Invisible Clouds' Effect on Earth's Radiation and Aerosol Retrieval

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Introduction

Invisible clouds in this study mean super-thin clouds which cannot be detected by MODIS but are classified as clouds by CALIPSO.

These sub-visual clouds may exist globally and may have effects on Earth-atmosphere radiation budget and remote sensing of aerosols.

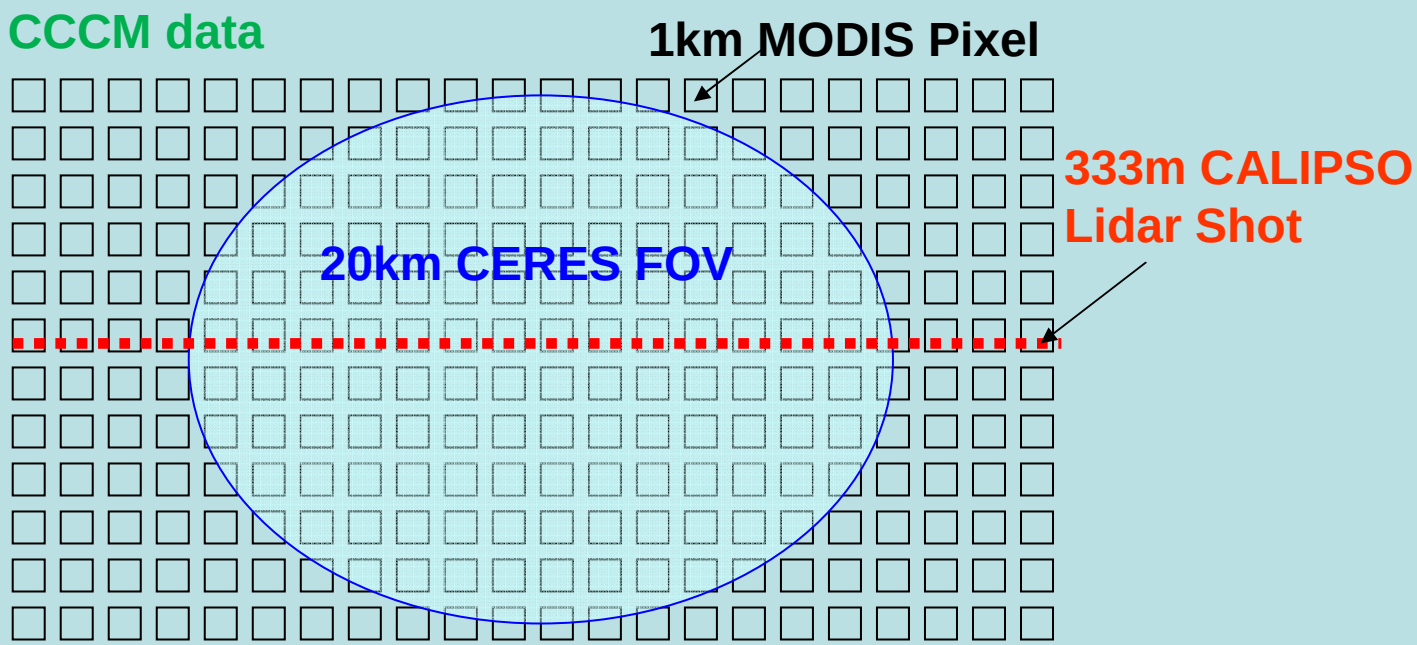
What are the infrared and shortwave radiation effects of these clouds?

In this study, 12-month (Jul 06 - Jun 07) CERES, MODIS, CALIPSO, and AIRS measurements are analyzed for these clouds.

Method and Data

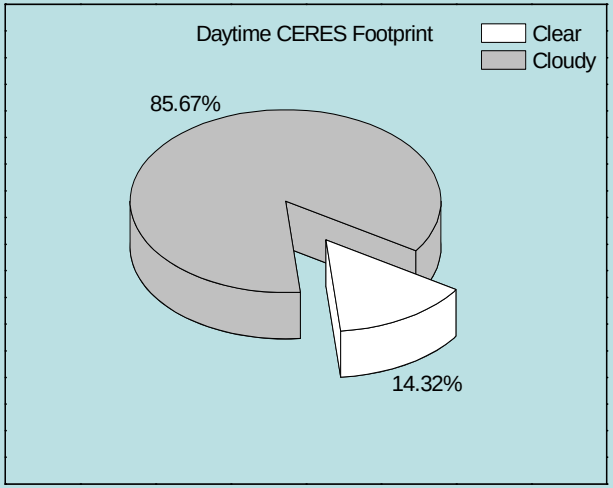
AIRS data – L3 daily 1°x1° gridded standard retrieval product V5

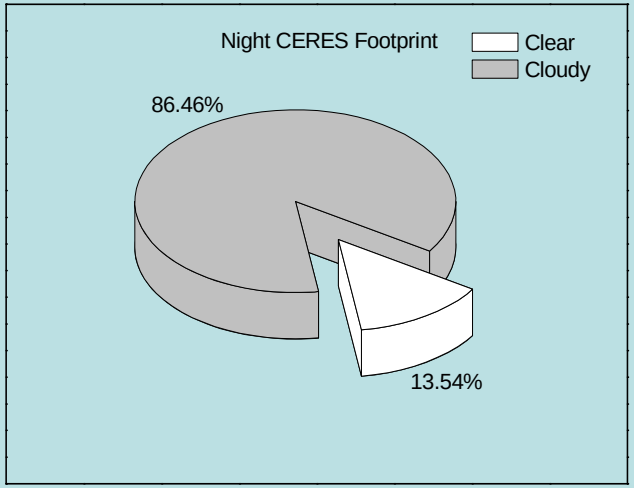
CCCM data – CERES, CALIPSO Beta, MODIS, and MOA



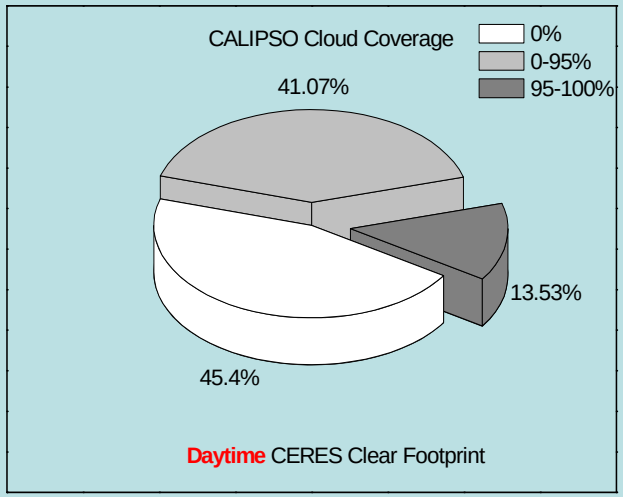
- **Cloud coverage percentage is calculated using along-CALIPSO-track CALIPSO and MODIS data.**

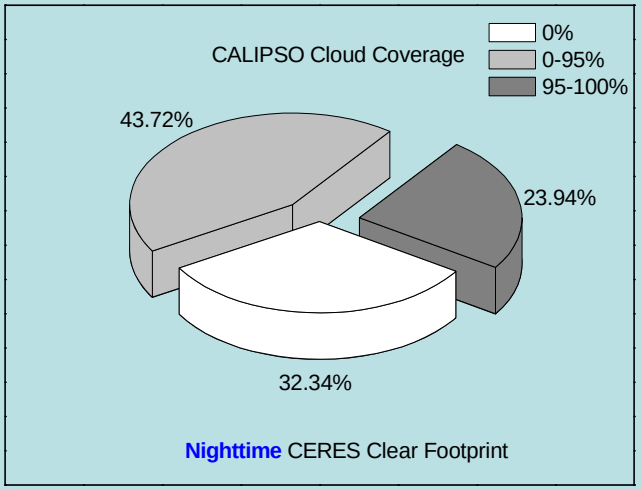
- **Radiation energy budget effect of invisible clouds is estimated on CERES FOVs of MODIS clear and CALIPSO cloudy.**





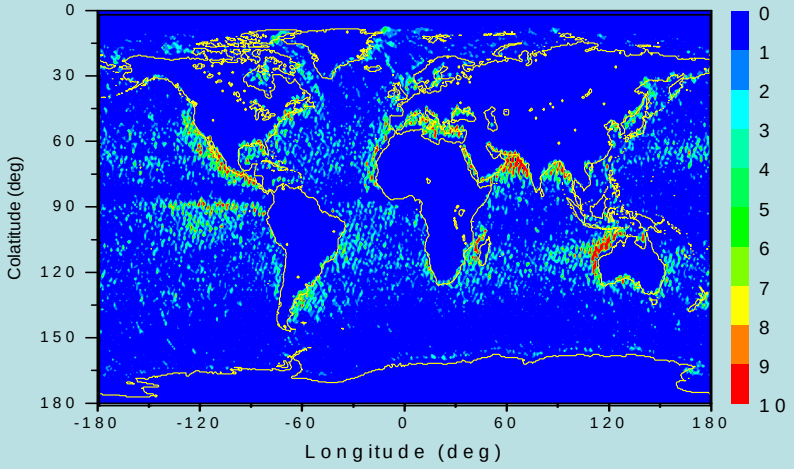
MODIS-derived 12-month clear percentage



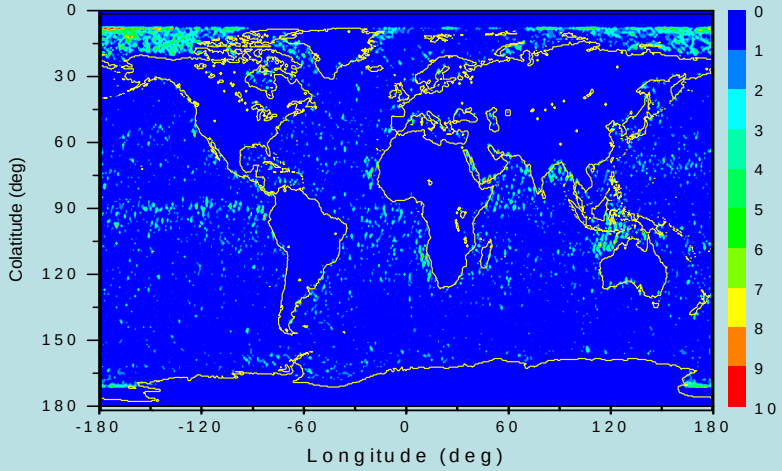


CALIPSO-derived cloudy percentage in MODIS-clear cases

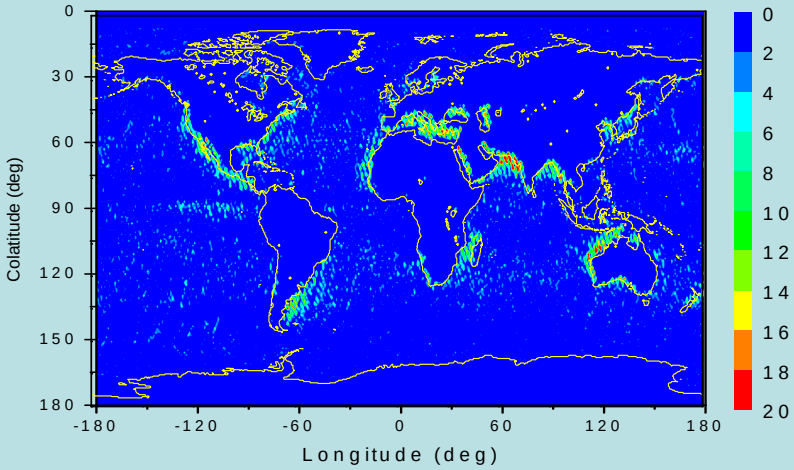
12-month CERES FOVs Sampling Distribution



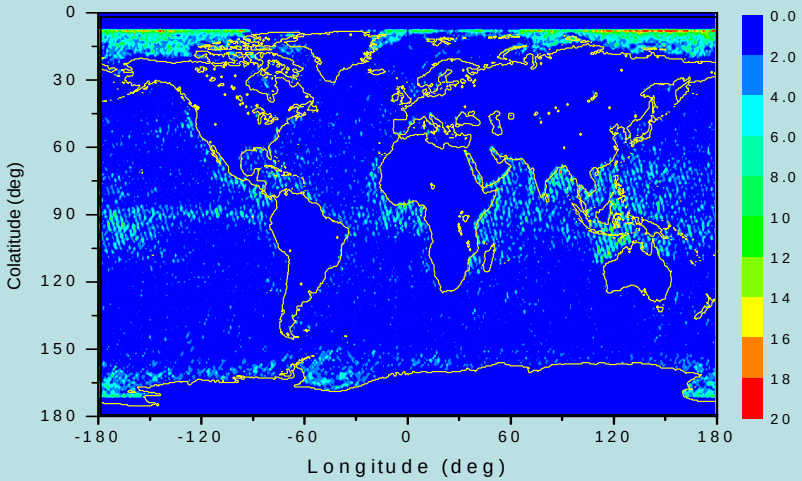
Daytime Purely Clear



Daytime Invisibly Cloudy

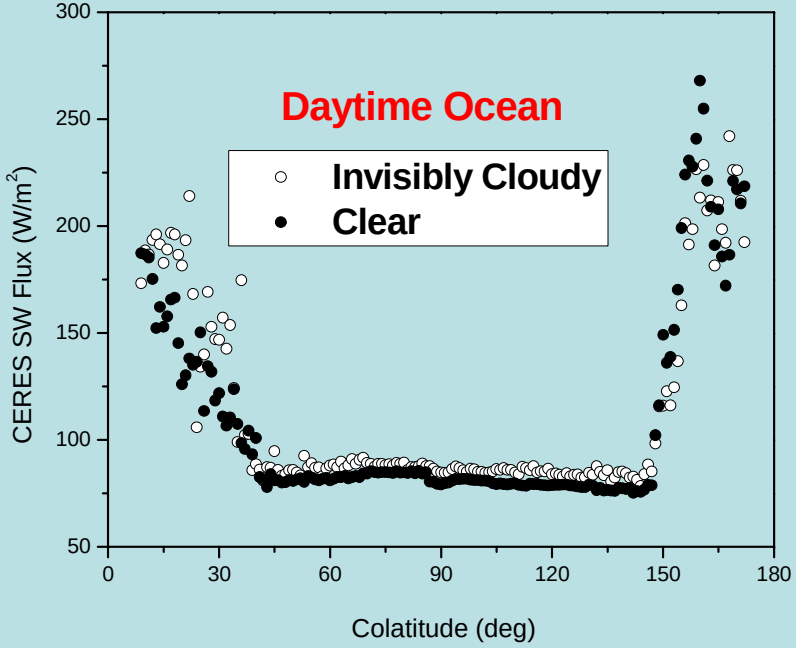


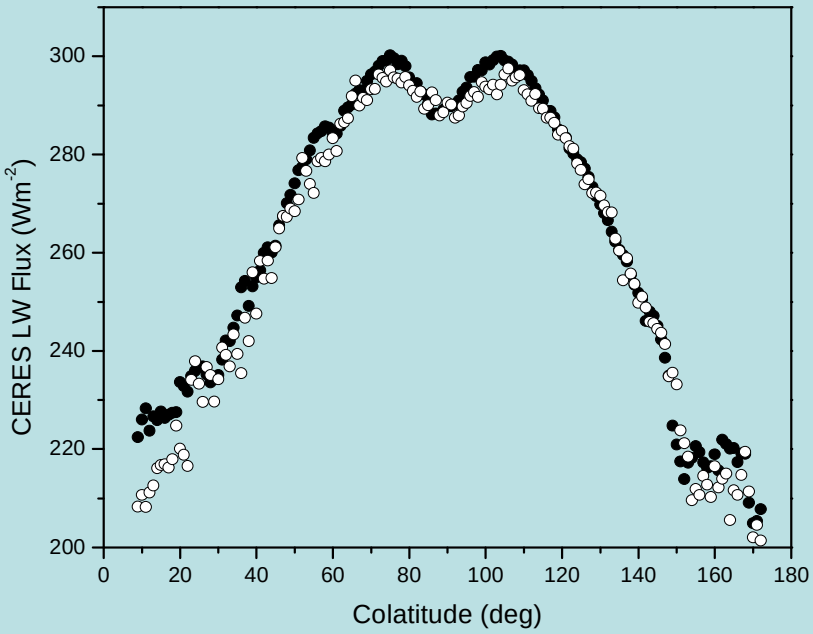
Nighttime Purely Clear

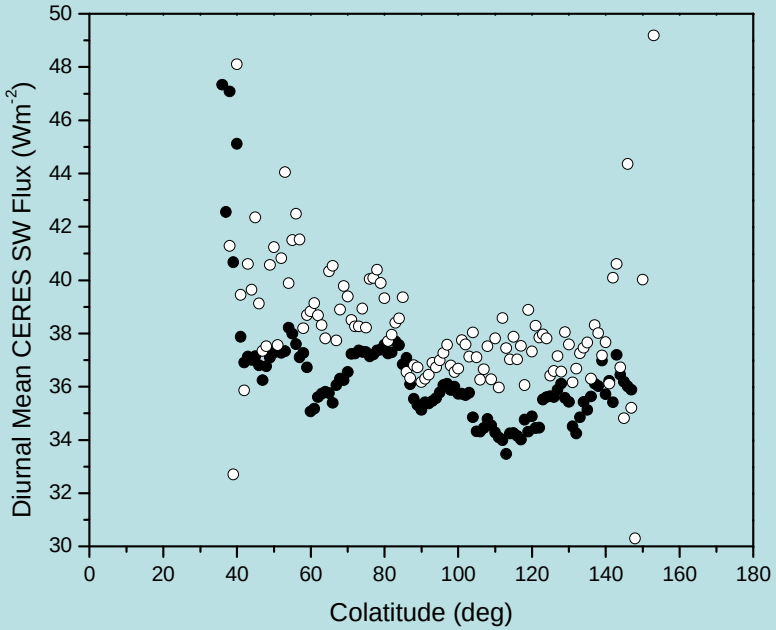


Nighttime Invisibly Cloudy

Daytime Invisible Clouds' Radiation Effect



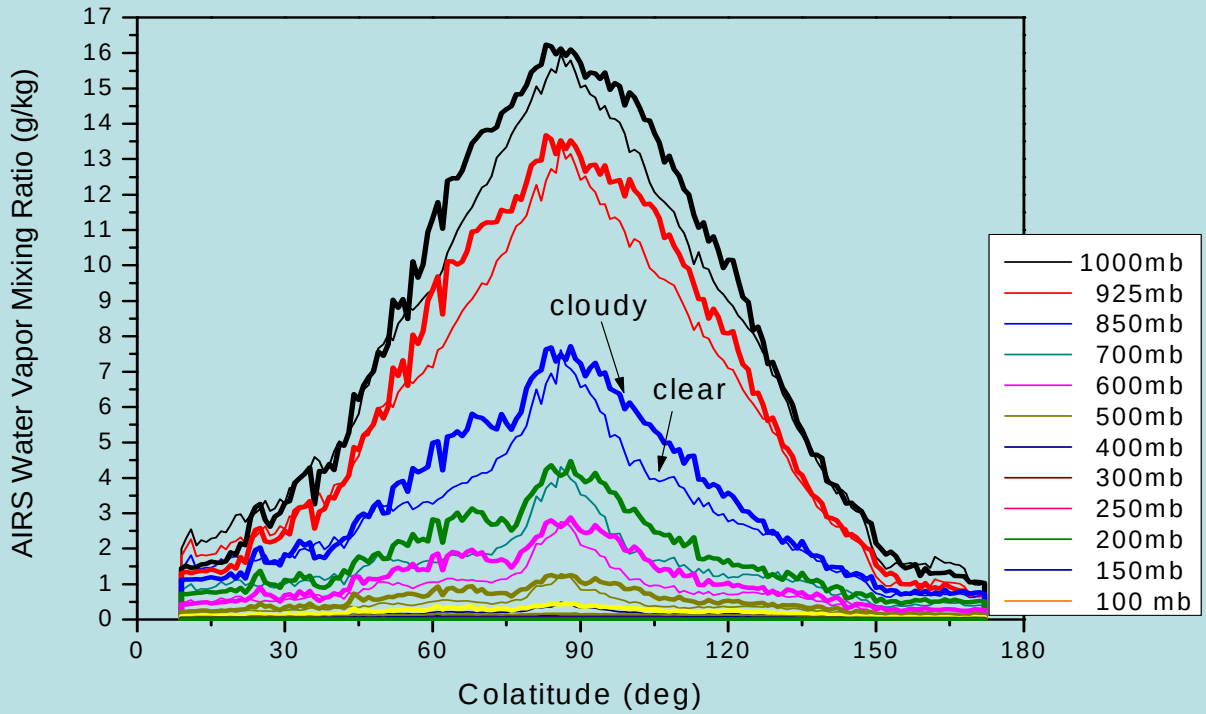




Instantaneous CERES SW flux is converted to diurnal 24-hour mean value by using previously made lookup tables from CERES TRMM processing-orbit data (Loeb & Manalo-Smith 2005).

Invisibly thin clouds have ~3 Wm^{-2} diurnal mean SW cooling effect.

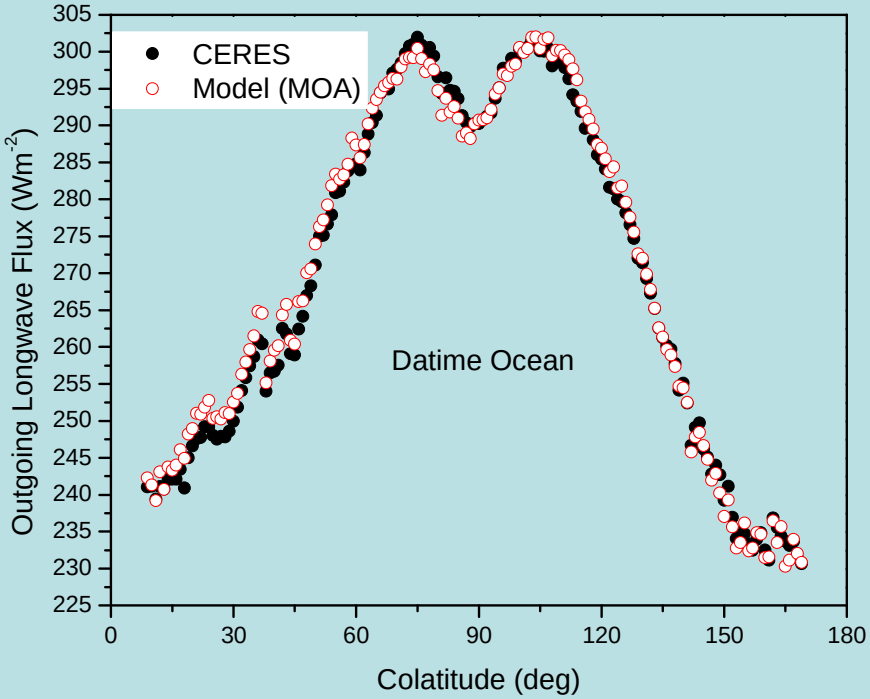
AIRS Humidity difference between clear and invisibly cloudy cases

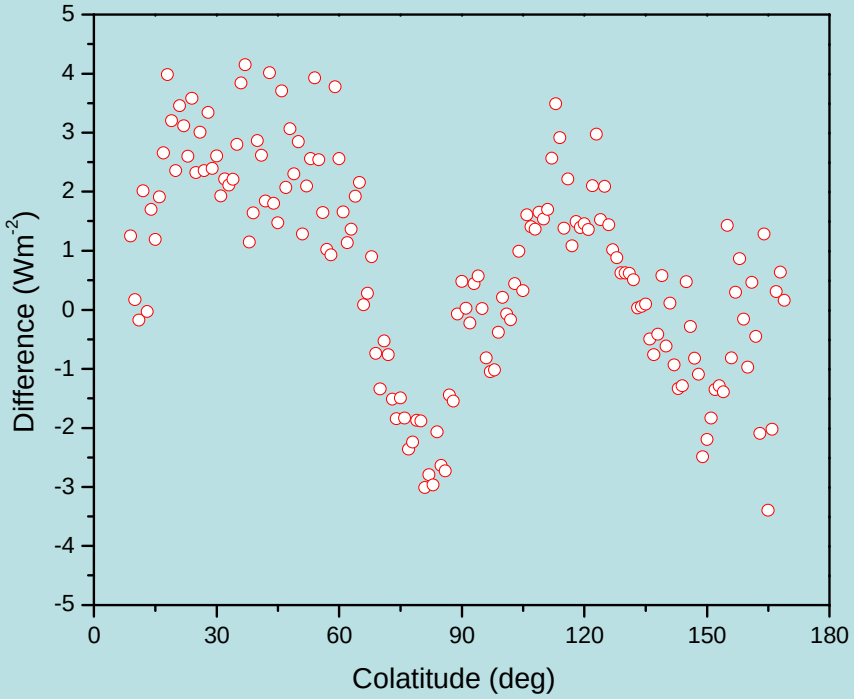


The CERES LW flux difference between clear and invisibly cloudy FOVs could be a result of water vapor absorption.

This makes the quantification of the invisible clouds' effect on LW radiation difficult.

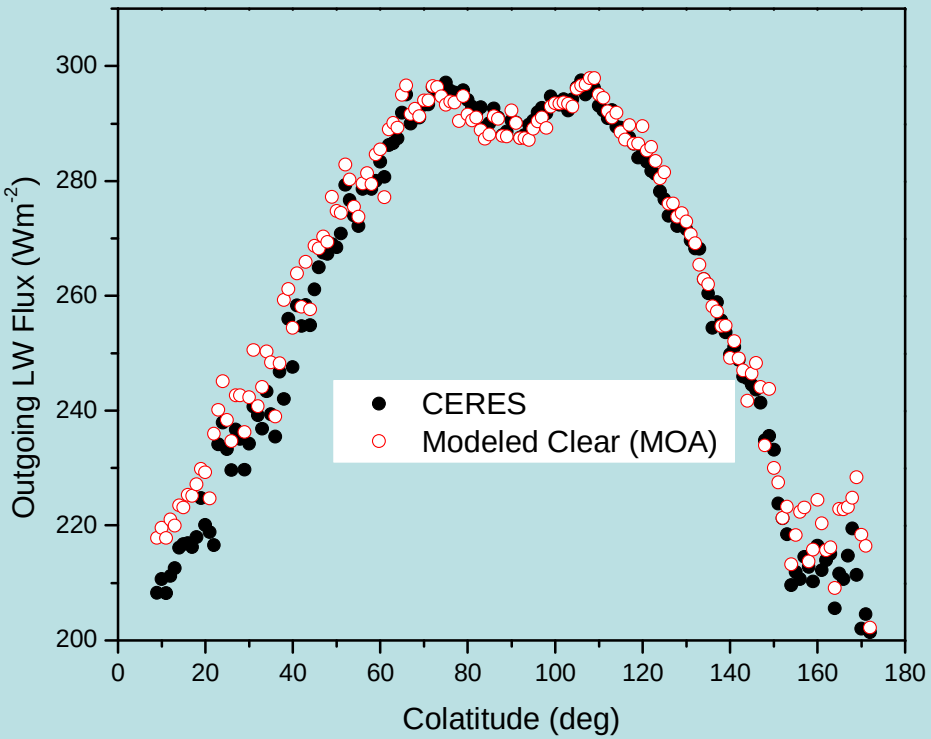
Modeling LW flux for daytime ocean





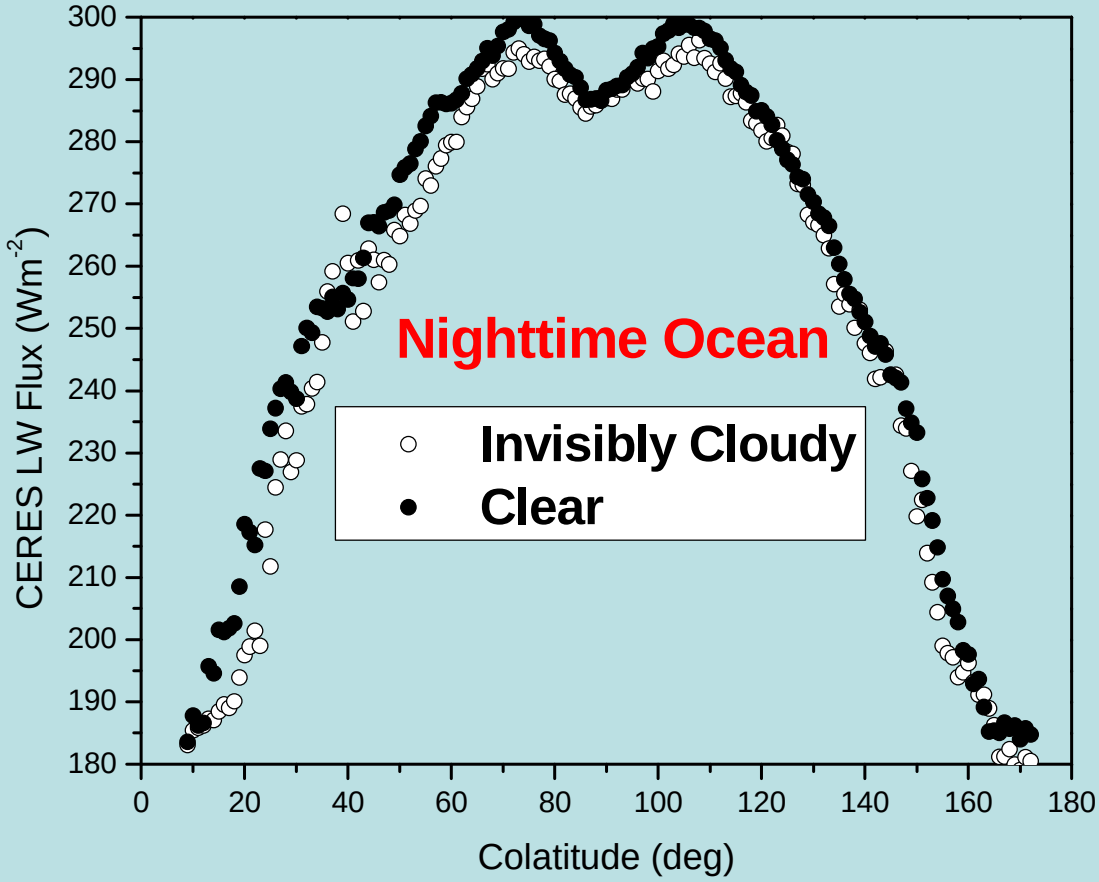
Comparison of CERES and modeled LW flux for clear FOVs

Effect of invisible clouds on LW flux



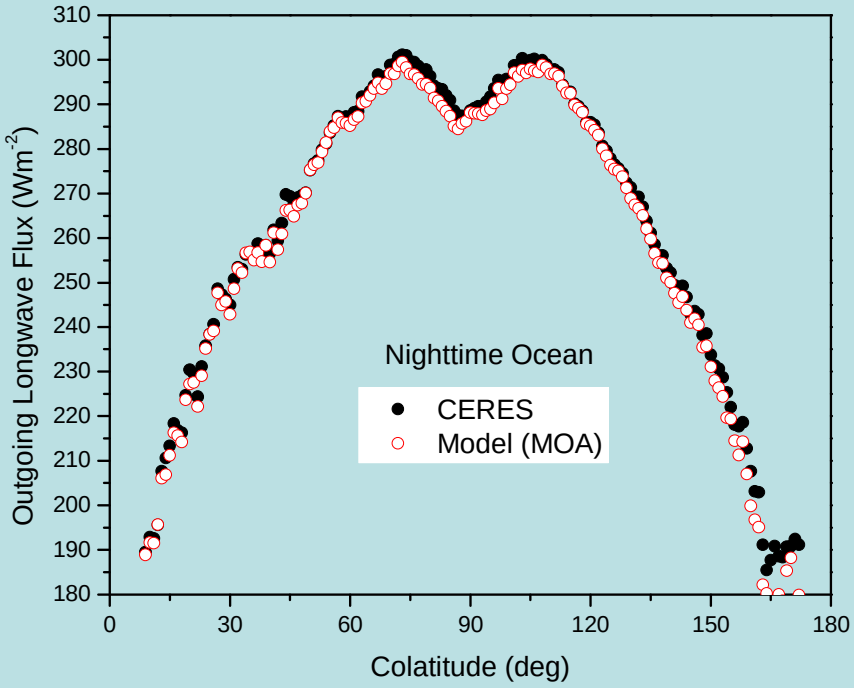
Comparison of CERES LW flux for invisibly cloudy FOVs with modeled LW flux for the same FOVs but clouds are removed in modeling

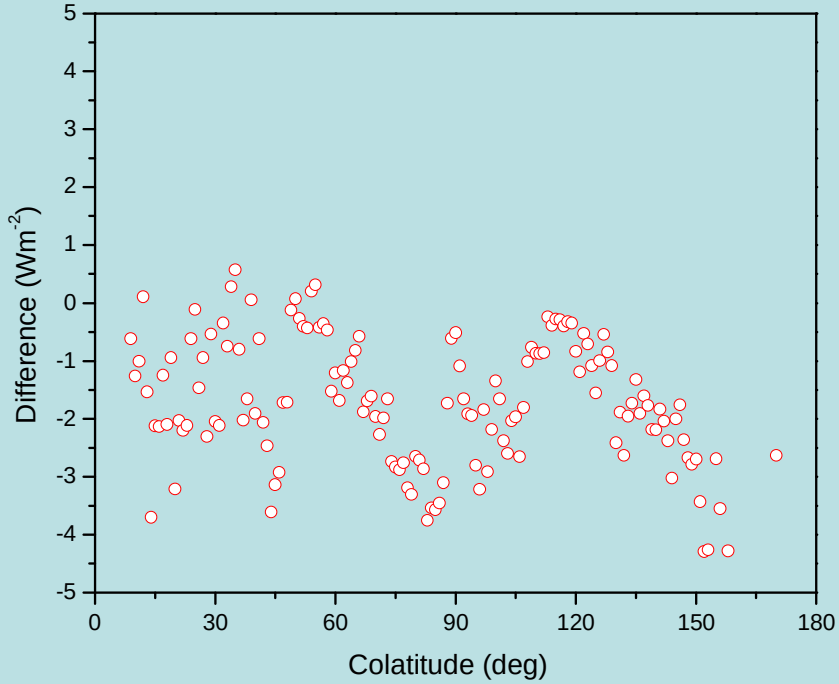
Nighttime Invisible Clouds' Radiation Effect



Comparison of CERES outgoing LW flux for clear and invisibly cloudy cases

Modeling LW flux for nighttime ocean





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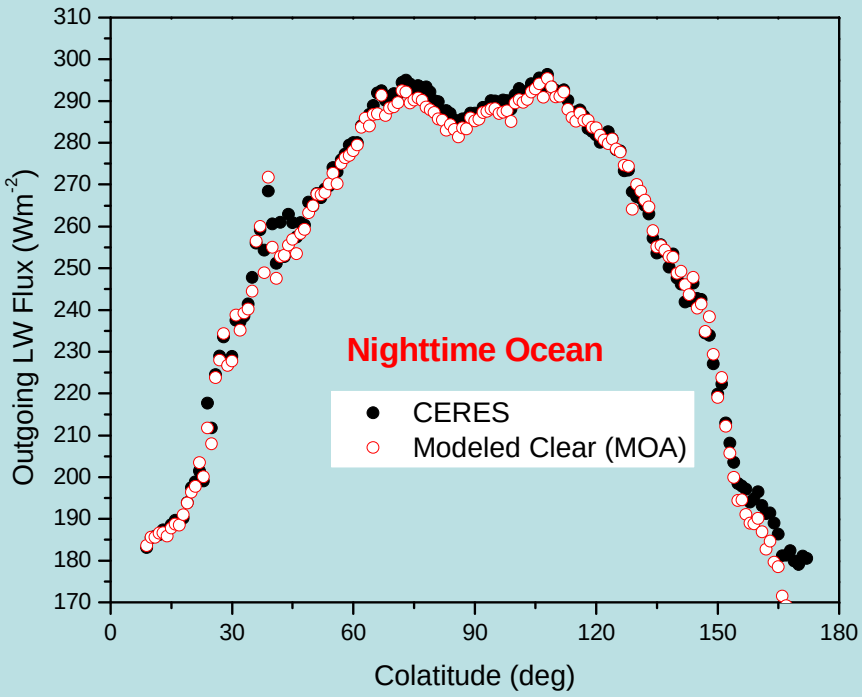
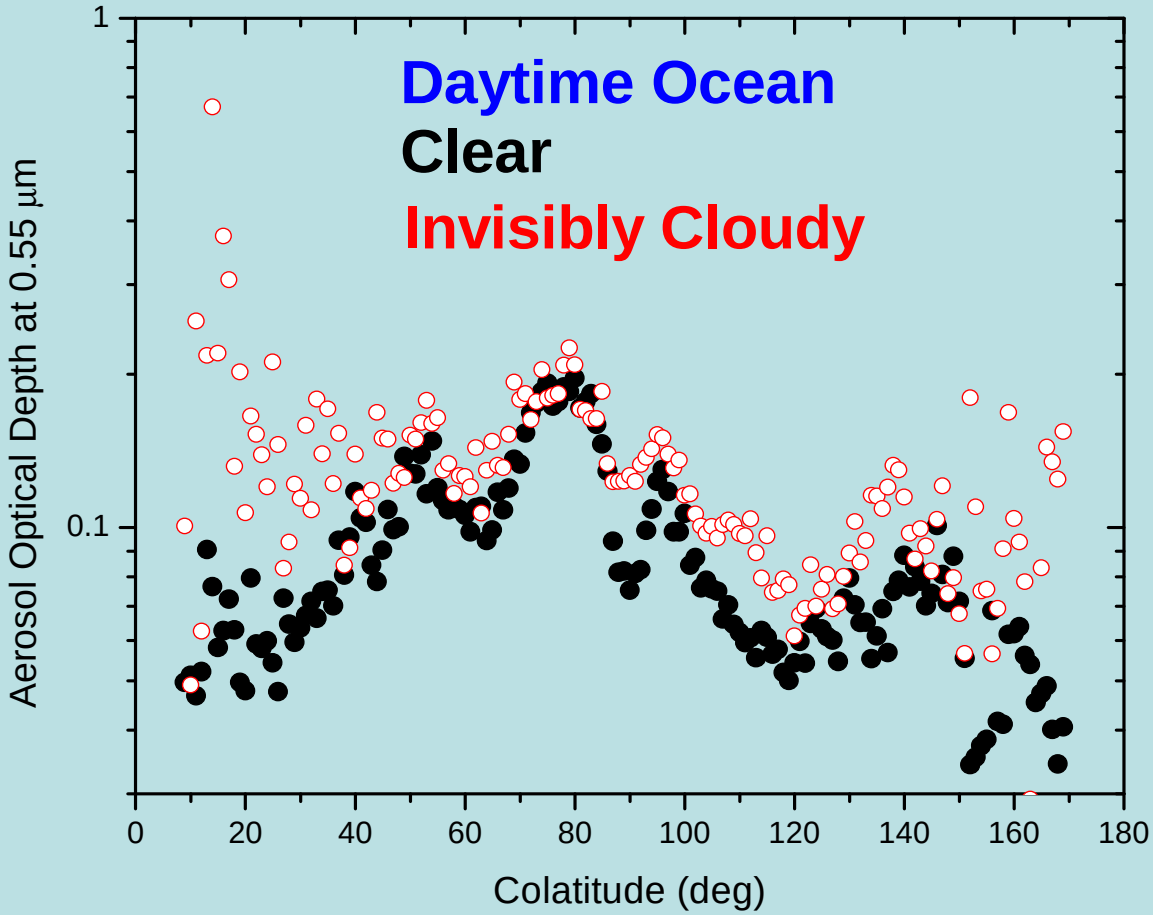


Comparison of CERES LW flux for invisibly cloudy FOVs with modeled LW flux for the same FOVs but clouds are removed in modeling

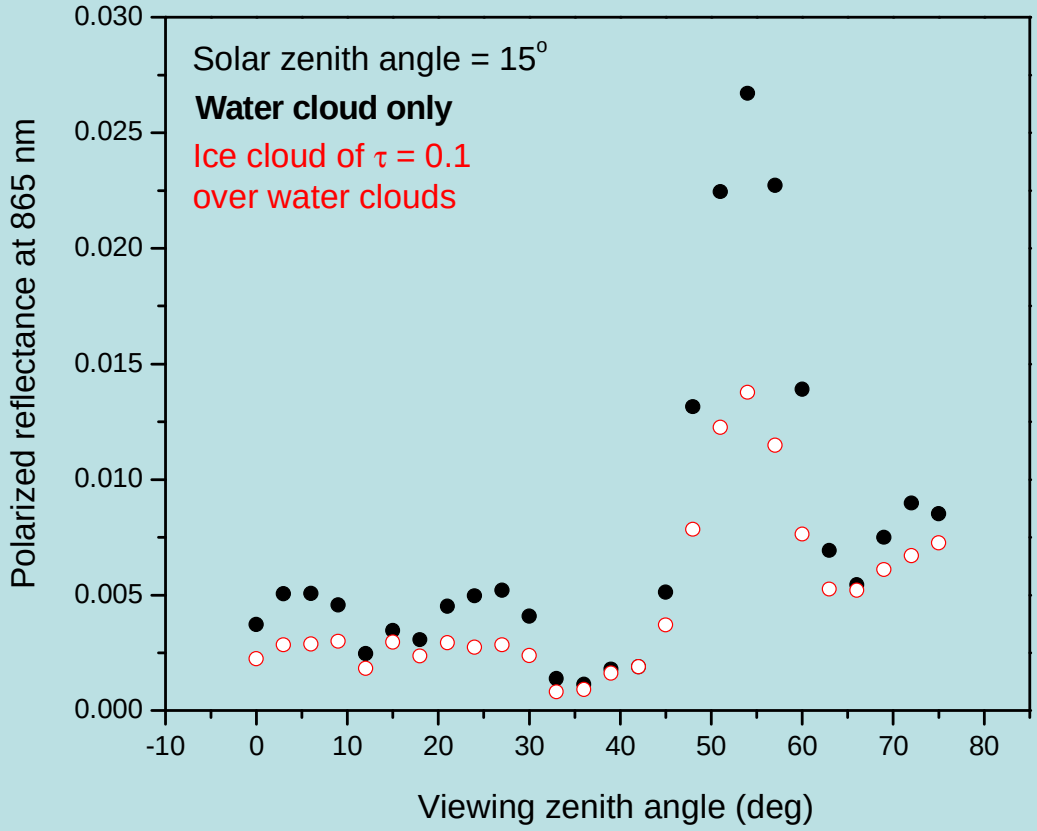
Invisible clouds' effect on LW is not significant, as in daytime

Effect of invisible clouds on MODIS aerosol product



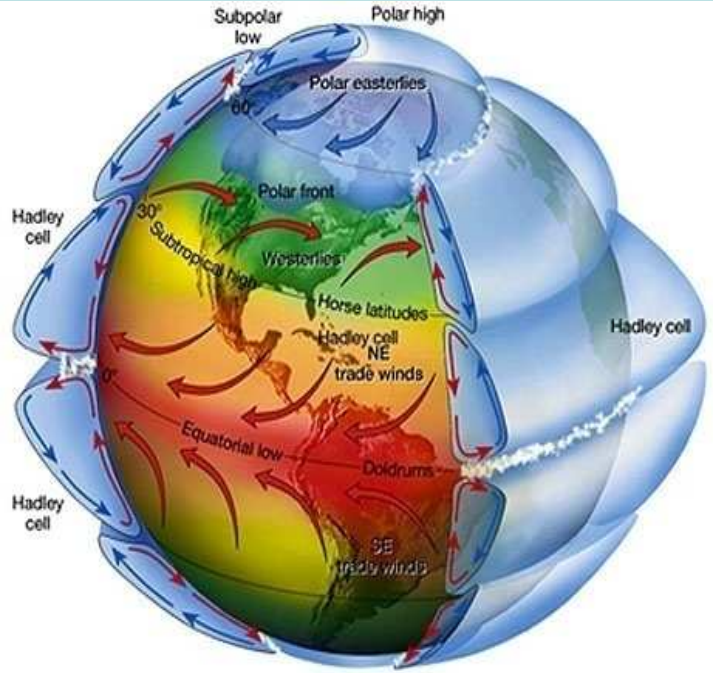
Zonal mean MOD04 aerosol optical depth at 0.55 µm for daytime ocean.

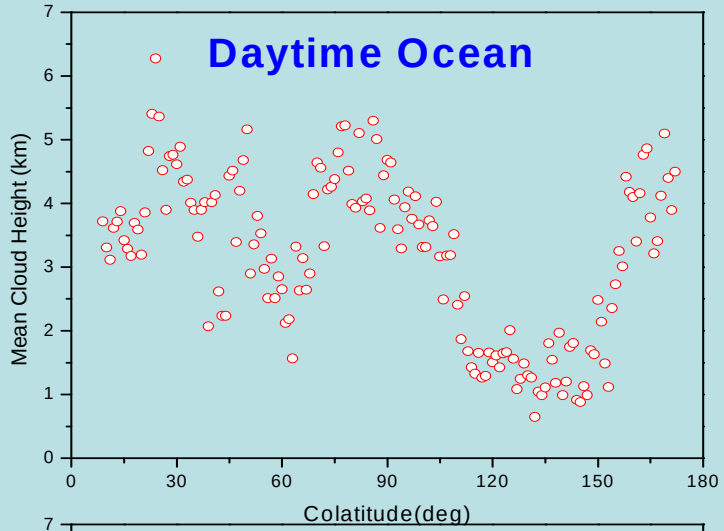
Effect of invisible clouds on polarized radiance

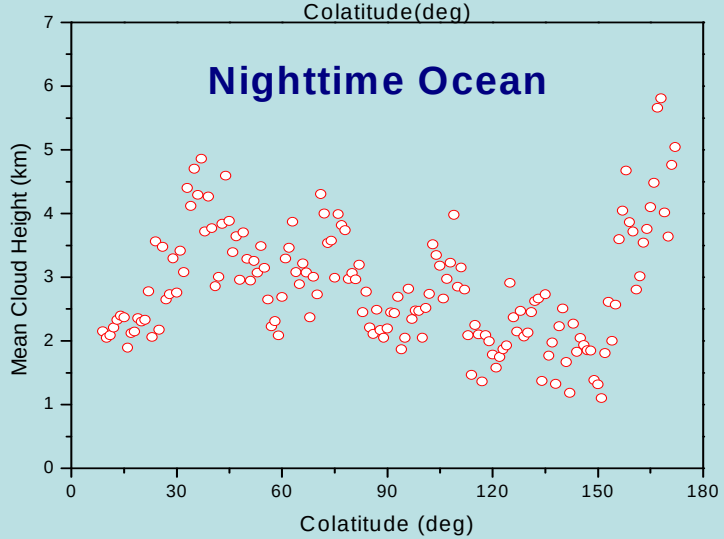


Polarized reflectance at a wavelength of 865 nm and at a relative viewing azimuth angle of 180º for a water cloud and for a layer of ice cloud over the water cloud, respectively. The optical thickness of the ice cloud layer is 0.1.

Correlation of Cloud Height with Transition Zones







Daytime invisible clouds' altitudes correlate with the transition zones between Hadley Cells, and Hadley and Mid-Latitude Cells, where air flows upward or downward.

Invisibly clouds are very probably new-born clouds at ITCZ or dying clouds at subtropical high zones

Conclusion

1. Up to 50% of MODIS-derived clear-sky scenes are actually covered by invisibly thin clouds.

2. Diurnal mean SW radiation effect of invisibly thin clouds is ~3 Wm^{-2} regional cooling effect. Invisibly thin clouds have insignificant effect on LW radiation.

3. The net radiation effect of the invisible clouds is estimated to be ~3 Wm-2 cooling effect regionally.

4. Invisibly thin clouds make the retrieved aerosol optical thickness from MODIS measurements significantly larger.

5. Invisible clouds can reduce the polarization of the Earth's radiation significantly. Its existence actually reduces the measurement errors of conventional instruments which do not account for the radiation's polarization nature.