Beyond IPCC plots

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What assumptions are we making?
The Chain of Uncertainty: Heat waves

1. Future Emissions
2. Global Climate Sensitivity
3. Regional Feedbacks
4. Random variability
5. Heat wave frequency
Future Emissions

Global surface temperature change (°C)

Model mean global mean temperature change for high emission scenario RCP8.5

Model mean global mean temperature change for low emission scenario RCP2.6

IPCC AR5 (2013)
The Chain of Uncertainty: Heat waves

Future Emissions → Global Climate Sensitivity → Regional Feedbacks → Random variability → Heat wave frequency
Random variability


Deser et al (2012)
Large ensembles can sample ‘weather’ noise.
The Chain of Uncertainty: Heat waves

- Future Emissions
- Global Climate Sensitivity
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The IPCC worldview: means and confidence
What is this assuming?

truth + error

More models: more confidence in projection
Another model?

indistinguishable

More models: better knowledge of distribution
The spectacular mean
Partly due to geometry...

The Cauchy-Schwartz inequality
... and partly due to tuning

Sanderson and Knutti (2012)
Truth centered now doesn’t mean truth centered later

Sanderson and Knutti (2012)
OK, so the ensemble members for future projections are indistinguishable from truth, right?
Some models are better than others (but the winner depends on what you look at...)

North America Skill (all seasons)
So can we find “emergent” constraints?
But correlation (on its own) is not conclusive.
Are we overestimating confidence because models are replicated?
And are we creating artificial emergent constraints?
Can we weight models to take account of interdependency?
Observable 1

Observable 2

Observed value

Observed value models
Model Independence

Observable 1

Observable 2

Radius of model similarity

0.5

1.0

0.5

0.33

1.0

0.33

0.33
Differences between CMIP mean states are much greater than those from initial conditions.
Overall weight

Observable 1

Observable 2

Overall weight

Observable 1

Observable 2

Overall weight
A weighting function for model quality and independence

\[ w(i) = \frac{e^{-\left(\frac{\delta_{i,\text{obs}}^{20c}}{D_q}\right)^2}}{1 + \sum_{j \neq i} e^{-\left(\frac{\delta_{ij}^{20c}}{D_u}\right)^2}} \]
A weighting function for model quality and independence

Weight of a given model \( i \)

\[
w(i) = \frac{1 + \sum_{j \neq i} e^{-\left(\frac{\delta_{ij}^{20c}}{D_u}\right)^2}}{\left(-\left(\frac{\delta_{i(obs)}^{20c}}{D_q}\right)\right)^2}
\]
A weighting function for model quality and independence

\[ w(i) = \frac{1 + \sum_{j \neq i} e^{-\left(\frac{\delta_{i,j}^{2D} c}{D_q}\right)^2}}{\delta_{i}^{2D} c} \]

Distance of model to observation

Model Quality metric

Quality Scaling parameter

Distance of model `i` to another model `j`

Similarity Scaling parameter

Model independence metric

Weight of a given model `i`
The Chain of Uncertainty: Heat waves

Future Emissions → Global Climate Sensitivity → Regional Feedbacks → Random variability → Heat wave frequency
• Instrumental Period
• Mean State
• Paleo Records
• Bayesian Combination

Data from Knutti et al (2008)
The Devil in the grid-box
Climate Sensitivity is a function of uncertain model parameters.
CMIP is an ensemble of best guesses – not a PDF

Rowlands et al. (2013)
So are PPEs the answer?
1. Constraint of large scale response variables

Stainforth et al. (2005)

There is no filter! (some ensemble members are demonstrably unlike Earth)

Most models look identical (many parameters do nothing of interest)

Some models are outside the CMIP climate sensitivity range, but cannot be ruled out

Stainforth et al. (2005)
Most PPE members look the same…

Yokohata et al, ClimDyn (2011)
Emergent constraints from large PPEs are statistically significant (but not robust to structural differences)
Conclusions

• The CMIP multi-model archive contains models of varying skill and interdependency.

• The distribution of model errors, and inter-model distances are a rich source of information which can provide mitigating strategies.

• CMIP is an ensemble of best guesses, so the resulting distribution cannot be interpreted as a PDF for future climate.

• PPEs can provide additional information on possible tails – but cannot replace the structural diversity of CMIP.
If it isn’t truth centered, can you make it so?
Application: Sea ice area projections (RCP8.5)

Knutti, Sedlacek and Sanderson (in prep)
Models which are closer together than could occur by chance alone...
A process of elimination: knocking out the worst performing and least independent models first.
But when to stop?
But when to stop?

- Removing replicates
- Removing poor performers
- Removing better models