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Aerosol Retrieval using the (Advanced) Along Track Scanning Radiometer

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With contributions form many other colleagues

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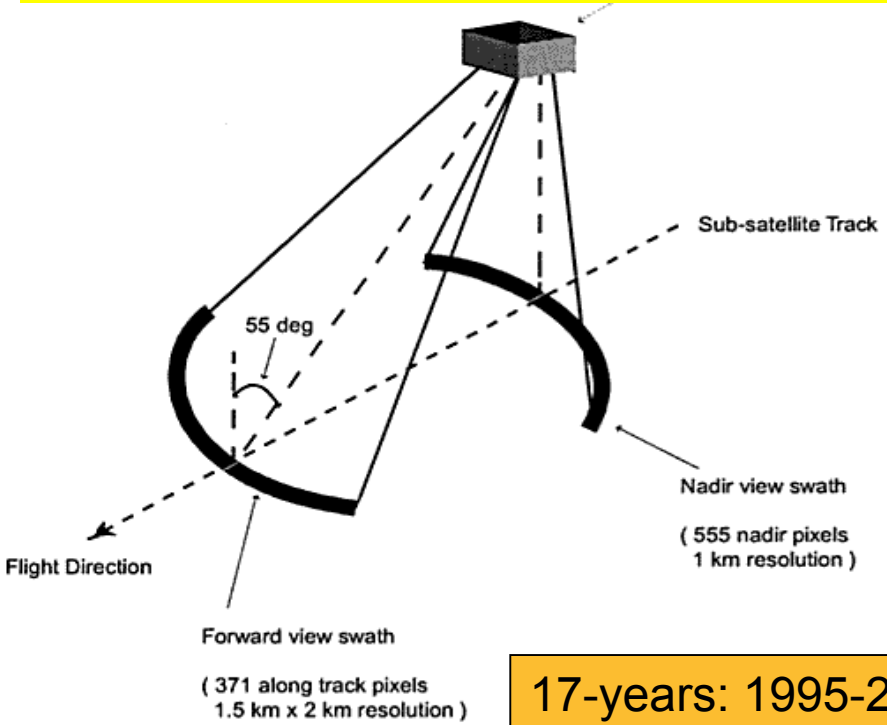
Helsinki, Finland

Kaufman Symposium, June 2016

- Sun synchronous
- Equator overpass time 10:00
- Swath 500km
- 7 Spectral Channels:
  - IR: 1.6, 3.7, 10.85, 12 μm
  - VIS: 0.555, 0.67, 0.865 μm
- Spatial resolution 1 x 1 km^2

AATSR lost on 6 April 2012 – SLSTR launched onboard Sentinel-3, 16 February 2016



- **AATSR has two viewing angles; forward at 55° , and nadir**
- Two viewing angles allow to account for surface effects on TOA radiation
- Over land the dual view aerosol retrieval algorithm (ADV) is used
- Over ocean the two views are used separately: forward and nadir

17-years: 1995-2012: ATSR-2&AATSR, extended with SLSTR

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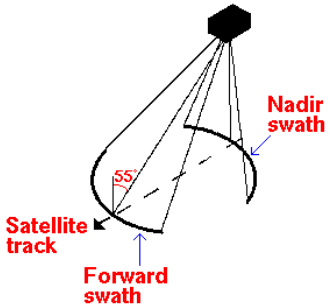
AATSR Dual View Algorithm (ADV): Aerosol retrieval over land



$$\rho_{TOA} = \rho_{atm} + \frac{R_{surf}}{1 - R_{surf} \cdot r} T_{down} T_{up}$$

$$\frac{\rho_{TOA}^{n} - \rho_{atm}^{n}}{T_{down}^{n} T_{up}^{n}} = \frac{\rho_{TOA}^{f} - \rho_{atm}^{f}}{k \cdot T_{down}^{f} T_{up}^{f}}$$

$$k = \frac{R_{surf}^{f}}{R_{surf}^{n}} \approx \frac{\rho_{TOA}^{f}(1.6\mu m)}{\rho_{TOA}^{n}(1.6\mu m)}$$

Using the two ATSR views, the land surface contribution to the TOA reflectance is effectively removed and the path radiance retained.

Improvements expected in v3.0 (current 2.30plume)

Veefkind et al., 1998

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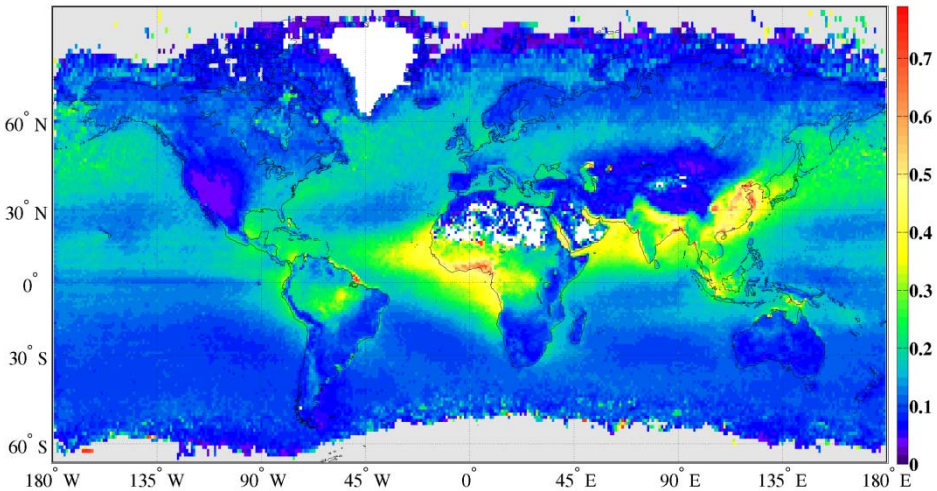
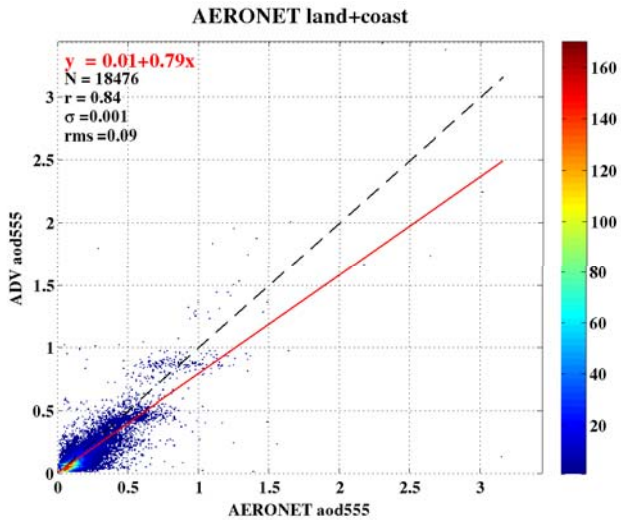
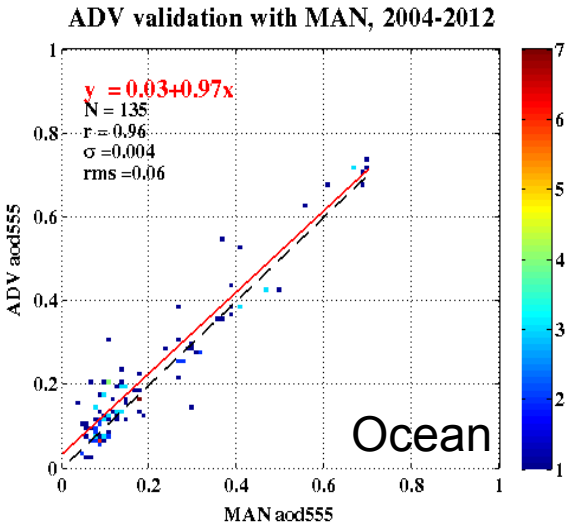
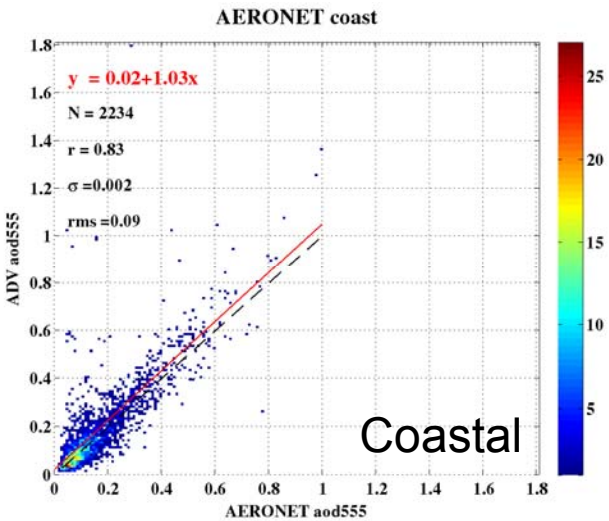
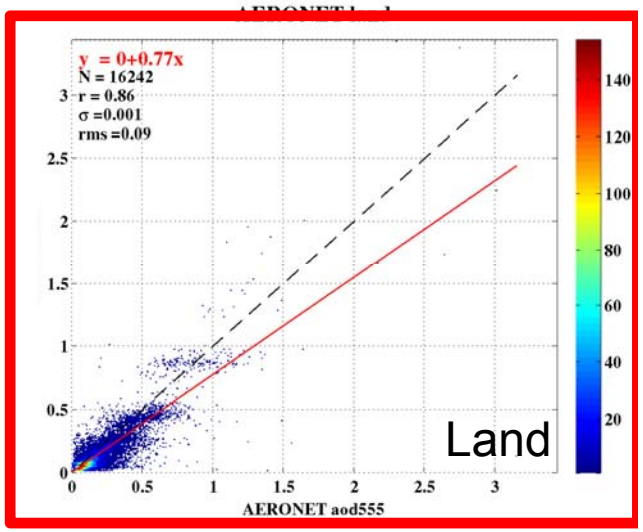
AATSR (2003-2011) aggregated AOD550 & validation





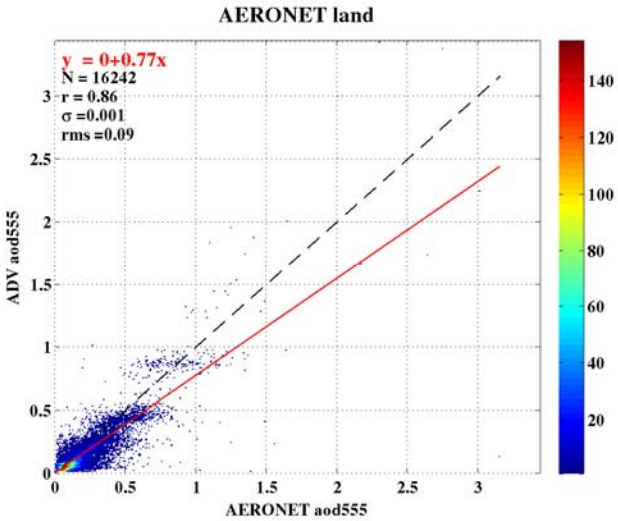


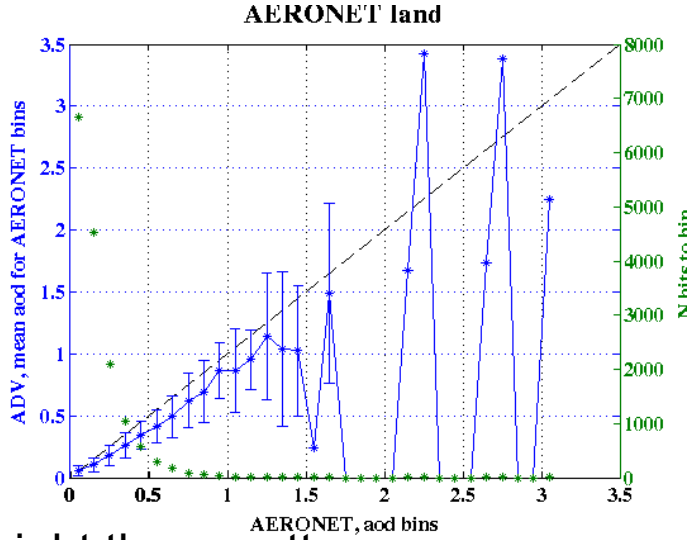




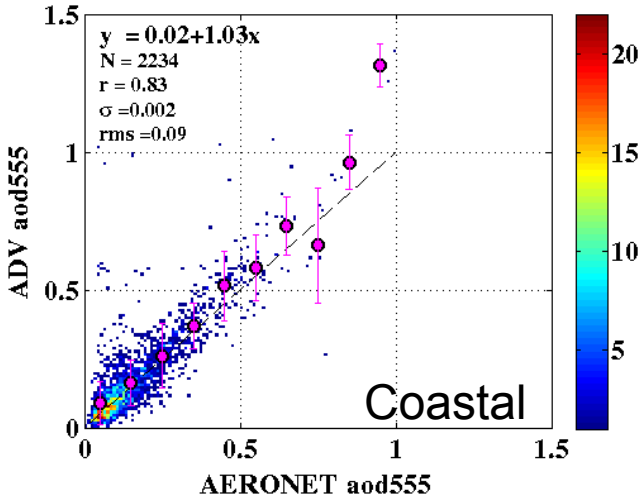
Kolmonen et al., IJDE, 2015

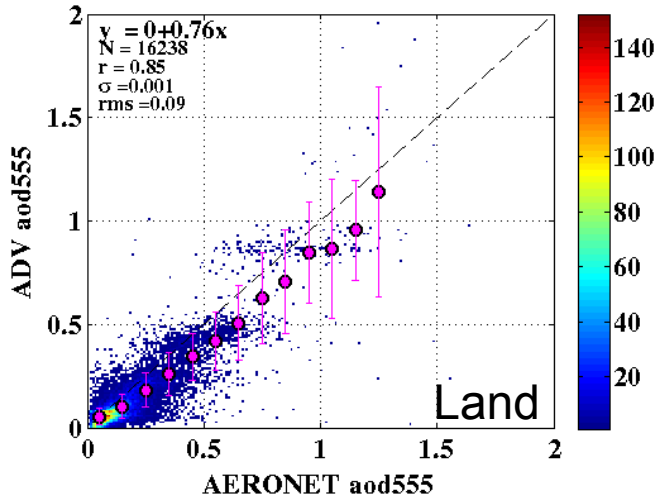
AATSR (2003-2011): validation





Binning gives better insight than scatter





Kolmonen et al., IJDE, 2015

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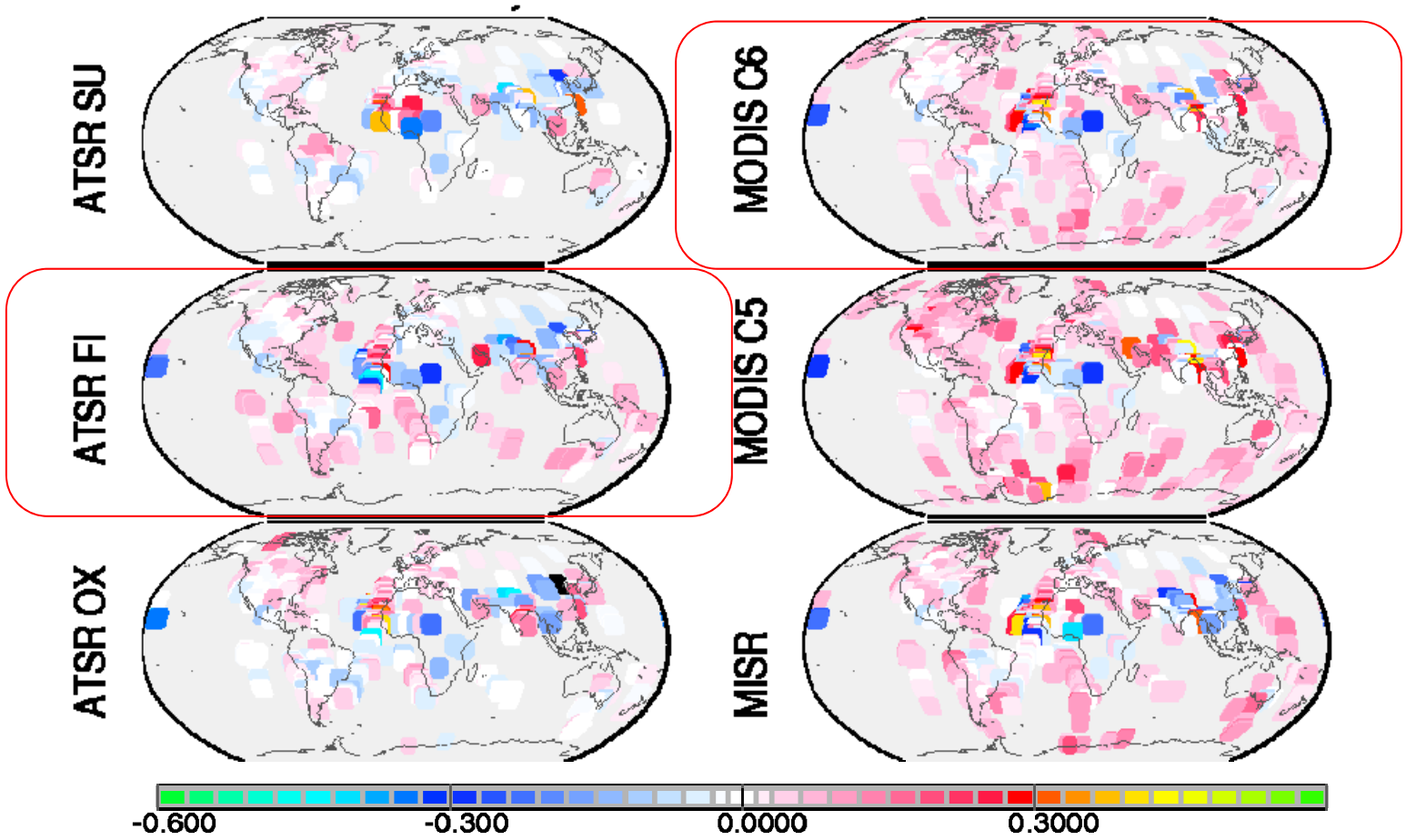
Comparison with other algorithms & instruments (2008)

AOD550 differences: Satellite – AERONET/MAN



Satellite lower <> satellite higher

Ref: Aerosol_cci

Comparison ADV with MODIS C6 (for 2008)

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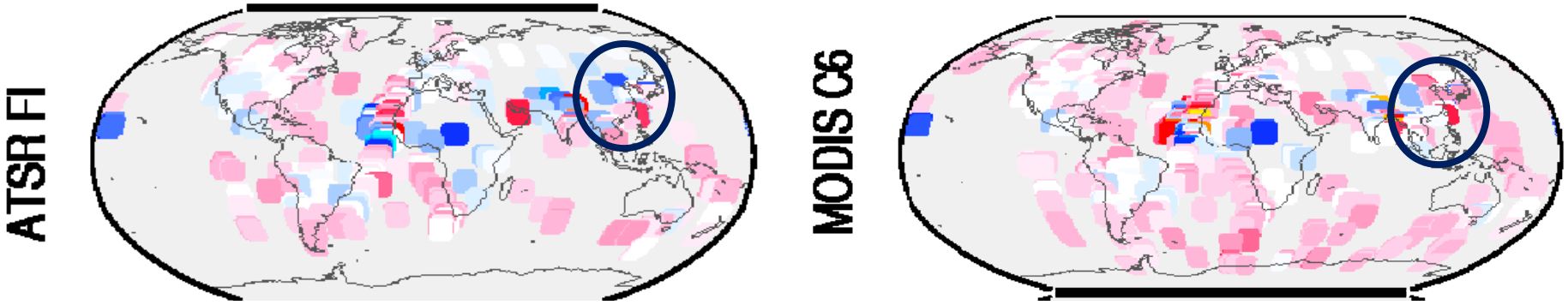
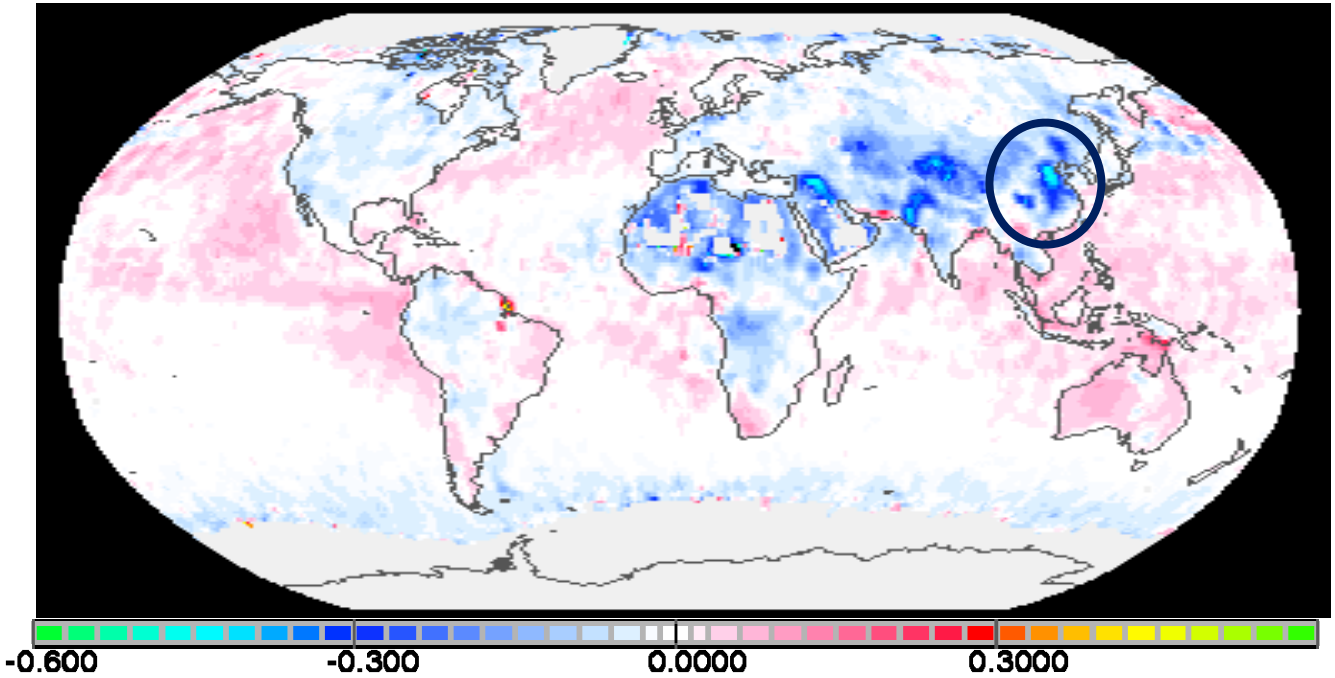
AOD550 differences: Satellite – AERONET/MAN



ADV/ASV - MODIS C6



ADV/ASV lower <> ADV/ASV higher

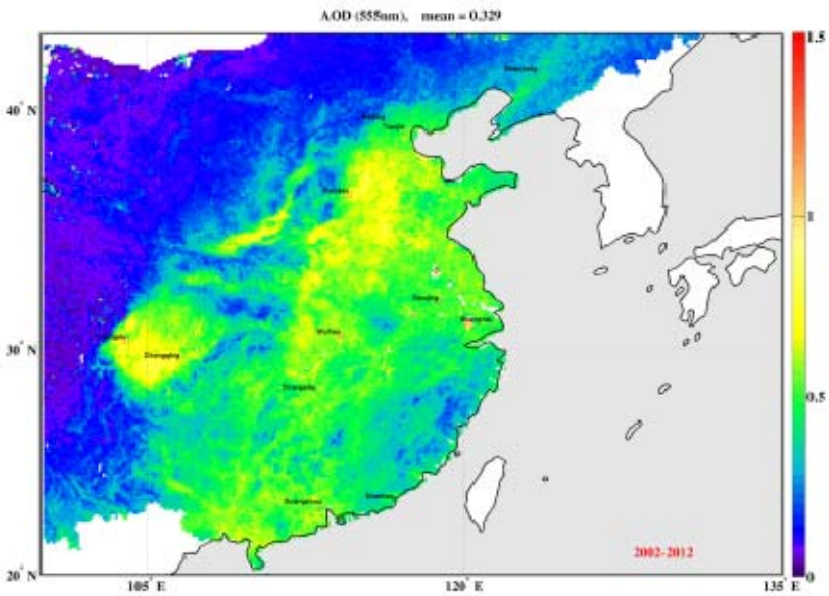
- AERONET provides independent validation, but gaps in coverage
- MODIS for reference
- Global AOD555 difference: -0.08
- Ocean: AATSR overall higher
- Land: MODIS overall higher, and much higher over high AOD areas

➢ Evaluate possible reasons for differences

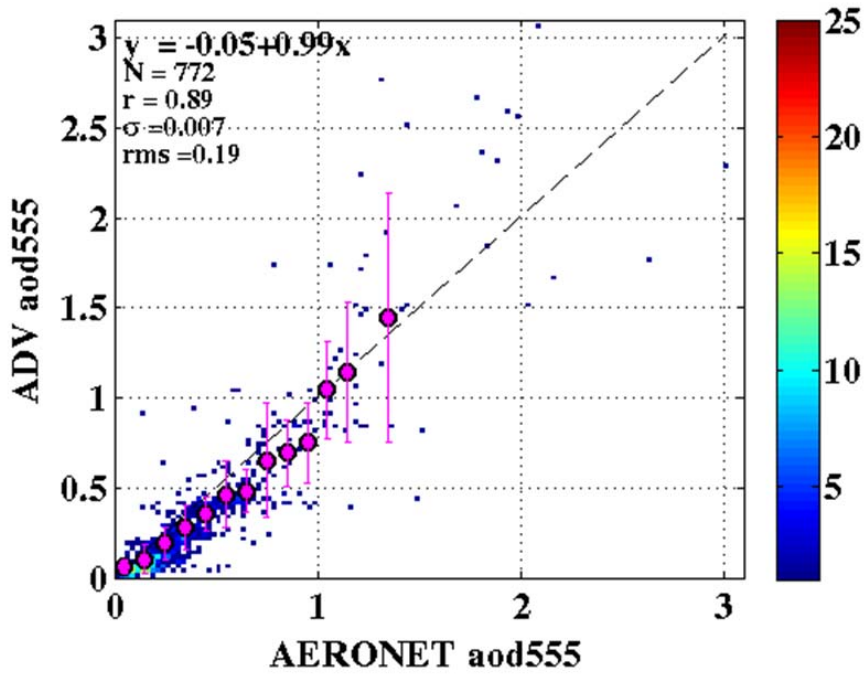
Ref: Aerosol_cci

AOD over China

AATSR AOD(555µm) 2003-2011 level 2



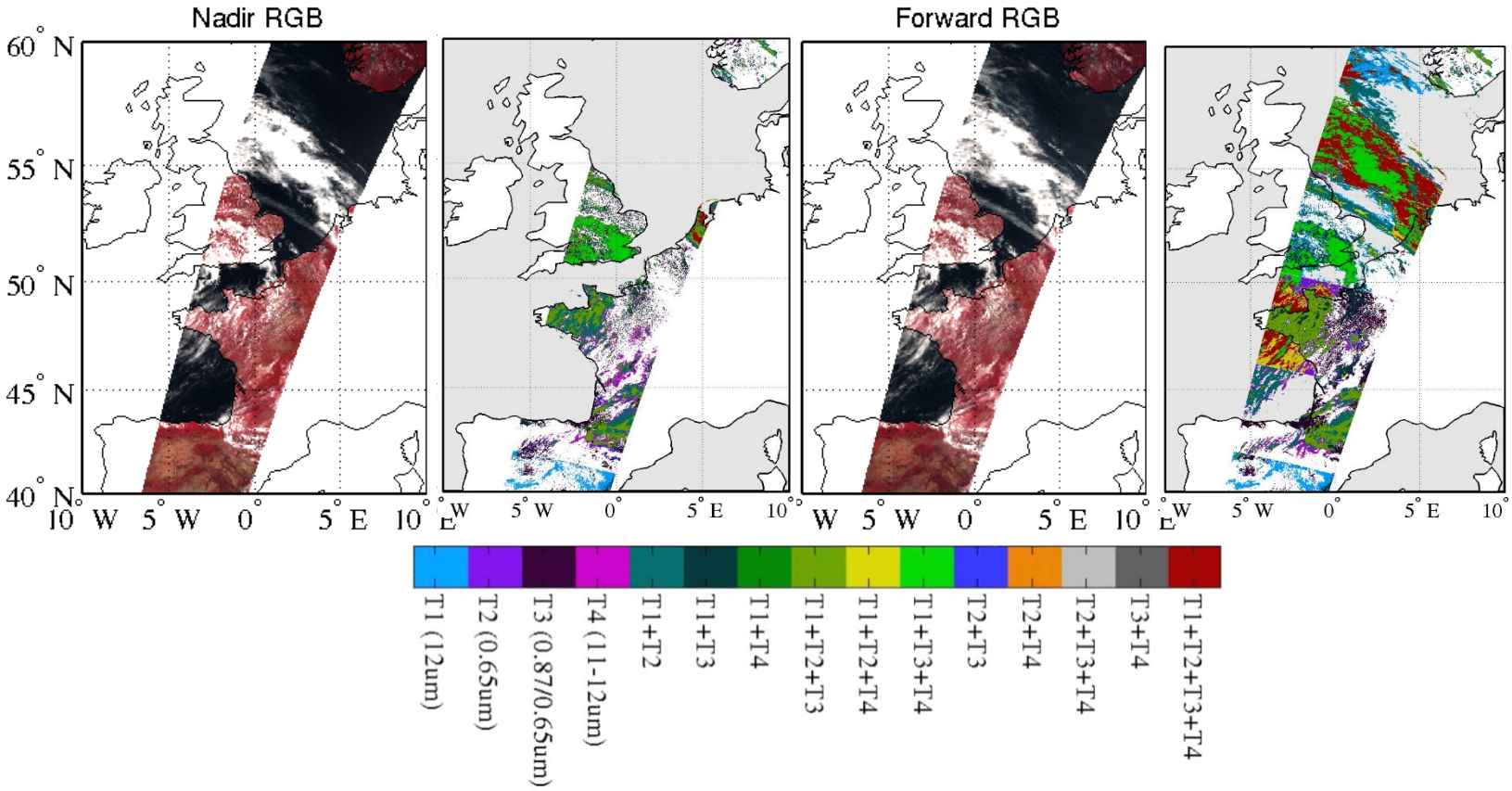
AOD AATSR validation against Aeronet 2003 -2011



Aerosol retrieval can usually only be done for clear sky. Therefore strict cloud detection is needed while also aerosol scenes should not be flagged as cloudy. At FMI a cloud post-processing scheme has been developed which removes a priori undetected clouds while retaining valid aerosol pixels.

Ref: MarcoPolo (EU FP7)

ADV cloud test evaluation (Europe)



L.Sogacheva

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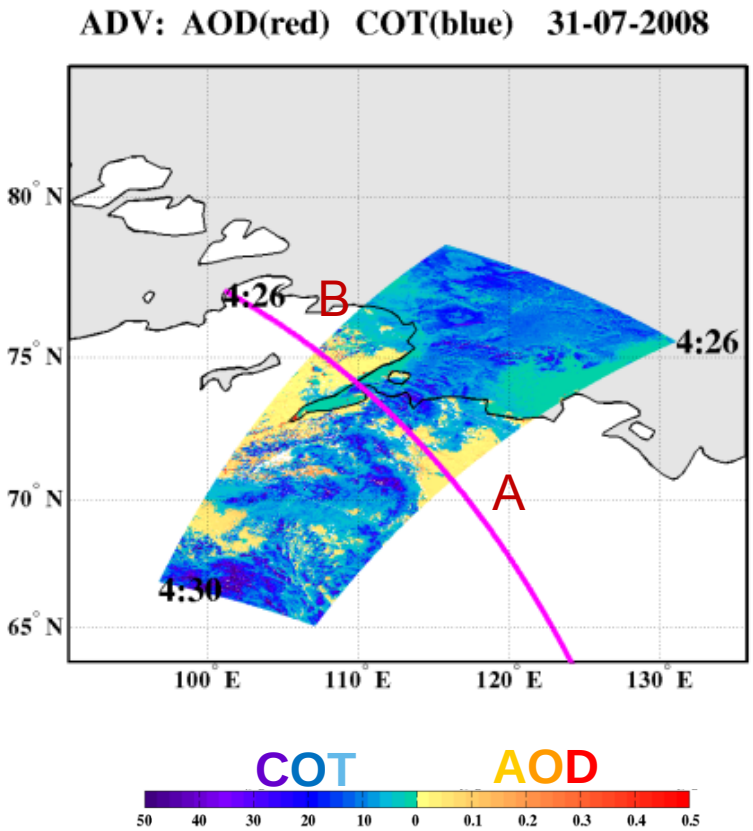
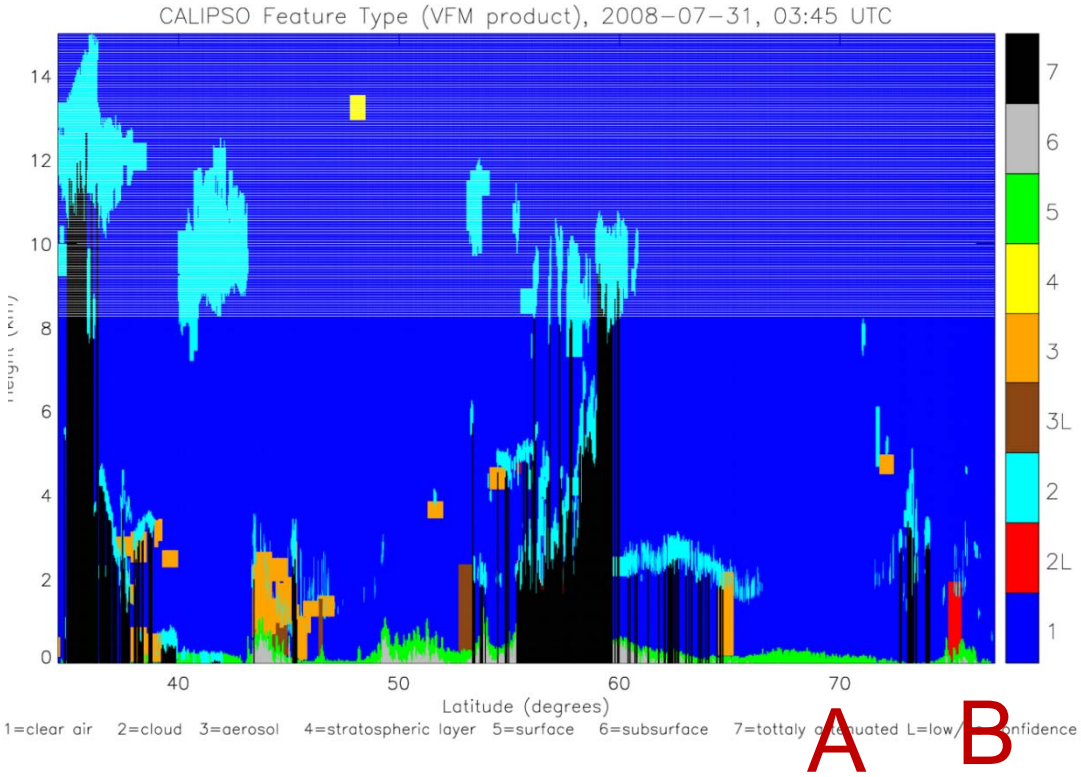
Cloud detection: validation vs CALIOP
Test case 1: 31-July-2008





Calispo – AATSR ~ 2 min;
ca. 15 match-ups used for analysis (1 summer)

(L.Sogacheva & E. Marinou)

2: cloud
3: aerosol
5: surface

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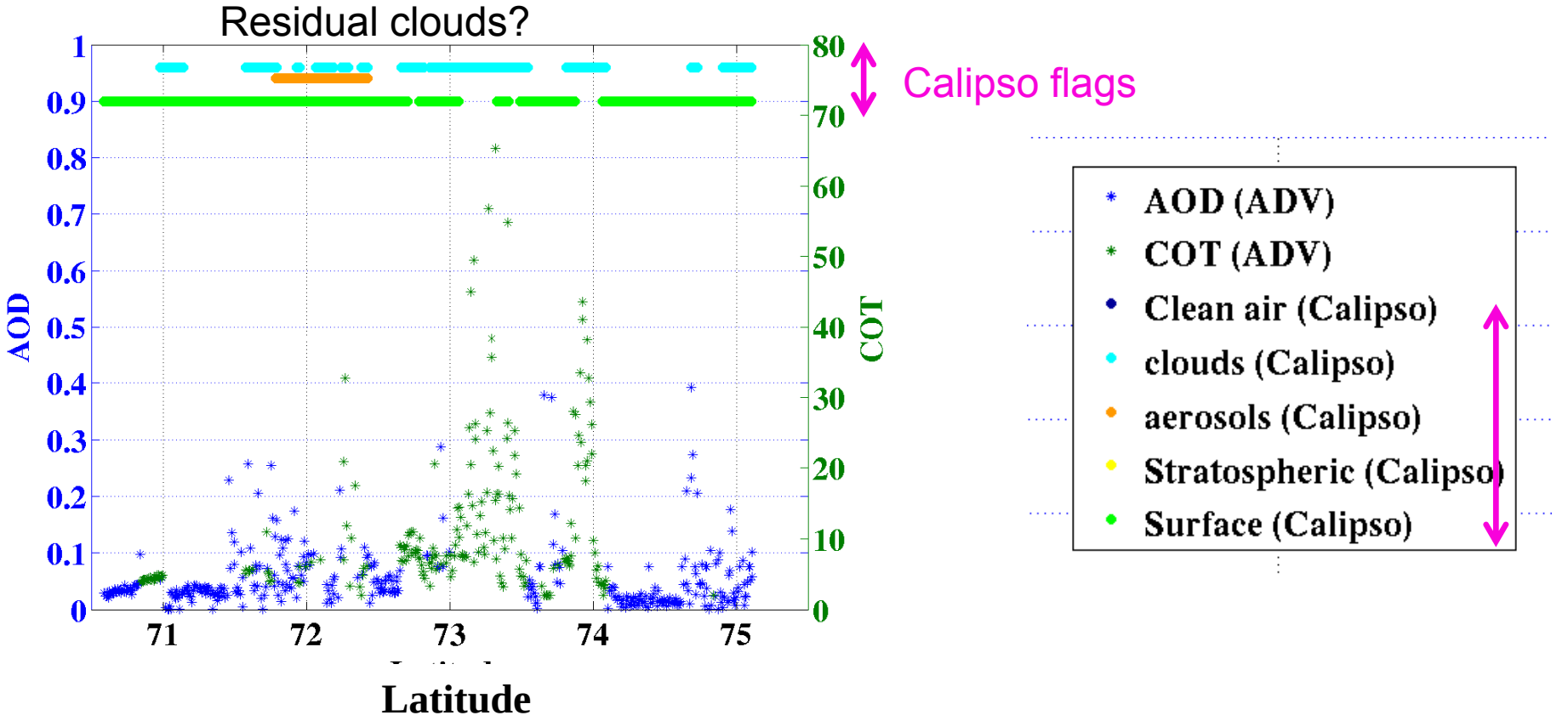
Test case 1

ADV and CALIPSO co-location



Calispo – AATSR ~ 2min

L.Sogacheva & E. Marinou)

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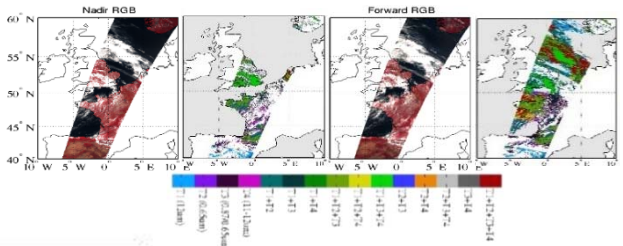
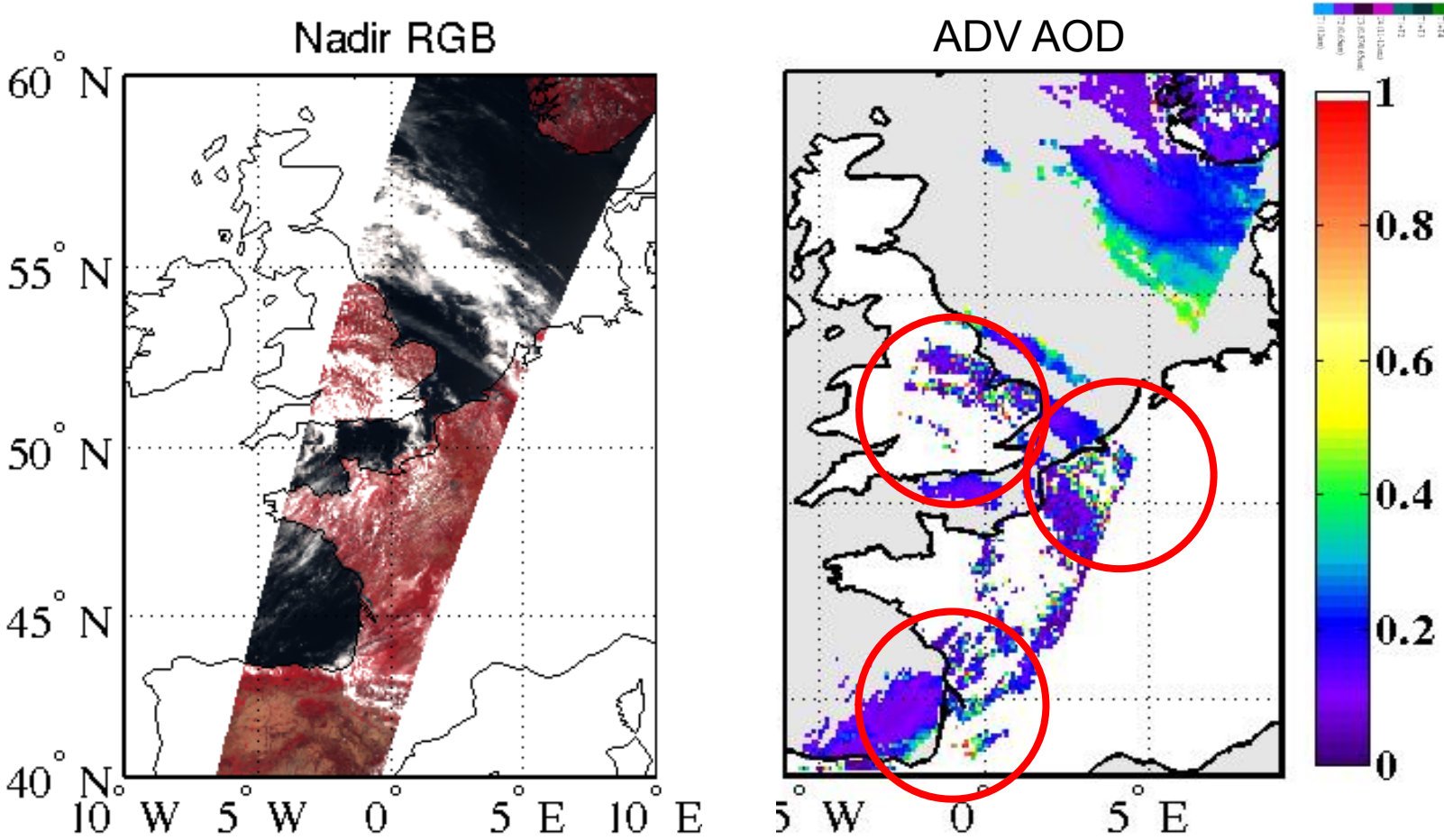
ADV AOD: residual clouds





L.Sogacheva et al., submitted

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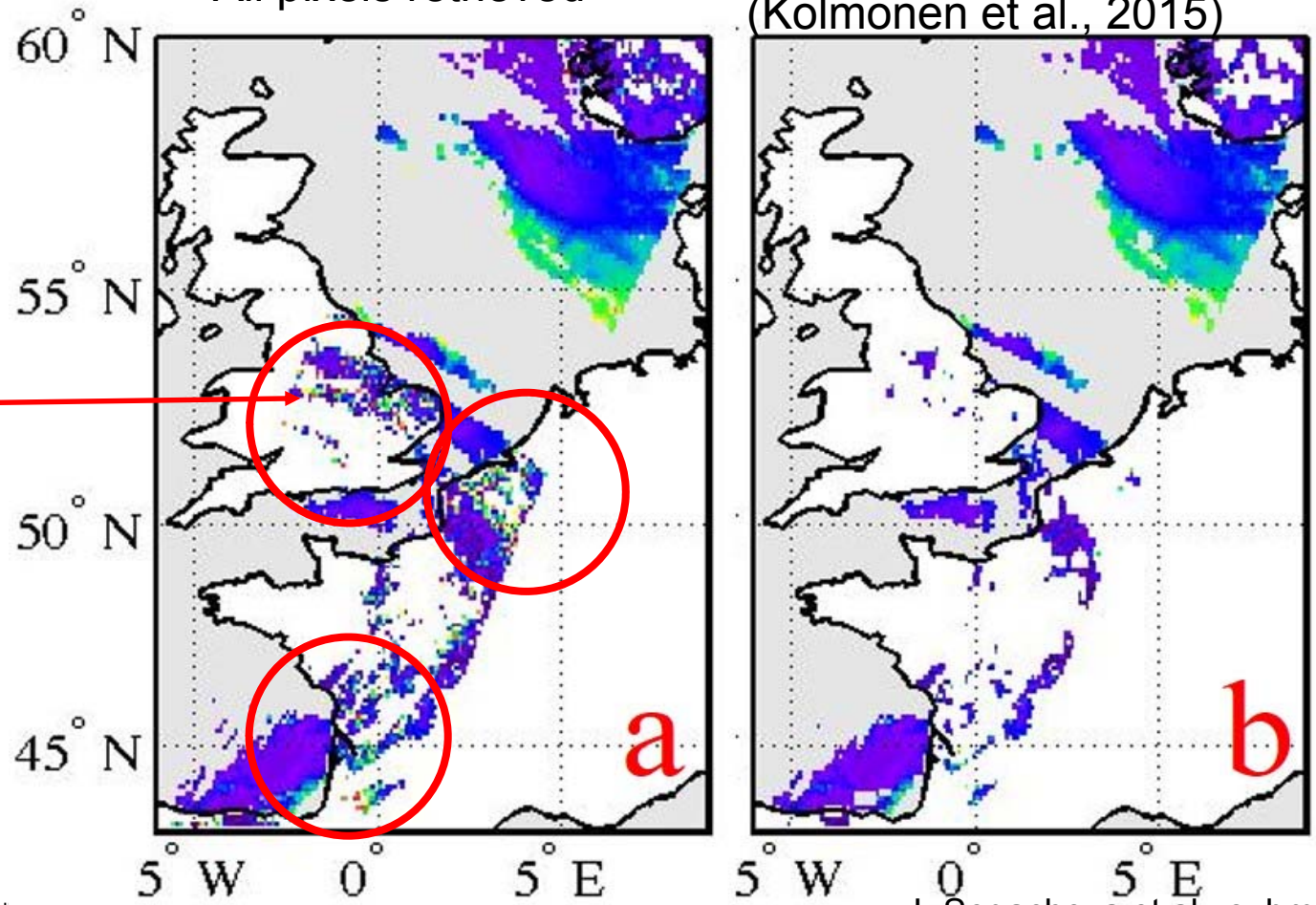
AATSR ADV AOD retrieval: needs for cloud post-processing

All pixels retrieved

Pixels left after cloud post-processing (Kolmonen et al., 2015)

Cloud contamination

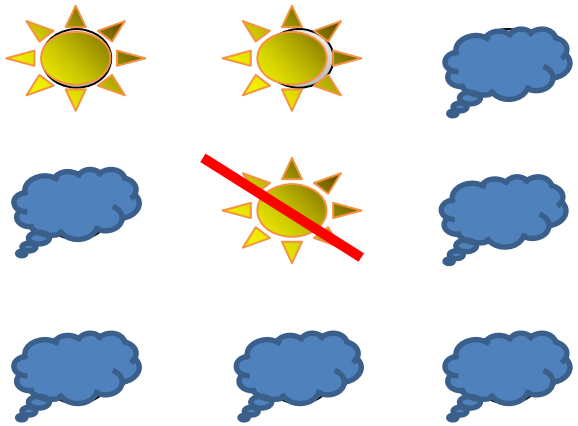


L.Sogacheva et al., submitted

Cloud Post processing (CPP)

- Applied to each retrieved pixel (10x10km^2)
- 9 nearest pixels are checked

1. Cloud edge test



If N of cloud free pixels <=3, pixel considered as cloud edge and discarded

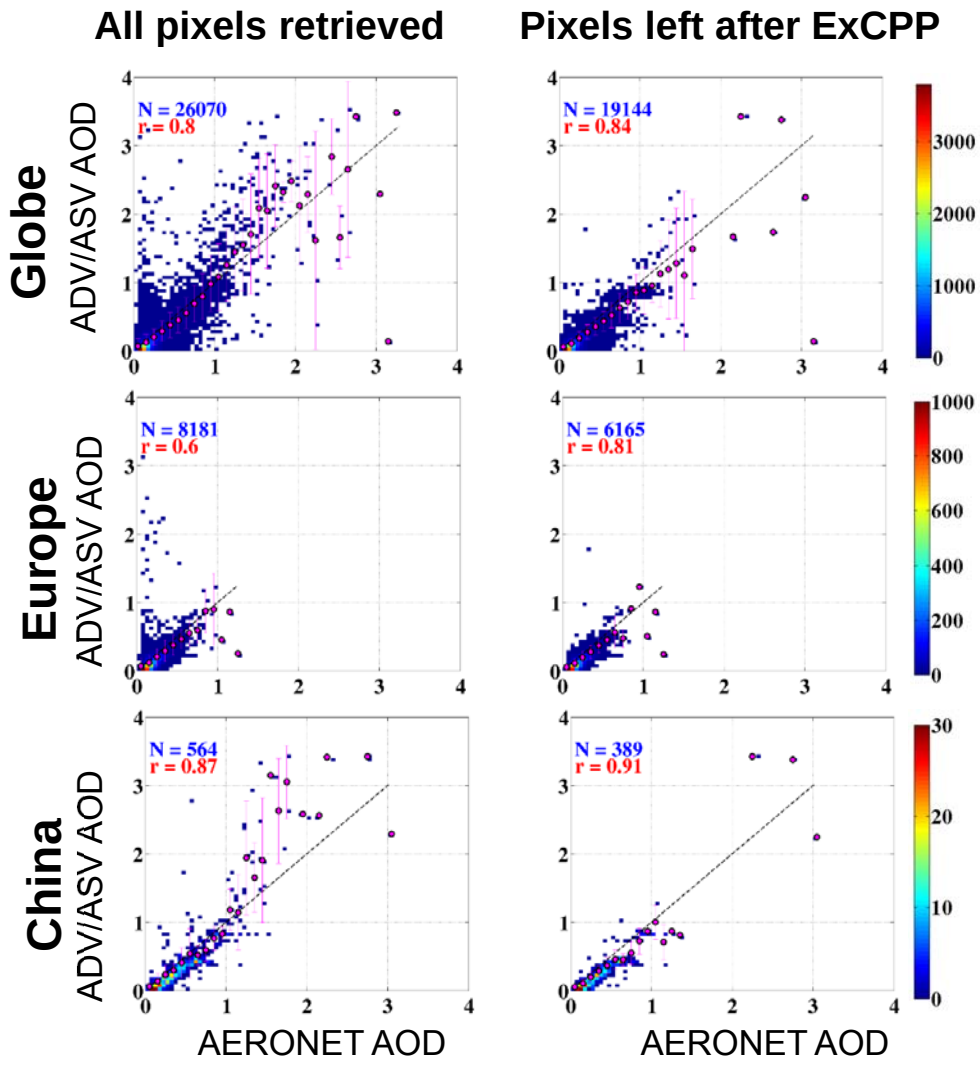
2. AOD standard deviation test

- If std(aod)>=0.1, the pixel is discarded

CPP -> ExCPP

Kolmonen et al., IJDE, 2015

AOD validation with AERONET

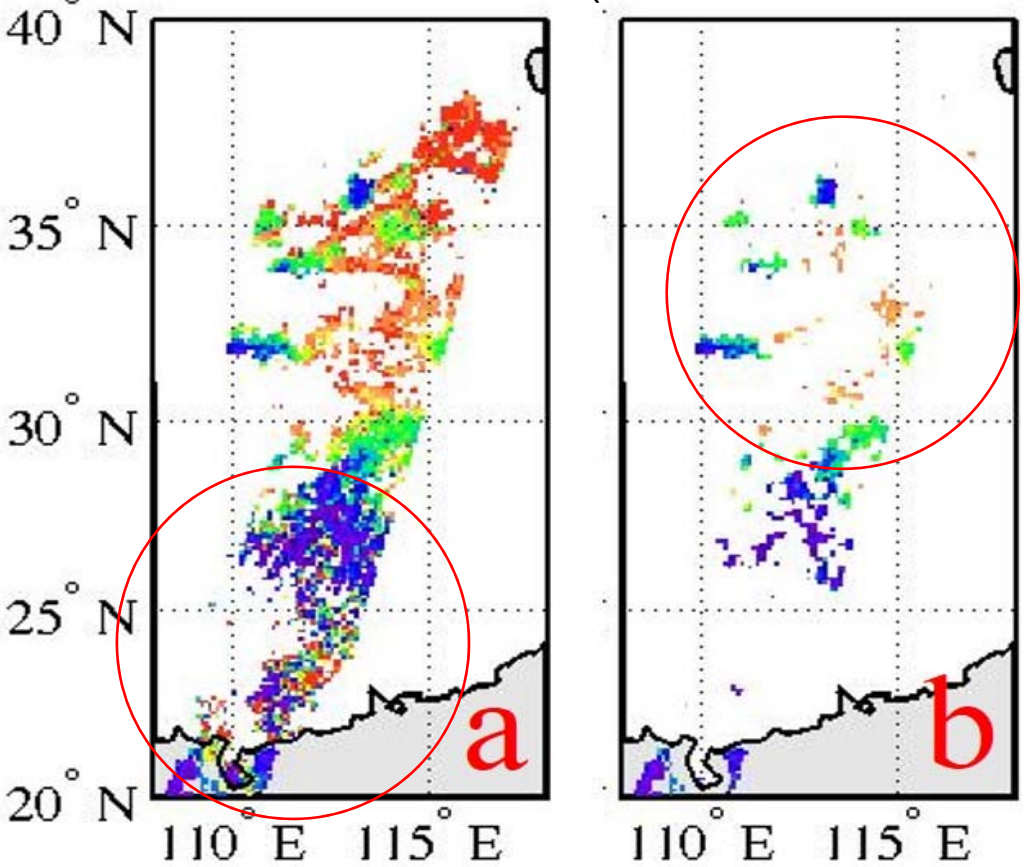


L.Sogacheva et al., submitted

ADV Cloud post-processing

All pixels retrieved

Pixels left with preliminary cloud post-processing (Kolmonen et al., 2015)



Cloud post-processing is done in ADV to remove **residual clouds**.

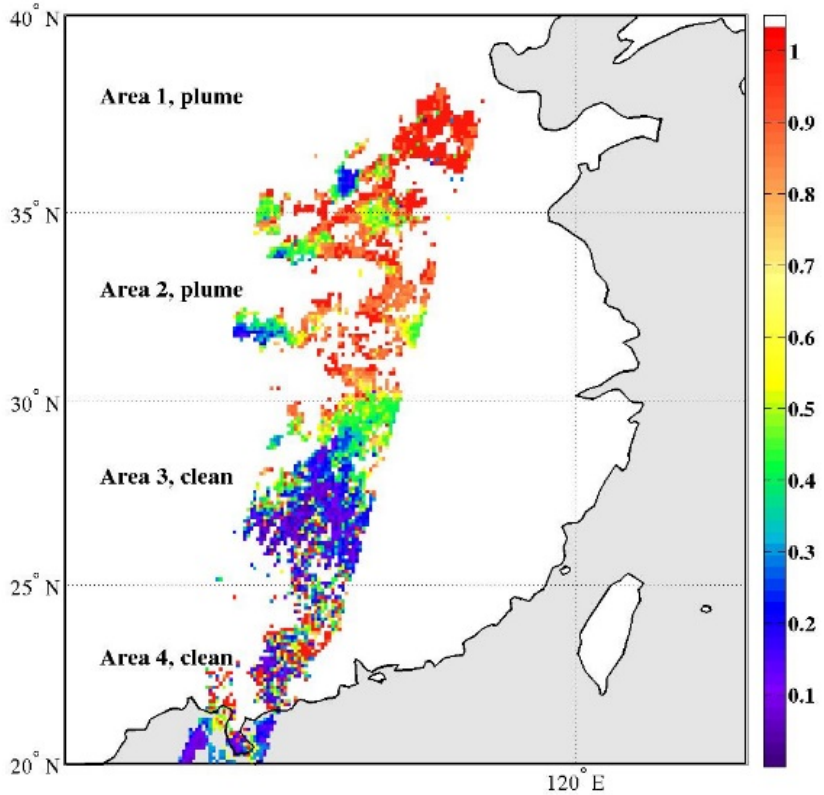
However, also areas with high AOD are affected. Therefore a **'plume'** detection scheme has been developed to identify such high AOD areas for which the post-processing is not applied. This effectively takes care of residual cloud removal while retaining high AOD

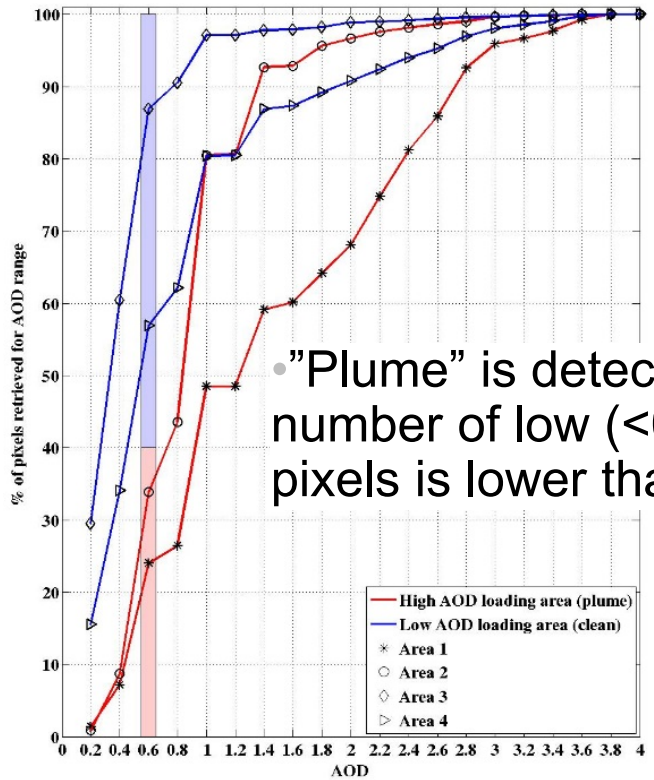
Result: improved validation metrics & coverage

L.Sogacheva et al., submitted

”Plume” detection method

- 3 years of AOD data visually checked
- more than 150 cases were chosen to develop the detection method
- Spatial varibility test: st dev (AOD) increased





- ”Plume” is detected, if number of low (<0.6) AOD pixels is lower than 40%

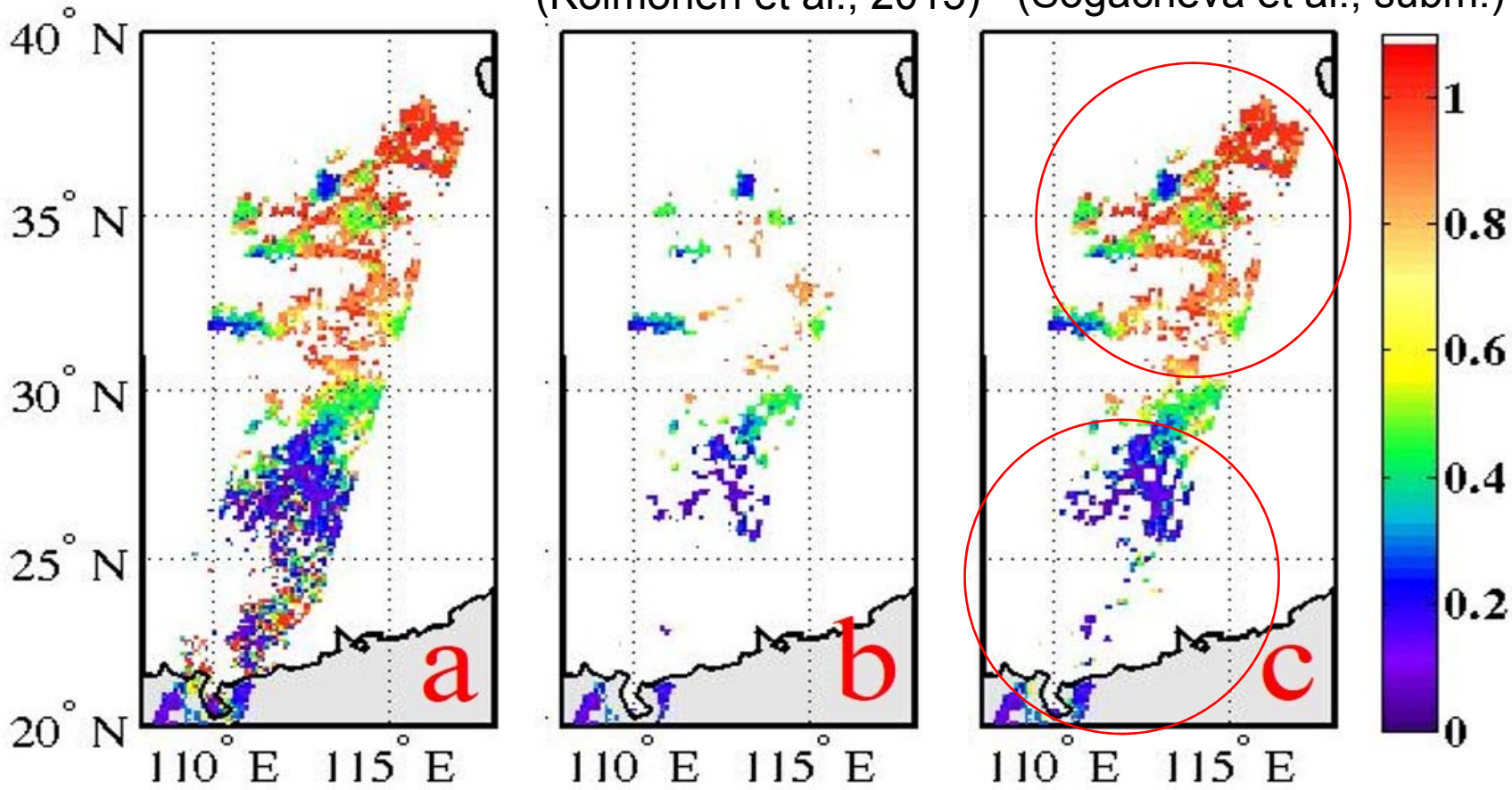
L.Sogacheva et al., submitted

Improved cloud post-processing

All pixels retrieved

after existing cloud post-processing (Kolmonen et al., 2015)

After improved cloud post-processing (Sogacheva et al., subm.)



L.Sogacheva et al., submitted

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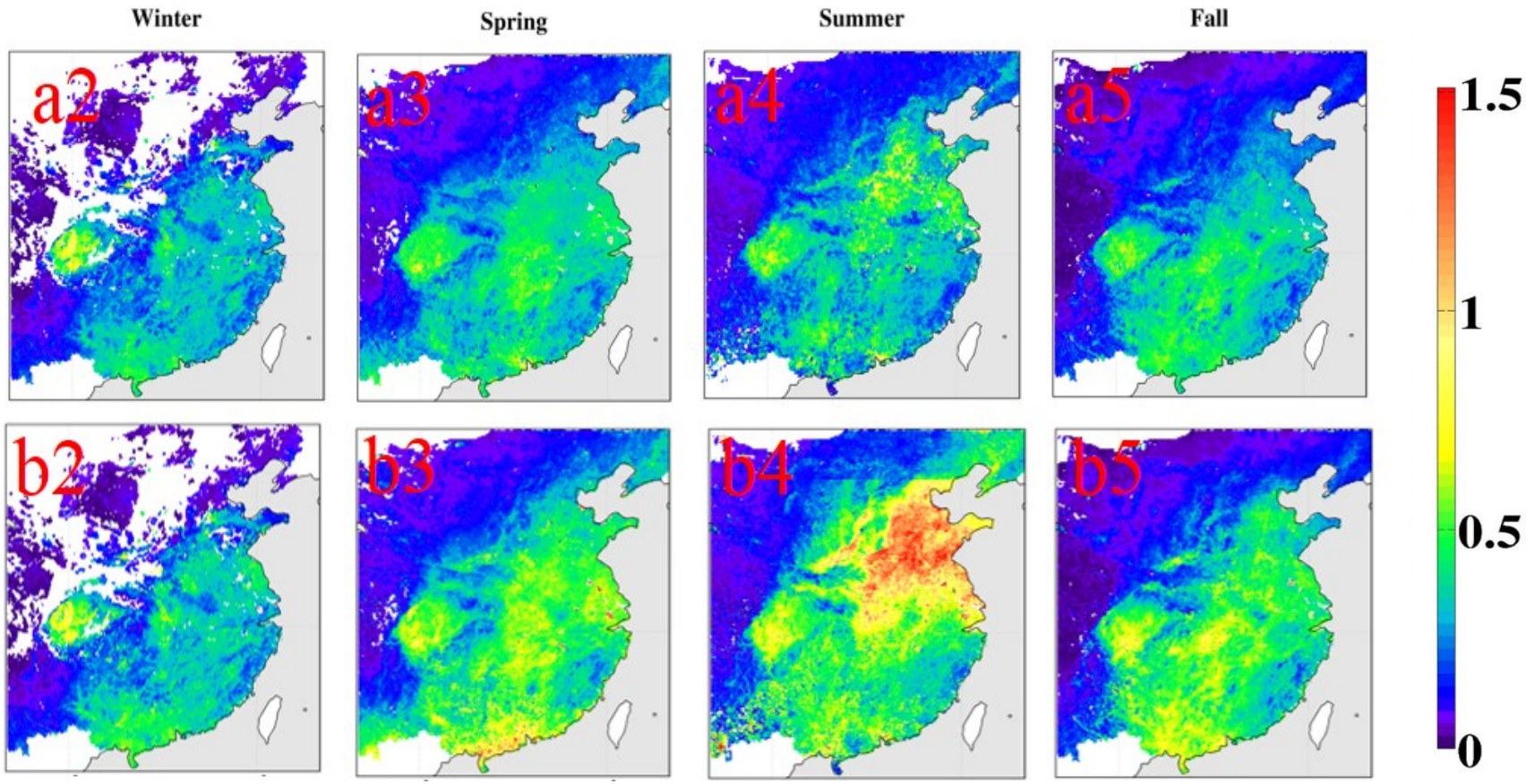
Seasonal AATSR ADV AOD 2003-2011

after cloud post- processing implementation: old and improved

old

Improved

Includes plume detection



L.Sogacheva et al., submitted

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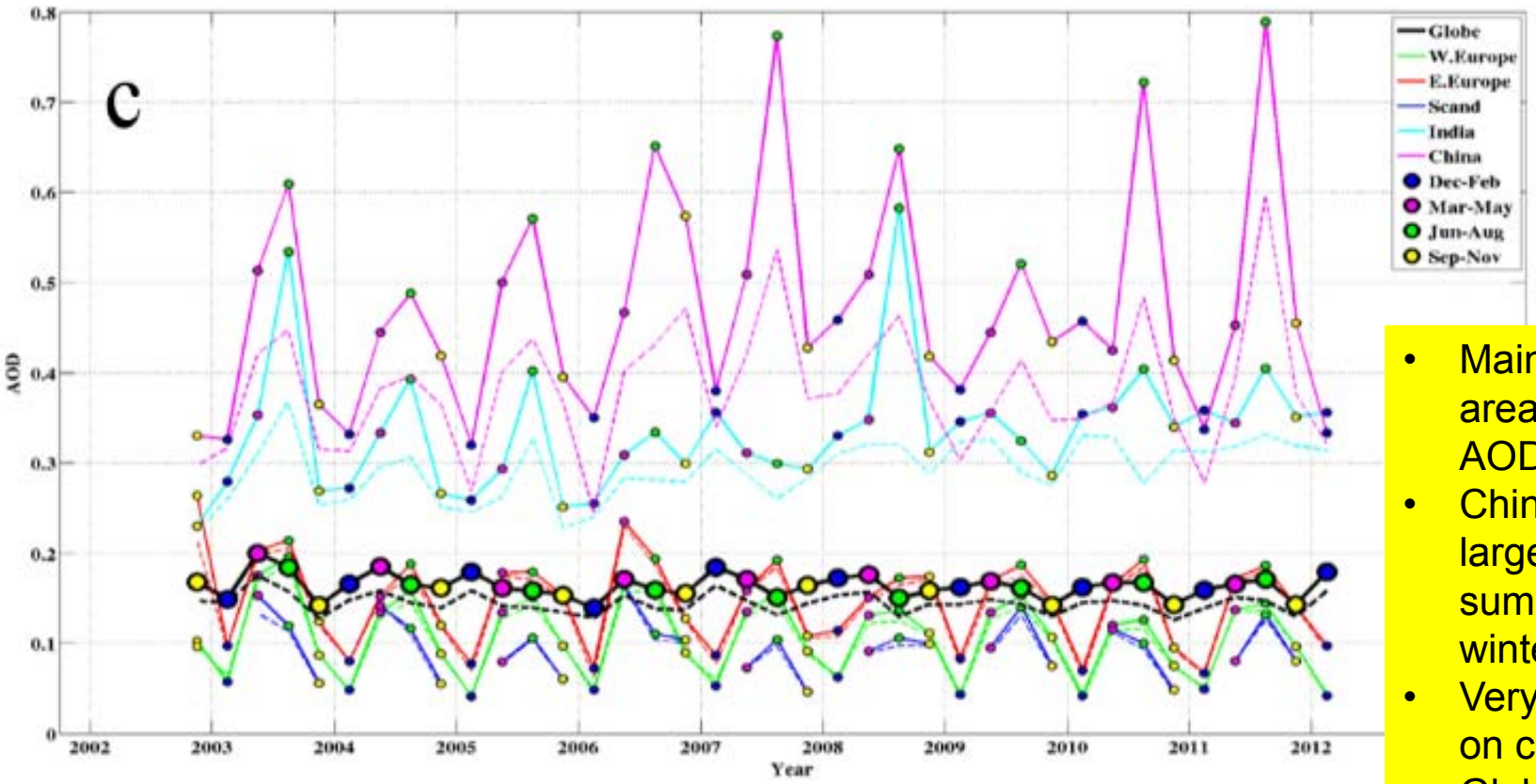
AOD seasonal variation

New cloud post-processing and plume detection



- Mainly affects areas with high AOD
- China, India: large effect in summer, less in winter
- Very little effect on cleaner areas
- Global over land ~0.02 higher

L.Sogacheva et al., submitted

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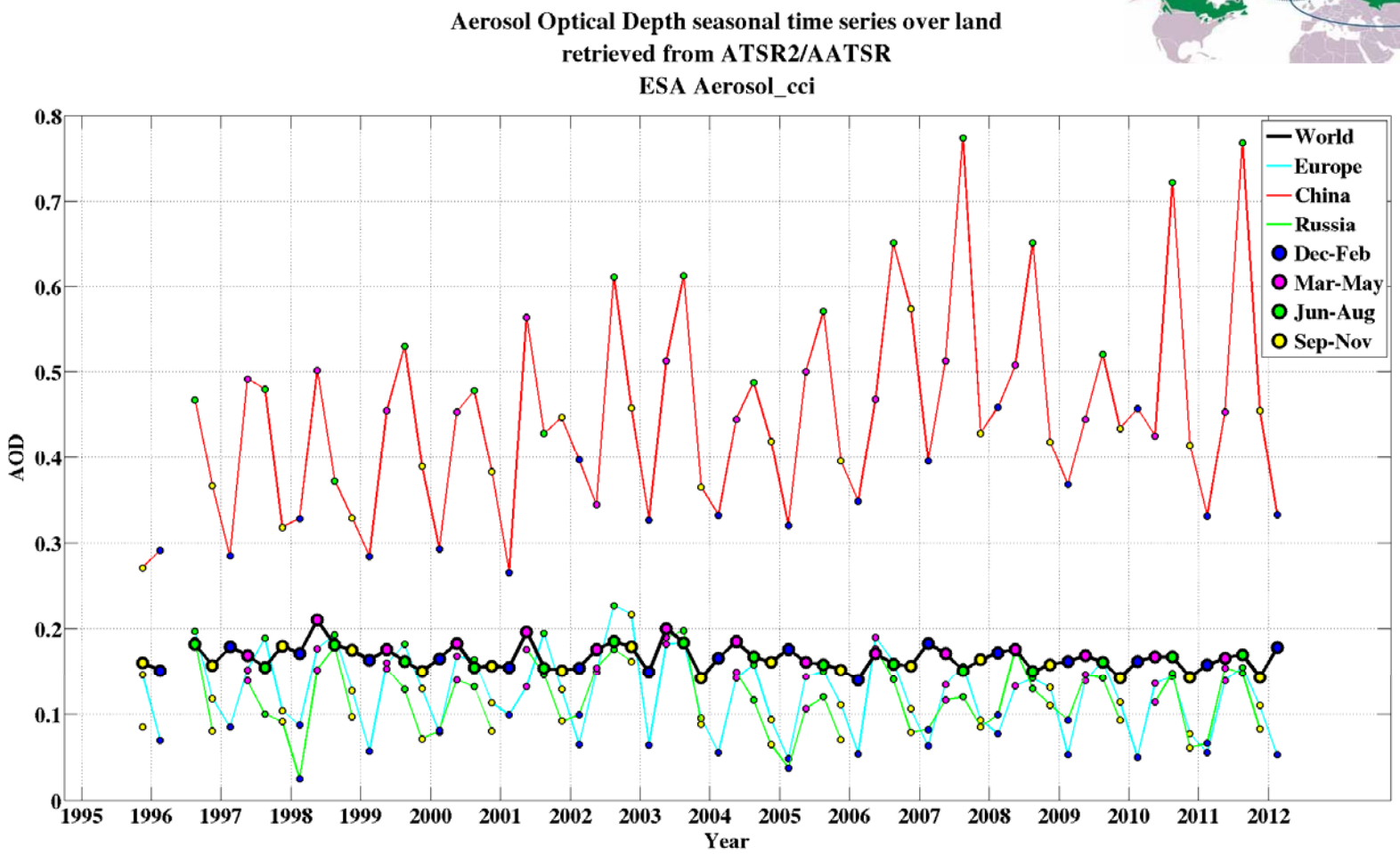
AOD time series over several regions of interest for PEEX



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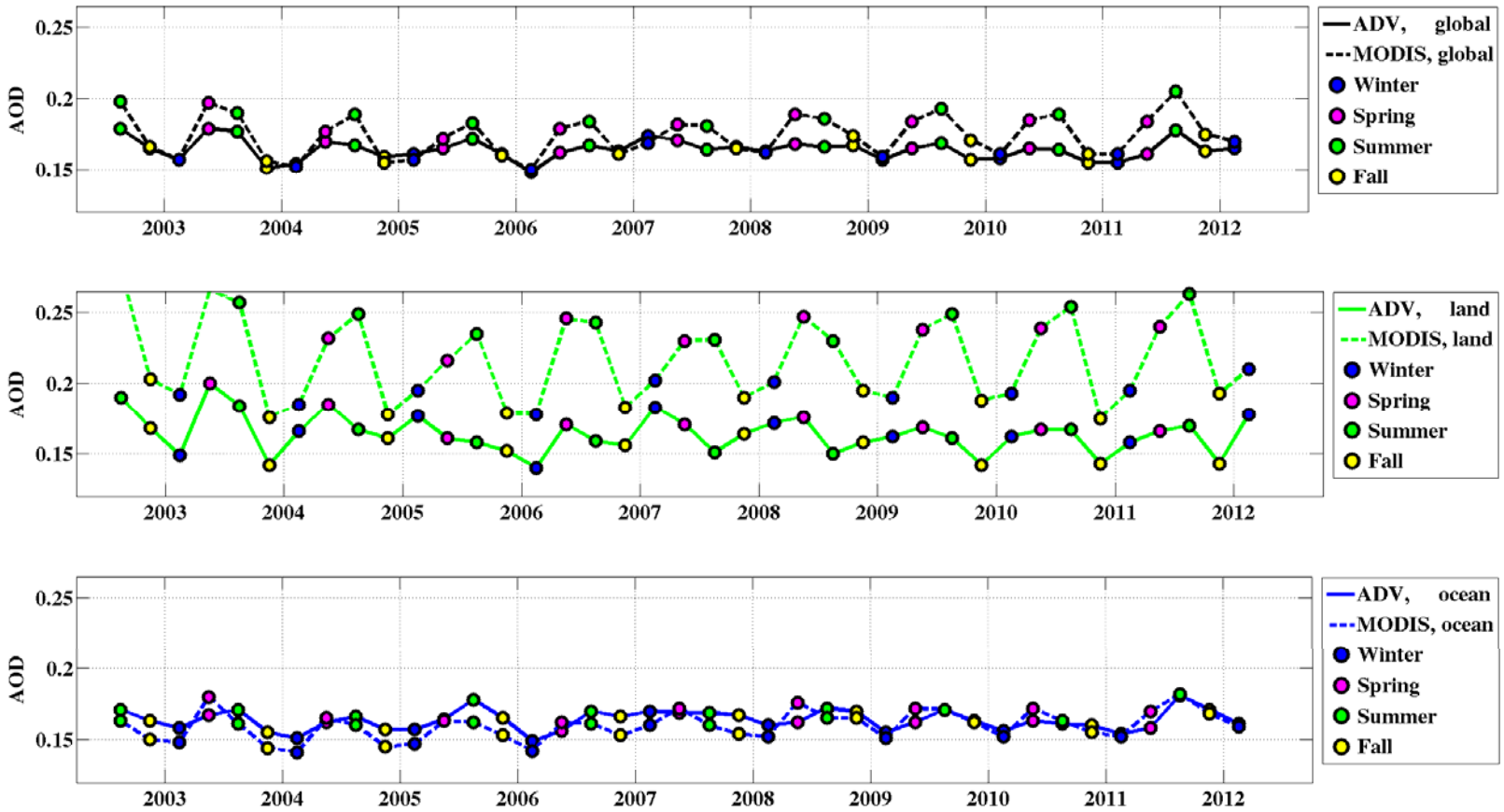
ADV and MODIS (DT&DB) : all pixels retrieved



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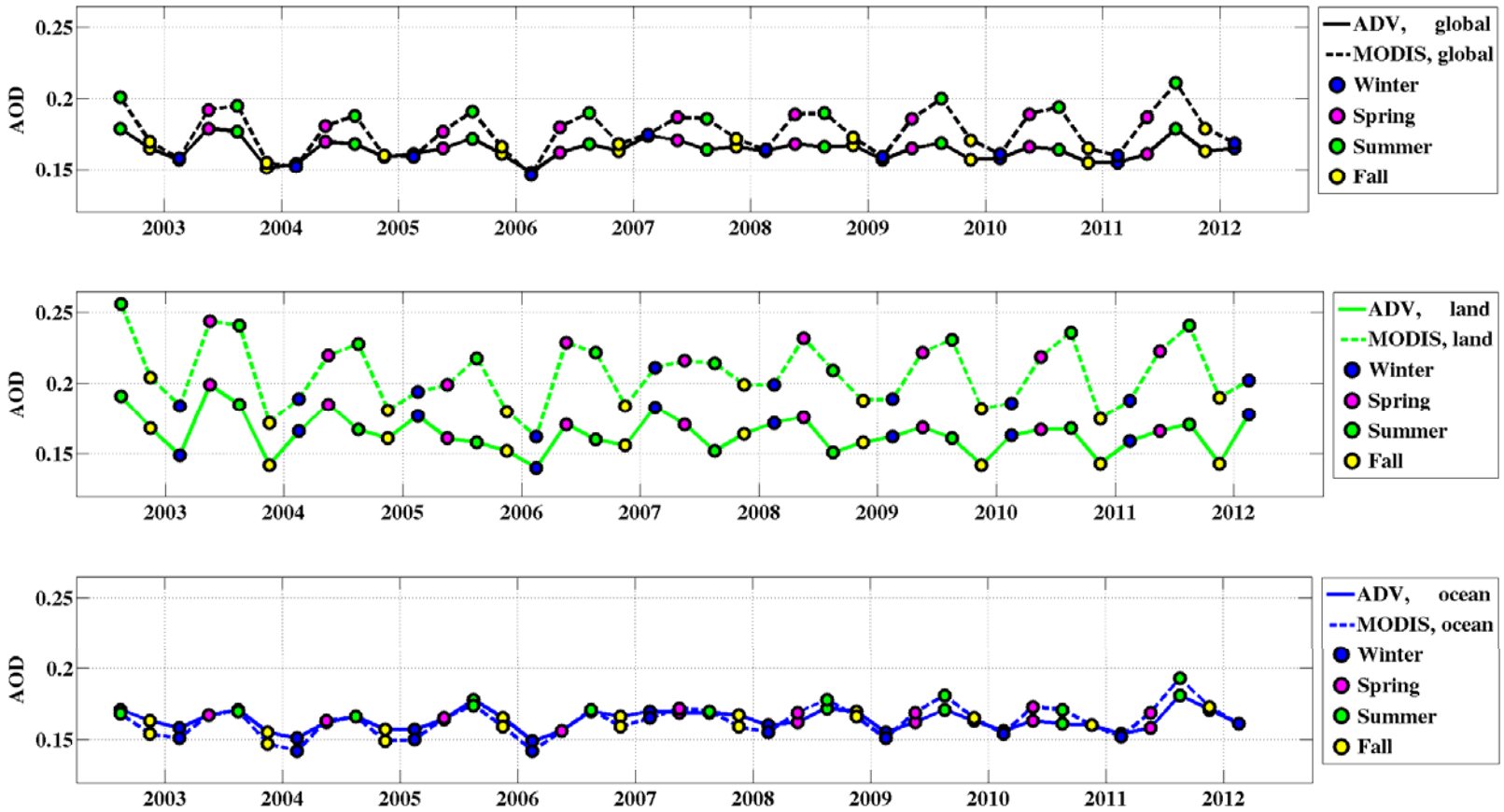
ADV and MODIS (DT&DB) : collocated pixels



Difference between AATSR and MODIS mainly over land: MODIS higher AOD and larger seasonal differences; co-location reduces these differences but does not eliminate them

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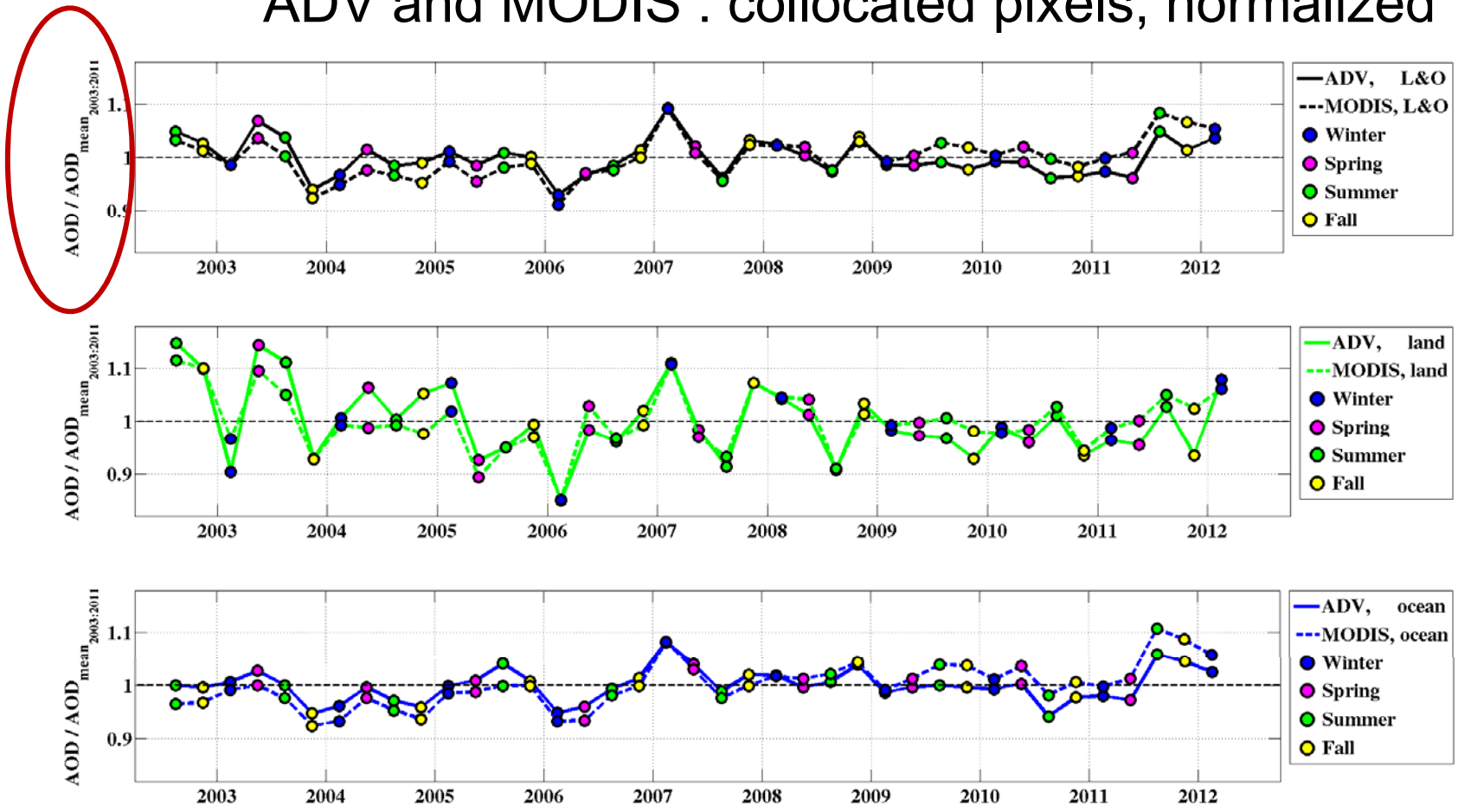
ADV and MODIS : collocated pixels, normalized



Normalisation to global mean for the study period (2003-2011) reduces the difference in seasonality

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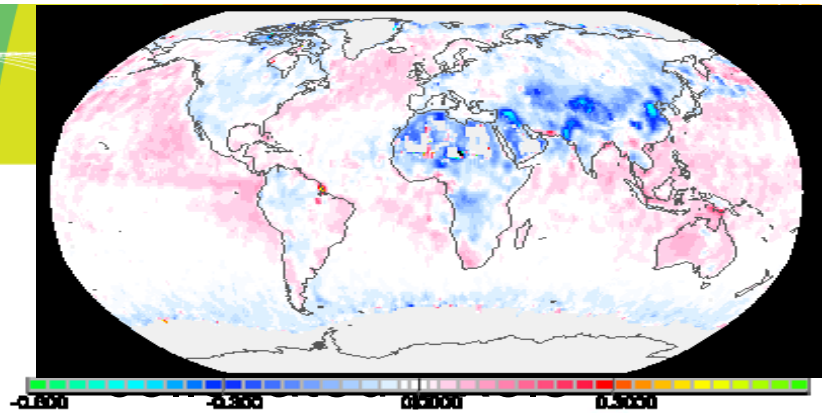
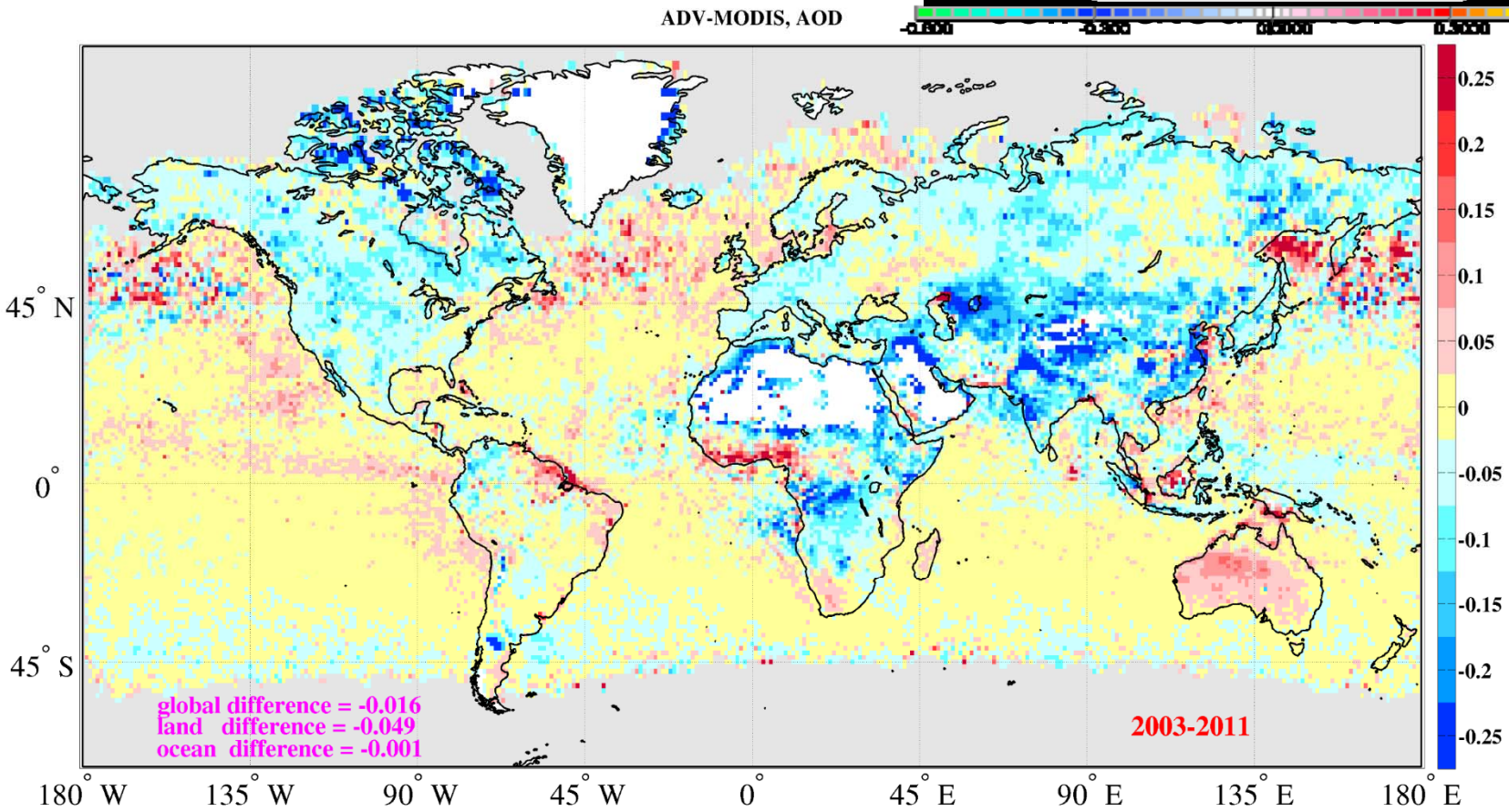
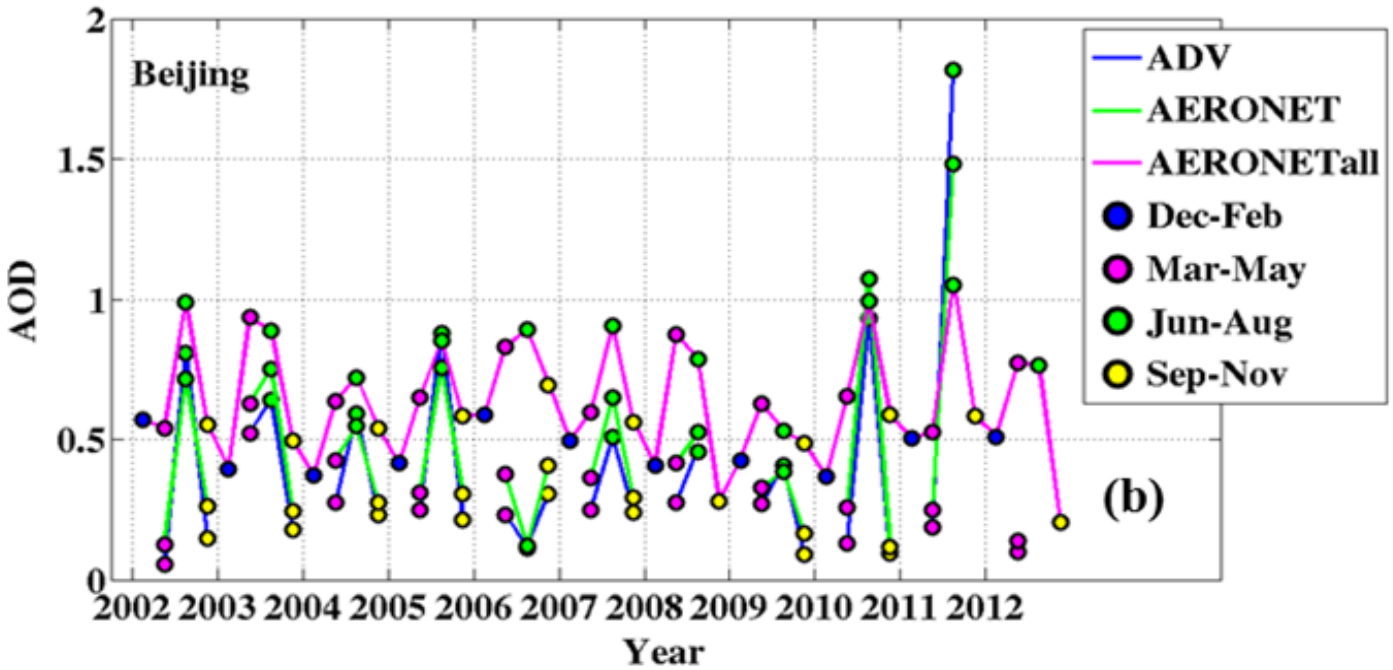
ADVaod – MODISaod





AATSR and AERONET AOD over Beijing:

winter minima and summer maxima; diurnal effects



Time series for seasonally (coloured dots) averaged AOD-ADV (blue line), AOD-AERONET in the time window ±30 min from AATSR over path (green line) and whole day AOD-AERONET (magenta line).

Ref: MarcoPolo (EU FP7)

Conclusions and outlook

- Satellites provide the spatial, vertical and temporal distribution of aerosols
- Cloud detection remains a problem, cloud post-processing is used to alleviate this problem
- Time series show yearly and seasonal variation
- AOD (difference) maps show the year to year variability
- The combination of different instruments provides complimentary information: CALIOP, MODIS, MISR, SeaWiFS, OMI, etc. (feature, types, AAI, coverage&complementarity, …)
- This information is used for inverse modelling to determine emissions
- These data need to be further analysed and interpreted, together with that from precursor gases and meteorological information, using models, information on emission sources and atmospheric processes to better understand the aerosol properties and their spatial and temporal variations

Acknowledgements

- Marco Polo is an EU FP7 project
- ATSR algorithm development is supported by ESA as part of the Climate Change Initiative (CCI) project Aerosol_cci