A small statistical contribution towards a global picture

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Outline of the Talk

- Introduce IPCC, its mission and contributions
- Outline the framework of the statistical analysis for an IPCC publication
- Develop a multivariate Bayesian analysis of Atmosphere-Ocean General Circulation Models

IPCC: 101

Intergovernmental Panel for Climate Change (IPCC)

- assesses scientific information relating to climate change
- formulates realistic response strategies

IPCC: Structure

IPCC: Assessment Reports


Fourth Assessment Report (AR4) is planned for 2007.
WG1: The Scientific Basis

Working group 1 is concerned with the scientific aspects of the climate system itself and climate change in particular.

- Observations
- Paleoclimate
- Climate Models and their Evaluation
- Understanding and Attributing Climate Change
- Global Climate Projections
- Regional Climate Projections

Study Climate with AOGCMs

AOGCM: Atmosphere-Ocean General Circulation Models

Numerical models that calculate the precise large-scale motions of the atmosphere and the ocean explicitly from hydrodynamical equations.

Models Do Not Agree

Example: Atmospheric Model

Input
- External forcings (radiation, volcanos, ...)
- Anthropogenic forcings (GHG, aerosols, ...)
- Initial conditions
- Flow dynamics, PDEs
- Discretization and simplifications
- Parametrization

Output
- Temperature and precipitation
- Pressure, wind, ...

Quantifying Uncertainty

- Variability of global temperature increase across 16 models. MAGICC/SCENGEN program (Wigley, 2003).
- Probabilistic description of regional climate changes. (Tebaldi et al. 2005).
- Gridded, global, spatial approach ...
Data

Data provided for the Fourth Assessment Report of IPCC:

- 19 models (CCSM, GFDL, HADCM, PCM, ...)
- At least $2.8^\circ \times 2.8^\circ$ resolution (8192 data points, T42) aggregate to $5^\circ \times 5^\circ$
- Different scenarios (A2: “business as usual”, A1B, B1)
- Temperature, precipitation, pressure, winds...
  seasonal averages over years 1980–1999 and 2080–2099, ...
- NCEP reanalysis as “observations”

Hierarchical Statistical Model

For models $i = 1, \ldots, N$, stack the gridded output into vectors:

\[
X_i = \text{simulated present climate}_i
\]
\[
Y_i = \text{simulated future climate}_i
\]

Objective:

Probabilistic description of simulated climate change

Basis Functions $M$

We need a “rich” truncated basis set $M$.

Current candidate:

- Harmonic functions on the sphere
- Indicators for continents, sea ice, ...
- Patterns of current climate from NCEP reanalysis

Covariance Matrix $\Sigma$

Examples of positive definite functions on the sphere:

1. representation using an infinite series of Legendre polynomials
   \[
   c(h; \sigma, \tau) = \sigma \left(1 - 2\tau \cos(h) + \tau^2\right)^{-3/2}
   \]
2. restriction of a positive definite function on $\mathbb{R}^3$ to the sphere
   \[
   c(h; \sigma, \tau) = \sigma \exp\left(-\tau \sin(h/2)\right)
   \]

We only parameterize the scale $\sigma$ of the covariance matrix $\Sigma$.

The “range” $\tau$ is chosen according an “empirical Bayes” approach.

Gibbs Sampler

Distribution of $\mu$ given the AOGCM outputs.

- Full conditionals for the parameters are available
- Gibbs sampler programmed in R
- Run many iterations: 5000 burn-in, keep every 10th
- Assessing convergence with:
  trace plots, different starting values, ...
Posterior 20% quantile of synthesized, modeled temperature change

Posterior median of synthesized, modeled precipitation change

Probability that we observe at least a 2°C modeled temperature increase

Discussion and Further Work

- Simple statistical model
- Provides probabilistic answers to climatologist’s questions
- Implement ensemble runs
- Generalize covariance parametrization
- Extend to multivariate setting