Use of space lidar observations to study the TOA longwave cloud radiative effect

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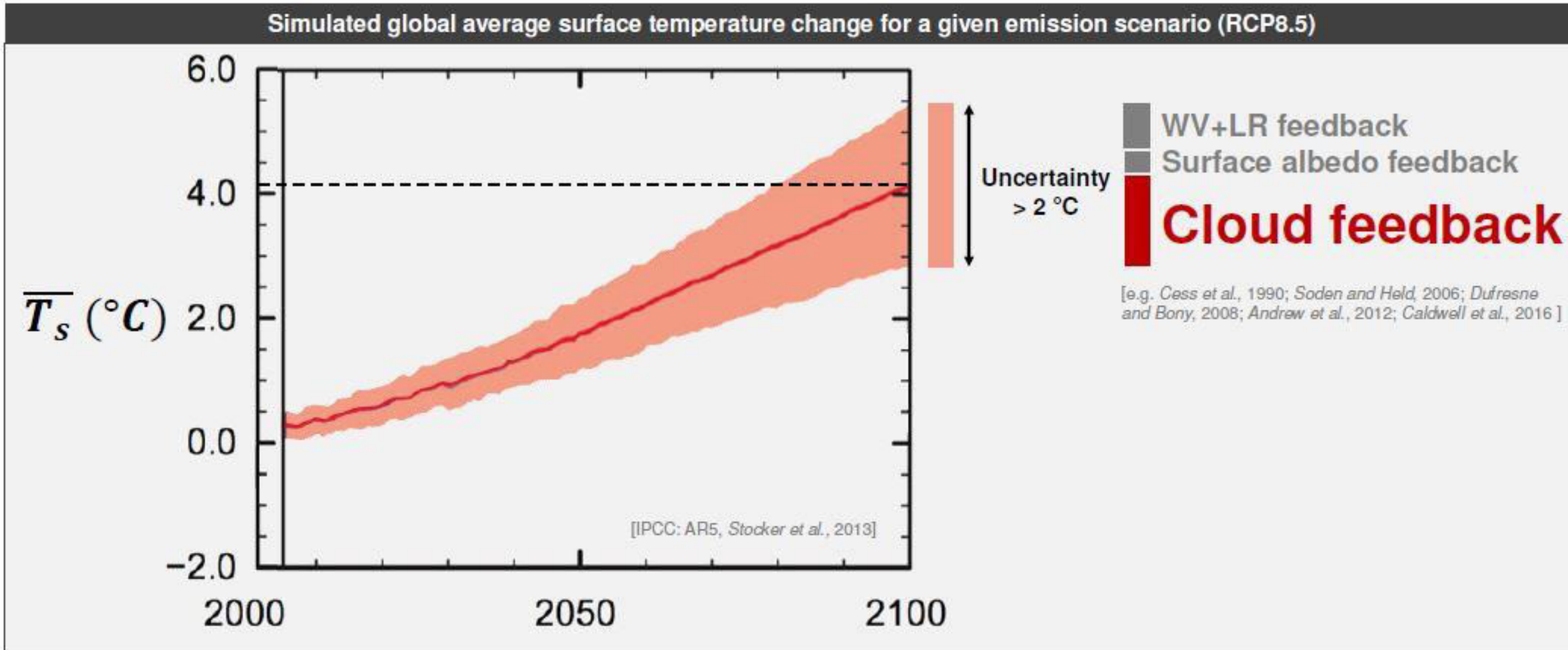
Outline

I - Motivation

II – Opaque and Thin clouds framework

III – Using this new observations to constrain the simulated LW cloud feedback

Motivation



Simulated global average surface temperature change for a given emission scenario (RCP8.5)
6.0
4.0
2.0
0.0
−2.0
2000
2050
2100
$\overline{T_s}$ (°C)
Uncertainty
> 2 °C
WV+LR feedback
Surface albedo feedback
Cloud feedback
[e.g. Cess et al., 1990; Soden and Held, 2006; Dufresne and Bony, 2008; Andrew et al., 2012; Caldwell et al., 2016]
[IPCC: AR5, Stocker et al., 2013]

Motivation

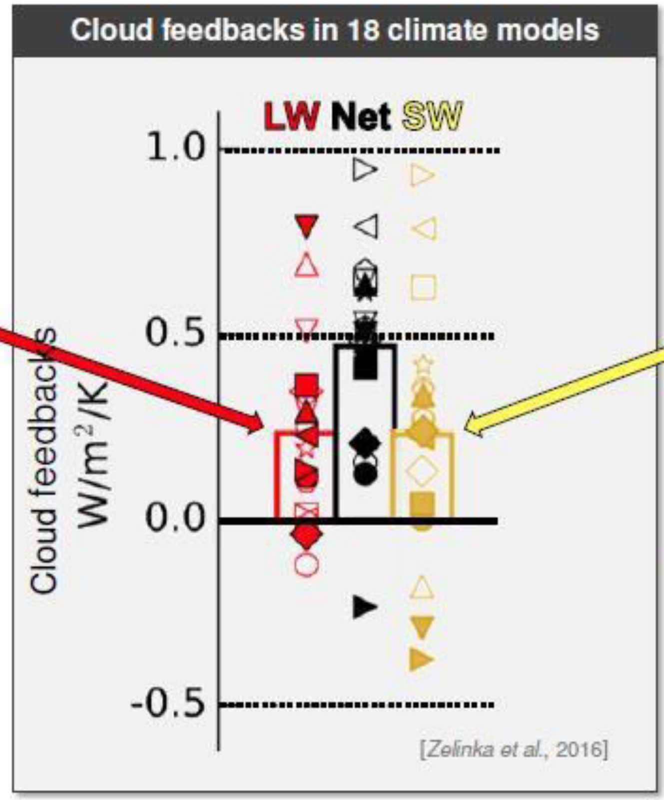
- Positive **LW** cloud feedback mainly due to **cloud altitude** change.

[e.g. *Zelinka and Hartmann*, 2010; *Soden and Vecchi*, 2011]

+

- Theoretical physical explanation of **cloud altitude feedback.**

[*Hartmann and Larson*, 2002]



- Positive **SW** cloud feedback mainly due to **cloud cover** change.

[e.g. *Webb et al.*, 2006; *Vial et al.*, 2013]

Large uncertainty on cloud feedbacks amplitude amongst models
Lack of observational constraints

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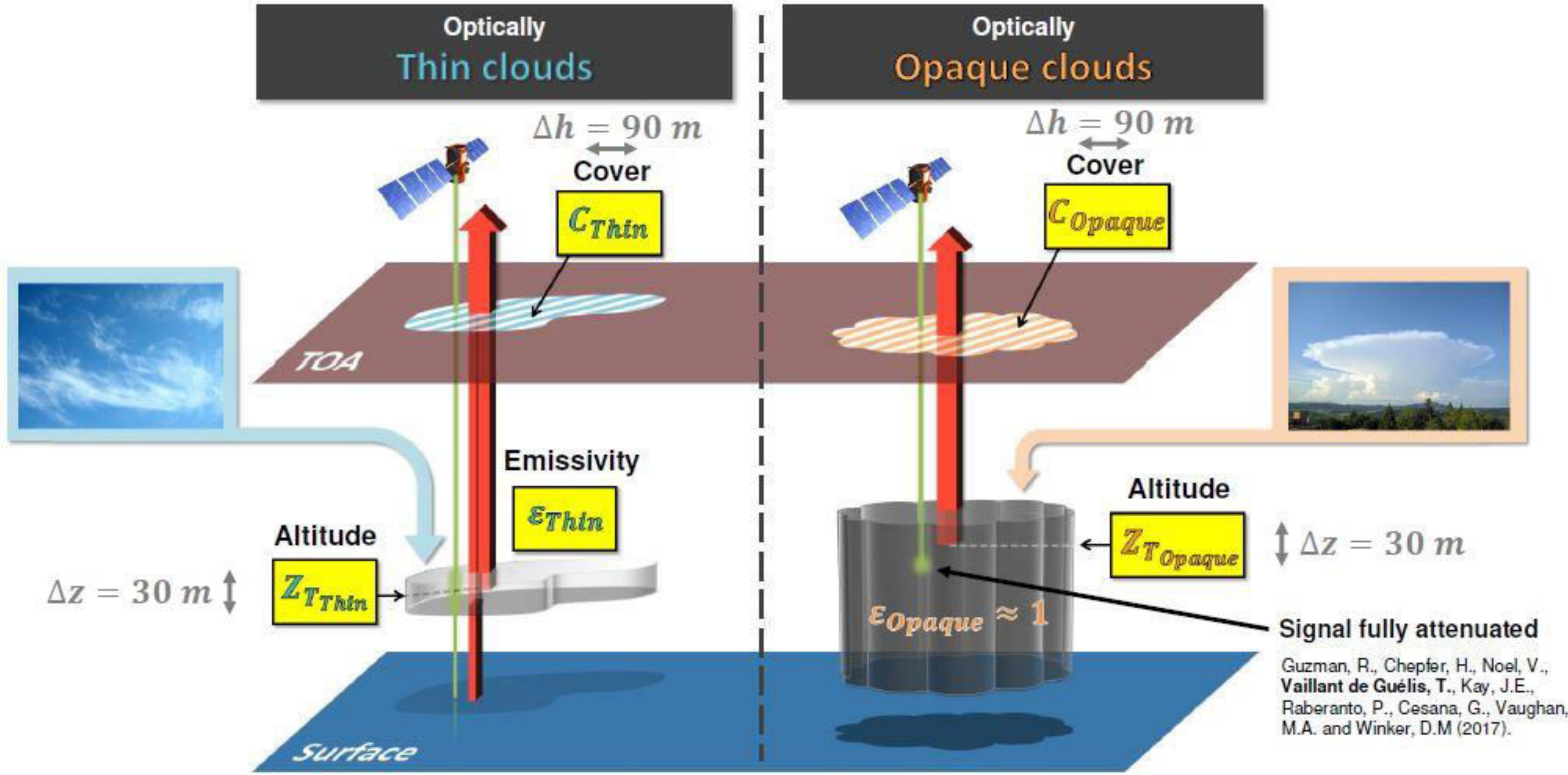
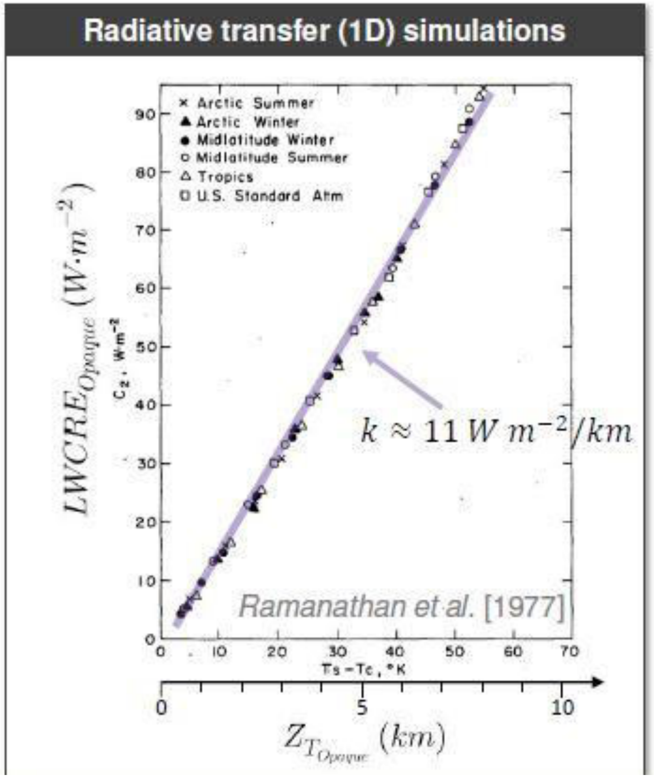
Opaque and Thin clouds framework

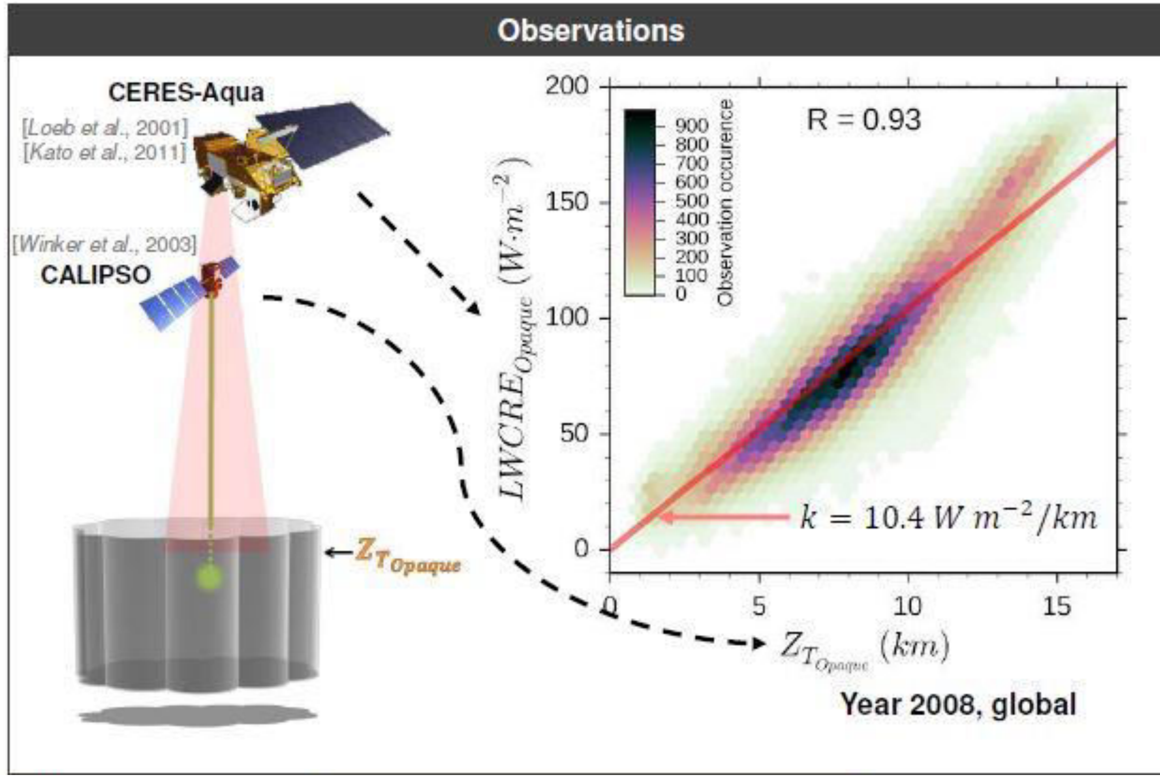


5 fundamental cloud properties observed by space-lidar to build a simple expression of the LW cloud radiative effect

Vaillant de Guélis et al. 2017a, AMT

Simple expression of the LW cloud radiative effect



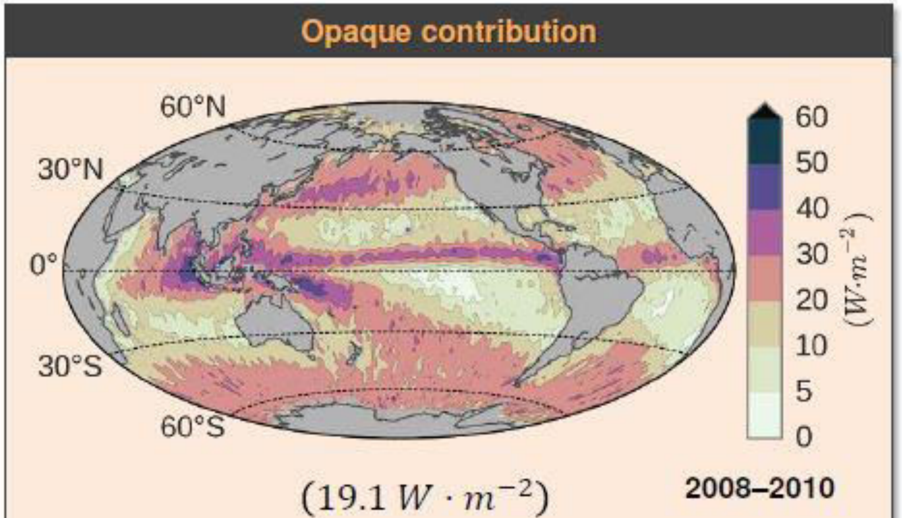


$$LWCRE_{Opaque} = 11 \times Z_{T_{Opaque}}$$

$$LWCRE_{Thin} = 11 \times \varepsilon \times Z_{T_{Thin}}$$

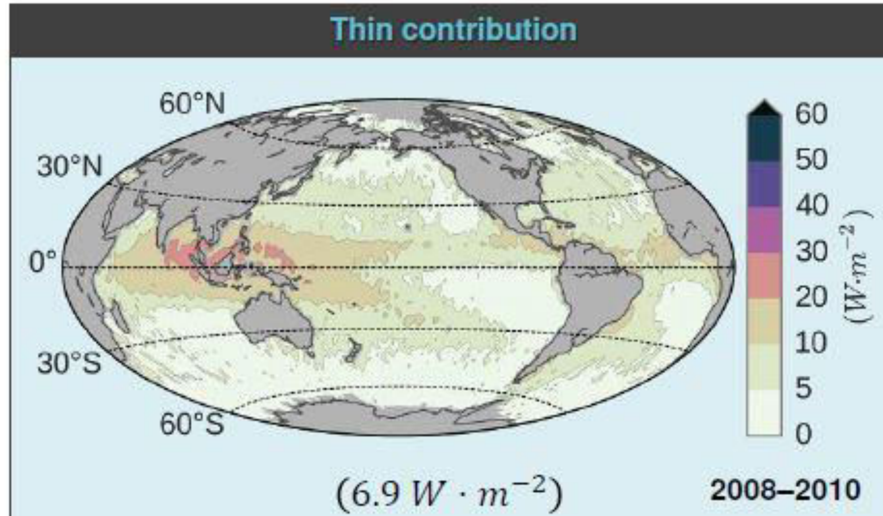
Vaillant de Guélis et al. 2017a, AMT

Opaque and Thin clouds contributions to LW CRE



Computed from **space-lidar** observations

$$LWCRE_{Opaque} = 11.\, Z_{T_{Opaque}}.\, C_{Opaque}$$

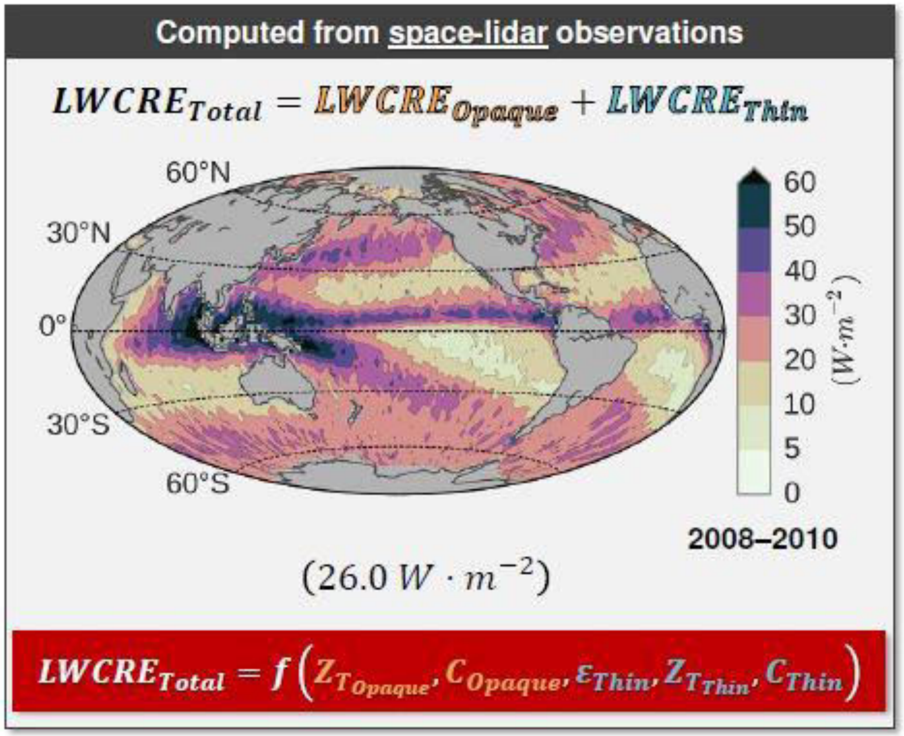


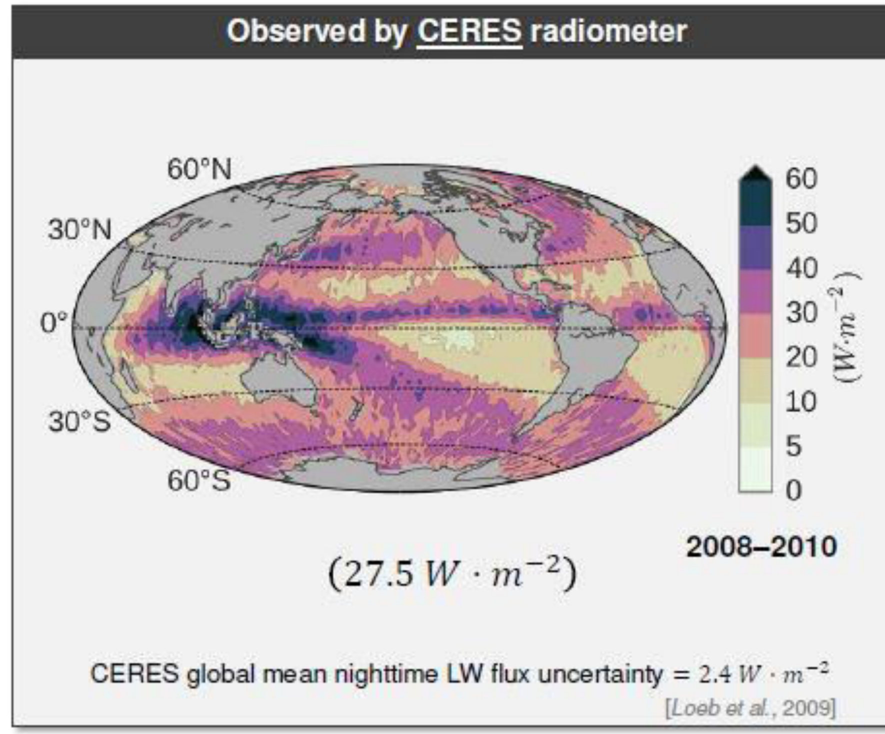
Computed from **space-lidar** observations

$$LWCRE_{Thin} = 11.\, \varepsilon_{Thin}.\, Z_{T_{Thin}}.\, C_{Thin}$$

Vaillant de Guélis et al. 2017a, AMT

Accurate estimate of the LW CRE at global scale





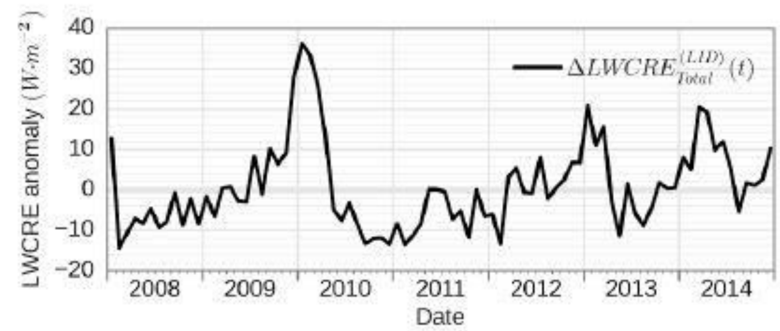
LW CRE expression validated against CERES observations

Vaillant de Guélis et al. 2017a, AMT

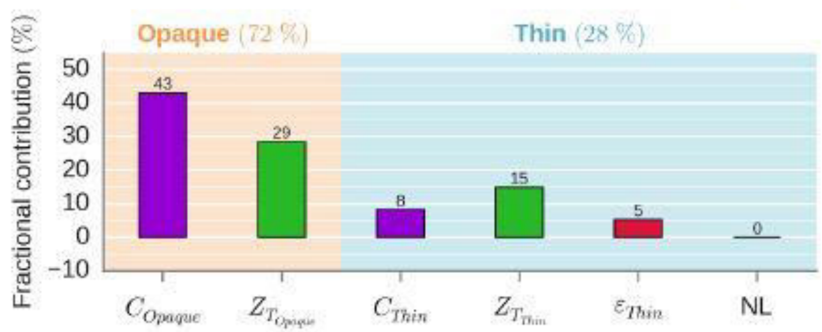
Regional study of the LW CRE temporal variations

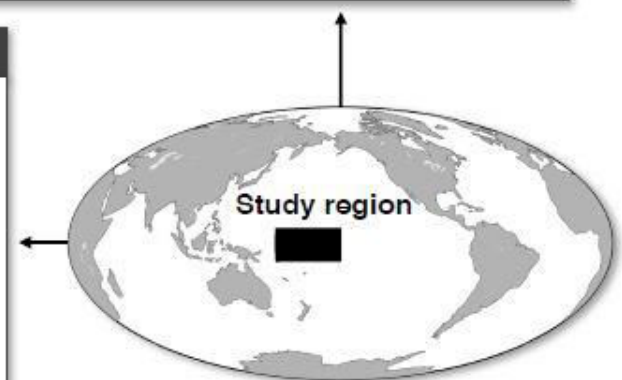
Total

$$\Delta LWCRE_{Opaque}(t) + \Delta LWCRE_{Thin}(t) = \Delta LWCRE_{Total}(t)$$



Cloud property contributions to the whole 2008–2014 $LWCRE_{Total}$ temporal variations





Opaque cloud cover and opaque cloud temperature drive the LW CRE in the Central Tropical Pacific

Vaillant de Guélis et al. 2017b, GRL

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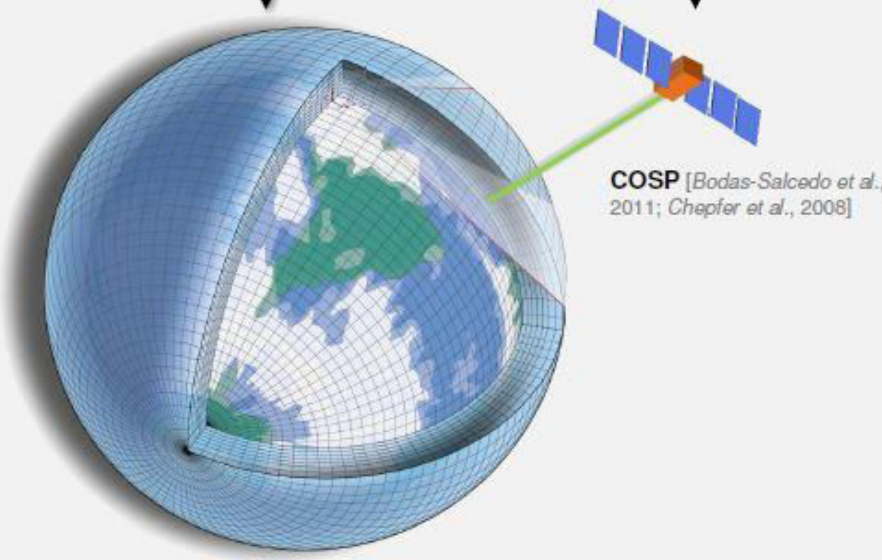
Consistent properties in models and observations

Model simulations

LMDZ6 climate model + Space-lidar simulator



Simulations performed by M. Bonazzola

→

5 simulated lidar-derived cloud properties

$Z_{T_{Opaque}}$

C_{Opaque}

ε_{Thin}

$Z_{T_{Thin}}$

C_{Thin}

→

Method apply to model simulations

LWCRE simple expression
&
LWCRE variations partitioning

2 model runs :
- AMIP
- AMIP +4K

Climate model : same 5 cloud properties from lidar simulator

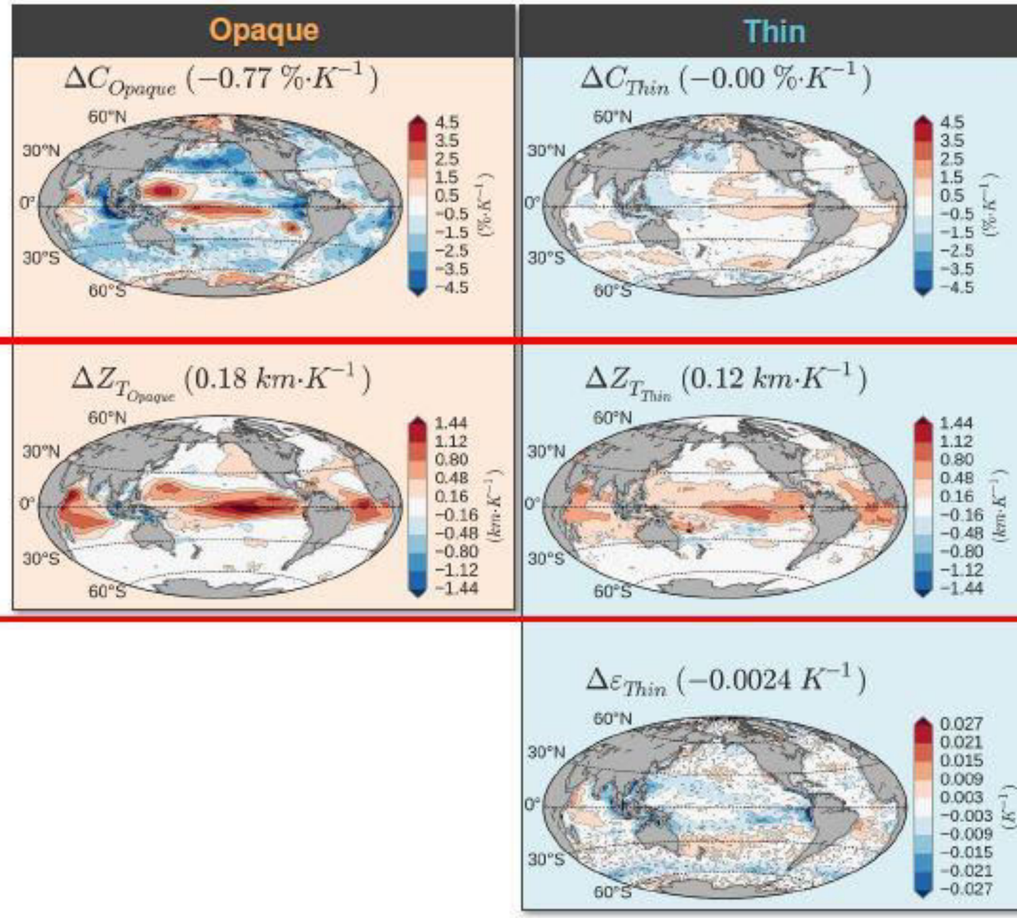
Difference between +4K and current climate clouds

Simulations only

Cover change $(\%.K^{-1})$

Altitude change $(km.K^{-1})$

Emissivity change (K^{-1})

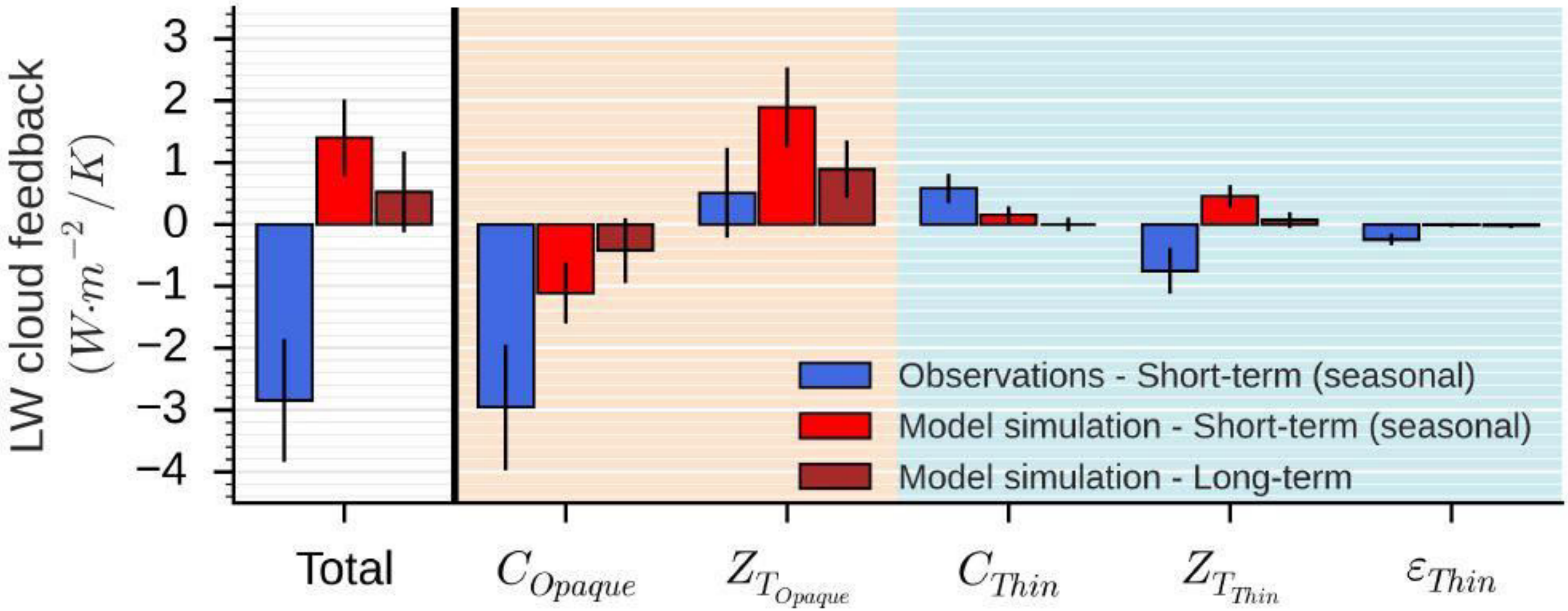


Opaque cloud altitude increases by 1 km per 1K increase in SST

Vaillant de Guélis et al. 2018, in prep.

Comparison between LW cloud feedbacks

Simulations and Observations

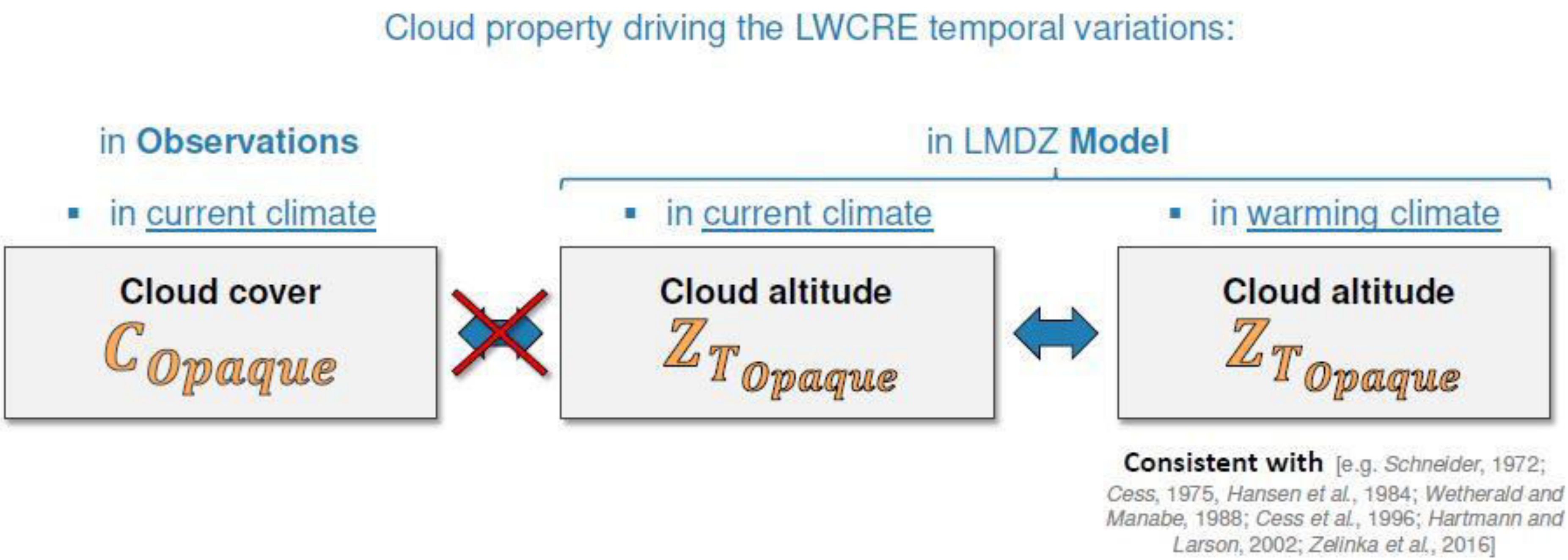


Model and observations strongly disagree on which cloud property drives the LW cloud feedback in current climate

Vaillant de Guélis et al. 2018, in prep.

Partitioning of current climate and +4K climate cloud feedbacks are hierarchically consistent

Will the simulated large LW cloud altitude feedback generally admitted be as strong as expected?



Conclusion/Perspectives

- CALIPSO Opaque and Thin clouds to estimate LW CRE
→ http://climserv.ipsl.polytechnique.fr/cfmip-obs

- CALIPSO Opaque and Thin clouds included in the lidar simulator (COSP v2) enabling straightforward comparisons between model outputs and the observations

- Useful framework to understand LW cloud feedback by identifying cloud properties driving the current climate variability

Thank you for your attention

Guzman, R., Chepfer, H., Noel, V., Vaillant de Guélis, T., Kay, J.E., Raberanto, P., Cesana, G., Vaughan, M.A. and Winker, D.M, *Direct atmosphere opacity observations from CALIPSO provide new constraints on cloud-radiation interactions*, Geophys. Res. Atmos., 122, no. 2, 1066-1085, doi:10.1002/2016JD025946, 2017.

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