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ECHAM6-CCN and its climate sensitivity

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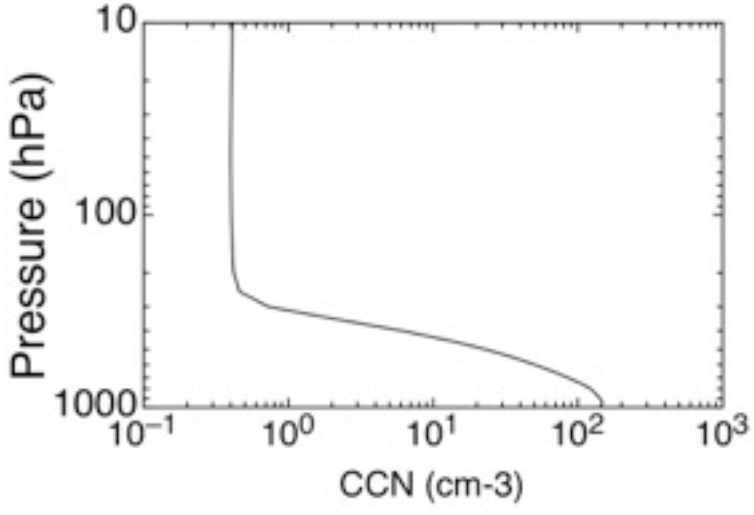
ECHAM6 coupled to a CCN climatology

- Rationale: can we account for aerosol effects using a simple aerosol/ CCN climatology?
- Combine AERONET aerosol observations and AeroCom model results
- Assume that all coarse mode particles acts as cloud condensation nuclei (CCN)
- Assume that only a fraction of fine-mode particles acts as CCN by a cut-off size based on supersaturation and on chemical distribution
- Distinguish the fine-mode particles between anthropogenic and natural CCN based on the AeroCom model results
- Only the anthropogenic CCN vary with time

Description of the CCN climatology (1)

- CCN data are available as monthly means from 1850 to 2100, at 1km and 8km (pressure-driven decrease between these 2 extremes)



- 4 different CCN subsets with different supersaturation levels are used. The final CCN concentration is chosen based on local, current updraft velocity:

W < 0.01 m.s-1	→	CCN at 0.07% supersaturation
0.01 m.s-1 < W ≤ 0.10 m.s-1	→	CCN at 0.10% supersaturation
0.10 m.s-1 < W ≤ 1.00 m.s-1	→	CCN at 0.15% supersaturation
W > 1.00 m.s-1	→	CCN at 0.20% supersaturation

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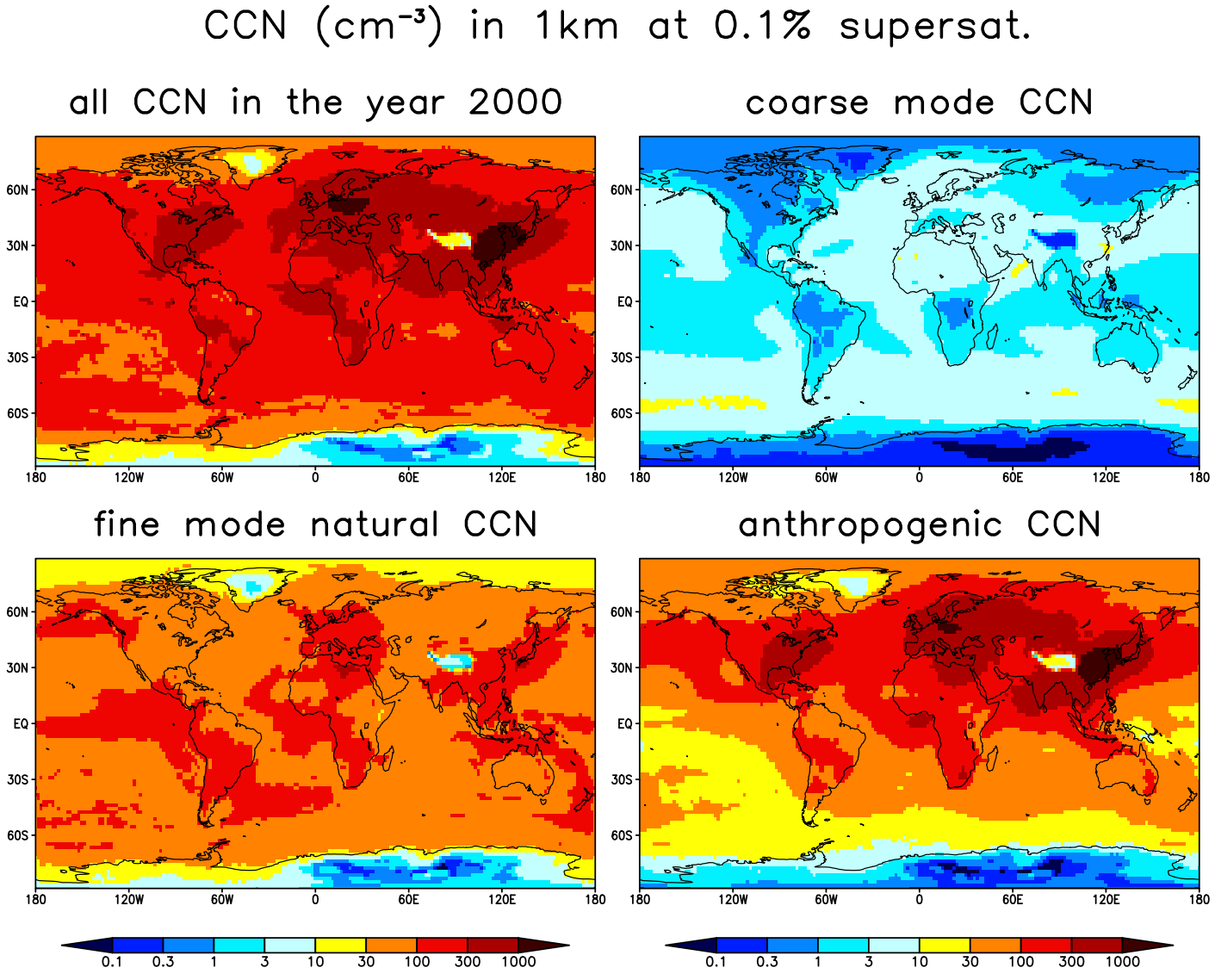
Description of the CCN climatology (2)

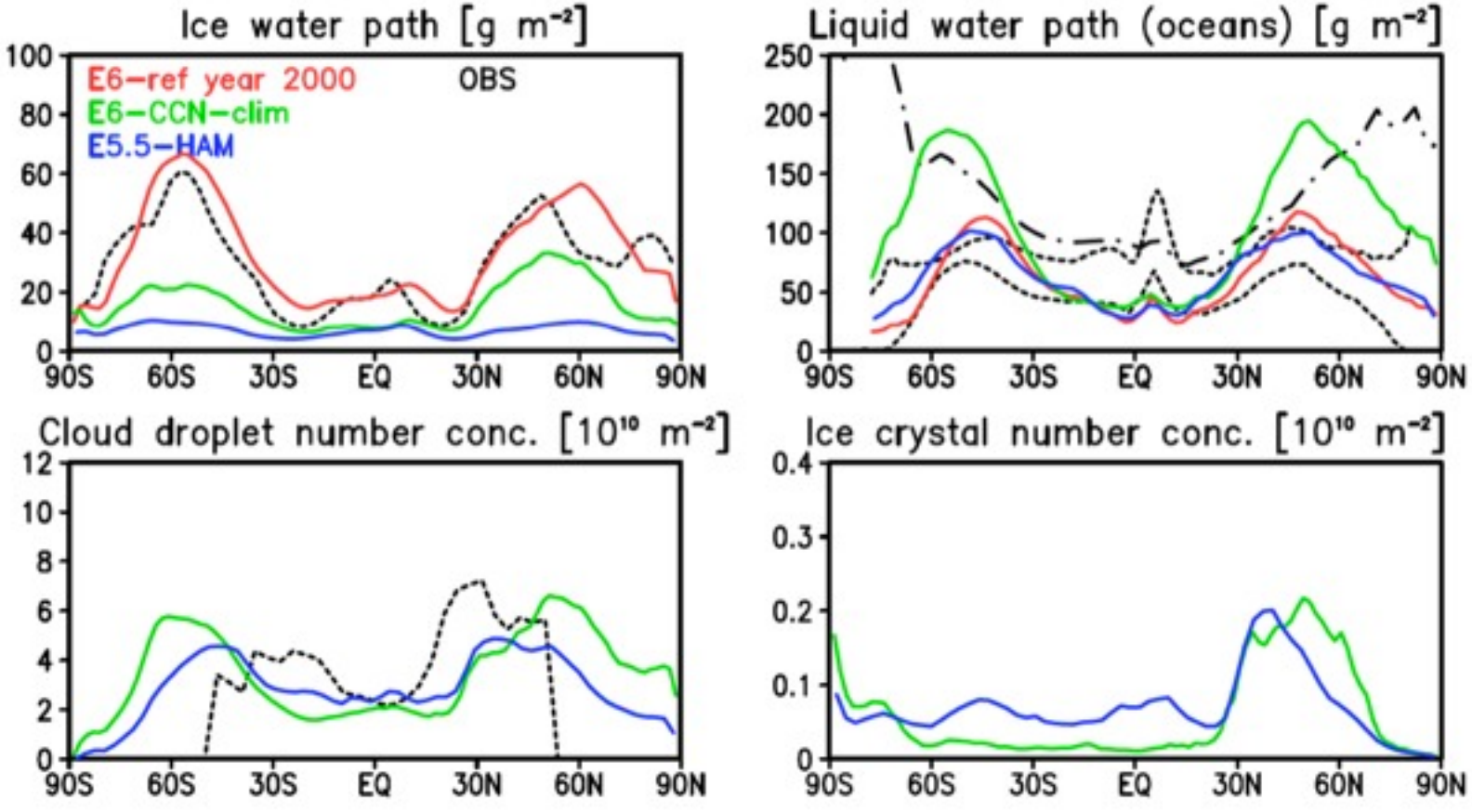


Model differences

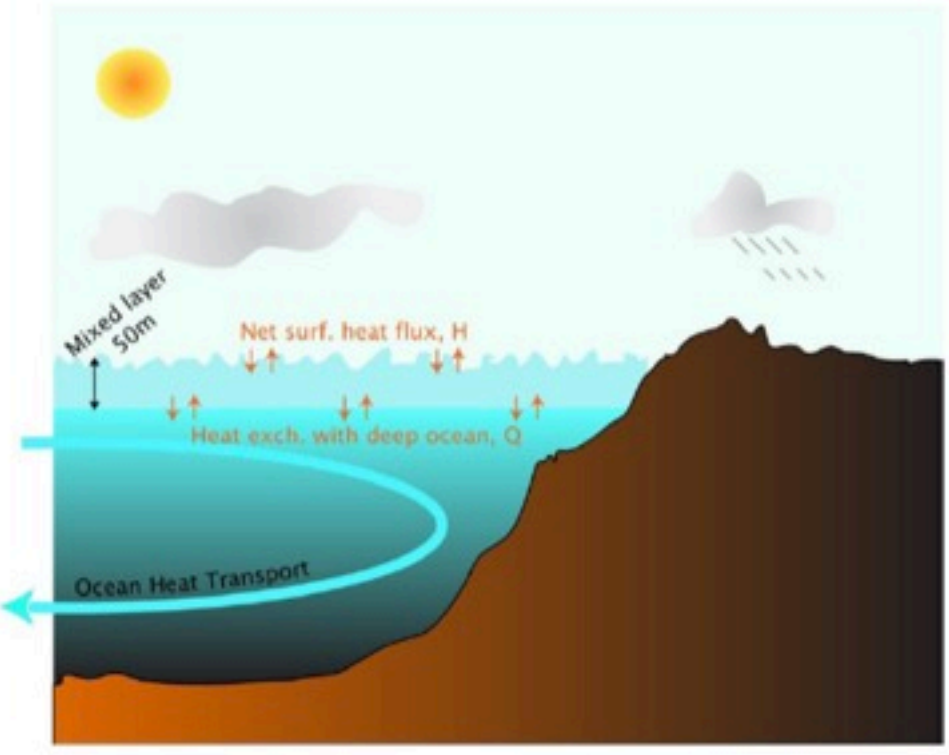
- Differences between ECHAM6-CCN and ECHAM6:
  - 2-moment vs 1-moment cloud microphysics
  - Autoconversion rate (rate of rain formation)
  - Aggregation rate (rate of snow formation)
  - Cirrus formation (the 2-moment scheme allows supersaturation with respect to ice)
  - Freezing and Bergeron-Findeisen process

- Differences between ECHAM6-CCN and ECHAM5.5-HAM:
  - Parameterizations of radiation, cloud optical properties and aggregation rate
  - CCN from aerosol climatology vs. HAM
  - Resolution: T63L47 (mid atm) vs. T42L19

Comparisons with observations



Mixed layer ocean simulations

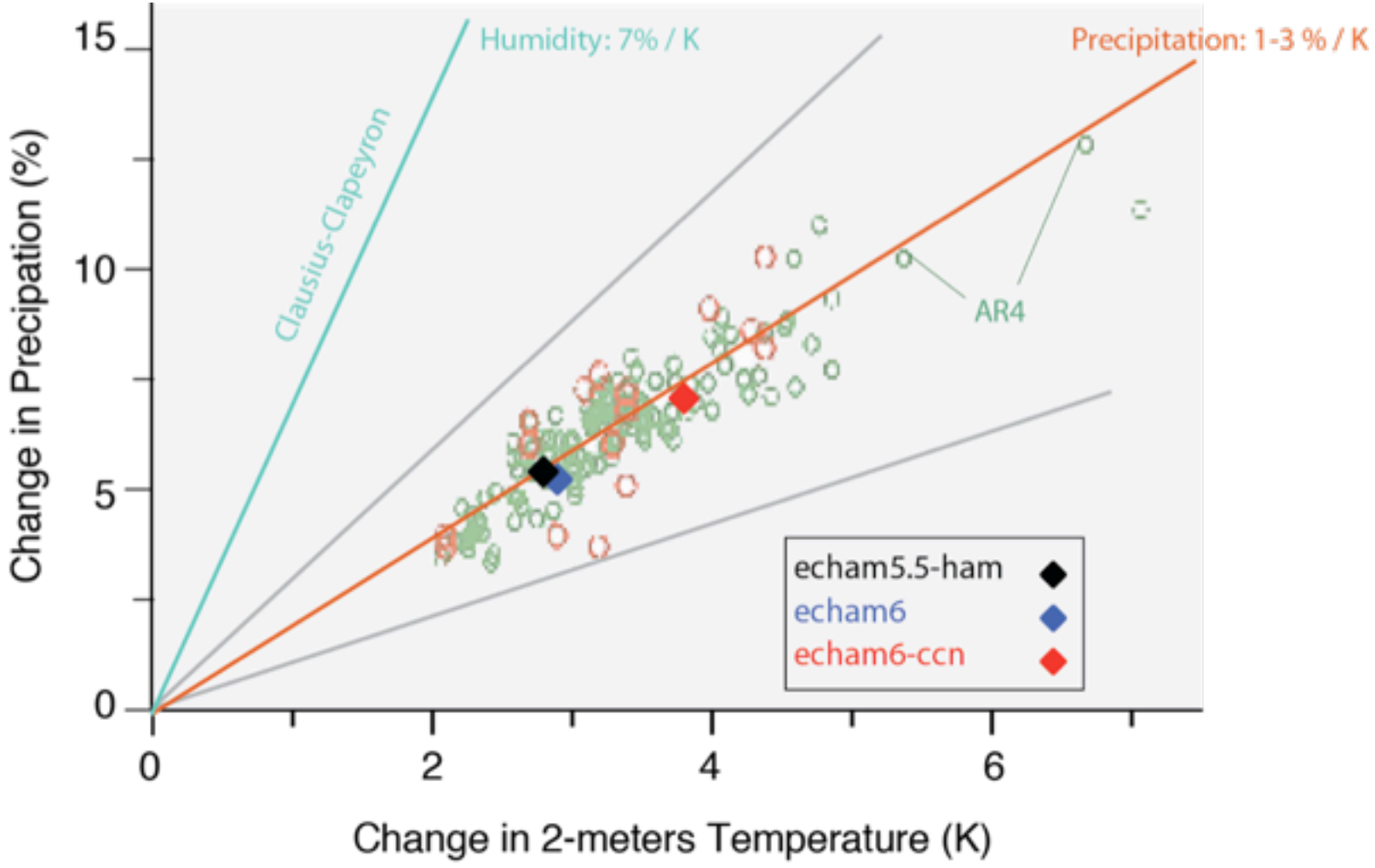


$$C_m \frac{\partial T_m}{\partial t} = H - Q$$

$$Q \simeq Q_{clim}$$

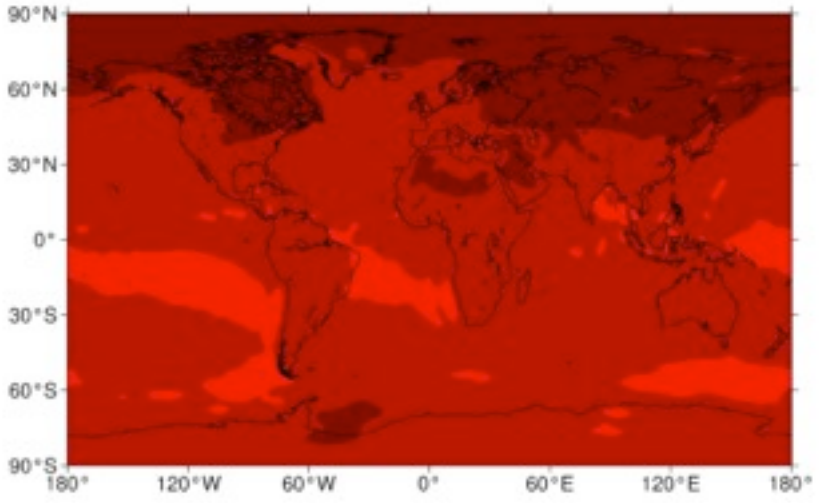
$$Q_{clim} = H_{clim} - C_m \frac{\partial T_{clim}}{\partial t}$$

Climate sensitivity

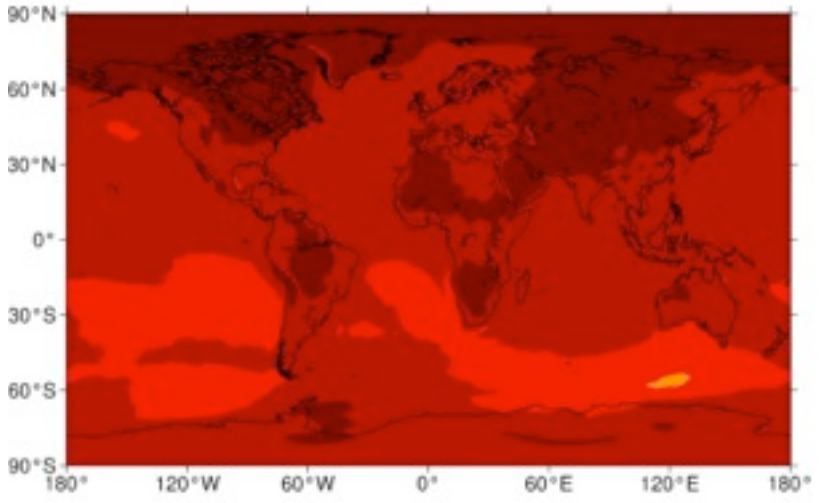


2m Temperature response

ECHAM5.5–HAM2.1, $2xCO_2$ – CTRL



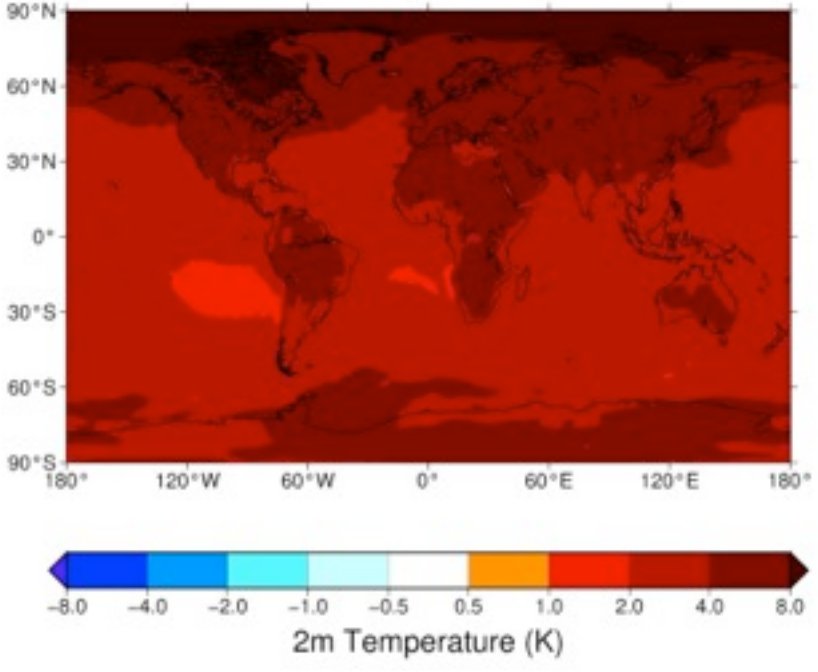
ECHAM6, $2xCO_2$ – CTRL



$\Delta T = 2.8$ K

$\Delta T = 2.9$ K

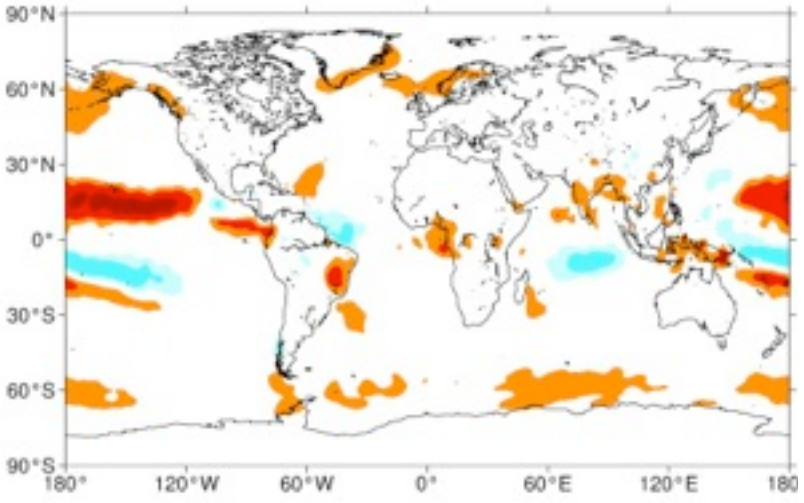
ECHAM6–CCN, $2xCO_2$ – CTRL



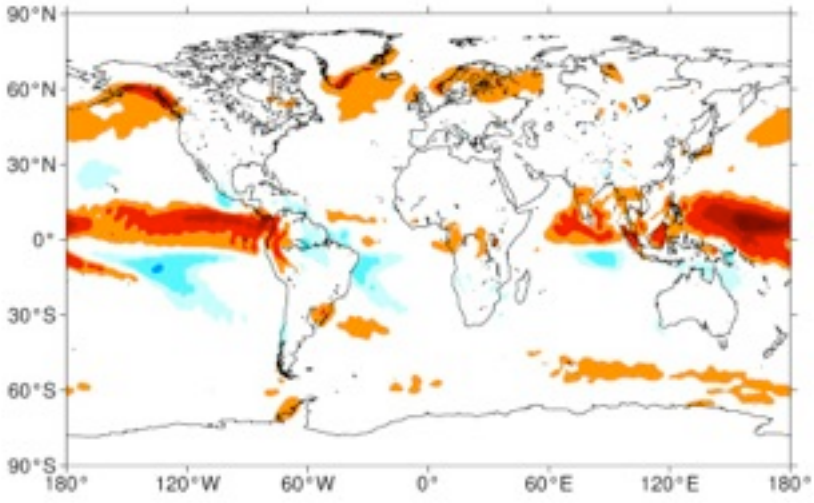
$\Delta T = 3.8$ K

Precipitation response

ECHAM5.5–HAM2.1, $2xCO_2$ – CTRL



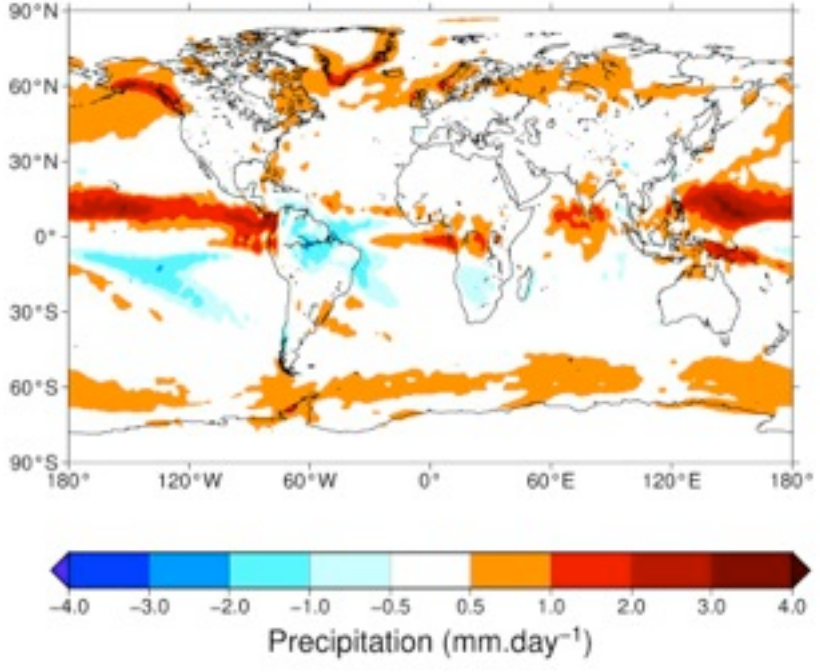
ECHAM6, $2xCO_2$ – CTRL



ΔP/P = 5.45 %

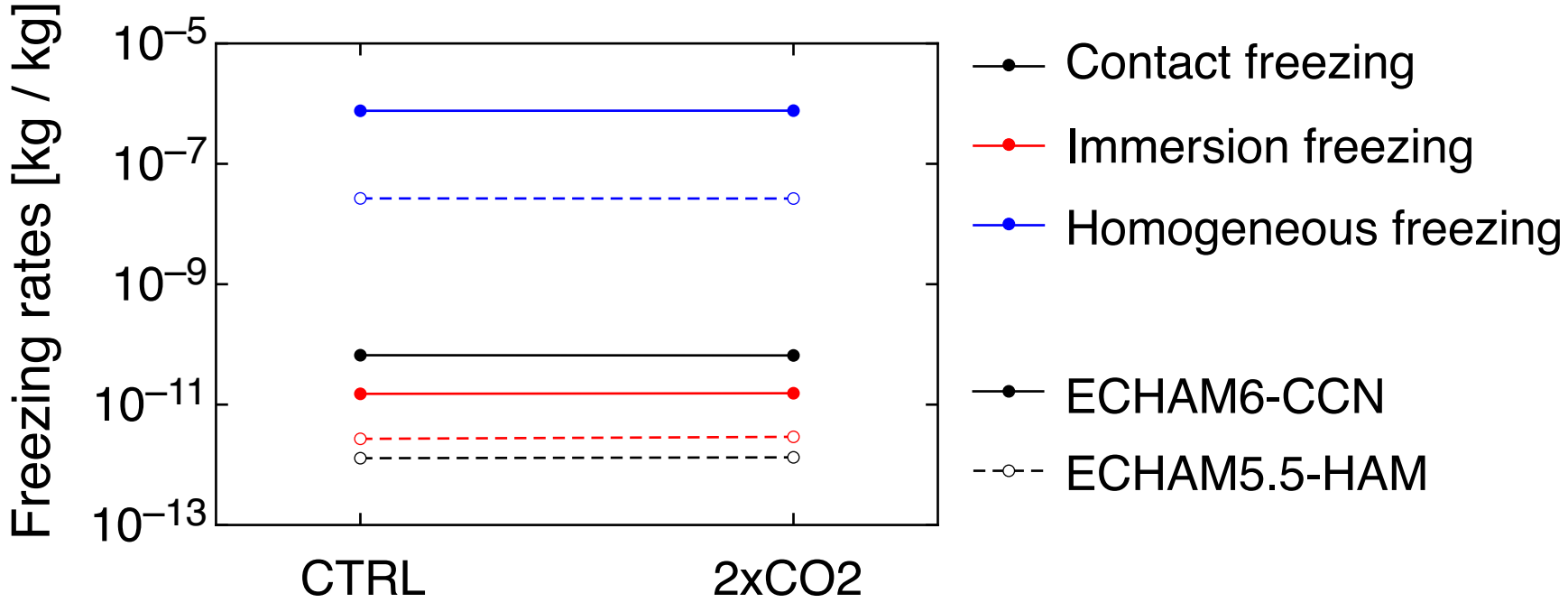
ΔP/P = 5.27 %

ECHAM6–CCN, $2xCO_2$ – CTRL



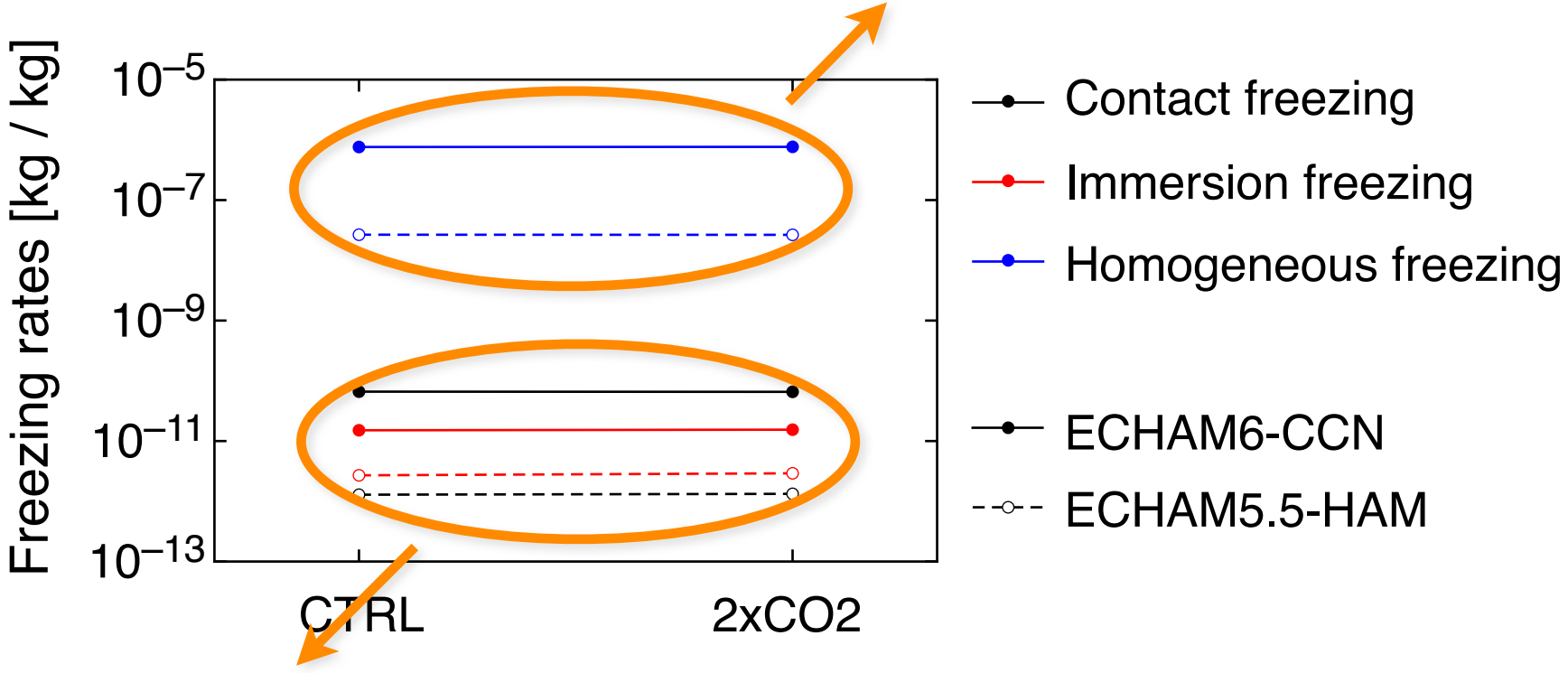
ΔP/P = 7.10 %

Different freezing mechanisms in ECHAM5.5-HAM and ECHAM6-CCN



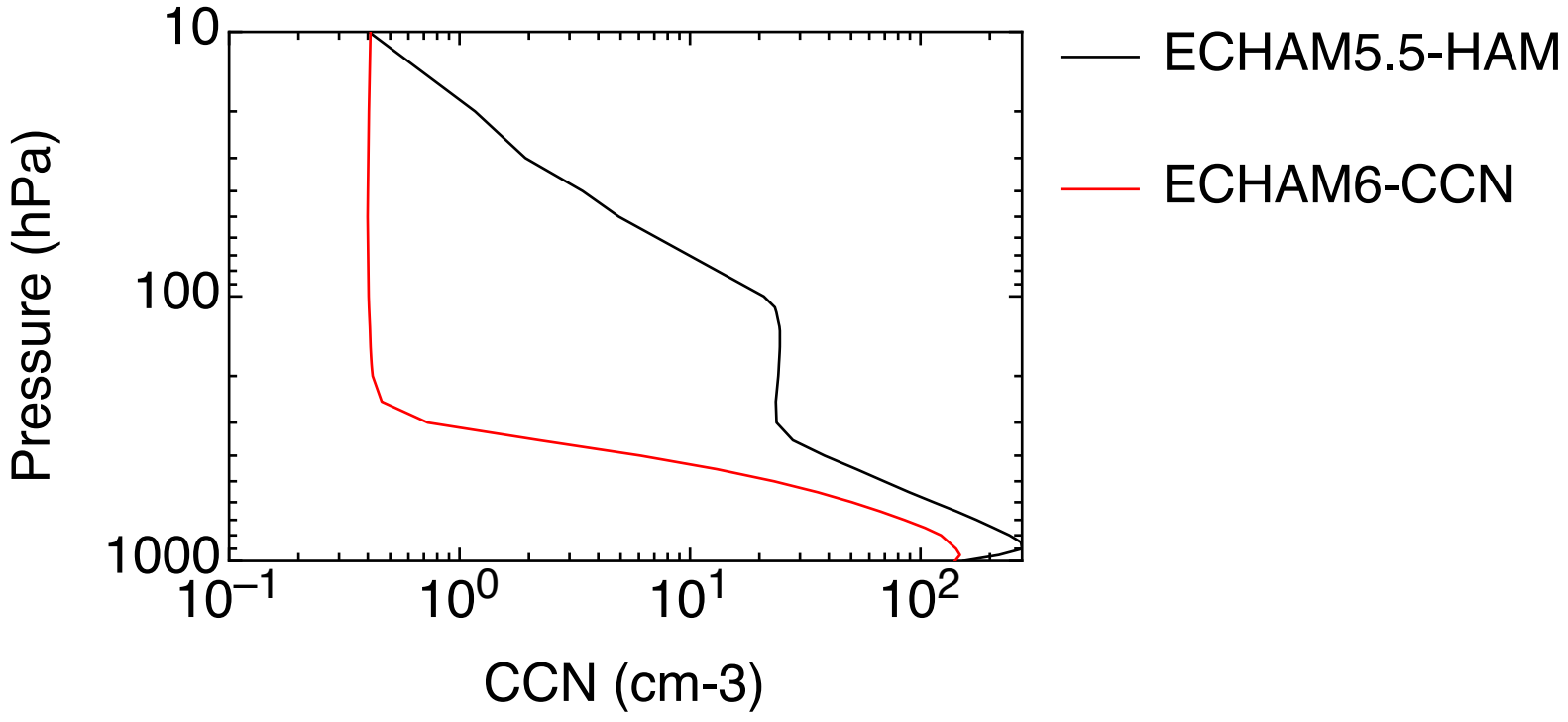
Different freezing mechanisms in ECHAM5.5-HAM and ECHAM6-CCN

More cirrus clouds => More warming



More efficient mixed-phase cloud glaciation
=>More precipitation

Different CCN profiles in ECHAM5.5-HAM and ECHAM6-CCN



- very low CCN concentrations in the case of ECHAM6-CCN may end up being a limiting factor for mixed-phase cloud formation, and therefore yield different regimes between ECHAM5.5-HAM and ECHAM6-CCN

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Conclusion

- ECHAM6-CCN presents a much higher climate sensitivity than ECHAM6 and ECHAM5.5-HAM
- The higher climate sensitivity as compared to ECHAM5.5-HAM is probably due to very different relative contributions from contact-, immersion- and homogeneous freezing
- Another likely source of differences is the very different CCN profiles (low CCN in upper troposphere in the case of ECHAM6-CCN)
- Still work-in-progress, further investigations to come soon!
- Possible surrogate for a CCN climatology: diagnostics from a full ECHAM6-HAM run

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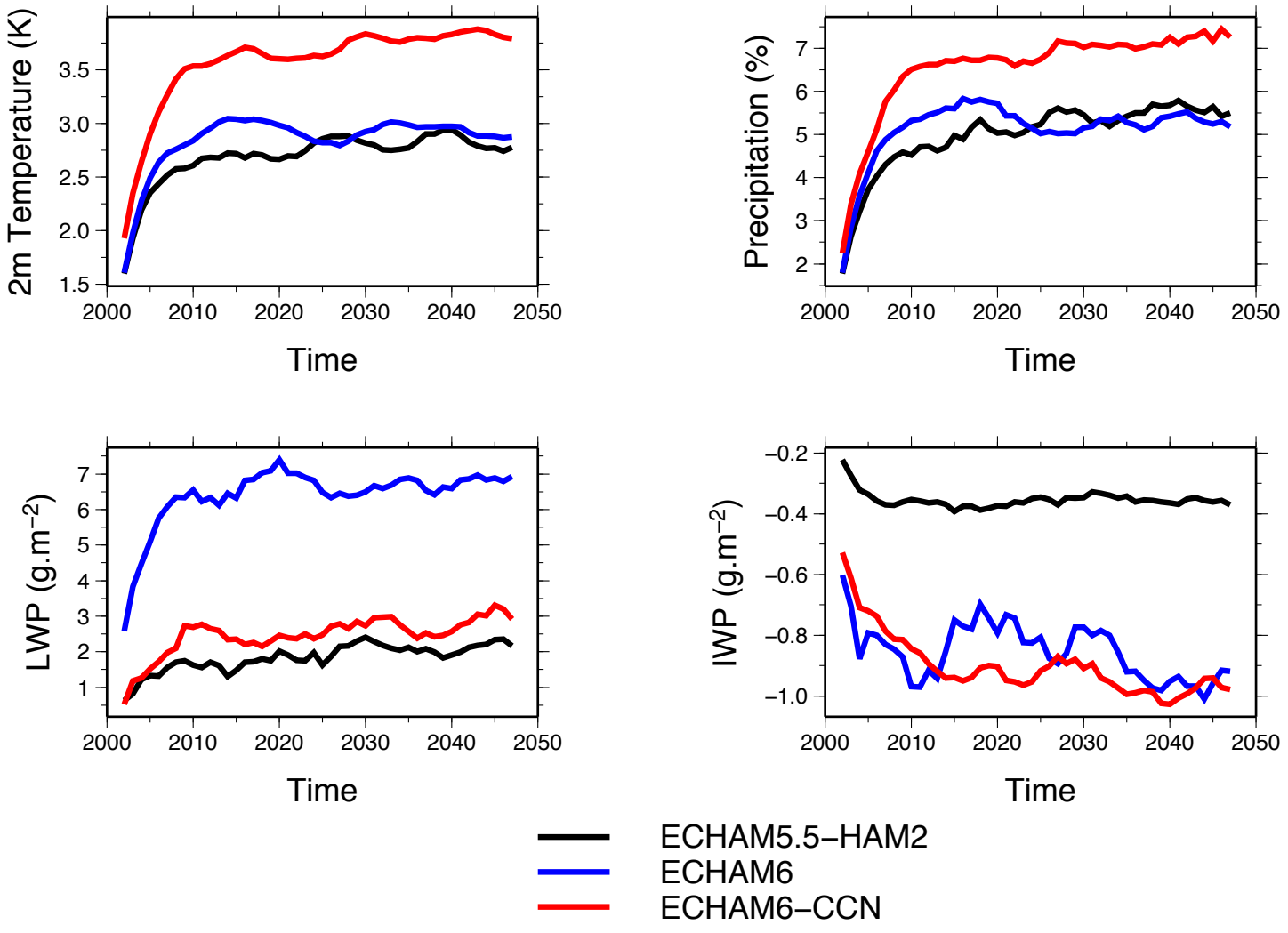
Annex

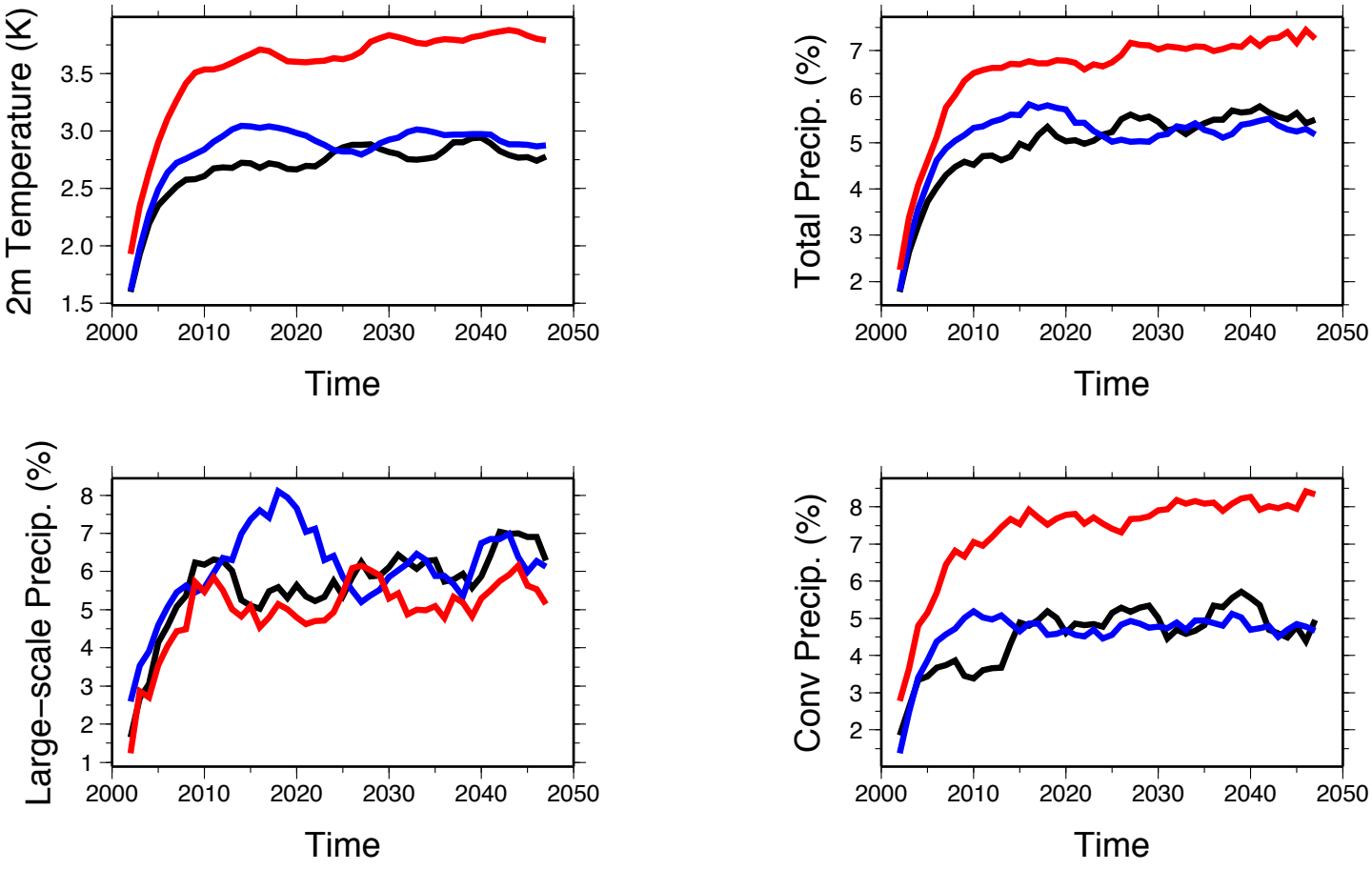
Time series

$2xCO_2$ – CTRL

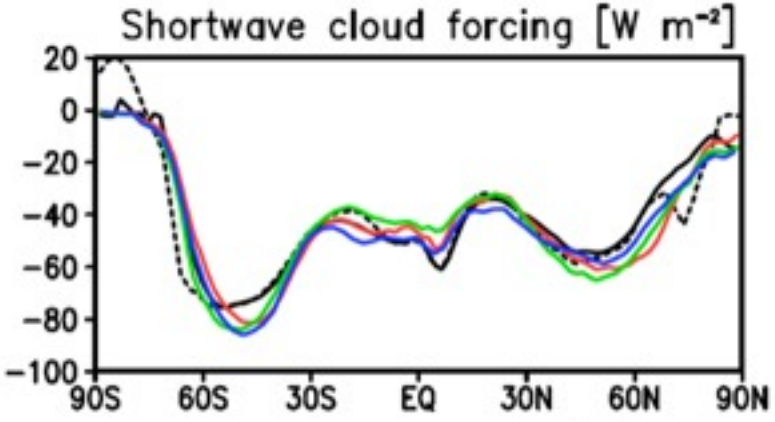


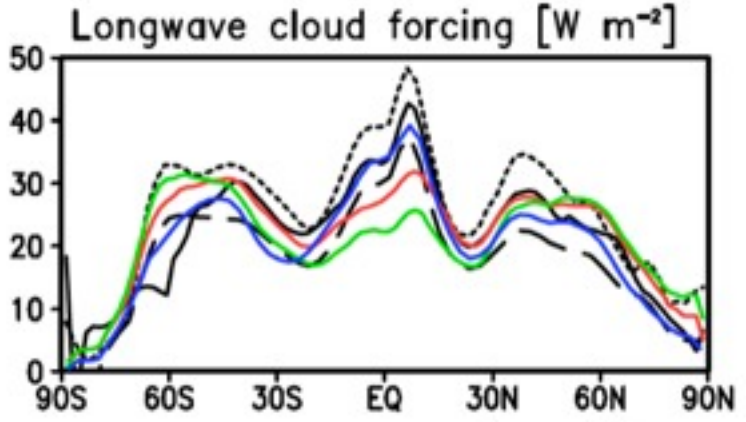
Convective vs stratiform precipitations

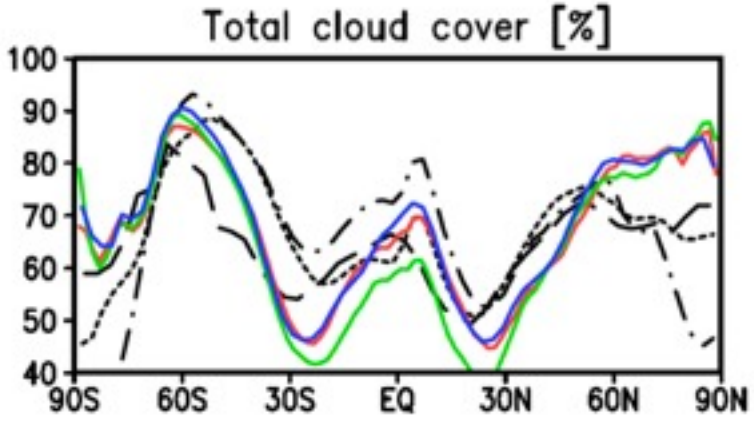
$2xCO_2$ – CTRL

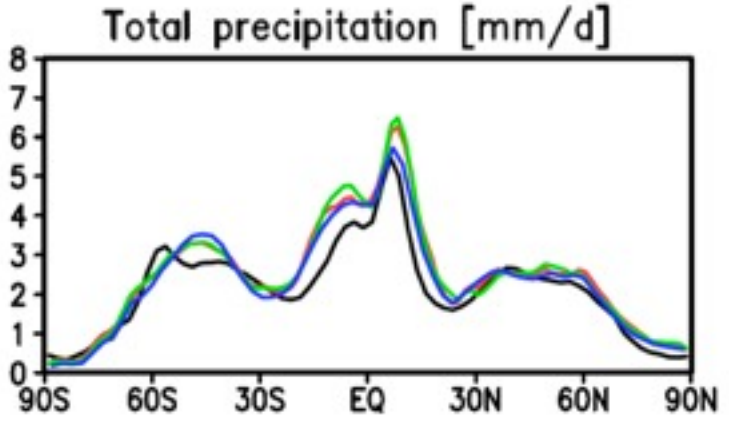


Comparisons with observations

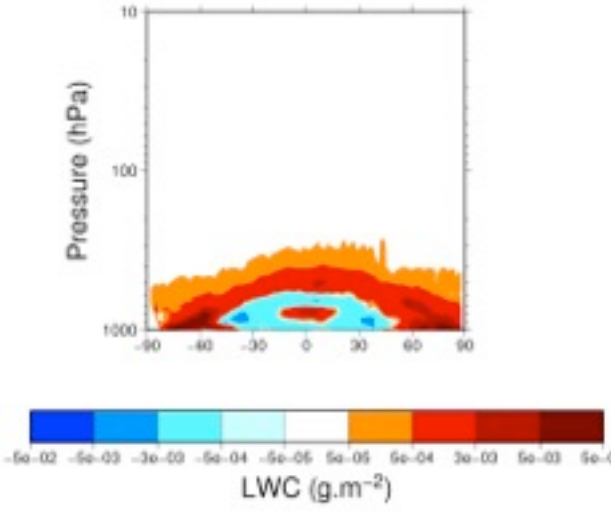




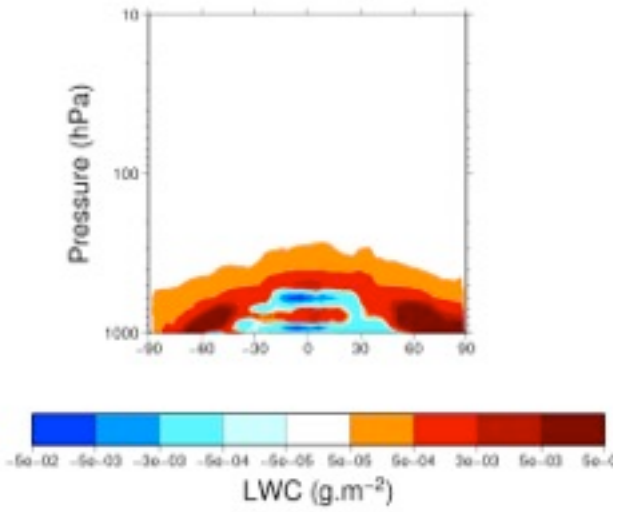




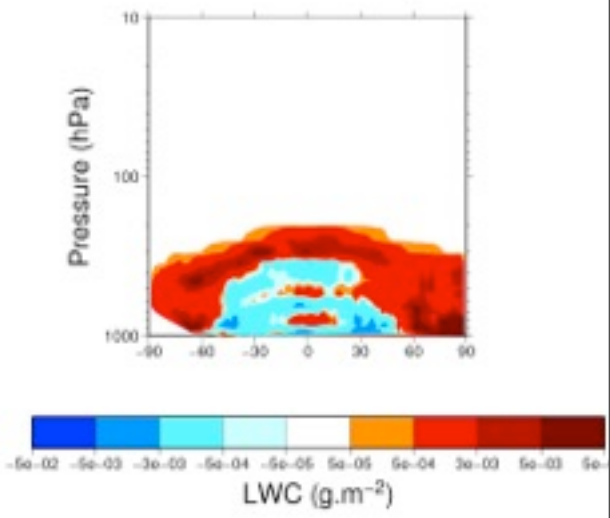
ECHAM5.5–HAM, $2xCO_2$ – CTRL



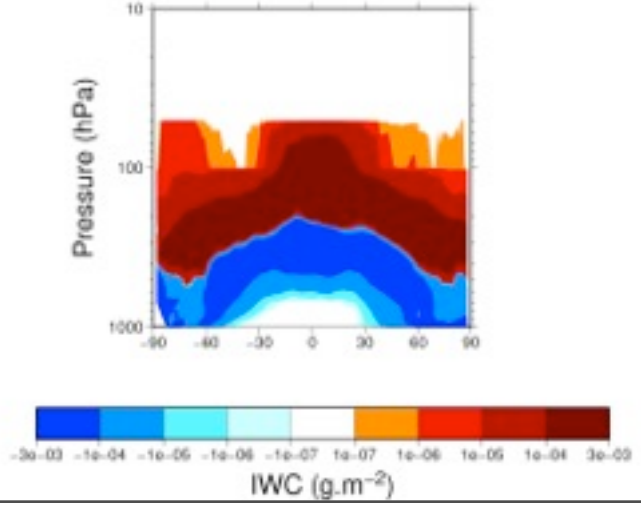
ECHAM6, $2xCO_2$ – CTRL



ECHAM6–CCN, $2xCO_2$ – CTRL



ECHAM5.5–HAM, $2xCO_2$ – CTRL



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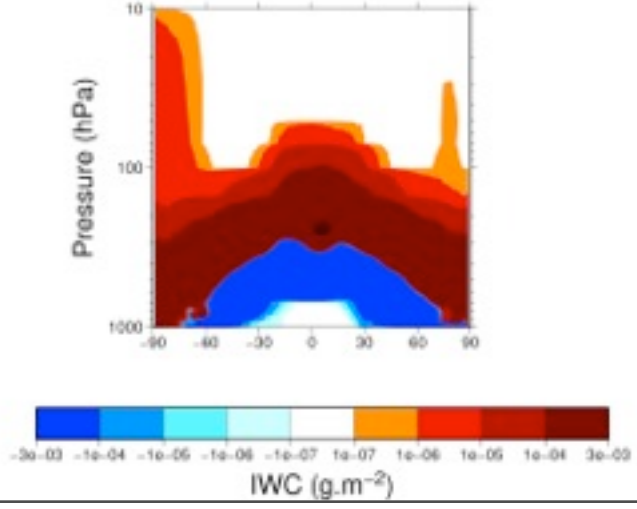

ECHAM6–CCN, $2xCO_2$ – CTRL