ESA Aerosol_cci progress on pixel level uncertainties

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Sources of uncertainties

Source of uncertainty	Description	Qualitative estimate of contribution
Cloud screening and safety zone	Capabilities depend on available spectral range (e.g. thermal bands are important); safety zone also masks elevated AOD around clouds	High for UV/VIS sensors, medium for stratospheric algorithms
Overpass time	Polar orbiting sensors provide typically one or two sun-synchronous overpass times per day	High when comparing to different sensors or against models
Land surface reflectance (BRDF)	Can be estimated from vegetation index and/or mid-infrared bands, drawn from a climatology or ECV, or retrieved alongside AOD from multi-view data	High for nadir-only sensors, with larger uncertainty at higher reflectances
Ocean surface reflectance	Estimated using white caps parameterisation and possibly a climatology of ocean colour	Medium
Calibration	Absolute radiance calibration is critical with spectral calibration being less critical due to the broad-band features considered	Medium
Aerosol optical properties	This includes spectral extinction, absorption, phase function and shape (degree of sphericity)	Medium to high for sensors with low information content, low for AOD < 0.15
Vertical aerosol profile	Different assumptions are made for different aerosol types but sensitivity at TOA is small for VIS/IR sensors, increasing in the TIR	Medium for UV observations and absorbing aerosol, low otherwise
Directional reflectance ratio	Ratio between nadir and forward views is transferred from mid-infrared to visible bands	Medium for multi-view sensors
Pixel size	Ranges from 1x1 km^2 for radiometers to 16x7 km^2 for polarization instruments to approximately 0.25x0.5˚ for spectrometers	Medium when pixels dimension approach 50 km (approximate scale of aerosol variation)
Temperature vertical profiles	Usually of very high accuracy and precision, but might be significantly affected by the presence of high absorbing aerosol load	Low to medium (only for TIR sensors)
Trace gas concentration profiles	Critical absorption bands are usually avoided	Low
Radiative transfer forward model	Typical accuracy < 1%	Low
Look-up table discretization	Uncertainty often a function of the number of discretization points	Low
Wind speed	Used to estimate ocean reflectance	Low
Sampling	Practically all sensors under-sample the aerosol fields in time; different samplings lead to bias between different products	Depends strongly on the repeat cycle of the sensor and its swath width
Aggregation to 10x10 km^2	Aims to improve the signal-to-noise ratio and exclude outliers	Reduces random error (but not systematic) and may decrease representivity of data

Aerosol_cci approach

Error propagation of dominant terms for different sensors (ATSR, IASI, GOMOS, …)

- One IASI example (ULB):

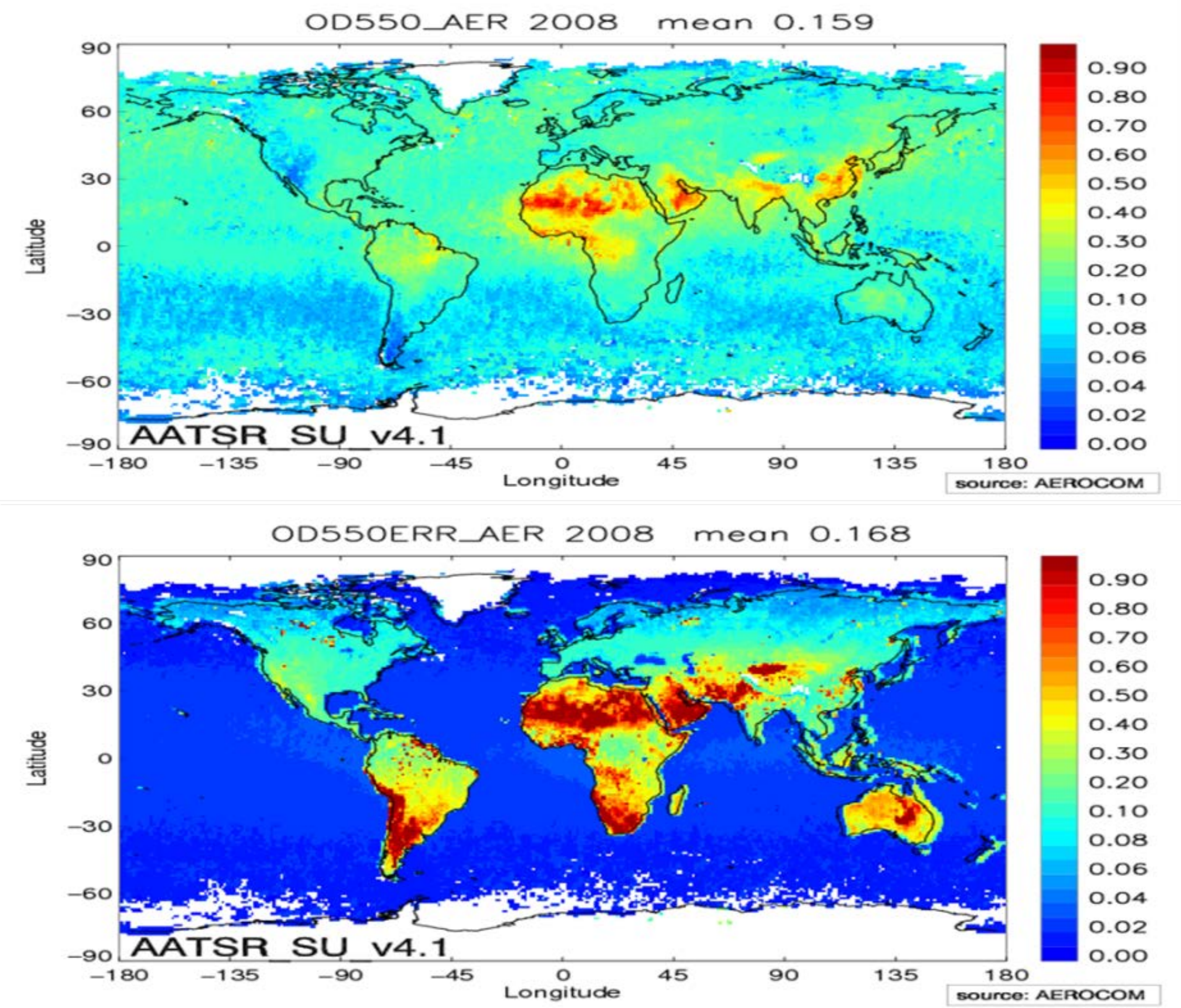
- Aerosol altitude: standard deviation of CALIOP heights, $\sigma_{ALT} = \sigma_{cal}$
- IASI instrumental noise on R: by definition $\sigma_R = 1$
- IASI instrumental noise on input channels: $\sigma_{BL} = 0.28$ K
- Temperature profile: $\sigma_{TEMP} = 1$ K
- Humidity profile: $\sigma_{HUM} = 10\%$

- Assumption: all contributions are random

- $$\sigma_{OD} = \sqrt{\left(\frac{\partial OD}{\partial A}\sigma_{ALT}\right)^2 + \left(\frac{\partial OD}{\partial R}\sigma_R\right)^2 + \left(\frac{\partial OD}{\partial B}\sigma_{BL}\right)^2 + \left(\frac{\partial OD}{\partial T}\sigma_T\right)^2 + \left(\frac{\partial OD}{\partial H}\sigma_{HUM}\right)^2}.$$

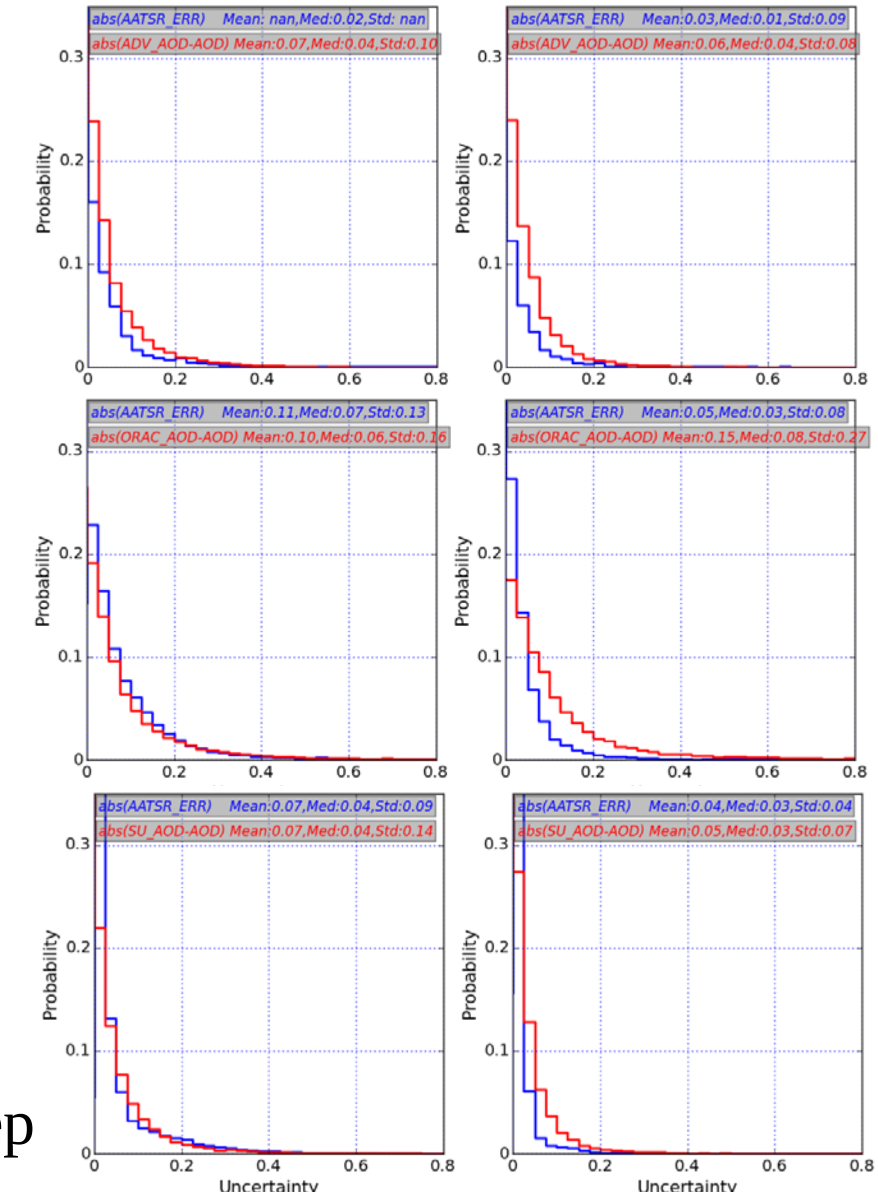
Partial derivatives * parameter uncertainties

Average Uncertainties



Validating Uncertainties

land ocean



ADV

ORAC

SU

uncertainty

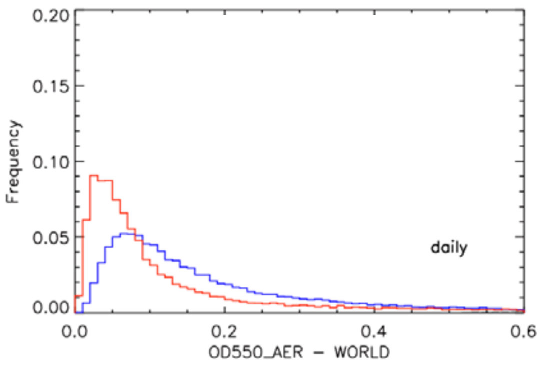
„true“ error

Stebel, et al., in prep

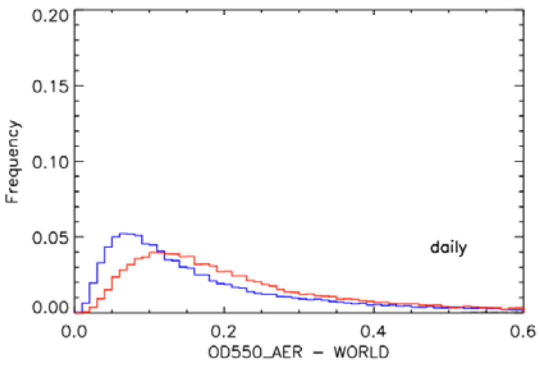
Uncertainties in data assimilation

- MACC model assimilation test / all 2008 / AOD550
- MODIS collection 5.1: fixed uncertainties (0.1 / 0.05), online bias correction
- AATSR ADV: pixel level uncertainties, no bias correction
- Validation against AERONET
- Both datasets improve correlation and rmse vs. no assimilation case (R_{MOD} = 0.90, R_{ATS} = 0.84, R_{no} = 0.71)
- Combined assimilation improves even slightly further (R=0.92)

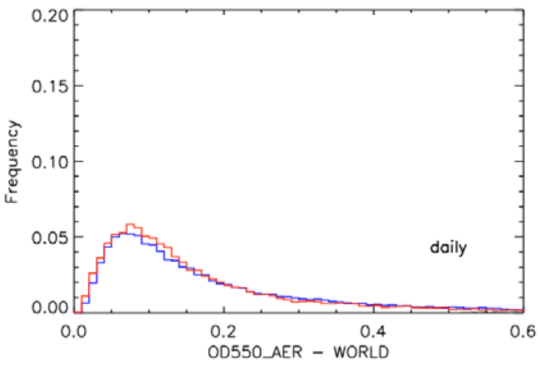
no assimilation



MODIS assimilation with fixed uncertainties



AATSR assimilation with pixel level uncertainties

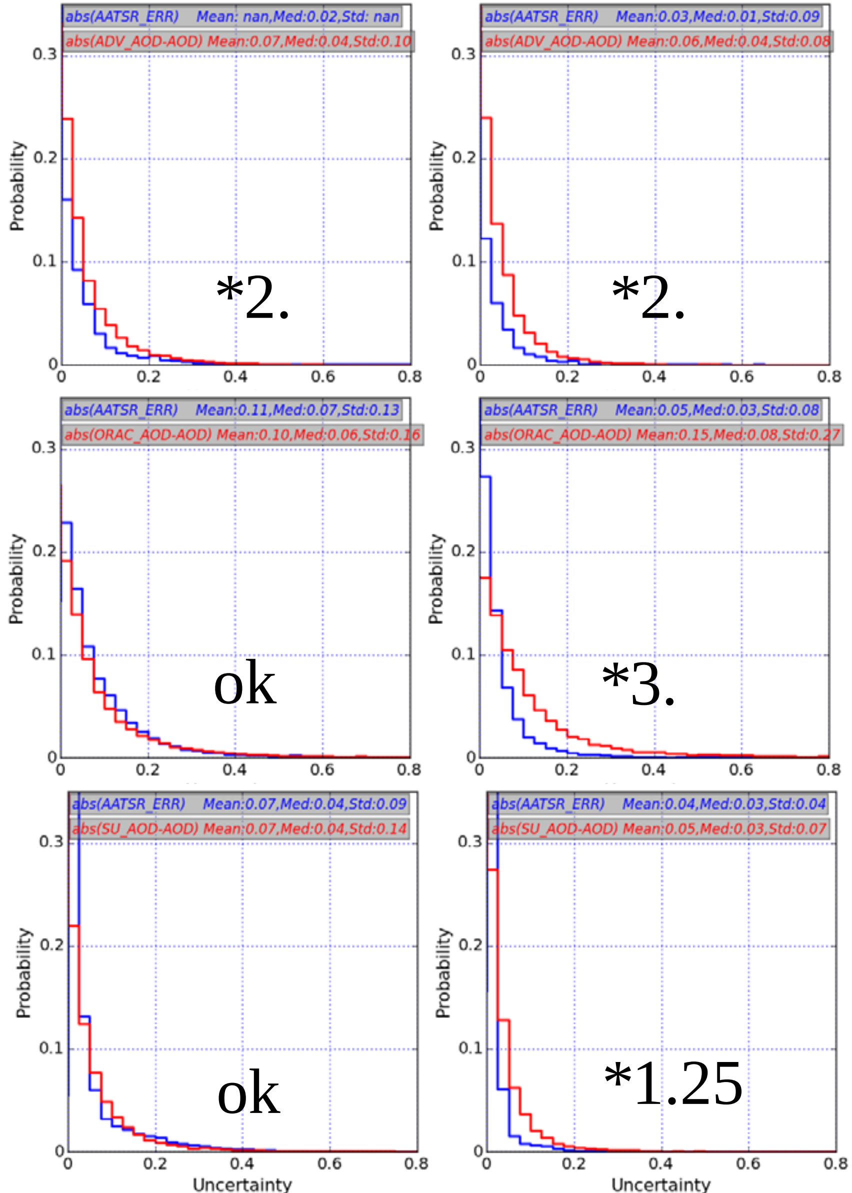


Angela Benedetti, priv. comm.

Uncertainties for ensemble

land ocean

uncertainty
„true“ error



ADV

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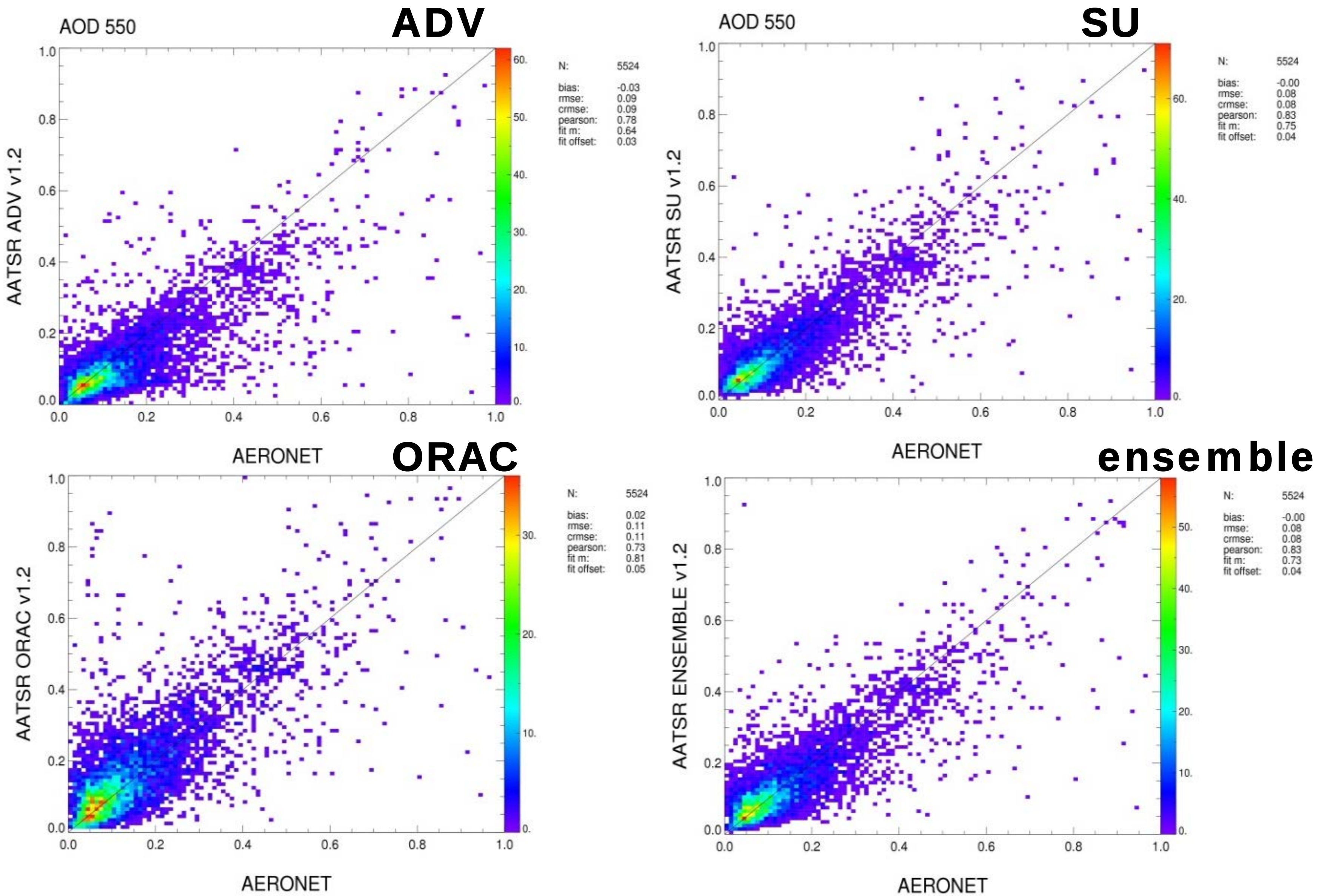
AATSR ensemble



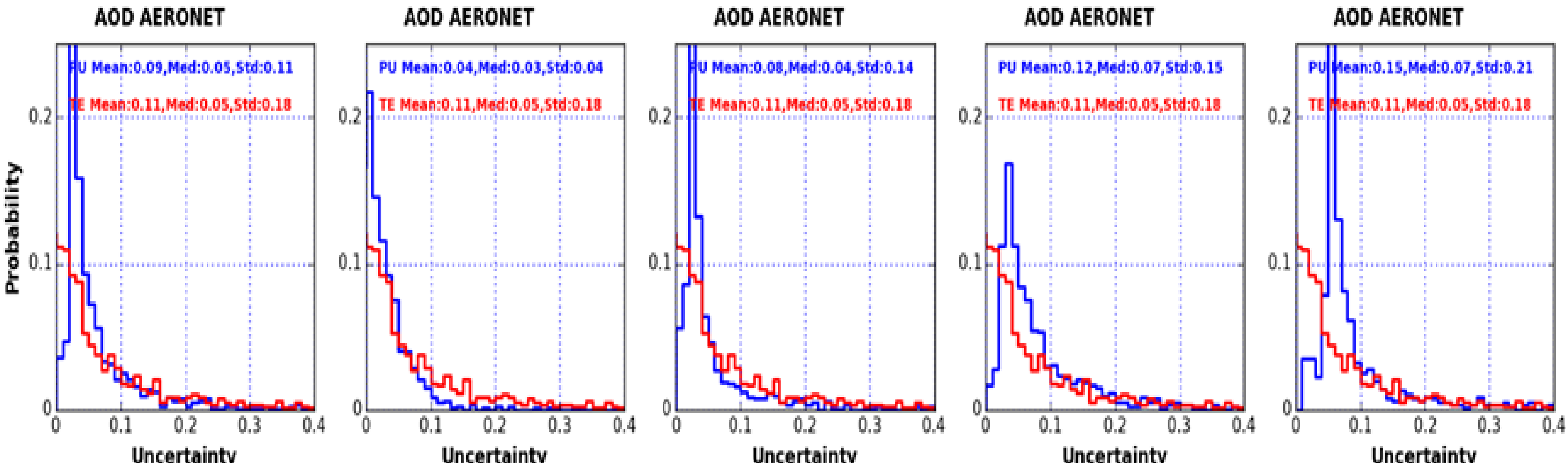
ASTR ensemble

Validation with AERONET for 2011				
	ADV 2.30	SU 4.21	ORAC 3.02	Ensemble 2.6
N	6557	6324	8532	6949
BIAS	-0.02	0.00	0.07	0.00
RMSE	0.10	0.11	0.20	0.10
CRMSE	0.10	0.11	0.18	0.10
Pearson	0.82	0.82	0.59	0.85
fit m	0.76	0.75	0.74	0.83
fit offset	0.02	0.05	0.12	0.03

Kosmale, et al., in prep

Daily gridded uncertainties

- mean uncertainty $\frac{1}{N}\sum_i \sigma_i$ (confidence in used pixels)
- standard deviation $\sqrt{\sum_i \frac{(AOD_i - \overline{AOD})^2}{N-1}}$ (natural variability)
- propagated uncertainty $\frac{1}{N}\sqrt{\sum_i \sigma_i^2}$ (independent random)
- sum of 2 and 3 (represent dominant sources of error)
- worst-case propagation $\frac{1}{N}[\sum_i (AOD_i + \sigma_i) - \sum_i (AOD_i - \sigma_i)]$, simplistic upper boundary of uncertainty



SU v4.21 Uncertainty „true“ error

Discussion (1)

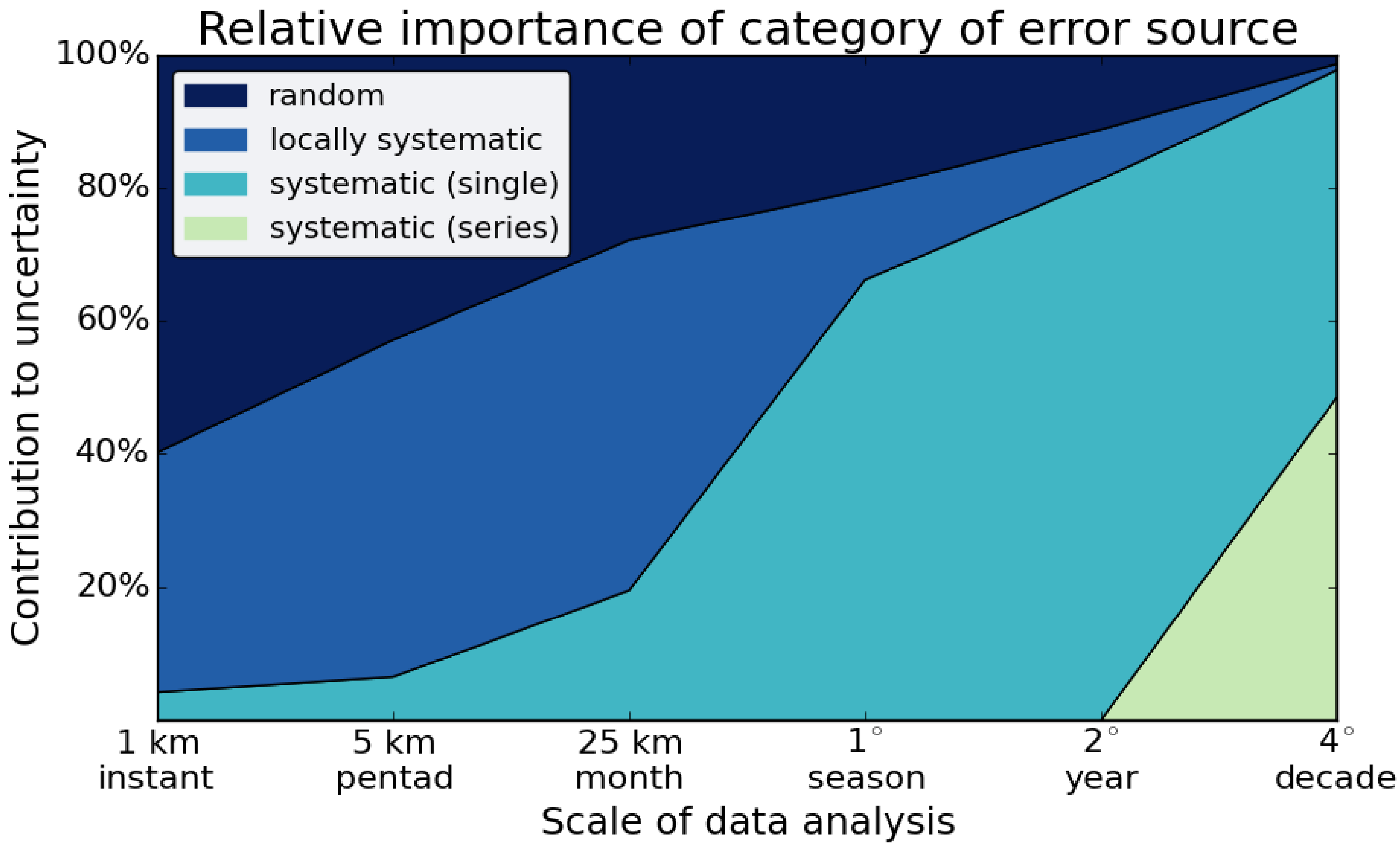
- Error propagation provides useful pixel-level uncertainties
  - Spatial / temporal variation of uncertainties
  - Weighting in ensemble
  - Weighting in data assimilation

Discussion (2)

- What we cannot (yet) cover
  - Uncertainty of cloud masks
  - Validation of uncertainties where no reference data exist (partial clouds, coastal water, …)
  - Separation into systematic / random (all known biases are corrected in the retrieval, all others are treated as random)
  - Rigid propagation to gridded datasets
  - Treatment of uncertainty terms with different correlations

- This information is described for users in
  - Pixel level flags
  - User guide / quality statement

Uncertainty on different scales



from http://dx.doi.org/10.6084/m9.figshare.1483408 (Chris Merchant, CCI SST project)

Fidelity and Uncertainty in Climate Data Records from Earth Observation (FIDUCEO)

Aims and outputs

- Learn to do well-characterised uncertainties in Climate Data Records (CDRs)
- Knowledge about observational stability from first principles
- New infra-red, visible and microwave “easy-FCDRs” with ε’s
- New CDRs for UTH, sea & lake ST, aerosol, albedo,
- Techniques, toolbox and training for tracing uncertainty from detector to geophysical product

Project headlines

- 4 year project under H2020
- 10 partners including a national metrological institute
- “Metrology for Earth Observation” across all wavelength domains for EO
- 2 international workshops
- 10 new datasets with rigorous traceable uncertainty info
- Cookbooks, open source tools, e-learning

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