About the observation of cloud changes due to greenhouse warming

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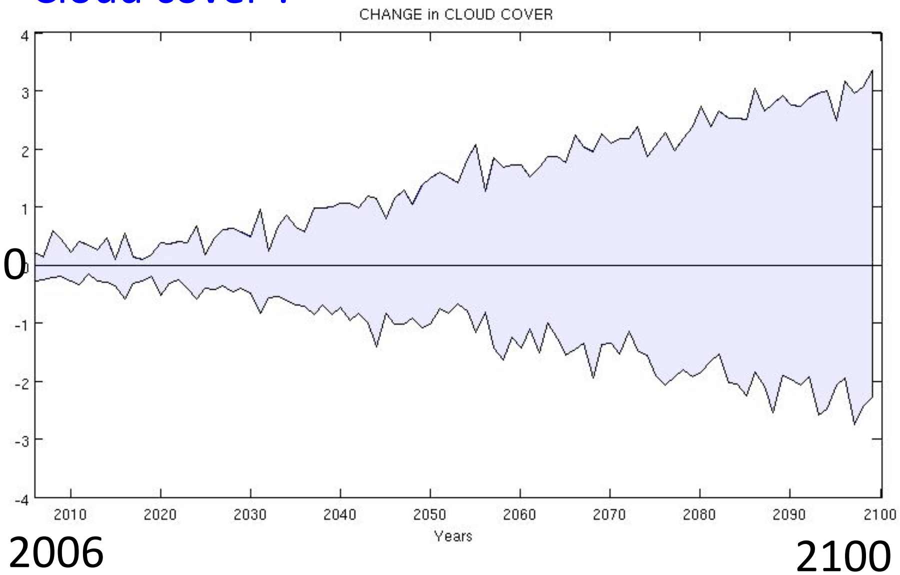
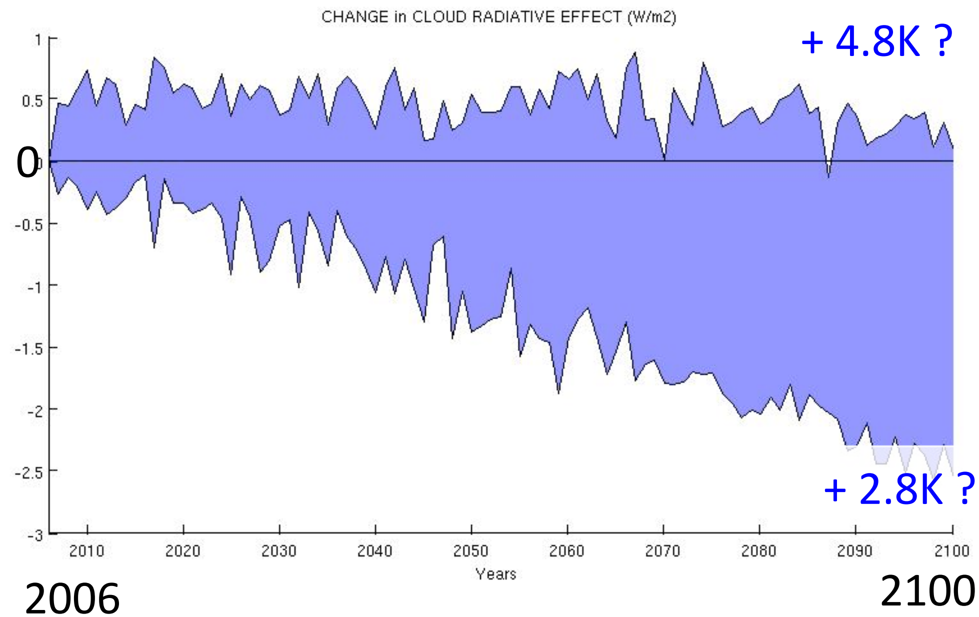
The predicted cloud responses to greenhouse warming are uncertain

For a given CO2 emission scenario (CMIP5, RCP8.5),

Cloud cover ?

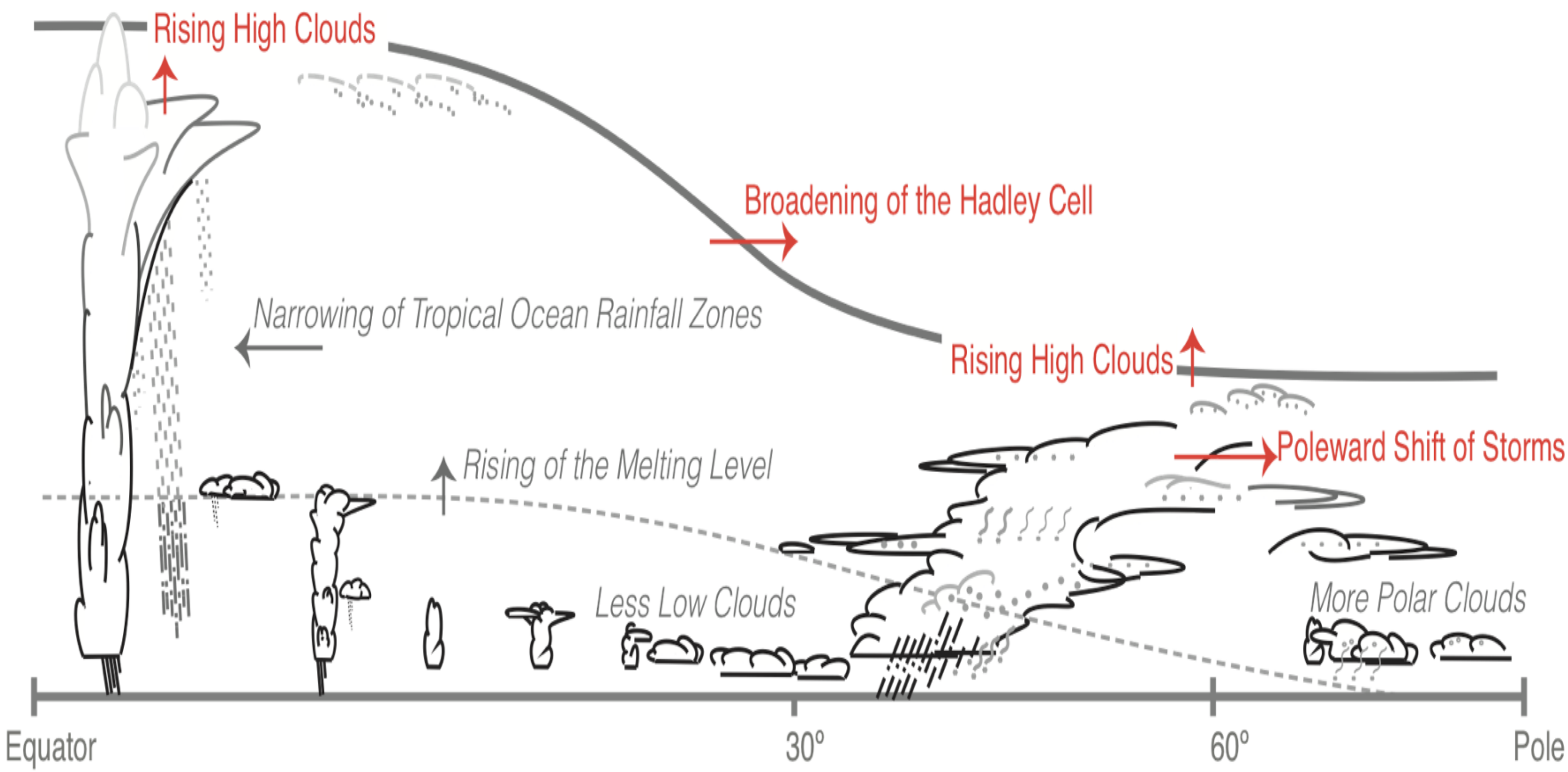


Cloud radiative effect ?



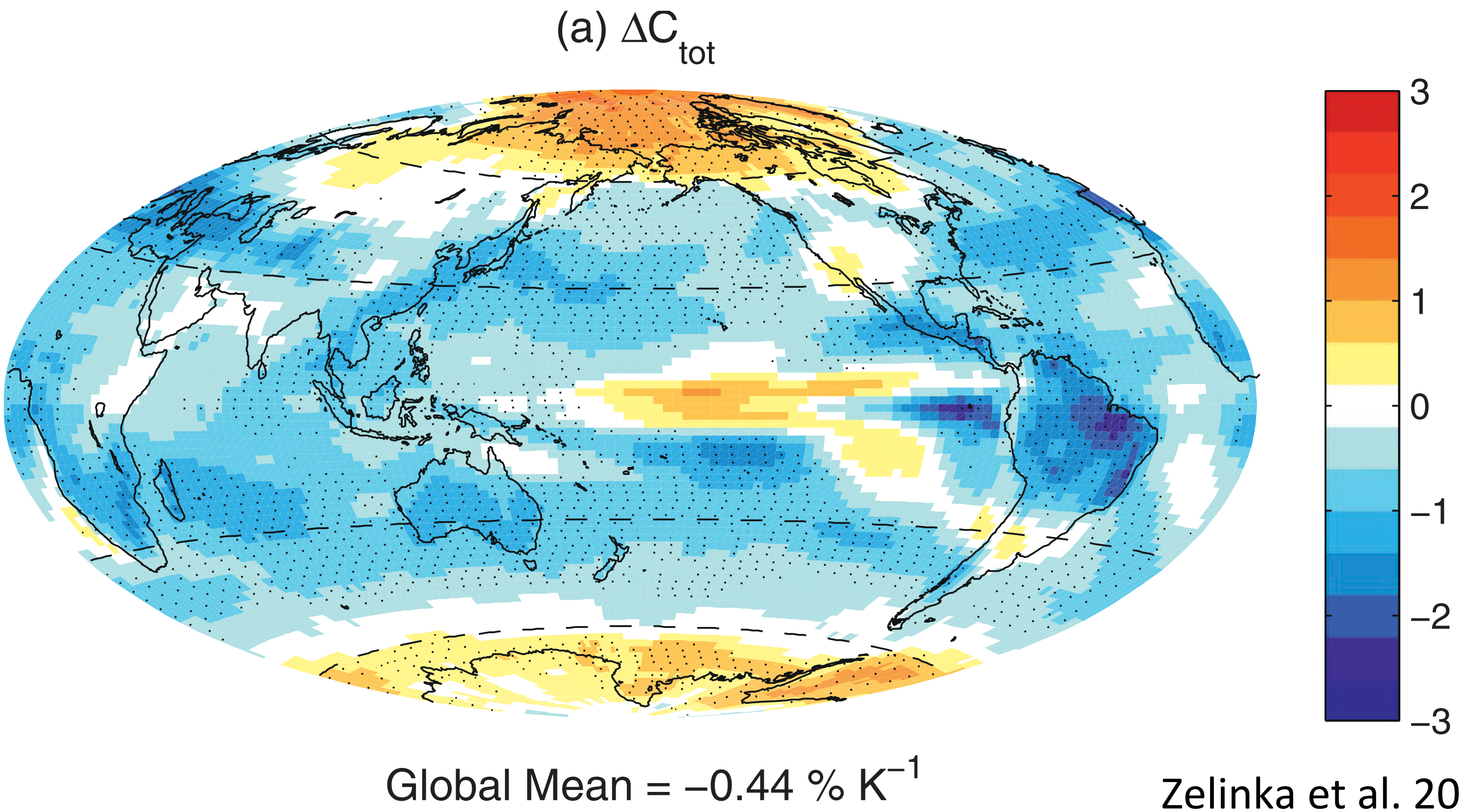
=> Clouds remains one of the largest uncertainty in climate prediction

Predicted cloud responses to greenhouse warming



IPCC, AR5, Chapter 7

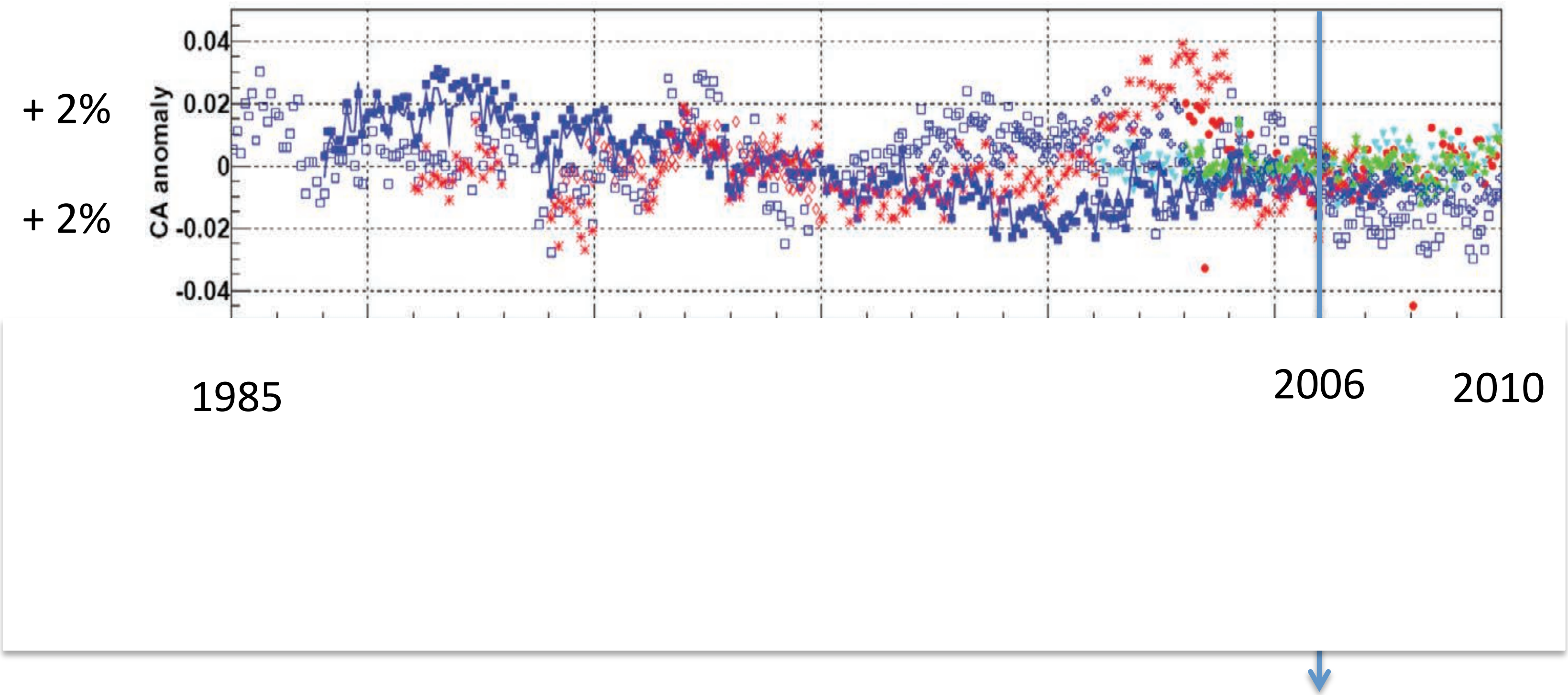
Predicted change in cloud cover



Zelinka et al. 2012
(ensemble mean change)

Global mean cloud cover decreases
Global mean cloud feedback positive 0.27 W/m2/K

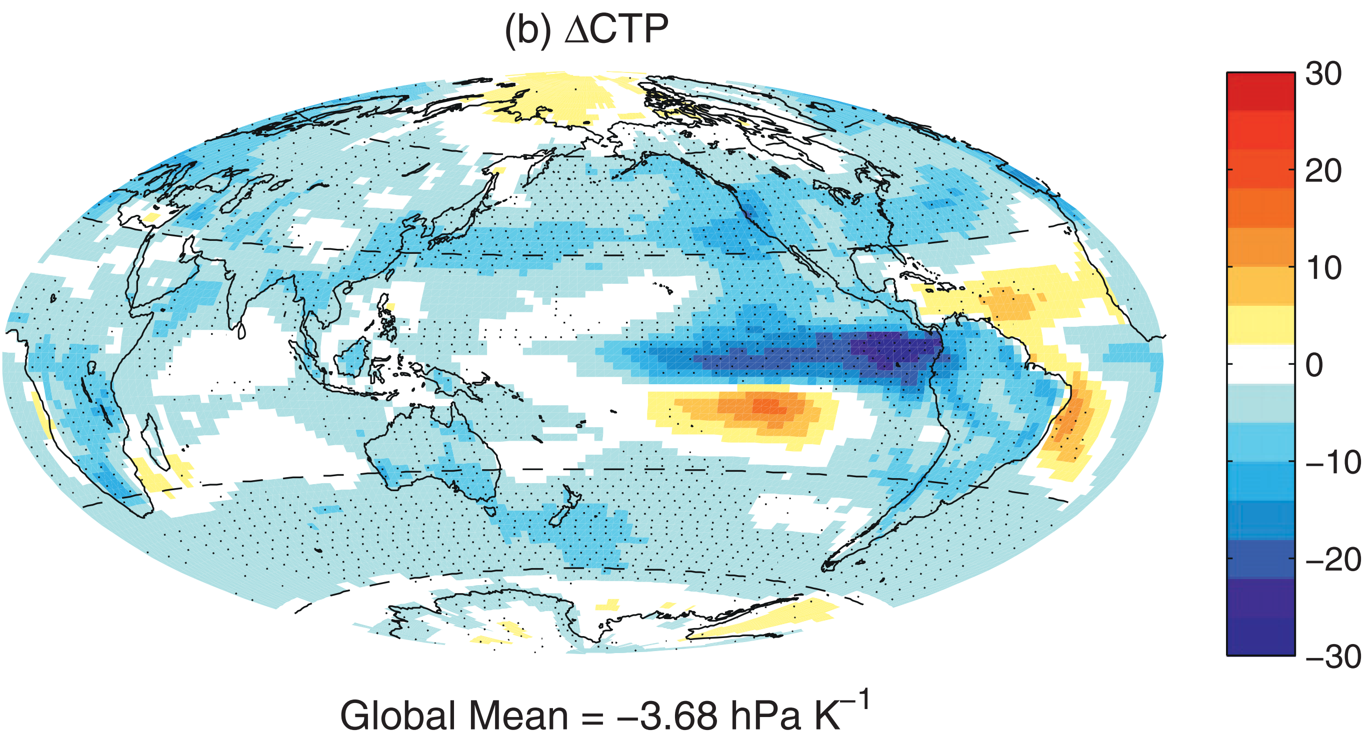
Observed change in cloud cover



« … At present, one can only conclude that global monthly **mean cloud amount is constant over the last 25 years** (…) **within the range of interannual variability** »

GEWEX Cloud Assessment Report, 2013

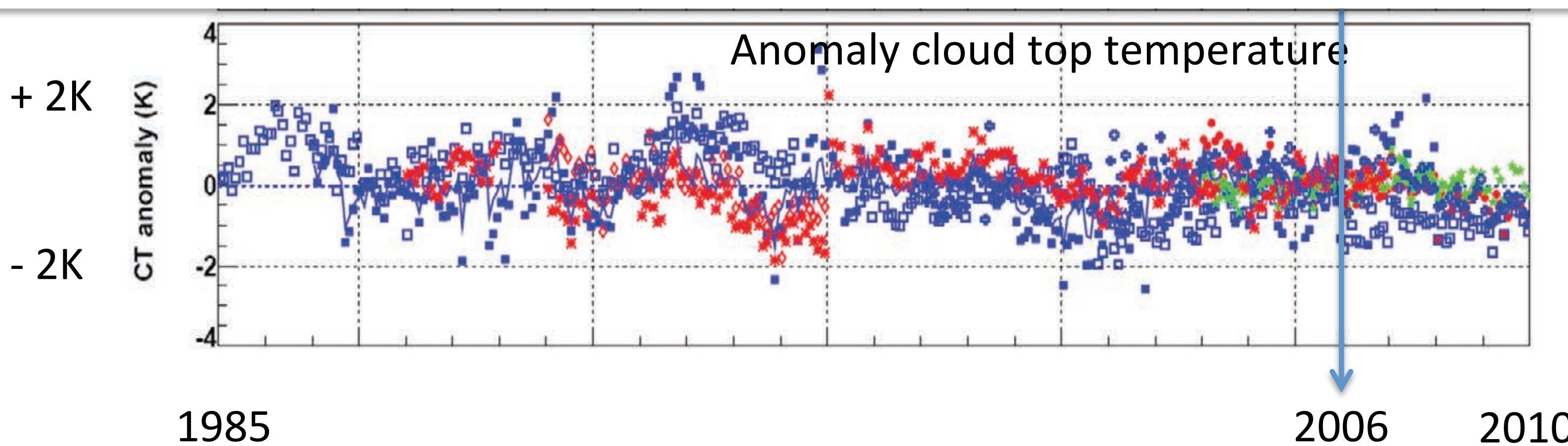
Predicted change in cloud altitude



Zelinka et al. 2012
(ensemble mean change)

High Cloud rise up
Global mean cloud feedback positive: + 0.33 W/m2/K

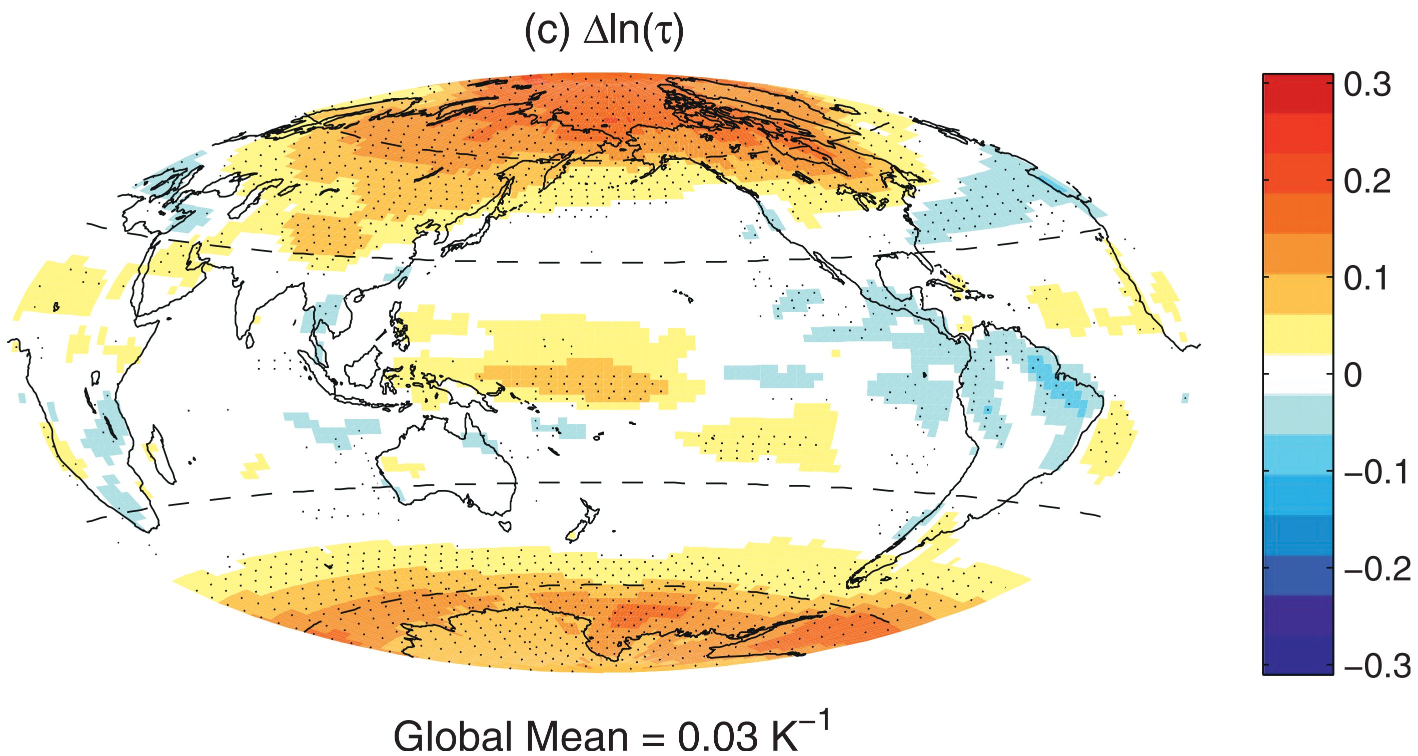
Observed change in cloud top temperature



« … At present, one can only conclude that global monthly **mean cloud amount is constant over the last 25 years** (…) **within the range of interannual variability** »

GEWEX Cloud Assessment Report, 2013

Predicted change in cloud opacity



Zelinka et al. 2012
(ensemble mean change)

Cloud optical depth increases very slightly
Global mean cloud feedback: + 0.07 W/m2/K

25 years of satellite records have so far proven unable to constrain the diversity in cloud feedbacks

Clouds do not change?

or

Clouds are changing but satellites do not document these changes ?

Difficulties:

1) Very small changes in cloud properties must be observed, requiring measurements which are accurate and stable over multiple decades

2) Observing signatures of forced cloud change requires targeting a cloud parameter which :

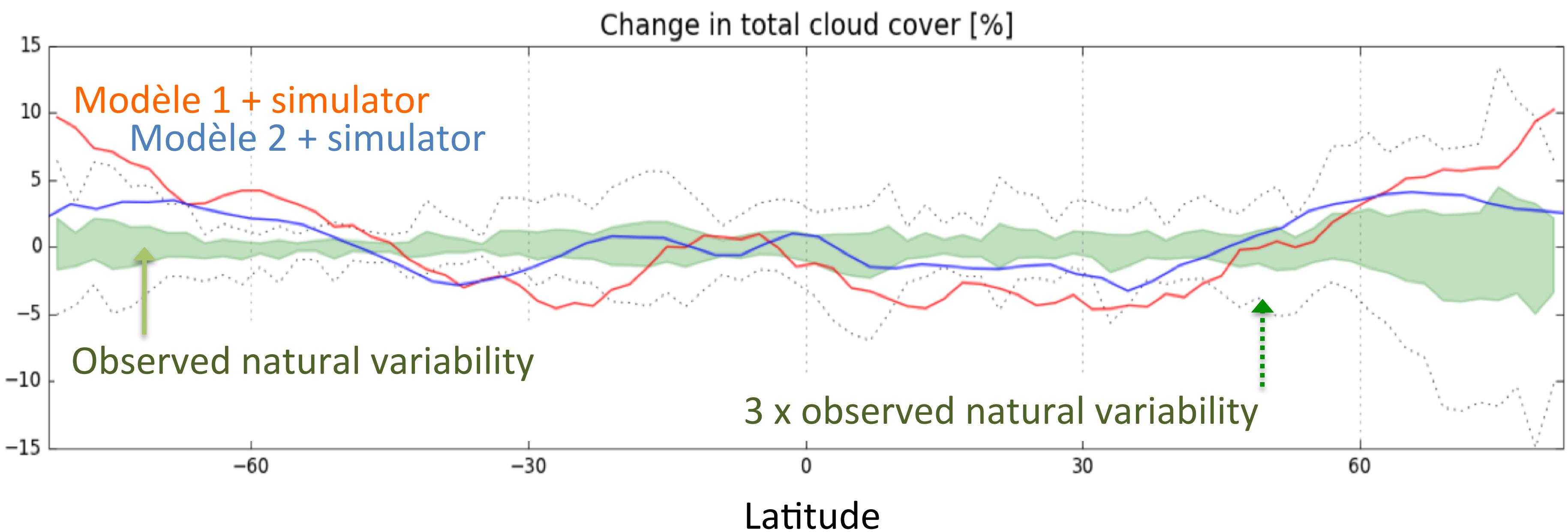
- has an expected variation induced by climate warming larger than its natural variability.

- can be measured with random and systematic uncertainties significantly smaller than the variation associated with natural climate variability.

« Project satellites in the futur » :

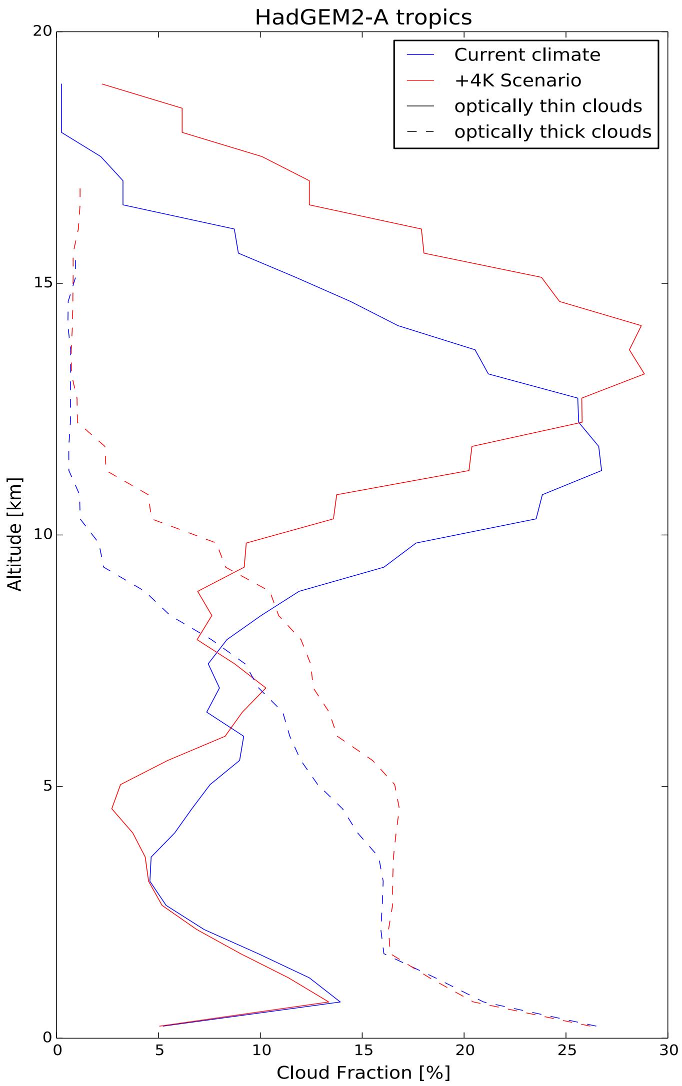
Simulate the observations that would be collected by a satellite if it was overflying a warming climate (+4K)

Cloud cover in a warming climate (+4K) ?



Predicted change falls within the range of variability in the current observation record

Cloud vertical distribution in a warming climate (+4K) ?



For one model:
- in the current climate
- in warming climate (+4K)

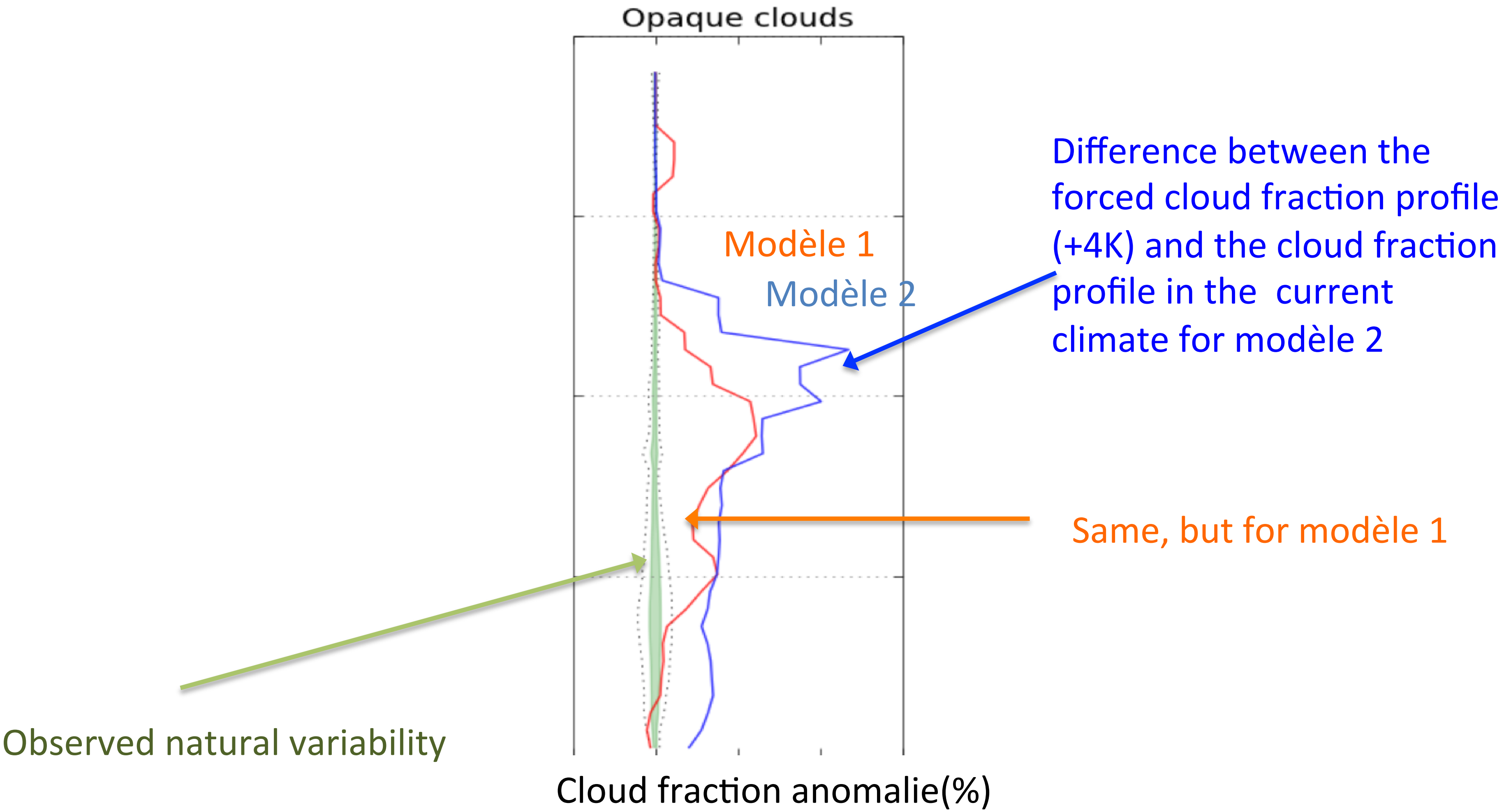
Climate model + Lidar simulator (COSP):

=>

The virtual lidar could observe the predicted clouds rise up in warming climate.

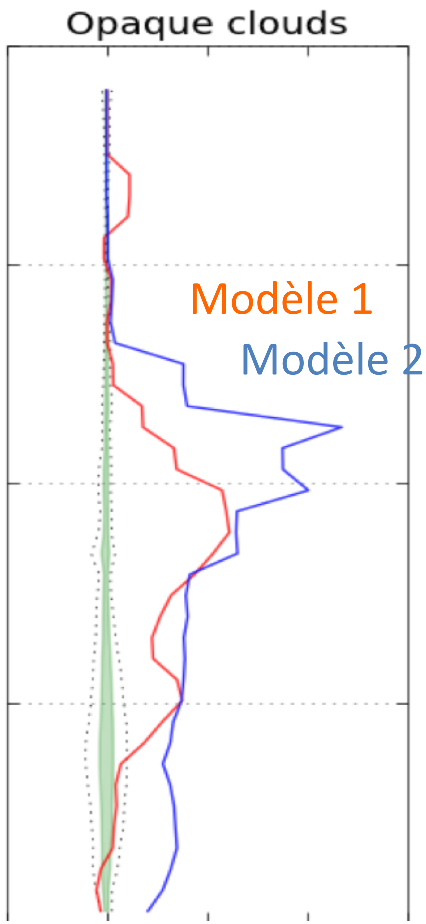
The predicted forced changes in cloud vertical distribution are much larger than the uncertainty in the lidar measurement of the vertical distribution

Cloud vertical distribution in a warming climate (+4K) ?



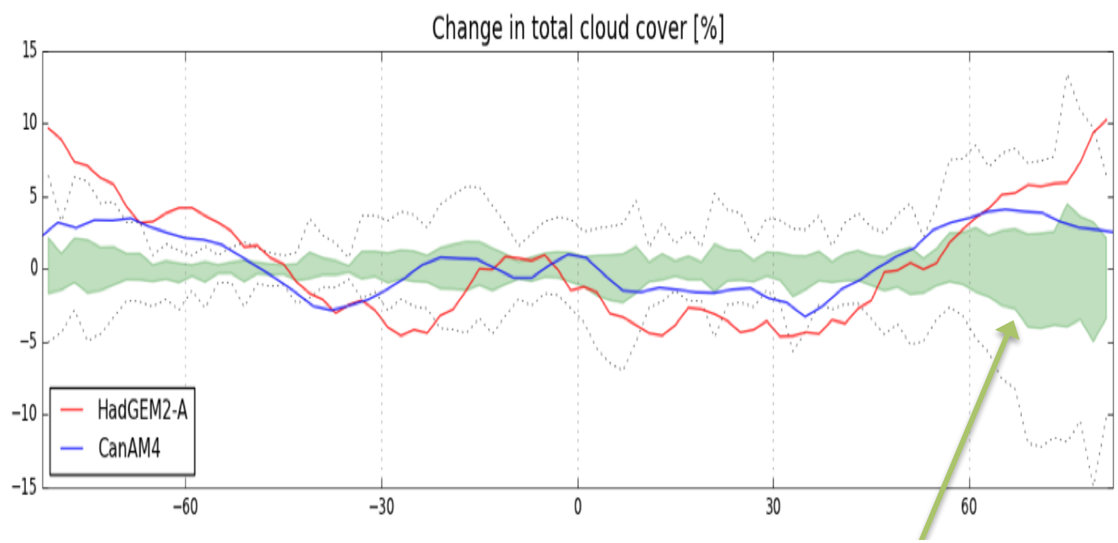
The predicted forced changes in cloud vertical distribution (directly measurable by spaceborne active sensors) are much larger than the currently observed variability

Cloud vertical distribution in a warming climate (+4K) ?



Cloud fraction anomalie(%)

Cloud cover anomalie(%)



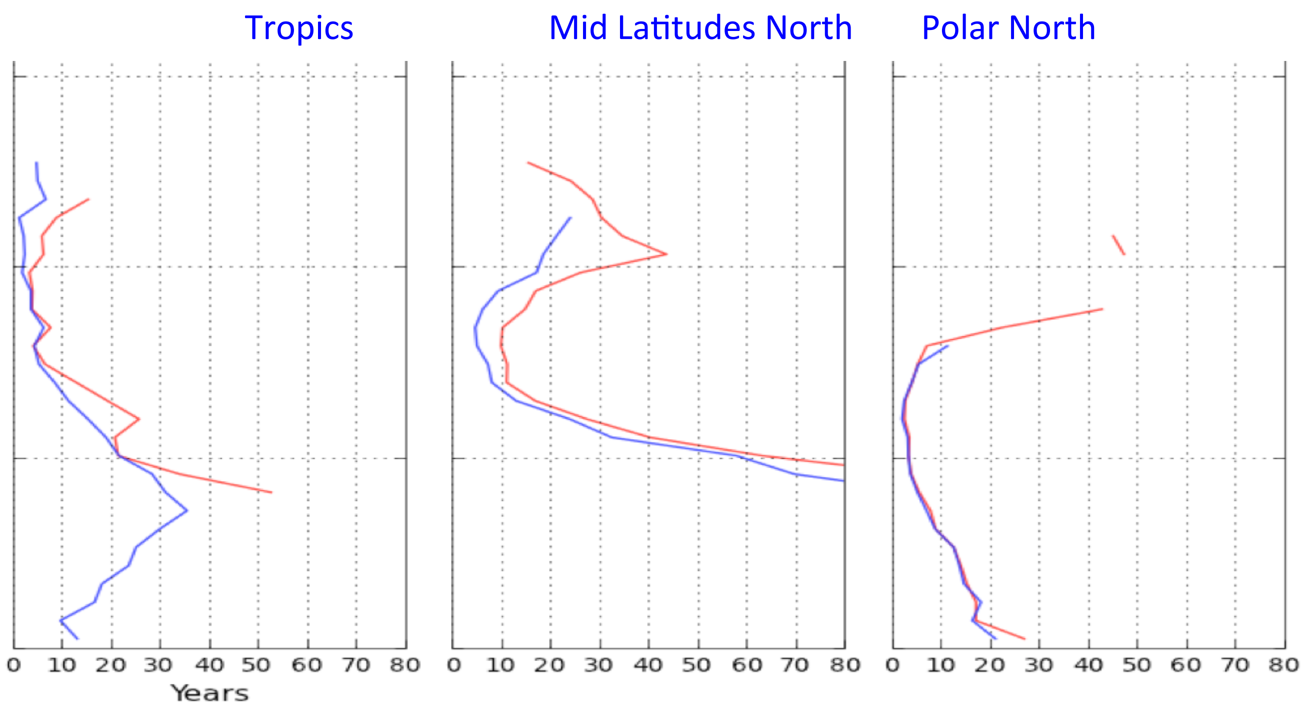
Observed natural variability

The cloud vertical distribution, observable by active spaceborne sensors, is a more robust signature of climate change than vertically integrated variables

Chepfer et al. submitted GRL

Number of years of lidar observations required to observed a change in cloud profile corresponding to three times the observed variability since 2006 ?

This result depends on CO2 emission scenario RCP8.5 (+ 3.8K +/- 1.2 K)



The predicted forced changes in cloud vertical distribution (directly measurable by spaceborne active sensors) are expected to first appear at a statistically significant level in the upper troposphere, at all latitudes.

=> 25 years of lidar data could potentially measure directly cloud response to greenhouse warming

Concluding remarks

- Clouds response to greenhouse warming is a major source of uncertainty in future climate prediction… (since the 70's !)

  …. because cloud feedbacks mechanisms are uncertain,

- Cloud feedbacks mechanisms are poorly constrained by observations yet

- Requirements to observe cloud changes induced by greenhouse warming:

  1) Very small changes in cloud properties must be observed, requiring measurements which are accurate and stable over multiple decades

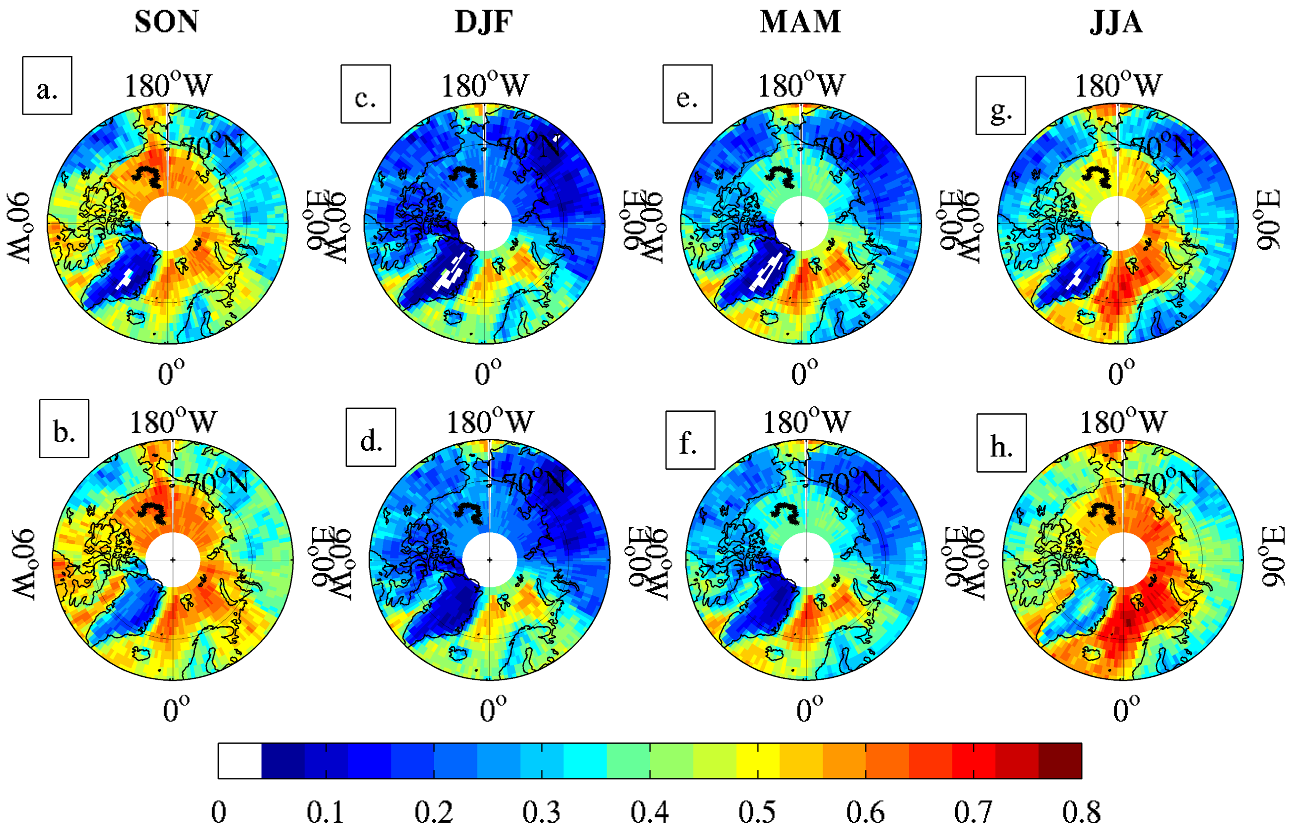
  2) Observing signatures of forced cloud change requires targeting a cloud parameter which :

  - has an expected variation induced by climate warming larger than its natural variability.

  - can be measured with random and systematic uncertainties significantly smaller than the variation associated with natural climate variability.

=> The vertical cloud distribution observed by active sensor could provide direct observational constrain on cloud feedbacks mechanism, and on the cloud response to greenhouse warming.

=> Need for 25 years active remote sensors data records !!



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0.6
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0.8

Need observations to constrain cloud feedback mecanisms

« Feedback Mechanisms Involving the Altitude of High-Level Cloud

The observational record offers limited further support for the altitude increase. *Observed cloud height trends do not appear sufficiently reliable to test this cloud-height feedback mechanism.*

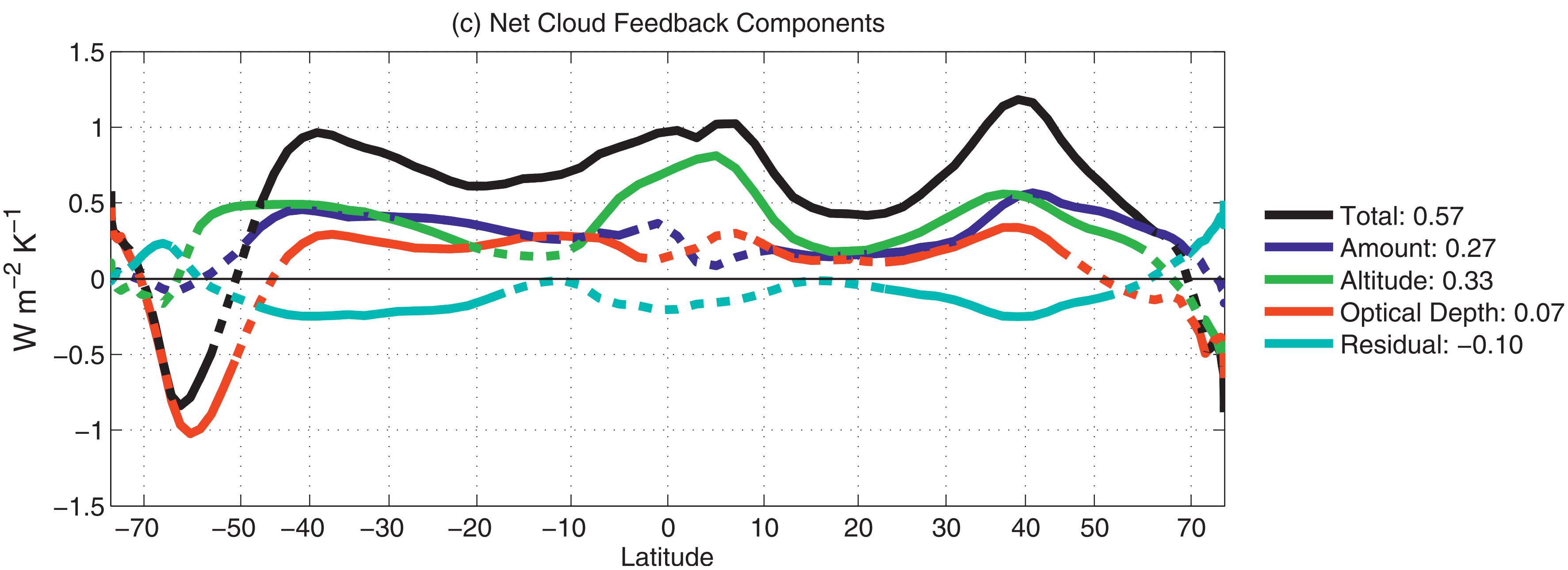
Feedback Mechanisms Involving the Amount of Middle and High Cloud

Model simulations, physical understanding *and observations* thus provide medium confidence that poleward shifts of cloud distributions will contribute to positive feedback, but by an uncertain amount. Feed- backs from thin cirrus amount cannot be ruled out and are an impor- tant source of uncertainty.

Feedback Mechanisms Involving Low Cloud

The tendency of both GCMs and process models to produce these positive feedback effects suggests that the feedback contribution from changes in low clouds is positive. However, deficient representa- tion of low clouds in GCMs, diverse model results, *a lack of reliable observational constraints*, and the tentative nature of the suggested mechanisms leave us with *low confidence* in the sign of the low-cloud feedback contribution. «

IPCC, AR5, Chapter 7



Zelinka et al. 2012

Predicted cloud responses to grenhouse warming

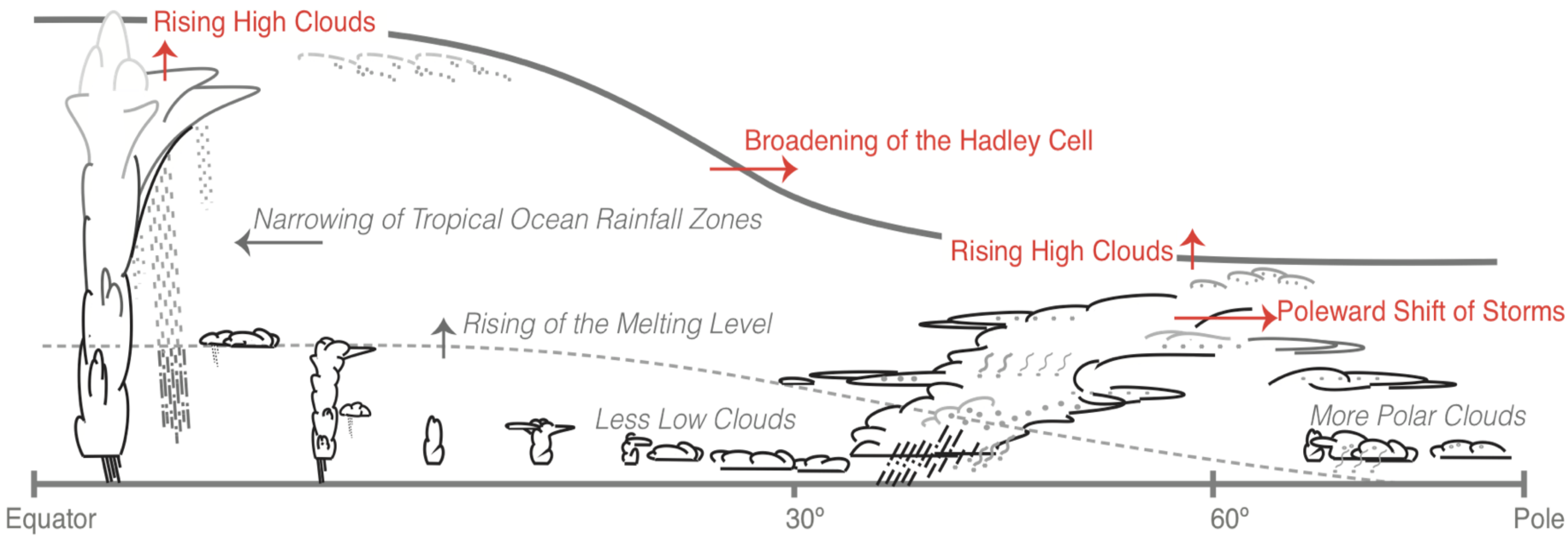
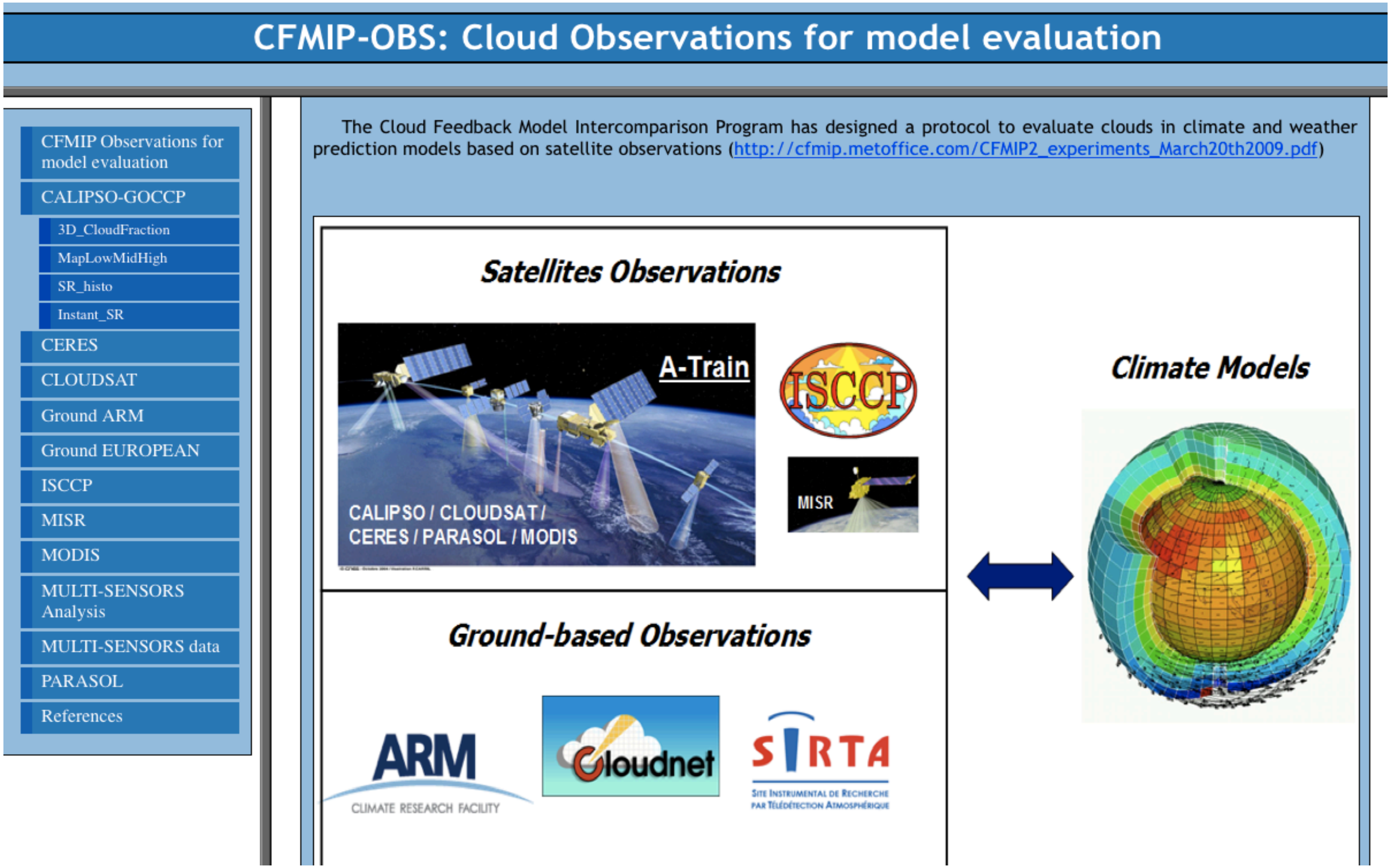


Figure 7.11 | Robust cloud responses to greenhouse warming (those simulated by most models and possessing some kind of independent support or understanding). The tropopause and melting level are shown by the thick solid and thin grey dashed lines, respectively. Changes anticipated in a warmer climate are shown by arrows, with red colour indicating those making a robust positive feedback contribution and grey indicating those where the feedback contribution is small and/or highly uncertain. No robust mechanisms contribute negative feedback. Changes include rising high cloud tops and melting level, and increased polar cloud cover and/or optical thickness (*high confidence*); broadening of the Hadley Cell and/or poleward migration of storm tracks, and narrowing of rainfall zones such as the Intertropical Convergence Zone (*medium confidence*); and reduced low-cloud amount and/or optical thickness (*low confidence*). Confidence assessments are based on degree of GCM consensus, strength of independent lines of evidence from observations or process models and degree of basic understanding.

IPCC, AR5, Chapter 7

- 1)Need for precise evaluation of the cloud description in climate models using obs
- 2) Need for improvement of the cloud description in climate models using obs
- => make the model more close to the actual physic => more confident in the simulations
- Learn from observations about cloud feedbacks

CLIMP will join CFMIP-OBS database & Obs4MIPs initiative



On http://climserv.ipsl.polytechnique.fr/cfmip-obs/ since 2008
On the ESGF under Obs4Mips/CFMIP-OBS and under CFMIP-OBS since 2012

Some references describing products included in CFMIP-Obs datasets on http://climserv.ipsl.polytechnique.fr/cfmip-obs/
Some references useing of CFMIP-Obs data and COSP to evaluate climate models on http://cfmip.net/publications

Outline

About the (uncertain) predicted cloud response to greenhouse warming

Can lidar help to reduce cloud-related uncertainties in climate predictions ?

Make Models and Lidar observations speak a common language

Examples on the evaluation of the clouds description in climate models using lidar observations

The future: could lidar provide direct unambiguous measurement of cloud response to greenhouse warming ?