Projection and uncertainty in CMIP5: Wasteful or useful?

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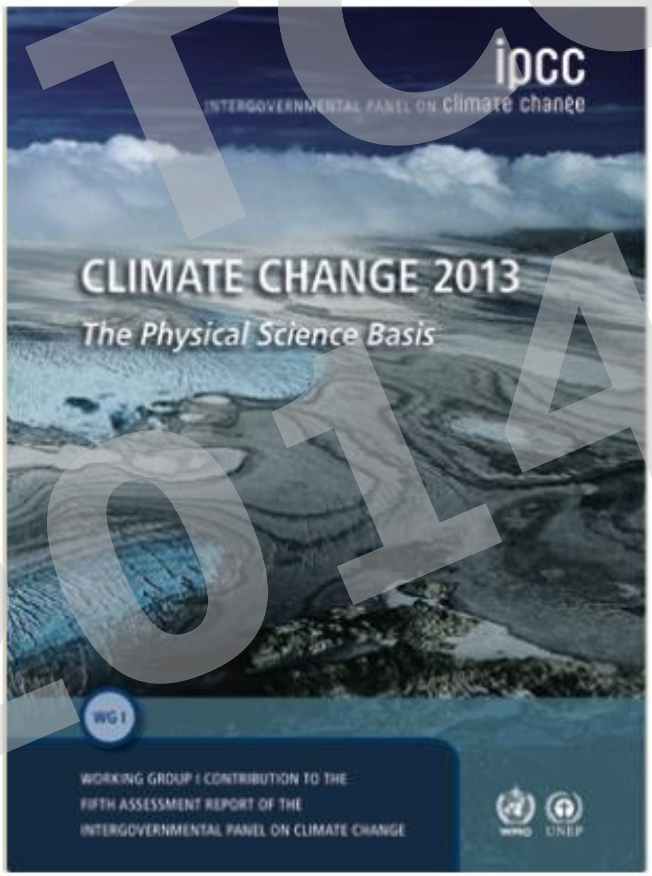
Messages from IPCC Report

Progress of Our Understanding

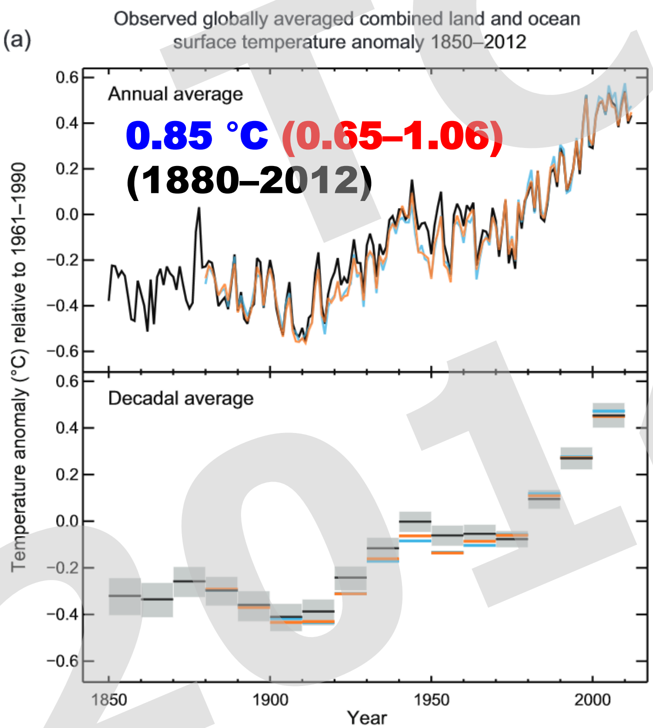


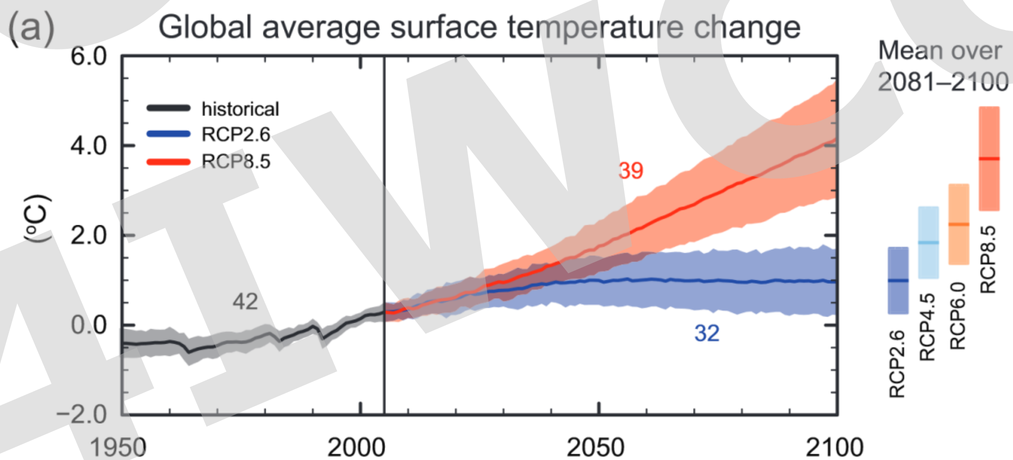
- FAR (1990): "unequivocal detection not likely for a decade"
- SAR (1995): "balance of evidence suggests discernible human influence"
- TAR (2001): "most of the warming of the past 50 years is likely (odds 2 out of 3) due to human activities."
- AR4 (2007): "most of the warming is very likely (odds 9 out of 10) due to greenhouse gases"
- AR5 (2013): "It is extremely likely (95%) that human influence has been the dominant cause of the observed warming since the mid 20th Century."

Messages from CMIP5 (1)

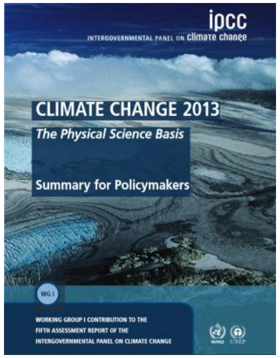
1. Global temperature increase is a general signal, but with a "certain range" (uncertainty)

3.7 °C (2.6–4.8)
(2081–2100, RCP8.5)





1.8 °C (1.1–2.6)
(2081–2100, RCP4.5)



Graphic courtesy of WG1 AR5 SPM (2013)

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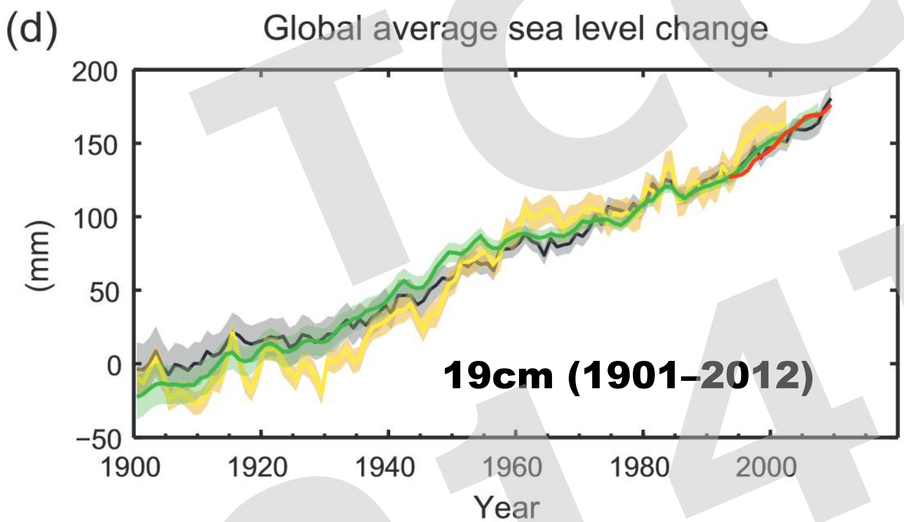
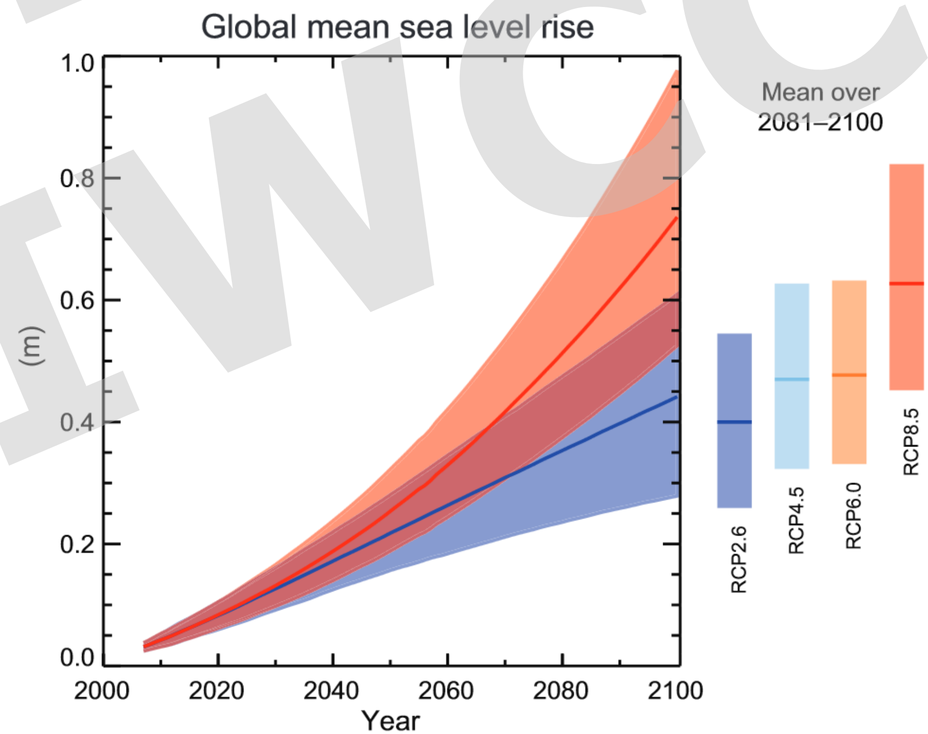
Messages from CMIP5 (2)

2. Sea level rise is a general signal, but with a "certain range" (uncertainty)





63cm (45–82)
(2081–2100, RCP8.5)

47cm (32–63)
(2081–2100, RCP4.5)

Graphic courtesy of WG1 AR5 SPM (2013), Picture courtesy of Google

Messages from CMIP5 (3)

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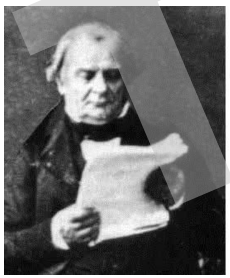
3. More frequent extreme rainfall is a general signal, but with a "certain (probabilistic) range" (uncertainty)

Clausius-Clapeyron law

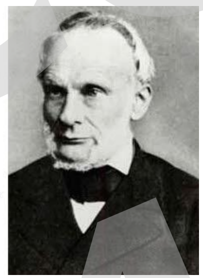


$$k = \left(1 - \frac{\delta}{\varrho}\right)\frac{dp}{dt}\,C.$$

E. Clapeyron (1834)

$$r = C\cdot(s-\sigma)\,\frac{dp}{dt}.$$

R. Clausius (1850)



Warmer atmosphere is more likely to deliver heavy rainfall events.

1. For stratiform precipitation, extremes increase with temperature at approximately the Clausius–Clapeyron rate
2. Convective precipitation responds much more sensitively to temperature increases than stratiform precipitation

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NATURE GEOSCIENCE | LETTER

Strong increase in convective precipitation in response to higher temperatures

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Affiliations | Contributions | Corresponding author

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Precipitation changes can affect society more directly than variations in most other meteorological observables[1, 2, 3], but precipitation is difficult to characterize because of fluctuations on nearly all temporal and spatial scales. In addition, the intensity of extreme precipitation rises markedly at higher temperature[4, 5, 6, 7, 8, 9], faster than the rate of increase in the atmosphere's water-holding capacity[1, 4], termed the Clausius–Clapeyron rate. Invigoration of convective precipitation (such as thunderstorms) has been favoured over a rise in stratiform precipitation (such as large-scale frontal precipitation) as a cause for this increase[4, 10], but the relative contributions of these two types of precipitation have been difficult to disentangle. Here we combine large data sets from radar measurements and rain gauges over Germany with corresponding synoptic observations and temperature records, and separate convective and stratiform precipitation events by cloud observations. We find that for stratiform precipitation, extremes increase with temperature at approximately the Clausius–Clapeyron rate, without characteristic scales. In contrast, convective precipitation exhibits characteristic spatial and temporal scales, and its intensity in response to warming exceeds the Clausius–Clapeyron rate. We conclude that convective precipitation responds much more sensitively to temperature

Uncertainty vs Signal (1)

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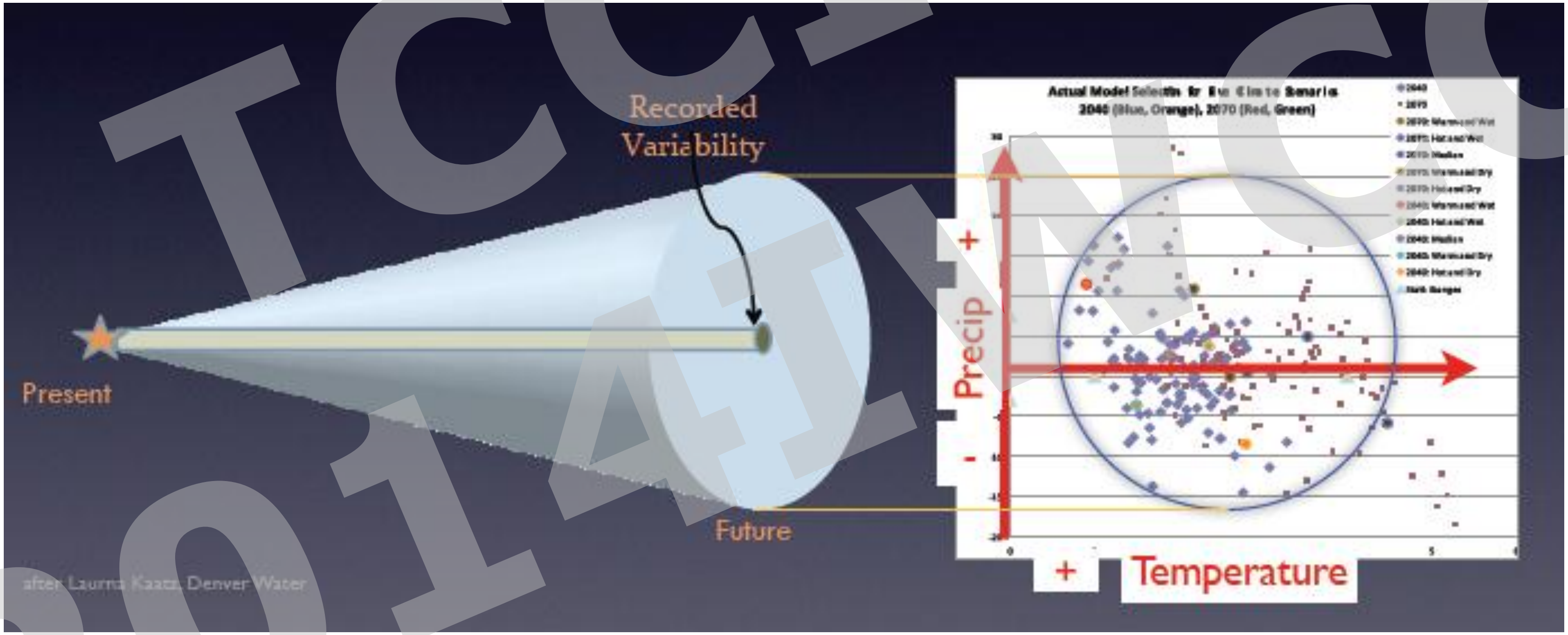
- Uncertainty more often raises a doubt about (or devalues) the credibility of the signal.

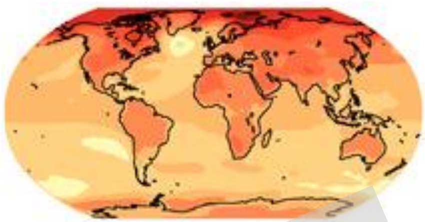
- In addition, the practical use of the large-scale signal incurs further uncertainty (e.g., the use in downscaling and process models).

Uncertainty vs Signal (2)

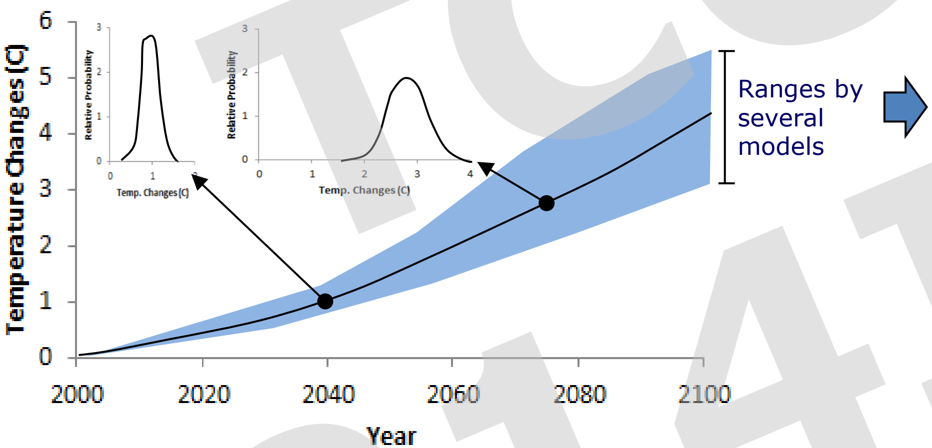


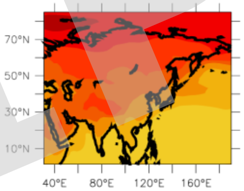
(Taken from “Facing the Practitioners Dilema” by Dr. Caspar Amman at the APCC Expert Workshop on Downscaling and Tailoring Climate Model Output)

Uncertainty vs Signal (3)

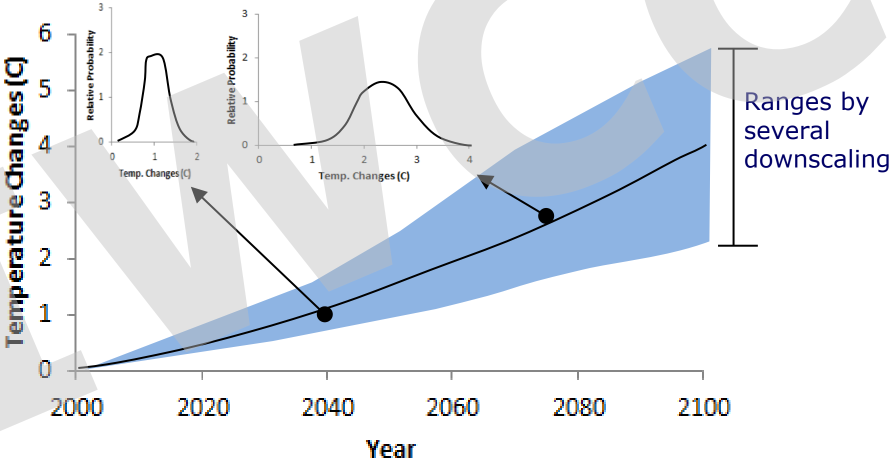


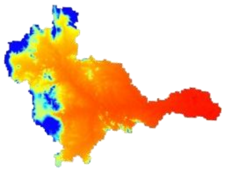
Global
Climate Change



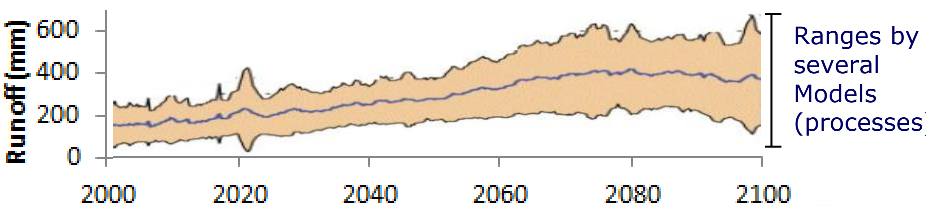


Regional
Downscaling



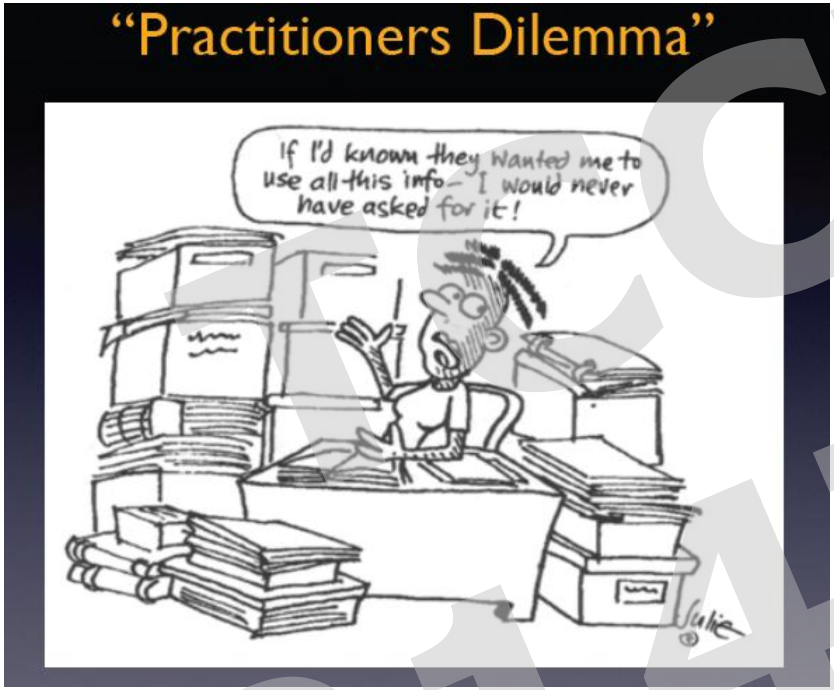


Watershed-scale
Hydrology Modeling



Uncertainty =
f (Input, Time, Domain, Processes)

Uncertainty vs Signal (4)



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- Reduce uncertainty without loss of generality
- Extract signal that beats uncertainty

Best model approach: Cloud feedback (1)

- Cloud feedback (large inter-model spread)
  - Observational evidences on co-variability
    - ✓ Increased SST
    - → Lower-troposphere destabilized
    - → Tradeoff from low stratiform cloud to cumuli form cloud
    - → High cloud increase due to enhanced deep convection (i.e., cloud anvil)
    - ✓ Subsidence (circulation)
  - Key variables: cloud amount (total, low, high), SST, low-troposphere stability (LTS), SLP, LCRF, SCRF, CRF

Best model approach: Cloud feedback (2)

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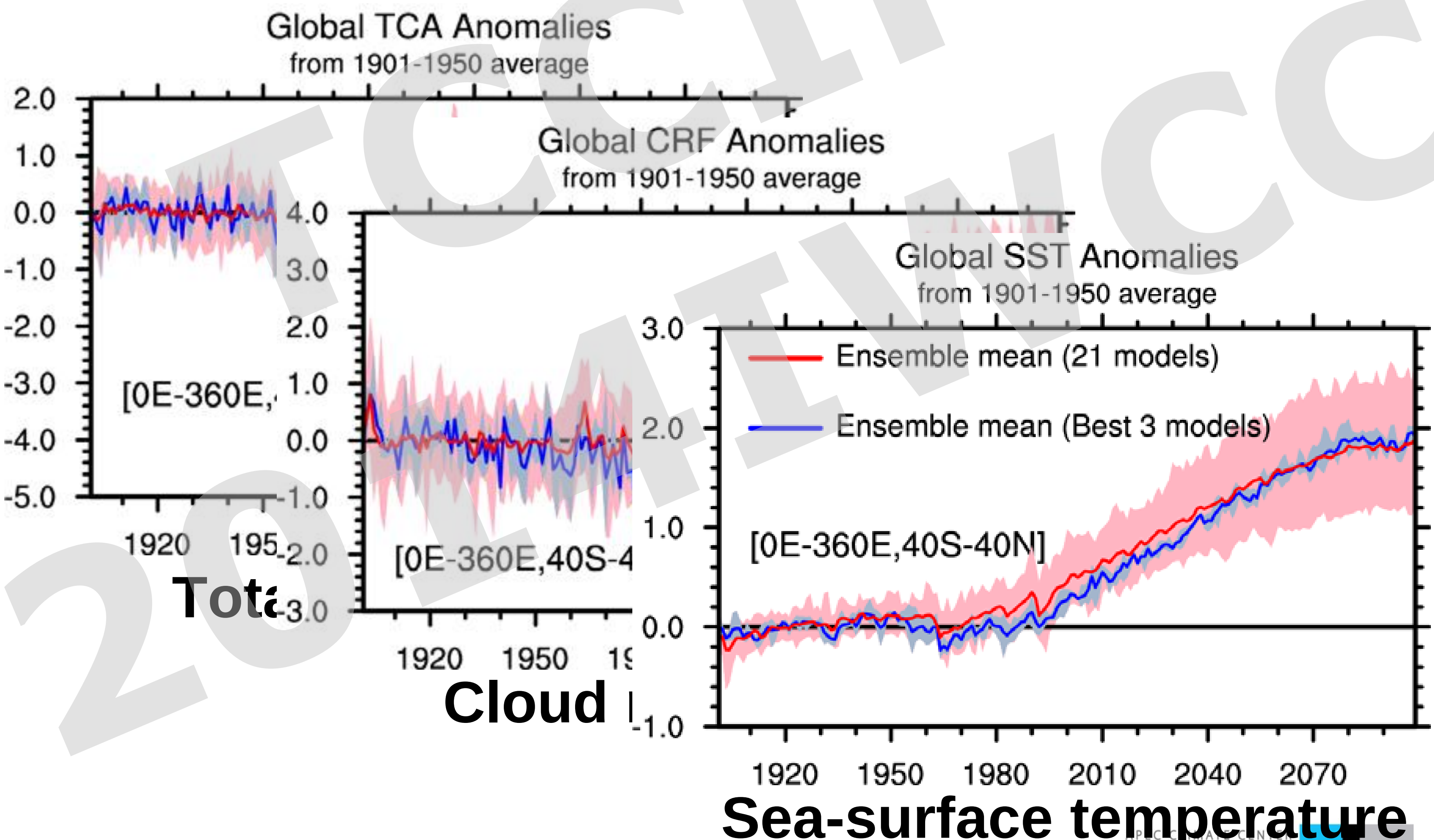
Uncertainty in CMIP5 simulations



Best model approach: Cloud feedback (3)

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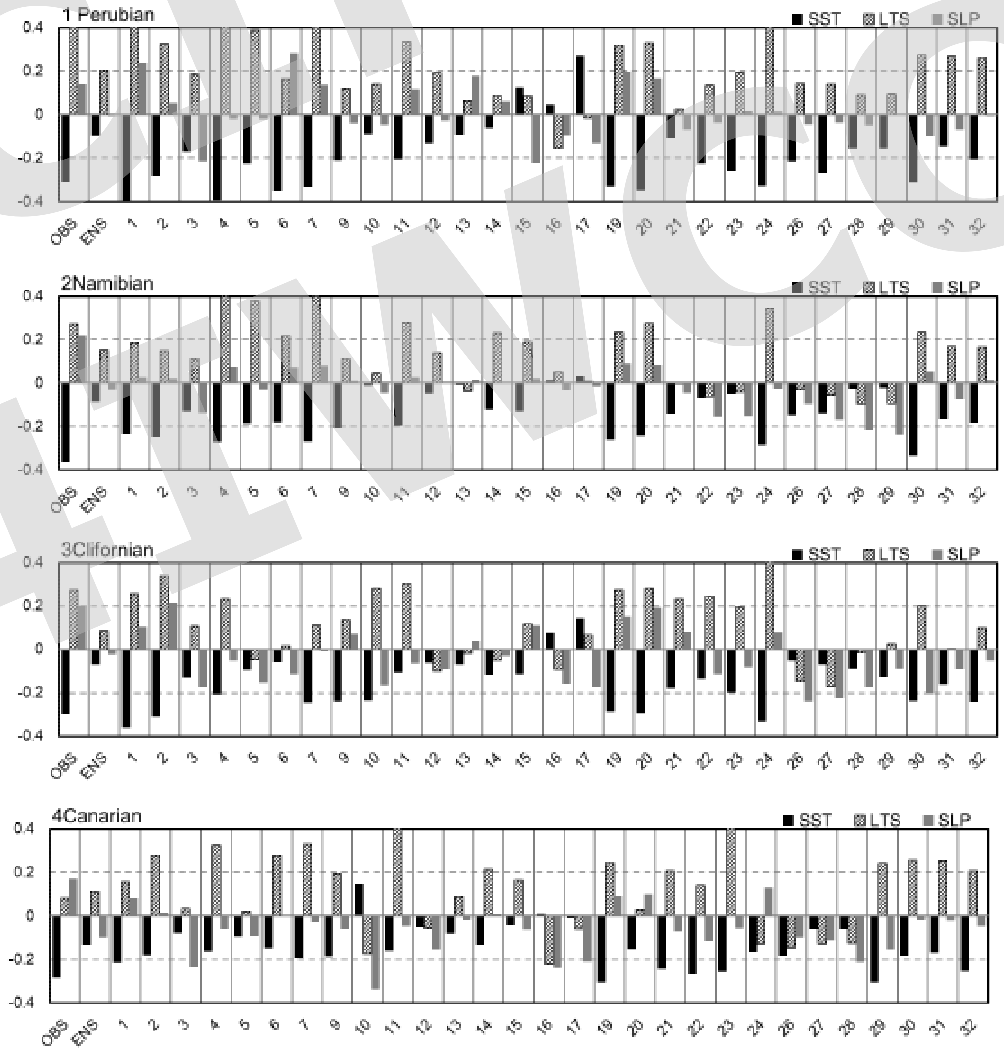
Best model selection

: PCC (obs vs model) of correlation map between TCA and

- SST (black),
- LTS (hatched),
- SLP (crossed)



Peruvian

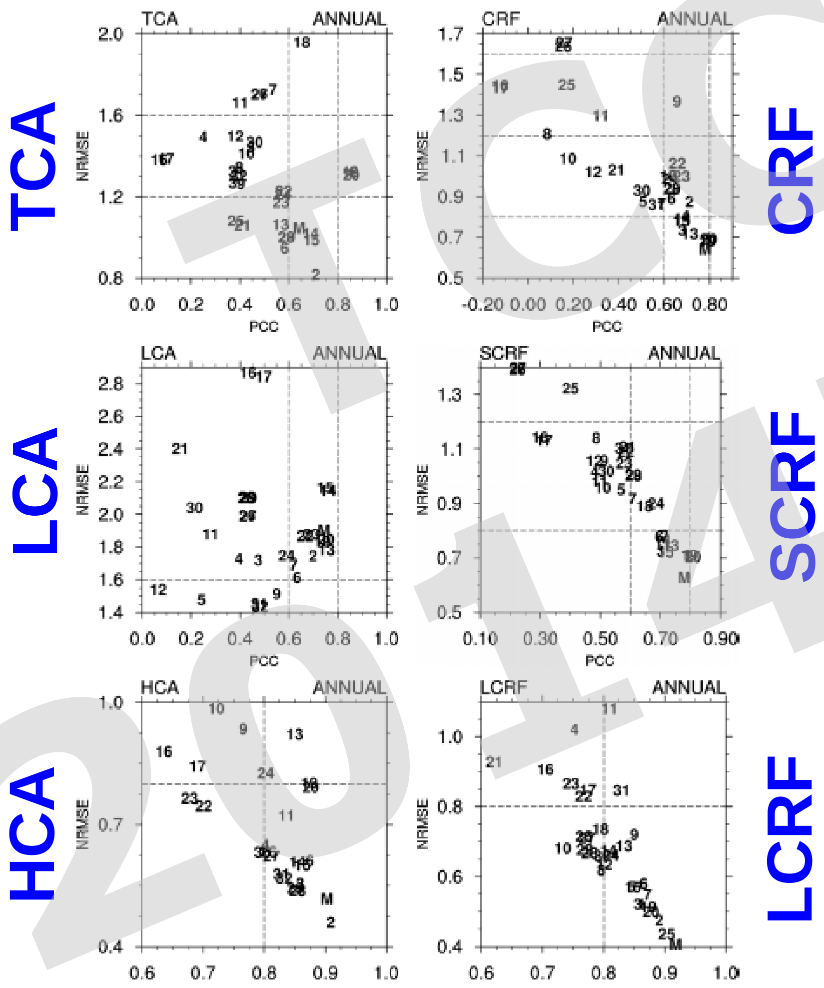
Namibian

Californian

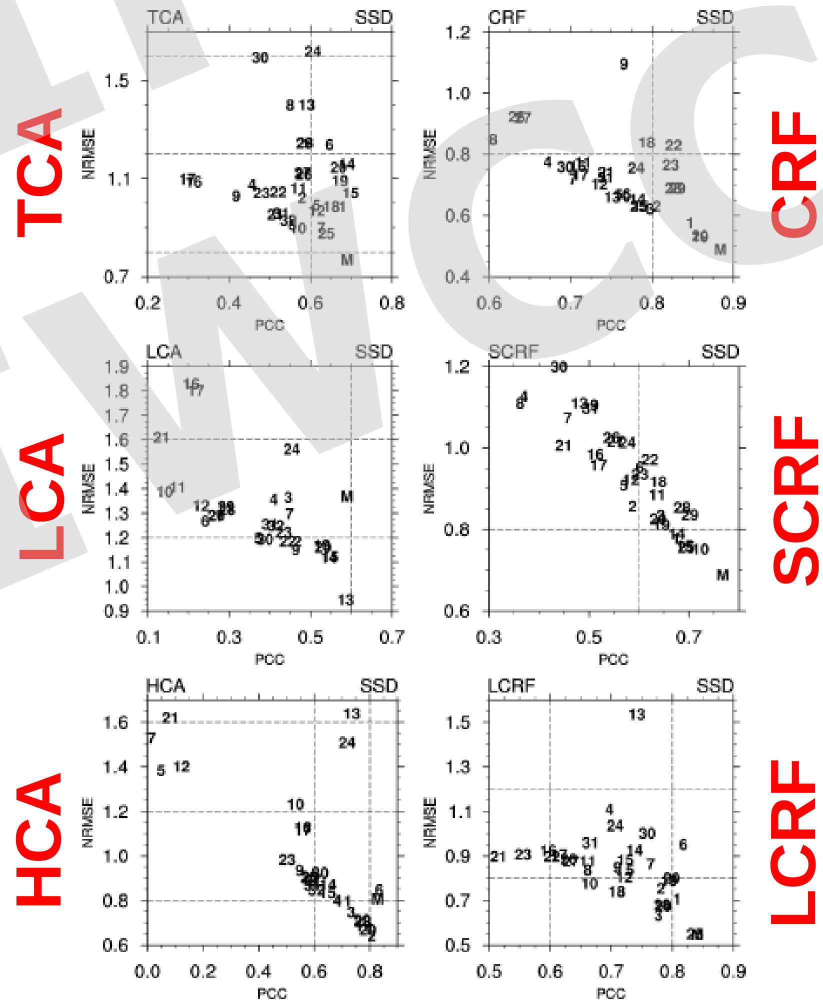
Eq. Eastern Atlantic

Best model approach: Cloud feedback (4)

Best model selection: PCC and NRMSE (obs vs model)



Climatology



Climatological annual cycle

Best model approach: Cloud feedback (5)

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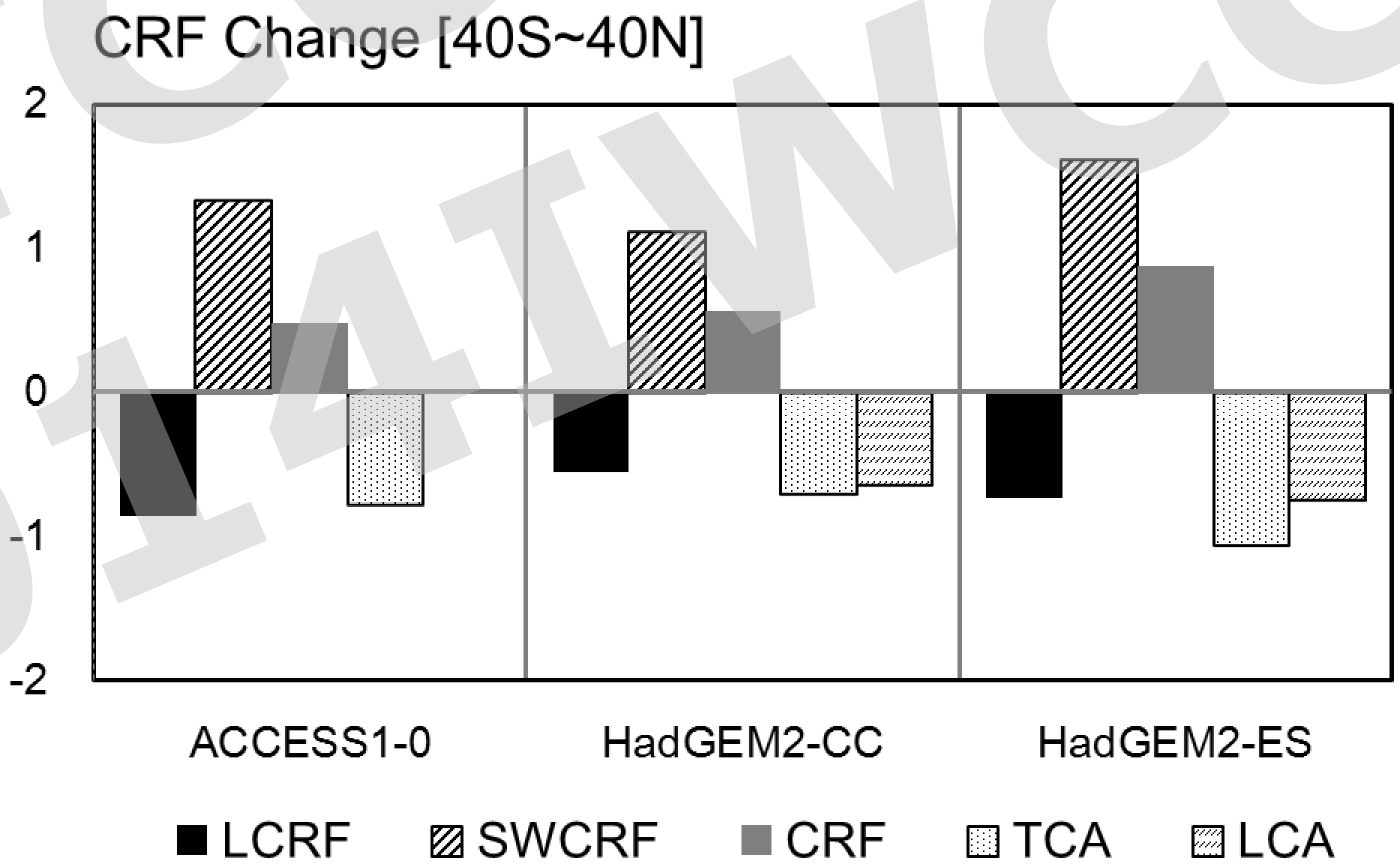
- **Consistency in future change in best models : (2080-2100)-minus-(1984-2005)**

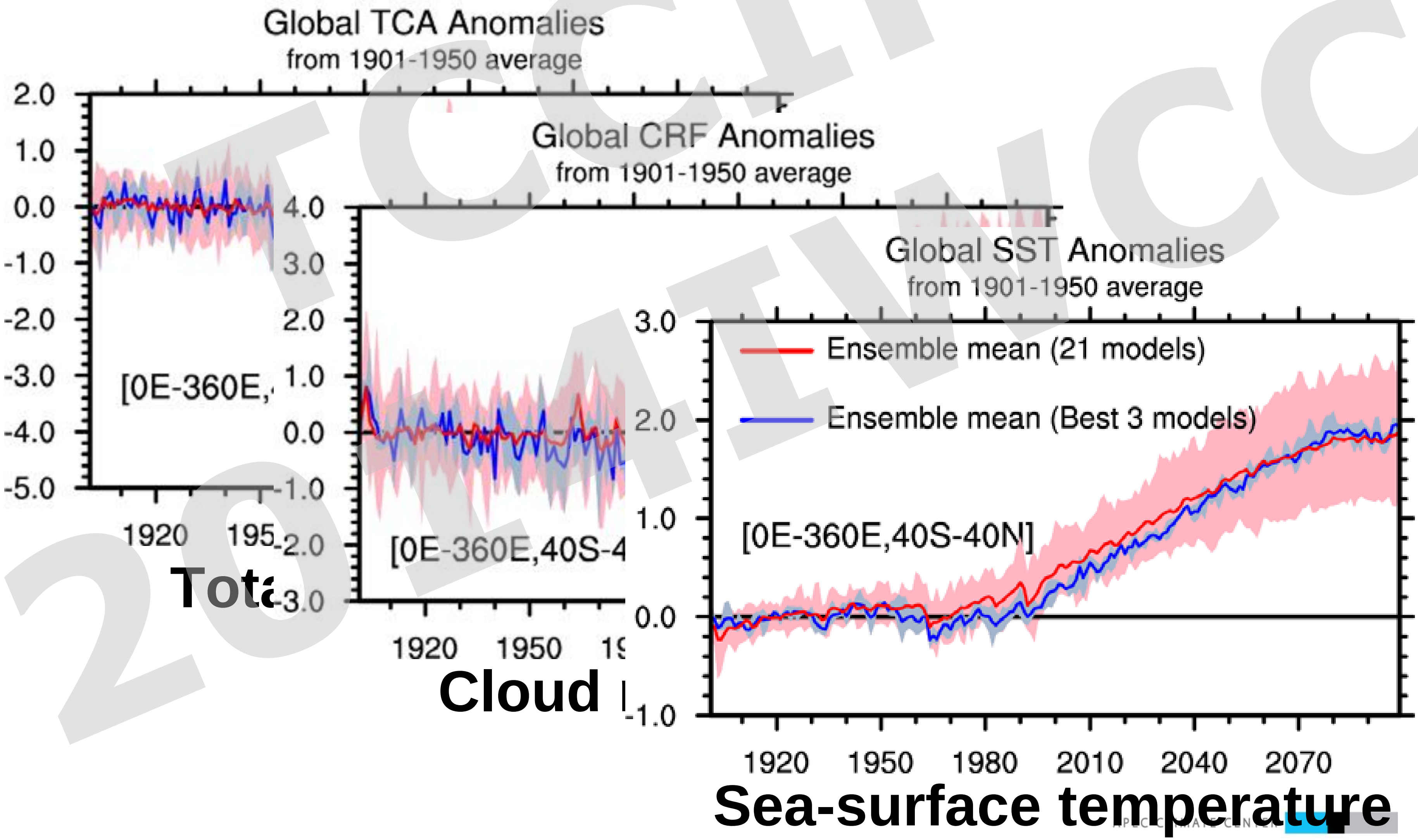
Radiative forcing [Wm^{-2}/K]

Cloud amount [%/K]



Best model approach: Cloud feedback (6)

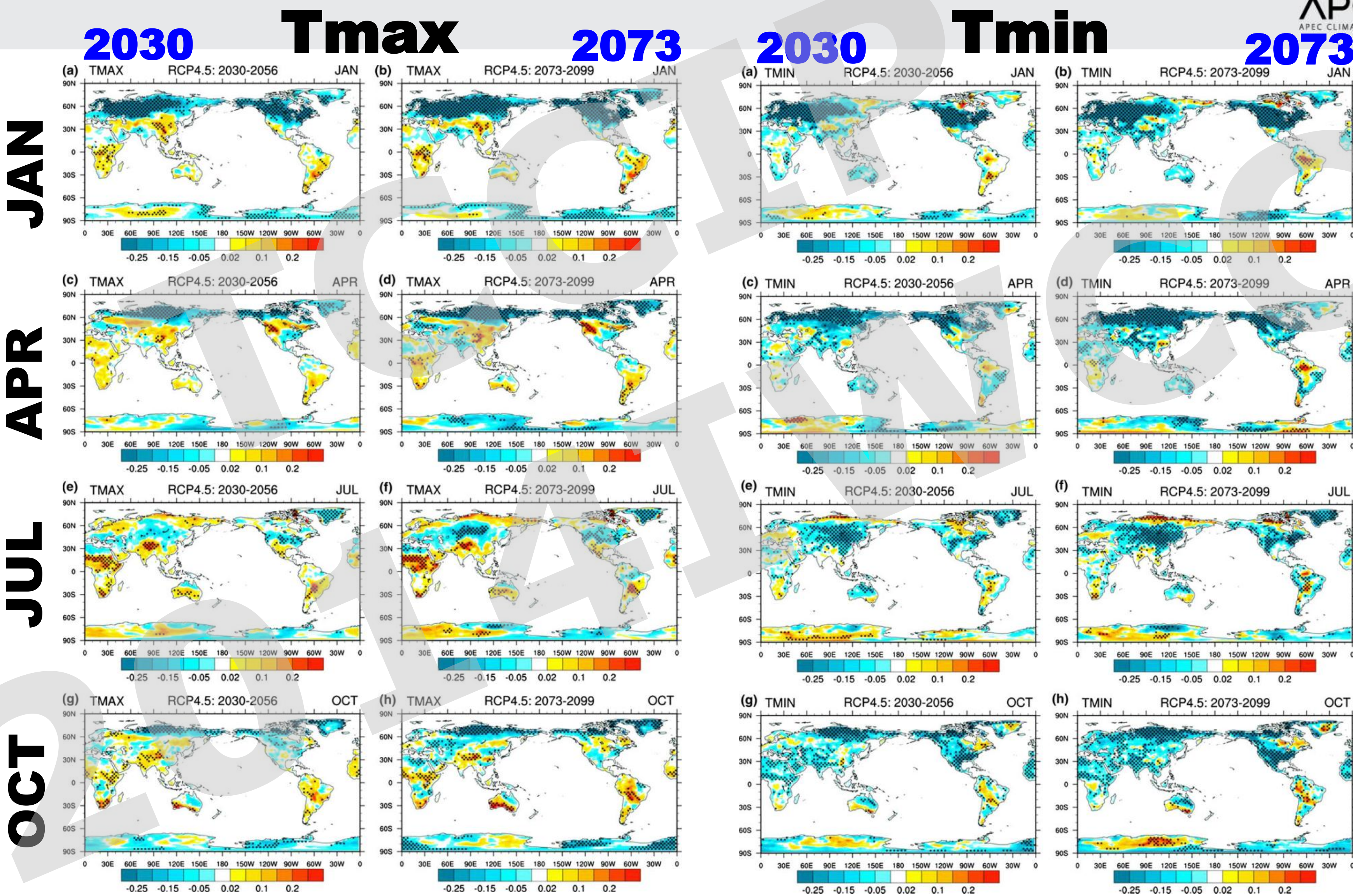
- **Reduction of uncertainty in best models**



Best model approach: Weather variability (1)

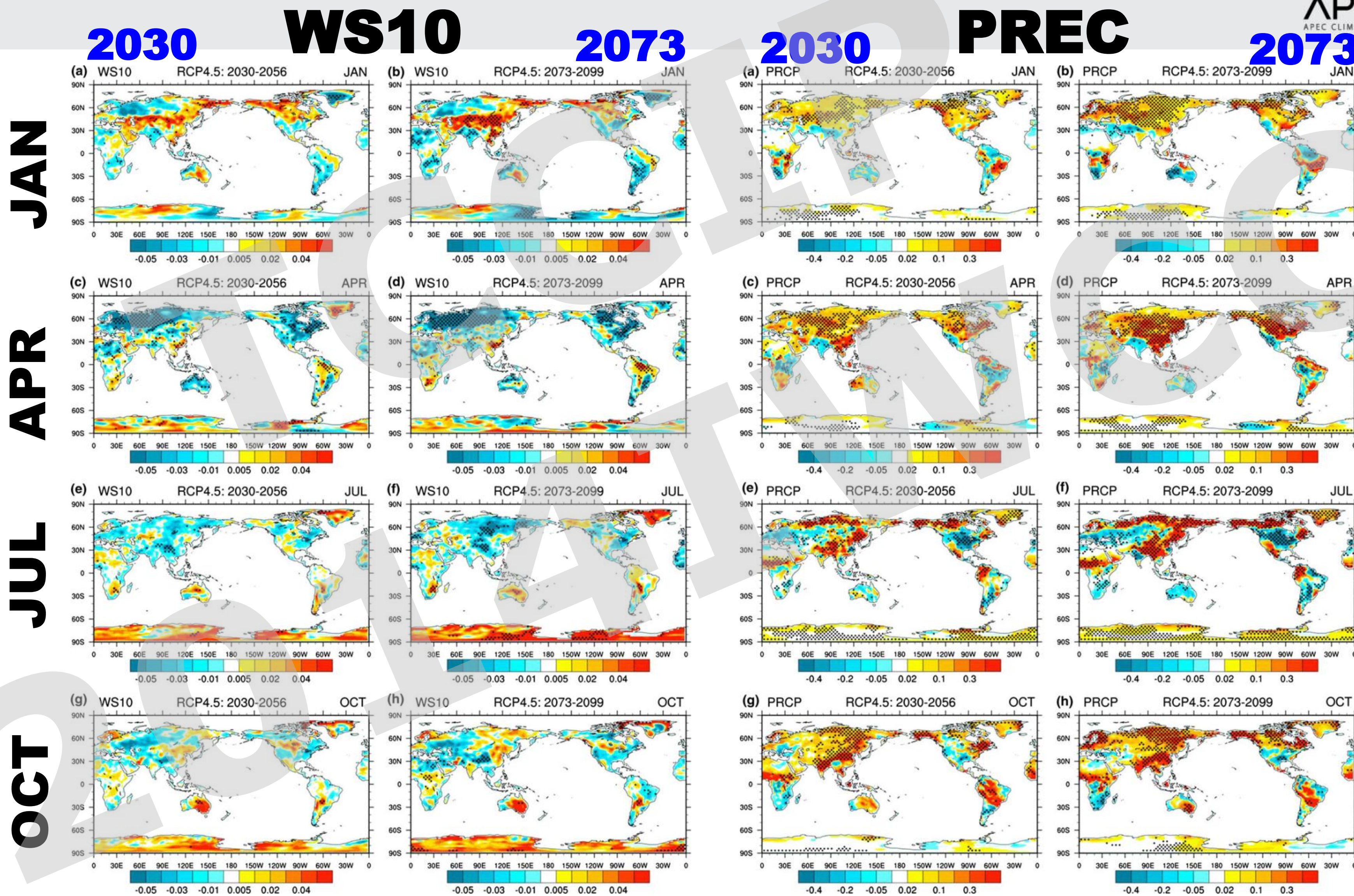
- **Interdiurnal variability (IDV)**
  : Magnitude of the difference in the daily variable between two consecutive days
- **Mean interdiurnal variability (MIDV)**
  : Averaging the IDV over the entire period for a particular month
- Reduction (increase) of MIDV means weakening (strengthening) of the synoptic systems.
- Three best models for Tmax, Tmin, WS10, PREC
- **Signal-to-Noise ratio**
  : Can best model signal beat inter-model spread?

Best model approach: Weather variability (2)



Best model ensemble beats inter-model spread!

Best model approach: Weather variability (3)



Best model ensemble beats inter-model spread!

Conclusions

- The results from the best model approach suggest (1) a reduction of uncertainty without loss of signal, and/or (2) detection of signal against inter-model spread.
- This method seems to be applicable to high-frequency variability.
- It is a potentially smarter way to use best models identified with well-designed metrics for processes and/or feedbacks of interest.

THANK YOU!