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Towards providing more reliable regional climate change projections

CLIVAR

Report from an online 4 week workshop in June and July of 2021

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MULTI-ANNUAL TO DECADAL CLIMATE PREDICTABILITY WORKSHOP, 20-22.09.2021

Can existing projections be used for climate adaptation?

To the extent that long-term projections are useful for climate change adaptation, we have the following general conclusions:

- Uncertainties in climatic relevant variables (e.g., surface temperature and precipitation) are dominated by model response uncertainty rather than internal climate variability at regional to global scales [Hawkins & Sutton 2009, 2011; Xie et al. 2015; Kumar and Ganguly 2018; Deser et al. 2020]
- "the use of these models to guide local, practical adaptation actions is unwarranted. Climate models are unable to represent future conditions at the degree of spatial, temporal, and probabilistic precision with which projections are often provided, which gives a false impression of confidence to users of climate change information." [Nissan et al. 2018]
- Adaptation measures can still be planned using information from climate model projections, but it is imperative to accurately describe the quality of the information [Dessai & van der Sluijs 2007; Pacchetti et al. 2021]

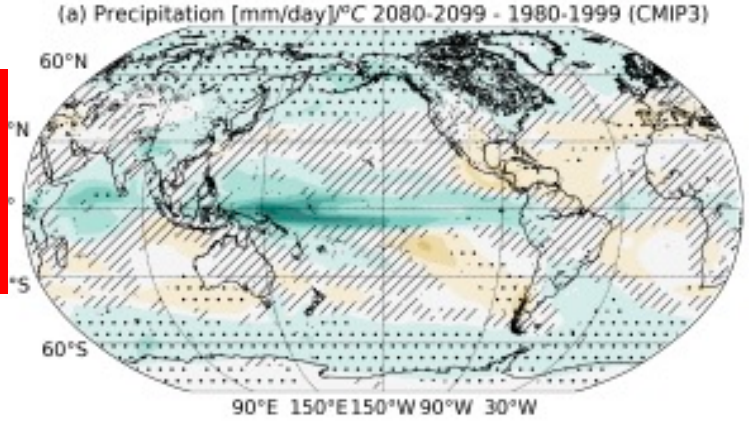
Progress has been slow in climate modelling

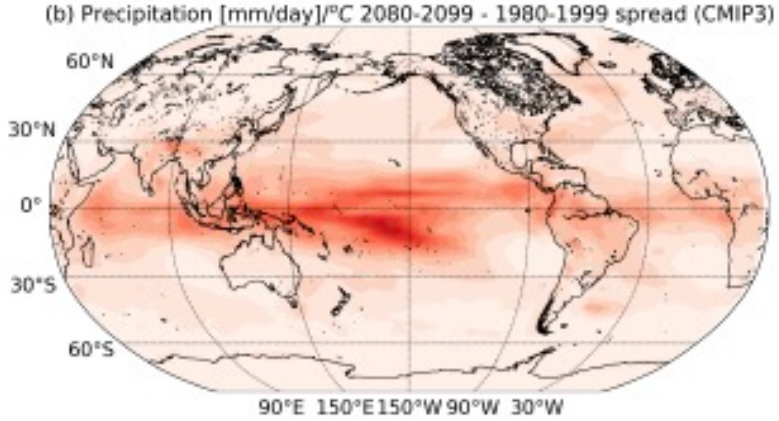
Projected rainfall change (mm/day/deg C)

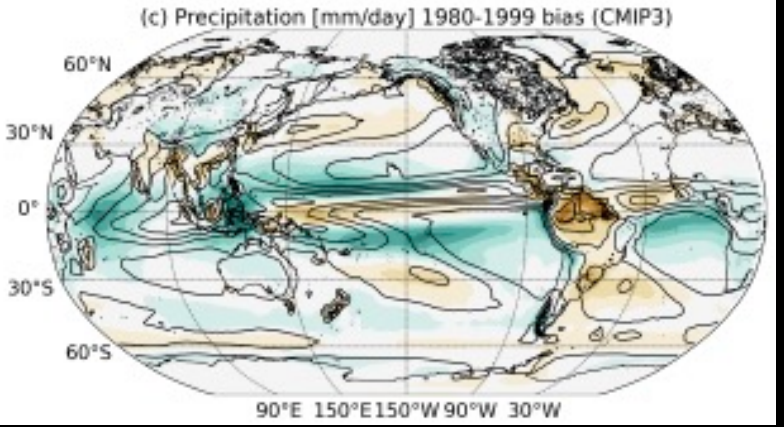
Projected rainfall spread (mm/day/deg C)

Rainfall bias (mm/day)

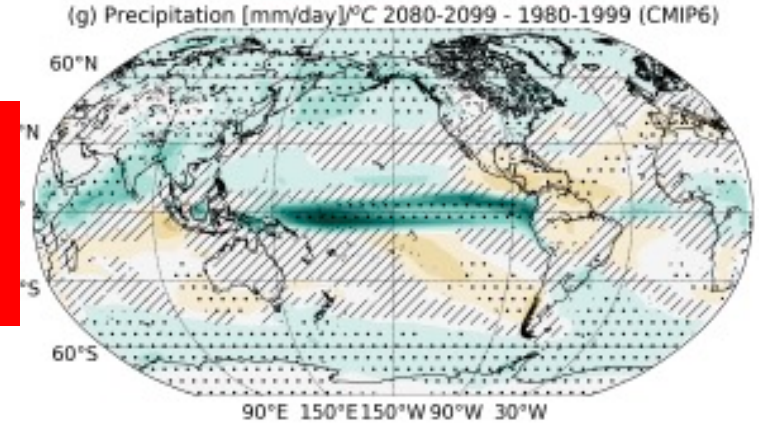
CMIP 3

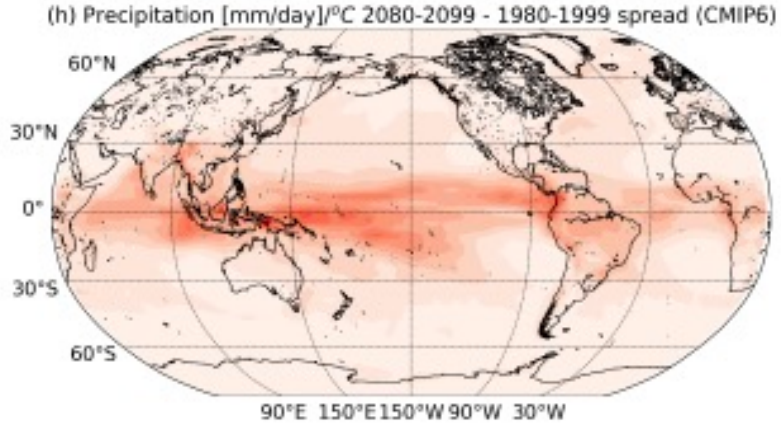


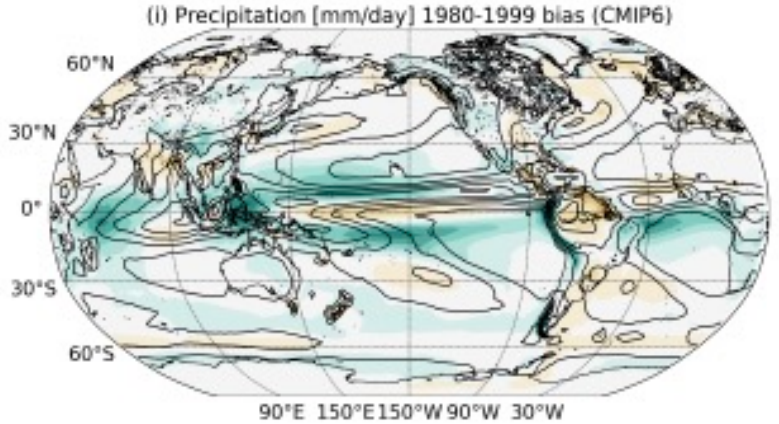


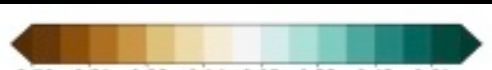


CMIP 6









Climate dynamics offers a pathway to constrain projections

- Can we understand uncertainties?
- Can we better use data that exists?
- How can we progress in the short and long-term?

Climate dynamics offers a pathway to constrain projections

While the model response uncertainties ultimately stem from the interactions of the parameterisations of sub-grid scale physics and the large-scale flow, uncertainties imprint themselves in climate dynamics that can be observed and assessed.

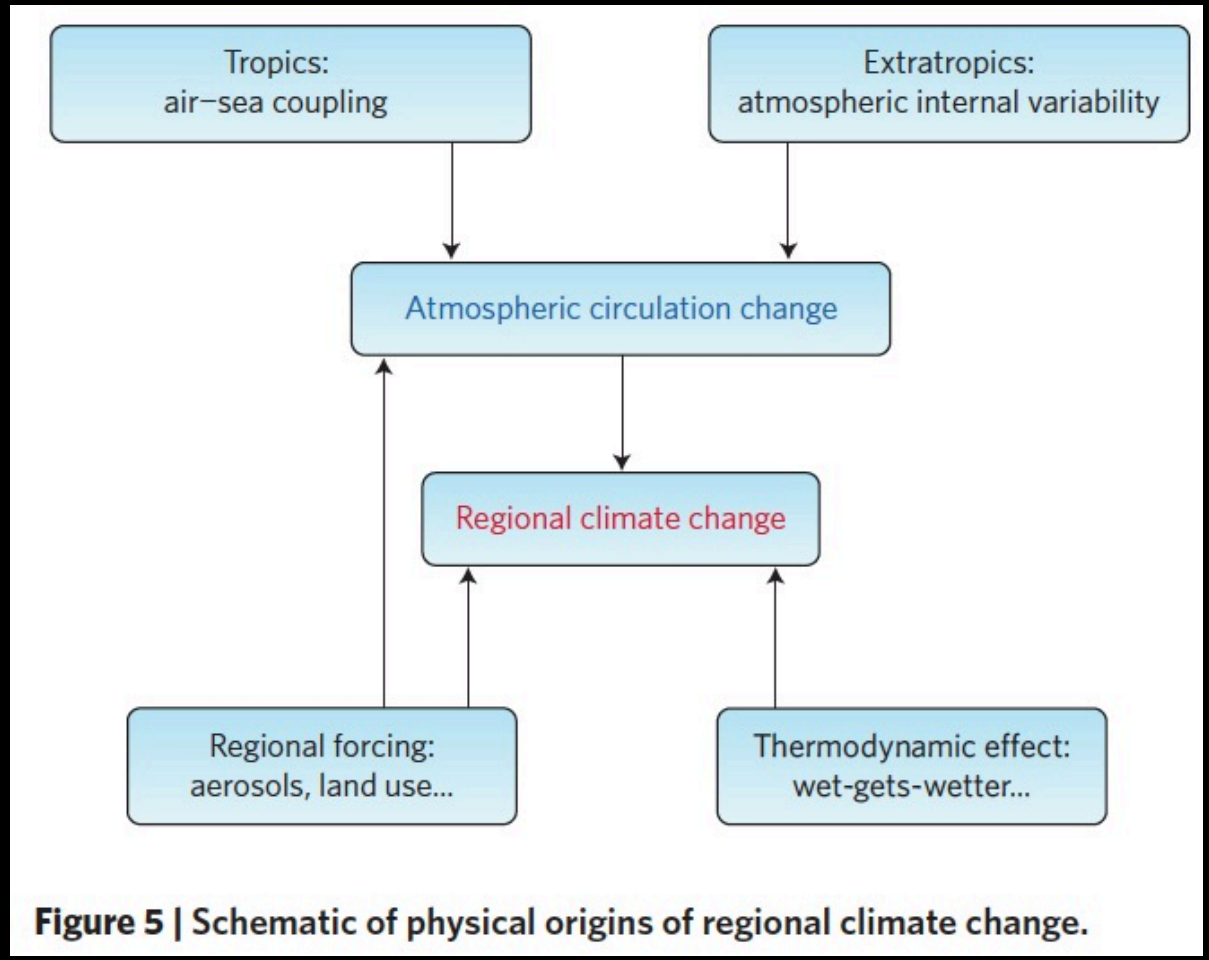
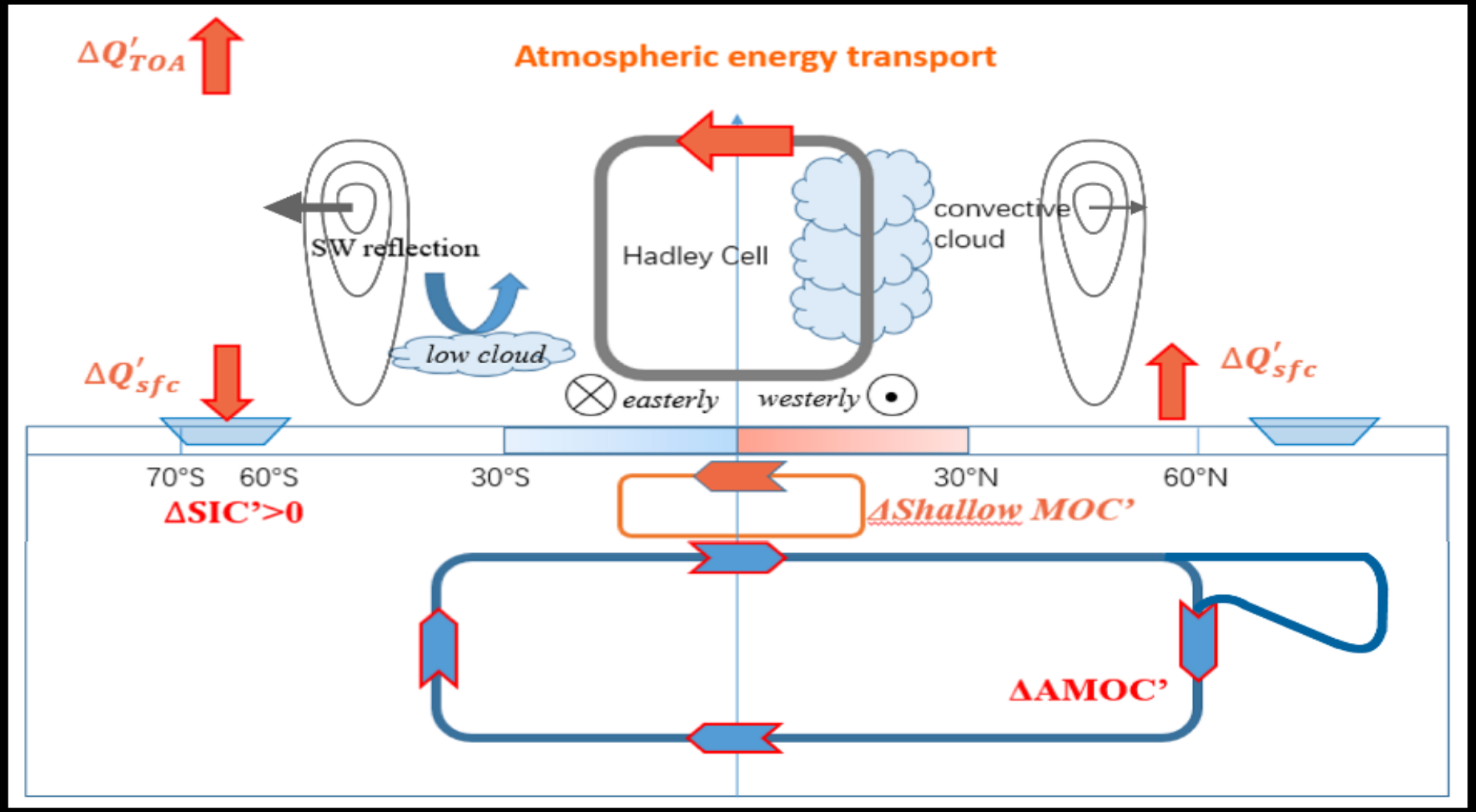


Figure 5 | Schematic of physical origins of regional climate change.

Xie et al. 2015

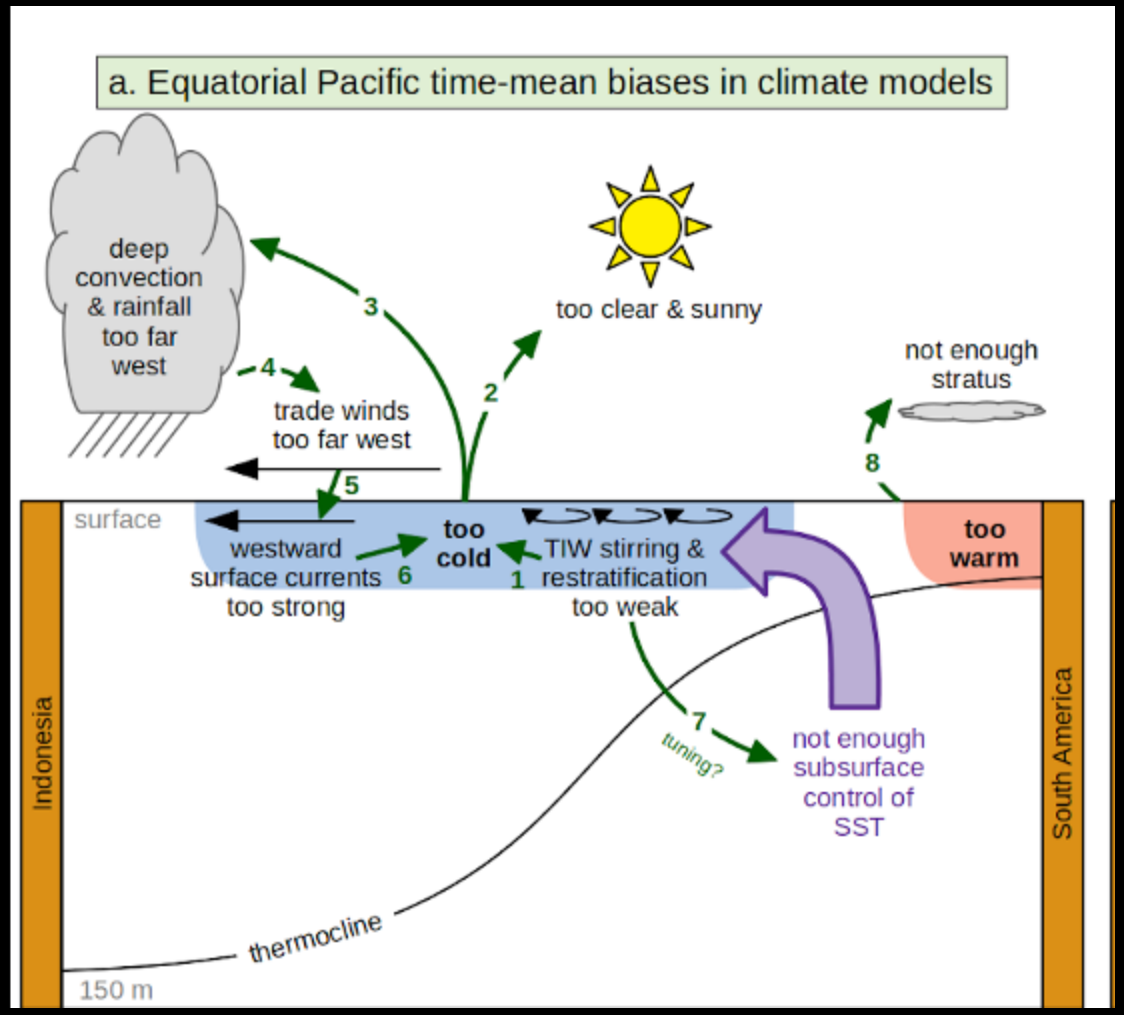
Energetics perspective of an interconnect climate



Kang et al.2008

Model errors in one region influence climate change in other regions

The tropical Pacific example -- connecting bias to mean change



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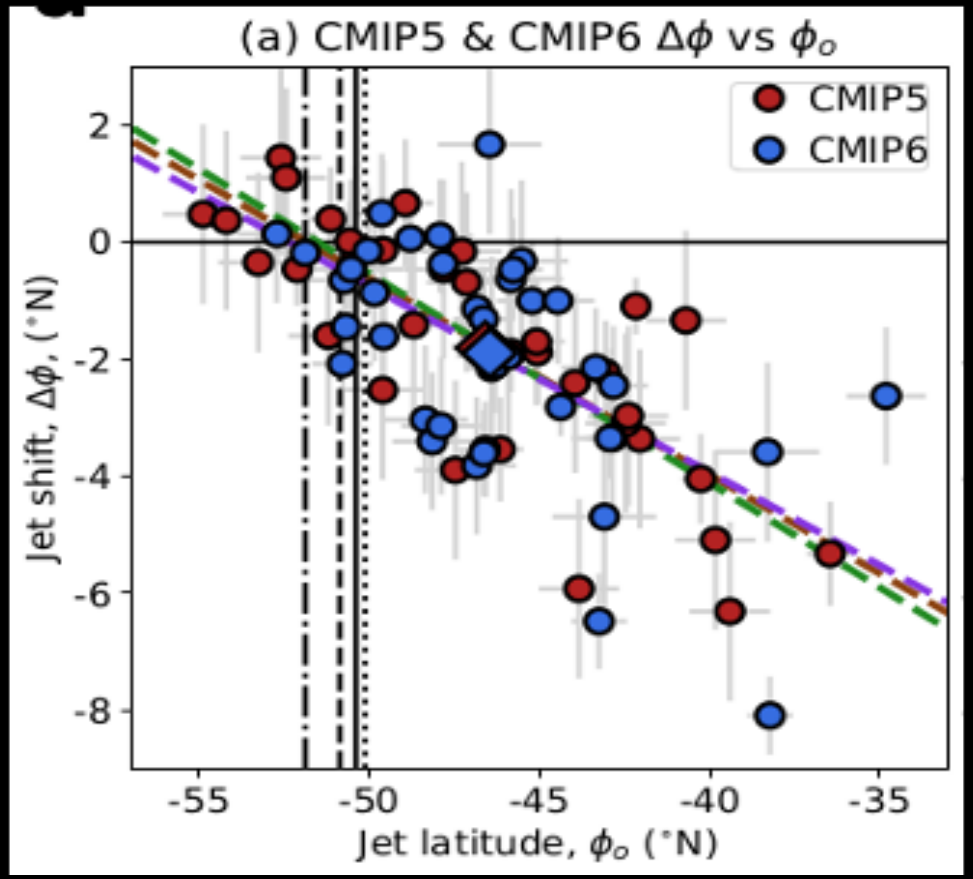
Better using existing data and methods, emergent constraints is an example

Relation between Southern hemisphere jet latitude shift under global warming and its present day position



- Statistics need to be robust, i.e., to changes in the model ensemble
- Statistics should come with a physical understanding

In addition:

- Large ensemble methods (model and observed) are needed to assess uncertainties and properly verify models
- Resouces: Climate Variability Diagnostics Package for Large Ensembles

Regional downscaling

- Regional models are needed, given computational costs of running similar global models
- Convective permitting models are the new frontier,
  - Reproduce key aspects, like diurnal cycle, land-hydrological cycle interactions
  - but still challenges regarding microphysical parameterisations and land-surface schemes.
- Smart ways needed to identify models for downscaling (e.g., storylines, lesser model errors)
- Smart ways to boost ensembles, e.g., emulators

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The promise of storm resolving models

One satellite image, three storm (~1 km res.) resolving models

Palmer and Stevens 2019

No need to parameterise atmospheric convection and meso-scale ocean eddies

NextGEMS https://nextgems-h2020.eu/

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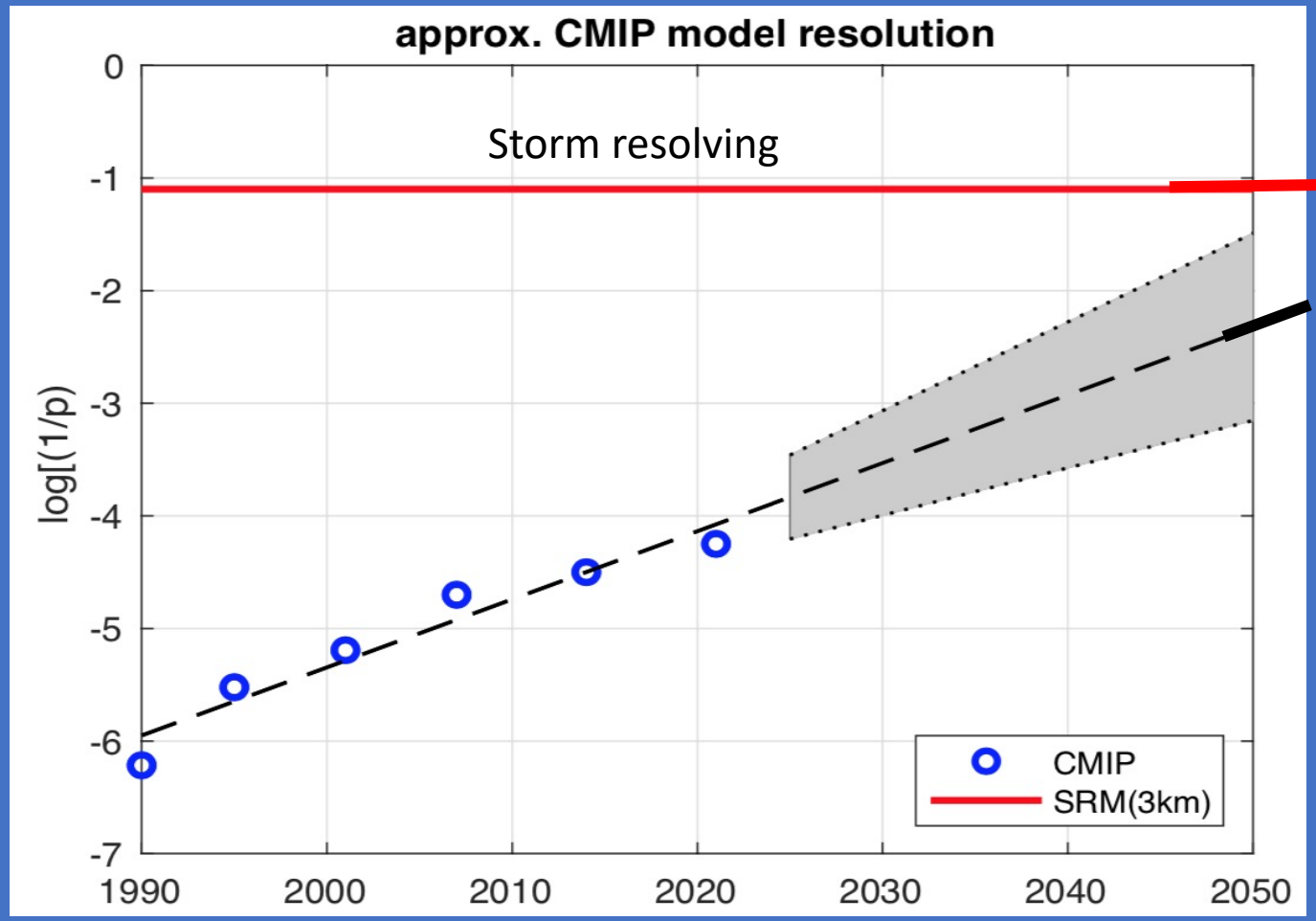
Global warming is outpacing our ability to model climate



3 degrees of warming?

Appropriate models available in 2070?

Progress can be accelerated by addressing issues related to insufficient personnel, computing resources, and observations, and gaps in theory.

Challenges and alternate approaches

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- Storm resolving models are unlikely to resolve all problems!!
  - Shallow convection, mesoscales in high-latitudes, cloud microphysics will not be resolved
- Parameter tunning approaches
  - Open, transparent, and documented
  - Approaches that are robust taking into account uncertainties, avoid over tuning (data assimilation)
- Online model corrections (flux-correction, supermodelling)
- Machine learning
  - Downscaling, accelerating/improving models
  - Extrapolation to situation not considered (Climate Change) is questionable
- New opportunities from observations
  - Evaluation of storm resolving models, new metrics (histogram of cloud water vapour)
  - Satellite and in-situ observations to evaluate air-sea interactions

Towards improved regional climate change projections

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- Progress has been slow
- Climate dynamics offers a pathway to understand uncertainties
- Provides better ways to use existing model data (i.e., emergent constraints) and downscale projections
- In the long-term increased model resolution offers promise to better represent climate dynamics (avoiding parameterisations)
- In the short-term, alternate approaches can accelerate progress (machine learning, model corrections, novel observations)

Thank you for your attention

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