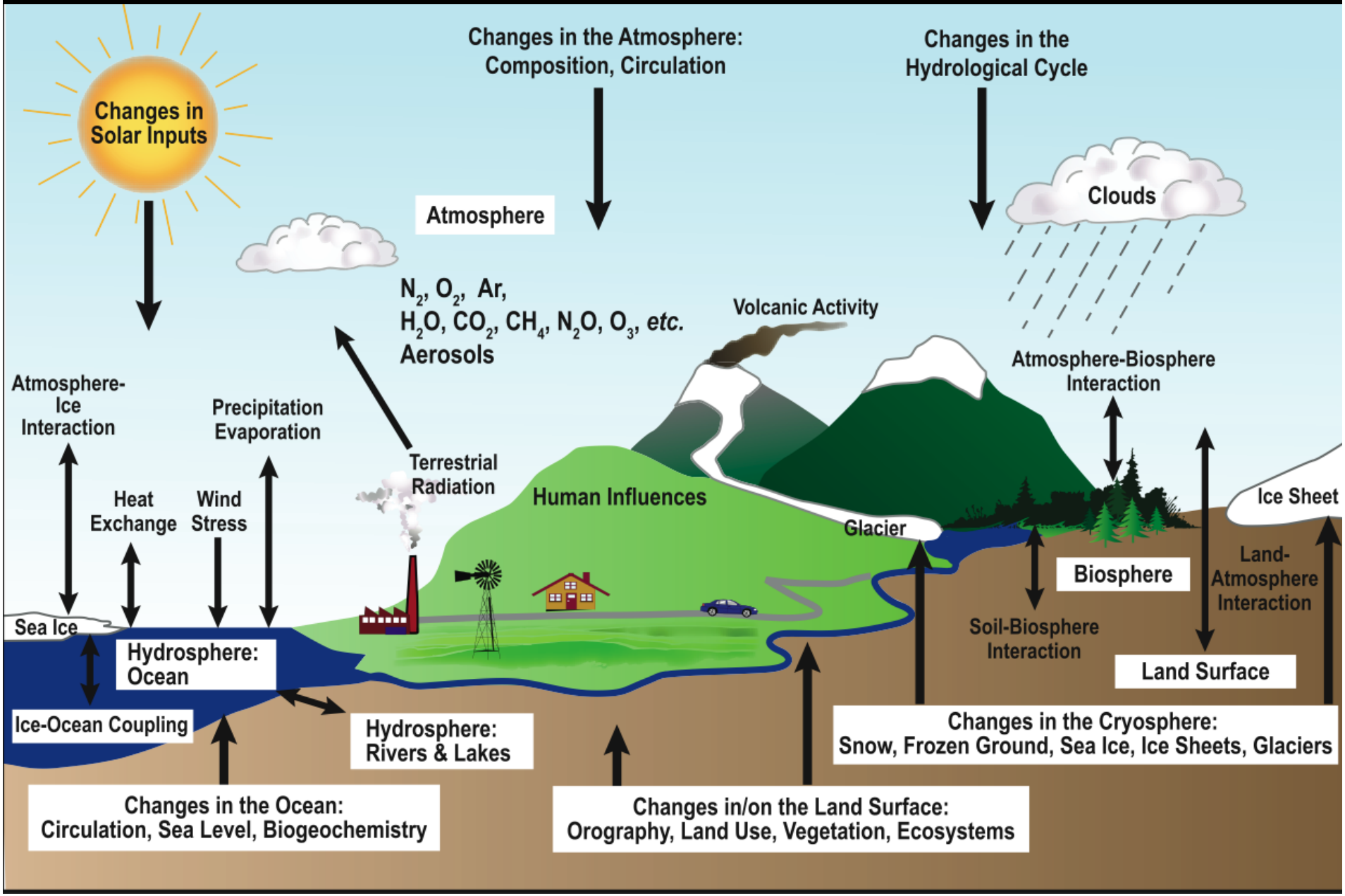
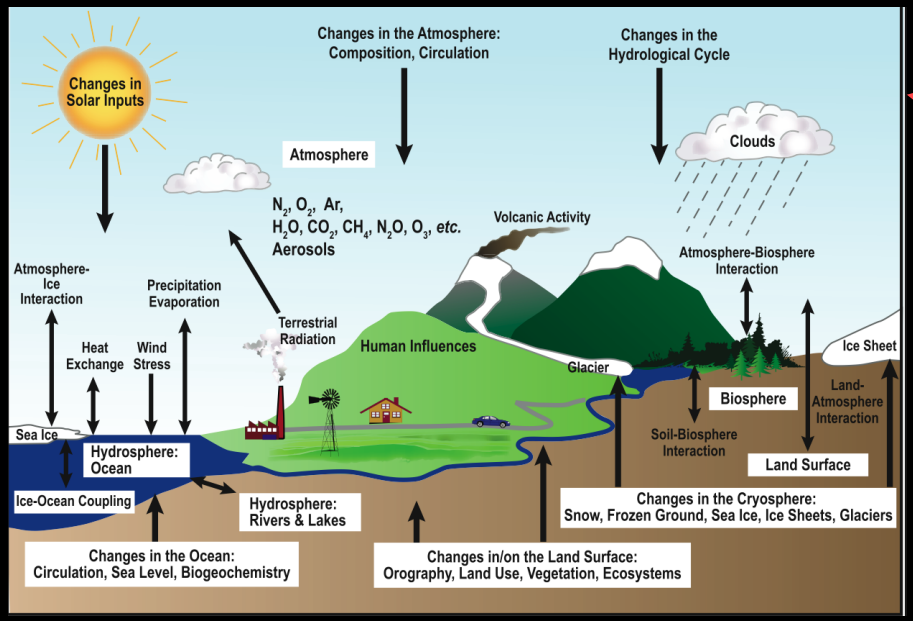
# Global Climate Models

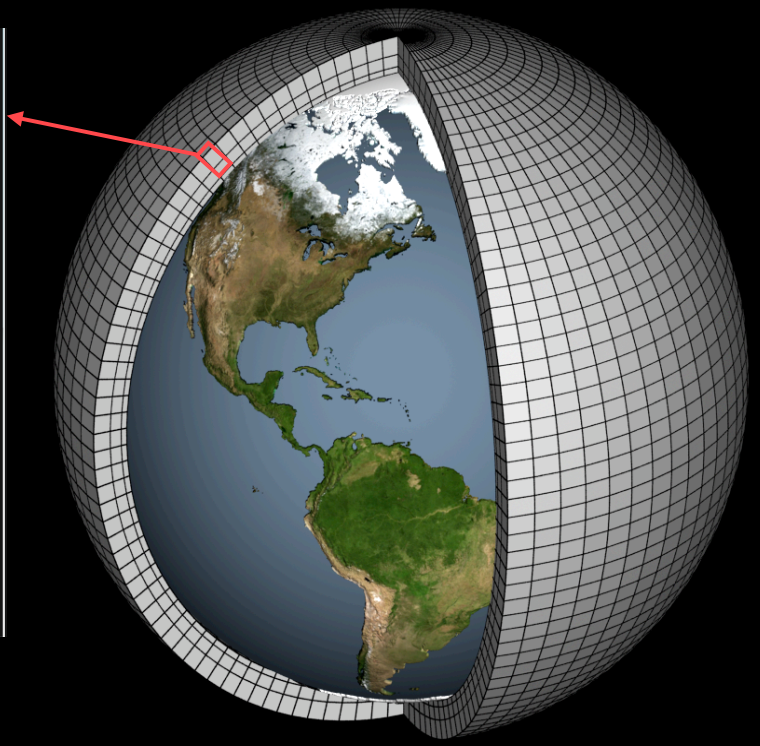
*How scientists simulate the climate system and project future climate scenarios*

# Scientists observe & measure all the factors that are known to influence Earth's climate



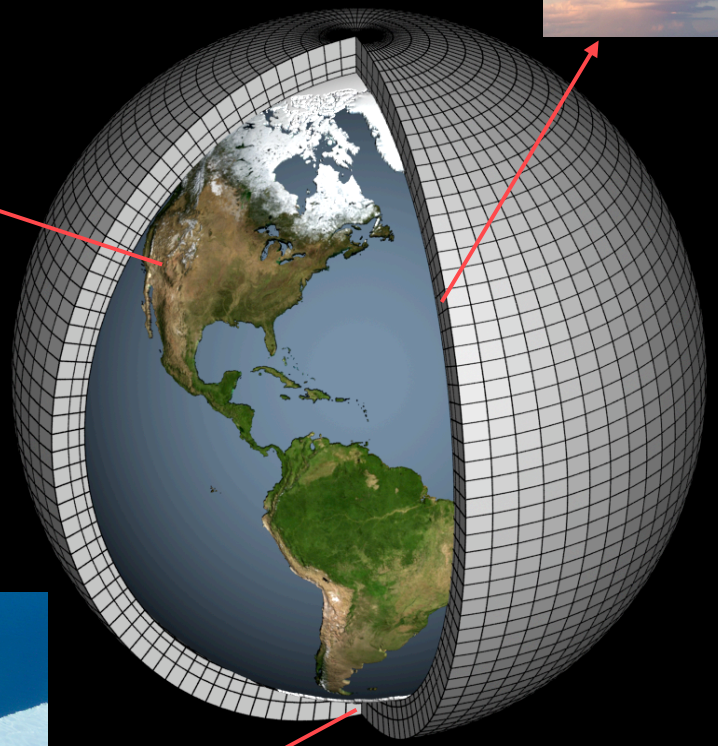
# Scientists apply that knowledge to a scaled-down, computer simulation of the planet: a global climate model



Modelers represent Earth's surface and atmosphere as a virtual world made up of interacting, three-dimensional boxes.

Physical characteristics and processes that occur in each box are cataloged



# Mathematical equations that represent the physical characteristics and processes are entered for each box

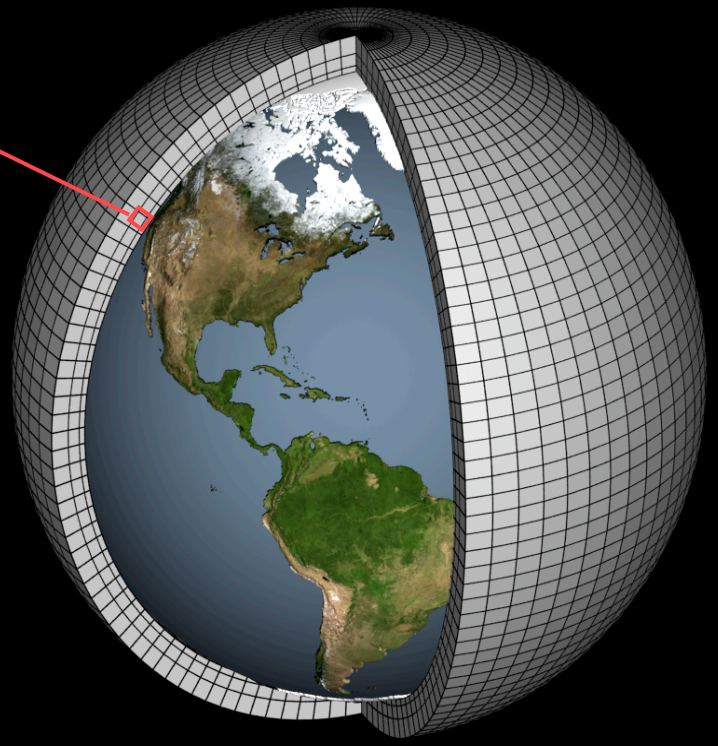
$$\frac{\partial u}{\partial t} = \eta v - \frac{\partial \Phi}{\partial x} - c_p \theta \frac{\partial \pi}{\partial x} - z\frac{\partial u}{\partial \sigma} - \frac{\partial(\frac{u^2+v^2}{2})}{\partial x}$$

$$\frac{\partial v}{\partial t} = -\eta \frac{u}{v} - \frac{\partial \Phi}{\partial y} - c_p \theta \frac{\partial \pi}{\partial y} - z\frac{\partial v}{\partial \sigma} - \frac{\partial(\frac{u^2+v^2}{2})}{\partial y}$$

$$\frac{\delta T}{\partial t} = \frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} + w\frac{\partial T}{\partial z}$$

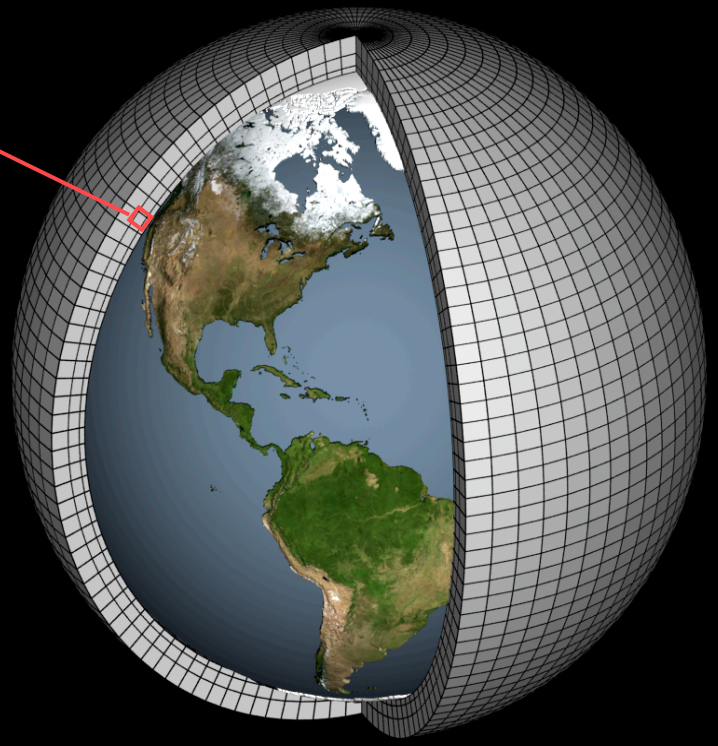
$$\frac{\delta W}{\partial t} = u\frac{\partial W}{\partial x} + v\frac{\partial W}{\partial y} + w\frac{\partial W}{\partial z}$$

$$\frac{\partial}{\partial t}\frac{\partial p}{\partial \sigma} = u\frac{\partial}{\partial x}x\frac{\partial p}{\partial \sigma} + v\frac{\partial}{\partial y}y\frac{\partial p}{\partial \sigma} + w\frac{\partial}{\partial z}z\frac{\partial p}{\partial \sigma}$$

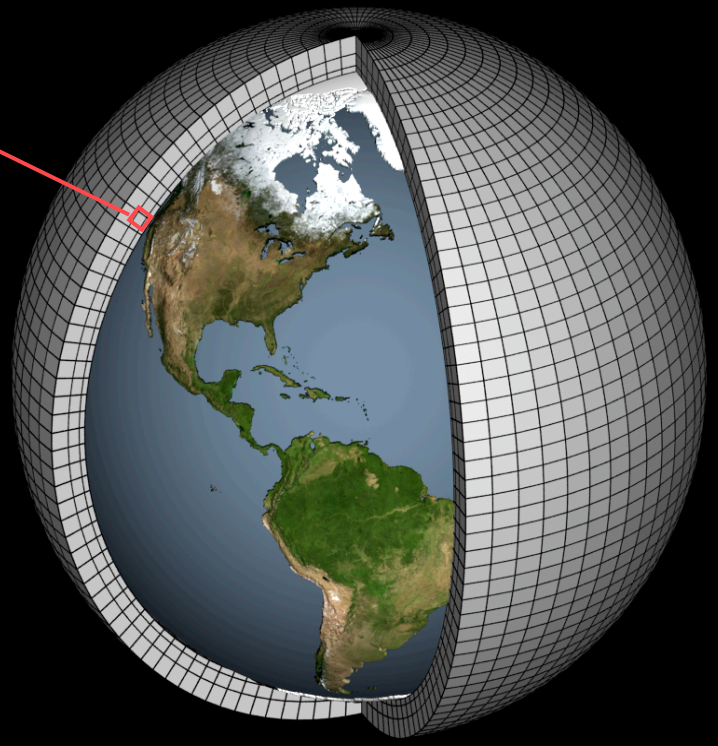


# Equations are converted to computer code and climate variables are set

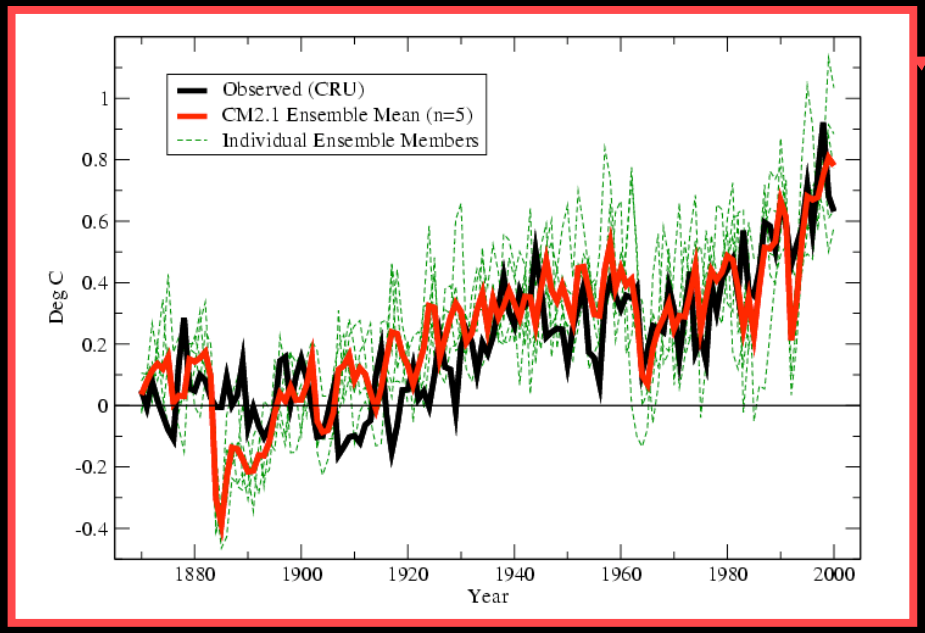
```
if (diagts .and. eots) then
  do 1500 m=1,nt
    do 1490 k=1,km
      fx = cst(j)*dyt(j)*dzt(k)/(c2dtts*dtxcel(k))
      do 1480 i=2,imtm1
        boxfx           = fx*dxt(i)*fm(i,k,jc)
        sddt            = (ta(i,k,m)-t(i,k,jc,nm,m))*boxfx
        svar            = (ta(i,k,m)**2-t(i,k,jc,nm,m)**2)
                          *boxfx
        n               = 0
        termbt(k,1,m,n) = termbt(k,1,m,n) + sddt
        tvar(k,m,n)     = tvar(k,m,n)     + svar
        n     = nhreg*(mskvr(k)-1) + mskhr(i,j)
        if (n .gt. 0 .and. mskhr(i,j) .gt. 0) then
          termbt(k,1,m,n) = termbt(k,1,m,n) + sddt
          tvar(k,m,n)     = tvar(k,m,n)     + svar
```

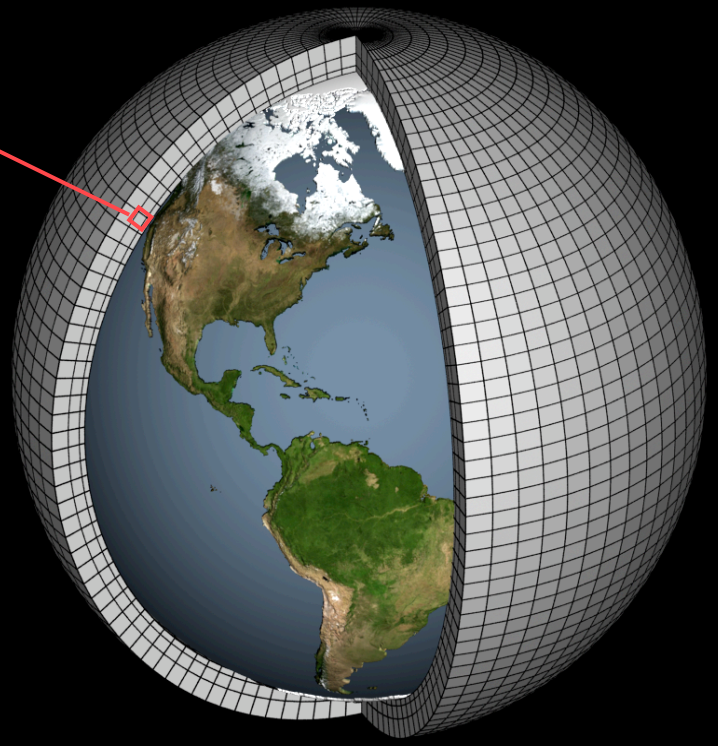


A supercomputer solves all the equations, passing results to neighboring boxes and calculating the next set of initial conditions

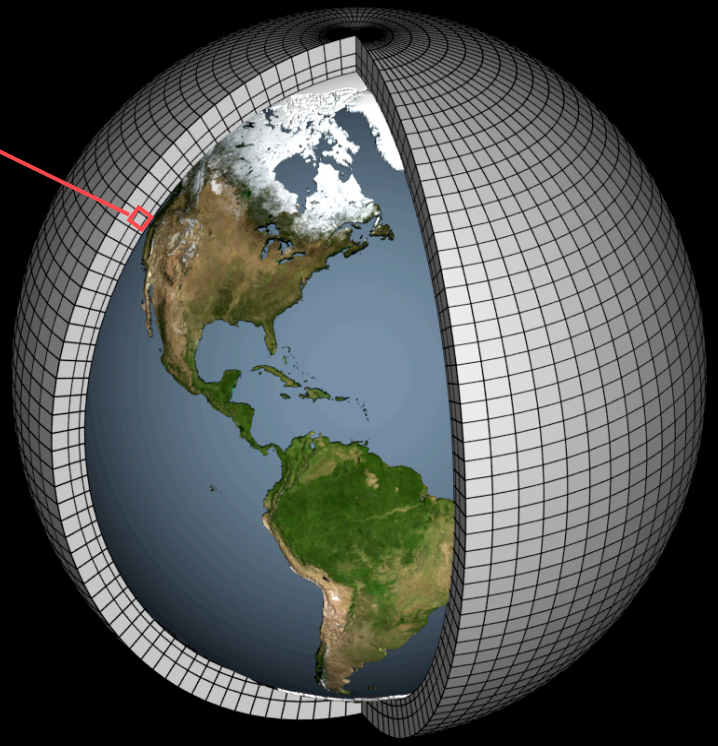



# Models are tested and refined by simulating past climate then checking how well the results match observations



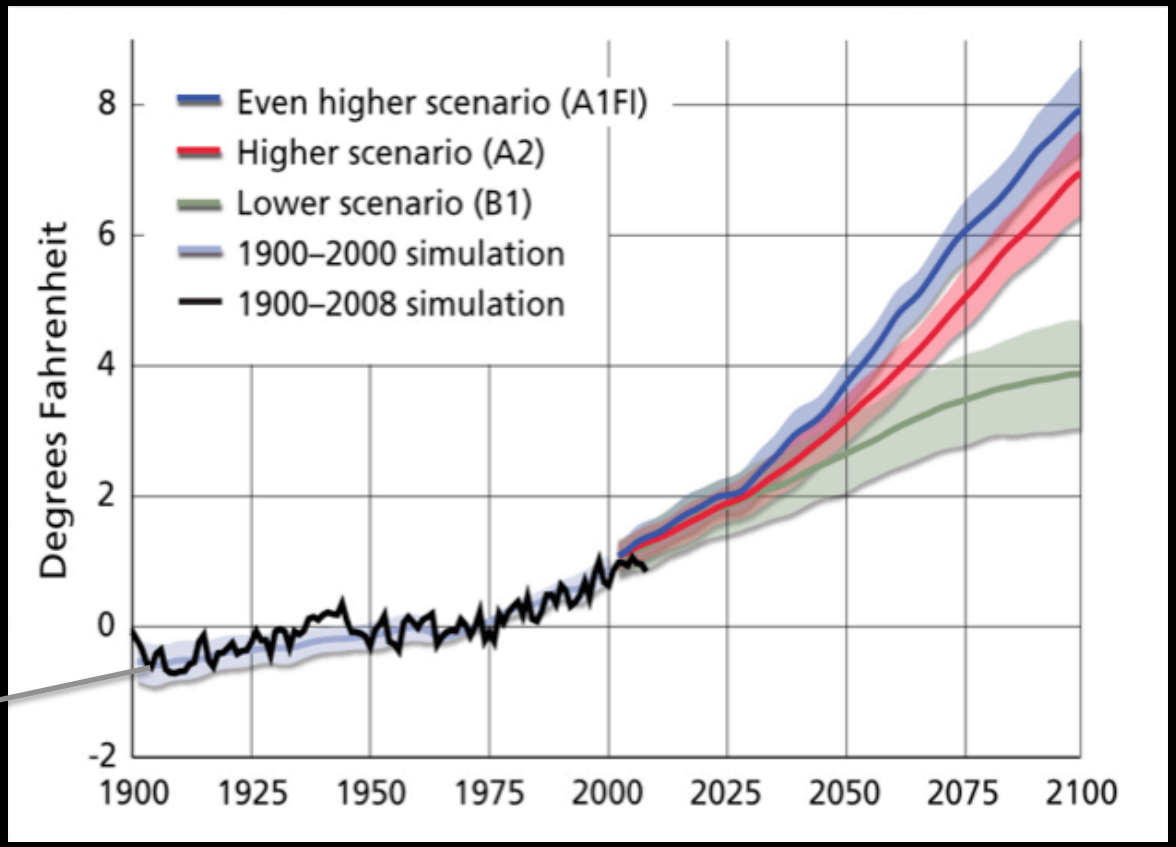
Models that successfully approximate past climate are considered valid for modeling future scenarios



# Climate models project temperature increases for various carbon dioxide emission scenarios

Studies suggest that a further increase of only 2°F would lead to severe, widespread, and irreversible impacts on Earth's environment.[1,2,3]

IPCC models successfully simulated climate conditions from 1900 to 2000.

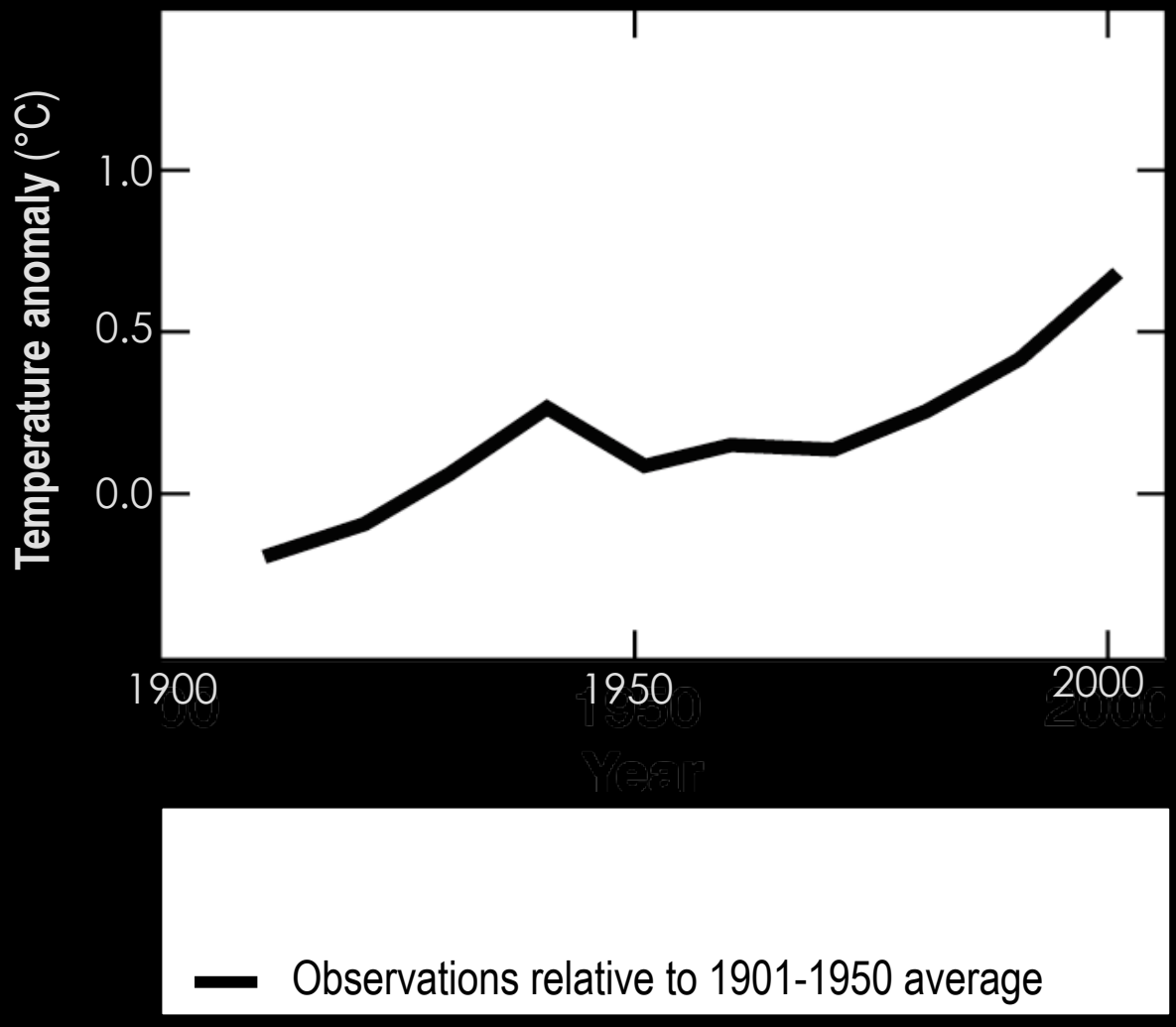


# Research groups around the world have developed a range of respected climate models

Modeling groups also work together, averaging results from their models with other models that used the same initial conditions.

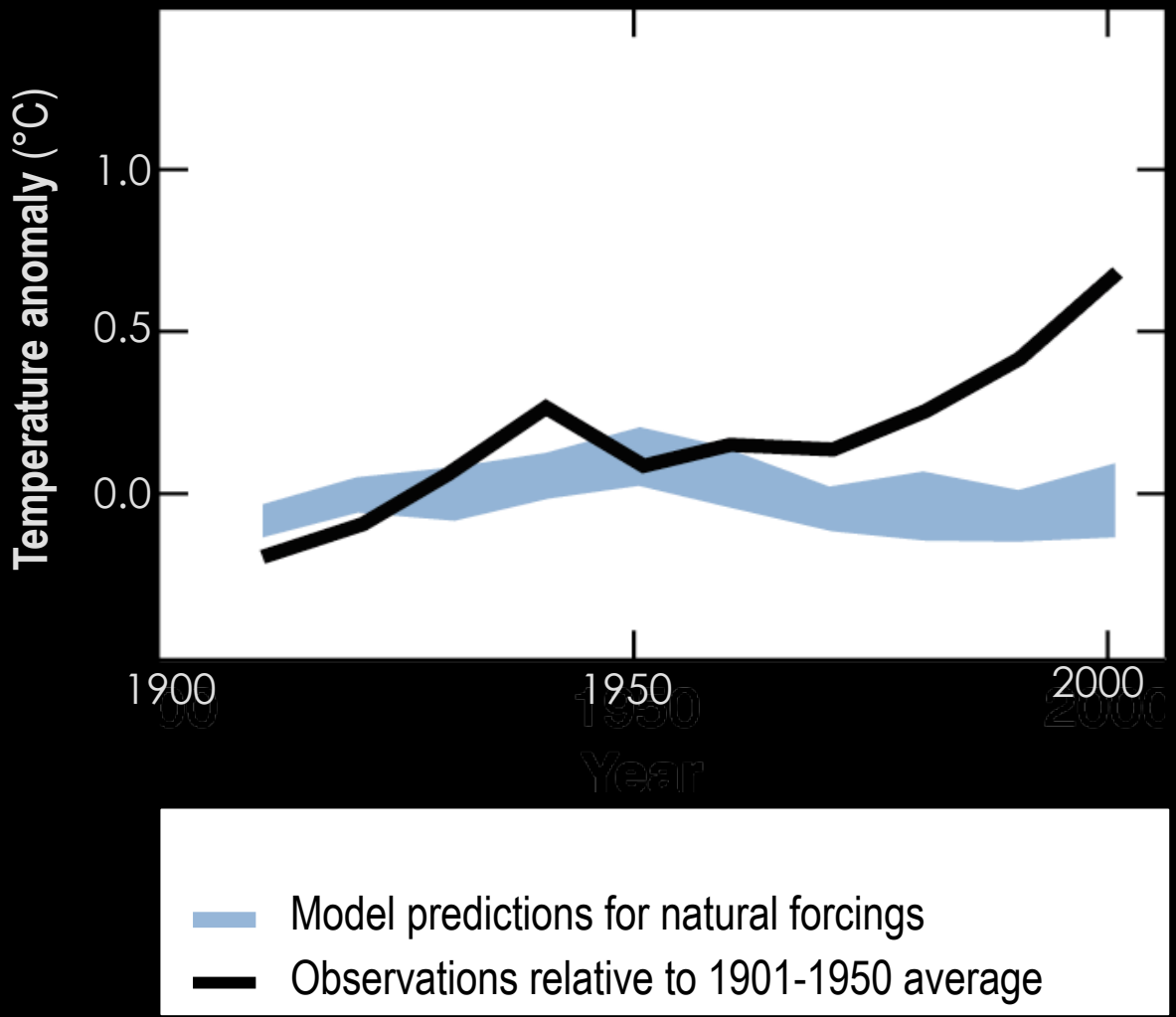
These multi-model results are called “ensembles.”

# We can use climate models to link effects to their causes



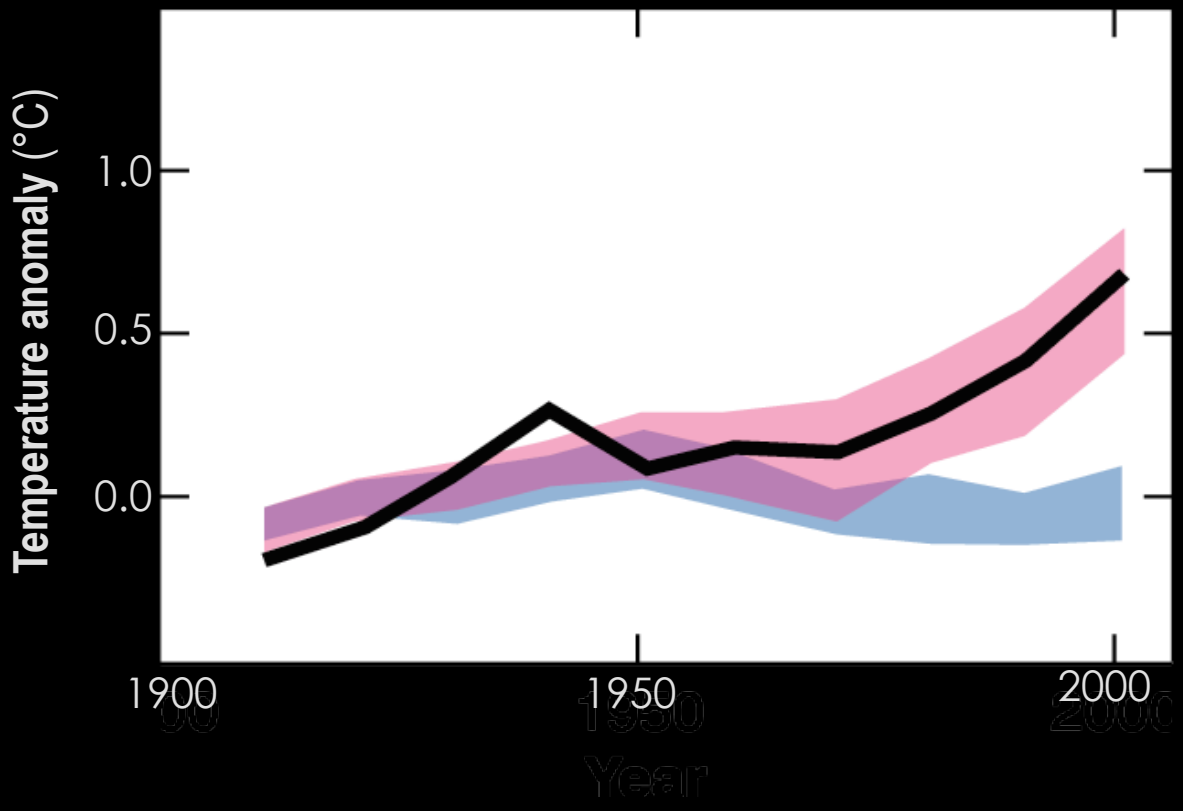

*IPCC, 2007, SPM*

# Models predict how global average temperatures would have changed due to natural forces only



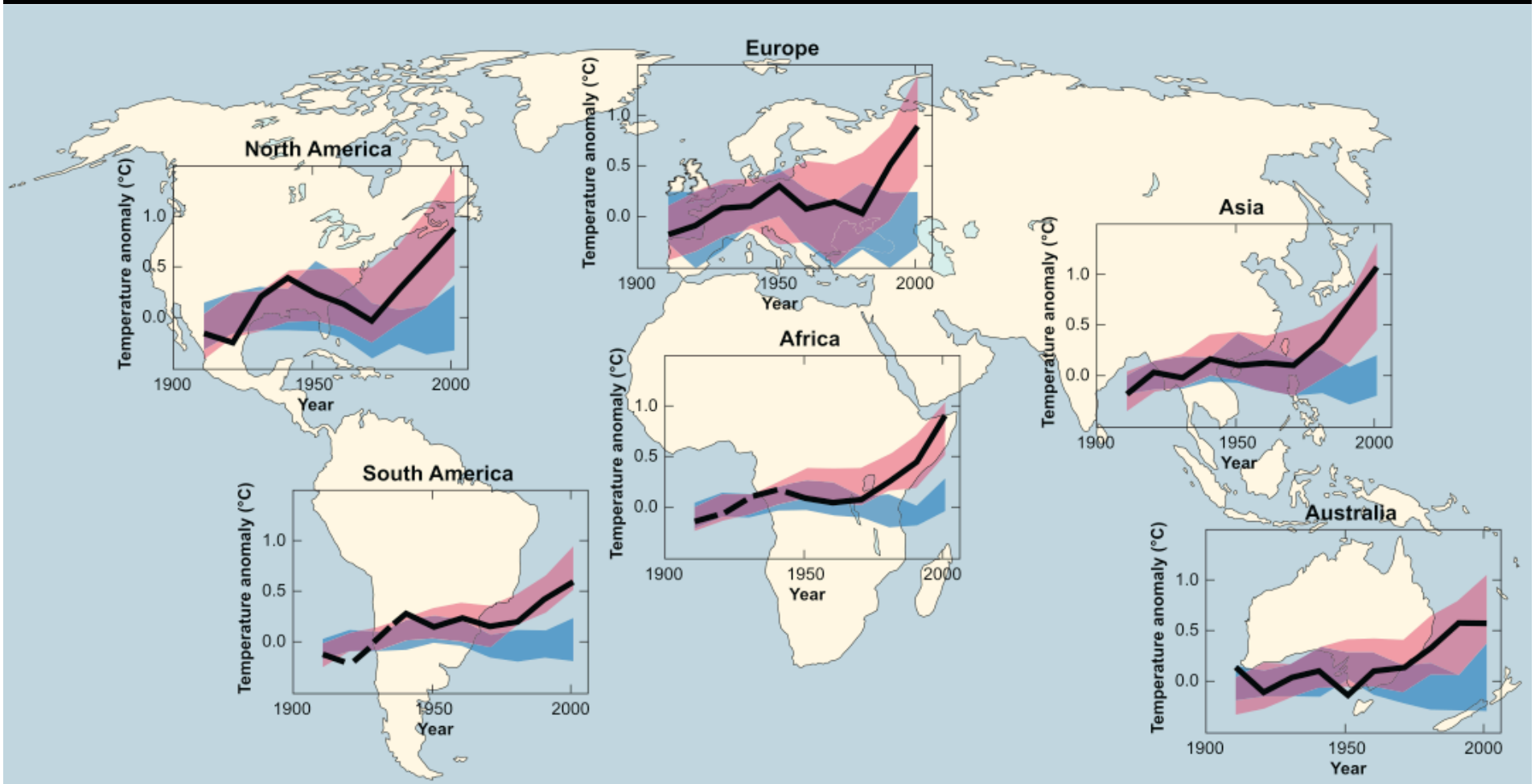

*IPCC, 2007, SPM*

# Models attribute global warming mainly to human origins




*IPCC, 2007, SPM*

# The pattern holds true on every inhabited continent




Model predictions for natural & human forcings

Model predictions for natural forcings

Observations relative to 1901-1950 average

*IPCC, 2007*