

Ocean subsurface studies from space-based lidar measurements

Xiaomei Lu,¹ Yongxiang Hu,²

¹ Science Systems and Applications, Inc. (SSAI), Hampton, Virginia 23666, USA
(xiaomei.lu@nasa.gov)

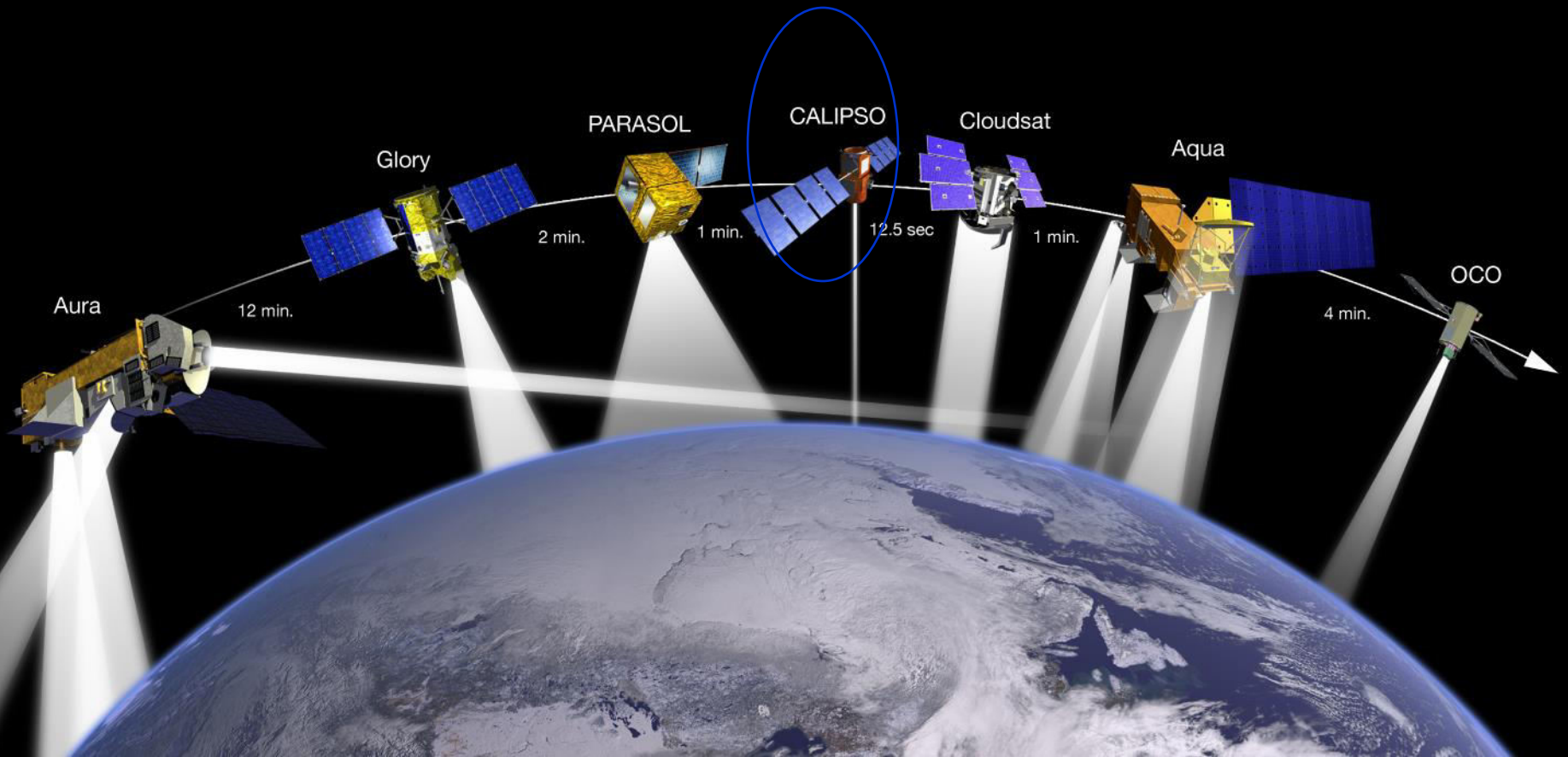
² Atmospheric Composition Branch, NASA Langley research Center, Hampton, VA, 23681, USA
(yongxiang.hu-1@nasa.gov)

Outline

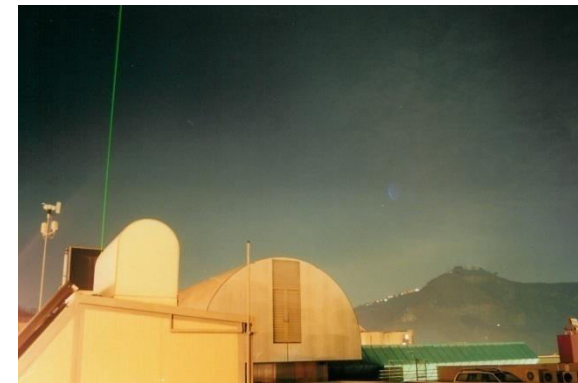
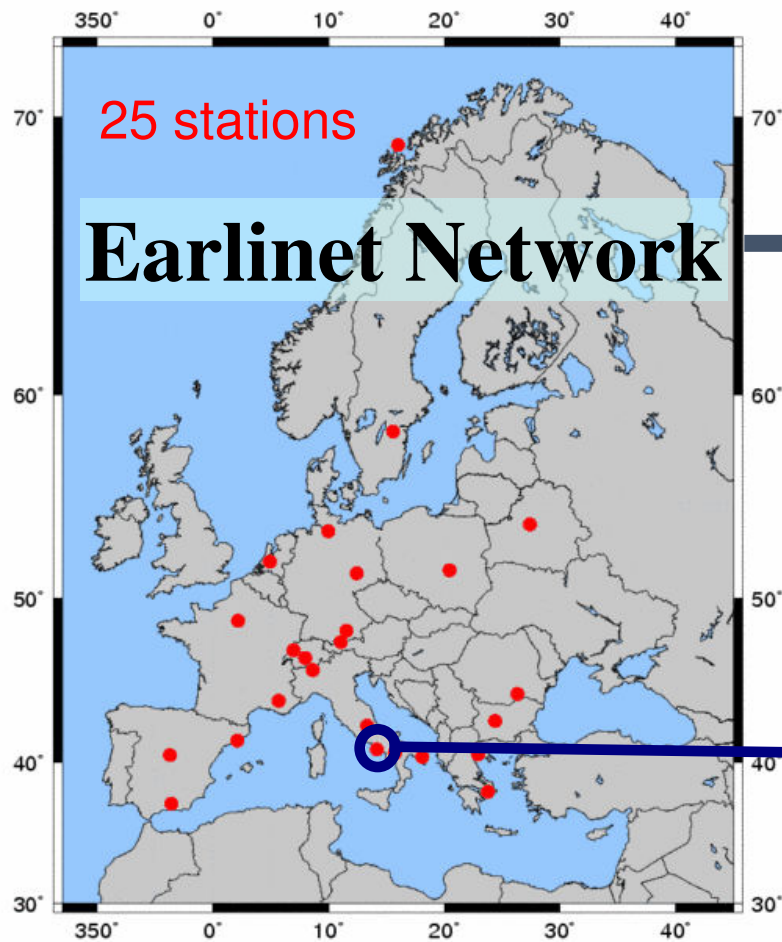
- Space-based and Ground-based Lidar
- Overview of CALIPSO mission
- Ocean Subsurface results from space-based lidar
- Particulate Organic Carbon (POC) Results

Afternoon Constellation Evolution

A-train

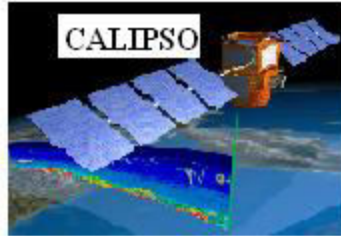


Ground-based lidar-EARLINET



Naples station (40.833° N, 14.183° E, 118 m. asl)

Combing the ground-based and space-based lidar measurements



Naples station
(40.833°N, 14.183°E, 118 m. asl)

Reference:

Xiaomei. Lu, Yuesong. Jiang, Xueguo. Zhang "An Algorithm to retrieve aerosol properties from analysis of multiple scattering influences on both Ground-Based and Space-Borne Lidar Returns," **Opt. Express** 17, 8719-8728 (2009)

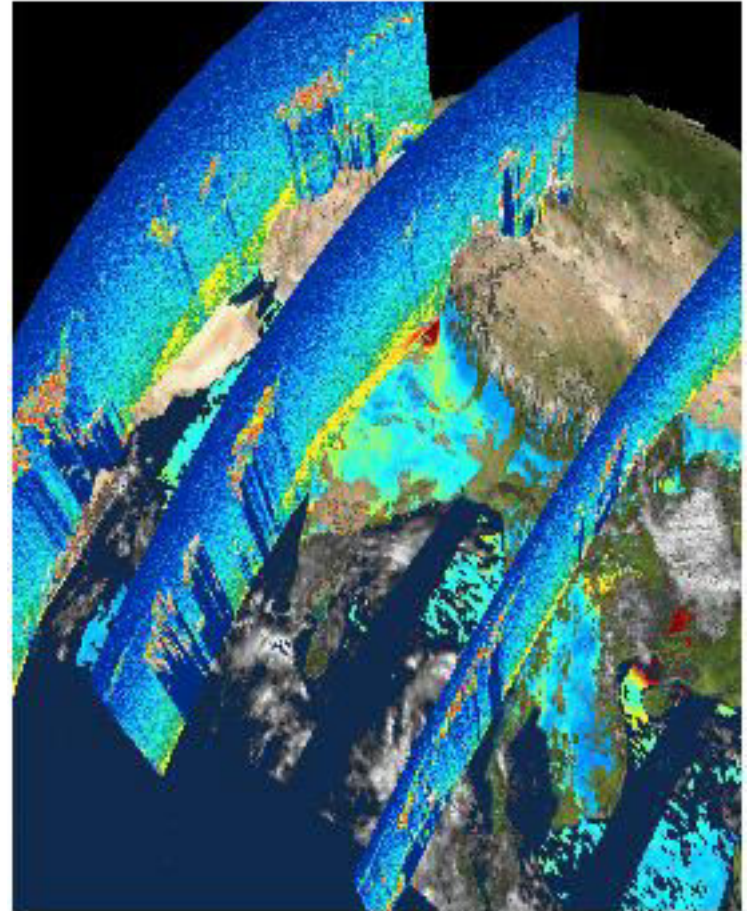
CALIPSO Mission Overview

CALIPSO: lidar measurements of aerosol and clouds

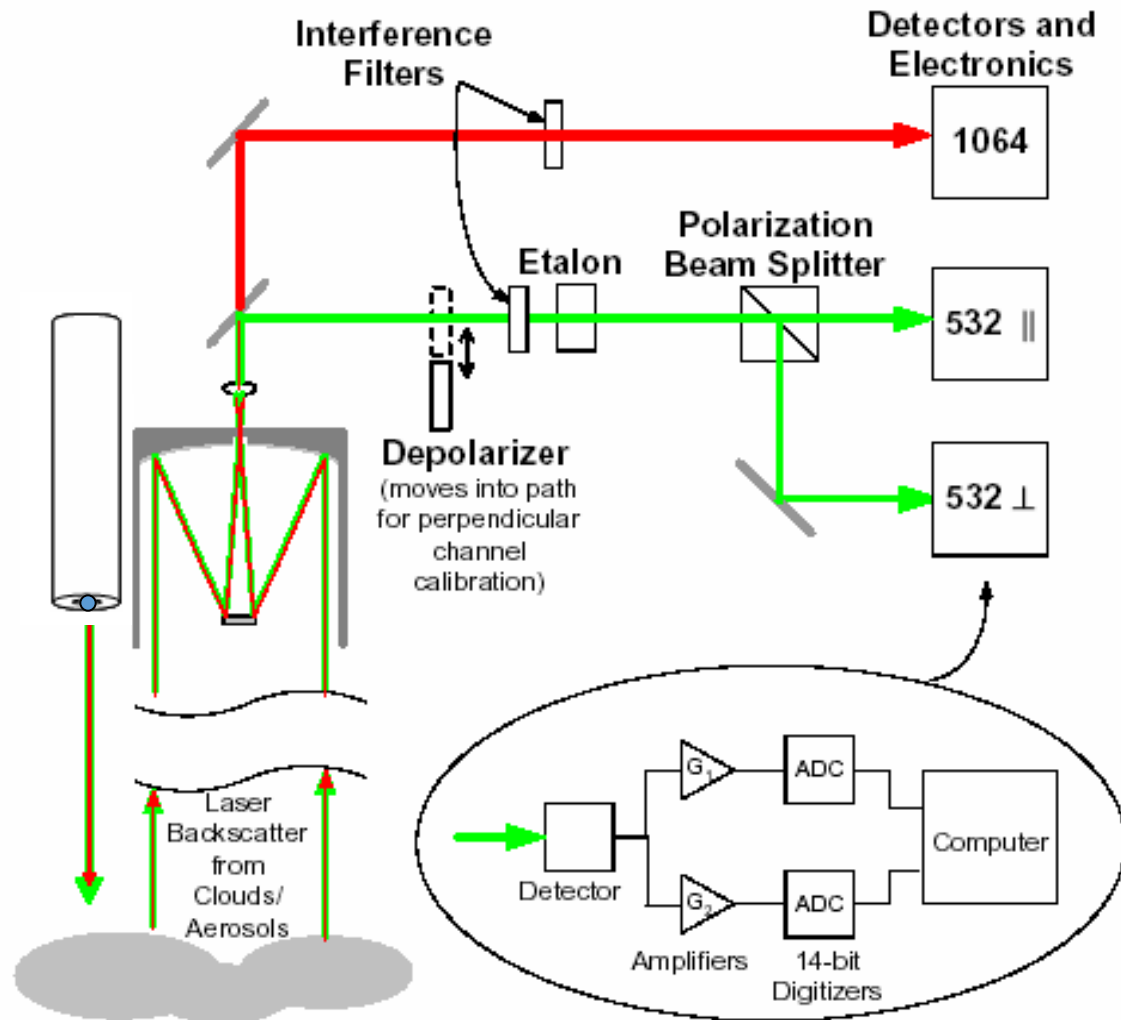
Launched: April 28, 2006

Operational Achievements:

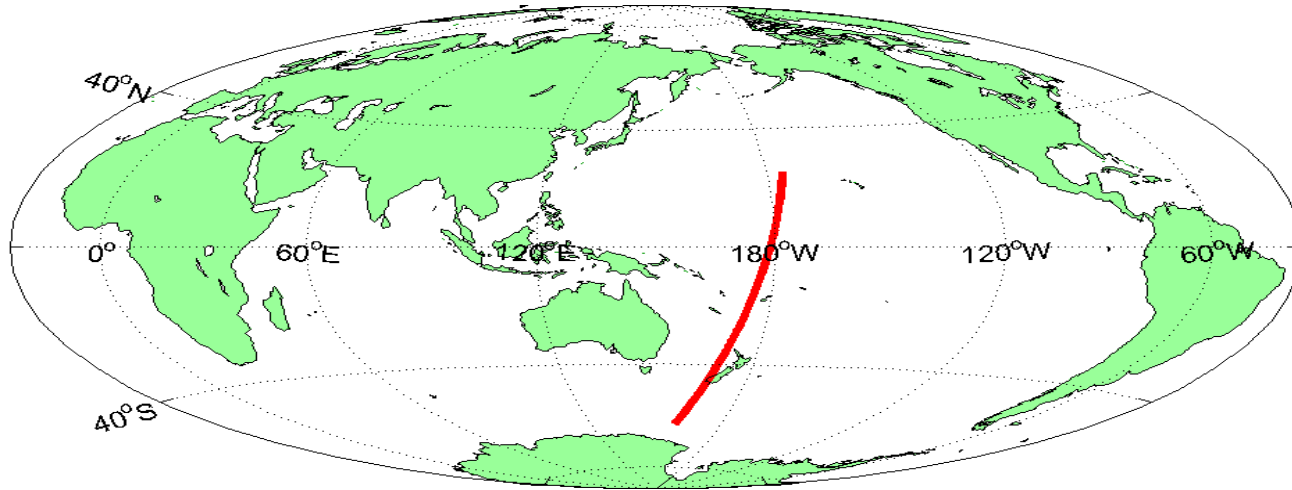
- Long term measurements: CALIPSO collected more than 9 years of measurements so far;
- Observations during day/night and for all seasons
- Data publicly available
- CALIPSO Adds the Vertical Dimension



Lidar station of CALIPSO



30 degree off-nadir measurement for ocean subsurface studies- 2014 July 17 Night



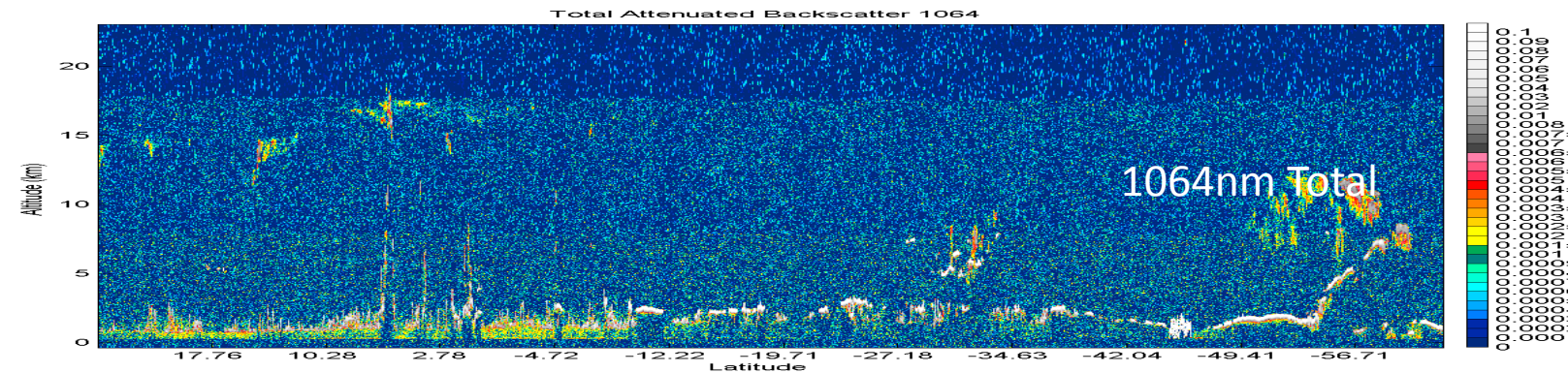
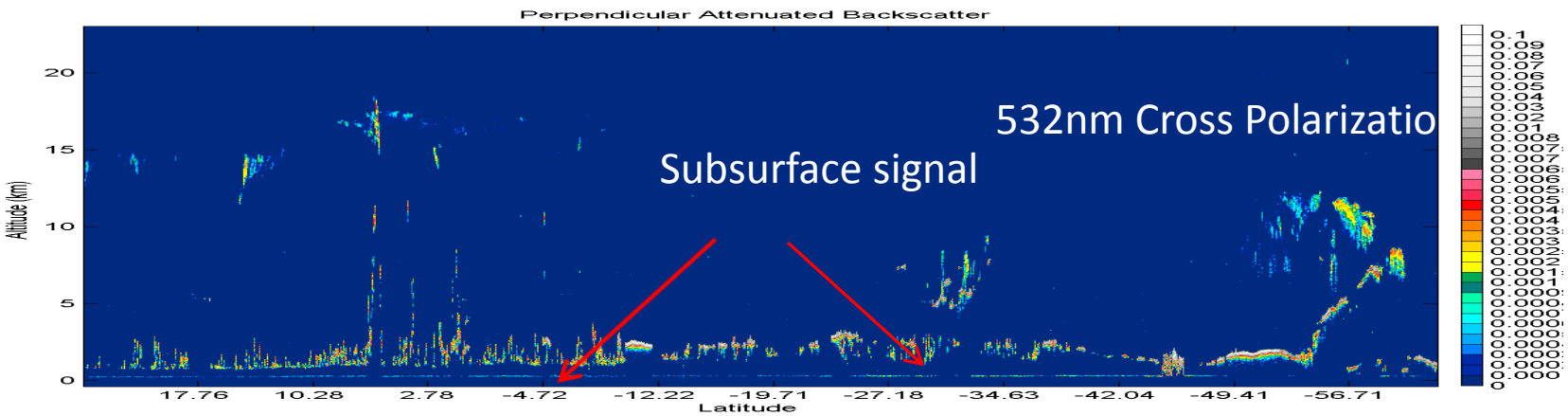
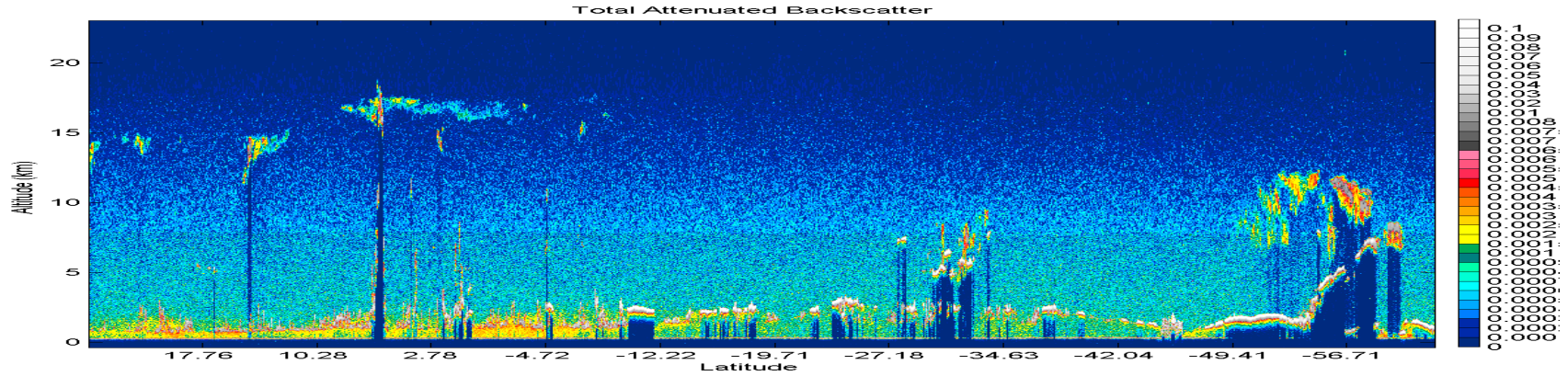
Why pointing CALIPSO 30 degree off-nadir: avoid ocean surface backscatter

1. Direct demonstration of CALIPSO ocean subsurface signals in both co-polarization and cross-polarization to convince the community that CALIOP can measure phytoplankton backscatter
2. Direct measurements of depolarization ratios of phytoplankton backscatter to improve CALIOP estimate of phytoplankton backscatter and biomass estimate

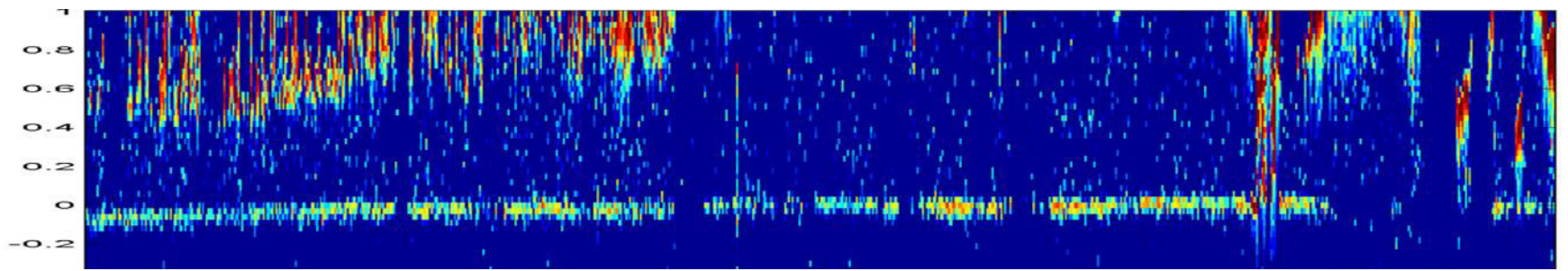
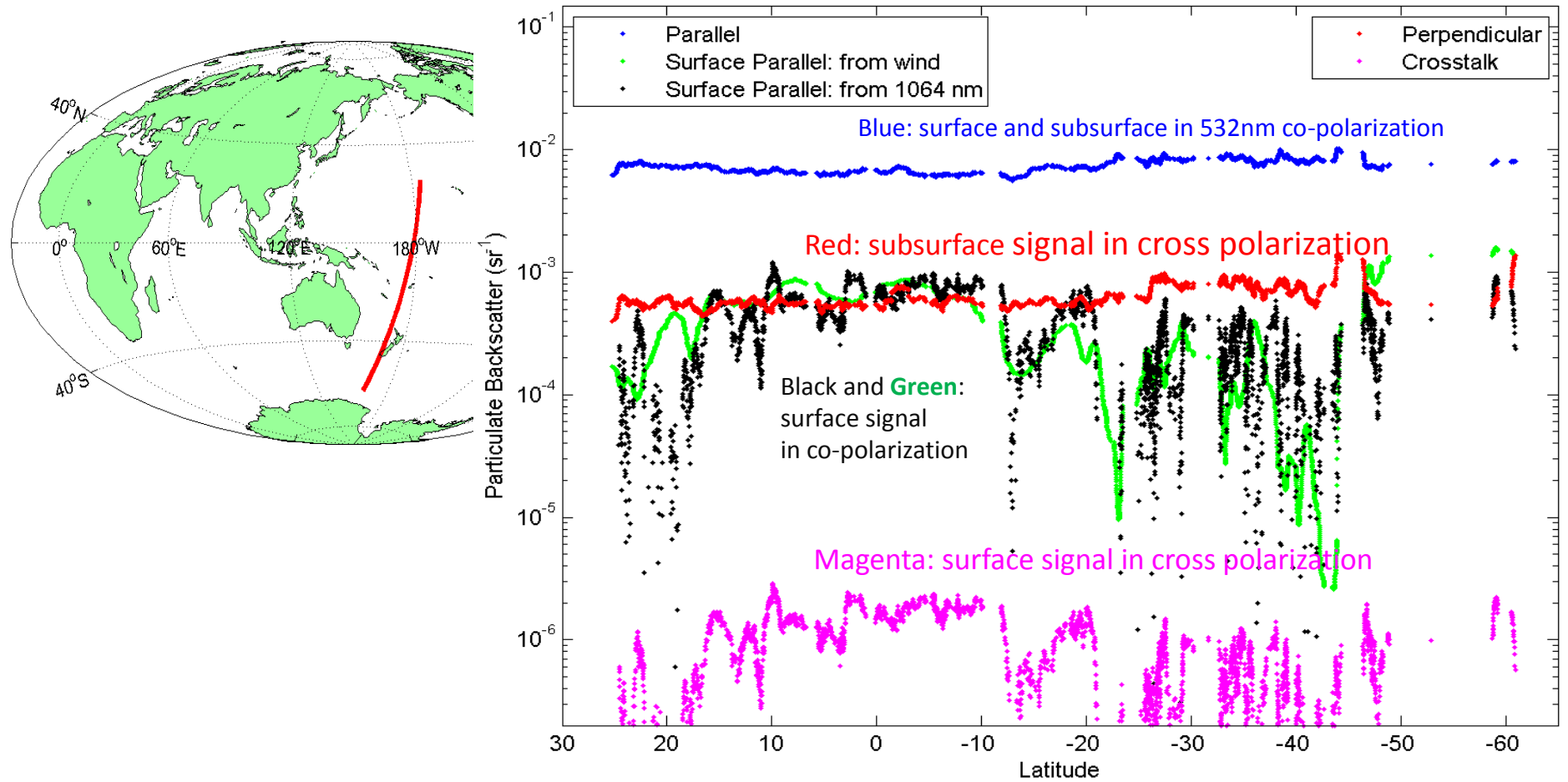
Behrenfeld, Hu, Hostetler, Dall'Olmo, Rodier, Hair, Trepte(2013), Space-based lidar measurements of global ocean carbon stocks, **Geophys. Res. Lett.**, 40, 4355–4360, doi:10.1002/grl.50816.

Lu., Hu, Trepte, Zeng, and Churnside (2014), Ocean subsurface studies with the CALIPSO spaceborne lidar, **J. Geophys. Res. Oceans**, 119, 4305–4317, doi:10.1002/2014JC009970.

subsurface

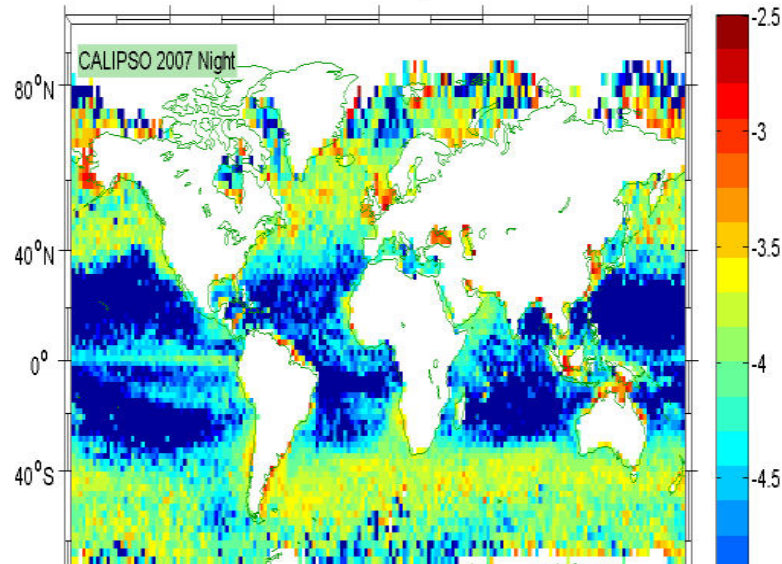
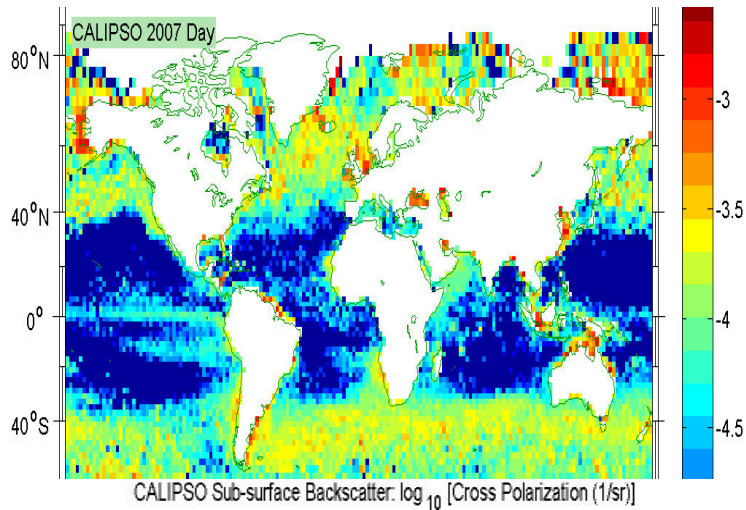


Surface signals are much weaker than subsurface signals and can be corrected using 1064nm measurements

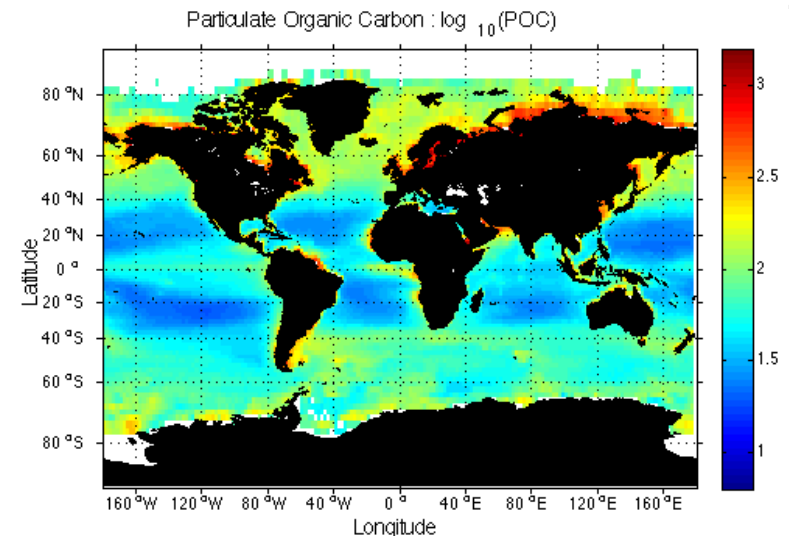
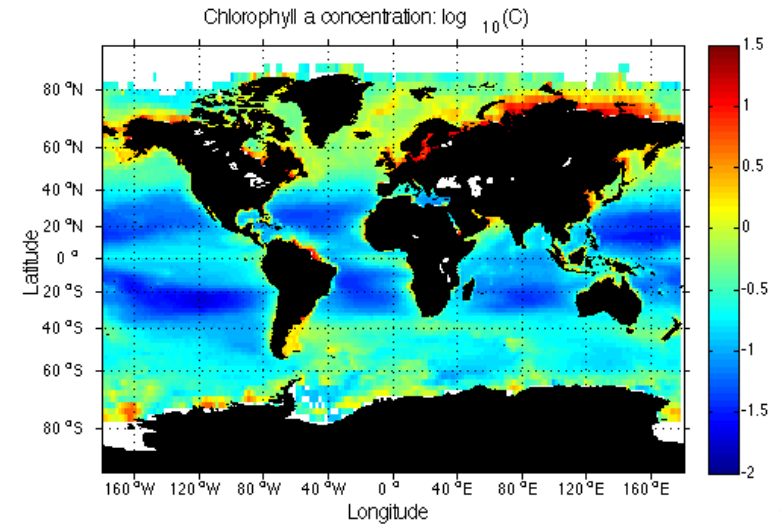


Ocean Subsurface results

Results from CALIPSO

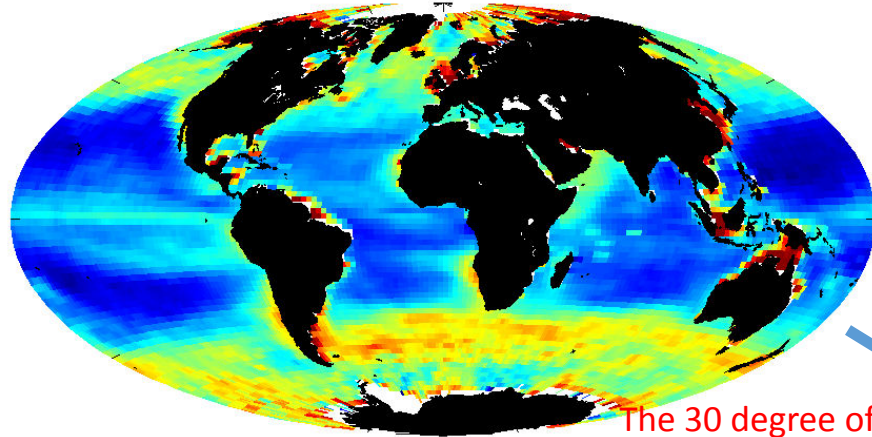


Results from MODIS



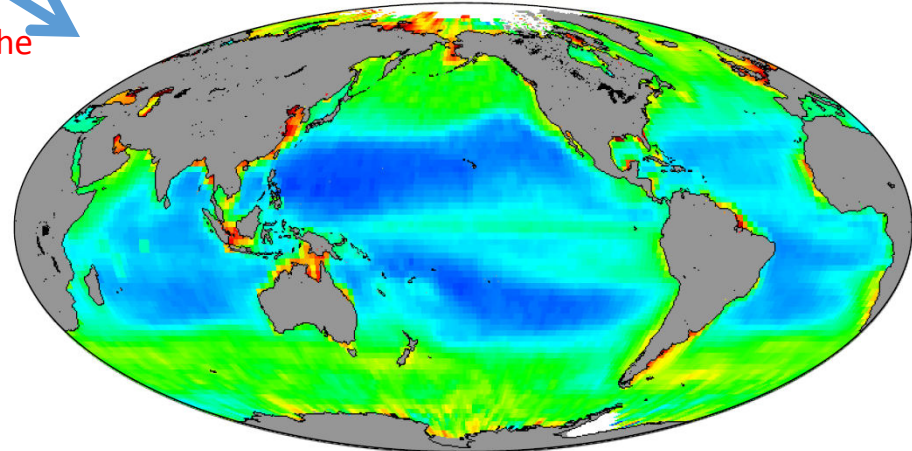
Applications: Improving Phytoplankton Particulate Organic Carbon (POC) Estimate from CALIPSO

CALIPSO Cross Polarization Phytoplankton Backscatter (Sr^{-1})

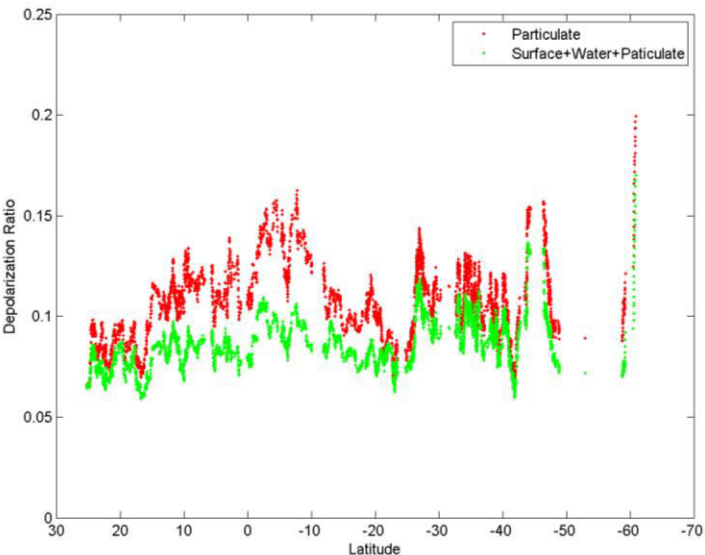


The 30 degree off-nadir measurement verifies the assumption about depolarization ratio

Particulate Organic Carbon (mg m^{-3}) from CALIPSO



Behrenfeld, Hu, Hostetler, Dall'Olmo, Rodier, Hair, Trepte, GRL, 2013



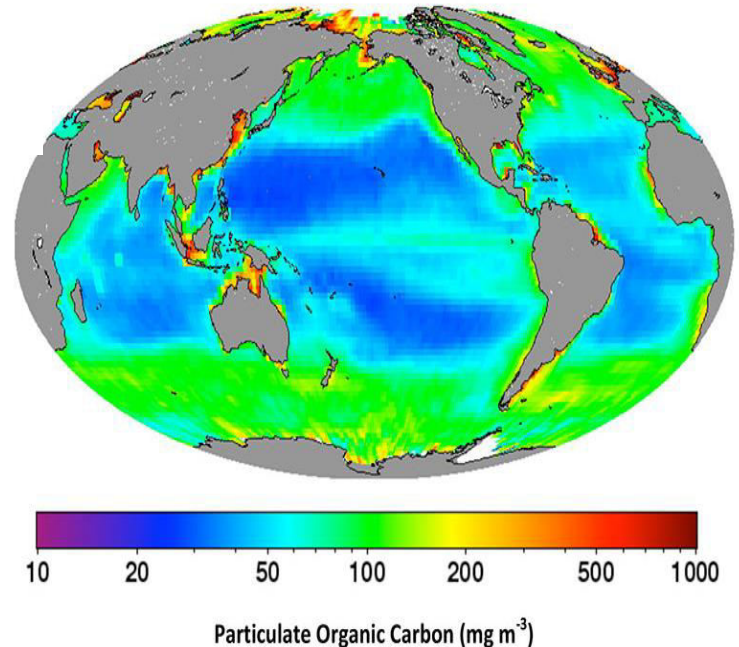
AGU's EOS Research Spotlight on CALIPSO Ocean subsurface measurements

EOS [*Earth & Space Science News*](#)

27 May 2015

[Hacking a Climate Satellite to See Beneath the Ocean's Surface](#)

When NASA launched its CALIPSO spacecraft, the space agency did not intend to estimate phytoplankton populations.



References

1. Behrenfeld, M. J., Y. Hu, C. A. Hostetler, G. Dall'Olmo, S. D. Rodier, J. W. Hair, and C. R. Trepte (2013), Space-based lidar measurements of global ocean carbon stocks, *Geophys. Res. Lett.*, 40, 4355–4360, doi:10.1002/grl.50816.
2. Xiaomei Lu, Yongxiang Hu, Charles Trepte, Shan Zeng, James H. Churnside, Ocean subsurface studies with the CALIPSO spaceborne lidar, *Journal of Geophysical Research: Oceans*, 2014, 119, 7, 4305.

Conclusion

1. CALIPSO satellite is tilted for one night-time orbit in July in order to measure phytoplankton backscatter at 30-degree off-nadir accurately
2. Subsurface signals are clearly seen in both polarization channels of 532 nm (green) CALIOP measurements, where surface signals are one (co-polarization) and two (cross-polarization) orders of magnitudes weaker than subsurface signals.
3. Depolarization ratios of phytoplankton backscatter are measured from space for the first time.
4. The operation helps reduce uncertainty in global carbon biomass assessment using CALIPSO ocean subsurface optical measurements.