

A comparison of cloud products from ISCCP and MODIS/TERRA and its implication on the estimative of Earth Radiation Budget

Center for Weather Forecast and Climate Studies (CPTEC)
Brazilian National Institute for Space Research (INPE)

Simone Sievert da Costa

satelite.cptec.inpe.br

Talk Outline

- **Comparison between ISCCP vs. MODIS**

  Understand basic difference on cloud properties from the two global dataset

- **A Study using ISCCP data: impact of multiple scattering by clouds particles on LW**

Comparison between ISCCP vs. MODIS

A overview of the dataset

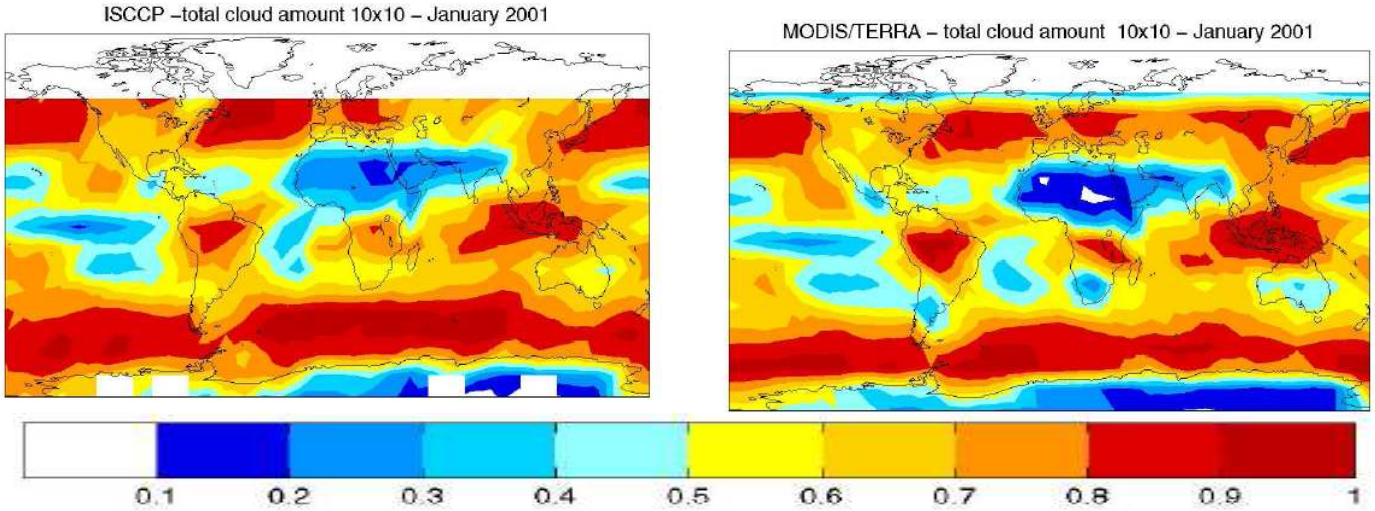
	ISCCP-D2	MODIS06-L2
Climatology period	1982-2006	from 2001 to present
Platform	**Geostationary:** GOES, GMS and METEOSAT **Polar:** NOAA	**Polar:** AQUA (afternoon overpass) & TERRA (morning overpass)
Data product Monthly mean	15 cloud classes on 2.5 grid: WP, CA, P_{cld_top}, T_{cld_top} (ice/liq)	liquid and ice particle on 1 grid: WP, CA, P_{cld_top}, T_{cld_top}, re
Sensor	Spectroradiometer	MODIS
N Chanel	2 (VIS/IR)	13 (VIS/NIR/IR)
Spectrum	0.6 and 11 μm	0.6 – 14.2 μm
Cloud cover mask	clear or cloudy	confident clear, probably clear probably cloudy or cloudy

In this study the preliminary comparison between these two satellite dataset is based on January 2001- TERRA monthly mean cloud products (CA, CTP, WP, total, liq, ice).

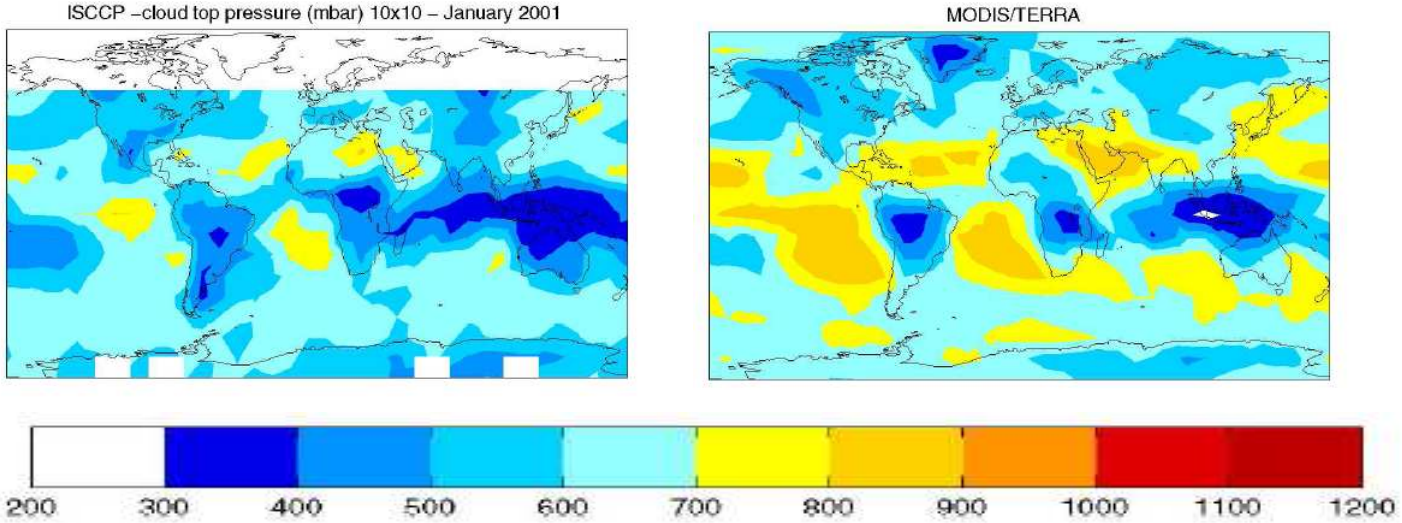
Comparison between ISCCP vs. MODIS

Cloud amount and cloud top pressure from two dataset have overall similar global features:

Total cloud amount



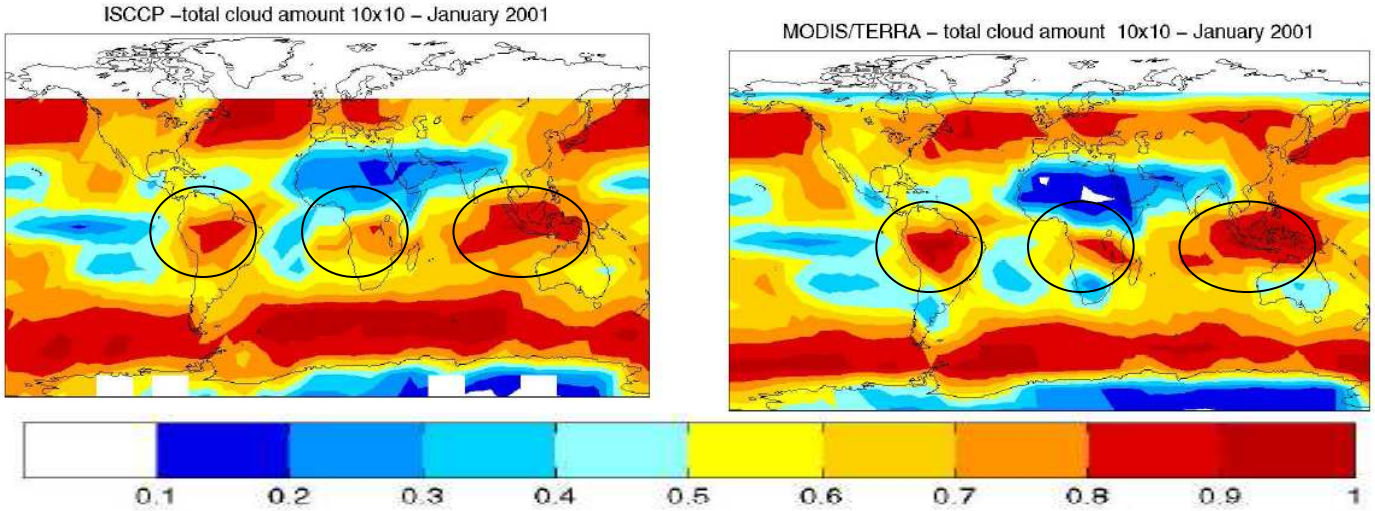
Cloud top pressure



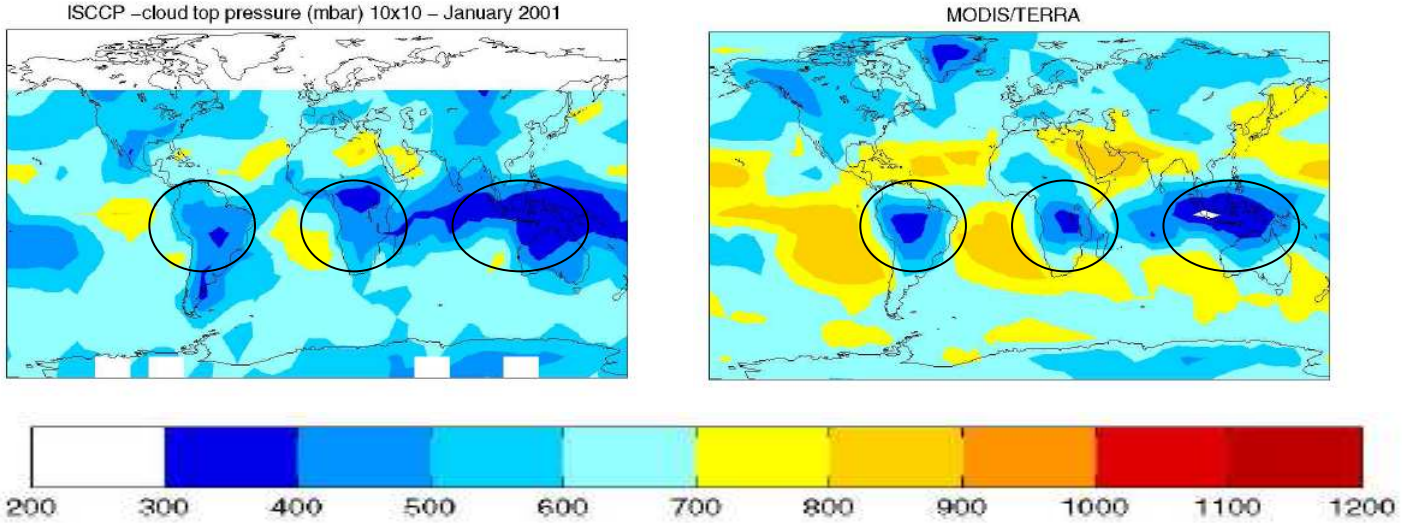
Comparison between ISCCP vs. MODIS

high frequency of cold and high clouds over the equator

Total cloud amount



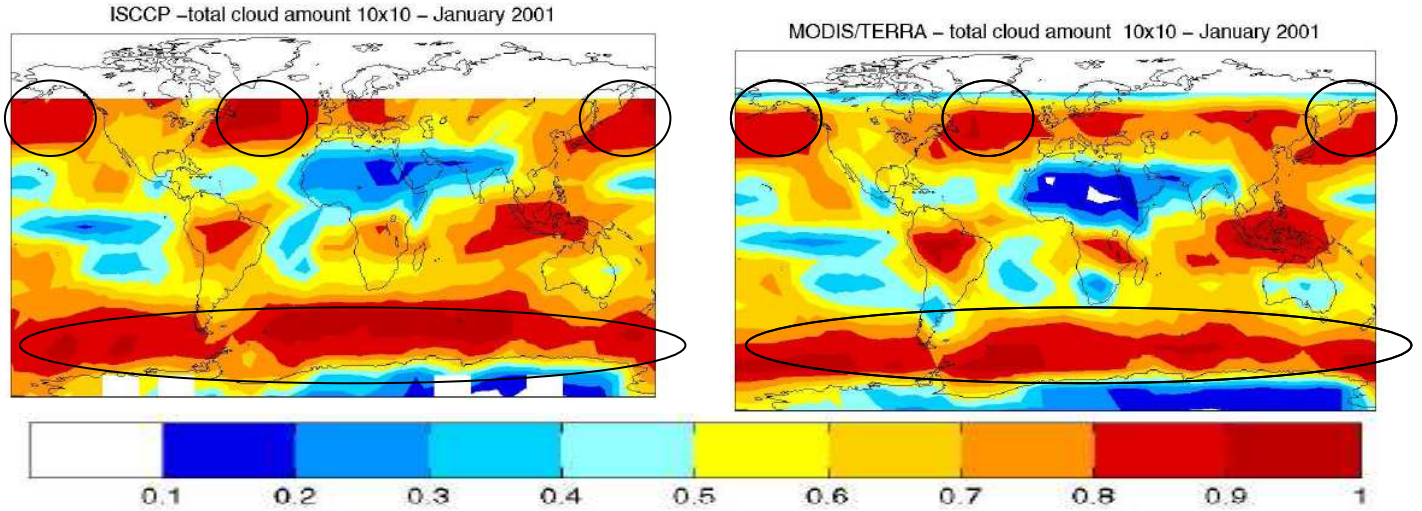
Cloud top pressure



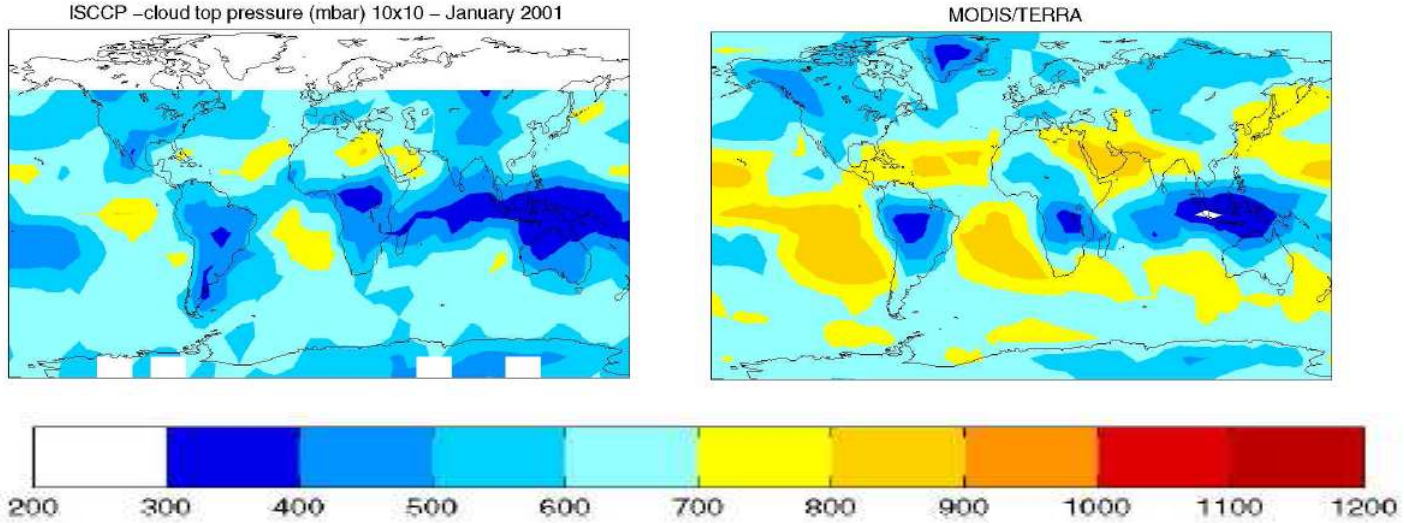
Comparison between ISCCP vs. MODIS

high cloud amount of warm clouds in the mid-latitude storm tracks regions,

Total cloud amount



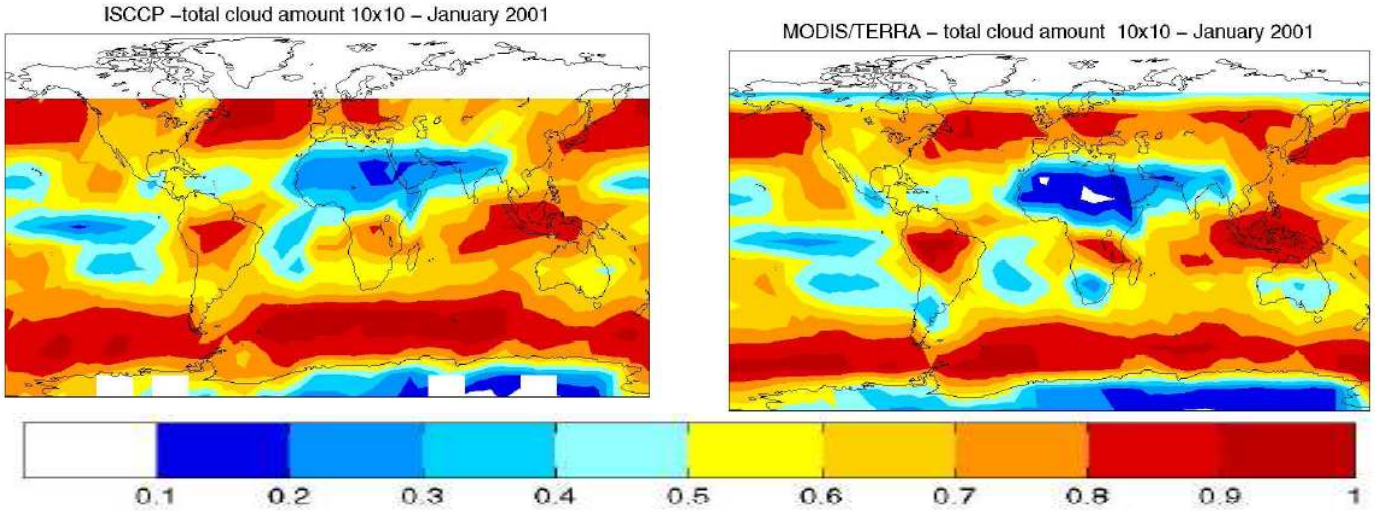
Cloud top pressure



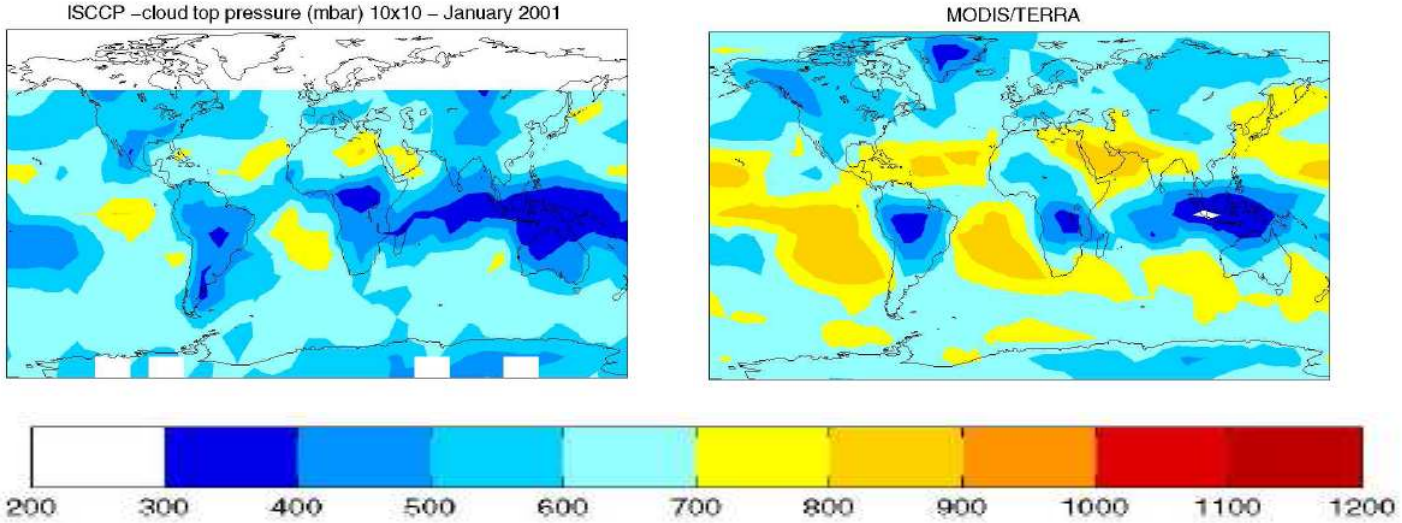
Comparison between ISCCP vs. MODIS

low cloud frequency over the sub-tropical Atlantic and the Pacific oceans and over desert regions.

Total cloud amount

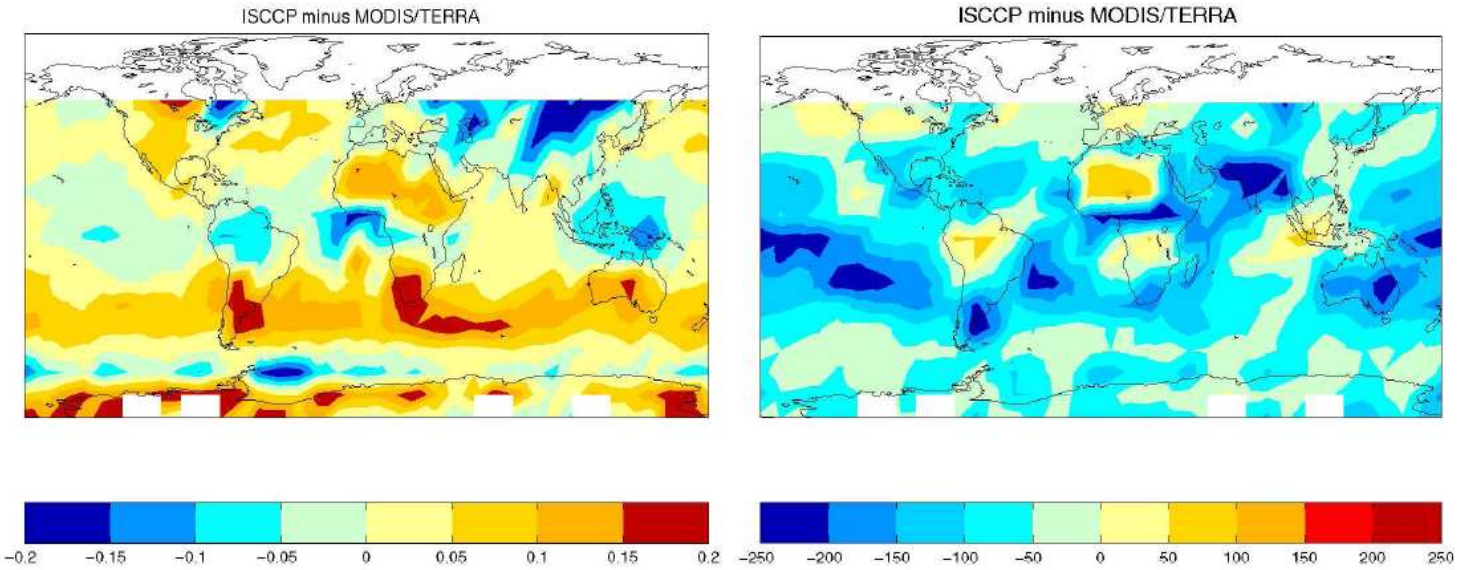


Cloud top pressure



Differences between ISCCP-MODIS

cloud frequency **cloud top pressure**



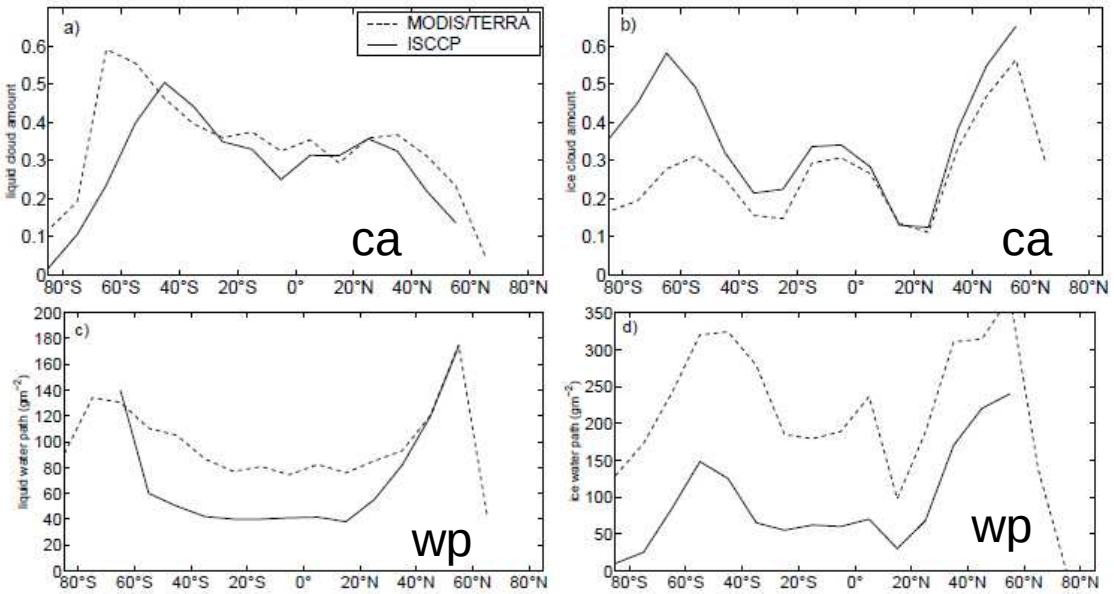
The main differences are:

a) ISCCP observes high clouds at lower frequency than MODIS at low latitudes. ISCCP applies a bispectral technique to retrieve cloud properties, which semi-transparent cloud occurrence, such as cirrus clouds, can be underestimated and misplaced to a lower level (Chang and Li, 2005)

b) ISSCP presents more cloud amount over desert regions than MODIS, that can be associated to dust contamination in ISCCP product during summertime (Stubenrauch *et al.*, 1999).

Differences between ISCCP-MODIS

liquid cloud particles ice cloud particle



Eliasson et al, 2010:**Assessing modelled spatial distributions of ice water path using satellite data**

(July 2006 to April 2008)

ISCCP, global mean = 32, std = 23

MODIS−aqua, mean = 58, std = 36

Figure 2 - ***January 2001 zonal mean cloud amount (a,b), water path (c,d) observed by for ISCCP and MODIS/TERRA for (left) liquid and ice cloud particles (right).***

Ice and water cloud amount have a reasonable agreement between ISCCP and MODIS, except over higher latitudes during summertime. Observe that the difference between ISCCP and MODIS for liquid water cloud amount has the same magnitude, however it has opposite signs for ice clouds at high latitudes.

The biggest difference between ISCCP and MODIS products is for water path. For instance, the ISCCP water path assumes cloud effective radius of 10 and 30 μm for liquid and ice particles, respectively. Such assumption makes the water path uncertain by 15 - 25 % for water clouds (Rossow *et al.*, 1989; Nakajima and King, 1990) and by 30 - 50% for thinner ice clouds.

Differences between ISCCP-MODIS

Cloud optical depth

$$\tau \alpha \, CA \frac{WP}{\rho \, r_e}$$

Although water path and effective radius from ISCCP and MODIS disagree by more than 50 % for some latitudes, the optical depth that is dependent on this variables are almost similar for low latitudes.

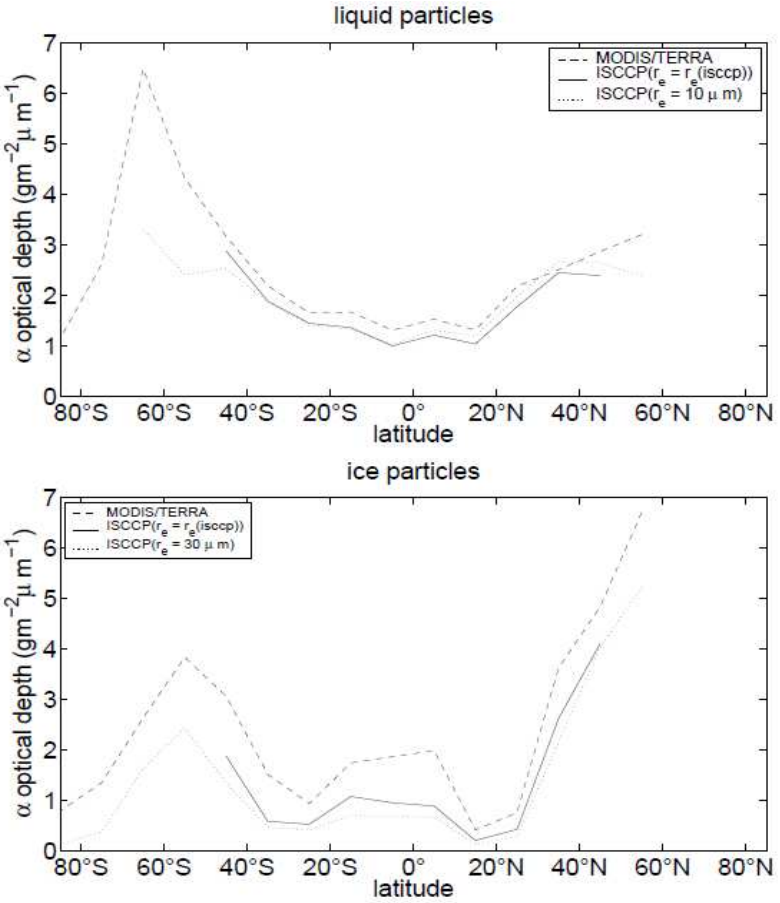


Figure 3 - ***Zonal mean optical depth for water and ice clouds using the ISCCP and MODIS cloud products.***

Impact of Multiple Scattering by Clouds on LW RT

Impact of Multiple Scattering by Clouds on LW RT

Motivation I

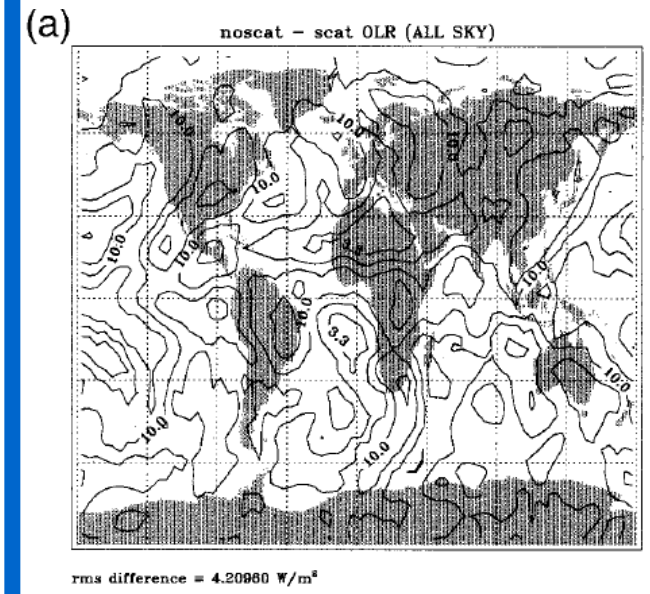
- Simplification in LW RT – neglecting clouds and aerosol scattering.
- Stephens (1980) - Pioneering study on clouds longwave scattering – small cirrus clouds reflectance of about 4 - 6 % may change by 10 % the broadband irradiance to 25% for at 11 μm atmospheric irradiances.
- Many studies tried to estimate the scattering effect on irradiances (Ritter andGeleyn, 1992; Eymet et al. 2004) and developed longwave multiple scattering parameterizations for GCM (e.g Edwards and Slingo, 1996 and Chou *et al.* 1999).

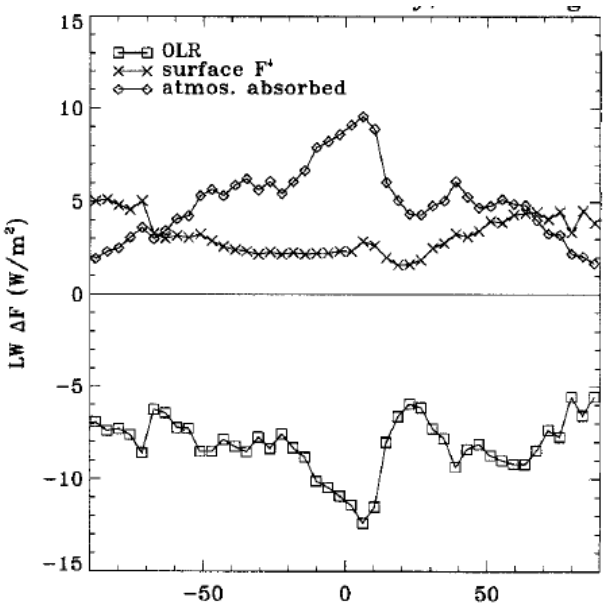
Although the potential importance of scattering of longwave (LW) radiation by clouds has been recognised, most studies have focused their analyses on high clouds under overcast conditions. One exception is Stephens et al. (2001)…

Impact of Multiple Scattering by Clouds on LW RT

Motivation II

From Stephens *et al.* (2001)





Simulations: GCM from Colorado State Uni.
RT - hemispheric mean two-stream code

Global mean OLR is 8Wm-2 lower when scattering by clouds particles is included.

This value (-8 Wm-2) seems too high, possibly because of simplifications in their 2STR radiative transfer scheme. For instance, Fu *et al.* (1997) suggested that none of the conventional 2STR approximations produce better irradiances than those from the simple absorption approximation.

Impact of Multiple Scattering by Clouds on LW RT

AIM

The present research aimed to study the effect of scattering by low, middle and high clouds on LW irradiances

Sensitivity tests are conducted to assess how changes in clouds and atmospheric properties and RT treatment affect LW scattering partly to compare with existing literature.

- Cloud altitude
- Cloud particle shape (sphe, n-spherical
- Microphysics of clouds (WP, re)
- Atmospheric conditions

Radiative Transfer:

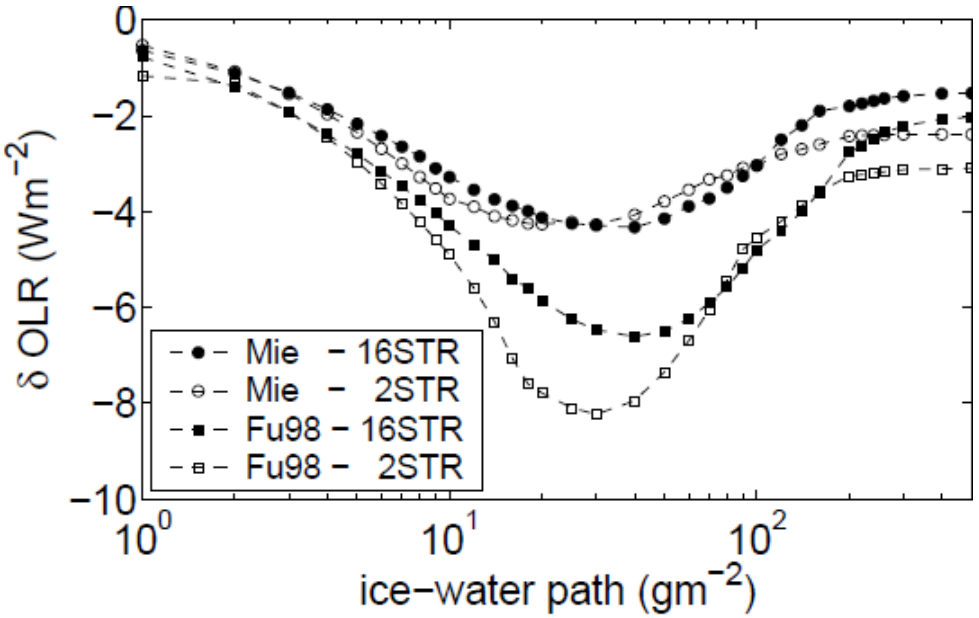
RFM (line-by-line, Duhia et al 1997)+ DISORT (Stamnes *et al.* (1988).)

Change in OLR due to scattering $\delta OLR = OLR_s - OLR_a$

δOLR = negative

Sensitivity tests

δOLR depends on cloud particle shape:



High clouds, tropical profile, re=30μm

Spherical ice particles at λ=10 μm

β= 0.06m-2g
ω = 0.51 and
g = 0.963
} Mie Theory

non-spherical particles at λ= 10 μm

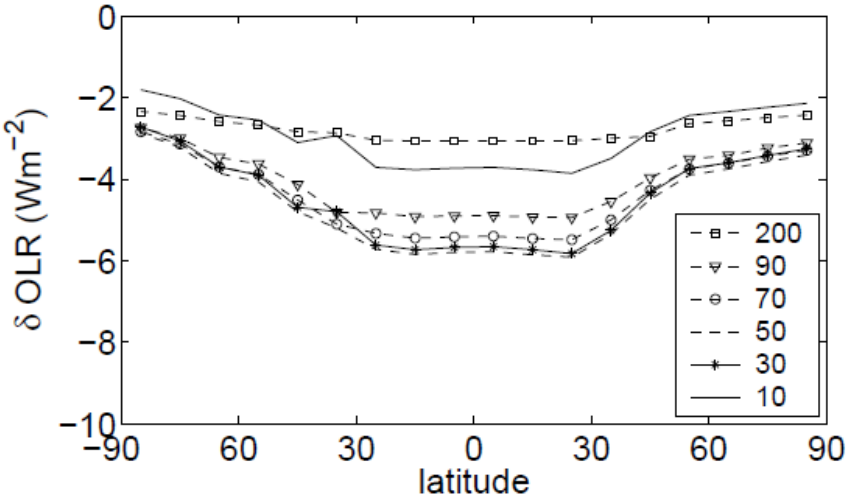
β= 0.06 m-2g,
ω = 0.61 and
g = 0.947
} Fu et al., 1998

Spherical particles backscatter less LW irradiance than hexagonal crystals, because spherical particles have both stronger absorption and smaller anisotropy when compared to hexagonal particles.

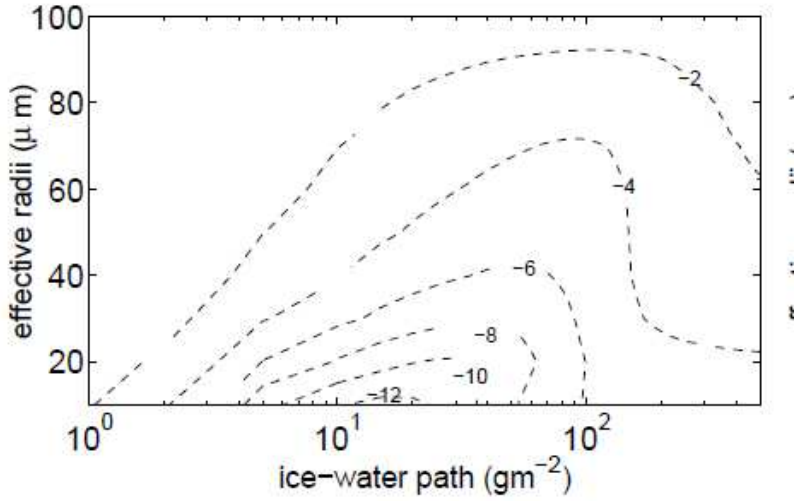
Sensitivity tests

δOLR depend on cloud particle size:

Change in OLR due IWP, re=40 μm. The atmospheric profiles from ECMWF.



Change in OLR due IWP and re. Standard tropical profile.



100 % high clouds composed by randomly oriented hexagonal crystal particles.

The sensitivities tests showed that OLR can be overestimated (up to 10 Wm-2) when LW scattering by cloud particles is neglected.

Methods: Radiative transfer and vertical profiles

Global estimates

Radiative Transfer:

Fu *et al.* (1997) - 4 Streams

Vertical profile

Pressure, temperature and water vapour profile derived from ECMWF monthly mean data averaged over 11 years (1980-91).

O_3 data from Li and Shine (1995) climatology.

CO_2, CH_4 and N_2O from IPCC (2001)

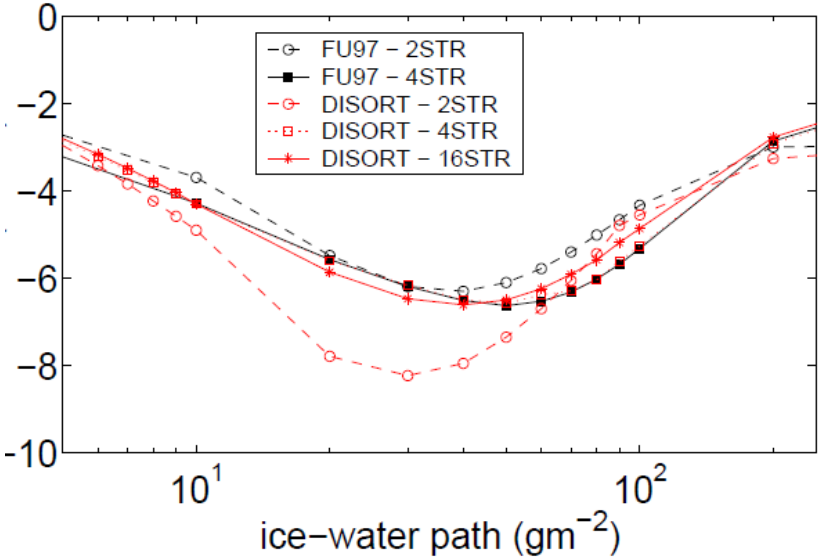
Clouds data

ISCCP version

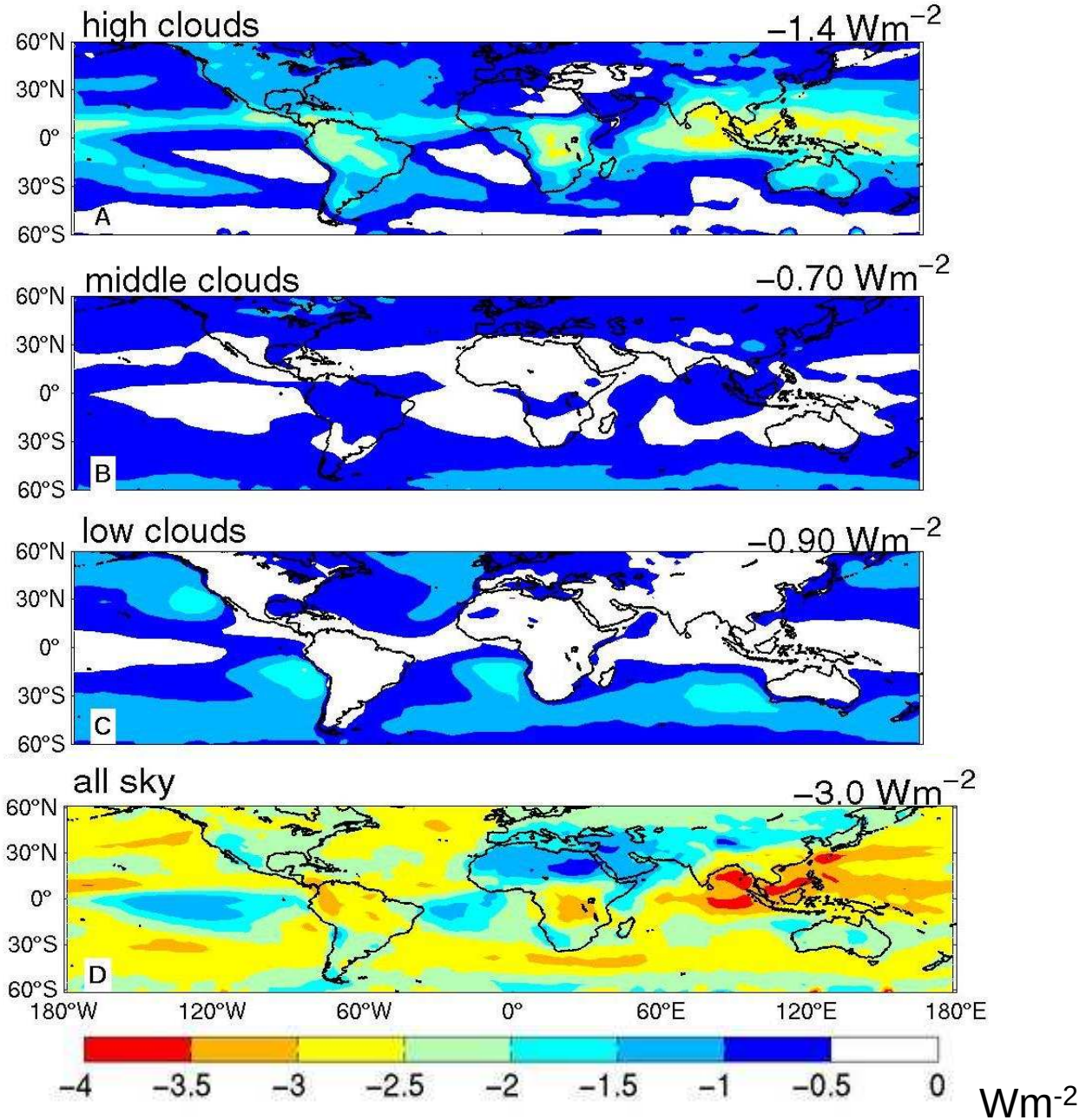
Water clouds is assumed spherical – optical properties derived using Mie Theory re = 10 μm.

Ice water clouds is assumed non-spherical – optical properties derived from Fu *et al*. 1998 re= 30μm.

.



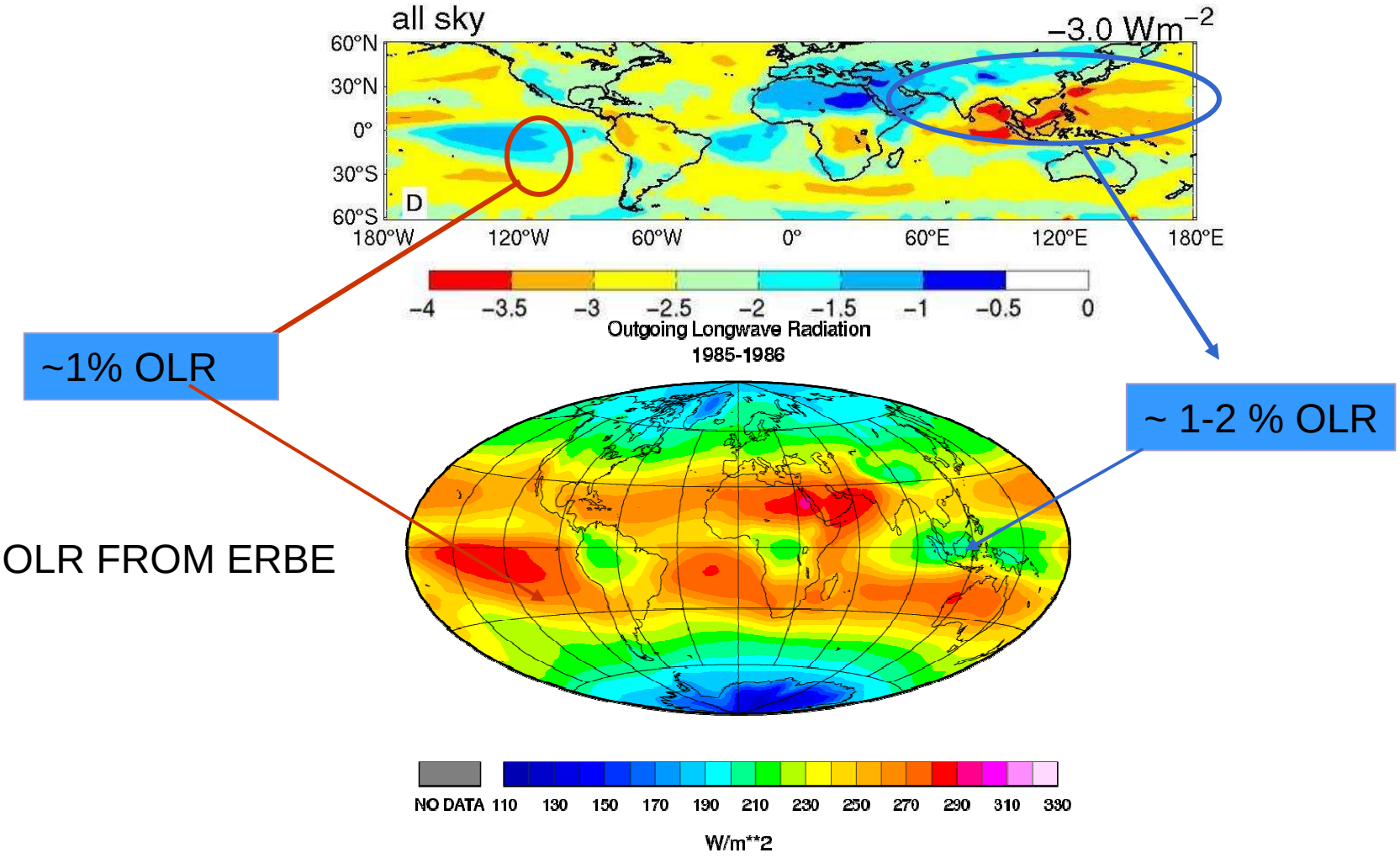
Global Annual mean scattering effect on OLR



How significant is the scattering effect on OLR?

In terms of accuracy on OLR estimates

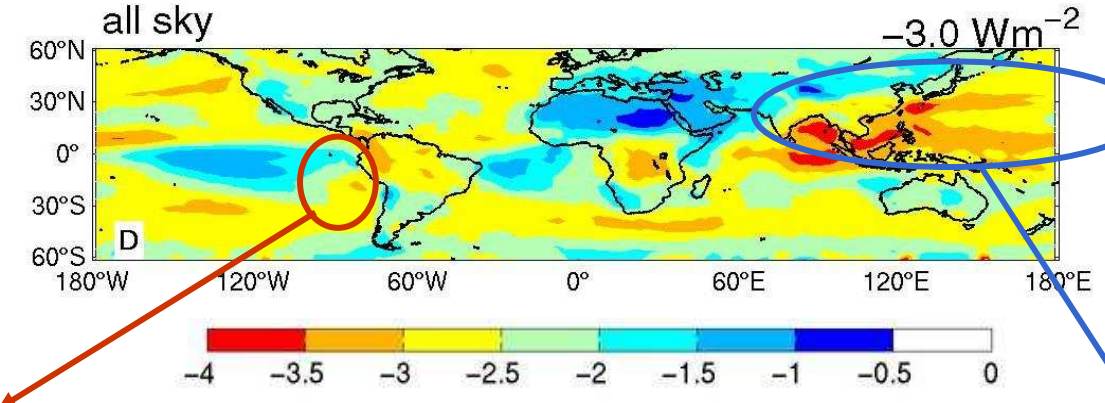
Global annual mean OLR = 240 Wm^{-2}



How significant is the scattering effect on OLR?

In terms of LW cloud forcing

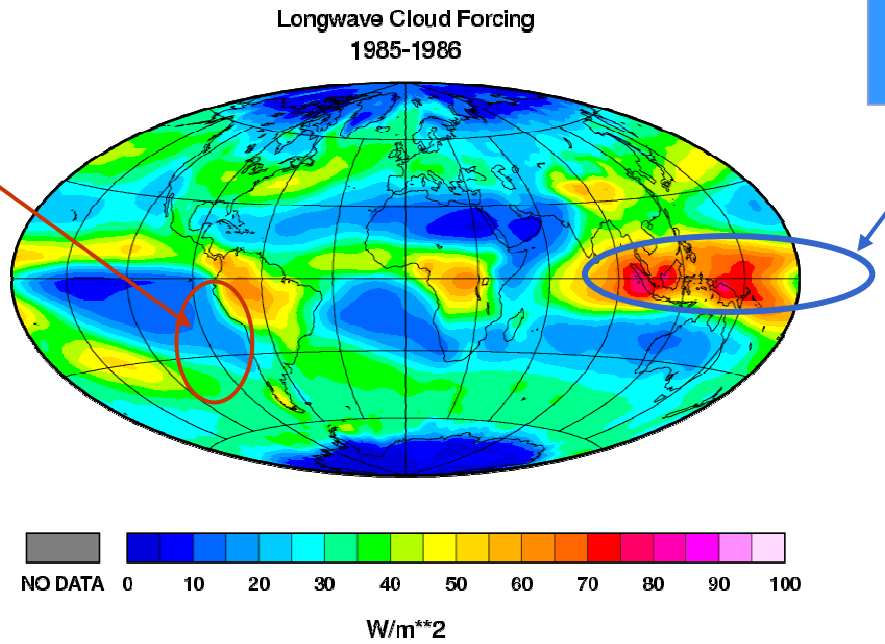
Global Annual mean 32 Wm^{-2}



~10 and 20% Cloud forcing

~ 5 % cloud forcing

LW Cld Forcing FROM ERBE



Summary 1

- The ISCCP cloud dataset is compared to cloud products from the MODIS on board of the Terra satellite. The main differences are:

ISCCP observes high clouds at lower frequency than MODIS at low latitudes. ISCCP applies a bispectral technique to retrieve cloud properties, which semi-transparent cloud occurrence, such as cirrus clouds, can be underestimated and misplaced to a lower level.

ISCCP presents more cloud amount over desert regions than MODIS, which can be associated to dust contamination in ISCCP product during summertime.

Although water path and effective radius from ISCCP and MODIS disagree for some latitudes, the cloud optical depth are almost similar for low latitudes.

Summary 2

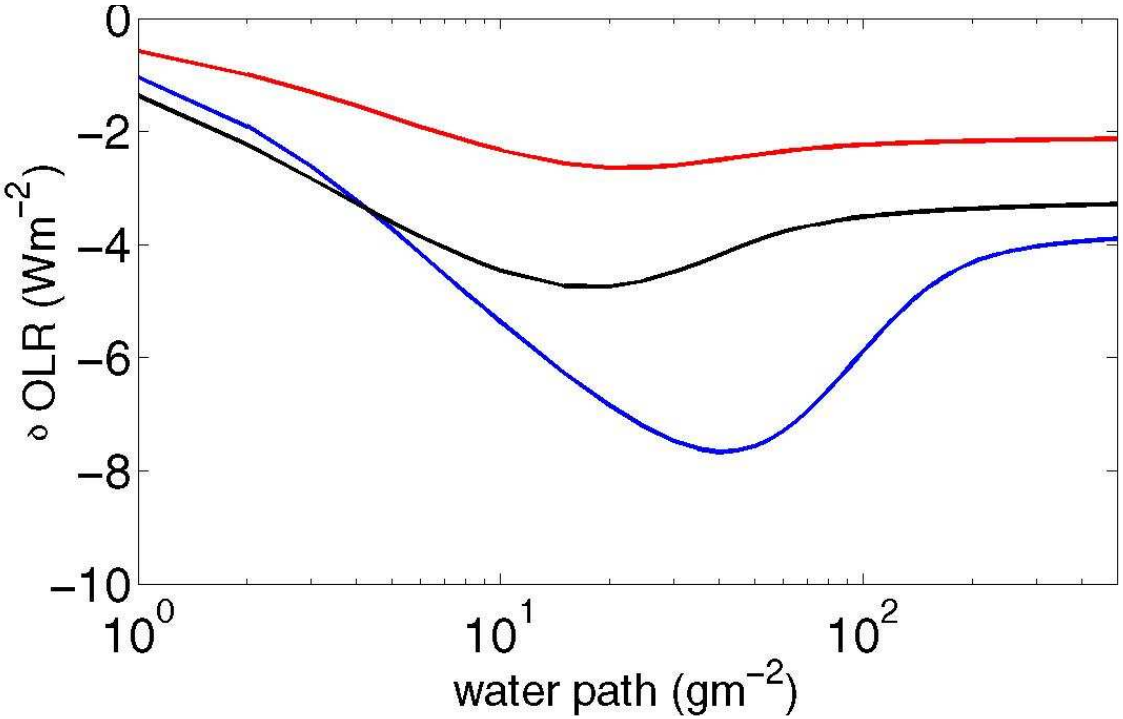
- Scattering by clouds reduces the cloud emission and therefore decreases the OLR. The reduction of OLR is due to the backscattering of upward irradiance.
- The δOLR magnitude depend on cloud optical properties, water vapour and the temperature difference between cloud top and surface temperature.
- Sensitive tests show that scattering effect on OLR is less than -10 Wm^{-2} for individual clouds.
- Scattering in low clouds has significant impact on OLR in regions of marine stratocumulus where the column water vapour is relatively low.
- The global annual mean multiple scattering effect on the OLR is estimated to be –3Wm^{-2}. This is small when compared to the typical OLR global value of 240Wm^{-2}. However, the OLR change of –3 Wm^{-2} is significant compared to cloud longwave radiative forcing (31 Wm^{-2}) and net cloud forcing (-14 Wm^{-2}).


Thank you
Simone Sievert da Costa
simone.sievert@cptec.inpe.br
DSA
CNPq

Impact of Multiple Scattering by Clouds on LW RT

δOLR varies with cloud altitude:

100 % clouds – tropical standard profile



Low –1-2 km re =10 μm

Middle 3 – 4 km re = 10 μm

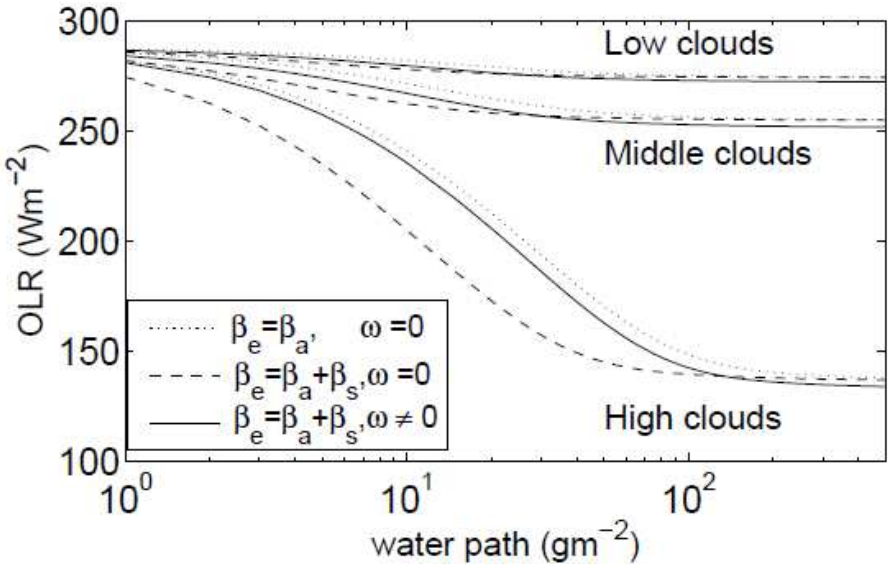
High 10 - 12 km re = 40 μm

Scattering effect on OLR depend on temperature difference between cloud top and surface.

- **Systematic comparisons of clouds as observed by MODIS and ISCCP**
- **Robert Pincus**, NOAA/ESRL, Boulder, CO; and C. P. Batstone and S. E. Platnick
- Since 1984 the ISCCP (International Satellite Cloud Climatology) project has been providing global estimates of those cloud parameters that affect the earth's radiation budget, including cloud amounts, cloud top pressure and temperature, and cloud optical depth. These estimates are made from observations in a few spectral channels made by a changing set of geostationary and polar-orbiting satellites, and have become a valuable data set for evaluating the predictions of climate models (among many other uses). The MODIS instrument, flying aboard the polar-orbiting Terra and Aqua platforms since 2000, also estimates these quantities. Substantially more spectral information is used in the MODIS retrievals than in ISCCP, making the retrievals more sensitive to marginal clouds, at least in principle. What can be gained by using MODIS observations, and how can models (for example) be compared with both ISCCP and MODIS?
- We compare MODIS and ISCCP estimates of cloud properties for the entire time period during which both are available. Estimates of monthly-mean cloud fraction within 2.5 degree regions are almost always within a few percent, indicating that the additional spectral information used by MODIS does not detect a large number of very thin clouds. Cloud top temperture, on the other hand, differs by several K, indicating that the CO2 slicing used by MODIS is more likely to predict higher cloud tops than the thermal emission tests used by ISCCP. We compare the predictions as a function of time, season, land/ocean, and cloud phase.

Impact of Multiple Scattering by Clouds on LW RT

δOLR varies with cloud altitude:



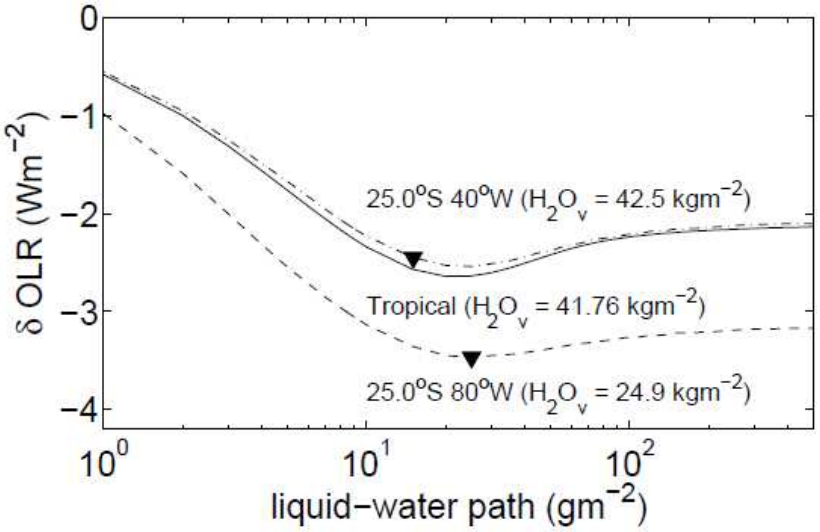
- Tropical std profile
Low (1 - 2 km) and middle (3 - 4 km) cloud particles are assumed to be liquid (re = 10μm),
high clouds (10 - 12 km) are composed of ice crystals (re = 30μm).

Scattering effect on OLR depend on temperature difference between cloud top and surface.

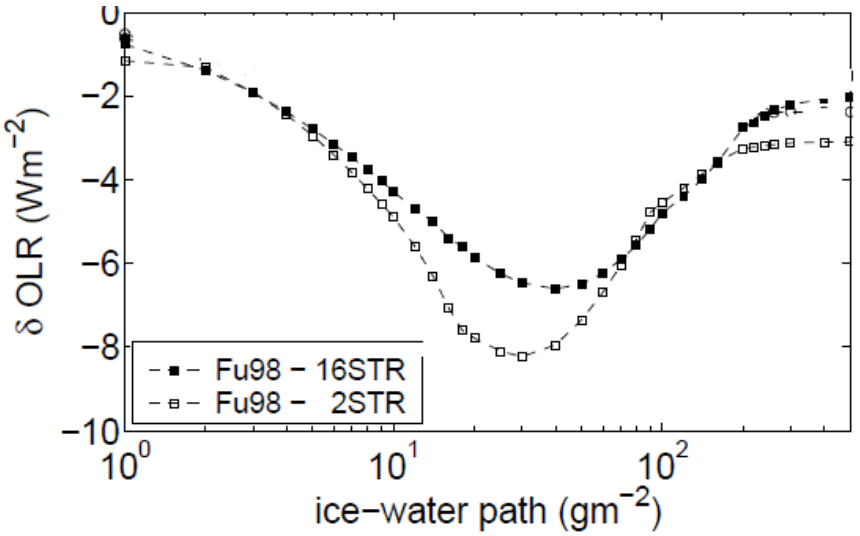
Impact of Multiple Scattering by Clouds on LW RT

δOLR varies with cloud altitude:

Low Clouds



High Clouds



Methods: Radiative transfer and vertical profiles

Global estimates

Radiative Transfer:

Fu *et al.* (1997) - 4 Streams

Vertical profile

Pressure, temperature and water vapour profile derived from ECMWF monthly mean data averaged over 11 years (1980-91).

O_3 data from Li and Shine (1995) climatology.

CO_2, CH_4 and N_2O from IPCC (2001)

Clouds data

ISCCP version D (cloud top pressure, water path and effective radius)

Water clouds is assumed spherical – optical properties derived using Mie Theory re = 10 μm.

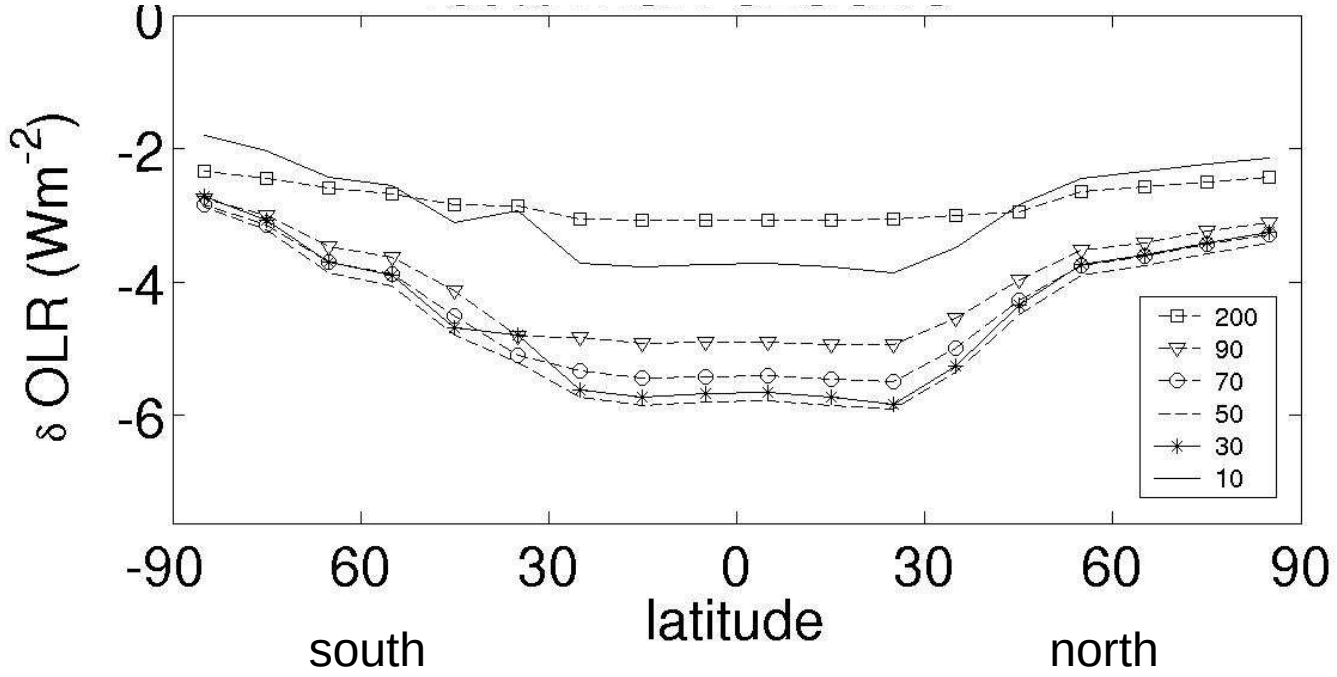
Ice water clouds is assumed non-spherical – optical properties derived from Fu *et al*. 1998 re= 30μm.

.

- Period ISSCP
- Variavies (TC, WP,)
- Paper king 1997
- Quem cancelou o talk no agu….
- VIS IR and NIR

Impact of Multiple Scattering by Clouds on LW RT

100 % - high clouds – cloud top (ISCCP) – 2 km thicker.



Scattering effect depend on cloud optical thickness, particle microphysical properties and atmospheric condition where clouds are placed.

Impact of Multiple Scattering by Clouds on LW RT

Conceptual model:

$$OLR_a = T_a F^+_{base} + (1 - T_a)\pi B$$

Neglecting scattering

$$OLR_s = T_s F^+_{base} + (1 - T_s - R)\pi B + R F^-_{top}$$

Abs+ Scattering case

$$\delta OLR = OLR_s - OLR_a = (T_s - T_a)(F^+_{base} - \pi B) + R(F^-_{top} - \pi B)$$

Clouds scattering properties on LW: $\omega > 0$ g=0.7-0.9



Change in OLR due to scattering δOLR = negative

Impact of Multiple Scattering by Clouds on LW RT

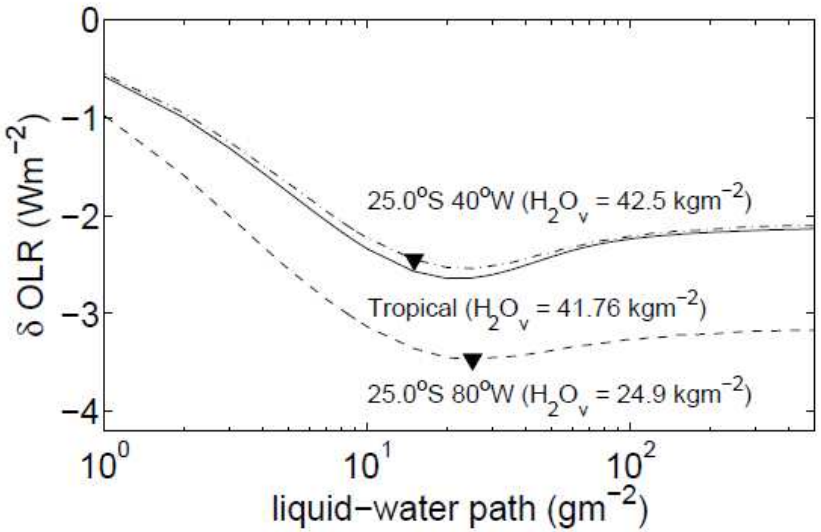
δOLR varies with cloud optical thickness:

$$\delta OLR = OLR_s - OLR_a = (T_s - T_a)(F^{\dagger}_{base} - \pi B) + R(F^{-}_{top} - \pi B)$$

- **Thin clouds**: $Ts \approx Ta \approx 1$ so $Ts - Ta = 0$, $R \approx 0$ ∴ δOLR small

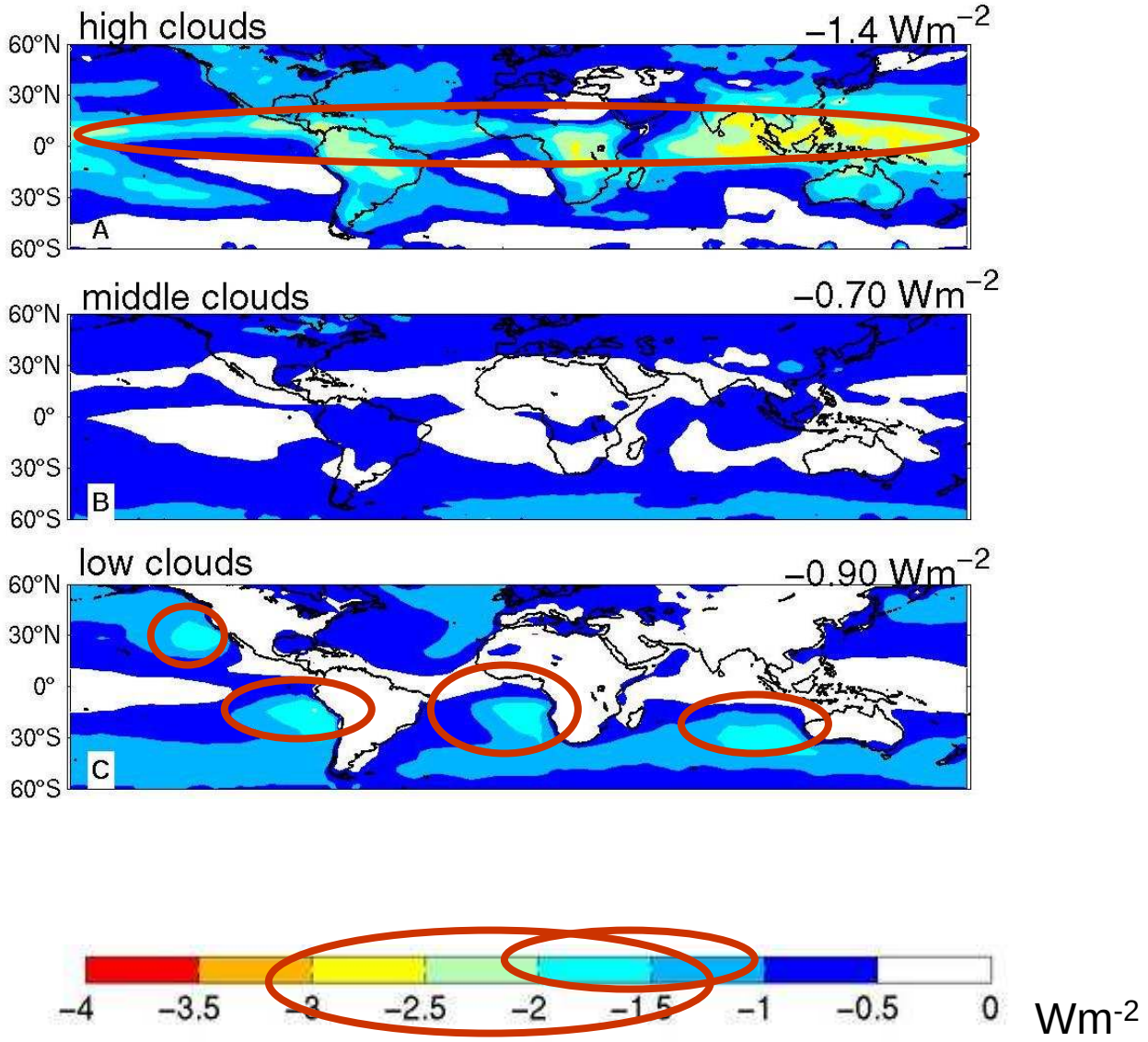
- **Increasing optical thickness :**
R increases monotonically ,
(*Ts* – *Ta***)** rises from 0 to maximum
∴ δOLR is largest

- **Thick clouds:** **(***Ts* – *Ta***)** ≈ 0
∴ δOLR small & basically due *R.*

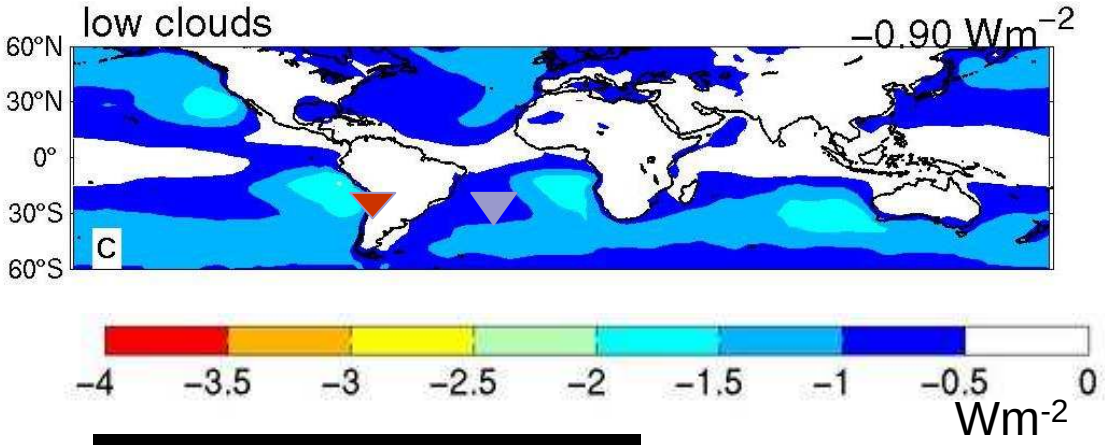


*Change in OLR due to longwave scattering by 100 %of low clouds as function of liquid-water path (*gm-2*). The low clouds are composed of spherical particles with effective radius = 10* mm. H2Ov *is the column water vapour.*

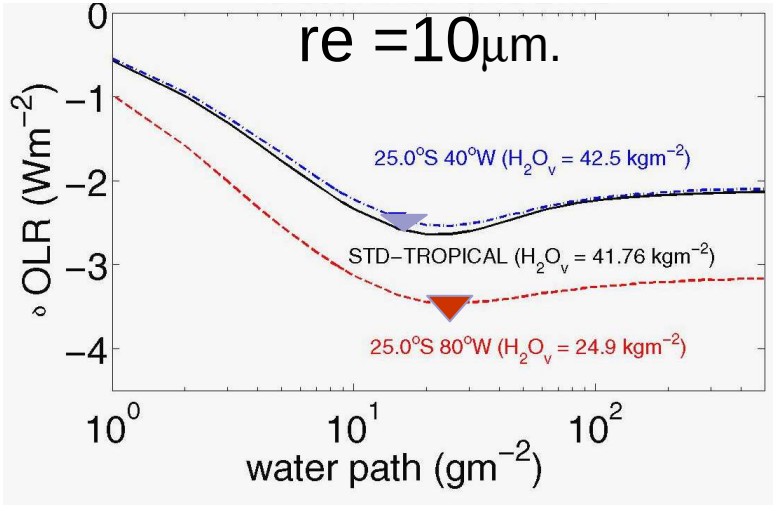
Scattering effect on OLR for different heights

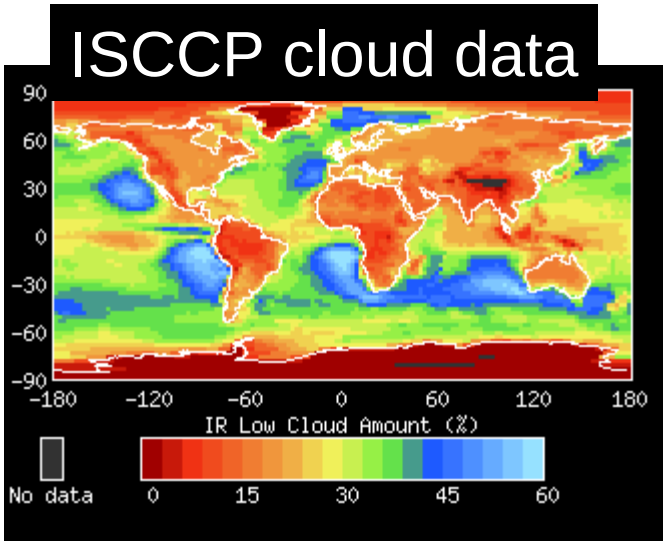


Low cloud scattering effect over dry regime



100 %low clouds (1-2 km)





Over the tropical Pacific Ocean (80ºW), a region characterized by strong subsidence and high cloud cover (around 60%), the δOLR can be significant.