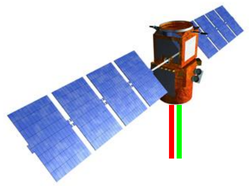

Potential New Lidar Observations for Cloud Studies

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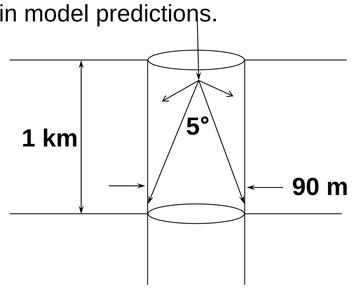
Summary: Shallow clouds dominate uncertainties in cloud feedbacks. High vertical resolution lidar profiles can provide new constraints.

The Problem

The response of clouds to global warming represents a major uncertainty in estimating climate sensitivity. These uncertainties have been tracked to shallow marine clouds in the tropics and subtropics. CALIOP observations have already been used extensively to evaluate model predictions of shallow cloud fraction and top height (Leahy et al. 2013; Nam et al 2012). Tools are needed to probe the lowest levels of the troposphere.

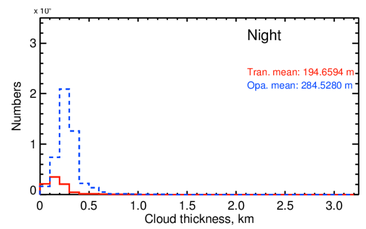
The large footprint of satellite lidars gives large multiple scattering from clouds which presents new possibilities for cloud retrievals to constrain model predictions.

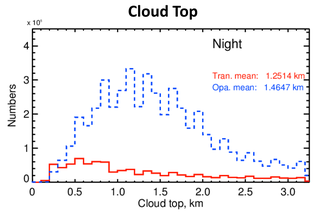
CALIOP viewing geometry:
altitude: 705km
receiver FOV: 130 μrad
footprint diameter: 90 m



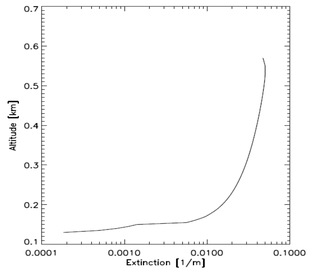
Observations from CALIOP

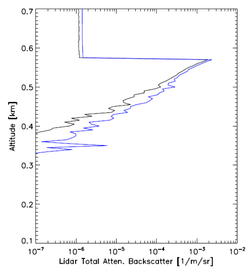
Cloud base height can also be measured for optically thin clouds (OD < 3), which tend to also be very shallow..





A retrieval of cloud droplet number concentration (CDNC) has also been developed (Zeng et al, 2014). This retrieval relies on MODIS effective droplet diameter (De) but does not depend on the MODIS assumption of cloud adiabaticity. Thus, discrepancies between the two CDNC retrievals are a marker for non-adiabaticity.





New Cloud Observations

Simple modifications of the CALIOP lidar could provide interesting new retrieval capabilities

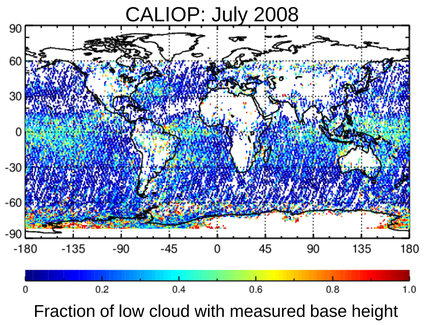
1)Altitude resolution from 30 m → 5 m would allow retrieval of extinction profiles in the cloud-top entrainment zone, critical for radiative-cooling.

2) An algorithm for deriving CDNC from CALIOP cloud-integrated signals and MODIS De has already been developed (Zeng et al. 2012). Retrieval of De from 2-λ depolarization profiles could then retrieve CDNC and De both day and night

3) Multiply-scattered lidar signals contain information on the thickness of shallow stratiform cloud. Dual FOV lidar (100 urad, 1 mrad) could allow retrieval of base height of opaque cloud layers.

CALIOP currently measures cloud base where clouds are broken or optically thin:

The challenge is to retrieve cloud base for overcast clouds with OD > 3. Multiply-scattered profiles from wide-FOV lidar contains information on cloud thickness (Davis et al, 2009) and may allow retrievals of cloud base height.



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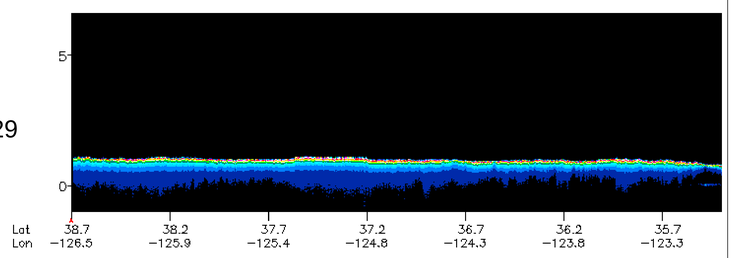

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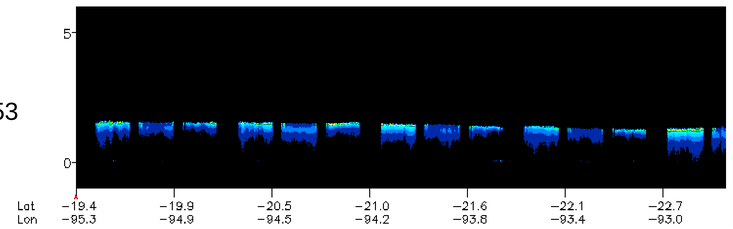

References:

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Louise Leahy, 2012: "On the nature and extent of optically thin marine low clouds", *J. Geophys. Res.*, **117**, D22201, doi:10.1029/2012JD017929

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Shan Zeng, et al., 2014: "Study of cloud droplet number concentration using the A-Train satellites", *Atmos. Chem. Phys.*, **14**, 7125–7134, doi:10.5194/acp-14-7125-2014.

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Water Vapor

Our current limited capabilities to measure water vapor in the lower troposphere – in and above the marine boundary layer – limit our abilities to understand critical cloud processes (eg: entrainment).

Differential absorption water vapor lidar (WV DIAL) can profile water vapor in and above the marine boundary layer at high resolution. Measurement simulations for an airborne instrument now in development at NASA LaRC illustrate capabilities in field campaign mode. Accuracies better than 5% at spatial resolutions of 150-300 m vertical and 6 – 20 km horizontal are achievable.

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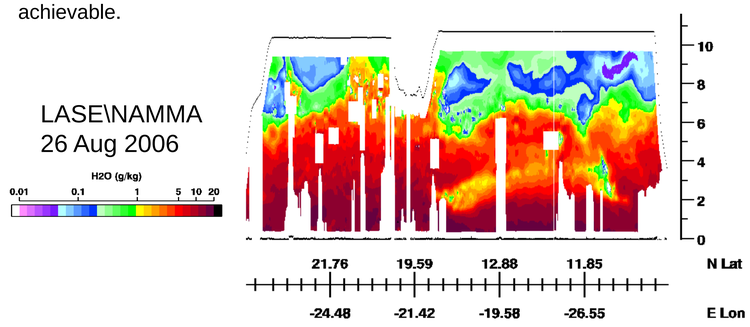
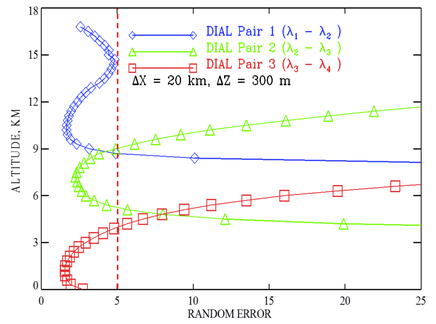
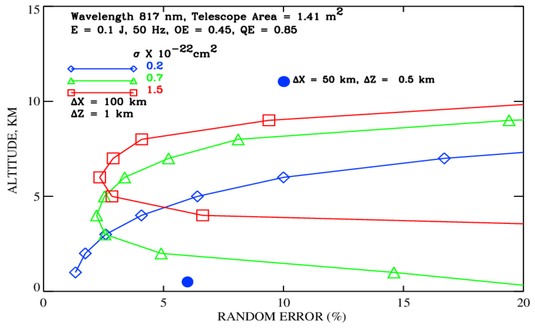


Use of 3 pairs of wavelengths near 935 nm enables water vapor profiling from UTLS to surface

Simulated water vapor profile measurements from the high altitude ER-2 aircraft. Multiple wavelengths allow good accuracy throughout the troposphere.



This technology is scalable to space for the next generation of active remote sensors:



Summary:

Shallow marine clouds are at the heart of current uncertainties in cloud feedbacks and limit our abilities to predict climate change.

Lidar is the only technique with sufficient vertical resolution to probe these clouds in detail. CALIOP has demonstrated the capabilities of satellite lidar to measure the occurrence and vertical distribution of shallow clouds. Future satellite lidars could provide additional measurement capabilities including cloud-top De, profiling, and retrievals of the base height of optically thick cloud.