Pixel level uncertainties

Overview + introduction

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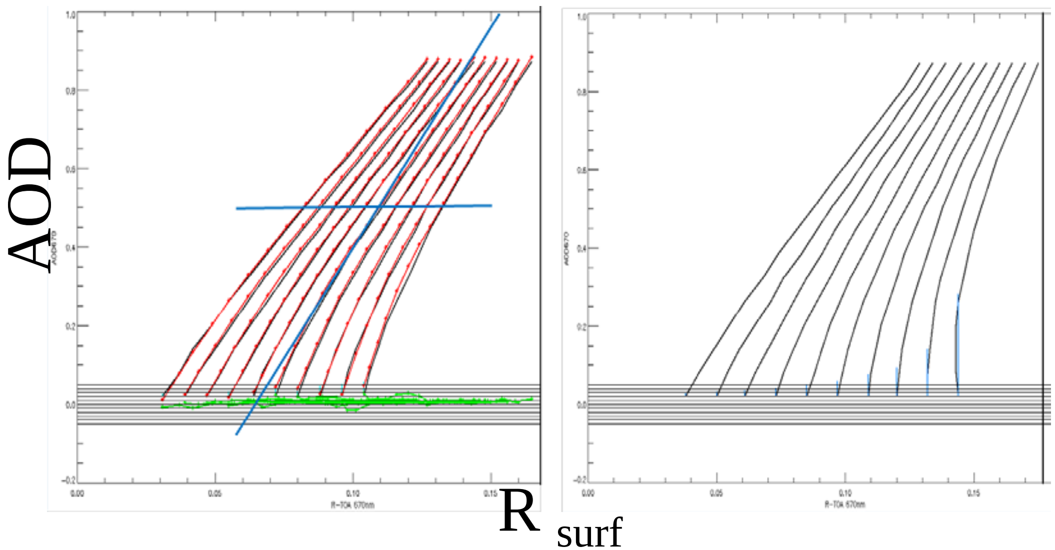
The concept of pixel-level uncertainties

- **Sensitivity to AOD varies largely with pixel conditions**
  - AOD
  - Aerosol properties, surface brightness / bi-directionality
  - Geometry, cloud situation, …



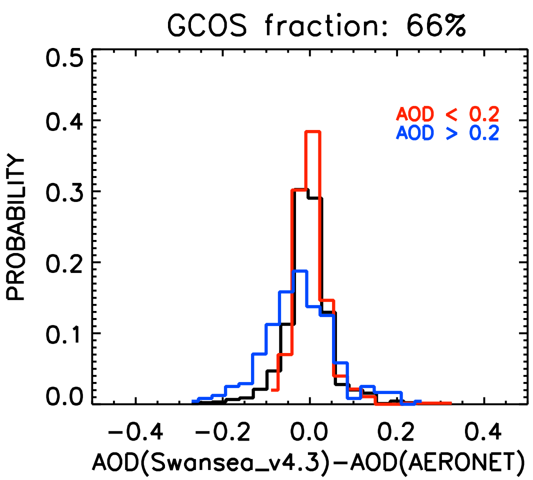
Example nadir radiometer: Dominant uncertainty terms bias corrected as much as we can do – random STD uncertainty

$$\sigma_{AOD} = \sqrt{\left(\frac{\partial AOD}{\partial R_{TOA}}\,\sigma R_{TOA}\right)^2 + \left(\frac{\partial AOD}{\partial Alb_{surf}}\,\sigma Alb_{surf}\right)^2 + \left(\sigma_{AOD}^{ensemble}\right)^2 + \sigma^2(0)}$$

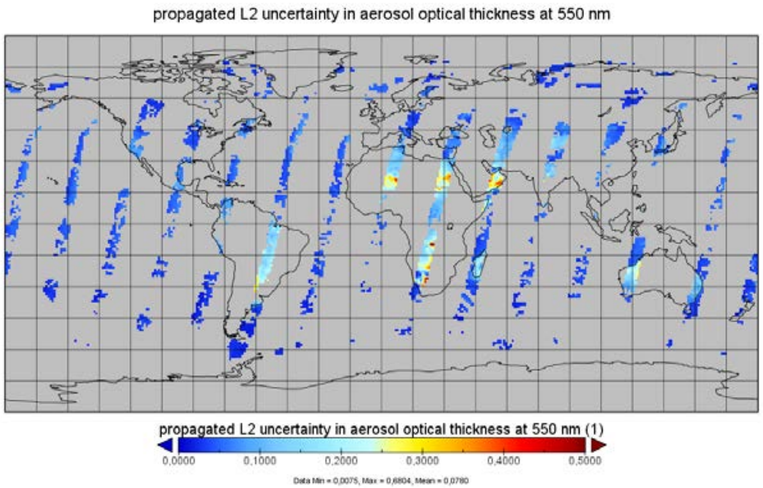
Uncertainties and validation

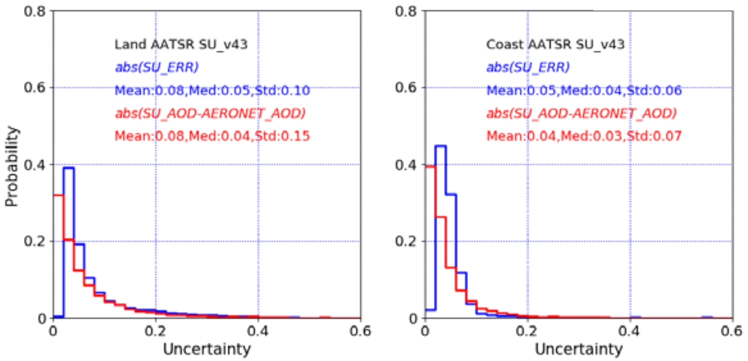
Ex posteriori validation and pixel-level uncertainty prediction need to be consistent

Validation to reference data stratified for different conditions



Prediction of pixel-level uncertainties by error propagation



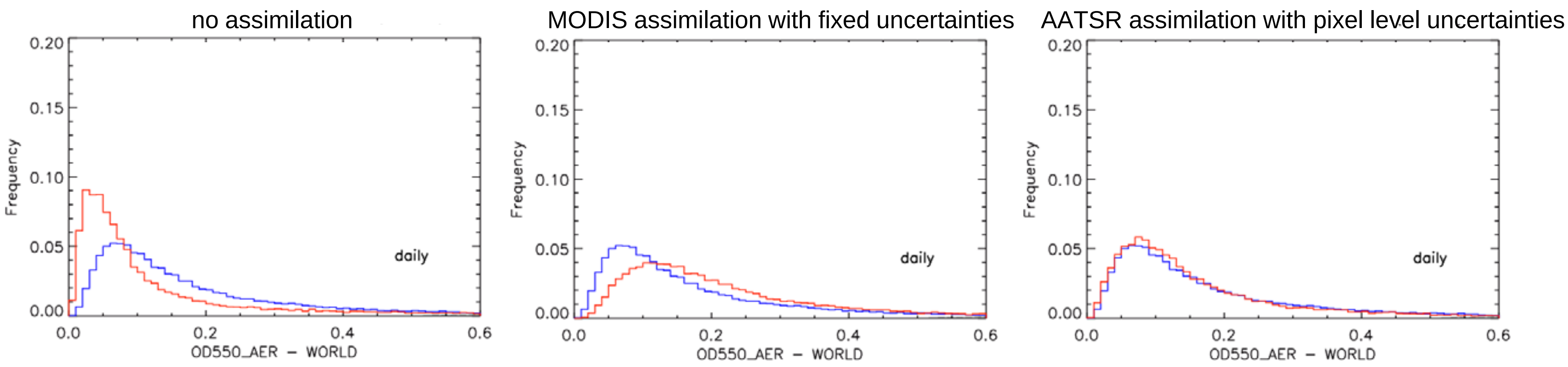


Validation of predicted uncertainties to reference data

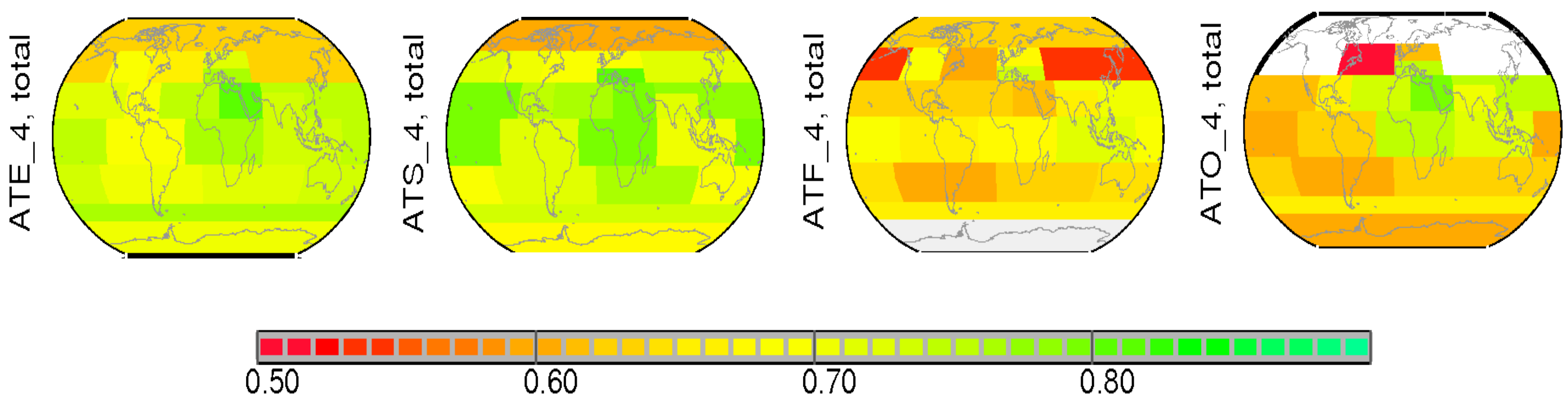
Document untreated / unvalidated uncertainties quality flags / quality statements (e. g. near clouds)

Who needs pixel-level uncertainties?

- Data assimilation



- Consistent data integration

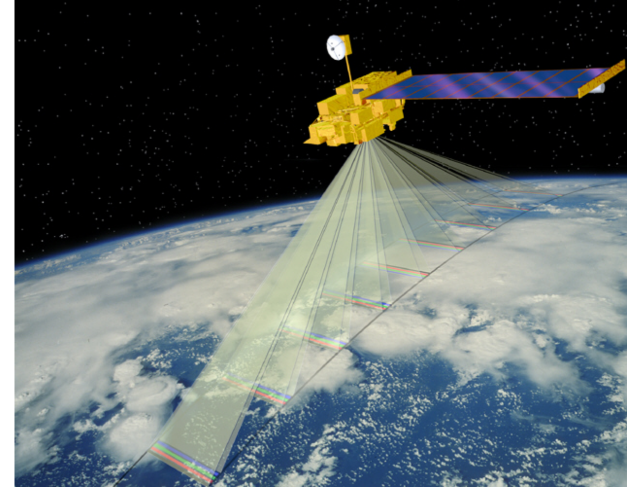


Components of Level 2 Error Model
(requires lots of data to pull out)

- **Can be as simple as RMSE as a function of AOD**
  - AOD can be from AERONET (diagnostic) or own AOD (prognostic).
  - But, RMSE is symmetric nor does it address massive outliers which are often the problem
- **Terms include:**
  - Differential Signal to Noise: Lower boundary minus total, including view angle/optical path length.
  - Lower Boundary Condition:
    - Ocean: Wind/glint/whitecap, class 2 waters, sea ice
    - Land: Surface reflectance model, snow, view angle/BRDF/hotspot
  - <u>Cloud mask</u>
  - Microphysical: Fine coarse/partition, P(θ)/g, ω_o, AOD
- **Biases are often folded into "random" error models. If they are known, why not correct for them?**
- **Radiance Calibration: Individual wavelengths propagate non-linear through retrievals and are not easy to incorporate.**
- **<u>Verification of errors is also needed</u>**

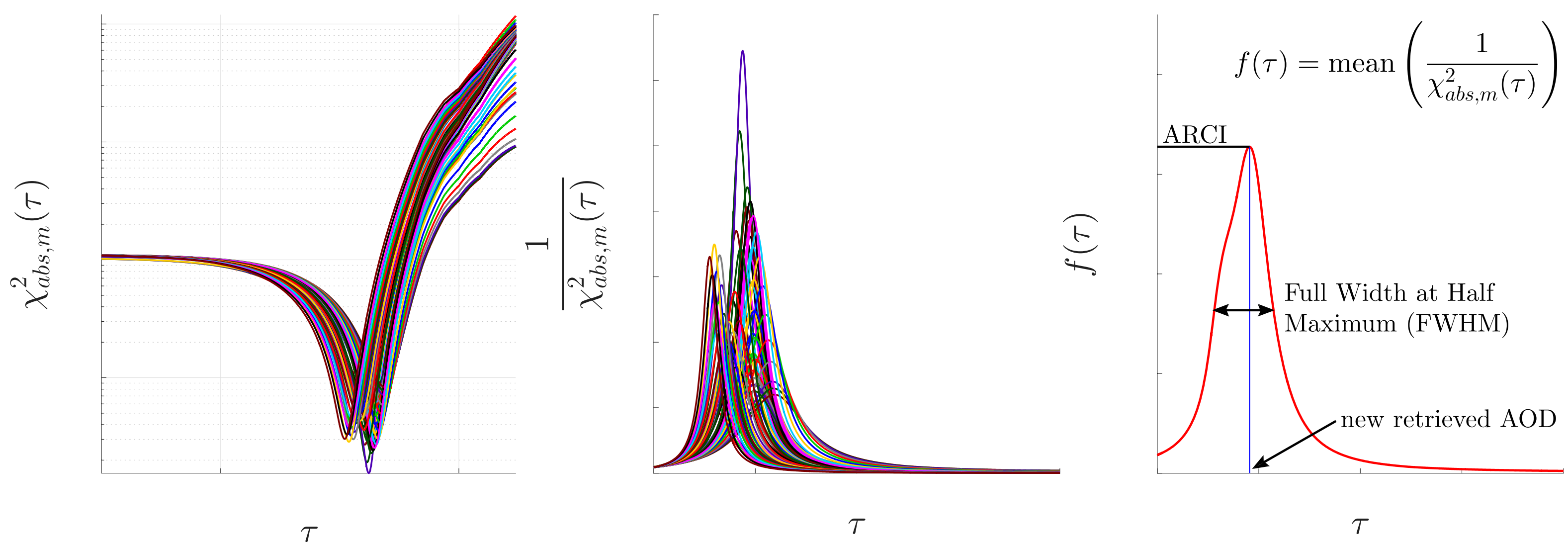
New MISR V23 dark water uncertainties

see poster by M. Witek / JPL



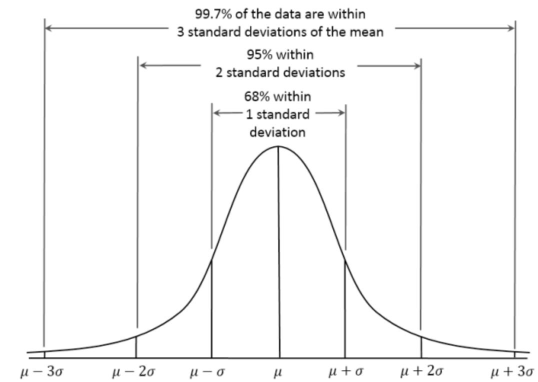
- MISR's aerosol retrieval algorithm calculates cost functions (χ^2_{abs}) between observed and pre-simulated radiances for a range of AODs and a prescribed set of aerosol mixtures (74).
- The new approach in dark water retrievals considers the entire range of χ^2_{abs} for all mixtures and does not impose thresholds on χ^2_{abs} to determine the success or failure of a particular mixture.
- The uncertainty depends on the combination of:
  a) absolute values of χ^2_{abs} for each aerosol mixture,
  b) widths of χ^2_{abs} distributions,
  c) spread of χ^2_{abs} distributions among the ensemble of mixtures.

$$\chi^2_{abs}(\tau) = \frac{\sum_{l=1}^{4} w_l \cdot \left[\sum_{j=1}^{9} v(l,j)\cdot \frac{\left[\rho_{MISR}(l,j)-\rho_m(l,j)\right]^2}{\sigma^2_{abs}(l,j)}\right]}{\sum_{l=1}^{4} w_l \cdot \left[\sum_{j=1}^{9} v(l,j)\right]}$$

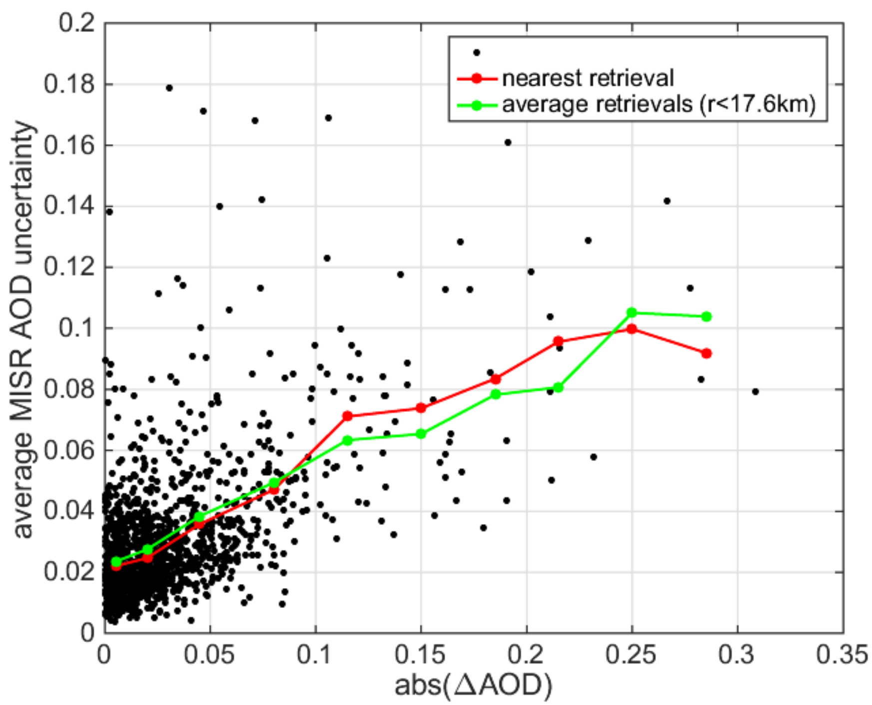


V22: $\tau = 0.174 \pm 0.003$ **V23**: $\tau = 0.182 \pm 0.049$

MISR uncertainty evaluation



Uncertainty generally increases with the difference between MISR and Aeronet AOD (based on ~1300 collocations)

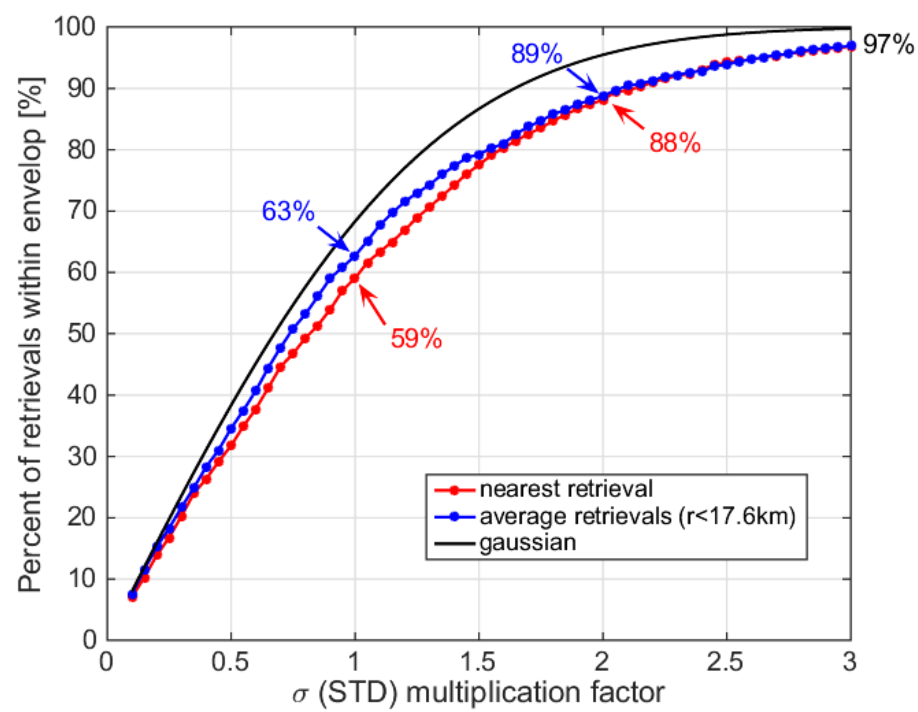


Legend explanation:

•"Nearest retrieval" - MISR retrieval closest to the Aeronet location

•"Average retrievals (r<17.6 km)" - all MISR retrievals that are within 17.6 radius from the Aeronet location

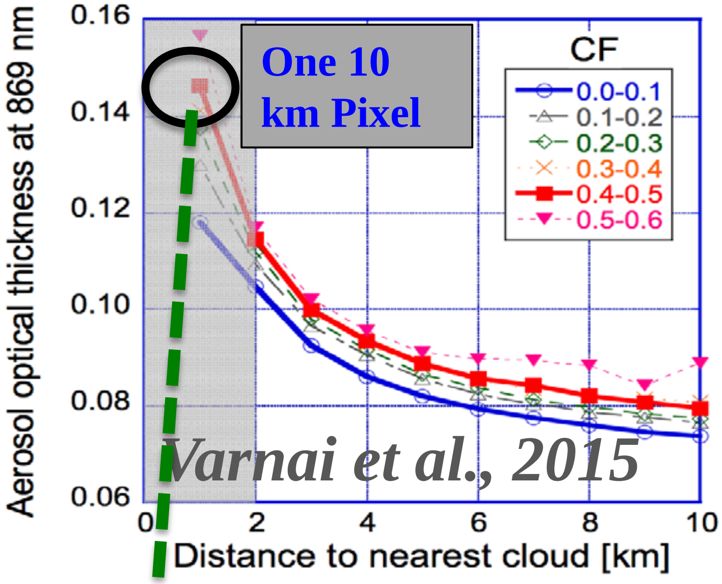
Retrieved uncertainty has characteristics similar to the standard deviation of the normal distribution: the 3-sigma rule (68-95-99.7) is followed closely.



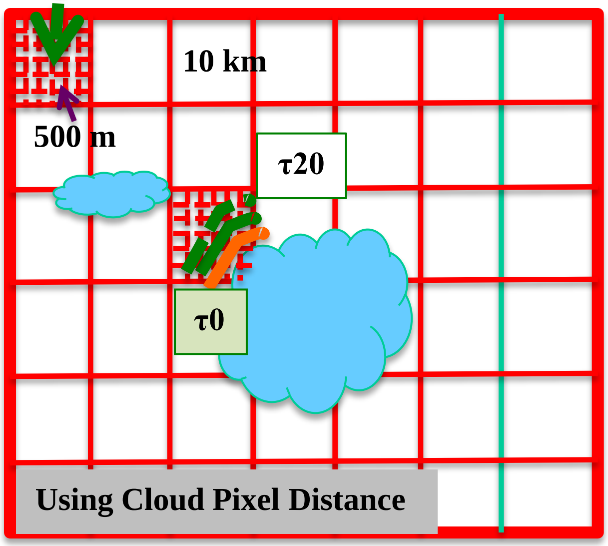
MODIS Dark Target Retrievals in Cloud Vicinity

see poster by F. Patadia / GSFC

Enhanced AOD near clouds



Schematic of One MODIS Granule



- **MODIS has :**
  - **(1) Observations at 500 m**
  - **(2) Distance of every 500m pixel from a cloud**

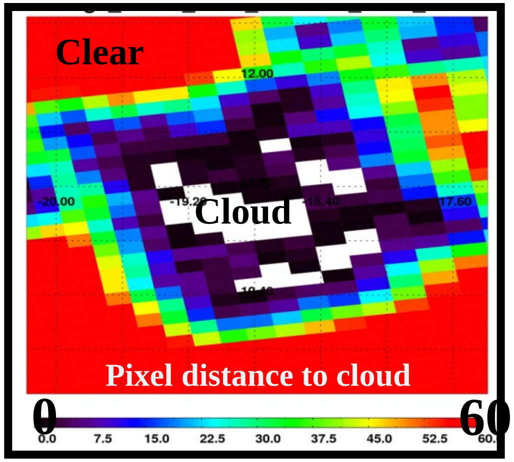
- **To estimate cloud effect, retrievals were done as a function of distance to cloud**

1) τ0 : All pixels used in C6
2) τ20 : pixels with cloud pixel distance > 20 (1 km away from clouds)

Hypothesis :

If C6 AOD is elevated due to clouds then τ20 - τ0 = Negative

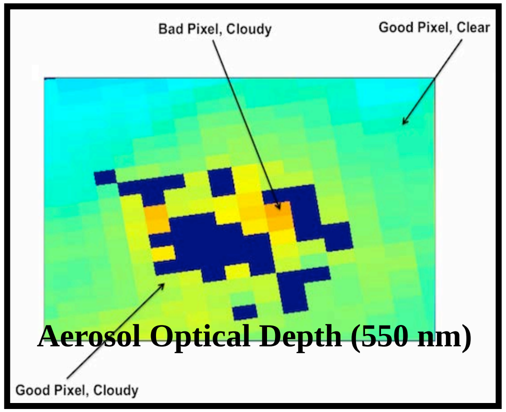
Investigating Reflectance Histograms @500 m

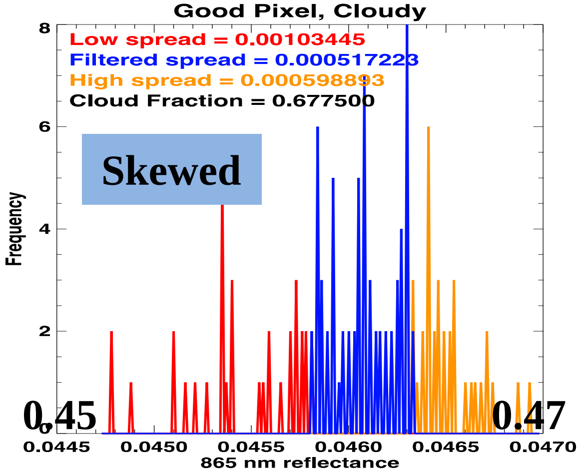


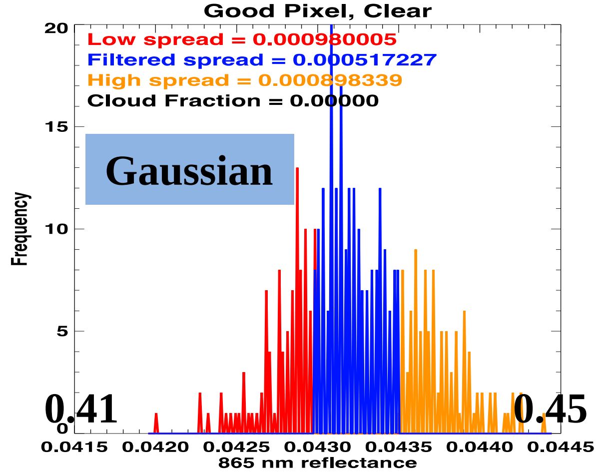
Histograms of 865 nm reflectance pixels with good and bad AOD retrievals, shows that

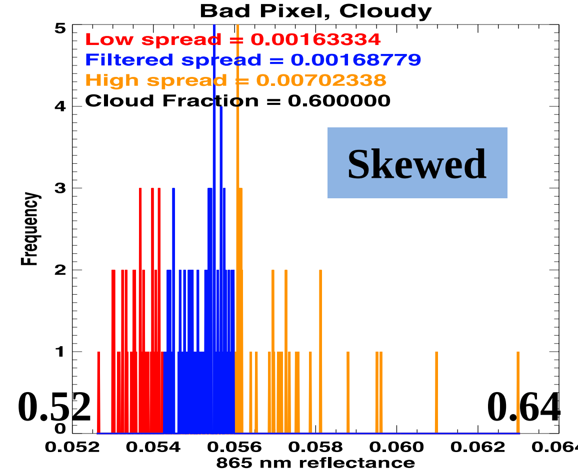
- Reflectance histogram of Clear-sky pixels is Gaussian
- Reflectance histogram of Cloudy region pixels are skewed
- Filter cut-off will govern high / low bias in AOD

Per-pixel reflectance histograms suggests retrieval possibility using median reflectance values (work in progress)





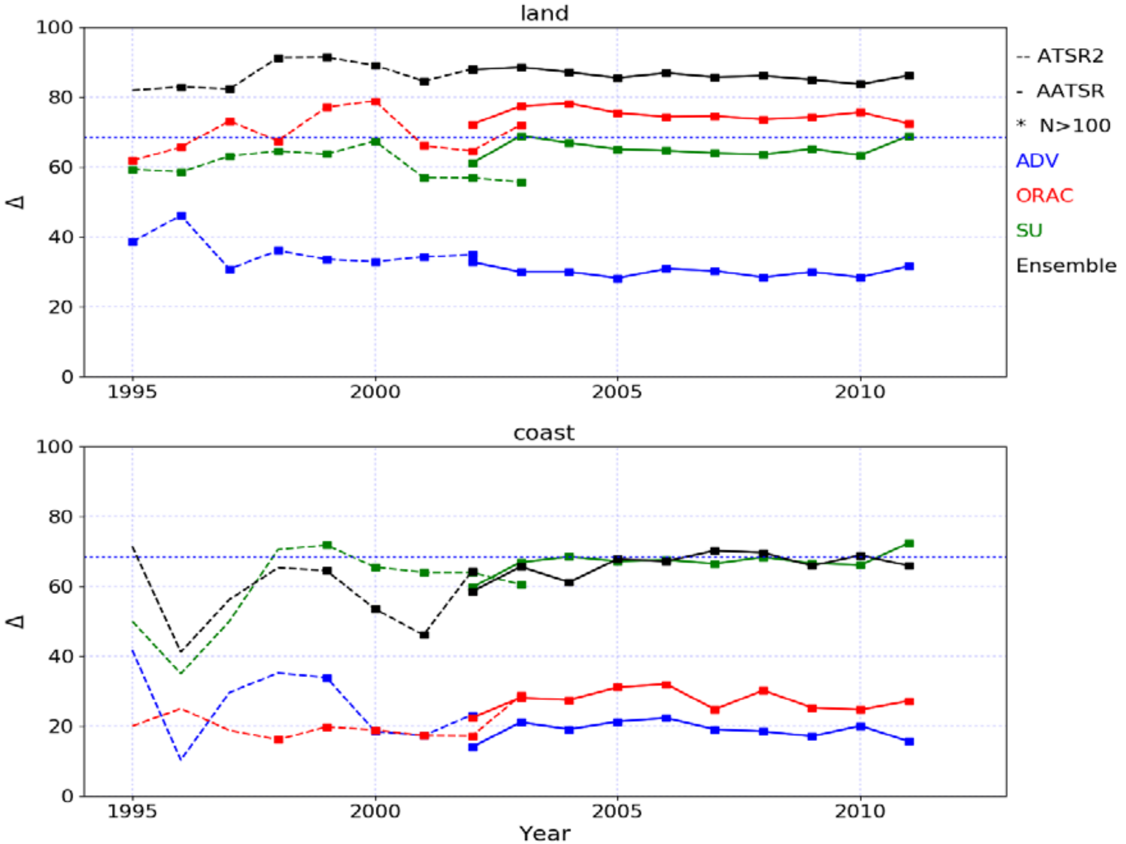




Aerosol_cci progress

- Long-term consistency of uncertainties (Aerosol_cci: ATSR 1995 – 2017)

$$\Delta = \frac{AOD_{\text{ATSR}} - AOD_{\text{AERONET}}}{\sigma_{\text{ATSR}}}$$



-> talk K. Stebel

Questions

- Can we achieve consistency validation <-> error propagation?
- How can we treat non-Gaussian distributions?
- How best validate pixel-level uncertainties?
- How to treat propagation from lv2 to lv3 (correlations)?
- How can we provide uncertainties for derived properties?
- Goals / deliverables until AEROSAT 2018
  - Overview / recommendation paper (-> talk A. Sayer)

AEROSAT 2016 / Beijing

- Use of uncertainties in models
  - Matching satellite – model on daily / hourly + colocation step needed (Schuttgens)
  - Large uncertainties in monthly means due to sampling
  - Satellite sampling in 1 degree box can provide histograms
  - More validation data as reference needed
  - How separate systematic and random uncertainties
- Good discussion of basic principles

- Use of linear regression and alternatives
  - Uncertainties of metrics need to be considered
  - Independent (trend) analysis need to be consistent
  - Obvious analysis create higher confidence than those highly tuned

- Uncertainties on different scales
  - Be aware of limitations in error propagation and in validating propagated uncertainties

-> conclusion: review / synthesis paper on characterizing uncertainties