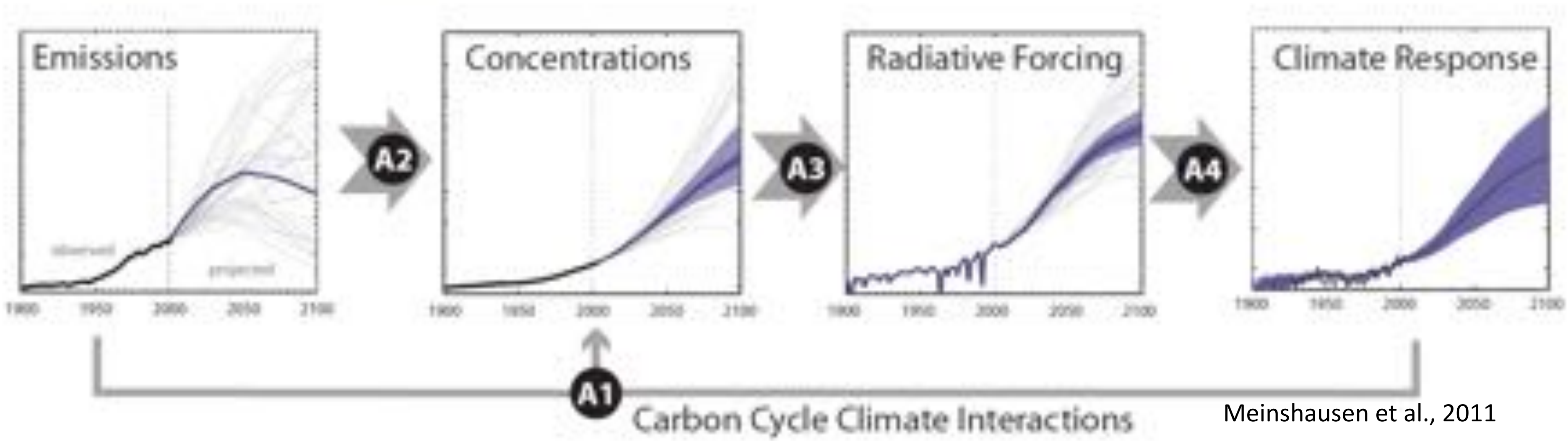
The Climate System: Approach

- By default, GCAM now uses the **Hector** (no longer MAGICC) simple carbon/climate model to compute climate related outputs.
- GCAM passes emissions to the climate model
  - Fossil fuel & Industrial CO_2, Land-Use Change CO_2, CH_4, N_2O, 26 halocarbons, SO_2, CO, NO_x, NMVOCs, BC, OC
- Hector computes atmospheric CO_2 concentrations, radiative forcing (direct and indirect), temperature change, air-land/air-sea fluxes, SLR, …

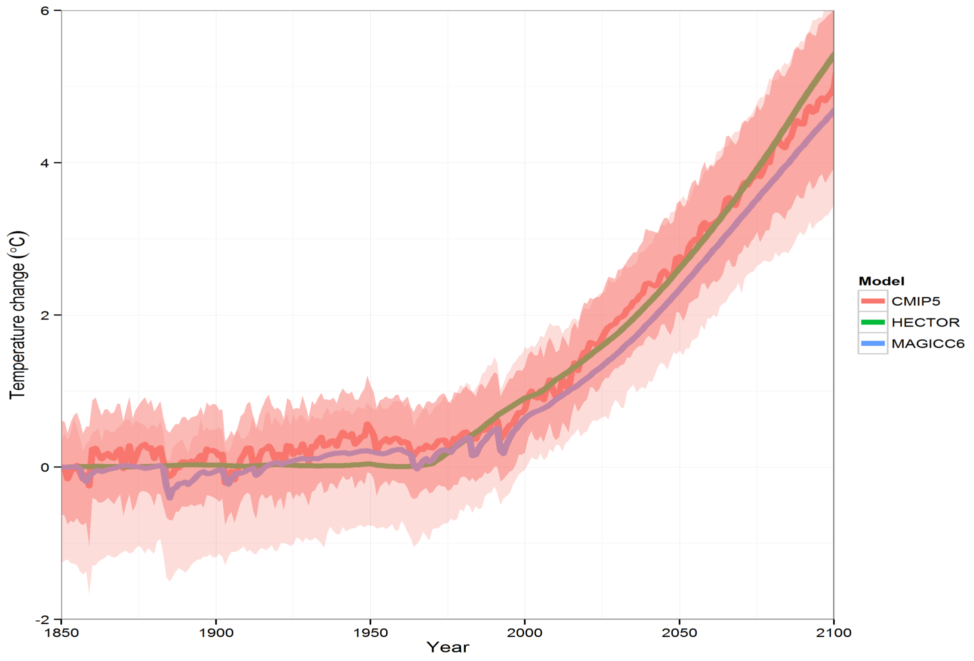


Meinshausen et al., 2011

Why the change? Hector philosophy and structure

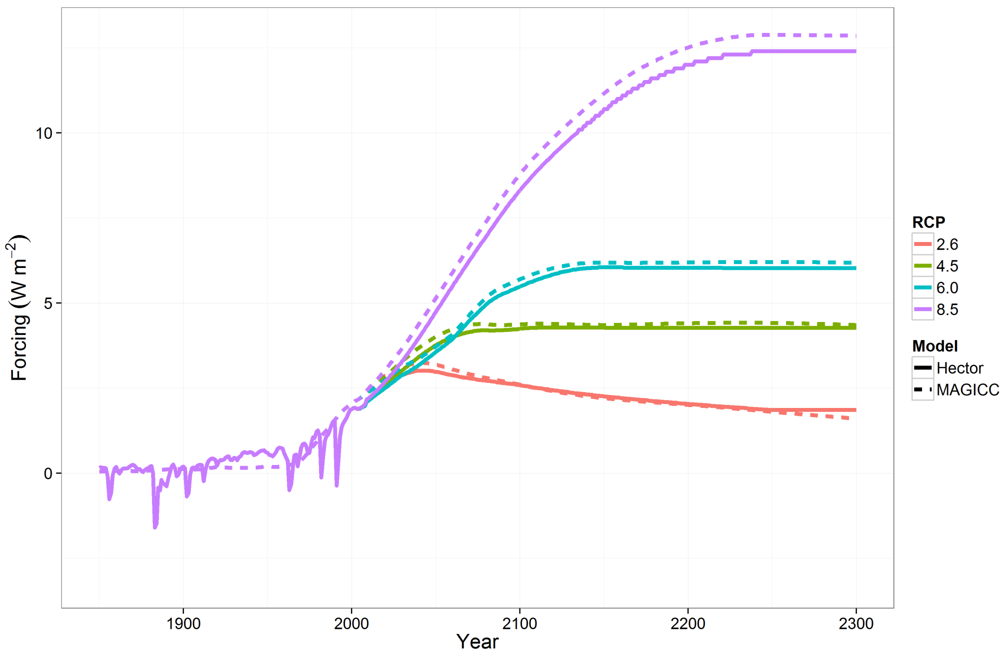
- Free and open source – community model
  - www.Github.com/JGCRI/hector
    - Option to incorporate other versions of Hector
  - Easy to use and well documented
- Strong science (e.g. active surface-ocean chemistry)
- Modular
  - Components can be enabled/disabled via inputs; e.g. you can compare two different ocean submodels
- Modern, clean structure
  - E.g. coupler enforces unit checking between submodels

Hector can track the CMIP5 median and individual models



Atmospheric Temperature – RCP8.5

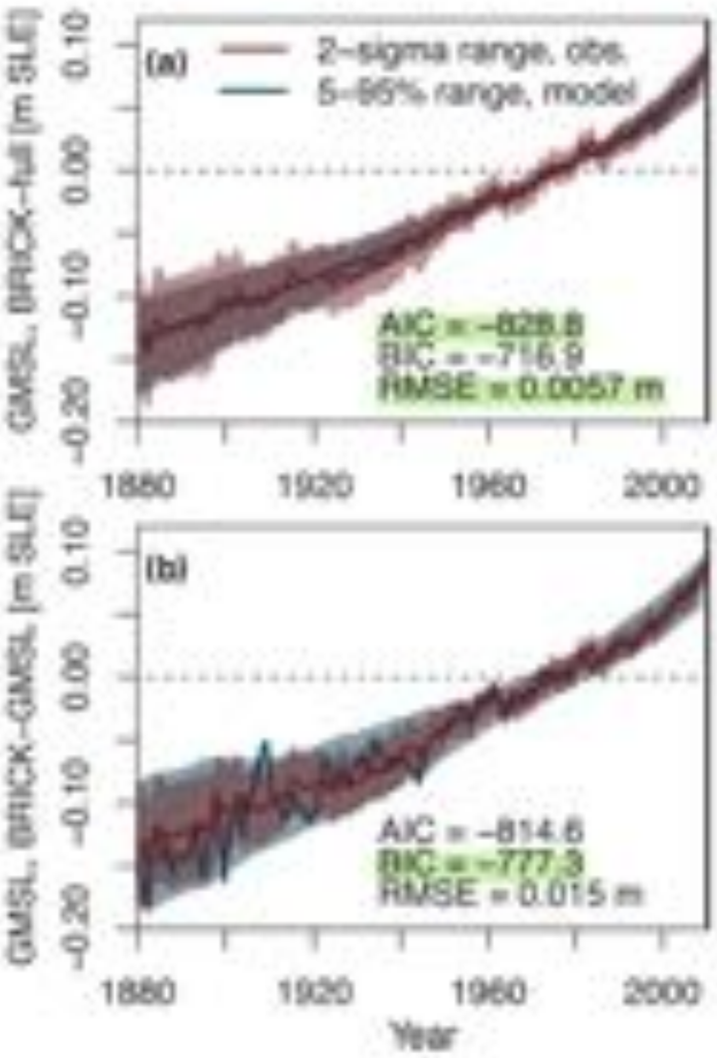
Radiative Forcing



Hartin et al., 2015 - GMD

Recent Hector developments

- Ben Vega-Westhoff and Ryan Sriver – UIUC
  - DOECLIM – ocean heat diffusion
  - BRICK – sea-level rise model
    - Contributions from Greenland, Antarctica, ice sheets and thermal expansion
- Adria Schwarber (UMD)
  - Fundamental impulse tests



Recent Hector developments

- Methods to emulate ESM outputs and capture the *coherent* spatial and temporal variability of the model
- Temperature and precipitation
- Robert Link, Abigail Snyder, Cary Lynch (all JGCRI) and Ben Kravitz (PNNL)

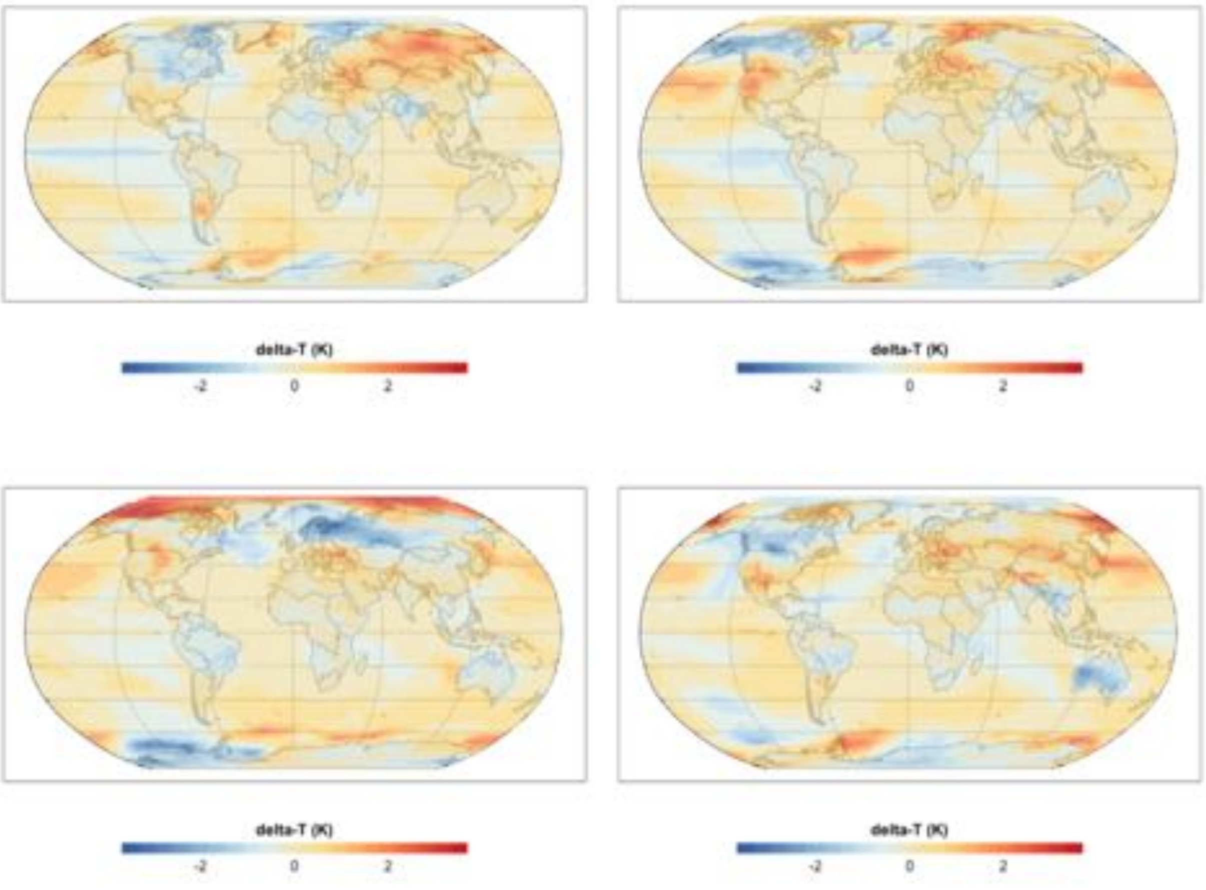


Figure 1. Year 2025 snapshot for variability fields generated using the procedure described in section 2.4. Each field is a different randomly generated realization of the temperature field's departure from the mean response. (sec. 2.3)

Recent Hector developments

- Hector can now be run as an R package
- One-line installation; help pages; vignettes
- Makes the stand-alone model much more accessible for many users
- Easy to run and integrate into e.g. sensitivity analyses
- Work by Robert Link; demos and vignettes by Alexey Shiklomanov

```r
library(hector)
ini_file <- system.file(
  "input/hector_rcp45.ini",
  package = "hector"
)
core <- newcore(ini_file)
run(core)
results <- fetchvars(core, dates = 2000:2100)
head(results)
```

```
##   year variable    value    units
## 1 2000       Ca 362.2546 ppmv CO2
## 2 2001       Ca 363.8910 ppmv CO2
## 3 2002       Ca 365.5739 ppmv CO2
## 4 2003       Ca 367.3020 ppmv CO2
## 5 2004       Ca 369.1146 ppmv CO2
## 6 2005       Ca 371.0644 ppmv CO2
```

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```r
run_with_beta <- function(value) {
  setvar(core, NA, BETA(), value, "(unitless)")
  reset(core)
  run(core)
  result <- fetchvars(core, 2000:2300)
  result[["beta"]] <- value
  result[["variable_unit"]] <- with(result, {
    sprintf("%s (%s)", variable, units)
  })
  result
}

mapped <- Map(run_with_beta, seq(0, 1, 0.05))
sensitivity_beta <- Reduce(rbind, mapped)
```