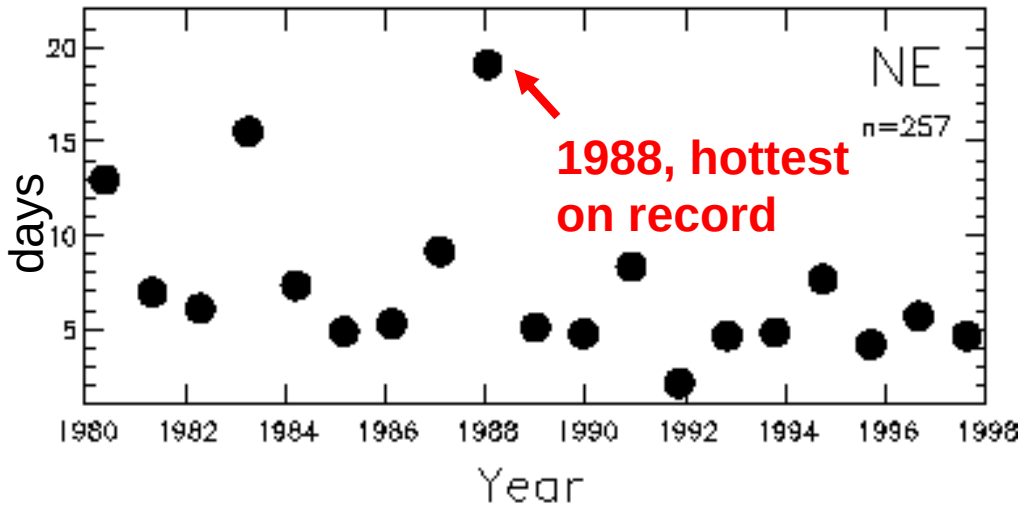
GCAP (Global Climate and Air Pollution):

One of six projects funded by EPA-STAR to study effect of climate change on air quality.

Number of ozone exceedances averaged over Northeast U.S. sites



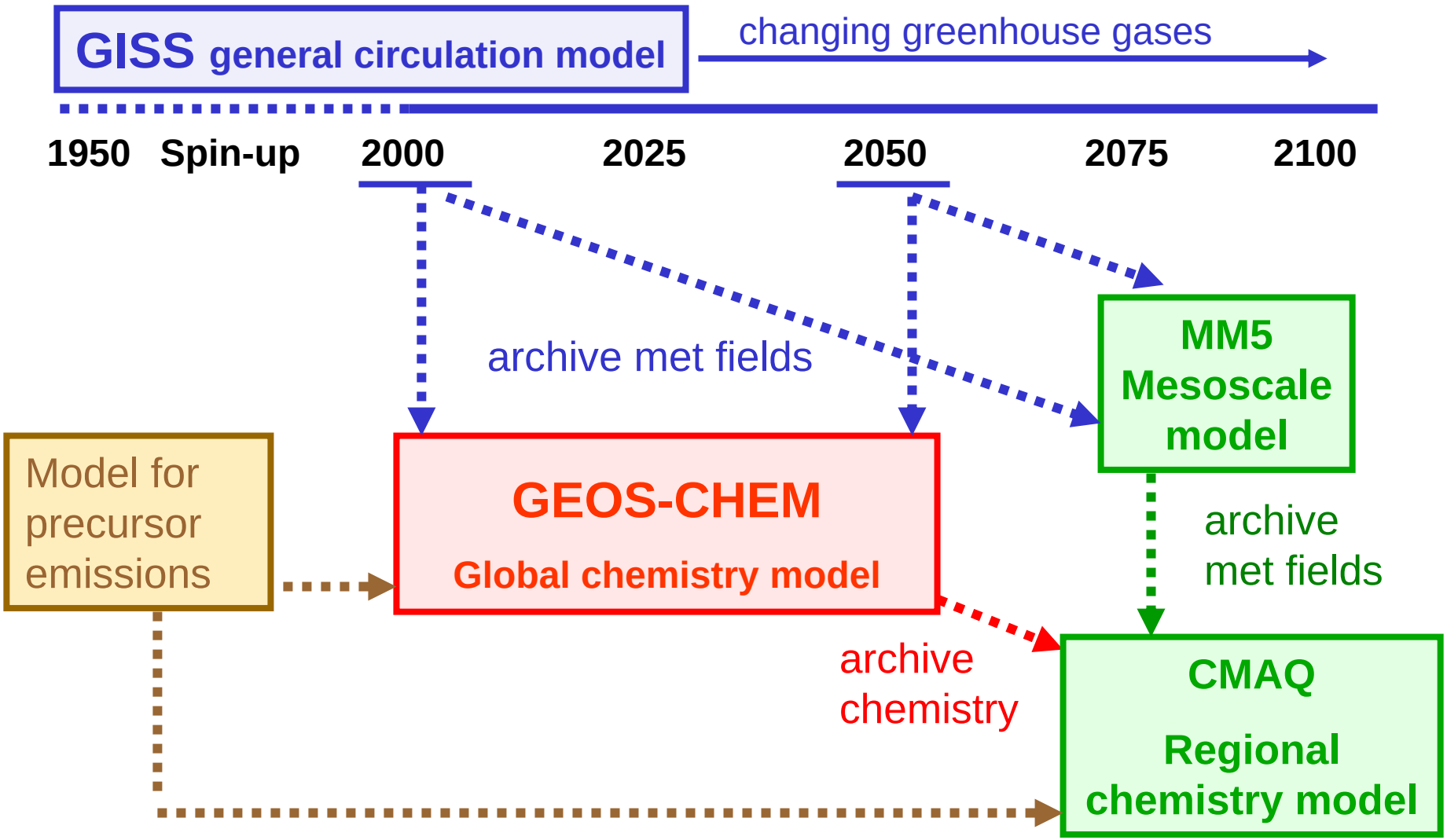
Future air quality will depend on changes in *both* meteorology and emissions.

Lin et al., 2001

Collaborators:

- Harvard University: Daniel J. Jacob, Loretta J. Mickley, Shiliang Wu
- Argonne: David Streets
- Caltech: John Seinfeld, Hong Liao
- Goddard Institute for Space Studies: David Rind
- Univ. Tennessee: Joshua Fu

Blueprint for GCAP: 5 models working together to provide information on climate change impacts



GCAP progress :

- GISS model III developed, validated ★
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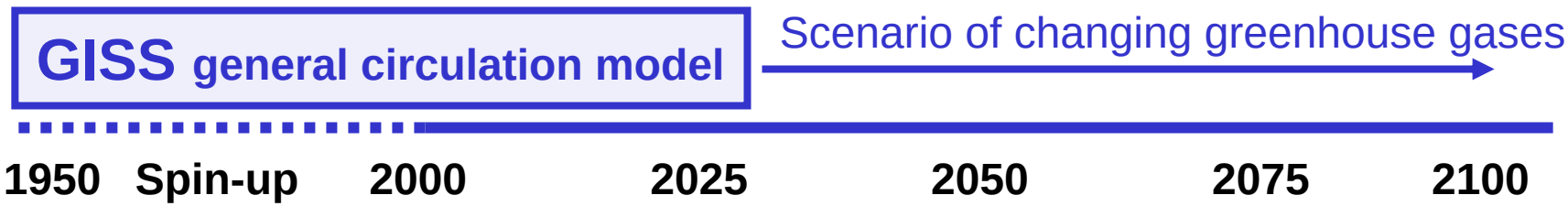
Implementing tracers of pollution into the GISS GCM

2 tracers with constant emissions over time:

- Carbon monoxide (COt)
- Soot (Black carbon, BCt)



constant anthropogenic emissions →

constant CO + OH sink →

changing rainout of Black Carbon PM →

changing circulation patterns →

changing boundary layer height →

Tracers show sensitivity of pollution to 3 facets of climate.

Early GCAP results:

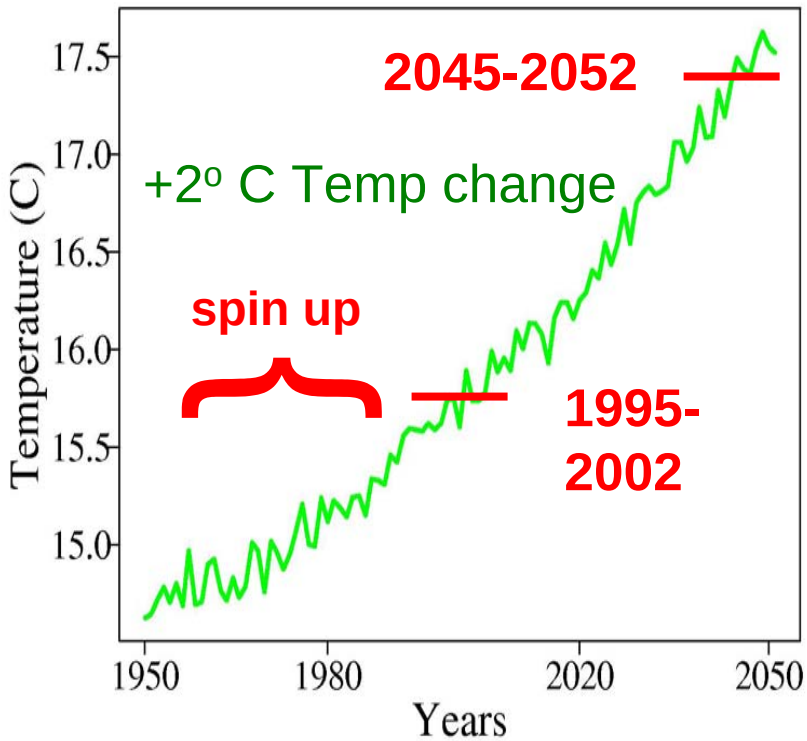
Effects of climate change on air quality over the Midwest and Northeast United States, using CO and BC tracers

Timeline

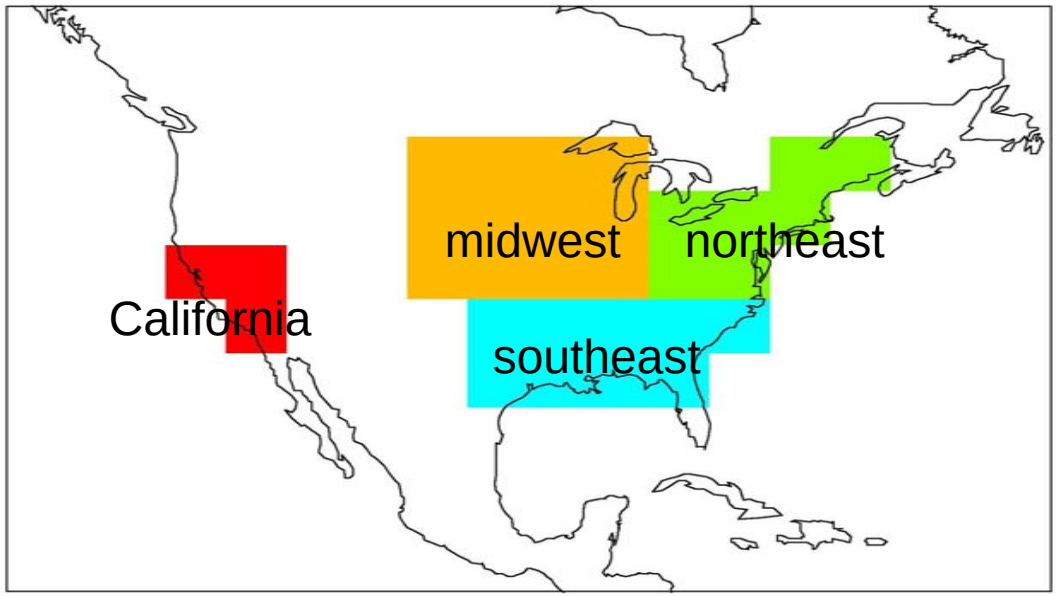
1950 — spin-up (ocean adjusts) — 2000 — increasing A1 greenhouse gases — 2050

Tracers of pollution meteorology implemented into coarse grid version of GISS GCM II' (9 layers, 4° x 5°)

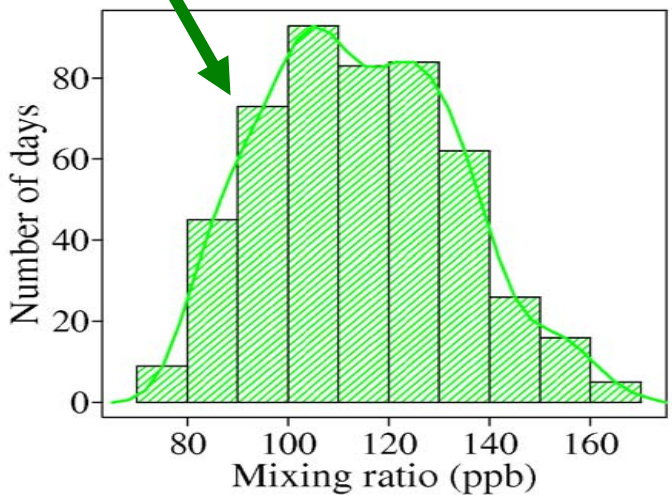
Increasing global mean surface temperature in model with A1 scenario of greenhouse gases →



Our approach: Look at daily mean concentrations averaged over specific regions for two 8-year intervals (1995-2002) and (2045-2052).



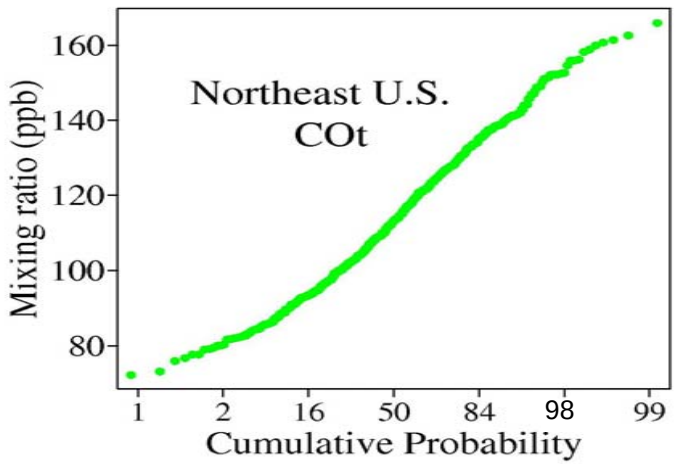
Histogram of COt concentrations averaged over Northeast for 1995-2002 summers (July-Aug)



We can graph the same results as a **Cumulative probability plot**.

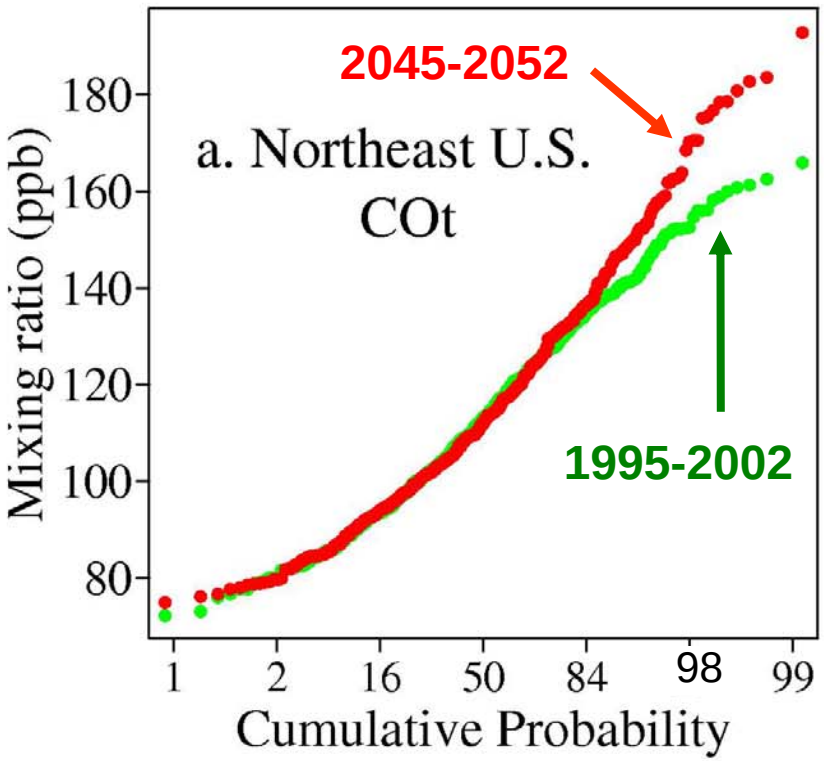
Each point indicates one day.

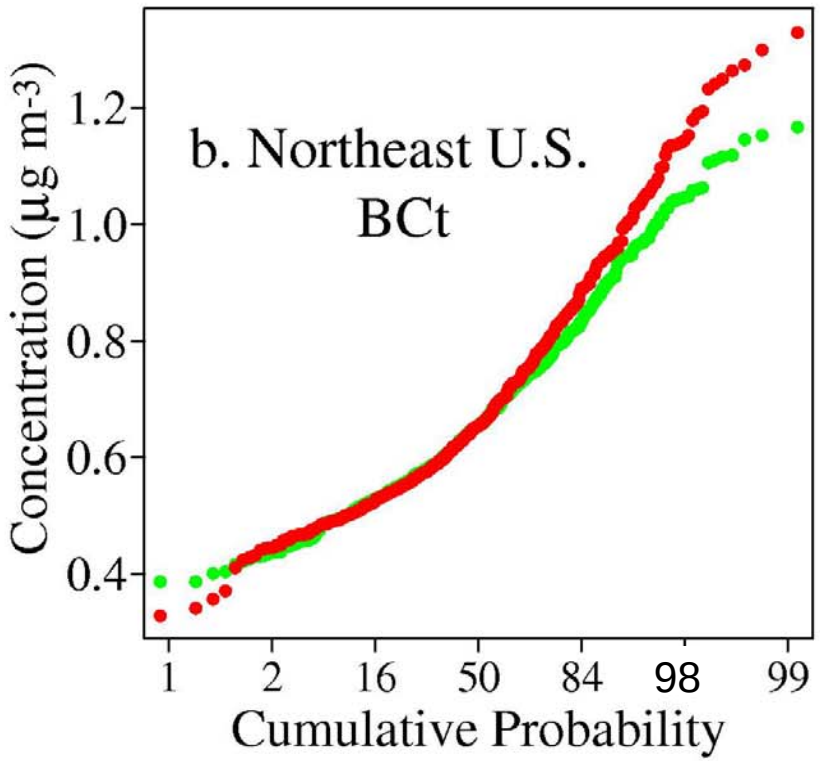
Plot shows the percentage of days below a certain concentration.



Frequency distributions for pollution tracers show higher extremes in 2050s compared to present-day.

July – August, similar results over the Midwest U.S.



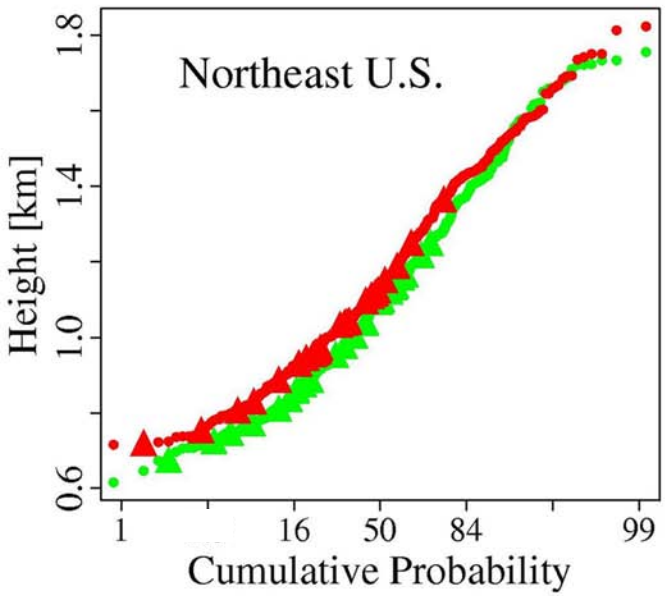


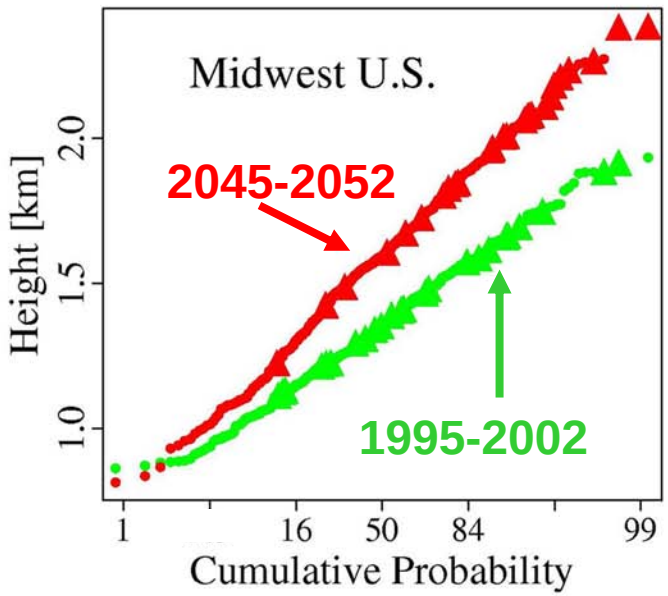
Mickley et al., 2004

Changes at the extremes are due *solely* to changes in **meteorology** (winds, boundary layer height, rainout?) -- **not emissions**!

How does depth of the boundary layer change with changing climate?

Maximum July-August boundary layer heights.





Triangles indicate days of high pollution.

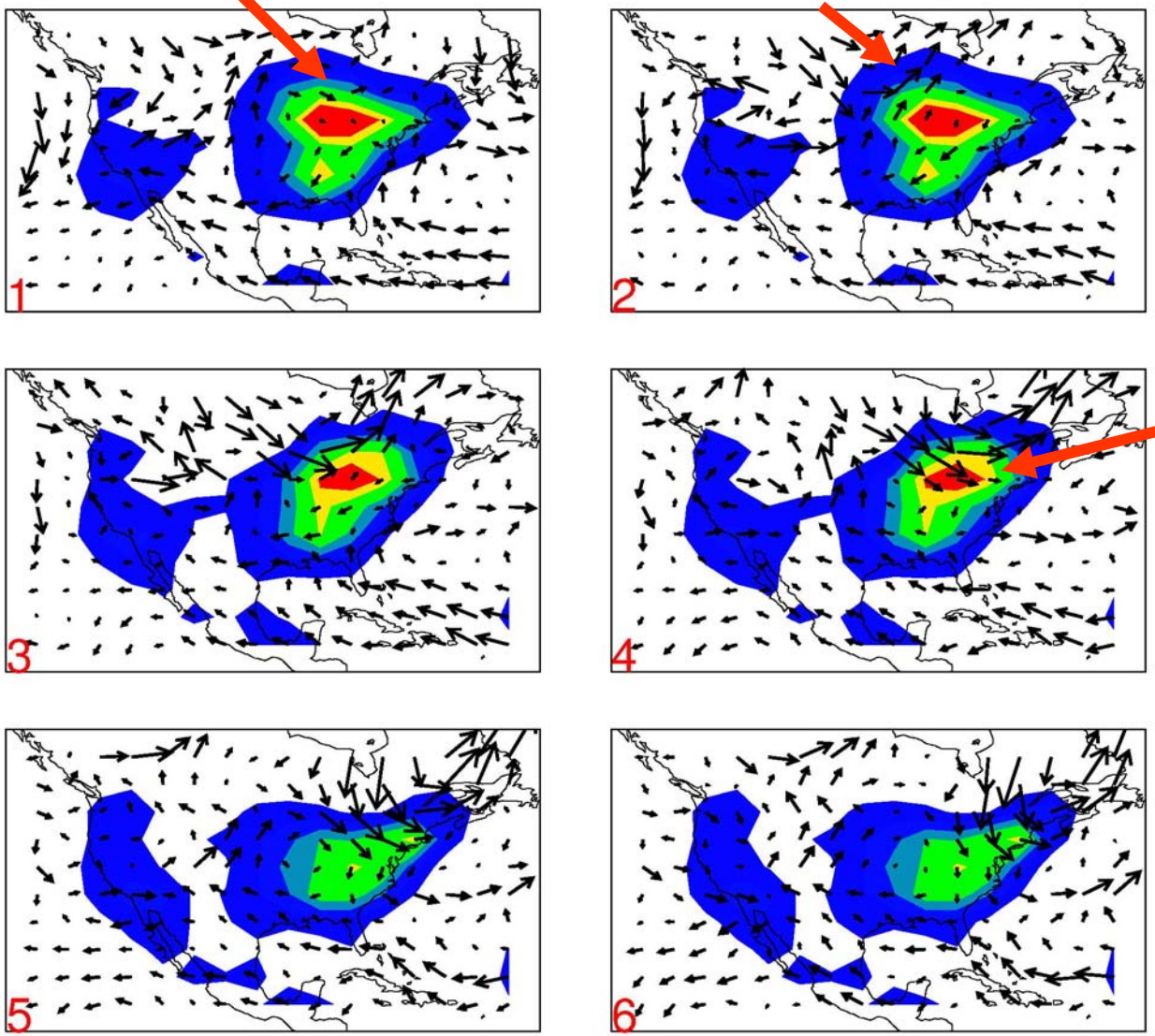
Higher boundary layer heights in future go in opposite direction to what is needed to explain air quality differences.

Evolution of a typical pollution episode over 6 days.

Less frequent cold fronts across mid-latitudes in the future atmosphere increases duration and severity of pollution episodes.

weak winds

cyclone (low pressure system)



We calculate a **20% decrease** in cold fronts coming from Canada in future summers.

cold front from Canada

Reasons: Reduced meridional temp gradient + more efficient latent heat transport.

BC 100 x μg/m^3

15 30 45 60 85 100

Conclusions

- Over the Northeast and Midwest, reduced cyclone frequency in future climate increases duration and severity of summertime pollution episodes.

- Mean episode duration increases from 2 days to 3-4 days.

- GCMs can be a powerful tool to investigate responses of air quality to climate change.

Future Plans for GCAP

- Calculate sensitivity of U.S. air quality to projected trends in climate and to anthropogenic emissions.

- Quantify impact of future Asian emissions on U.S. air quality, taking climate change into consideration.

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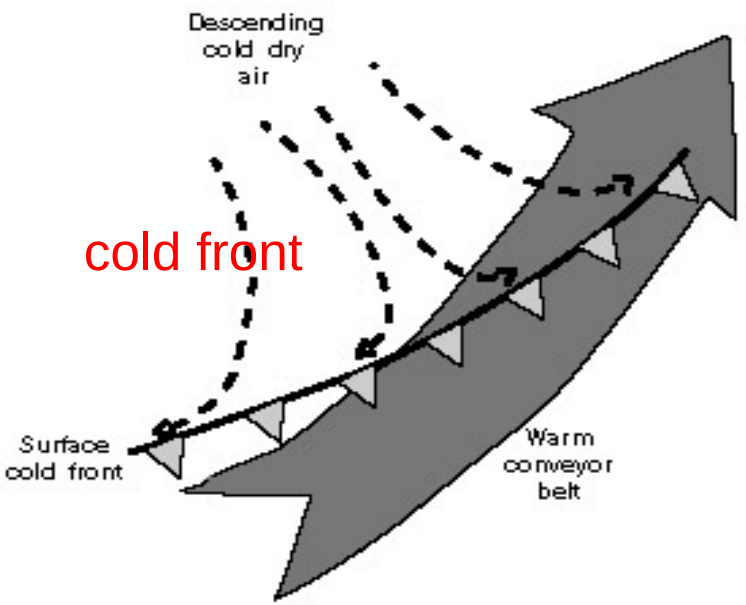
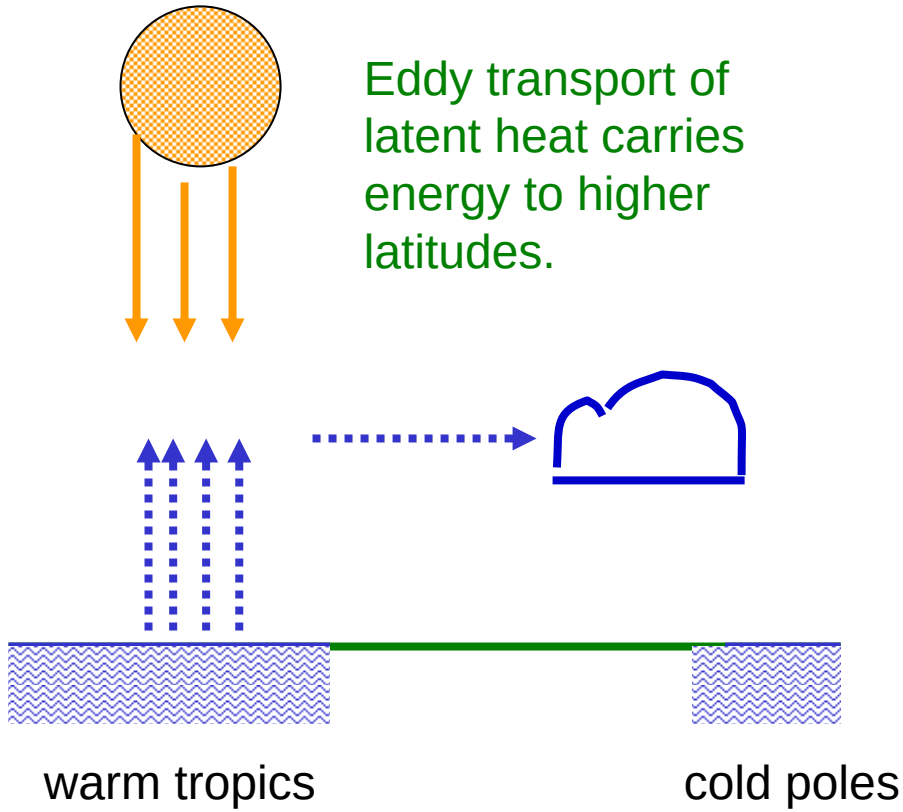
Extra slides

Climate change affects the meridional transport of energy in the model.

Mid-latitude cyclones push warm air poleward ahead of front, push cold air equatorward behind front.





Eddy transport of latent heat carries energy to higher latitudes.

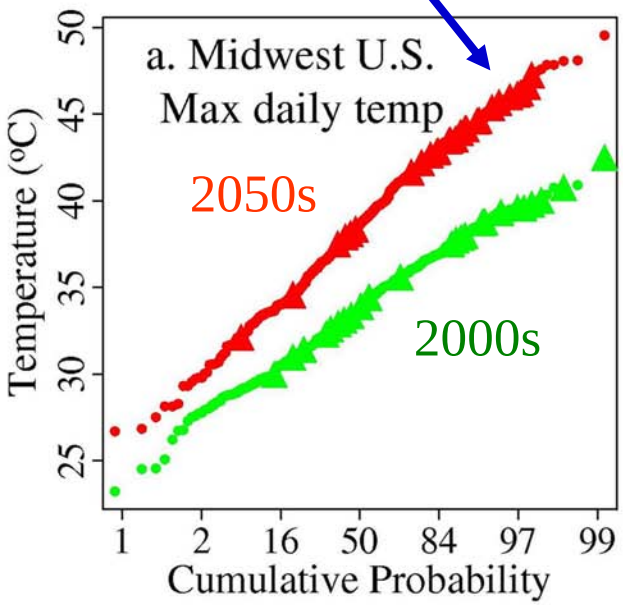
Reduced meridional temperature gradient + more efficient transport of latent heat

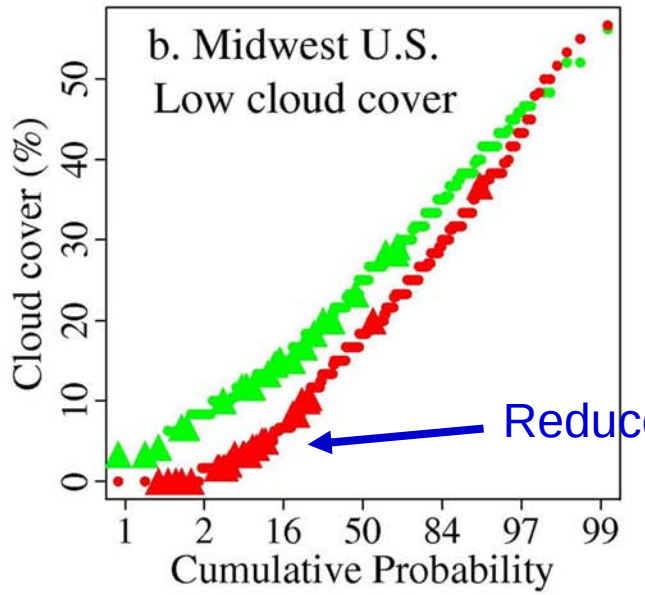
Fewer cyclones generated +
More persistent pollution events in future

How do you translate our results into “ozone alert days”?

Back-of-envelope calculation: high-pollution days (top 5% of days in present-day scenario) occur about 60% more frequently in future over Northeast and Midwest.

Hotter maximum temperatures





Triangles indicate days of highest BCt concentrations.

Reduced cloud cover

Higher maximum temperatures and reduced cloud cover suggest increased ozone production, amplifying effect of stagnation.