Linking cold pools – memory – precipitation frequency

Convective parameterizations increasingly include aspects of convective memory, although strategies differ.
Cold pools are one candidate to capture memory, and they are prognostically represented in some models.
Here, we attempt to improve memory by modifying the cold pool scheme in the IPSL – LMDZ model.
It leads to increased precipitation variability, potentially solving a long-standing modelling issue.

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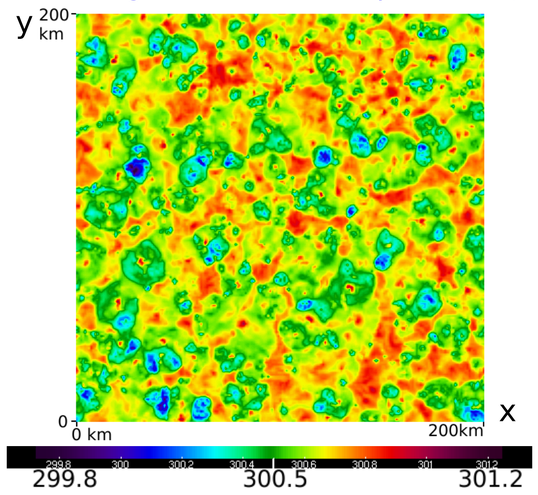
1. KEY POINTS

- Increasing the cold pool number density (number of cold pool per unit area) in the GCM allows to modify the memory properties. It improves some aspects of memory but deteriorates others.
- When cold pools are more numerous, they are less cold and weaker to trigger convection: it alters one of the memory processes.
- This leads to more sporadic convective precipitation, and therefore more precipitation variability.

2. MOTIVATION

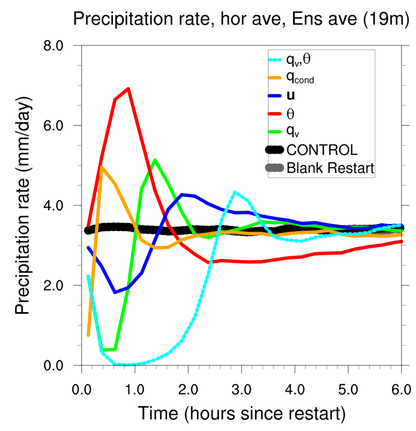
- In GCMs it usually rains too often and too little. This may result from inaccurate convective memory.
- Cold pools are one mechanism responsible for convective memory.
- The IPSL – LMDZ model already has a cold pool scheme with 3 prognostic variables. But the cold pool number density is a constant: there is no dynamics of cold pool population.
- CRM simulations over ocean show that there is about 1 cold pool every 30 km: much more than the default value.
- Can we improve the cold pool scheme to better represent convective memory and therefore improve precipitation variability in time and space?

Horizontal view of
PBL-Averaged Potential Temperature (K)

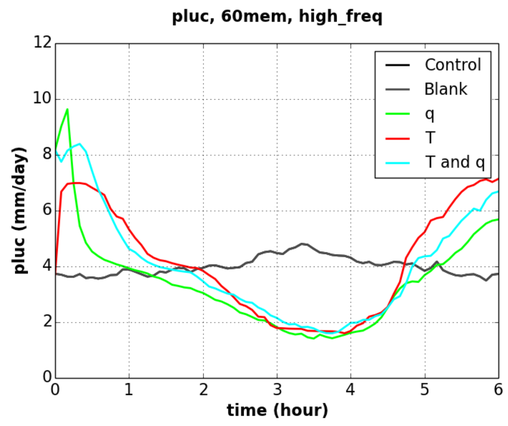


3. COMPARING CRM-SCM CONVECTIVE MEMORY

WRF

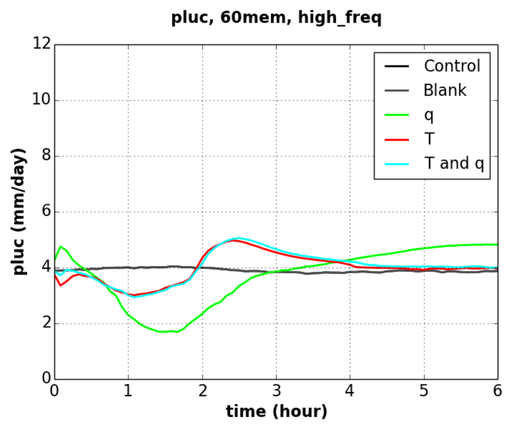


Default LMDZ



- We compare convective memory in various models by the precipitation response to initial homogenisation (colours show homogenisation types).
- Default LMDZ exhibits memory with the right time scale, but wrong water vapour memory.
- Modified LMDZ (default cold pool number density *100) has better behaviour variability, weaker oscillations, but worse response amplitude and time scale.

Modified LMDZ



4. 1D SENSITIVITY TESTS ON COLD POOL NUMBER DENSITY: THERMODYNAMICS AND TRIGGERING

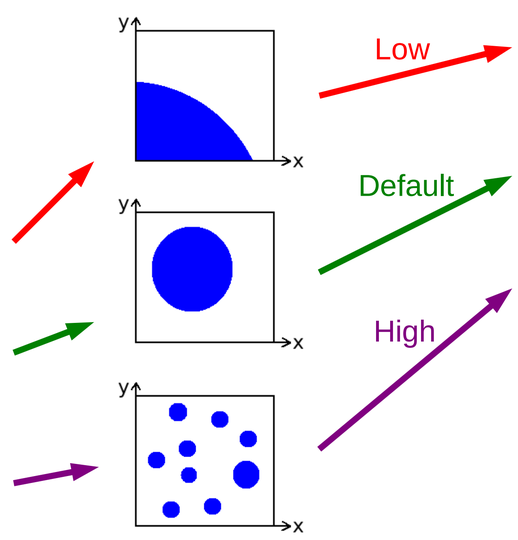
LMDZ runs: 1D, Radiative-Convective Equilibrium state, No forcing.

Impact of cold pool number density (colours). **More numerous** cold pools means:
→ **less cold**,
→ **weaker humidity anomalies**,
→ **less powerful to trigger convection**

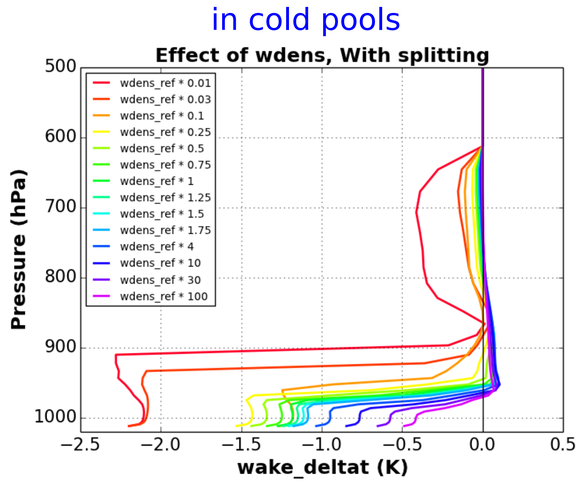
Low cold pool number density (default/100)
→ 1 cold pool every 3500km

Default cold pool number density in IPSL model
→ 1 cold pool every 350km

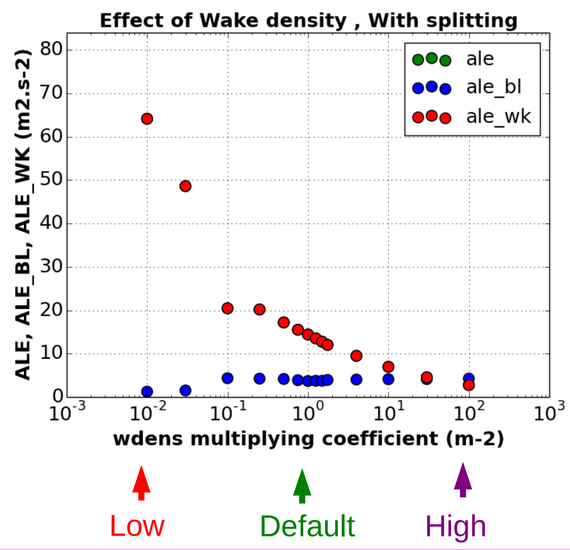
High cold pool number density (default *100)
→ 1 cold pool every 35km



Temperature anomaly
in cold pools



Cold pool (ale_wk) and thermal (ale_bl)
ability to trigger convection



5. 3D SENSITIVITY TESTS: MORE SPORADIC PRECIPITATION

LMDZ runs: 3D, 10 years (1980-1989).

Maps show the number of days with convective precipitation.

Numerous cold pools
→ decrease in the areas which experience convective precipitation every day.

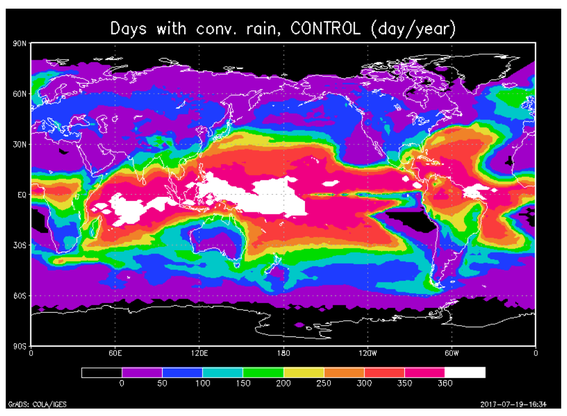
High cold pool number density:
- more representative of cold pools over ocean
- manages to make convective precipitation **more sporadic**.

Satellite-derived observations from Stephens et al 2010, and from Trenberth and Zhang 2018.

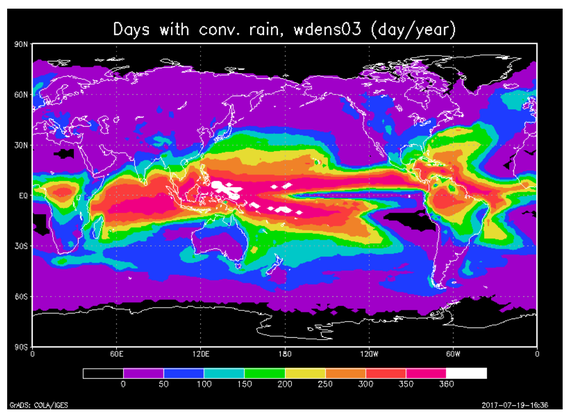
Maps show precipitation frequency.

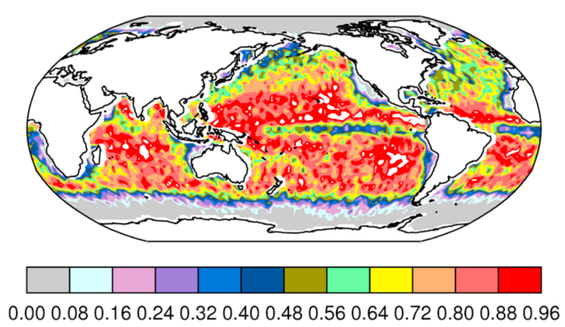
Difficult to conclude by comparing model and observations: probably improvements? Definitely a good sensitivity!

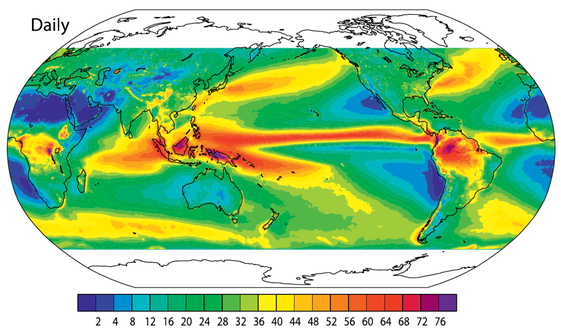
Default number density



High number density (default*250)







6. CONCLUSION

- When increasing cold pool number density, behaviours closer the oceanic cold pools appear: less cold, less humid at the surface, less dry aloft, less able to trigger convection.
- For the highest cold pool number densities, we even have a competition between cold pools and thermals to trigger convection.
- This allows for more sporadic convective precipitation, which improves the model over ocean.

7. PERSPECTIVES

- Cold pool number density in the model should at least be different over land and ocean.
- The cold pool number density could eventually become a prognostic variable of the cold pool scheme → cold pool dynamics
- We now have a method to assess convective memory in a hierarchy of models.

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