Emulating SLCFs for impacts, IA and policy analysis

There is a need for simple representations of the global and regional impacts of SLCFs. Some of the relevant questions:

- What are the global and regional impacts of SLCF emissions?
  - Historically temperature, precip also of interest ((feedbacks harder)
  - Also health & ecosystem (surface conc, deposition, irradiance changes,…)
- What are the uncertainties in these relationships?
  - There are often quite large, so important to quantify uncertainty ranges
- Capture relevant influences (emissions, temperature, etc.)
  - e.g., influence of NOx emissions, temperature on aerosol/ozone, etc.
  - Useful to normalize (e.g., forcing per unit emission)
  - Need to be reproducible across models
- Regional influences are becoming more important
  - Adding regional dimension increases the dimensionality of any parameterization since generally need to include cross-regional effects
- Temporal dynamics are also important
  - Much of the SLCF interest is over the next several decades. Temporal response to aerosol changes are quite different from well-mixed GHGs.

Example 1: Simple models for diagnostic analysis

Ghan et al. (2013) developed a simple model for the aerosol indirect effect (IDE)

- About 25 equations, parameterizations, and pdfs
  - Simple is not necessarily that simple
- Could reproduce the aerosol indirect forcing from some complex models
- Was unable to reproduce the results from some other models

Indicates that we do not fully understand the fundamental reasons why complex models differ in their results for aerosol IDE.

- Difficult to construct emulators/simple models if we don't understand what is going on in the more complex models.
- Question: do we need to make fundamental progress in understanding IDE before we can implement more nuanced relationships for aerosol IDE in IAMs?

Example 2: Surface ozone & ozone forcing

Wild et al. (2013) developed a parameterization based on HTAP model simulations for surface ozone

- Developed using emission perturbation experiments in 5 world regions (and perturbation for global methane)
- Some non-linear terms included
- Magnitudes vary for: influence of within-region emissions on regional ozone & long-range transport.

Global parameterizations are also used (e.g. in MAGICC)

$$\begin{aligned} d(\mathrm{O_3})/dt = \ & 5.0d(\ln C)/dt + 0.125dE(\mathrm{NO_x})/dt \\ & + 0.0011dE(\mathrm{CO})/dt \\ & + 0.0033dE(\mathrm{VOC})/dt, \end{aligned}$$

Purpose is to represent the relevant relationships

- Only need to be as “accurate” as the state of the science
- Uncertainty is not always addressed

Modeling needs

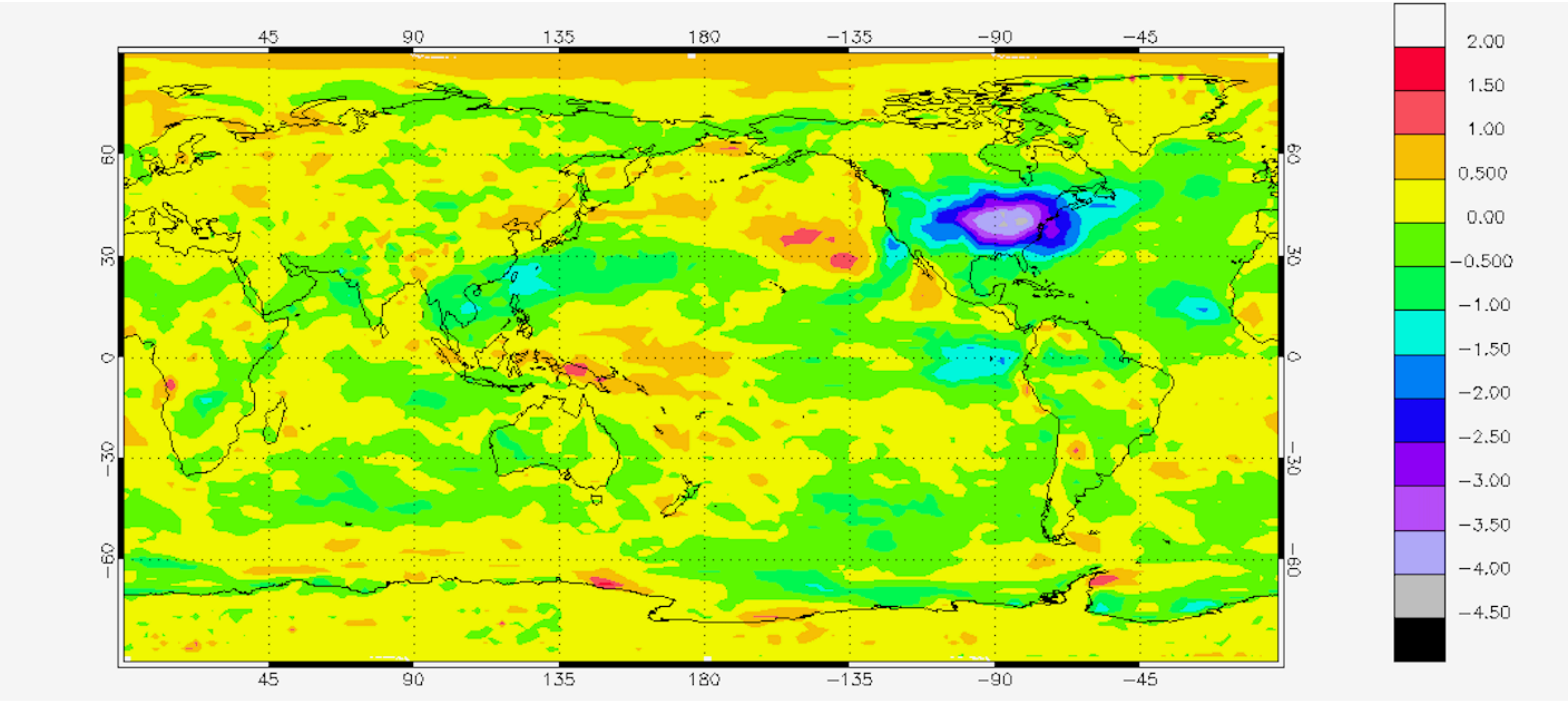
- Appropriate diagnostics/variables from planned model runs
  - Particularly radiative forcing
  - Others?
- Single forcing (equilibrium) experiments with well defined emission perturbations
  - Critical for understanding impacts of specific forcers
  - Basic information needed to understand linearity and interactions between forcers, and to develop pattern scaling
- Single forcing fully coupled model experiments
  - Its not clear how models differ in dynamical responses to SLCFs.
  - Would need to do ensemble experiments to get a reasonable signal using a realistic emissions change.
  - Perhaps use “step” emissions changes
- Regional emission perturbations runs
  - As regions get smaller, inter-regional influences will increase
- This is not just about forcing!

Sensitivity of climate to global or regional emissions of SLCFs: idealized simulations

Design

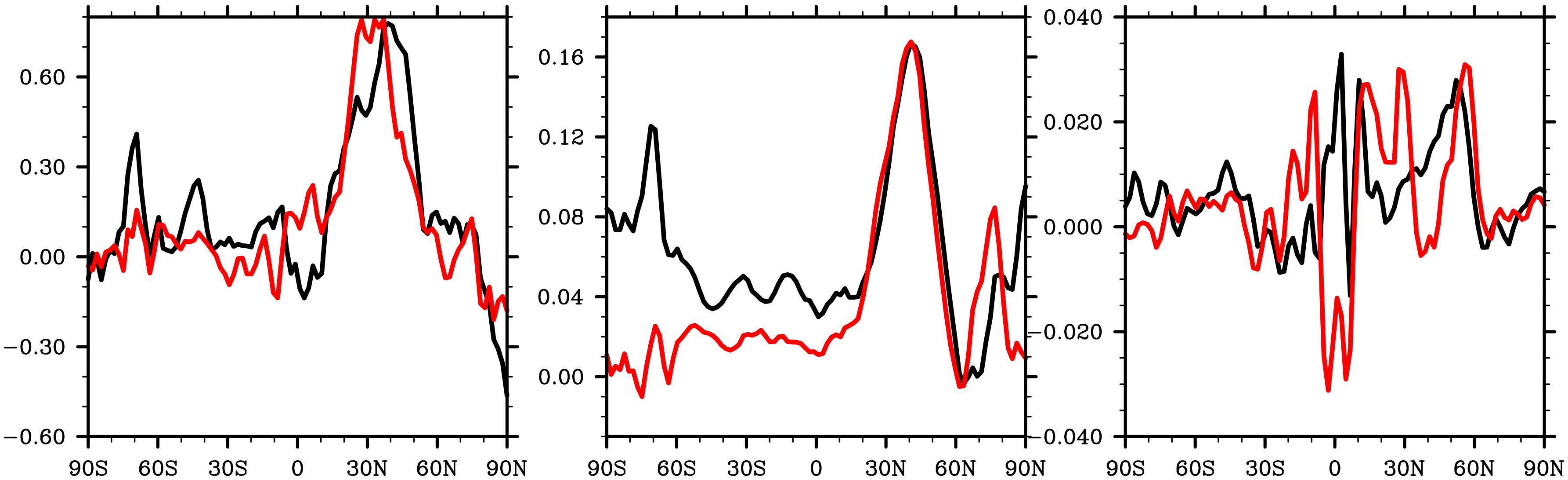
- ESM simulations for constant 2000 forcing
- Set regional SO2 emissions to 0 over US or China
- Will be performed by CESM, NASA, GFDL and UKMO

FLNT-FSNT US=0



Annual zonal mean

Delta SW | Delta TS | Delta precip



Black: US=0

Red: China=0

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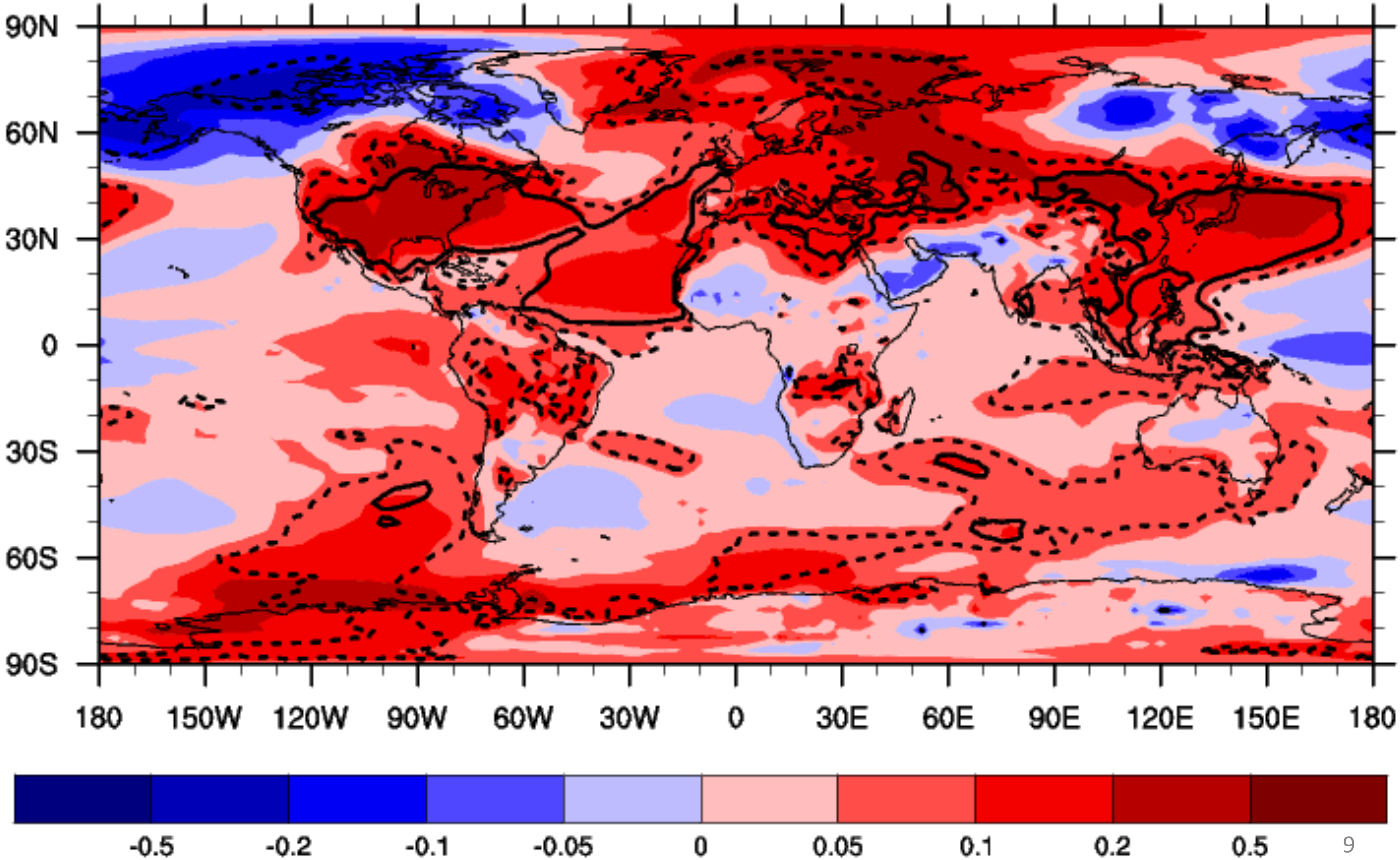
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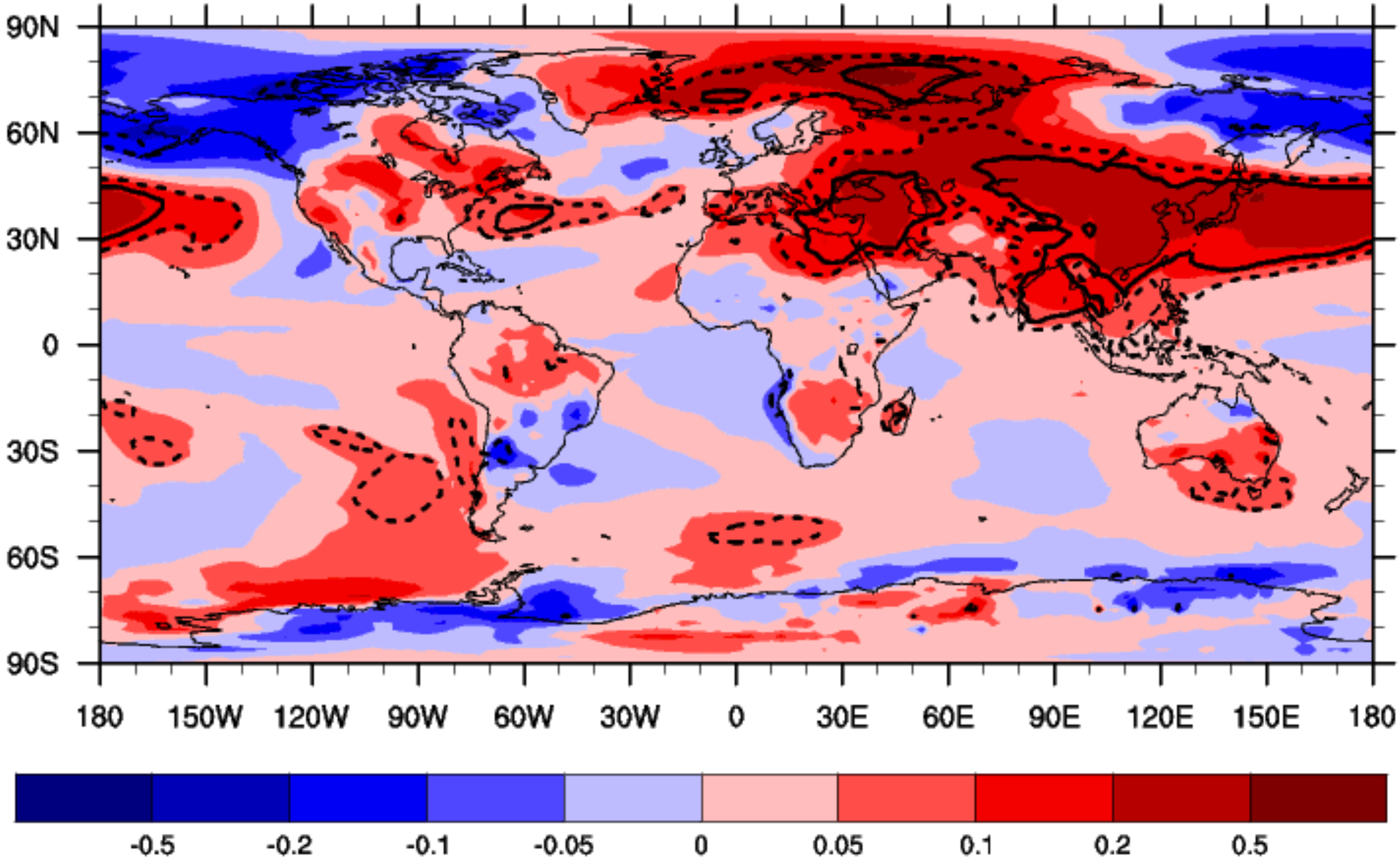
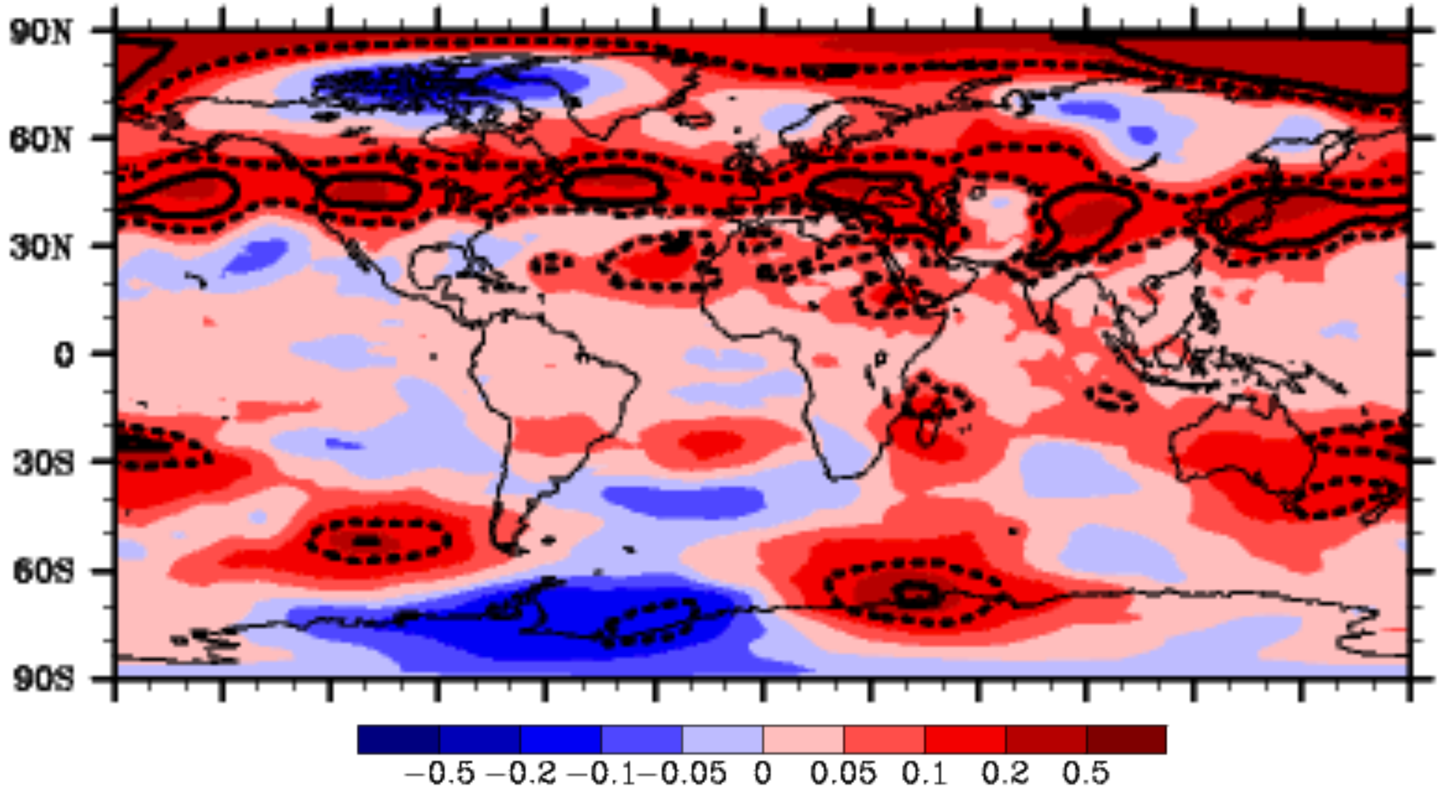
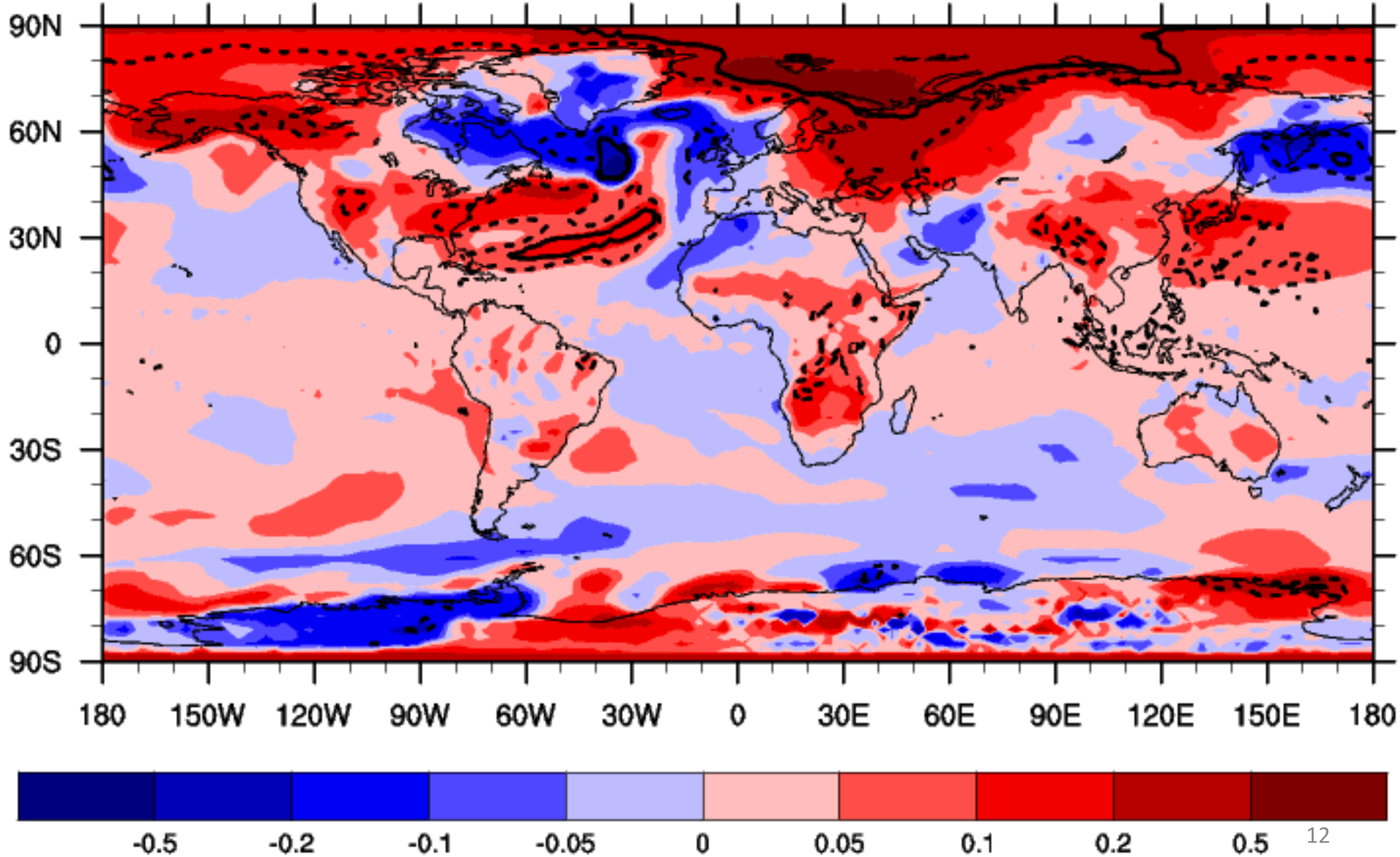


T500 (JJA, China = 0)



GISS T US =0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