Hysteresis and delay behaviour of tropical rain belts

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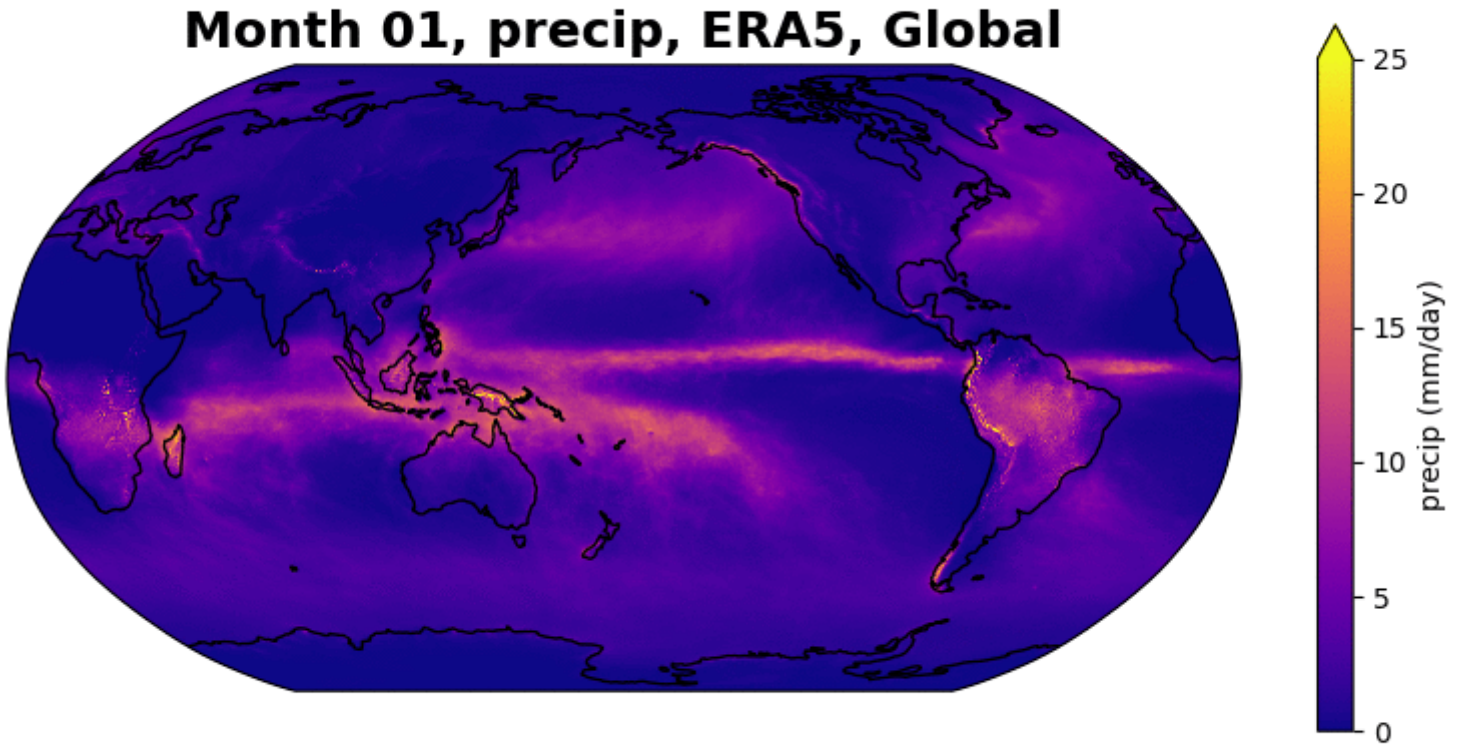
ZMT LEIBNIZ CENTRE for Tropical Marine Research

Leibniz Association

Seasonal cycle of the tropical rain belt

ERA5 climatology



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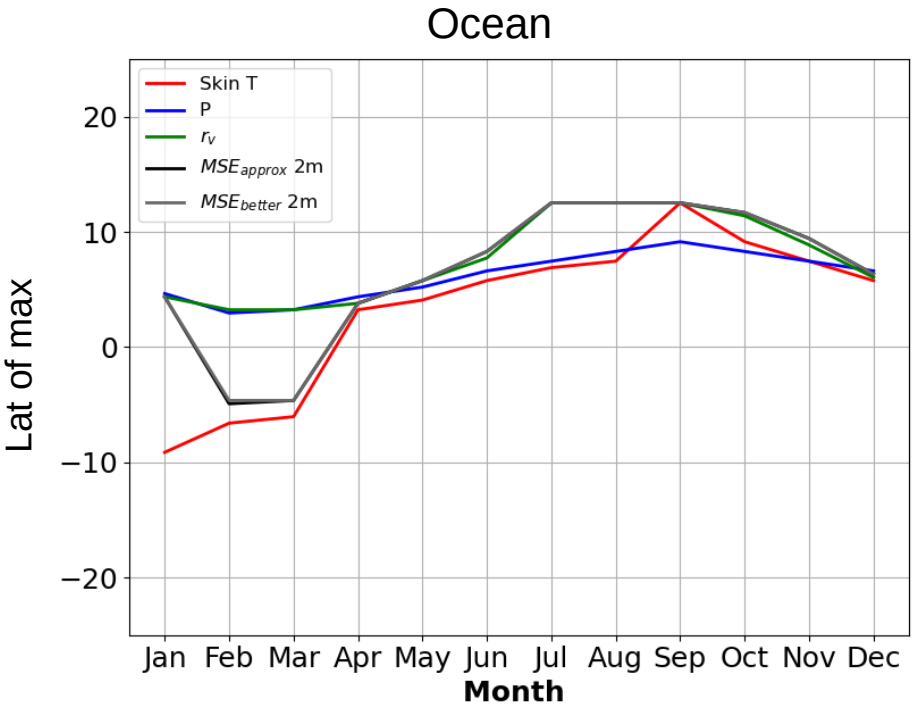
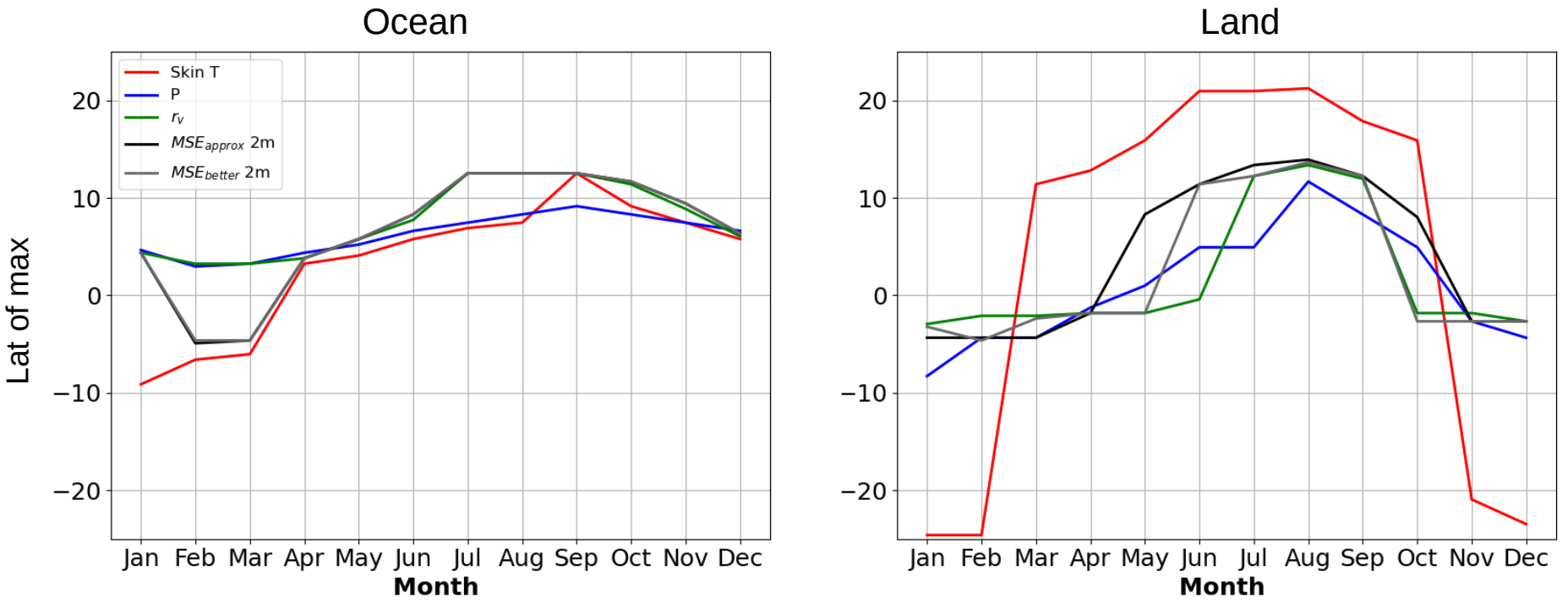
Does P follow the thermodynamic variables ?



With ERA5 data

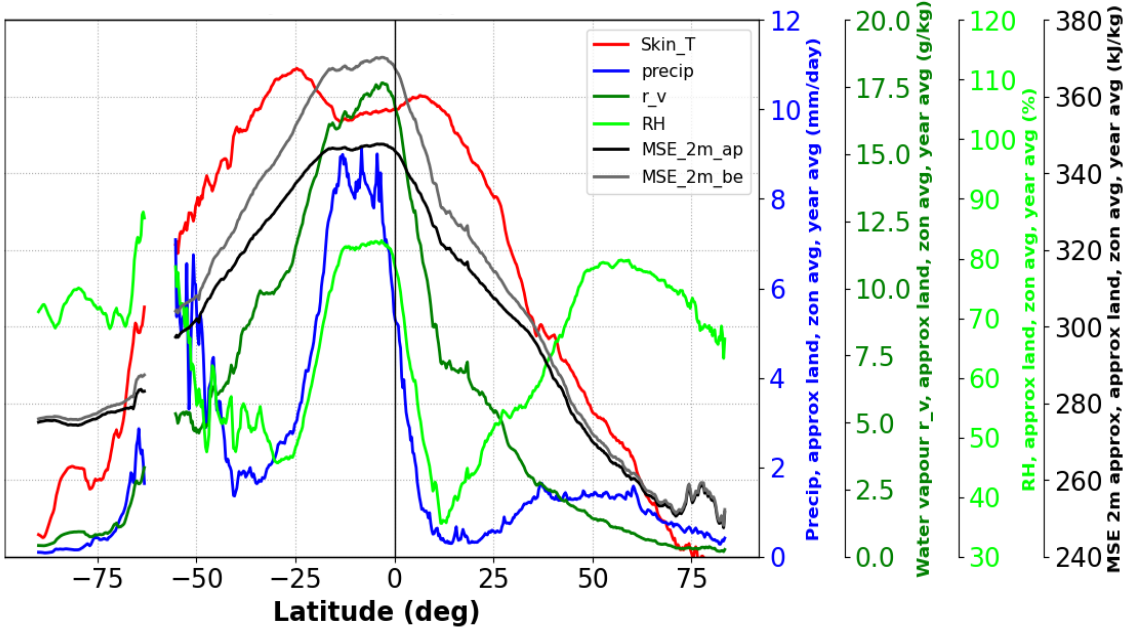
Does P follow the thermodynamic variables ?



With ERA5 data

Does P follow the thermodynamic variables ?

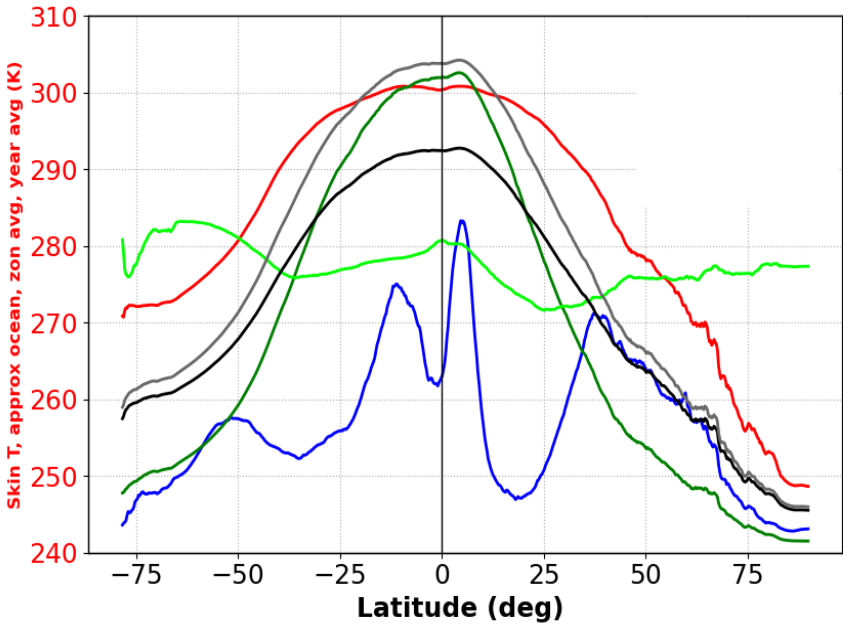
Land (Jan)



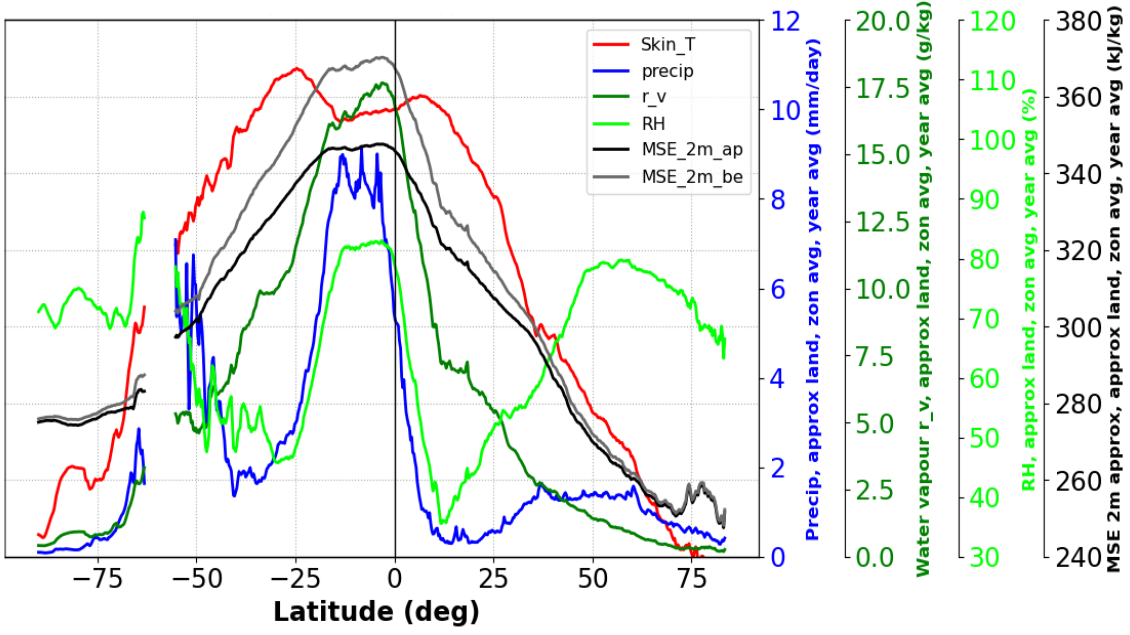
With ERA5 data

Does P follow the thermodynamic variables ?

Ocean (Jan)



Land (Jan)



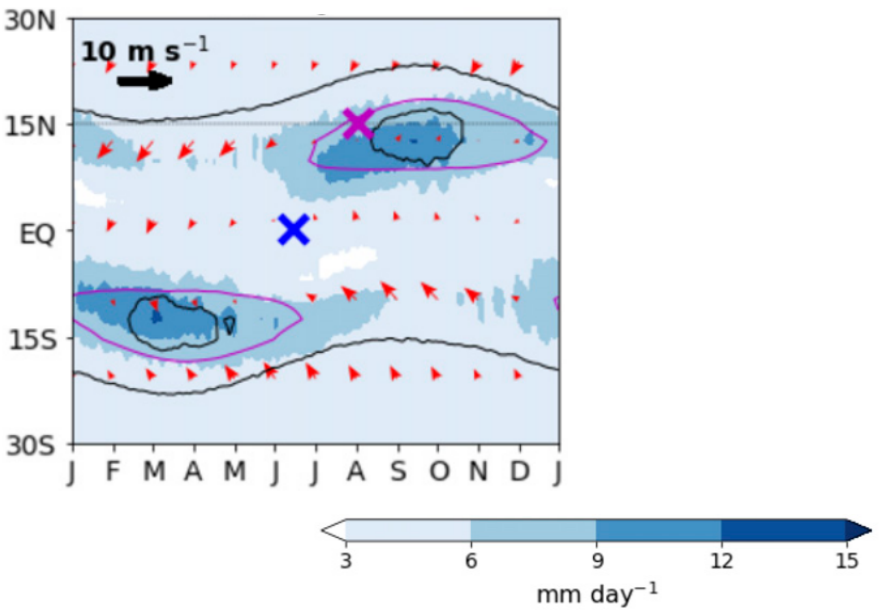
With ERA5 data

Idealised studies of the tropical rain belt

Many studies with GCM + slab ocean

There are asymmetries of P with respect to the solar forcing.

Aquaplanet



(Zhou and Xie 2018)

Idealised studies of the tropical rain belt

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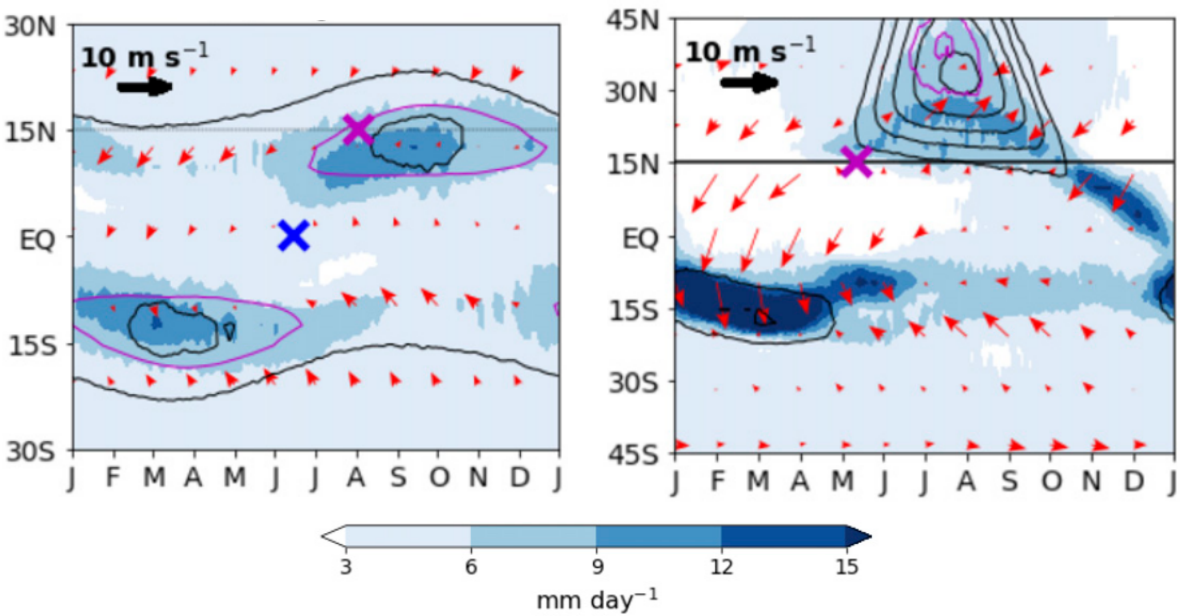
Aquaplanet

With land North of 15°N



(Zhou and Xie 2018)

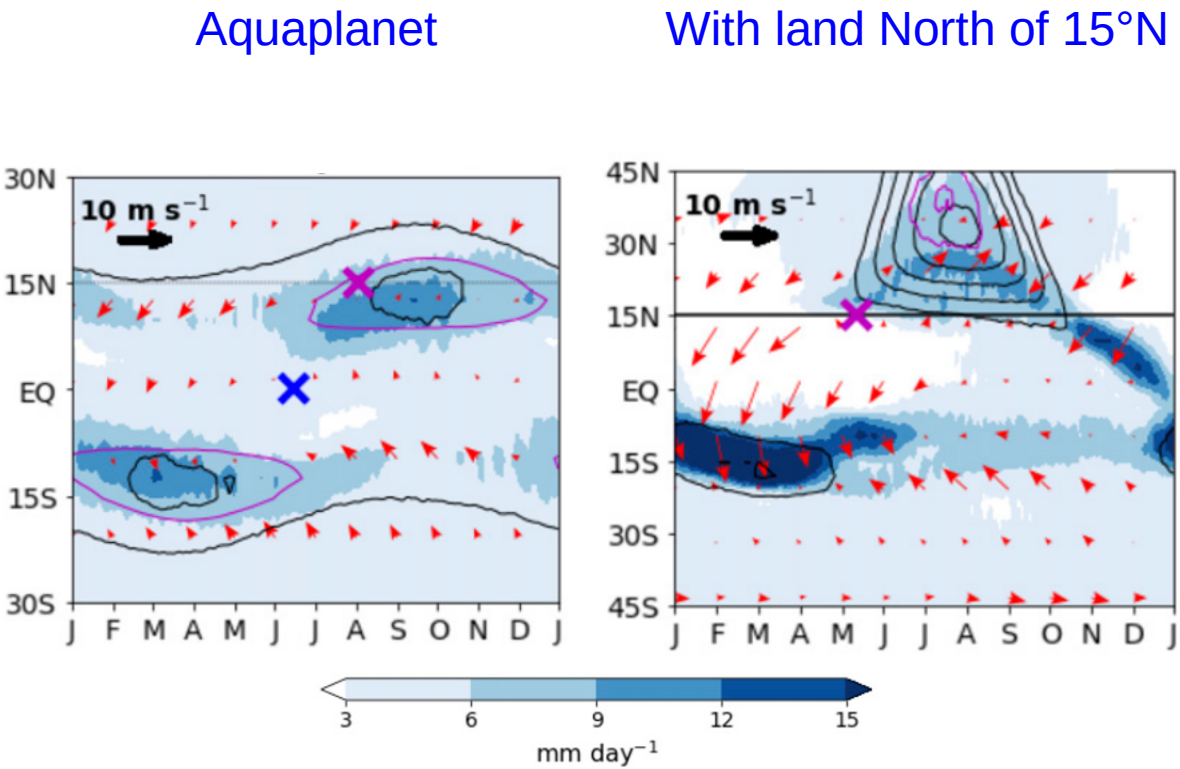
Idealised studies of the tropical rain belt

Many studies with GCM + slab ocean

There are asymmetries of P with respect to the solar forcing.

We expect this to be due to ocean memory.

But is there any memory in the atmosphere for the tropical rain belt migration ?



(Zhou and Xie 2018)

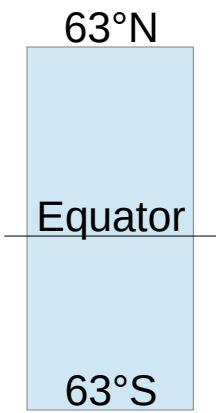
Idealised simulations with imposed SST

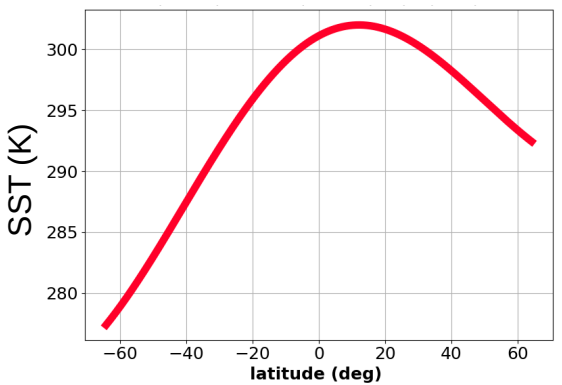
- WRF idealised simulations over a rectangular aquapatch
- Domain: 63°S-63°N (lat), 4800 km (lon)
- Grid spacing: 30 km (coarse)
- Periodic BC on x-axis
- Symmetric BC on y-axis (free-slip, no flux)
- With Coriolis
- No convection scheme (explicit) [or Kain-Fritsch]
- Imposed SST, varying with latitude and time: $\Phi_{0,max} = 24\,°N$

$$SST(\Phi) = T_0 - \Delta T\left(\sin\Phi - \sin\Phi_0(t)\right)^2$$

(Boos and Kuang 2010)

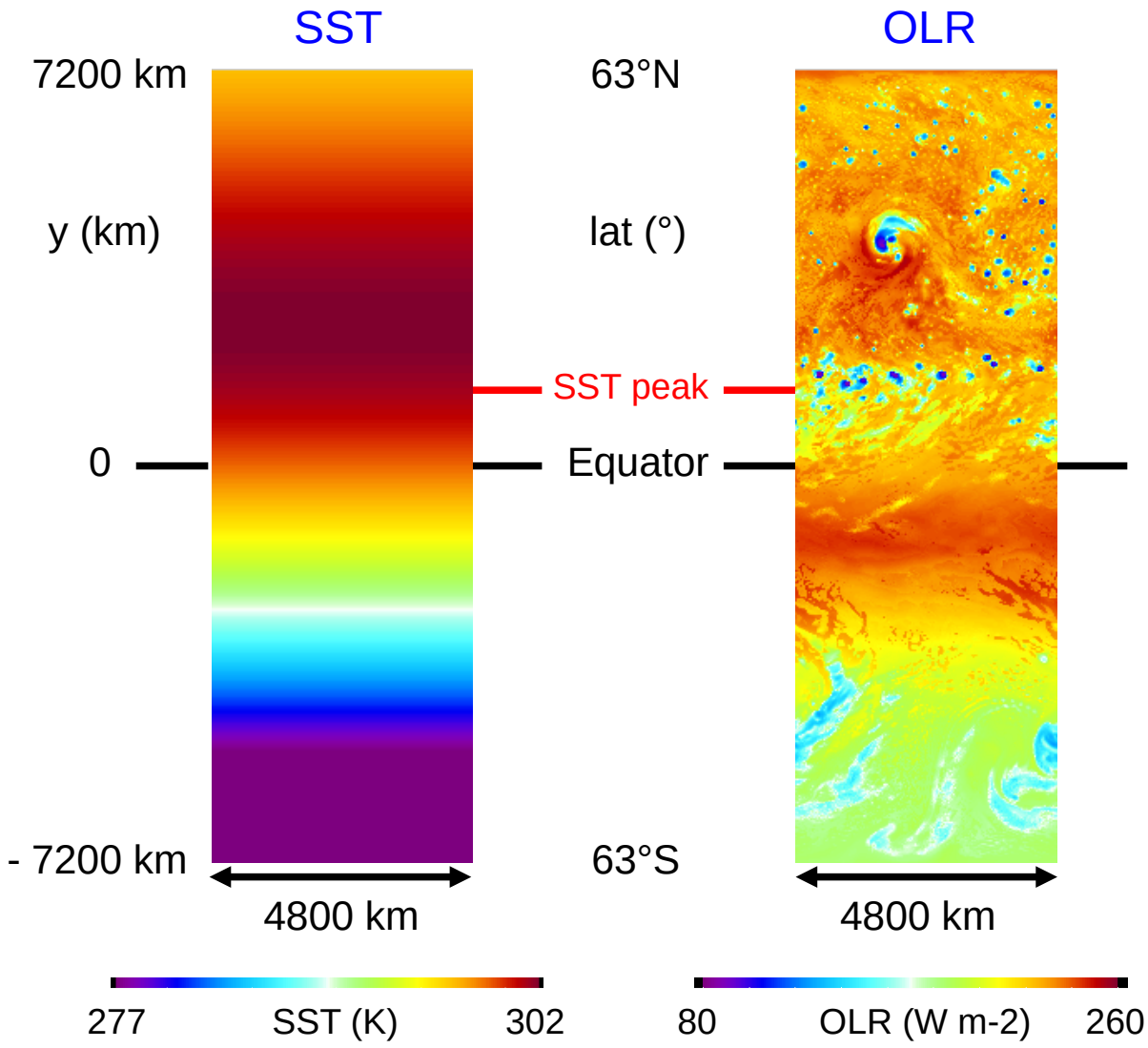
$$\Phi_0(t) = \Phi_{0,max}\cos\left[\left(t - t_{solstice}\right)\frac{2\pi}{T_{year}}\right]$$



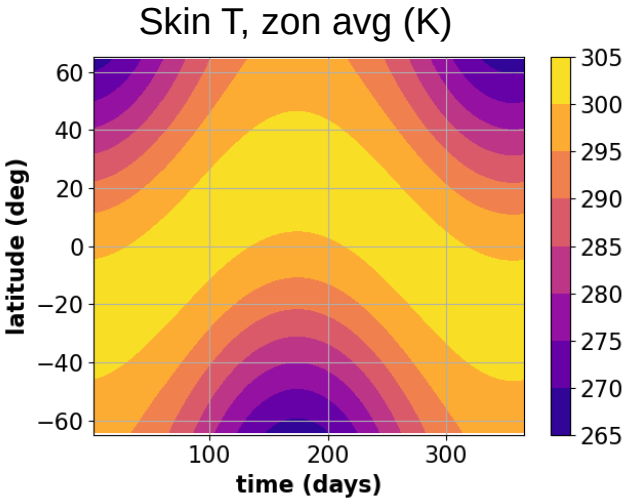


Spatial organisation

- Some Tropical Cyclonic features
- More convection in summer hemisphere, slightly away from the Equator
- Drier subtropics in the winter hemisphere
- Mid-latitudinal features



Hysteresis in the thermodynamic response to seasonal cycle



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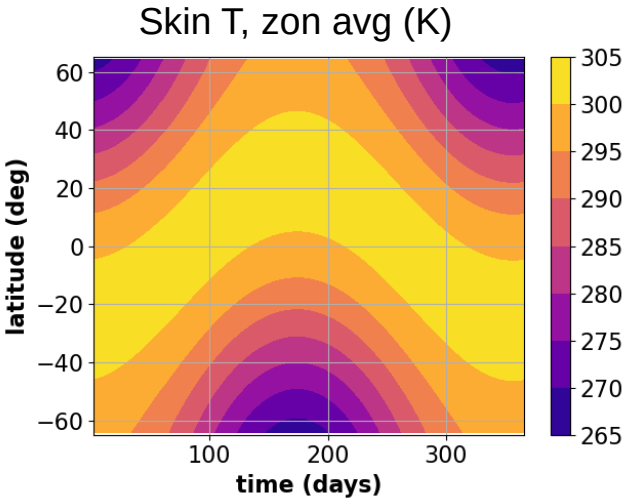

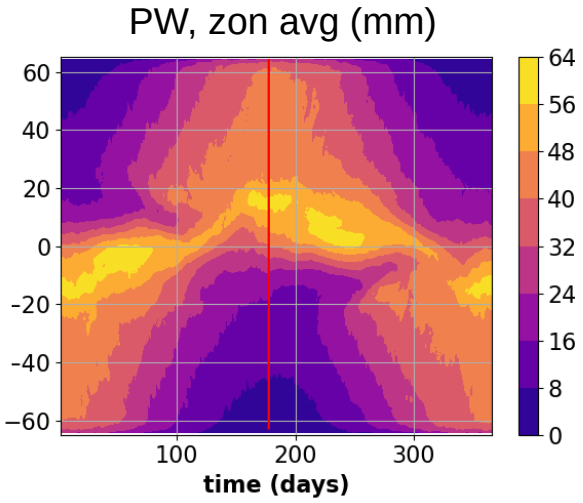

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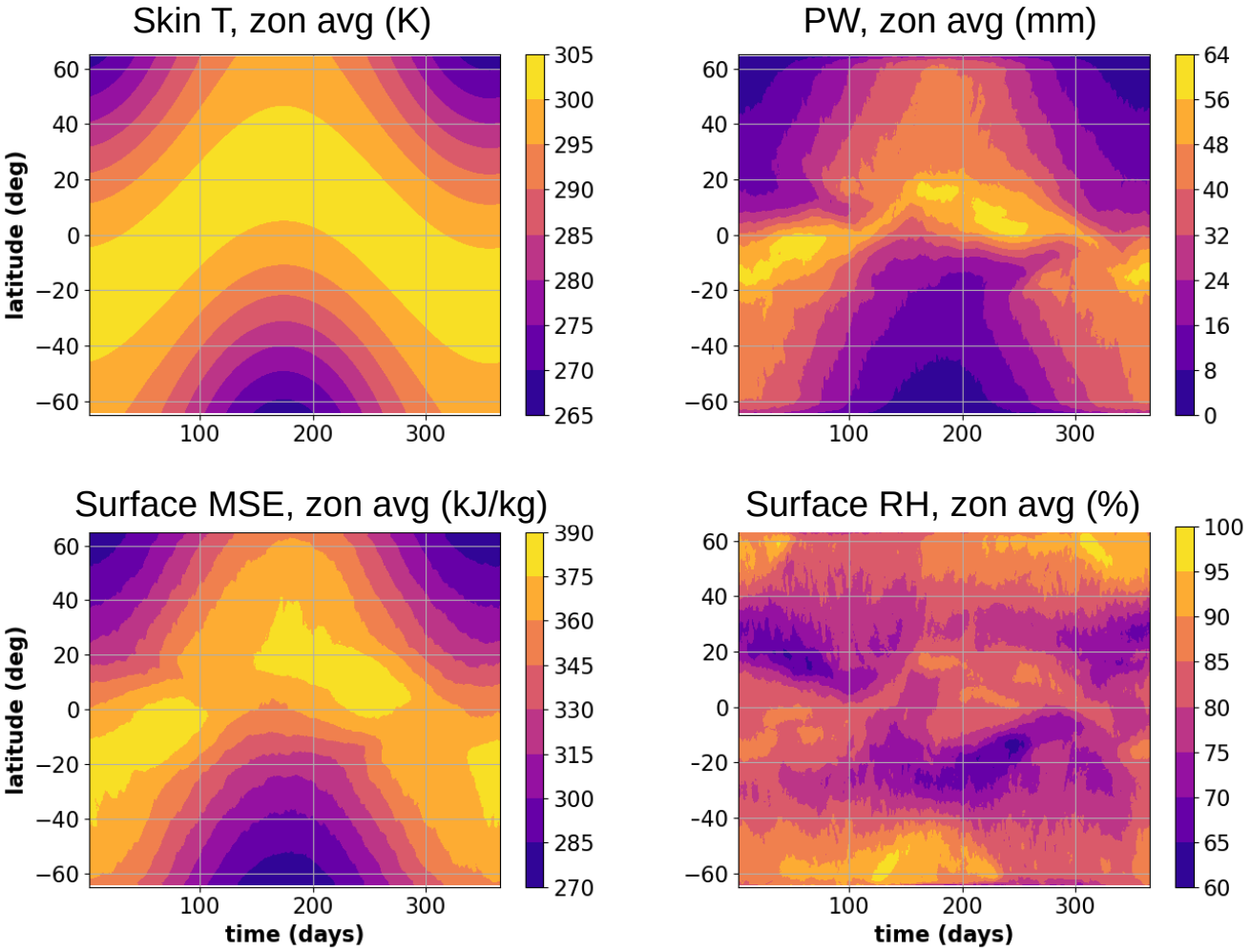
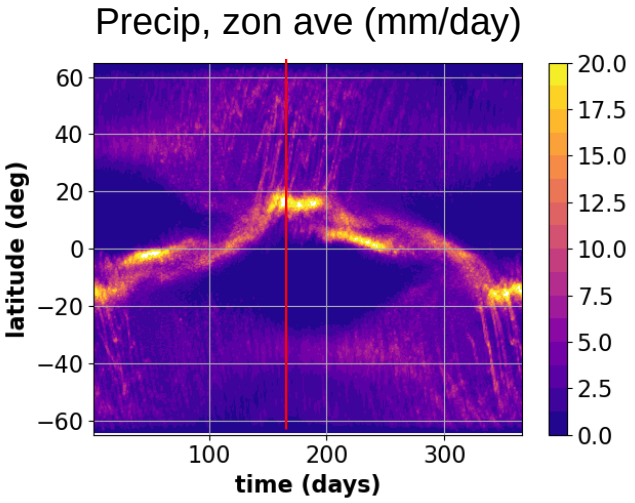


Hysteresis in the precipitation response to seasonal cycle



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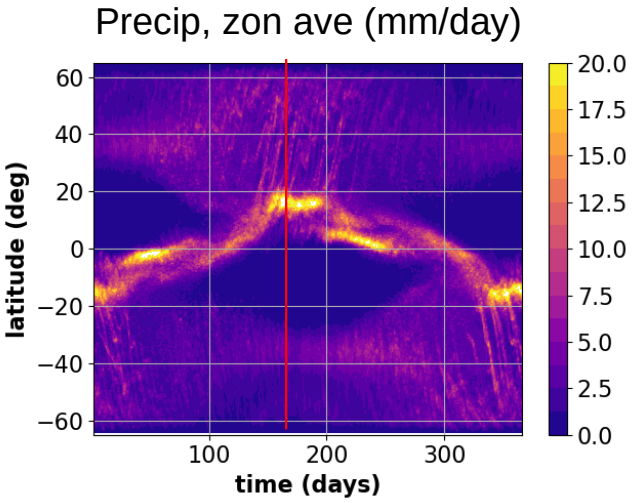

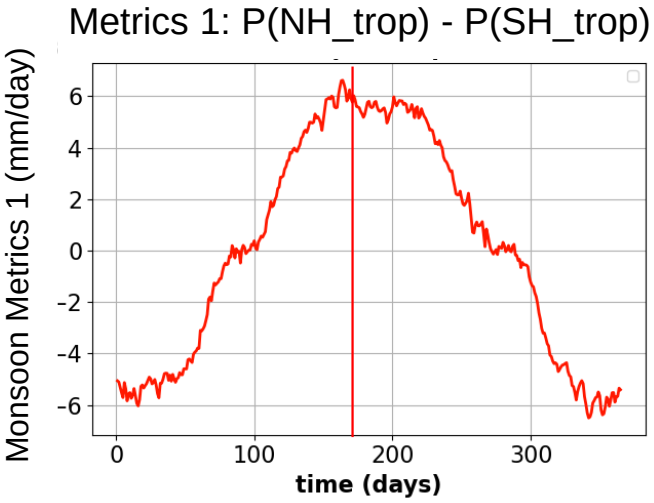

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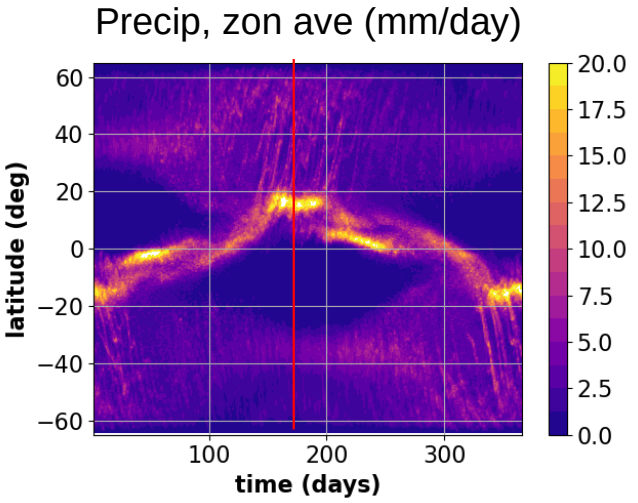

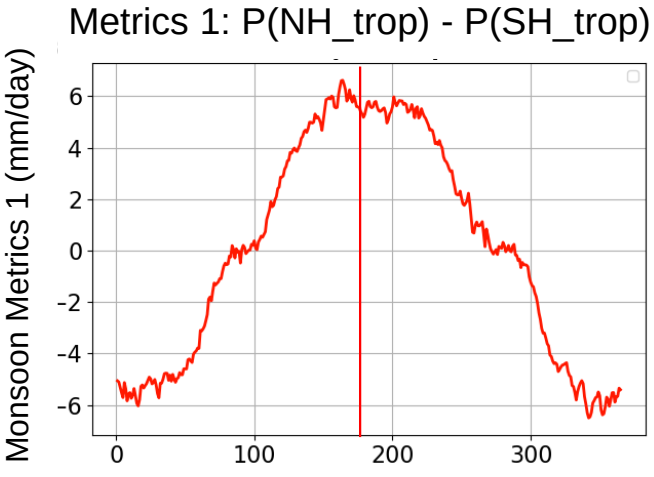

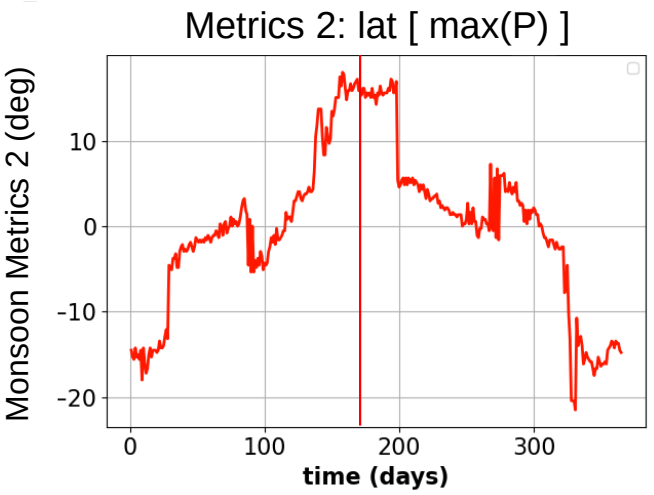

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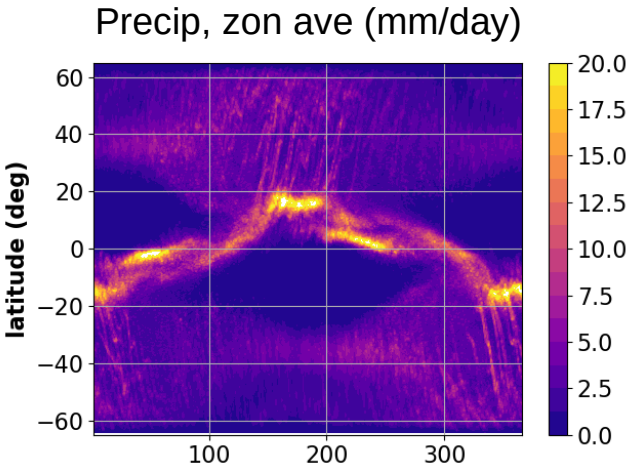

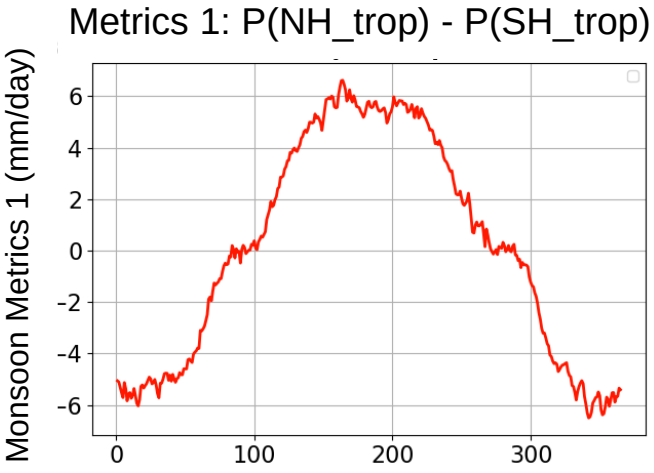

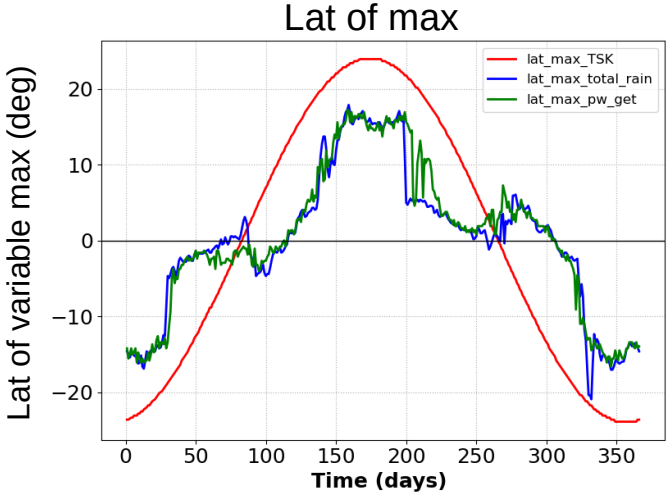

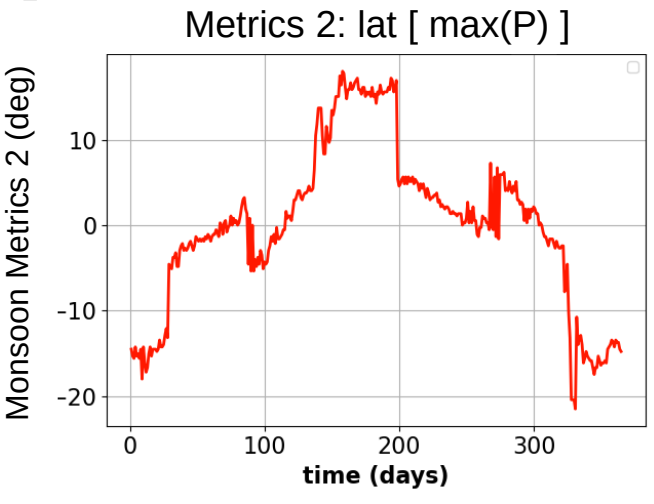

Conclusion

(A) Without any ocean, we still get a hysteresis and delayed seasonal migration of the tropical rain band. So there is a substantial atmospheric memory here.

(B) 3 hysteresis behaviours: asymmetry before and after solstice, sticky ITCZ at the Equator, rapid/delayed monsoon onset/retreat

(C) The tropical rain belt would be best described by a regime shift between a single peak structure and a double peak structure. Conceptually, the ITCZ is not always “a peak”.

(D) There are sharp tropical rain band peak jumps, but the rain band envelope has a much smoother variability, hence a smooth-sharp duality.

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