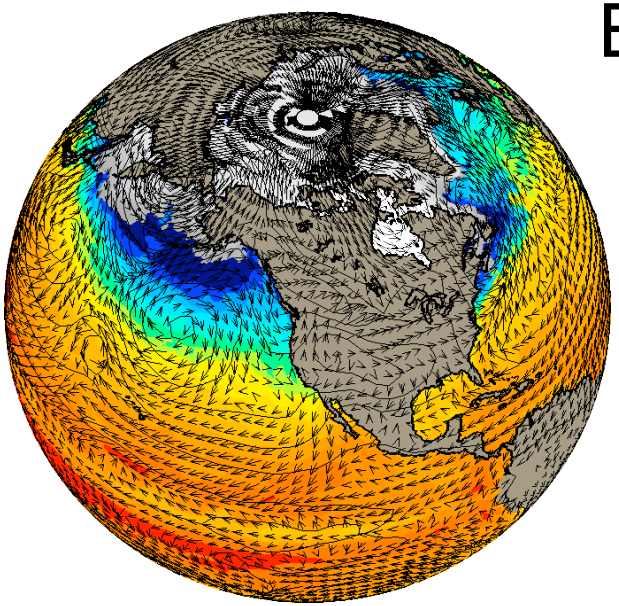
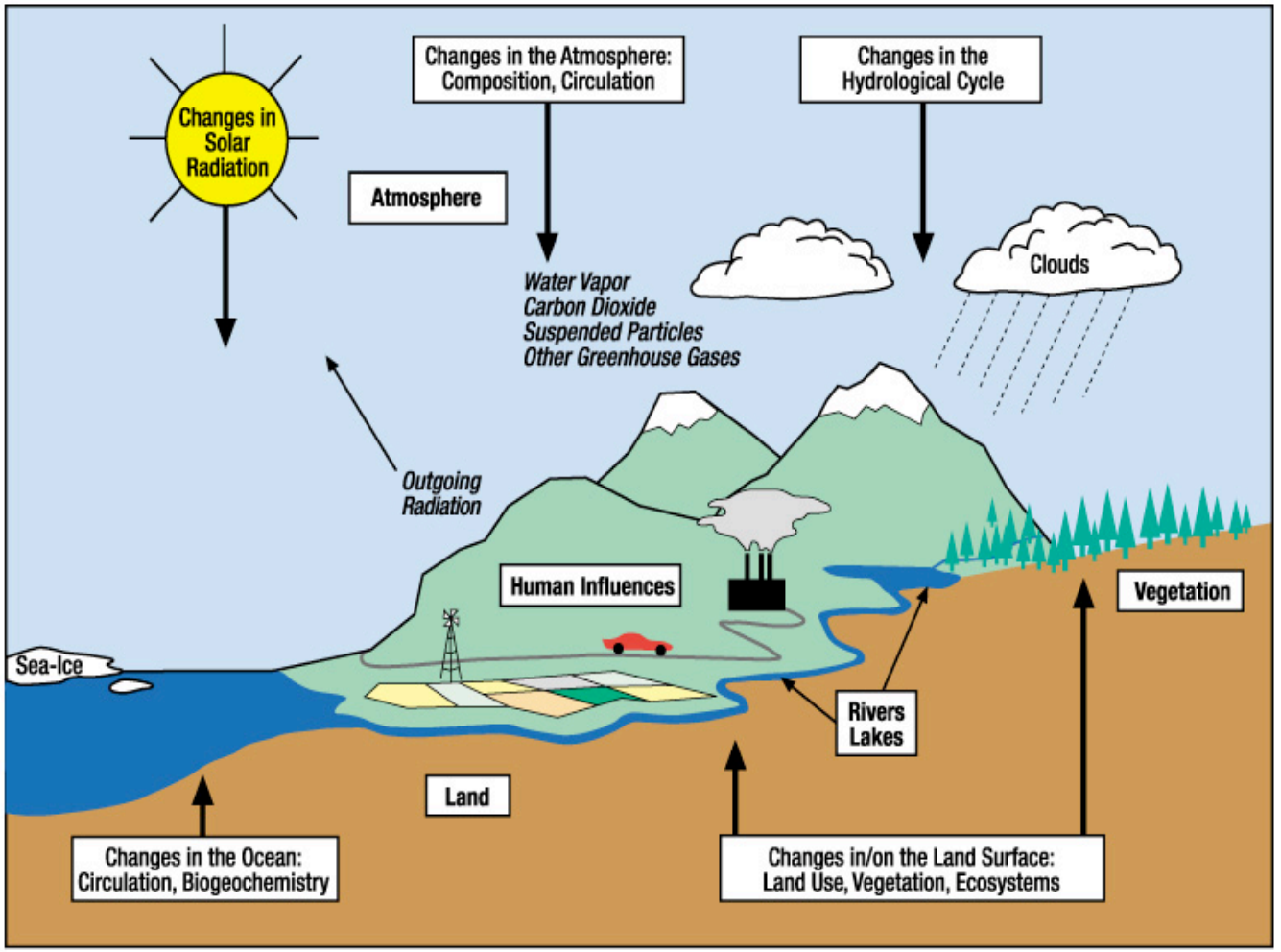
The Climate System and Climate Models

Gerald A. Meehl
National Center for Atmospheric Research
Boulder, Colorado

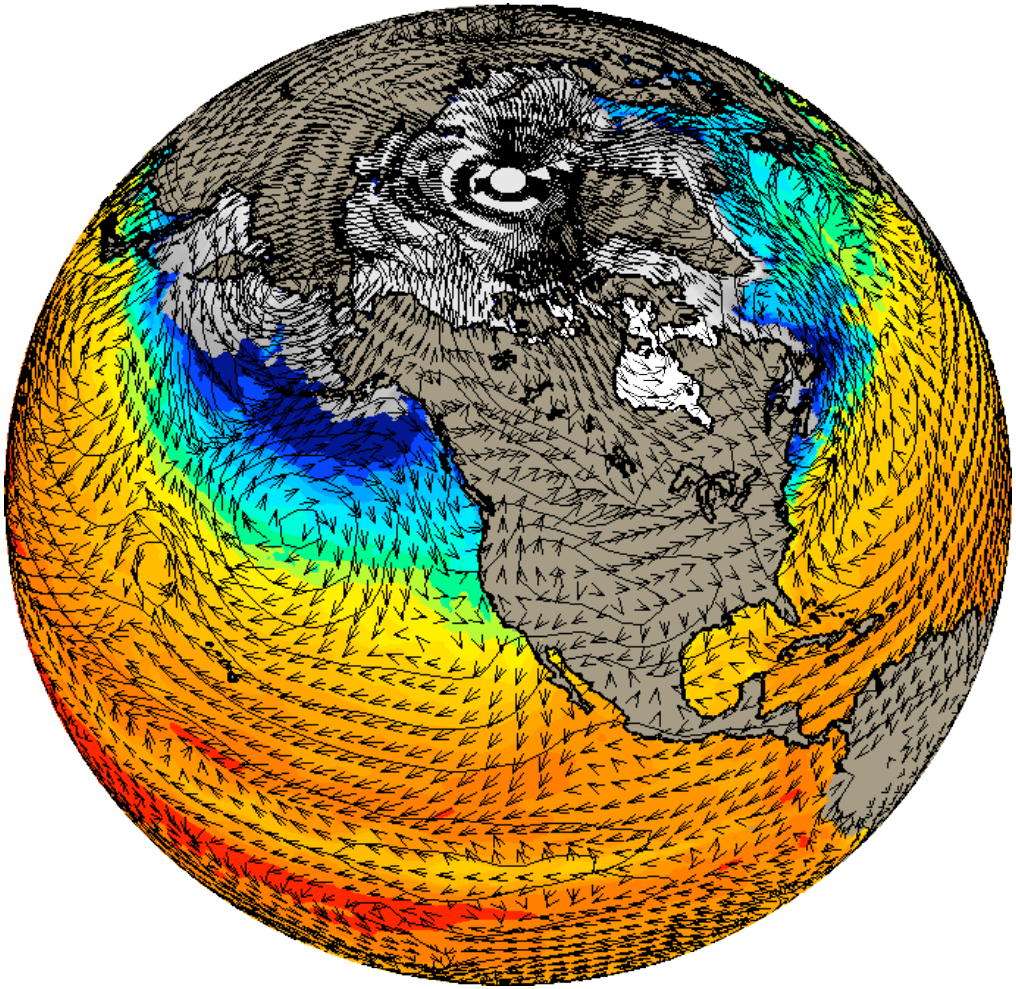


NCAR

The “climate system” includes all components of the physical earth system that affect weather and climate, including atmosphere, oceans, sea ice, and land surface processes



The mission of the “climate system” (atmosphere and ocean): move the excess heat out of the tropics to where it’s colder so the heat can radiate to space



Climate dynamics 101

Sunlight is most intense in the tropics

Warmest sea surface temperatures (SSTs) = highest rainfall

Warm air rises

What goes up must come down

Rising air = rain

Sinking air = dry

Trade winds, ocean upwelling

El Nino La Nina

So the heat is getting to colder climes…then what happens?

Surface temperature contrast = “baroclinic instability” (i.e. storms form)

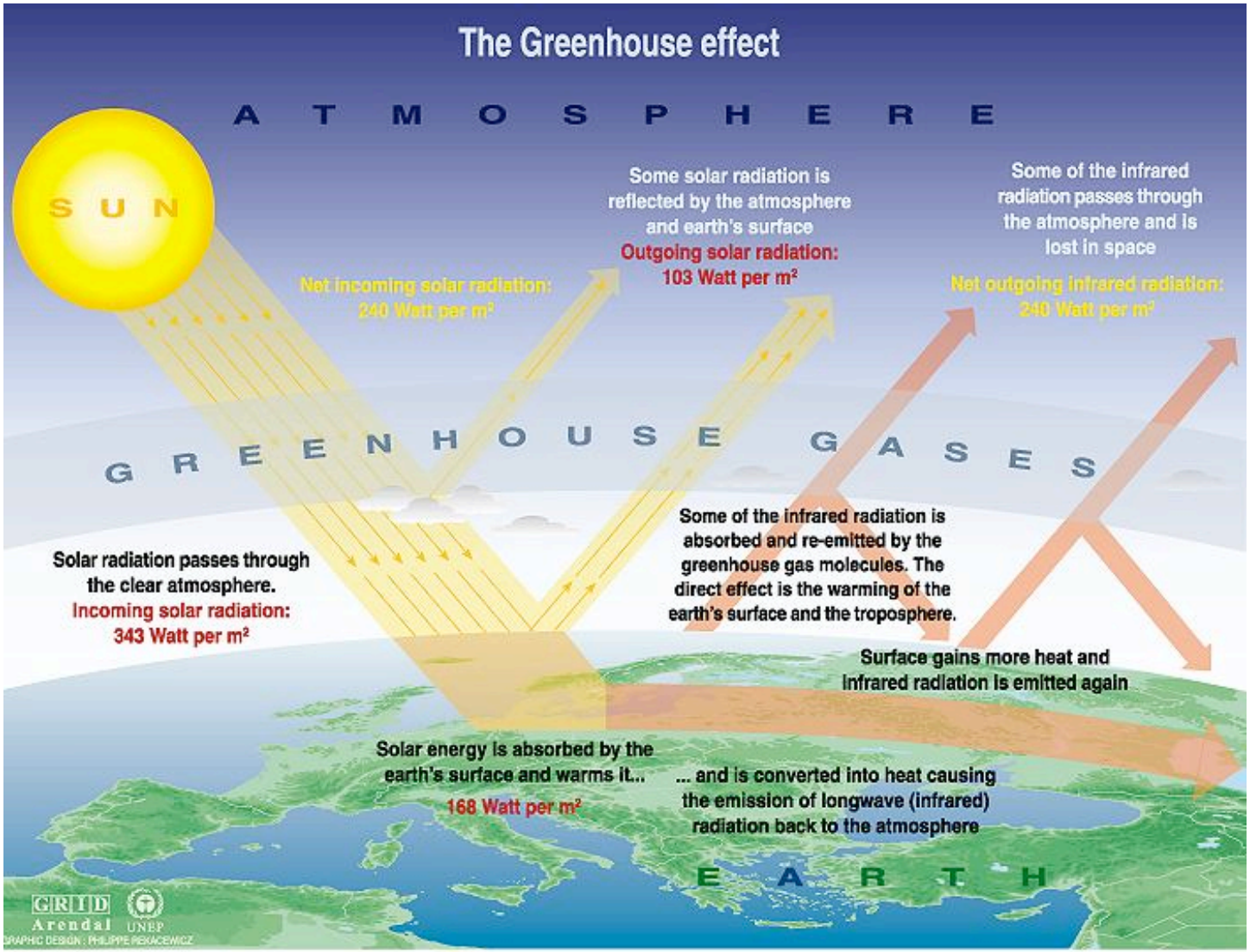
Surface temperature contrast = strong upper level winds (the “jetstream”)

Storms mix warm air from the south and cold air from the north

The farther north the warm air gets, the easier it is to radiate heat to space

Ocean currents also carry heat north (i.e. the Gulf Stream)

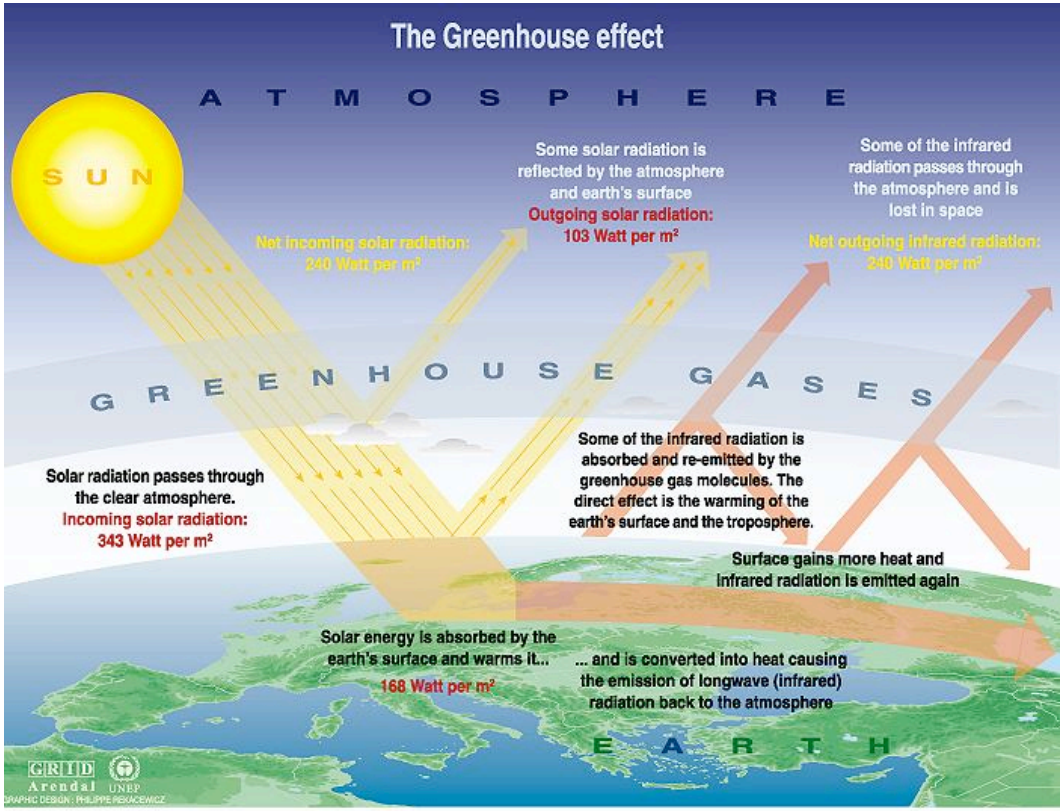
But not all the heat radiates to space because of greenhouse gases—the greenhouse effect!



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

What's global warming, and why is it happening?

When we burn fossil fuels, we release more carbon dioxide (CO_2) into the atmosphere, trapping more heat, and the climate warms



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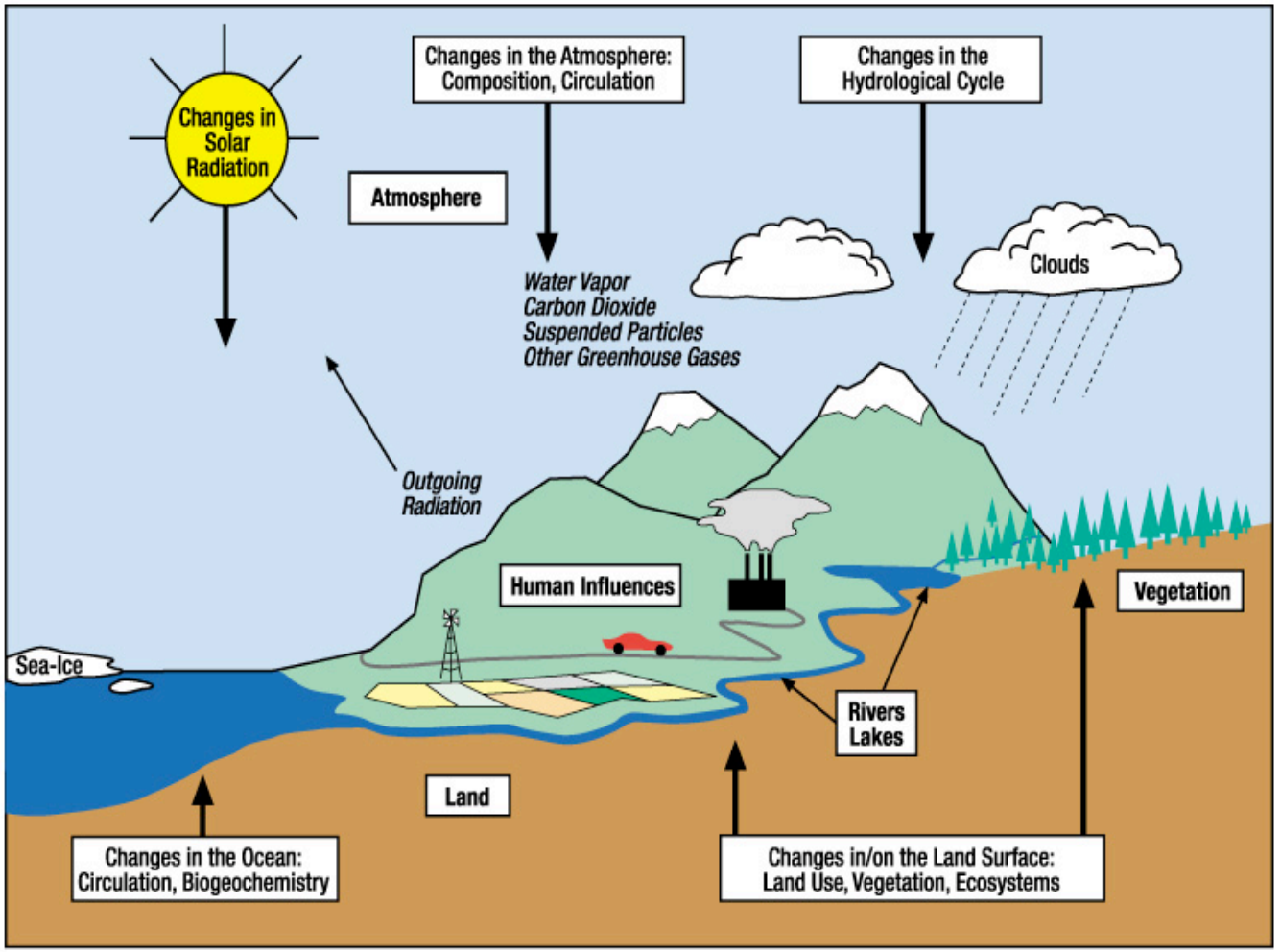
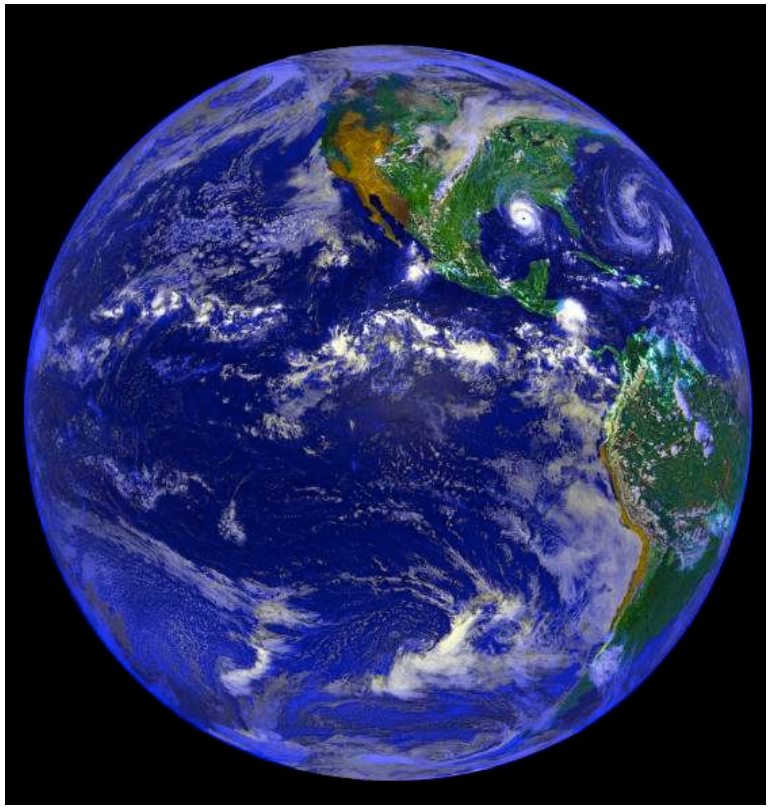
This seems really complicated—how can we ever figure out what's going on?

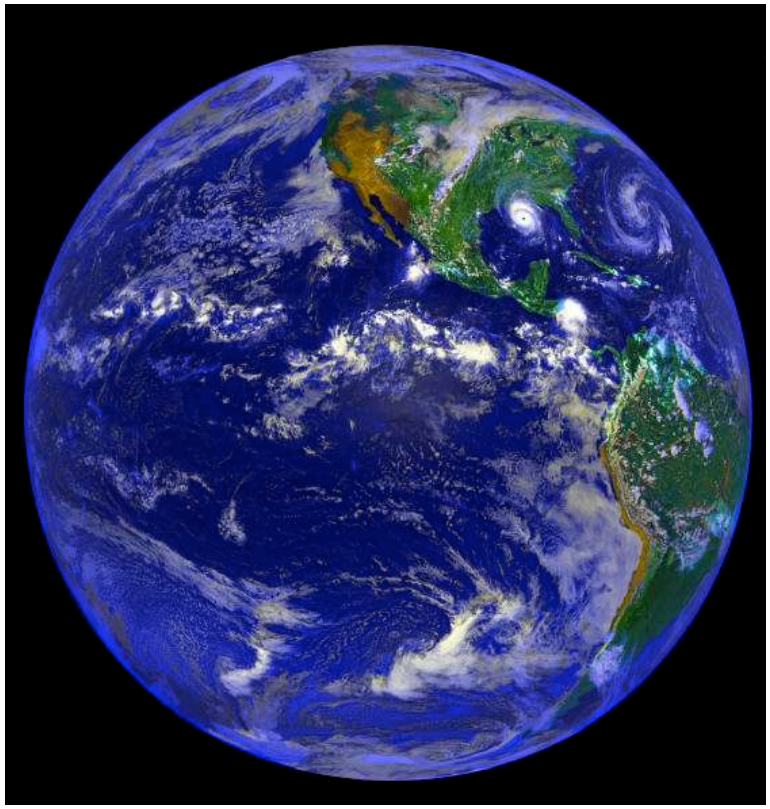
We use tools to help understand all the interactions: Computer climate models

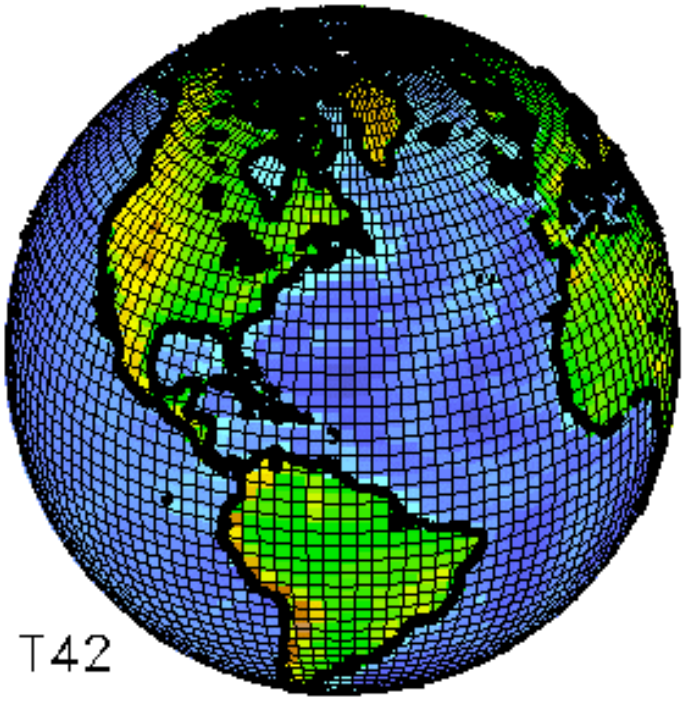
Climate models are a lot like weather forecast models, but include interactive ocean, land surface, and sea ice components, and also account for changes in atmospheric constituents like greenhouse gases



How can a climate model simulate this?

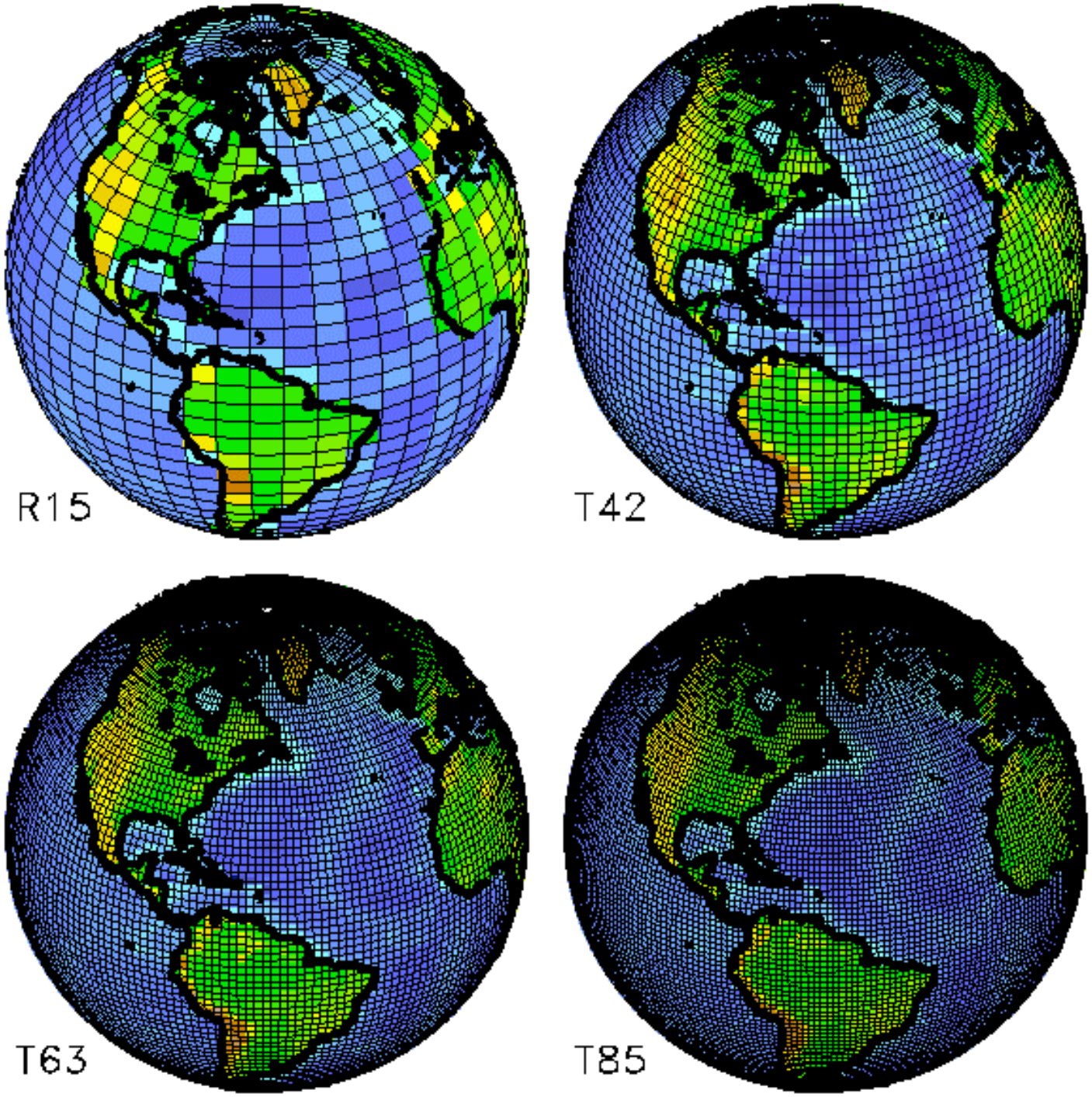




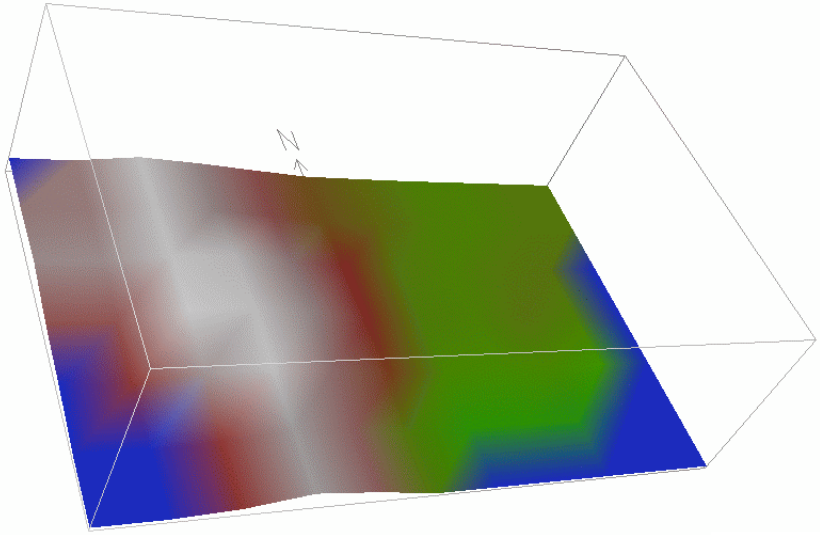


It divides up the world into a latitude-longitude grid, and solves all the equations at each grid point

Higher model "resolution" means more grid points, better regional detail, but more computer time

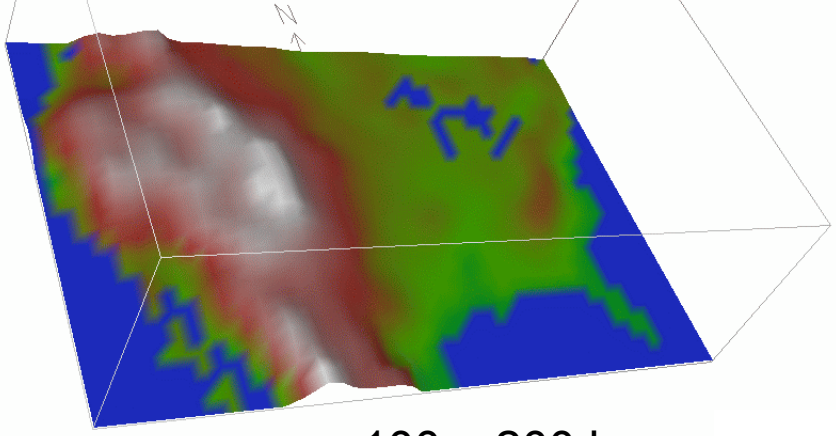


Climate Models circa early 1990s



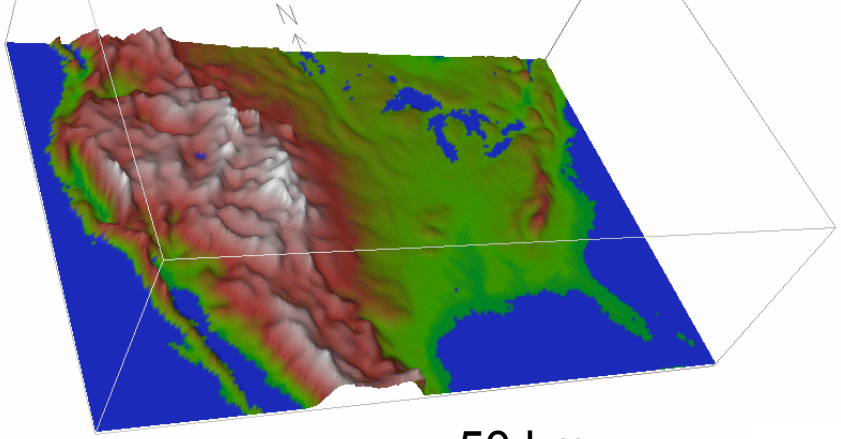
~500 km

Global coupled climate models in 2007 and new ESMs



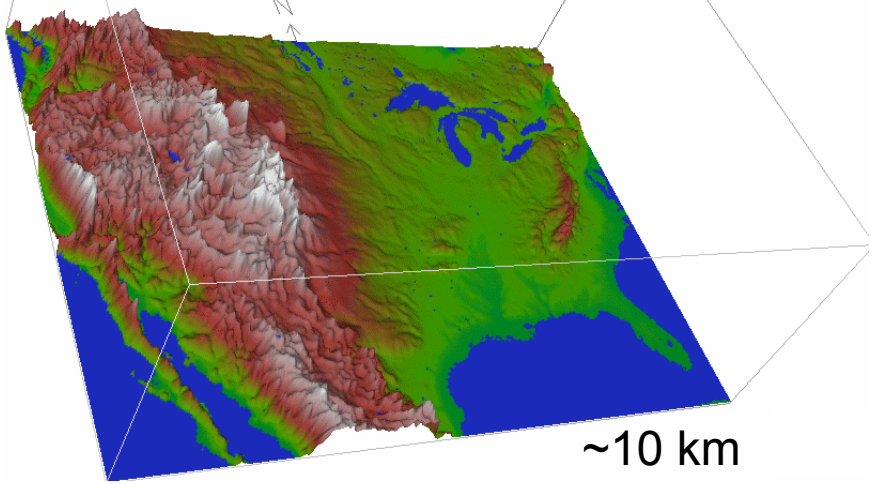
~100 – 200 km

New decadal prediction models



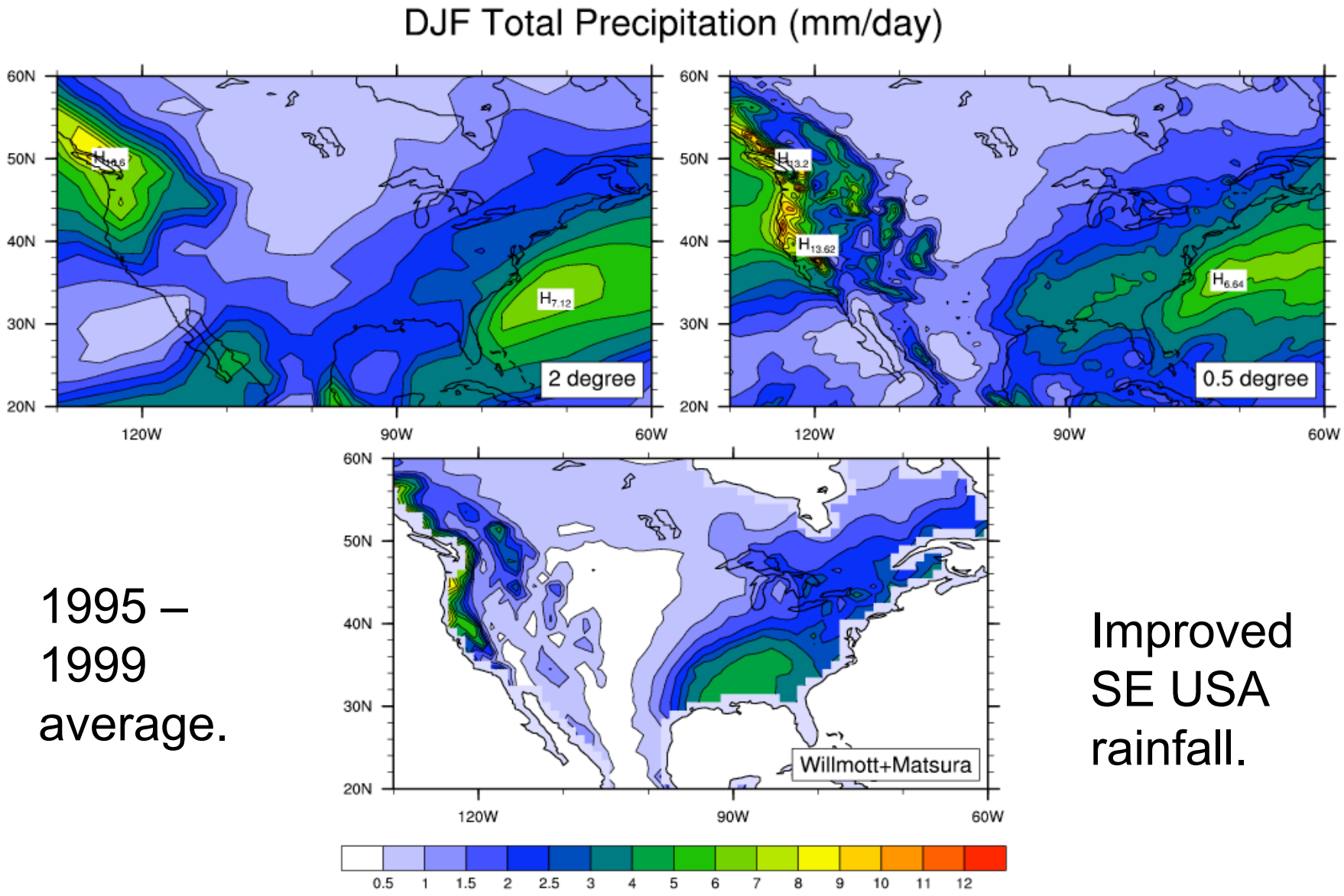
~50 km

Global coupled models in 5 yrs post-IPCC AR5



~10 km

Developmental version of CCSM3.5 (last 20 years of 20th century)



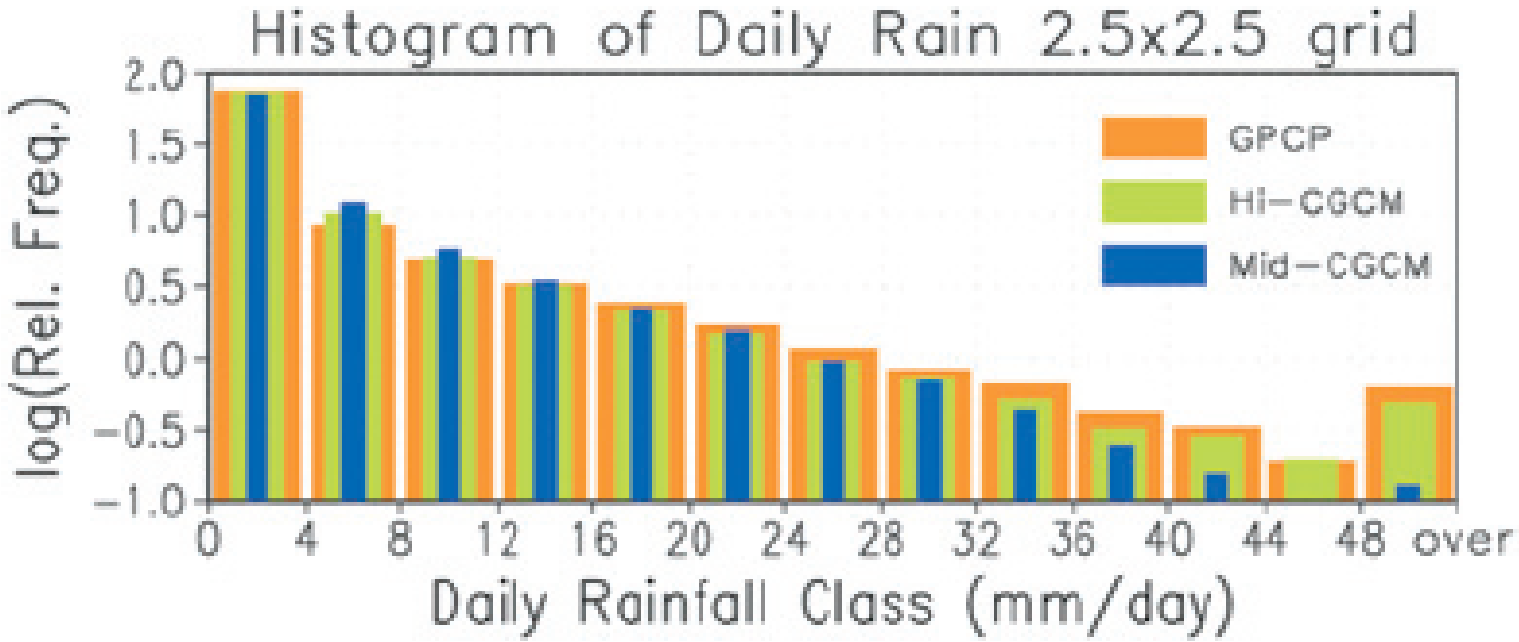
1995 – 1999 average.

Improved SE USA rainfall.

Need higher resolution to simulate extreme precipitation events

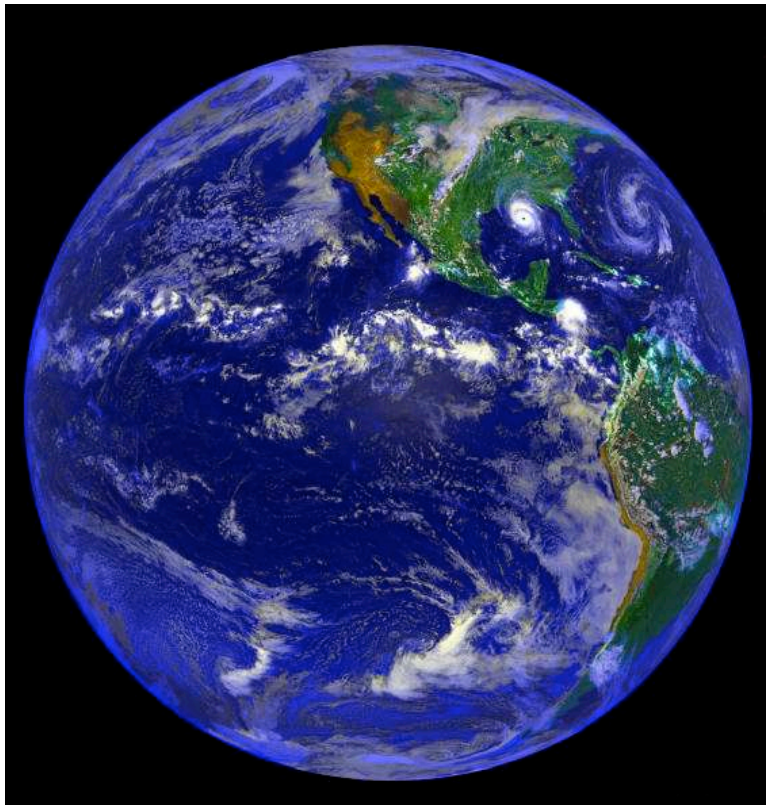
Hi-CGCM = T106 (~100 km)

Mid-CGDM = T42 (~240 km)

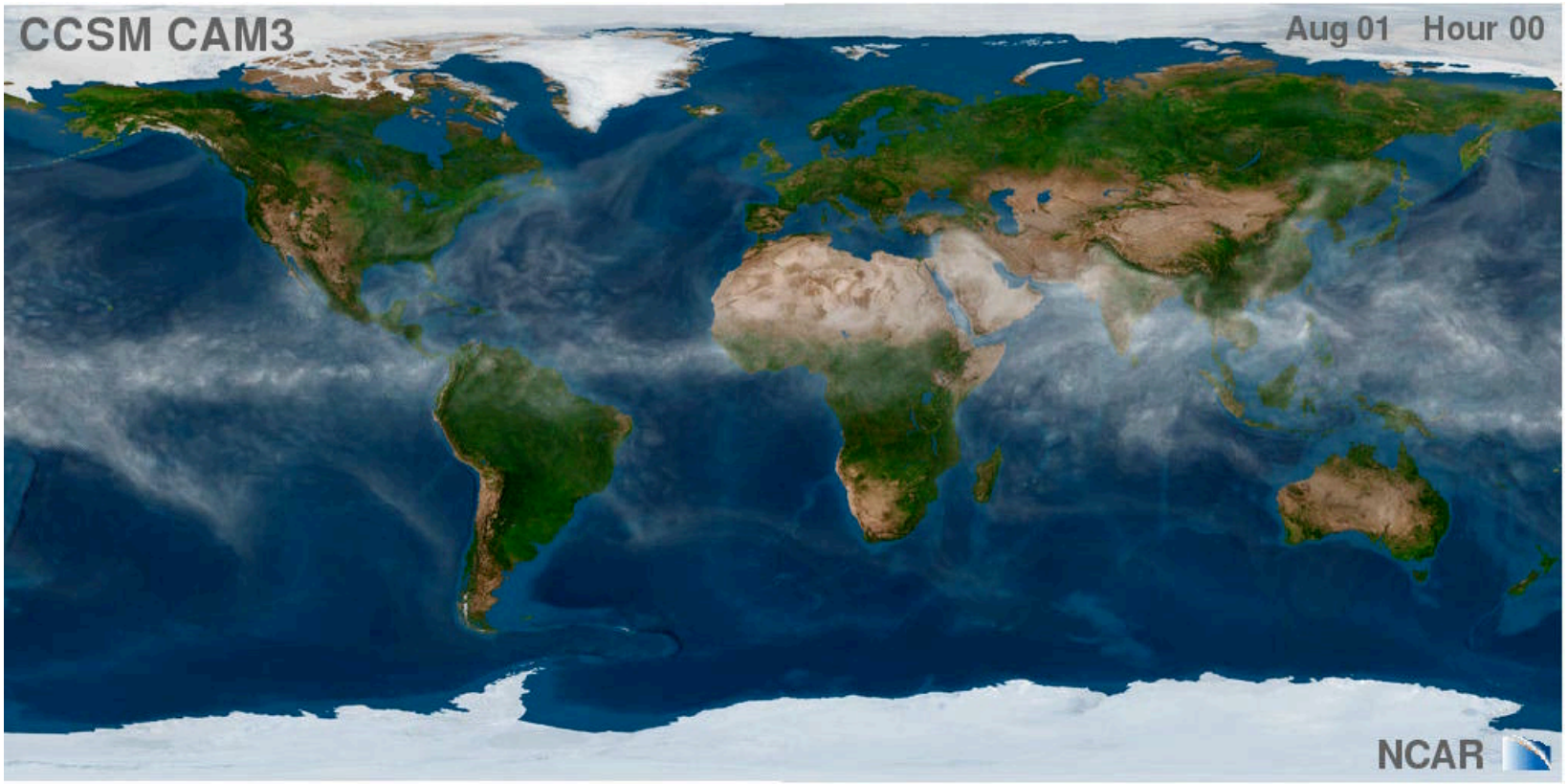


(Kimoto et al., 2005)

This is what we're trying to simulate:



Climate Model Simulation

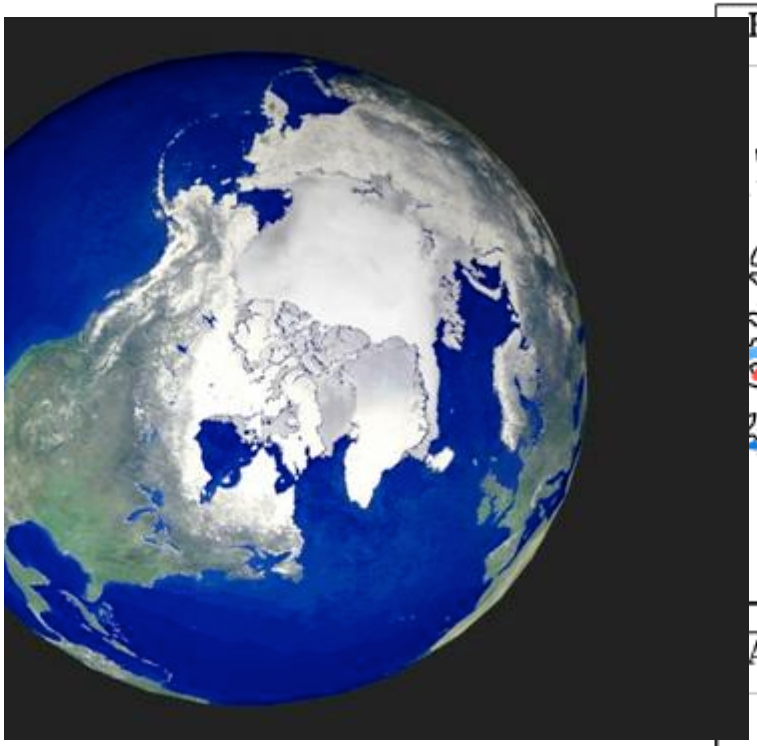


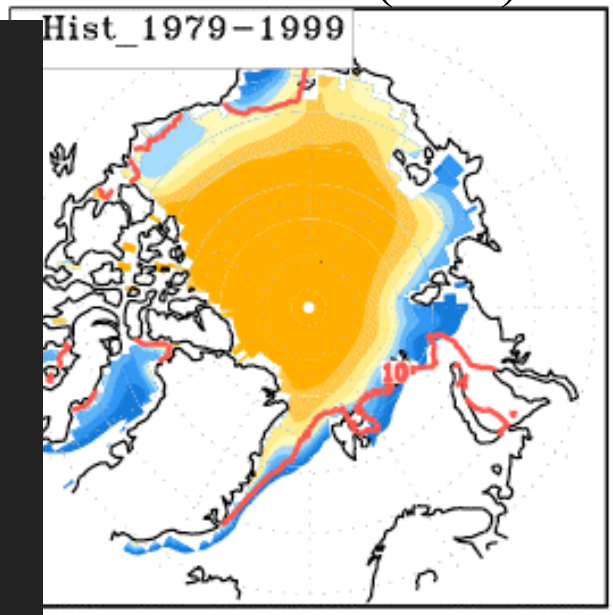
How do we know the models are any good?

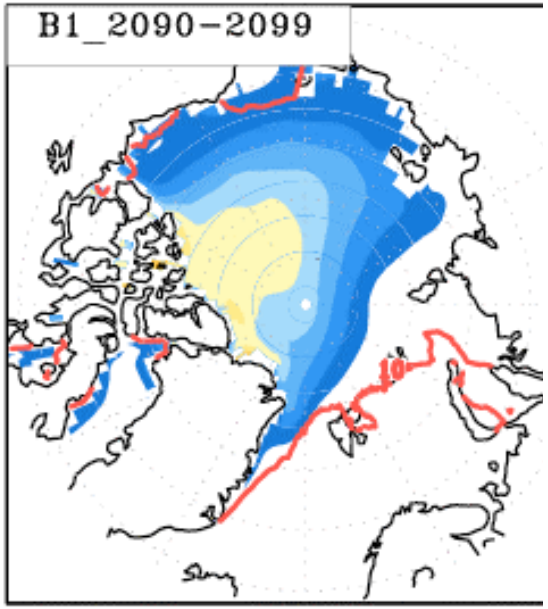
They must be able to simulate observed phenomena in the climate system.

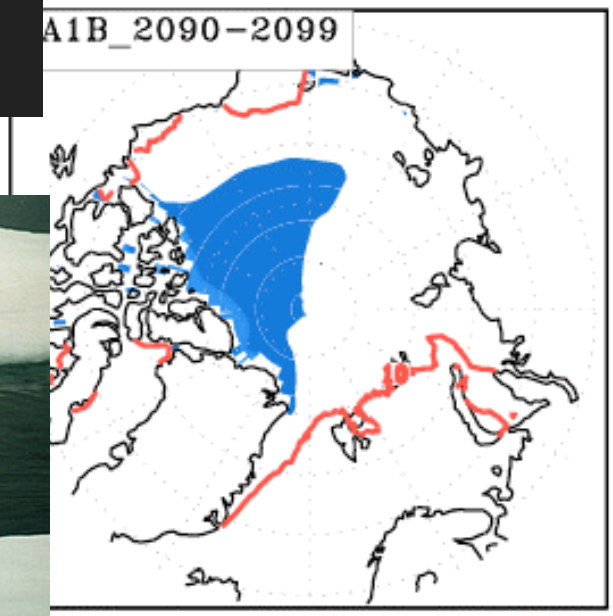
What about sea ice?

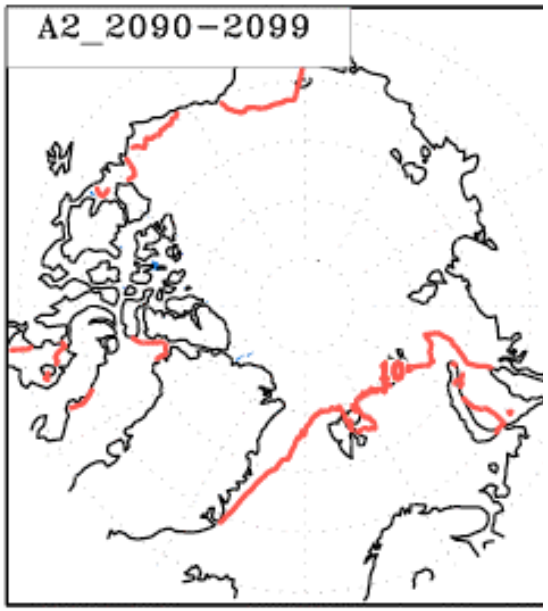
CCSM3 SUM(JAS) Sea Ice Concentration











A severe test of the models is if they can simulate El Niño

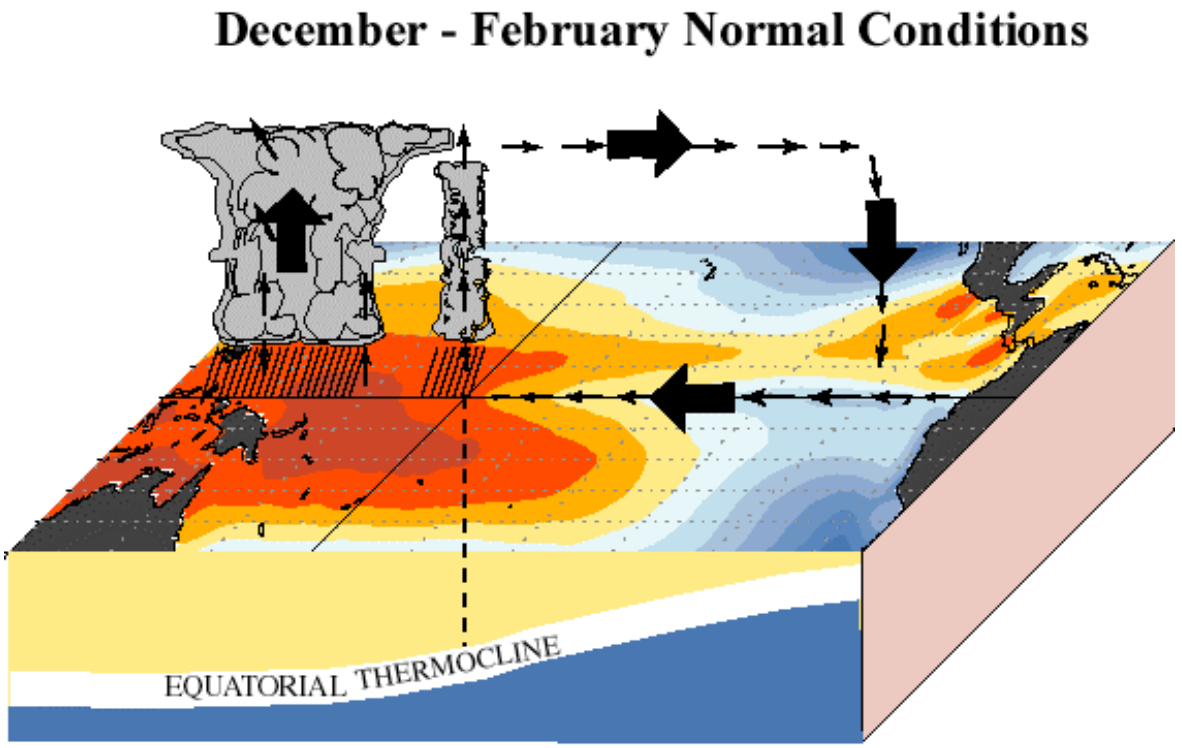
To produce an El Niño event, the model must be able to capture the dynamically coupled interactions between atmosphere and ocean that produce El Niño

What is El Niño?

- **El Niño is a warming of the equatorial eastern Pacific Ocean**
- **It occurs about once every 2 to 7 years**
- **The name is Spanish, meaning 'the boy child' because it affects the coast of South America at Christmas**
- **La Niña is the opposite of El Niño and is a cooling of the eastern equatorial Pacific Ocean**

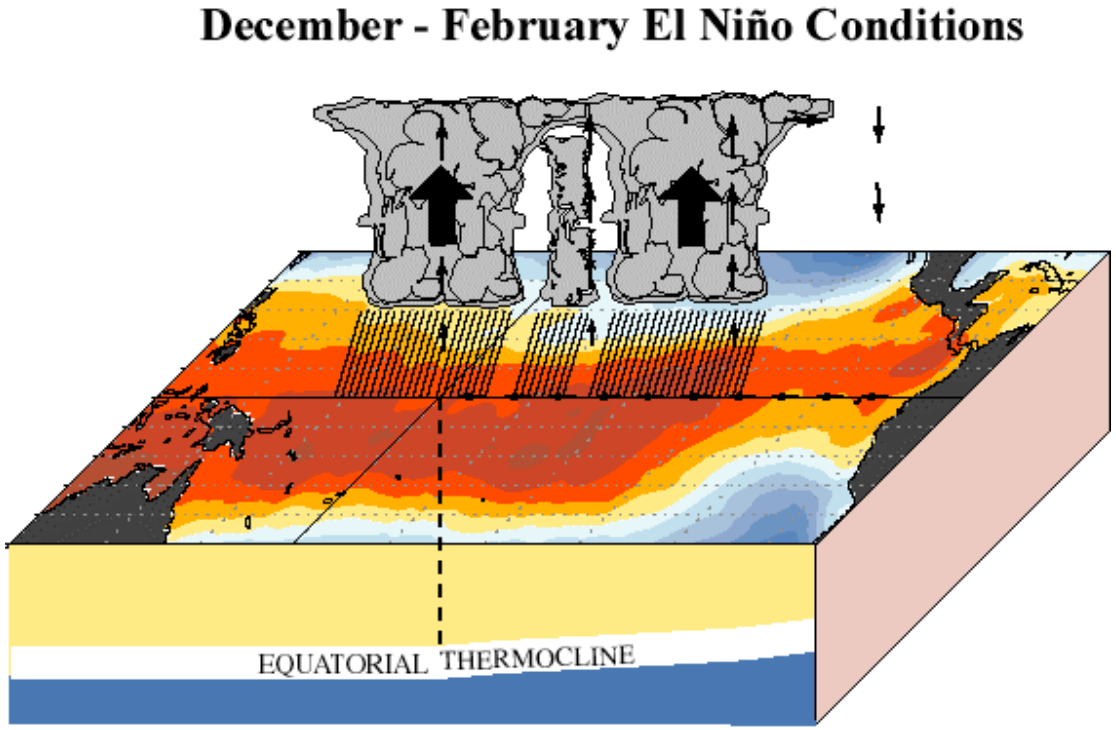
Normal conditions in the equatorial Pacific

- **Normally, the warmest water in the equatorial Pacific Ocean is in the west, north of Australia, with much colder water near the South American coast**
- **The main rainfall region and low pressure is over the warmest water, with winds blowing from east to west across the Pacific**



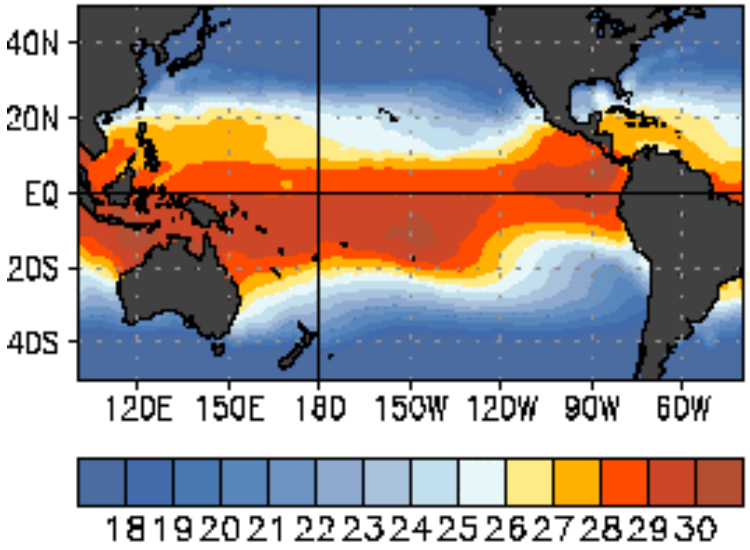
El Niño conditions

- **During El Niño, the eastern equatorial Pacific warms, so that the warmest waters are in the central Pacific**
- **The easterly winds weaken and reverse in the west Pacific**
- **The region of heavy rainfall moves to the central Pacific, with pressure falls in the central and east Pacific and pressure rises in the west**

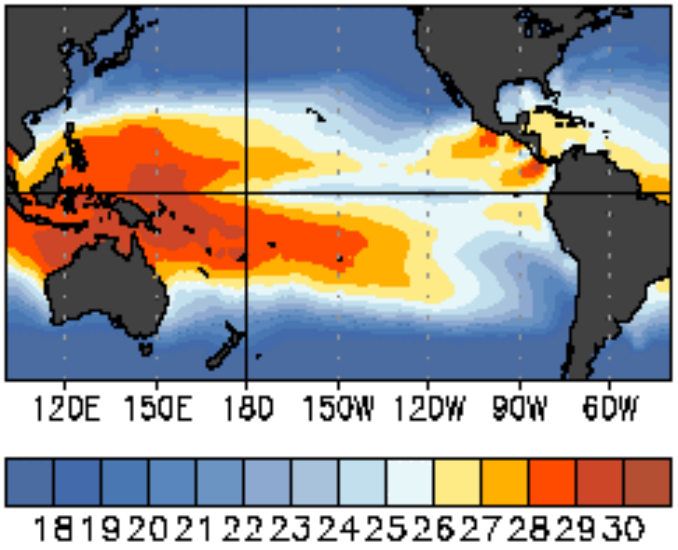


OCEAN TEMPERATURES (°C)

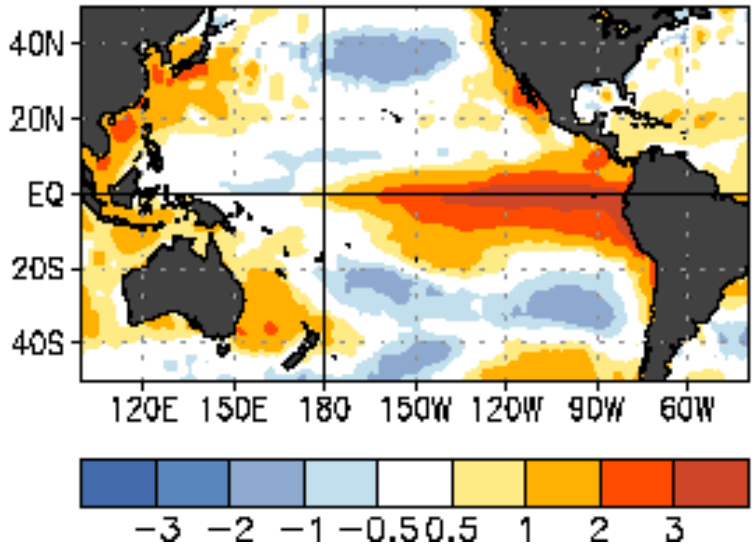
EL NIÑO
Jan-Mar 1998

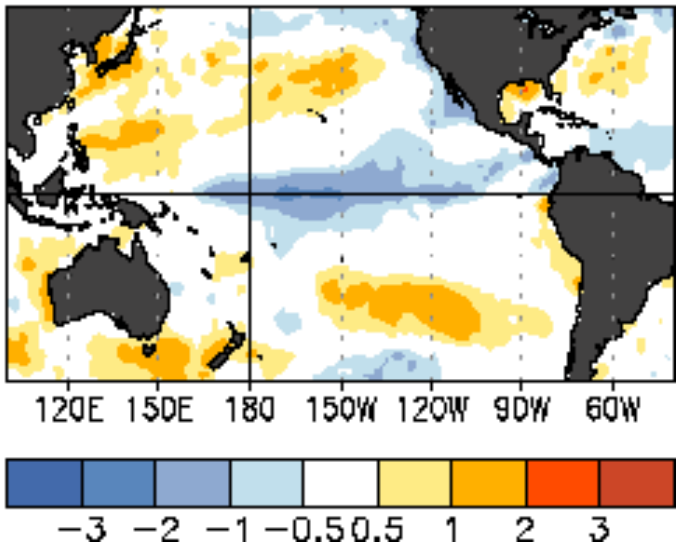


LA NIÑA
Jan-Mar 1989



OCEAN TEMPERATURE DEPARTURES (°C)



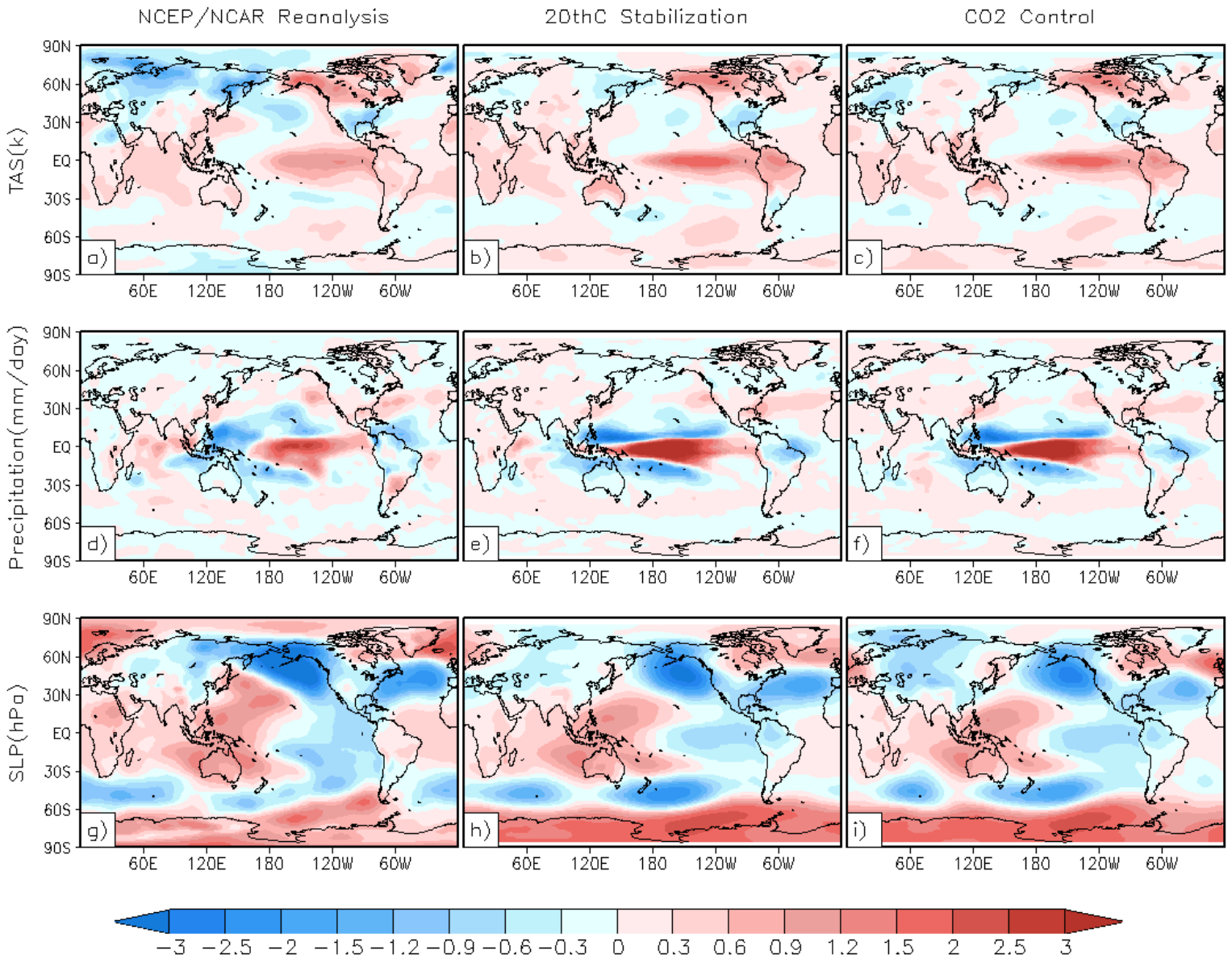


Observed El Nino Model simulations of El Nino

Temperature

Precipitaiton

Sea level pressure

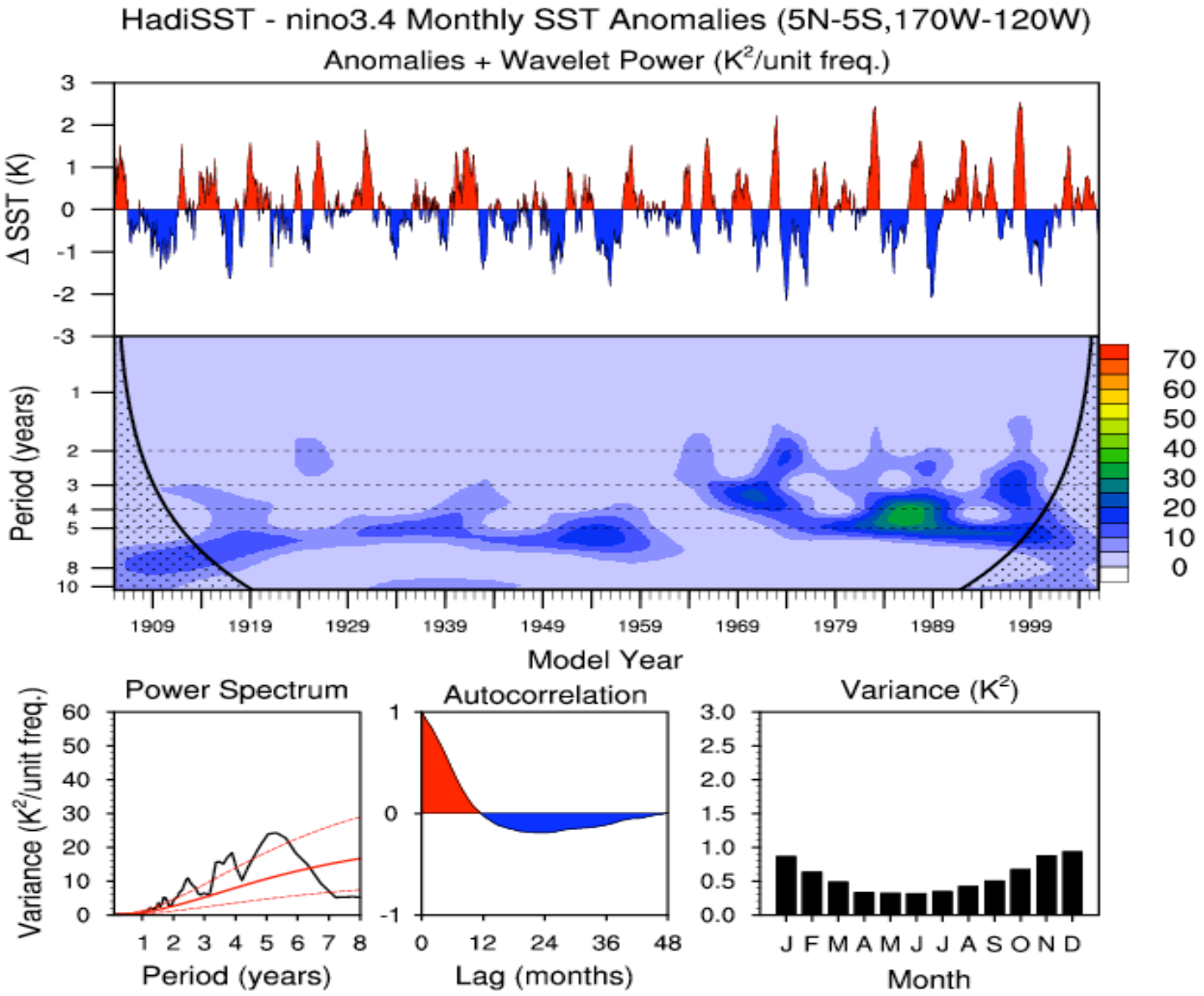


1. The climate system (atmosphere and ocean) moves the excess heat of the tropics poleward where it is radiated to space
2. Naturally occurring greenhouse gases trap some of that heat and make the planet habitable
3. Increasing the concentrations of greenhouse gases (e.g. CO2 in the atmosphere from the burning of fossil fuels) increases the amount of heat trapped in the system, and the result is a warmer planet
4. Global climate models are used for climate change projections. Statistical downscaling techniques or regional models embedded in the global models are used to obtain climate change information for smaller regions
5. Current climate models can simulate what we observe in the climate system, like El Nino events

HadISST

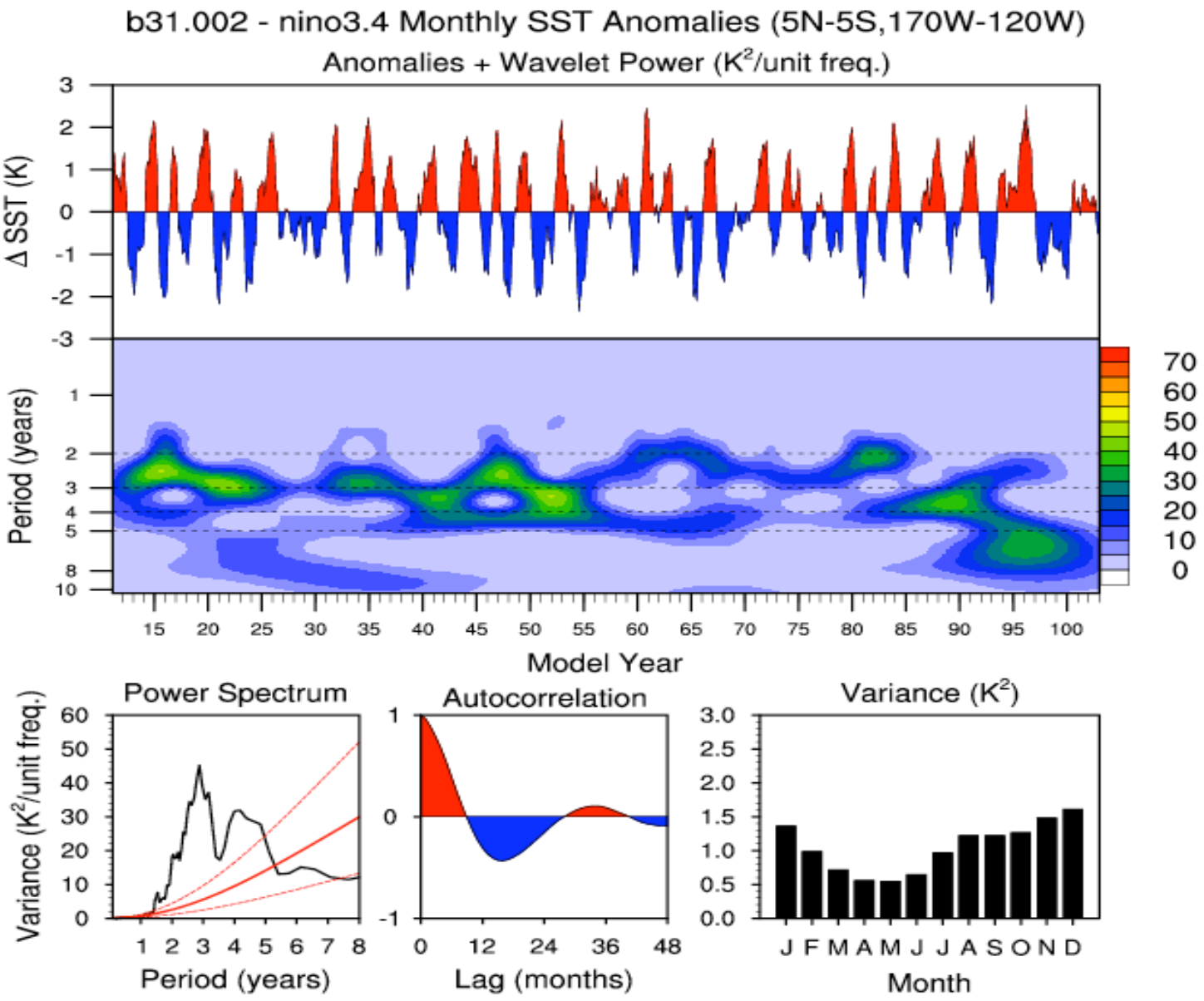
Obs

(100 yrs)



Neale and Richter mods

CCSM3.5



Nino 3 SST correlation for 1980 - 1999