Proposal for AOGCM radiative forcing diagnostics in CMIP6

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Presented by K. Taylor to the WGCM's 17th Session

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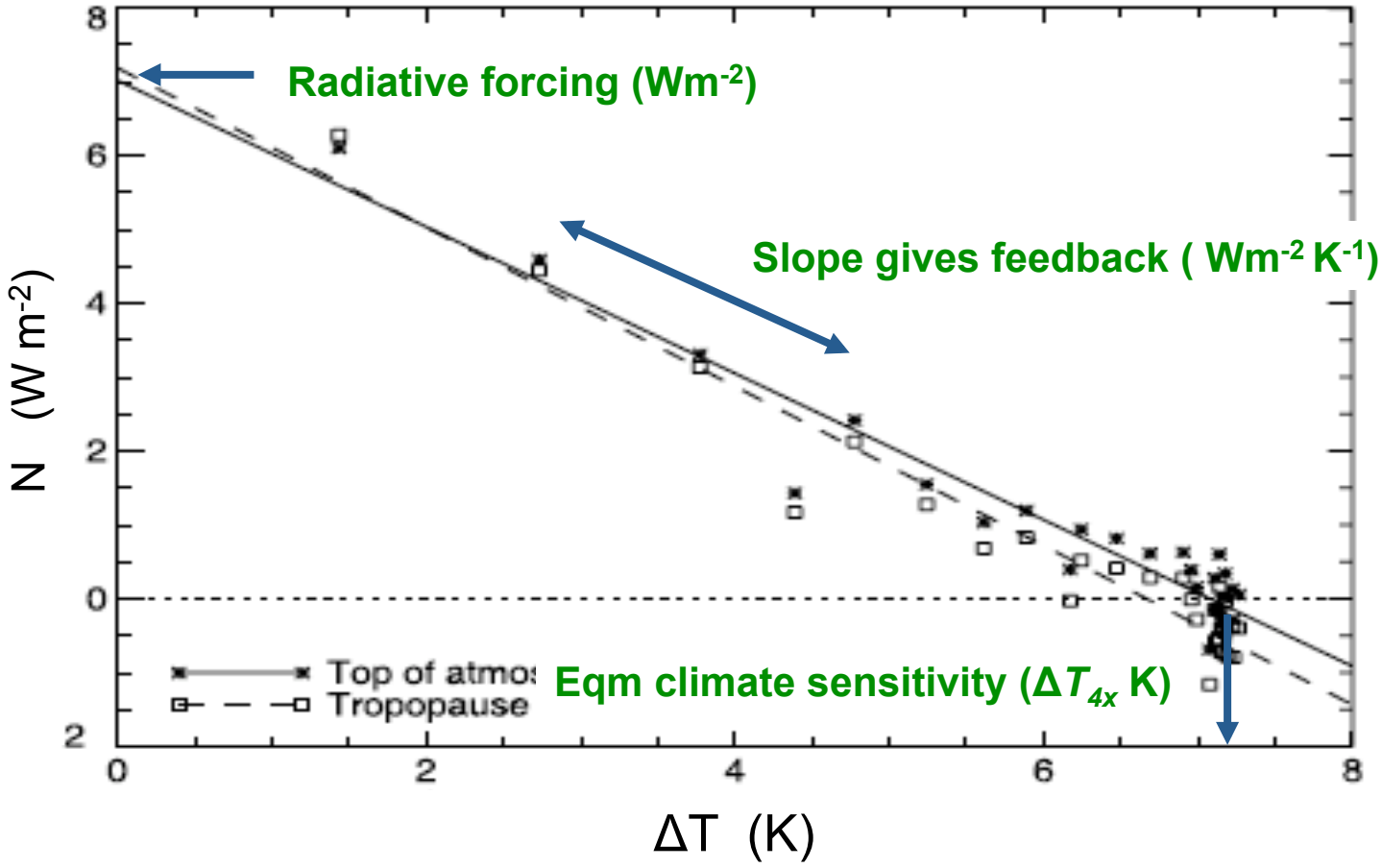
Motivation

- Why do CMIP models respond differently to the ~same "forcing" (concentrations/ emissions)?
- Distinguish between
  - "fast" (within weeks) model radiative response to imposed change – i.e., effective* radiative forcing
  - Radiative response to global temperature change (paced by ocean thermal inertia) – i.e., climate feedbacks

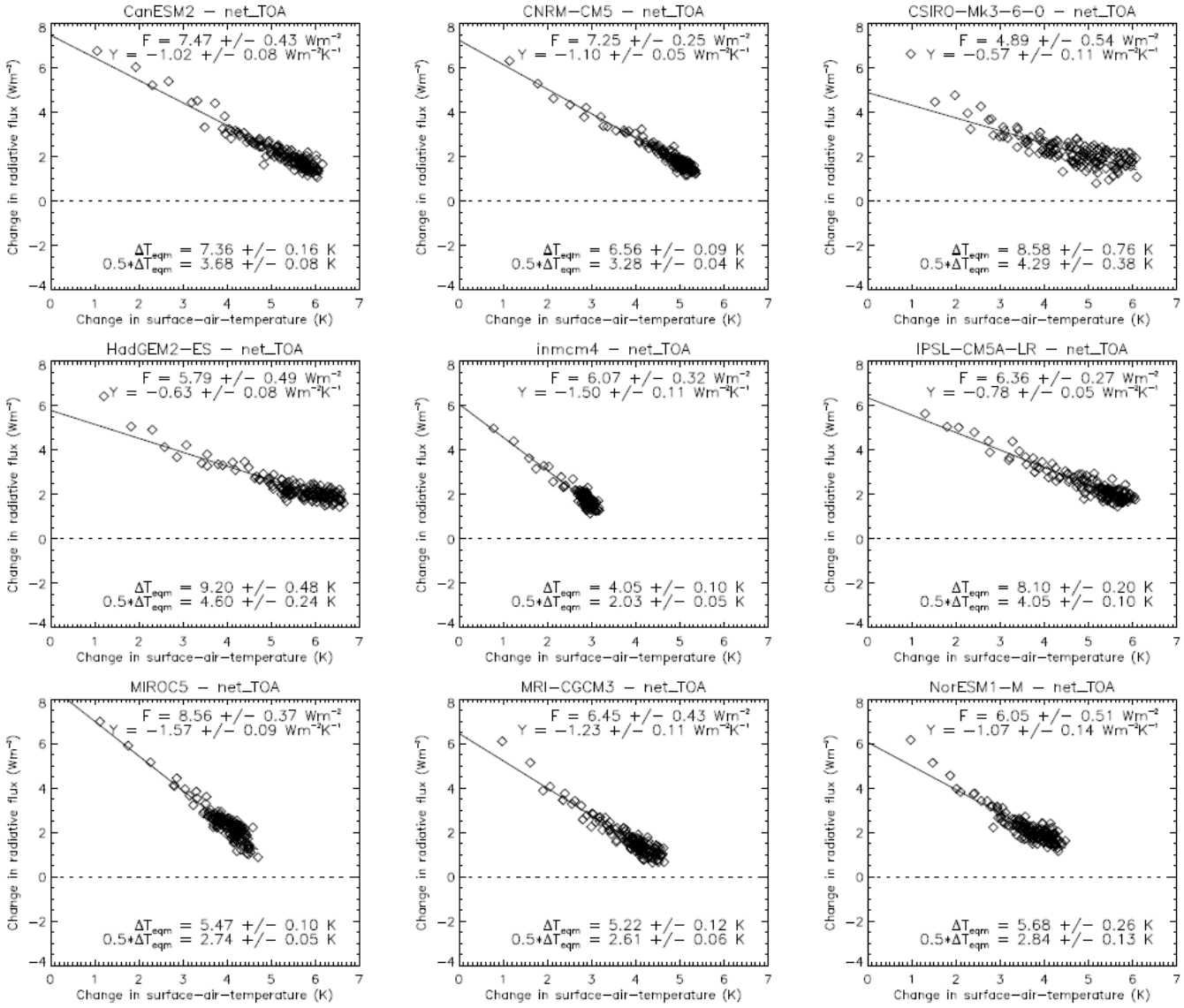
* With effective radiative forcing, climate sensitivity is found to be nearly independent of forcing agent (ERF used in AR5 to quantify drivers of climate change)

For CO_2 effective radiative forcing & climate sensitivity can be diagnosed by imposing a step increase



Gregory et al. (2004)

CMIP5 model abrupt4xCO2 results



<u>Ranges</u>

Climate fdbk (-Y) =
0.6 – 1.6 W m^{-2} / K

Forcing =
4.9 – 8.6 W m^{-2}

2xCO_2 equilibrium climate sensitivity =
2.0 – 4.6 K

Andrews et al. (2012)

How can we diagnose effective radiative forcing in historical and other runs?

- CMIP5 did a poor job diagnosing RF and ERF
  - Need a simple approach that is easily implemented by modeling centers.
- Two options:
  - Fixed SST (and sea ice) method
  - Alternative method based on assumption of climate sensitivity invariance
  - **Fixed SST method may have less uncertainty**
- Particularly important to determine ERF for **aerosol**

RF (without rapid adjustments) best compared in offline models

Fixed SST diagnostic procedure

- Use control run as baseline
- Prescribe evolving forcing agents, but with SST's and sea-ice climatology from the control
- Difference in two runs is a measure of effective radiative forcing, which is
  - Simple to implement
  - Can resolve "fast" adjustments into SW, LW, clear-sky, and cloud components.
  - Can make use of ISCCP diagnostics to provide details of aerosol cloud forcing and other rapid adjustments (e.g. Zelinka et al., 2013)

Suggested Priority of Integrations

1) concentrate on diagnosing transient forcing
2) raise the priority of aerosol

1. 4xCO2 – constant forcing
2. Historical and future runs (with control SST & seaice)
   a) All forcings
   b) Aerosol precursors
   c) WMGHGs
   d) Total Anthropogenic
   e) Natural
   f) Individual forcing runs

Tests needed

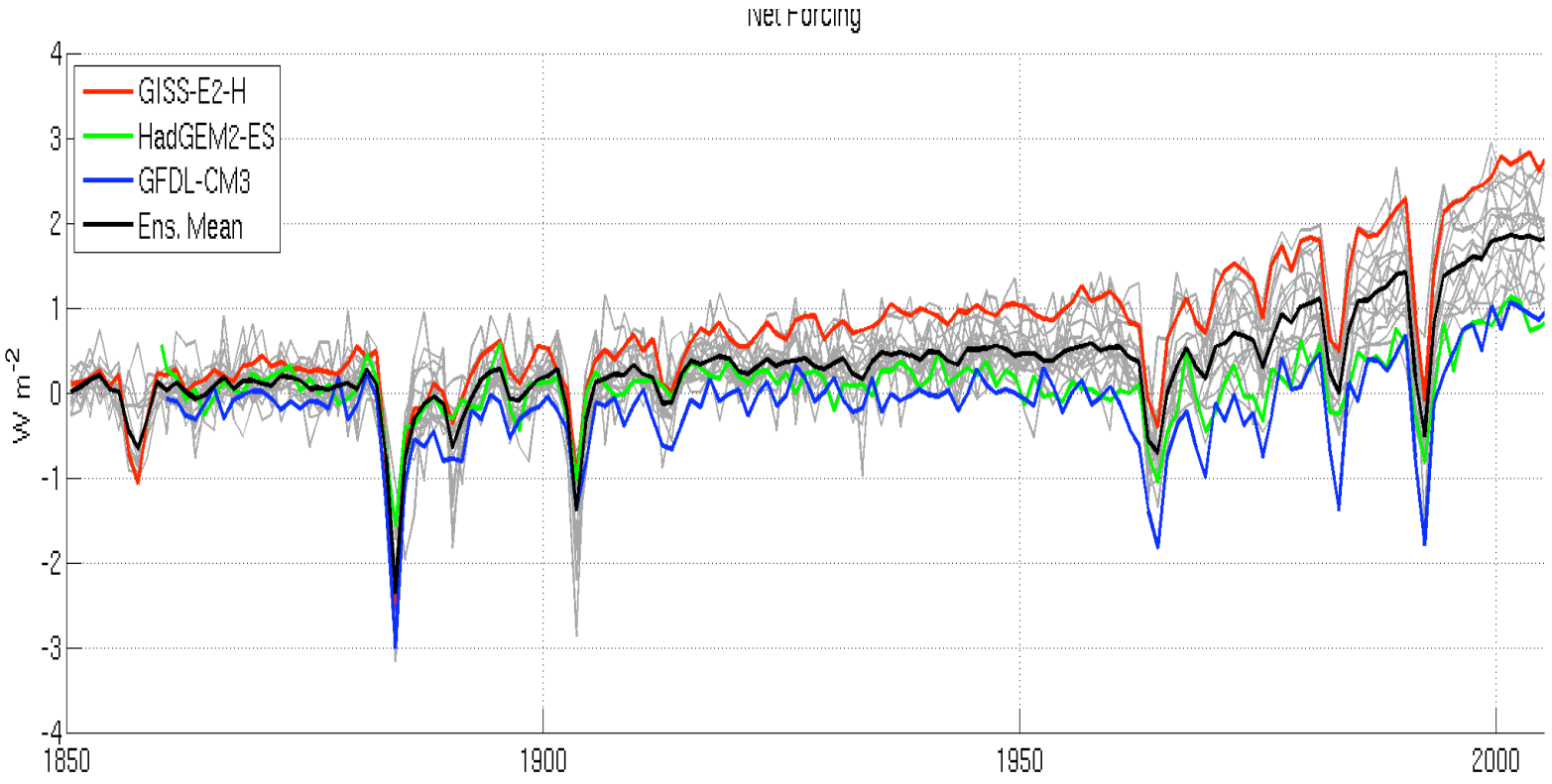
- Subset of models should run forcing experiments with different climatologies to test how forcing might depend on base-state
  - Pre industrial, present-day and 2100.
- Also need to test averaging period and /or size of ensembles that maybe needed

→ We will do these tests and try to publish the approach (others?)

Alternative method could be used to reduce computational expense

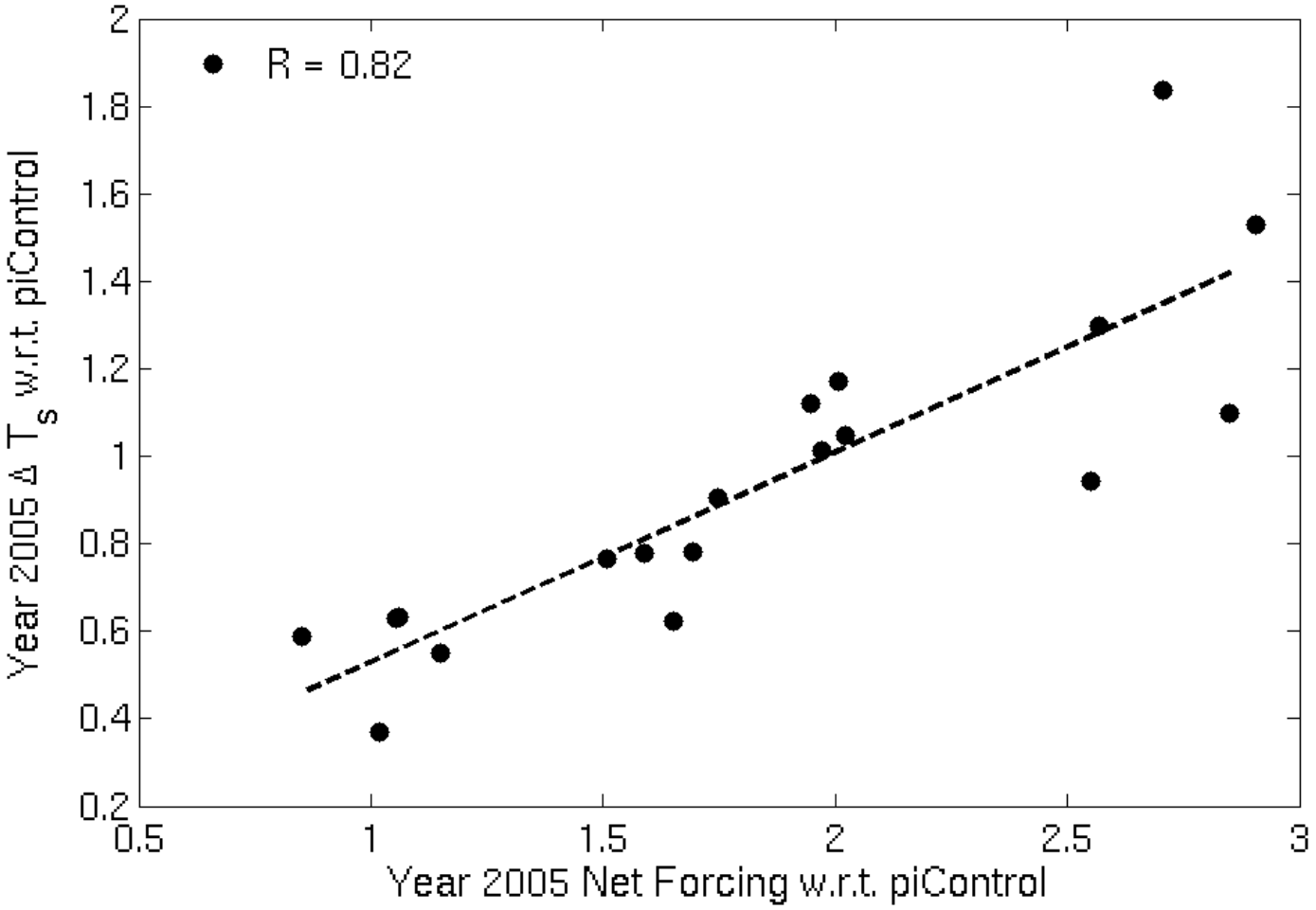
- Forster & Taylor (2006):
  - Diagnose model climate feedbacks using Gregory method.
  - Assume feedbacks are independent of forcing agents and climate state
  - Compute forcing by removing feedback component of perturbation in TOA fluxes

Radiative forcing diagnosed for CMIP5 historical runs



Courtesy of Mark Zelinka
(similar to Forster et al., 2013)

In CMIP5 historical runs, differences in effective radiative forcing explain a large portion of the differences in temperature change



Courtesy of Mark Zelinka
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Summary: Recommend increased emphasis in CMIP5 to quantify differences in effective radiative forcing

- Further study needed to determine best method
- Preliminary evaluation:
  - Fixed SST method advantages:
    - Fewer assumptions (likely more accurate)
    - Somewhat less noisy
    - Possible to examine dependence of feedbacks on climate state and forcing agents
  - FT06 advantages:
    - Can be computed from historical and future all forcing runs already planned
    - For “individual” forcing, can be computed from detection/ attribution runs already proposed

Assessing the accuracy of radiation parameterizations for CMIP6: Clear-sky fluxes and forcings

Robert Pincus, Eli Mlawer, Bill Collins, James Manners, Lazaros Oreopoulos, V. Ramaswamy

2 October 2013

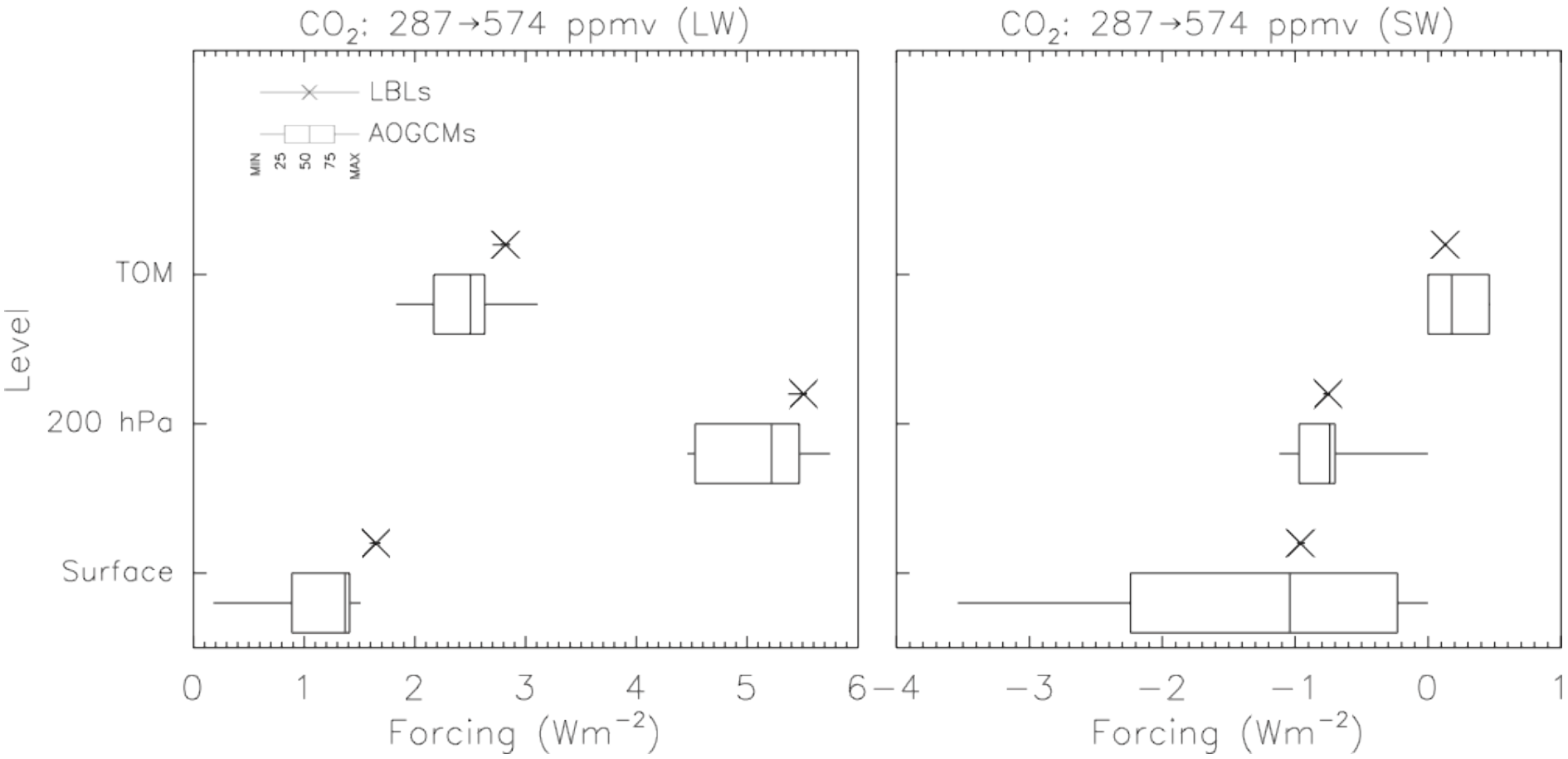
Rationale

- Our understanding of radiative transfer is quite complete, especially for clear skies
- Our parameterizations do not always reflect this certainty
- Sloppiness in parameterizations likely contributes a small portion of the total diversity in e.g. forcing...
- ... but this diversity is unnecessary. It should be identified (and ideally removed)
- Parameterization accuracy for some important applications (e.g. 4xCO_2) is unknown

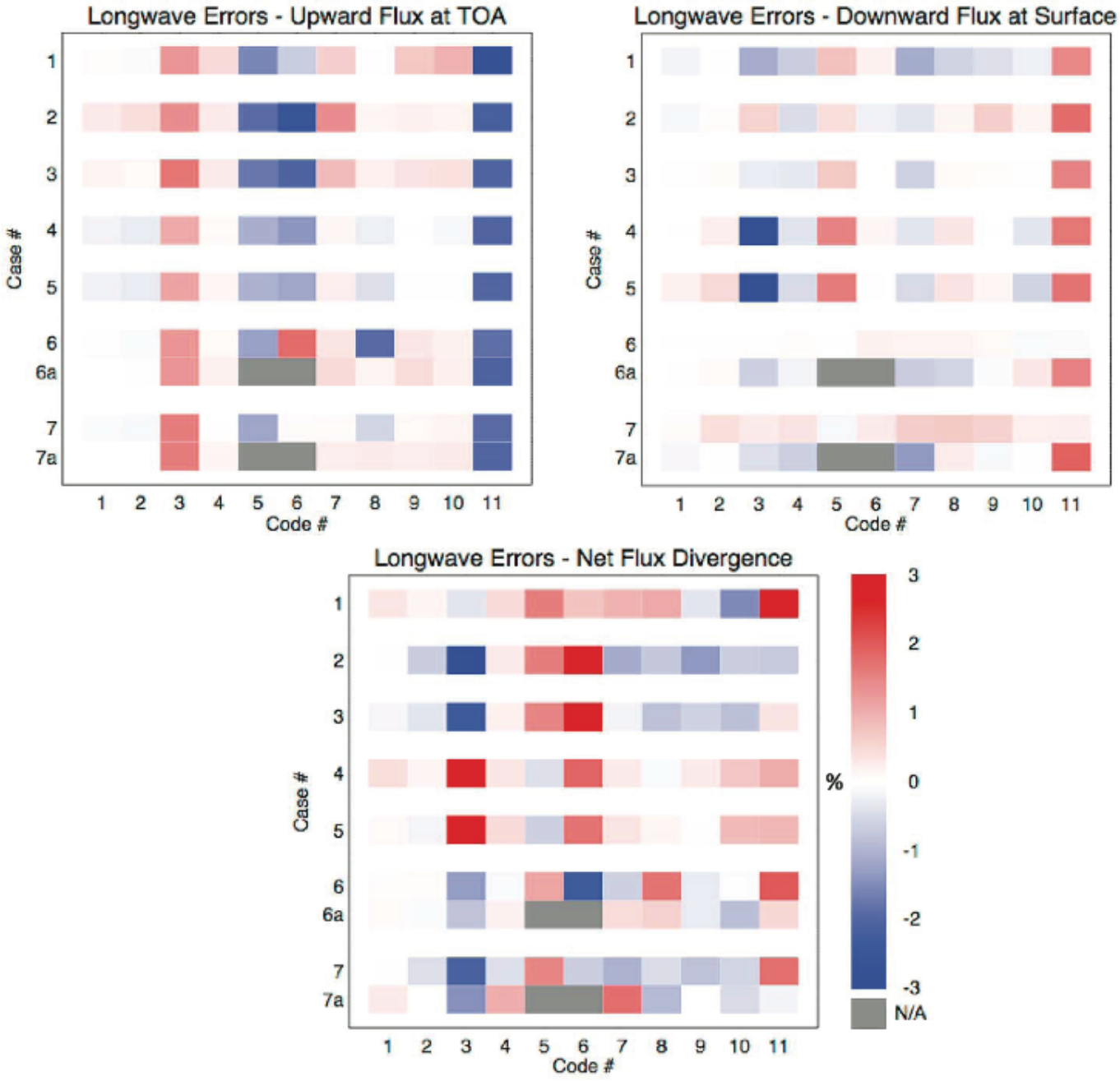
RTMIP2 proposal

- We suggest that CMIP6 be linked to a compact radiation parameterization intercomparison building on
  - RTMIP for CMIP3 (participation by 14 of 16 centers)
  - Continual Intercomparison of Radiation Codes

Large forcings stress parameterizations

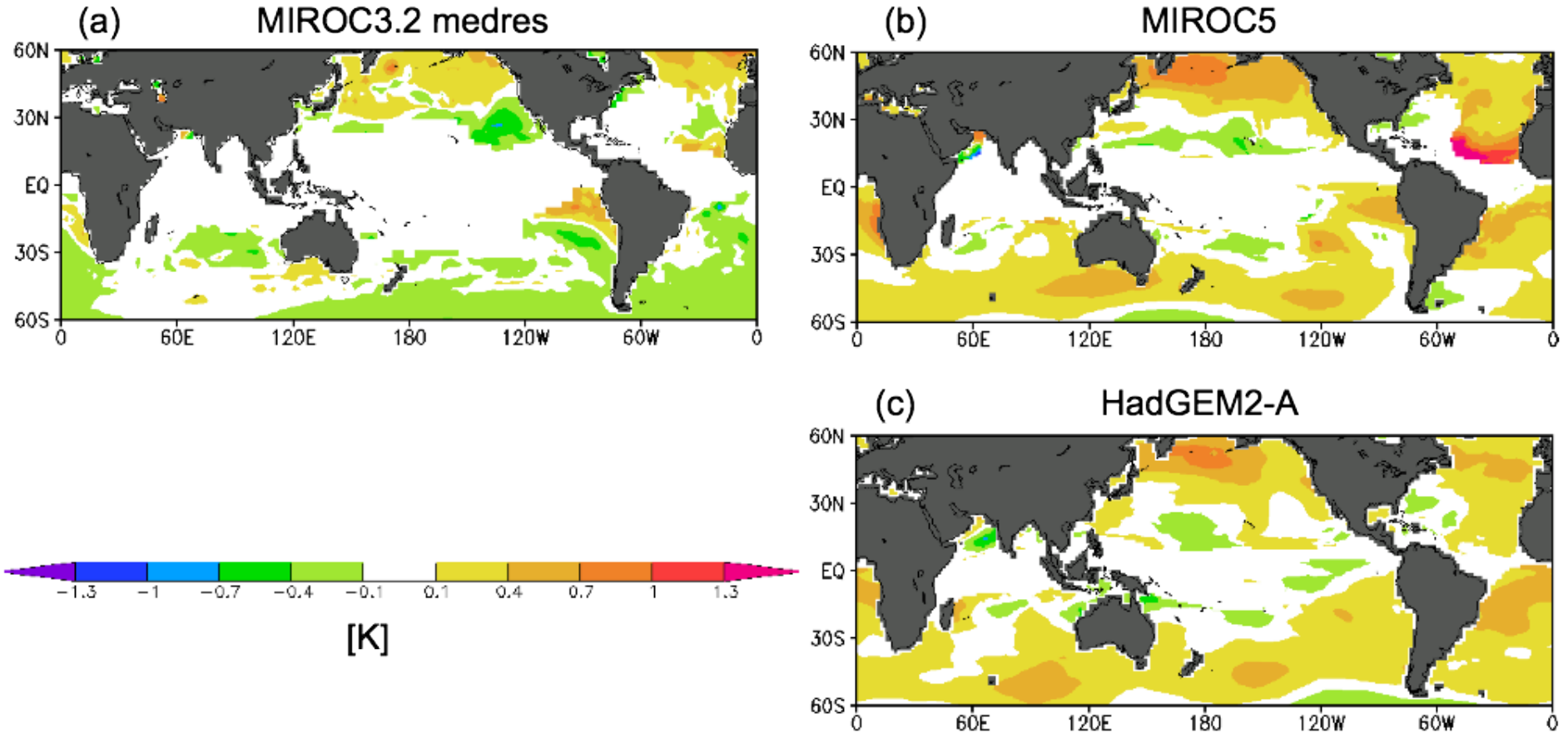


Collins et al (2006)



Oreopoulos et al (2012)

Parameterization errors confound diagnosis of climate change



Ogura et al (2013)

Implementation

- We will provide
  - a large (~1000) set of well-defined (gas-only) atmospheres
  - a set of ~10-20 perturbations including "future" profiles
  - reference calculations from one or more line-by-line models
- Perturbations will assess forcings (CO_2, H_2O, O_3, CH_4, ...) in isolation and in relevant combinations
- We will request from modeling centers
  - off-line and/or single-step calculations for these atmospheres
- The computation burden for centers is trivial

Implementation

- We will request
  - fluxes at TOA, surface, intermediate levels
  - forcing at TOA, surface, intermediate levels including stratosphere
- Results will be published on the ESG

Aerosols?

- Some members of our group are also interested in understanding the diversity of aerosol optical depth given concentrations.
  - Would this be useful? Does it belong as part of the RTMIP effort?