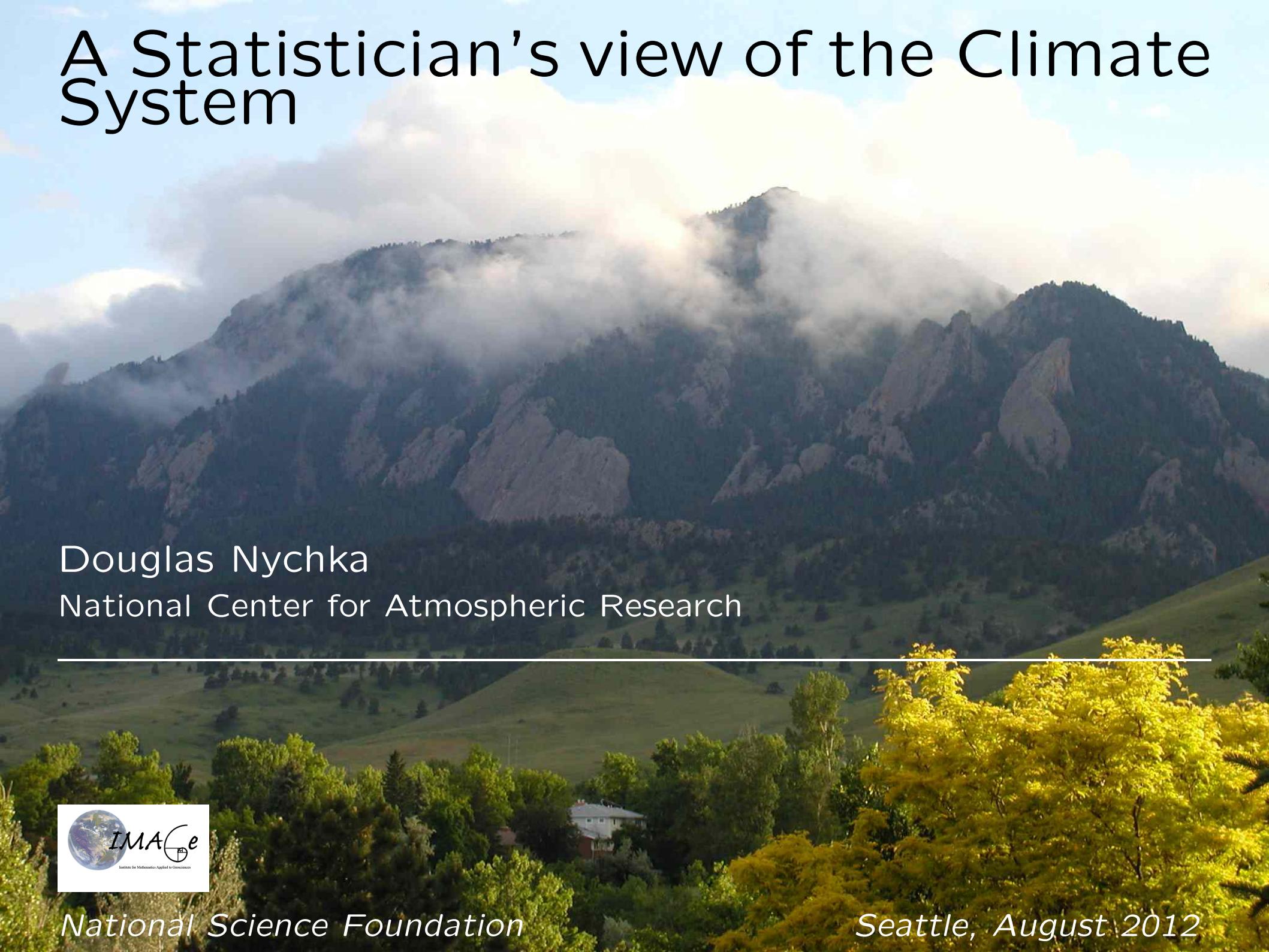


# A Statistician's view of the Climate System



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# Outline

- Weather vs. Climate
- Issues of Climate Change
- Earth's climate system:  
Green house effect, Thermohaline Circulation, ENSO, Water
- Climate Data

*Climate is what you expect . . .  
weather is what you get.*

*Weather:* A thunderstorm.

or unusual rainfall



*Climate:* E.g. a 30 year average rainfall for this area.

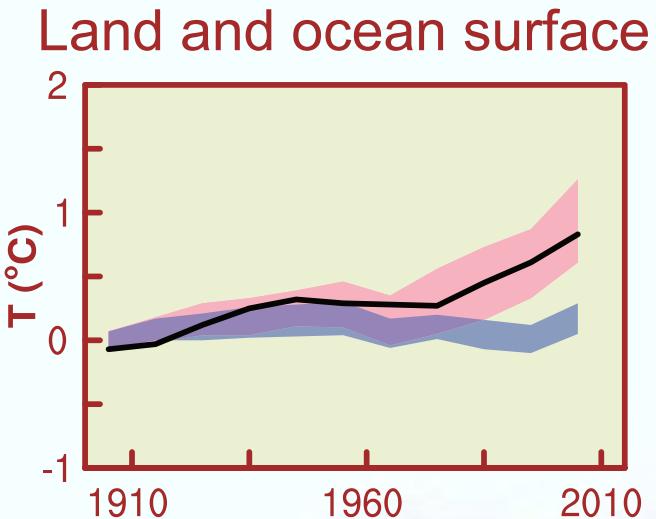
# Seeing different climate



# Human activities and warming:

IPCC Fourth Assessment Report:

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.



Observations

*Climate models:*

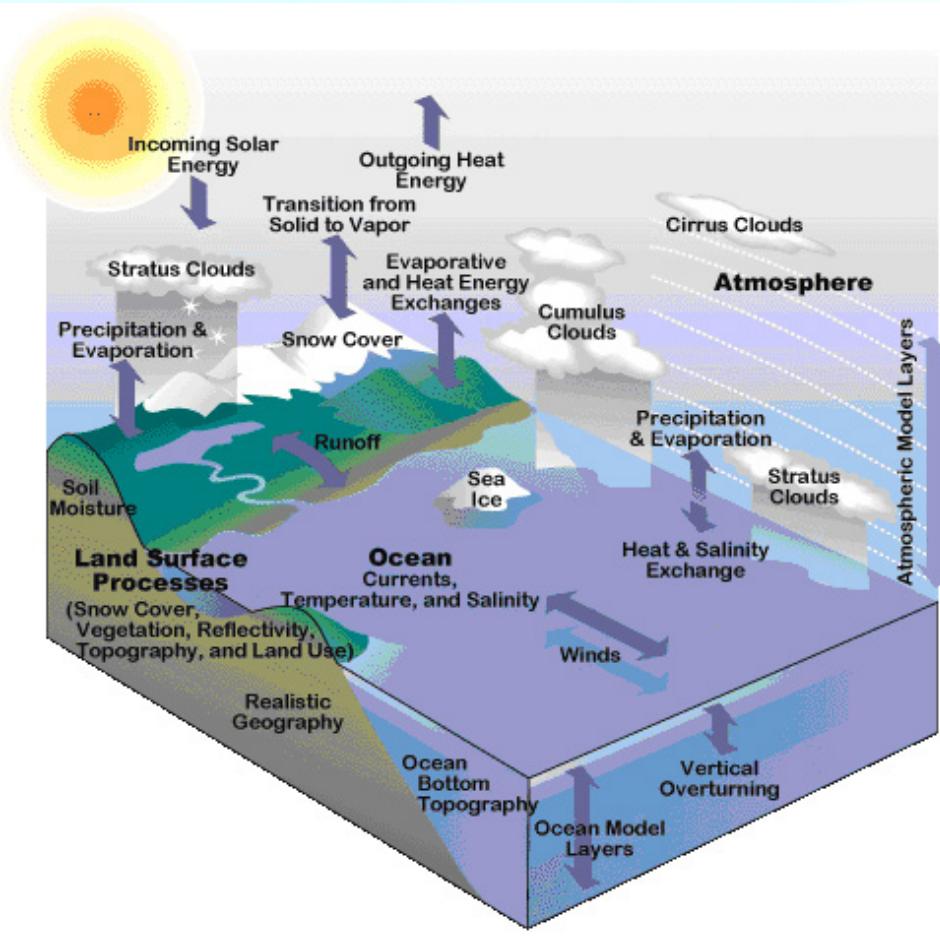
with human greenhouse  
gases

without

# Climate system model components:



# Coupled components

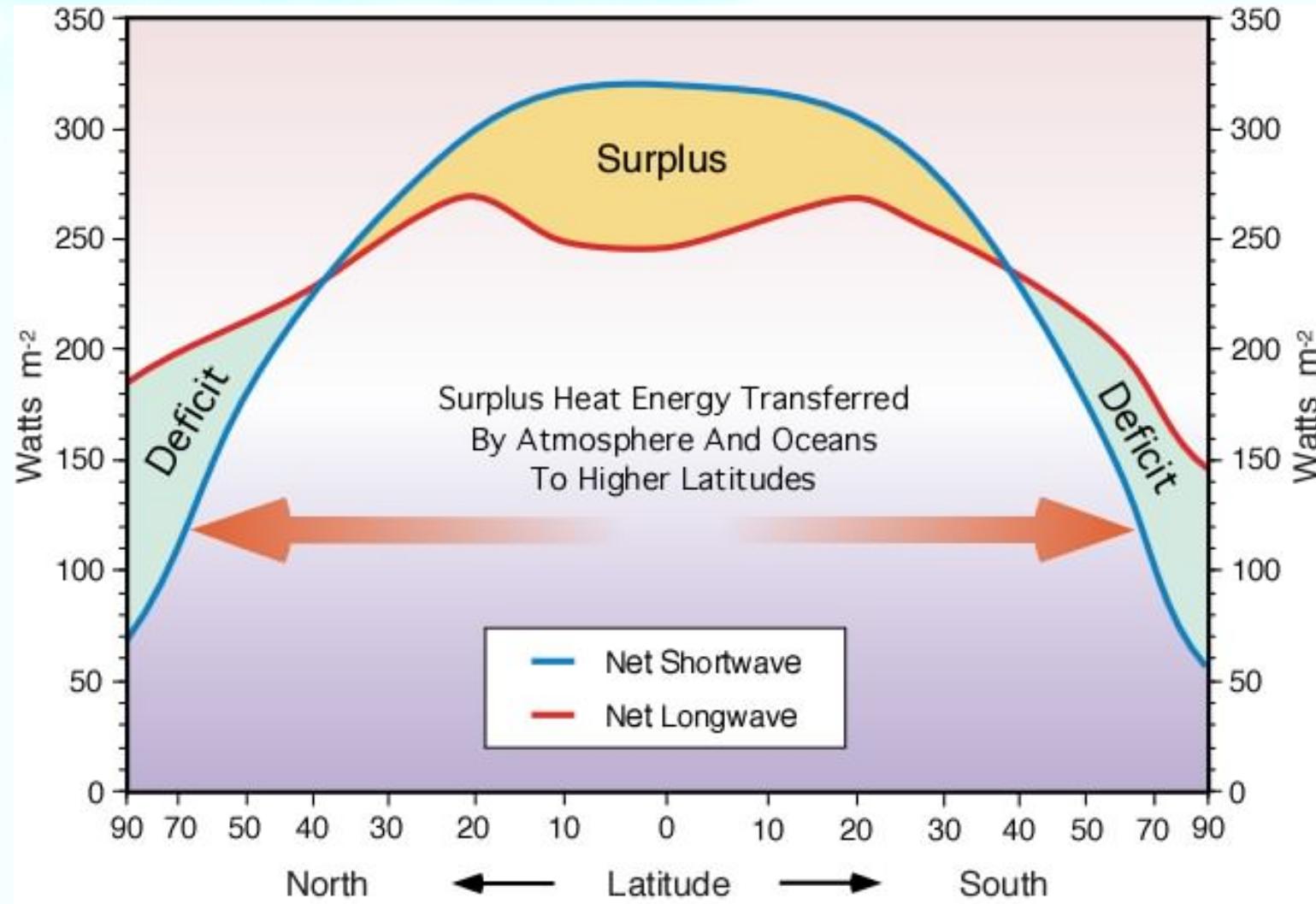


Many different time scales:

- clouds/land ( ~ hours )
- deep ocean ( $\sim 10^3$  years).

Most of the processes  
essentially transfer energy.

# What does the climate system do?

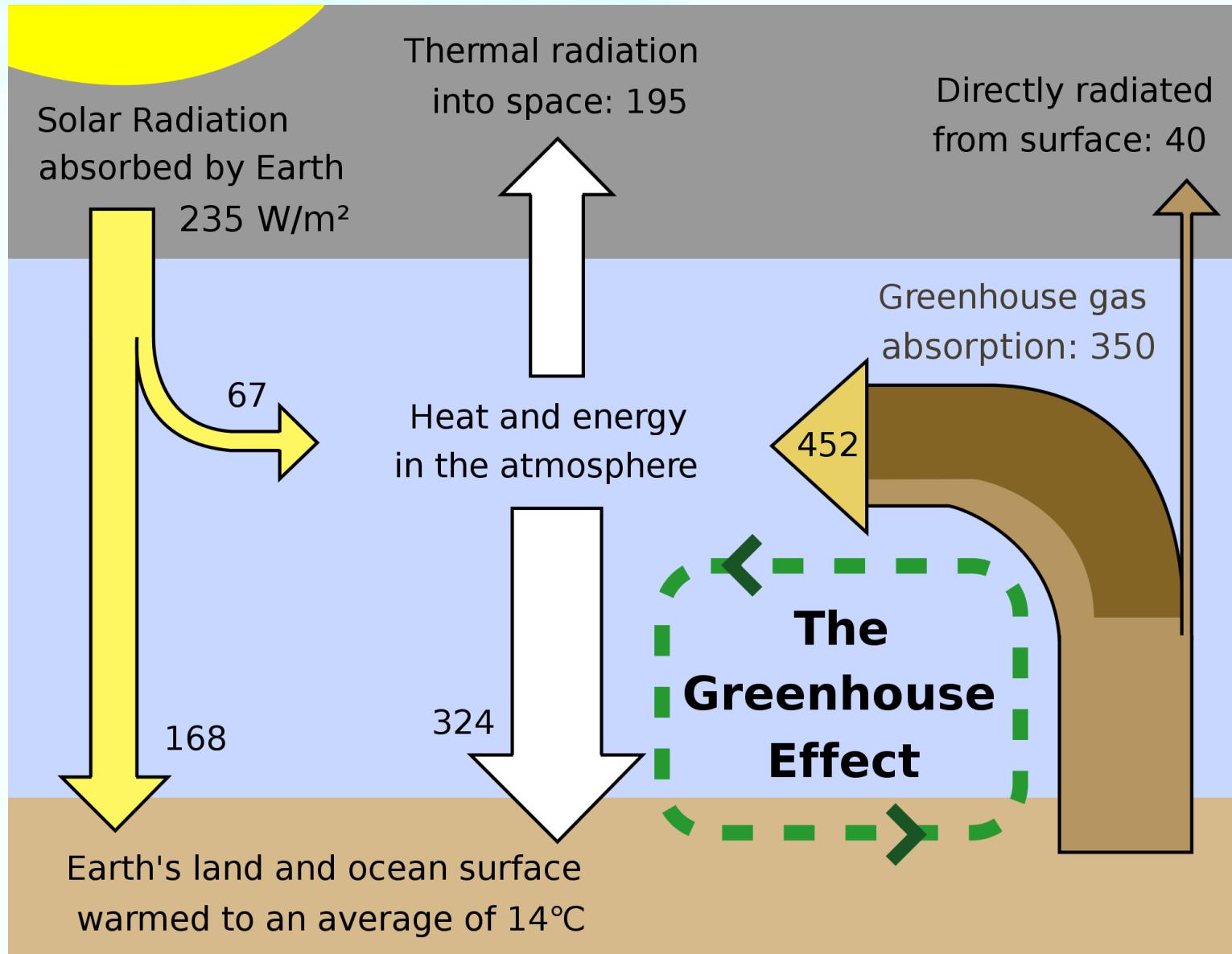


*Incoming radiation at the equator is transferred to the poles.*

Details ...

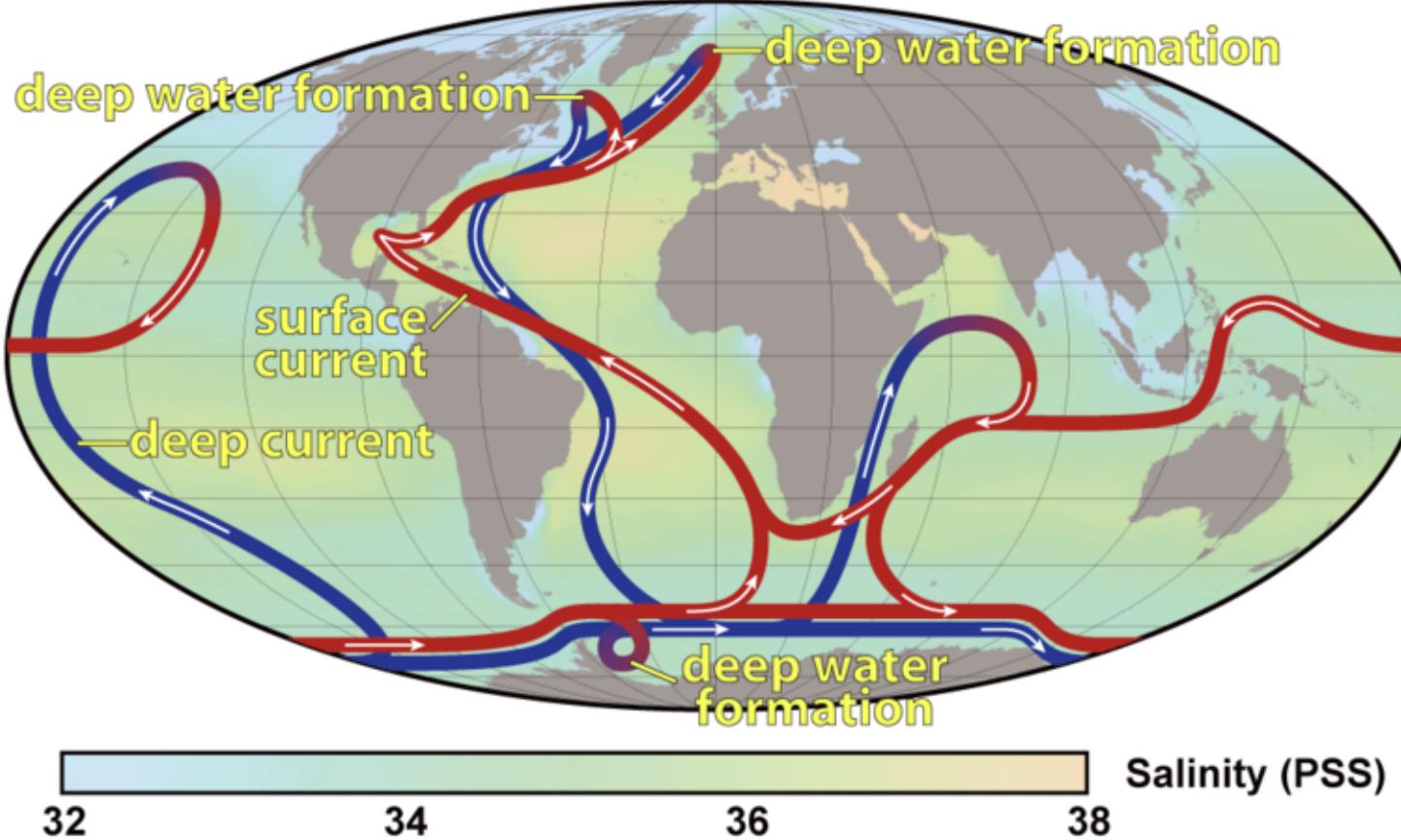
D. Nychka Statistician's climate system

# What about CO<sub>2</sub>

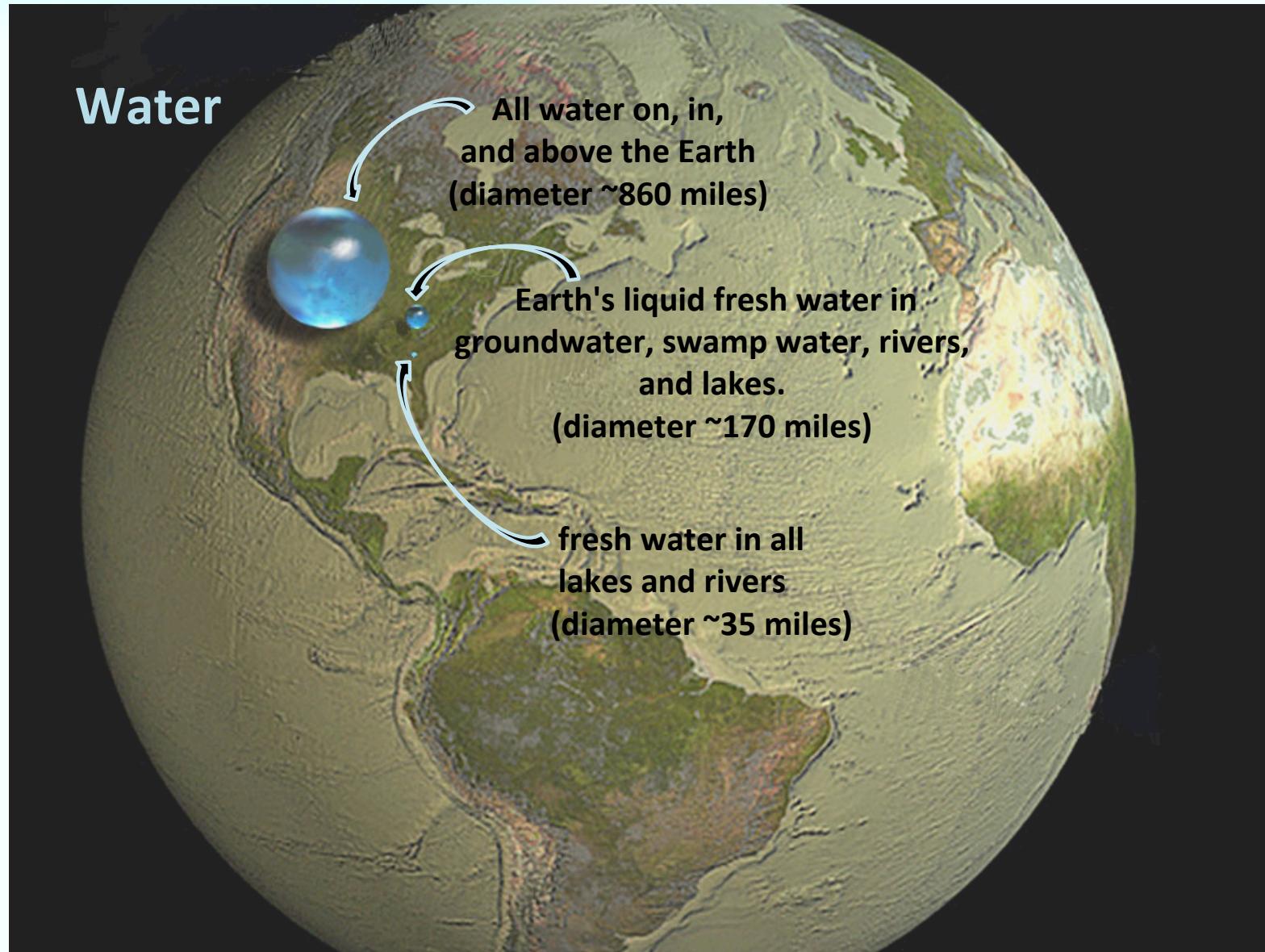


# What about the Ocean?

## Thermohaline Circulation



# hydrologic cycle and societal impacts



# Climate Data



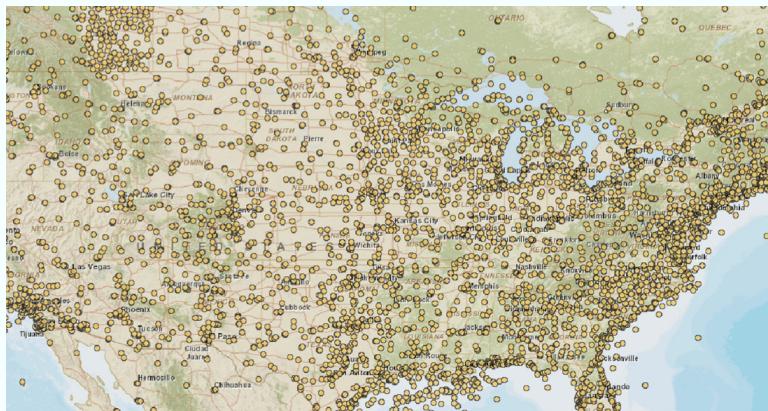
# Surface variables

- Temperature (min and max)
- Rainfall.
- Surface pressure.
- Relative humidity, wind speed
- Cloud cover, radiation.

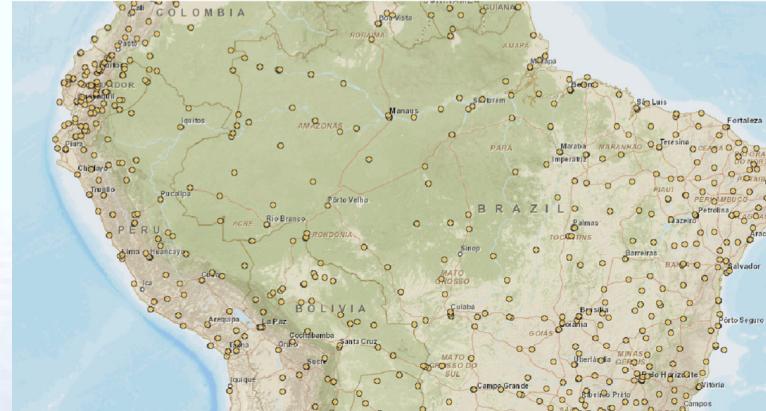


## Coverage

North America



South America

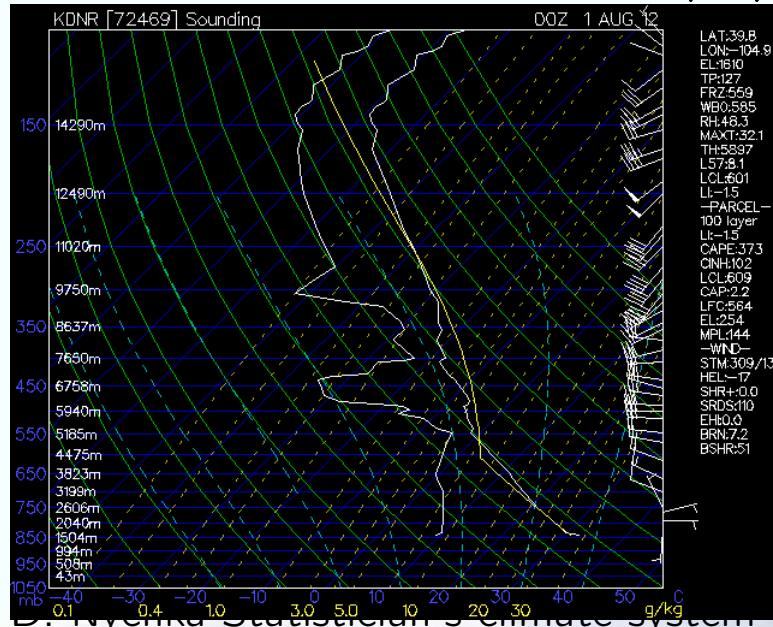


# Upper Air

## Radiosondes

- Temperature
- Water vapor
- Pressure.
- Wind speed and direction

Skew-t plot Denver 0Z 8/1/2012

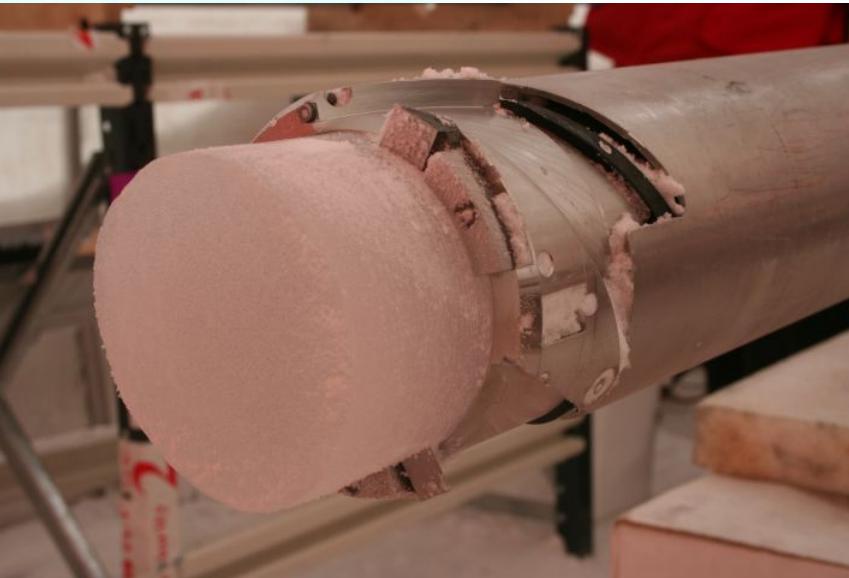
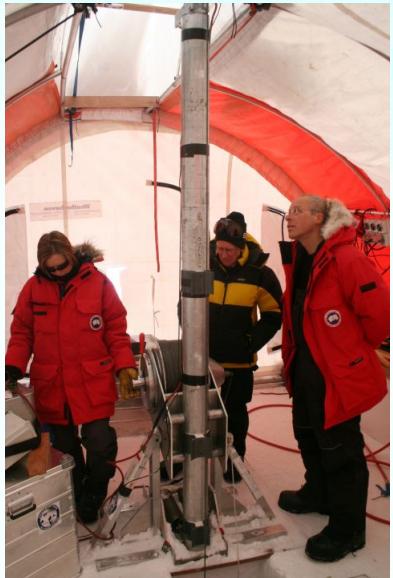


# Some Chemistry

- Towers measuring CO<sub>2</sub> fluxes
- Dry and wet deposition
- Flask samples of CO<sub>2</sub>



# Law Dome, East Antarctica



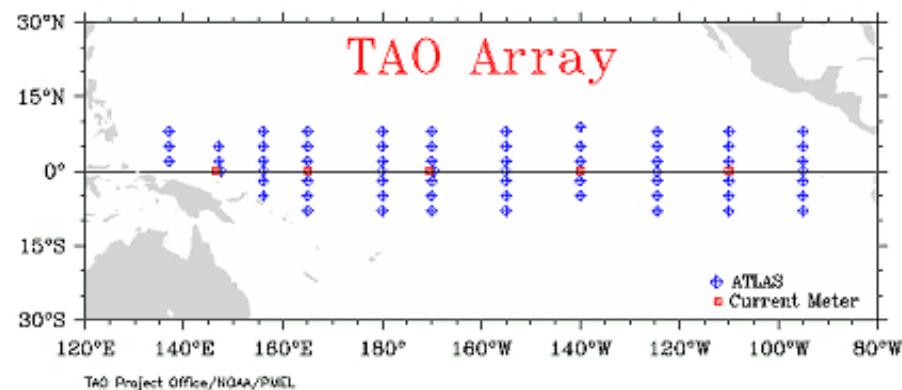
Ice core drill and glaciologists from the Australian Antarctic Division and Antarctic Climate and Ecosystems CRC, Law Dome, East Antarctica

# Ocean measurements

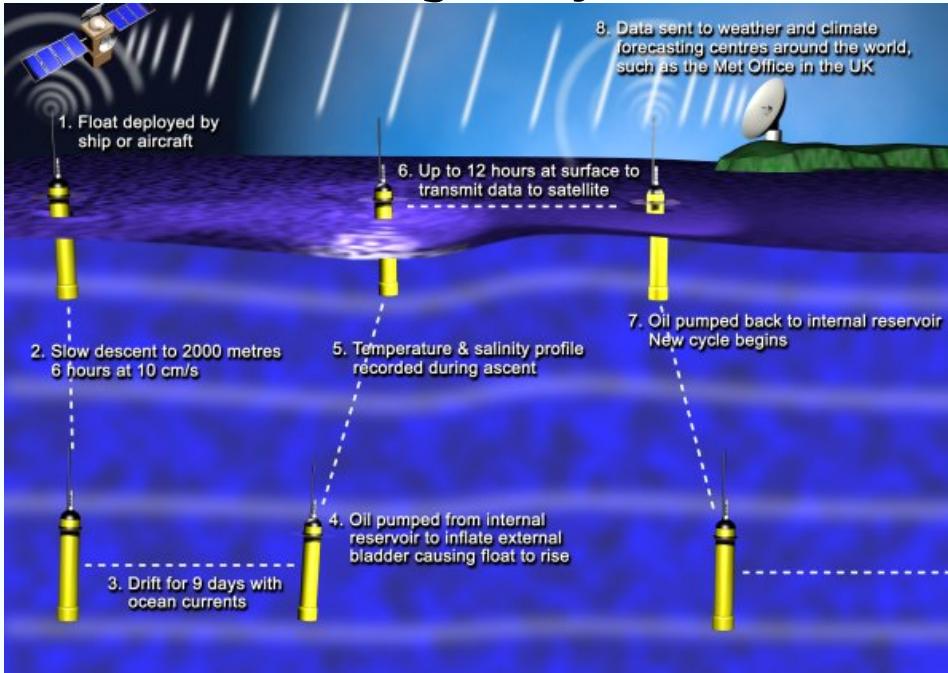
- Expendable bathythermograph (XBT)



- Stationary buoys



- ARGO drifting buoys



Buoys descend from surface and drift at depth (1000m) and periodically ( 10 days) ascend from 2000m to transmit data. In the ascending stage temperature and salinity are measured.  $\approx$  3000 floats deployed

# Gridded Data Products

Irregularly spaced observations are converted into values on a regular grid to make it easier to plot or compare to model output or other data products.

*Some examples based on observations*

- CRU: The UEA Climatic Research Unit's Global Climate Dataset Global, monthly tmin, tmax, precip, and others at 50km, 1901-present
- UW: Gridded Meteorological Data from the University of Washington For the US, monthly tmin, tmax, precip, wind at 25km 1949-2000
- UDel: Data from Willmott, Matsuura, and Collaborators at University of Delaware Global/land monthly tmin, tmax, precip at 50km resolution from 1895- present.
- PRISM: Parameter-elevation Regressions on Independent Slopes Model For the US, monthly tmin, tmax, precip at 4km resolution from 1895- present.

# Common Reanalyses

The data products are the sequence of states  $\{x_t\}$  – complete and physically coherent geophysical fields.

- NCEP2: NCEP-DOE Reanalysis 2 and NARR: NCEP North American Regional Reanalysis
- ERA40: From the European Center for Medium Range Weather Forecasting

# What is a climate model?

We have a dynamical system,  
"state"  $x$  and "parameters"  $F_t$ .

$$x_t = g(x_{t-1}, F_t)$$

$g$  includes all the physics of the system.

*Weather:*  $x_t$

Time step is on the order of minutes!

*External influences:*  $F_t$

CO<sub>2</sub> produced by human activity.

Incoming solar radiation.

Volcanic activity.

*Climate:*  $E[x_t]$

or the distribution of  $\{x_t\}$  from a distribution of different initial conditions



# How is this model computed?

*Atmosphere Ocean General Circulation Model (AOGCM):*

Physically based, large computer code.

Snapshot NCAR CAM simulation



Climate models simulate weather and this is aggregated to infer climate.

*The "true" climate for a model must be estimated!*

# Big Iron to run the models

1 day of the super's time  
 $\approx$  5 years simulation



Terabytes of model output  
"data"



100s of contributors



# Climate Model Experiments:

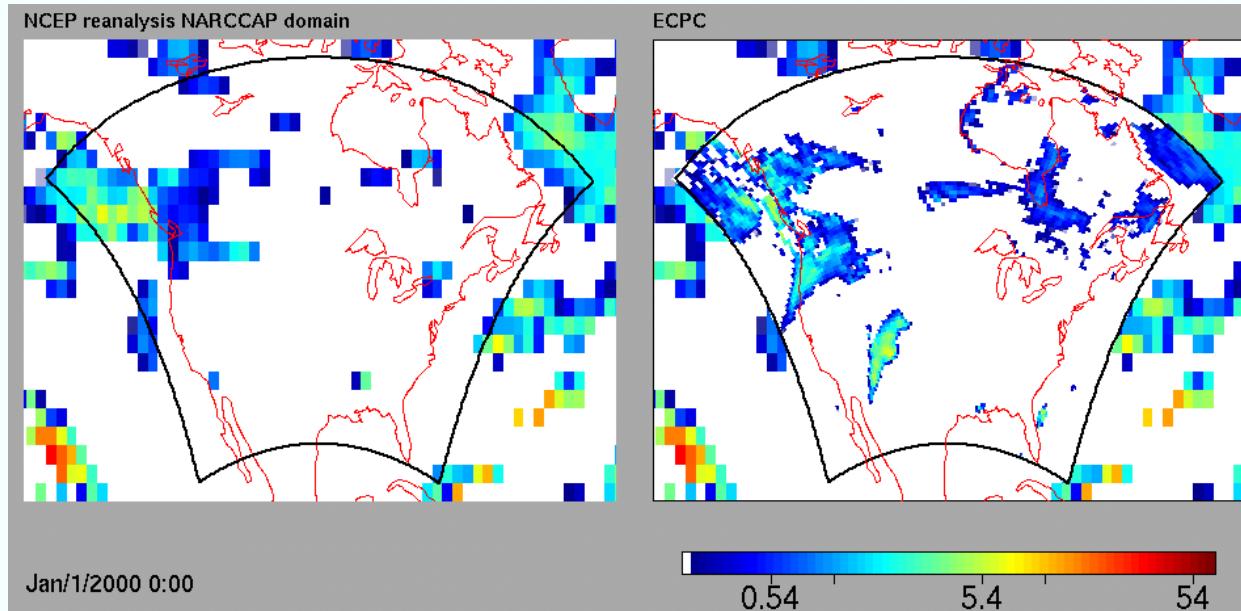
- A numerical laboratory for studying physical processes
- Testing whether scientific understanding is adequate to reproduce current climate
- Creating *projections* about future climate based on different scenarios.

# A climate model grid box (?)



# An approach to Regional Climate

- Nest a fine-scale weather model in part of a global model's domain.  
Regional model simulates higher resolution weather based on the global model for boundary values and fluxes.



A snapshot from the 3-dimensional RSM3 model (right) forced by global observations (left)

- Consider different combinations of global and regional models to characterize model uncertainty.

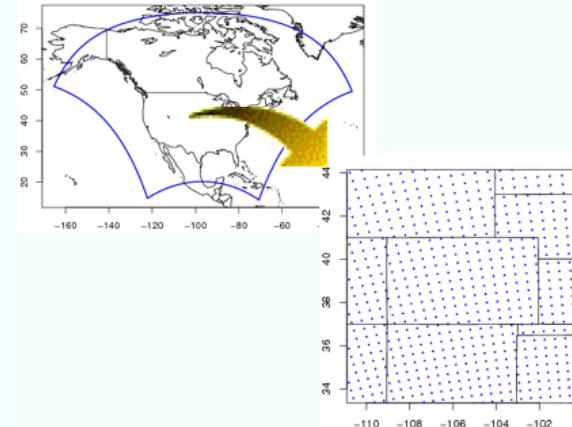
# NARCCAP – the design

*4GCMS × 6RCMs:*

*12 runs – balanced half fraction design*

*Global observations × 6RCMs*

*× High resolution global atmosphere*



| GLOBAL MODEL | REGIONAL MODELS |     |       |       |     |      |
|--------------|-----------------|-----|-------|-------|-----|------|
|              | MM5I            | WRF | HADRM | REGCM | RSM | CRCM |
| GFDL         |                 |     | ●     | ●     | ○   |      |
| HADCM3       | ○               |     | ●     |       | ●   |      |
| CCSM         | ●               | ■   |       |       |     | ■    |
| CGCM3        |                 | ■   |       | ●     |     | ■    |
| Reanalysis   | ●               | ●   | ●     | ●     | ●   | ●    |

*A designed experiment is amenable to a statistical analysis and can contain more information.*

*But just 2-d temperatures fields are 72Gb of data.*

# Thank you!

Questions?

