Relationship between surface thermodynamic contrasts and precipitation intensity in idealised monsoon simulations: control runs and metrics

Maxime Colin, Jan O. Haerter, Vishal Dixit

maxime.colin@leibniz-zmt.de

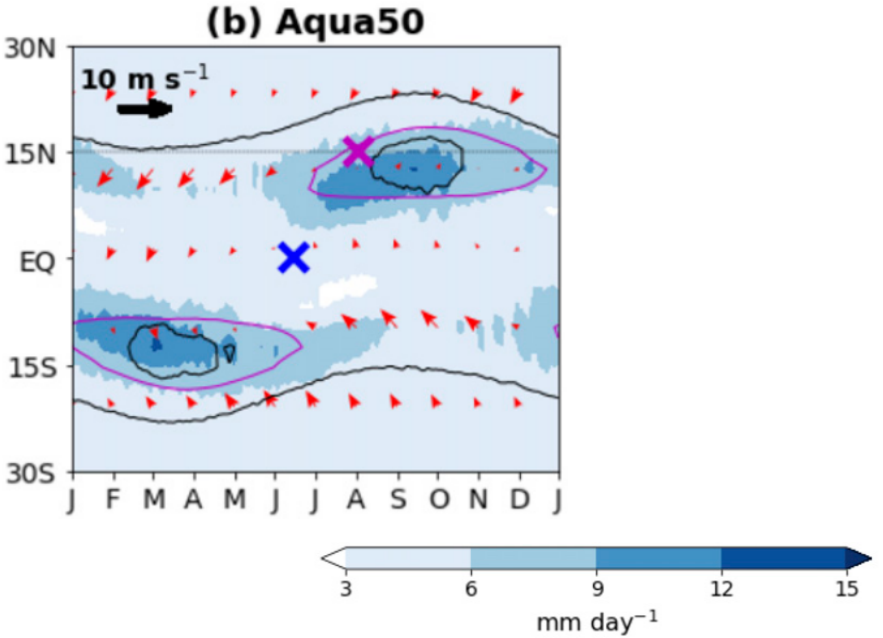
ZMT LEIBNIZ CENTRE for Tropical Marine Research

Leibniz Association

Does the surface temperature contrast matter at all for monsoon precipitation intensity ?

Traditional view of monsoon:
large-scale sea breezes…

Aquaplanet



(Zhou and Xie 2018)

maxime.colin@leibniz-zmt.de

Does the surface temperature contrast matter at all for monsoon precipitation intensity ?

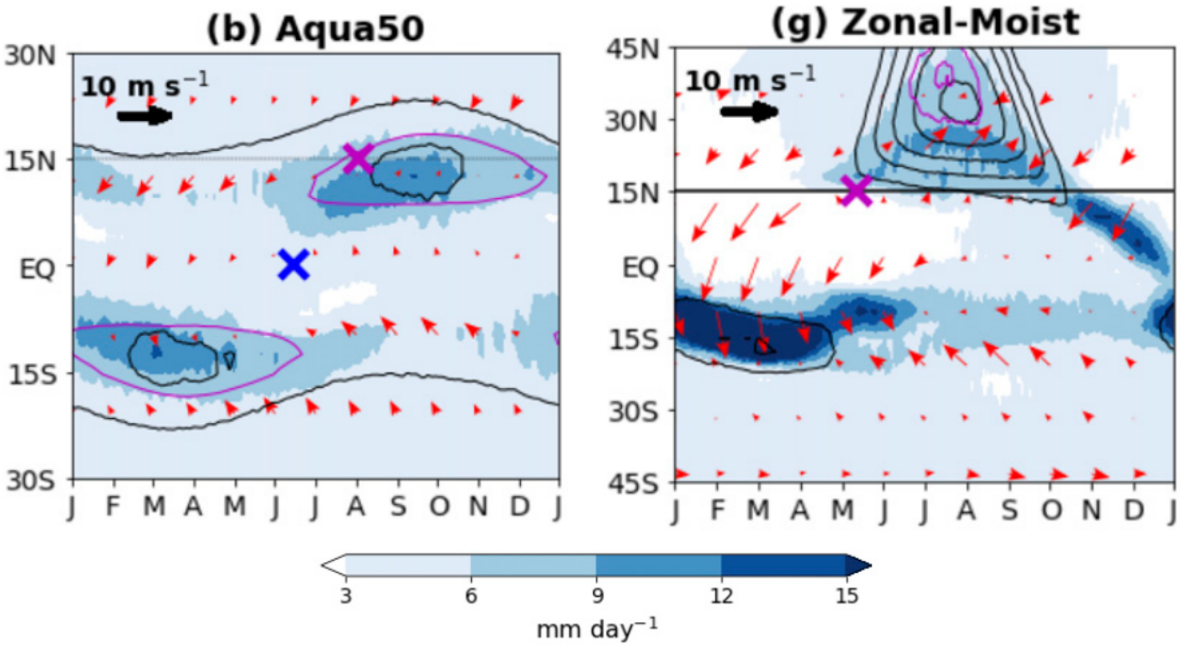
Traditional view of monsoon:
large-scale sea breezes…

That doesn't work so well…

(Gadgil 2018, Hill 2019, Geen et al 2020)

Aquaplanet

With land North of 15°N



(Zhou and Xie 2018)

maxime.colin@leibniz-zmt.de

Questions and strategy

QUESTIONS:

- Does the surface temperature contrast matter at all for monsoon precipitation intensity ?
- Do monsoon non-linearities come from convective processes, dynamical feedbacks, or non-linearities in the forcing ?

STRATEGY:

- Very few idealised simulation studies of monsoons at relatively high resolution (and with resolved convection).
- So we devise a modular framework to simulate idealised monsoons at higher resolutions.

maxime.colin@leibniz-zmt.de

Idealised simulations with imposed SST

- WRF idealised simulations over an aquapatch
- Imposed SST with peak at 12°N (or 24°N, or Eq)
- Grid spacing: 10 km, 20 km, 30 km (for now)
- Domain: 21°S-21°N to 63°S-63°N
- Periodic BC on x-axis
- Symmetric BC on y-axis
- Either no convection scheme, or Kain-Fritsch

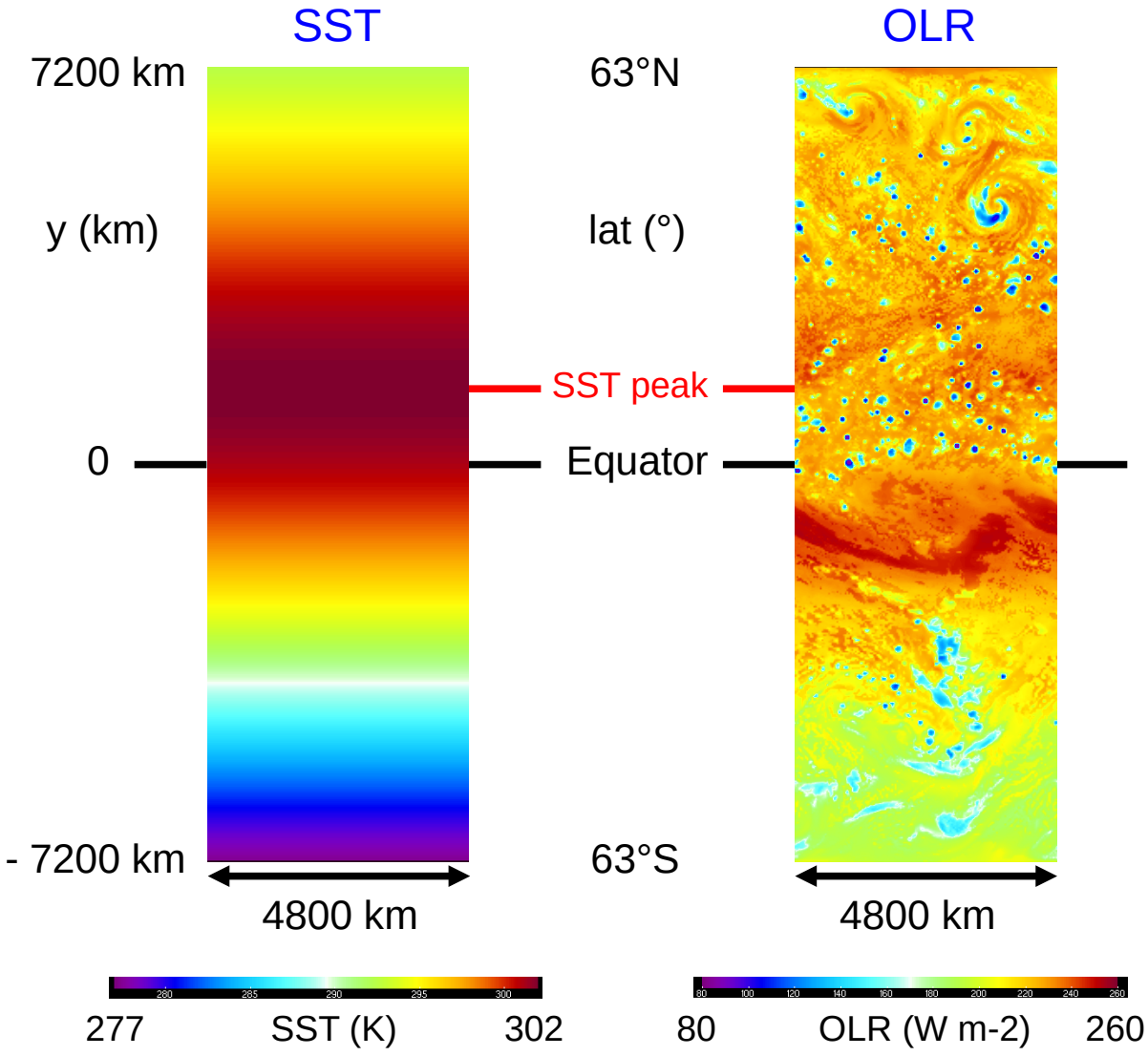
$$\mathrm{SST}_{\mathrm{LH}} = T_0 - \Delta T(\sin\phi - \sin\phi_0)^2$$

(Boos and Kuang 2010)

	Lat SST peak	Coriolis	Grid spacing	Domain	Convection	Notes
Simu 022	12°N	Yes	10 km	21°S-21°N	resolved	TCs, Pb at North boundary
Simu 029	12°N	Yes	20 km	42°S-42°N	resolved	TCs
Simu 034	12°N	Yes	30 km	63°S-63°N	resolved	TCs, better steady state
Simu 035	12°N	Yes	30 km	63°S-63°N	KF scheme	Very different spatial org
Simu 021	Eq	Yes	10 km	21°S-21°N	resolved	Double ITCZ

Spatial organisation

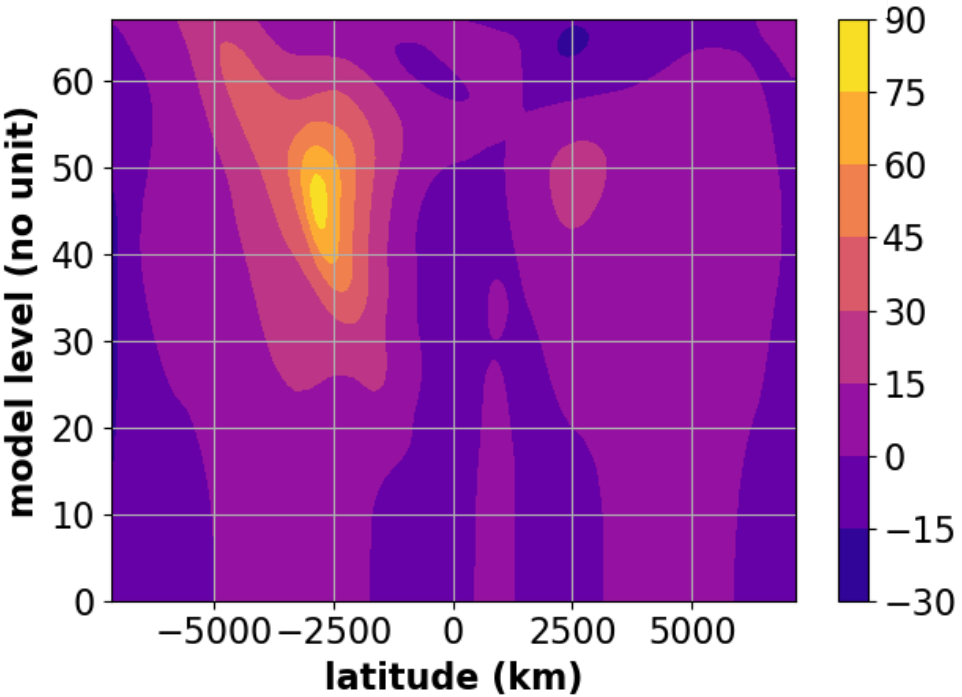
- Many Tropical Cyclones
- Mid-latitudinal features
- More convection in NH, slightly away from the Equator
- Drier subtropics in the winter hemisphere
- If SST peaks at Equator, double ITCZ



maxime.colin@leibniz-zmt.de

Circulation with subtropical jets and Trade winds

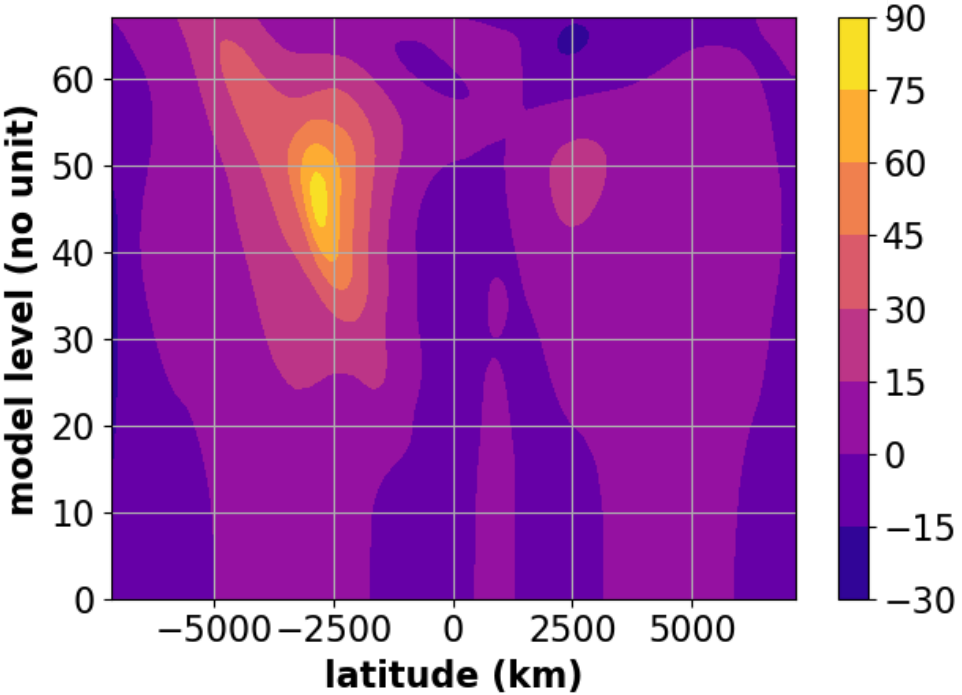
U-wind, zon ave (m s-1), Simu 034



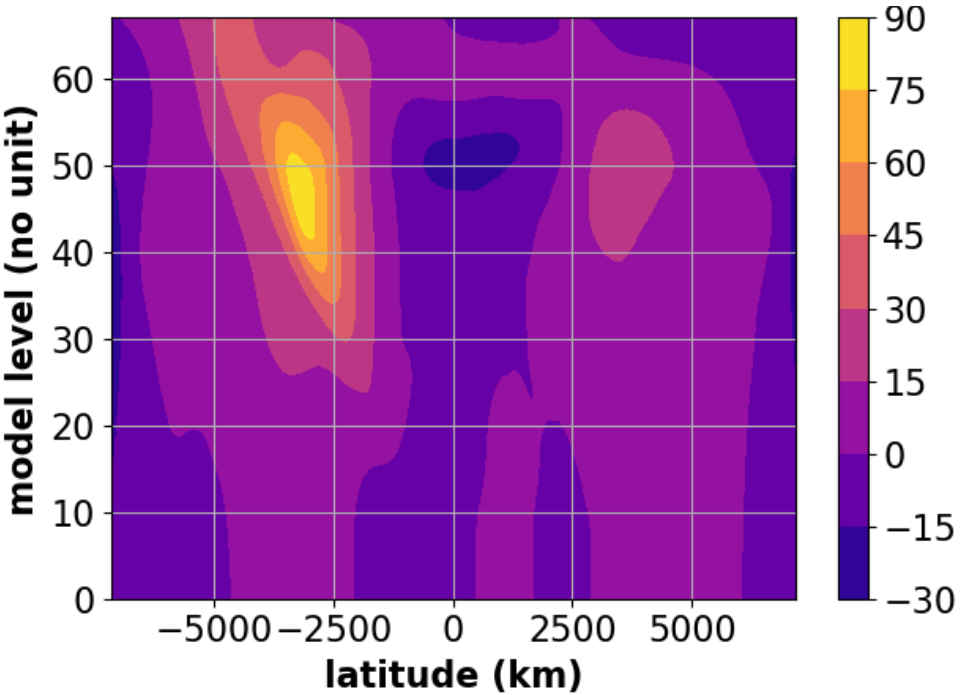
maxime.colin@leibniz-zmt.de

Circulation with subtropical jets and Trade winds

U-wind, zon ave (m s-1), Simu 034



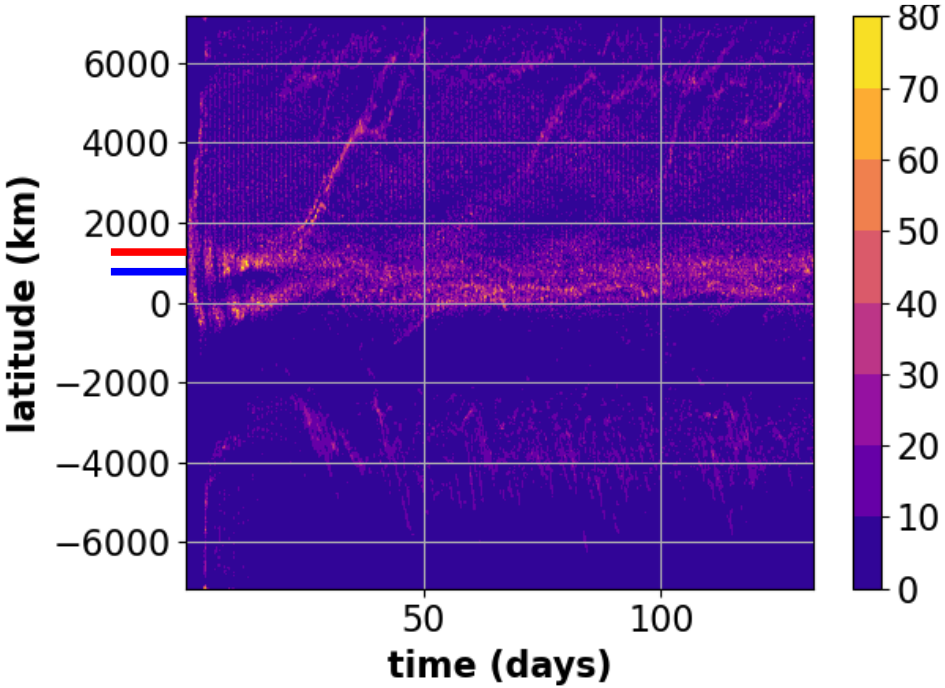
U-wind, zon ave (m s-1), Simu 035



maxime.colin@leibniz-zmt.de

An ITCZ shifted to the North, but not as far as the SST peak

Rain rate, zon ave (mm day-1), Simu 034



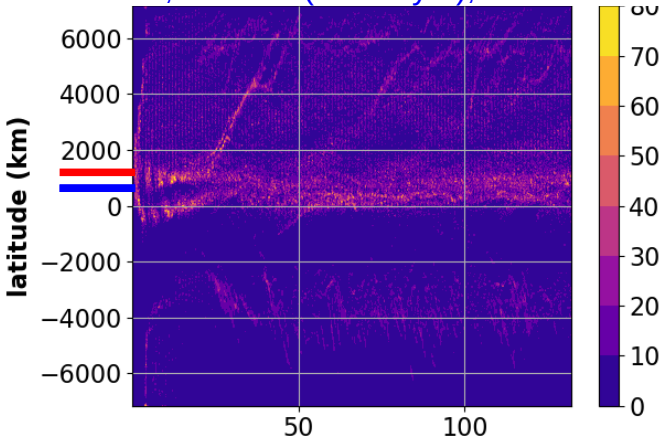
Reasonable summer ITCZ features
(“monsoon-like”)

How to define a good monsoon metrics ?

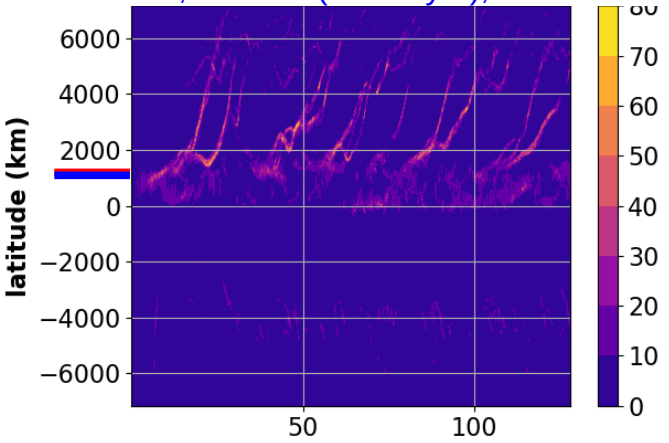
maxime.colin@leibniz-zmt.de

An ITCZ shifted to the North, but not as far as the SST peak

Rain rate, zon ave (mm day-1), Simu 034



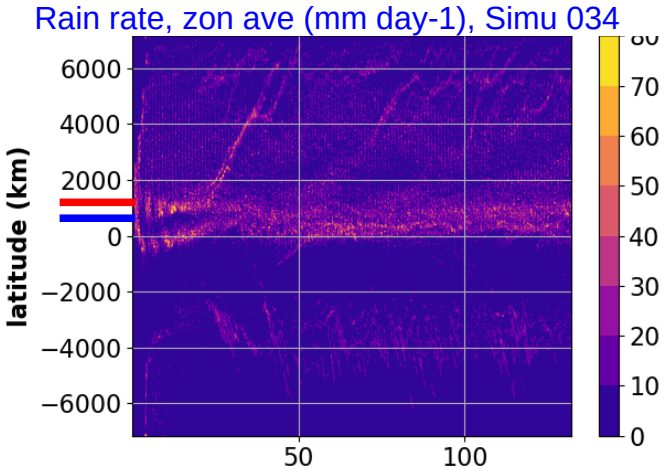
Rain rate, zon ave (mm day-1), Simu 035

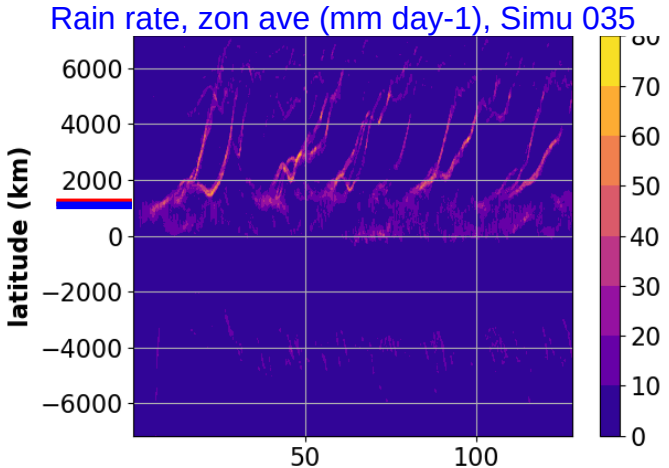


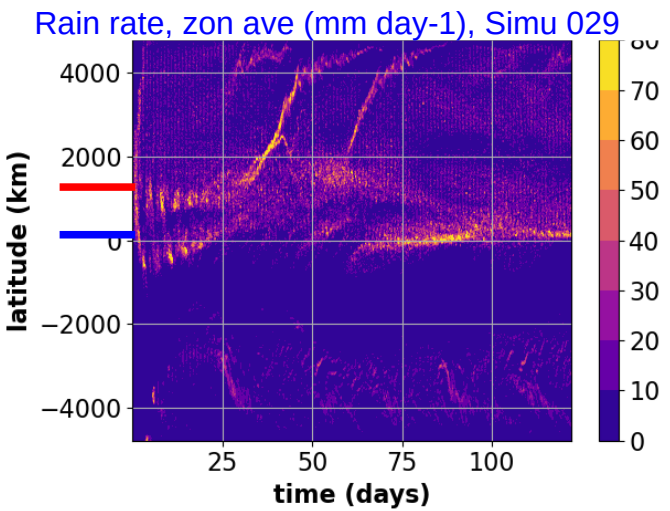
- 034: Big domain + explicit convection
- 035: Big domain + KF convection
- 029: Smaller domain, higher resolution
- 021: SST peak at the Equator, even smaller domain

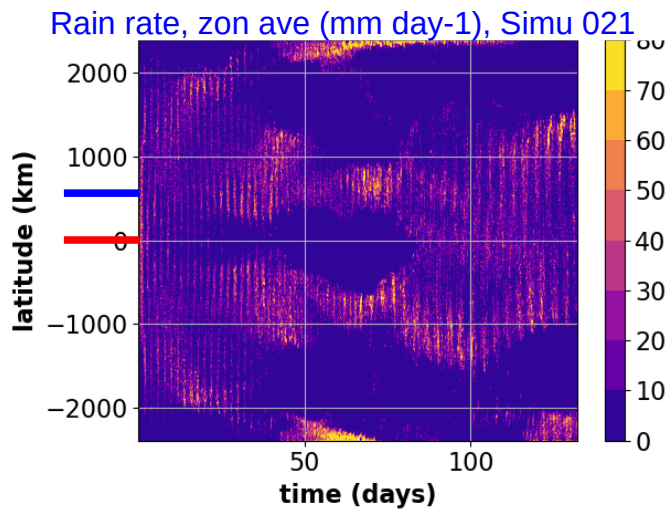
maxime.colin@leibniz-zmt.de

An ITCZ shifted to the North, but not as far as the SST peak







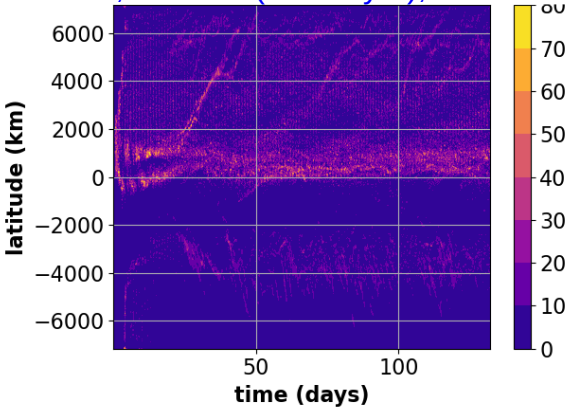


- 034: Big domain + explicit convection
- 035: Big domain + KF convection
- 029: Smaller domain, higher resolution
- 021: SST peak at the Equator, even smaller domain

maxime.colin@leibniz-zmt.de

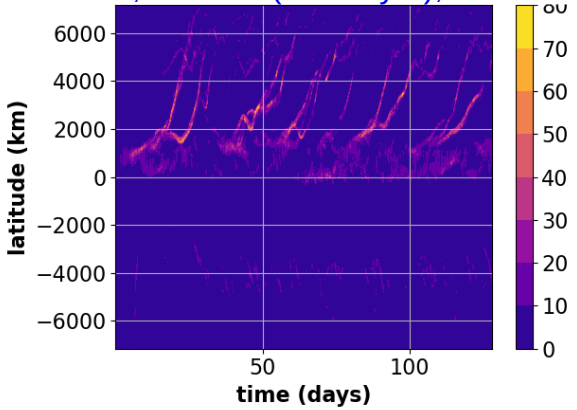
A monsoon metrics

Rain rate, zon ave (mm day-1), Simu 034



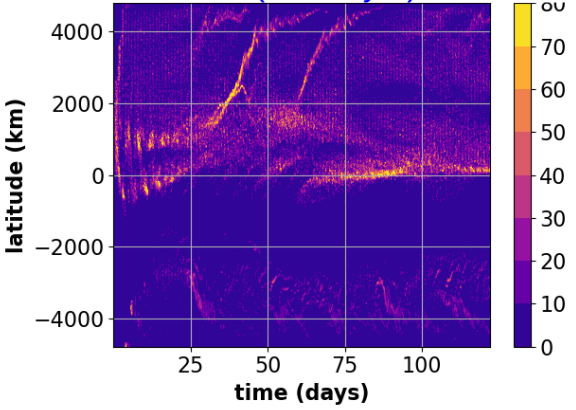
MM = 3.5 mm day-1

Rain rate, zon ave (mm day-1), Simu 035



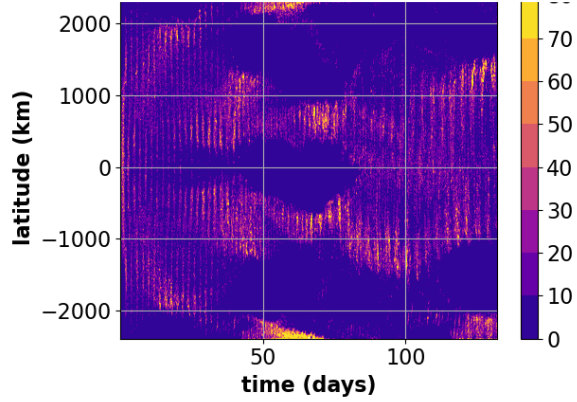
MM = 4.4 mm day-1

Rain rate, zon ave (mm day-1), Simu 029



MM = 3.5 mm day-1

Rain rate, zon ave (mm day-1), Simu 021



MM = 0.15 mm day-1

Monsoon metrics based on difference between tropical precipitation P in each hemisphere:

MM = <P_NH_trop> - <P_SH_trop>

- 034: Big domain + explicit convection
- 035: Big domain + KF convection
- 029: Smaller domain, higher resolution
- 021: SST peak at the Equator, even smaller domain

maxime.colin@leibniz-zmt.de

Conclusion and future work

- These control simulations manage to capture some general features associated with real monsoons: tropical cyclones, large-scale circulation (subtropical jets, Trade winds), precipitation distribution with latitude.
- The simulation with a convection scheme is the most different
- We have defined a monsoon metrics suitable for our simulations

- Series of simulations with various SST gradients: how do they influence monsoon intensity? And with asymmetric land ?
- Control of monsoon intensity by T or MSE or other thermodynamic variables ?
- Linear or non-linear relationships ?

maxime.colin@leibniz-zmt.de

maxime.colin@leibniz-zmt.de

Thank you

Photo by
Maxime Colin