Progress with scenarioMIP
&
Some initial changes in model behaviour compared to CMIP5

Colin Jones

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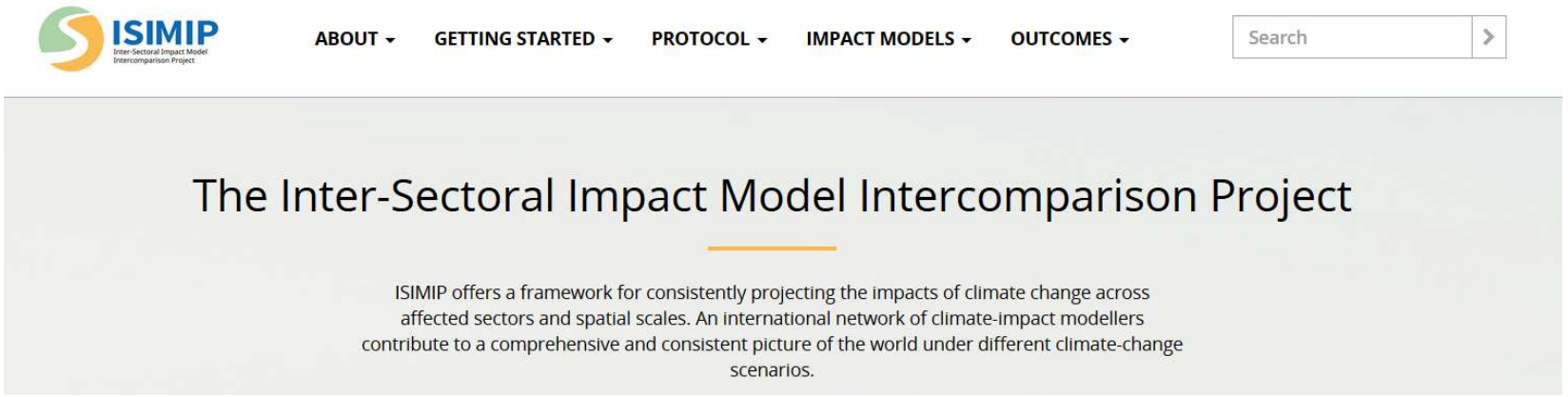
Presented at a CRESCENDO-ISIMIP workshop on selecting CMIP6 ESMs for ISIMIP3; which feeds into AR6 WG II (impacts) in the same way CMIP6 feeds into AR6 WGI (WGII report released 6 months after WGI).



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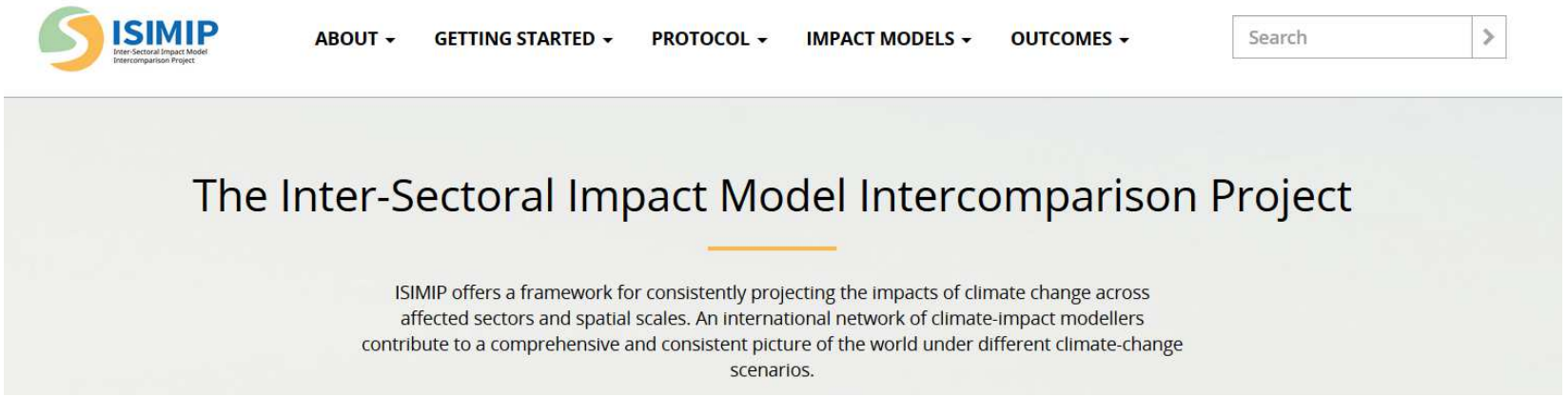

A subset of CMIP6 models will be used for ISIMIP3: UKESM1 should be one of these

Having the required data on the ESGF by ~Sept 2019 is a prerequisite for being chosen

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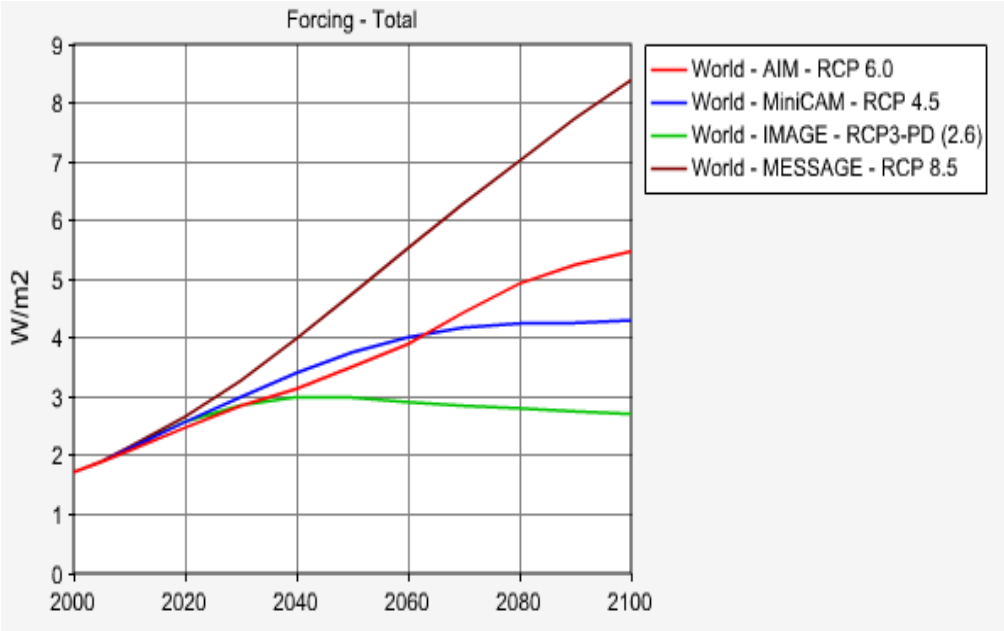
Background: CMIP5 & SSPs

- 4 Representative Concentration Pathways: 2.6, 4.5, 6.0, 8.5 Wm^{-2}
- 5 Shared Socioeconomic Pathways (SSPs)



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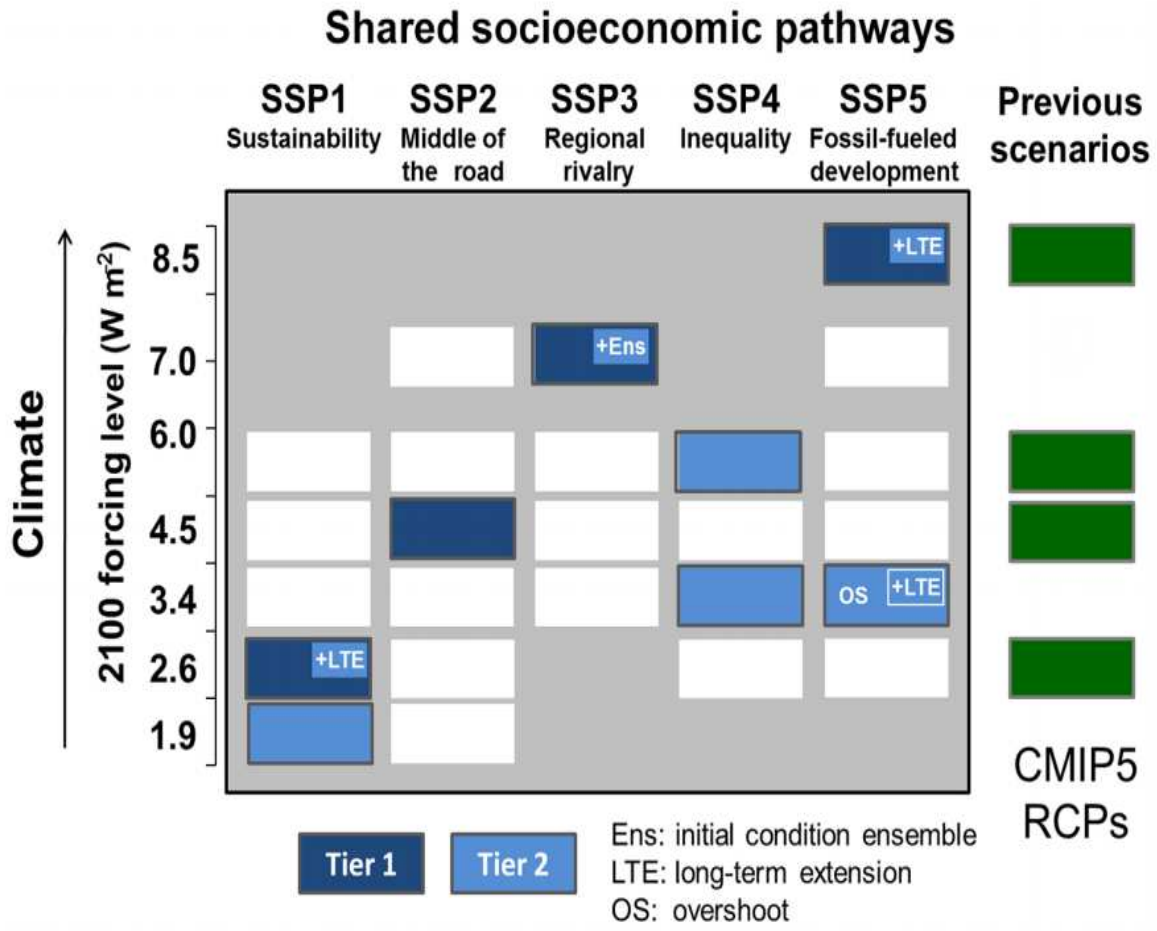
O'Neill et al., 2015

The (CMIP6) scenarioMIP matrix

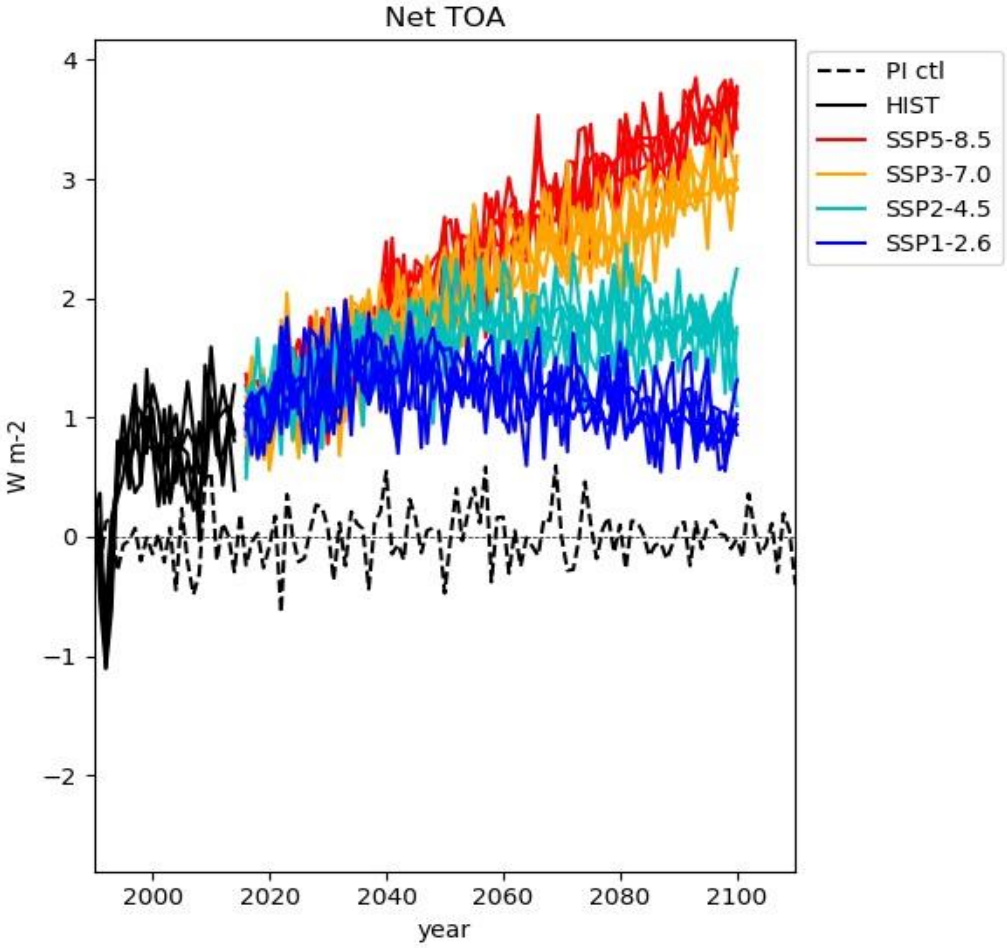


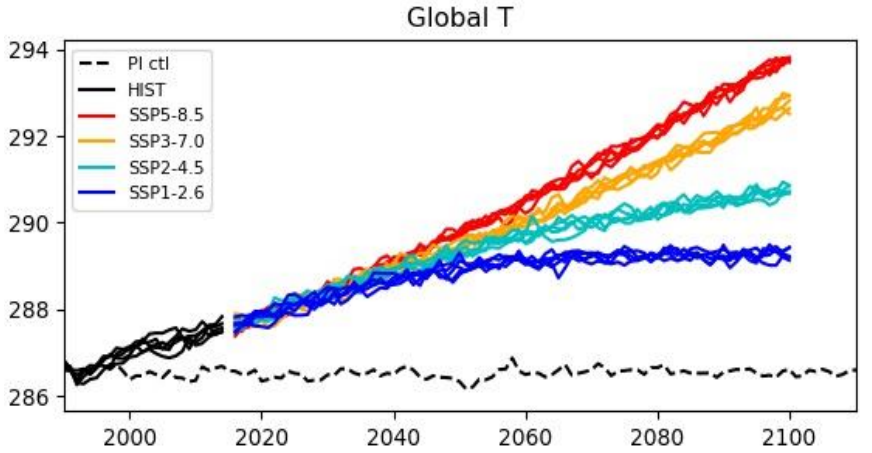
Designed to allow a joined up analysis of future Earth system change across:

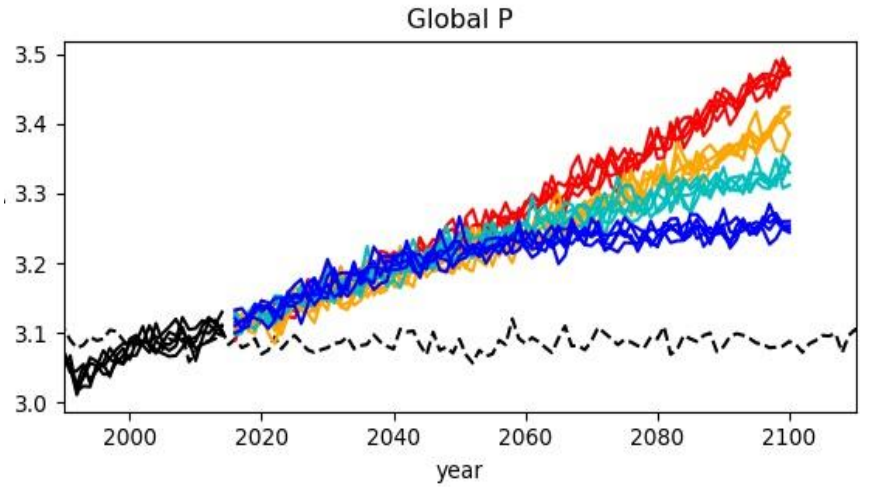
- Earth system-climate response
- Adaptation challenges considering both socio-economic scenarios and climate change impacts
- Mitigation potential/demands considering the future socio-economic backdrop to policy making

Net TOA radiative forcing and global temperature and precipitation response

UKESM1 piControl, historical and 4 Tier 1 ssp126, ssp245, ssp370 and ssp585







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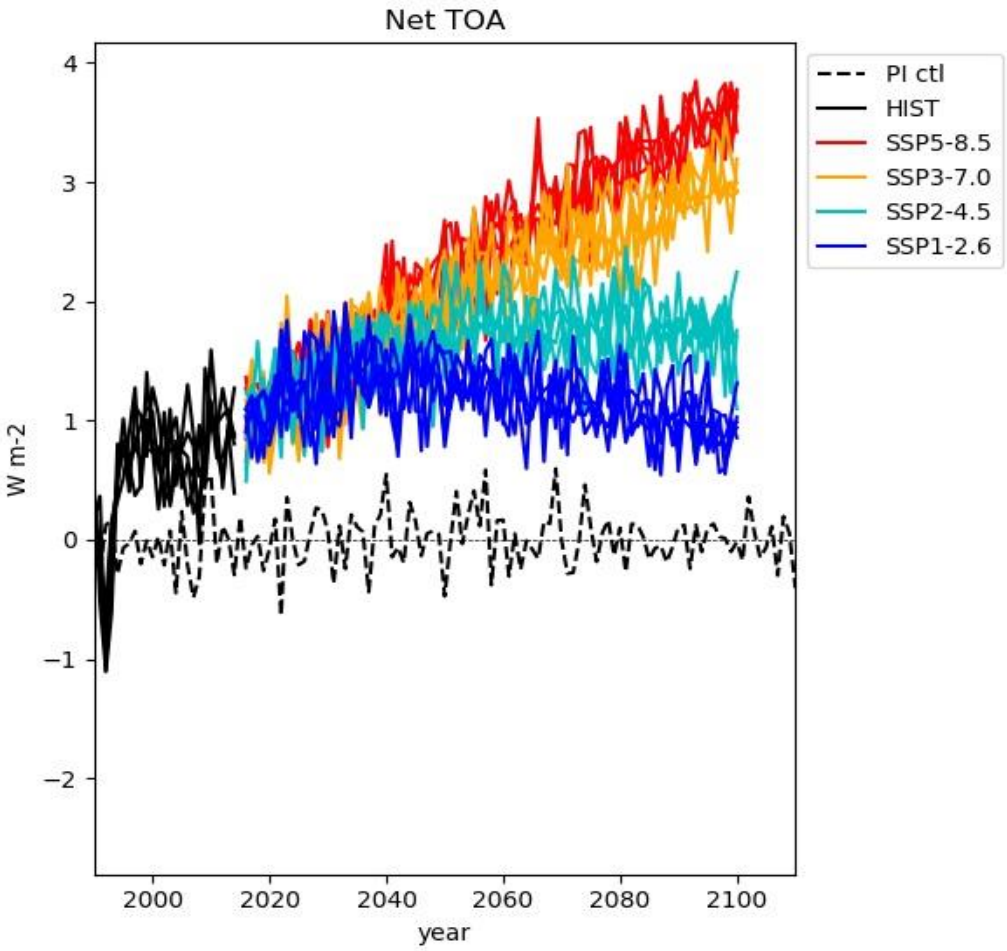

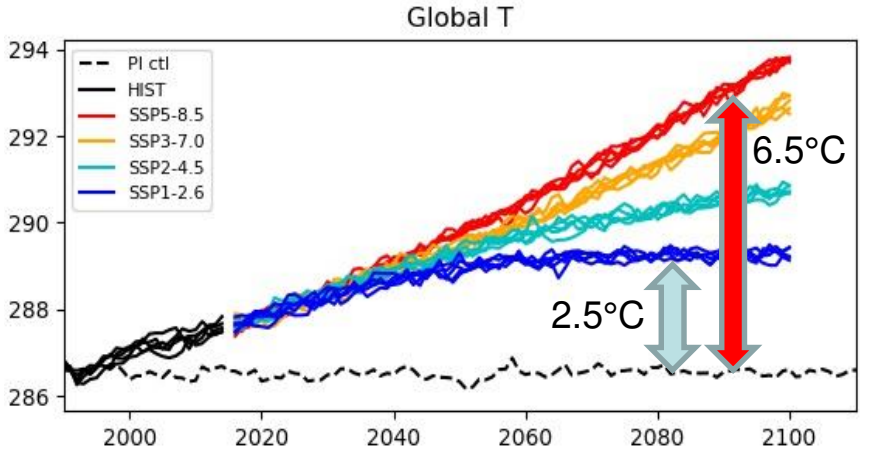

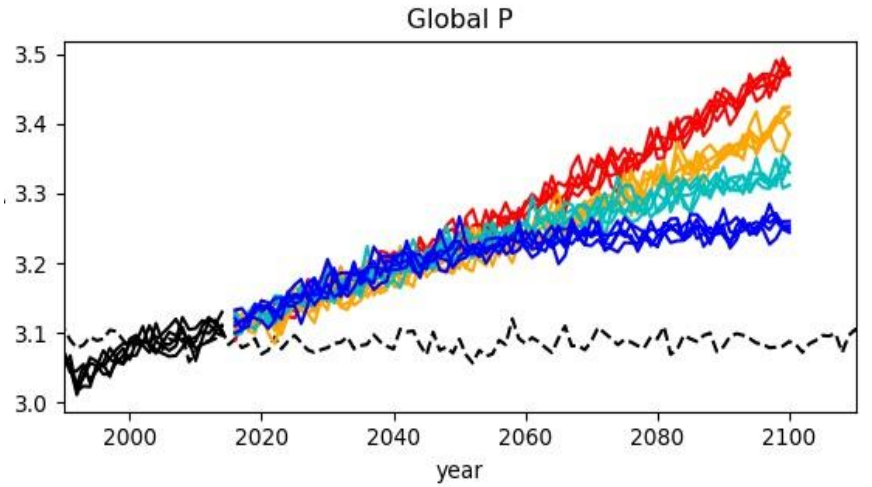

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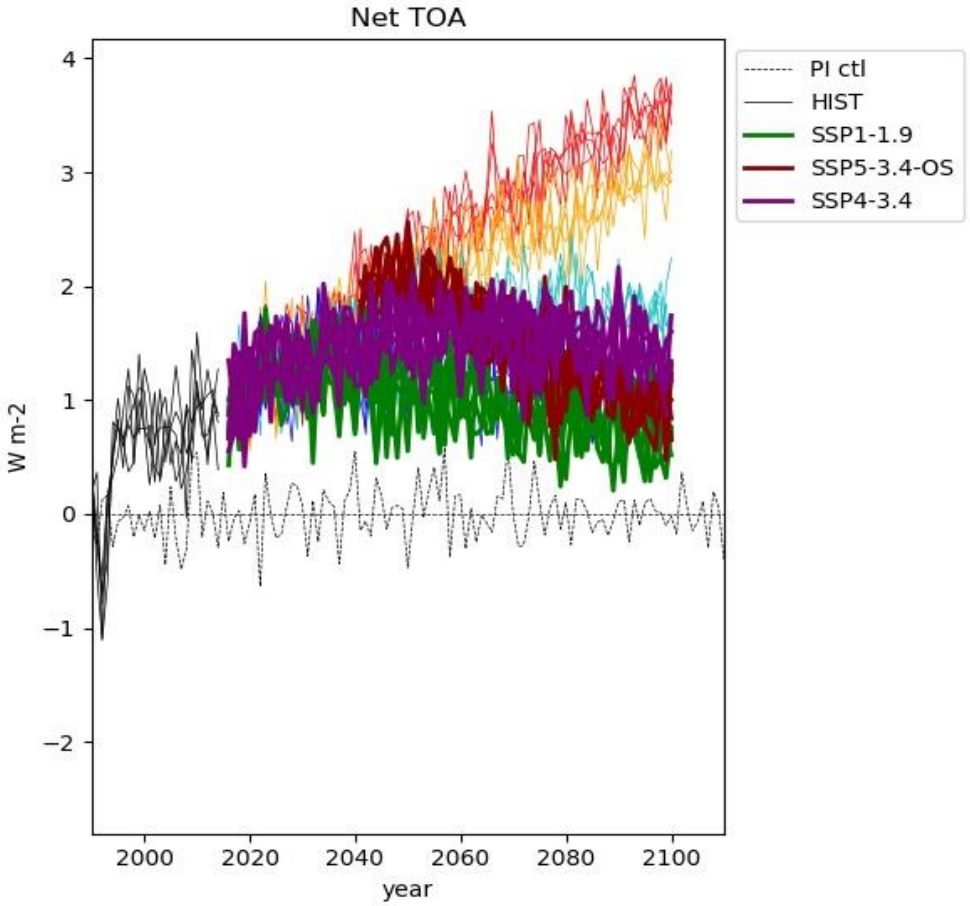
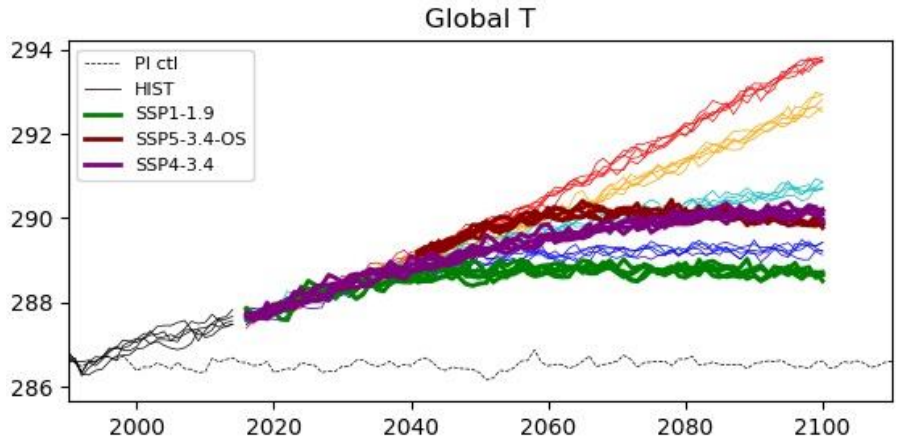
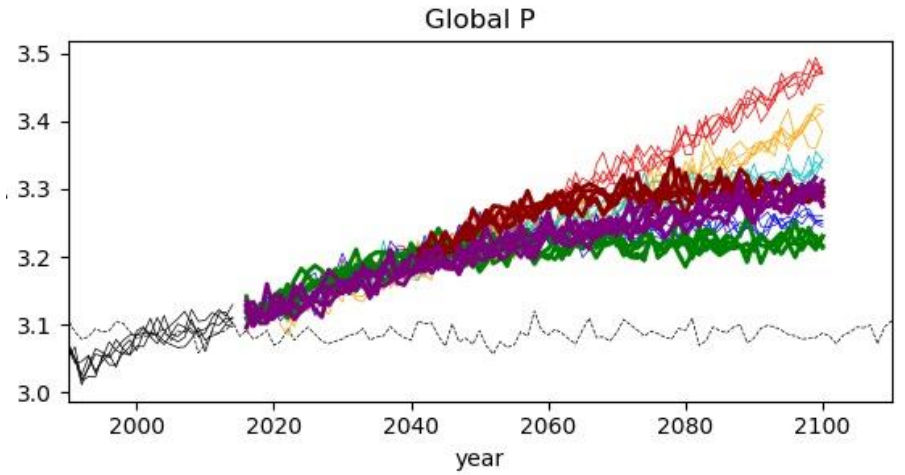
Net TOA radiative forcing and global temperature and precipitation response

UKESM1 piControl, historical and 3 Tier 2 ssp119, ssp434 and ssp534-OS







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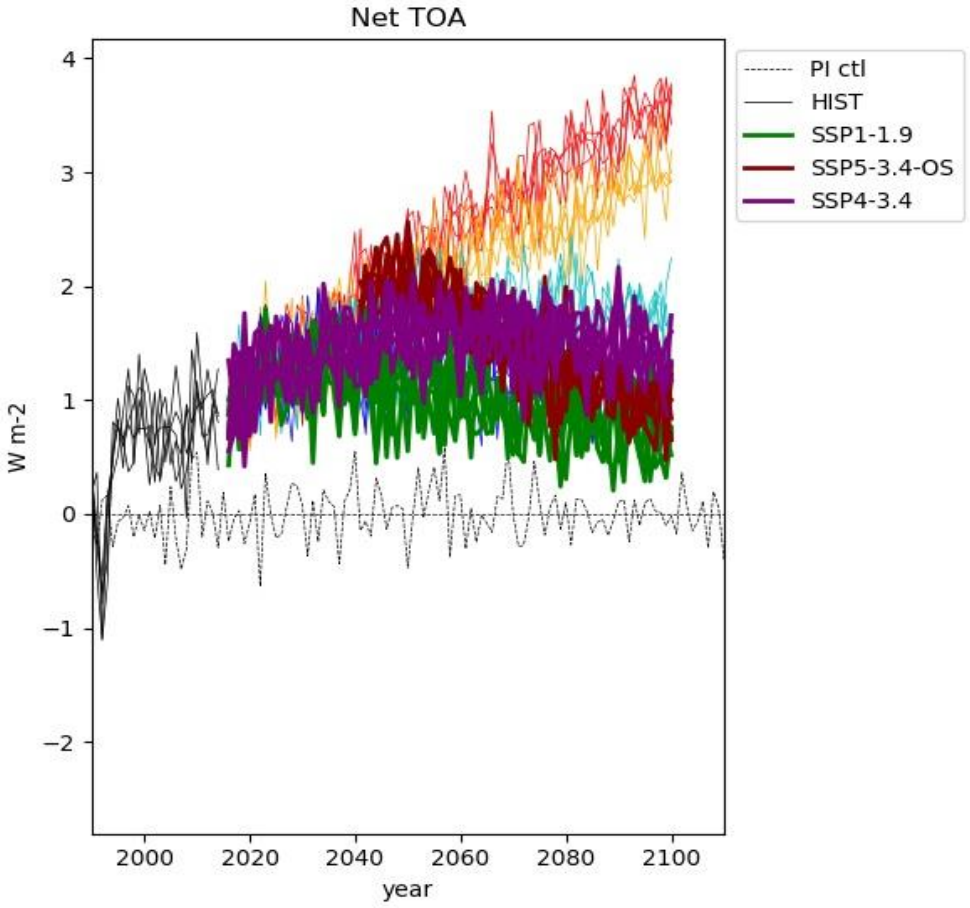

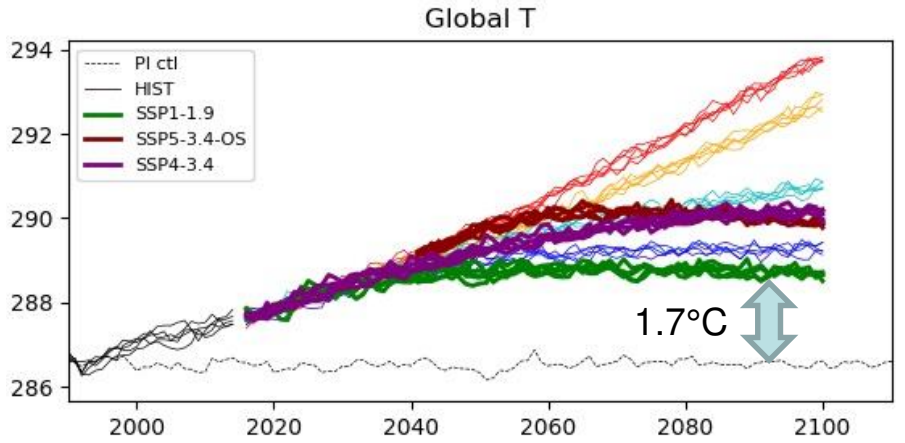

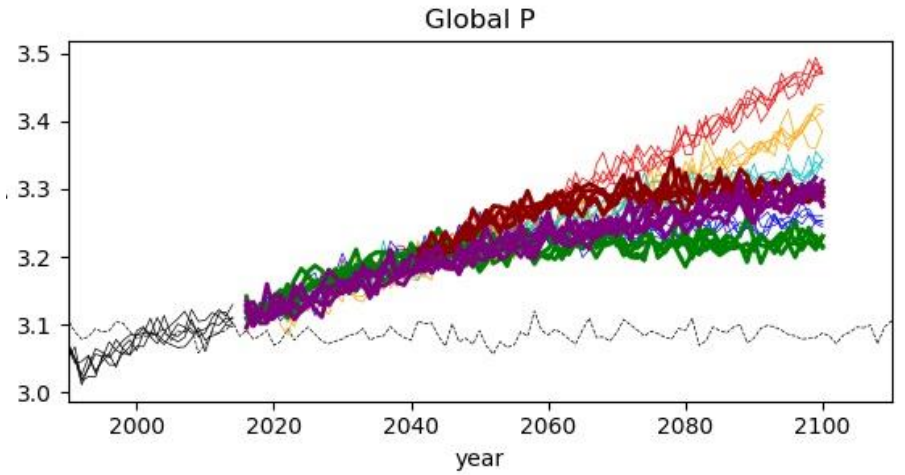

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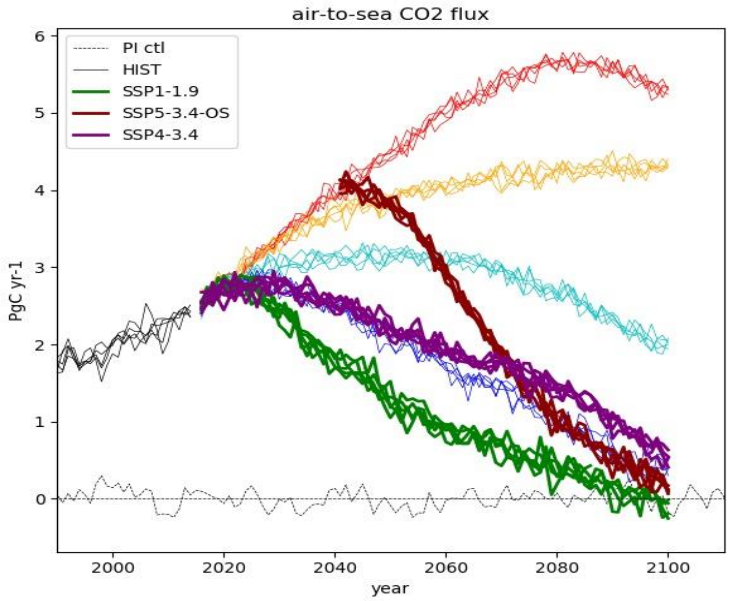
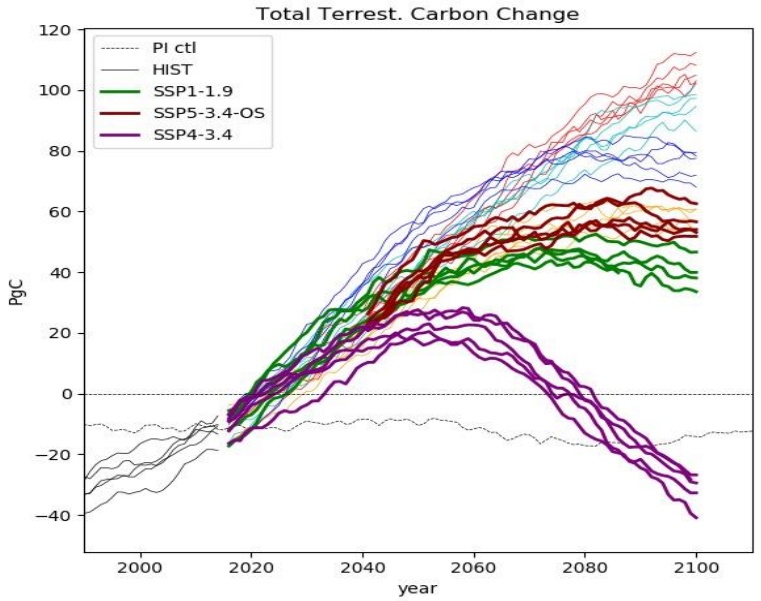
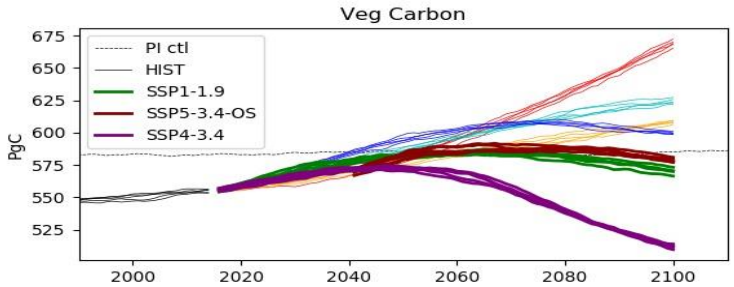
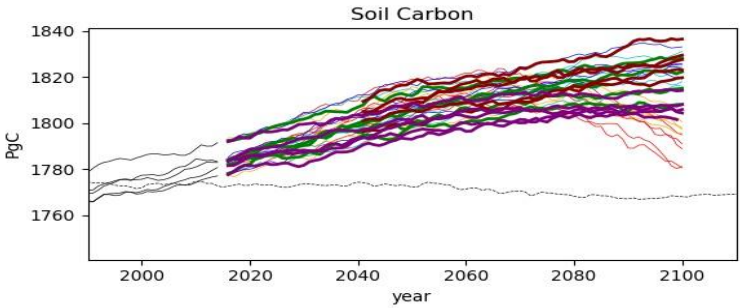
Marine and carbon uptake in the future projections (per ssp)









Terrestrial C uptake varies across the ssps : Different Land use ?

Ocean uptake decreases rapidly in overshoot/stabilization ssps.

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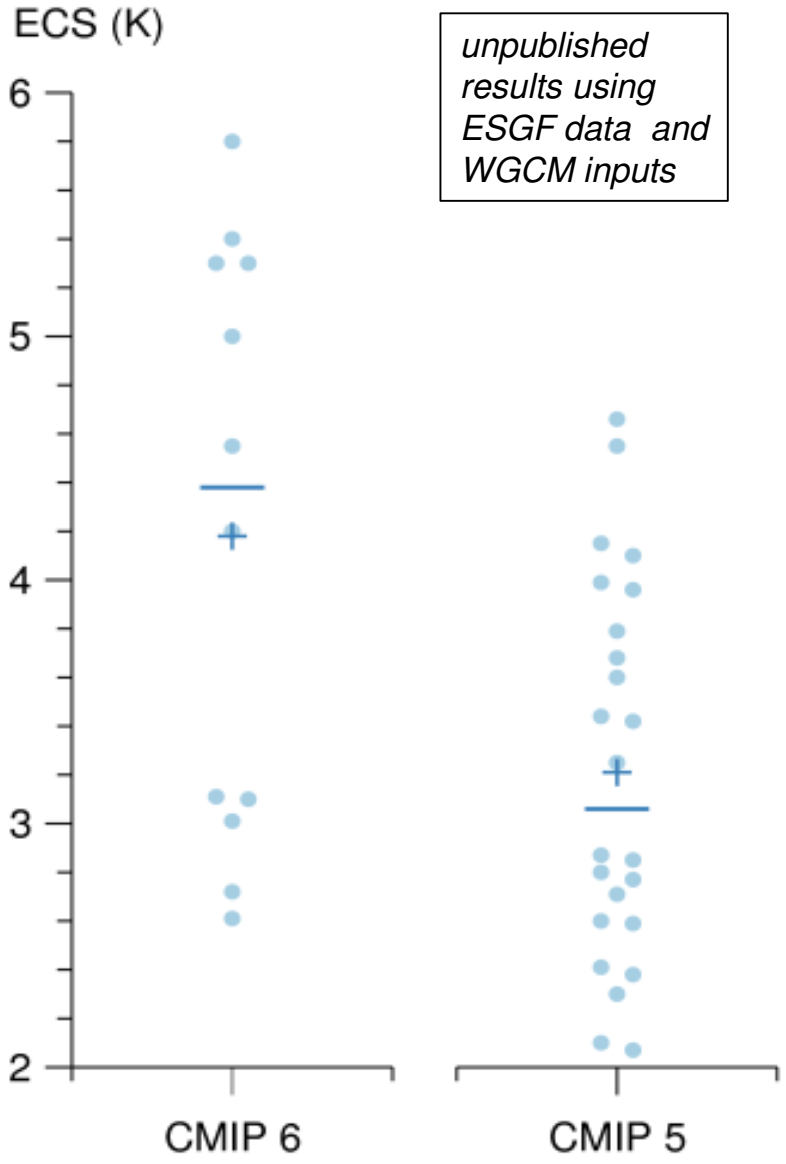
Update from the WCRP CMIP6 workshop, Barcelona

Emergent properties of the CMIP6 ensemble: ECS

- Even at this early stage, clear evidence there will be a number of high sensitivity models (above top of the CMIP5 range)
- WCRP sponsored ECS assessment will likely lower *very unlikely* from 6C to ~4.5C



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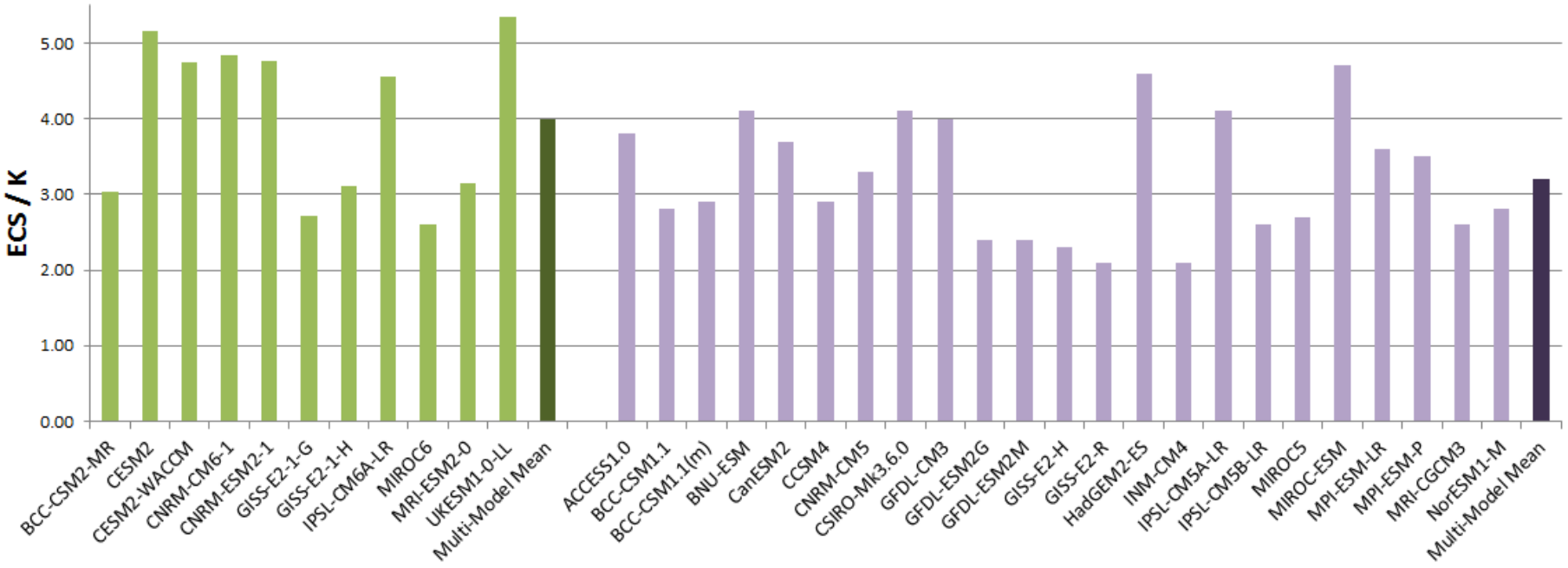
ESMValTool Result Browser at
http://cmip-esmvaltool.dkrz.de/

Equilibrium Climate Sensitivity

Change in global mean surface temperature at equilibrium due to a doubling of atmospheric CO_2 concentration



CMIP6

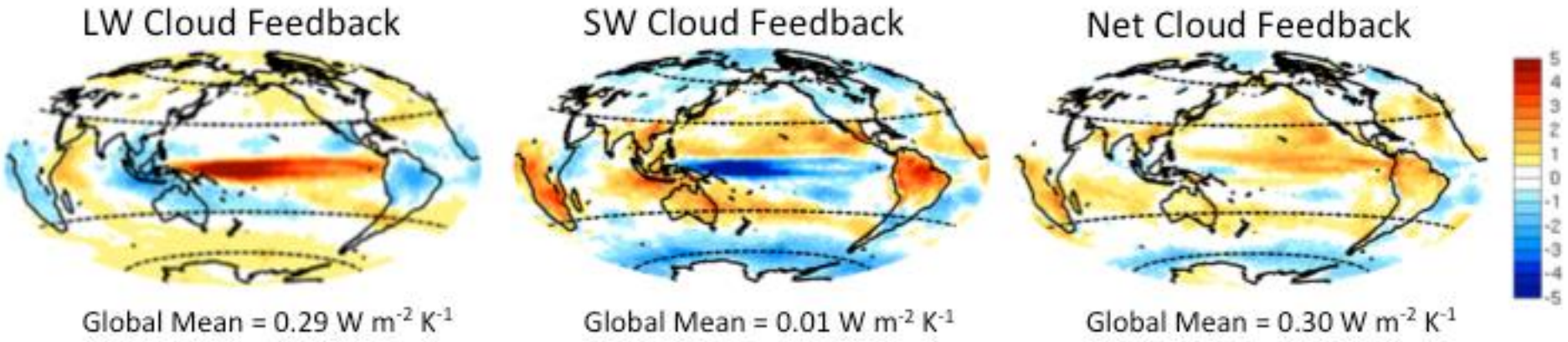
Current Range: 2.7 – 5.3 K (mean: 4.0 K)

CMIP5

Range: 2.1 – 4.7 K (mean: 3.2 K)

Changes in cloud feedbacks CMIP5 to CMIP6

Cloud feedbacks in 2xCO_2 experiments in CMIP5 models



- There is some cancellation between SW and LW cloud feedbacks
- In terms of net cloud-radiation feedback, most (tropical) cloud feedbacks are positive (amplifying warming)
- Apart from in the high (>50°S) Southern Hemisphere

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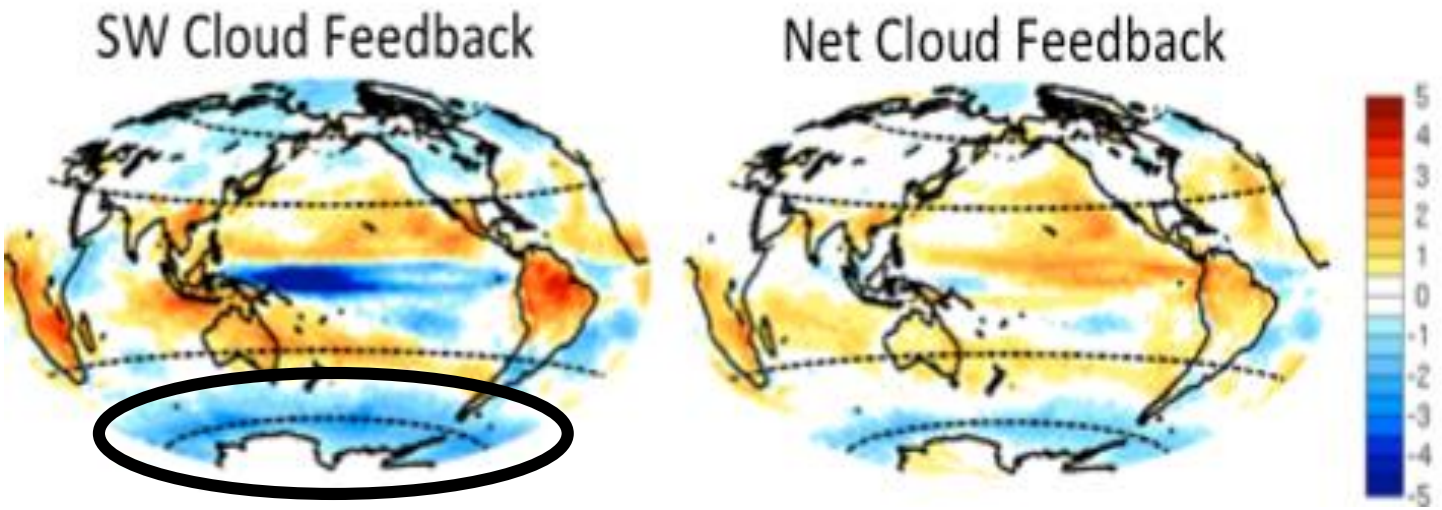
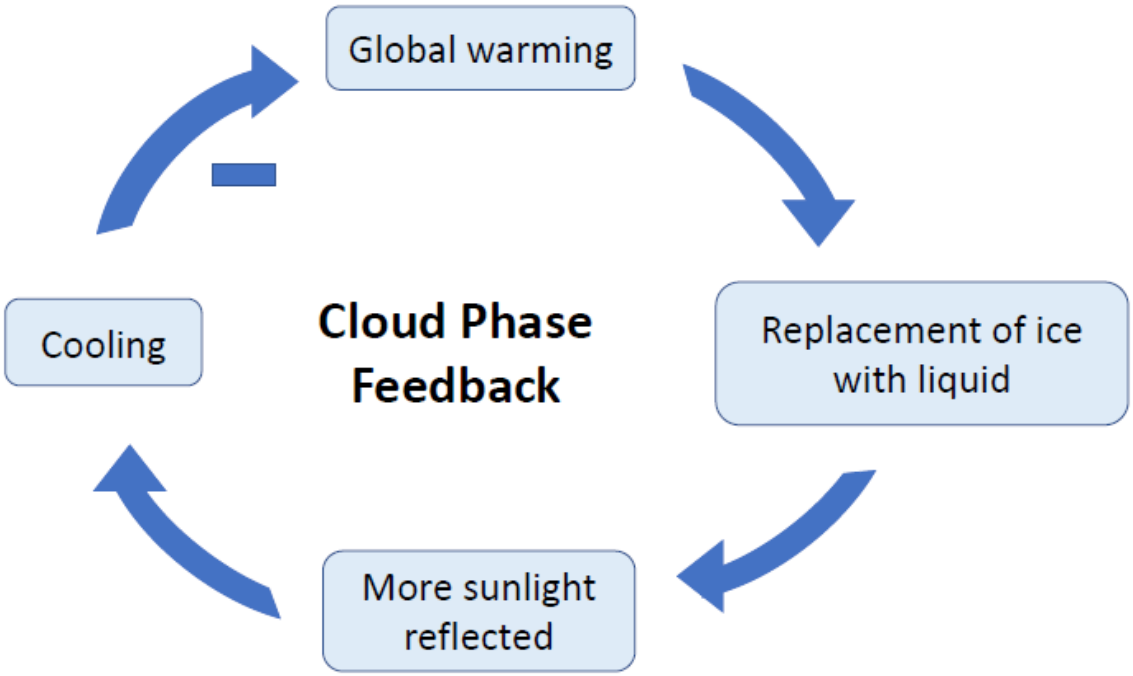
Cloud feedbacks in CMIP5 models



- **CMIP5 models:** "present-day" clouds in this region primarily composed of ice crystals
- As the region warms in the simulated future, these clouds change (microphysical) phase to be composed mainly of liquid droplets
- For a given water content a cloud made up of (physically smaller) liquid droplets will be more reflective to solar radiation than the "same" cloud composed of (larger) ice crystals
- A predominantly liquid cloud will also tend to precipitate less than a cloud composed of both ice and liquid, resulting in more water staying in the liquid cloud
- The above 2 points cause the **negative (cooling)** cloud optical depth feedback in CMIP5 models, partially balancing the tropical **positive (warming)** cloud feedbacks

CMIP5: Mid to high latitude negative cloud (phase) optical depth feedback acts to decrease global warming (and climate sensitivity).



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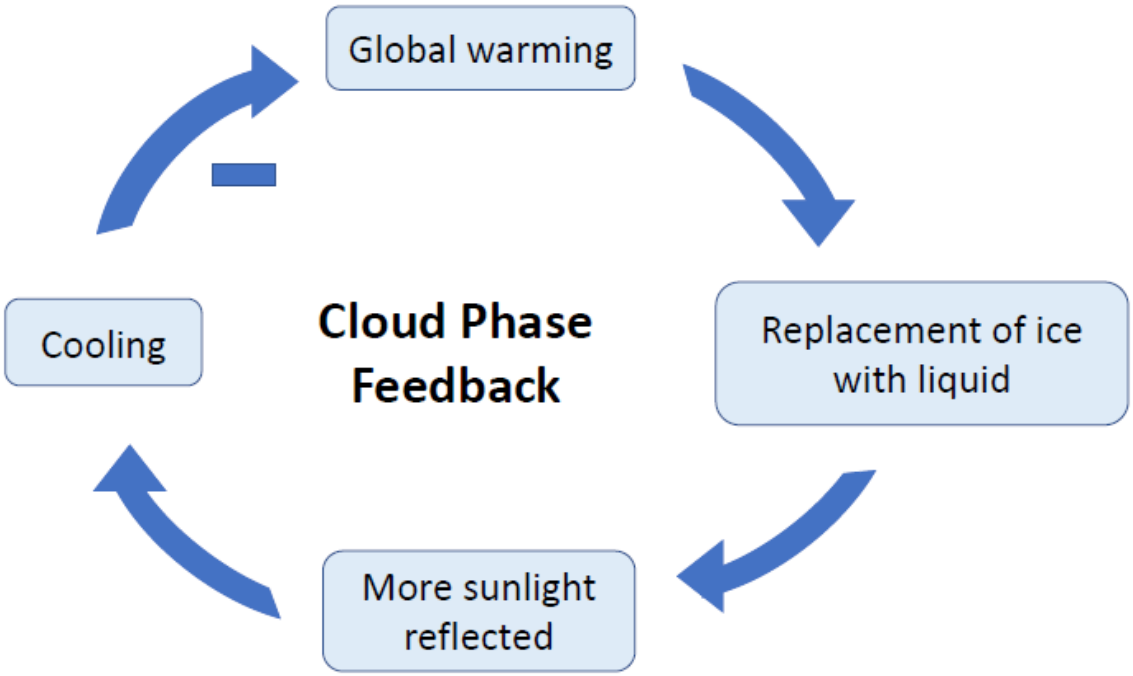

Problem: Observations suggest (present-day PD) clouds in this region **are not** primarily composed of ice crystals rather mainly of **super-cooled liquid droplets**

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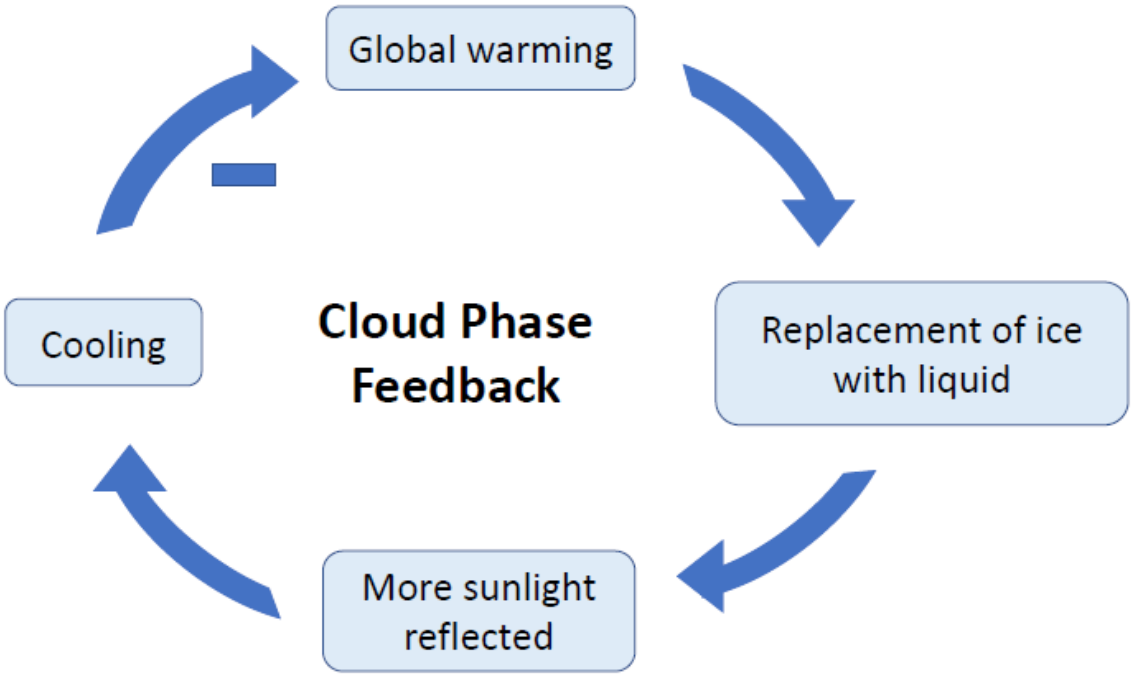
CMIP5: Mid to high latitude negative cloud (phase) optical depth feedback acted to decrease global warming (and climate sensitivity).



Problem: Observations suggest (present-day PD) clouds in this region **are not** primarily composed of ice crystals rather mainly of **super-cooled liquid droplets**

In CMIP5 (& earlier models) the negative cloud phase feedback may be spurious (or too large) because of a **systematic bias in cloud phase in the present-day**

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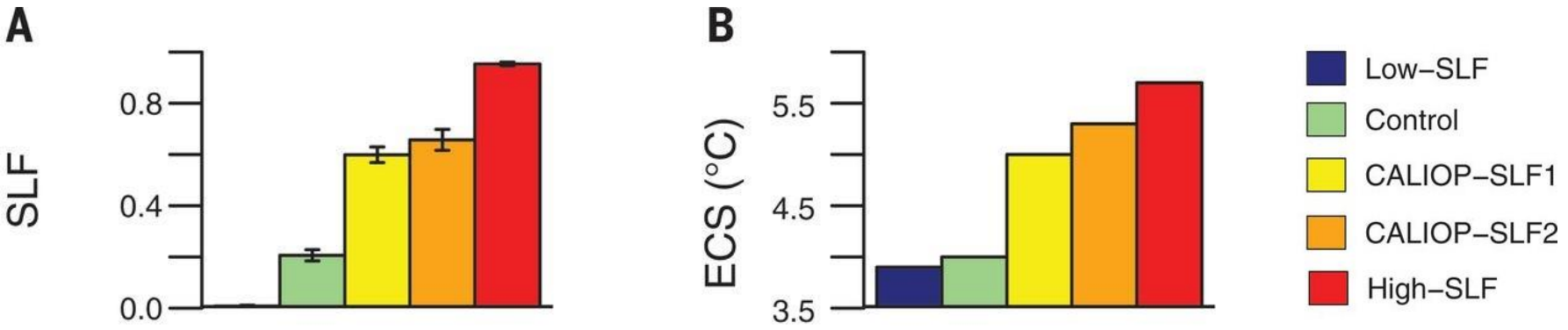
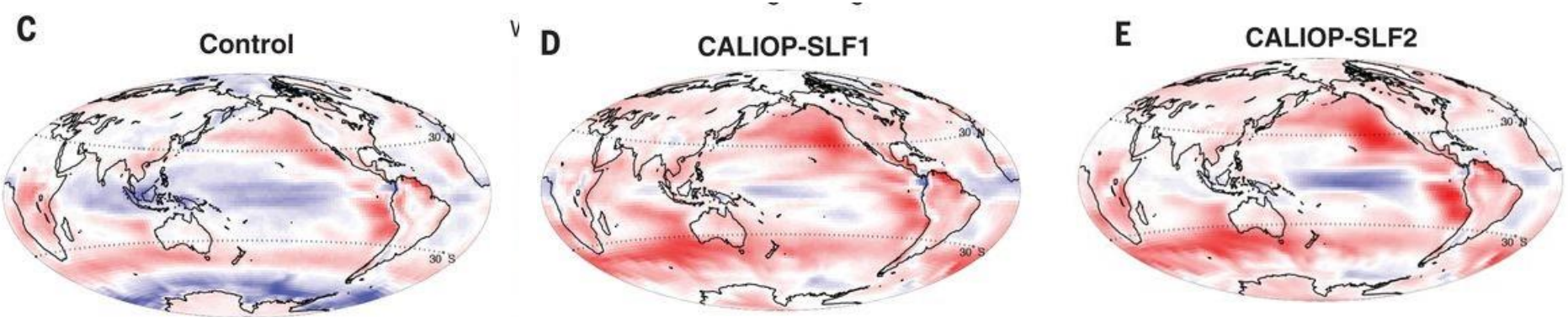
Tan et al. 2016: Forced CAM5 to have the “correct” present-day amount of super-cooled water (SCL) over the Southern Ocean. This led to an increase in the model climate sensitivity from ~3.7K to 5.3K as the SCL fraction increased



The primary driver of this change in ECS was reduction/removal in the Southern Ocean negative (cloud phase/optical depth) feedback



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ESMValTool Result Browser at
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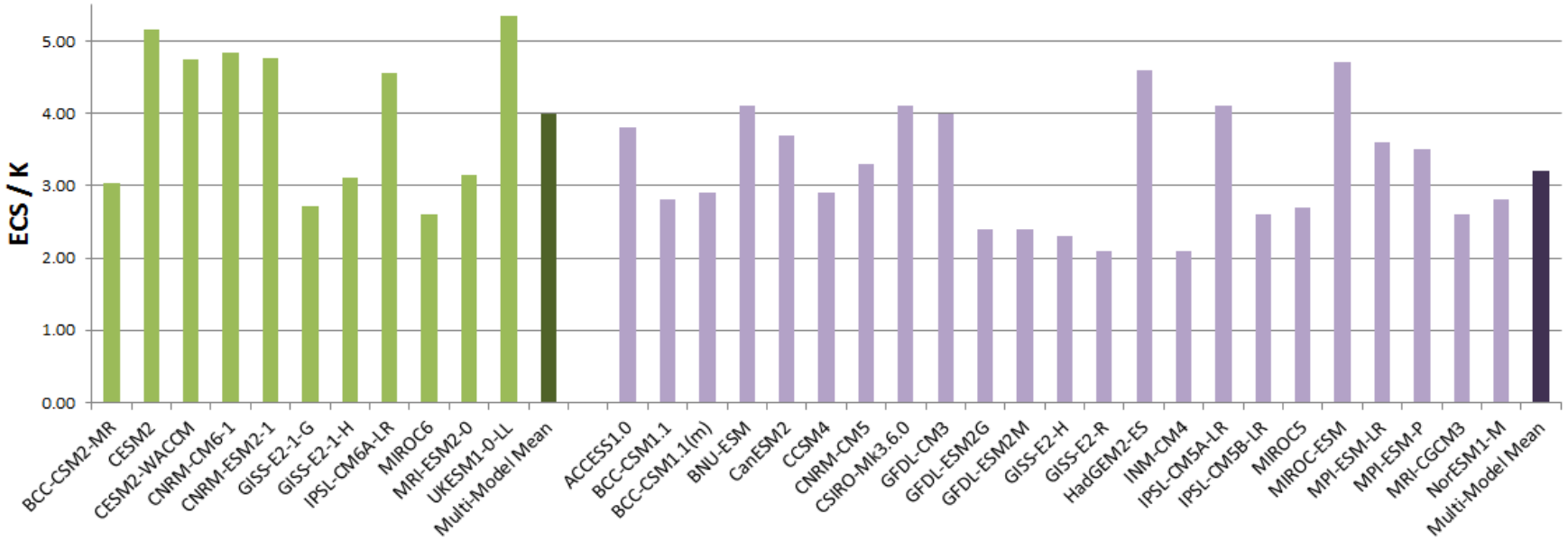
Equilibrium Climate Sensitivity

For UKESM1 increased ECS relative to the CMIP5 model is mainly Due to a significant reduction in the S.Ocean negative cloud phase feedback & improved SCL clouds in the PD



CMIP6

Current Range: 2.7 – 5.3 K (mean: 4.0 K)

CMIP5

Range: 2.1 – 4.7 K (mean: 3.2 K)

At least: 3 other CESM2/CAM6 based models, HadGEM3 and CanESM to come with ECS > 5K

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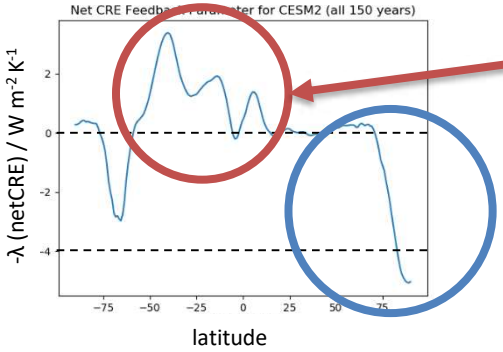
Net cloud radiative effect feedback
Multi-model analysis using ESMValTool

CESM2 (ECS = 5.16K)



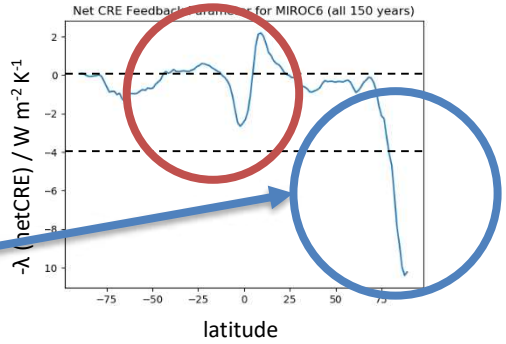
More warming

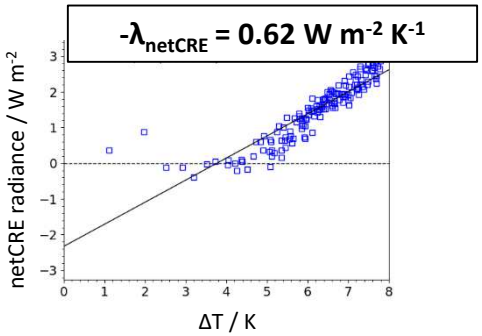
- Less low-level clouds?
- Other effects?

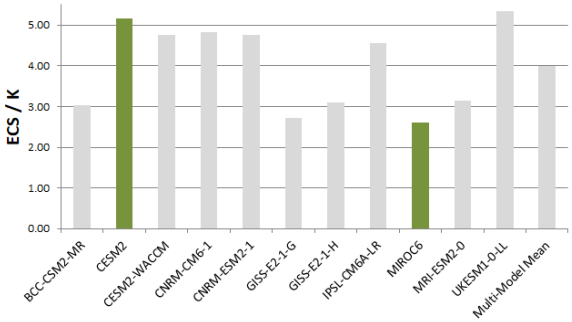
Less cooling

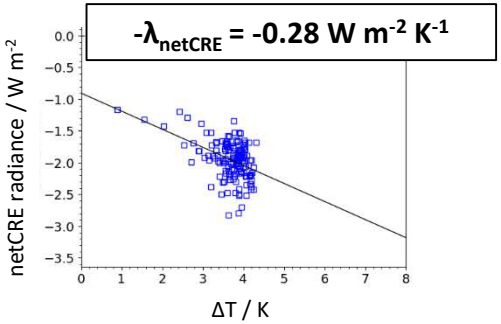
- More clouds?
- Phase change?
- Other effects?

MIROC6 (ECS = 2.72K)









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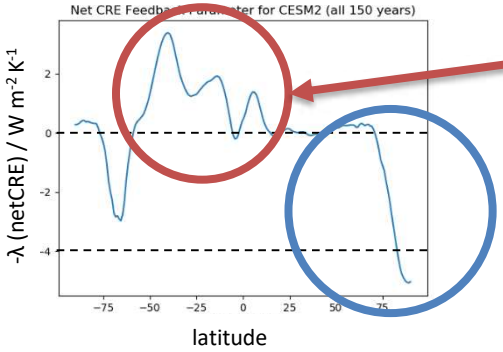

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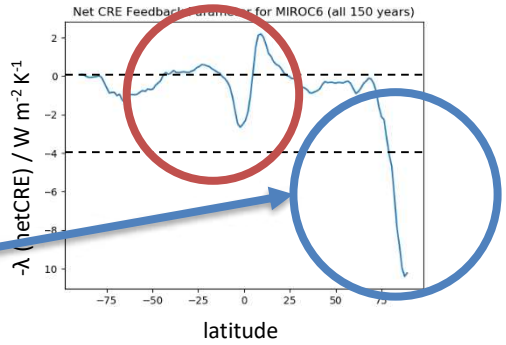

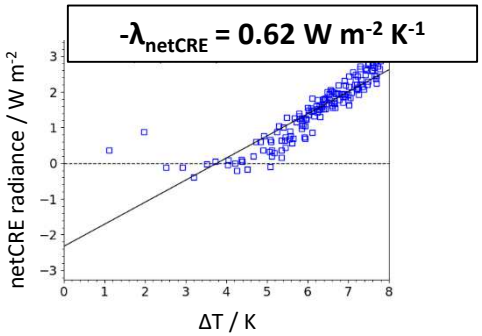

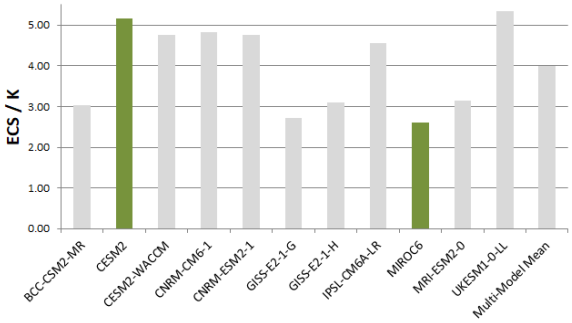

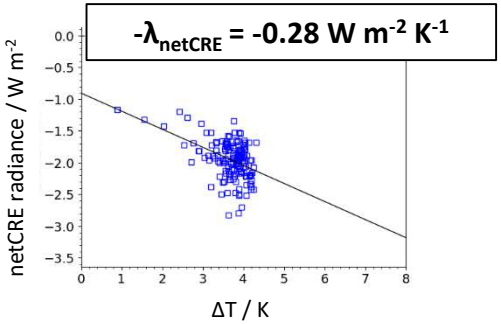

"We could not show UKESM1, as the variable "rsdt" is missing. Could you ask your people to upload it."

Getting our data onto the ESGF **VERY SOON** will determine how many multi-model papers (referenced in AR6) UKESM1 appears in. **For the project this is as important as making the runs and writing the papers**

Thanks

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