Estimating radiation effect of invisible clouds with a synergy of CERES, MODIS, CALIPSO, AIRS, and AMSER-E data

Wenbo Sun
Science Systems and Applications, Inc.
Norman G. Loeb
NASA Langley Research Center

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, 10-month (Jul 06 - Apr 07) CERES, MODIS, CALIPSO, AIRS, and AMSER-E measurements are analyzed.

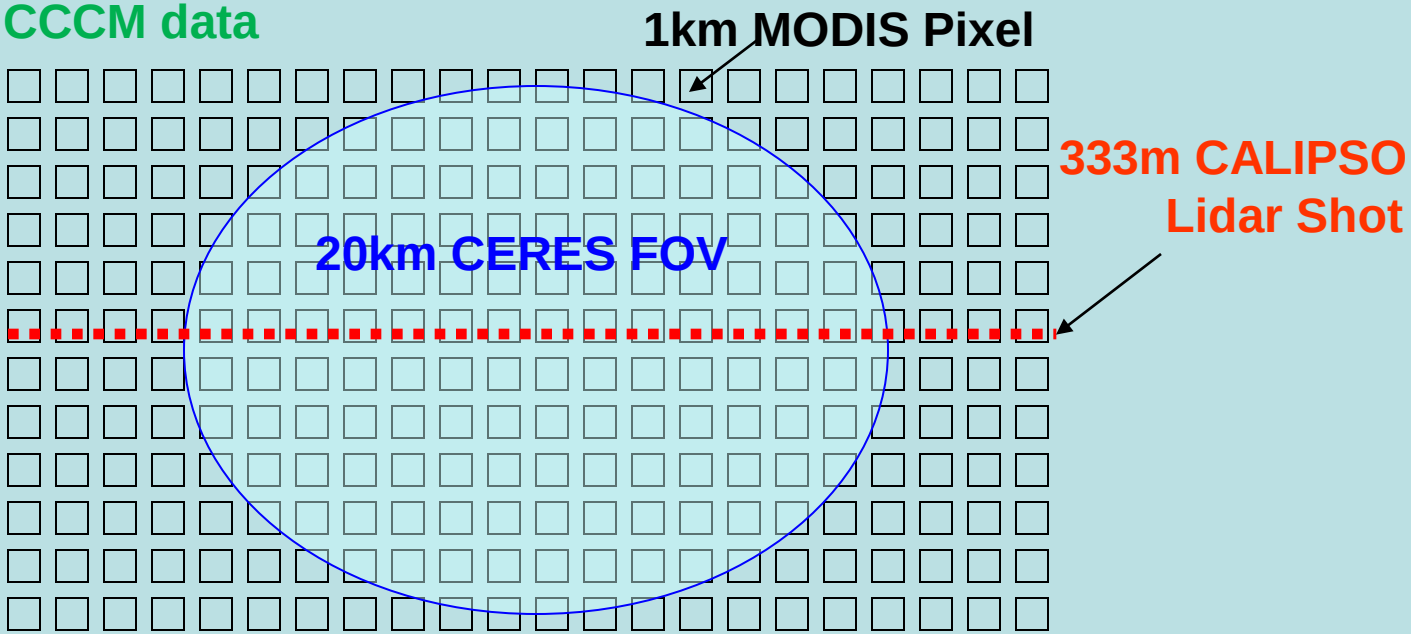
Method and Data

AIRS data – Temperature & Humidity profiles

AMSR-E data – Checking the accuracy of AIRS Humidity

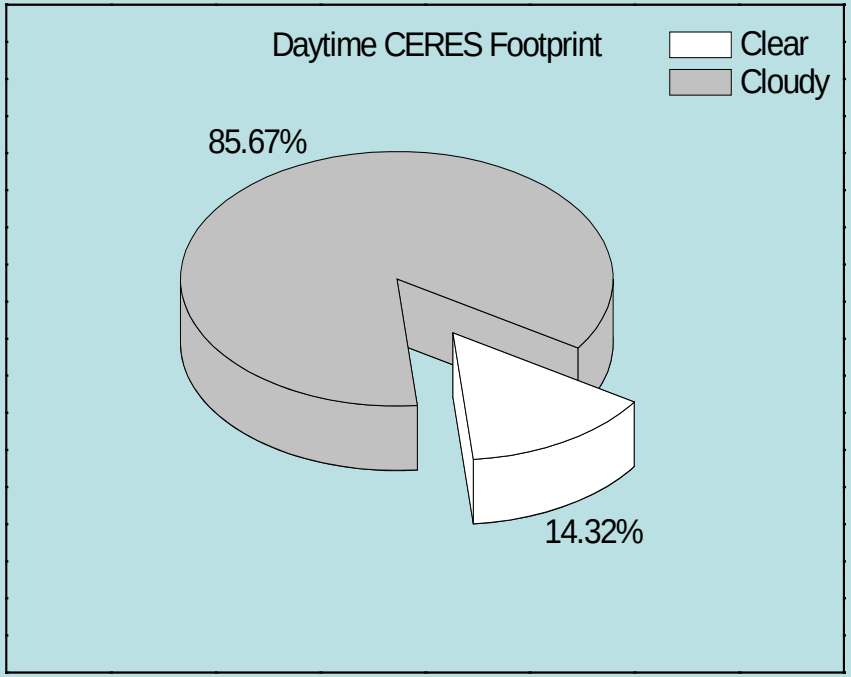
CCCM data – CERES, CALIPSO, and MODIS

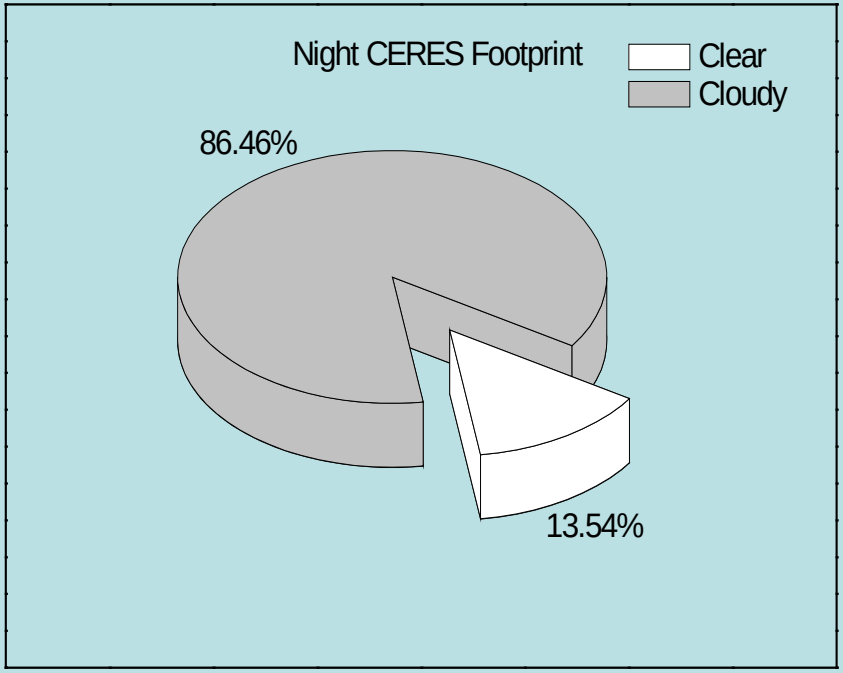
CCCM data



Invisibly cloudy CERES FOVs:
MODIS clear & CALIPSO cloudy

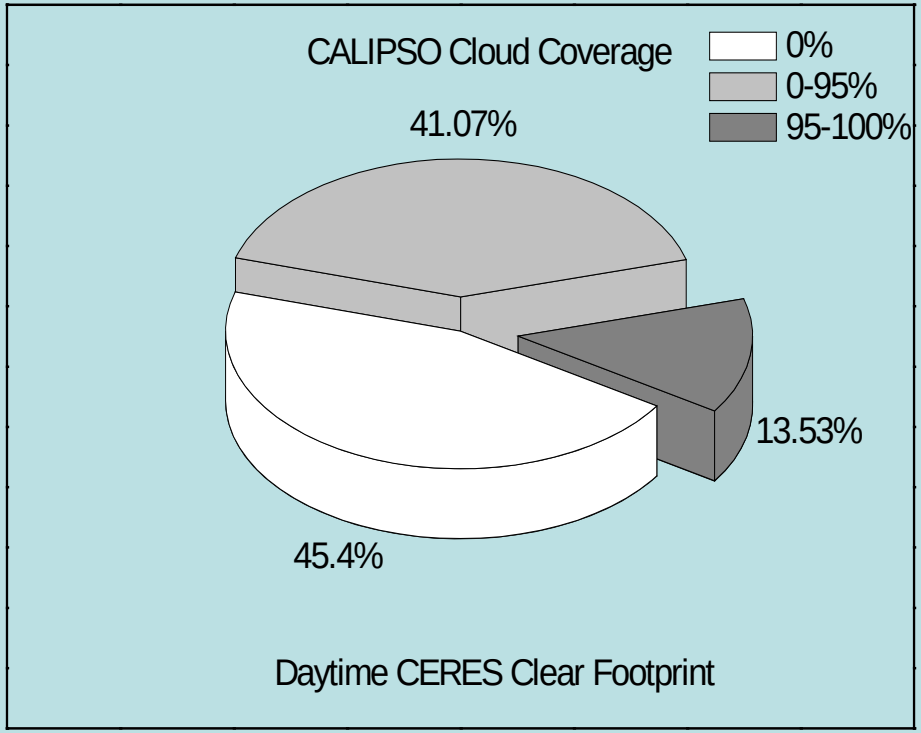
~15% of CERES FOVs are claimed clear by MODIS





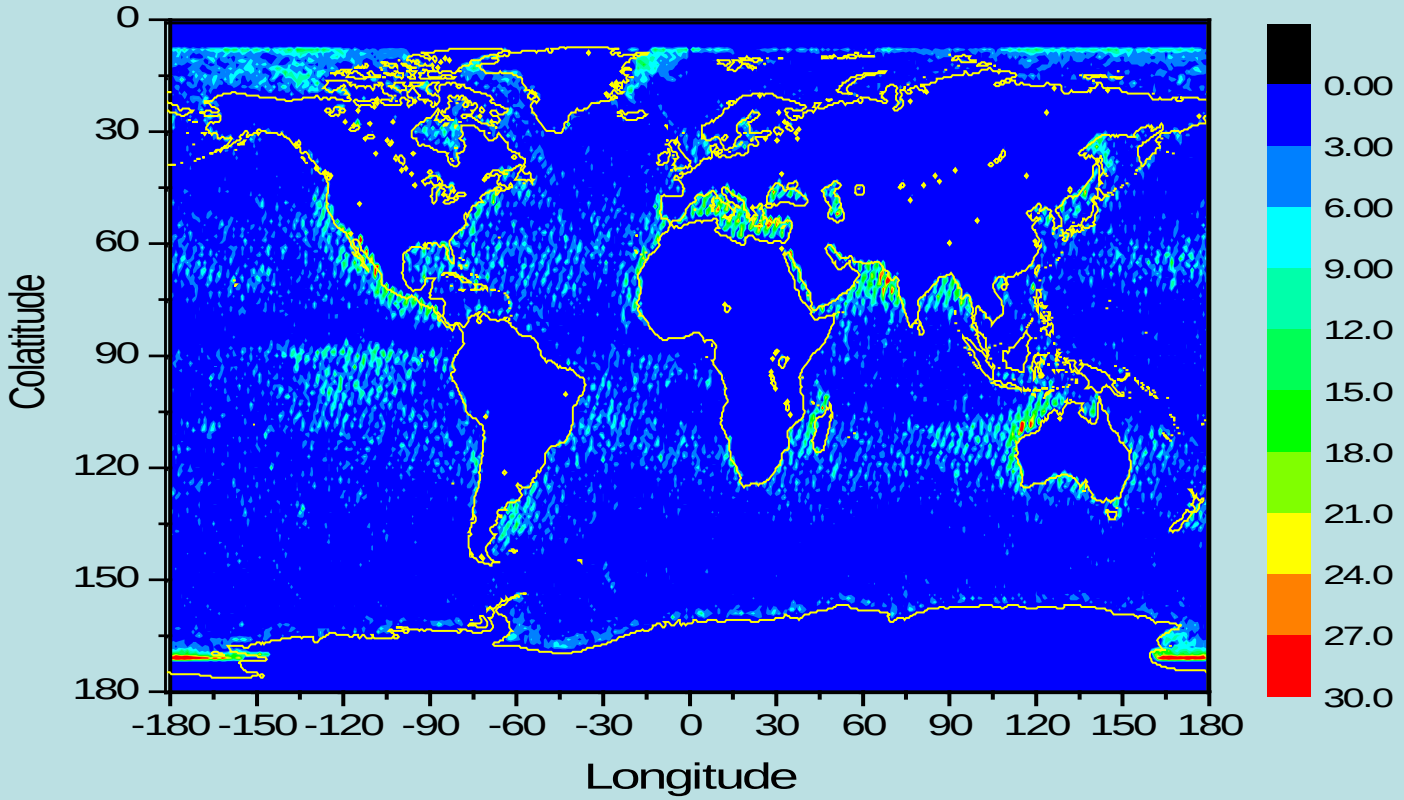
MODIS-derived 10-month clear percentage of CERES FOVs

Daytime Radiation Effect



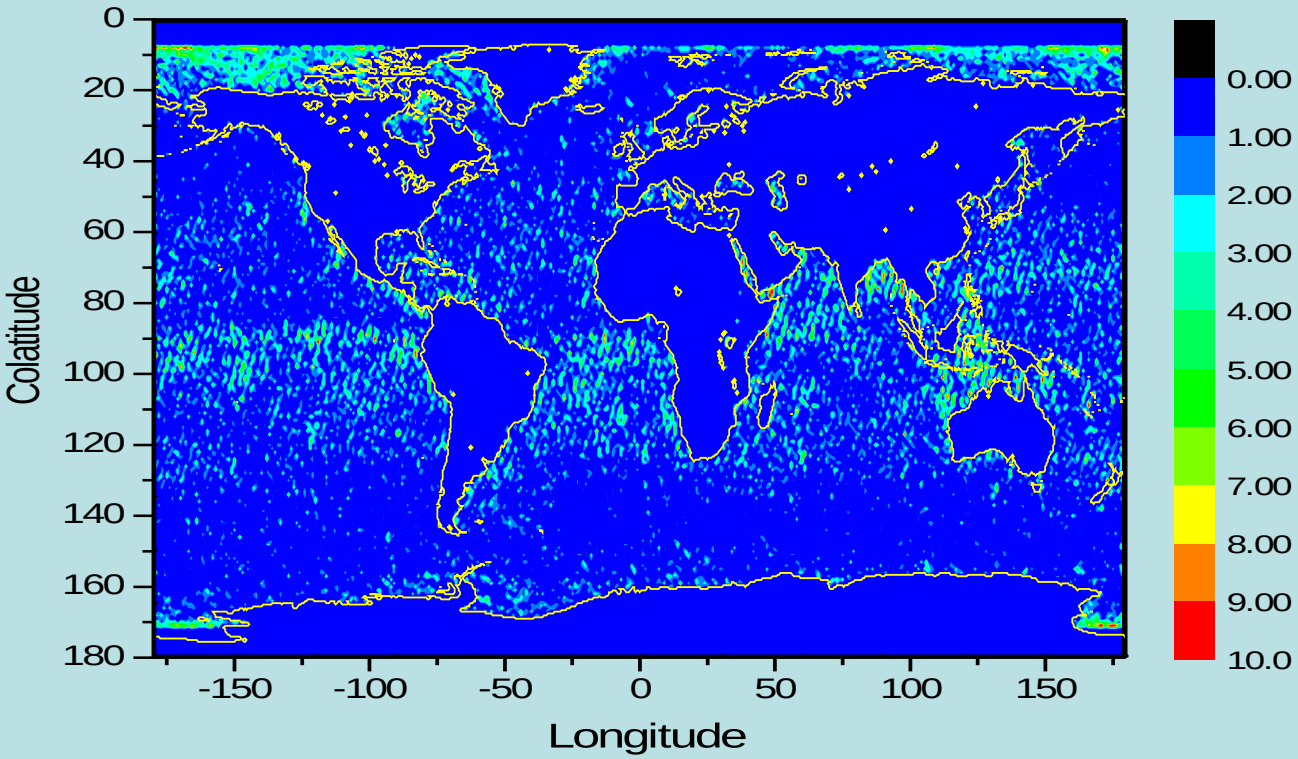
CALIPSO-derived 10-month cloudy percentage in MODIS-clear CERES FOVs

10-month CERES FOVs of MODIS clear & CALIPSO clear

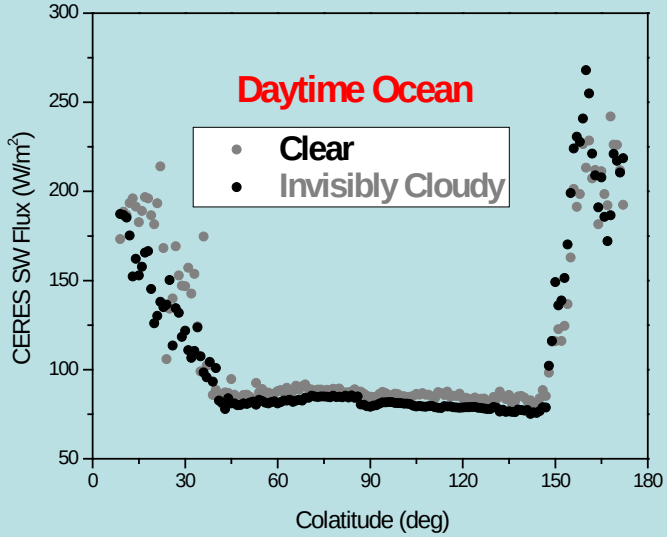


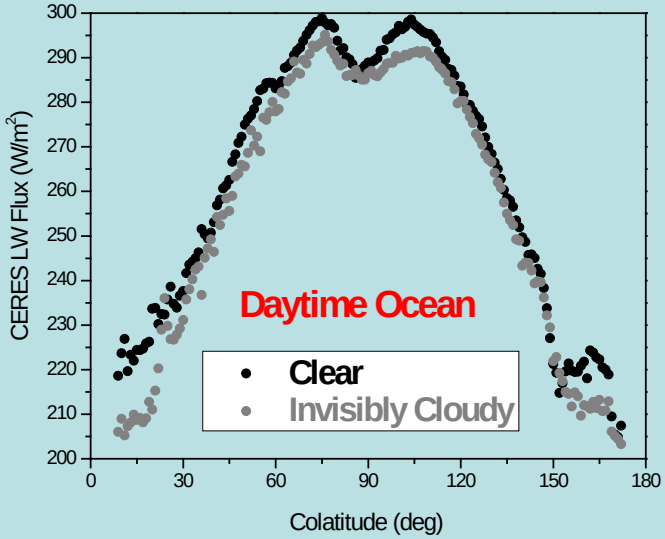
Daytime Purely Clear Sampling

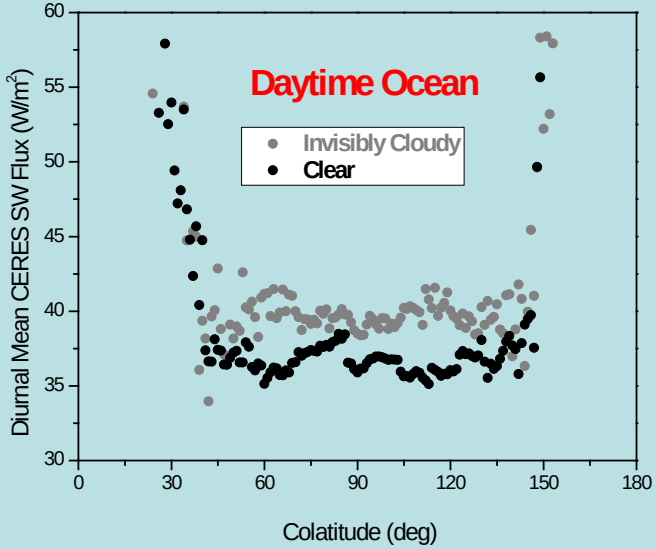
10-month CERES FOVs of MODIS clear & CALIPSO overcast



Daytime Invisibly Cloudy Sampling

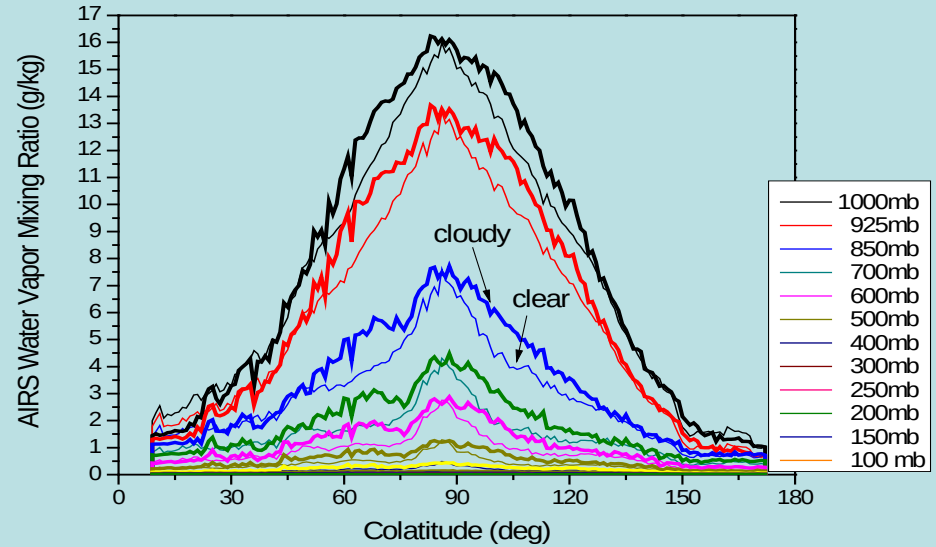


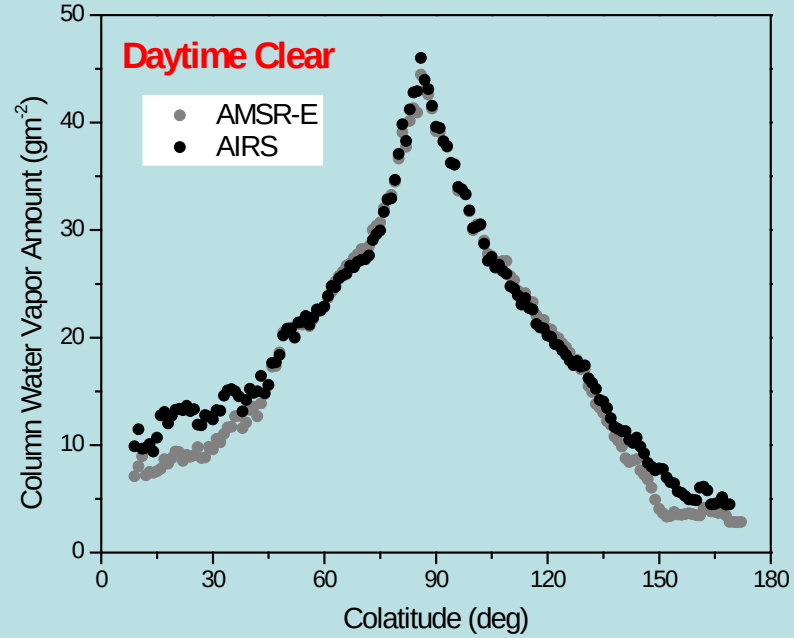


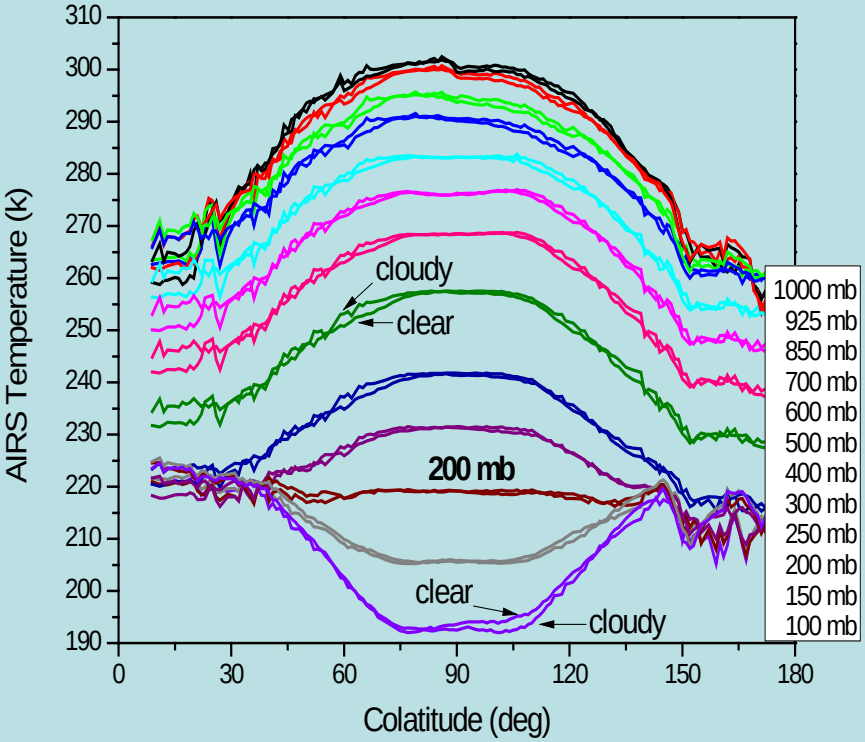


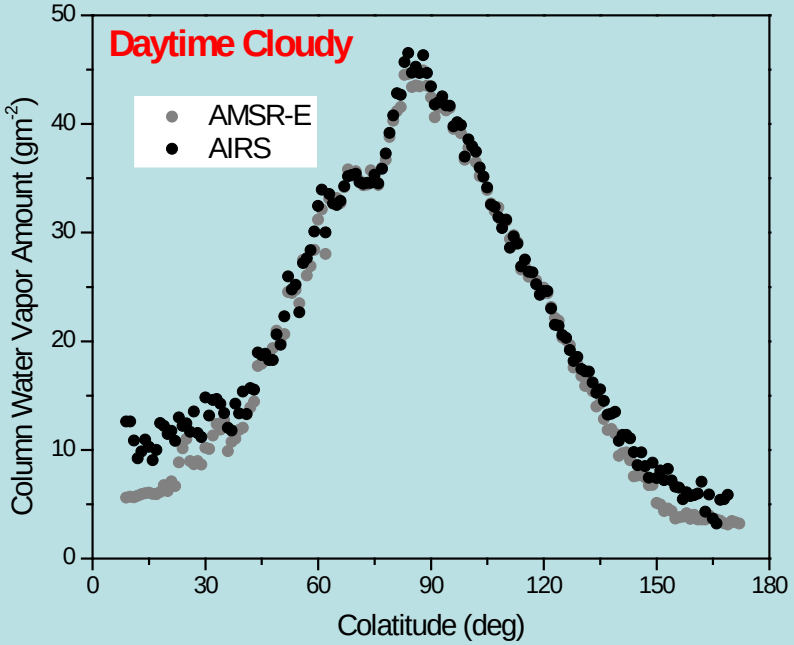
Instantaneous CERES SW flux is converted to diurnal 24-hour mean value by using previously made lookup tables from CERES TRMM processing-orbit data (Loeb & Manalo-Smith 2005)

Invisibly thin clouds have ~5 Wm^{-2} diurnal mean cooling effect at SW

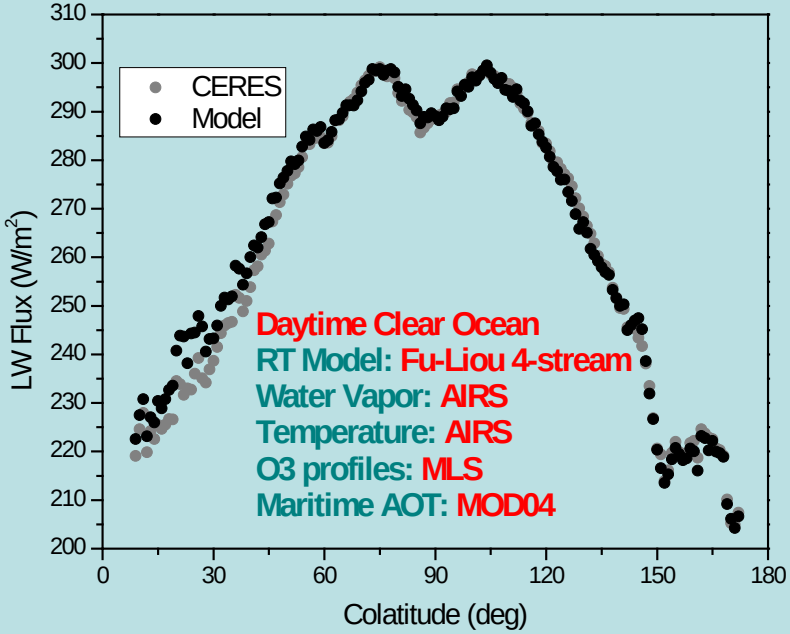

AIRS Water Vapor Mixing Ratio (g/kg)
Colatitude (deg)
cloudy
clear
1000mb
925mb
850mb
700mb
600mb
500mb
400mb
300mb
250mb
200mb
150mb
100 mb


Daytime Clear
AMSR-E
AIRS
Column Water Vapor Amount (gm^{-2})
Colatitude (deg)


AIRS Temperature (k)
Colatitude (deg)
cloudy
clear
200 mb
clear
cloudy
1000 mb
925 mb
850 mb
700 mb
600 mb
500 mb
400 mb
300 mb
250 mb
200 mb
150 mb
100 mb

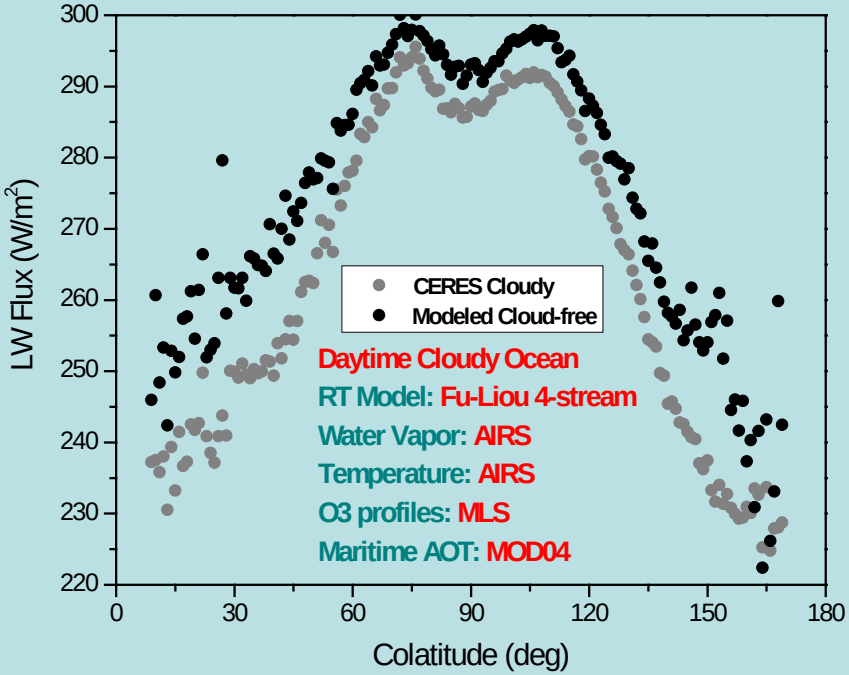

Daytime Cloudy
AMSR-E
AIRS
Column Water Vapor Amount (gm^{-2})
Colatitude (deg)

Modeling LW flux for daytime ocean

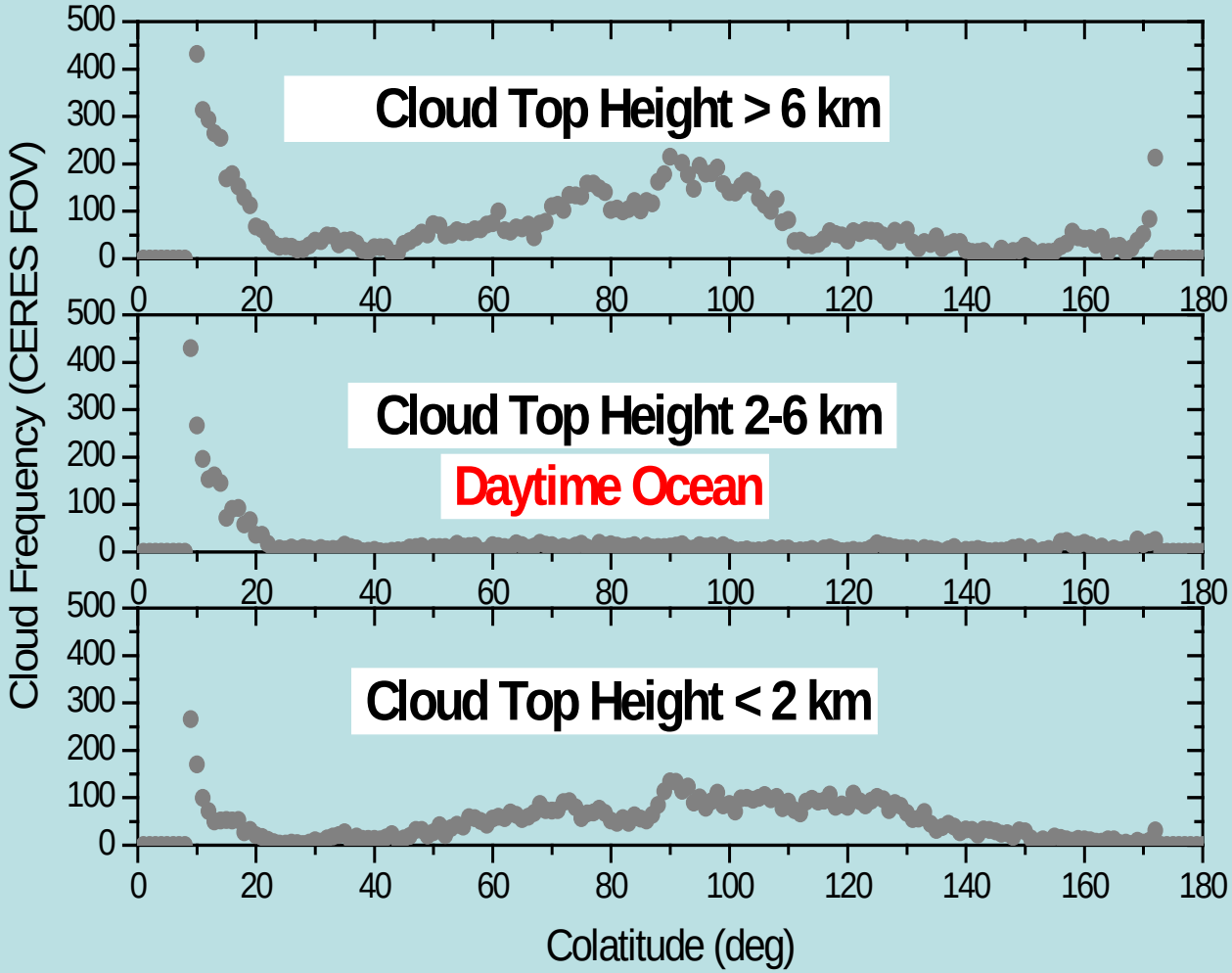


Comparison of CERES and modeled LW flux for clear FOVs

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

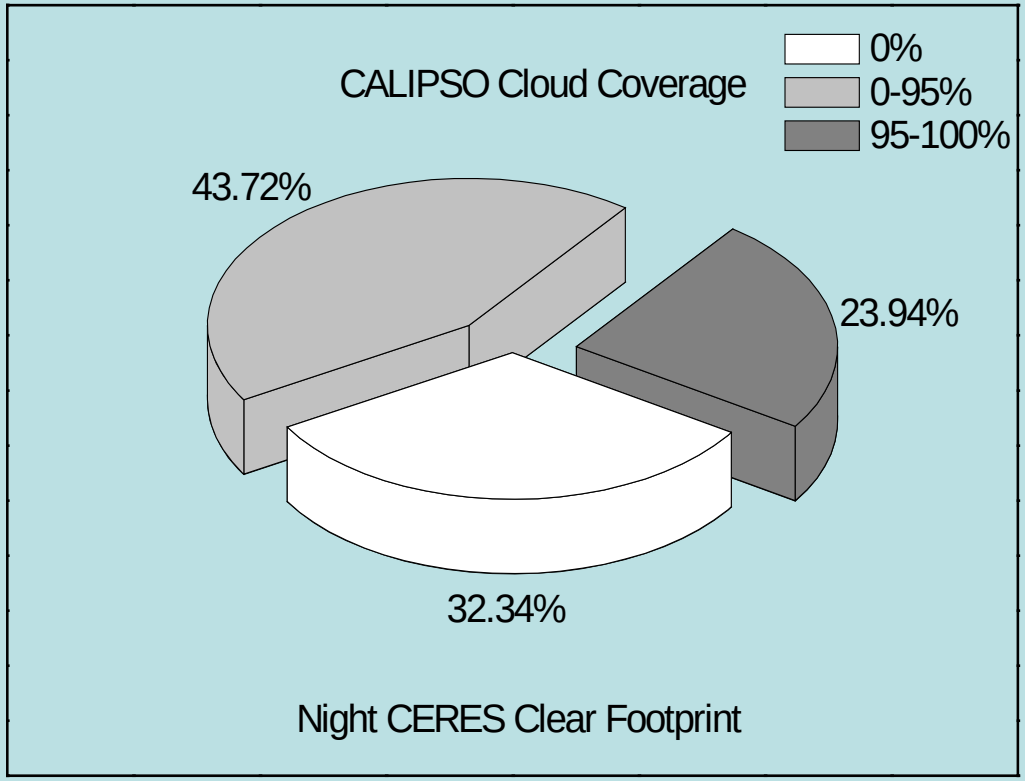


Invisible clouds account for ~7.5 Wm^{-2} warming effect at LW



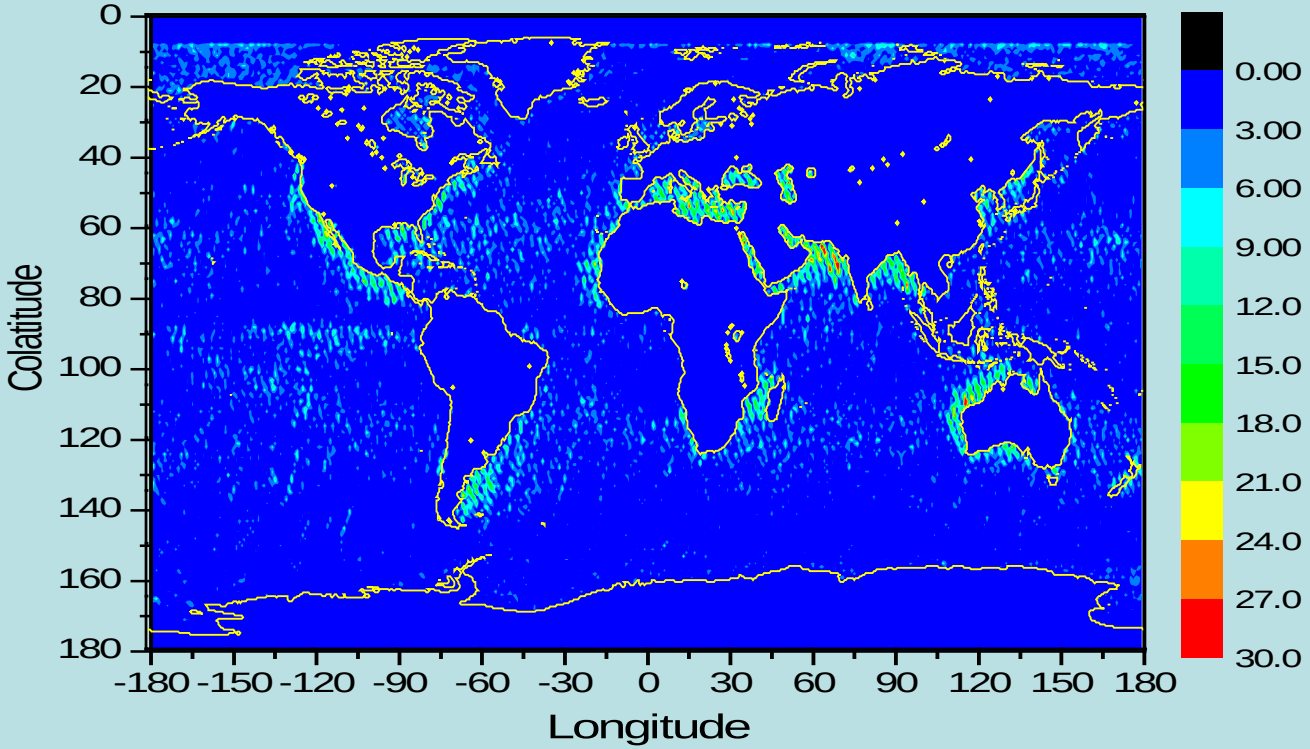
Zonal and altitude distribution of invisible cloud occurrence Frequency (in the unit of CERES FOV number) for daytime oceans.

Night Radiation Effect



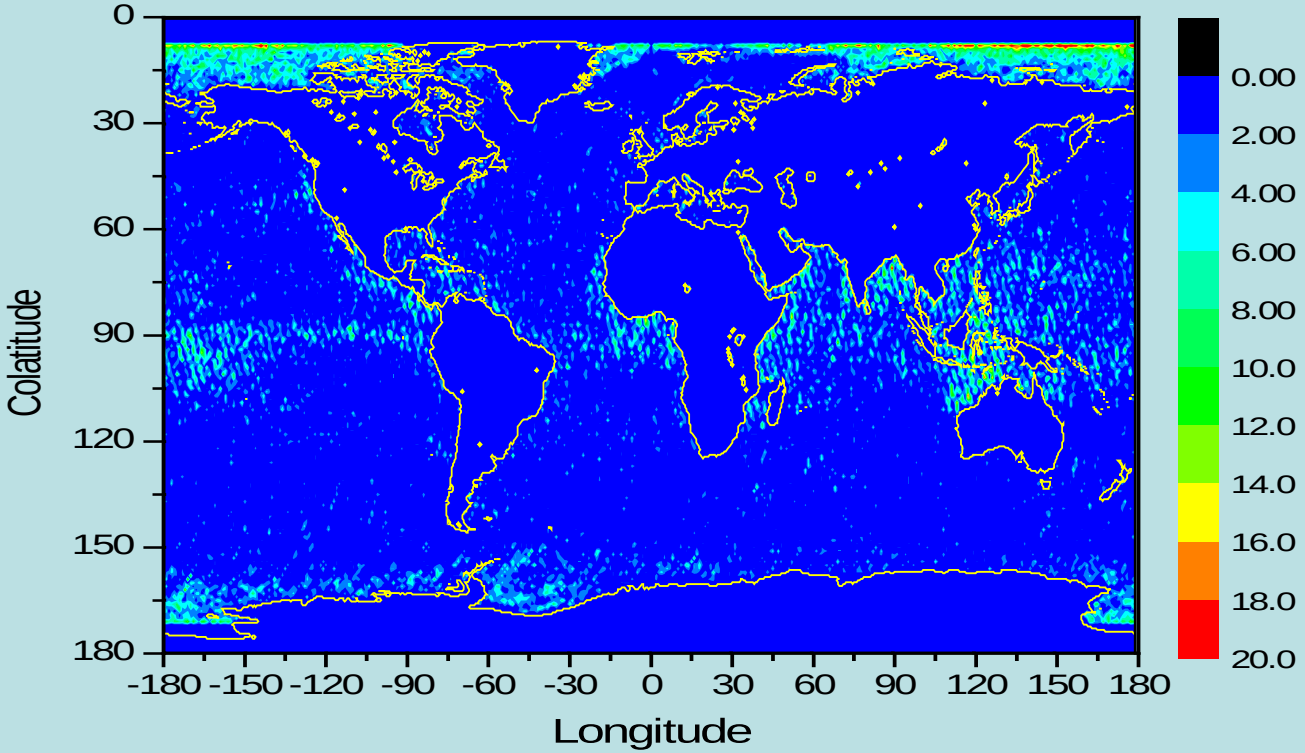
CALIPSO-derived 10-month cloudy percentage in MODIS-clear CERES FOVs

10-month CERES FOVs of MODIS clear & CALIPSO clear

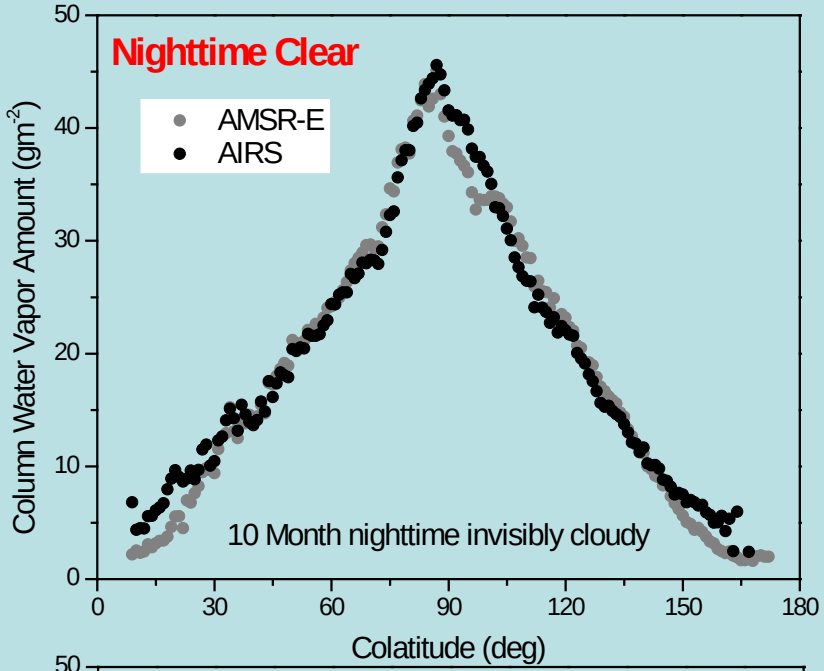


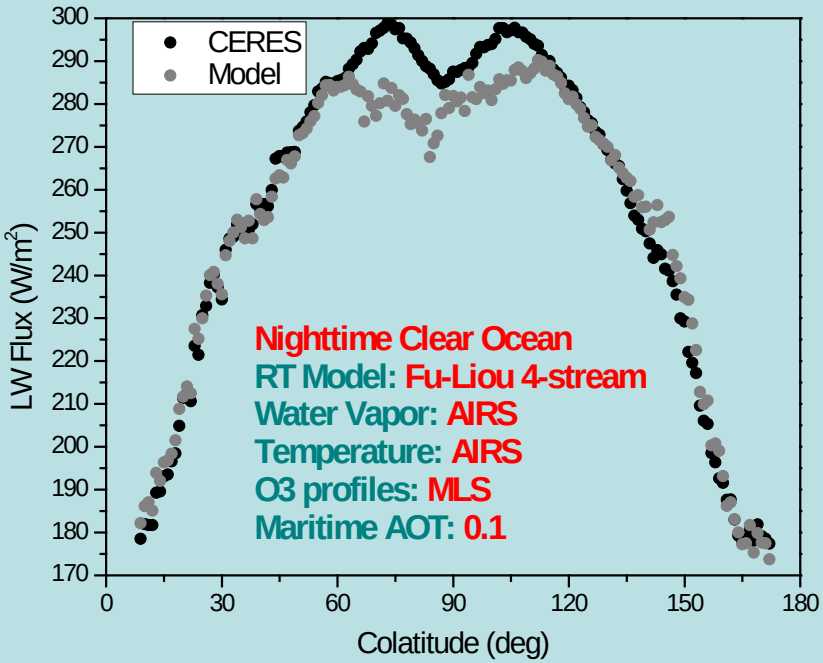
Night Purely Clear Sampling

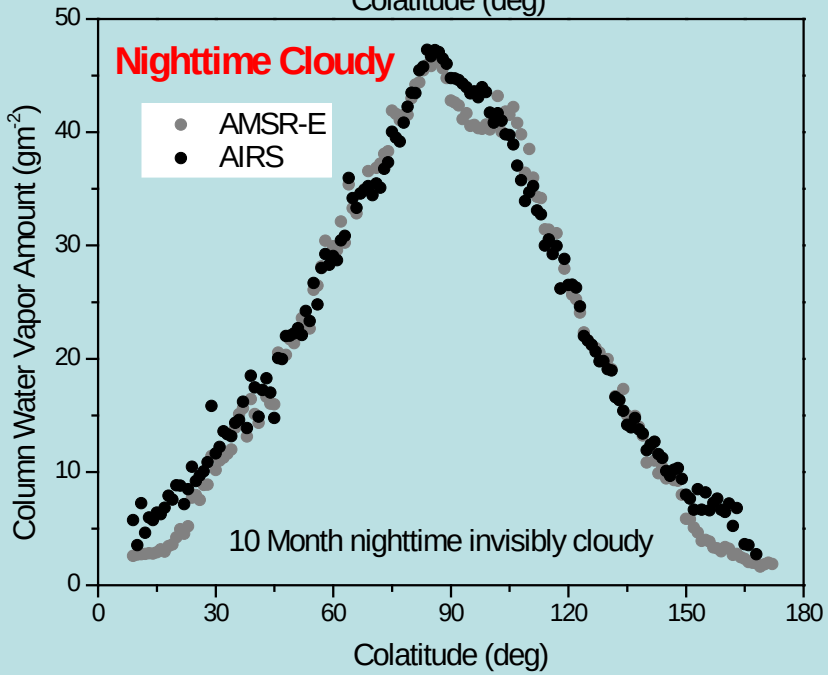
10-month CERES FOVs of MODIS clear & CALIPSO overcast



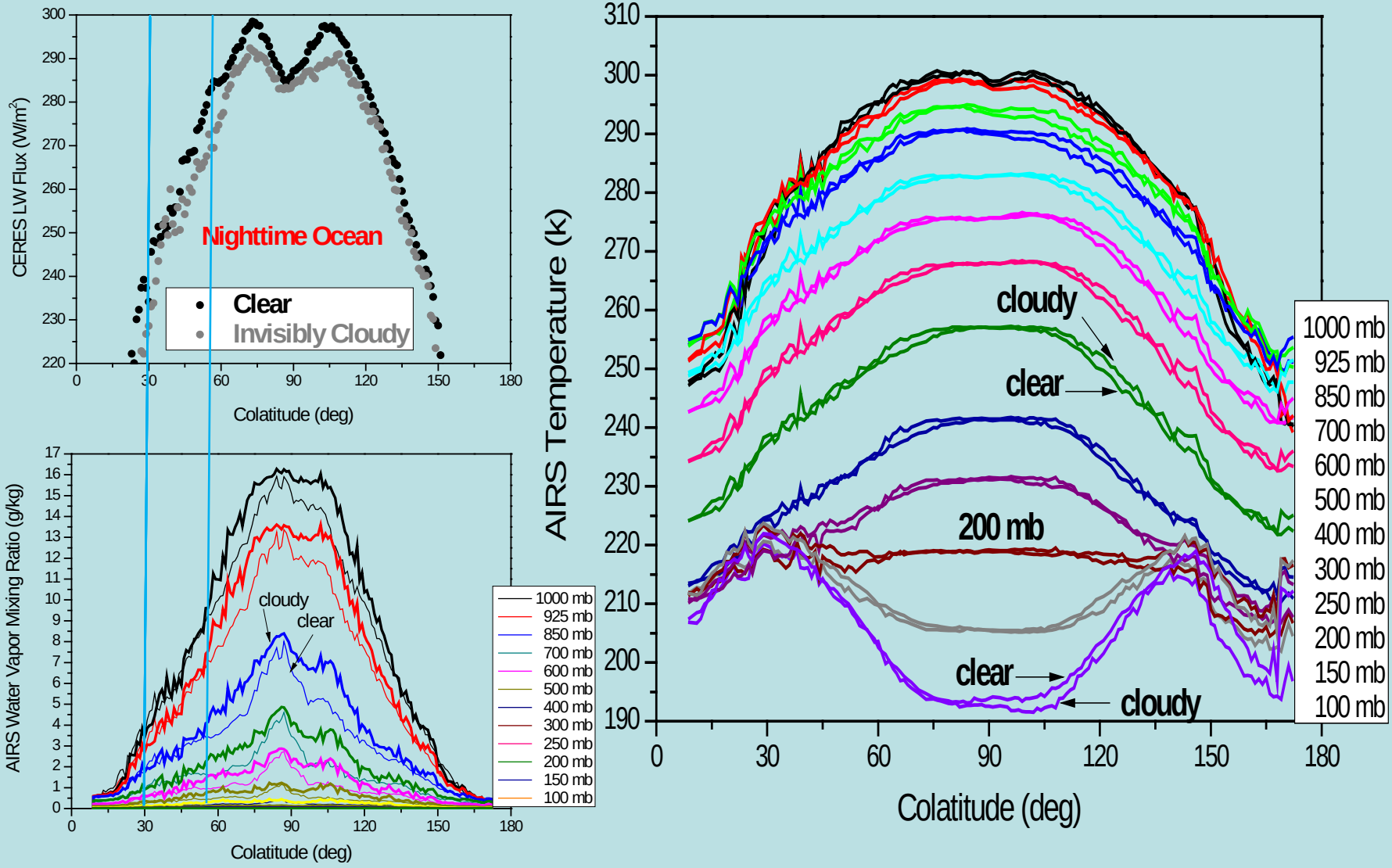
Night Invisibly Cloudy Sampling



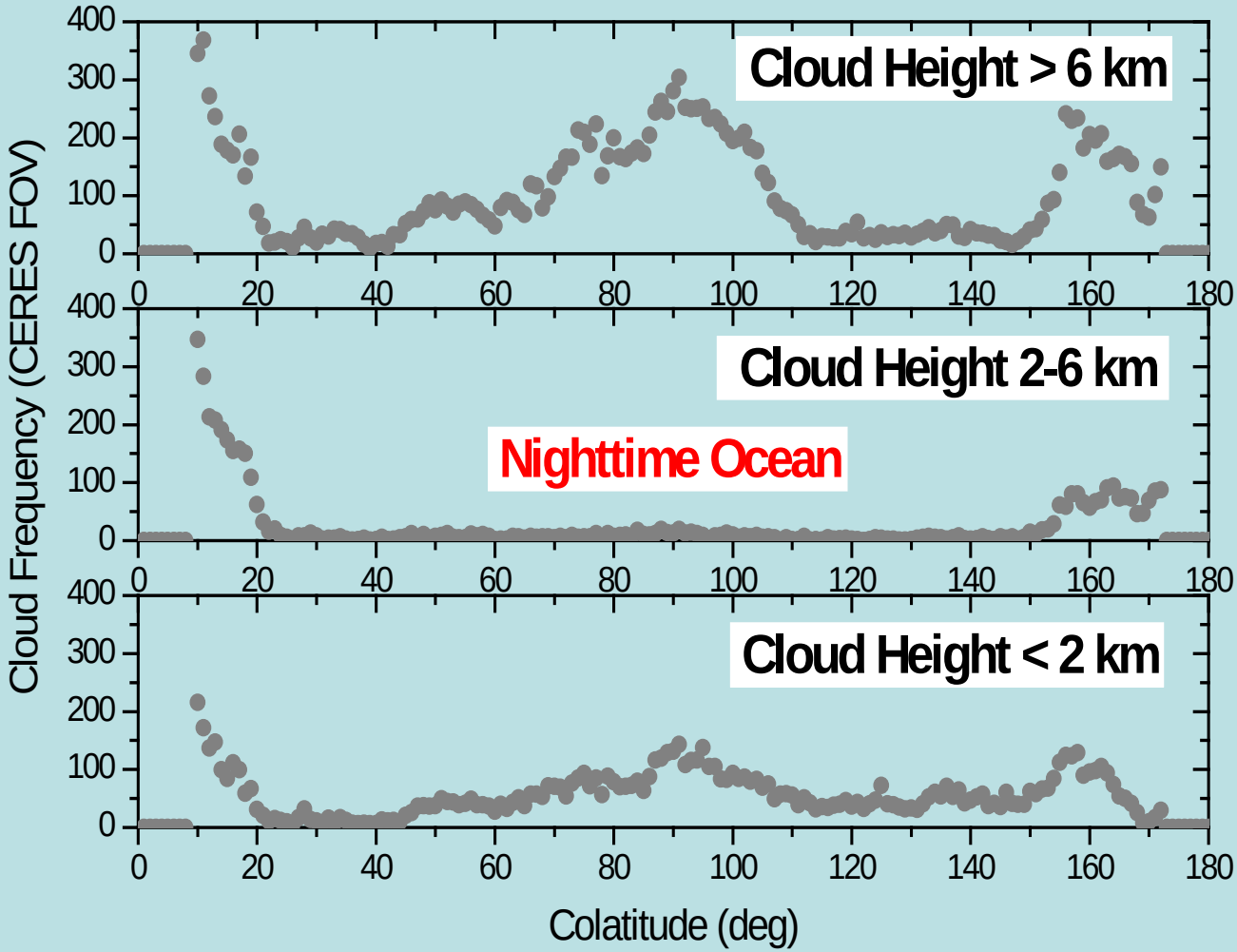




In mid- and low-latitude regions, nighttime clear ocean LW flux from model is much smaller than CERES measurements. This is very possibly due to the errors in AIRS temperature data caused by clouds undetected by AIRS cloud-screening algorithm.

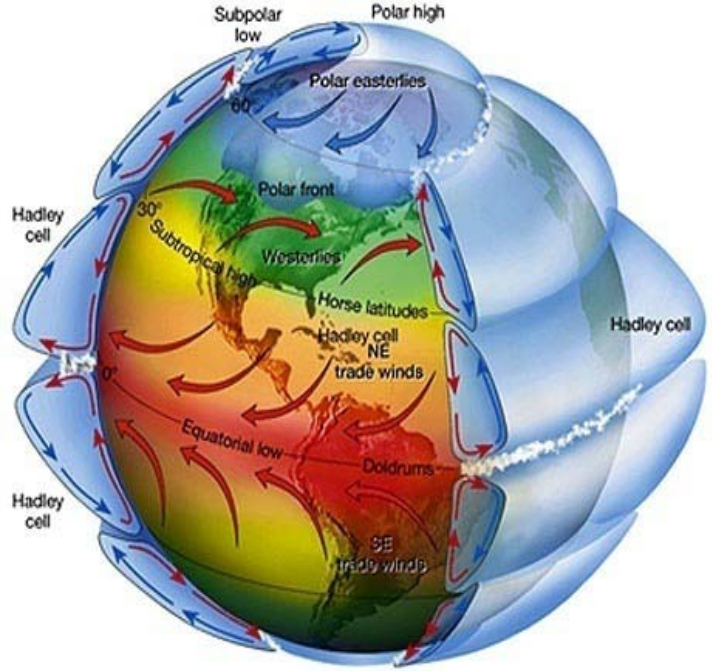


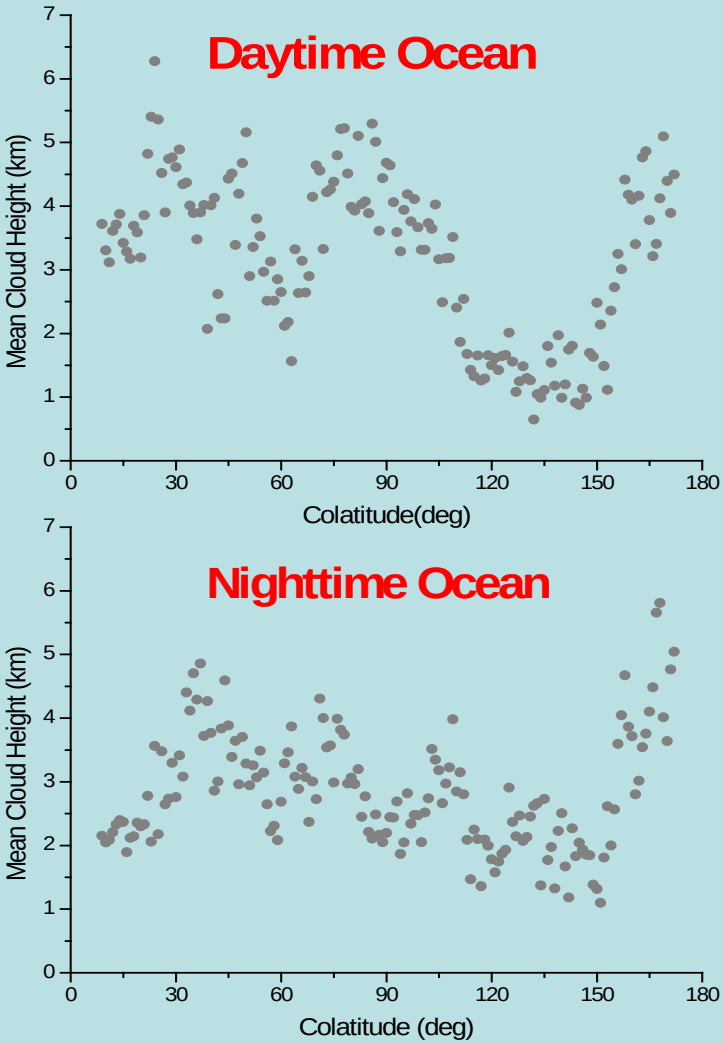
Invisibly clouds have ~7.5 Wm^{-2} warming effect at LW



Zonal and altitude distribution of invisible cloud occurrence frequency (in the unit of CERES FOV number) for nighttime oceans.

Correlation of Cloud Height with Transition Zones

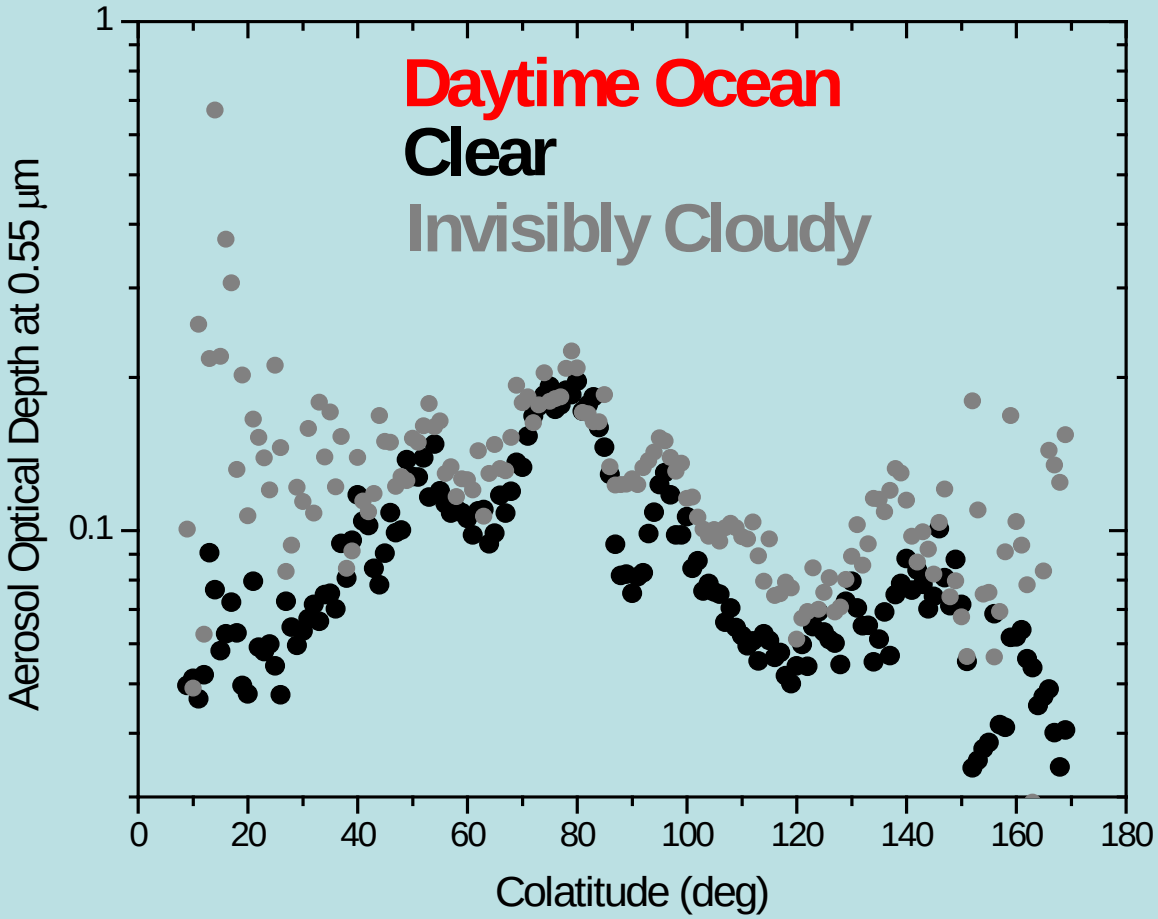




Daytime invisible clouds' altitudes correlate with the transition zones between Hadley Cells, and Hadley and Mid-Latitude Cells, where air flows upward or downward.

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

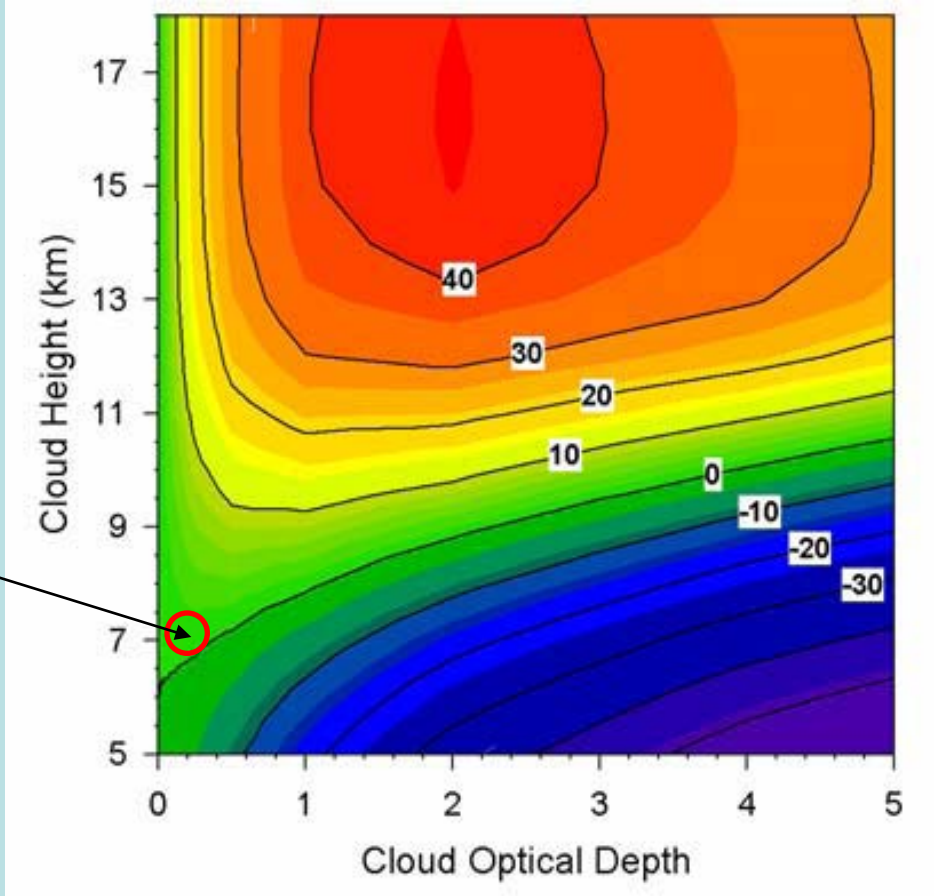
Effect on MODIS Aerosol Product



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

CERES measurements are consistent with RT model calculations for super-thin clouds

Our story happens here



Net TOA cloud radiative effect of ice clouds from radiative transfer model for midlatitude summer atmosphere, surface albedo is 0.07, and particle effective radius 60 μm.

Conclusion

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

2. Invisibly thin clouds could account for ~1-10 Wm^{-2} instantaneous regional cooling effect at SW in daytime. These clouds have an instantaneous regional warming effect of ~1-10 Wm^{-2} at LW, day and night.

3. Diurnal mean SW radiation effect of invisibly thin clouds is around ~5 Wm^{-2} regional cooling effect; diurnal mean LW radiation effect of invisibly thin clouds is around ~7.5Wm^{-2} regional warming effect.

4. Regional diurnal mean radiation effect of invisibly thin clouds is ~2.5 Wm^{-2} net warming.

5. With a ~40% global coverage of invisible clouds, the net radiation effect of the invisible clouds is estimated to be ~1.0 Wm-2 warming, globally mean.