3MT convection: historical evolution.

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Summary

- Introduction: why do we need to parameterize convection?
- Convection: positive feedbacks, instability, predictability. Historical evolution of our understanding of convective processes.
- Problems in parameterizations (2003).

Why do we need to parameterize convection?

Until when?

Convection, a subgrid-scale phenomenon

Subgrid-scale convection - Computation time

Model	Resolution / Computation time
GCM (Global Circulation Model) ARPEGE	60km, 15mn, Cs,As,St Comp. Time = 1
LAM (Limited Area Model) ALADIN	10km, 8mn, SCME Comp. Time = 70
CRM (Cloud Resolving Model) AROME	2.5km, 60s, Cb Comp. Time = 10000
LES (Large Eddy Simulations)	50m, 5s, Cu, Sc Comp. Time = 10^8!

Convection: a challenge for our understanding faculties

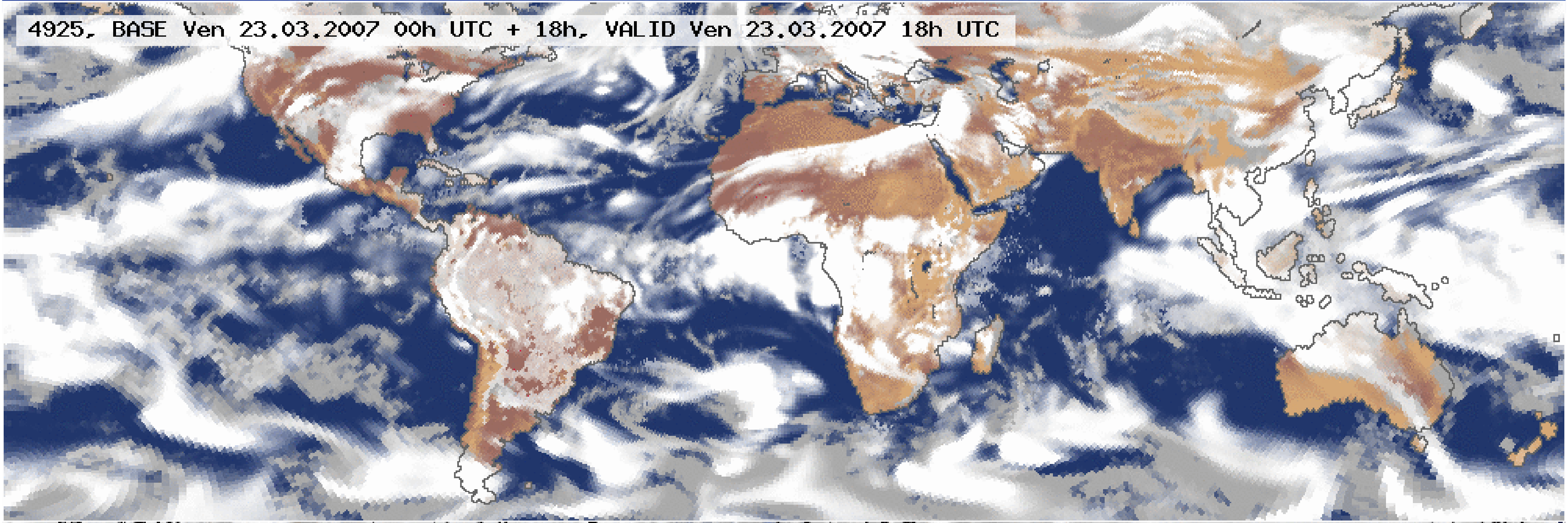
Local source of convective motions: buoyancy, Archimedes (287 av. J.C.).

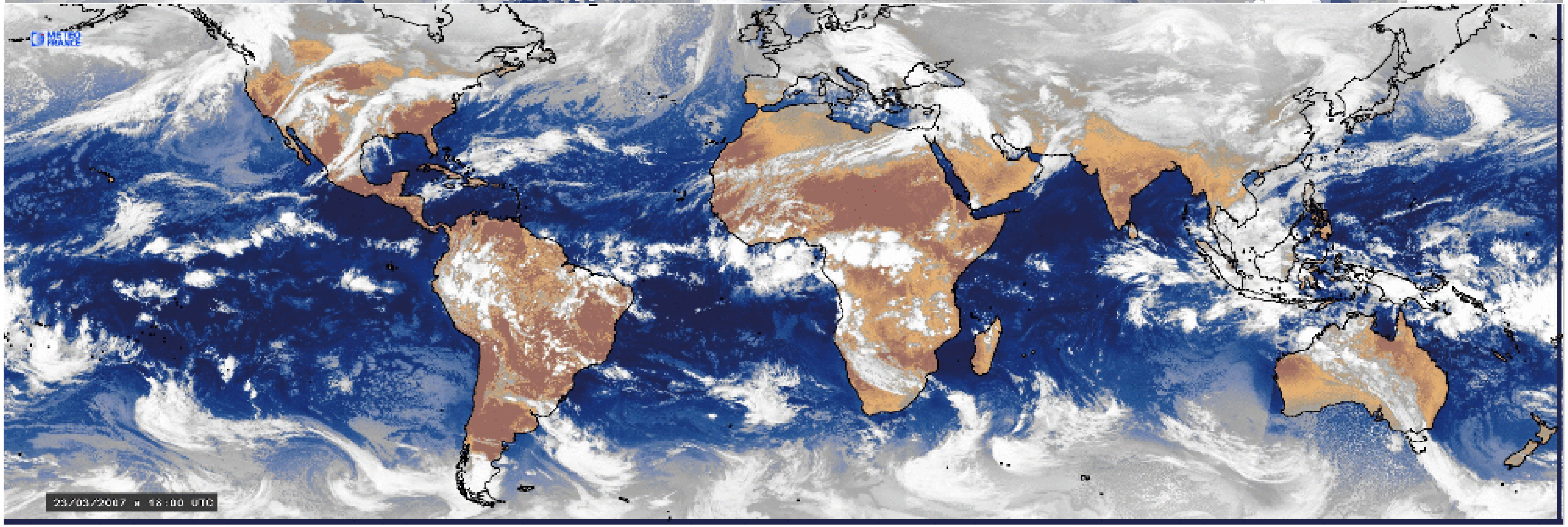
Mean effect of an ensemble of convective updrafts and downdrafts, each driven by the buoyancy force: still a young subject, 2000 years after Archimedes!

Parameterize = simple concept = theorize = understand.

Convection: prediction quality? Positive feedbacks?

Quality: Midlatitudes vs Tropics





Quality: Midlatitudes vs Tropics

Predictions are more accurate at Midlatitudes than in the Tropics:

- Coriolis force → horizontal stabilization.
- Tropics: the major process is convection.

Convection (at all latitudes) → difficult to predict (more difficult to predict, in general, than baroclinic instability).

Link predictability ⇔ involved processes

- Quality

↑

- Predictability

↑

\+ Sensitivity to initial conditions

↑

\+ Instability

↑

\+ Positive feedbacks

Convection: instabilities

Convection: 5 instabilities:

- CAPE.
- CISK.
- WISHE.
- Saturation deficit.
- Cold pools.

Convective concepts

CIFK: Conditional Instability of the First Kind:
« Precipitating convection is driven by vertical moist instability ». Energie source: CAPE: Convective Available Potential Energy.

CIFK is a 1D process: no horizontal circulation taken into account.

Archimedes (287 av. JC), Espy (1841)

Lifting ➔ Buoyancy ➔ Upward force ➔ Lifting.

Convective concepts

CISK: Conditional Instability of the Second Kind:

« Precipitating convection is driven by low level's dynamical moistening » Energy source: L * water vapour tendency due to humidity convergence.

CISK is a 2D or 3D process: the positive feedback involves horizontal circulation.

Charney, Eliassen, Kuo, Ooyama (1960-1970), GATE (1974), Bougeault (1985), …

Dynamical convergence ➔ available water vapour ➔ condensation ➔ differential heating ➔ dynamical convergence.

Convective concepts

WISHE: Wind Induced Surface Heat Exchange:
« Convection is driven by physical low level's moistening » Energy source: L * surface evaporation.

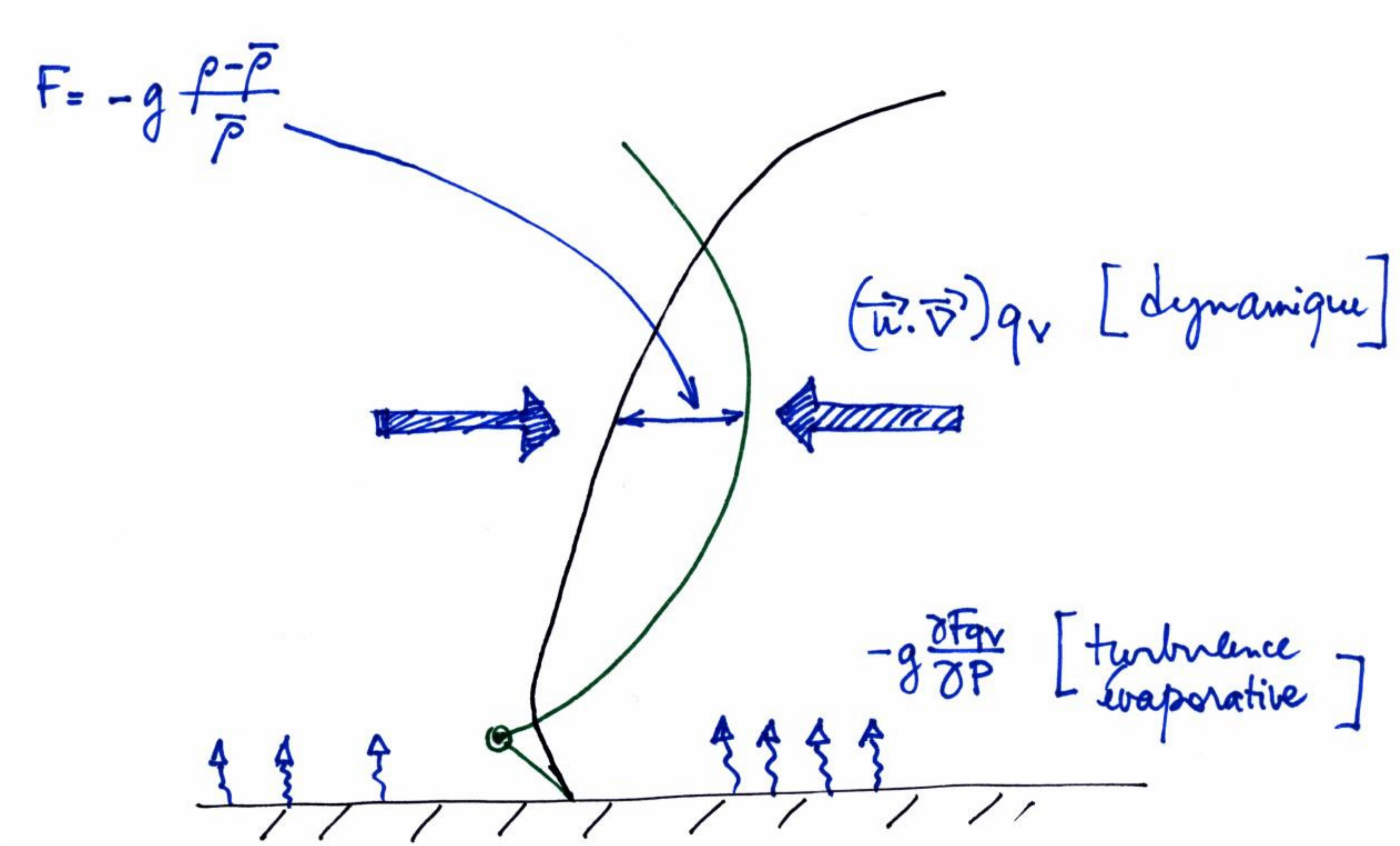
Important role in polar lows and tropical cyclones: WISHE is also called ASII: Air-Sea Interaction Instability

Emanuel, Yano, Raymond (1984-1990)

Condensation ➔ differential heating ➔ surface wind ➔ surface evaporation ➔ condensation.

Convective concepts

ARPEGE/ALADIN operational scheme is CIFK, CISK and WISHE.



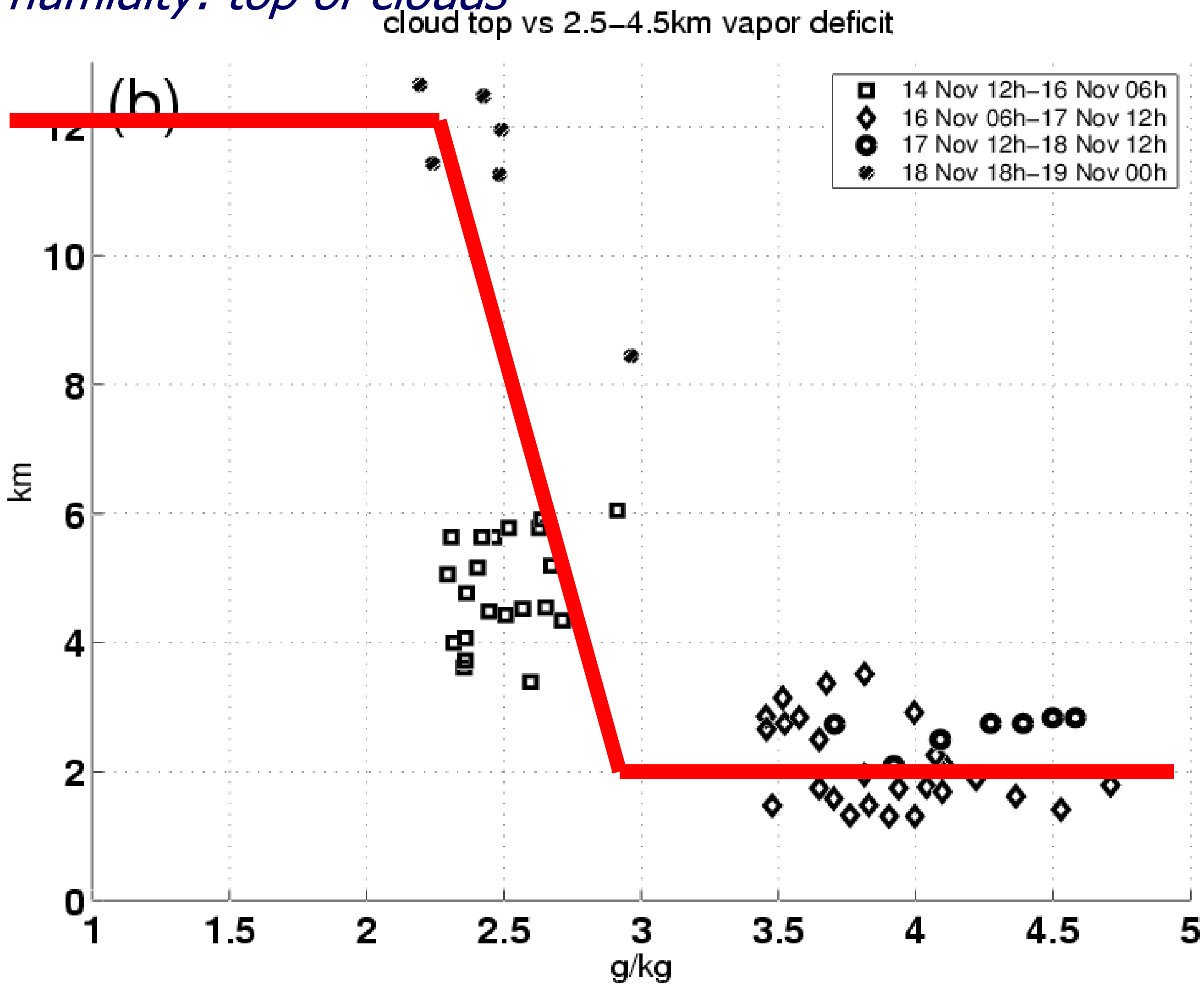
Mass-flux profile is locally proportional to buoyancy, and integrally proportional to available water vapour (dynamics + turbulence) ➔ CIFK, CISK and WISHE processes are all present.

Convective concepts

More recently in litterature: CIN (Convective INhibition) and mid-tropospheric humidity SATDEF… ➔

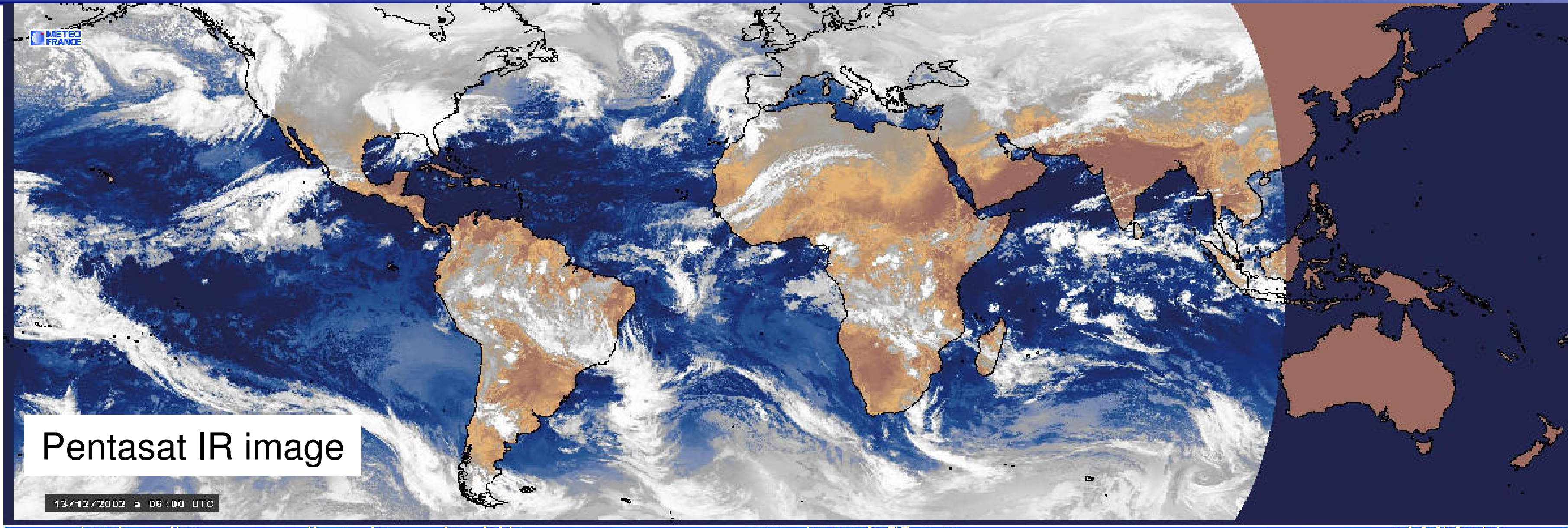
Convective concepts - SATDEF

Sensitivity to humidity: top of clouds

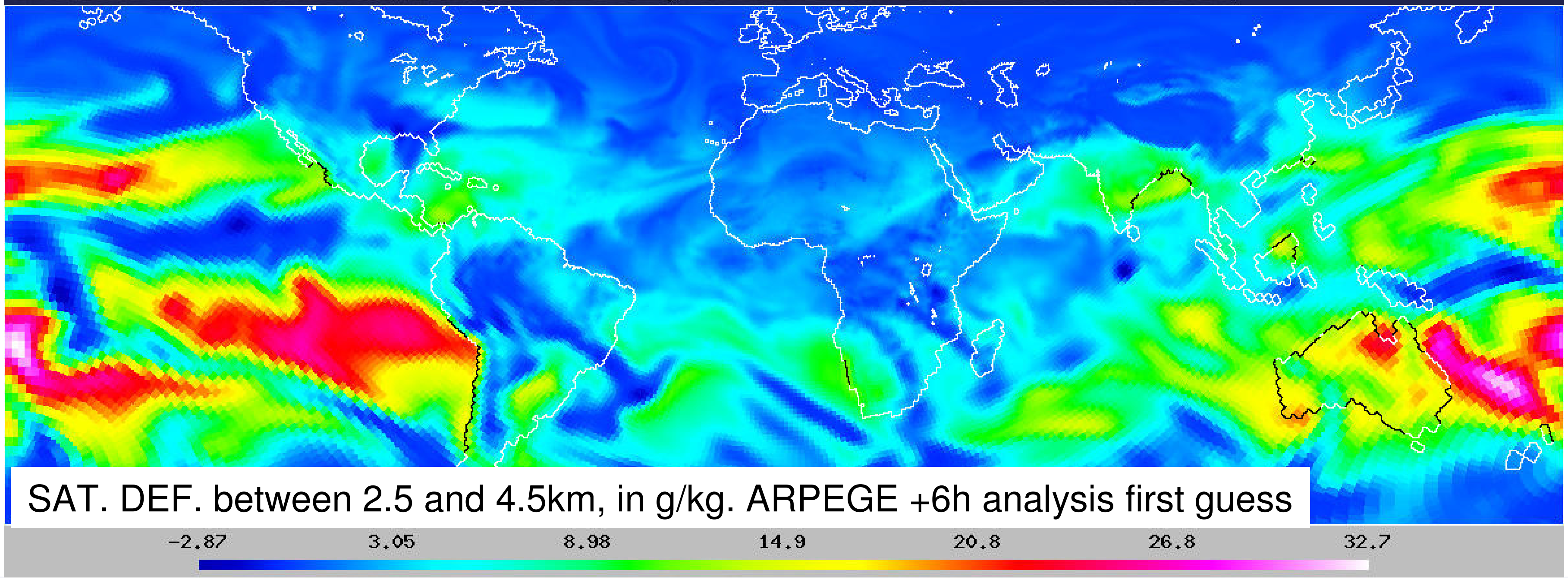


TOGA-COARE / J.L. Redelsperger, D. Parsons, F. Guichard, JAS 2002

Convective concepts - SATDEF



Pentasat IR image



SAT. DEF. between 2.5 and 4.5km, in g/kg. ARPEGE +6h analysis first guess

Convective concepts - SATDEF

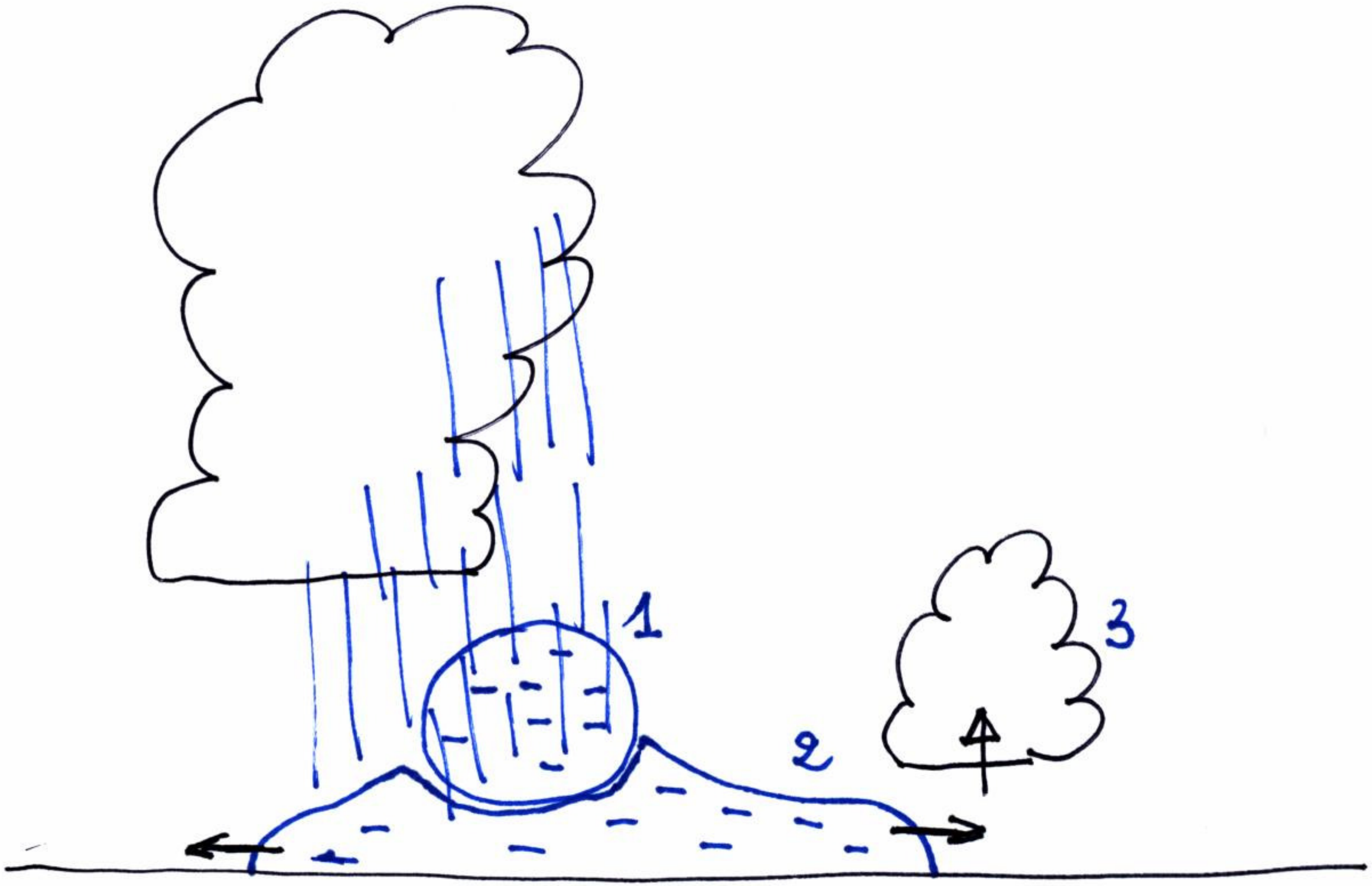
SATDEF: Saturation Deficit: « Convection is favoured if mid-tropospheric layers (between 2 and 5 km) are moist ». Energy source: less cooling by evaporation inside updrafts!

Plays a role in the diurnal as in the bimodality in the Tropics (dry air intrusions / recovery periods).

Redelsperger, Parsons, Guichard (2002)

Moister air in mid-troposhere ➔ less evaporation in updrafts ➔ stronger updrafts ➔ higher top of clouds ➔ moistening of higher layers.

Convective concepts – cold pools



Convective concepts – cold pools

Image: source Larry Di Girolamo, GCSS Workshop New-York, 2006

Larry Di Girolamo, about RICO (Rain in Clouds over Ocean):

1. « Lines along cold pools: 90% of the time. »

2. « Precipitation closely related to mesoscale organization, along cold pools. »

3. « Clouds ~ 3 - 4 km contribute most to the total precipitation. »

➔ Transition from shallow non-precipitating ➔ shallow precipitating ➔ congestus ➔ cumulonimbus: a collective effect of multiple and successive clouds.

Convective concepts – cold pools

Cold pools: « Convective transition from shallow to deep involves a collective cloud mechanism, via uplifting by cold pools.». Energy source: adiabatic lifting by cold pools.

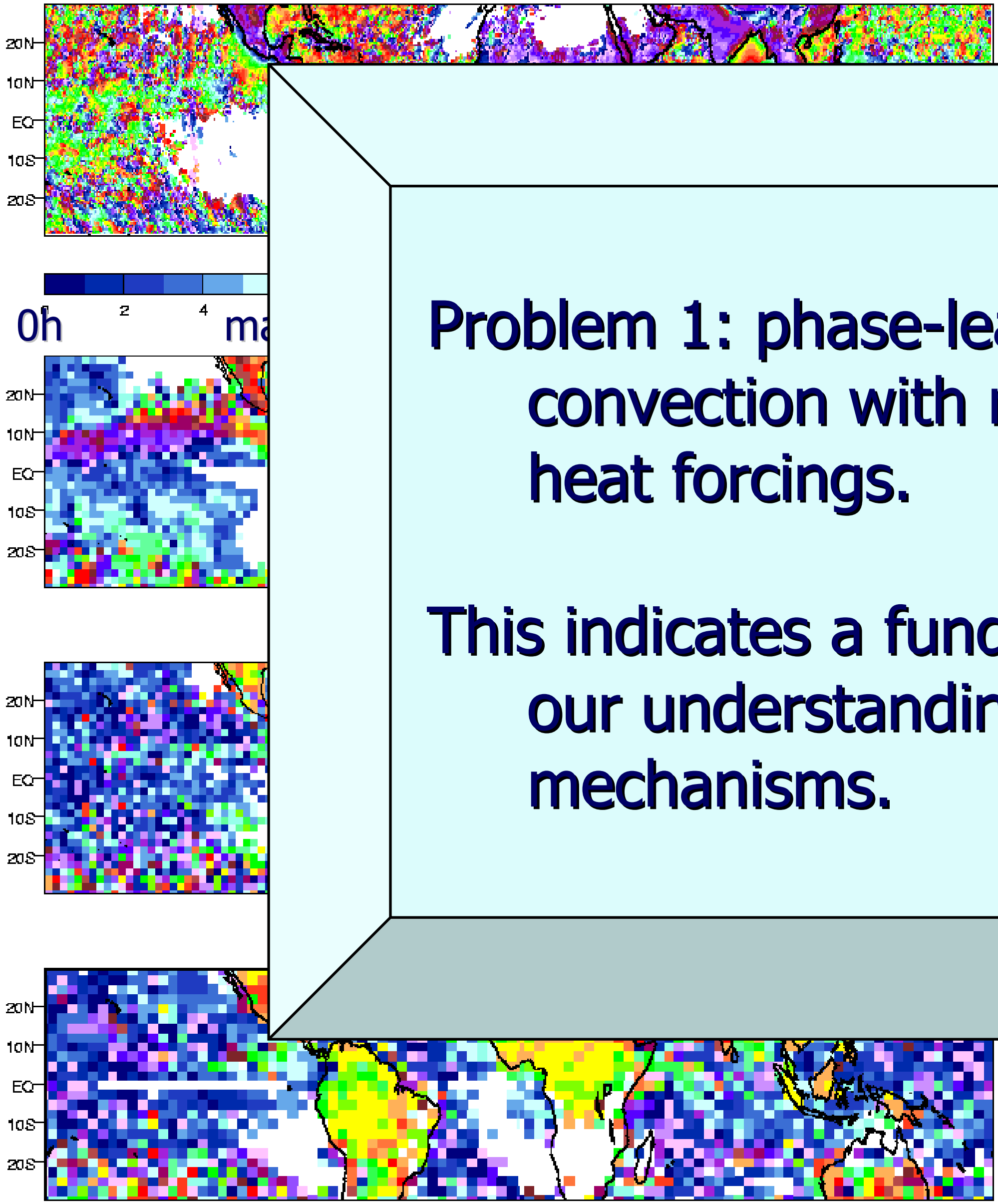
Important role in diurnal cycle (phase-lag) as in the bimodality in the Tropics (dry air intrusions / recovery periods).

Guichard et al. (2004), Khairoutdinov et Randall (2006)

Ascent ➔ precipitation ➔ evaporation outside the cloud evaporation ➔ cold pool ➔ density current ➔ new and stronger ascent.

Problems?

Diurnal cycle



Problem 1: phase-lead of predicted convection with respect to surface heat forcings.

This indicates a fundamental difficulty in our understanding of the transition mechanisms.

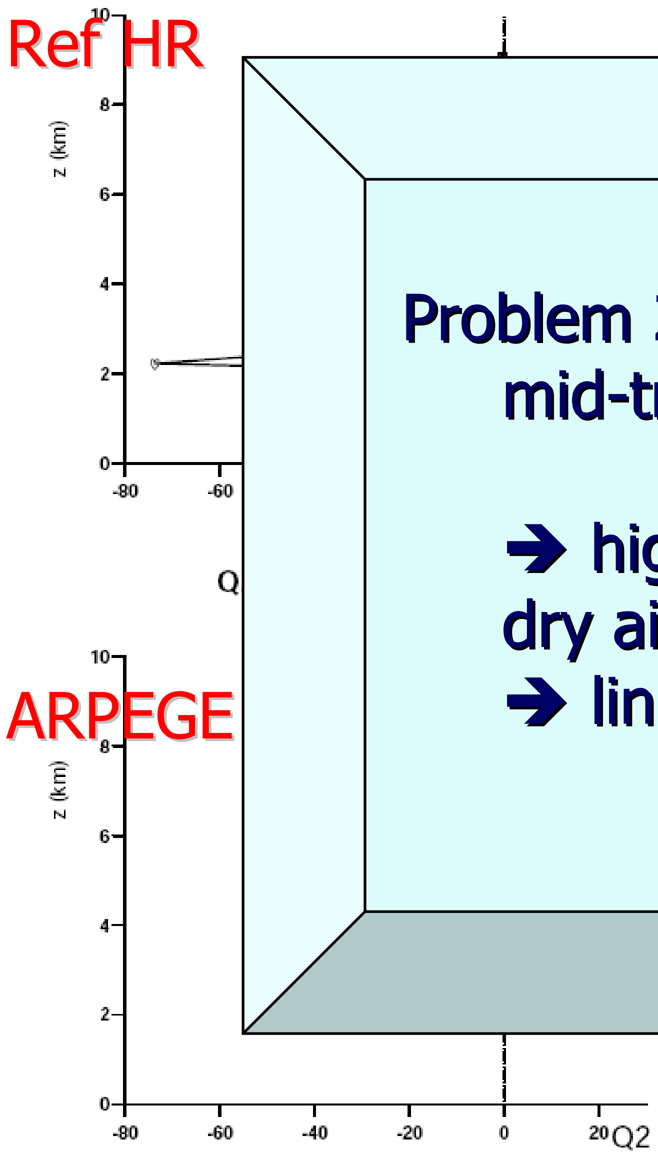
Unified Climate Model

Yang and Slingo MWR 2001

Sensitivity to mid-tropospheric humidity

Q2 (K/day), CSRM Meteo-France CNRS

Q2 (K/day), CSRM MetOffice



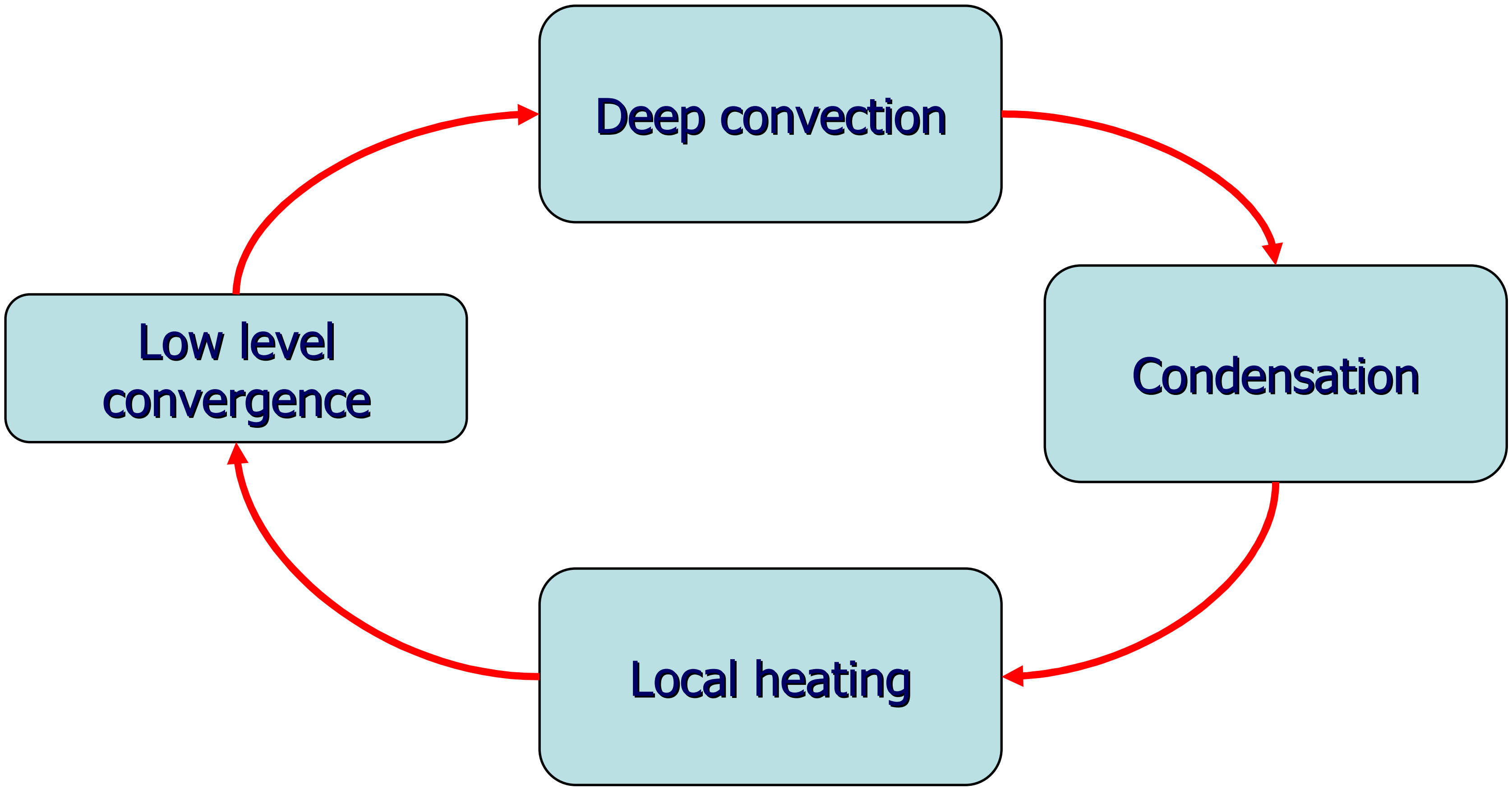
Problem 2: underestimated sensitivity to mid-tropospheric humidity

➔ high convective clouds even in dry air

➔ link with the diurnal cycle?

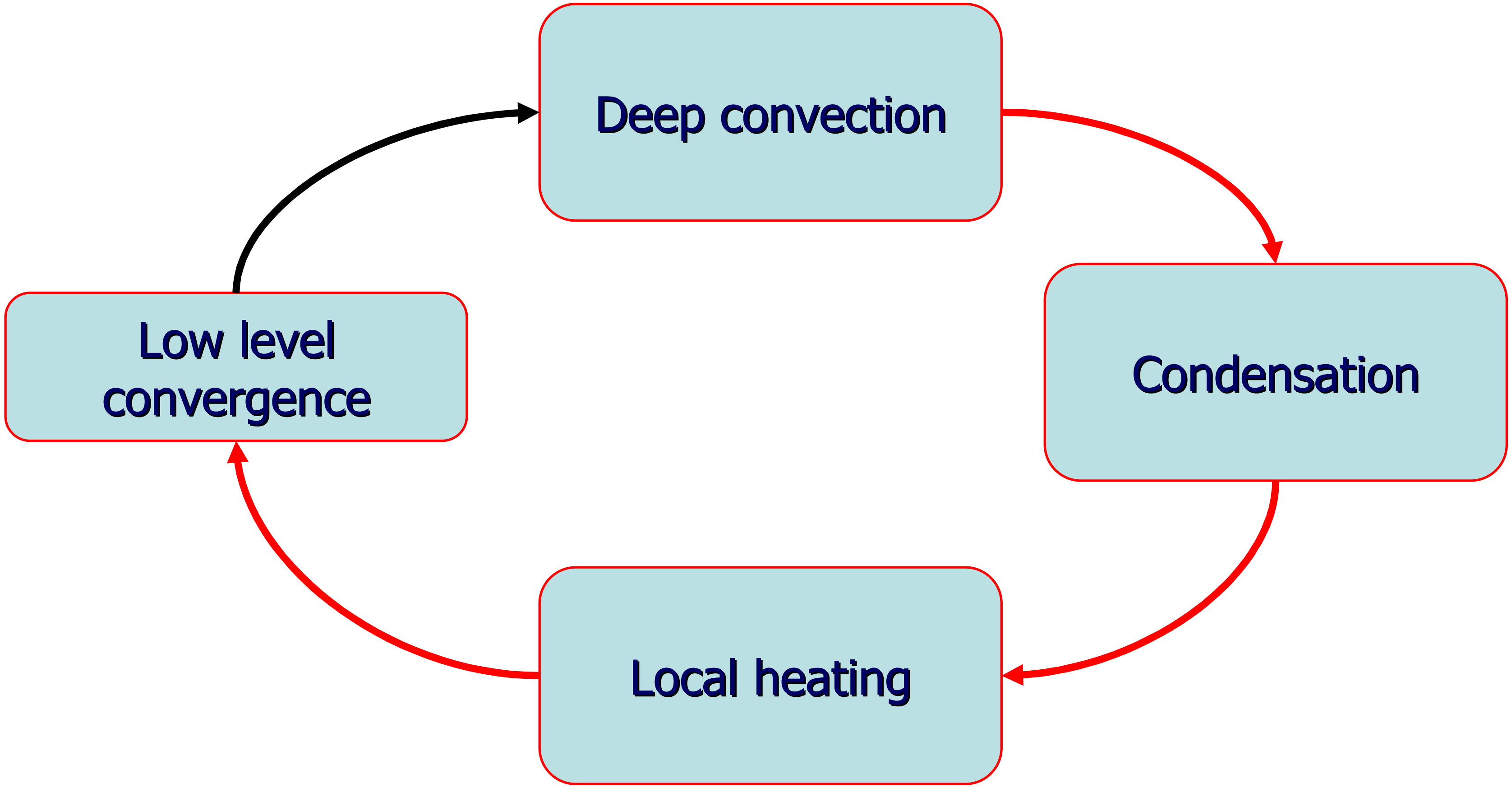
The CISK mechanism

CISK (Convective Instability of the Second Kind) 1960s: instability mechanism:



The CISK mechanism: a closure?

CISK: an instability or a closure? (Kuo 1974, Anthes 1977) CISK as a causality. Convection as a « small scale process ». « CISK scool of thinking ».



The CISK closure: questionnable!

- Mapes (1998): simplified model of the equatorial band, to study the tropical response to a local heating. Local heating ➔ ascent at mesoscale.

- Mapes (1997): CISK closures are like considering convective clouds as puppets of their own circulations!

- Randall et al. (1997): Cb anvils are convective, ascent at the center of MCS is convective.
  What is still non-convective in the Tropics?

The CISK closure: questionnable!

Problem 3: the CISK instability concept has been converted into a closure, i.e. a causal relation.

However, convection should no longer be considered as a small scale process forced by a larger scale and non-convective one!

Summarizing problems

1. Phase-lead of the predicted diurnal cycle of convection (and thus too short transitions from shallow to deep).

2. Underestimated sensitivity of convection to mid-tropospheric humidity.

3. Causality problems (even more true at high resolution ~5 km): what is non-convective? What part of the resolved circulation is « already » convective? How to define the forcing and the forced processes?

Fin