Customer perspectives on polarimetry for aerosol and cloud applications, and what we can do to improve usage

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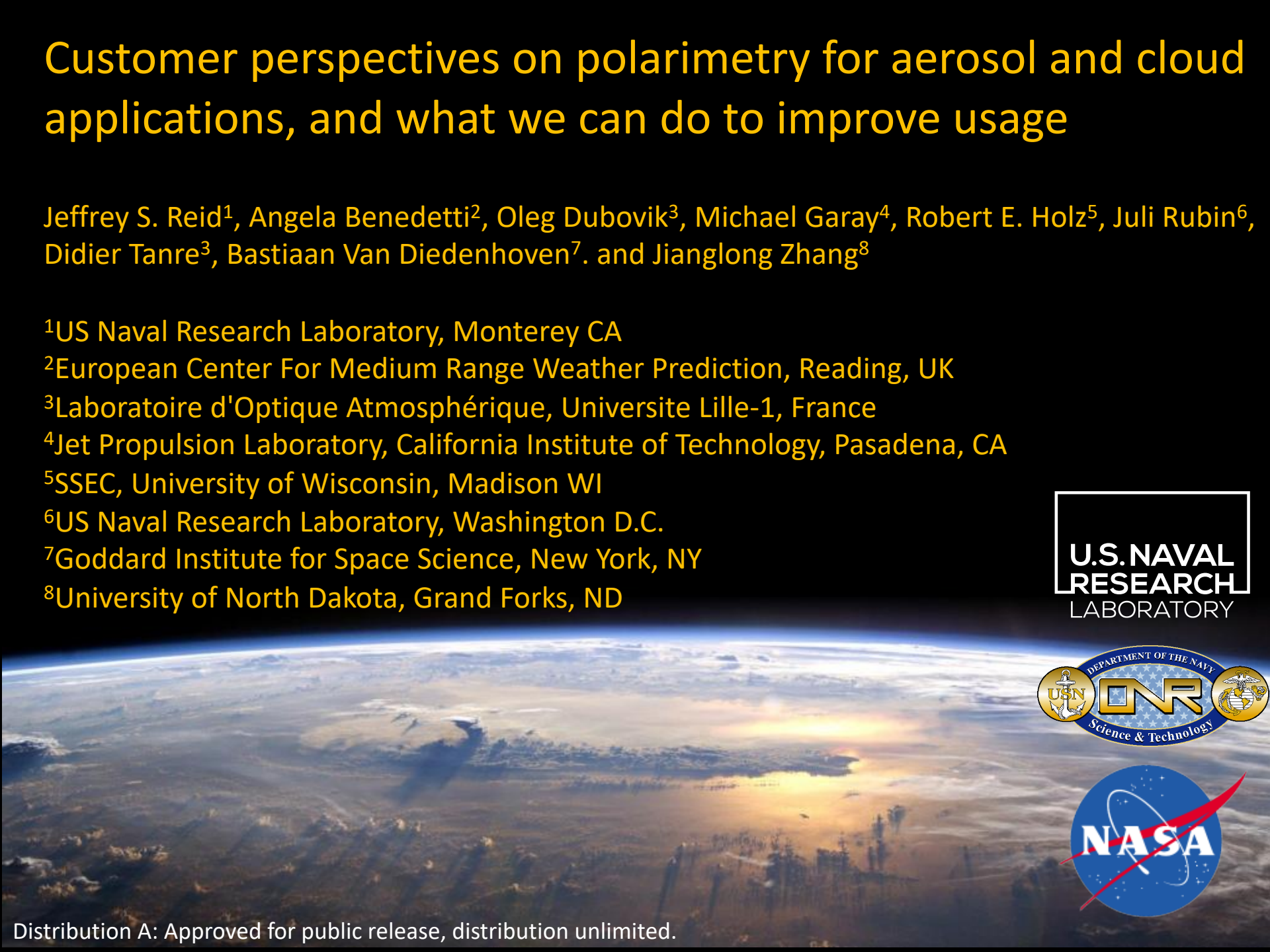

Bottom Line Up Front

- Theoretically the addition of polarization should vastly improve the information content available to retrievals of aerosol and cloud properties. But use has been limited. Why?
- Think about customers-Imagery to data assimilation.
- Key recommendations from ICAP for use.
  - Make it accessible
  - Make it fast
  - Provide a real point by point error bar
- Key lessons learned from NASA GSFC
  - Visualization is the key, e.g., Worldview
  - Make well thought out data files HDF5/ CF Compliant netcdf, in an easy repository
  - Budget to educate and create tools for people, e.g., Panoply, worldview, tools…
- Bottom line bottom line-community will use what is easy, not necessarily what is best for them. So make the best easy.

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Adapted from 5 years ago. What kind of measurements are useful and available?

Polarimeters theoretically have most of the marbles

Marching on to new measurements!
Where does polarimetry fit?

Constellation, e.g., lidar, ir,

Component radiances, atmosphere & land
Stereography cloud and plume heights

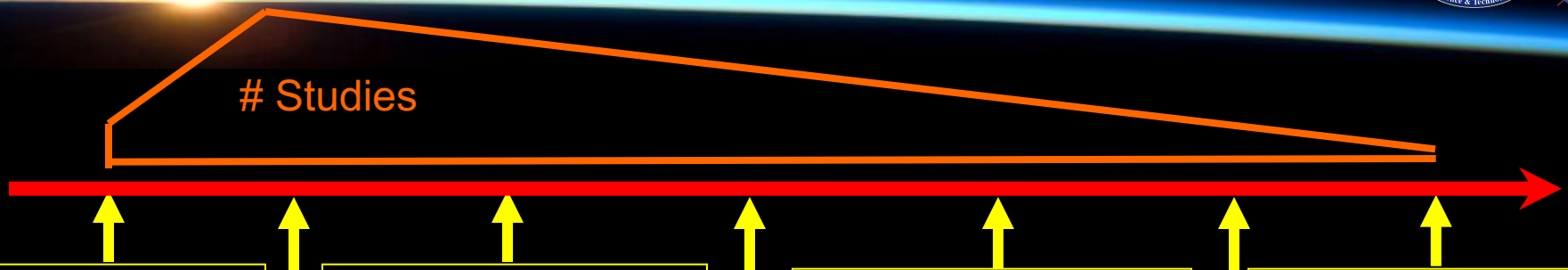
Aerosol particle and cloud droplet size
Absorption AOD and/or ω_o

"Speciated" AOD & Typing (danger)
Fine & Coarse AOD
Spectral AOD
AOD-Land & Ocean

Biggest needs: Where we can't normally get data, bright deserts, snow/ice, cloud edges, high angles, synergy with geostationary. And error models.

Who is your customer and what do they want?

(Approximate and not meant to offend…)



Imagery/ Contextual

"Advantage of Human Eye"

Cases, Parametric Modeling and Lower Order Process Studies

Correlations de-emphasize bias

Seasonal Climatology

Basically want to know were stuff is. Can do one-up corrections

Trend Climatology

Need to de-trend biases in retrieval and in sampling

Model Aps, V&V, Inventory

Have stronger time constraints and need spatial bias elimination.

Higher Order Process Studies

Push multi-product and satellite data

Data Assimilation

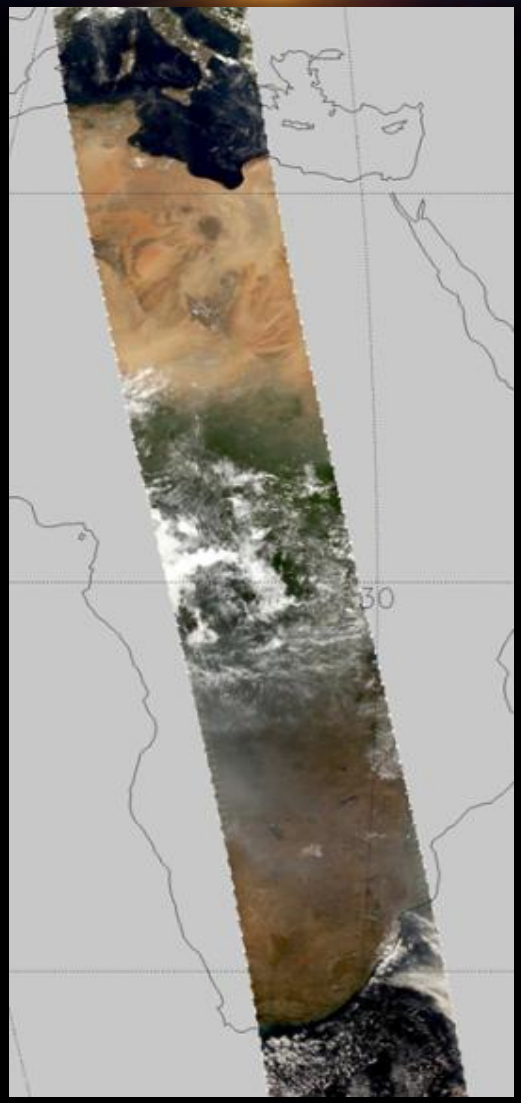
Quantify bias & uncertainty everywhere and correct where you can.

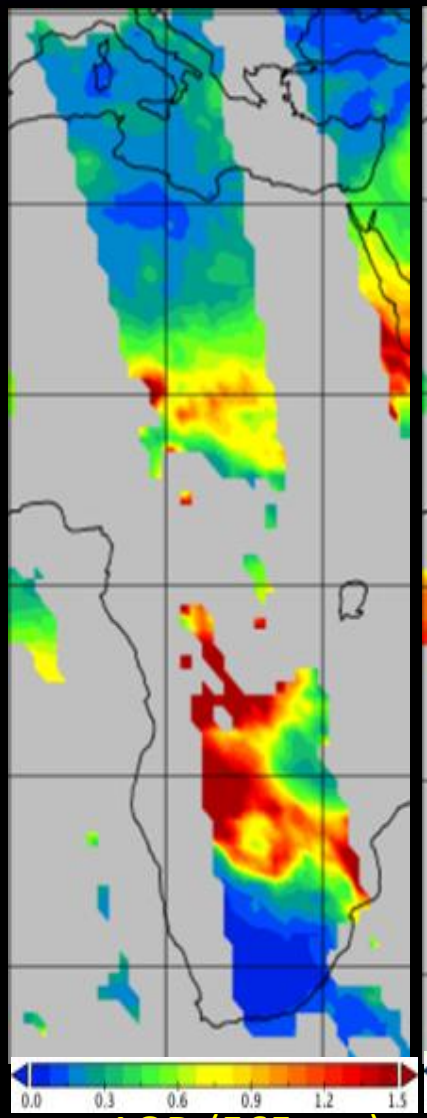
Polarization can fit into all of these, but….

V&V statistics must speak to each of these applications!

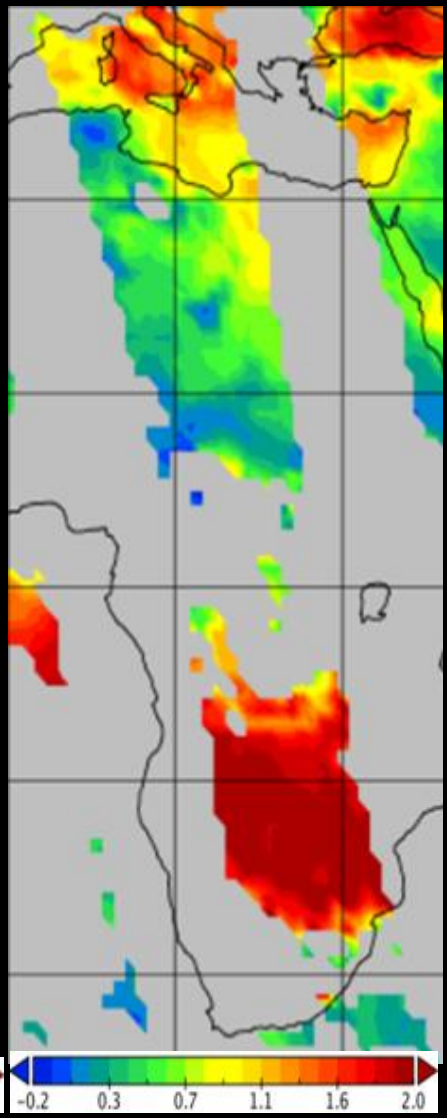
Imagery: It all starts on what you can see….

The verification sniff test. Adapted from Litvinov et al

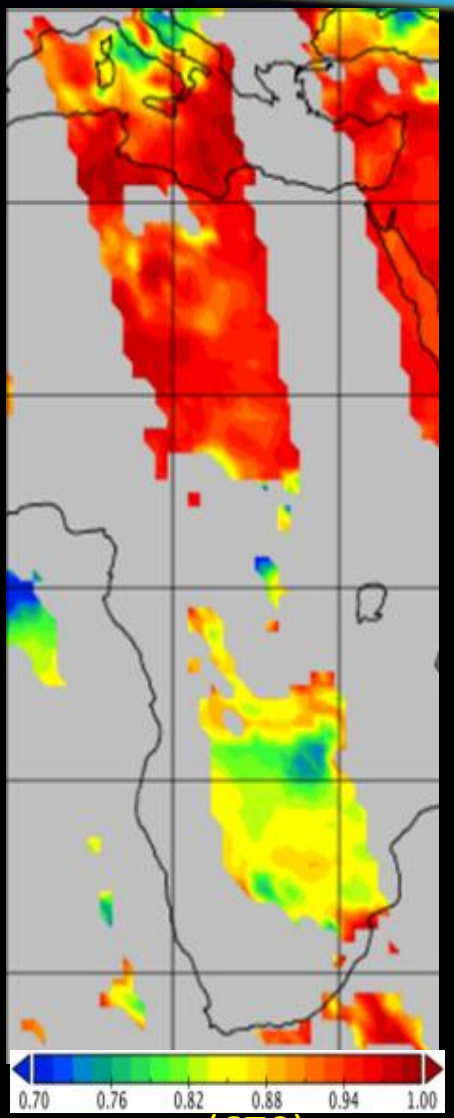




AOD (565 nm)



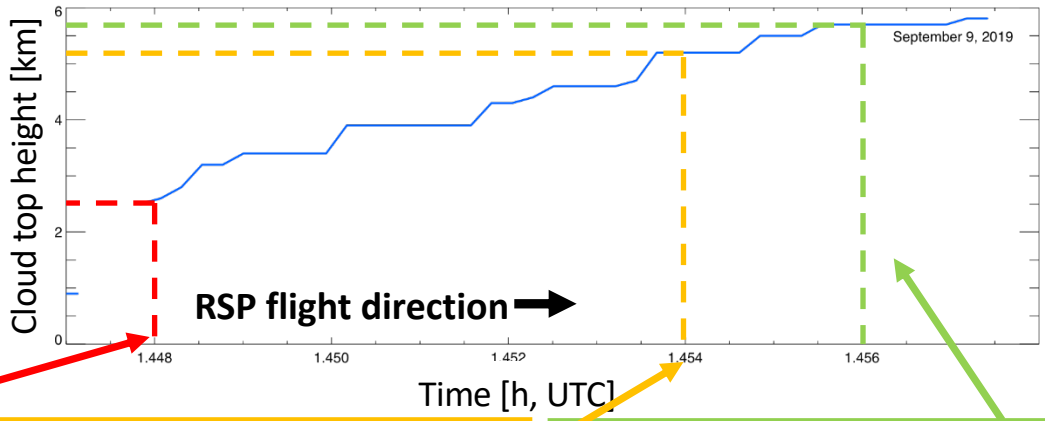
AE



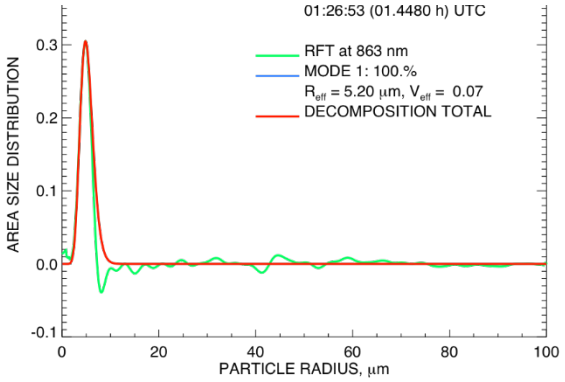
$\omega_o(670)$

Process Studies: There is more to the cloud world than r_{eff}. CAMP^{2}Ex RSP cloud drop retrievals

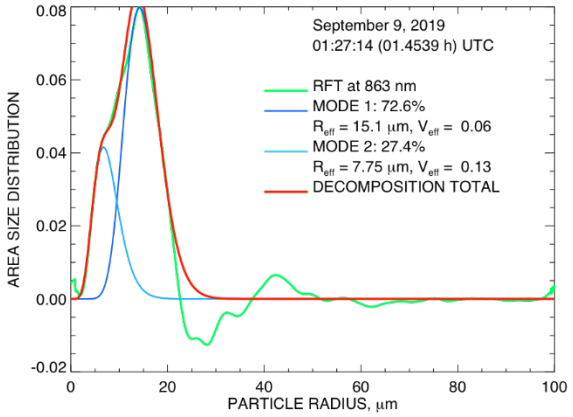
- Multi-model DSD retrieval (Alexandrov et al., JQSRT 2012)
- RSP example of convective tower observations
- Multiple modes appear as cloud top height increases



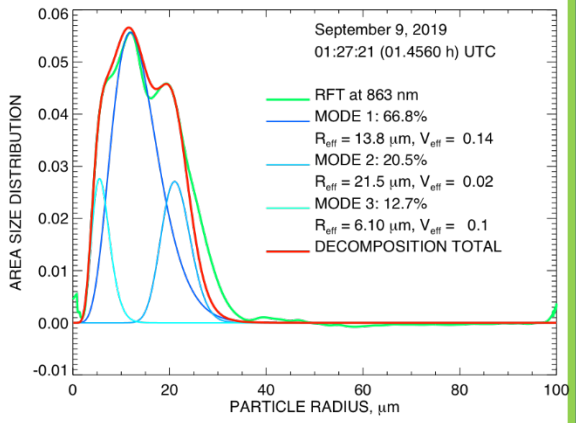
Mono-modal DSD at 2.5 km height



bi-modal DSD at 5.2 km height



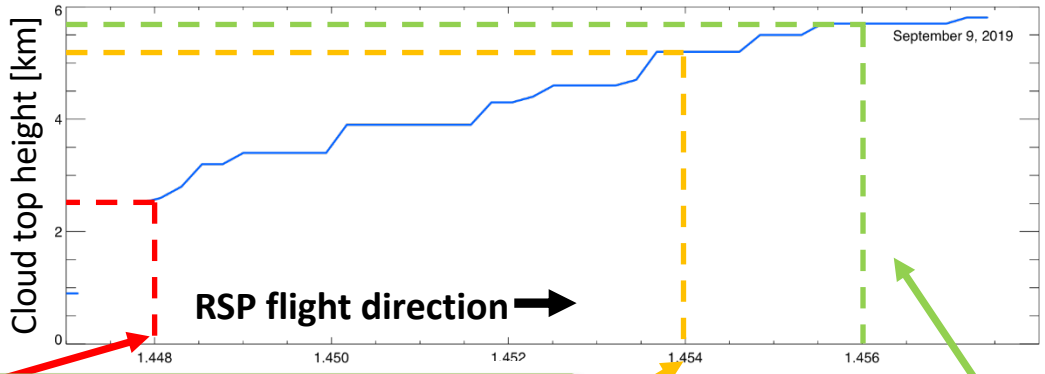
tri-modal DSD at 5.7 km height



Courtesy van Diedenhoven

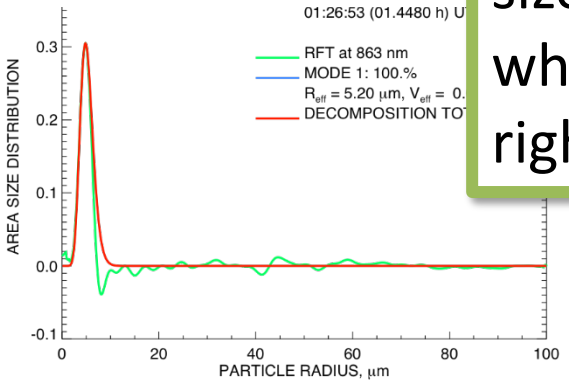
Polarimetric droplet size distribution retrieval verification.

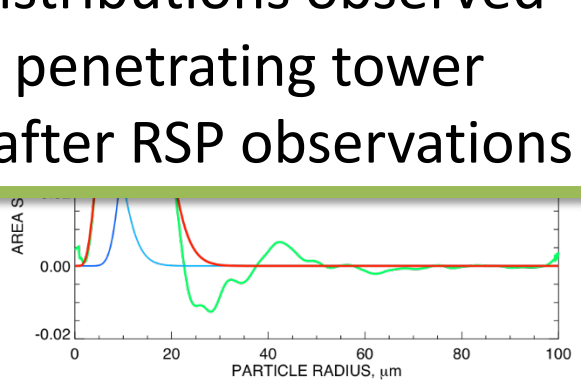
- Multi-model DSD retrieval (Alexandrov et al., JQSRT 2012)
- RSP example of convective tower observations
- Multiple modes appear as cloud top height increases



FCDP in situ probe number size distributions observed when penetrating tower right after RSP observations

Mono-modal DSD at 2.5 km height





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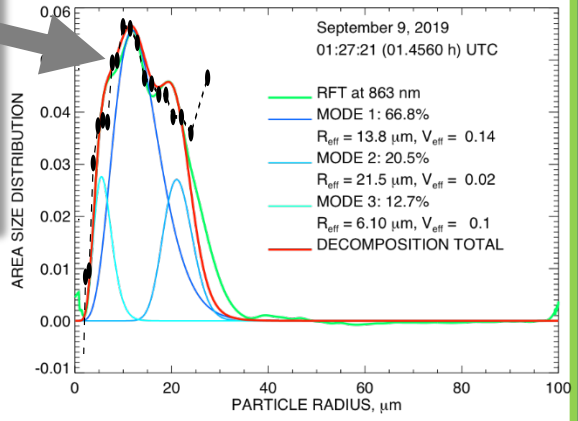


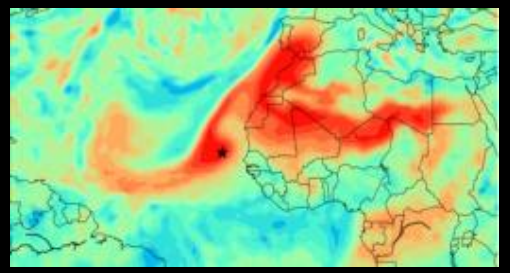
Courtesy van Diedenhoven

Now data assimilation. The most stringent application yet ensemble methods can be forgiving.

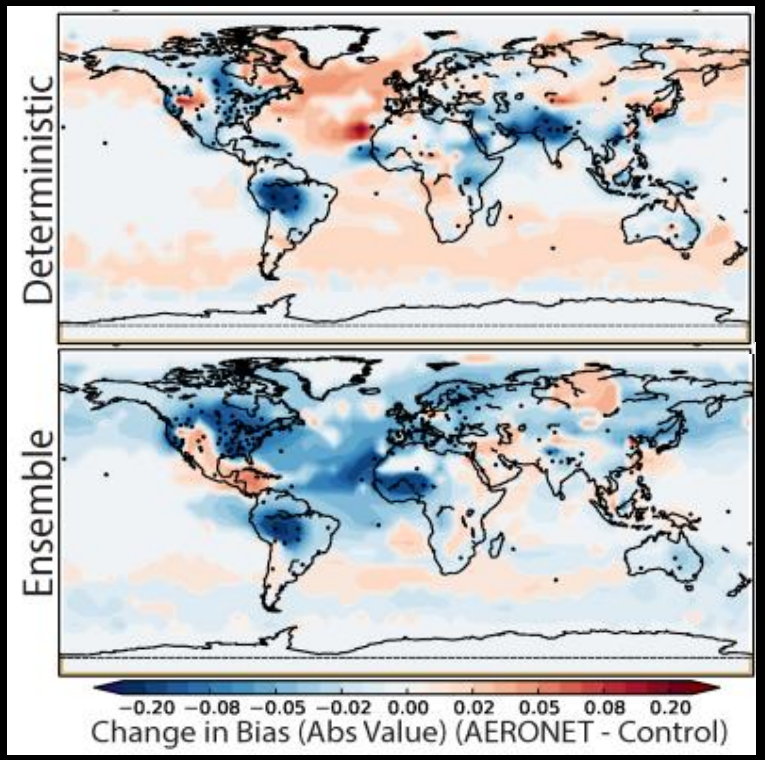
- Many talk about Aerosol DA, few understand more than the basics.
- Poor coverage and nasty adjoints make variational methods problematic.
- Need good error bars. Bad data is worse than no data, but a realistic error bar cures most ills.
- New ensemble and hybrid methods spread information better on composition, sources function, and in some cases meteorology.
- If DA works for AERONET AODs, then it should for polarimeter data, provided you give realistic error bars.

2D Var NAAPS AOD, Error Correlations

Ensemble NAAPS Error Correlations



AERONET AOD Assimilation, Rubin et al., 2016



So what gives? Why is the community not beating down the doors for polarimetry? A little NWP use customer context

WMO convened a panel asking "what we want." The response is in Benedetti et al, 2018. To quote

Regardless of data type, whether in situ or from remote sensing, there are three guiding principles that should be considered.

- **Make it easy!** "Data should be easily accessible, publicly available, reasonably well documented, and, for baseline quantities, encoded into a similar format. Currently data distribution is diffuse and potential users have difficulty maintaining and evaluating global-scale data outside of the largest and most consistent networks…"

- **Make it fast!** "Timeliness requirements also vary by center. Based on the consensus of centers, 3 h latency is preferred, and 6 h is adequate, especially for satellite products. There is nevertheless value in 12 h or even multiday delivery for evaluation and model refinement purposes, including surface particulate matter monitoring. Timeliness should be a goal, but not necessarily a requirement…"

- **Make it well characterized!** "Realistic error bars or error models must be provided. The operational community can easily cope with uncertain data, provided that uncertainty is known on a data point-by-data point basis..."

Plus-Work as part of a system! The community recognizes it needs a constellation approach….

Benedetti, A., Reid, J. S., Knippertz, P., Marsham, J. H., Di Giuseppe, F., Rémy, S., et al.: Status and future of numerical atmospheric aerosol prediction with a focus on data requirements, Atmos. Chem. Phys., 18, 10615–10643, https://doi.org/10.5194/acp-18-10615-2018, 2018.

Making it easy #1. The lowest bar is visualization, but it is a double edged sword

- Easy visualization is a form of capabilities marketing.
- There is value in polarization derivative products for simple imagery and scene interpretation.
- Visualization tools allow for quick discovery of case studies to garner interest.
- But
  - Visualization shows the warts as well as the gold
  - Pay attention to details (resolution, color bar etc).
  - Website skin/format is also crucial for speed of delivery

MISR and Worldview as an example. Should do this with GCOM-C SGLI

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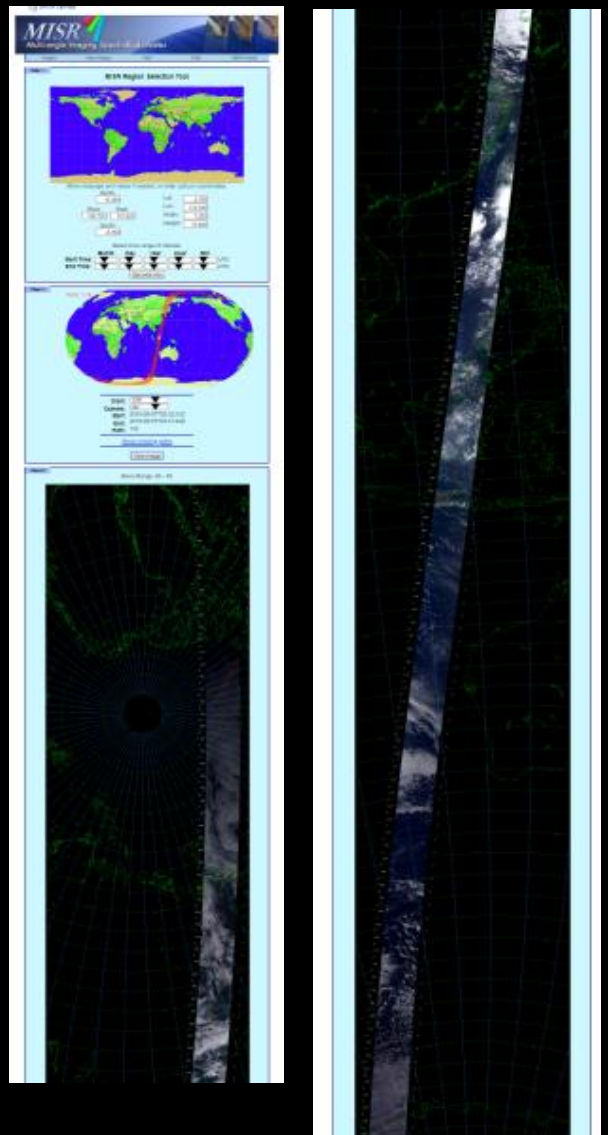
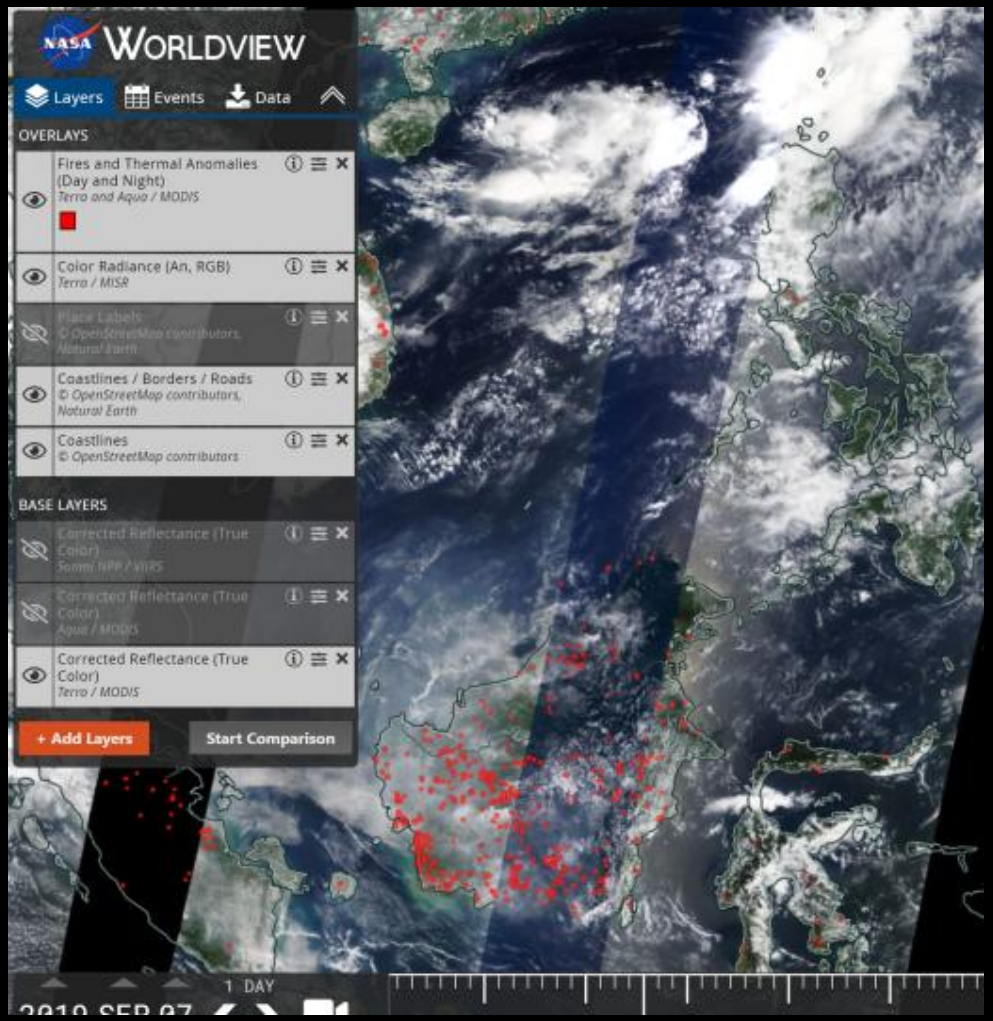
This has value



But to start most people want this

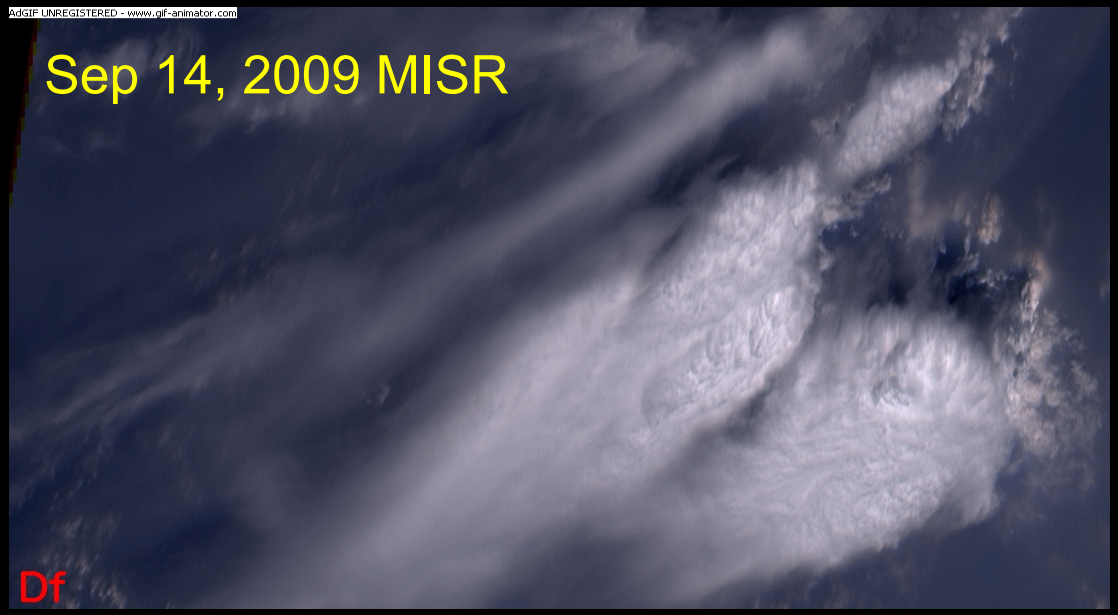


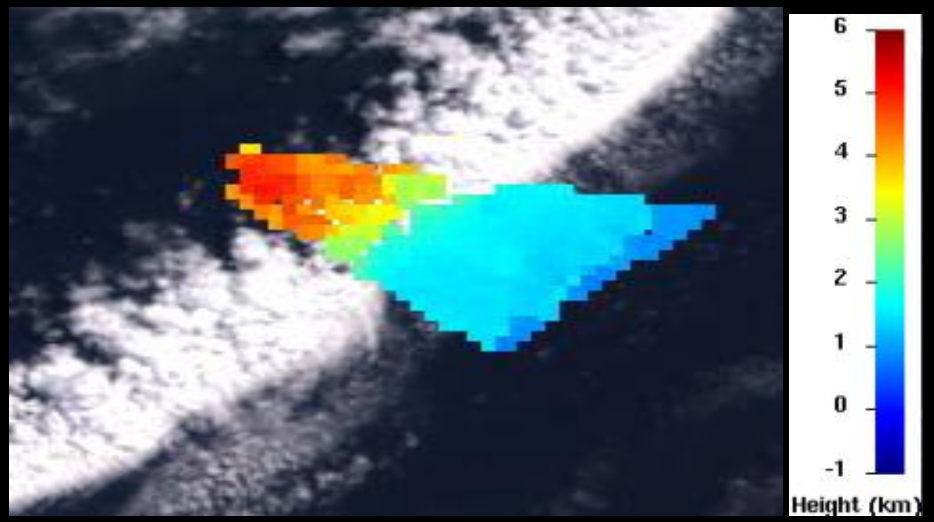
Easy #3: Education

- Lets face facts, higher order radiative transfer can be “complicated.”
- Most customers have to take the product on faith, for good and ill. This can go both ways, from boosters to boo-ers. Honesty is the best policy.
- There needs to be a concerted effort for simplified course material with real examples to educate the user base. I know there is not a budget line for this.

Easy #4 MISR Minx

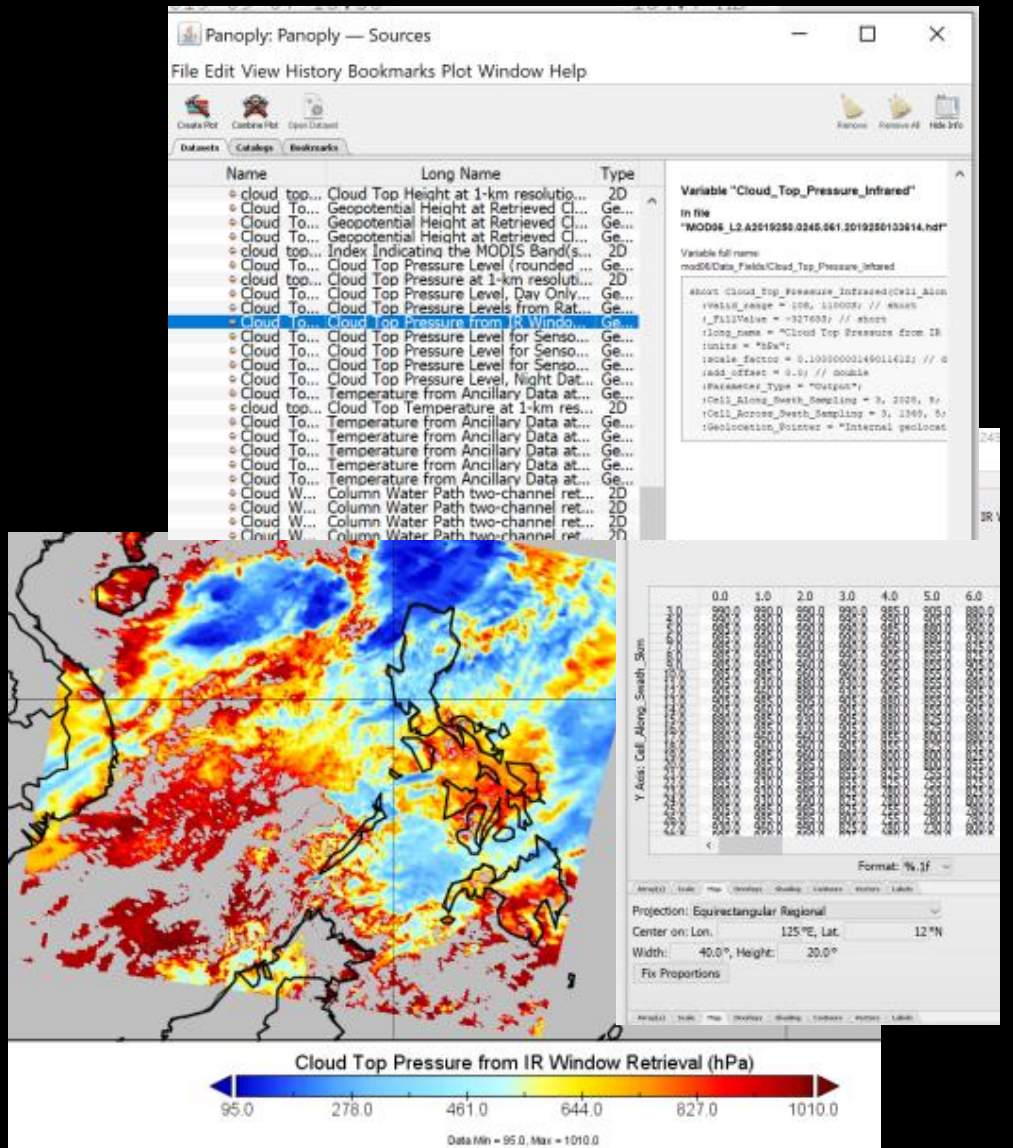
- Minx for MISR enabled MISR's unique capabilities.
- It is not just eye candy, smoke plume and multi level clouds are great examples of applications, as well as basic education.
- But, MISR still needs to make data access easy for people.
- Yes, I know there is no budget lien for this either.





Easy #5 : The GISS Panoply Example

- Panoply is heavily used by the community as a netcdf/grib viewer
- Allows for tractable hand analyses
- It is important to keep to cf conventions
  - Variable names
  - Proper navigation & timestamps
  - Projections
  - Well described data
- We often have a “panoply test” for in ICAP



Easy #6: Access
Lessons from the LAADS working group

- Look at NASA GSFC data systems as a role model. It's not perfect, but they are ahead of the curve.
- Beware of legacy. It's a balance. Besides, disks are cheap.
- Access is more than an ftp site (even if you can get it).
  - Discovery (e.g., Worldview)
  - Packaging/formatting (e.g., CF compliance, georectification, don't be too clever)
  - FTP is going away, and the community does not have a good replacement.
  - Interoperability, integration and cross DAAC collaboration
  - Scripts (downloading and processing).
  - Speed/Consistency of download
  - Metadata & ephemeris
- Moving targets of concern.
  - IT security vs access. Ordering tools are going the wrong way.
  - Cloud computing
  - Data ownership
  - Subcontractors
  - Project specifics

Make it fast

- Let's be honest we will take what we can get. But we won't do a bunch of one ups.
- Consistent near real time data promotes use
- How fast is fast?
  - <1 hour nowcasting
  - 3-6 hours for typical assimilation cycle
  - 12 hours for sweep runs
  - 24-72 hours to get into automated verification systems

Give us real error characterization

- Higher order process studies and data assimilation typically assume data is de-biased and errors are spatially uncorrelated.
- Customers need a point wise error estimate, with both estimated bias and uncertainty-prognostic error model. A regression to AERONET does not cut it.
- Typical terms (not independant)
  - Geometry: viewing geometry, scattering angle, aggregation
  - Surface: Albedo, BRDF, snow/ice, glint,
  - Clouds: mask, brightening, and shadows.
  - Microphysics : $P(\theta)$ or g , ω_o, Fine-coarse partition
- Understanding sampling and contextual biases are important.

Don't do your job? We assign big error bars -> Big error bars mean no impact -> No impact means no customer.

Research to Operations, or is it Operations to Research?????

- One of the greatest myths is that operational data records require less fidelity than climate data records. Nothing is further from the truth, although agency leadership still has not fully recognized this.
- The second greatest myth is that only Operations wants data in near real time. The future is moving to towards big data, multiple sensor and sensor-model products. GMAO and Copernicus look a lot like operational centers too…
- Don’t exclusively think like an engineer or climate scientist, think like all of your potential customers.
- The fusion of multiple sensors with models is inevitable and positive. Don’t fight it. Be part of the process.

Conclusions

- Polarimetry fits a fairly unique niche for atmospheric science research, but circumstance & packaging may be hindering demand. Bottom line up top, make it easy & listen to your customers. Think Betamax.
- Follow the rules of make it accessible, make it fast, make it well characterized.
- Visualization is important marketing. Generate or enable tools to allow users to explore capabilities. Wolrdview, Panoply and Minx are good success stories.
- Pay special attention to accessibility, and all that entails.
- Parting advice: Don’t compete with everything, stay in your lane and emphasize your unique capabilities.