Multi-model uncertainty II
Ben Sanderson
I

Perturbed Physics,
and why
we’re all kidding ourselves
So, you want to build an ensemble?

- 81x3 15yr simulations
- ~2 million hours CPU time
- ~60 MWh (on Jaguar)
- 94 tonnes CO₂ emitted (coal)
- 17 round-the-world flights
- 1/2 million bikes up the Mesa
- 1x10⁻⁷K additional warming above RCP4.5 (S=3.5K)

Sanderson(2011)

Have a question first.
1. Constraint of large scale response variables

Stainforth et al. (2005)
1. Constraint of large scale response variables
2. Optimal Parameter Search

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2. Optimal Parameter Search
3. Plausible worlds

McSweeney and Jones, UKMO press release
1. Constraint of large scale response variables

2. Optimal Parameter Search

3. Plausible worlds

3. Process understanding

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Sanderson et al (2011)
From ensemble to probability

Murphy et al. (2004)
Prior Sensitivity

(a) Uniform sensitivity

(b) Uniform feedbacks

(c) Climate sensitivity

Uniform prior in $S$
Uniform prior in $1/S$
Uniform prior in TCR

Frame et al (2005)
Bayesian Representation

- Probability of a future Climate $y_f$ given a set of observations ‘o’
- Prior probability of simulating future climate existing at ‘x’
- Observational and systematic discrepancy at ‘x’
- Expert prior parameter distribution

Murphy et al. (2007)
Transfer Function approach

Knutti et al. (2006)

Piani et al. (2005)
Sanderson (in press)
Systematic Differences

Yokohata et al (2010)

Sw Cloud Feedback at 880-800hPa
[W m$^{-2}$ K$^{-1}$]

HadCM3
MIROC
Is one model enough?

Yokohata et al., ClimDyn (2011)
Multi-model ensembles
(but not as many as you think)
Just weight them?
With what?

Santer et al (2009)
Is the past even relevant?

Abe et al (2009)
Transfer functions?

Sanderson et al (in prep)
In special cases...

Qu and Hall (2007)
A matter of interpretation

truth + error

indistinguishable
The Bayesian Approach
The spectacular mean...
The Cauchy-Schwartz inequality

\[ \frac{1}{n} \sum \| m_i - O \|^2 = \frac{1}{n} \sum \| m_i - M \|^2 + \| O - M \|^2 \]

mean obs-model distance  mean model-mean distance  obs-mean distance

ensemble member
observations
ensemble mean

The Cauchy-Schwartz inequality
A reliable ensemble?

Surface air temperature rank histogram

Bias 7.99  Spread 3.04

Annan and Hargreaves (2010)
Sanderson and Knutti (in press)
Model Similarity

Masson et al (2011)
Sanderson and Knutti (PNAS, submitted)
Observation Weighted
Uniform Sample
Individual Sensitivities
Cluster 1: $P=0.31$
- NorESM1–M(5)
- MRI–CGCM3(5)
- GISS–E2–R(5)
- CNRM–CM5(5)
- CESM1–CAM5
- CCSM4(5)
- CCSM3(3)
- BCC–CSM1.1(5)

Cluster 2: $P=0.16$
- GFDL–ESM2M(5)
- GFDL–CM3(5)
- GFDL–CM2.1(3)
- GFDL–CM2(3)
- CSIRO–MK3.0(3)

Cluster 3: $P=0.14$
- MPI–ESM–LR(5)
- MPI–ECHAM5(3)
- MIROC5(5)
- MIROC3.2–MEDRES(3)
- MIROC3.2–HRES(3)
- MIROC–ESM–CHEM(5)
- MIROC–ESM(5)

Cluster 4: $P=0.14$
- HadGEM2–ES(5)
- HadGEM2–CC(5)
- HadGEM1(3)
- HadCM3(3)

Cluster 5: $P=0.10$
- CanESM2(5)
- CCCMA–CGCM3.1–T63(3)
- CCCMA–CGCM3.1(3)

Cluster 6: $P=0.07$
- MRI–CGCM2.3.2A(3)
- IPSL–CM5A–LR(5)
- IPSL–CM4(3)

Cluster 7: $P=0.04$
- NCAR–PCM1(3)
- IAP–FGOALS1.0–G(3)
- GISS–E–H(3)

Cluster 8: $P=0.03$
- INMCM4(5)
- INMCM3(3)

2070–2100 Warming relative to 1970–2000 (K)

Sanderson and Knutti (PNAS, submitted)
III

Bringing it all together
The future is super-ensembles

Yokohata et al (2010)
Sanderson (Climatic Change, in press)

(a) CMIP-3 constraint = 0.5K

(b) CMIP-3 constraint = 1.5K

(c) CMIP-3 constraint = 3K
Conclusions

• PPEs – decide on a question first
• Remember your result is dependent on model structure
• PPEs are rarely ‘reliable’
• MMEs have smaller dimensionality than N
• An ensemble of best guesses is not a PDF
• A full uncertainty treatment must consider both parametric & systematic uncertainty