Agenda for Chemistry-Climate Interactions Working Group

1. Pipeline of research
2. Current model capabilities
3. Model weaknesses
4. Technical issues

Co-chairs: Loretta Mickley, Becky Alexander

Pipeline of Research

- Climate/ Mediterranean air quality: Study of the effect of climate change on air quality over the Mediterranean , using GEOS-Chem as boundary conditions for a regional model. Giannokopolous, Varotsos.

- GCAP Phase 2: Study of the impact of climate on US air quality and mercury deposition. Wu, Yoshitomi, Tai, Sturges, Mickley, Streets, Seinfeld, Pye, Fu, Byun, Kim, Lam, Rind, Jacob. EPA

- Oxidation capacity of Last Glacial Maximum: Study of how oxidation capacity of the atmosphere has changed since LGM, using GCAP + observed oxygen isotopes in sulfate from ice cores. Alexander, Sofen, Kaplan, Murray, Mickley. NSF

- US aerosols/ climate: Project to look at how 1950-2050 trend in aerosols influences regional climate over US. Includes study of both direct and indirect effect. Leibensperger, Mickley. EPRI

- Land cover/ climate/ chemistry: Project to look at how changes in climate can affect land cover, which in turn can affect chemistry. Wu, Tai, Kaplan, Mickley. NASA

Pipeline of Research

- Wildfires/ climate/ chemistry: Continuing (?) study of the effect of climate on wildfires in the US and Canada, and the subsequent impact on air quality. Logan, Spracklen, Hudman, Mickley, Rind. EPA (pending)

- Climate/ US air quality: Similar to GCAP phase 2, but with an emphasis on regional modeling and with new IPCC scenarios. Mickley, Shindell, various EPA people. EPA

- Interested in adding the cryosphere and studying impact of various sea ice change scenarios (cover ,thickness) to bromine and mercury chemistry. Feyie Wang

- Co-benefits of climate and air quality controls; coupled chemistry-climate-economy modeling. (Not yet with GEOS-Chem) Noelle Selin

- Climate change effect in East Asia. GEOS-Chem model driven by CCSM3 meteorology. Rokjin Park

Current Model Capabilities

- Linkage with both BIOME4 and LPJ models (Jed Kaplan)
- Paleo (LGM) to future (2100) climate scenarios
- Changing land cover, 2000-2100 A1B scenario
- Calculation of the indirect effect of GEOS-Chem aerosols
- Aerosol emission inventories for recent past: 1950-2000
- Use of met fields from the GISS Model E, GISS GCM 3, and CCSM3
- Mercury emission inventories 2000-2050 for multiple scenarios
- Wildfire emissions 2000-2050, A1B climate
- Cyclone tracker (useful to see if cyclone frequency changes, applied post-simulation)

Emissions

- New fires for A1B scenario
- They are not yet on server.
  Contact Moeko Yoshitomi

Model (GISS) Weaknesses

- Unreliable rain (important for aerosol simulations)
- Overestimate of ozone over the US (not as much as GEOS-5)
- Misplaced Bermuda High
- Dust emissions too low at 4°x5° resolution (fine at 2°x2.5°)
- High nighttime ozone
- Low boundary layer heights over land
- Problems with nitrate aerosol over the US (Havala Pye)
- Drizzle over Canada/Siberia impacting fire predictions (Rynda Hudman)

Model (CCSM3) Weaknesses

- CCSM3 most met fields well matched with other GCMs
- Coupled model with the ocean
- Potential problems with SST
- Double ITCZ

Improvements/Additions in Pipeline

- Influence on CO_2 on isoprene emissions. Collete Heald
- Taking into account new experimental results and how thinking on SOA has changed. Havala Pye
- Snowpack radiative transfer calculations for photochemistry in polar regions. Becky Alexander
- Will eventually be able to do coupled chemistry-climate simulations within the ESMF framework

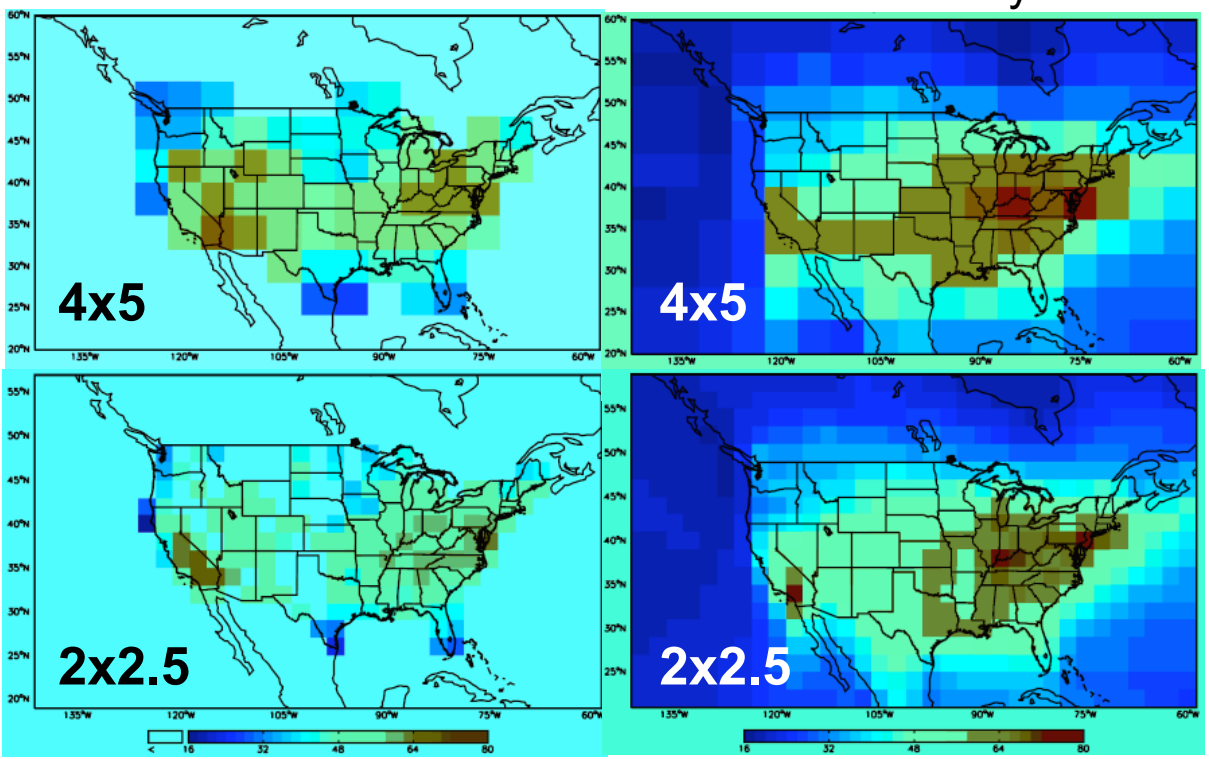
Technical Issues

- Model resolution: when is finer better? We (LJM) will move to 2x2.5 GISS model in next phase of wildfire project.
- Interannual variability + ensembles: how can you tell when you have a signal?
- Need for GISS and CCSM3 wiki.
- Downscaling to regional climate models:
  - how much nudging is optimal within the regional model domain?
  - Need to get a sense of uncertainties (Jennifer Logan's participation in Atmospheric Chemistry and Climate Activities)
- Cyclone tracking: Use Eric Leibensperger's diagnostic
- Need better dust representation in 4x5.

Model resolution: when is finer better?
I will probably have generated GISS 2x2.5 met fields within a year.

On our fastest machines, 2x2.5 GCAP takes 1 week/ model year. The 4x5 takes just a couple days. The issue in climate studies is that you usually need to look at several model years to be confident of the signal that you see. Then if you want to do sensitivity studies . . .

Observed 1980-1998 GEOS-Chem 2 years



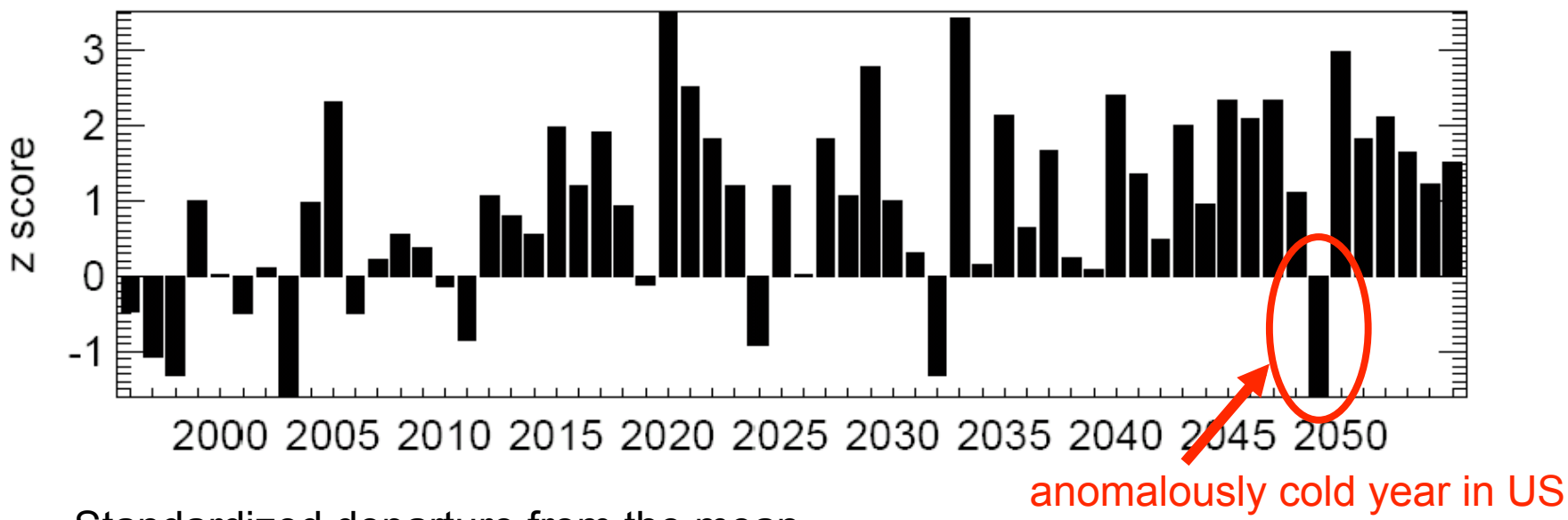
JJA surface ozone at 2 resolutions:

Yoshitomi

Interannual variability + ensembles: how can you tell when you have a signal?

How many years are sufficient? Depends on question asked and the size of the perturbation. Can we come up with any guidelines for the optimal number of model years?

Predicted biomass burned by fires in the West, 1996-2055



Standardized departure from the mean

Spracklen et al., 2009

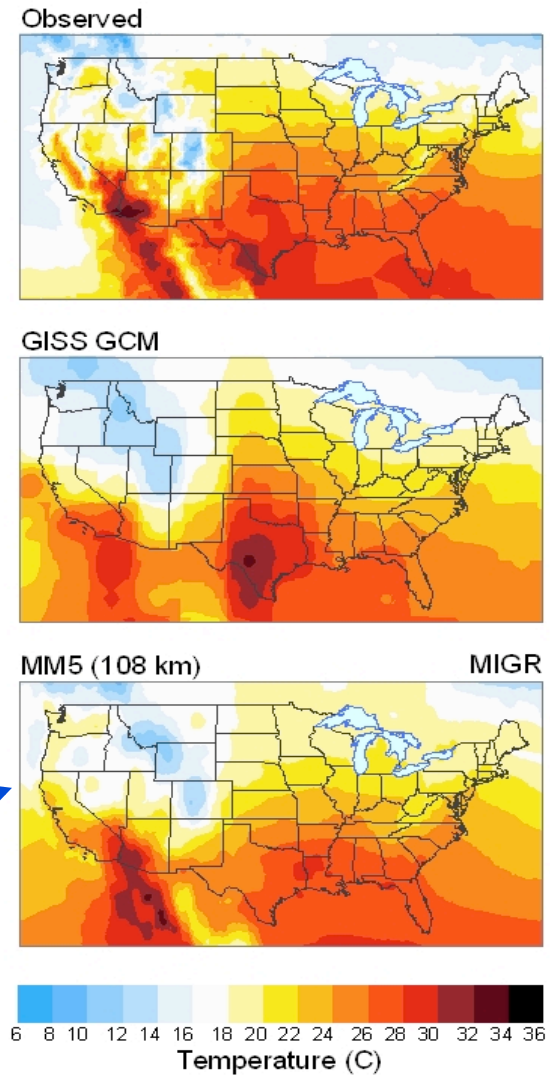
Downscaling from global and regional climate models.

Big issue is downscaling of met fields from GISS GCM to regional climate models. If we nudge the regional model only at the boundaries, we miss some important climate signals, like changes in cyclone frequency. If we nudge within the domain, how much is enough nudging?

Can we devise some way to determine the optimal degree of within-domain nudging for a chemistry-climate study?

Or should we just use smaller model domains to make sure the regional model doesn't invent its own climate?

JJA 1990s temperatures from the GISS-GCM and MM5, mean over 5 summers, Lynn et al.



Regional model nudged only at lateral boundaries.

Instantaneous 2-m Temperature Fields

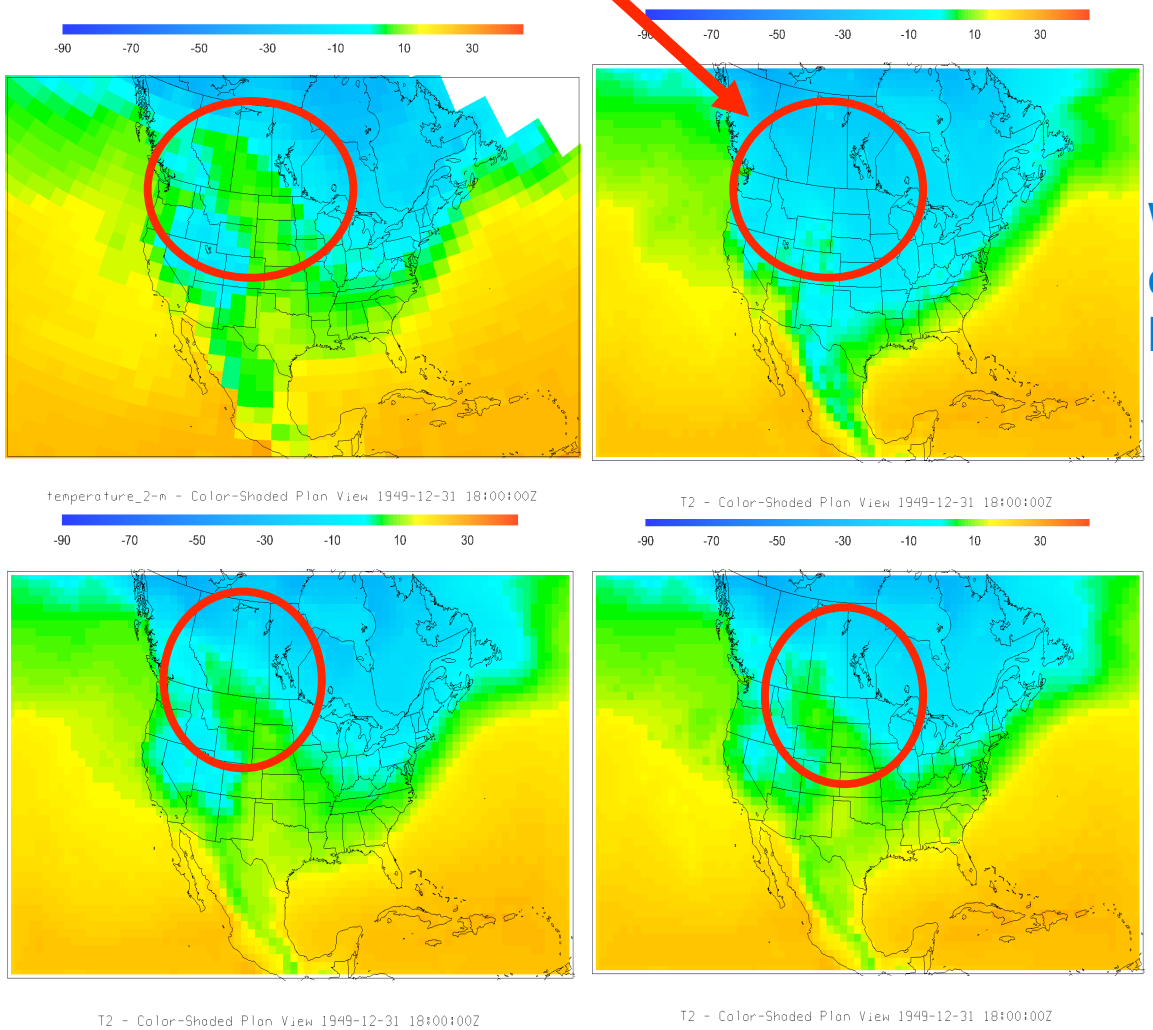
Nudging only at the lateral boundaries leads to cooler (-10°C) temperatures over Canadian Rockies and throughout Midwest.

GISS GCM

WRF nudged only at boundaries

WRF nudge experiment A

WRF nudge experiment B



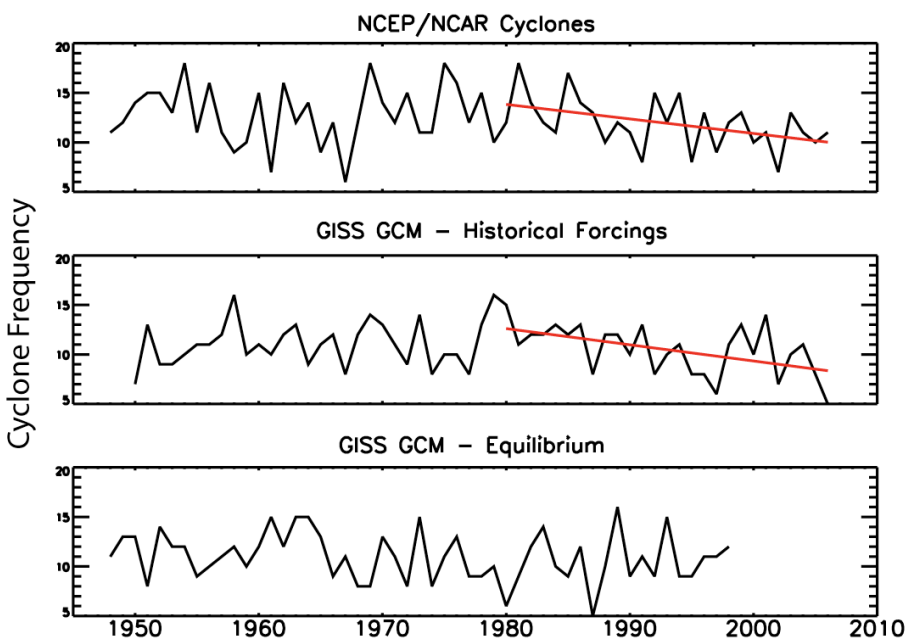
18 UTC 31 Dec 1949 (30.5 days into simulation)

Slide from Tanya Otte.

Downscaling from global and regional climate models: cyclone frequency.

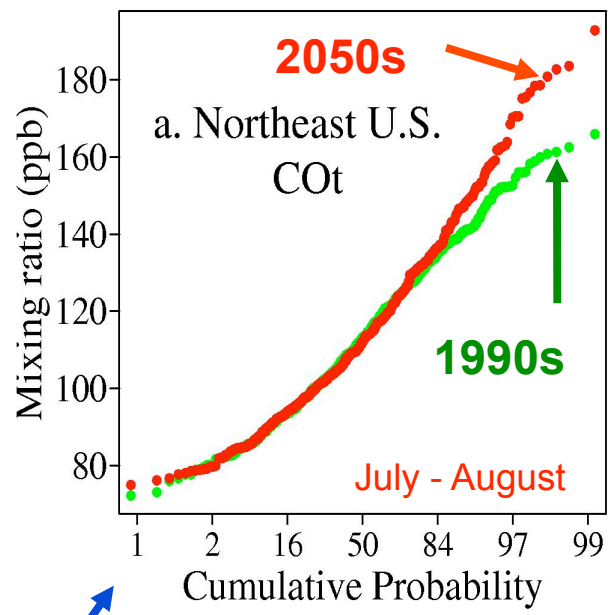
Most global models calculate a decline in cyclone frequency in response to climate change and the reduction in meridional temperature gradient, but many regional models seem to fail to capture this trend.

Trend in JJA cyclone number in S. Canada



Leibensperger et al., 2008

Response of tracers of pollution to more persistent stagnation

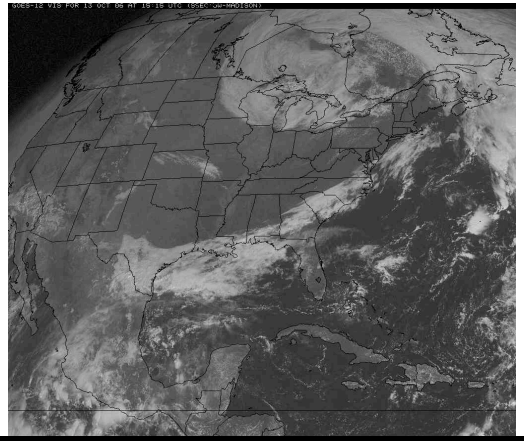


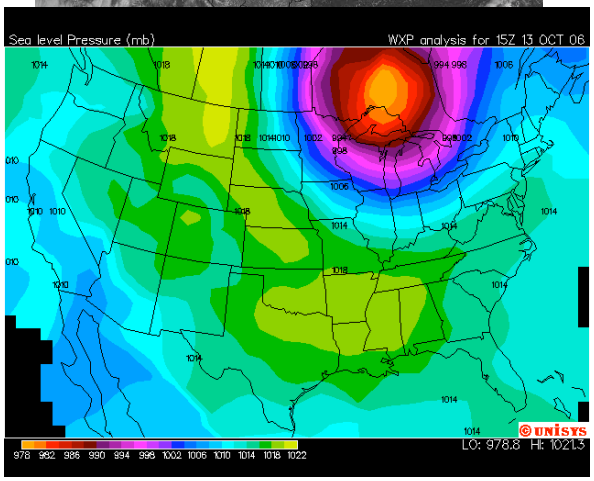
Results are from GISS GCM; regional model using BCs from same GCM shows no change in cyclone frequency.

Cyclone tracking: Eric Leibensperger is working with GISS cyclone tracker

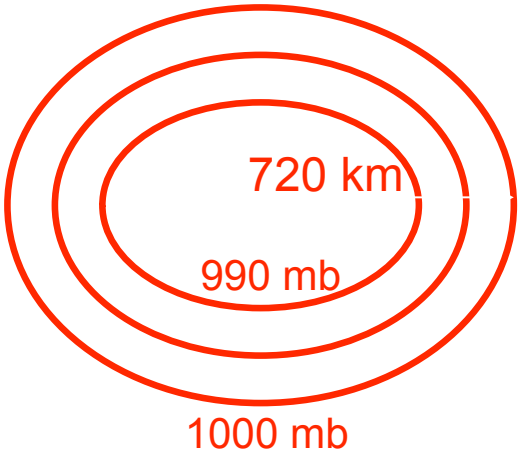
Requirements for the identification of a cyclone:

- Sea level pressure minimum of at least 720 km
- Duration of at least 24 hours





Storms are tracked by assuming a maximum storm velocity of 120 km/hr. A pressure minimum within UΔt km of a minimum from the previous time step are considered to be the same



Use 4x daily SLP fields

[Bauer and Del Genio, 2007]

Talk for Thursday a.m. follows. . . . .

New capabilities of GEOS-Chem for the study of chemistry-climate interactions

Loretta J. Mickley, Harvard

1. Application of meteorological fields from past and future climates

INPUT

GHG and aerosol content

Sea level, topography

→

GISS GCM

Physics of the atmosphere

Qflux ocean or specified SSTs

→ met fields →

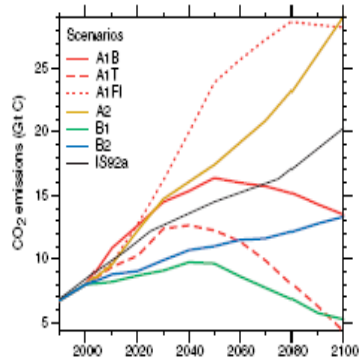
GEOS-Chem

Emissions

Chemical scheme

Deposition

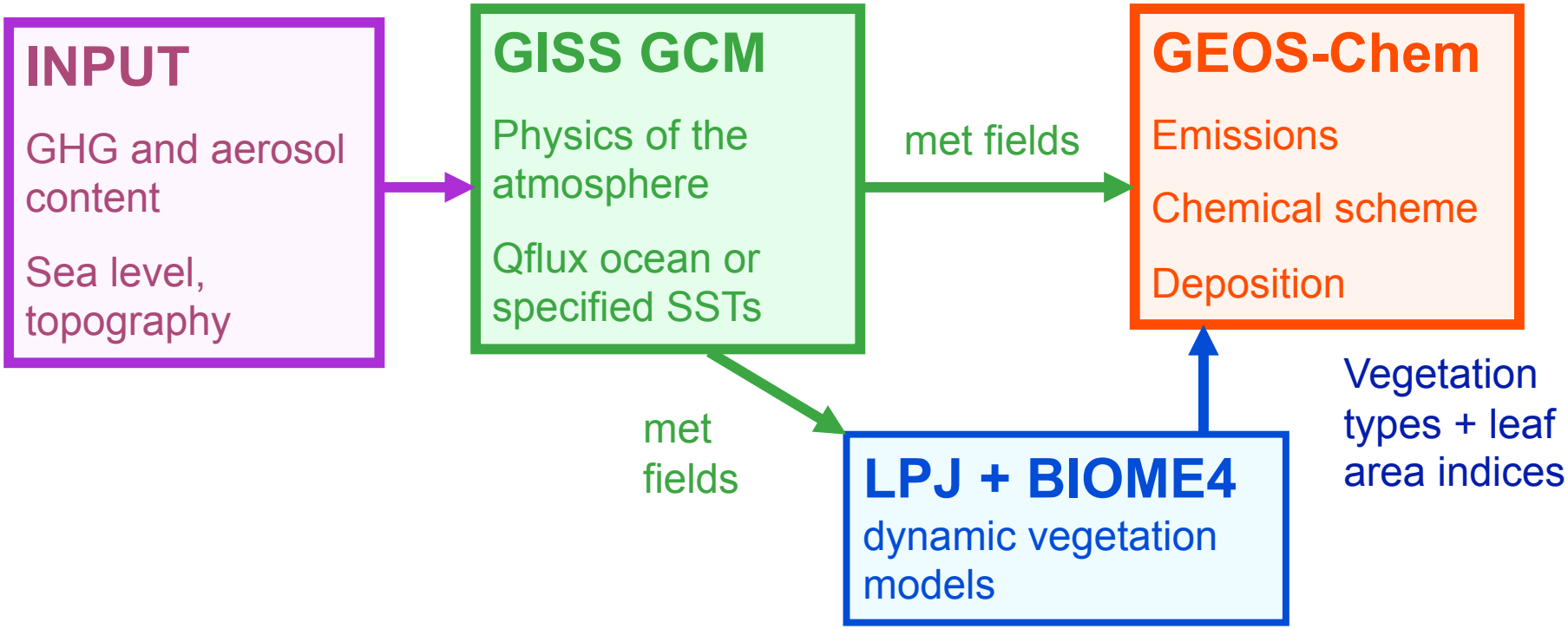
We have the ability to apply both future IPCC scenarios + paleo greenhouse gas levels to the GISS GCM.



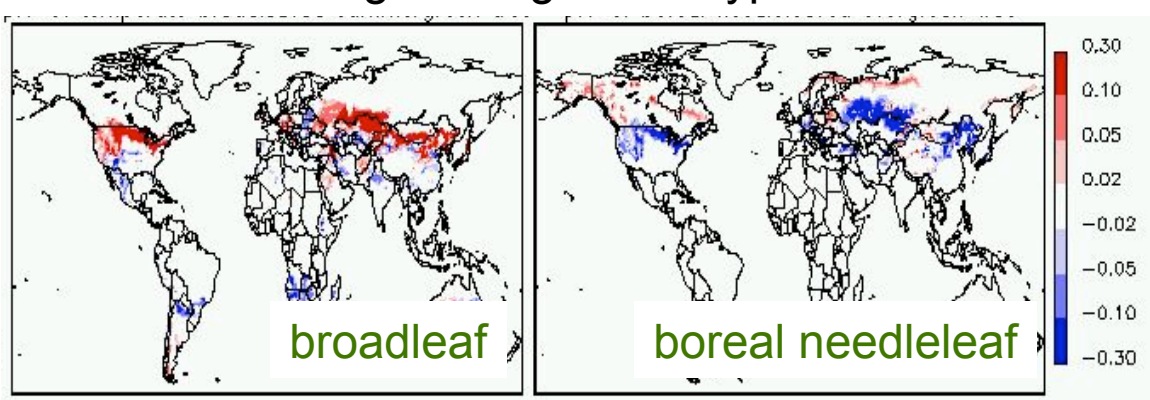
CO_2 scenarios

Alexander, Sofen, Murray, Kaplan, Mickley, Wu, Jacob, Pye, Seinfeld, Liao, Streets, Fu, Byun, Rind, Yoshitomi

2. Application of changing land cover to GEOS-Chem



2000-2050 change in vegetation type



We can apply land cover from future or past (ice age) climates.

Wu, Kaplan, Tai, Mickley, Murray

3. Application of changing area burned to GEOS-Chem

INPUT

GHG and aerosol content

Sea level, topography

GISS GCM

Physics of the atmosphere

Qflux ocean or specified SSTs

met fields

GEOS-Chem

Emissions

Chemical scheme

Deposition

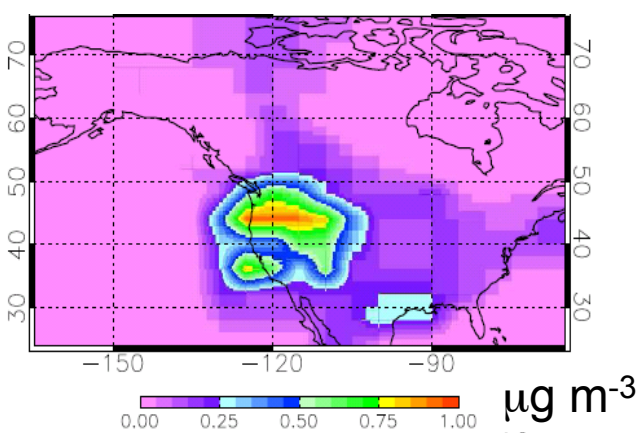
met fields

wildfire emissions

Area burned prediction scheme

Uses observed relationships between meteorology and area burned

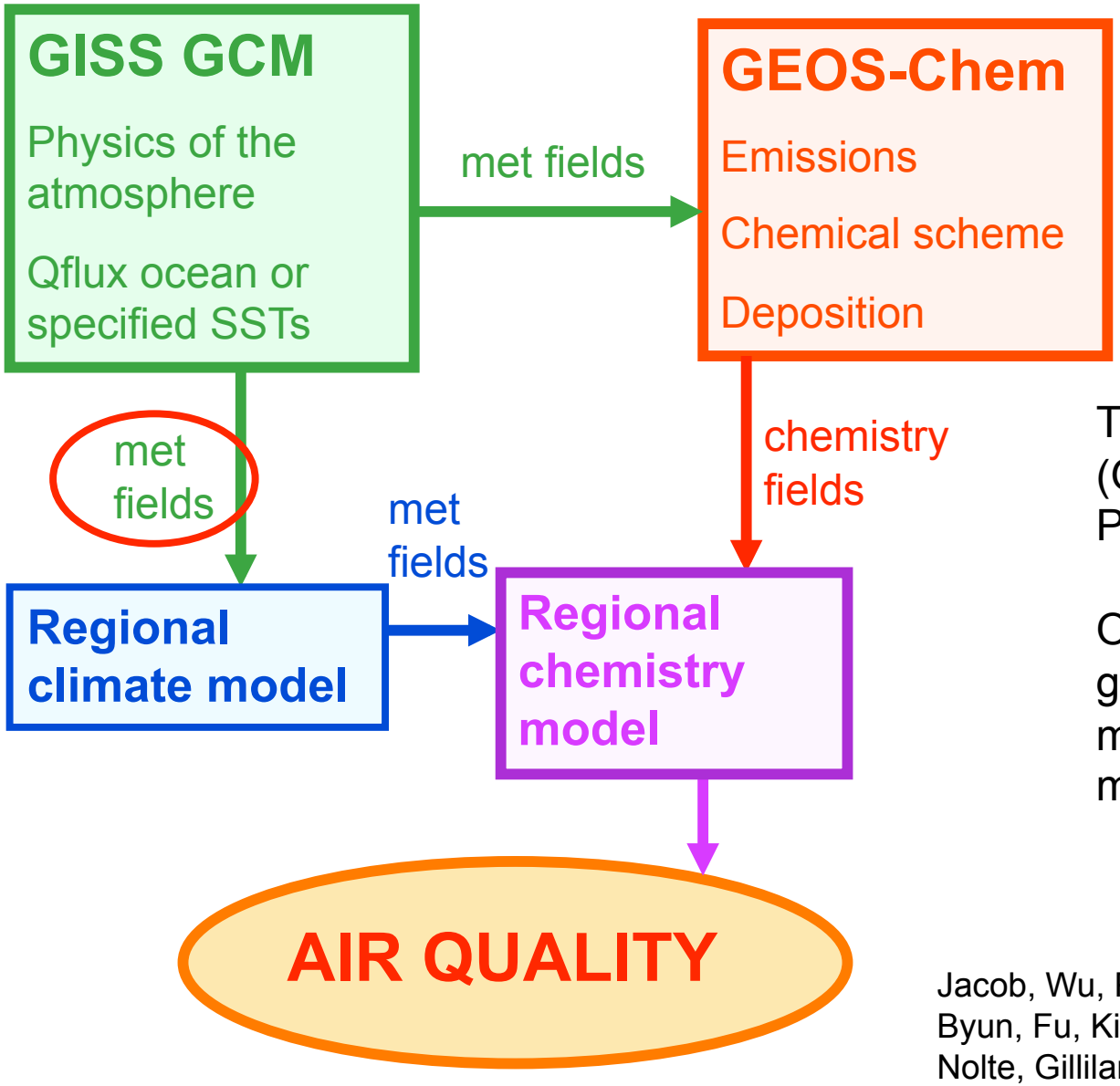
2000-2050 change in surface OC concentrations



We can simulate the effect of changing climate on wildfire emissions.

Logan, Spracklen, Hudman, Mickley

4. Archival of finely time-resolved meteorological and chemical fields for use in regional models



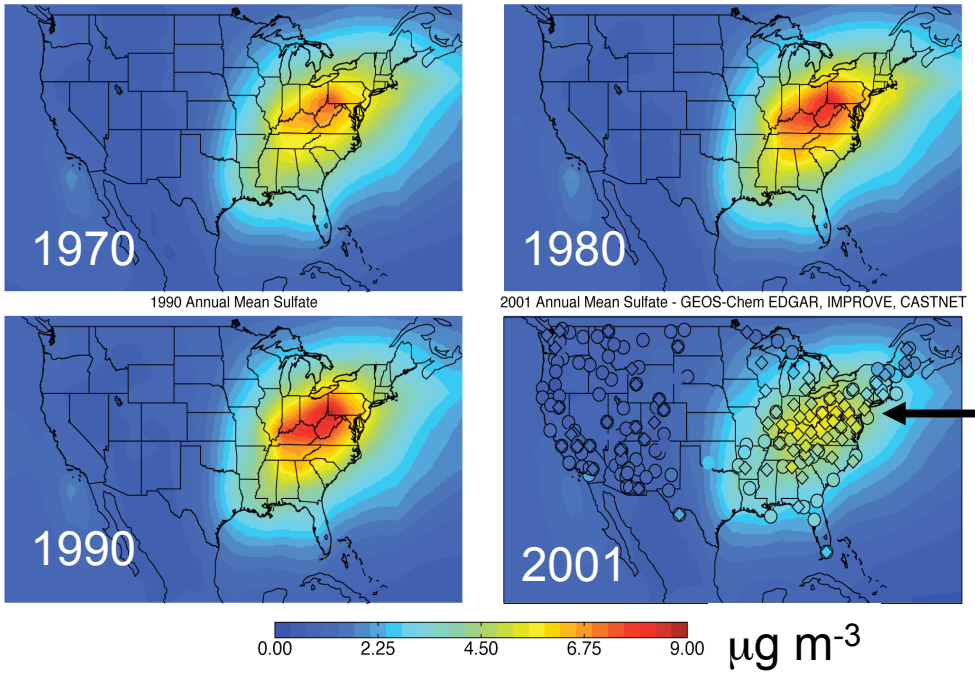
This is the basic **GCAP** (Global Change and Air Pollution) setup.

One issue in downscaling global meteorology is how much to nudge regional model within the domain.

Jacob, Wu, Pye, Seinfeld, Streets, Rind, Byun, Fu, Kim, Lam, Varotsos, Giannopolous, Nolte, Gilliland, Leung, Gustafson, Mickley

5. Past and future emissions inventories available for use in GEOS-Chem.

- 2000-2050 IPCC scenarios for ozone precursors, BC, OC (Streets)
- 1950?-2050 mercury emissions, based on historical fuel use + IPCC storylines (Streets) [need to check this]
- 1950-2000 BC + OC emissions (Bond)
- 1950-2000 EDGAR emissions of NOx and SO_2.



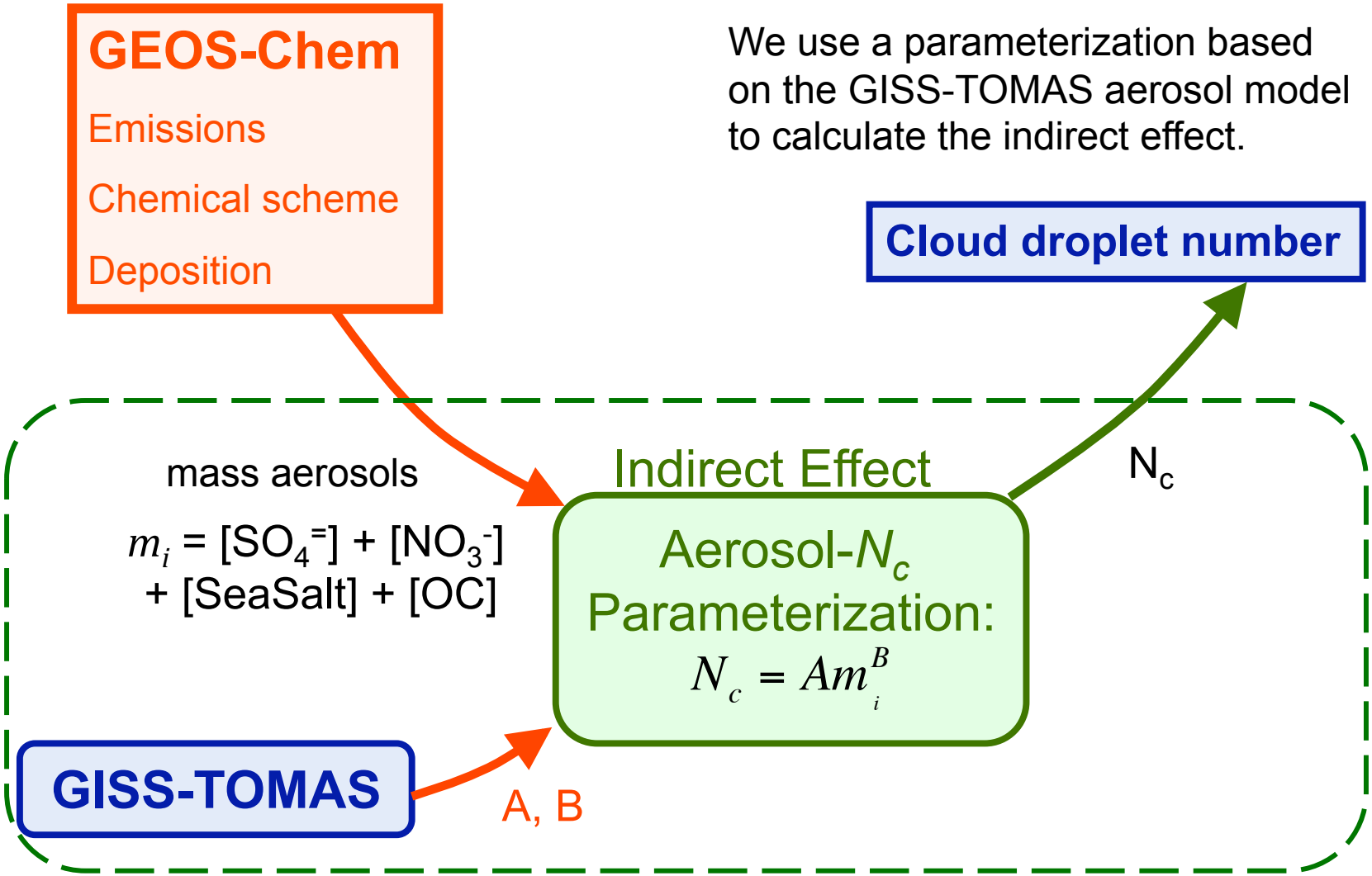
Calculated trend in surface sulfate concentrations, 1970-2001.

Circles show observations from IMPROVE + CASTNET

Leibensperger, Sturges

6. Calculation of the aerosol indirect effect using GEOS-Chem aerosol output.

We use a parameterization based on the GISS-TOMAS aerosol model to calculate the indirect effect.



Leibensperger, Seinfeld, Chen, Adams, Nenes