# Interpreting inter-model spread in regional precipitation projections

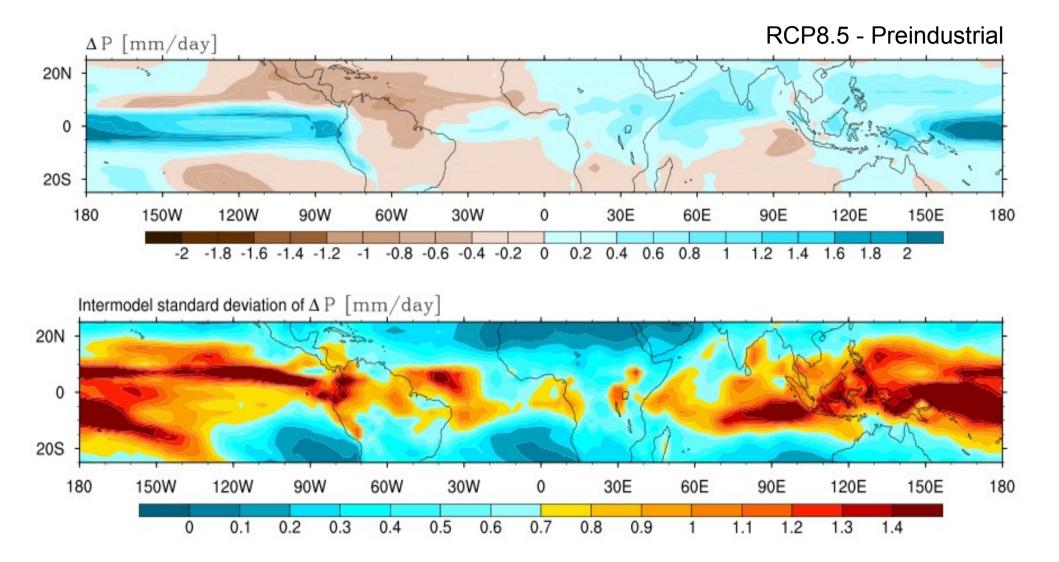
#### Boutheina Oueslati, Sandrine Bony and Jean-Louis Dufresne

#### LMD/IPSL, CNRS, Paris

Thanks to Camille Risi

CFMIP/EUCLIPSE meeting - July 2014

# **Annual mean precipitation : Changes and Spread**



Models : IPSL-CM5B-LR, CNRM-CM5, MPI-ESM-LR, IPSL-CM5A-LR, MIROC5, CanESM2, HadGE2-ES, FGOALS-s2, MRI-CGCM3, NorESM1-M, inmcm4

# Analysis methodology (Bony et al., 2013)

Water budget 
$$P = E - \begin{bmatrix} V \cdot \nabla q \end{bmatrix} - \begin{bmatrix} q \nabla \cdot V \end{bmatrix}$$
  
 $H_q = \begin{bmatrix} \omega \frac{\partial q}{\partial p} \end{bmatrix}$ 

 $\omega\,$  can be decomposed as:

 $\omega = \Omega + (\omega - \Omega)$ , with  $\Omega(p) = \overline{\omega} \Phi(p)$ 

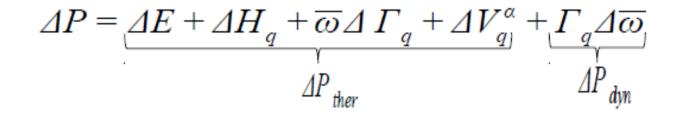
Then,

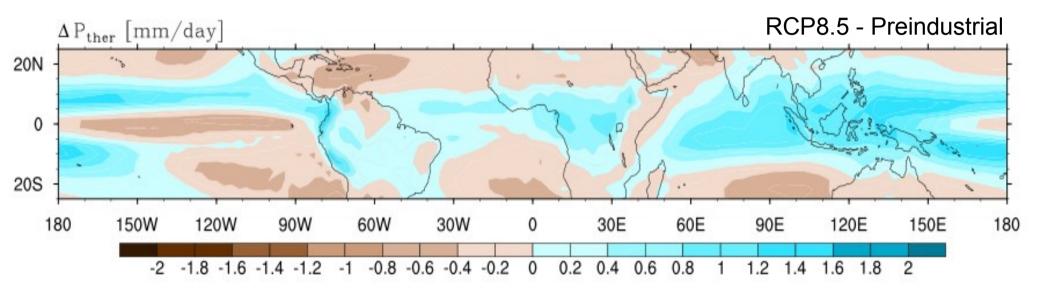
$$P = E + H_q + \overline{\omega} \Gamma_q + V_q^{\alpha}, \quad \text{with} \quad V_q^{\alpha} = -\left[ (\omega(p) - \Omega(p)) \frac{\partial q}{\partial p} \right]$$
$$\Gamma_q = -\left[ \Phi(p) \frac{\partial q}{\partial p} \right]$$

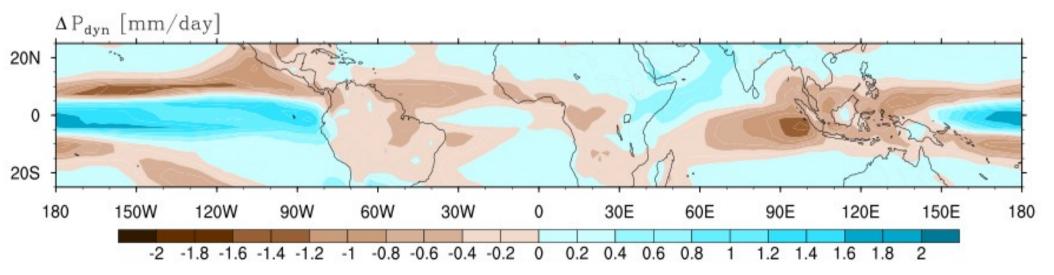
$$\Delta P = \Delta E + \Delta H_q + \overline{\omega} \Delta \Gamma_q + \Delta V_{q}^{\alpha} + \Gamma_q \Delta \overline{\omega}_{dp}$$

$$\Delta P_{ther}$$

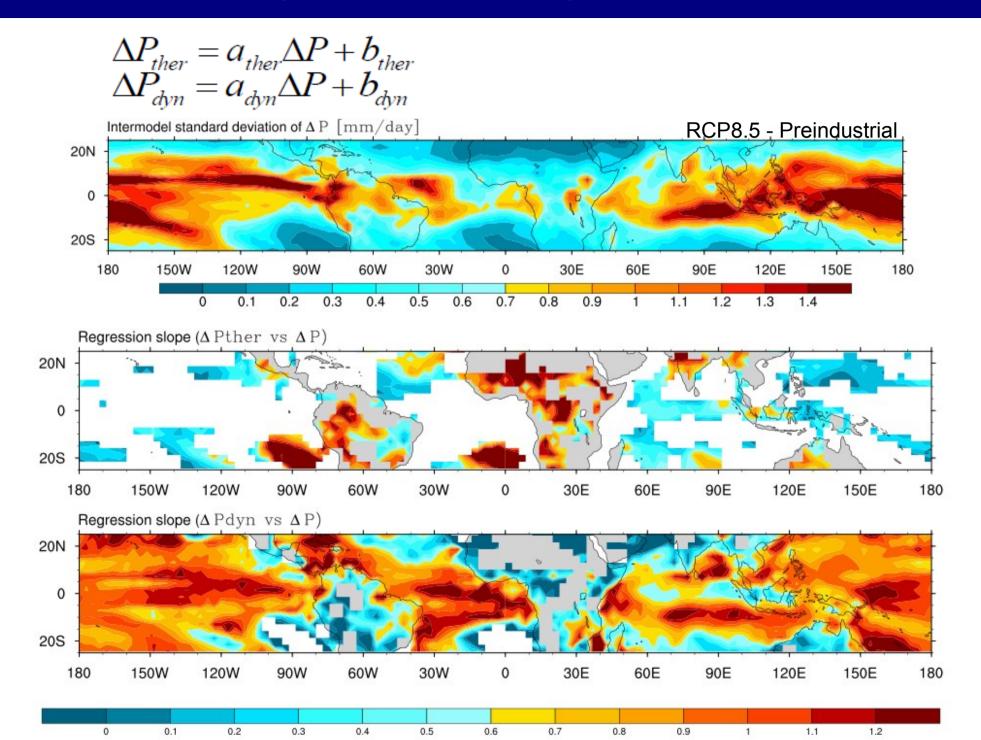
#### **Role of dynamic and thermodynamic processes**



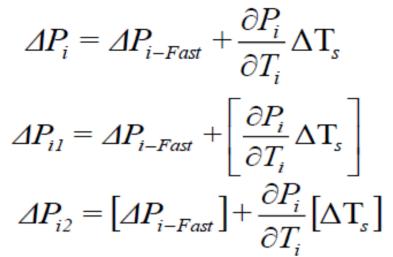




#### Role of dynamic and thermodynamic processes



#### Fast vs Long-term processes



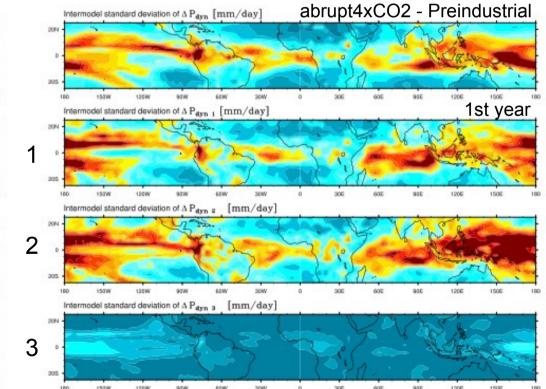
Intermodel standard deviation of  $\Delta P_{ther} [mm/day]$ Intermodel standard deviation of  $\Delta P_{dyn} \ [mm/day]$ 20N 150W 150W 1208 2.044 1206 150E 125W 2.034 SOW 935 Intermodel standard deviation of  $\Delta P_{dyn 1} \left[ mm/day \right]$ Intermodel standard deviation of  $\Delta P_{ther 1} [mm/day]$ 20N 150W 1208 diam'ne A PROPERTY. TAPAK! 305 605 90E 1206 150E en an an 474044 0.000 A COMP. 605 945 1206 180 205 Intermodel standard deviation of  $\Delta P_{ther \ g} \ [mm/day]$ Intermodel standard deviation of  $\Delta P_{dyn 2}$  [mm/day] 20N 2 205 4.044 205 1205 1500 180 150% 12036 OOE 945 1500 205 1205 Intermodel standard deviation of  $\Delta P_{ther 3}$  [mm/day] Intermodel standard deviation of  $\Delta P_{dyn 3}$  [mm/day] 20N 208 3 150W 150W 1200 120W 200 1500 120W 1500 90W 6044 20W 6.0 M

> 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.2 1.3 1.4 1.5 0.1 1.1

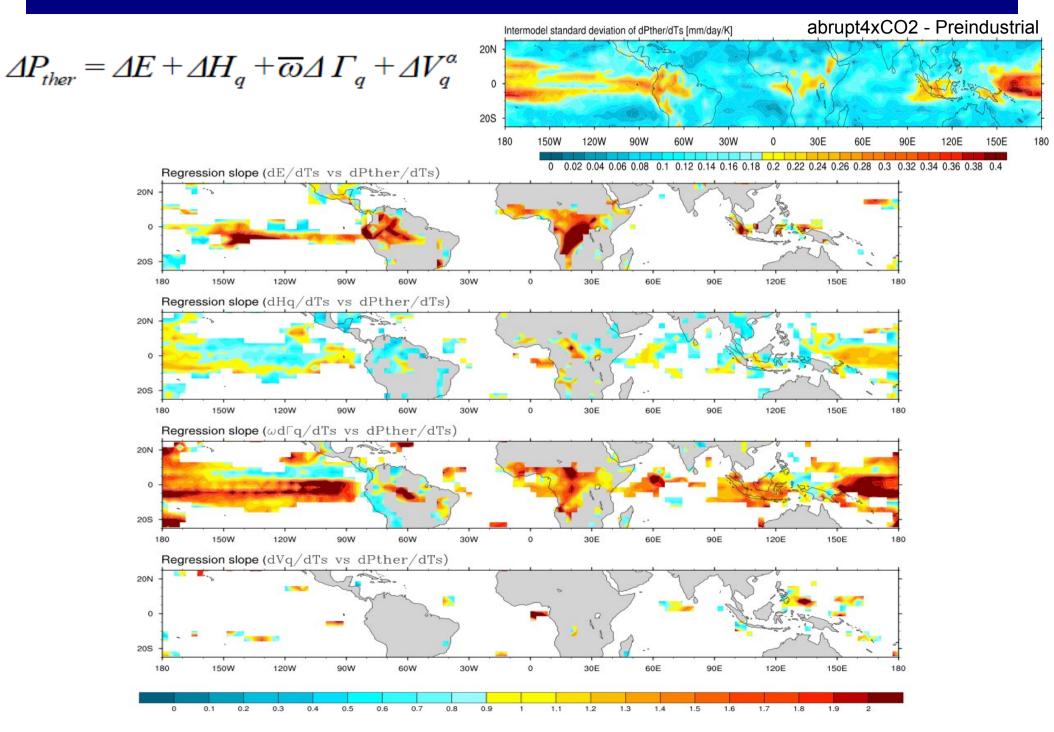
Multi-model mean

i: ther ou dyn

$$\Delta P_{i3} = \left[ \Delta P_{i-Fast} \right] + \left\lfloor \frac{\partial P_i}{\partial T_i} \right\rfloor \Delta T_s$$



# Interpretation of the thermodynamic component (dPther/dTs)



#### Interpretation of the thermodynamic component

Intermodel standard deviation of dPther/dTs [mm/day/K] 20N 0 20S 180 60W 30E 60E 90E 120E 150E 180 150W 120W 90W 30W 0 0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2 0.22 0.24 0.26 0.28 0.3 0.32 0.34 0.36 0.38 0.4

R = 0.90.80 0.70 [mm/day] inmcm4 0.60 NorESM1-M 0.500.40 MRI-CGCM3 America) 0.30 FGOALS-s2 0.20 HadGEM2-ES п 0.10 South 0.00 CanESM2 -0.10 MIROC5 -0.20 S -0.30 IPSL-CM5A-LR  $\Delta P_{\rm ther}$ -0.40 MPI-ESM-LR -0.50 CNRM-CM5 -0.60-0.60 -0.50 -0.40 -0.30 -0.20 -0.10 0.00 0.10 0.20 IPSL-CM5B-LR ΔE (N South America) [mm/day]

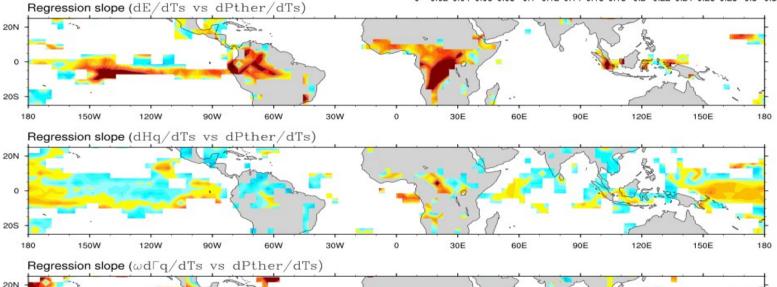
# Role of evaporation

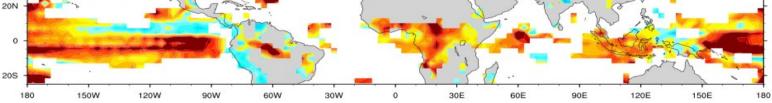
# Interpretation of the thermodynamic component (dPther/dTs)

 $\Delta P_{ther} = \Delta E + \Delta H_{q} + \overline{\omega} \Delta \Gamma_{q} + \Delta V_{a}^{a}$ 

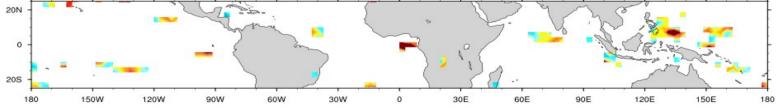
Intermodel standard deviation of dPther/dTs [mm/day/K] 20N 0 20S 180 150W 120W 90W 60W 30W 30E 60E 90E 120E 180 0 150E

0 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2 0.22 0.24 0.26 0.28 0.3 0.32 0.34 0.36 0.38 0.4





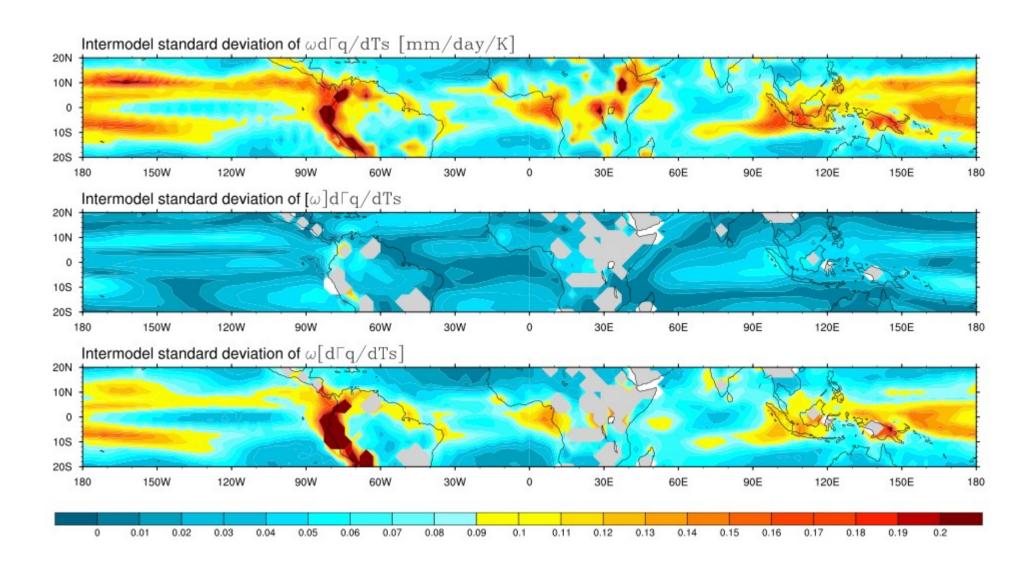




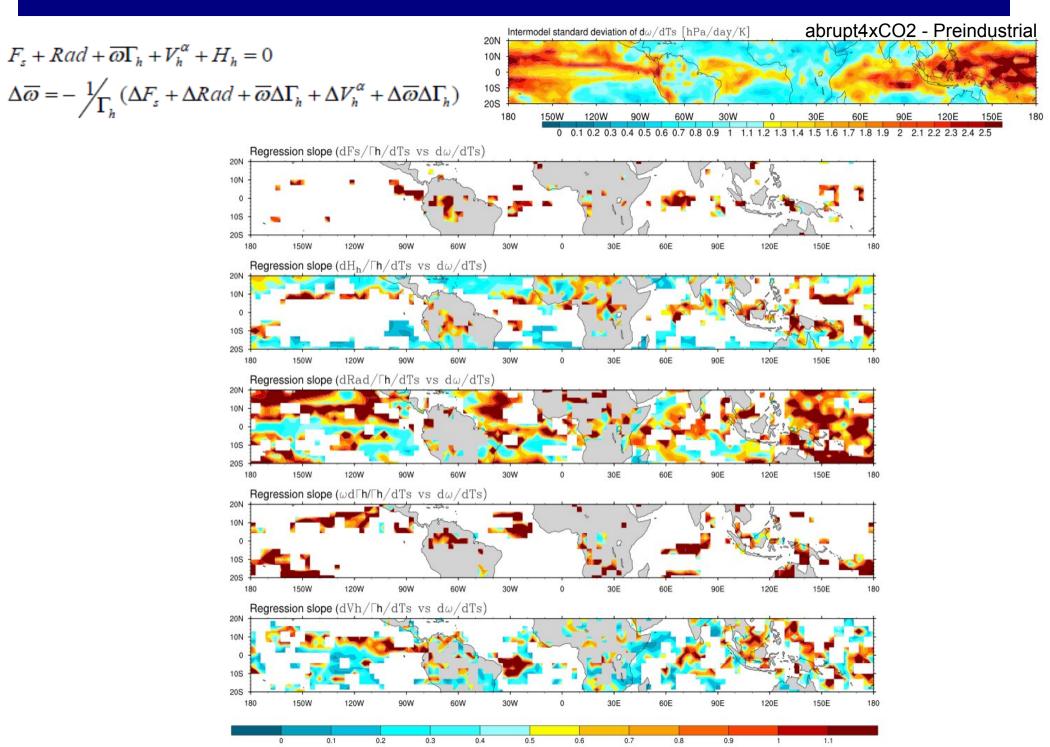
## Interpretation of the thermodynamic component

## Role of climatology

$$\overline{\omega} \varDelta \Gamma_q \to \left[ \overline{\omega} \right] \varDelta \Gamma_q \\ \searrow \overline{\omega} \left[ \varDelta \Gamma_q \right]$$

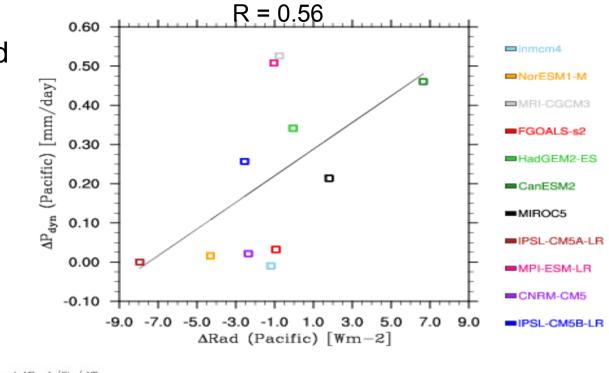


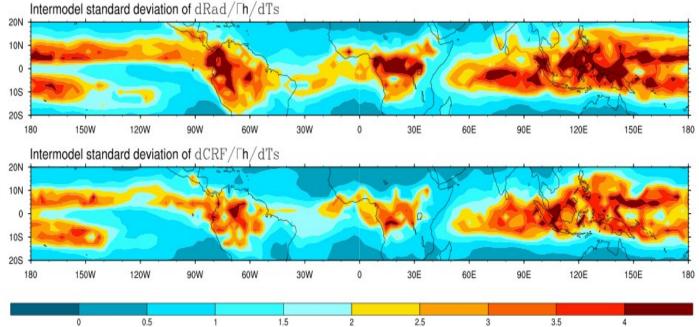
#### Interpretation of the dynamic component (dPdyn/dTs)



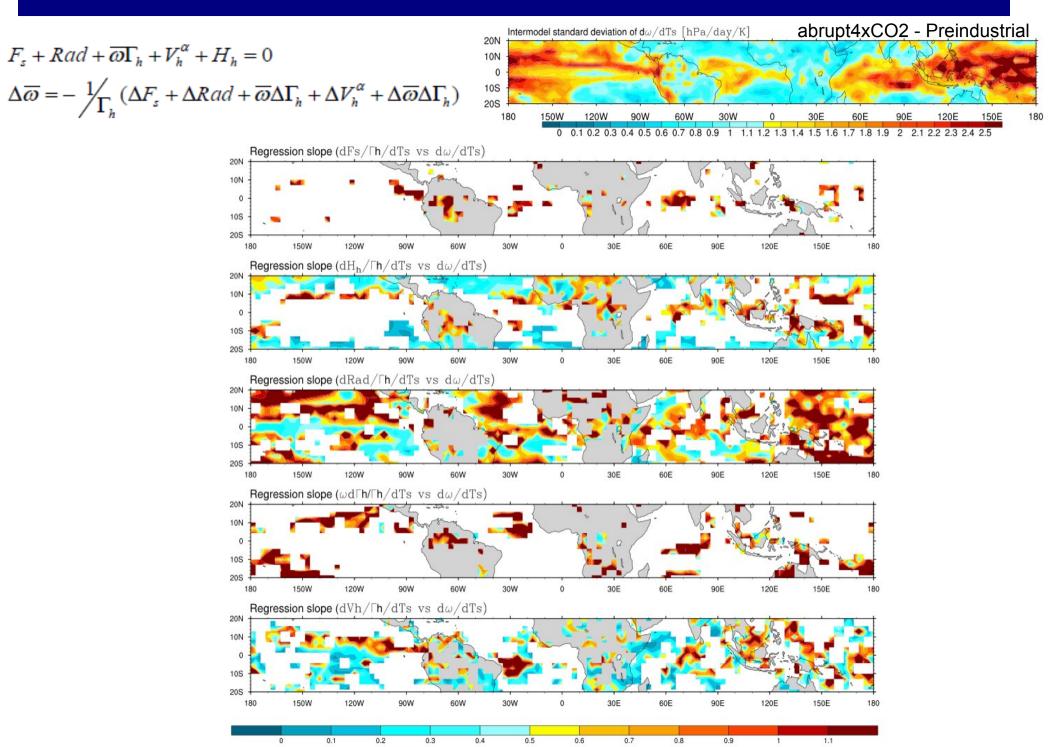
# Interpretation of the dynamic component

Role of radiative cooling and cloud radiative effect





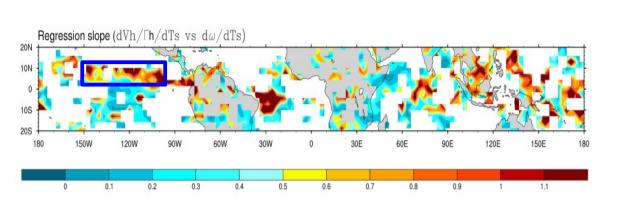
#### Interpretation of the dynamic component (dPdyn/dTs)

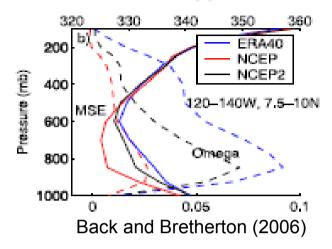


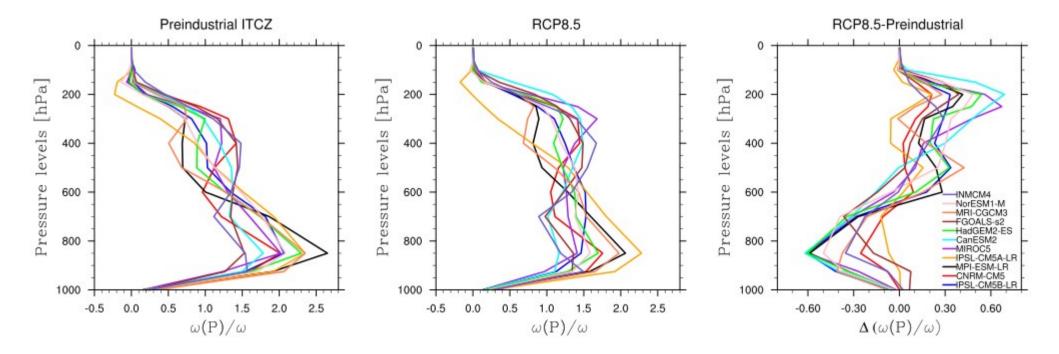
#### Interpretation of the dynamic component

# Role of w vertical profile

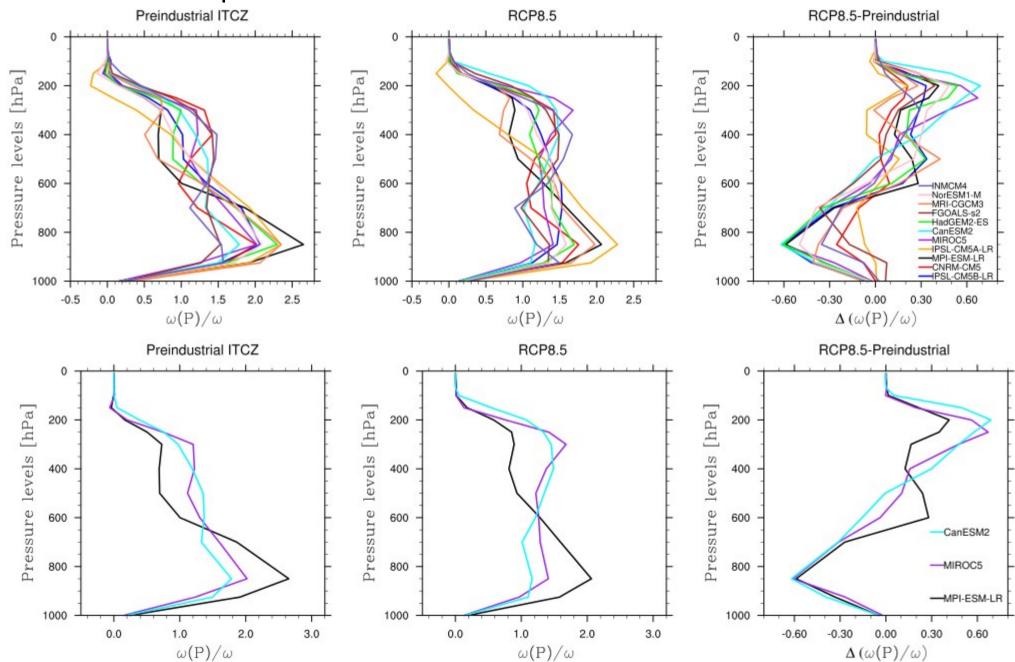




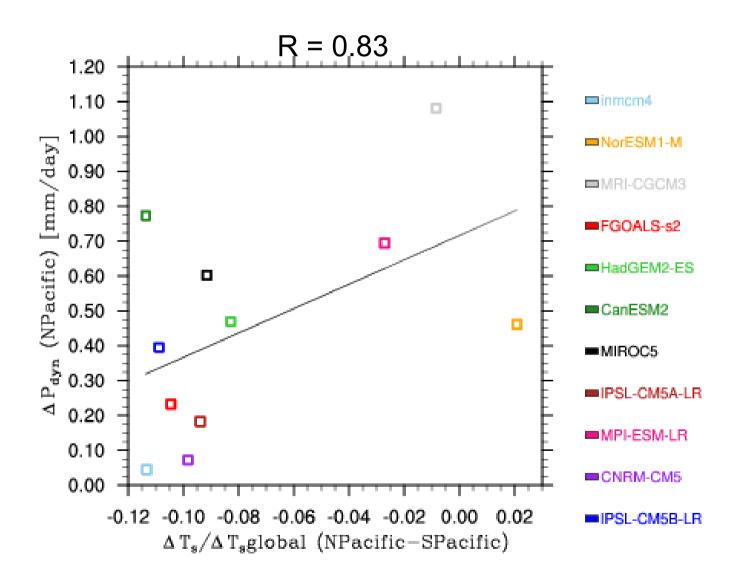




### Role of w vertical profile



Role of SST gradients on w vertical profile



# Conclusions

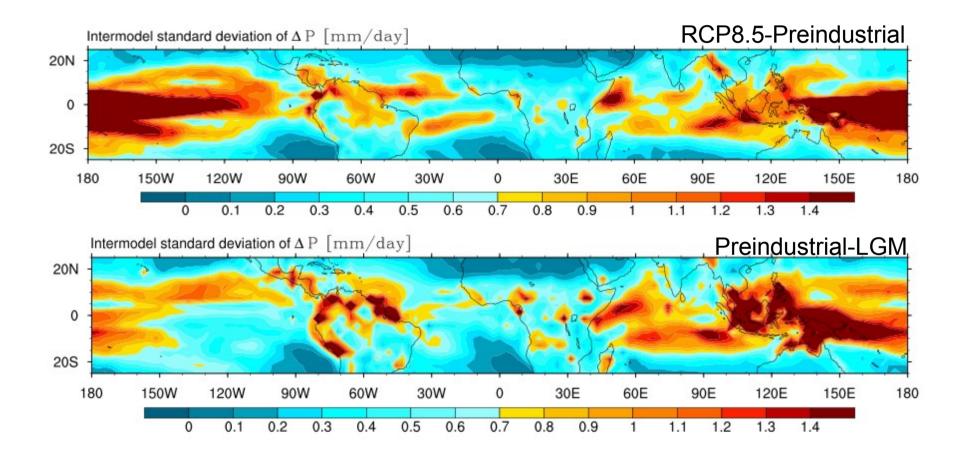
The present study investigates possible sources of intermodel spread in precipitation projections:

- The dynamic component dominates over oceans and along continental coasts through the spread in CRE and w vertical profile

- The thermodynamic component dominates over continental interiors through the spread in evaporation and w climatology

# Outlook

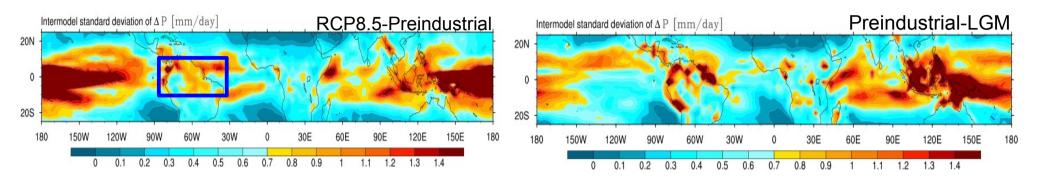
Comparison with paleoclimate simulations (Last Glacial Maximum, Mid-Holocene)

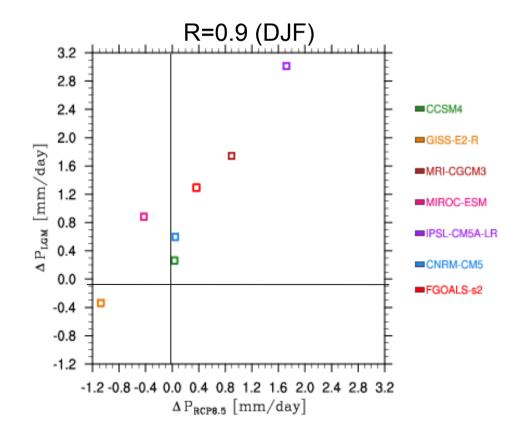


Models: FGOALS-g2, CNRM-CM5, MIROC-ESM, MRI-CGCM3, GISS-E2-R, CCSM4, MPI-ESM-P

# Outlook

#### Comparison with paleoclimate simulations (Last Glacial Maximum, Mid-Holocene)





Thank you for your attention

# **Relative changes in annual mean precipitation**

