CALIPSO: Lessons Learned, and Future Perspectives

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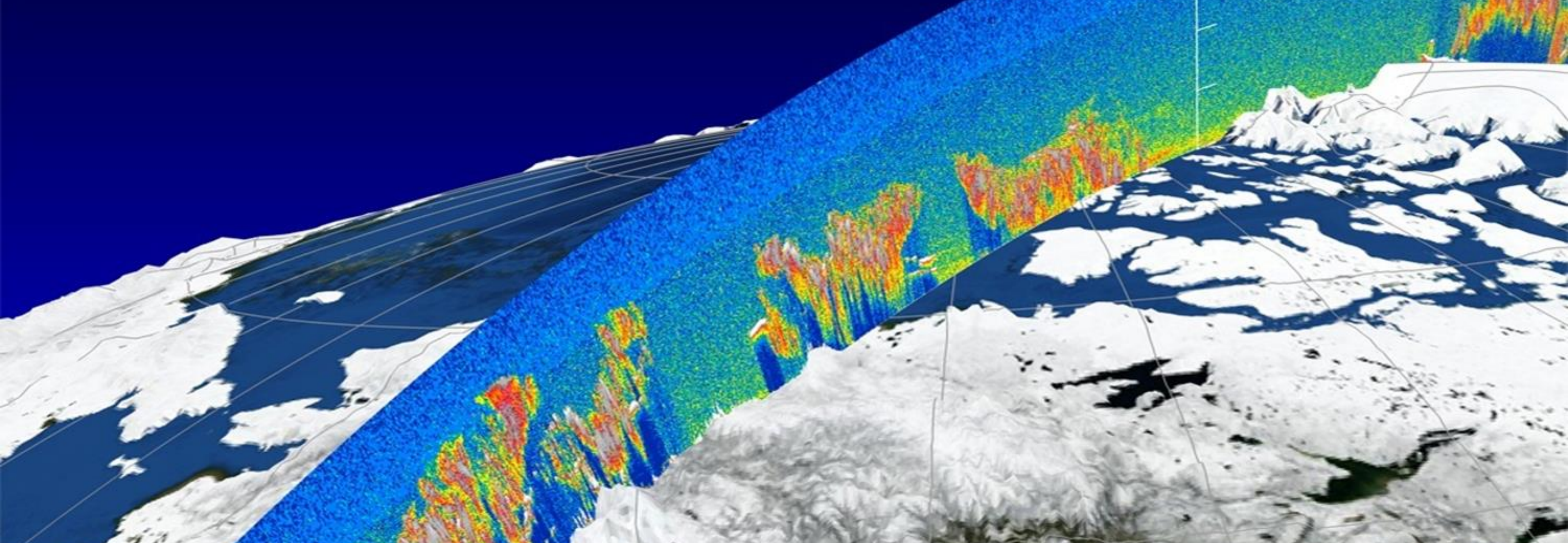
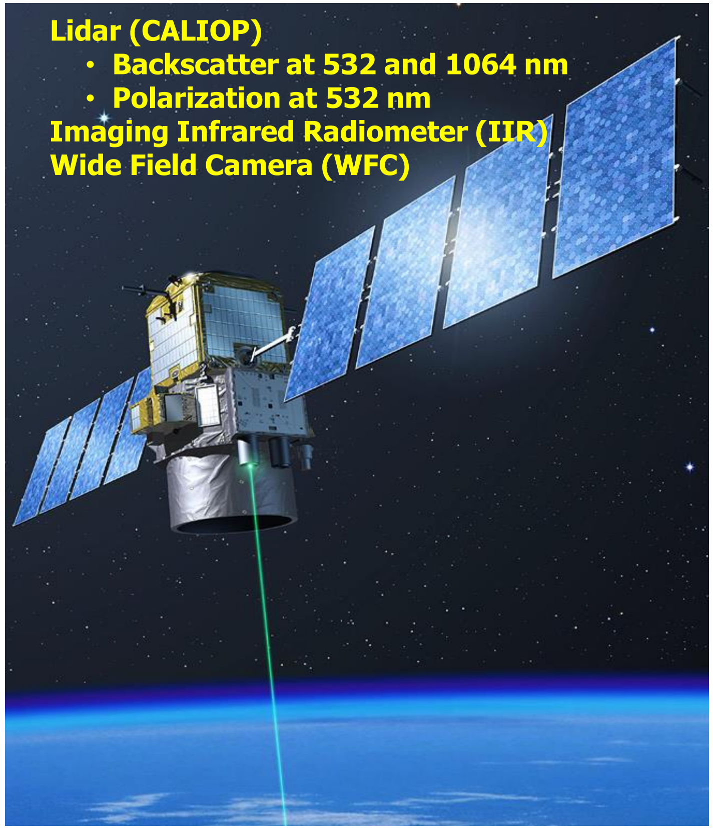
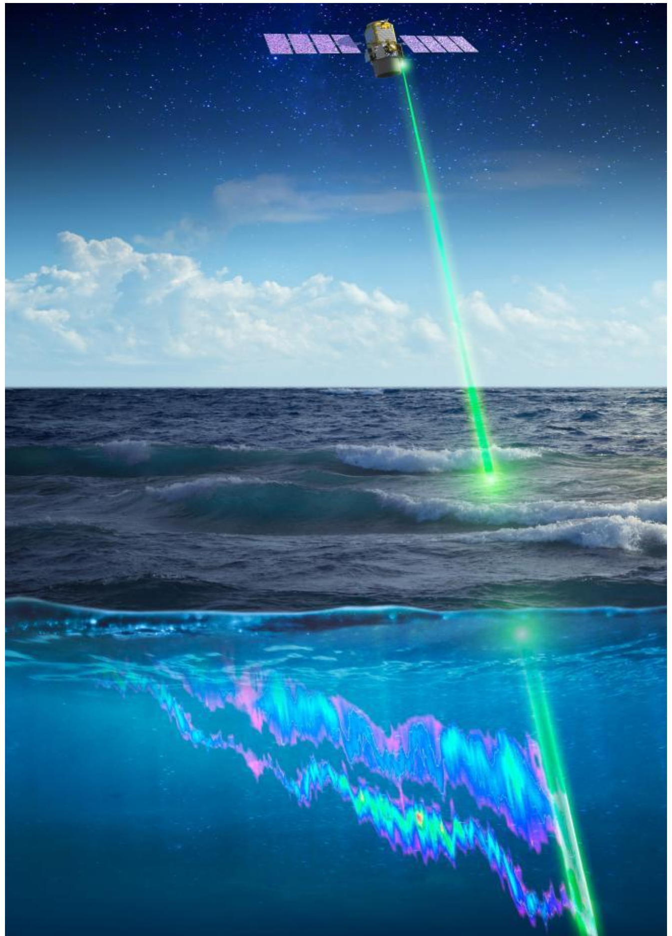


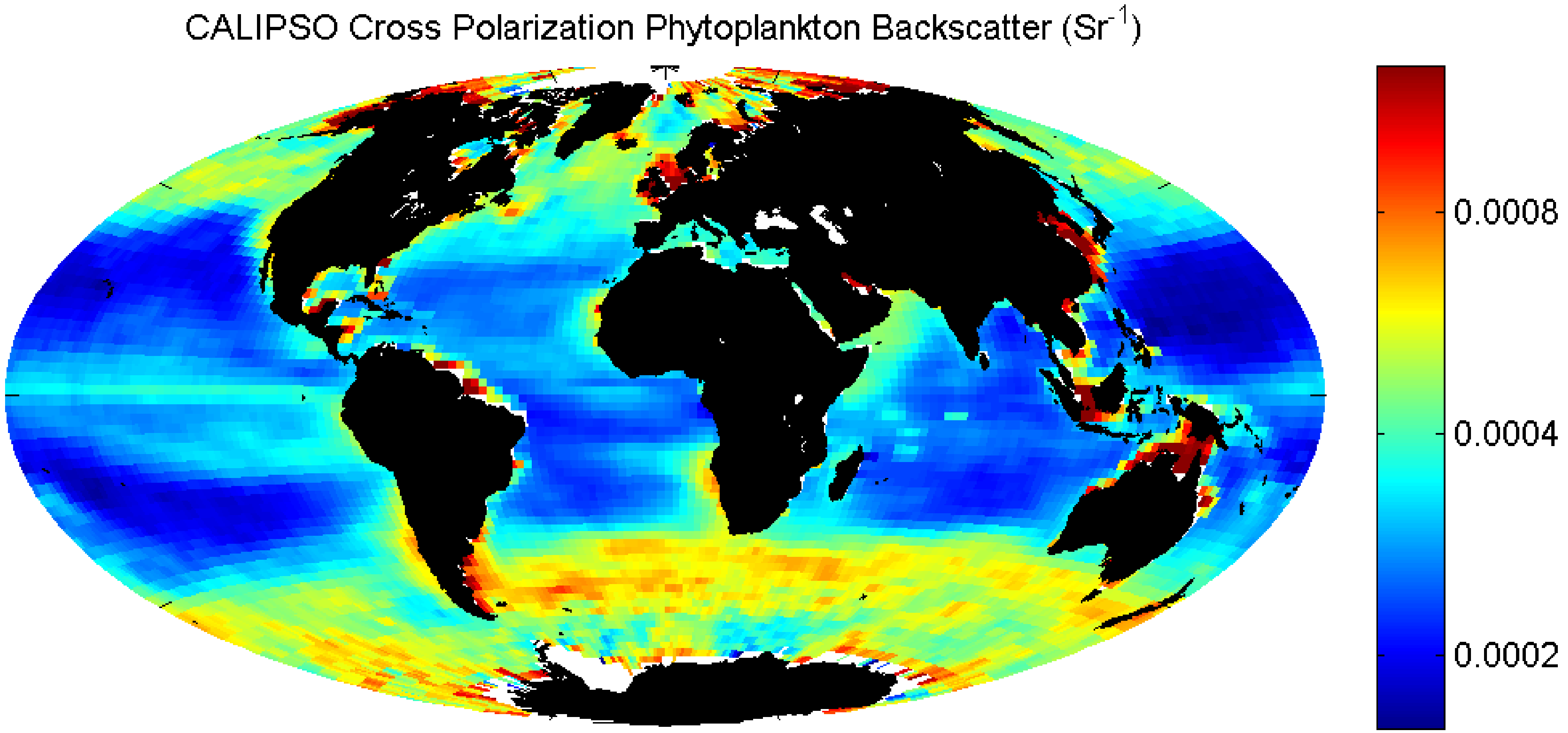
Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) (2006 – 2020?): first satellite mission with profiling lidar



- 13 years of continues lidar measurementss in the A-train constellation so far, and going
- Designed for measurements of 3D distributions of aerosols and clouds
  - vertical resolution: 30 m
- ocean measurements from CALIOP data
  - Sea-surface wind speed (1064 nm channel)
  - Highly accurately calibrated 532 nm cross polarization measurements for particulate backscatter (b_{bp}) estimates

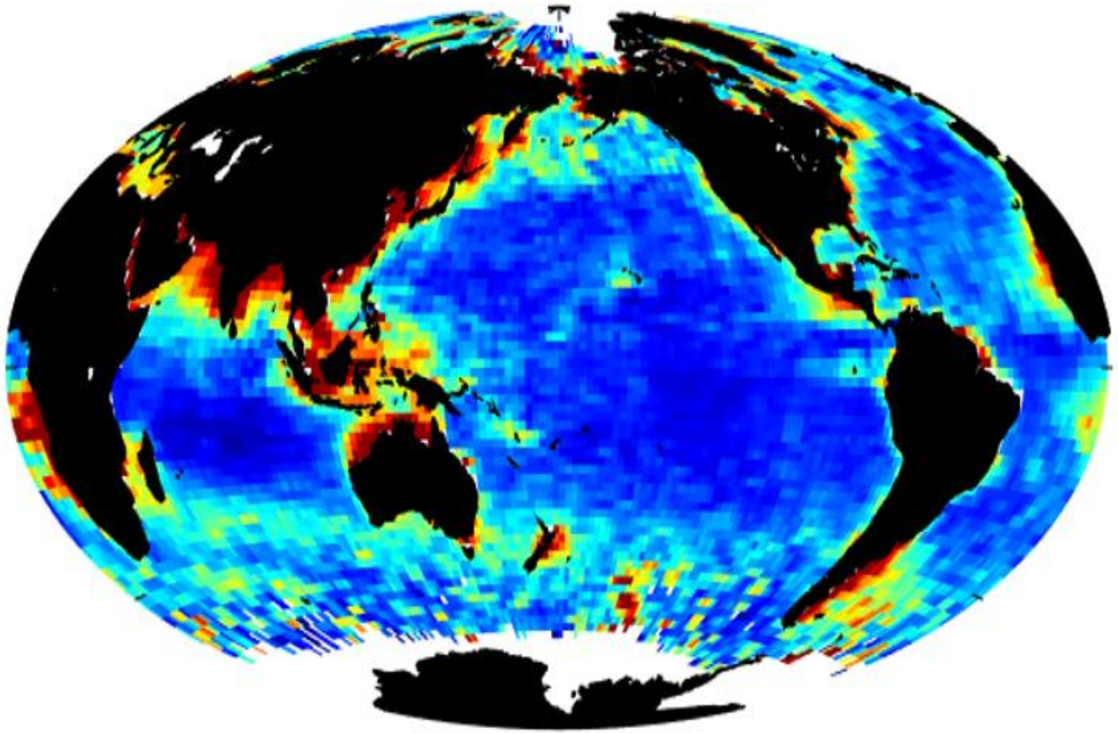


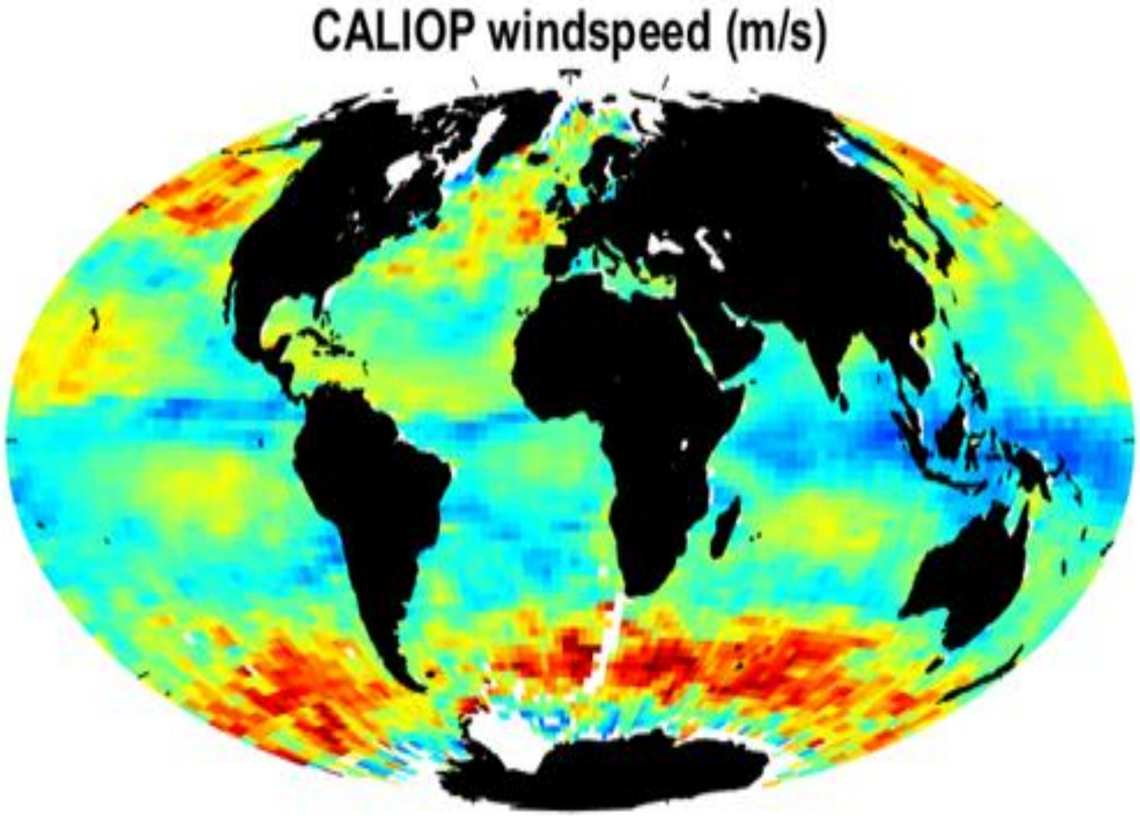
CALIPSO's ocean subsurface measurement



CALIPSO’s relevant ocean surface and aerosol measurements

CALIPSO provide accurate aerosol characterization in coastal and turbid waters





CALIOP ocean subsurface measurements is accurately calibrated

Information: cross polarization backscatter profile

Accurate Calibration (day and night):

ocean surface backscatter vs theory (thus calibrate out aerosol/air/clouds above)

$$\left(\beta_s = \frac{0.0207}{4\pi<\sigma^2>} = \frac{0.0207}{4\pi[0.003+0.00512*Wind]} \right) \qquad (Hu\ et\ al.\ 2008)$$

Science data:

1. Direct measurement of BBP (Behrenfeld et al., 2013; Lu et al., 2014)
2. High latitude measurements (Behrenfeld et al., 2017)
3. Day-night difference for studying zooplankton migration (Behrenfeld et al., 2019)
4. Accurate day and night measurements of subsurface backscatter and aerosol optical depth in coastal and turbid waters

CALIPSO's measurements in coastal and turbid waters are better than open ocean measurements

Open ocean measurements: Cross polarization only (linearly proportional to b_{bp})

Coastal and tubid waters:

- Co-polarization
- Cross polarization
- beam attenuation coefficients (more details in later part of the talk)

Reason: we can more accurately remove transient response of ocean surface backscatter more accurately in coastal and turbid waters

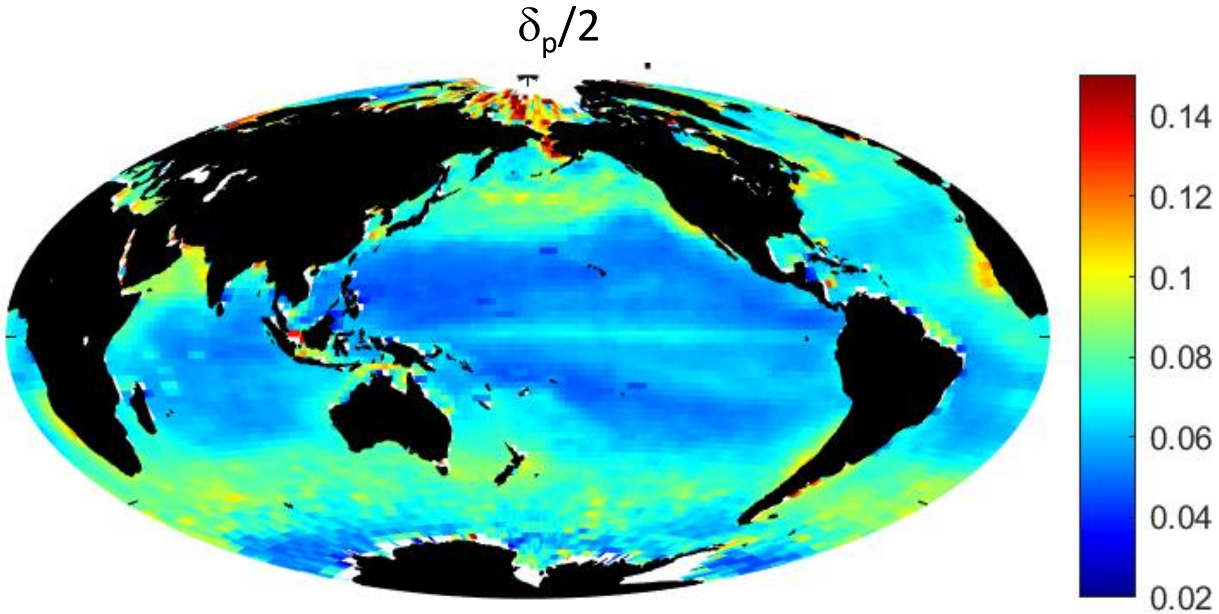
CALIPSO cross polarized backscatter: direct measurement of particulate backscatter coefficient (B_{BP})

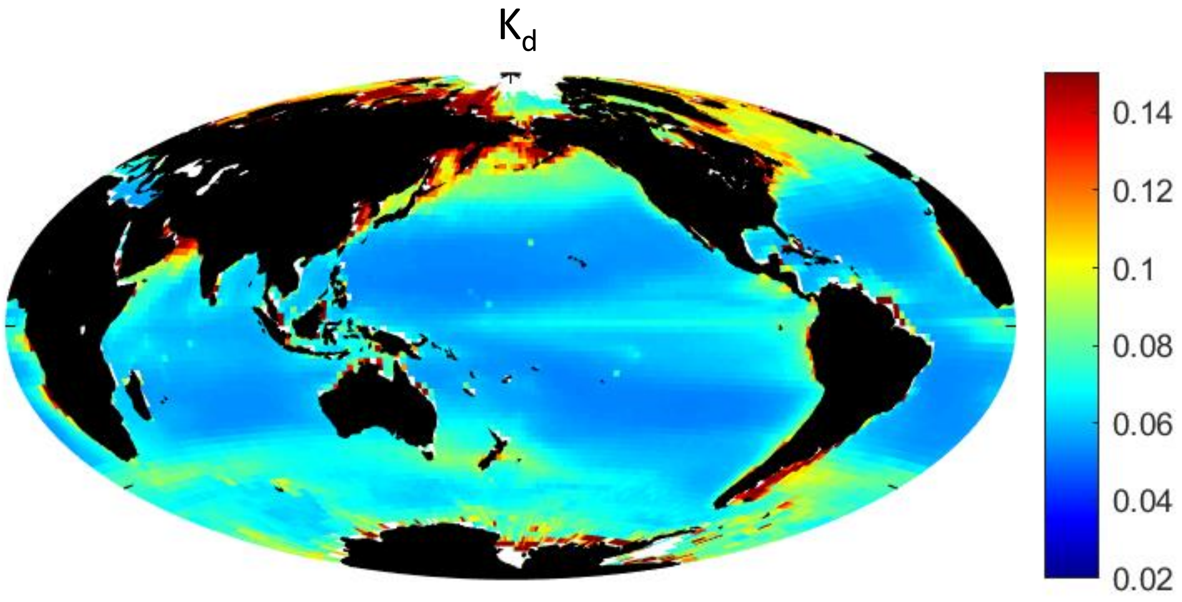
CALIPSO Cross-Pol Backscatter $= \int C * BBP * depolarization * \exp(-2K_d z)\, dz$

$= C * BBP * depolarization / (2K_d) \approx$ **B_{BP}** $* C$

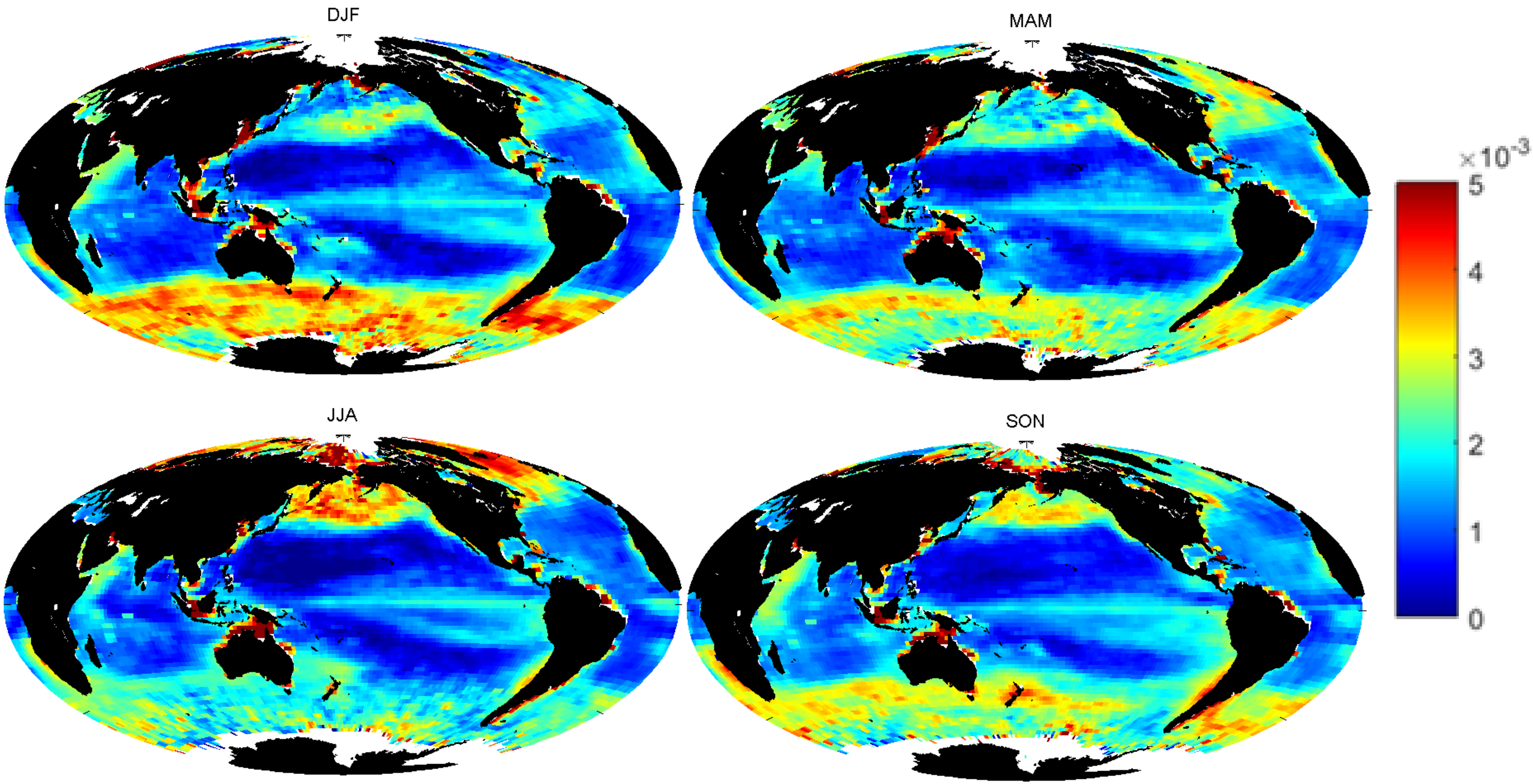
(C here is an anisotropy factor of 180 degree backscatter)

$$\frac{particulate\ depolarization}{2} \approx K_d$$

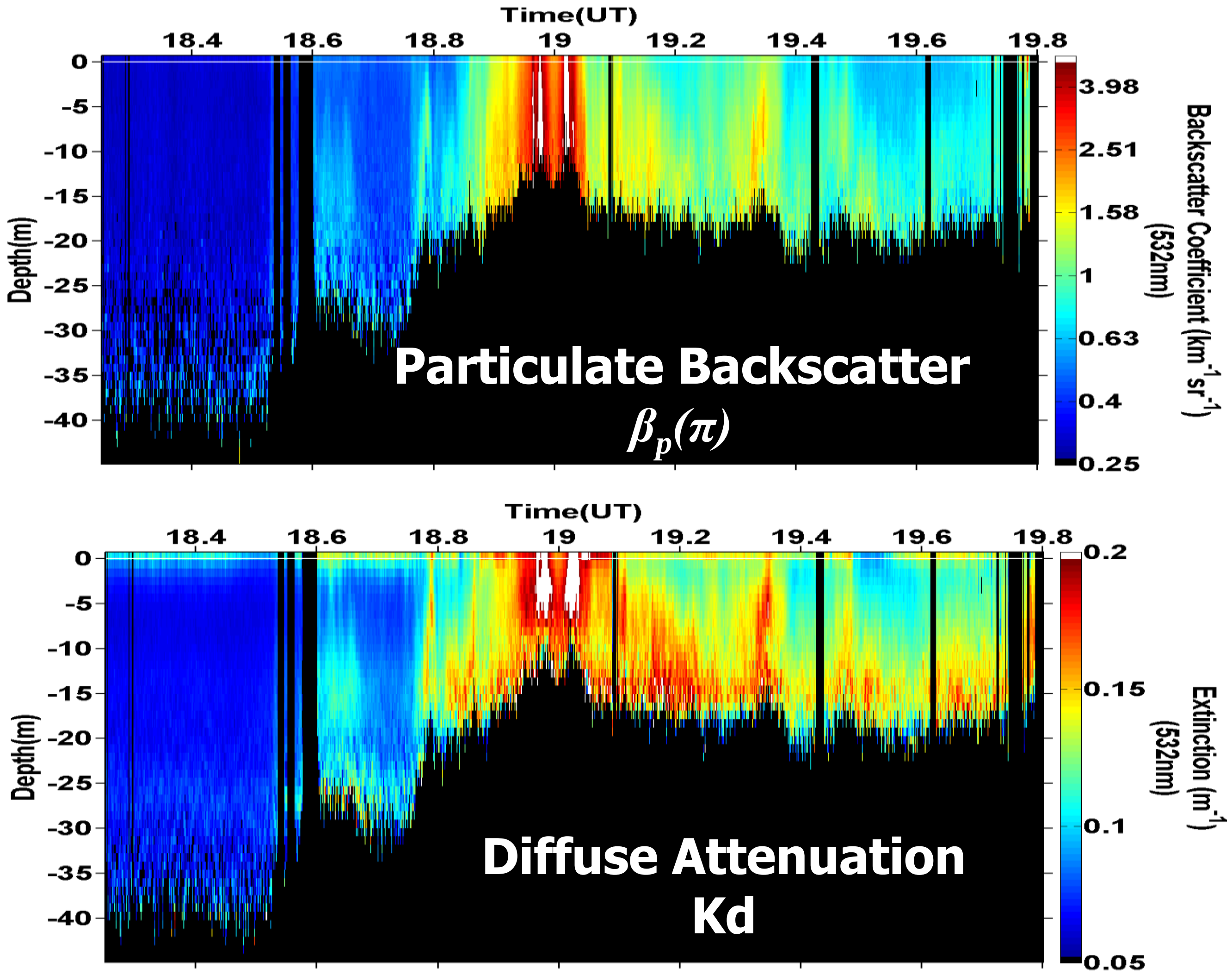




Seasonal Variations of CALIPSO particulate backscatter (B_{BP}) (2007-2008)



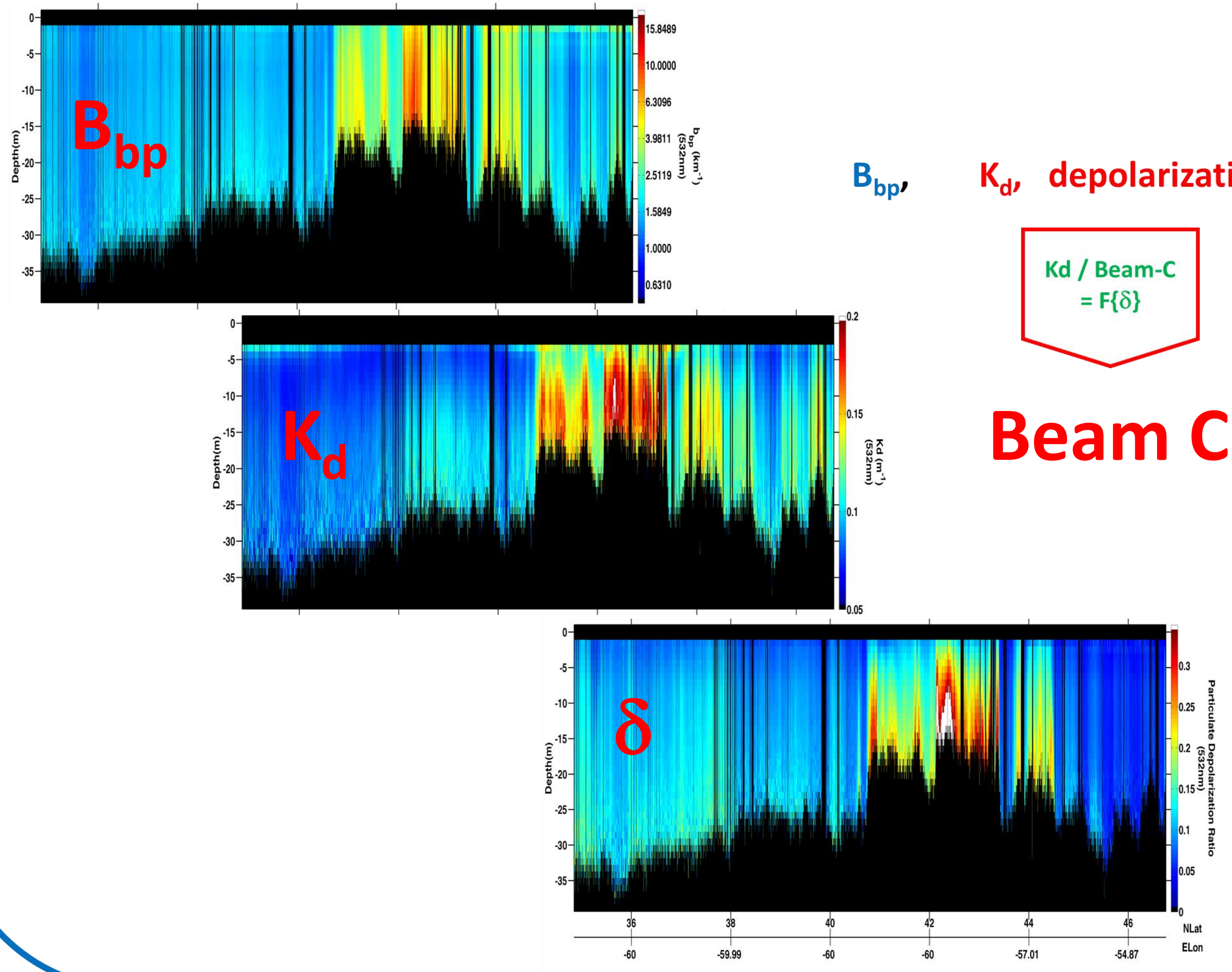
CALIPSO BBP: verified using HSRL measurements, which provides independent retrievals of particulate backscatter and attenuation



Hostetler et al., 2018

What we might get from lidar on A-CCP

(we want to thank Paula for keeping fighting for it)



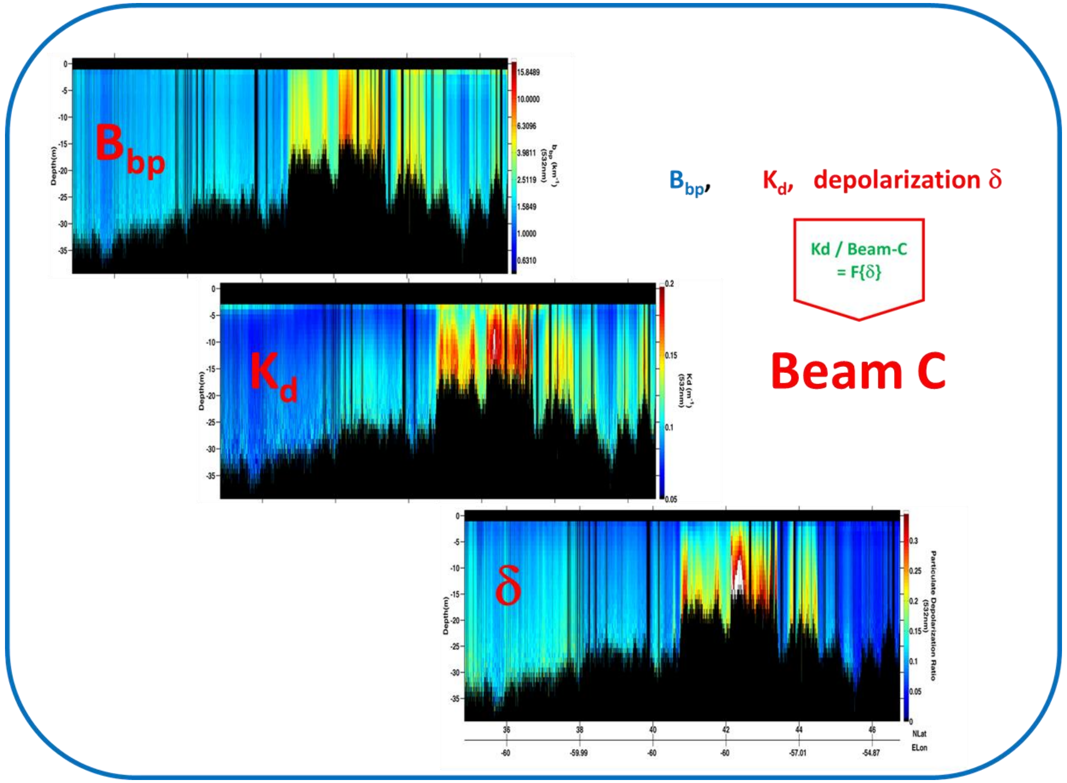
B_{bp}, K_d, depolarization δ

Kd / Beam-C = F{δ}

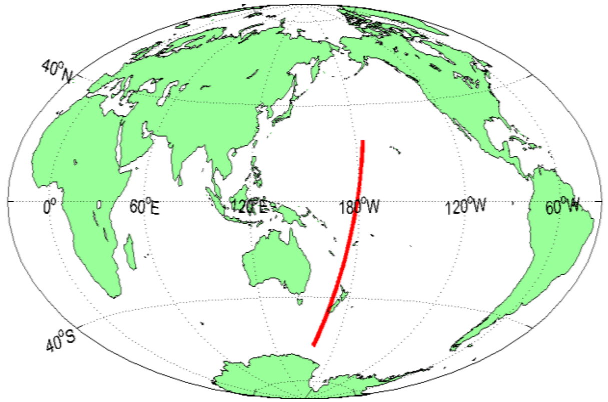
Beam C

Lidar on A-CCP: what's new for coastal water measurements comparing with CALIPSO

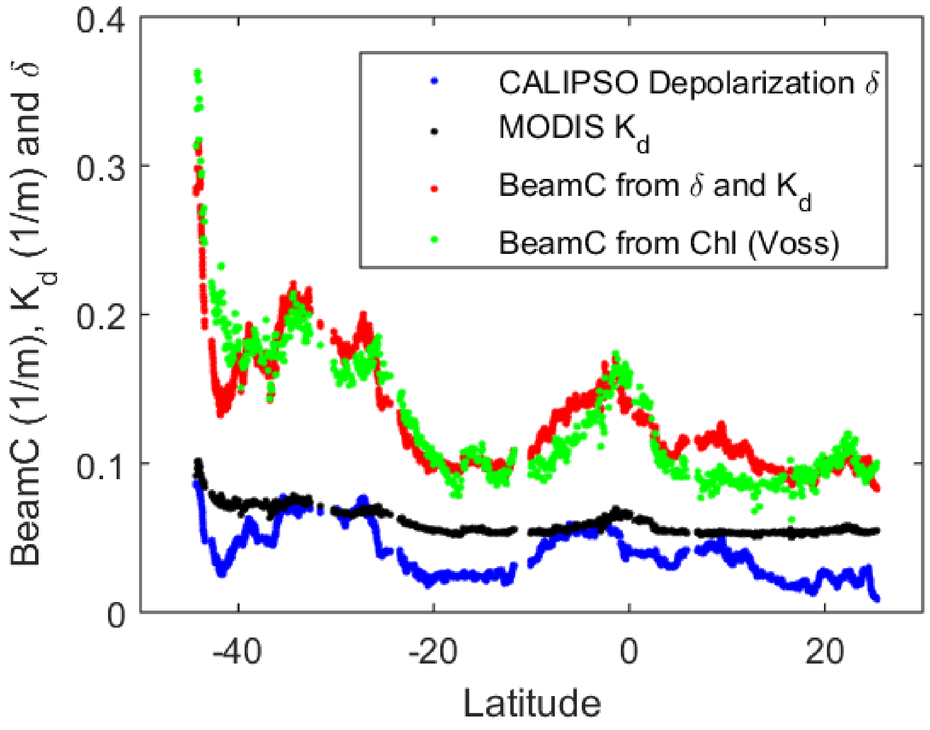
- vertical profiling of b_{bp} due to fast sampling
- measurements of Kd (fast sampling, and/or Brillouin scattering channel)
- potential measurements of beam-c (more details in next page) profiles



Lidar depolarization ratio: the link between effective attenuation coefficient and true attenuation coefficient (poster 33)

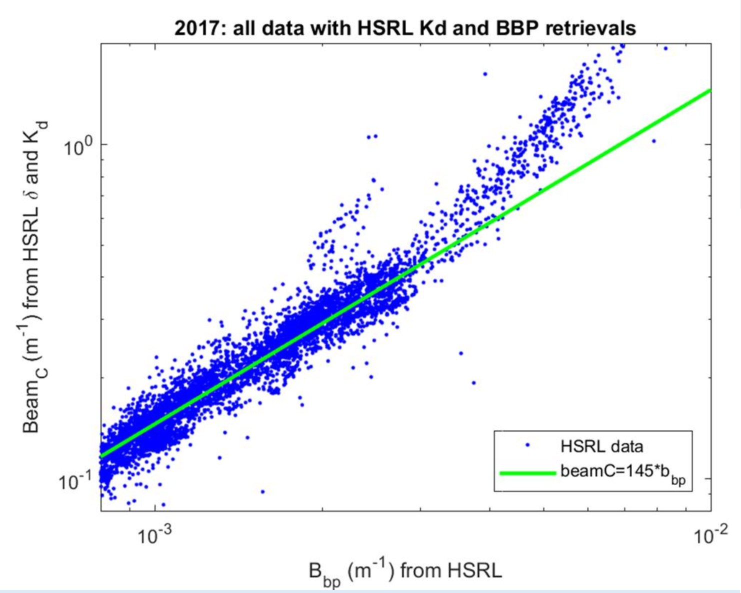


Kd / BeamC = f(depolarization ratio)

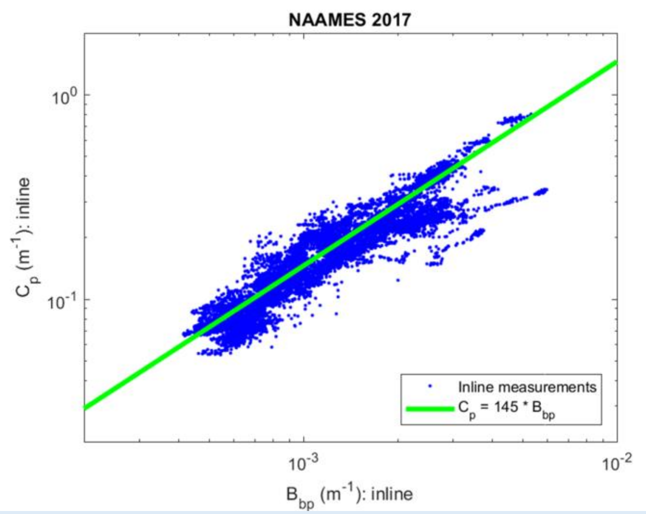


Verification of theory during NAAMES

HSRL Lidar



Ship measurements (Boss and Chase)



What's down the road for lidar besides A-CCP? (e.g., multi-purpose lidar for NASA's Incubator, EV, …)

- Profiling entire mixed layer and deeper
- Dynamic properties as well (e.g., turbulence, salinity)

Will be enabled by lasers with deeper penetrating wavelengths and coherence (e.g., blue laser, OAM beam, entanglement of signal and idler, squeezed photon, …), improved low noise detection (e.g., time-correlated single photon counting; temporal and phase matching techniques such as quantum parametric mode sorting, …)

More importantly:

what do you want NASA to do with lidar ? We want your suggestions