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Experimental designs to enhance seamlessness across space and time or Simulation designs

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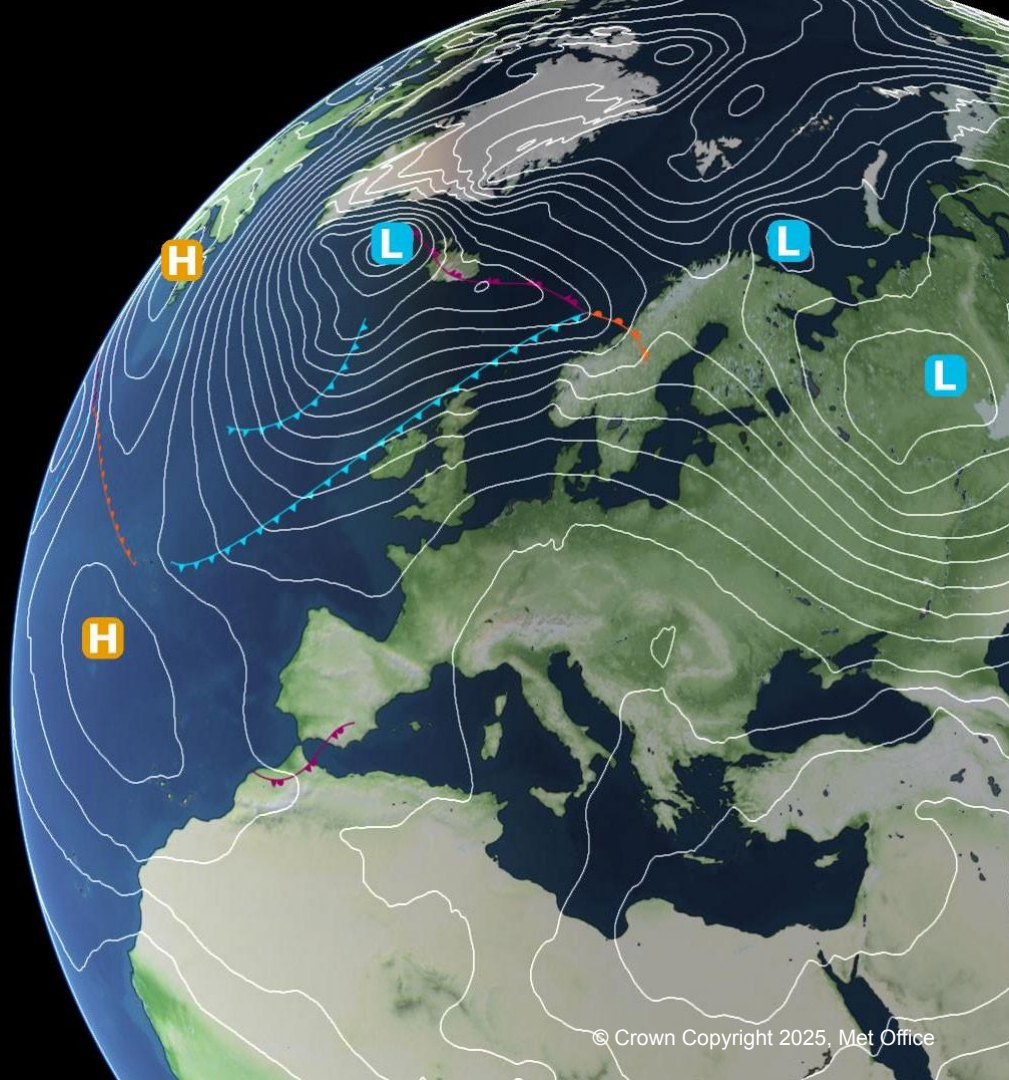

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Outline

- Multi-decadal coupled climate simulation designs
  - current GAL-GC simulation design
  - CMIP
  - HighResMIP
  - others (e.g. DestinE)
- Why change, why now?
- Pros and cons of change
- Initial analysis of CMIP6 vs CMIP6 HighResMIP simulations

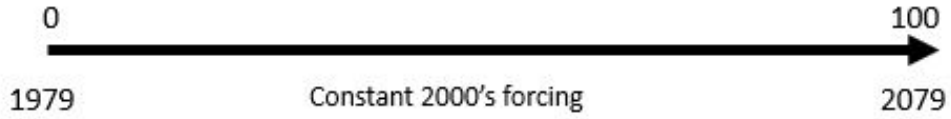
Full disclosure

- I co-lead HighResMIP, so obviously I think it is a good experimental design (and it seemed to work well in CMIP6) 😊
- My challenge is to try and convince you…

Coupled model simulation designs(1)

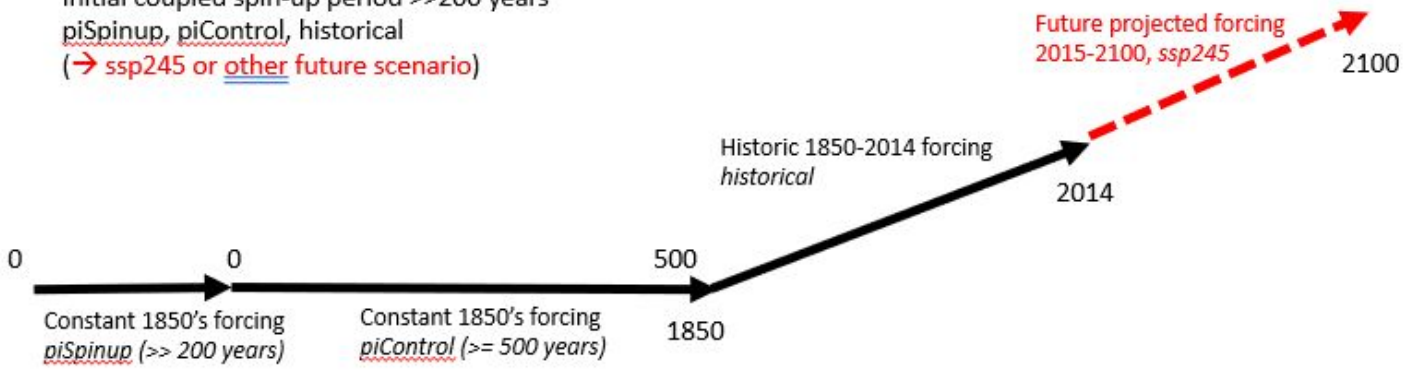
GC coupled simulations

Coupled climate, 1979-2079
Forced by constant year-2000 forcings
Initialised from present-day ocean and atmosphere



CMIP DECK coupled simulations

Coupled climate, 1850-2014 (→ 2100)
Forced by constant 1850 and historic forcings (→ projected)
Initial coupled spin-up period >>200 years
piSpinup, piControl, historical
(→ ssp245 or other future scenario)



Coupled model simulation designs(2)

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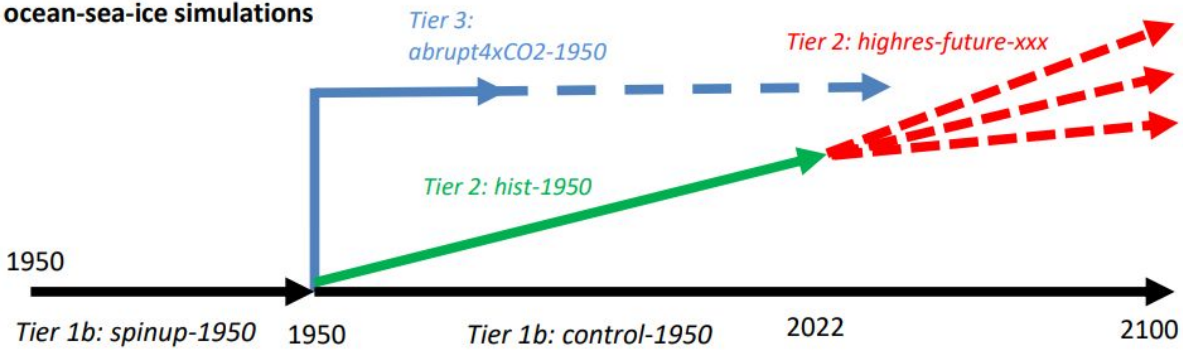
HighResMIP (CMIP7)

Coupled atmosphere-land-ocean-sea-ice simulations



Main components:
spinup-1950
control-1950
hist-1950

Destination Earth
Similar to HighResMIP (CMIP6) but starting in 1990 rather than 1950

What could be used “regularly” within a GC development cycle

- I think we’d agree that the full CMIP experiment is too long to be used frequently within a (2 year) GC development cycle
- The DestinE design is quite short and would not give much information on aspects of variability
- So I propose to compare the current GC setup with HighResMIP
  - whether both HighResMIP control-1950 and hist-1950 simulations are needed every time is an open question, this doubles the cost (but they can run in parallel)
  - whether spinup-1950 is needed every time is also a question

- Acknowledge that monthly to decadal simulations can provide similar information to above, though diagnostic outputs are more constrained, and can’t use frequently within GC development cycle

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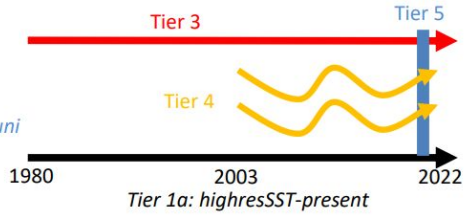
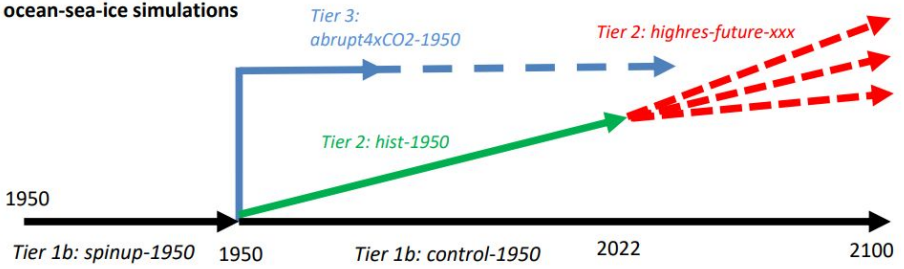
CMIP7 HighResMIP2 simulation design

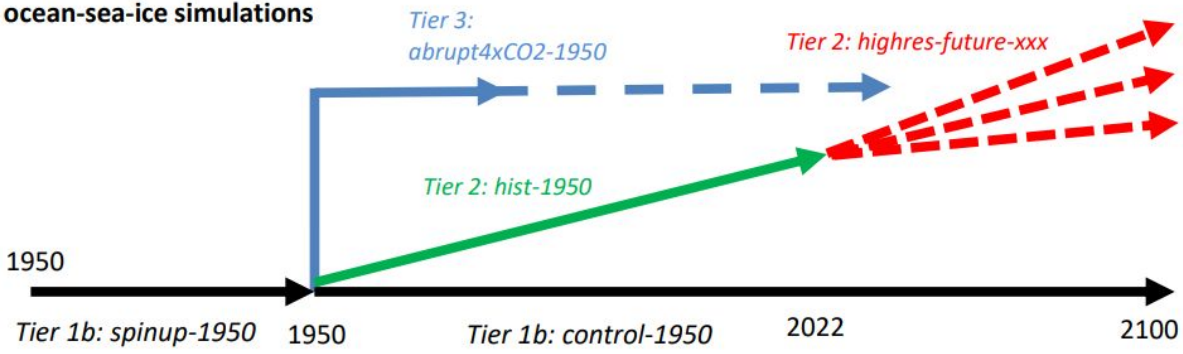
Atmosphere-land-only simulations
Tier 1a – *highresSST-present*
Tier 3 – *highresSST-p4kuni*
Tier 4 – *highresSST-pxxkpat*
Tier 5 – e.g. *highres-yr2020, highres-yr2020-p4kuni*



Coupled atmosphere-land-ocean-sea-ice simulations



Coupled atmosphere-land-ocean-sea-ice simulations



Why change now?

- GC simulation design came from CMIP3 (I think), but is no longer used in CMIP
- Transition from UM to LFRic/Momentum is an opportunity to reconsider choices
- HighResMIP in CMIP6 was new, and quite successful
- As CMIP moves towards continuous updates of forcing, we would be able to extend simulations to present day
  - would be extremely useful for e.g. understanding extreme years such as 2023-4
- Increasing interest in both high resolution and AI/ML development and training datasets
  - in a constant year-2000 dataset, every real year is out of sample

Pros (changing to HighResMIP)

- Simulations using historical forcings are immediately useful to a wider community than model development:
  - we can directly compare with observations
    - for analysis of forced trends
    - for forced variability and extremes
  - giving us larger ensembles to look at such features
  - existing databases of multi-model, multi-resolution comparisons (CMIP6 HighResMIP, CMIP7 HighResMIP2)
  - we are able to look at e.g. historical variability (at least from 1950) without resorting to full CMIP-style piSpinup, piControl, 1850-1950 (~500+ years simulation)

- We can look at climate properties of the model (e.g. ECS, spatial trend patterns) much more quickly
  - admittedly some of these we'll need to understand the mapping between CMIP and HighResMIP simulations
- Includes a short spinup-1950, so we separate a chunk of the model drift from the analysis period
- 1950-based experiment the TOA is lower (so reduced ocean drift), though also less well-constrained TOA

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Cons

- Interannually varying forcing will make it more difficult to disentangle model development changes
- Breaking from past experimental design makes it difficult to make comparisons over many past development cycles
- TOA in year-2000 is better constrained than in 1950
- GC simulation is one simple workflow rather than 2/3 different pieces
  - less person time needed
- HighResMIP is more expensive:
  - it has parallel control-1950 and hist-1950 simulations (each ~100 years), so more expensive if both these are run each time for evaluation, as well as ~50 years spinup

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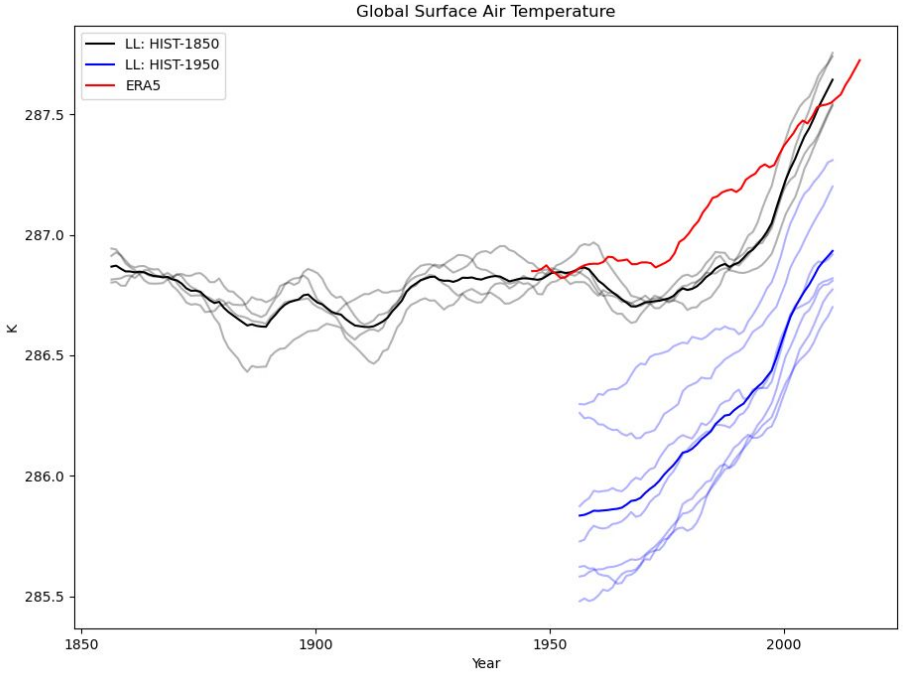
Initial analysis CMIP6 vs CMIP6 HighResMIP

- See Michael Lai's poster for more details (Poster session 1, 1.2)
- Global means and ECS
- Trends

1850 vs 1950 simulations

Global mean surface air temperature

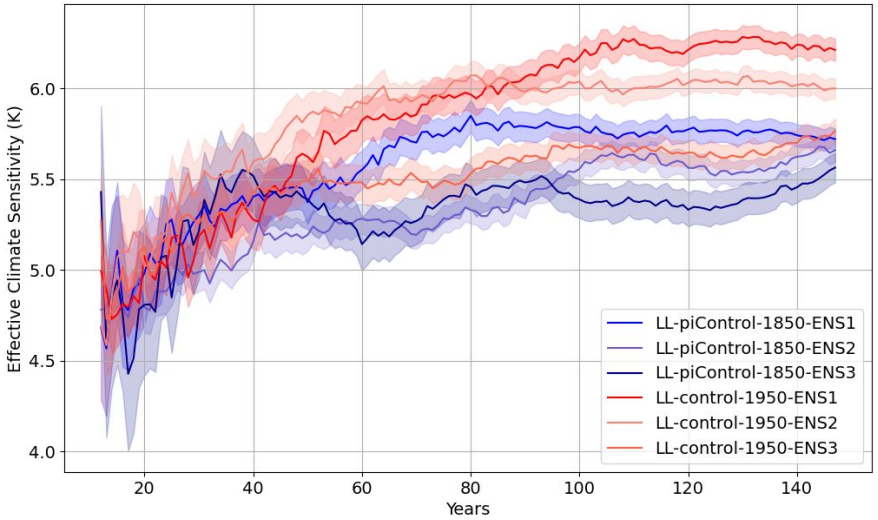
(we know the mean state is different, at least partly due to aerosol choices in HighResMIP1)



Effective climate sensitivity (ECS)

Usually calculated based on 1850 control and 4xCO2 simulations (~150 years each + ~200 years piSpinup)

Using HighResMIP saves 150 years from spinup (cheaper, so also more possible for higher resolution models)



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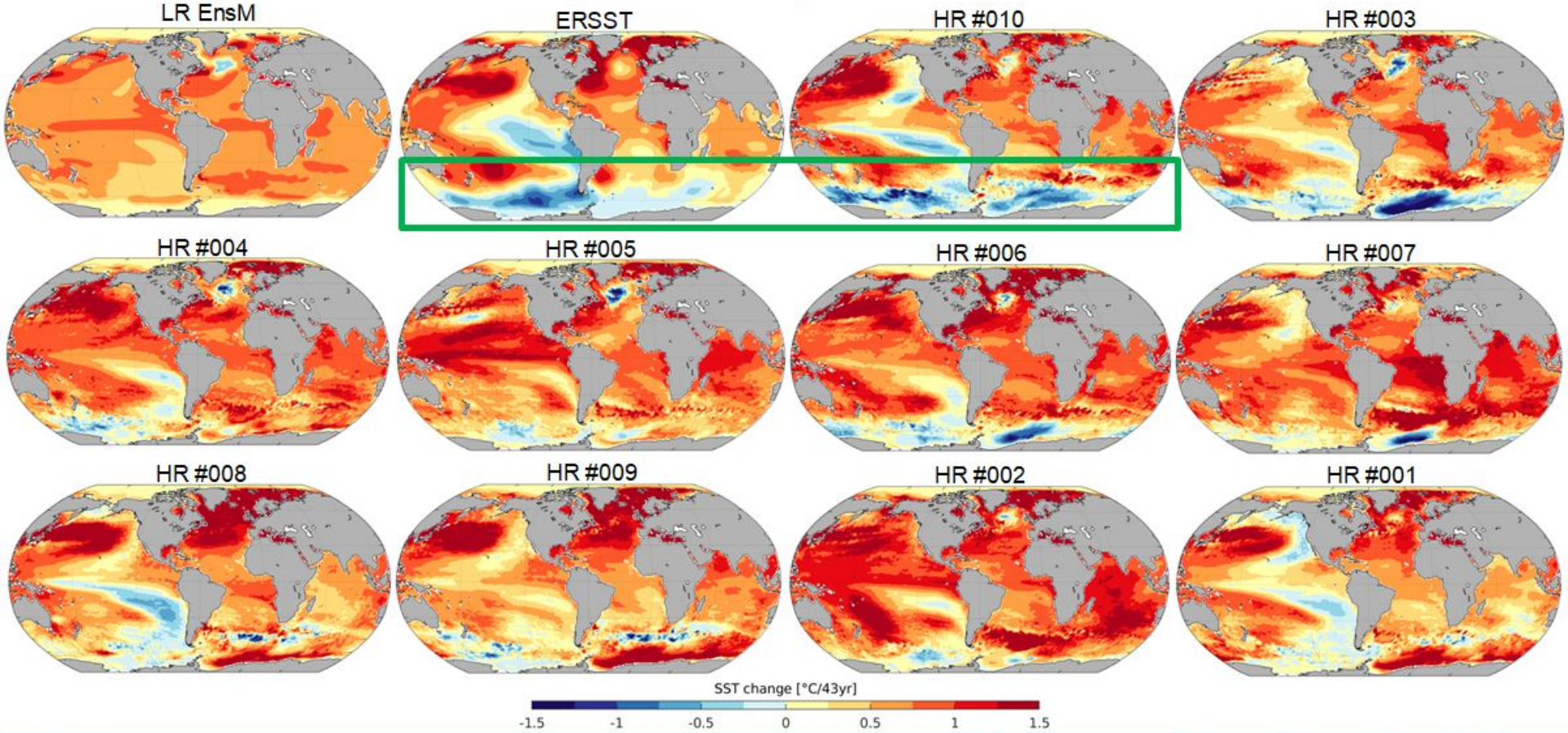
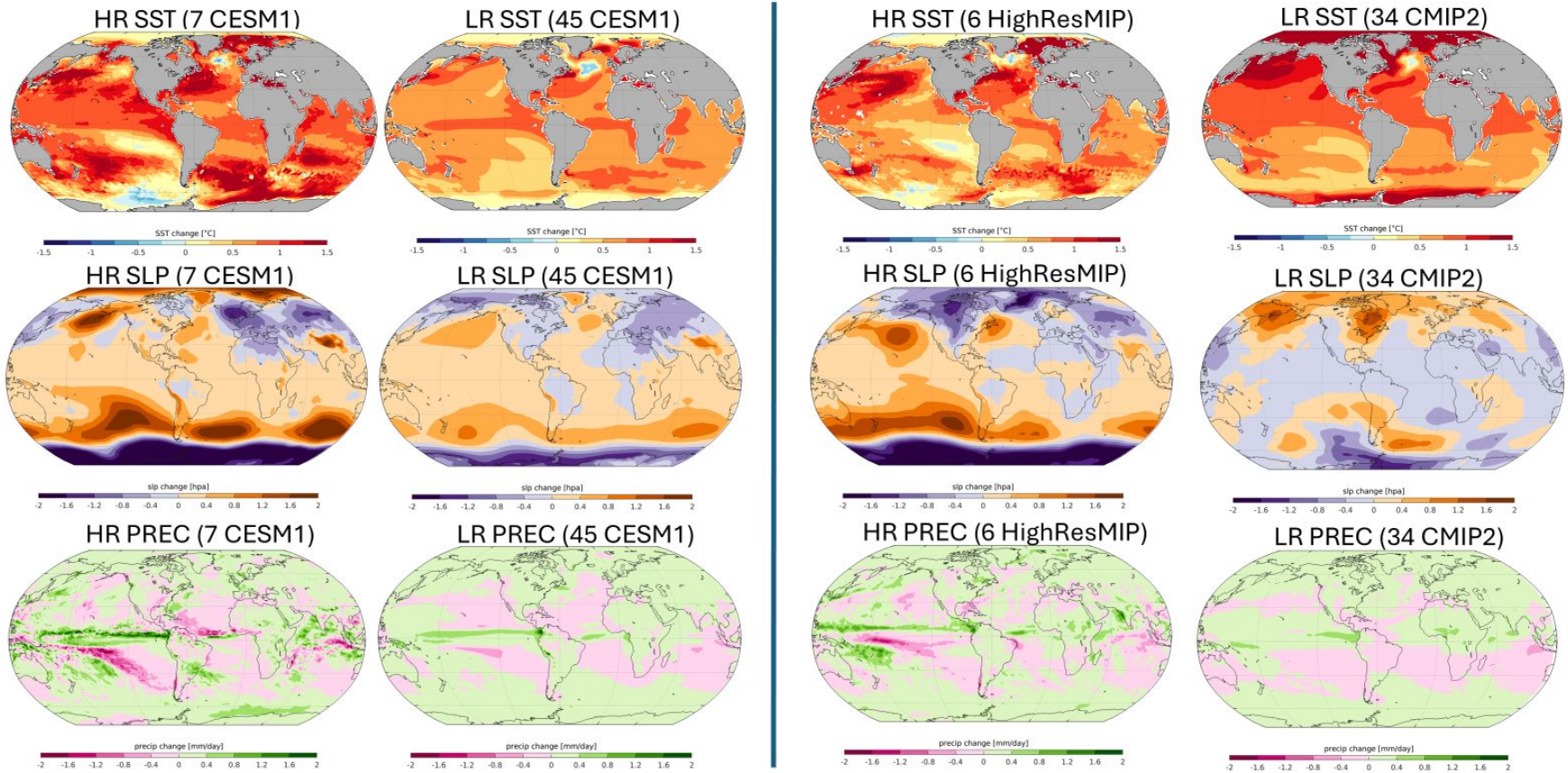
Historic SST trend patterns

- As part of CMIP, we're very interested in being able to reproduce the global surface temperature evolution between 1850-present
- However, for impacts we need to know regional patterns of change
- In the last few years it has become clear that historic trend patterns sit outside the CMIP ensemble
  - remember the CMIP ensemble contains 100's of ensemble members from ~40 models for 1850-present day
  - hence CMIP is not representing uncertainty in present-day variability
- The MESACLIP project (Texas A&M, NCAR) have produced a 10 member ensemble (1920-2100) with 25-10km coupled model
  - of these 10 members, 1-3 members look pretty convincing

SST Linear Trend (1980-2022) in Each Ensemble Member



CESM1 vs HighResMIP: Linear Trend



Courtesy Ping Chang, MESACLIP project

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Summary

- Now is a good time to at least consider our choices in simulation design
- Current GC coupled simulations are very good for assessing model changes, but not for assessing model against observations
- HighResMIP offers a potential design, but it is certainly not perfect

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Questions