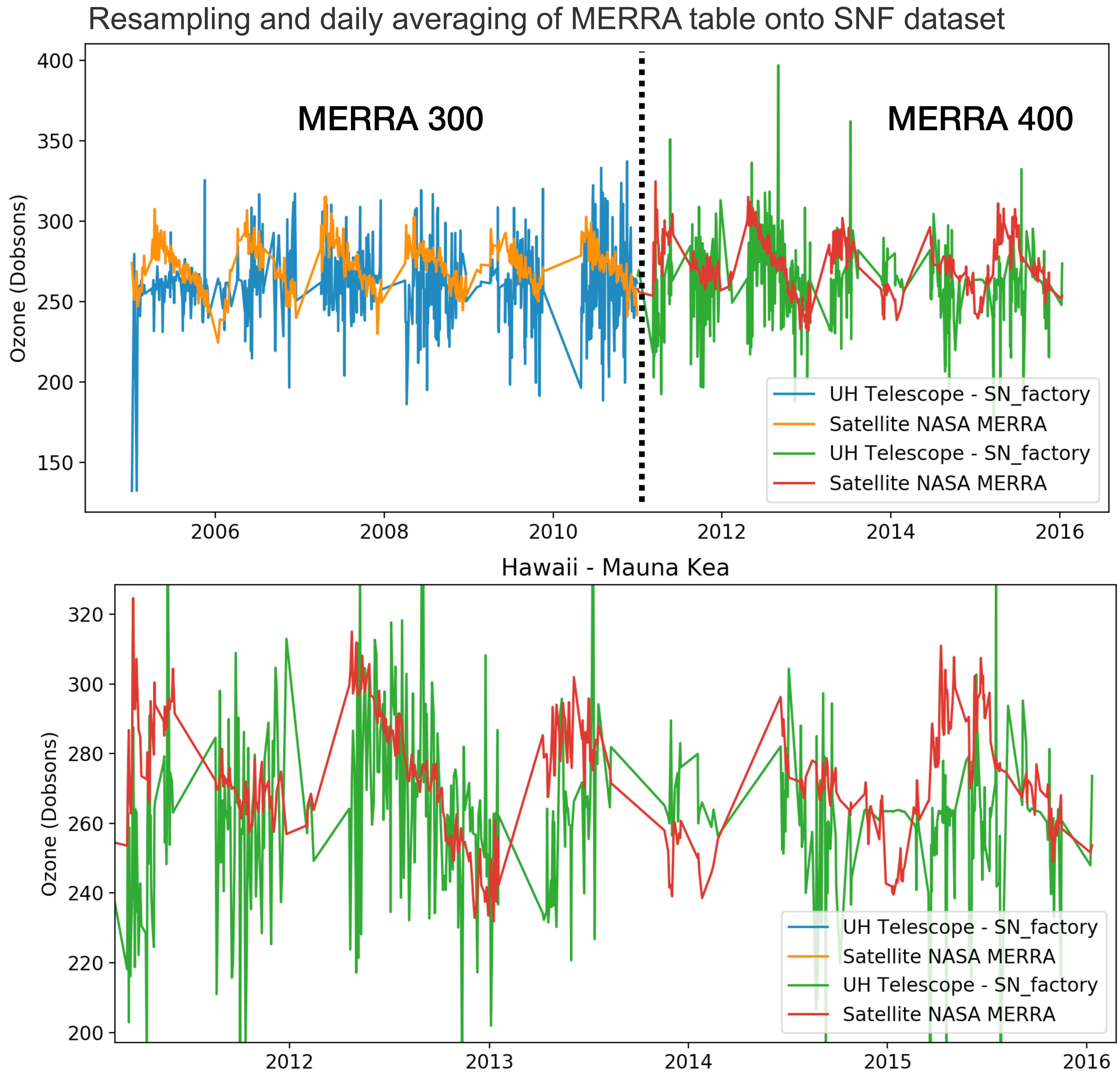


FIGURE 7.3 – Photométrie synthétique de EG131 (production NH) dans les filtres SNfactory (les • correspondent aux nuits photométriques, les ∘ aux non photométriques).



Resampling and daily averaging of MERRA table onto SNF dataset
MERRA 300
MERRA 400
Ozone (Dobsons)
400
350
300
250
200
150
2006
2008
2010
2012
2014
2016
UH Telescope - SN_factory
Satellite NASA MERRA
UH Telescope - SN_factory
Satellite NASA MERRA
Hawaii - Mauna Kea
Ozone (Dobsons)
320
300
280
260
240
220
200
2012
2013
2014
2015
2016
UH Telescope - SN_factory
Satellite NASA MERRA
UH Telescope - SN_factory
Satellite NASA MERRA