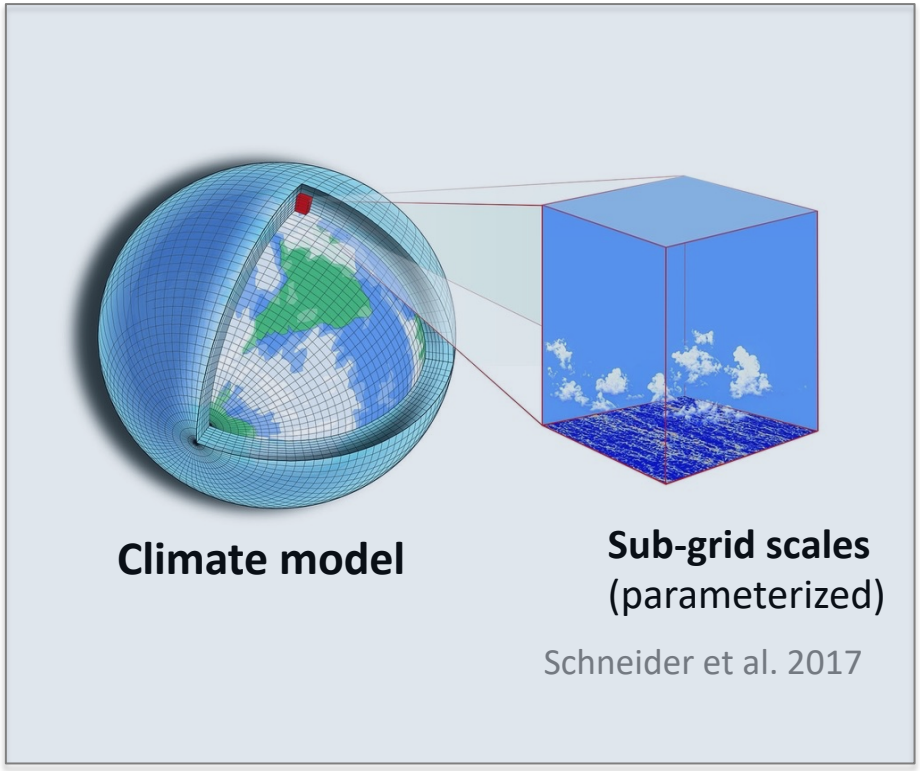
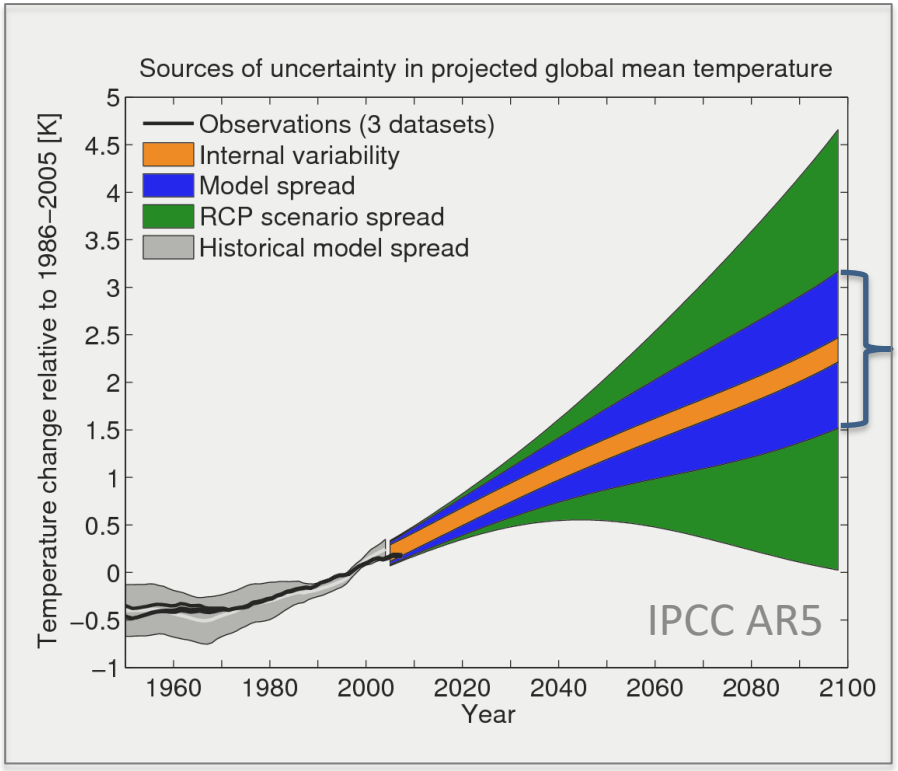
Topic 5: Sensitivity of equilibrium climate to physical parameterizations

Background

- Imperfect parameterizations of physical processes are responsible for the bulk of uncertainty in future climate projections. Therefore, improving climate simulations requires better parameterizations.





Q: How to extract the impact of different model parameterizations on the simulated climate?
A: By running lots of climate simulations using different combinations of parameterizations.

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Numerical experiments

- **Setup:** simplified aquaplanet world (i.e., Earth-like planet, ocean only, prescribed SST, no annual cycle/seasons, retained diurnal cycle, zonally-symmetric forcings and results)

- **Data:** sixteen 12-month averaged WRF aquaplanet simulation outputs:
  - present climate ("control"; 8 simulations using different combinations of parameterizations)
  - future climate ("climate change"; uniform 4K increase of SST; 8 simulations)

  Variables included:
  - Horizontal and vertical velocity components
  - Cloud cover
  - Water vapor and temperature profiles
  - Precipitation
  - Radiative fluxes at the top of the atmosphere

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List of aquaplanet simulations

Experiment name	Parameterization 1: Microphysics	2: Convection	3: Boundary layer	4: Radiation
St	WSM-6	GFS (AS)	MYNN-3	RRTMG
MPwdm	WDM-6			
MPmor	Morrison			
COkf		Kain-Frisch		
COtie		Tiedtke		
PBLnn2			MYNN, level 2	
PBLysu			YSU	
RAcam				CAM

Differences in the sets of parameterizations with respect to ***St*** experiment

Column of a climate model
(subgrid processes)

Reference: *Cesana, G., Suselj, K., & Brient, F. (2017). On the dependence of cloud feedbacks on physical parameterizations in WRF aquaplanet simulations. GRL, 44. doi: 10.1002/2017GL074820*

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Example questions to be answered

- Is aqua-planet climate a good approximation of the Earth's climate?
- Quantify the role of physical parameterizations for the control climate:
  - Which climate zones and physical quantities are most sensitive to physical parameterizations?
  - Which physical parameterizations control that variability?
- Investigate the role of physical parameterizations in the simulated "climate change" scenario:
  - How do atmospheric properties change with climate change?
  - How sensitive are these changes to different physical parameterizations?

Example results (1): Is aquaplanet climate any realistic?

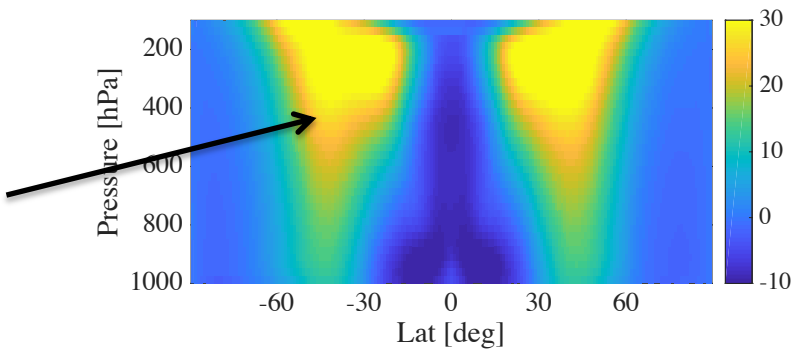
Hypothesis: Main features of the aquaplanet climate are comparable to real climate
Methodology: compare zonally-averaged fields from the St experiment and reanalysis

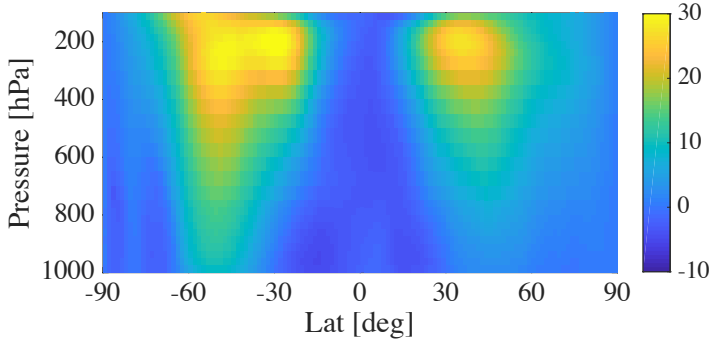
Aqua-planet: WRF/St
(simplified world)

Zonal wind [m s^{-1}]

Reanalysis (ECMWF/Interim)
(real world)

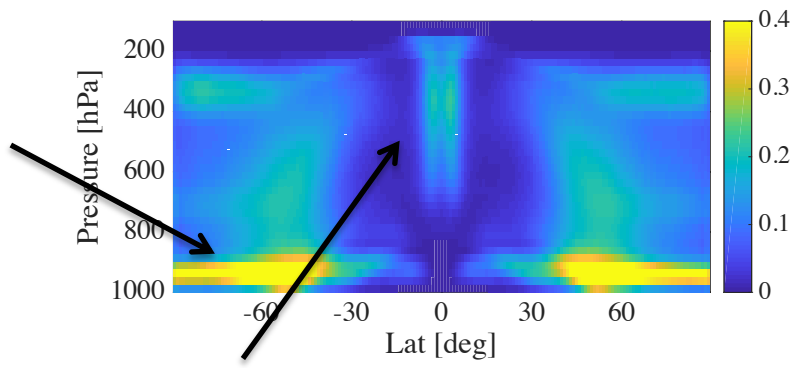
Stronger mid-latitudinal jet

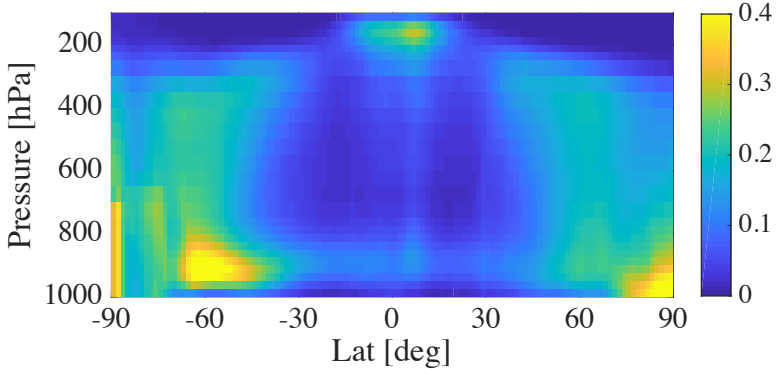




Cloud fraction

Higher near-surface cloudiness





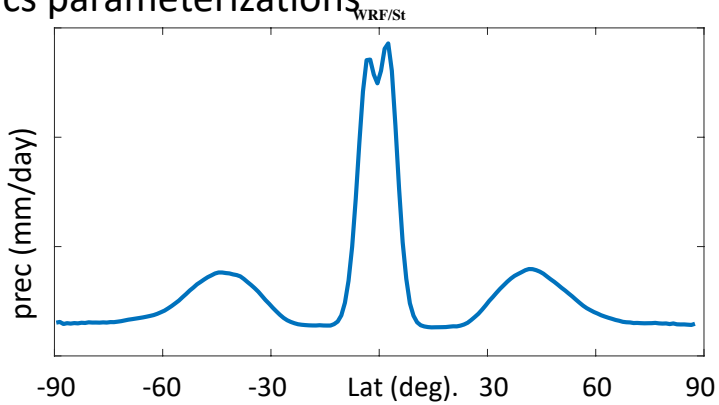
More tropical mid-level clouds

Example results (2): Sensitivity of control climate to physical parameterizations

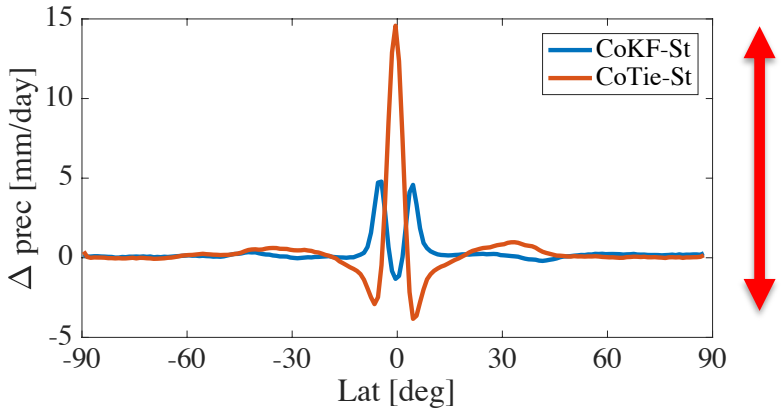
Hypothesis: Convective and microphysics parameterizations determine the dynamics, cloud structure and precipitation patterns in the tropics

Methodology: Compare precipitation variability for the control climate due to convection and microphysics parameterizations

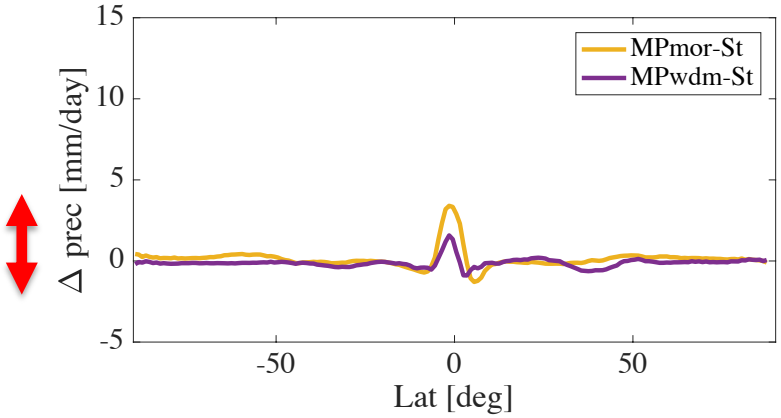
Zonally-averaged surface precipitation from WRF/St



Differences in surface rain rate - convection
(2 parameterizations from WRF/St)



Differences in surface rain rate – microphysics
(2 parameterizations from WRF/St)

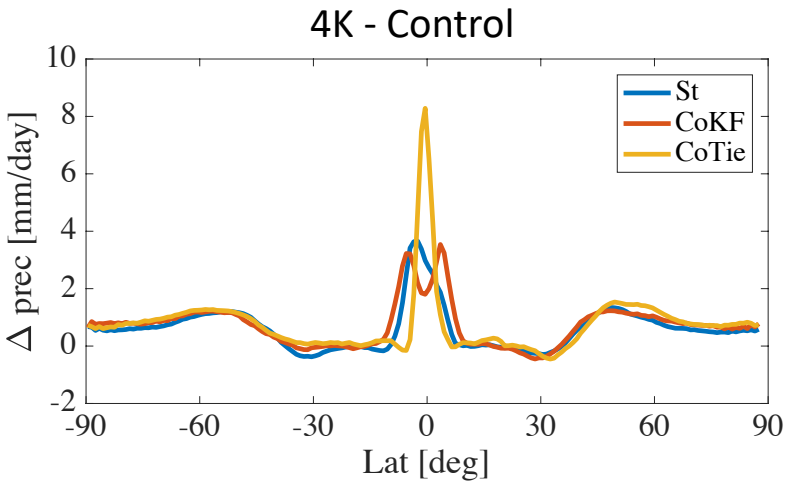


Example results (3): Sensitivity of climate response to increased SST

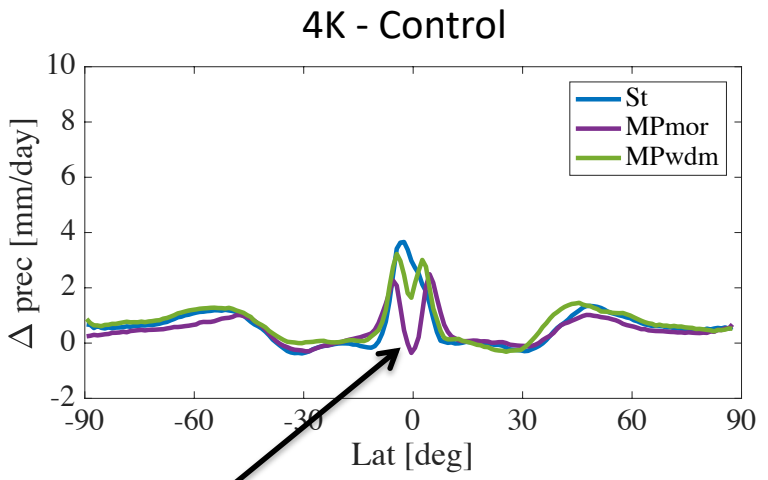
Hypothesis: Climate change uncertainty in the tropics is mostly sensitive to convection parameterizations

Methodology: Compare control and warm climate statistics in the tropics

Changes due to different convection parameterizations



Changes due to different microphysics parameterizations



Microphysical parameterizations strongly impact the variability of tropical rain changes to climate warming

Your task

- Familiarize yourself with the available data sets
- Study the simple examples provided above
- Formulate your own hypothesis
- Use the available data to verify/quantify your hypothesis
- Make a story based on your results

Good luck!

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