PERTURBED CLOUDS IN A CHANGING CLIMATE

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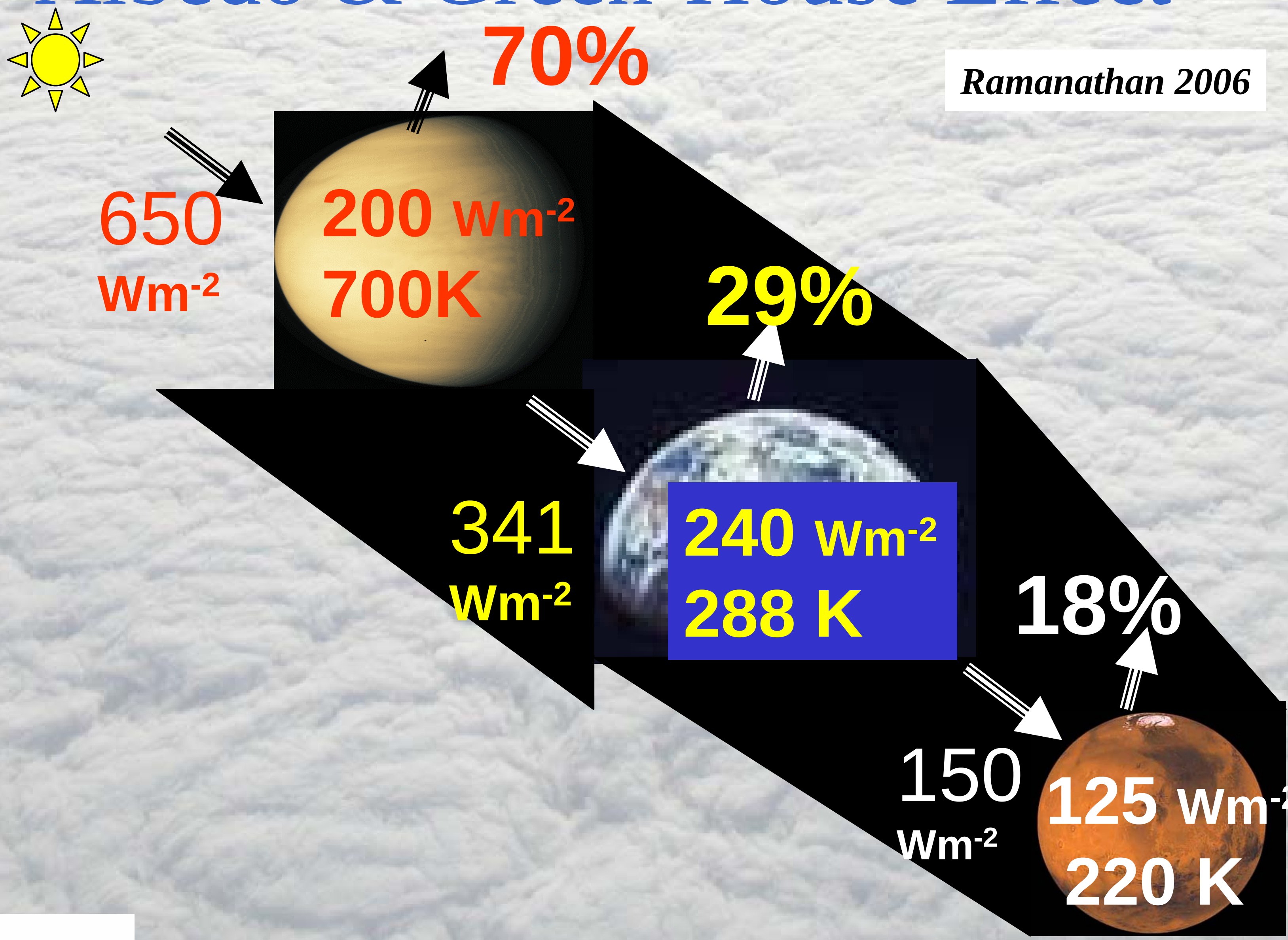
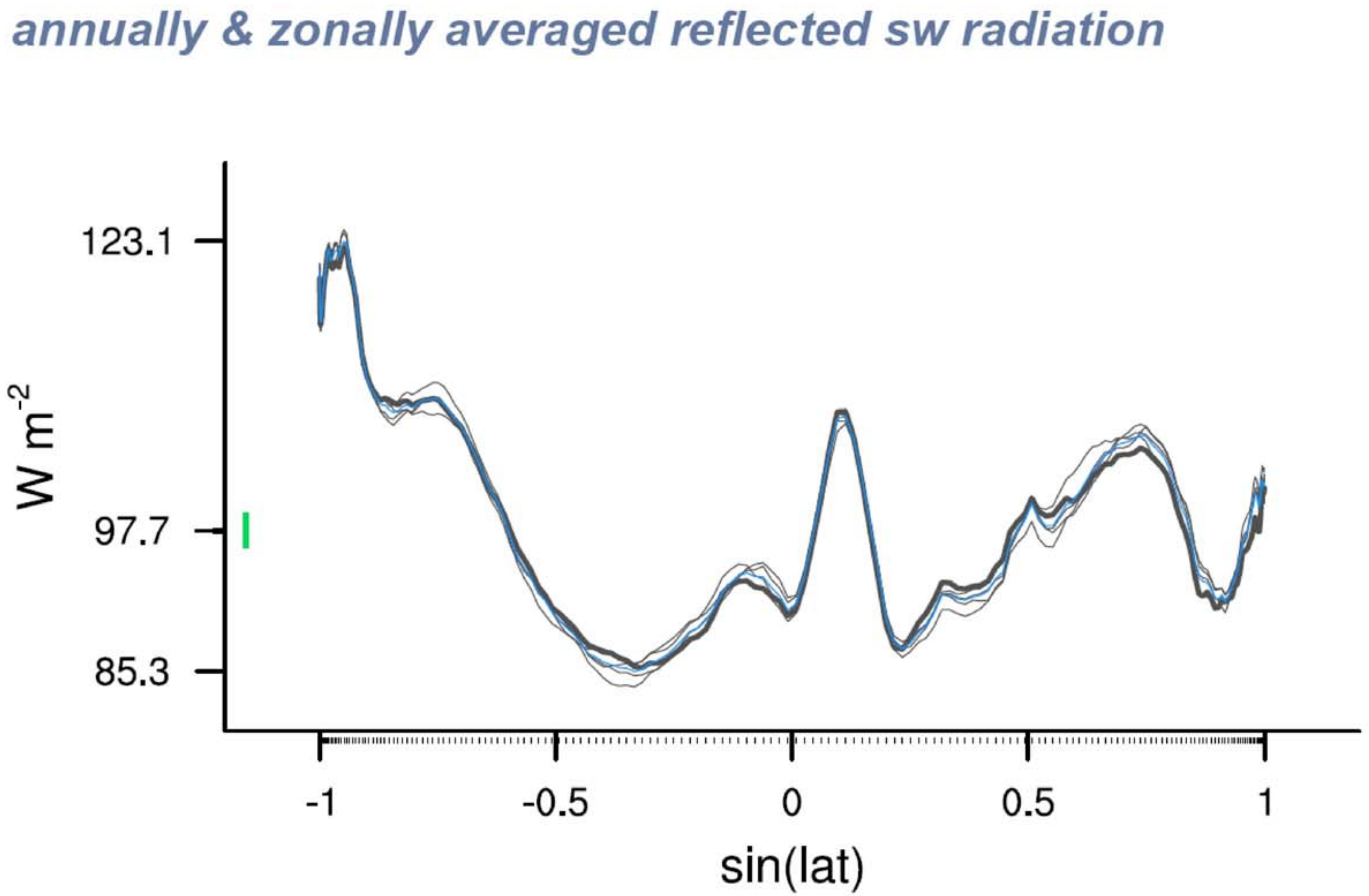
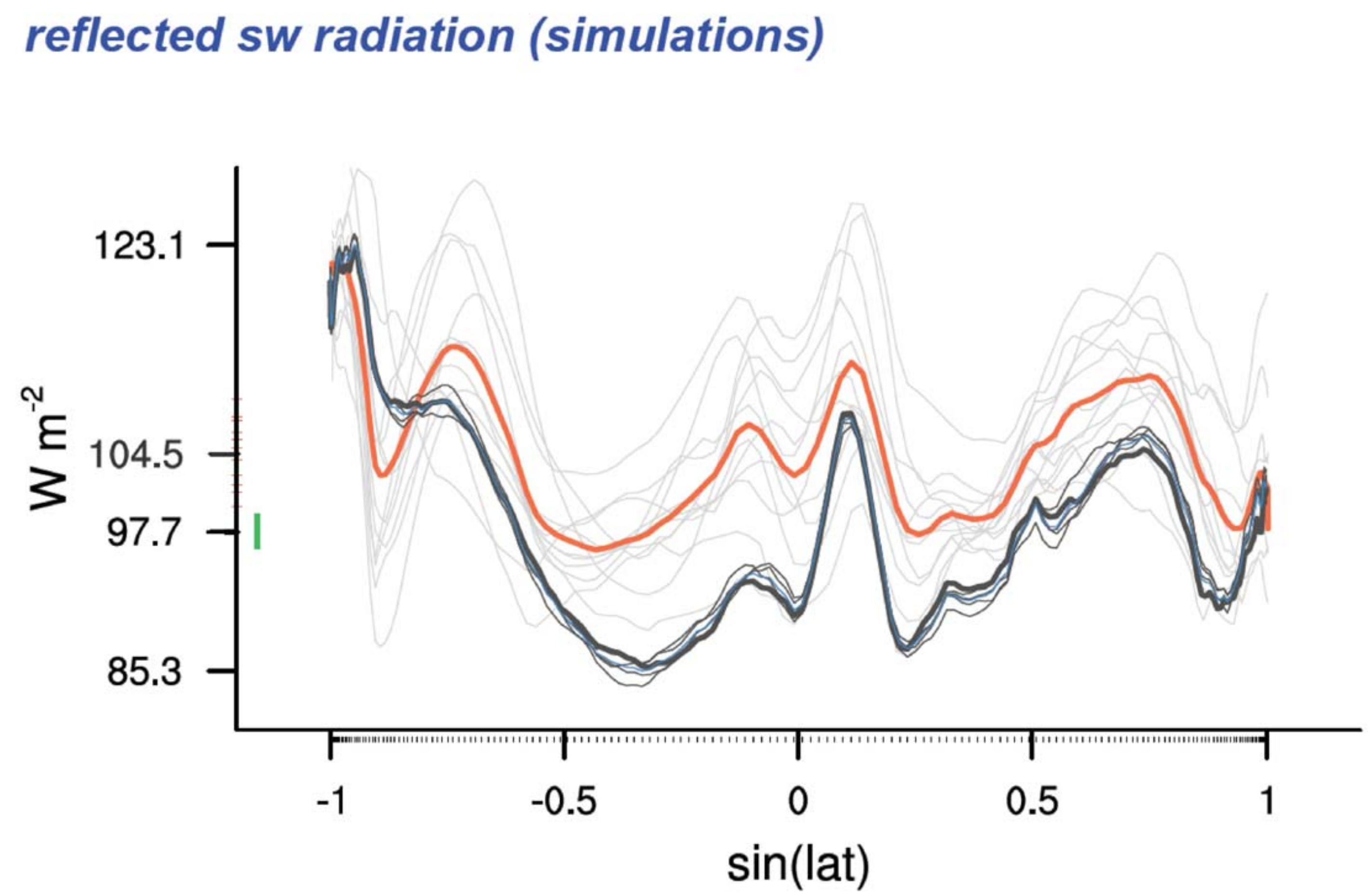
Albedo & Green-House Effect



Albedo & Green-House Effect

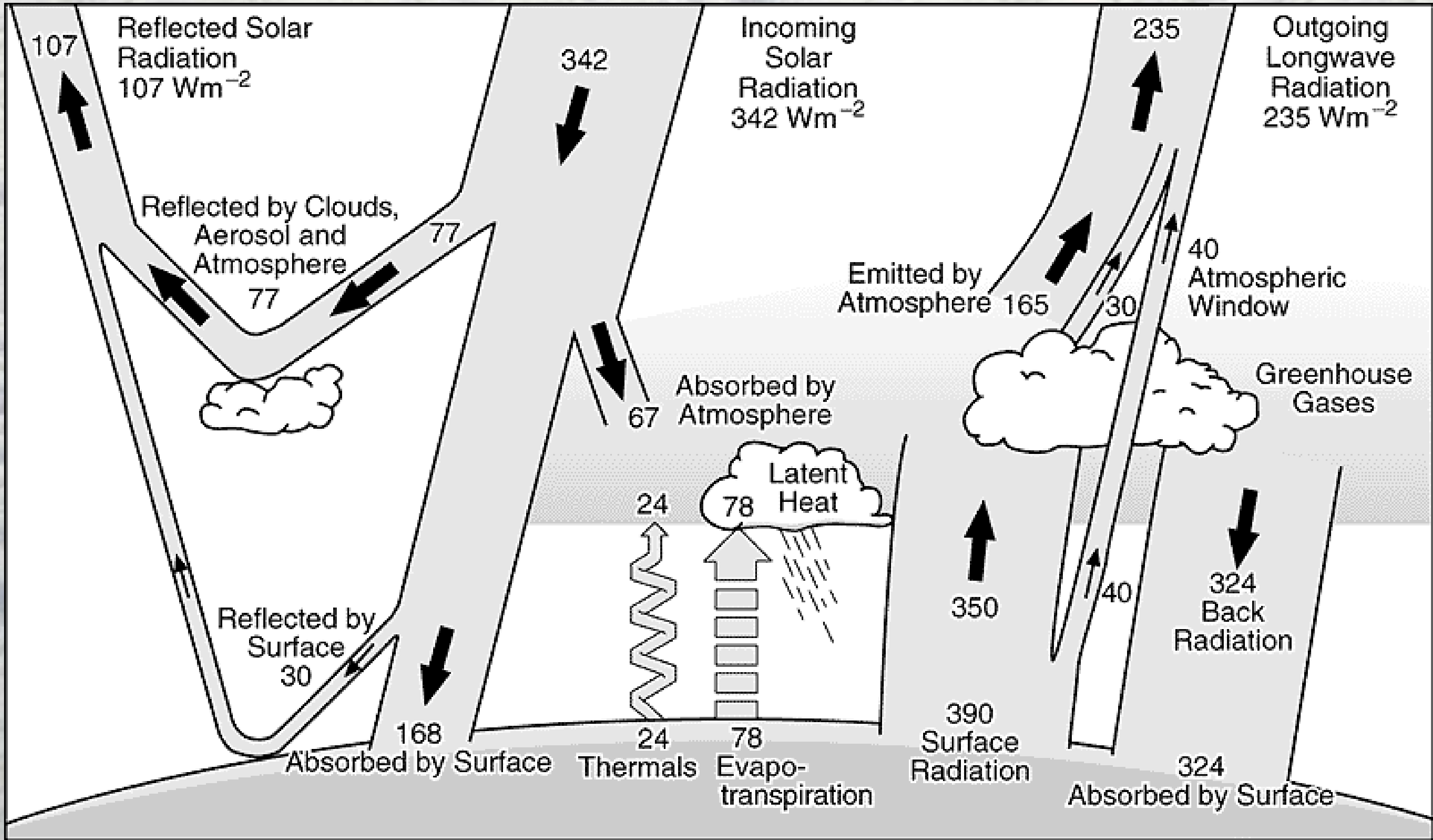


Albedo & Green-House Effect



- 101-106 W/m2 (Wild et al., survey)
- 107 W/m2 (Trenberth and Kiehl (ERBE)
- 101 W/m2 (CERES)

Albedo & Green-House Effect



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ACAS EUFAR School De Bilt 20 April 2008 J.-L. Brenguier

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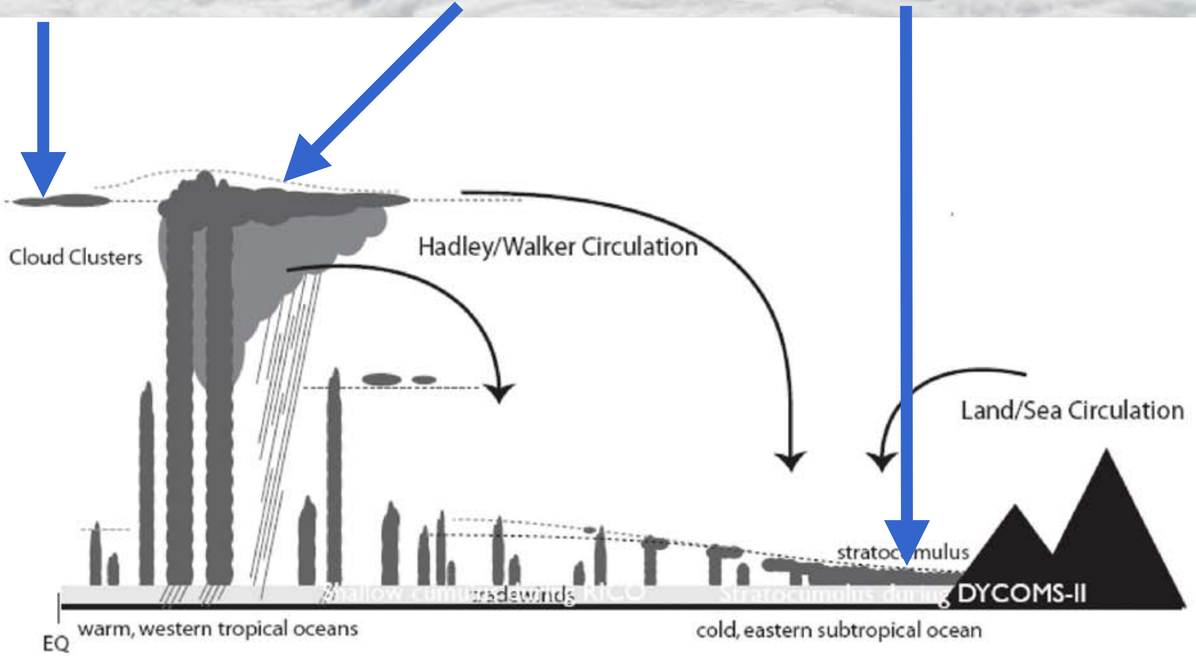
Albedo & Green-House Effect

Low albedo 10%
High GHE

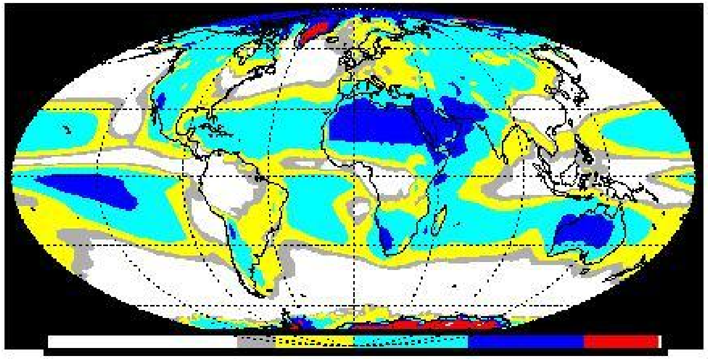
High albedo 80%
High GHE

Medium albedo 50%
No GHE

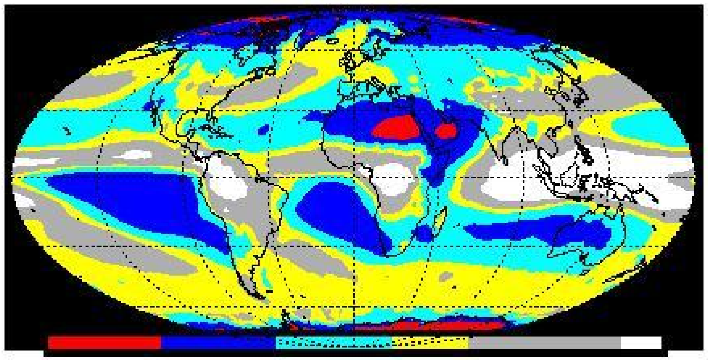


Albedo & Green-House Effect

OBSERVED (ERBE) SW CLOUD FORCING [W m^{-2}], 1985-1989



OBSERVED (ERBE) LW CLOUD FORCING [W m^{-2}], 1985-1989



Source: Ramanathan et al (1989 & 1991); Harrison et al (1990)

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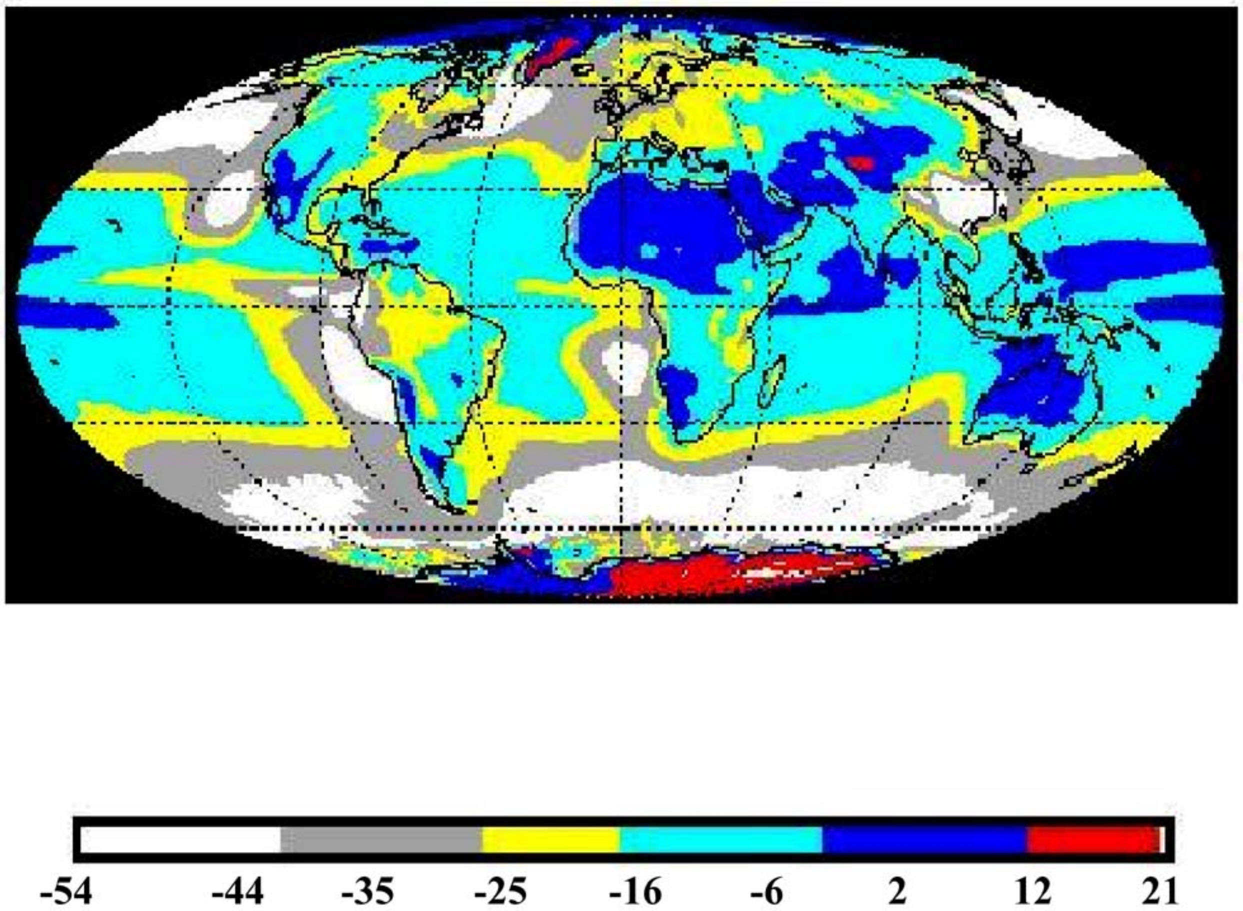
Albedo & Green-House Effect

Fig. 1. Observed (ERBE) Net Cloud Forcing [W m^{-2}], 1985-1989

Source: Ramanathan et al, 1989; 1994; Harrison et al, 1991



The net cloud forcing is the effect of clouds on the radiation budget at the top-of-the atmosphere.

The Cloud in Climate Paradoxe

The « cloud radiative forcing » is, by definition, the variation (-) of the Earth radiation budget if all clouds were removed.

The short wave contribution (albedo) annual mean is about – 47 Wm^{-2} .

The long wave contribution (green house effect) is + 29 Wm^{-2}. Globally, the albedo effect is greater than the green-house effect, so that clouds are cooling the Earth.

If all clouds were suddenly transparent, the Earth radiation budget would increase by 18 Wm^{-2}, a significant increase compared to a doubling of CO_2 ~ 4 Wm^{-2}.

That means that a small modification of cloud cover or cloud radiative properties will have a huge impact on climate.

Fouquart: http://www.futura-sciences.com/fr/comprendre/dossiers/doc/t/climatologie/

The Cloud in Climate Paradoxe

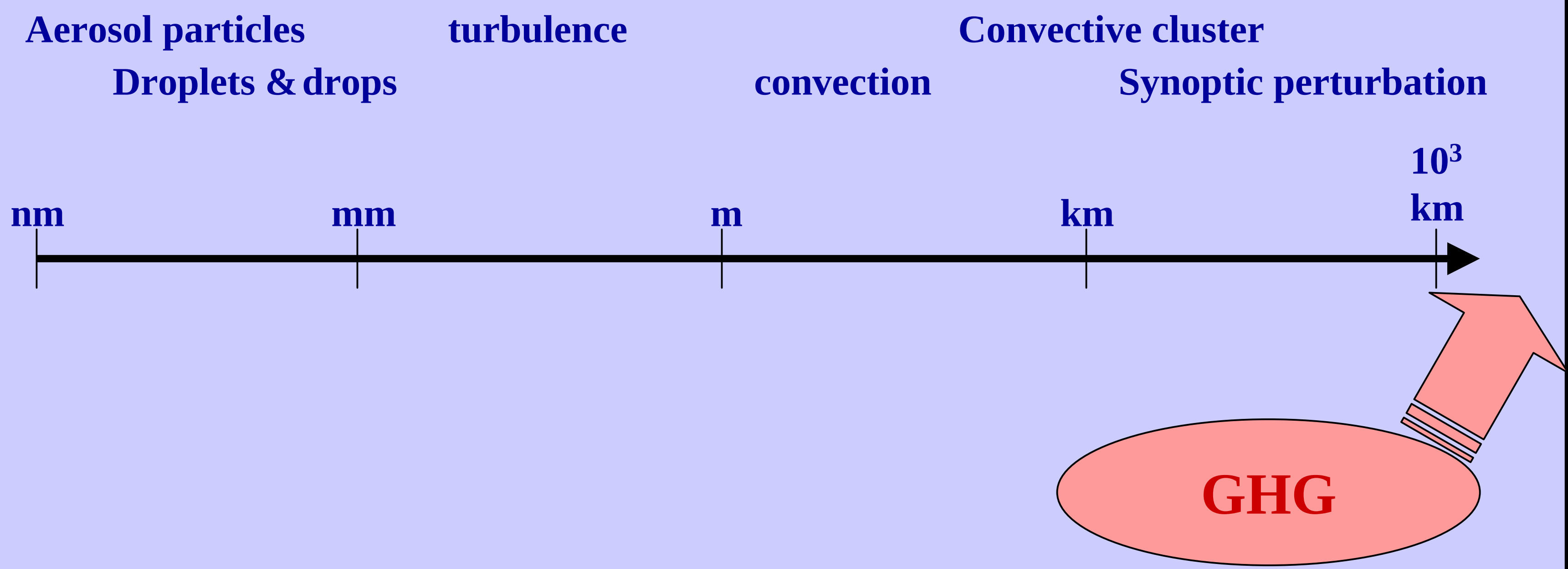
Cloud albedo varies from less than 1 % (invisible cirrus) to almost 90 % (cumulonimbus).
Their green-house effect varies from 0 to + 50 Wm^{-2}.
Their life time varies from a few minutes to days.
Their spatial distribution is very heterogeneous.

But, together, their maintain the Earth albedo constant at 29%, to better than 1 %, since thousands of years.

Climate models are able to simulate the observed global temperature change, but they are unable to place clouds at the right location, with the correct albedo and GHE properties.

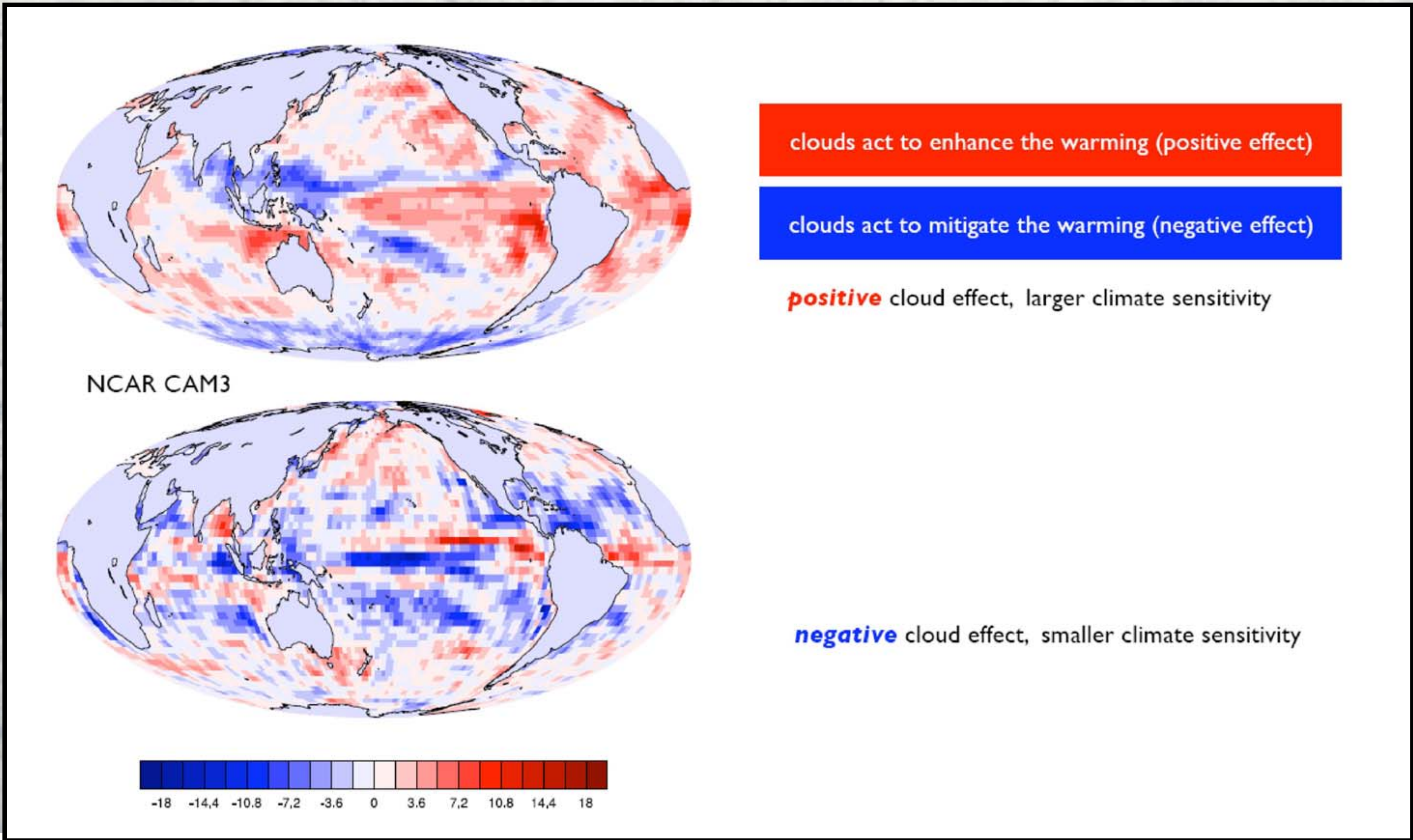
What are the feed-back processes ?

Radiative forcings and feedbacks

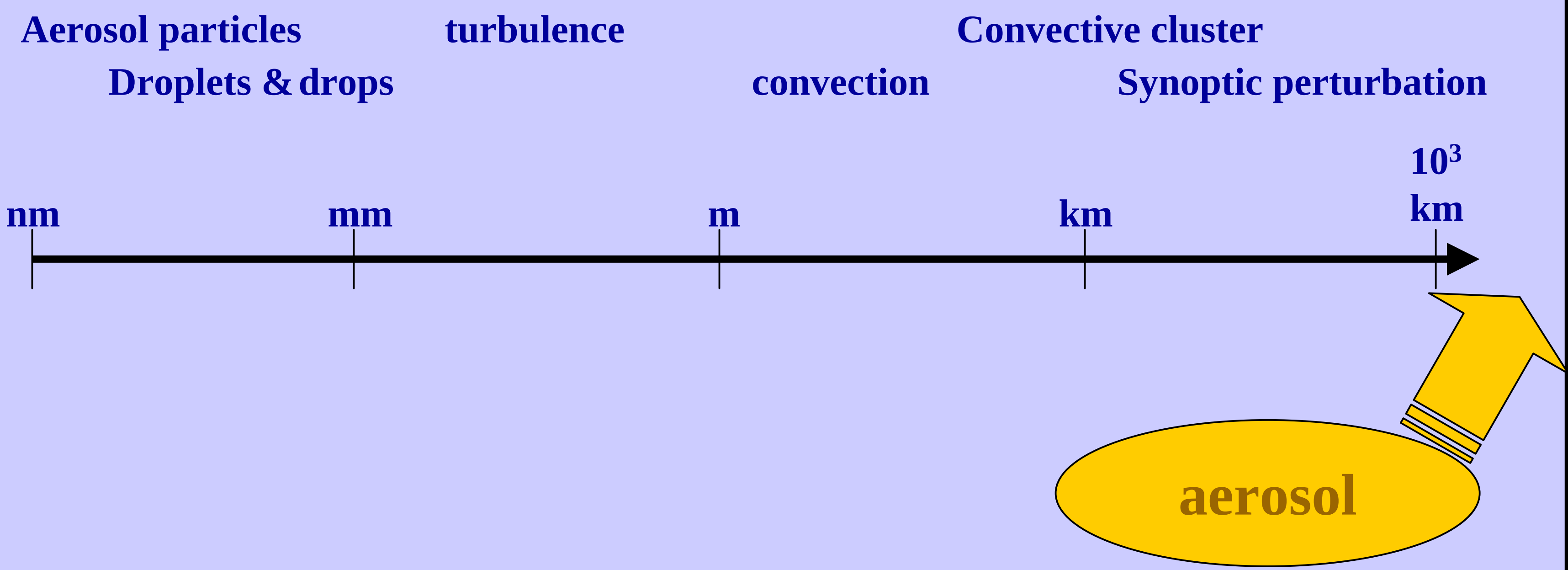


Temperature ↗
Water vapour mixing ratio ↗
Low level cloud cover ↗ ⇒ negative feedback
High level cloud cover ↗ ⇒ positive feedback

Radiative forcings and feedbacks



Radiative forcings and feedbacks

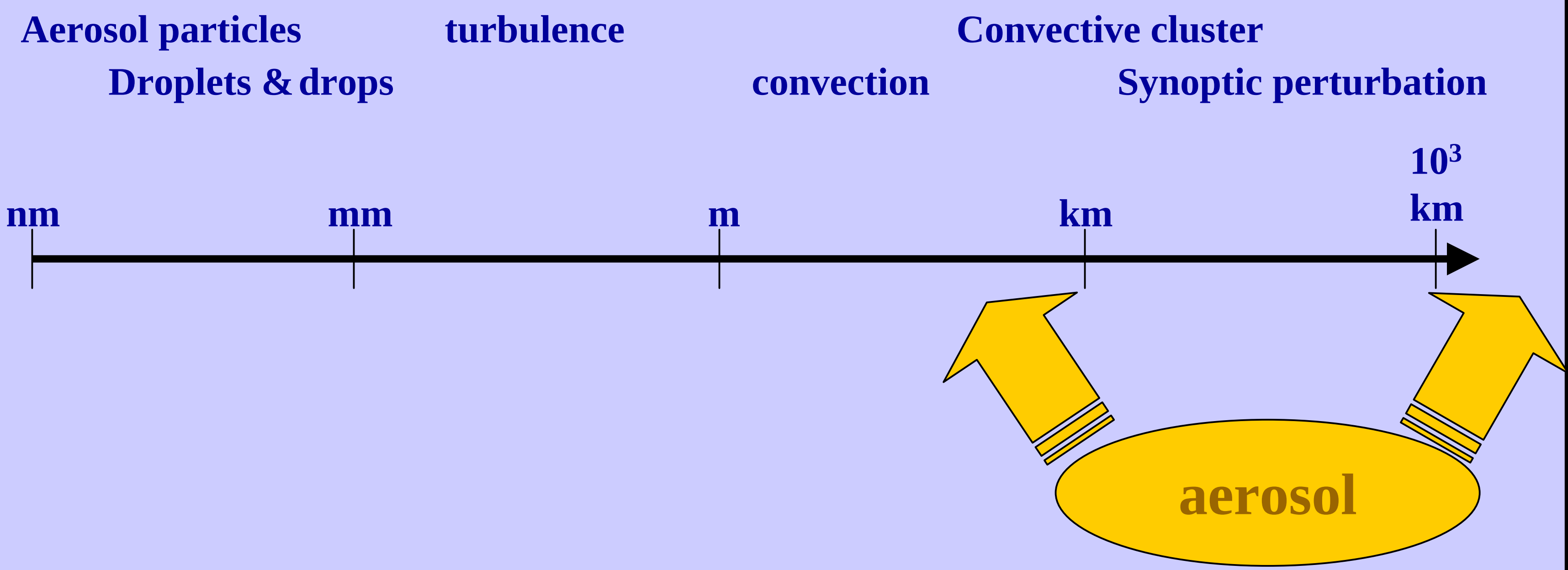


Earth albedo ↗ ⇒ Temperature of the atmosphere ↘

Absorption by aerosol ↗ ⇒ Temperature of the atmosphere ↗

Unlike GHG, aerosol are not uniformly distributed

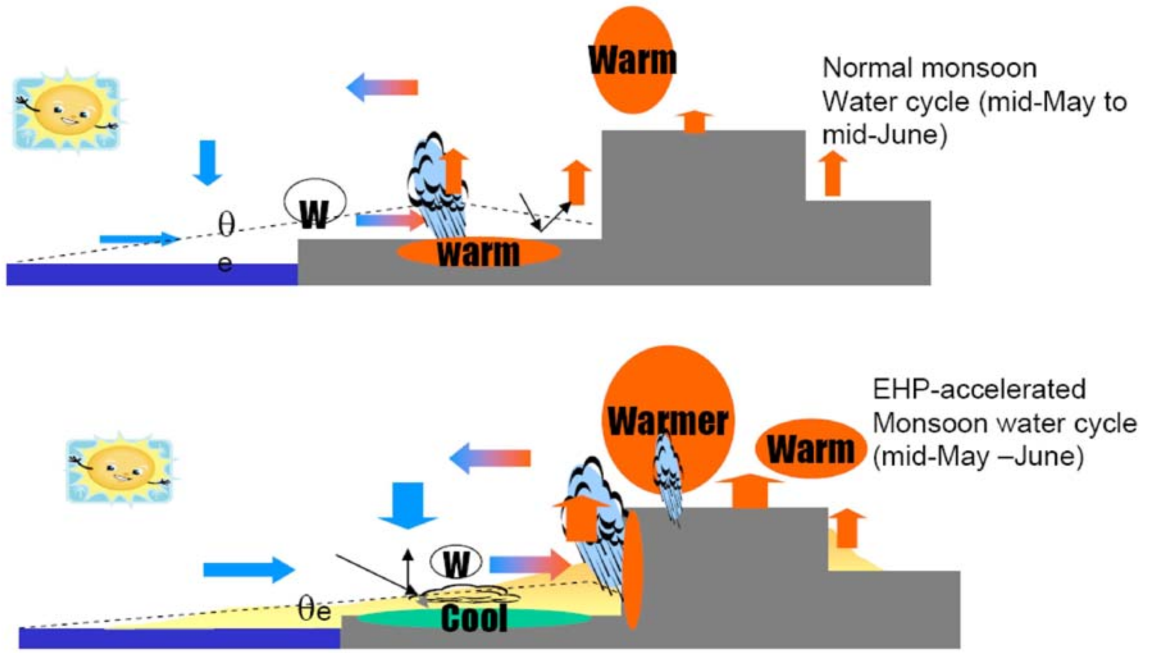
Radiative forcings and feedbacks



At the regional scale, aerosol can impact the general circulation by heating/cooling some specific atmospheric layers

Radiative forcings and feedbacks

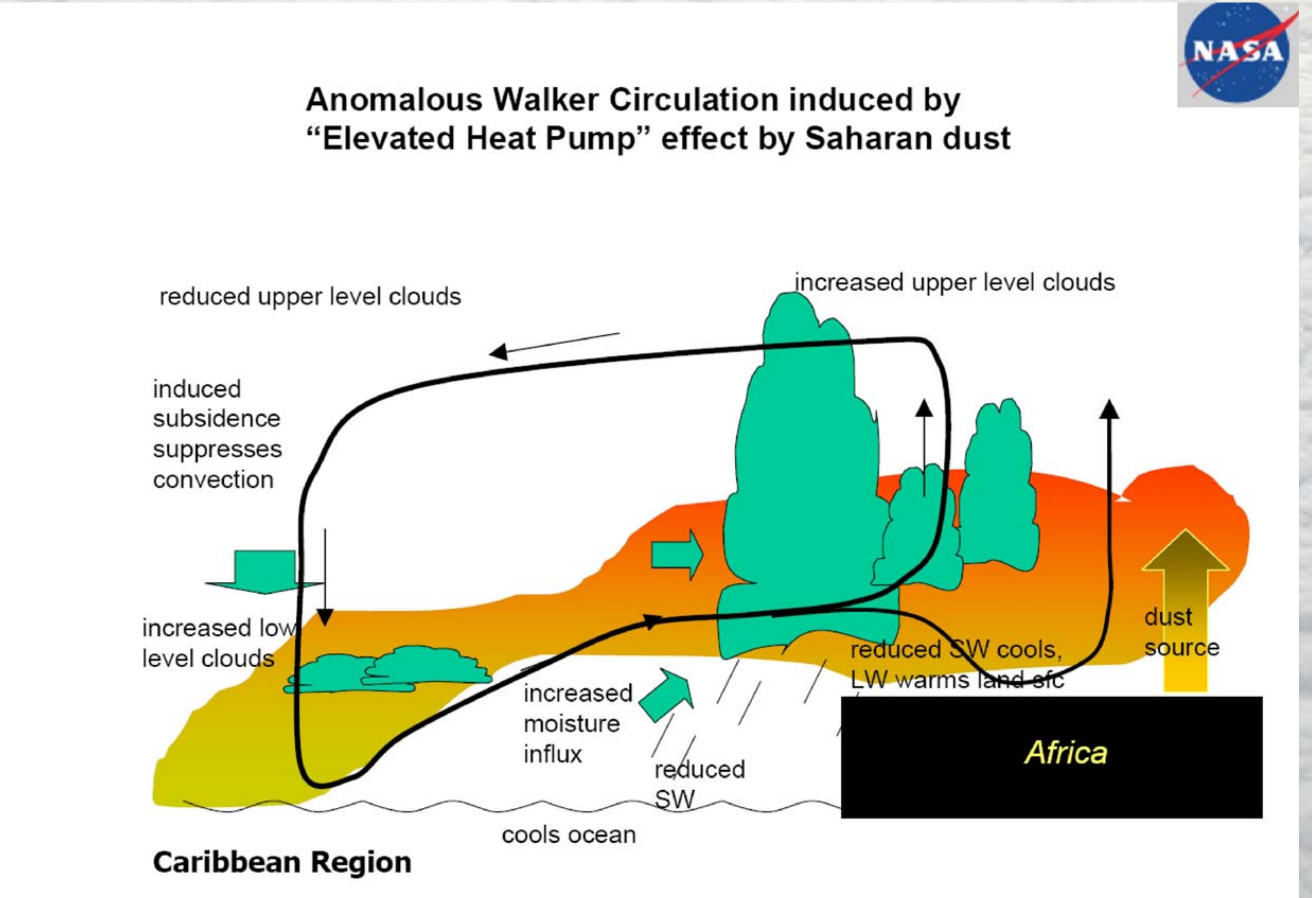
The Elevated Heat Pump (EHP) hypothesis (Lau et al. 2006, Climate Dynamics)



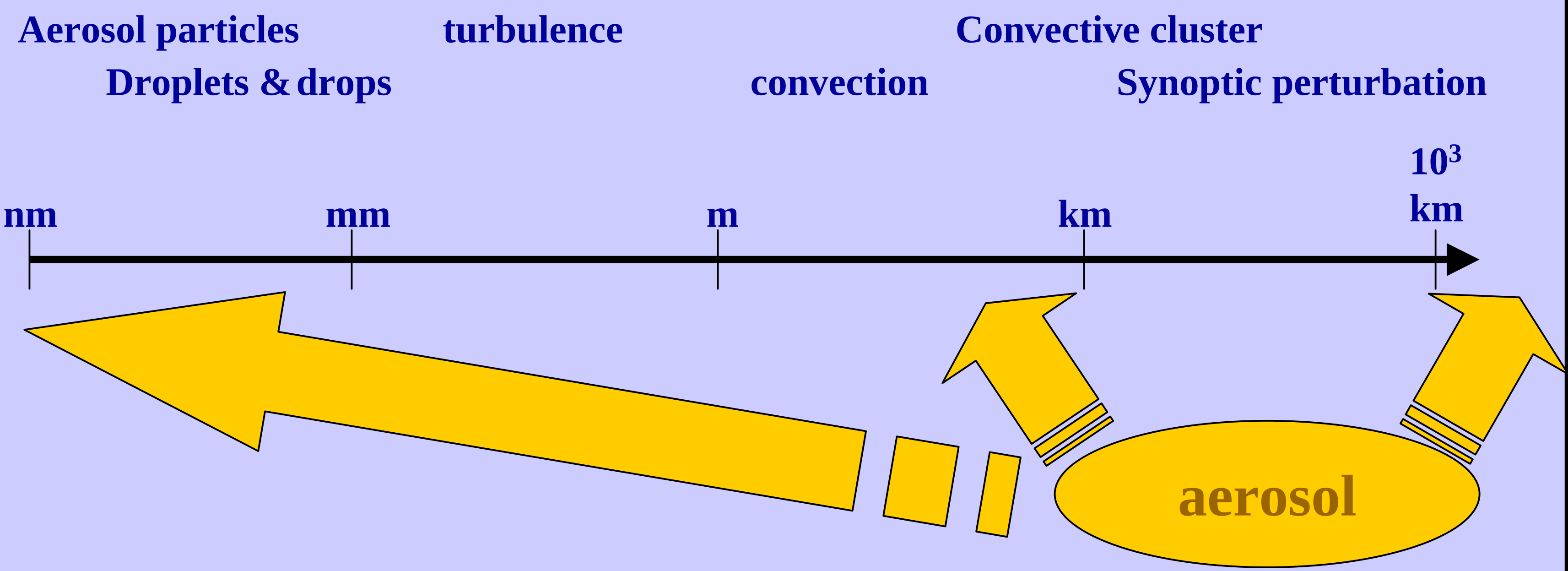
EHP postulates:
a) anomalous heating of Himalaya foohills, and warming of the upper troposphere over TP in MAM
b) an advance of the rainy season in northern India/Napal region in May-June
c) In June-July, the increased convection spreads from the foothills of the Himalayas
to central India, resulting in an intensification of the Indian monsoon.

Lau and Kim (2006, GRL)

Radiative forcings and feedbacks



Radiative forcings and feedbacks



With its nucleating properties, CCN and IN, the aerosol can impact cloud microphysical properties

Do cloud microphysical changes have an impact on cloud radiative properties ?

1er Effet Indirect de l'Aérosol

Some aerosol particles act as droplet embryos (CCN).

When the CCN concentration increases, the droplet concentration generally increases.

At constant LWP, droplets in polluted clouds are smaller than in pristine clouds

More numerous and smaller droplets (cst LWP) have a higher extinction

At constant LWP, the albedo of polluted clouds is stronger than the one of pristine clouds (Twomey effect)

Can we assume that cloud microphysical and radiative properties can be modified, whithout assuming that their life cycle will also be affected

(constant LWP) ?

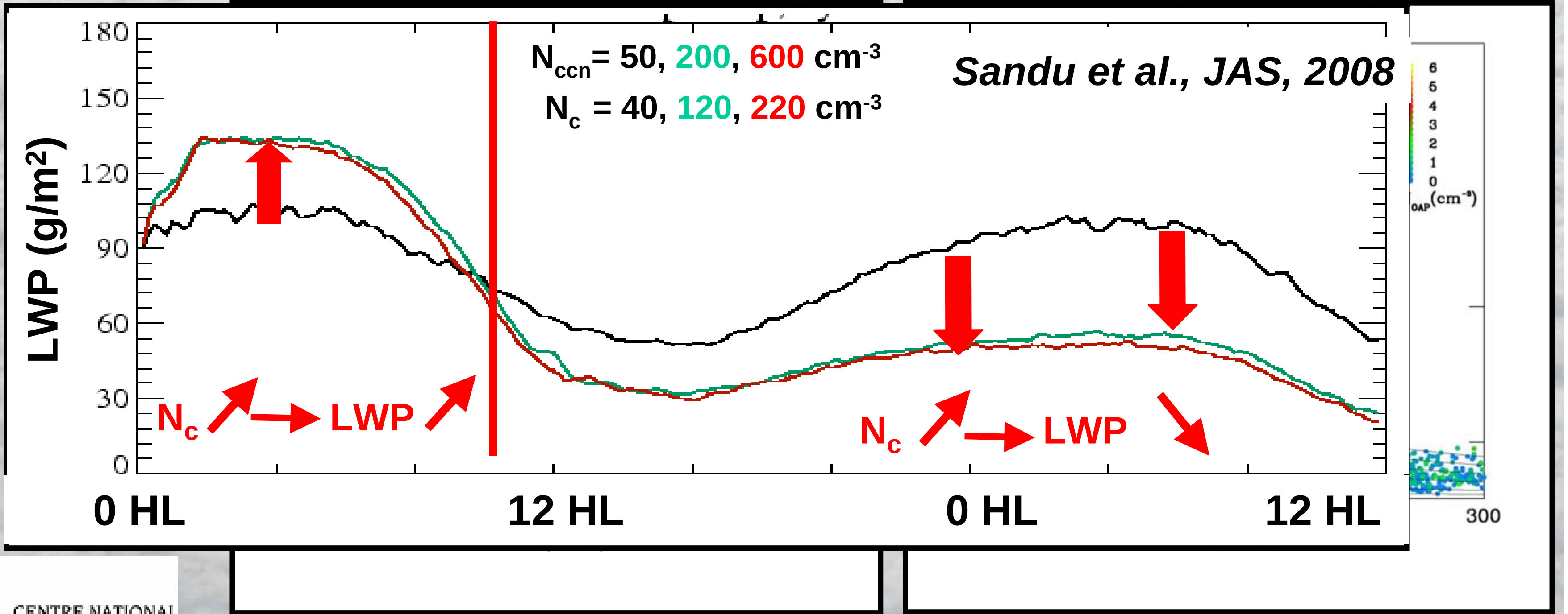
Additional Indirect Aerosol Effects

When droplets are smaller, their probability of coalescence is reduced, hence inhibiting the formation of precipitation

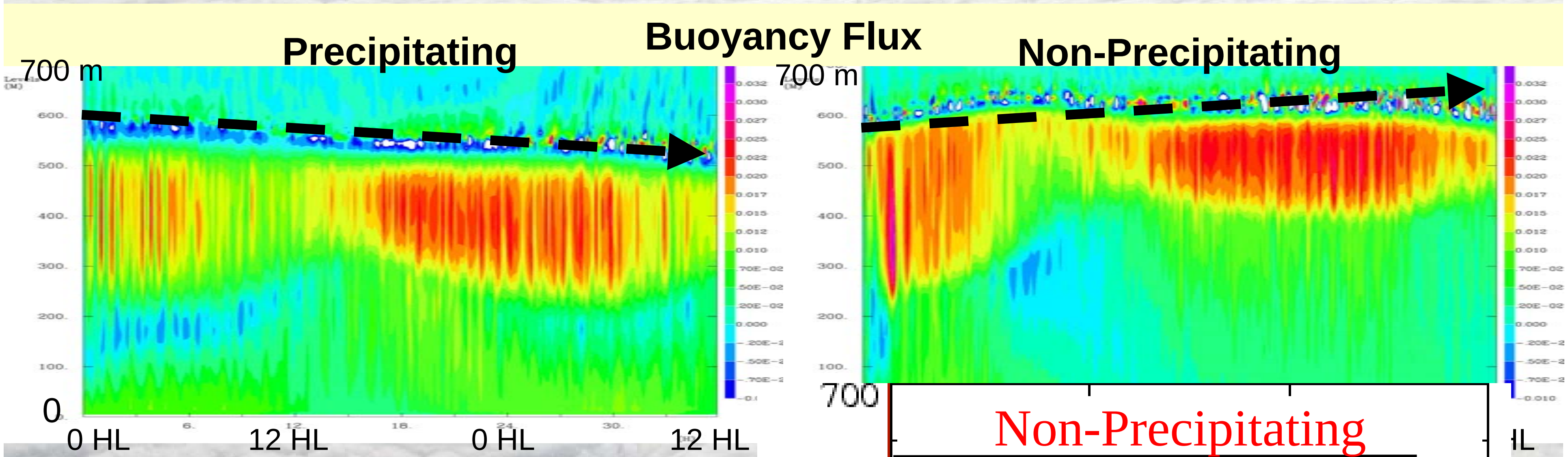
In boundary layer clouds, precipitation remove the condensed water

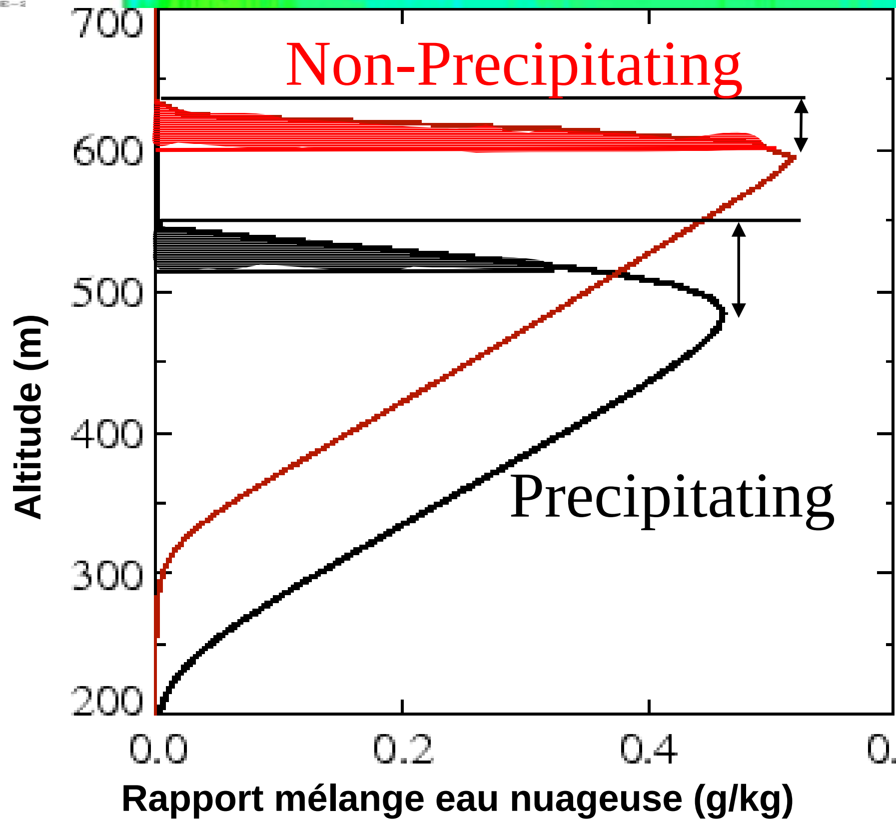
The LWP of polluted clouds shall therefore be higher than the one of pristine clouds, hence their albedo shall be higher (Albrecht effect) (négative feedback)

All LES simulations of this process reveal rather the contrary.



Additional Indirect Aerosol Effects



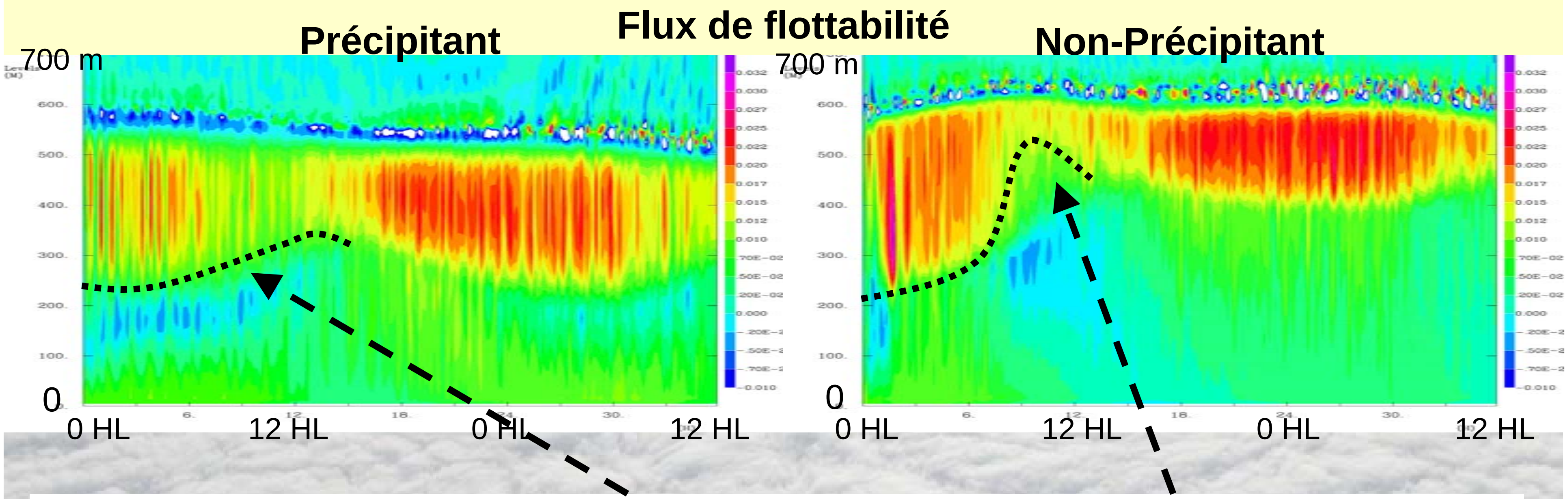


Précipitation Inhibited

⇒

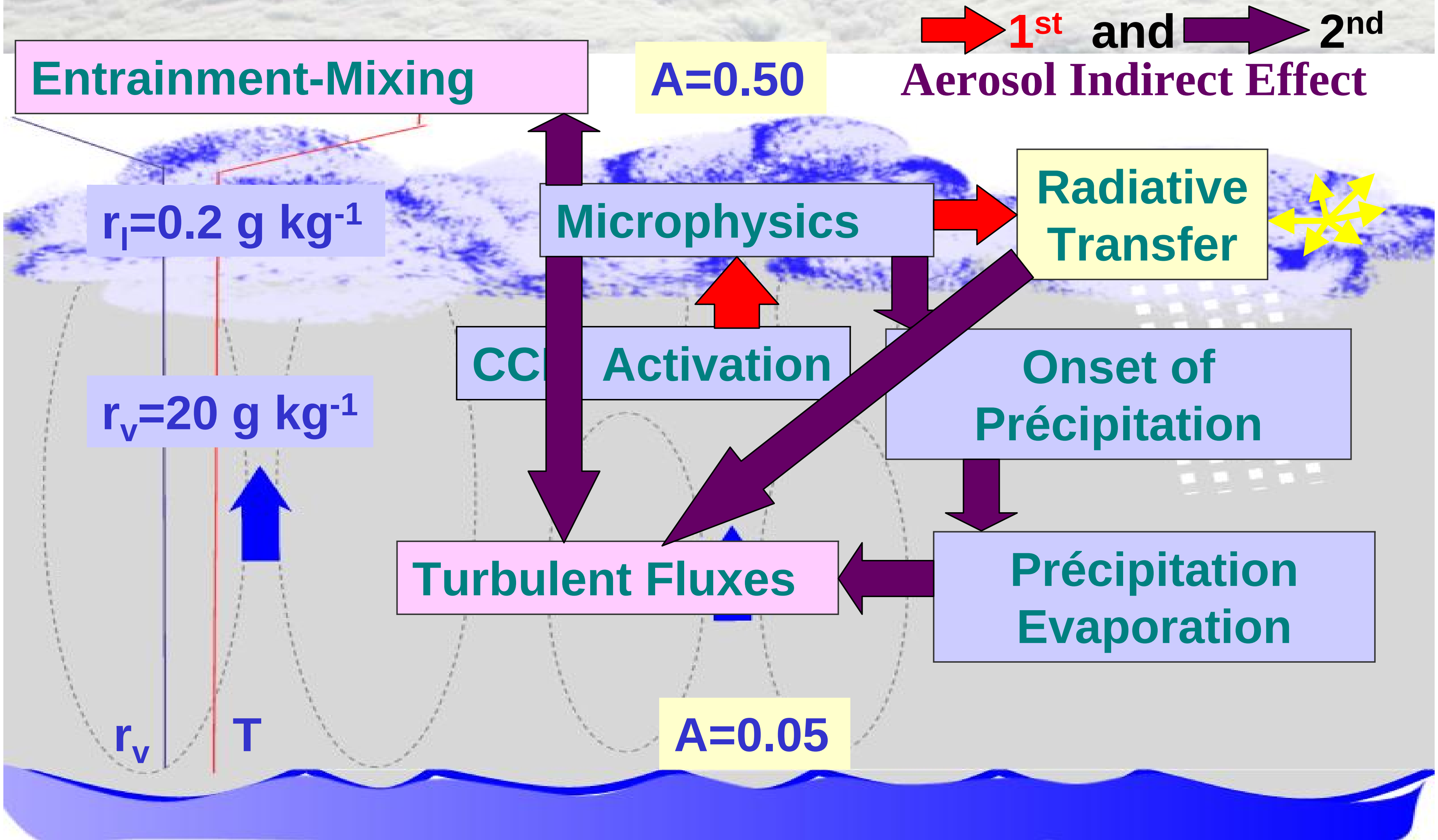
Top entrainment reinforced

Additional Indirect Aerosol Effects



Precipitations reduce the nocturnal coupling and inhibit the diurnal decoupling

Cloud Control Parameters



Conclusions (de la micro à l'échelle régionale)

CCN activation processes onto droplets are well known, as well as droplet condensational growth, collision and coalescence, rain formation and precipitation. Ice formation is not as well documented (ice multiplication).

The dynamical processes (convection) that control cloud development and dissipation, and the coupling with cloud microphysics are also relatively well understood.

The control parameters for cloud and rain formation are not measurable nor predictable with a high enough accuracy to detect a possible aerosol impact on cloud dynamics.

Cloud parameterizations in GCM do not presently allow us to correctrly simulate the spatial and temporal cloud distributions.

Conclusions (à l'échelle globale)

Climate models have been precisely tuned to simulate the obsedrved tgemperature change.

Clouds however are not correctly simulated.

All GCM predict and global warming in the next century, but they diverge significantly on the prediction of the precipitation trend, either an increase of +2%/K or a decrease -0.5%/K

One key to understand climate is to identify the feedback processes that maintain constant the Earth albedo despite the strong spatial ,and temporal heterogeneity of clouds and cloud radiative properties.

Significant effrot are now devoted to the design of multidisciplinary field experiments at the regional scale and the development of cloud parameterizations that are suited to the grey zone (model resolution from less than 1 km to 10 km)