Contributions of Climate and Global Change postdocs to progress in large-scale atmospheric and climate dynamics

Richard Seager
Lamont Doherty Earth Observatory

- The intervention of atmospheric dynamics into the science of climate **change**
- The basic workings of the climate system - ‘numerical climatology’
- Drought and hydroclimate

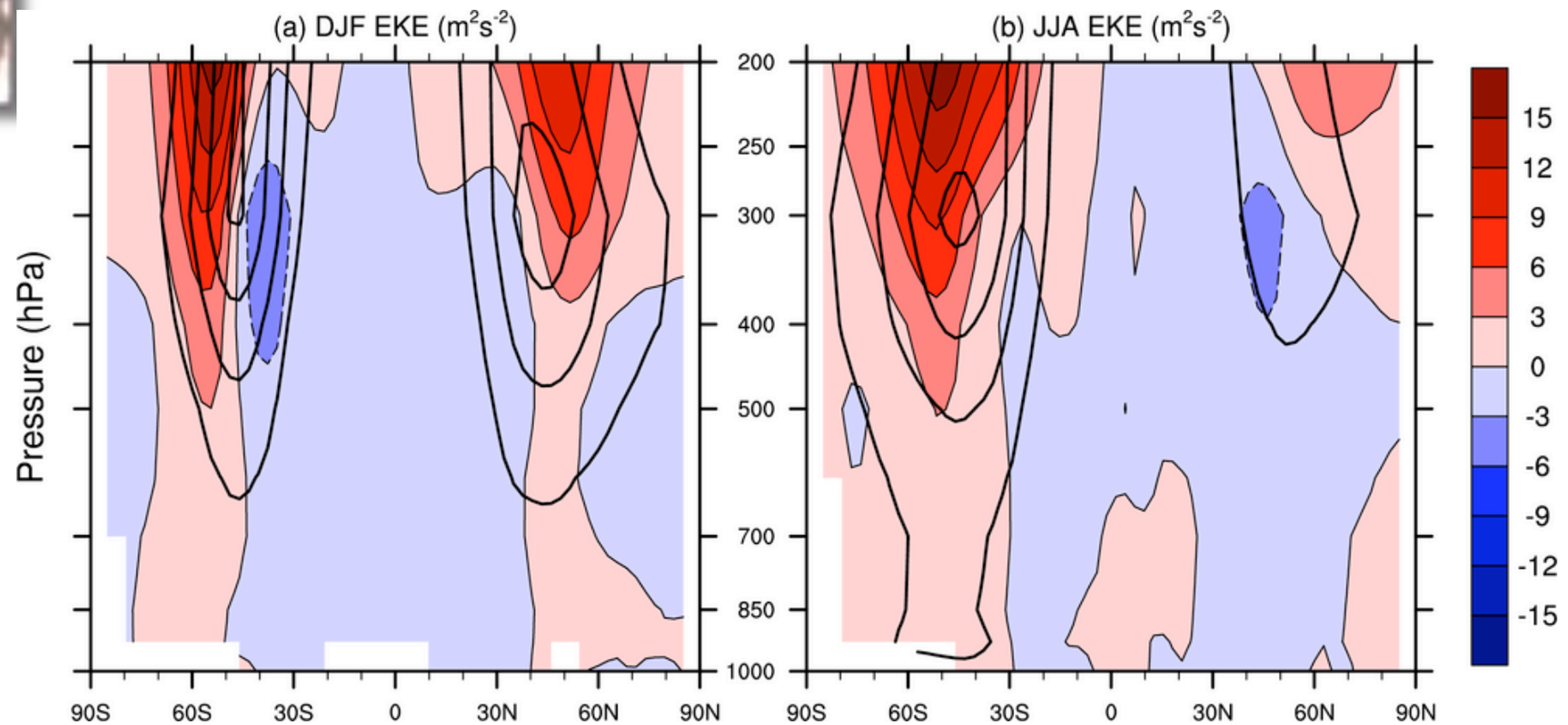
Atmospheric dynamics and climate change

Jeff Yin

Largely an intellectual backwater until ...

A consistent poleward shift of the storm tracks in simulations of 21st century climate

Jeffrey H. Yin
ESSL/Climate and Global Dynamics Division, National Center for Atmospheric Research, Boulder, Colorado, USA



Why does the Hadley Cell expand and the jets and storm tracks shift poleward under global warming?

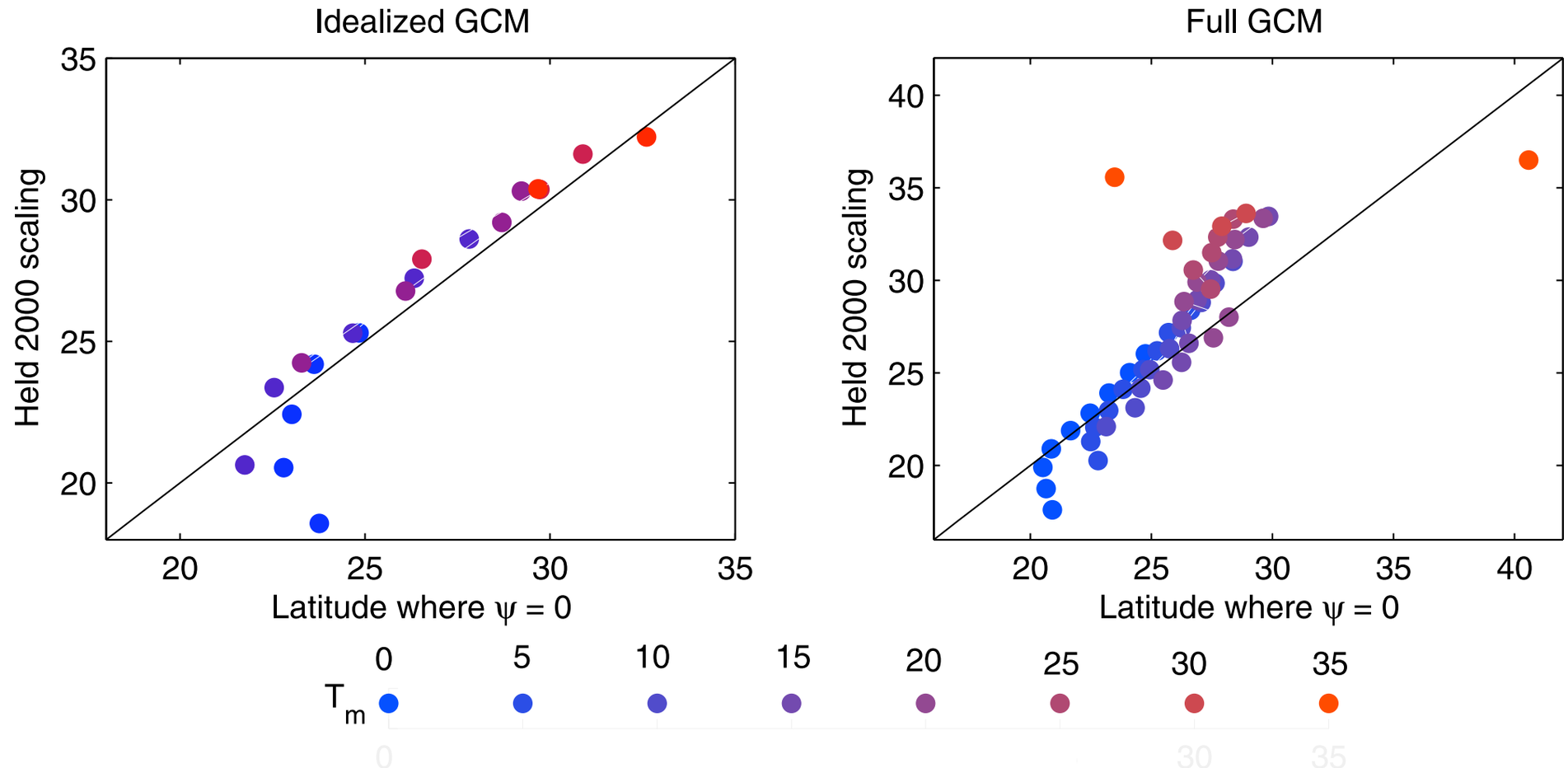
Dargon Frierson

Gang Chen

Jeff Yin

David Lorenz

Hadley Cell expands as mean temperature increases according to Held (2000) scaling with width determined by latitude where baroclinic eddies begin to form

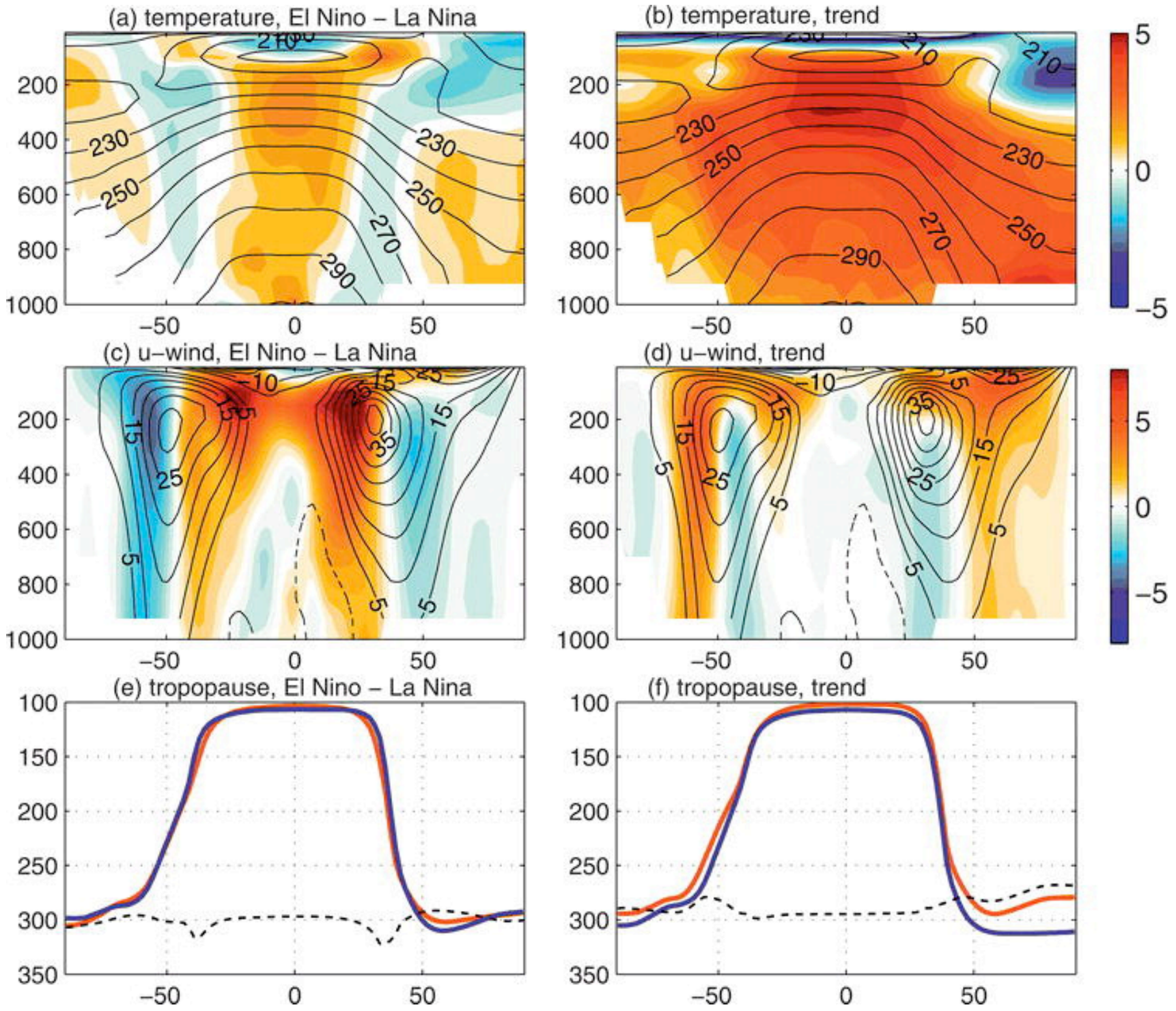


Frierson, Lu and Chen 2007

$$\phi_H \sim (H\Delta_v)^{1/4}$$

tropopause height dry static stability

According to the Held scaling jets/ storm tracks may shift poleward ‘cos of broad tropical/ subtropical warming.
But what causes that? Quite unlike El Nino-induced tropical warming.

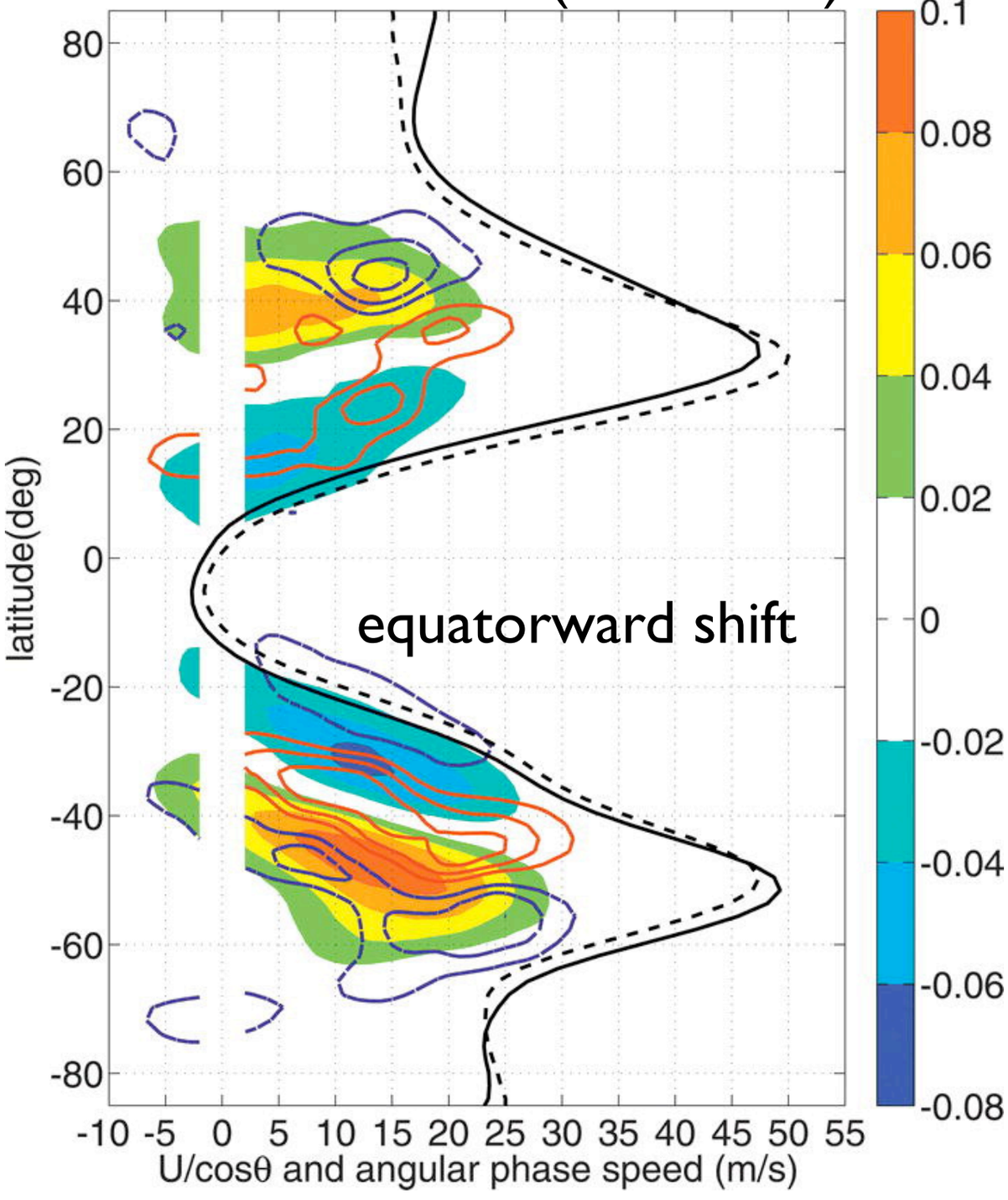


blue - La Nina or 2001-2020
red - El Nino or 2081-2100

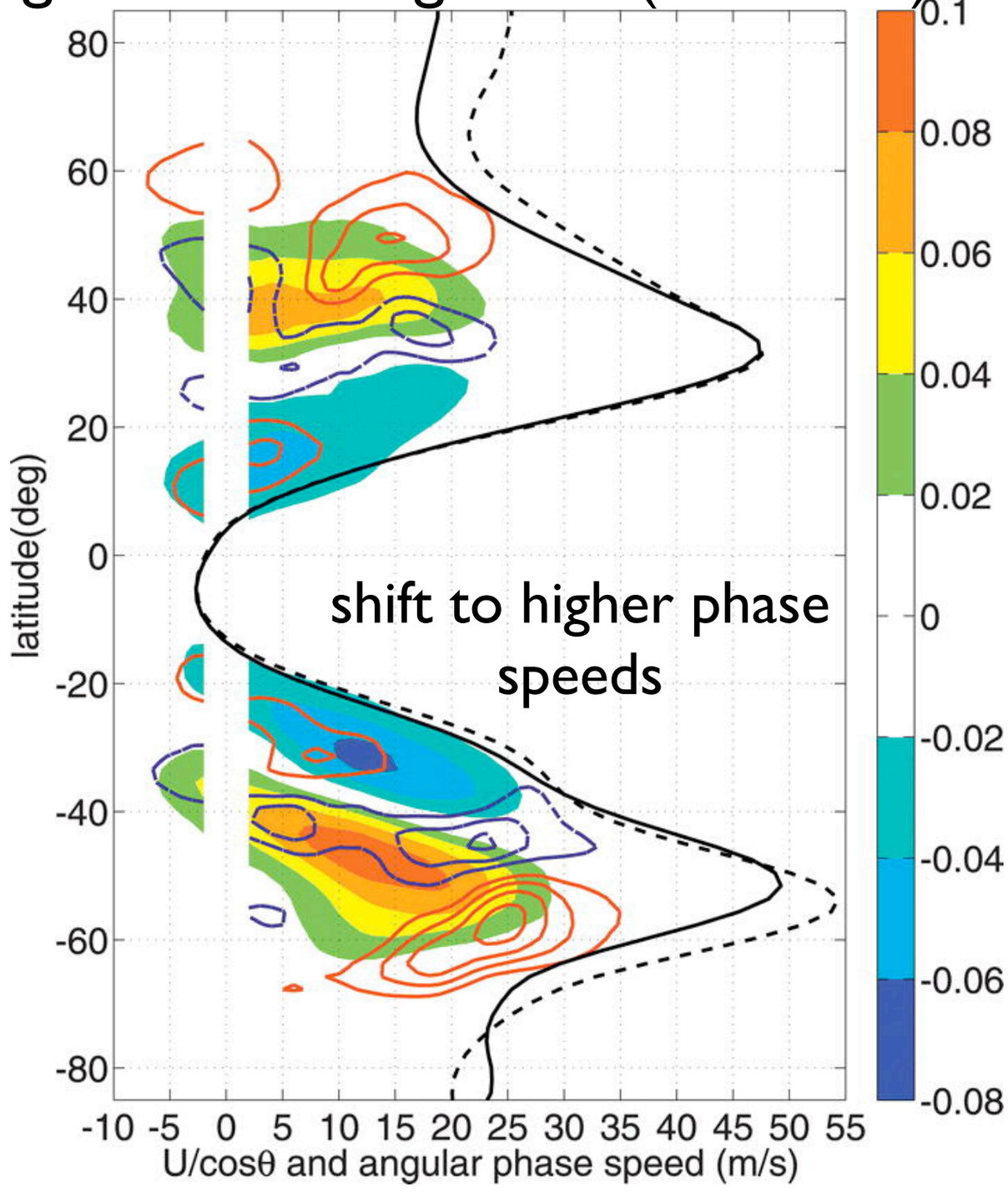
Lu, Chen, Frierson (2008)

co-spectra of eddy momentum flux convergence, climatology(colors)

El Nino-La Nina (contours)



global warming trend (contours)



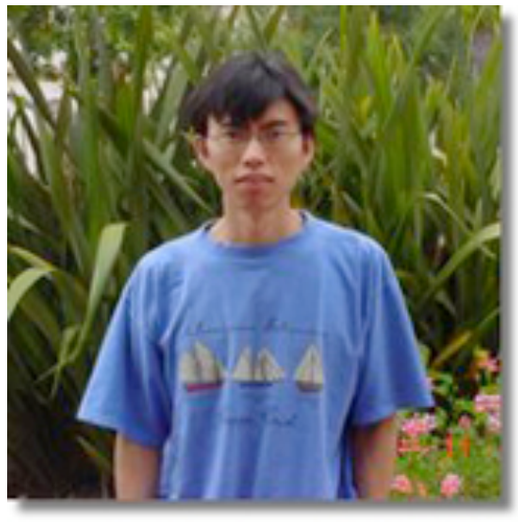
Lu, Chen, Frierson (2008), Chen, Lu, Frierson (2008)

Argument 1: Broad warming into the subtropics shifts latitude of energy generation poleward.
What causes the subtropical warming? Actually eddy-driven (Wu et al. 2010, 2011 in prep.) so this leaves the mystery.

Argument 2: Increased phase speed of eddies causes subtropical critical line to move poleward and, hence, eddy momentum flux convergence pattern and, hence, jet and storm track.
What causes the increased phase speed? Radiatively-driven stronger lower stratospheric winds?
Any role for changes in wave refraction (c.f. ENSO)?

The makings of the Earth's climate - numerical climatology

Ric Williams



Zhiming Kuang

Yohai Kaspi

huh?

Jeff Yin

Is the Gulf Stream responsible for Europe's mild winters?

By R. SEAGER[1]*, D. S. BATTISTI[2], J. YIN[2], N. GORDON[1], N. NAIK[1], A. C. CLEMENT[3] and M. A. CANE[1]

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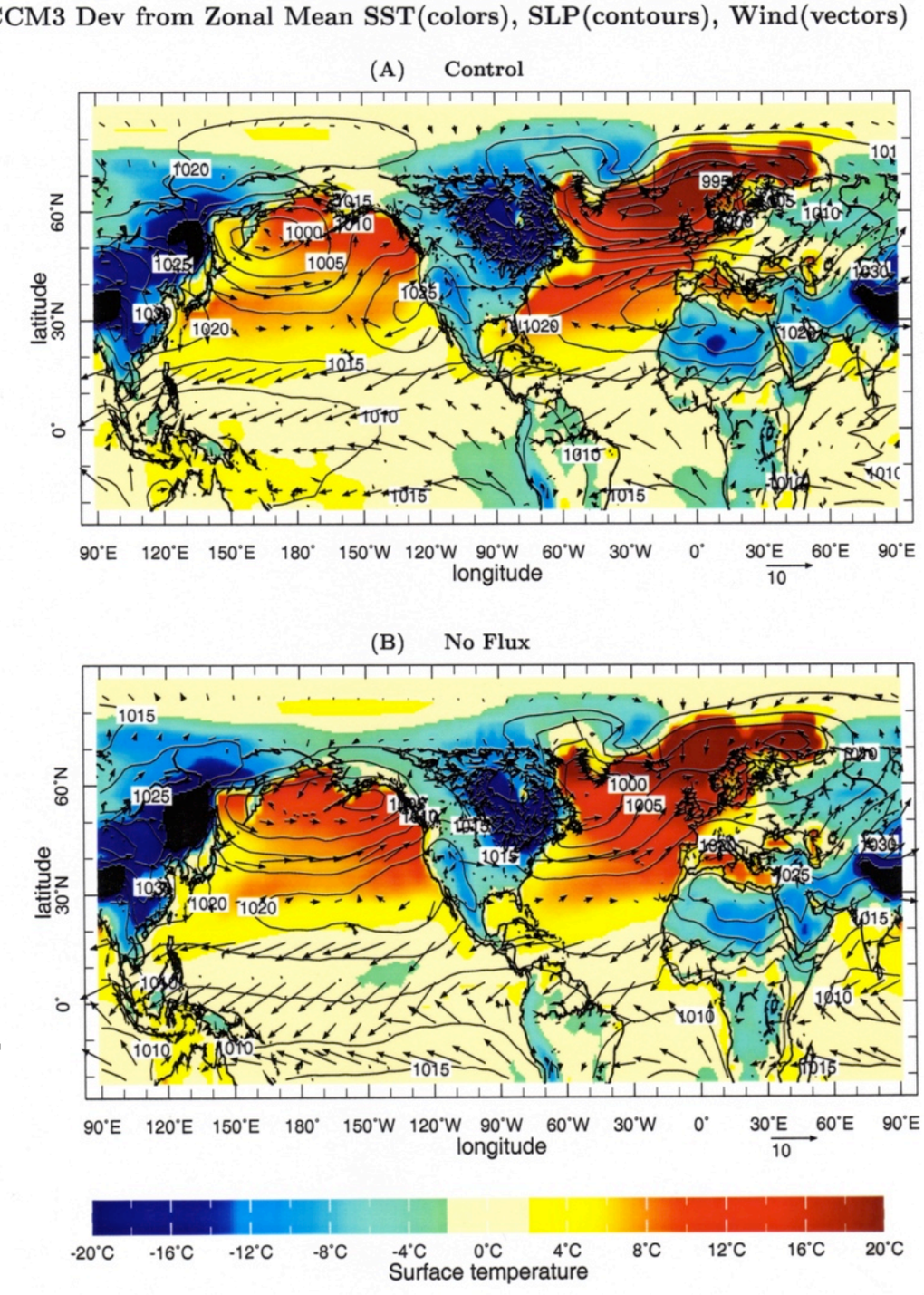
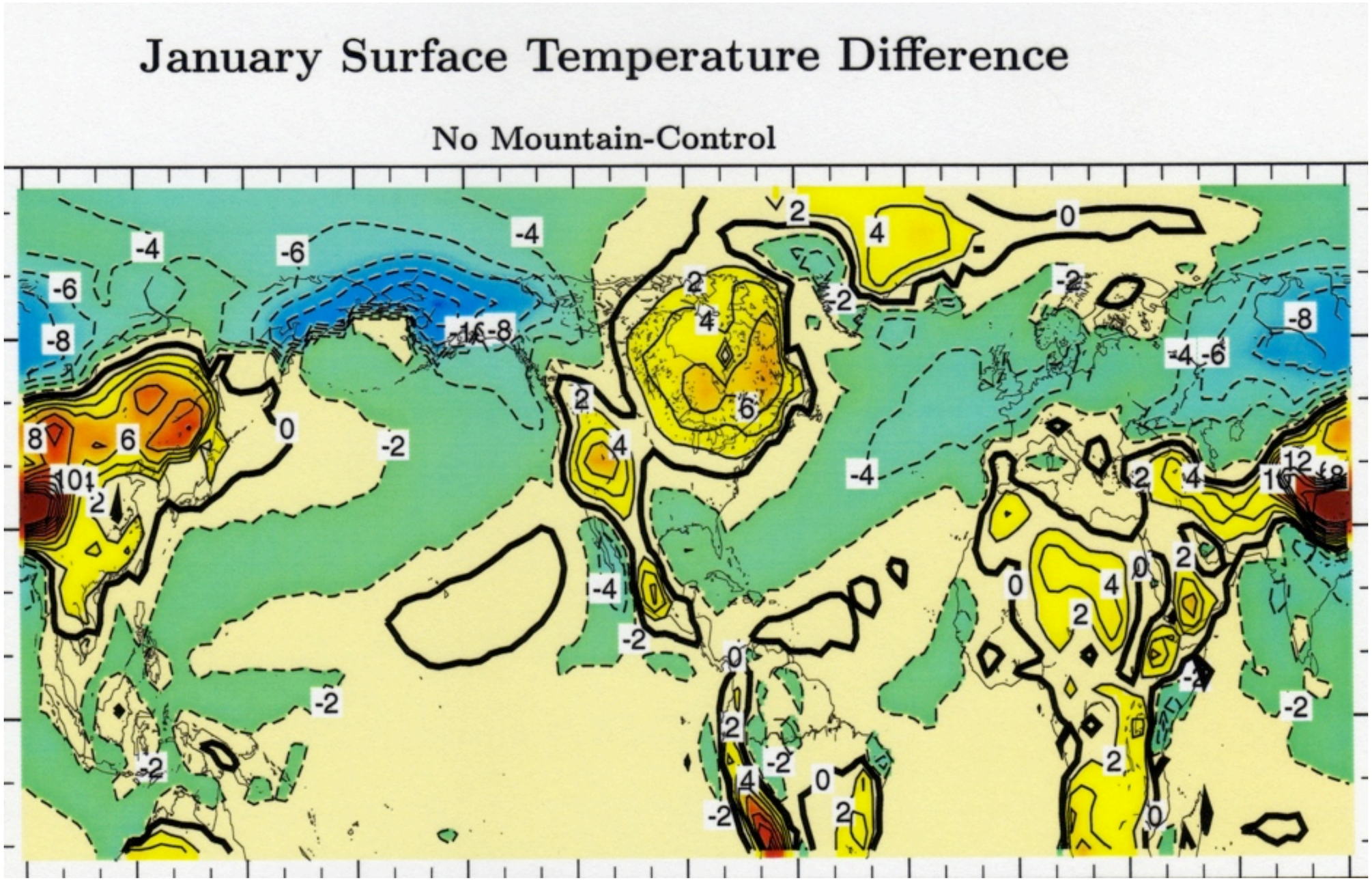
(Received 23 July 2001; revised 19 April 2002)

Departure of winter temperature from zonal mean, CCM3 model



North-south flow forced by mountains cools eastern North America and warms western Europe



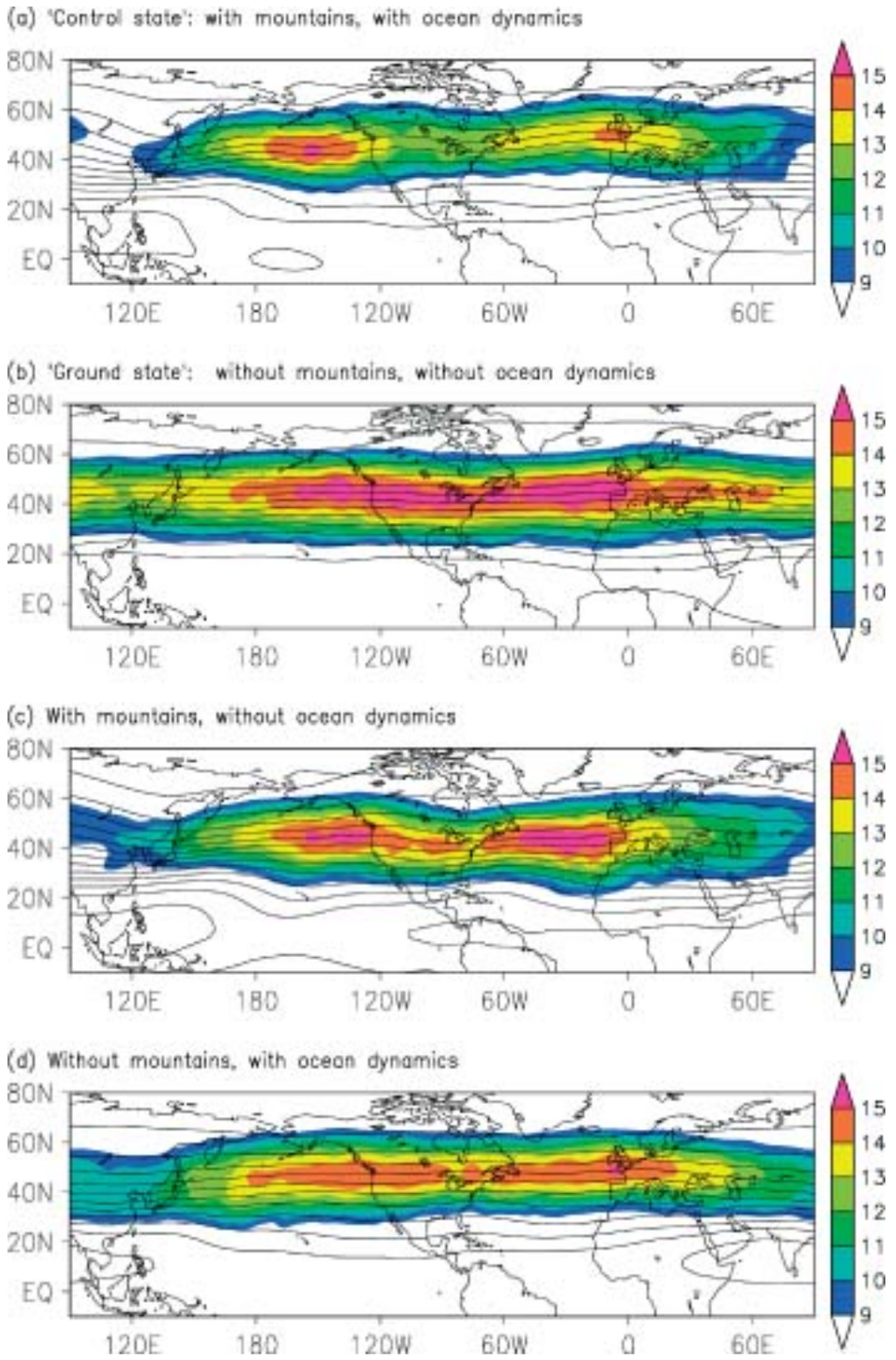
So the Rockies play a basic role in the distributions of mid-latitude climates ...
Storm tracks also influenced by mountains, oceans

with mountains and OHT

NO mountains *NO* OHT

with mountains *NO* OHT

no mountains *with* OHT



transient EKE

Williams et al. (2007), Wilson, Sinha, Williams (2008, 2010)

But massive heat release in winter in Kuroshio and Gulf Stream proper may CAUSE COOLING OVER CONTINENTS TO THE WEST .... idealized model responses to imposed WBC-style heating:

rotation rate

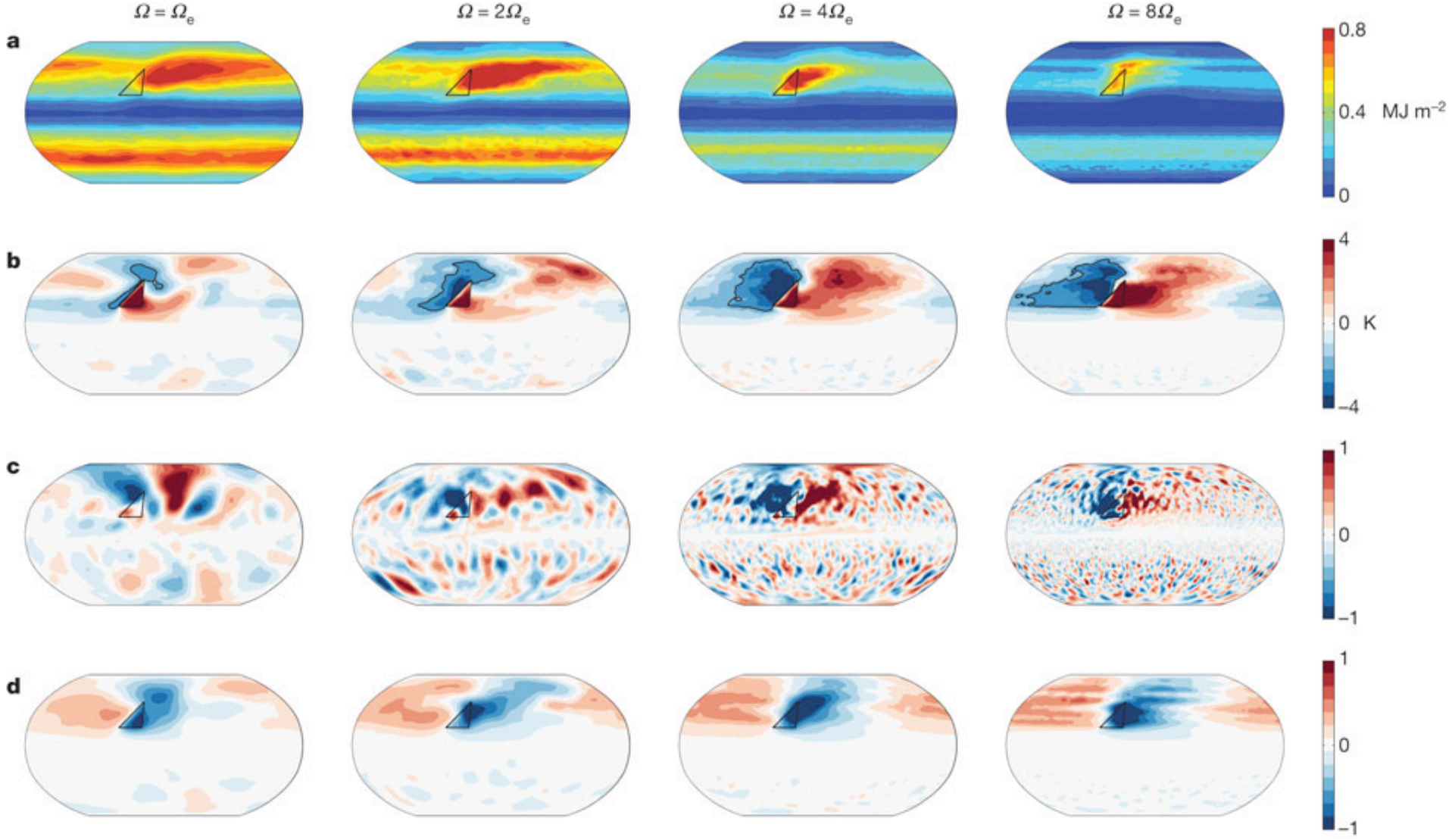
1X 2X 3X 4X

transient EKE

T*

v*

SLP*



increasing zonal extent of cooling with rotation rate consistent with increased group velocity of Rossby waves forced by WBC heating

Kaspi and Schneider (2011)

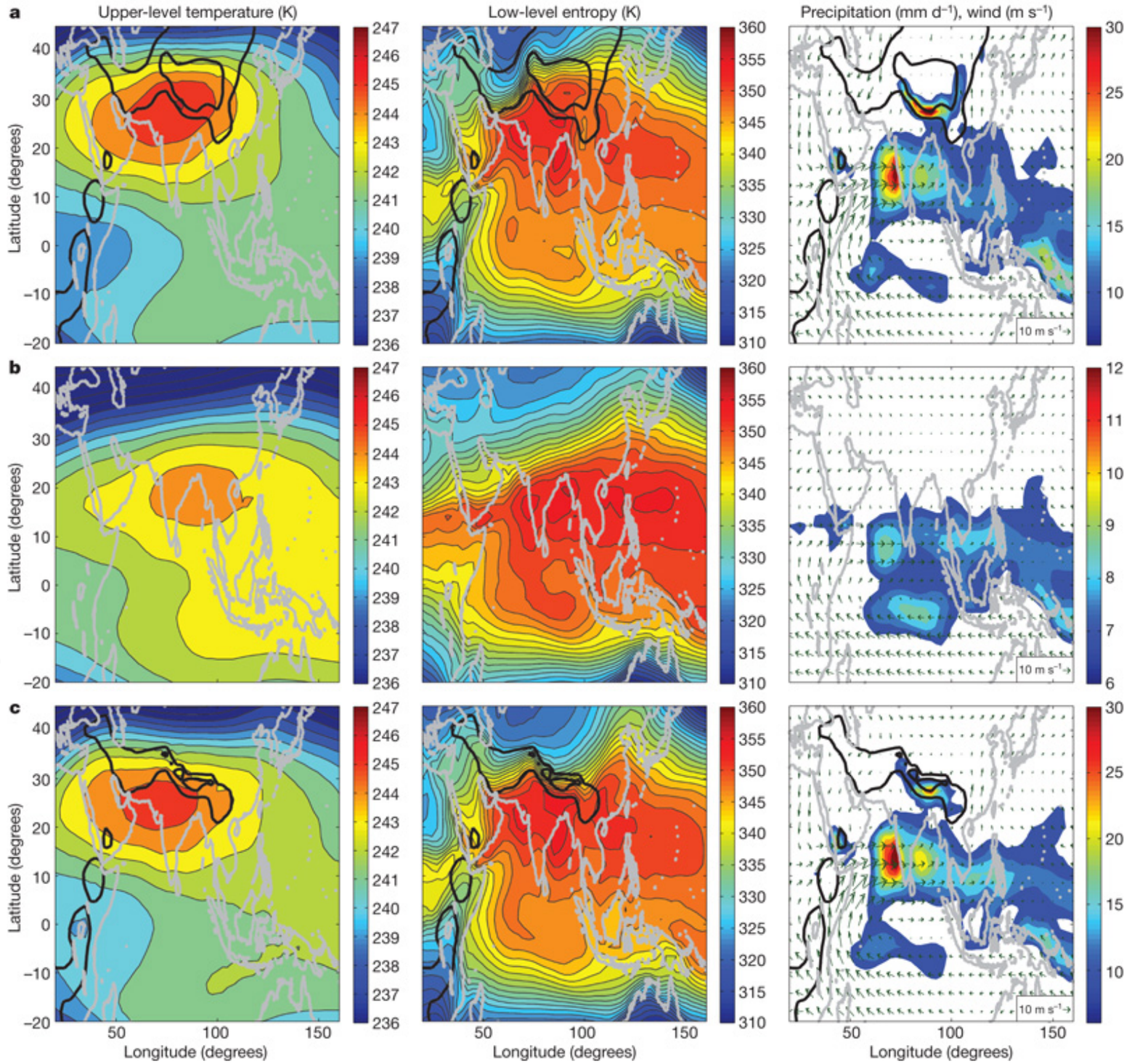
And while canards are falling ...

Asian monsoon does not require Tibetan plateau heating (Boos and Kuang 2010)

full model

no mountains

Himalayas but no Tibetan plateau



Drought and the hydrological cycle

Nir Krakauer

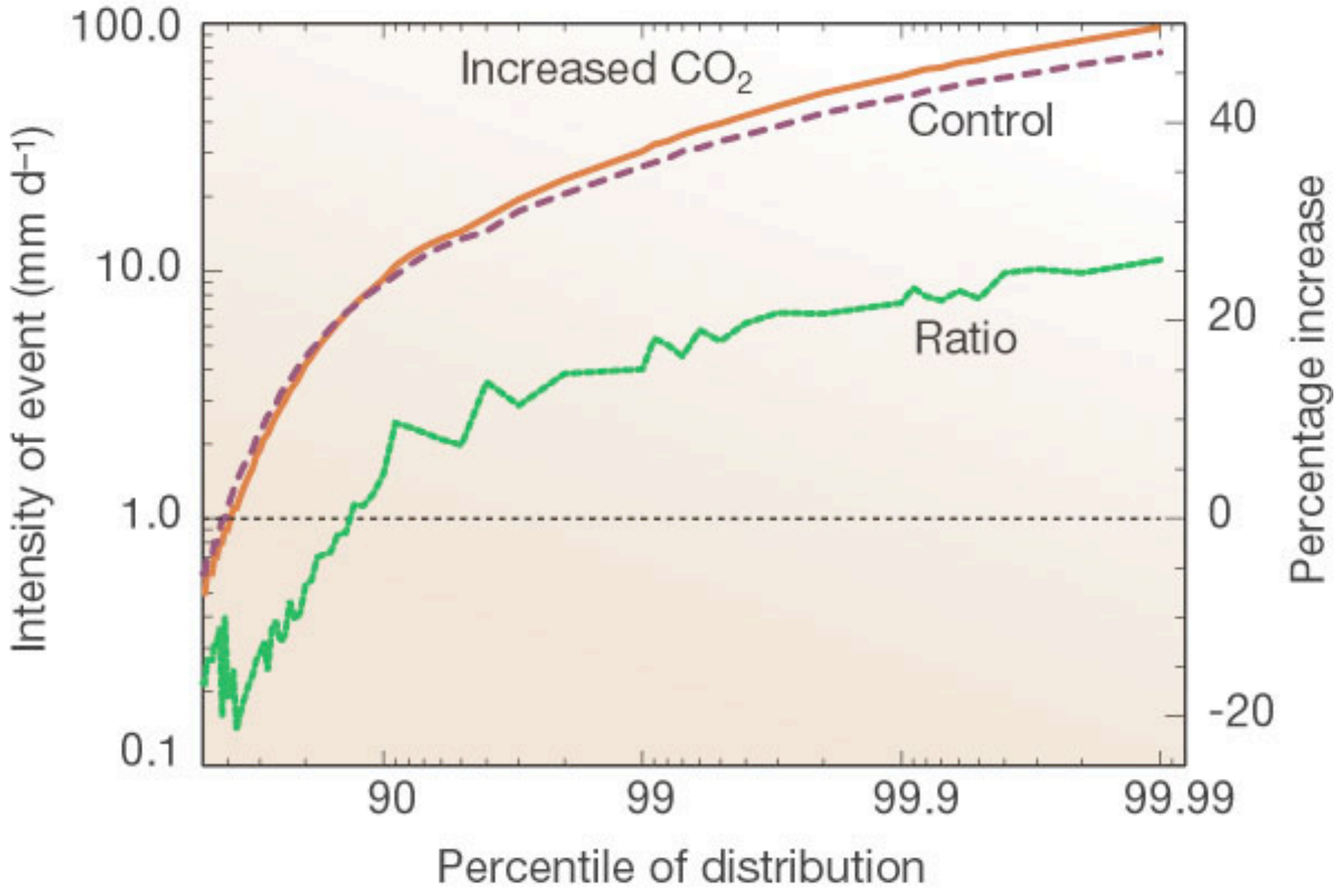
Ben Cook

David Lorenz

‘nuff already!

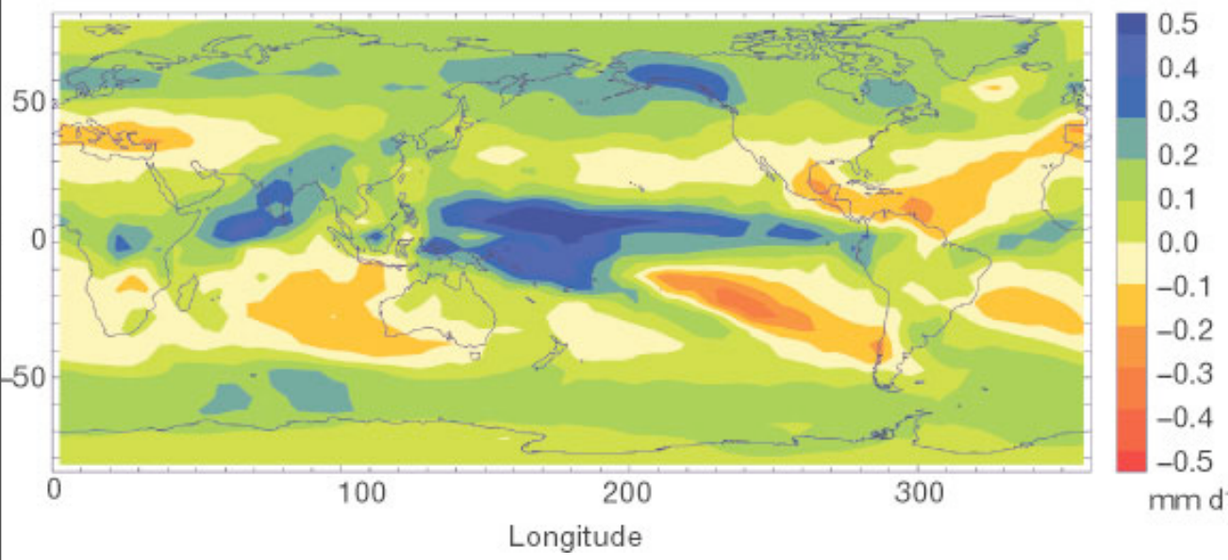
Myles Allen

After Trenberth (1999), Allen and Ingram (2002) popularized the idea of more of total precipitation falling in the heaviest precipitation events



Increase follows C-C scaling for moisture availability with additional enhancement for tropical extremes

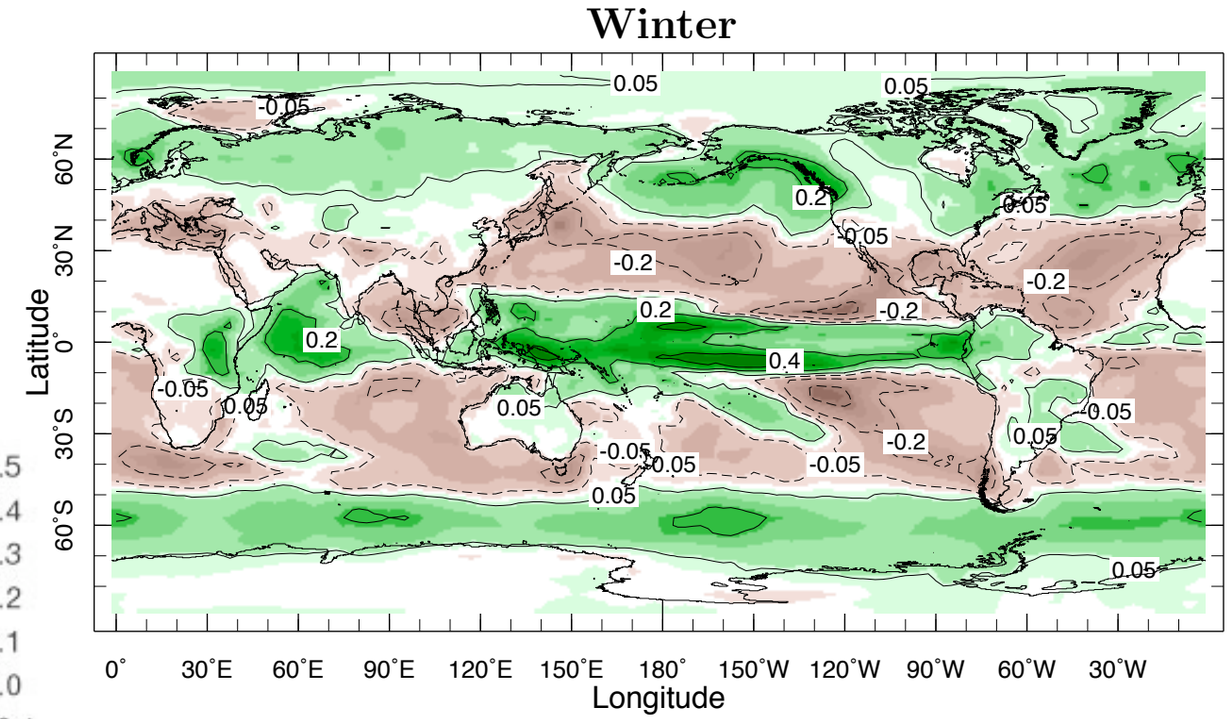
Precipitation change for 2XCO2 in 14 CMIP2 models

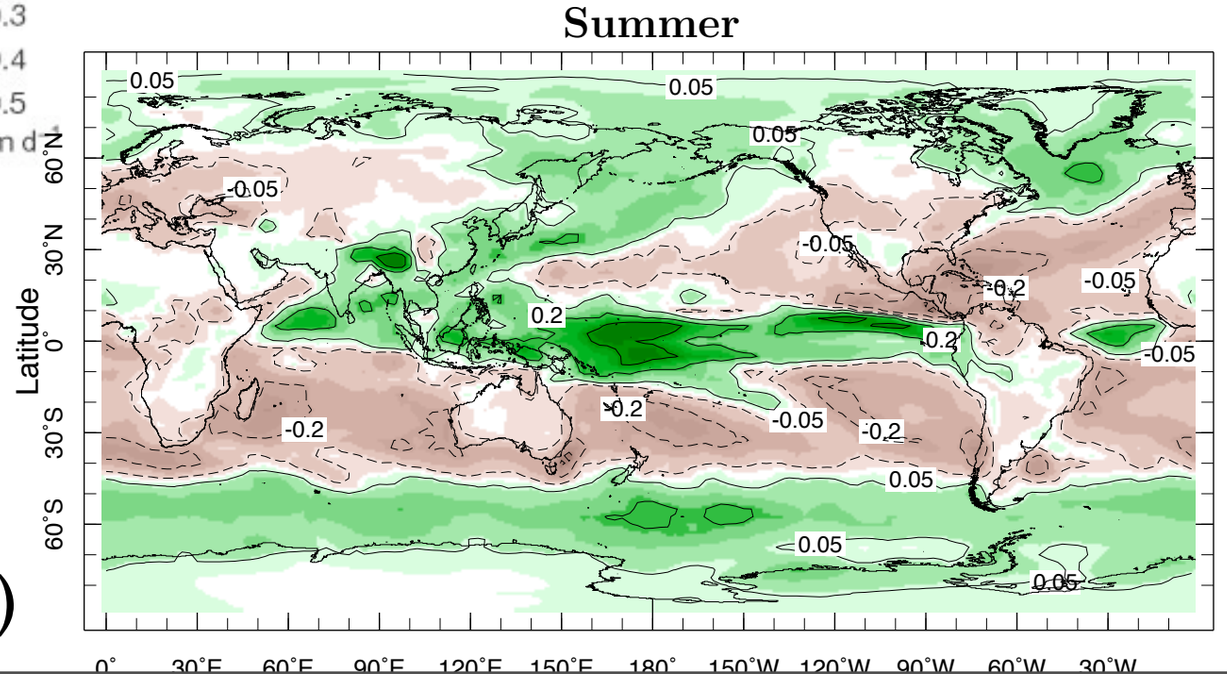


Allen and Ingram (2002)

CMIP3 models

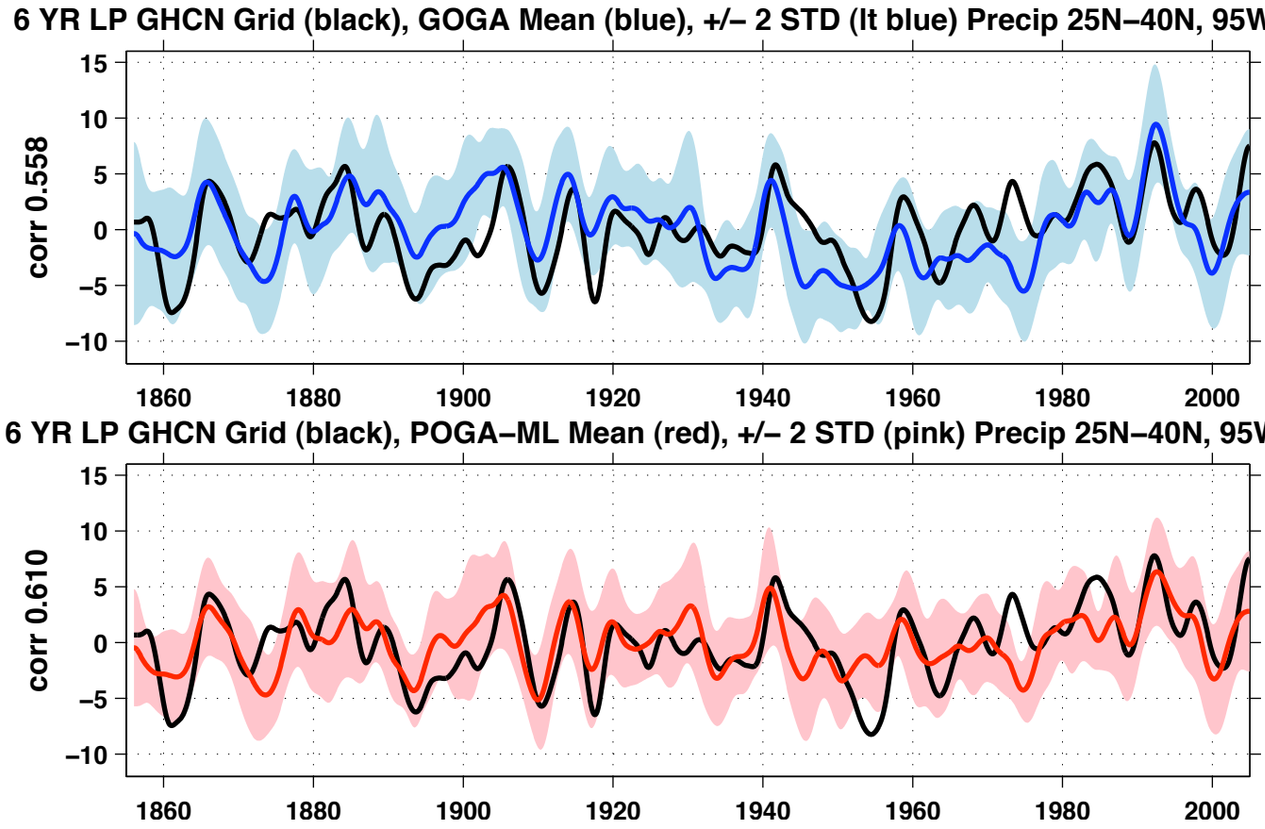
24 Model Mean IPCC P-E (2021 to 2040) - (1950 to 1999)



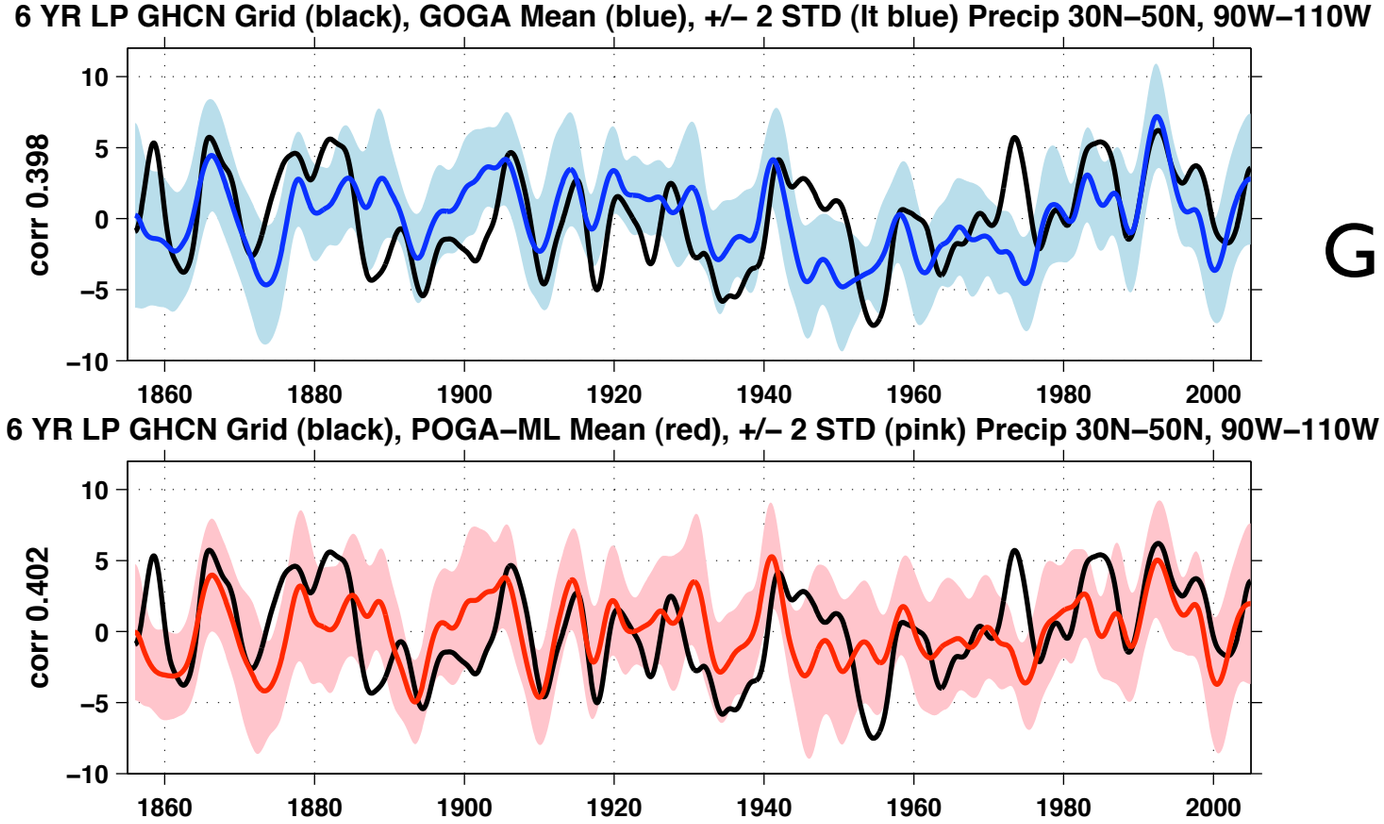


Seager and Vecchi (2010)

Reproducing the precipitation history of North America with SST-forced models (Seager et al. 2005)



Southwest N. America



Great Plains

The great droughts (Dust Bowl, 1950s, 1998-2004) were forced by small tropical SST anomalies

The Dust Bowl drought was centered north of usual Pac-Atl SST-forced droughts.

The Dust Bowl drought was also unique in that wind erosion, caused by poor land use practices, created vast dust storms

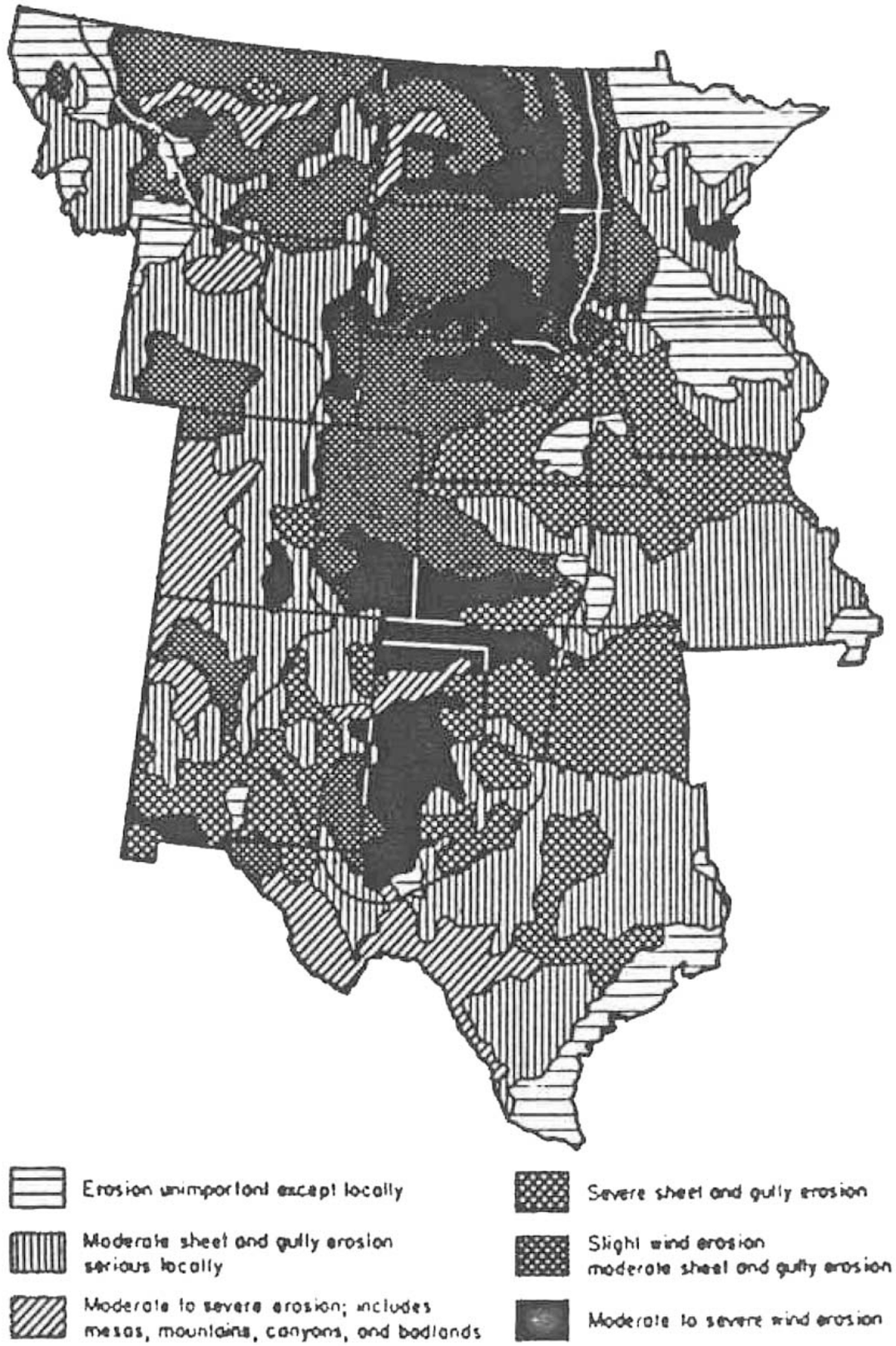
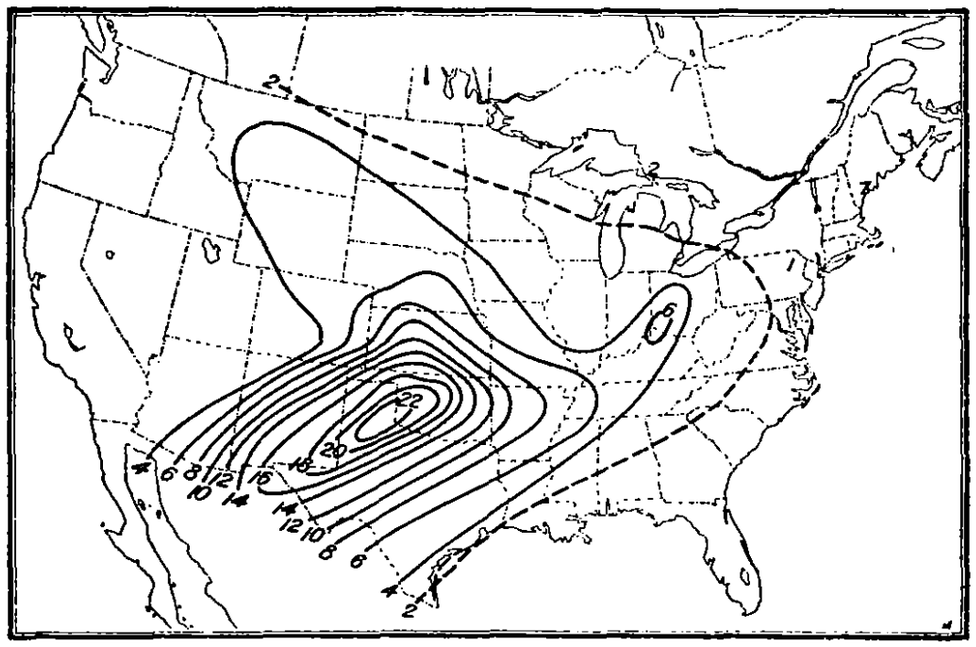


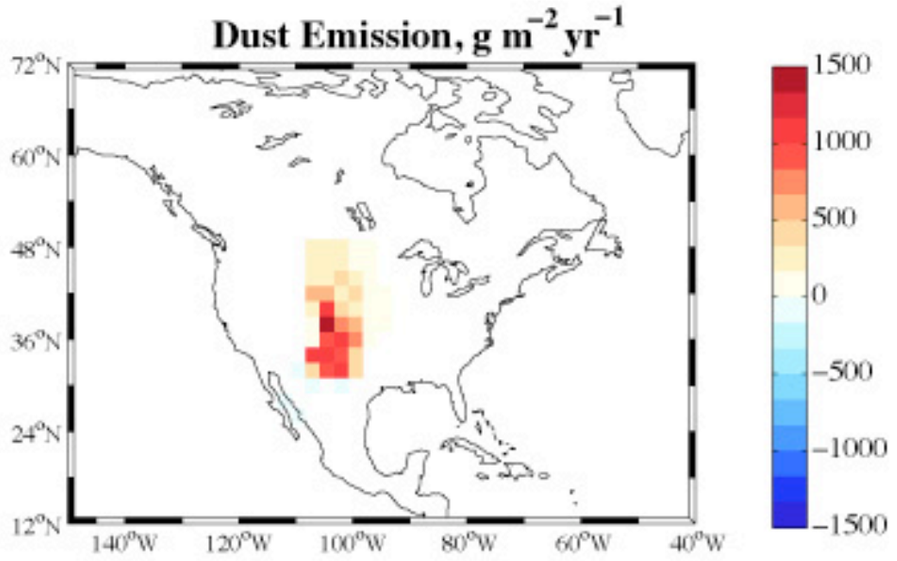
FIG. 1.—Wind erosion in the Great Plains in the 1930s. An irregular line bounds the Great Plains region as delimited by the Great Plains Committee. Source: Adapted from "General Distribution of Erosion" (U.S. Dept. Agriculture, Soil Conservation Service, August 1936).

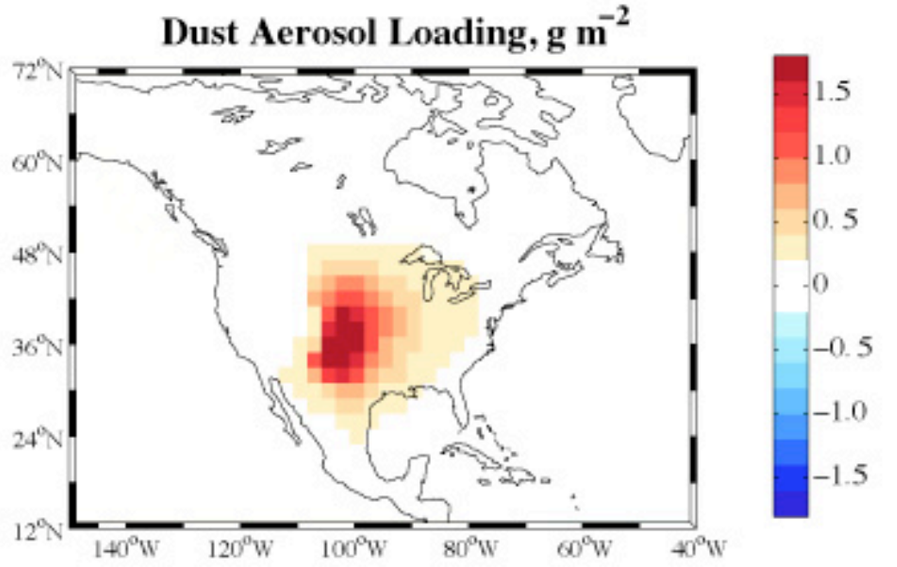
contemporary observations of dust storms and modeled (GISS) dust storms
Cook et al. (2008, 2009, 2010)

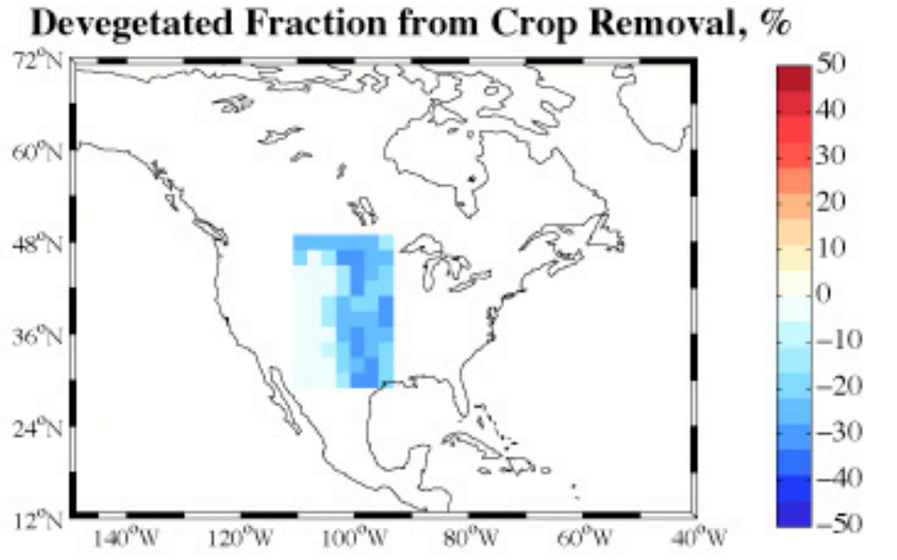


Number of days with duststorms, or dusty conditions, March 1936.—W. A. M

Martin, 1936



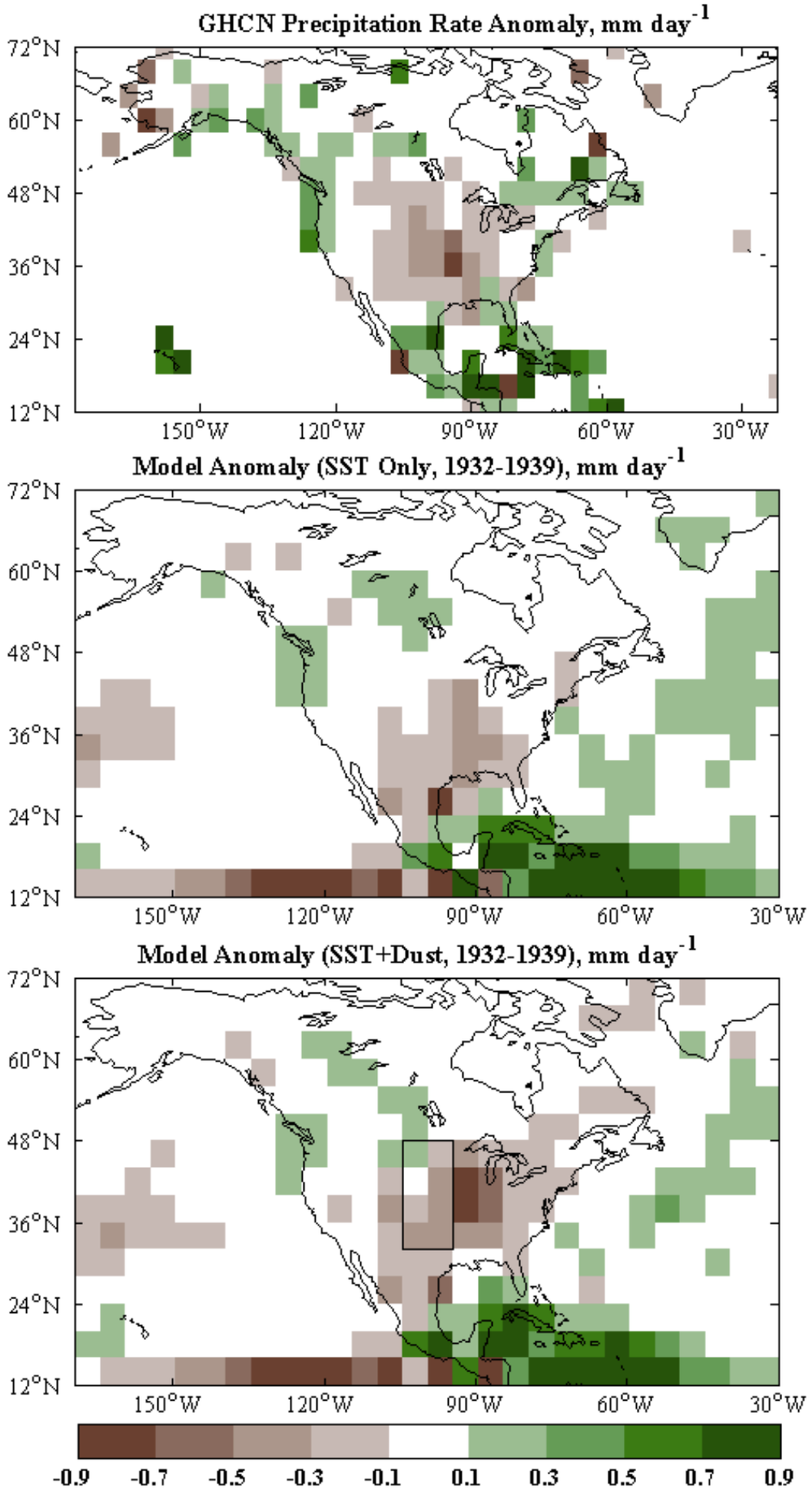




Based on wind erosion maps convert portions of model grid boxes to bare soil

Model created dust storms, the dust interacted with solar and longwave radiation intensifying the drought and moving it north

Cook et al. (2009)

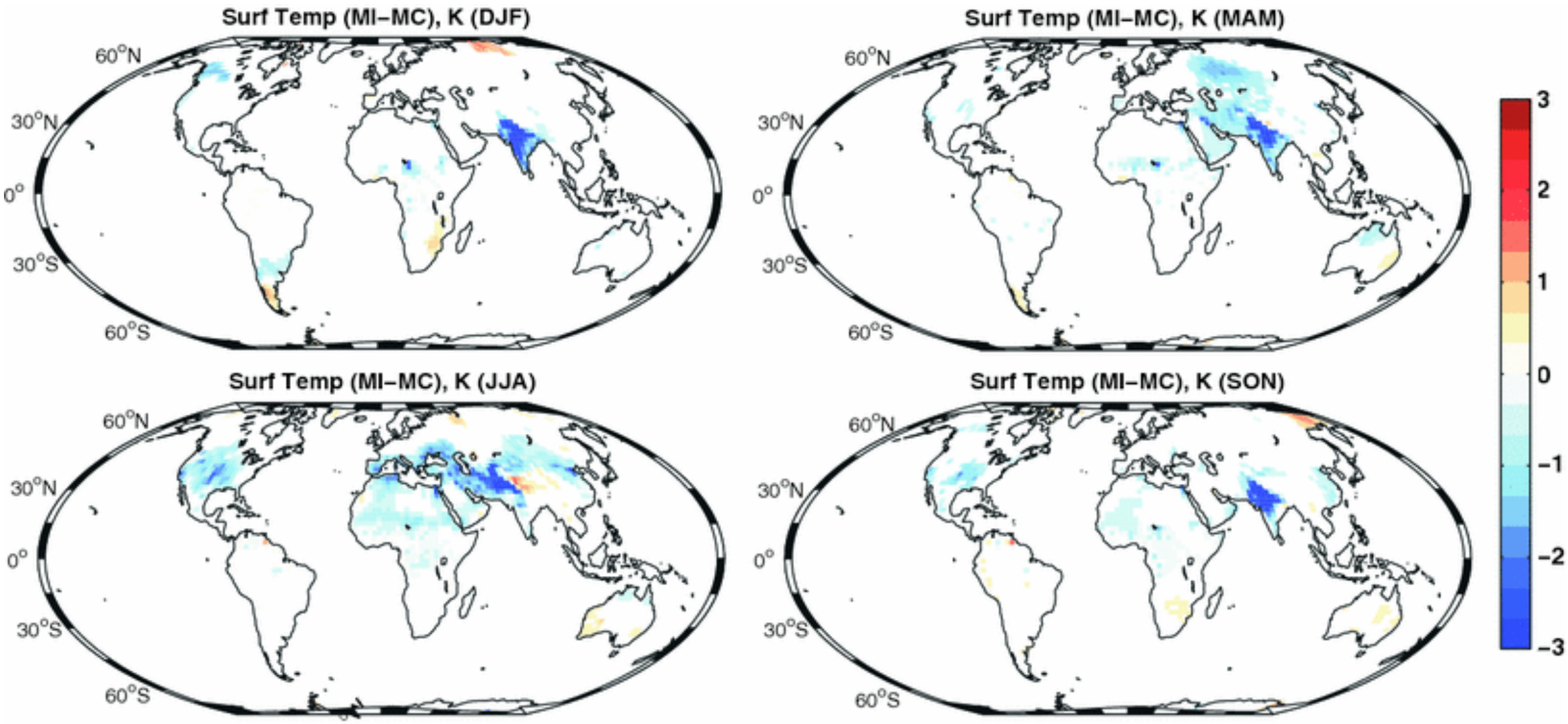


Observed 1930s precipitation anomaly

Modeled with SST forcing only

Modeled with SST forcing and interactive dust

Direct human intervention in the hydrological cycle .... irrigation locally cools temperature (and alters precip)



Modeled surface temperatures, with irrigation minus no irrigation

Cook,Puma, Krakauer (2010)

Summary

NOAA postdoc fellows, as postdocs and in subsequent careers, are all over the most important topics in large-scale climate dynamics, climate change and hydroclimate and in many cases are defining the research frontiers

NOAA should be very proud of a vastly successful program