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Using CALIPSO's New Ocean Derived Column Optical Depths

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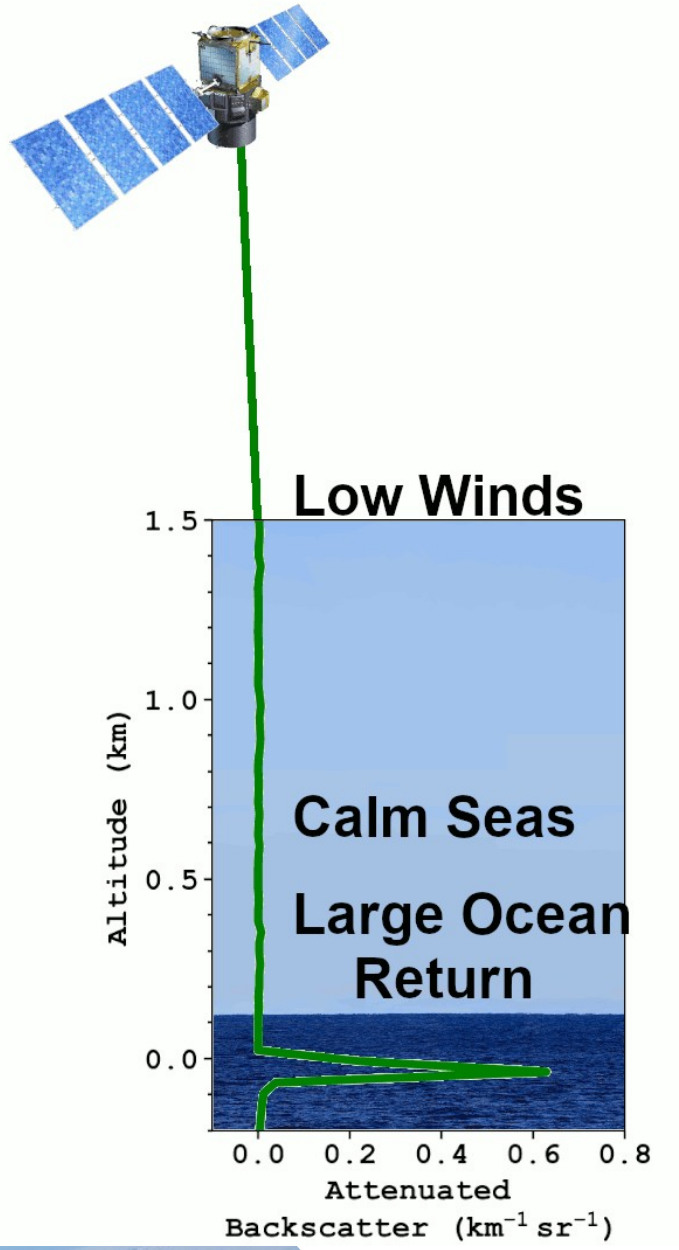
Introduction

NASA's Cloud-Aerosol LIdar with Orthogonal Polarization, an instrument aboard the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation satellite launched in 2006
Credits: NASA/Timothy Marvel

- Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard CALIPSO
  - Active direct detection of clouds and aerosols
  - Estimation of optical properties
  - Small but significant fraction below detection threshold
  - Requires CAD, typing, and a priori assumptions
- Ocean Derived Column Optical Depths (ODCOD)
  - Adaptation of Venkata & Reagan 2016
  - Passive style estimate of effective column optical properties from CALIPSO ocean return
  - Does not require CAD or aerosol typing
  - Mostly independent single instrument estimate of effective total column optical depth

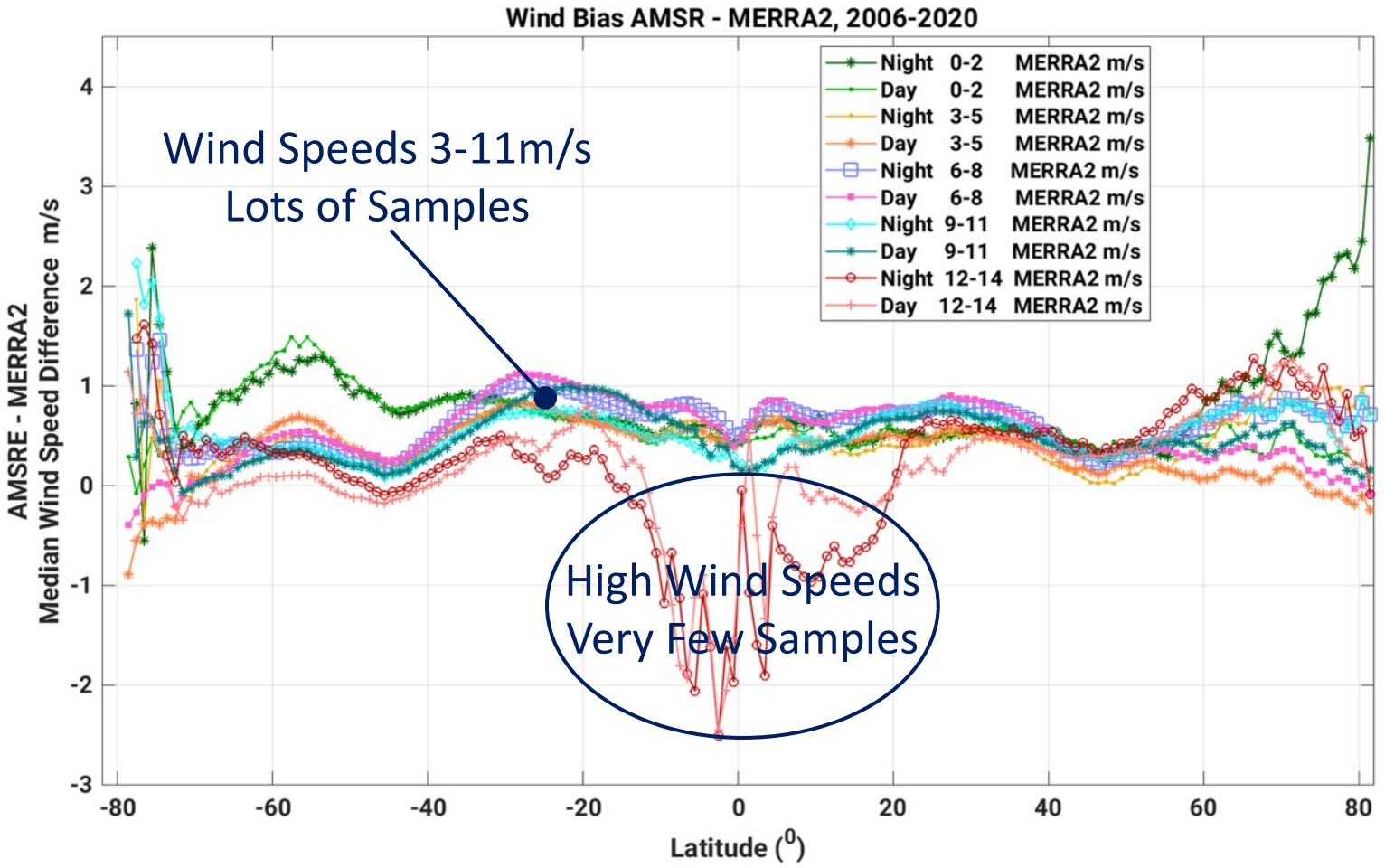
Venkata, S.L., Reagan, J.A., Aerosol Retrievals from CALIPSO Lidar Ocean Surface Returns. Remote Sensing 8(12) 1006 (2016). https://doi.org/10.3390/rs8121006



Technique

- ODCOD uses the magnitude of CALIPSO's ocean surface return compared to a modeled ideal ocean return to estimate optical depth
- The surface points are fit to a model lidar ocean return by an iterative shifting and scaling technique
- Only 3 measured points at 532nm make up the surface return
- An accurate wind speed estimate is required to calculate a model surface reflectance
- Returns with surface saturation or negative surface anomalies are not attempted
- Surface depolarization is tested to ensure no sea ice or shallow water sea floor is in the return

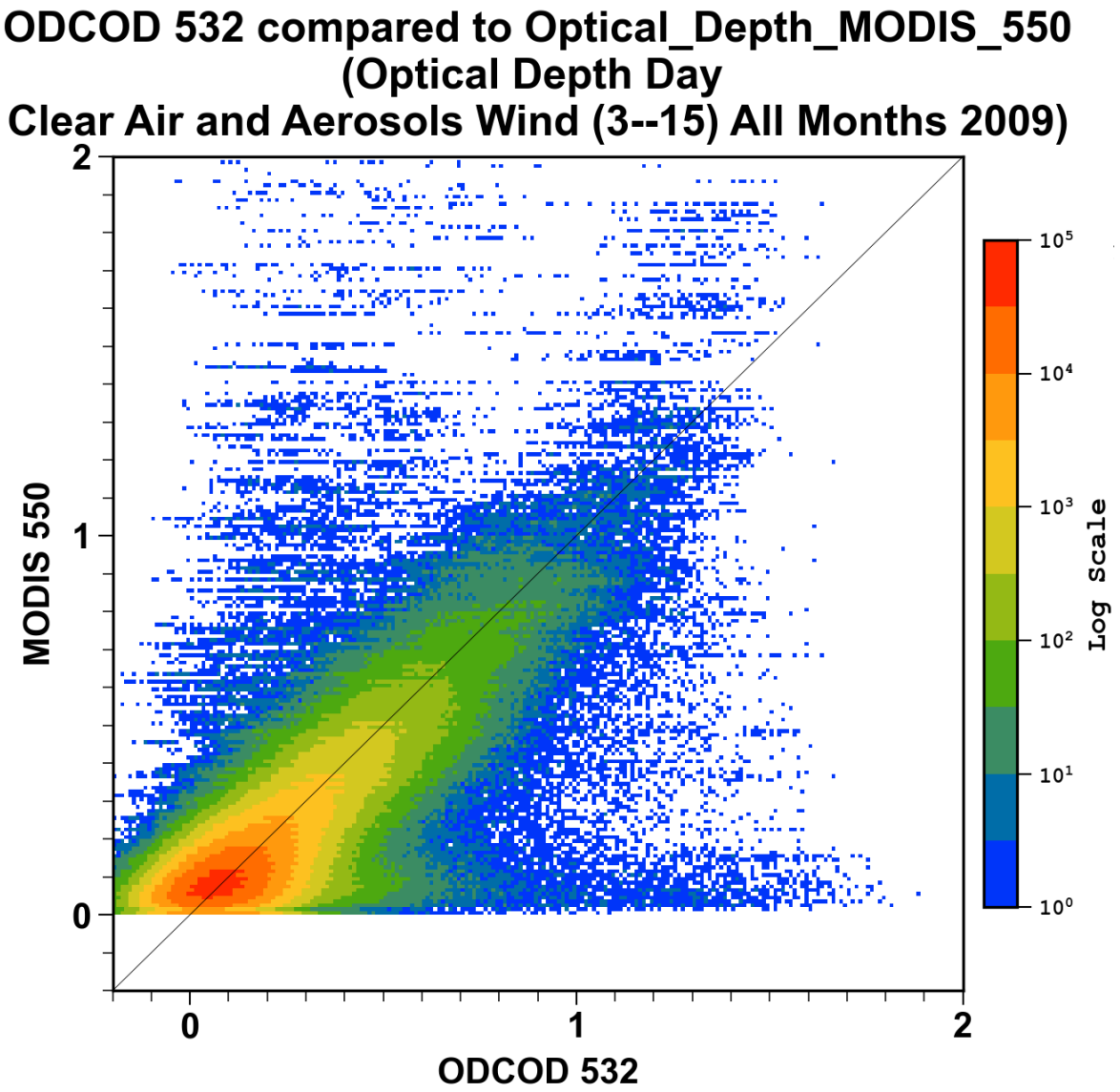
Sensitivity to Wind Speeds

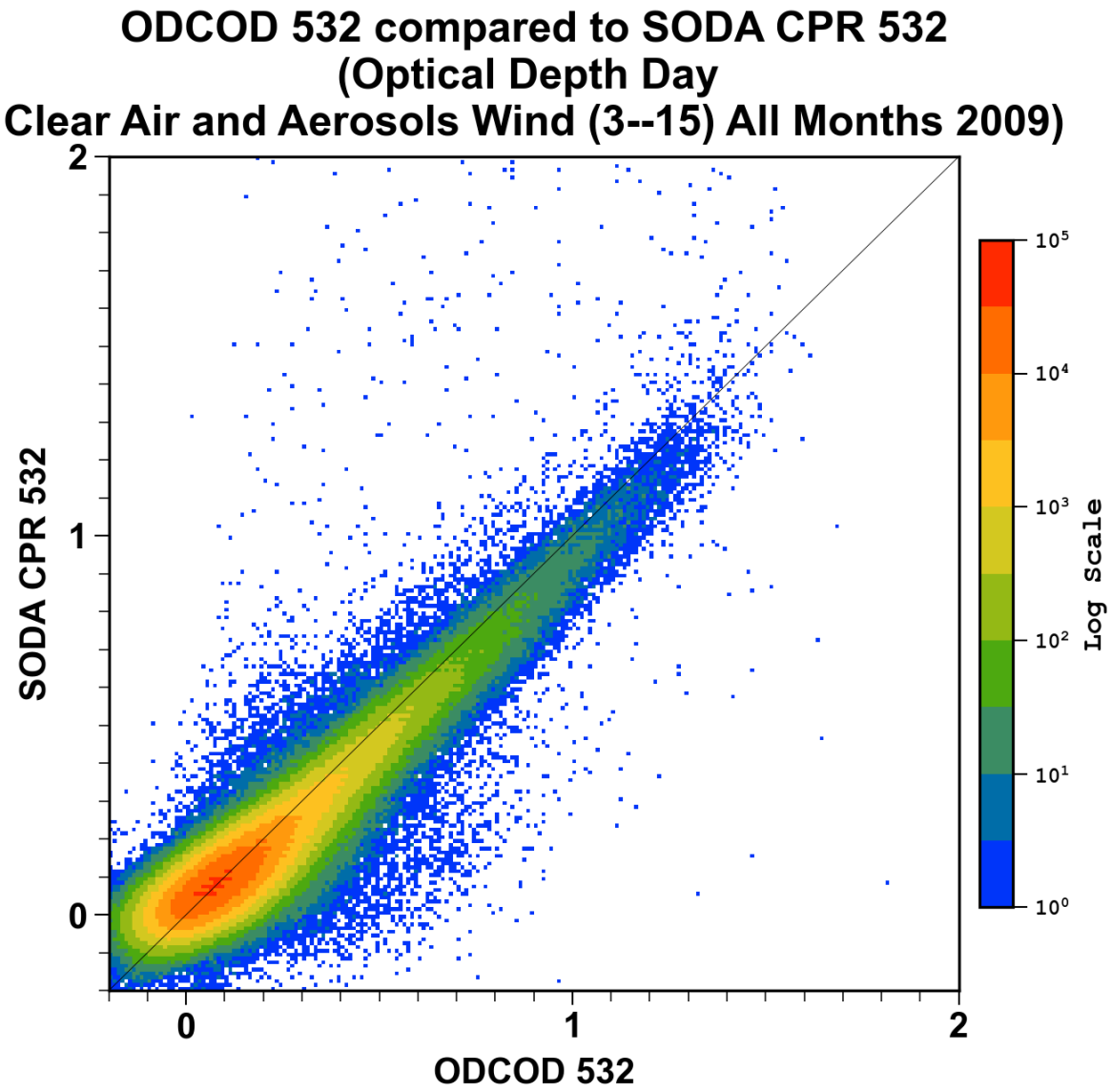


- ODCOD uses wind speeds from the MERRA-2 meteorological data used throughout the CALIPSO processing
- MERRA-2 winds have a low bias (Carvalho 2019 and CALIPSO Team Investigation)
- For ODCOD, -0.5m/s bias would translate to ~0.02 high bias in optical depth
- Use AMSR derived lookup tables to apply corrective scaling to MERRA-2 winds

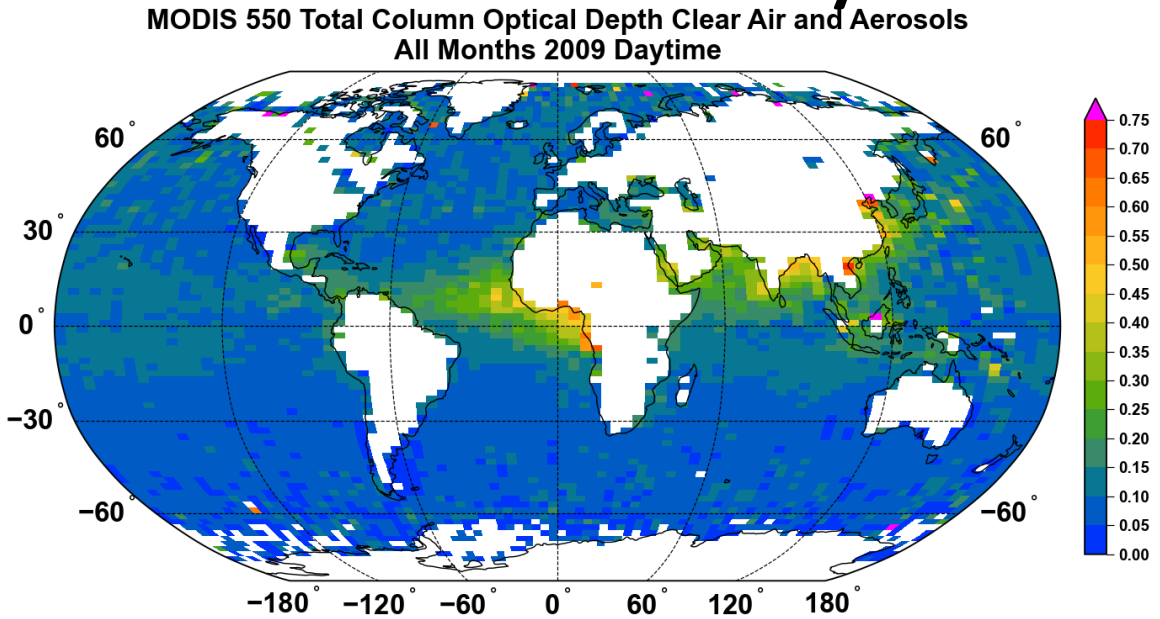
Carvalho, D. An Assessment of NASA's GMAO MERRA-2 Reanalysis Surface Winds, Journal of Climate, 32(23), 8261-8281 (2019). https://doi.org/10.1175/JCLI-D-19-0199.1

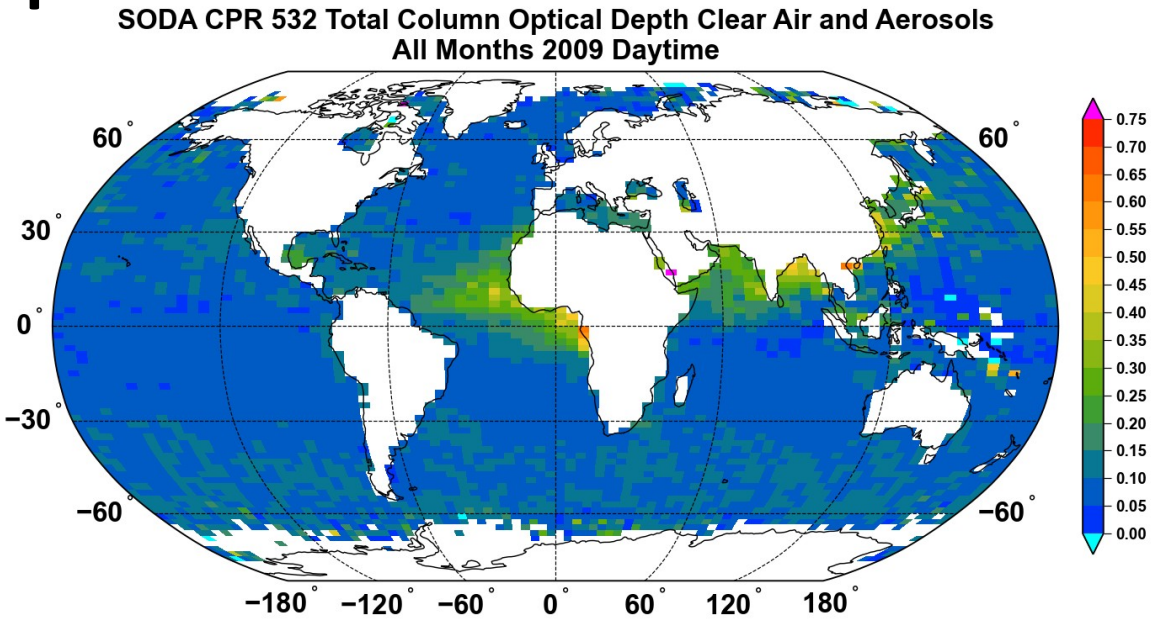
Daytime Comparisons

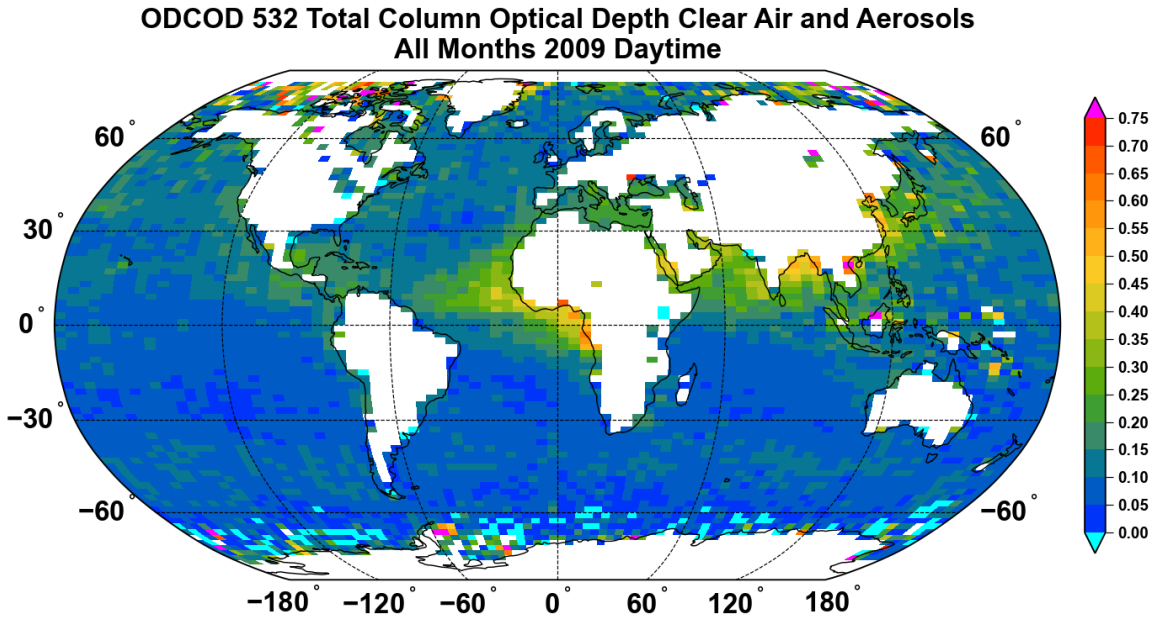




Daytime Comparisons







- MODIS is a large grid daytime only product
- SODA requires colocation with CloudSat which is not available at night after 2011
- ODCOD is available for the entire CALIPSO data record both day and night

ODCOD Validation

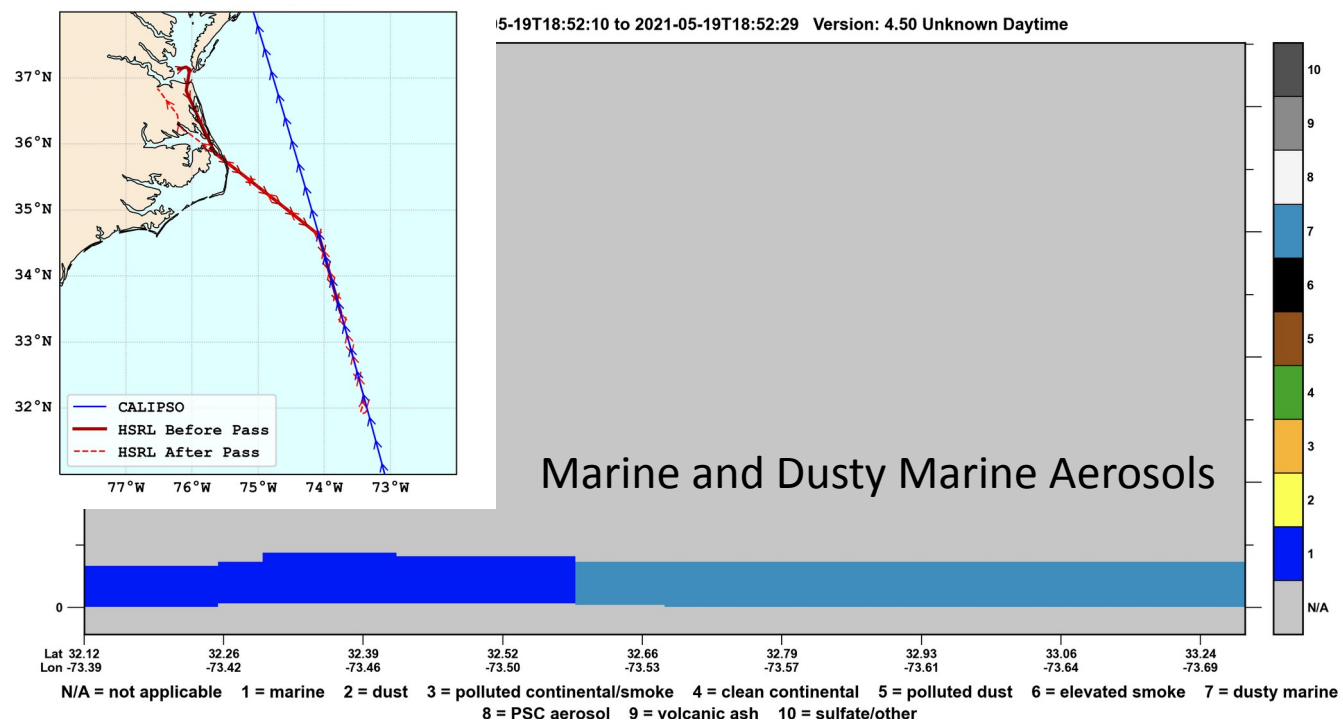
May 19th, 2021

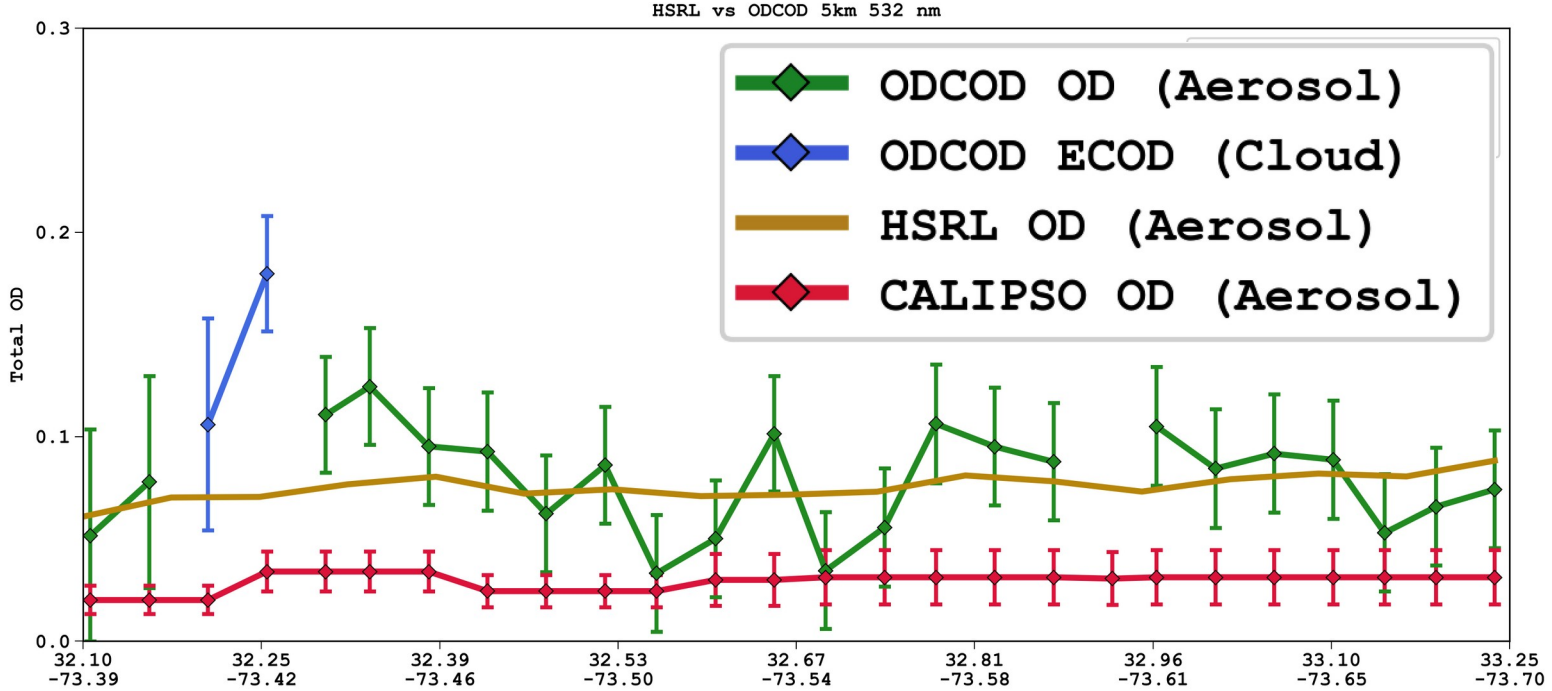
- HSRL-2 deployed during ACTIVATE
- Off North/South Carolina
- Mostly Aerosols Only and single layer scene

CALIPSO
Tropospheric + Stratospheric Optical Depth in Red

HSRL-2
Optical Depth in Gold

ODCOD
Aerosol Optical Depth in Green
Cloud *Effective* Optical Depth in Blue



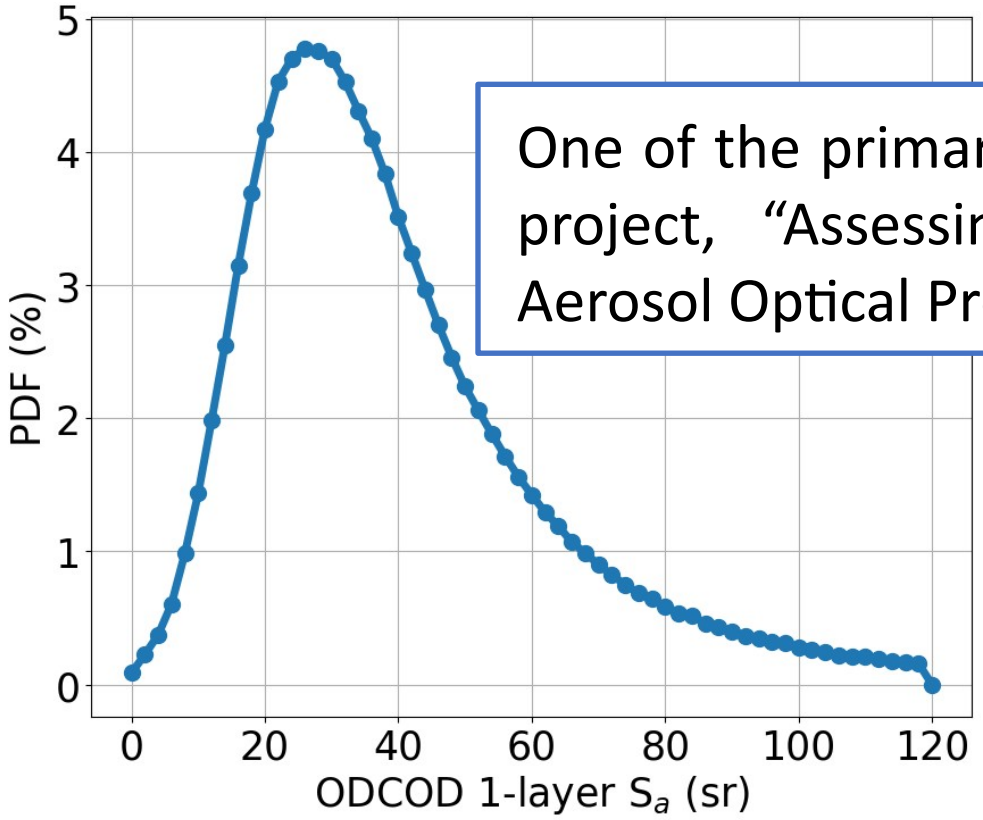


Data Filtering and Cautions

- Basic pre-filtering has already been done
  - ODCOD does not attempt a retrieval when any of the following occur
  - Undetected Surface, Surface Saturation, Negative Surface Anomaly, Surface Depolarization Ratio below threshold
- Wind Speed
  - Surface Reflectance model suggestion 3 – 15 m/s
- ODCOD QC Flag
  - Use values less than 64 (i.e., bits 0-5 are valid, higher bits are failures)
- ODCOD Effective Total Column Optical Depth
  - “Total Column” includes all particulates within the column, detected and undetected
  - "*Effective* Optical Depths" are not corrected for multiple scattering effects introduced by clouds and aerosols within the column
  - ODCOD’s effective optical depths are not generally expected to match the column optical depths also reported in the CALIOP level 2 data products

Application: ODCOD-based lidar ratio

- Currently, CALIPSO retrieves aerosol extinction coefficient and AOD by solving the lidar equation, simplified via an assumed lidar ratio (S_a).
- The prescribed lidar ratio is a function of aerosol type.
- **Ongoing work endeavors to refine the selection of lidar ratios (S_a).**



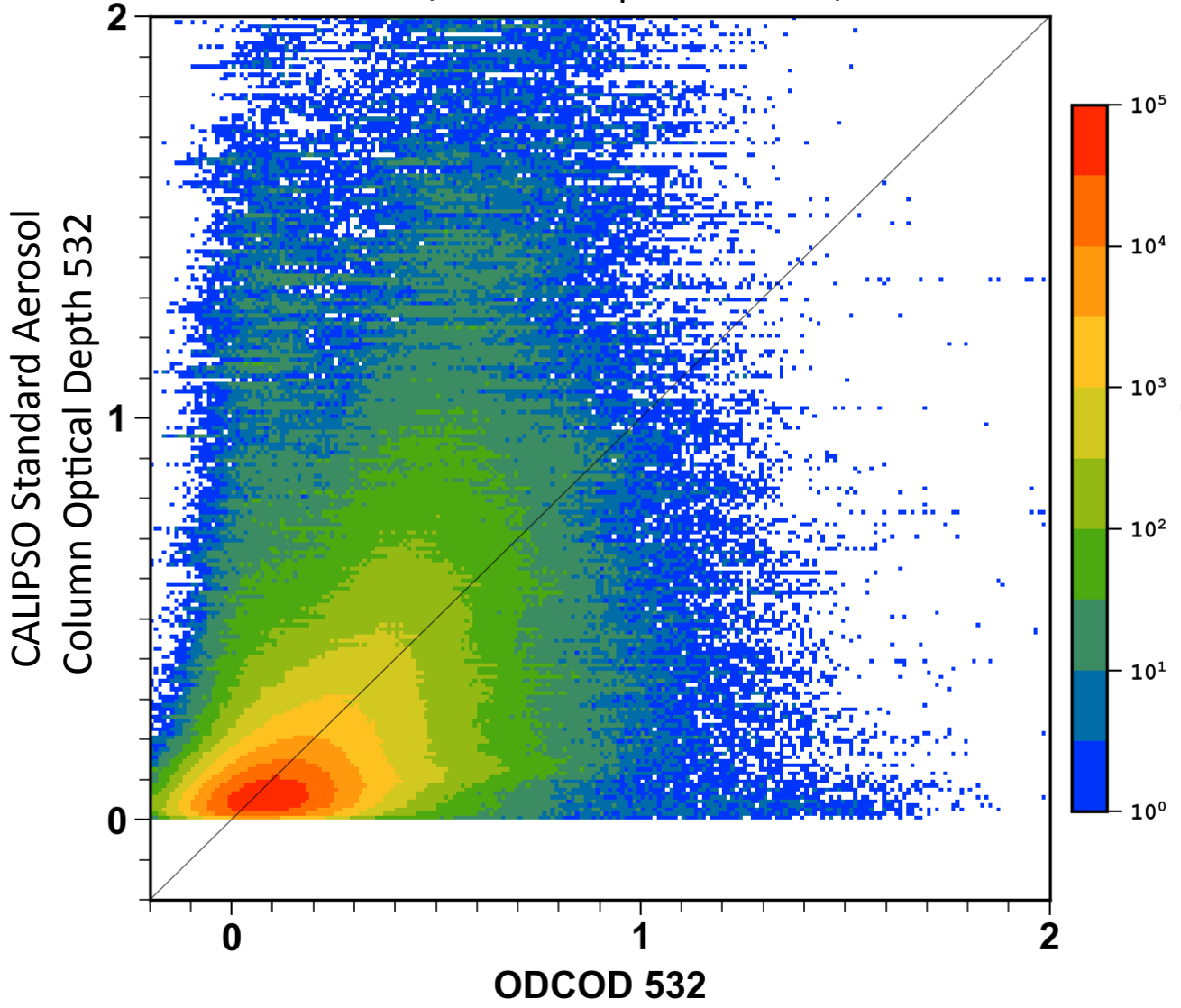
Computed daytime lidar ratio over the global ocean for 2017

One of the primary goals of the ROSES funded project, "Assessing and Improving CALIPSO Aerosol Optical Properties"

- We iteratively derive column S_a by solving the
  f CALIPSO
  constrained with
  easonable lidar ratio range with values somewhat consistent with other datasets.
- Future analysis will exploit the CALIPSO-ODCOD synergy for computing aerosol-specific S_a.

Application: CALIPSO Evaluation

532 nm ODCOD (x-axis) vs CALIOP's standard aerosol column optical depth retrievals (y-axis)
2009 global, daytime and nighttime,
3 m/s < wind speed < 15 m/s



N = 14190584

	ODCOD 532
Min:	-0.7784
Max:	2.6815
Median:	0.1111
Median MAD:	0.0620
Mean:	0.1301
Std Dev:	0.1253

	CALOD532
Min:	0.0001
Max:	4.3489
Median:	0.0702
Median MAD:	0.0300
Mean:	0.1038
Std Dev:	0.1383

	(X - Y)
Min:	-3.5981
Max:	2.1258
Median:	0.0282
Median MAD:	0.0587
Mean:	0.0263
Std Dev:	0.1300

ODCOD provides a tool for evaluating:

- CALIPSO total column optical depth retrievals
- cloud-aerosol discrimination
- aerosol typing
- lidar ratio assignment
- And more

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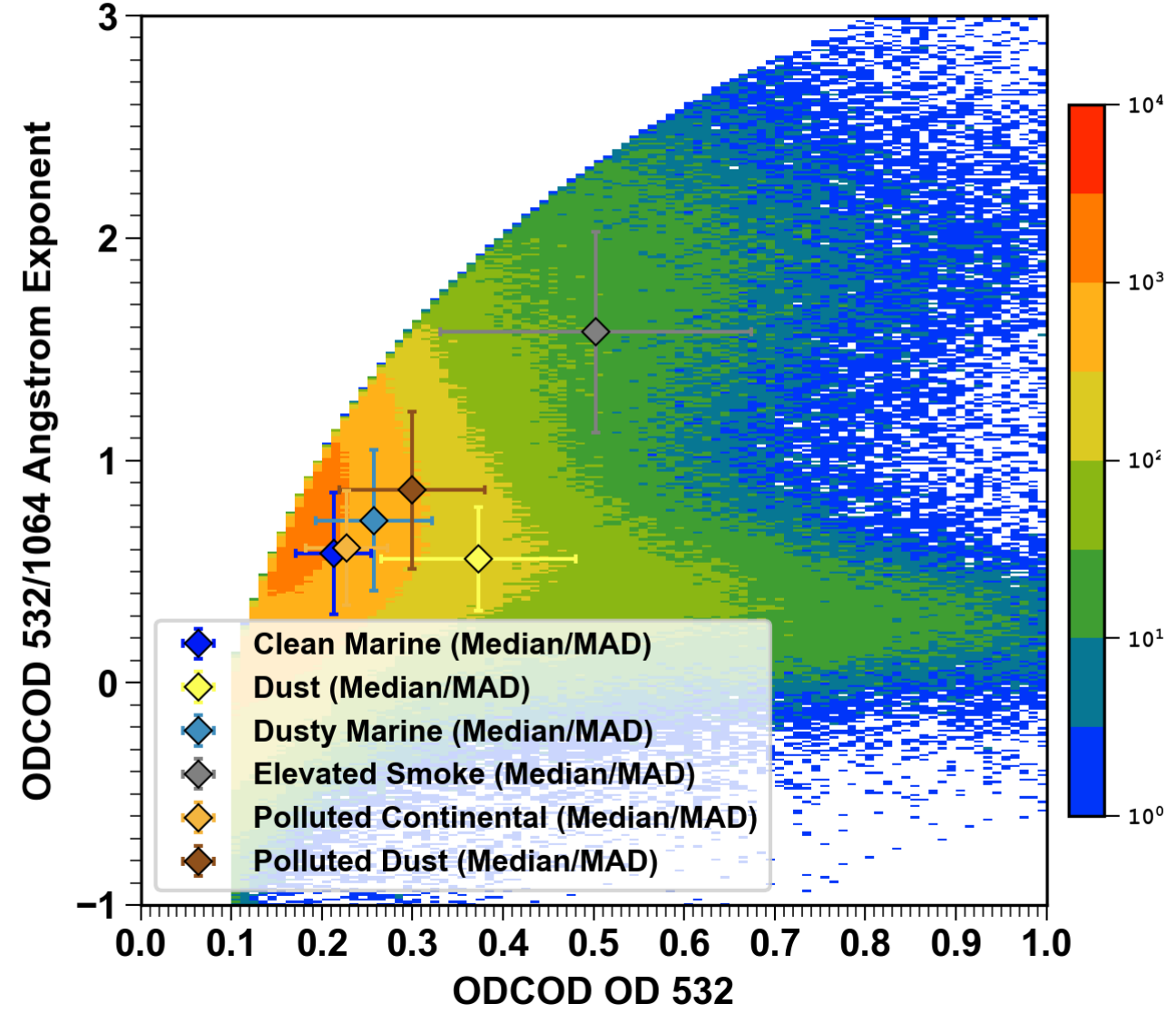


Application: Future Angstrom Exponents

- ODCOD at 1064 will not be in Level 2 Version 4.51
- However, fully expected to be in Version 5
- Will provide estimates of Angstrom Exponents
  - Useful in CALIPSO CAD
  - Aerosol subtyping

Conclusion

- ODCOD at 532 provides a validated and useful estimate of Total Column Effective Optical Depth
- ODCOD is available for the entire CALIPSO mission
- ODCOD is incredibly useful for evaluating CALIPSO
- ODCOD highlights how much untapped potential is still in the CALIPSO data record even after 16 years

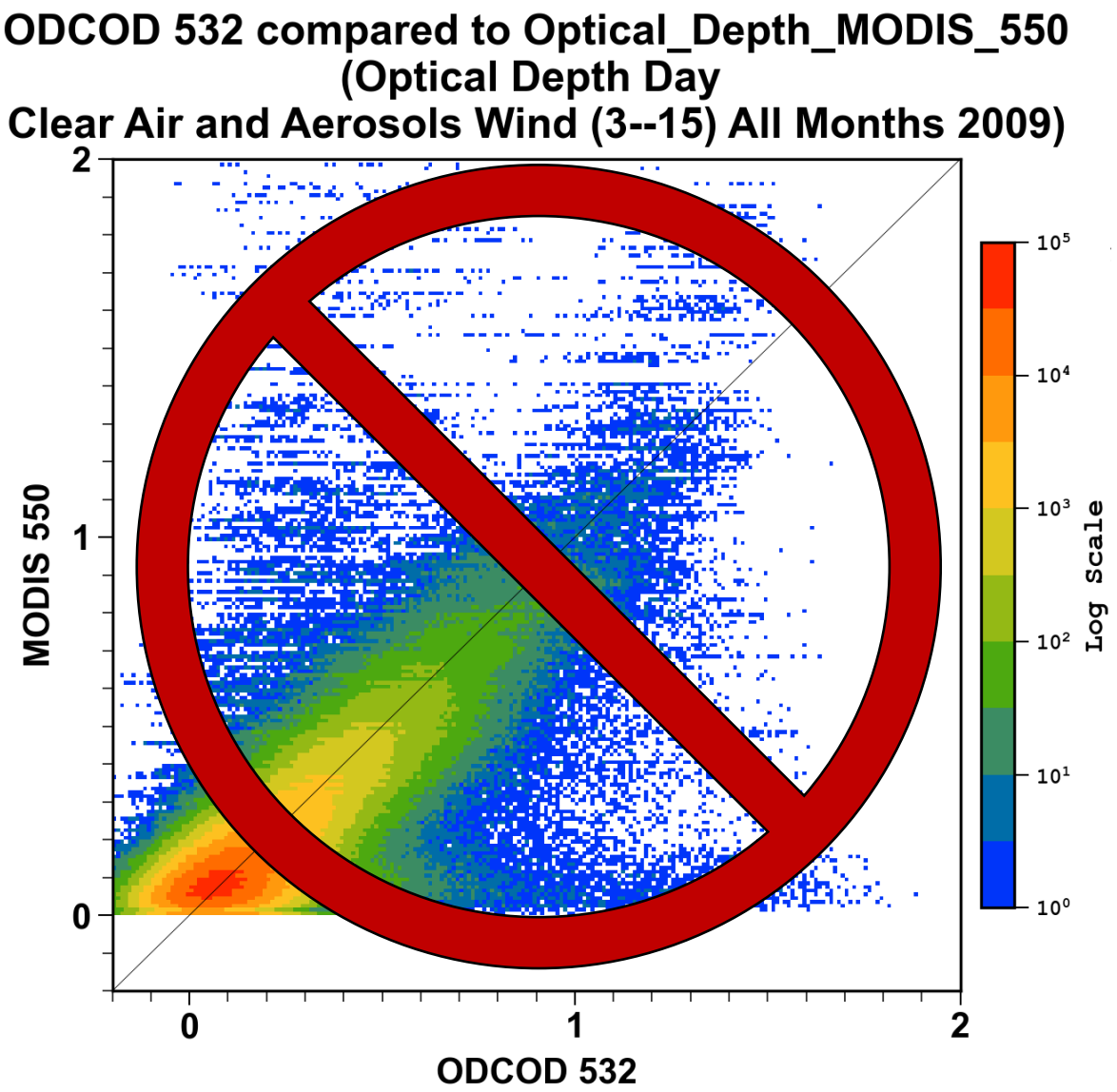
Please Check out the Poster, *"CALIPSO's New ODCOD Product Compared to Langley's HSRL and HSRL-2"*

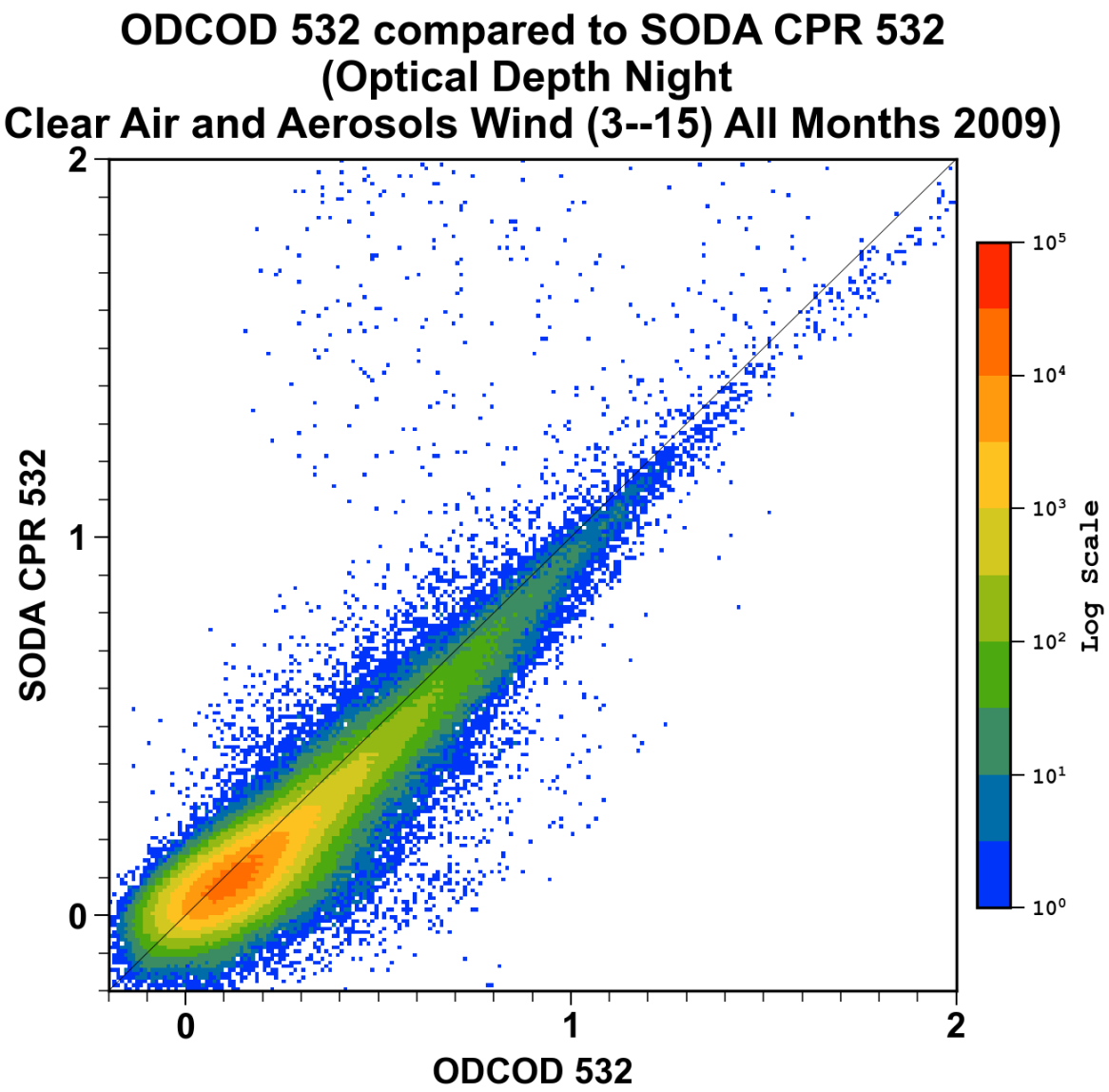
Contact me with any questions about ODCOD!!

Rob Ryan: robert.a.ryan@nasa.gov

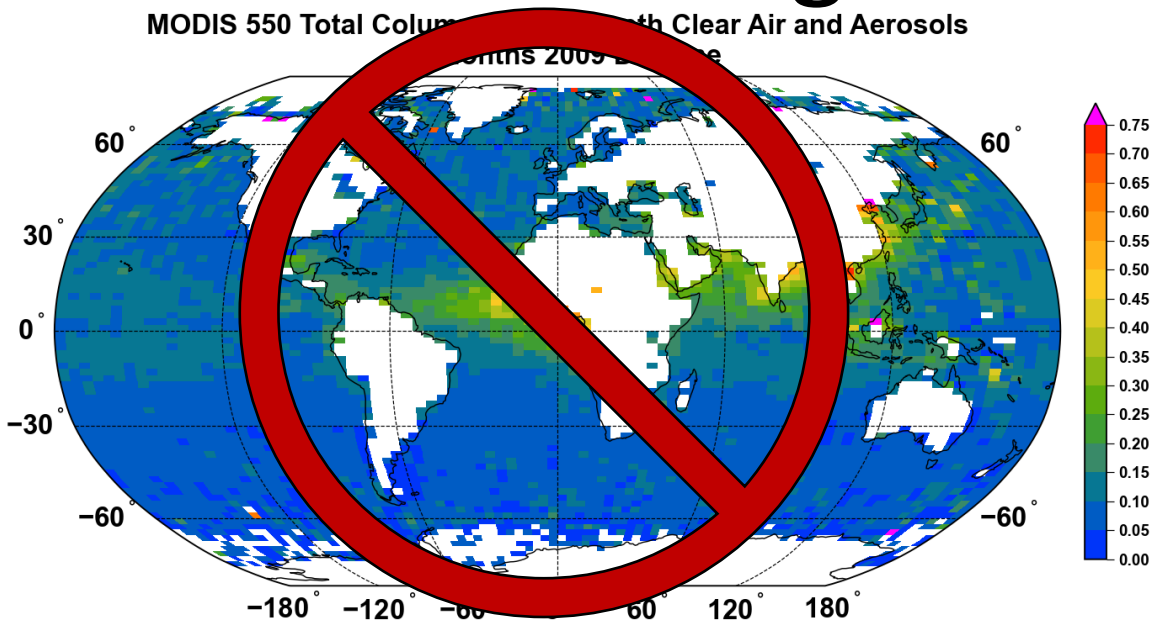
Additional Slides

Nighttime Comparisons

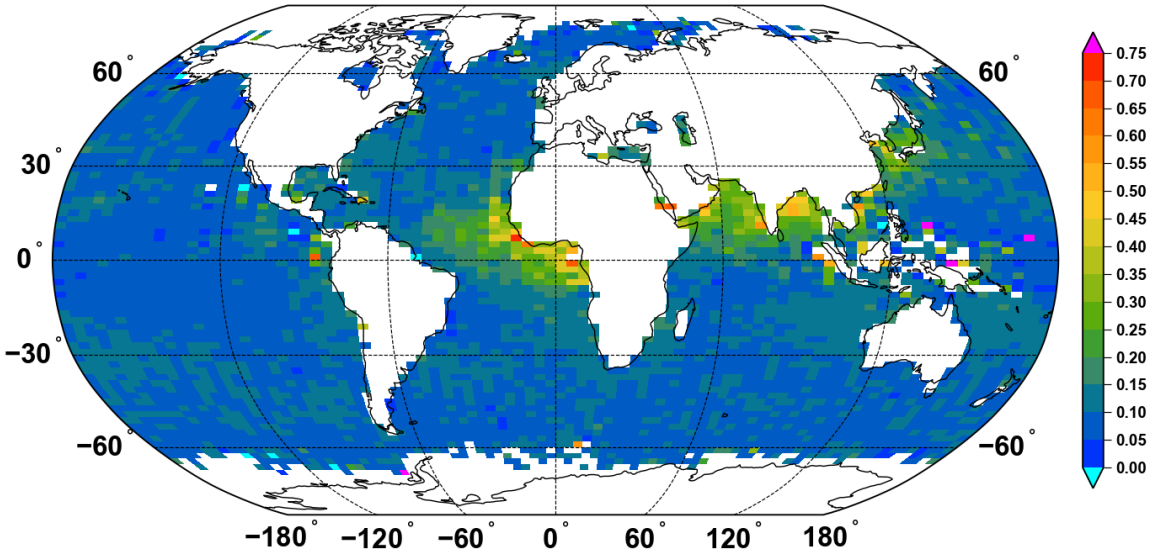




Nighttime Comparisons



SODA CPR 532 Total Column Optical Depth Clear Air and Aerosols
All Months 2009 Nighttime



ODCOD 532 Total Column Optical Depth Clear Air and Aerosols
All Months 2009 Nighttime