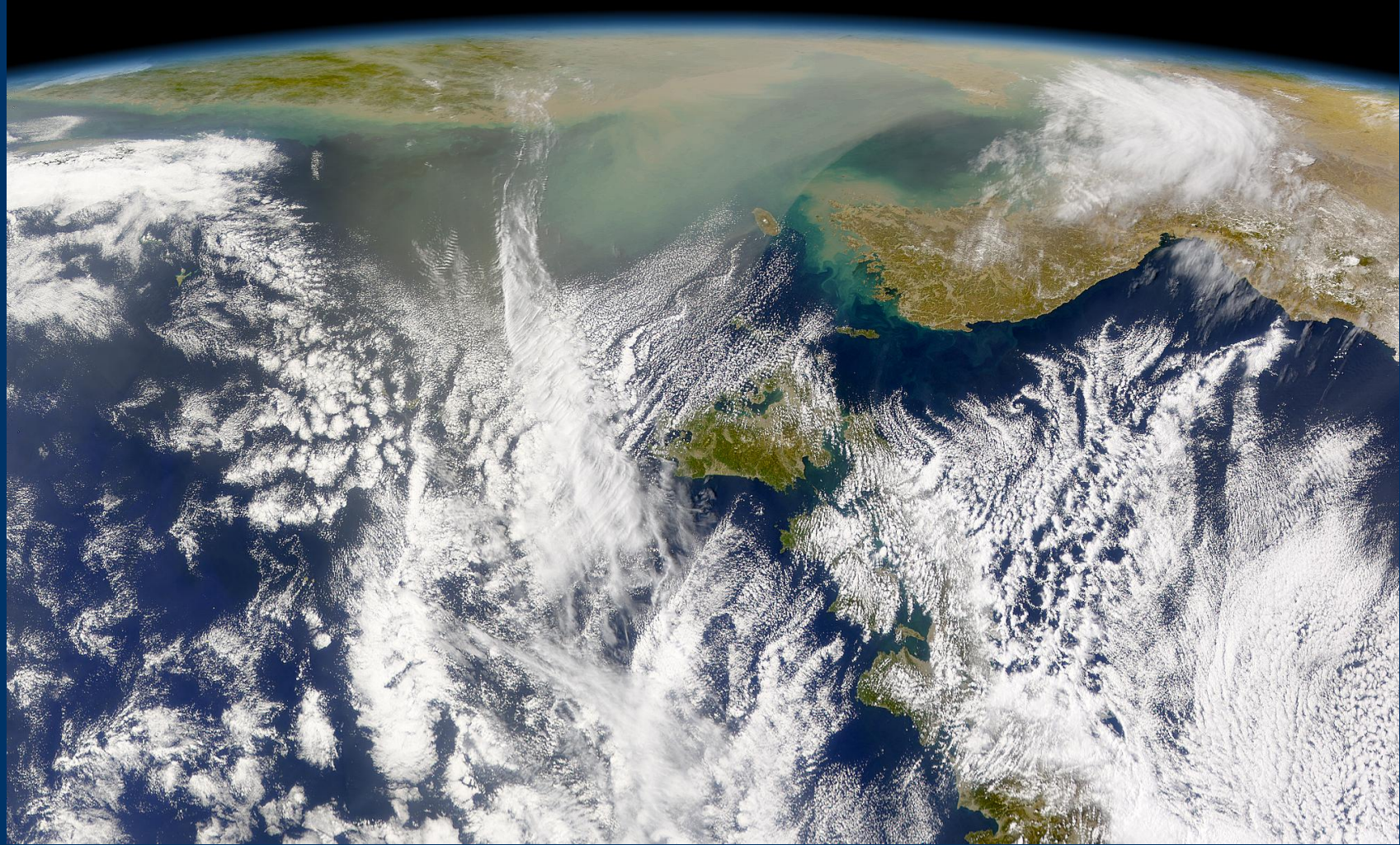
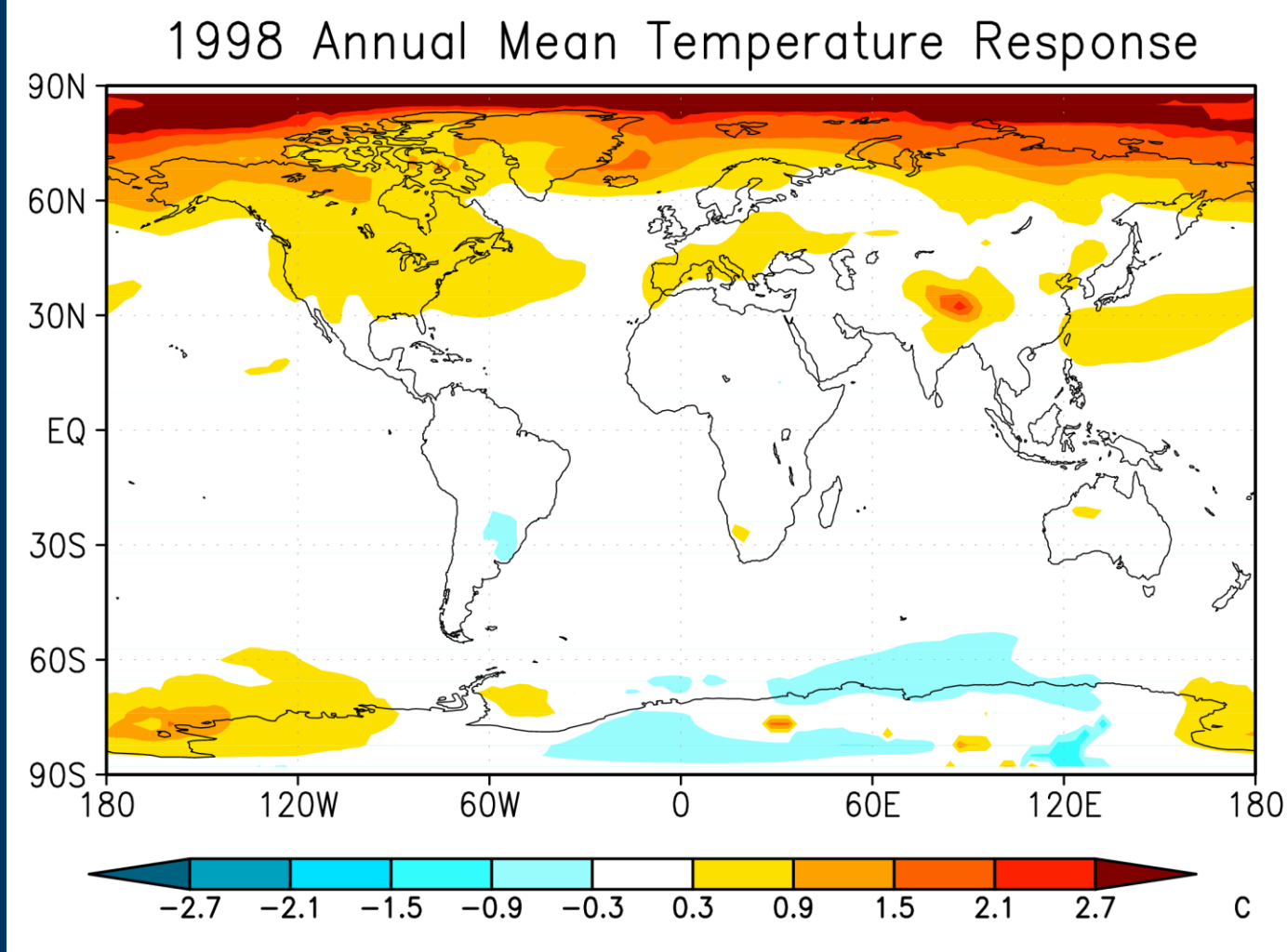


Amplified Eurasian springtime warming from snow darkening



Mark Flanner

Large model sensitivity to snow darkening

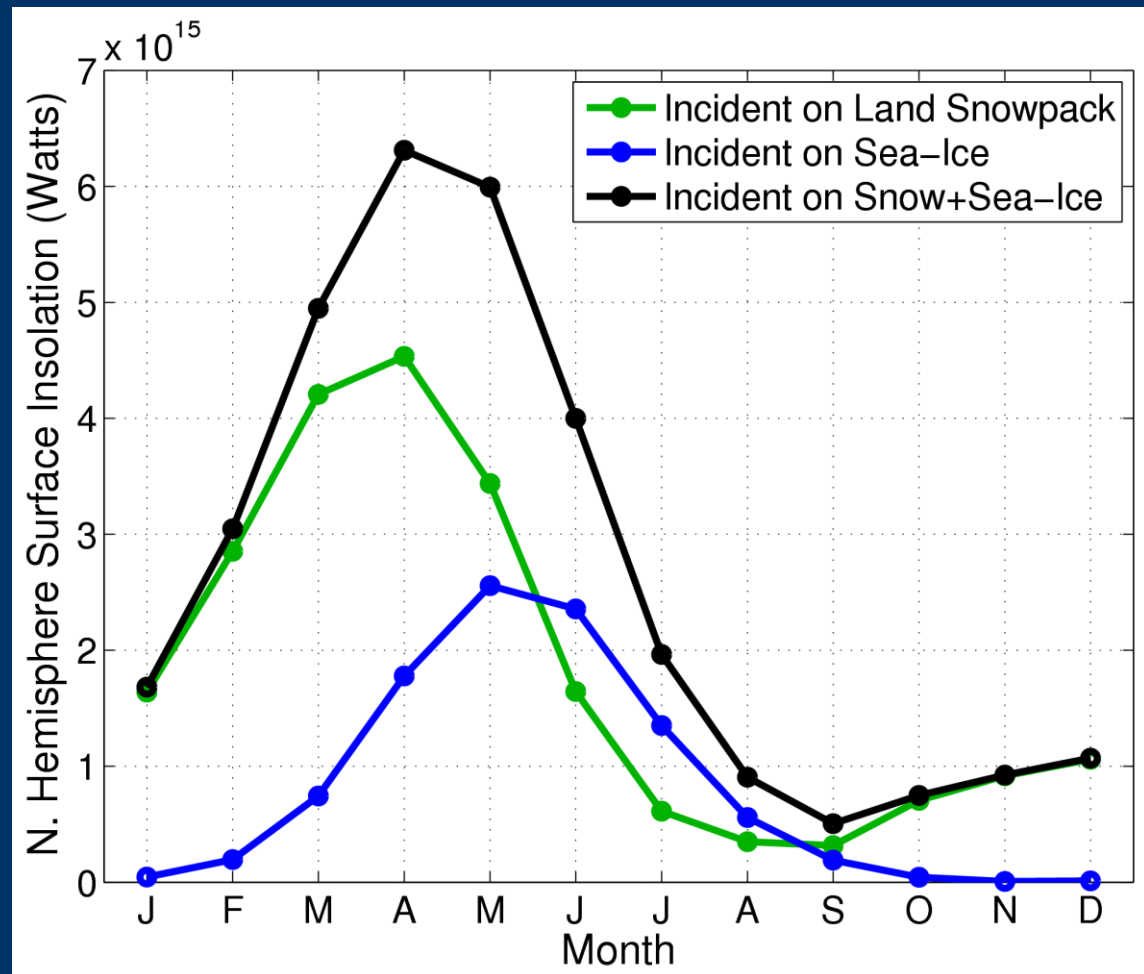


Flanner et al. (2007), *J. Geophys. Res.*

Do observations support this?

Springtime susceptibility to snow changes

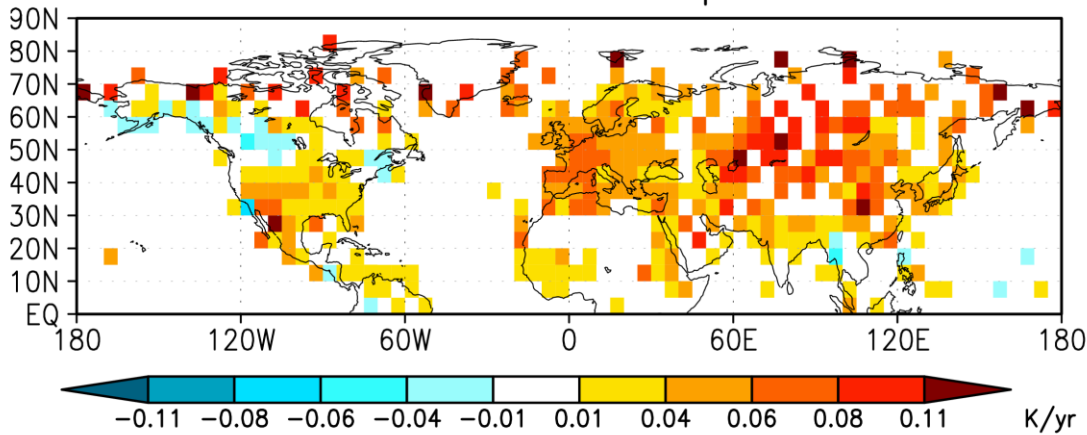
- Land-based snow reflectance changes exert greatest influence on Earth's energy budget during March-April - also when snow-albedo feedback is strongest



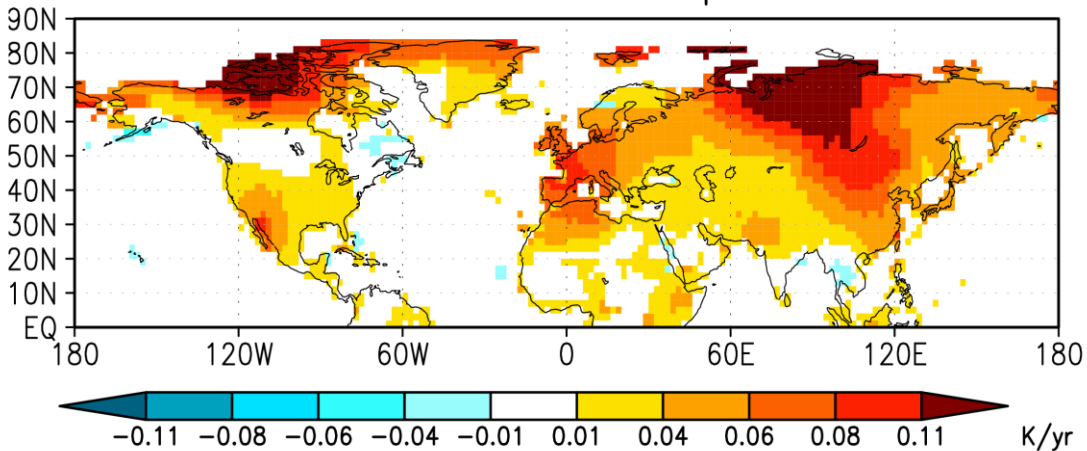
Springtime trends in temp and snow cover

- 1979-2007 warming rate is 3x greater over Eurasia than North America.
- Snow cover loss over:
Eurasia: ~14%
North America: ~7%

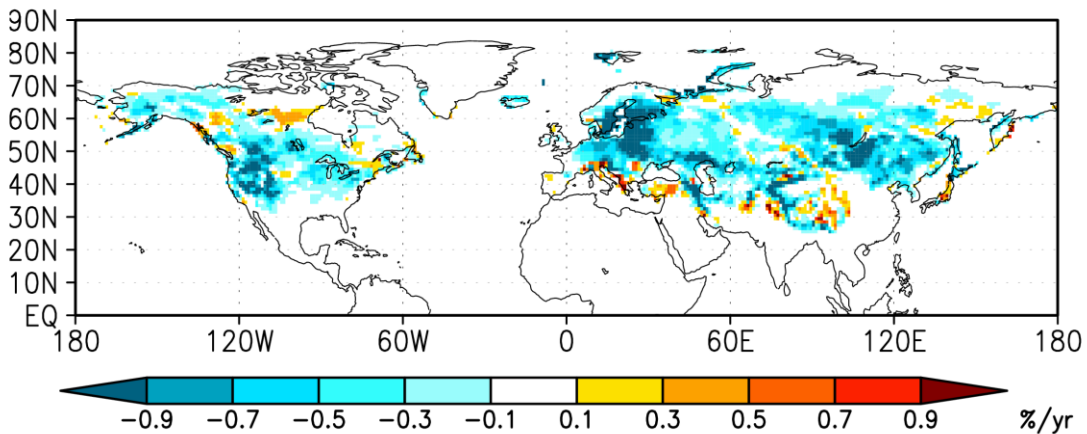
CRU 1979–2007 MAM Temperature Trend



GISS 1979–2000 MAM Temperature Trend



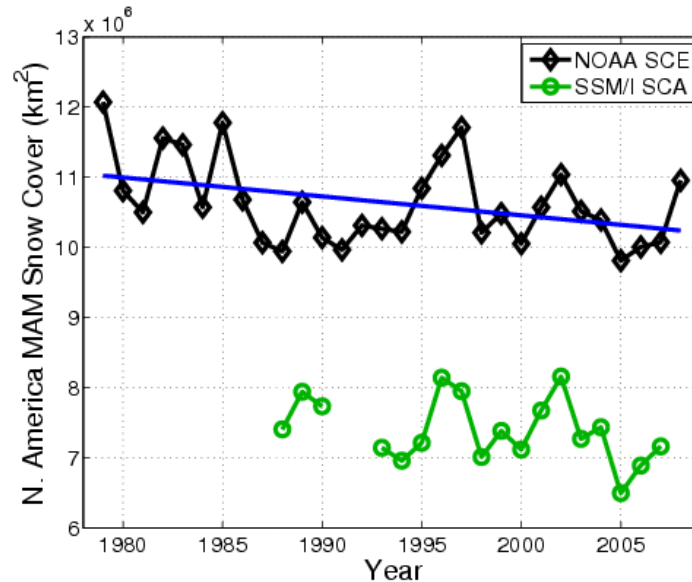
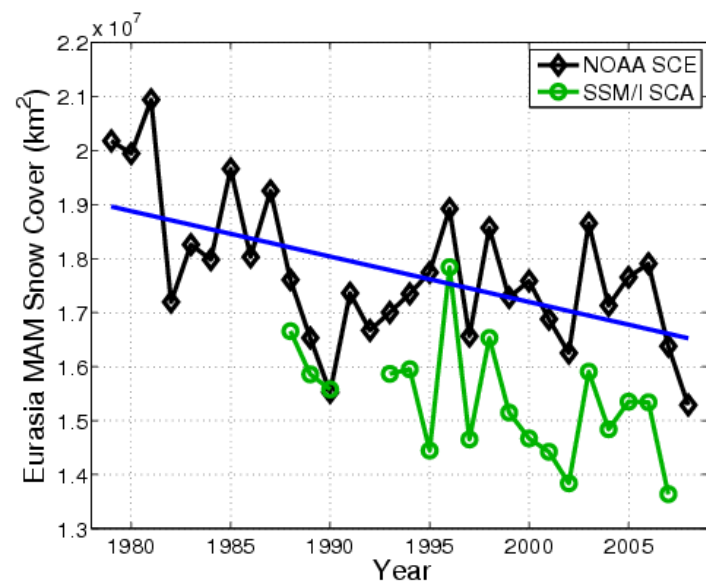
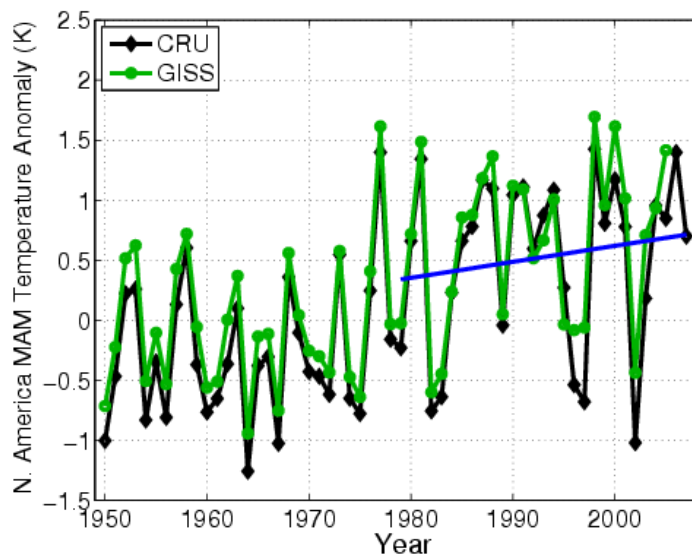
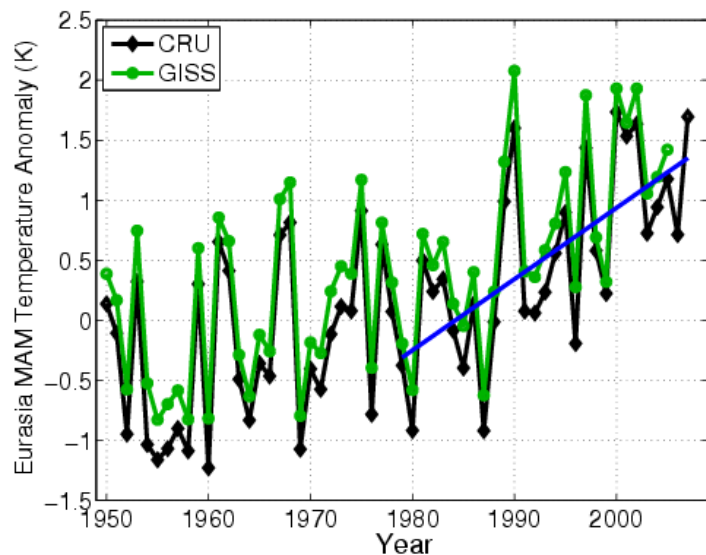
NOAA 1979–2000 MAM Snow Cover Trend



Springtime T and SCE trends

Eurasia

North America



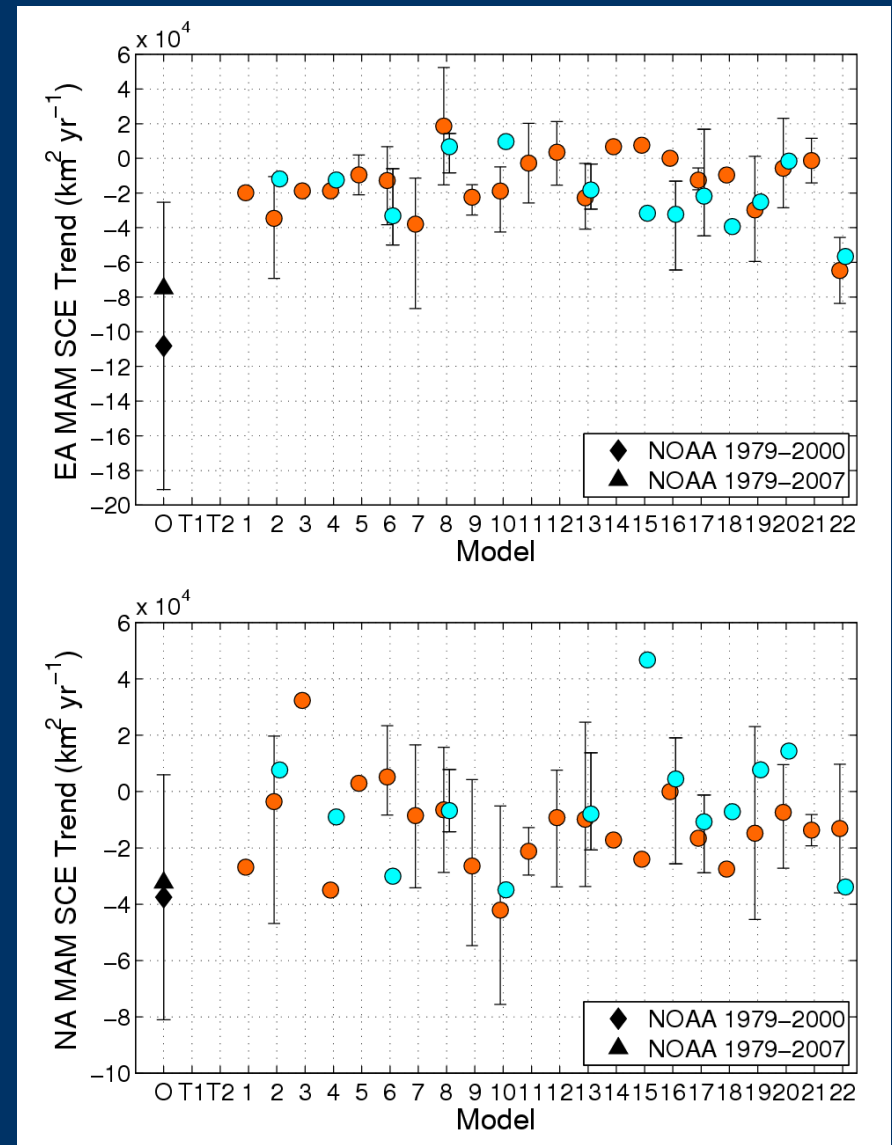
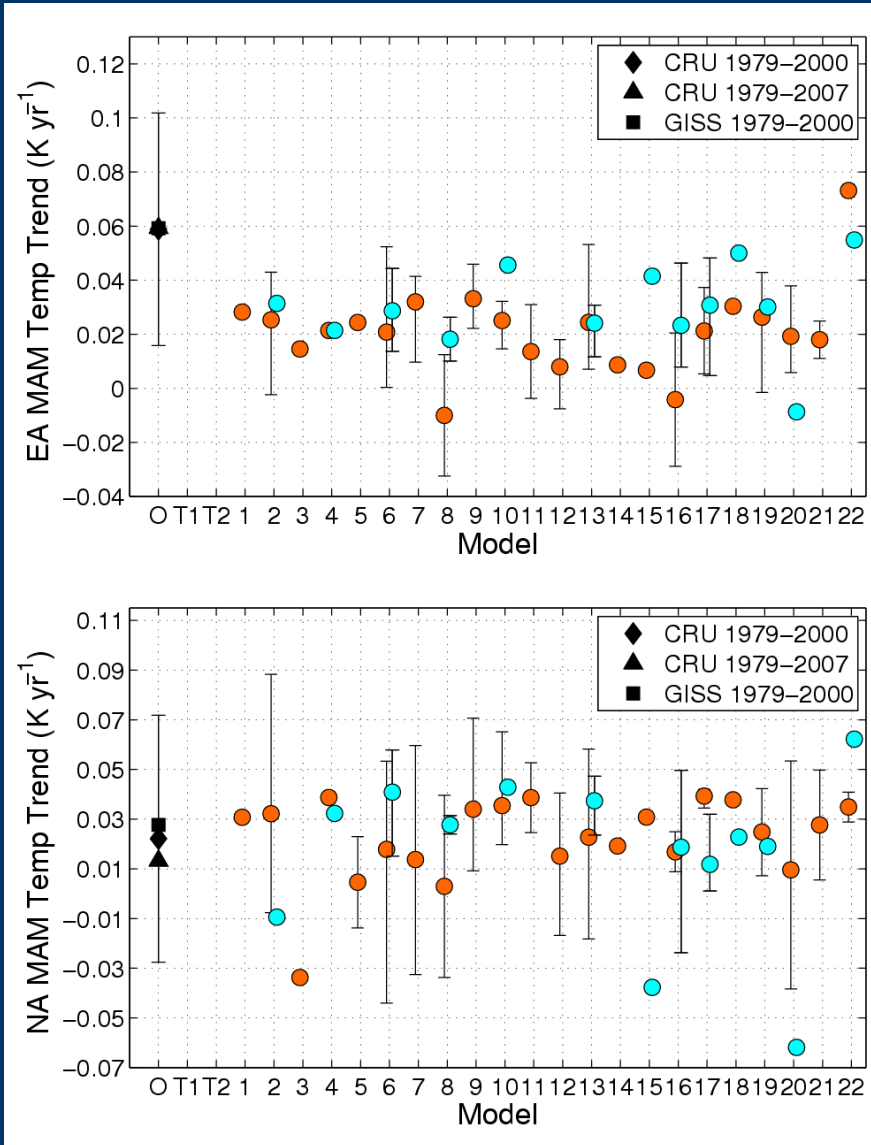
March-May
averages over land
north of 30°

IPCC Model Predictions

Springtime temperature trends

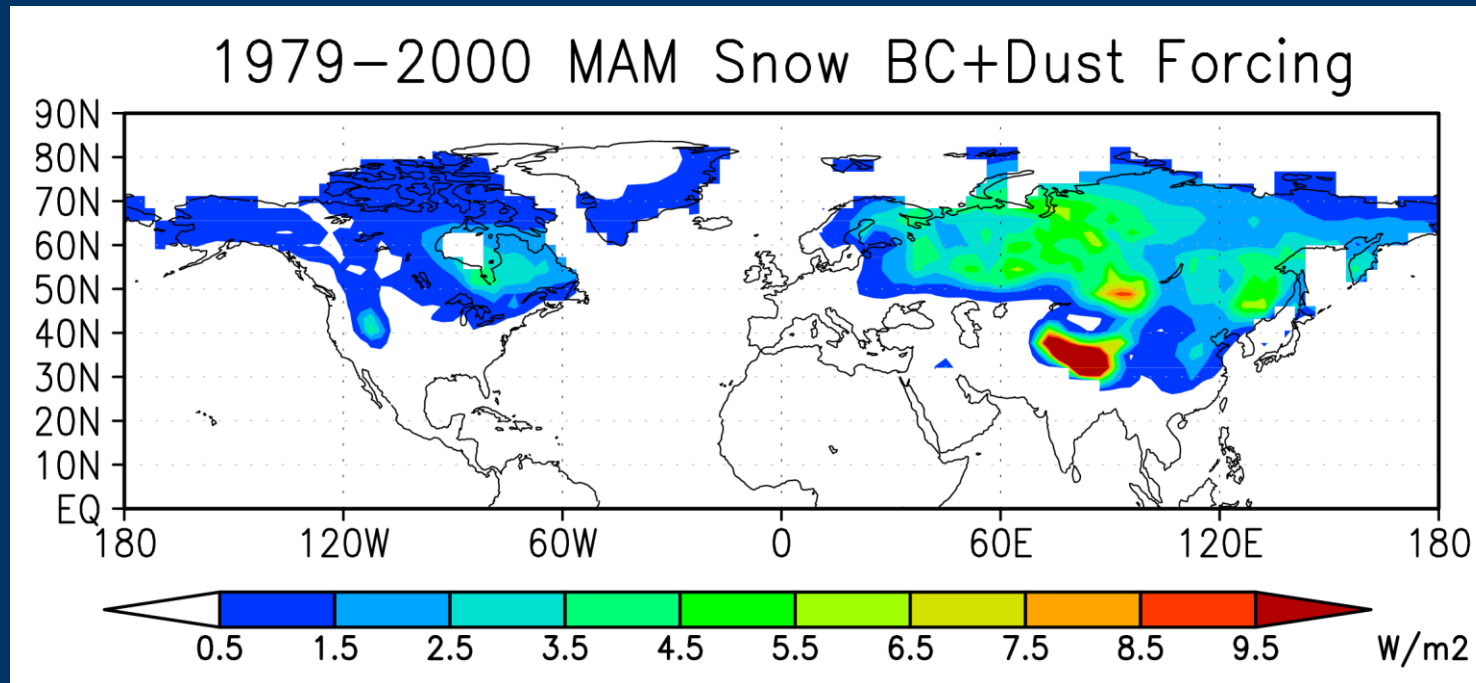
Springtime snow cover trends

Top: Eurasia
Bottom: North America



Snow darkening from atmospheric aerosols

- Prognostic transport of black carbon and mineral dust, deposition to snow (SNICAR model)
 - Time-evolving BC emissions [*Bond et al.*, 2007]
- 1979-2000 Surface forcing over springtime snow:
 - Eurasia: +3.9 W/m²
 - North America: +1.2 W/m²

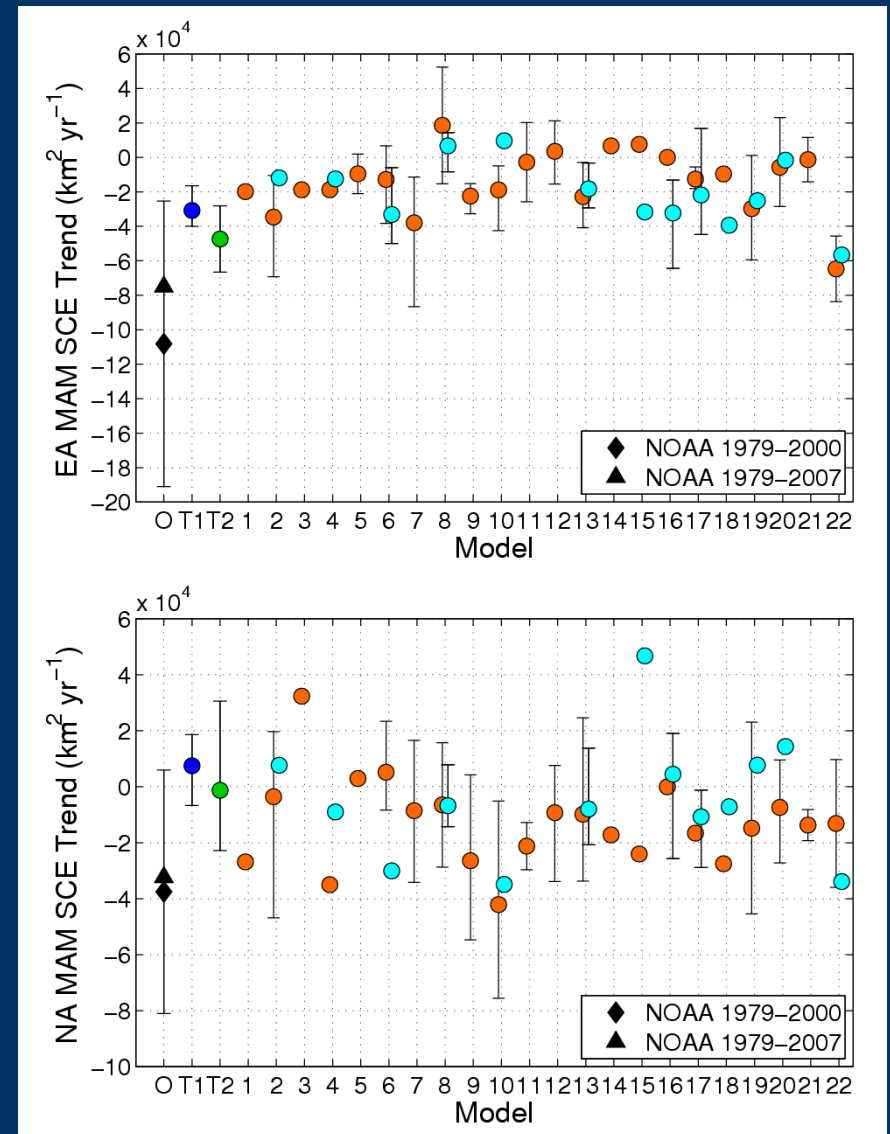
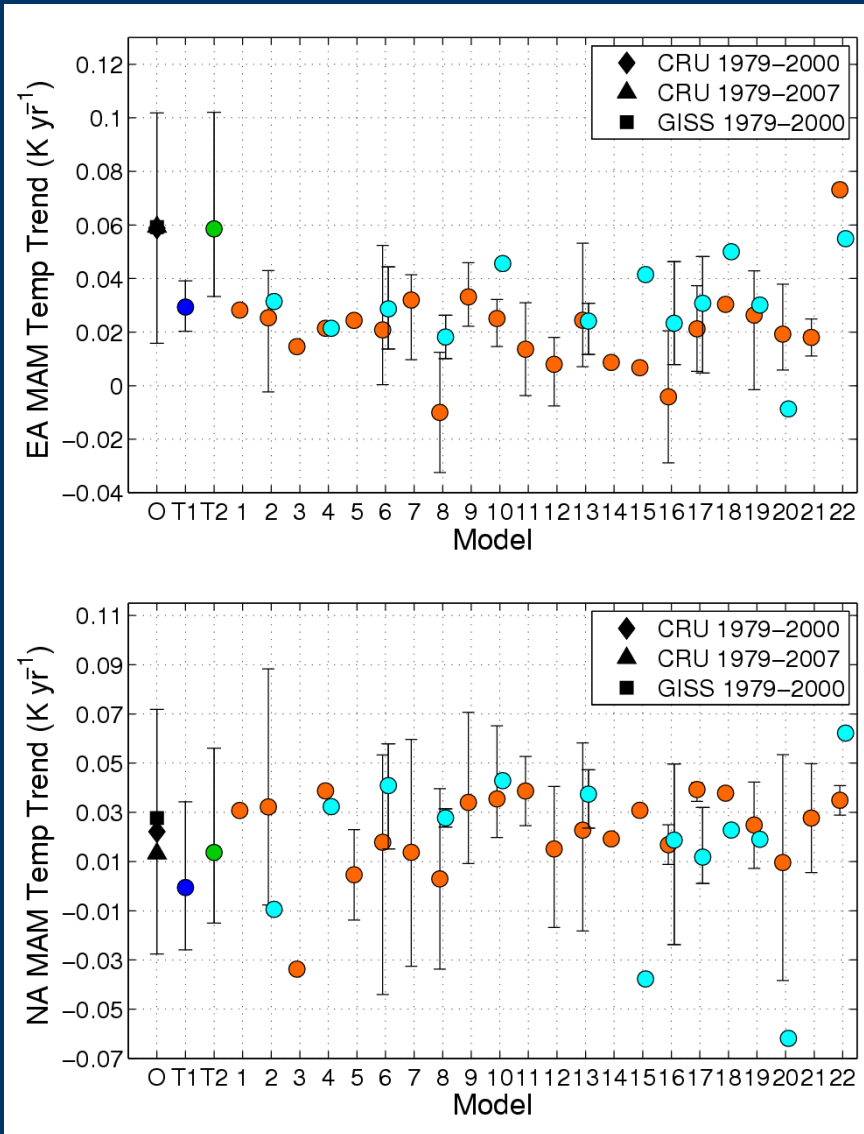


Modeled springtime climate trends

Springtime temperature trends

Springtime snow cover trends

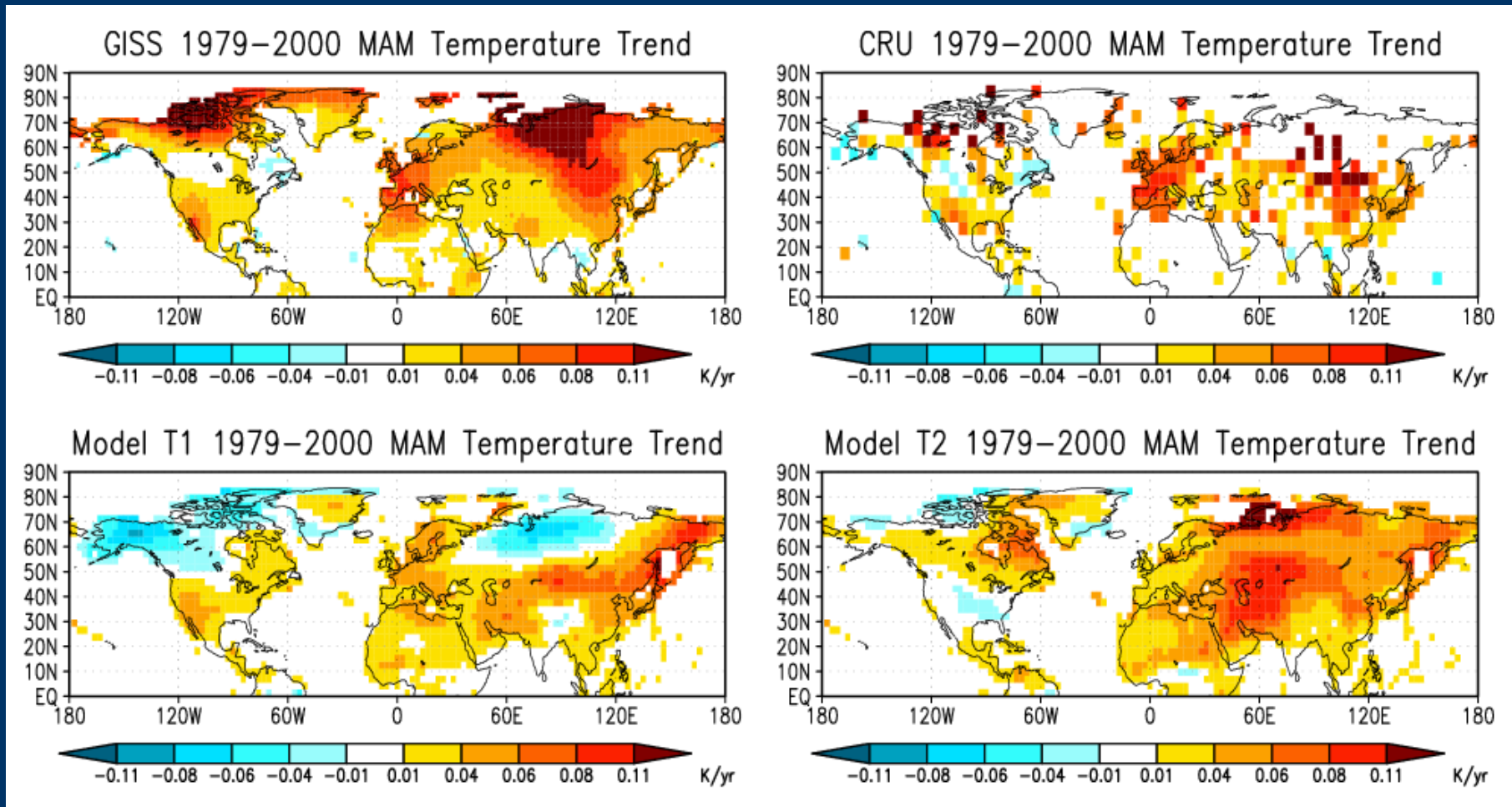
Blue: CAM/CLM without snow darkening
Green: CAM/CLM with snow darkening



Springtime warming trends

GISS temperature analysis

CRU temperature analysis



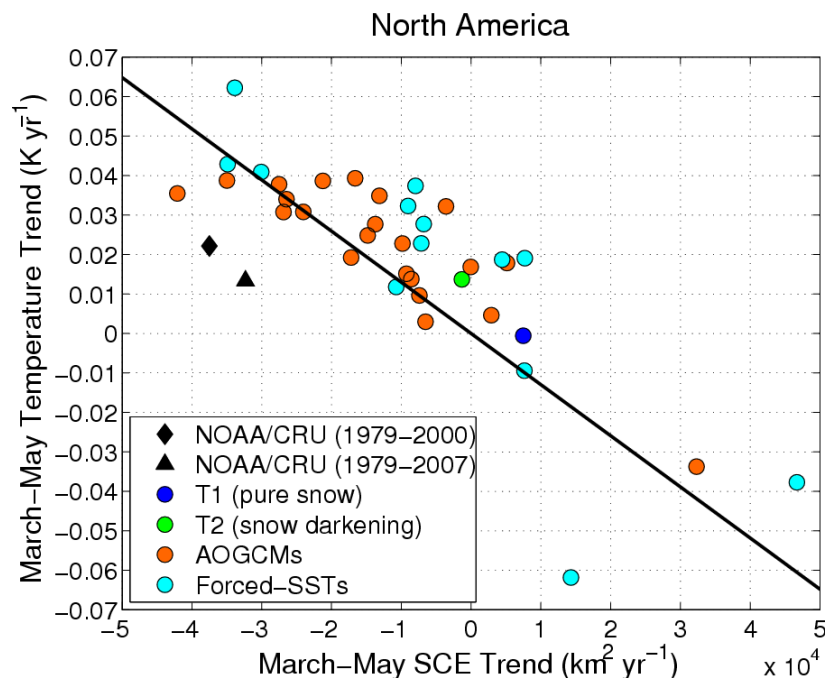
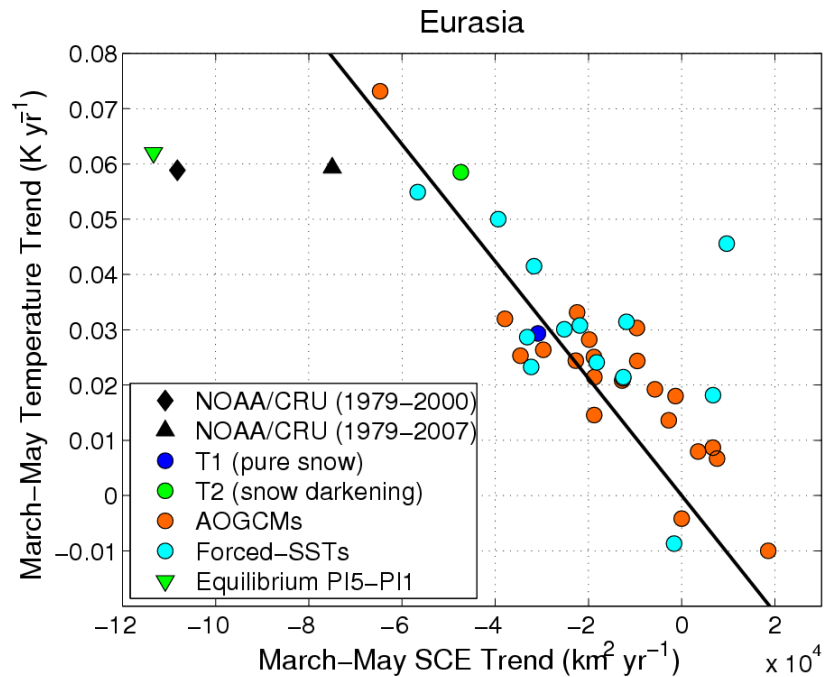
CAM/CLM without snow darkening

CAM/CLM with snow darkening

(5-member ensembles with forced SSTs and sea-ice)

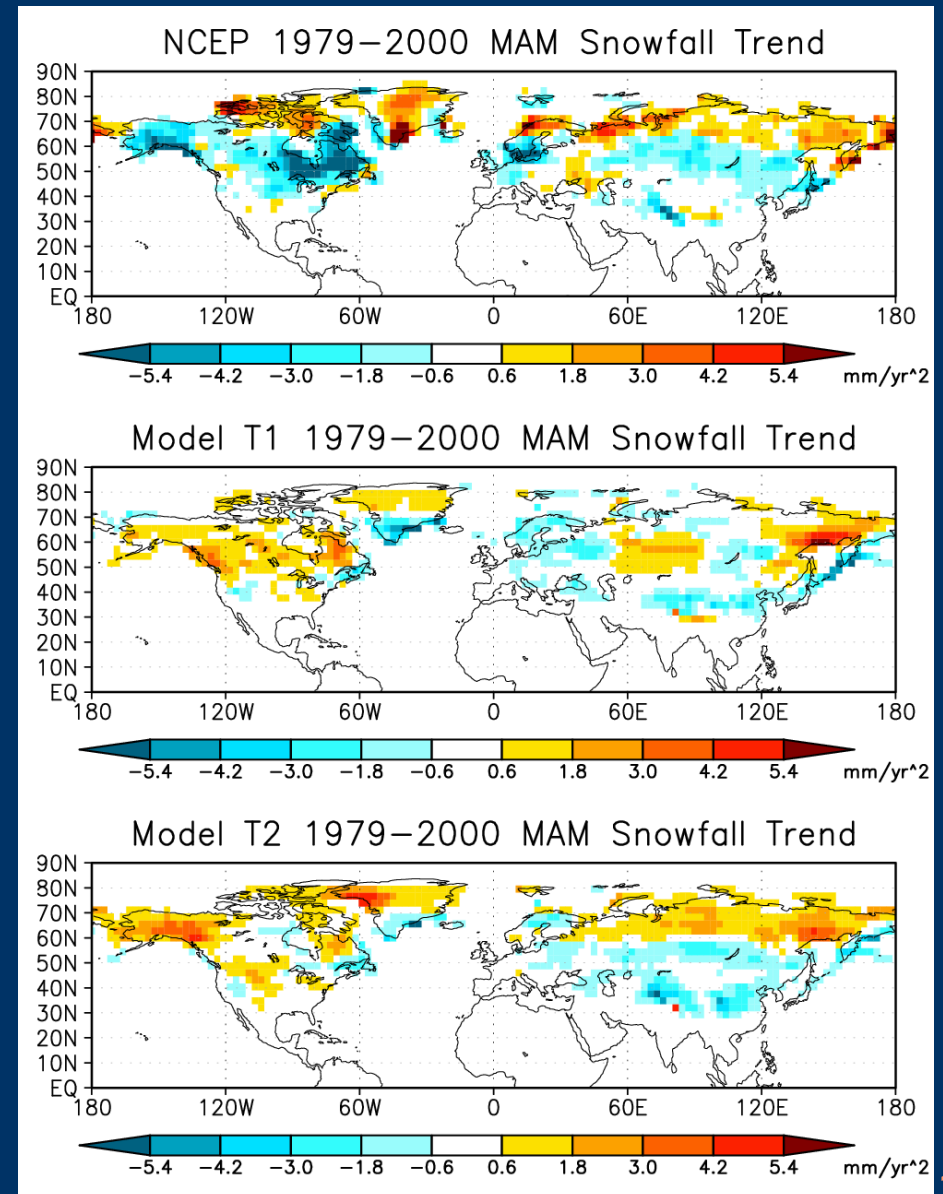
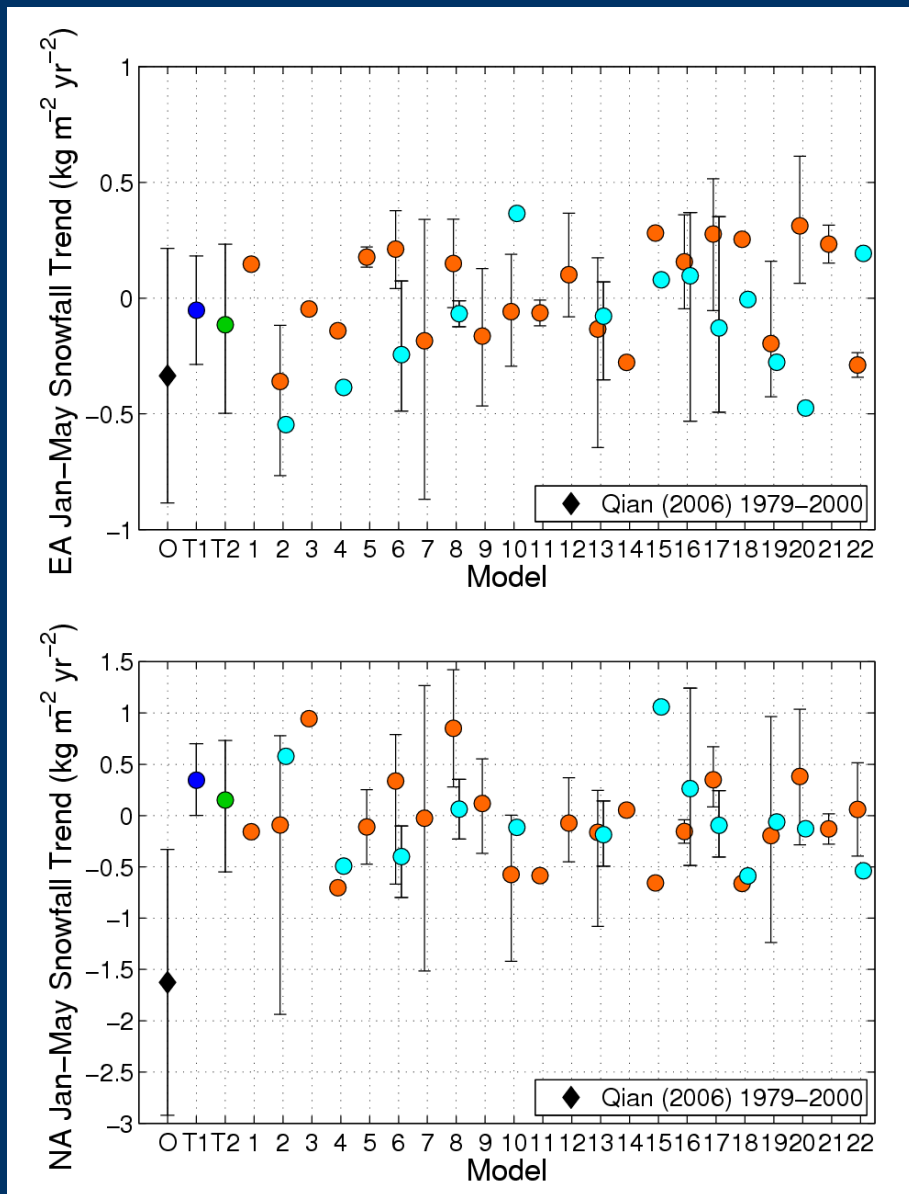
Warming vs. SCE decline

- Simulated warming and snow cover loss rates are correlated, but observations show greater snow loss / warming ratio than any model predictions (over 1979-2000)



Snowfall trends

- Snowfall biases contribute to snow cover biases over North America, but probably not over Eurasia



Conclusions

- Springtime Eurasia has warmed more rapidly than North America (since 1979)
- IPCC AR4 models (including those with forced SSTs and sea-ice) tend to predict similar warming rates over both continents
 - 21 of 22 models underpredict Eurasian warming
- Hypothesis: Snow darkening is contributing to greater warming over Eurasia, where BC and dust emissions are greater
 - We estimate 3x greater springtime snow darkening over Eurasia (3.9 W/m^2)
 - CAM/CLM experiments support hypothesis, but do not resolve snow cover trend bias observed in all AR4 models