



Tropical Three-dimensional Cloud Climatology during El Niño Events with CALIPSO Level-3 Cloud Products



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Abstract

A previous case study showed opposite cloud anomalies at high, middle and low altitude regions during a weak 2006/2007 El Niño and a moderate 2009/2010 El Niño. In this work, we use CALIPSO L3 Cloud Products to provide a comprehensive picture of cloud anomalies during all recent five El Niño events since 2006, with a particular focus on thin cirrus clouds at high altitudes, which are challenging for passive sensor detection algorithms. Specifically, the vertical cloud anomalies are calculated with the L3 3-D Cloud Occurrence Product, the horizontal cloud anomalies are from the L3 GEWEX product, and the ice cloud extinction profiles and ice water content are obtained from the L3 Ice Cloud product. These findings will improve current knowledge of ENSO from a new perspective.

Overview of three CALIPSO L3 Cloud Products

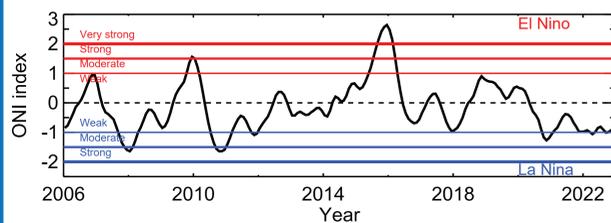
Cloud Occurrence Product and CALIPSO-ST GEWEX product

- **Input data:** V4.10 L2 5-km merged layer (05kmMLay) product;
- **Output data:** day, night, day + night;
- **Quality filters** applied to L2 data: confident cloud feature; high confidence cloud phase; exclude low altitude water clouds identified from coarse horizontal averaging (cloud top ≤ 8.2 km, HA = 5/20/80 km);
- **Cloud Occurrence Product** reports vertically resolved cloud occurrence at 60-m vertical resolution from -0.5 km to 20.2 km, and horizontal grid 2.5° lon by 2.0° lat. Cloud observations are represented as sample counts;
- **CALIPSO-ST GEWEX product** provides column cloud amount, low-level, mid-level, and high-level cloud amounts at horizontal 1.0° lat by 1.0° lon grid.

Ice Cloud Product

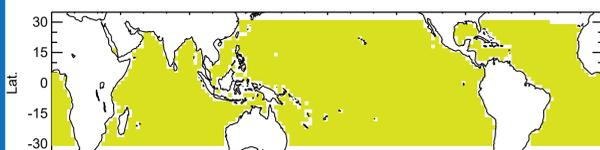
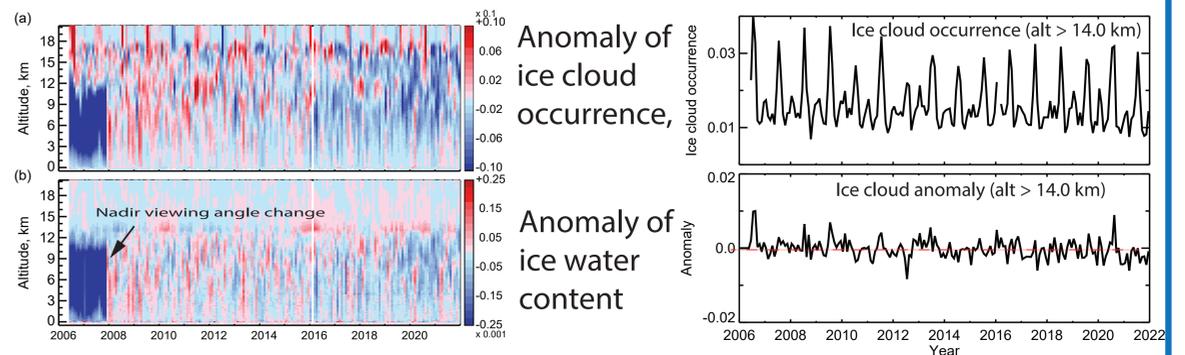
- **Input data:** V4.10 L2 5-km profile (05kmCPro) product;
- **Output data:** day, night, day + night;
- **Quality filters** applied to L2 data: confident cloud feature; high confidence ROI; extinction QC and uncertainty test; range filter; overlying optical depth threshold filter (OverlyingOD ≤ 2.0);
- **Ice Cloud Product** reports histograms of ice cloud extinction coefficients and ice water content at 120-m vertical resolution from -0.5 km to 20.2 km, and horizontal grid 2.5° lon by 2.0°.

Recent El Niño events



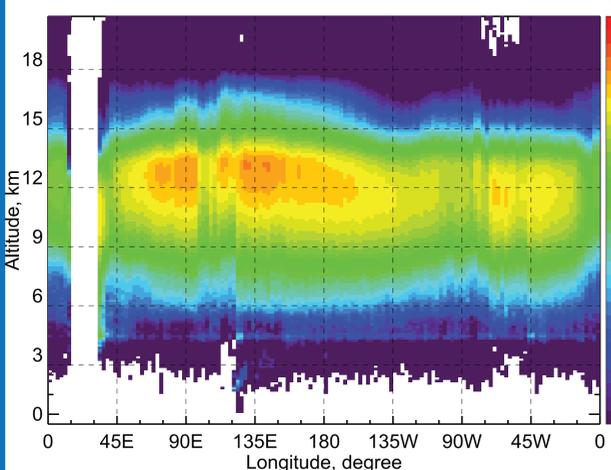
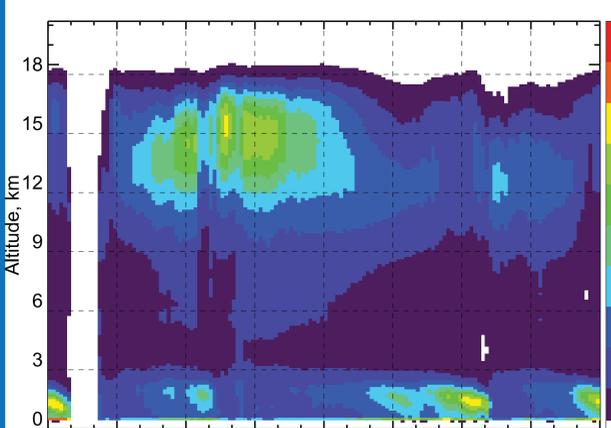
El Niño	Category
2006-2007	Weak
2009-2010	Moderate
2014-2015	Weak
2015-2016	Very strong
2018-2019	Weak

Global long-term trend of ice clouds



Tropical cloud climatology

- Tropical ocean 30° S - 30° N 100% water surface day + night 2006/06 - 12/2016
- All cloud occurrence

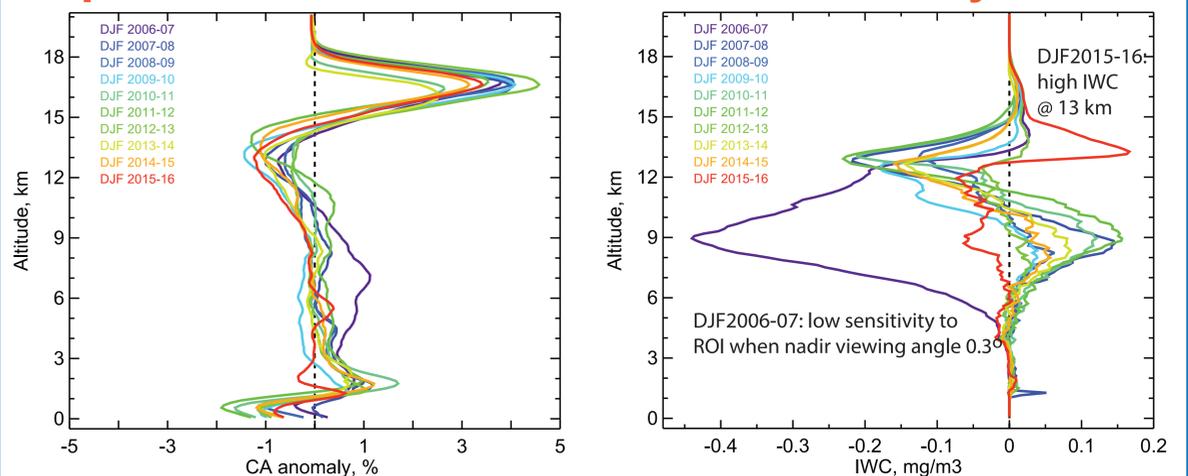


- Ice water content

Acknowledgements

This work was supported by NASA SMD through the CALIPSO project

Tropical ice cloud occurrence and IWC anomaly



Discussion and summary

- CALIOP detection sensitivity of ROI is affected by nadir viewing angle. It is lower with angle 0.3° than 3.0°. It impacts considerably the retrieved IWC.
- Opposite middle cloud anomaly is observed in 2006-2007 and 2009-10. Similarly opposite IWC anomalies at high and middle altitude are seen in 2015-2016 and other El Niño events.
- CALIPSO L3 cloud products are specially designed for cloud climatology analysis. They allow convenient seasonal, annual and interannual aggregation. They also provides valuable information on thin cirrus clouds at high altitude.