CALIPSO Ocean Surface Wind Speed and Comparisons with other A-train Wind Speed Measurements

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Outline

- Introduction of CALIPSO
- Wind speed from CALIPSO: basic concept
- Comparisons of wind speeds from collocated AMSR-E, CALIPSO and Cloudsat
- What's new from CALIPSO wind speed
- Uncertainties/future improvements and data availability

CALIPSO Mission Overview

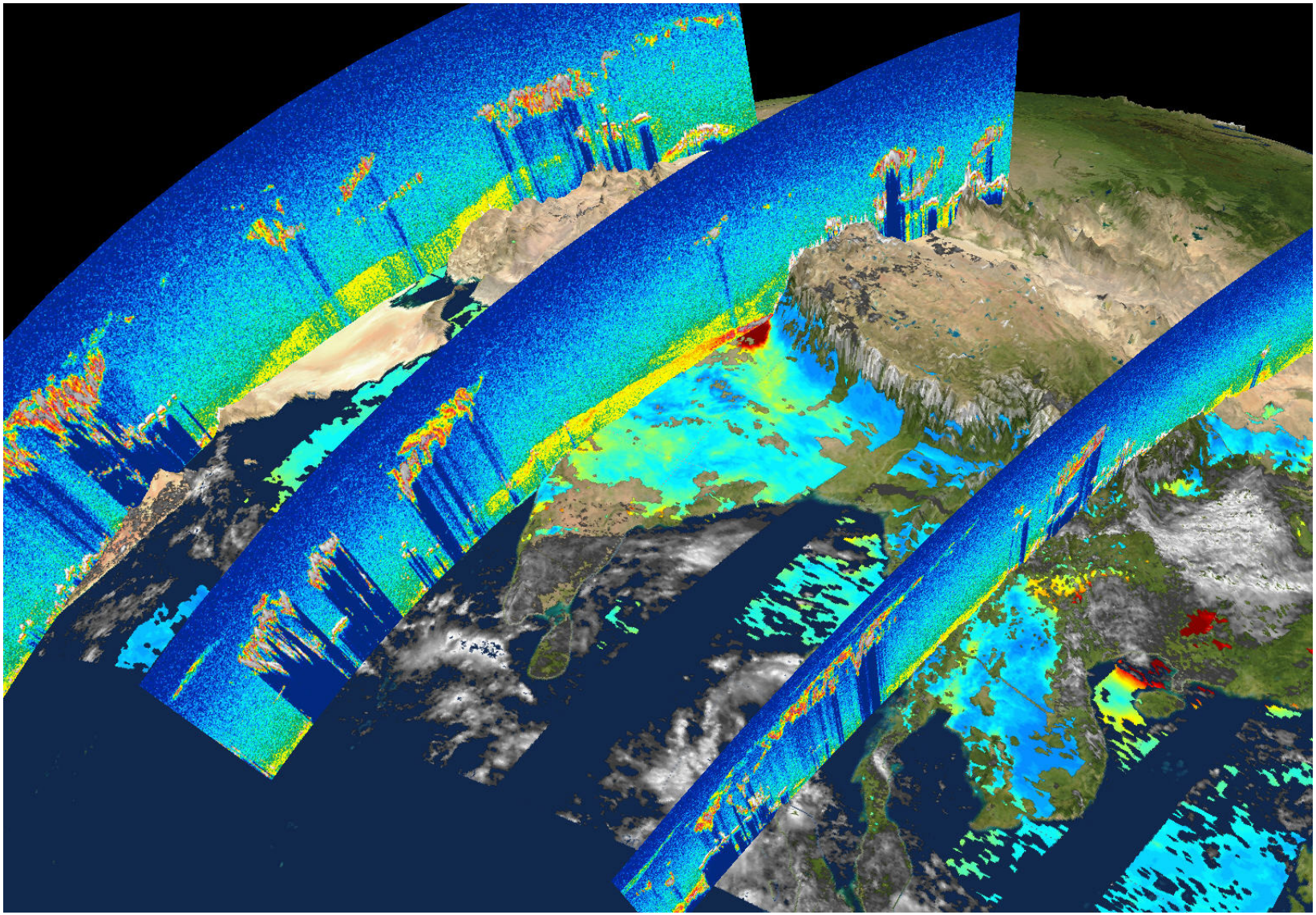
CALIPSO: lidar measurements of aerosol and clouds

Launched: April 28, 2006

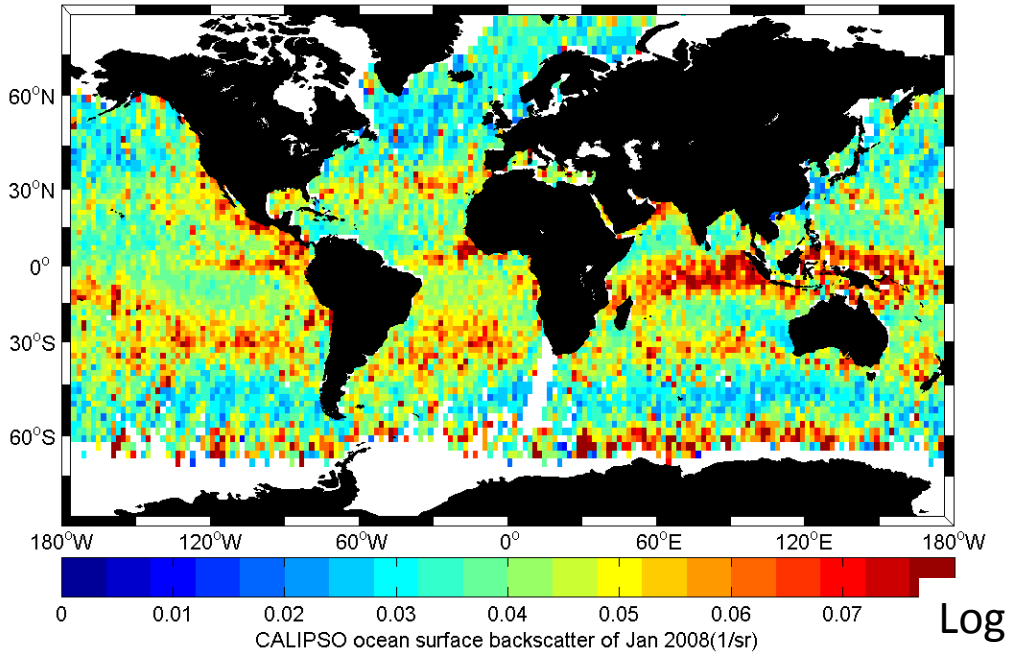
Operational Achievements:

- Long term measurements: CALIPSO collected more than 4 billion laser shots so far; may last until 2017; new satellite missions with similar lidars (CATS on ISS start 2014; Earthcare starts 2016)
- Observations during day/night and for all seasons
- Data publicly available

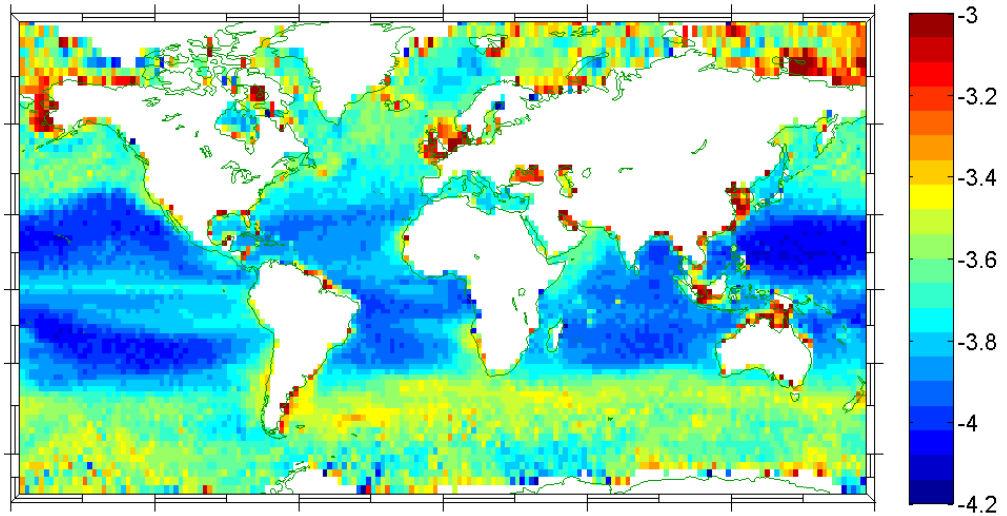
CALIPSO Adds the Vertical Dimension



CALIPSO also provide quantitative measurements of ocean surface and ocean subsurface backscatter



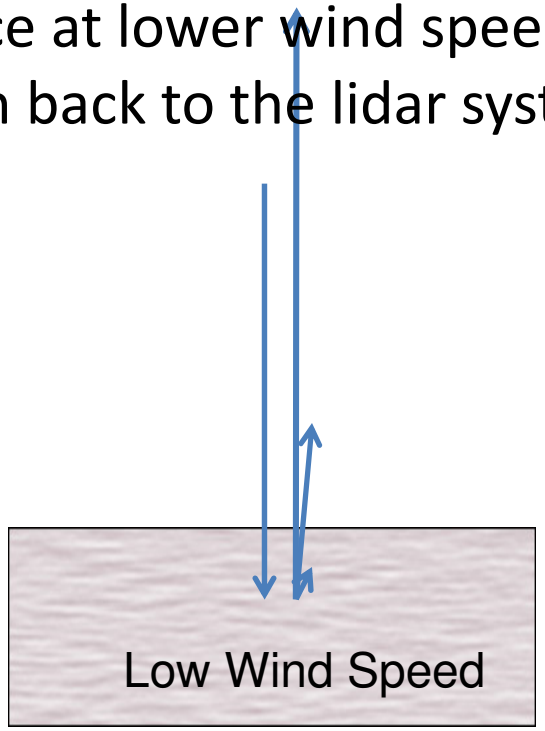
Log (annual mean subsurface backscatter (1/sr)

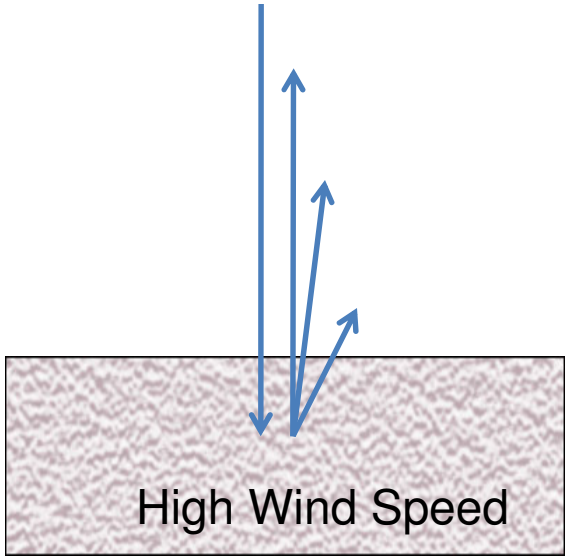


Deriving Sea surface wind speed from CALIPSO:

- The signal: ocean surface lidar backscatter signal from specular reflection
- The physics: higher wind → rougher surface → lower backscatter

(nadir pointing laser; 2% sea surface reflection at 1064nm wavelength; higher probability of laser beam normal to sea surface at lower wind speed, thus more chance of specular return back to the lidar system)



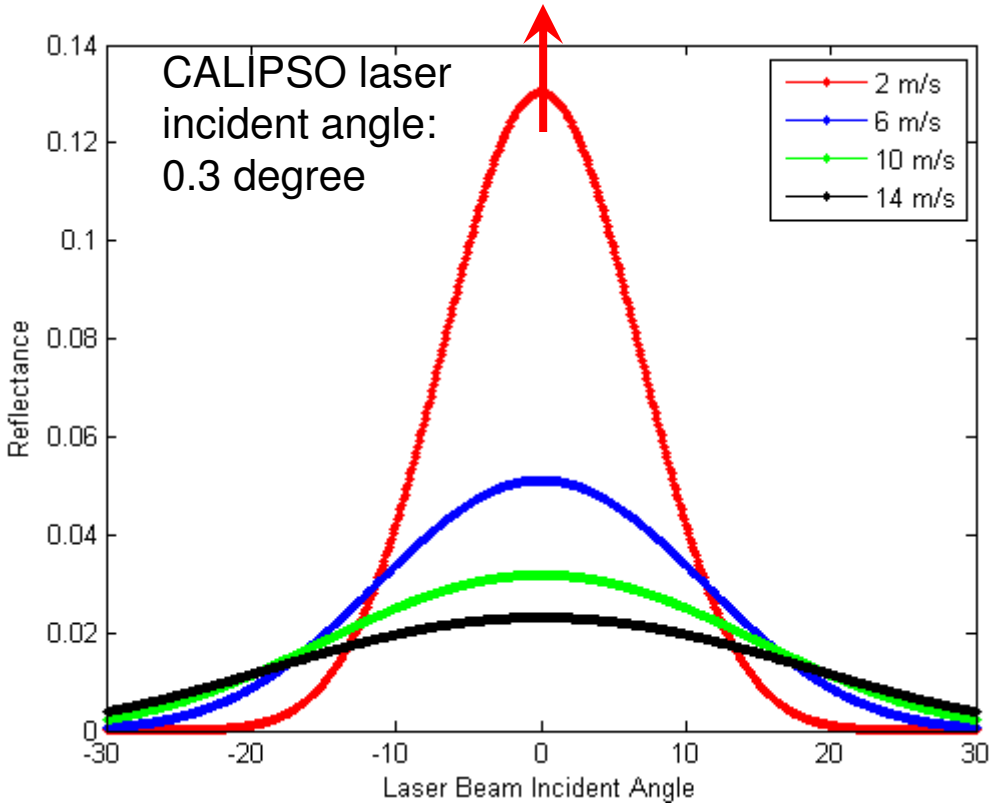


wind speed inversely proportional to CALIPSO lidar backscatter

Sea surface lidar backscatter (after a few corrections) = **c / [<s²>]**

Linear relation between wind speed and wave slope variance [<s²>] (Cox-Munk):

Lidar backscatter from ocean surface = c / (a+b*wind)



$$P(s)ds = \frac{c}{< s^2 >} e^{-\frac{s^2}{2<s^2>}} ds^2$$

$$< s^2 >= a * Wind + b;$$

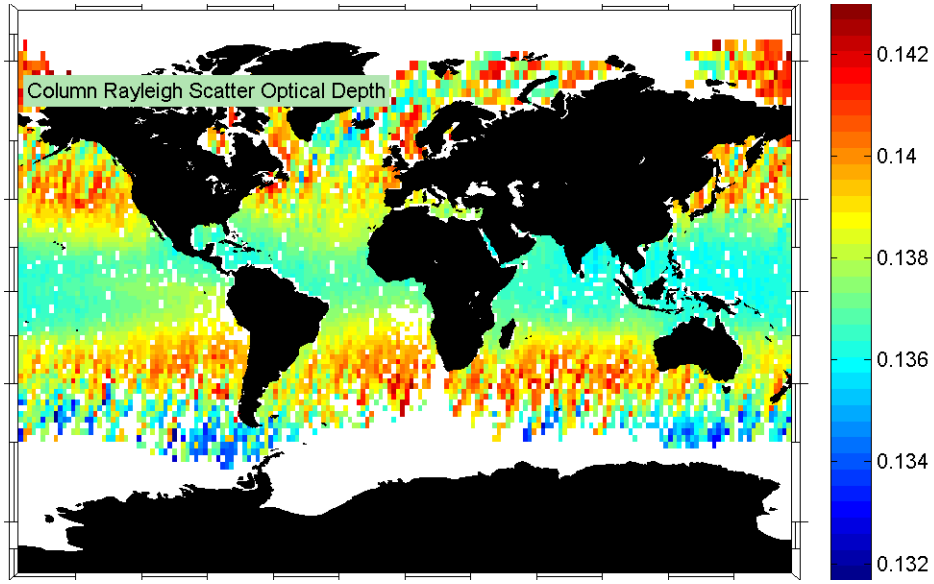
Estimating wind speed from CALIPSO: procedures

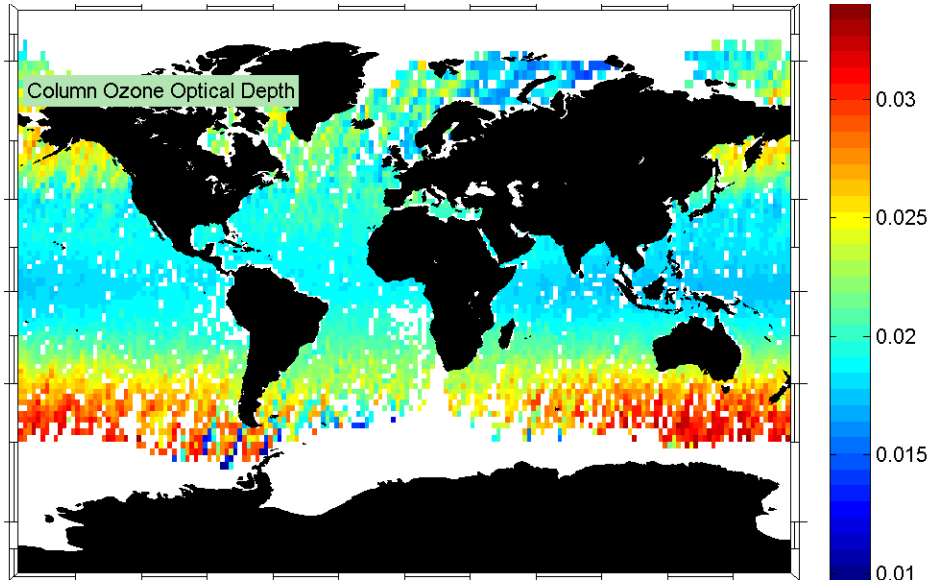
- Calibrating backscatter intensity by comparing clear backscatter with theory
- Correcting for atmospheric two-way transmittance
- Correcting for backscatter from ocean subsurface backscatter
- Estimating mean square wave slope =

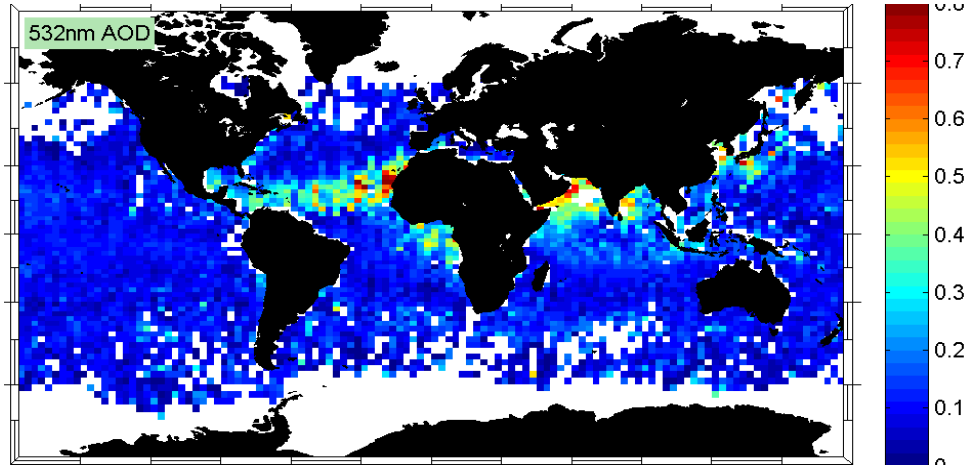
$$0.02 / [4\pi \text{ corrected sea surface lidar backscatter}]$$

Then we can estimate wind speed from mean square slope using Cox-Munk type of mss – wind speed relation

Estimating wave slope variance from CALIPSO: Correction for atmospheric attenuation (molecular scatter, absorption and aerosol/cloud scattering)





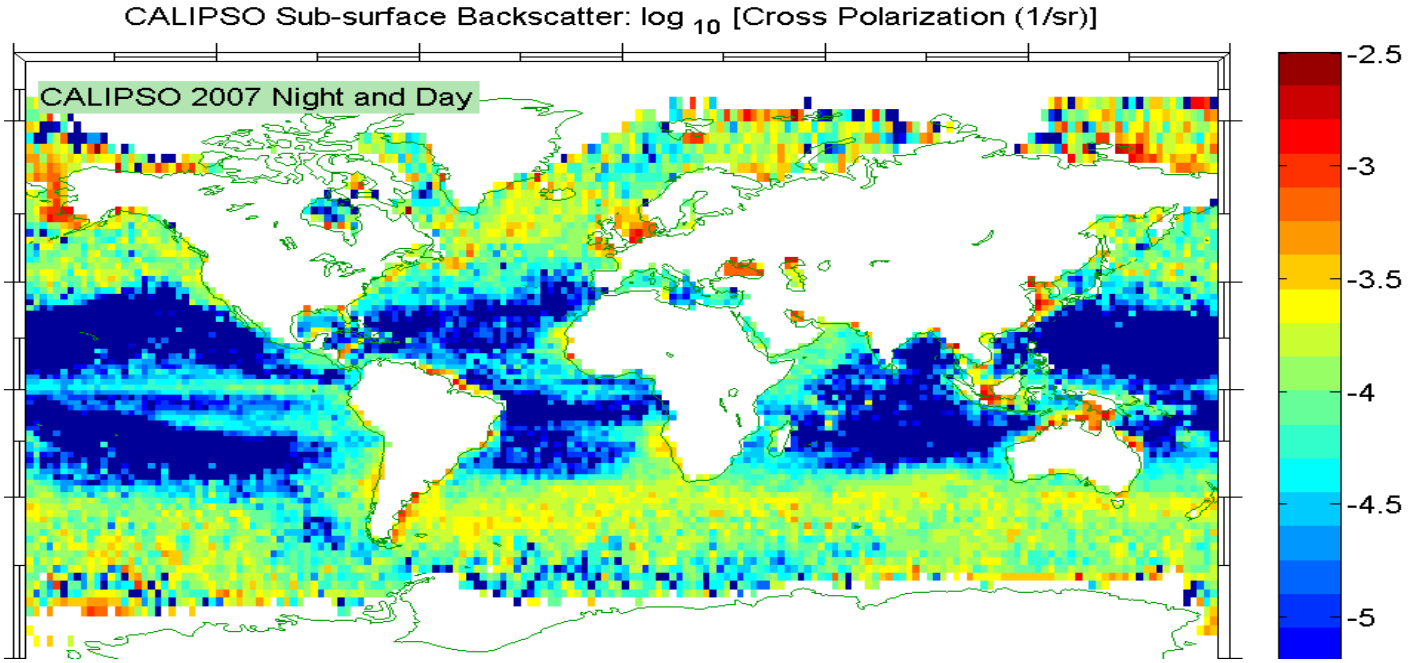


Estimating wave slope variance from CALIPSO: Correction for other backscatter (in water particulates and Rayleigh, and Bubbles)

Difference between specular reflection from waves vs other backscatter: backscatter from waves does not change state of polarization (cross-polarization backscatter = 0)

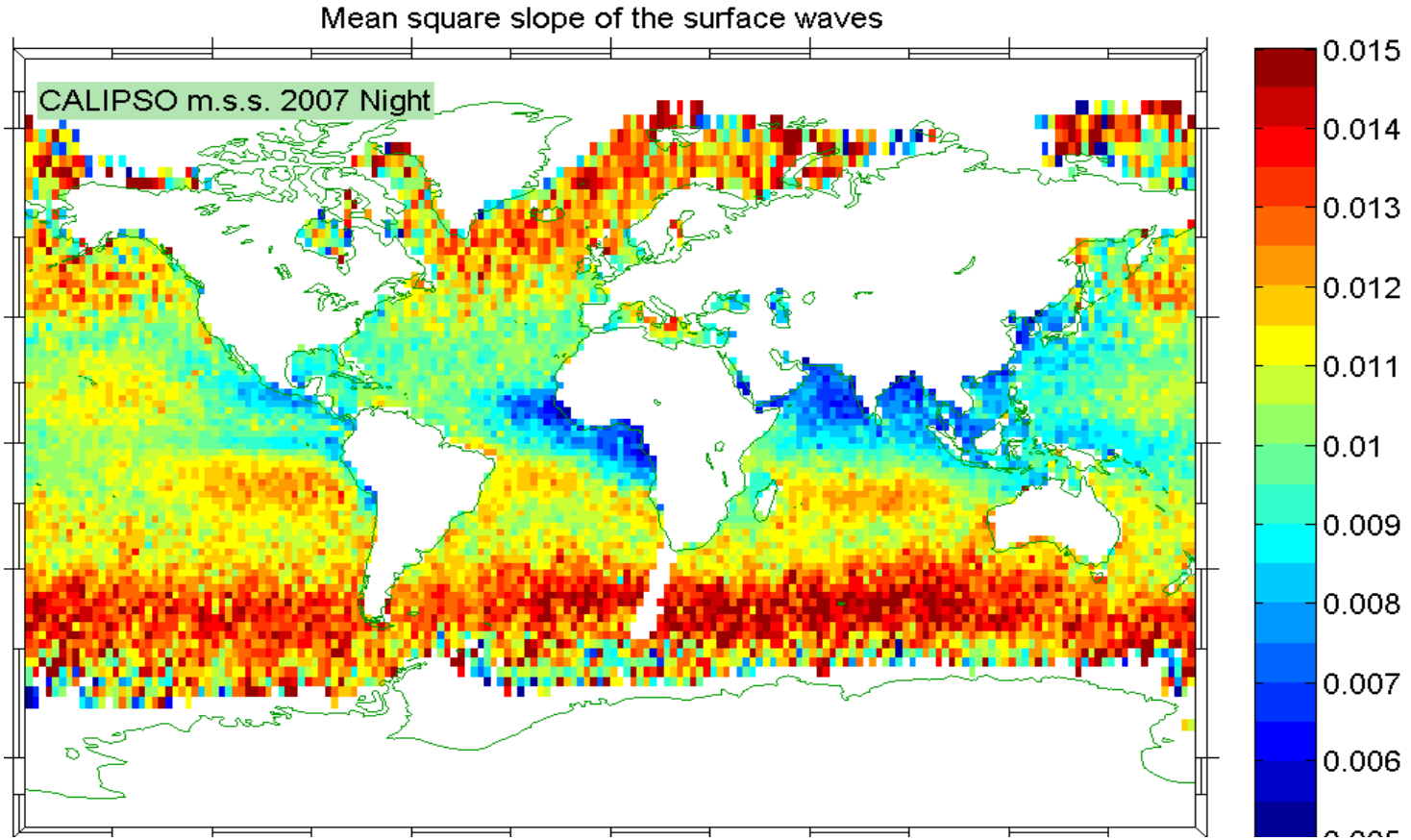
A simple algorithm (Hu et al., 2008):

other backscatter = cross-polarization / 0.125

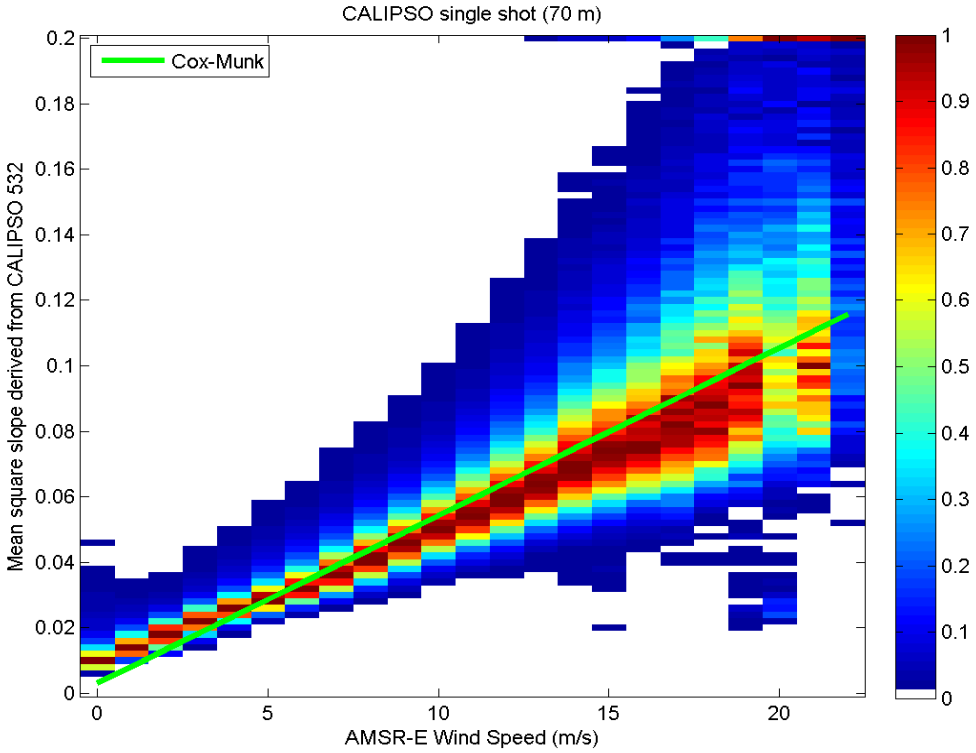


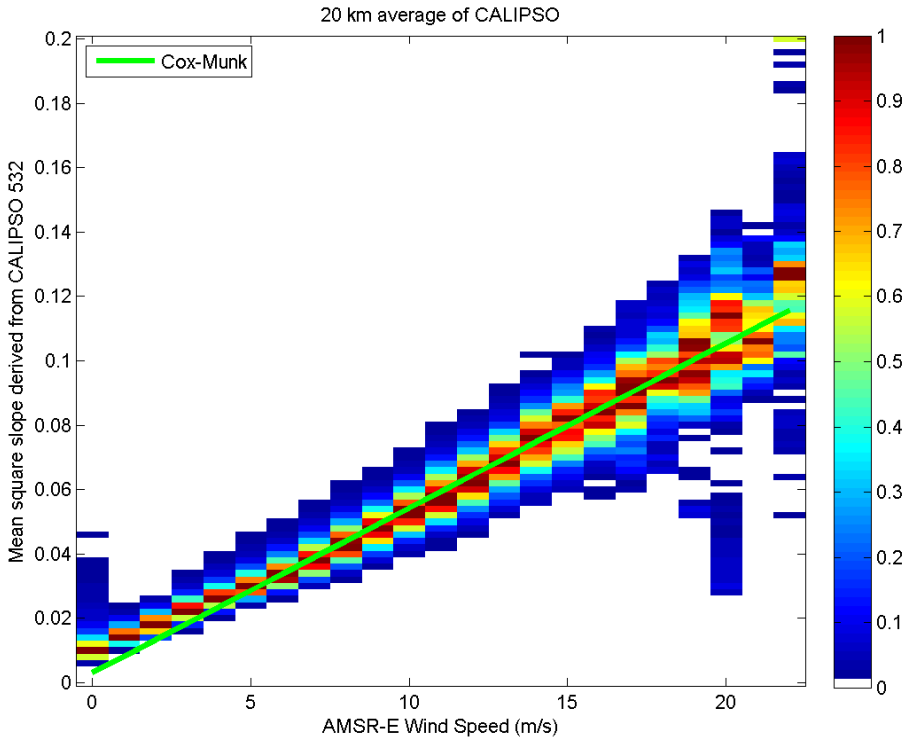
Mean square Wave Slope (MSS) from CALIPSO

MSS = 0.02 / [4π * sea surface lidar backscatter]
= 0.02 / [4π * (0.003 + 0.00512* V)]

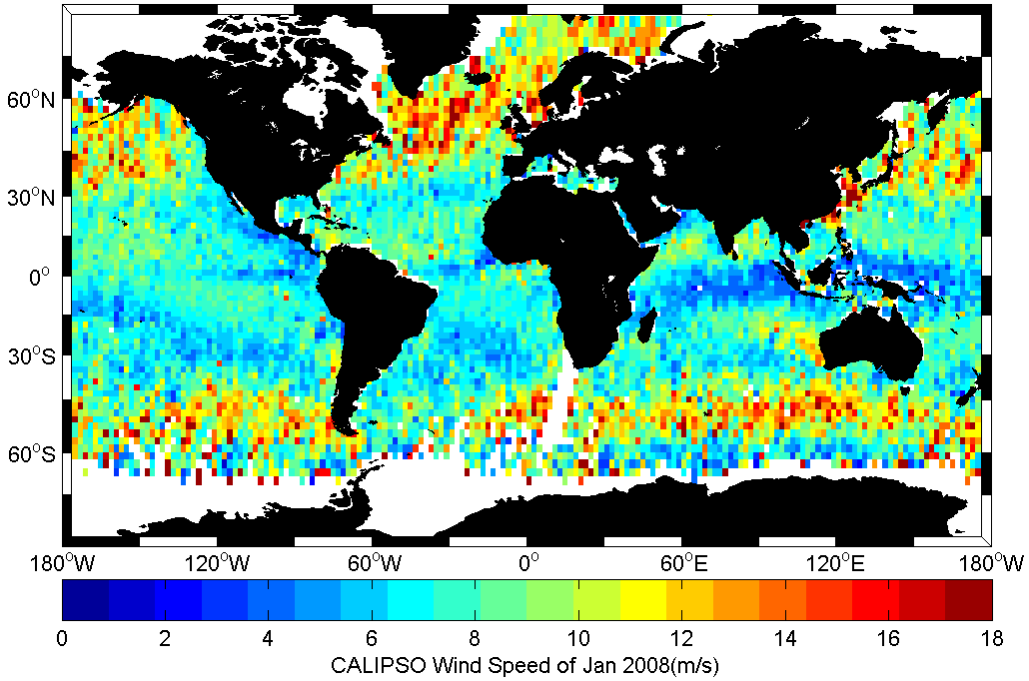


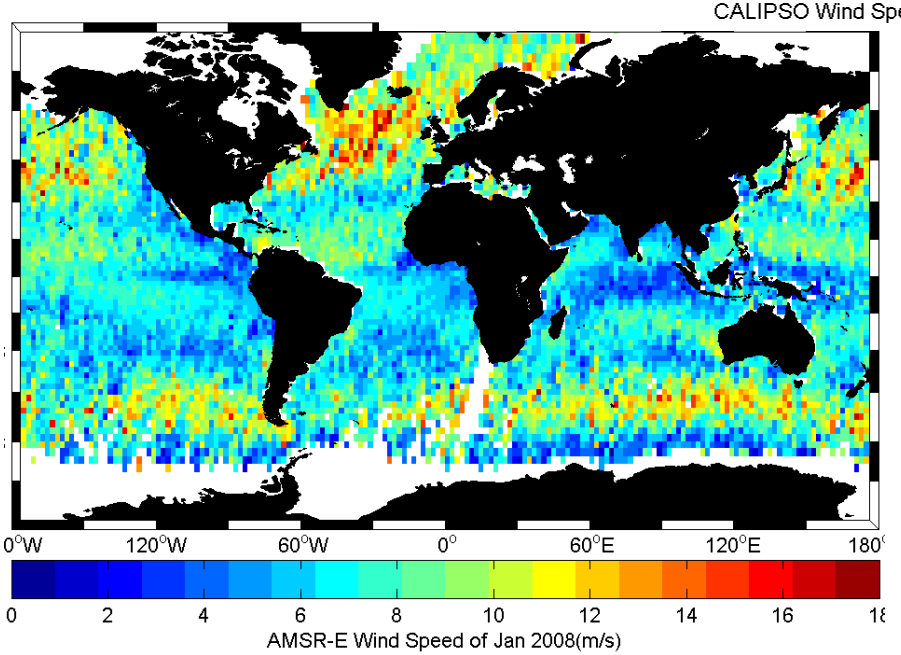
CALIPSO mean square slope vs AMSR-E wind speed

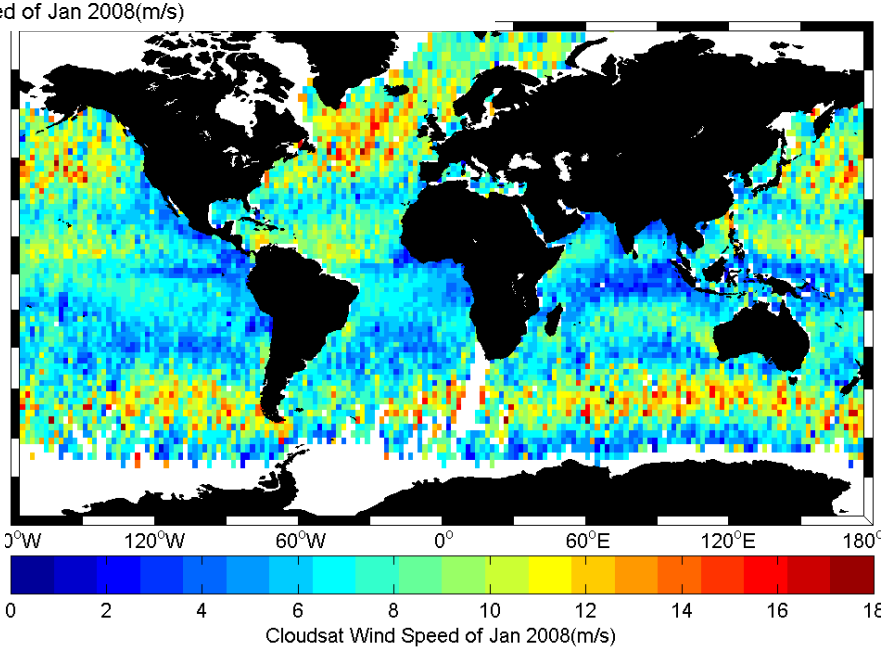




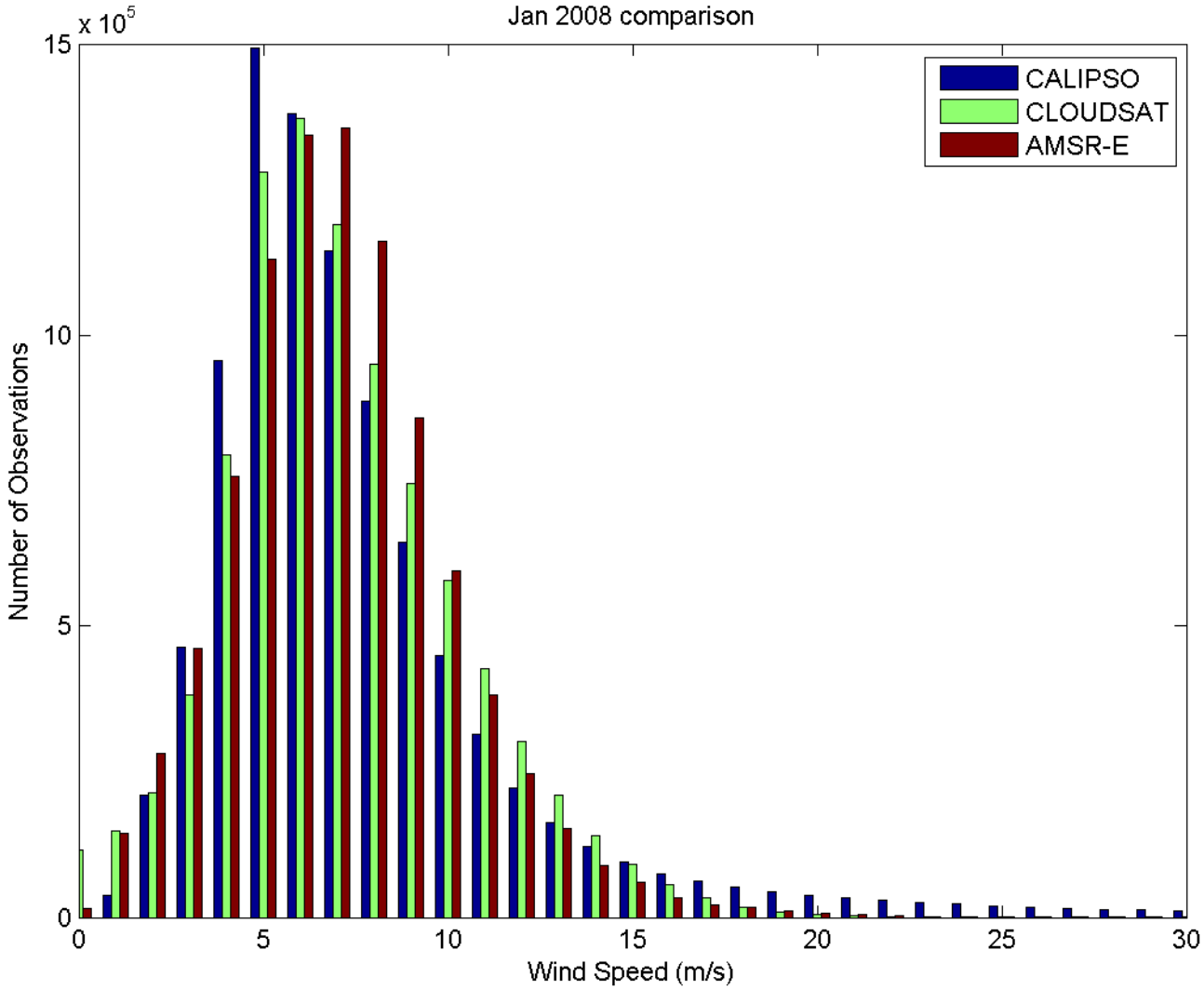
Monthly mean wind speed comparison: CALIPSO vs AMSR-E and Cloudsat:



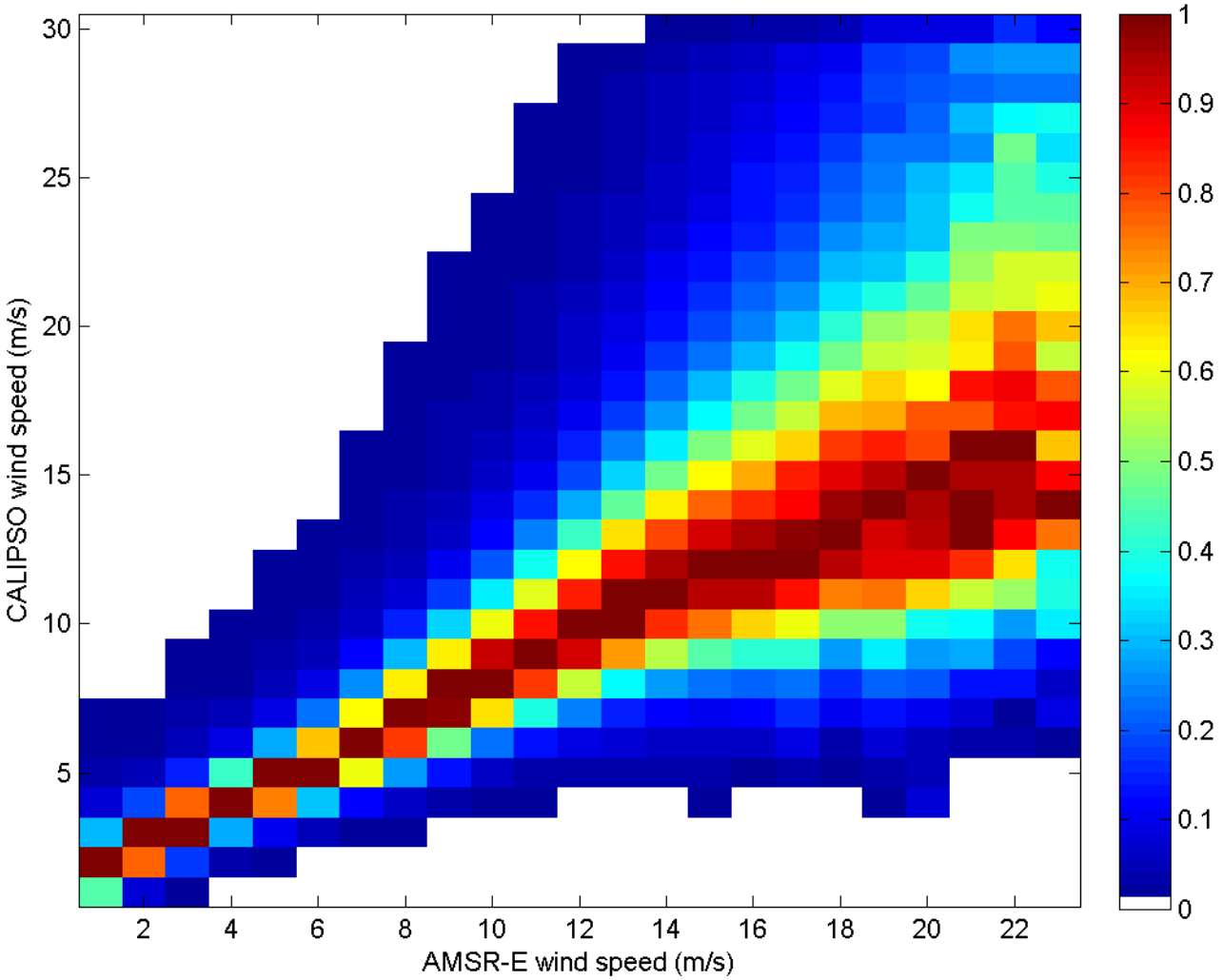




CALIPSO high resolution wind speed:
Broader distribution, similar mean value, larger higher order moments

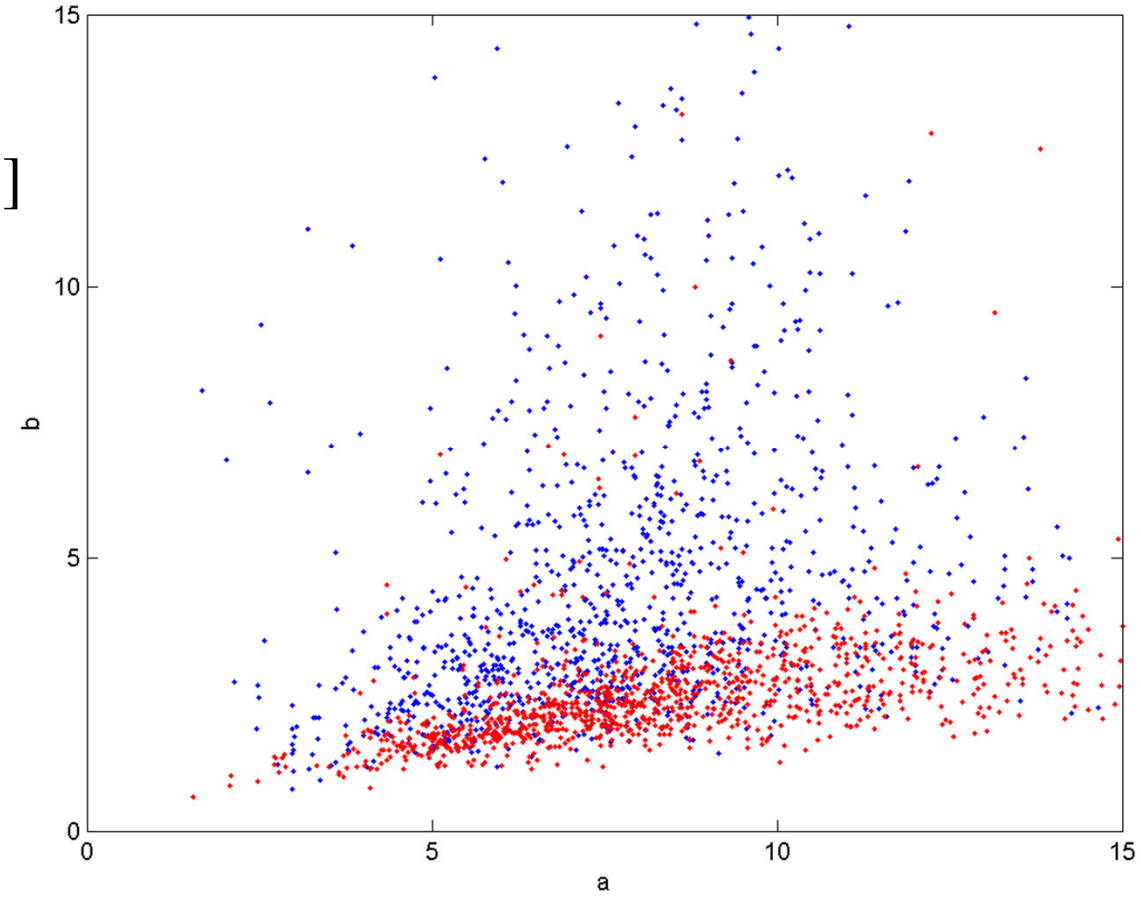


CALIPSO and AMSR-E wind speed comparisons



Shape Factor of Weibull Wind Distribution: CALIPSO (red) vs AMSR-E (blue)

$$P(x) = \frac{b}{a}\left(\frac{x}{a}\right)^{b-1} \exp\left[-\left(\frac{x}{a}\right)^{b}\right]$$



The relation between a and b of Weibull distributions from AMSR-E (blue) and CALIPSO (red).

Why consider CALIPSO wind speed statistics?

CALIPSO wind speed can be estimated at its very small footprint (70 meter).

Consider mean surface wind 7 m/s, CALIPSO wind speed is equivalent to 10 second averaged wind speed from Buoy wind statistics; AMSR-E wind speed is more like hourly mean Buoy wind speed statistics.

CALIPSO wind speed statistics can provide complementary information for estimating some physical parameters that may require higher order moments of wind speed.

Uncertainties/future-improvements and Data availability

Primary sources of uncertainty in existing CALIPSO wind speeds:

- backscatter intensity calibration
- atmospheric corrections
- potential saturation of lidar at low wind speed (V < 1 m/s)

Future improvements:
detailed uncertainty analysis and assigning confidence level

CALIPSO wind speed data availability:

- All 7 years of research data product are available; will produce wind data as long as lidar lasts (likely to 2017); Future missions with similar spacebased lidars (Earthcare, CATS, …)
- Not part of official CALIPSO data product (our data center cannot spend resource to archive without seeing real community interest)
- I will be very happy to provide the data to researchers who are interested in using the data (email yongxiang.hu-1@nasa.gov)