Typhoon Nida; November 28, 2009

Typhoon Nida was the most intense tropical cyclone during 2009, with a minimum central pressure of 980 hPa. Nida formed late in the season from a monsoon trough, and became a Category 5 Typhoon. The A-Train had an overpass of the storm when it was at or near maximum intensity, with sustained winds of 150 knots and central pressure of 980 hPa. The A-Train was near the eye of the Typhoon, which was in this case covered at high altitude with cirrus clouds observed by the IR and CALIOP. The radar observed heavy rain near the ocean surface. The Nida overpass makes an ideal case study for understanding how the instruments perform while observing deep convection. The optical depth of the storm varies, so a comparison can be made of one big convective system that has many varied conditions associated with it. The core of Nida is opaque to the lidar, but the edges of the storm are transparent. The cloud tops reach to 18 km, not only above the eyewall and core, but also at the transparent edges of the storm where they remain as high. CALIOP sees a very thin, weak layer of barely visible cirrus at 19 km above the eye. The IR has shown the variation in effective particle size and optical properties. This Typhoon suggests that a much more detailed case study of Typhoon Nida will be rewarding.

The View from the Top: CALIOP Ice Water Content in the Uppermost Layer of Tropical Cyclones

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Introduction: NASA’s CALIOP satellite carries both the Cloud and Aerosol Lidar with Orthogonal Polarization (CALIOP) and the Imaging Infrared Radiometer (IRR). The lidar is ideally suited to viewing the very top of tropical cyclones, and the IRR provides critical optical and microphysical information. The lidar and the IRR work together to understand storm clouds since they are perfectly co-located, and big tropical cyclones provide an excellent complex target for comparing the observations. There is a lot of interest from these case studies for understanding both the observations and the tropical cyclones, and we are just beginning to scratch the surface of what can be learned. Many tropical cyclone cloud particle measurements are found on the mid and lower regions of storms, but characterization of cyclone interaction with the lower atmosphere may be important for determining the total momentum and moisture transport budget, and perhaps for predicting storm intensity as well. A surprising amount of cloud ice is to be found at the very top of these big storms.

CALIOP measures 532 nm backscattered light, at both parallel and perpendicular polarizations. The backscattered signal, with 60 nm vertical resolution, provides an accurate measurement of tropical cyclone cloud top heights. Ice water content is parameterized from optical extinction coefficients, using an empirical relationship derived from aircraft measurements (Heymsfield et al., 2005). Extinction coefficients are retrieved at the 532 nm band penetrates the cloud deck, until attenuation occurs at an effective optical depth of approximately three, with some penetrations depths greater than this due to multiple scattering effects. Depolarization by cloud ice particles provides some insight about particle phase and habit. CALIOP sensitivity to cloud ice water content in the uppermost layer is 0.1 mg/m³ Avery et al. (2012), a detection range that includes sub-visible cirrus and allows CALIOP to accurately measure cloud top height in the storm core and also in the associated rain bands and extended cirrus ahead.

The IRR has 3 medium-resolution channels centered at 8.65, 10.6, and 12.05 µm. The Level 1 IRR radiances are registered on a reference grid centered on the CALIOP ground track, with 1 km horizontal resolution over a 68 km swath. Effective emissivities and optical depths are retrieved for suitable scenes selected according to the vertical information provided in the CALIOP Level 2 products (Garnier et al. 2013a). Ice crystal effective diameters are derived using a split-window technique and two effective microphysical indices are defined as the 12.5-0.8 and 12.05-12.65 ratios of the natural logarithm of the co-emissivities (Pentz et al. 1991; Garnier et al. 2013a). Three crystal models have been selected in the ERBE long wave data base in 2000 as representative of the families of relationships between both microphysical indices. The IRR’s MIP are built deriving the FRAUDOM radiative transfer model (Dublasun et al. 2009a) assuming a mono-disperse distribution. The shape index (7 for plates-like, 9 for columns-like) and 9 for solid-columns-like) refers to the crystal model providing the best agreement between the 12.5±0.8 and 12.05±12.65 infrared cloud ice water paths (WIP) is estimated from a simplified expression linking optical depth and effective diameter as in Stephens (1978).

LITE Observes Super Typhoon Melissa

The first Black and White composite of clouds observed in a tropical cyclone from space. The first observations of Super Typhoon Melissa, on September 15, 1994, with 532 nm backscatter measured by the Lidar In-space Technology Experiment on Space Shuttle Discovery. The mission was a critical precursor to the Clouds and the Lidar with Orthogonal Polarization on the CALIOP satellite, operational in June, 2006. The Lidar was described in Dibben et al. (1999).

The CALIOP and IRR operational products (Version 3) are available at:
NASA LaRC ASDC (http://eosweb.larc.nasa.gov/) and ICARE (http://www.icare.univ-lille1.fr/)

References:
Mesinger and Deng (2011) CALIOP Process Description Document
Mesinger and Deng (2011) CALIOP Process Description Document
Platt et al. (2003), J. Appl. Meteor., 42, 195-209
Winker et al. (2000) Appl. Optics, 39, 6270-6289

Hurricane Sandy; October 29, 2012

NOAA/NASA GOES-13 15 µm IR images from October 29, 2012, enhanced by the SSEC at the University of Wisconsin, CIESM. The images show the saturated enhancement and merging with an extratropical system just before Sandy. The CALIOP Satellite retrieval tracks these overpasses of Sandy on this day occurred at ~7:15 UTC (nighttime overpass, outlaid in blue) and ~17:15 UTC (daytime overpass, outlaid in red). During the night the VIRS instrument also captured an image of Sandy with Day/night DayMODIS and CloudSat also provide data.

A) Total Backscatter

These images were made with the VIRS day/night band using data from the lidar footprint. The IRR’s MIP is much larger, the CALIOP satellite overpass points in green. windy points A, B, C and D, and with the corresponding low points on the CALIOP and IRR data plots. The smaller image shows the location of Hurricane Sandy on the previous NPP MODIS split band IR swath images of Hurricane Sandy.

B) Cloud Temperature and Ice Water Path

Cloud Temperature and Ice Water Path: Plot A is the cloud temperature and average temperature from the SABO GEOS 5.27 interpolated meteorological assimilation. The range of temperature is largest for the extratropical clouds. Plot B and C are the CALIOP ice water path. The blue line indicates the thick clouds and rain, while CALIOP provides cloud top height and ice water content above 15 km.

C) Ice Water Content

Climatological melt of a tropical cyclone from space. These first attempts to characterize Super Typhoon Melissa, on September 15, 1994, with 532 nm backscatter measured by the Lidar In-space Technology Experiment on Space Shuttle Discovery. The mission was a critical precursor to the Clouds and the Lidar with Orthogonal Polarization on the CALIOP satellite, operational in June, 2006. The Lidar was described in Dibben et al. (1999). Daytime overpass of Sandy, just before landfall. The A-Train passed over the western edge of Hurricane Sandy on October 29 at ~17 UTC, 3 am EDT. The images illustrate how the CloudSat radar and CALIOP are in providing a rapid assessment of the Hurricane. CloudSat (left) identifies the thick lower clouds and rain, while CALIOP provides cloud top height and ice water content above 15 km.

Anvil Clouds at 0.63 µm from the CALIOP on the left, with IIR Ice Water Path on the right. The IIR channel is 15-20 km deeper, which is consistent with the CALIOP observations. Optical and Microphysical Cloud Particle Properties derived from the IRR 8.65, 10.6 and 12.05 µm channels also show the difference between the more tropical and extratropical Cirrus associated with Sandy. The optical depth (D) and effective diameter (D) is larger in the extratropical Cirrus as compared to the ice water path (O). A shape index also varies (H: 7 for aggregative-like, 8 for plate-like, and 9 for solid-columns-like).

Hurricane Sandy Ice Water Content from CALIOP

The CALIOP phase detection, extinction qualification flag. GEOS 5.27 is the current production version of the GCM for use in the CloudSat and CALIOP retrieval. The CALIOP extinction retrieval uses a range invariant extinction to backscatter (laser) ratio (Young and Vaughan, 2003) for each 5 km horizontally analyzed segment of cloud. A constant lidar ratio may not always be true for deep convective clouds.

These observations were made with the VIRS day/night band using data from the lidar footprint. The IRR’s MIP is much larger, the CALIOP satellite overpass points in green. windy points A, B, C and D, and with the corresponding low points on the CALIOP and IRR data plots. The smaller image shows the location of Hurricane Sandy on the previous NPP MODIS split band IR swath images of Hurricane Sandy.