Atmosphere Opacity observed by CALIPSO-link with cloud LW feedback

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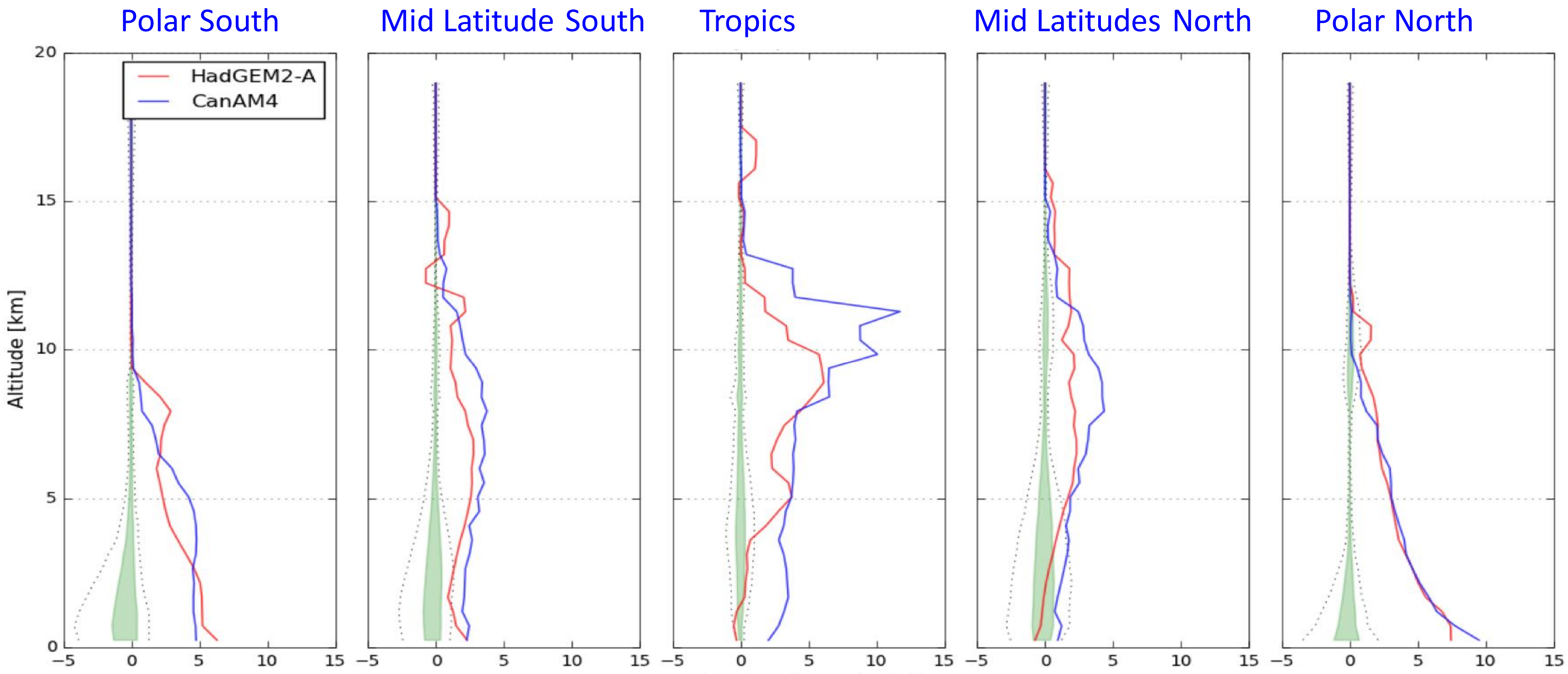
Background

The cloud vertical distribution is more sensitive to a forced climate warming than vertically integrated variables



Predicted forced change in the Cloud fraction profile (%)
(AMIP+4K/COSP/lidar – AMIP/COSP/lidar)

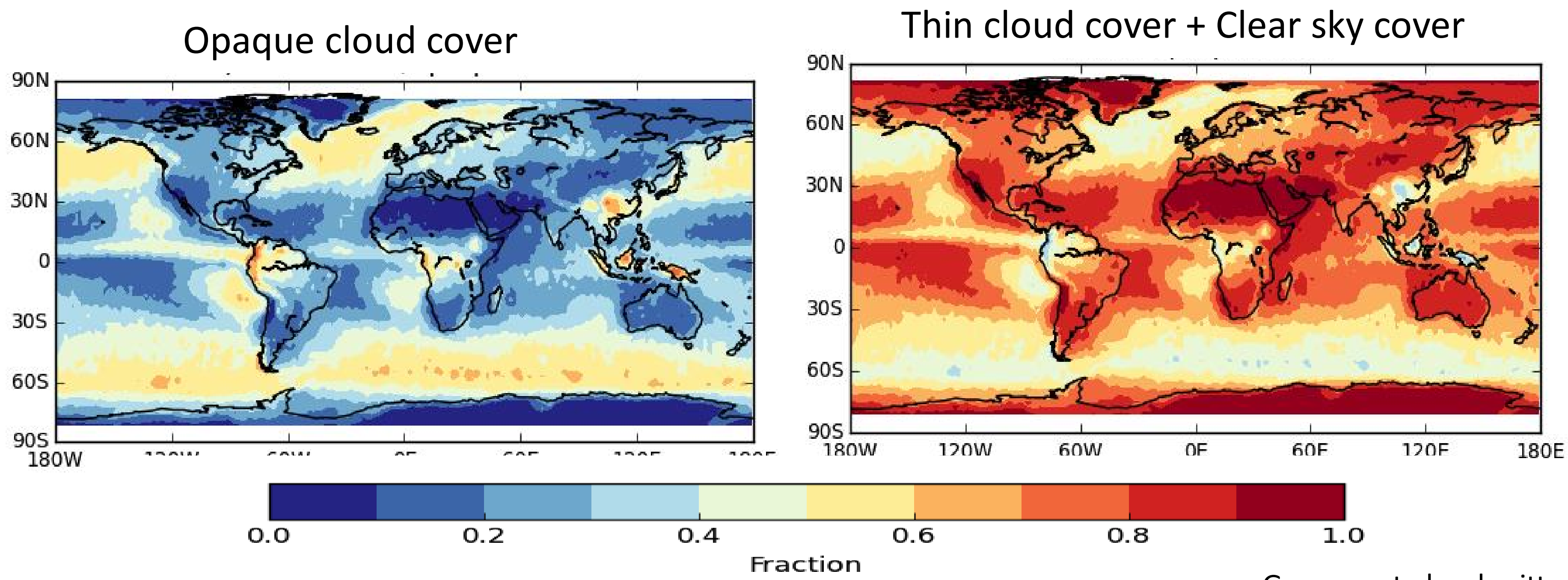
Chepfer et al. 2014

The expected forced change in the cloud vertical distribution (+4K) >> observed natural variability

Background

Where the lidar is fully attenuated before reaching the surface
about 30 %

Where the lidar sounds entirely the atmosphere down to the surface
about 70%



Guzman et al, submitted

Consistent with Kato et al.

Consistent with M. Vaughan inputs

Calipso sounds entirely the atmosphere from the TOA to the surface in shallow cumulus and over continent most of the time

Calipso is fully attenuated before to reach the surface in deep convective clouds and in the mid-latitude storms

Background

Opaque Cloud Cover
+
Thin cloud Cover
+
Clear sky cover
=
100%

Guzman et al, submitted

Deep convective Tropical opaque clouds (w500<0)

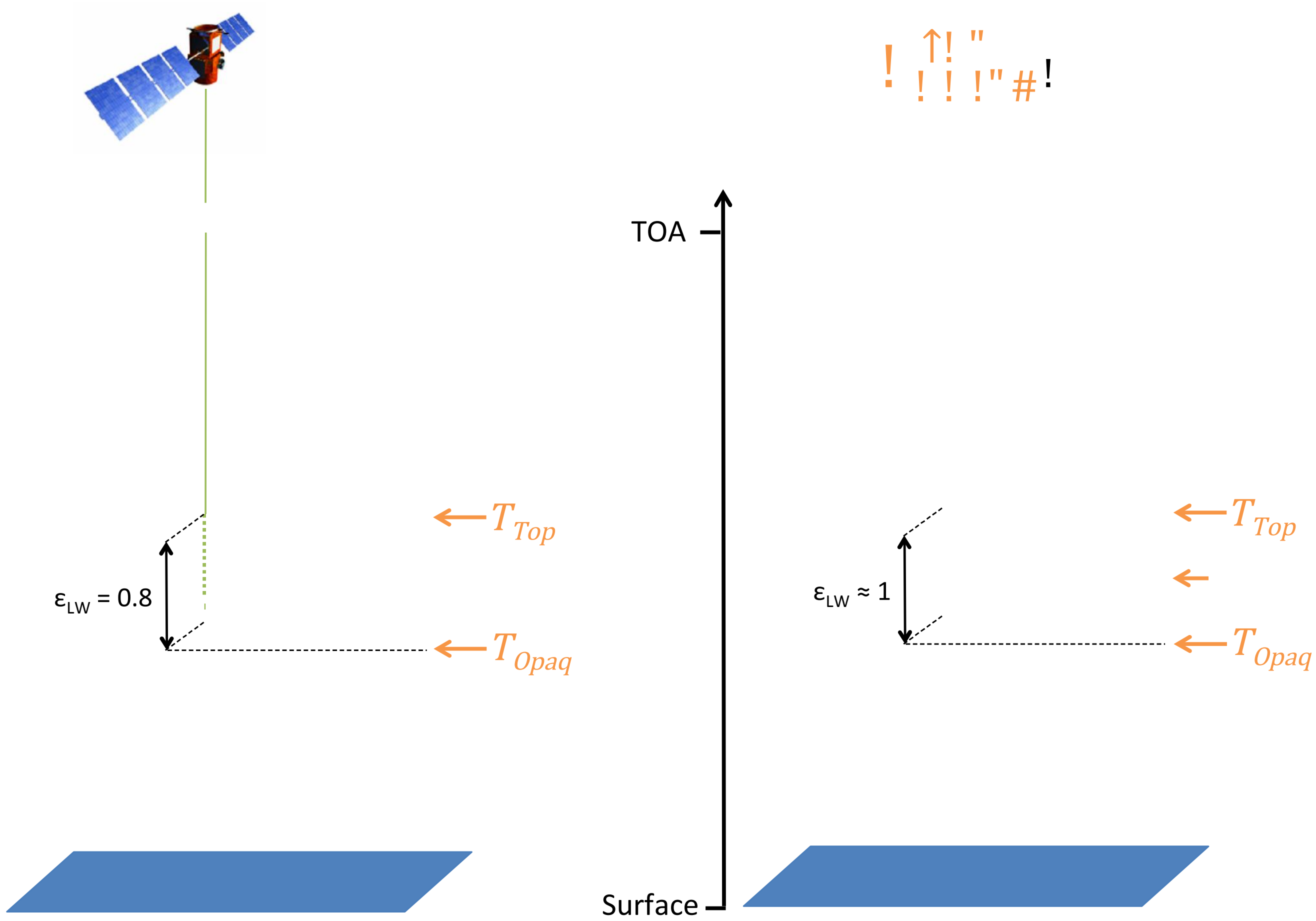
Expected Cloud Feedback mechanism :

Deep convective clouds are expected to rise up as surface temperature increases => Positive LW cloud feedback, … how much ?

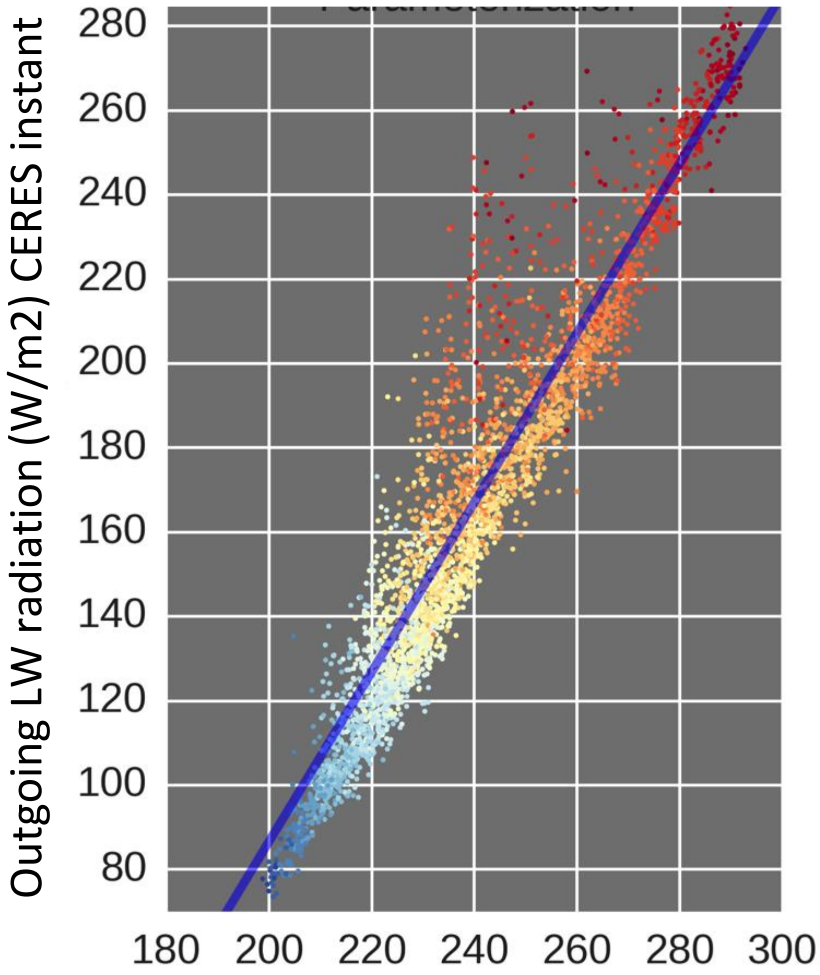
Hartmann et al. 2002
Zelinka et al. 2012
Wang et al. 2002
O'Gorman et al. 2013
Chepfer et al. 2014,
…

…

The altitude where the lidar is fully attenuated (in opaque cloud) drives LW outgoing rad: a direct precise stable measurement



The altitude where the lidar is fully attenuated (in opaque cloud) drives LW outgoing rad: a direct precise stable measurement



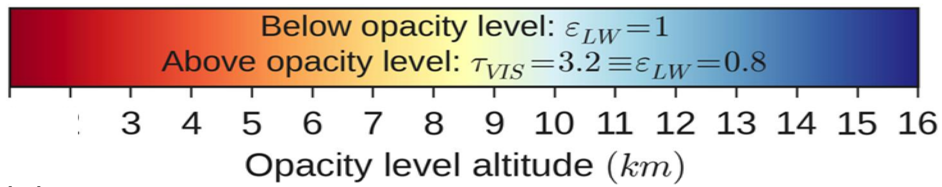
Temperature of emission : Tthick (K)
From CALIPSO (zopaque) + ré-analysis T(z)

Dots = Observations in single columns/profiles where the lidar is fully attenuated

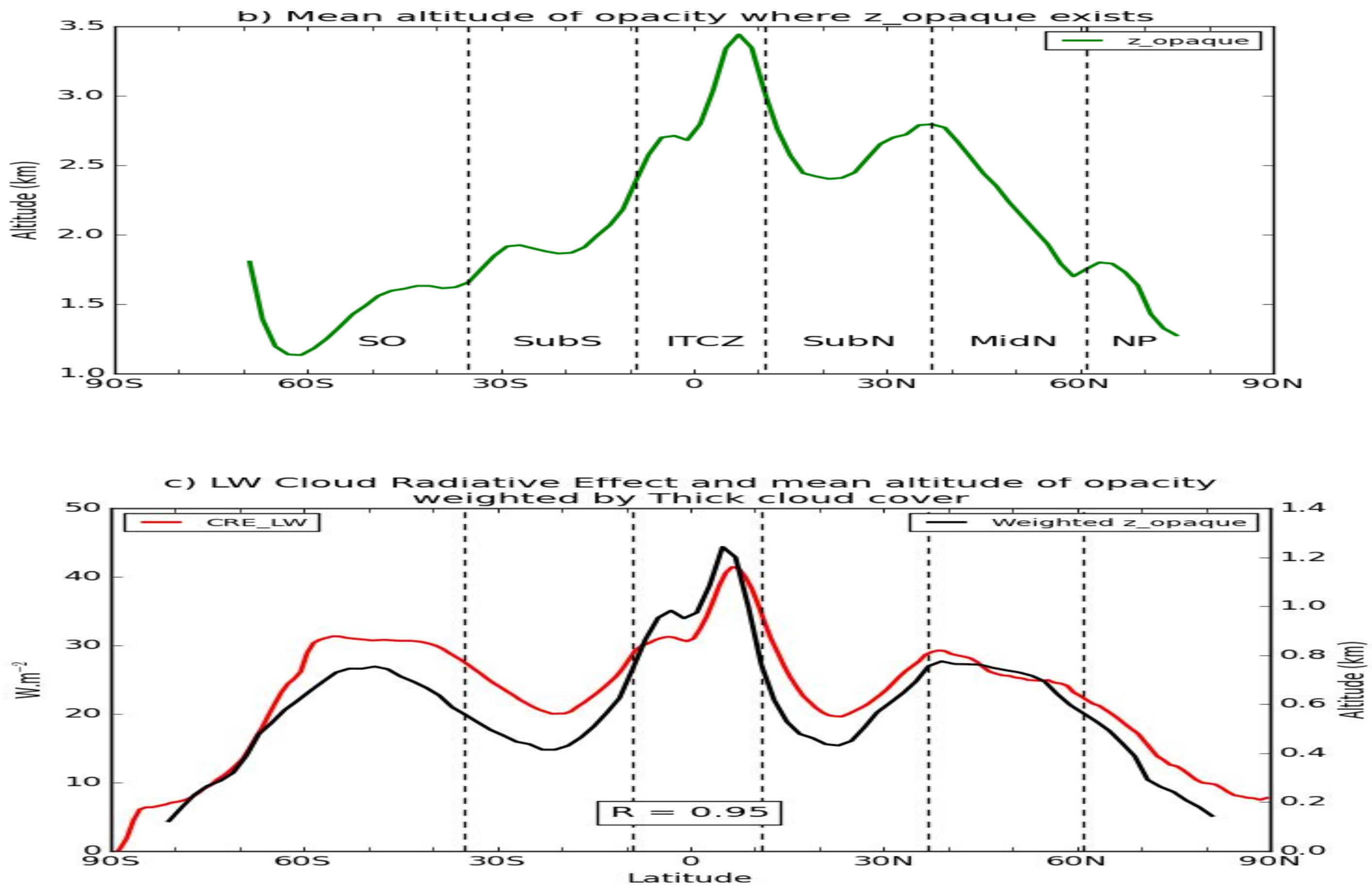
Blue line= theoretical direct radiative transfer computations, independent of observations

Slope = 2.0 W/m2/K ,
consistent with Wang et al. 2002

Sherwood et al, 2004, Garnier et al. 2015



Observations:
Calipso opaque cover, altitude of opacity .vs. LW CRE



Guzman et al.,
submitted

Questions explored in this study

- Which record length is required to detect a cloud LW feedback signature = when does the forced cloud change goes out of the natural variability?

- How gaps or shifts in calibration between successive lidar missions impact the required record length ?

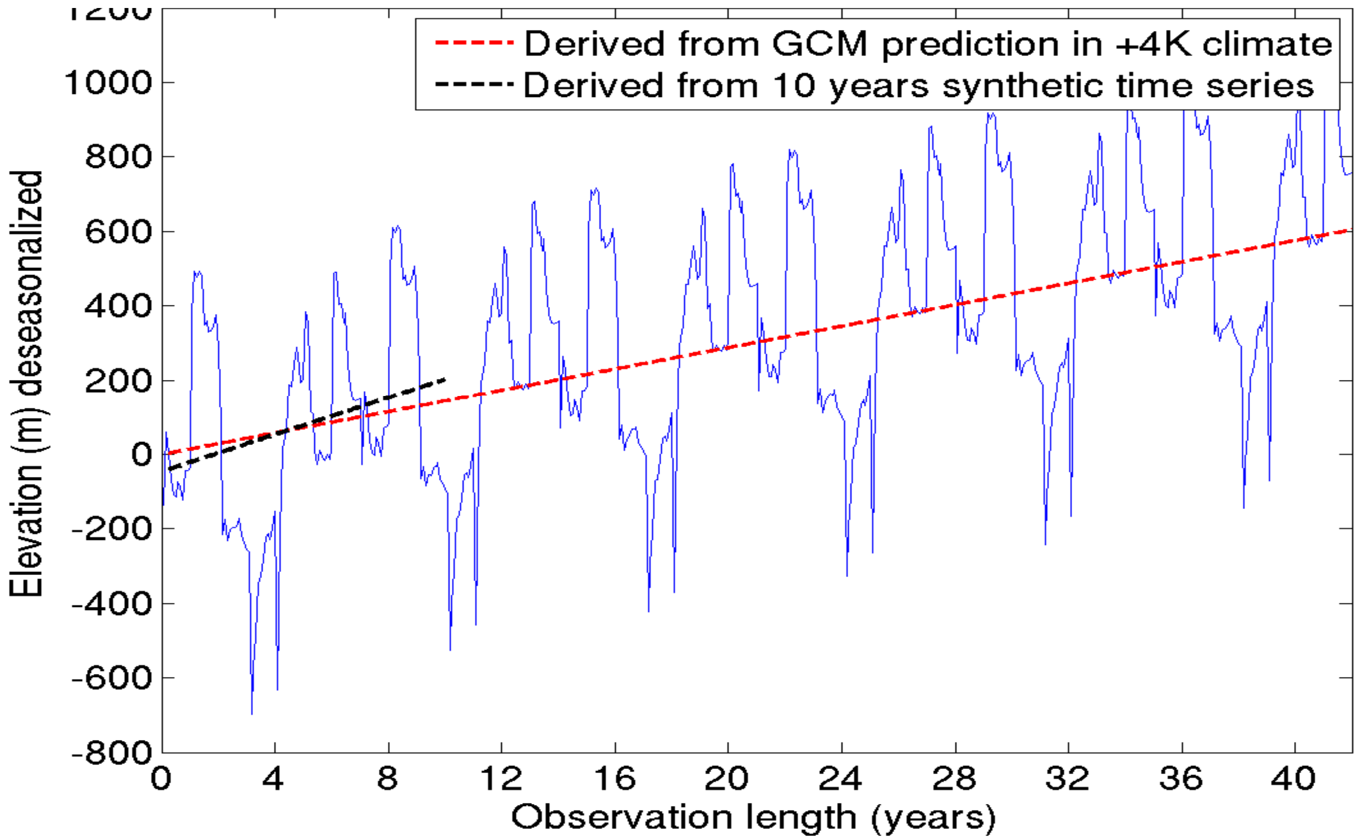
2) Built synthetic lidar time serie constrained by the inter-annual variability from the actual Caliop record, and by the expected forced change predicted by AMIP+4K (assumed in 100 yrs) and AMIP as seen from a lidar in space (COSP/lidar). Method adaptes from Loeb et al.2009

3) Estimate the length of the lidar record required to provide an observational constrain on cloud feedbacks: when the forced signal goes out of the noise from natural variability

4) Estimate the impact of gaps and inter-calibration bias between lidar missions

About the detectability of a forced opaque cloud elevation change in the tropical deep convection using lidars

Change in elevation of opaque clouds (w500<0)

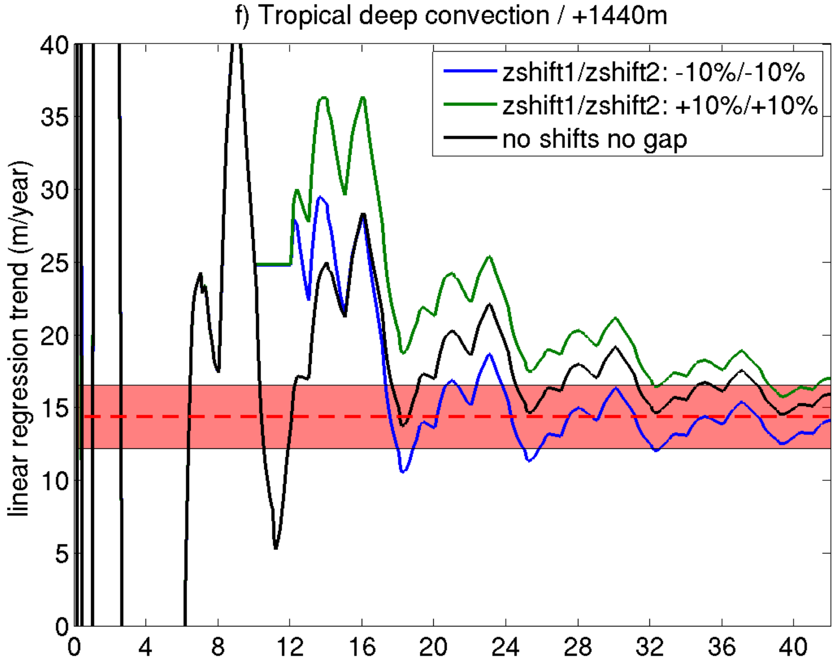


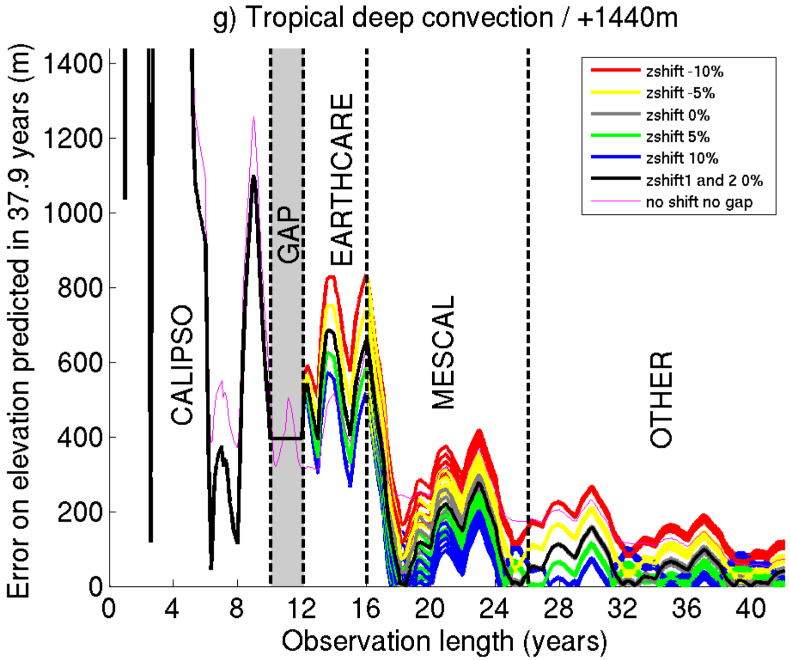
When no shift, no gap between successive lidar missions (ideal)

Trend in elevation of opaque clouds

About the detectability of a forced thick cloud elevation change in the tropical deep convection using lidars

When gaps and inter-calibration biases between successive lidar missions





Concluding remarks

- The space active sensor (lidar,radar) are powerful process oriented tool for studying clouds: vertically precisely resolution , high horizontal resolution , accurate, stable in time,

- Potential to constrain high cloud tropical LW feedback mechanism,

- A third lidar/radar in space after Calipso and EarthCare would likely allow to observe the cloud response to greenhouse gazes forcing,

- Gaps between successive lidar/radar missions and inter calibration bias will delay the capability of a detection of the cloud response to greenhouse gazes forcing

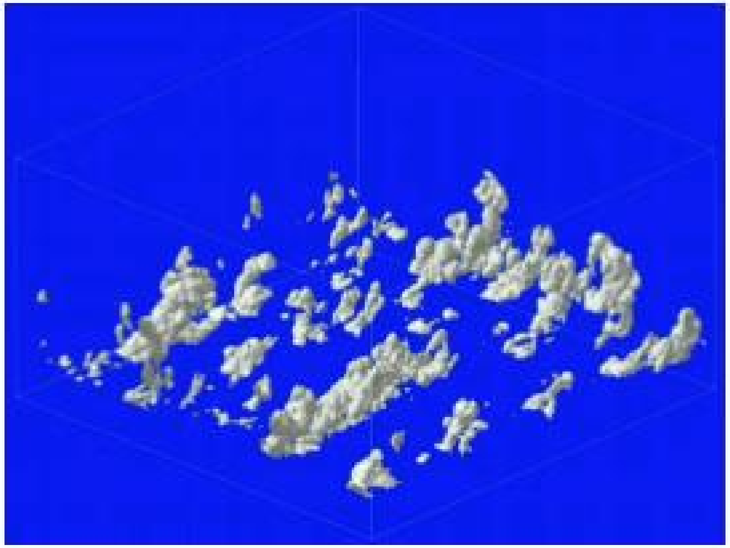
What scale ? Ask Pier

LES

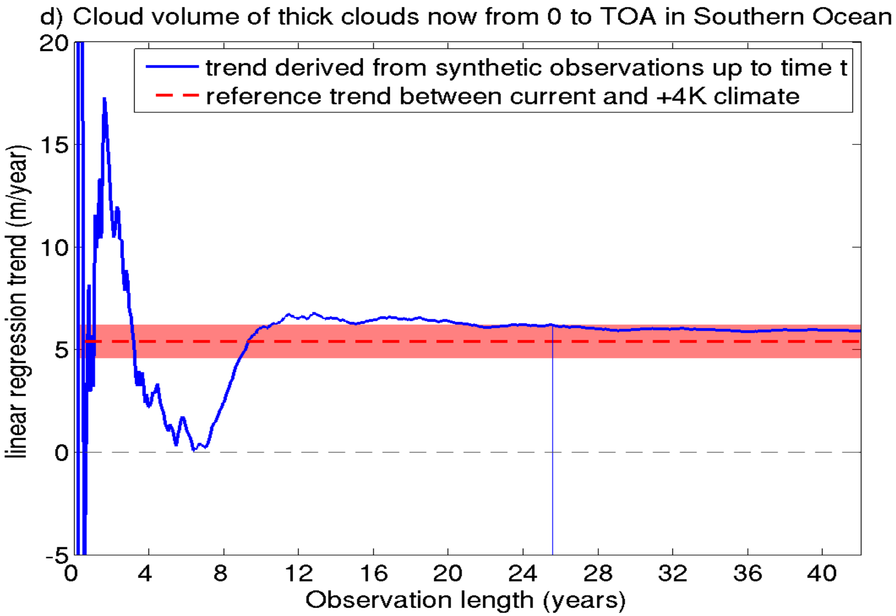
Heus

TU Delft

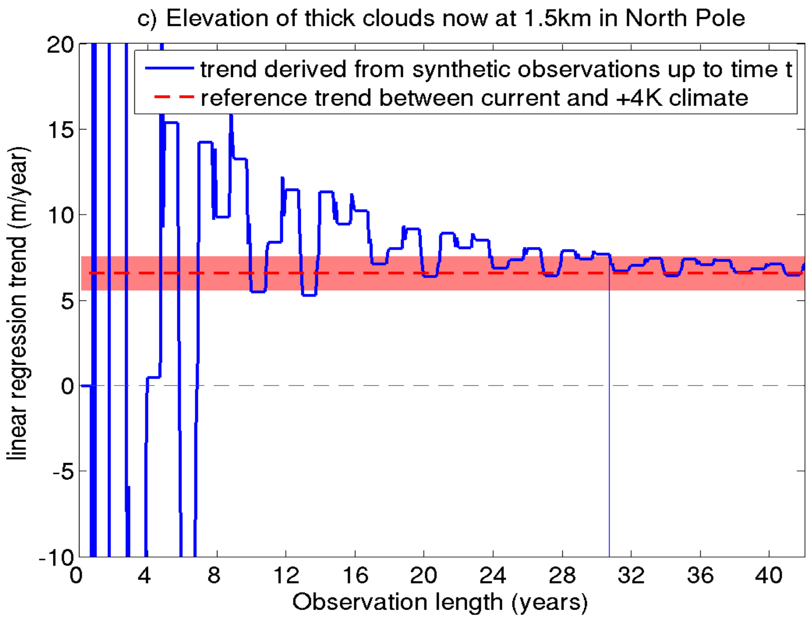
CMWF-08



2. **Cumulus.** Cumulus. Height (km): base=1, top=2, liquid composition, no precip, process: release of conditional instability.



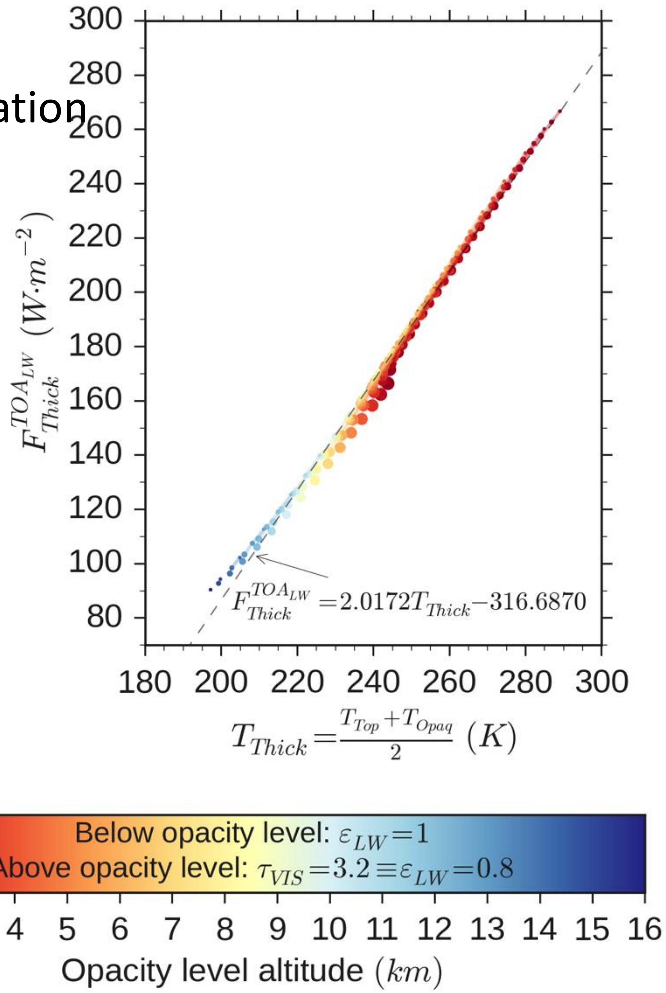
d) Cloud volume of thick clouds now from 0 to TOA in Southern Ocean
trend derived from synthetic observations up to time t
reference trend between current and +4K climate
linear regression trend (m/year)
Observation length (years)

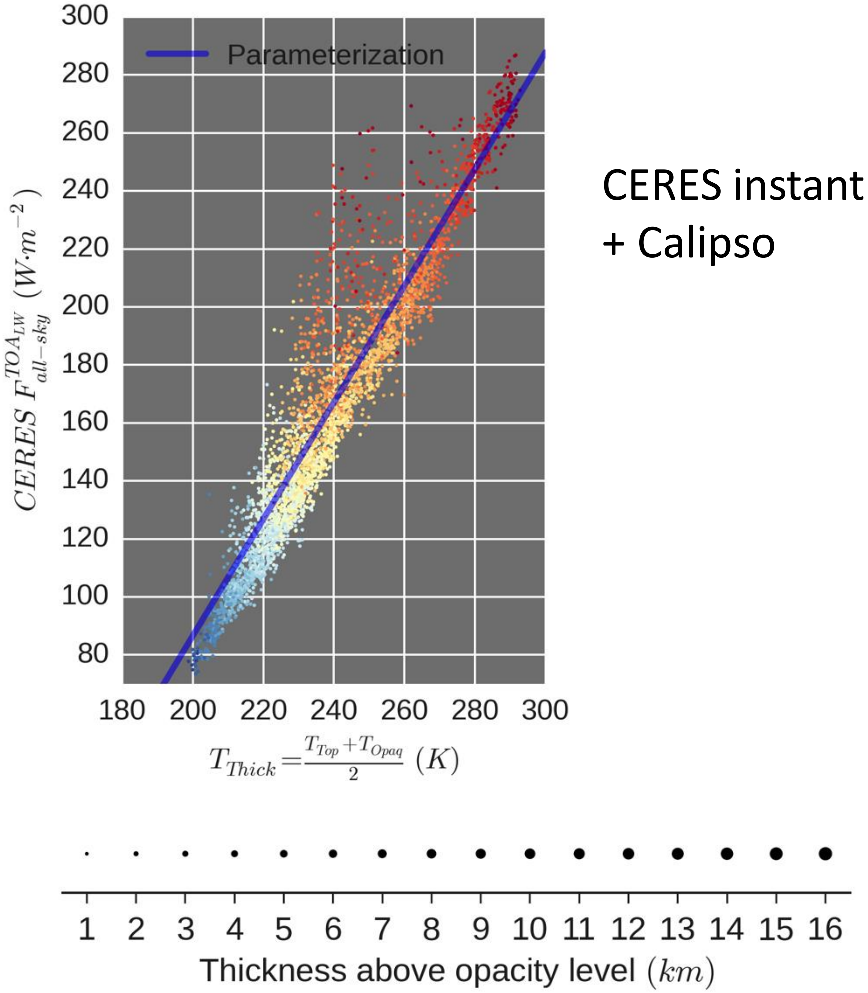


c) Elevation of thick clouds now at 1.5km in North Pole
trend derived from synthetic observations up to time t
reference trend between current and +4K climate
linear regression trend (m/year)
Observation length (years)

The altitude where the lidar is fully attenuated : a precise stable measurement for LW outgoing radiations

RT computation





CERES instant
+ Calipso

k = 2.0 W·m^{-2}/K cohérent avec [Wang et al. 2002]

Flux LW TOA total : regroupement des colonnes

$$F_{Tot}^{\uparrow TOA\,LW} = C_{CS}F_{CS}^{\uparrow TOA\,LW} + C_{Thick}F_{Thick}^{\uparrow TOA\,LW} + C_{Thin}F_{Thin}^{\uparrow TOA\,LW}$$

$$C_{CS} + C_{Thick} + C_{Thin} = 1$$

$$F_{Thick}^{\uparrow TOA\,LW} = f(T_{Thick})$$

$$F_{Thin}^{\uparrow TOA\,LW} = f\left(T_{Thin}, \varepsilon_{LW}, F_{CS}^{\uparrow TOA\,LW}\right)$$

Clear sky cover

Thin cloud cover

Thick cloud cover

TOA

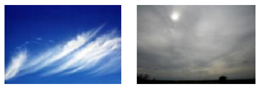
Optically "thick" cloud

T_{Top}

$$T_{Thick} = \frac{T_{Top} + T_{Opaq}}{2}$$

T_{Opaq}

$\varepsilon_{LW} \approx 1$



Optically "thin" clouds

T_{Top}

$$T_{Thin} = \frac{T_{Top} + T_{Base}}{2}$$

T_{Base}

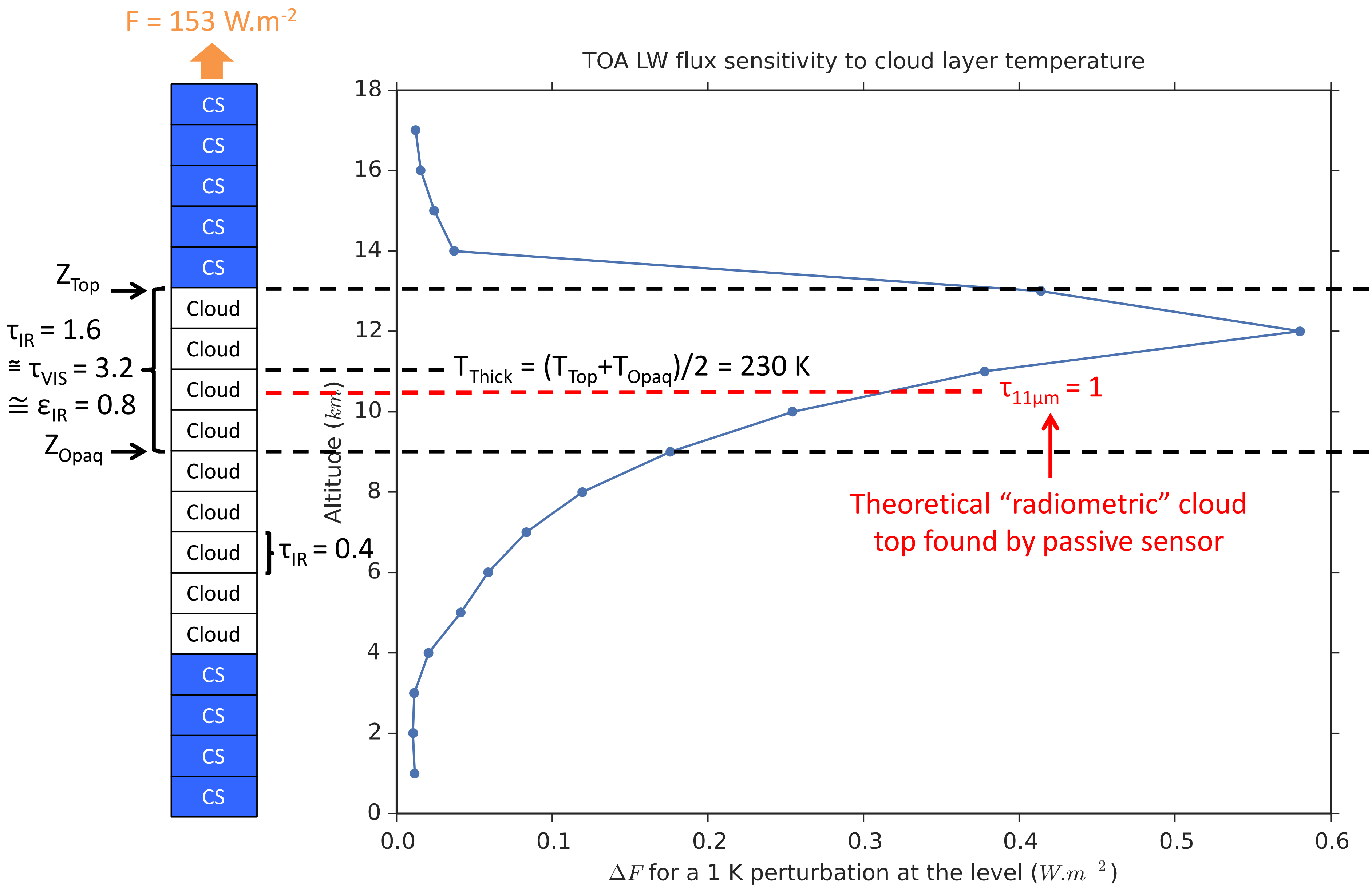
ε_{LW}

$\varepsilon_{LW} < 1$

SST

SST

Surface



F = 153 W.m-2
CS
Cloud
Z Top
τ IR = 1.6
≅ τ VIS = 3.2
≅ ε IR = 0.8
Z Opaq
τ IR = 0.4
TOA LW flux sensitivity to cloud layer temperature
T Thick = (T Top+T Opaq)/2 = 230 K
τ 11µm = 1
Theoretical "radiometric" cloud top found by passive sensor
Altitude (km)
ΔF for a 1 K perturbation at the level (W.m−2)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
2
4
6
8
10
12
14
16
18

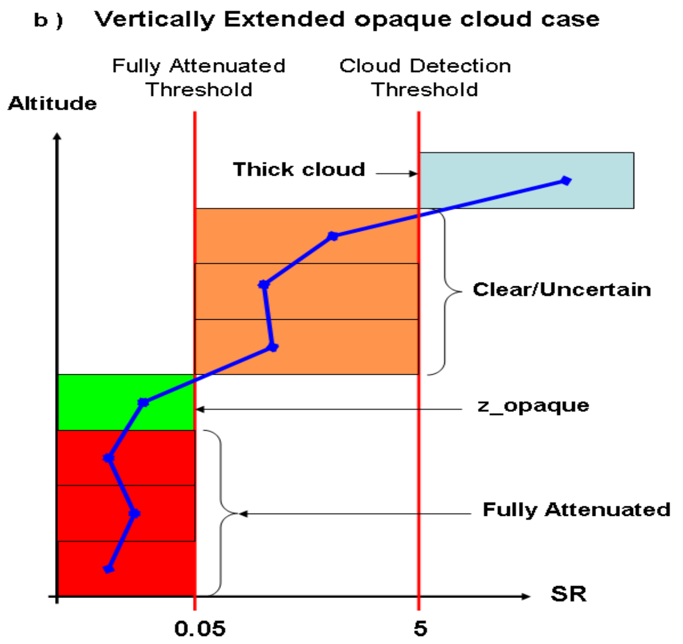
2 – L' algorithme OPAC

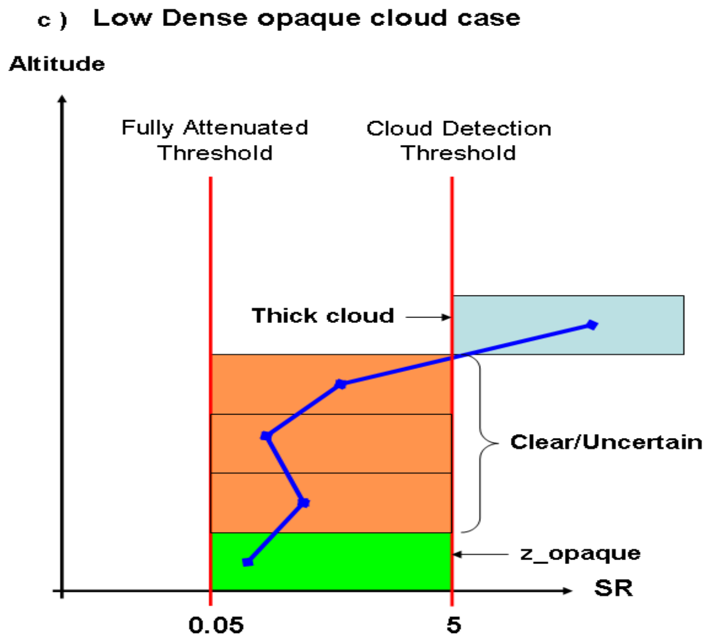
Quand l' atmosphère n' est pas sondée jusqu' à la surface
→ Détermination de l' altitude d' opacité z_opaque

On se place dans **le cadre de GOCCP** pour déterminer **z_opaque** :
Couches atm. de 480 m, **SR** = ATB532 / ATB_moléculaire, SR > 5 → Cloud

- Deux cas de figure sous le nuage le plus bas détecté :

SR < 0.05 existe ou **SR > 0.05 seulement**





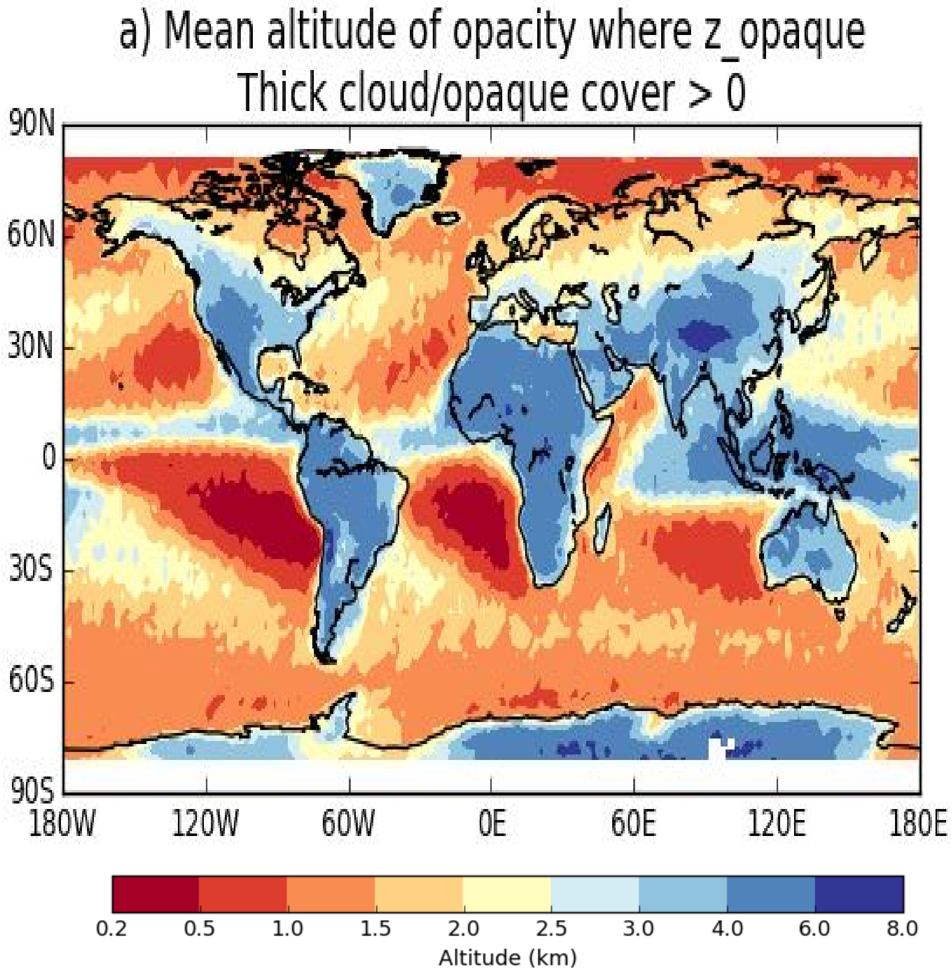
3 – Résultats (GOCCP-OPAC)

Level 3 : 2D Maps

Moyenne z_opaque calculée sur les profils opaques uniquement :

→ **Structures de la circulation grande échelle apparaissent**

→ z_opaque élevé (4-6 km) dans des régions peu nuageuses (déserts)



3 – Résultats (GOCCP-OPAC)

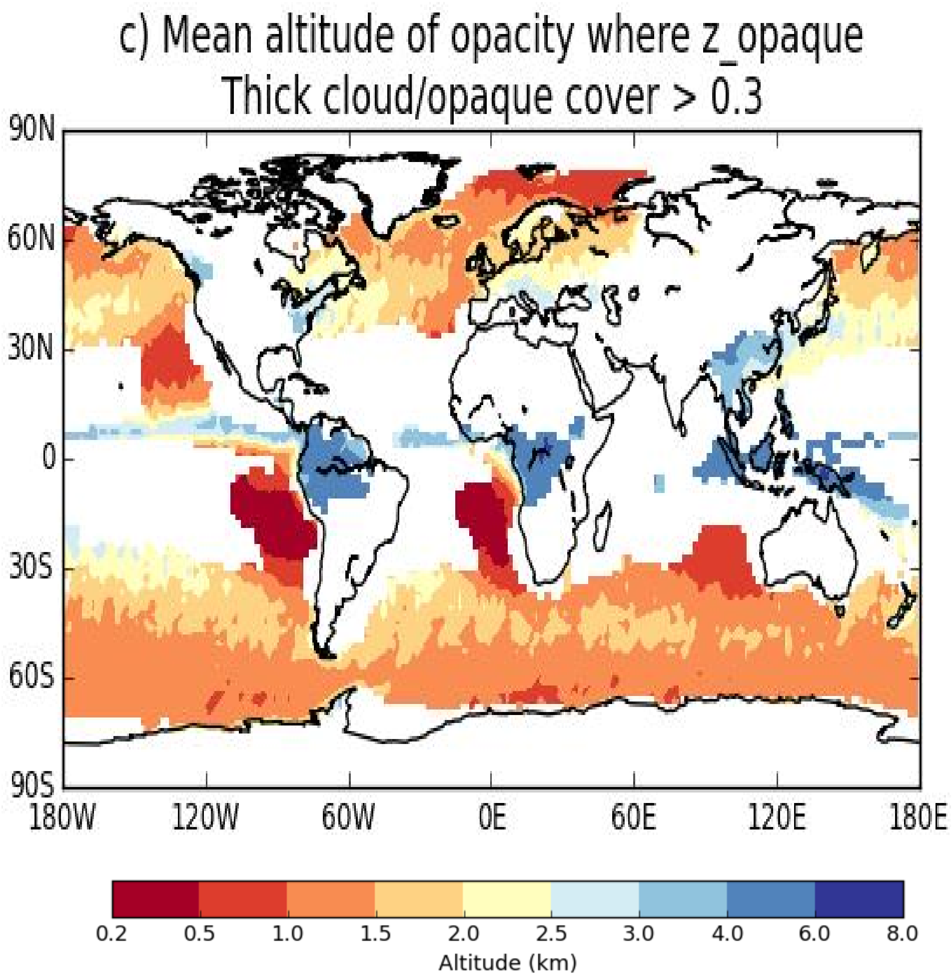
Level 3 : 2D Maps

Moyenne z_opaque pour régions où +30% des profils sont opaques

→ zones de convection profonde (z_opaque ~5 km)

→ stratocumulus (z_opaque < 1 km)

→ Southern Ocean (~1,5 km)
→ Storm track HN (1-2 km)



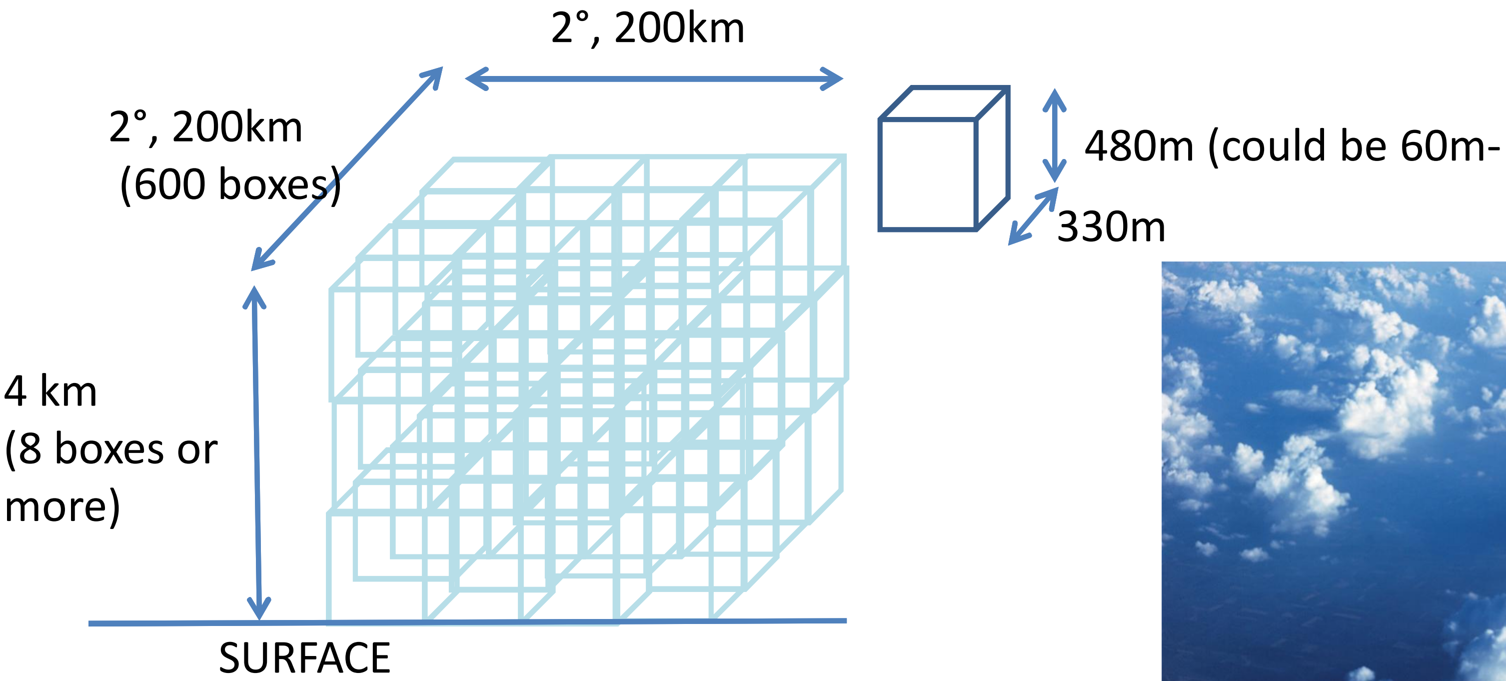
Subsidence Tropical clouds (w500>0) between 0 and 4 km of altitude

where Calipso sounds most of the time entirely the atmosphere from the TOA to the surface

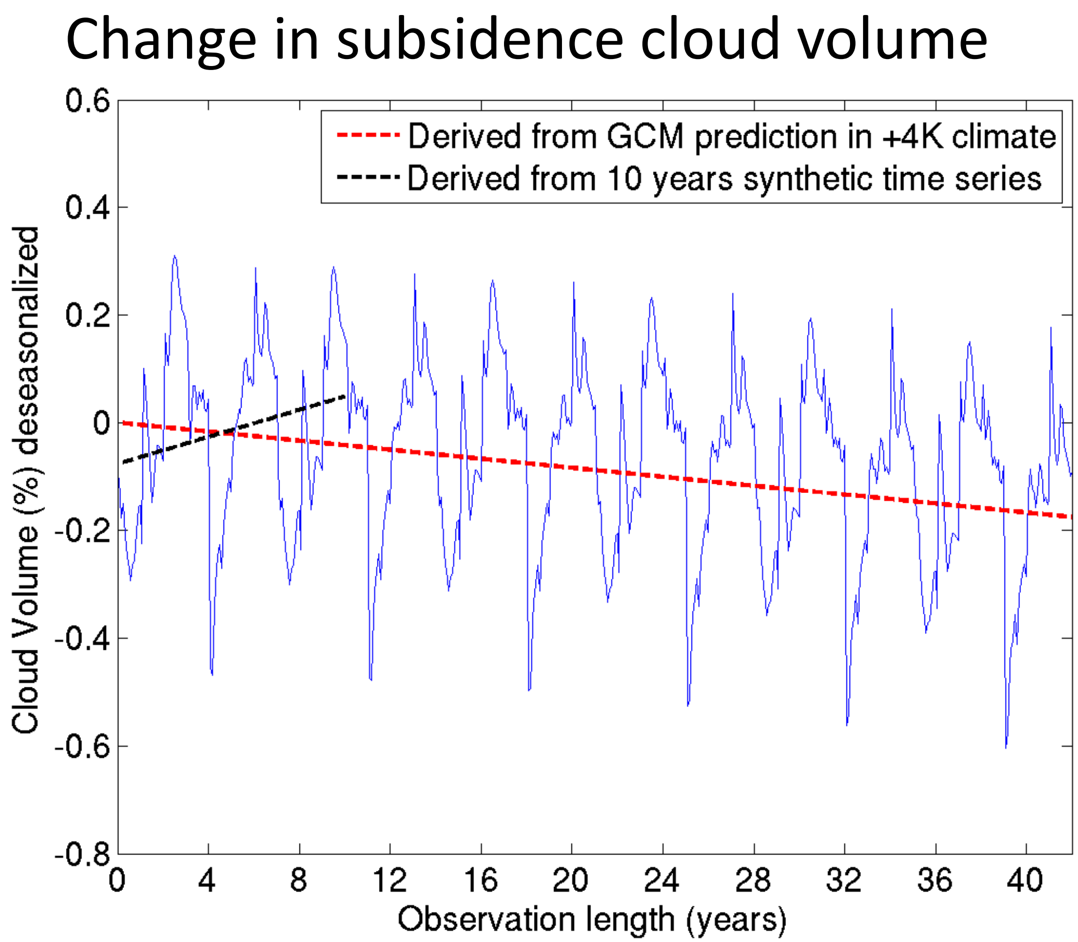
SW cloud feedback
Bony et al.
Qu et al., …

“The cloud volume” = the volume of the boundary layer (0-4km) filled with cloud

The cloud volume contains the 3D cloud information contrarily to the cloud cover or the cloud vertical profile



About the detectability of a forced cloud volume change in the tropical subsidence using lidars



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When no shift, no gap between successive lidar missions (ideal)