Validation of OCI aerosol and cloud properties

Andrew Sayer

GESTARII-UMBC at NASA GSFC

andrew.sayer@nasa.gov

OCI required atmospheres data products and main heritage validation sources

Not an exhaustive list or guaranteed to always be available!

Quantity	Range	Uncertainty goal
Aerosols		
AOD at 380 nm	0-5	Max (0.06 or 40%)
AOD at 440, 500, 550, 675 nm	0-5	Land: Max (0.06 or 20%) Water: Max (0.04 or 15%)
FMF at 550 nm over water	0-1	0.25
Clouds		
Cloud mask	-	-
CTP (for COT>3)	100-1000 mb	60 mb
COT	5-100	Liquid: 25%; Ice: 35%
CER	5-50 μm	Liquid: 25%; Ice: 35%

Aerosols: **Sun photometry**, e.g. Aerosol Robotic Network (**AERONET**) and Maritime Aerosol Network (**MAN**)

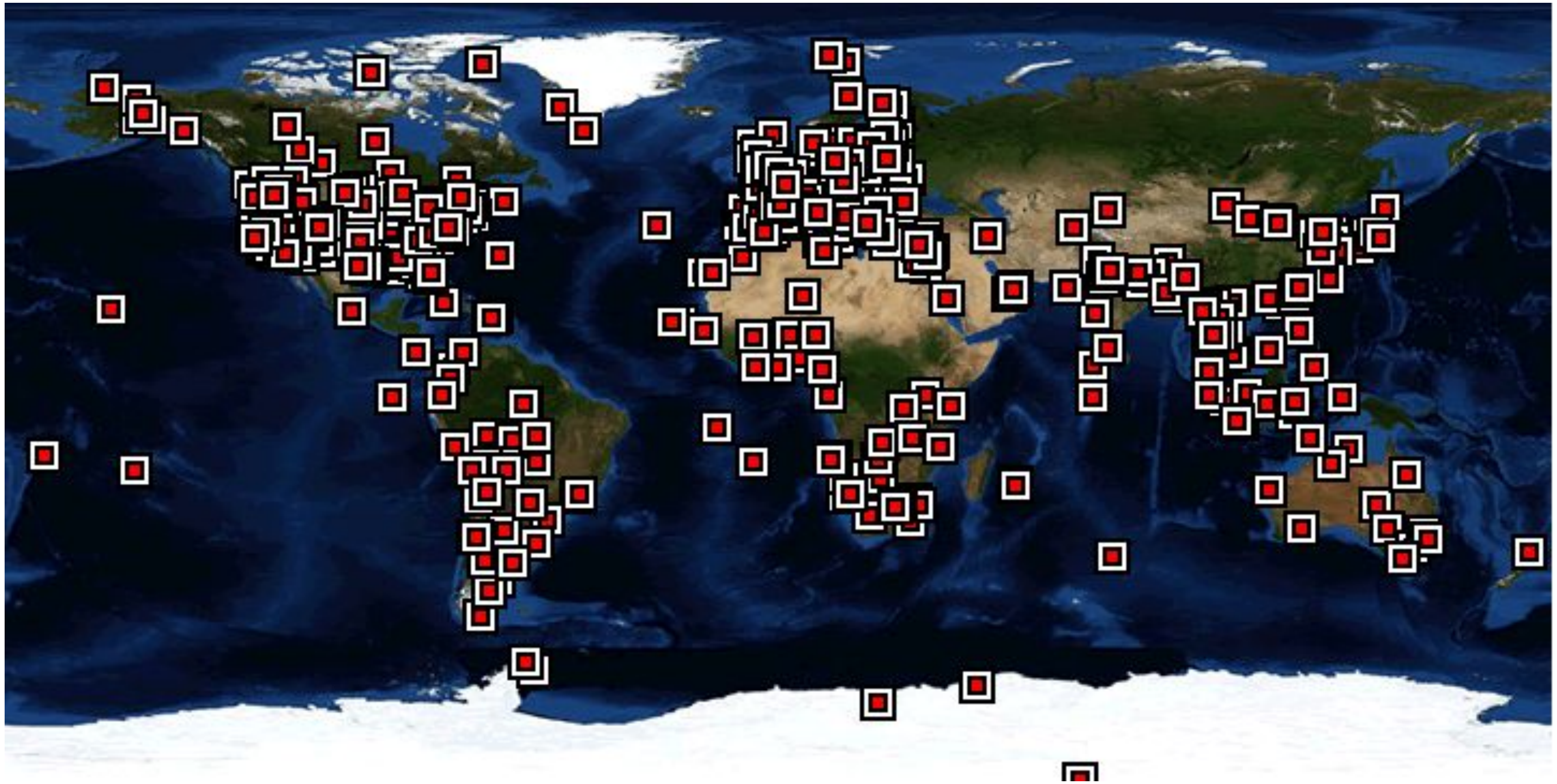
Cloud mask, CTP: Ground/space **lidar**, **radar**, and **microwave radiometers**

COT, CER: **Cloud probes** on aircraft


Aerosols

AERONET is the primary validation source for most satellite remote sensing and modeling approaches

- Hundreds of active sites covering a *variety of aerosol and surface conditions*
- High observation *frequency*, low *latency*, long *time series*
- *Freely available* data
- *Consistent* measurement, calibration, and processing protocols
- But:
  - Some sampling gaps
  - Limited densely-sampled (<<100 km spacing areas)

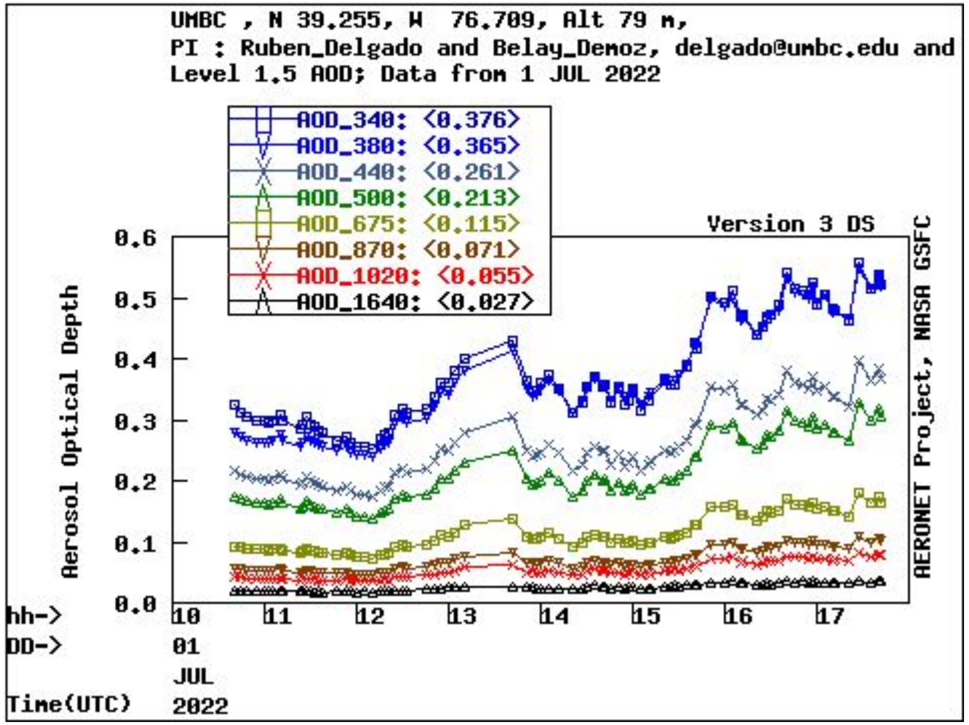


Sites active in 2022, from https://aeronet.gsfc.nasa.gov

Sun photometry provides accurate AOD and more

- *Autonomous* operations
- Spectral AOD uncertainty 0.01-0.02
- Water vapour, derived Ångström exponent & FMF
- Sky-scans for additional aerosol properties

Video by A. Sidel, from https://earth.gsfc.nasa.gov/climate/data/deep-blue/science



UMBC direct-Sun data from https://aeronet.gsfc.nasa.gov

The Maritime Aerosol Network is a ship-based complement to AERONET

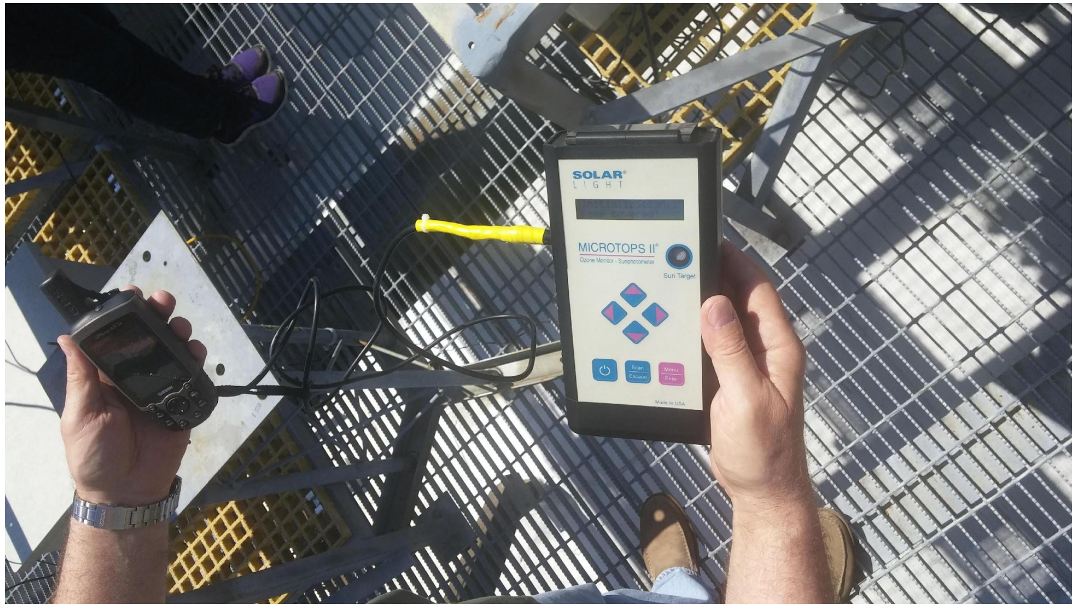
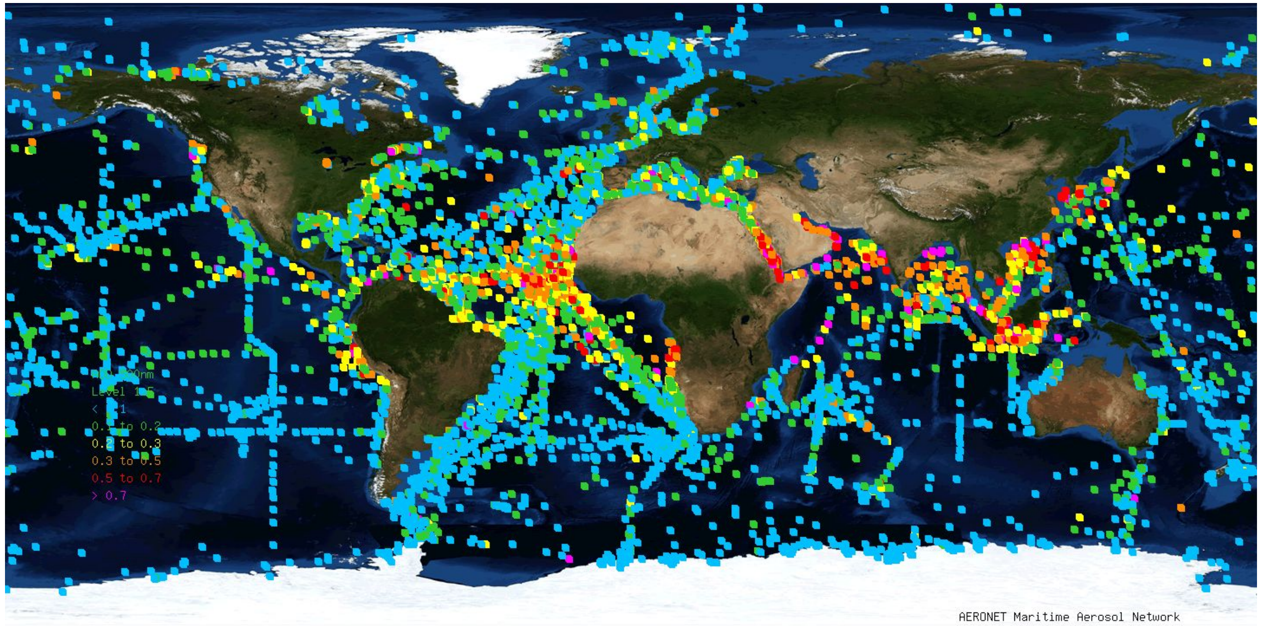


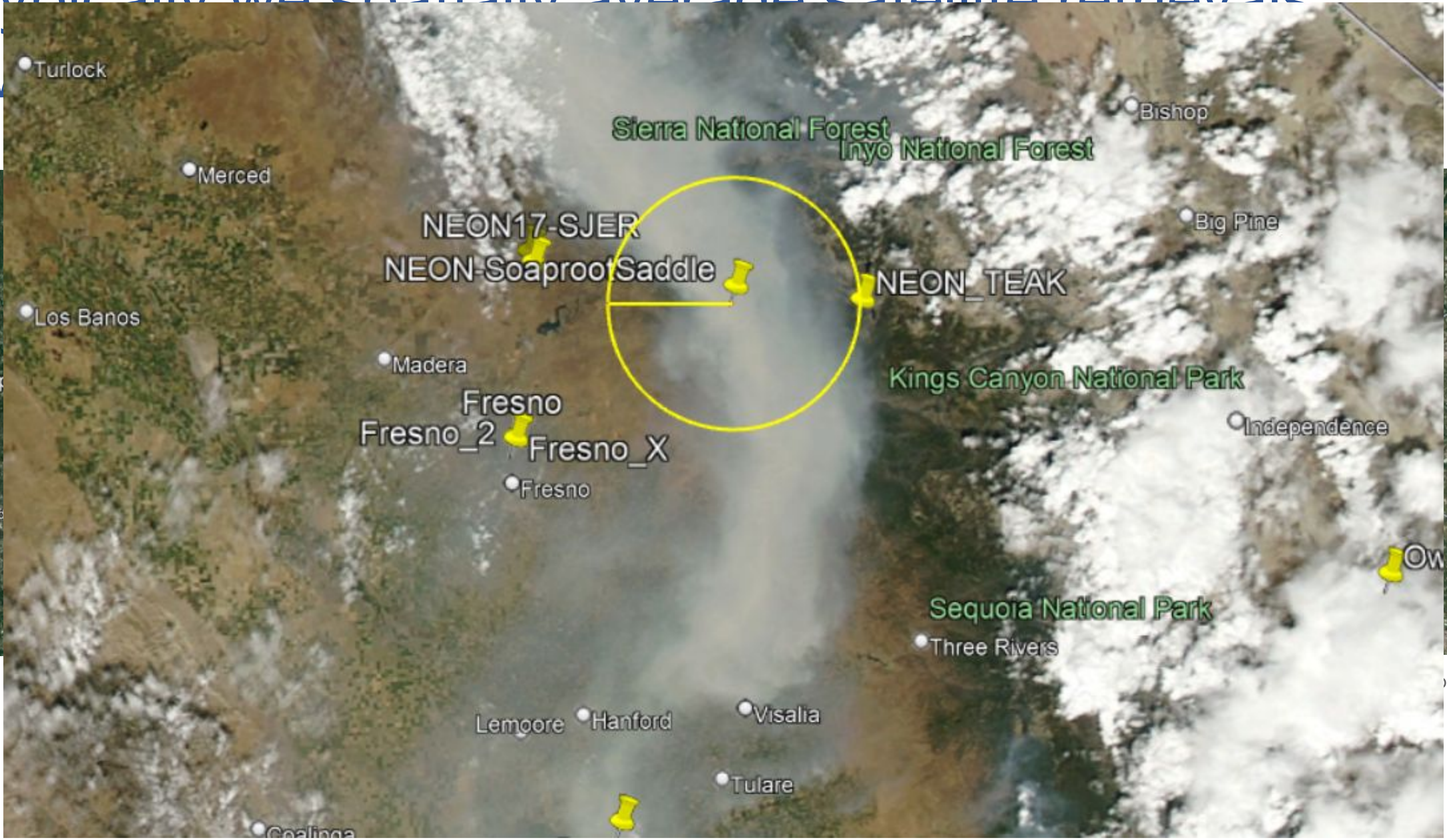
Photo by B. Howl, from https://earth.gsfc.nasa.gov/climate/data/deep-blue/science



MAN cruises up to present, from https://aeronet.gsfc.nasa.gov

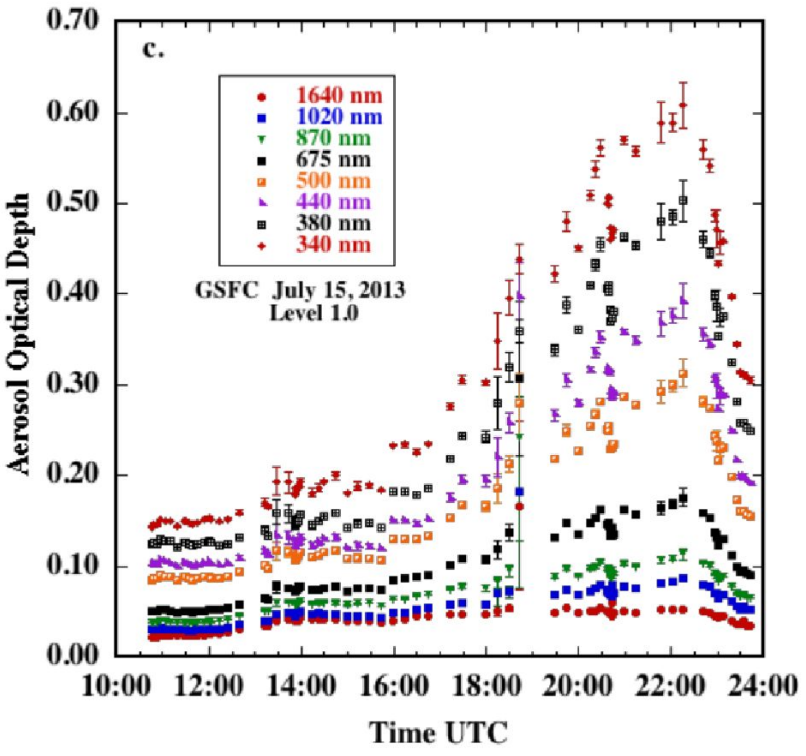
- Hand-held instruments operated *manually*
- AOD uncertainty ~0.02
- Sparse but some common *repeat routes*

Typically we spatially average satellite retrievals
W

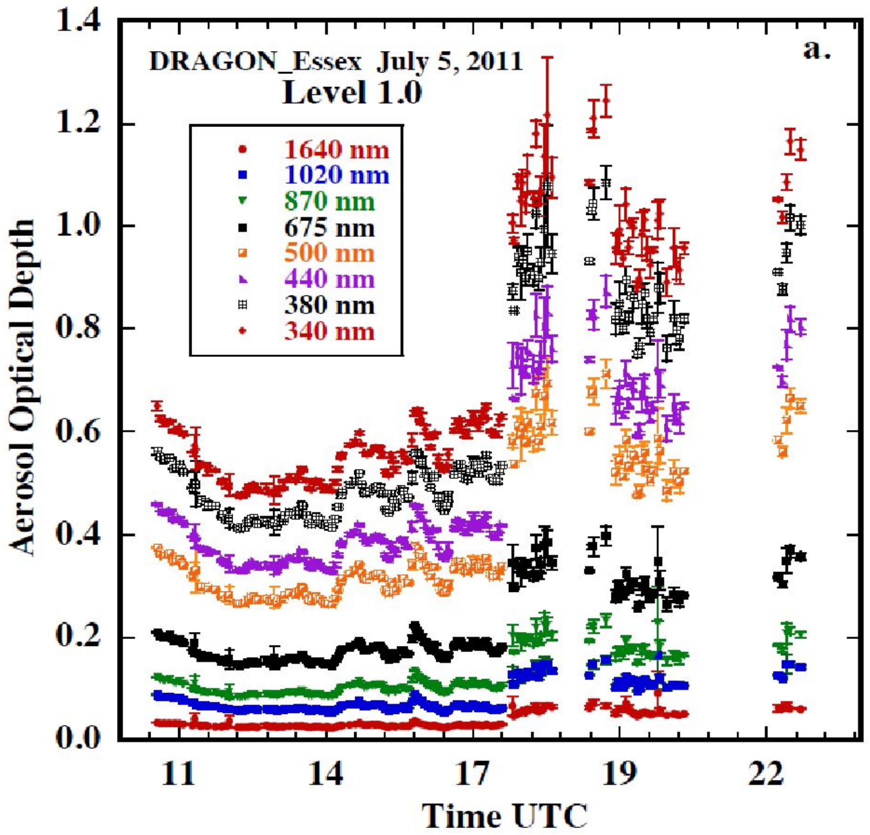


ogle Earth

… and temporally average ground observations within ±30 minutes

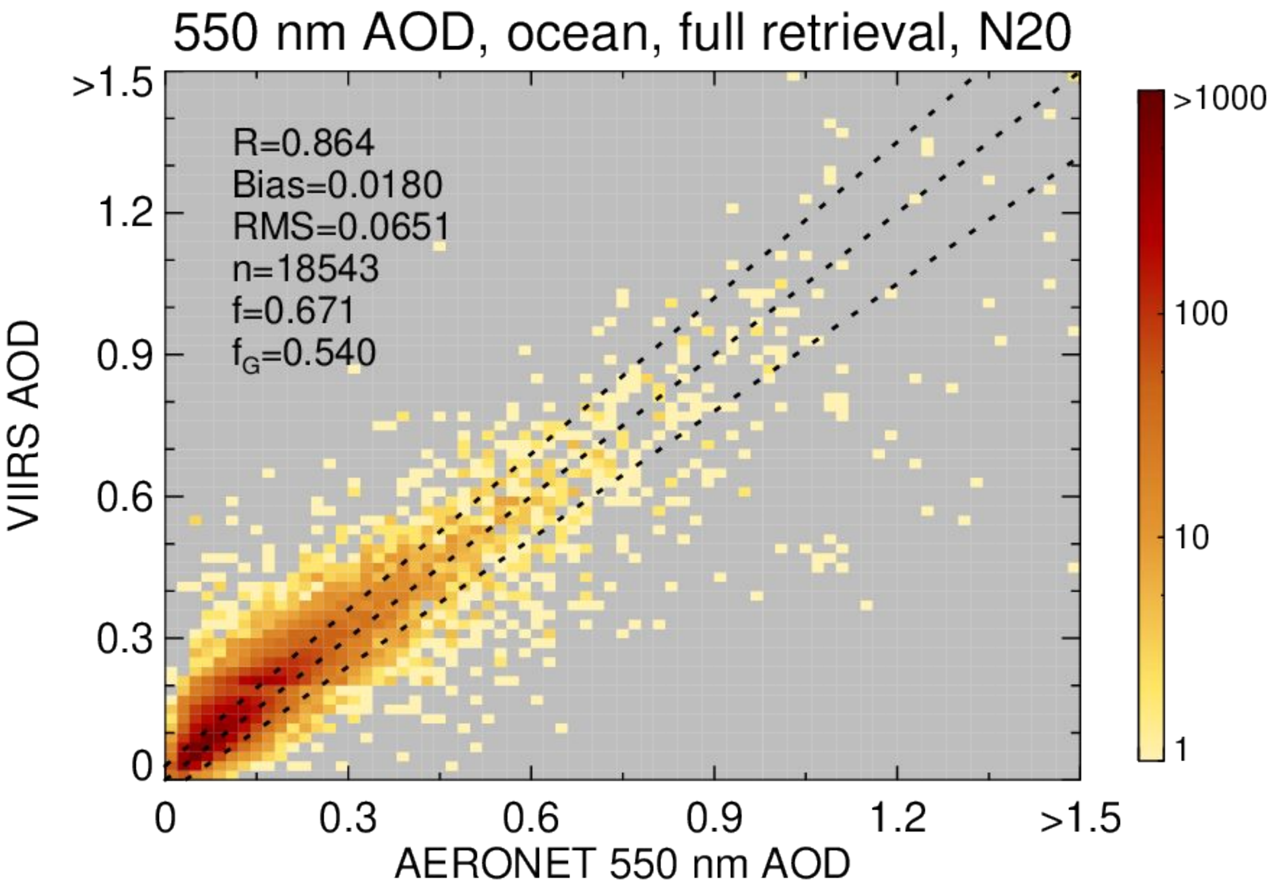


Eck *et al.*, ACP (2014)

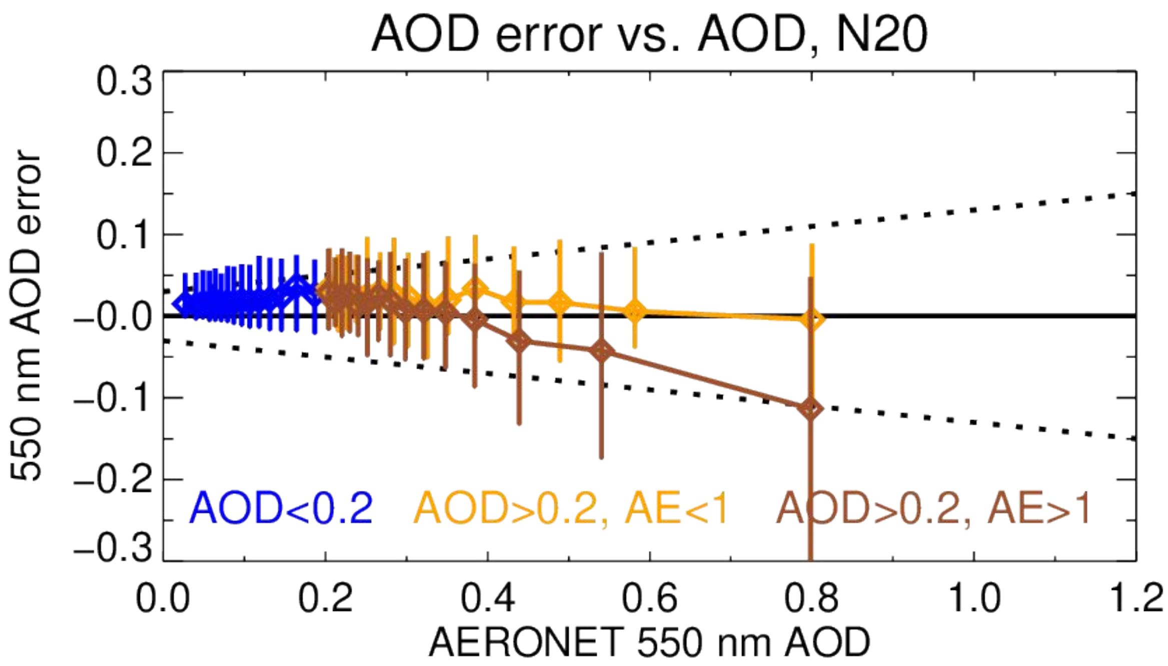


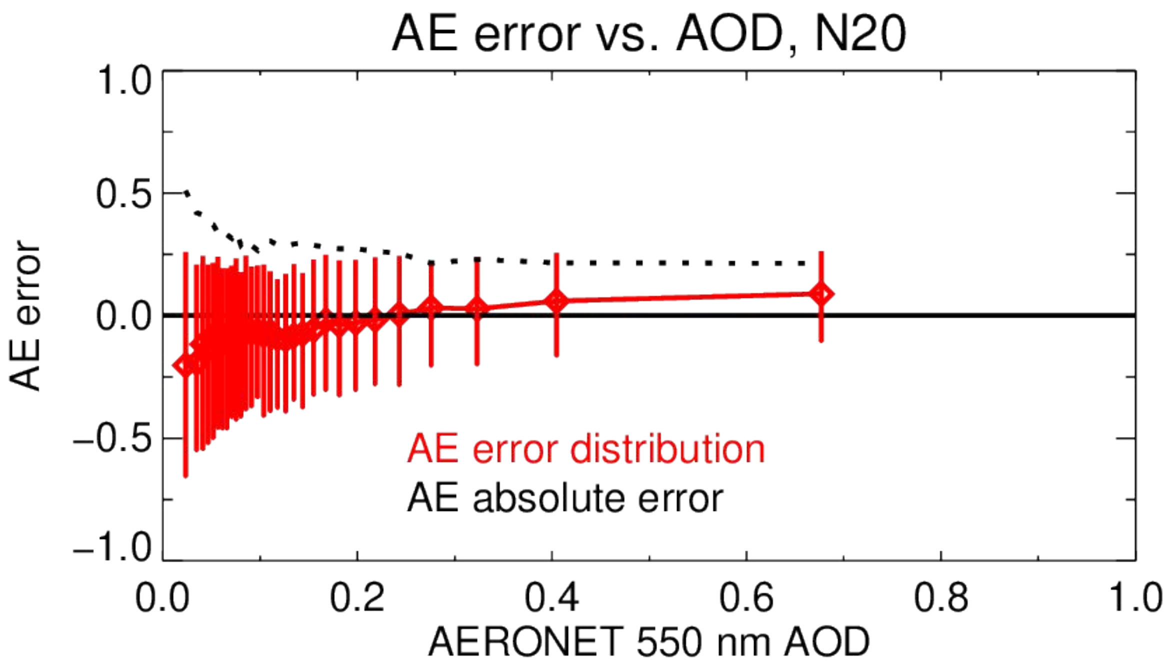
Simple statistics can give us a basic picture…

- Measures relating to:
  - Degrees of *association* (correlation)
  - *Bias* (mean, median)
  - Error *magnitude* (mean or median absolute error; root mean squared error)
  - Performance *relative to expectation* or *goal* (pixel-level uncertainty, application requirement, etc…)
- Each has *caveats* relevant to interpretation!
  - Data are not independent random draws, skewed distributions, variable errors, etc…
  - Many papers use statistics *inappropriately*, please take care

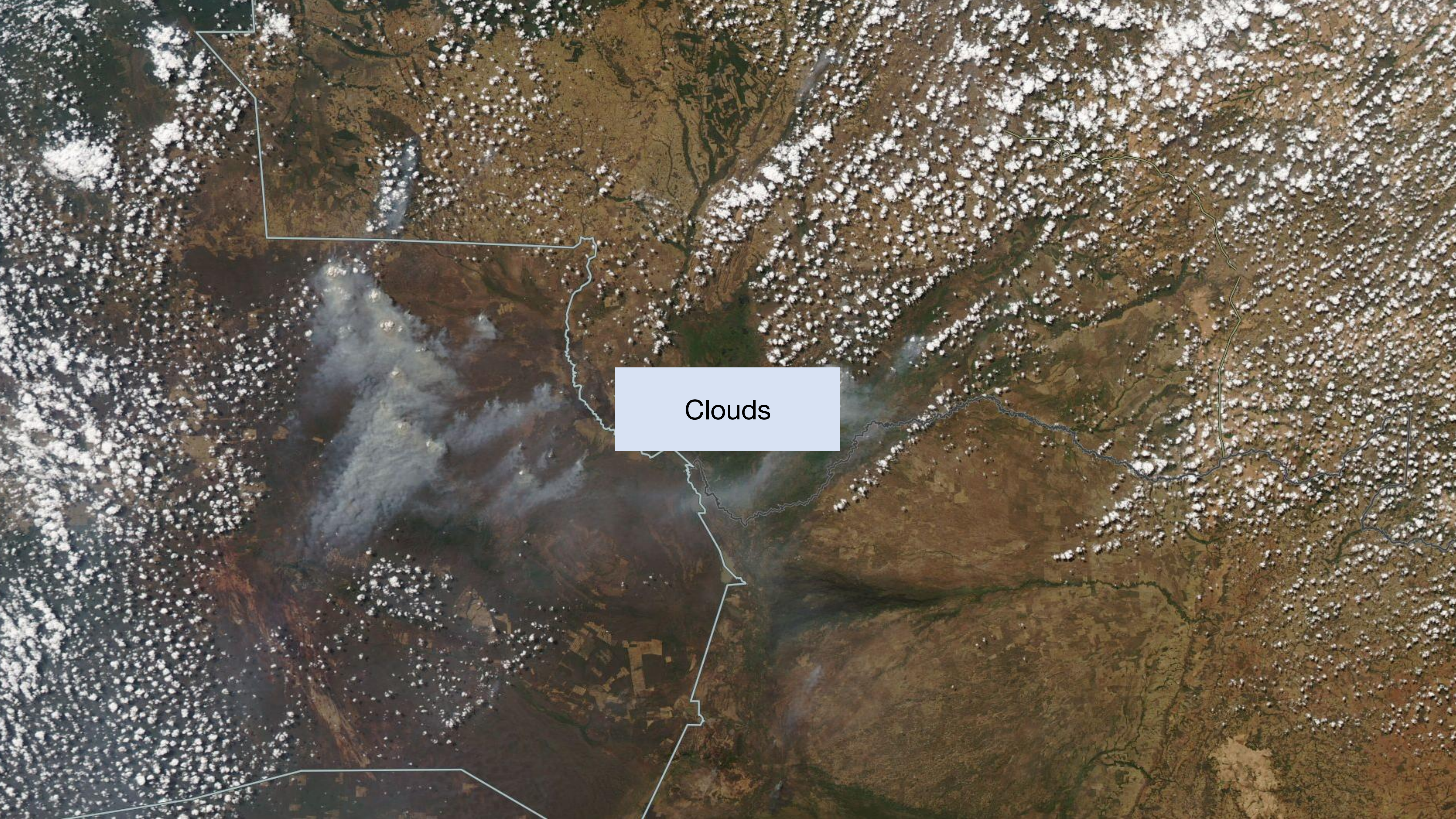


… but more detailed analysis is warranted, where data volume permits

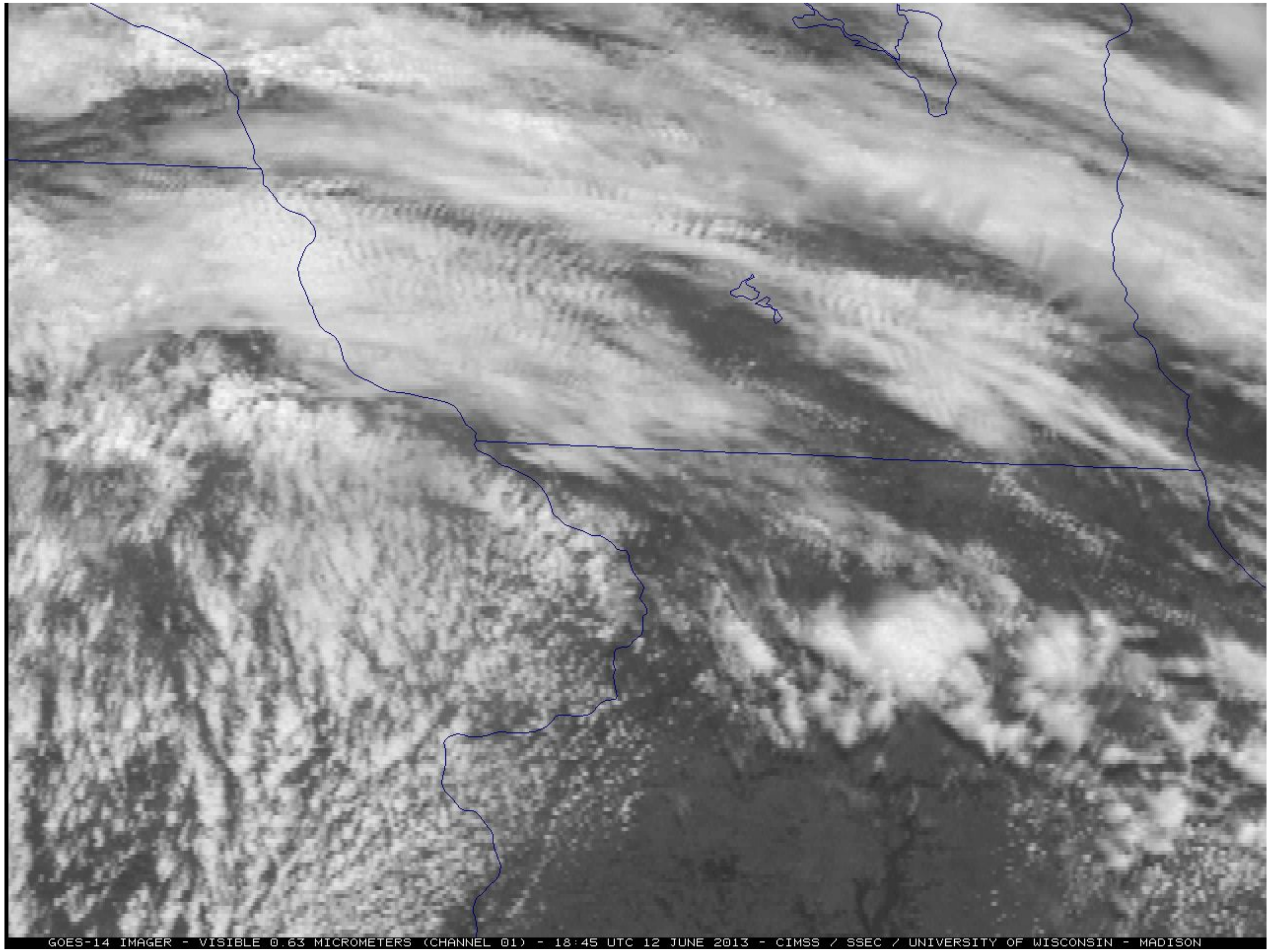




- Stratified analyses give insights relevant for data *users* as well as algorithm *refinement*
- Remember the retrievals we validate are a *specific subset* of the retrievals we have
  - Can generalise the statistics you get, but only so far

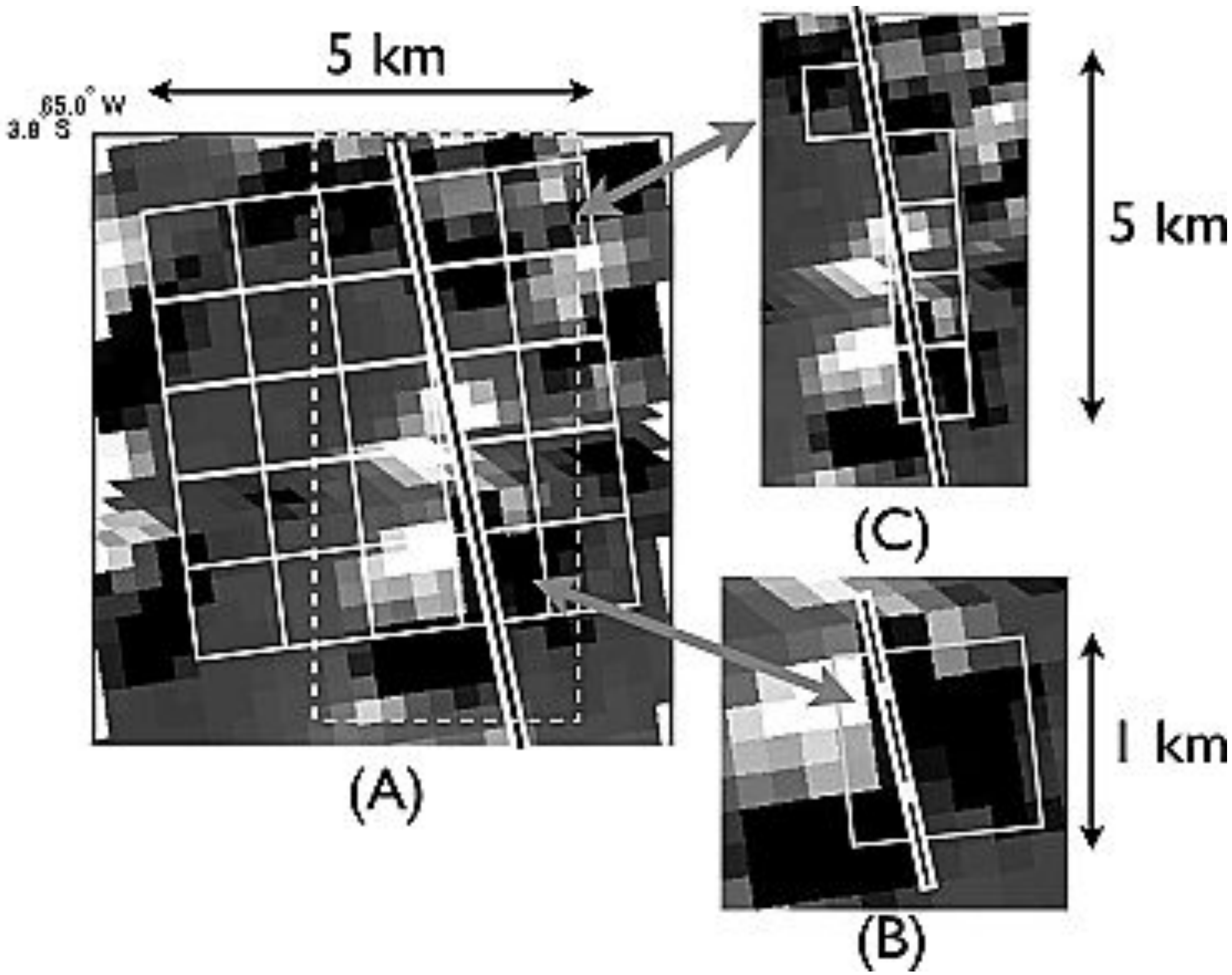

Clouds

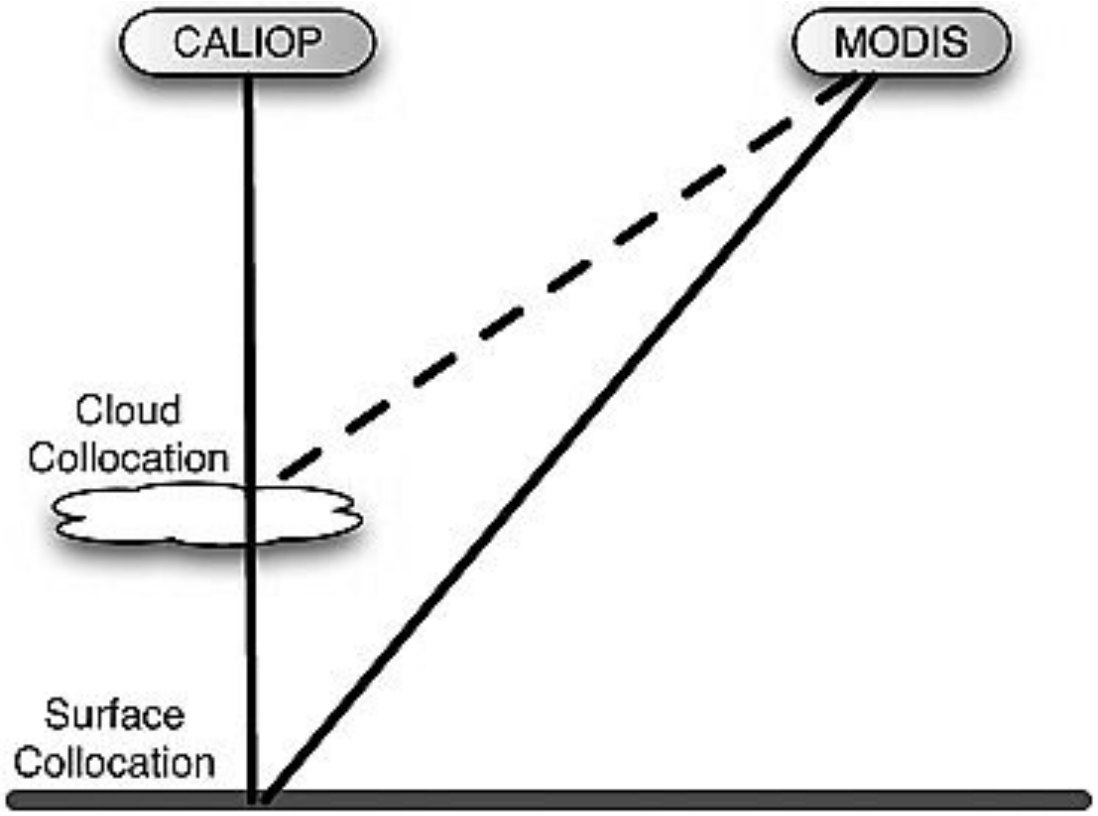
Cloud systems can evolve really, really quickly



GOES-14 Super Rapid Scan from
https://cimss.ssec.wisc.edu/satellite-blog/archives/13256

Pixel selection for matchups can be difficult

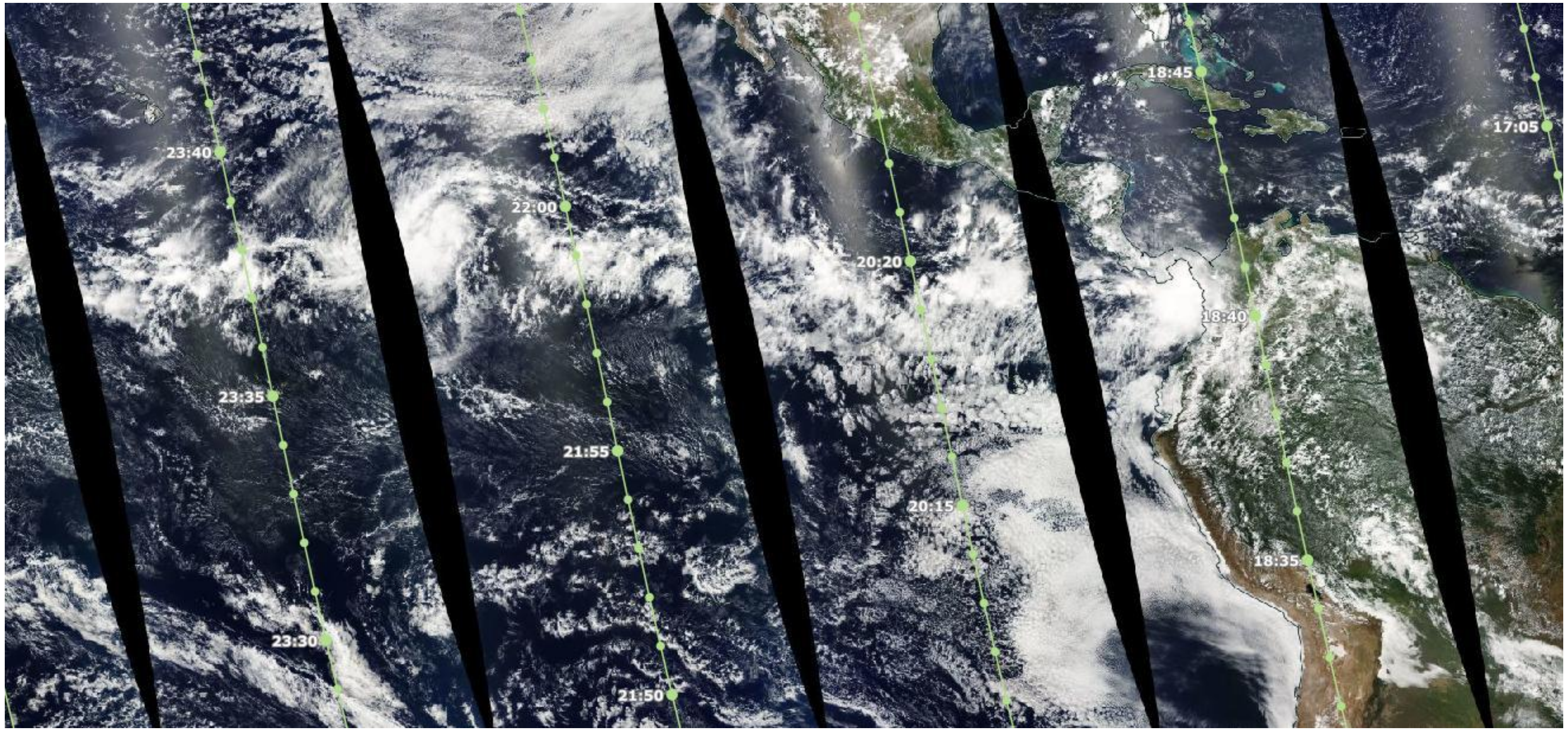




Holz *et al.*, JGR (2008)

The most reliable ground truth for cloud mask comes from active sensors

- Lidar, radar, microwave radiometer…
- Highly sensitive but generally *single track* or *single point*
    - *Curtain,* not *swath*
- Limited spaceborne options in next few years
    - Several ground sites
    - Airborne data
- Other sensor types and human observers exist



Wang *et al.*, JGR (2016)

Evaluating classifications use different metrics from continuous variables

- Most commonly, with a *confusion matrix*
  - Subset for dependence on e.g., surface type
- Overlap with metrics in e.g. machine learning, medical research disciplines
  - See right-hand side of https://en.wikipedia.org/wiki/Confusion_matrix

	Truth	
Retrieval	Positive	Negative
Positive	True positive (TP)	False positive (FP)
Negative	False negative (FN)	True negative (TN)

$$Accuracy = \frac{TP + TN}{TP + FP + FN + TN}$$

Many resources to evaluate cloud mask are also useful for cloud altitude

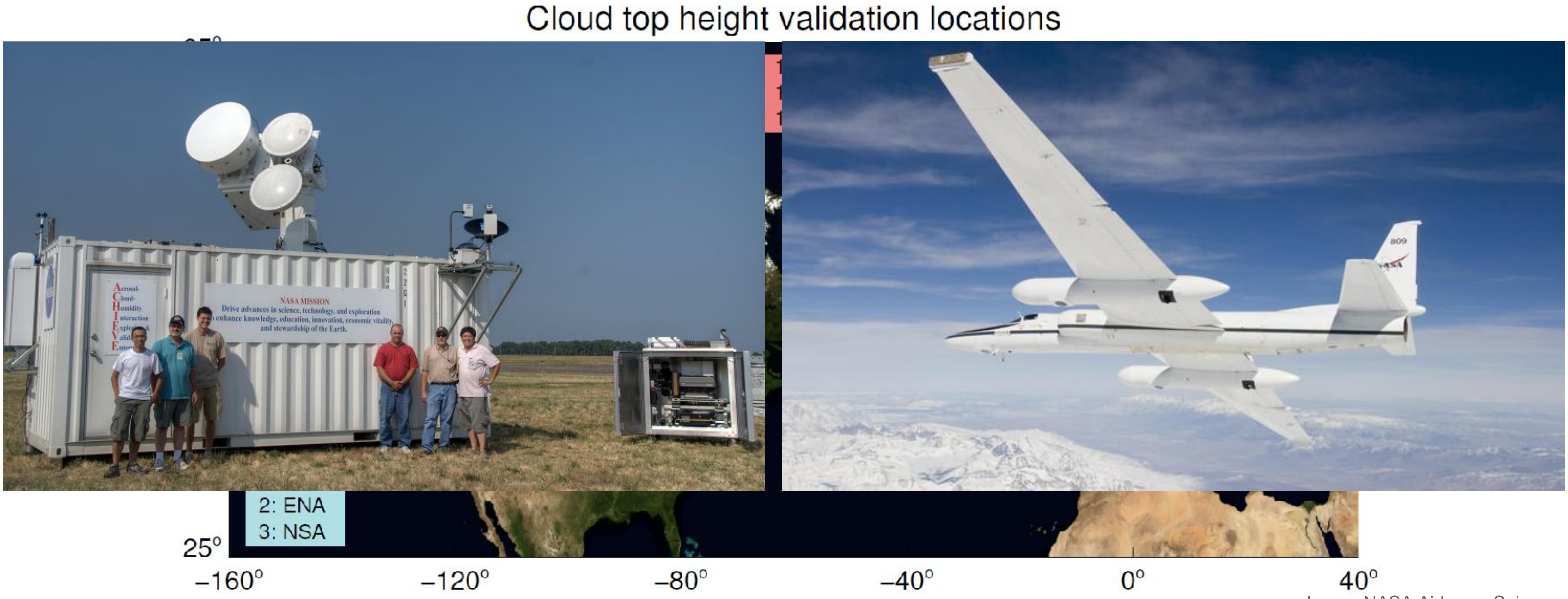
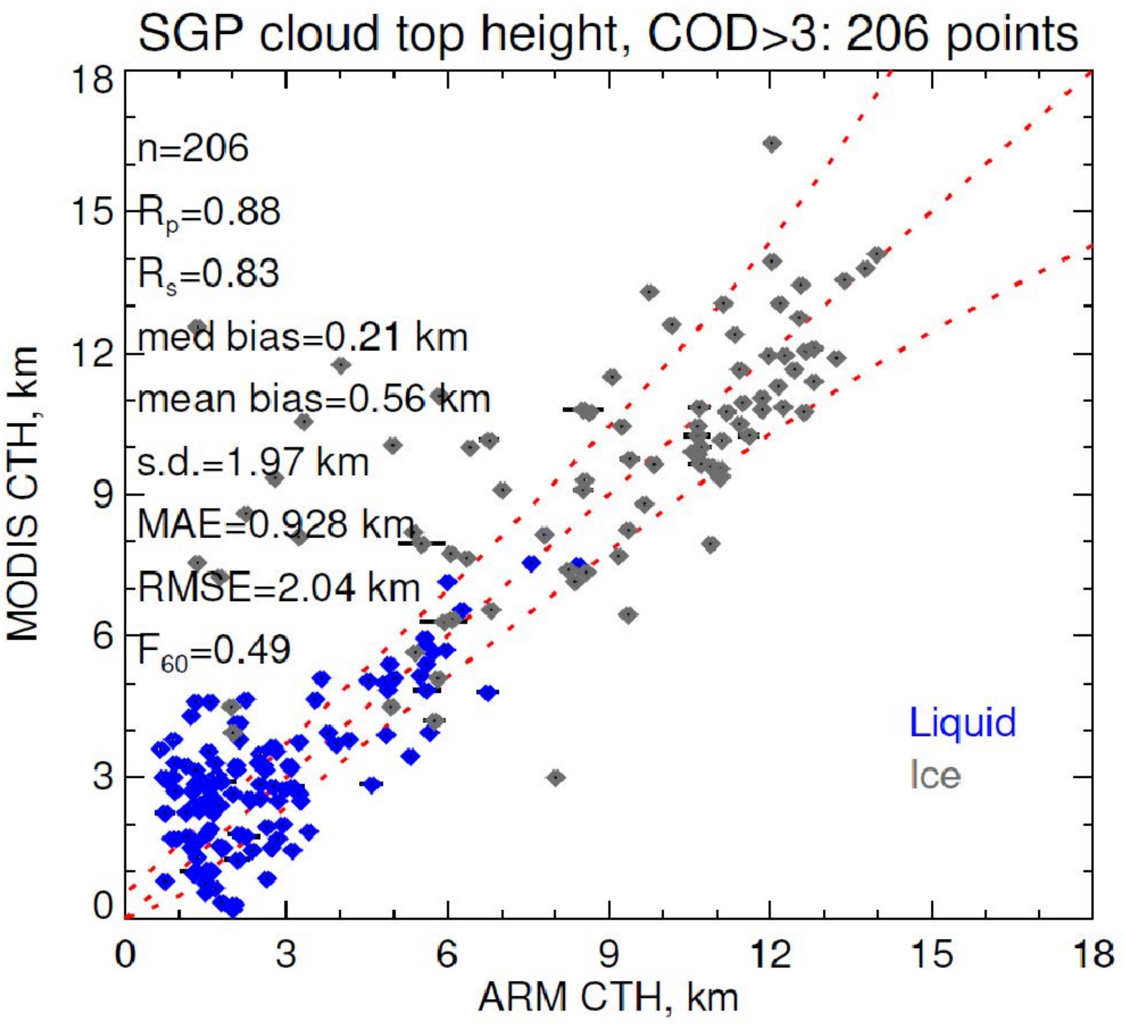


Image NASA Airborne Science
https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-046-DFRC.html

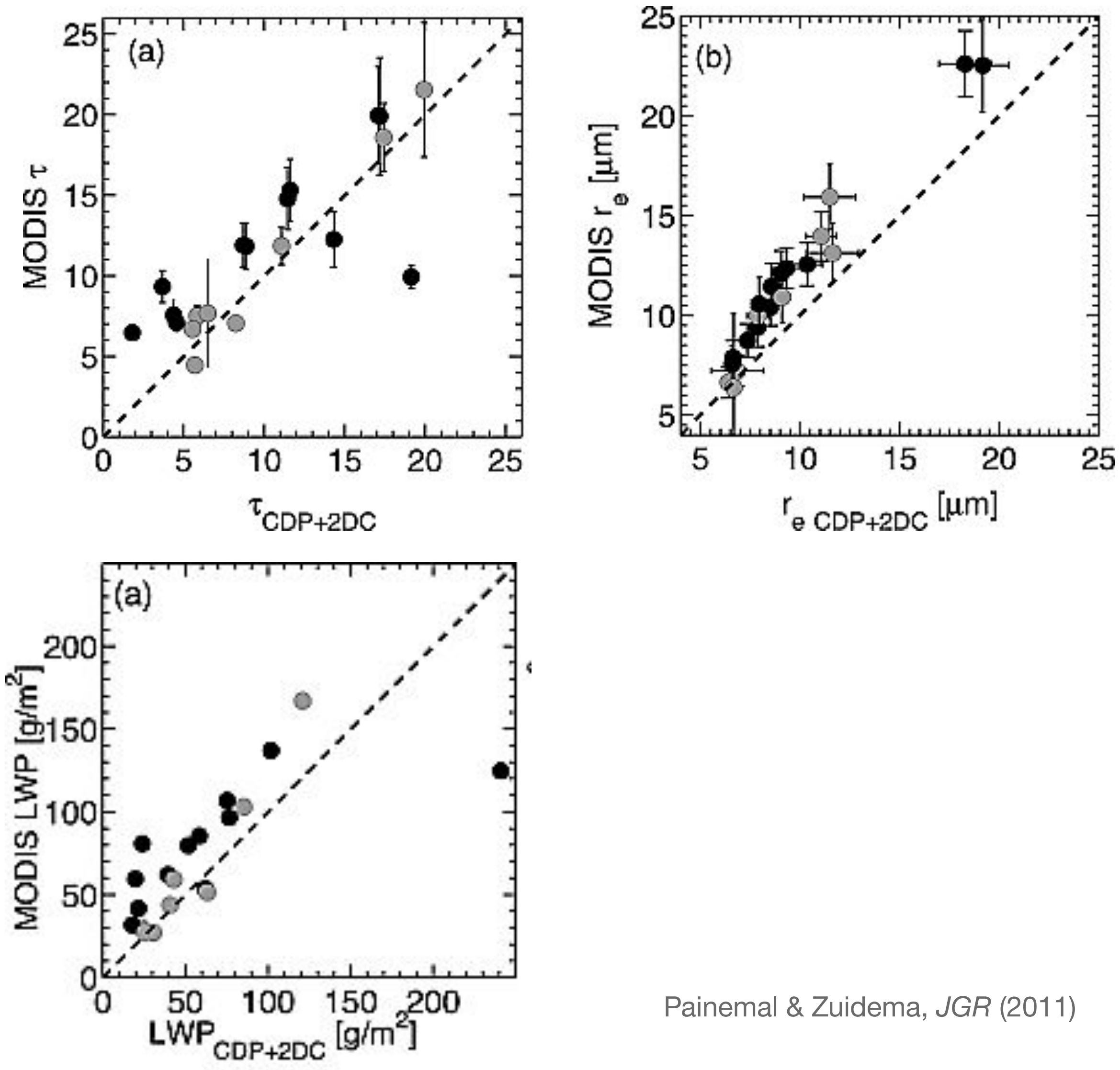
For cloud validation it can be useful to stratify by number of layers and optical thickness

Single-layer, COT>3



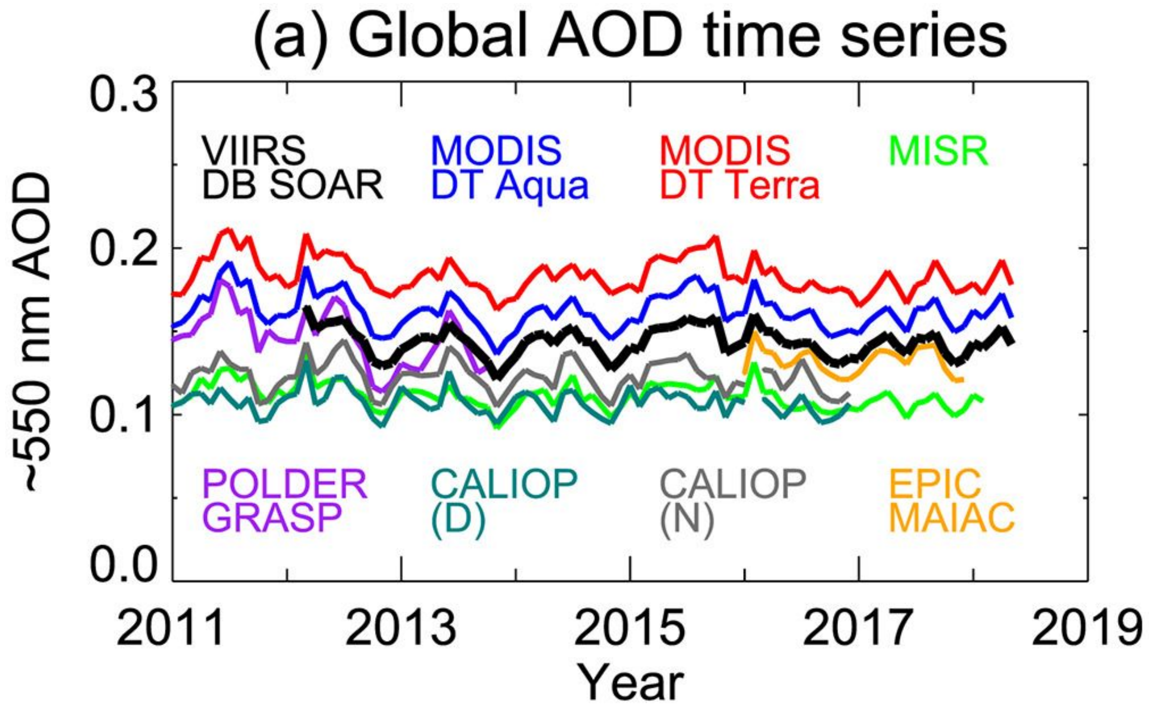
True validation of COT and CER is difficult

- Limited/no large-scale true reference-quality data
  - Too many assumptions in most cases
  - Can use *cloud probes* on aircraft flying in spirals but limited scenes
    - Heterogeneity still a problem
    - Measurement uncertainty can be a problem
- Most of what is done is *looking at consistency* with other satellite products
  - This is *not true validation*

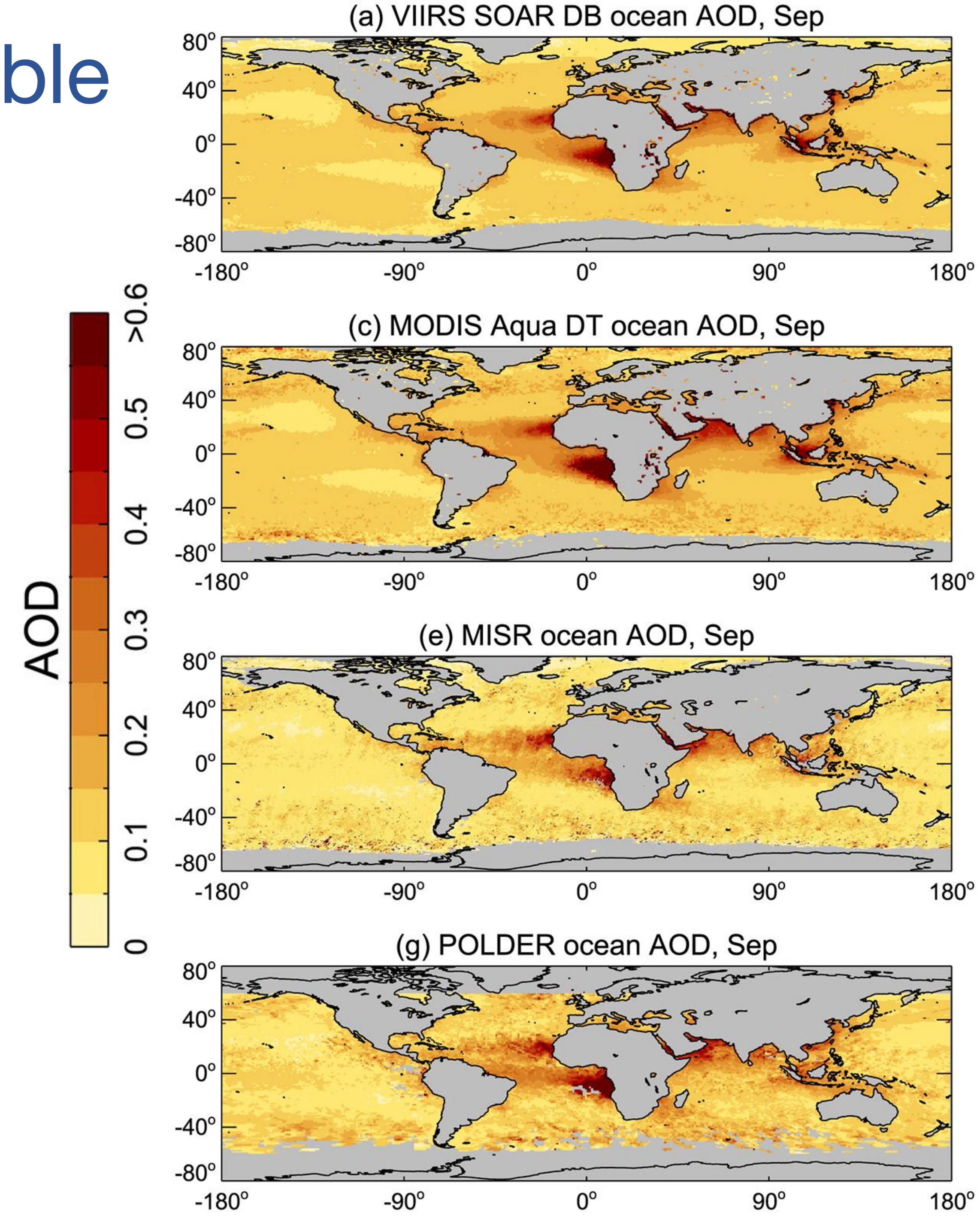


Painemal & Zuidema, *JGR* (2011)

Consistency checks are valuable but are not really validation



- How close is close enough?
- How close do we expect them to be?
- Are they consistent because they're *all good* or because they're *all bad*?



References and resources

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- Aerosols

  - AERONET and MAN data from https://aeronet.gsfc.nasa.gov
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- Clouds

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