NATS 101
Section 13: Lecture 24

Weather Forecasting
Part I

Forecasting weather and climate is REALLY important—and that is the main reason why use our tax dollars to do it!

Goes to the core of one of reasons to study weather and climate I mentioned the first day of class.

So how can we solve the problem?

Simple approach vs. complex approach

The simple forecasting approaches should be used as a "sanity check" to see if the complex approach are worth it.

Simple Approach #1
Persistence Forecast

Persistence: **Future atmospheric state is the same as the current state.**

Good Example: Tropical rainforest during wet season. It's raining today, so predict rain for tomorrow. How is this related to the general circulation?

TODAY

HIGH: 83°F
LOW: 70°F

THURSDAY

HIGH: 83°F
LOW: 70°F

FRIDAY

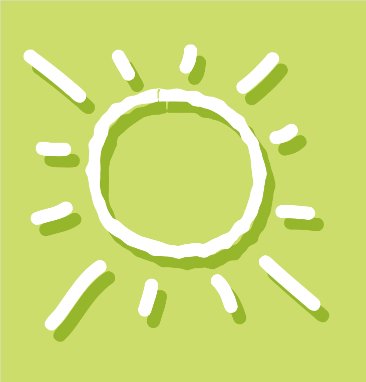
HIGH: 83°F
LOW: 70°F

Simple Approach #2
Trend forecast

Trend: **Add past change to current condition to obtain forecast for future state**

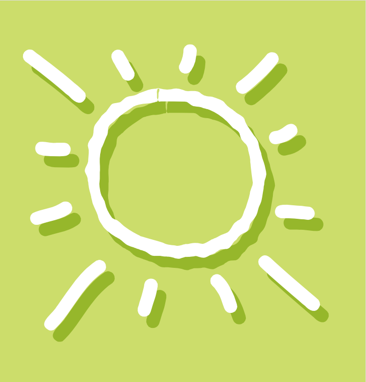
Good Example: Temperature in Tucson increasing at 3°F per hour in the morning on a clear, calm day. Use this to forecast temperatures later in afternoon because the surface heats at a steady rate due to solar heating.

9 AM



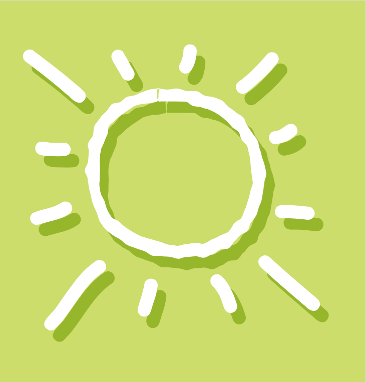
93°F

12 PM



96°F

3 PM

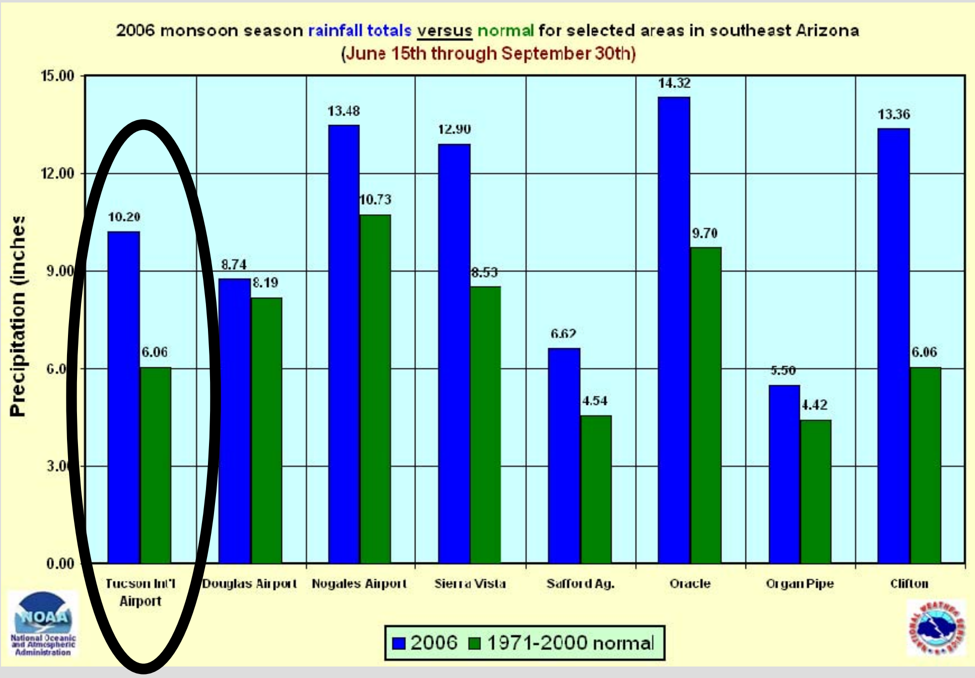


99°F

Simple Approach #3
Climatology forecast

***Climatology*: Forecast future state as the average of past weather for a given period**

Good example: Forecast about six inches of rain to occur during the monsoon in Tucson, the average for the 1971-2000 period.

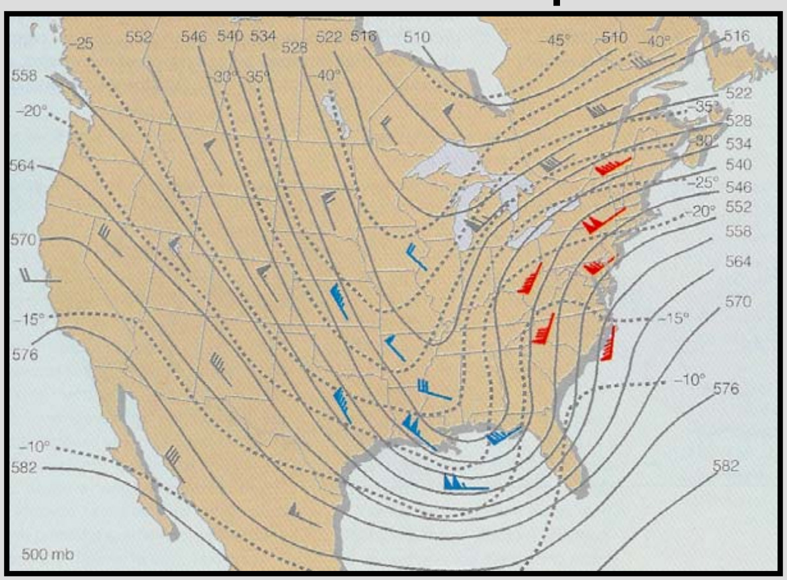


Simple approach #4: Analog forecast

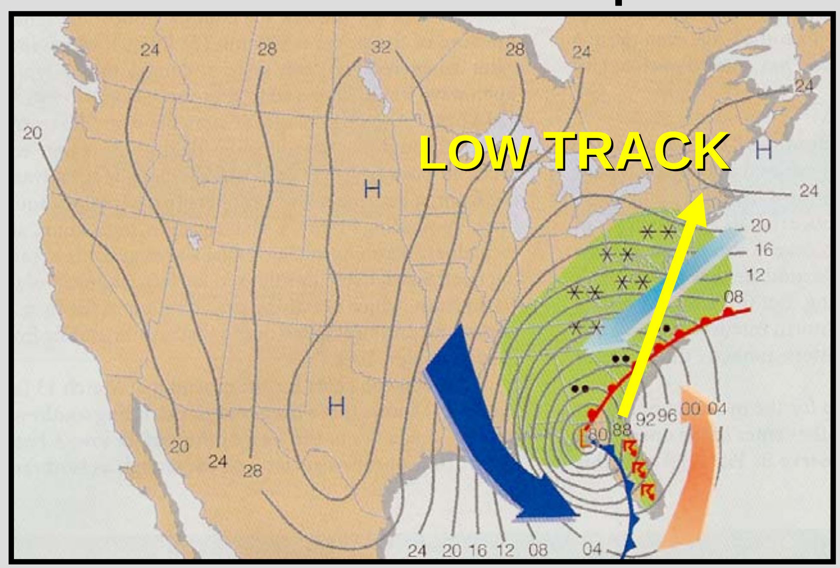
Analog: **Find a previous atmospheric state that is like the current state and forecast the same evolution.** ***This one does require some more skill because no two situations are EVER exactly alike…***

Good example: If a surface low pressure forms in the eastern Gulf of Mexico with a deep upper-level trough to the west, a Nor'ester will roll up the Eastern seaboard—like the 1993 Superstorm

500-mb MAP: 1993 Superstorm



SURFACE MAP: 1993 Superstorm



The complicated way to make a forecast is to *use a physical and mathematical model of the atmosphere, starting from an observed state at an initial time*.

This is called

Numerical Weather Prediction (NWP)

Why do Numerical Weather Prediction?

NUMERICAL WEATHER PREDICTION IS ONLY USEFUL IF YOU CAN SHOW IT DOES WHAT?

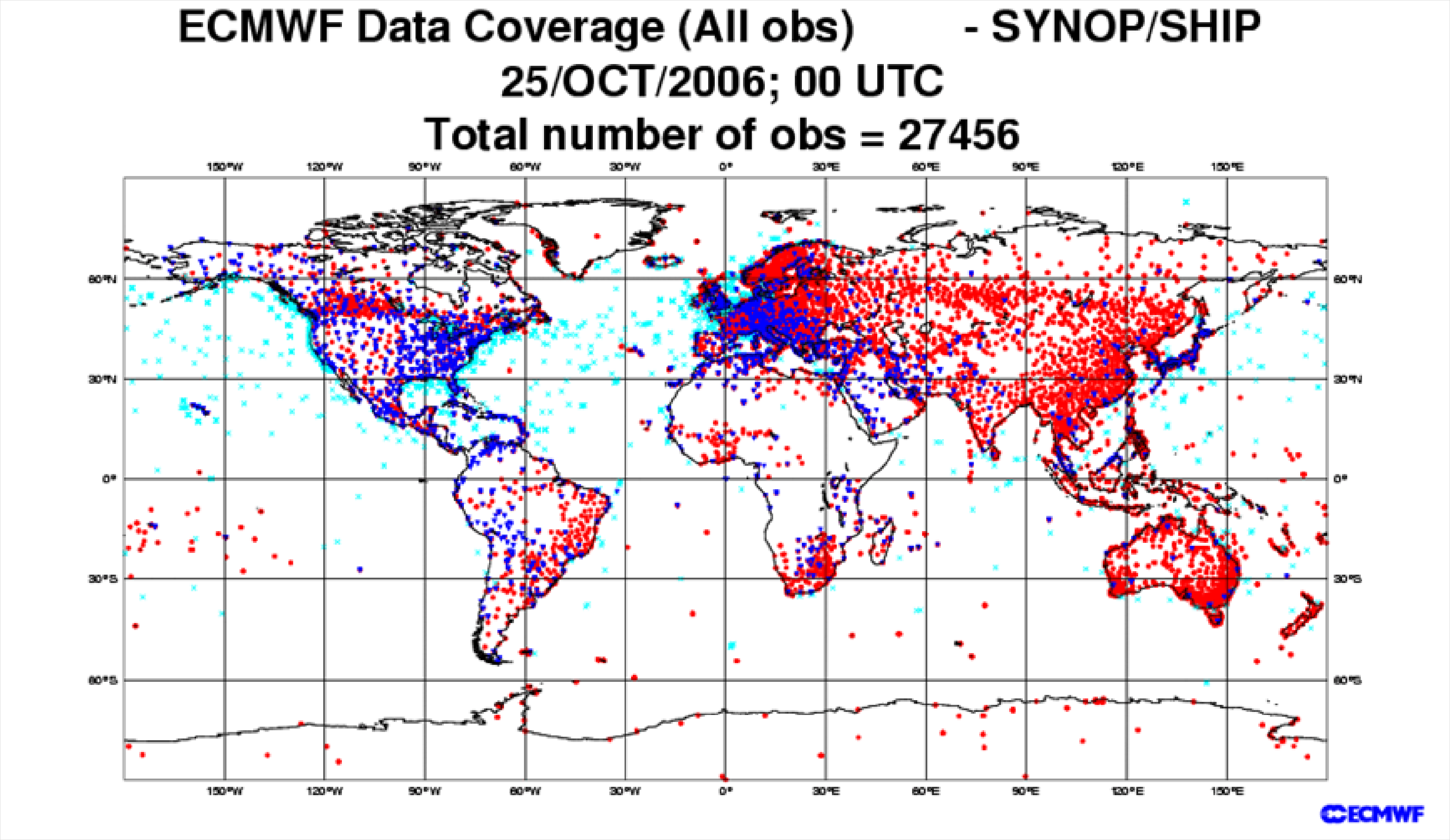
Steps in Numerical Weather Prediction

1. ANALYSIS: Gather the data (from various sources)

2. PREDICTION: Run the NWP model

3. POST-PROCESSING: Display and use products

Analysis Phase: Surface data



Surface data comes from surface meteorological stations and ships at sea.

ASOS: <u>A</u>utomated <u>S</u>urface <u>O</u>bserving <u>S</u>ystem

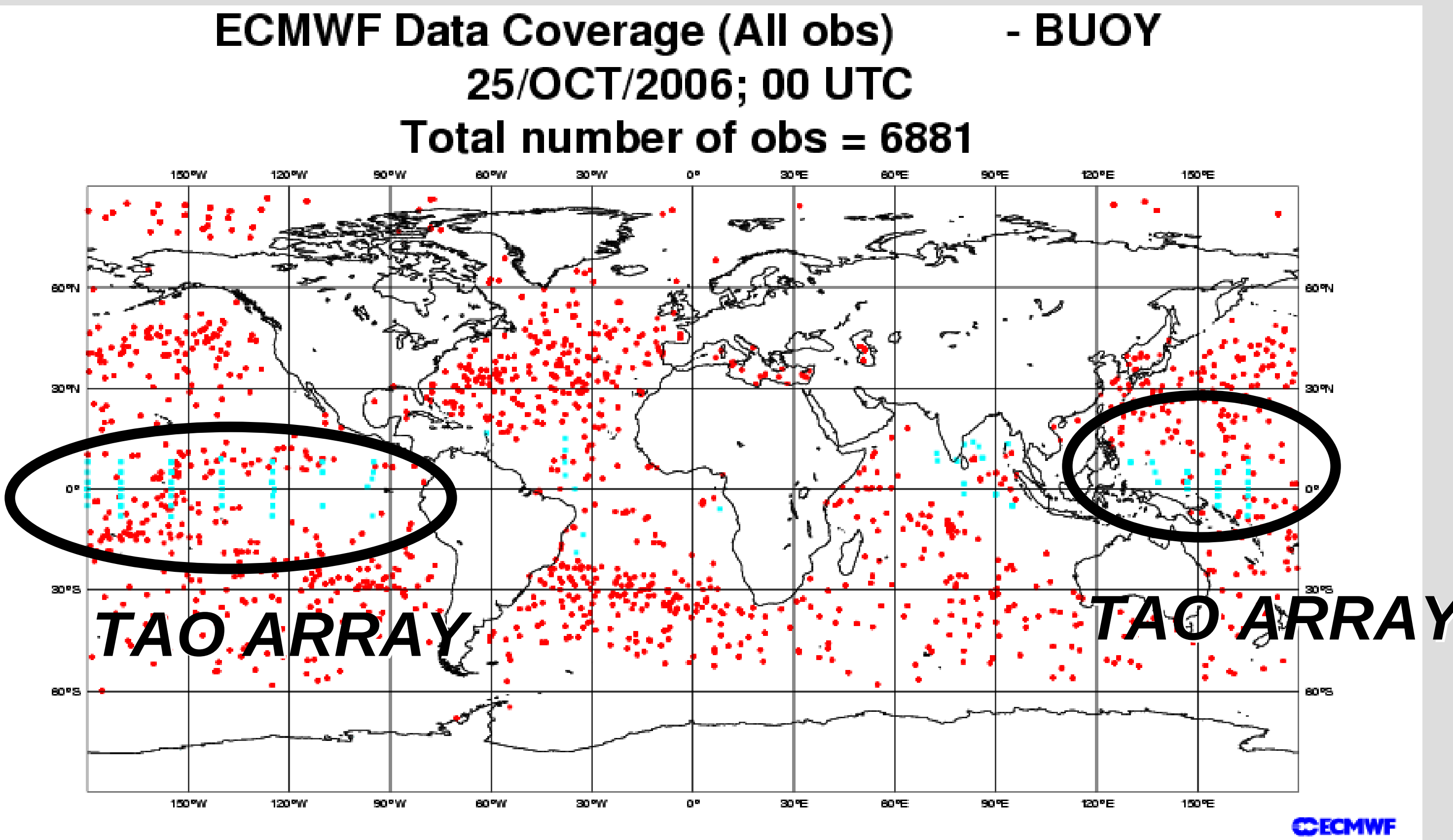
Electronic sensors to measure all elements of weather:

Temperature
Pressure
Moisture
Wind speed and direction
Visibility
Precipitation and precipitation type

Located at virtually every major airport.

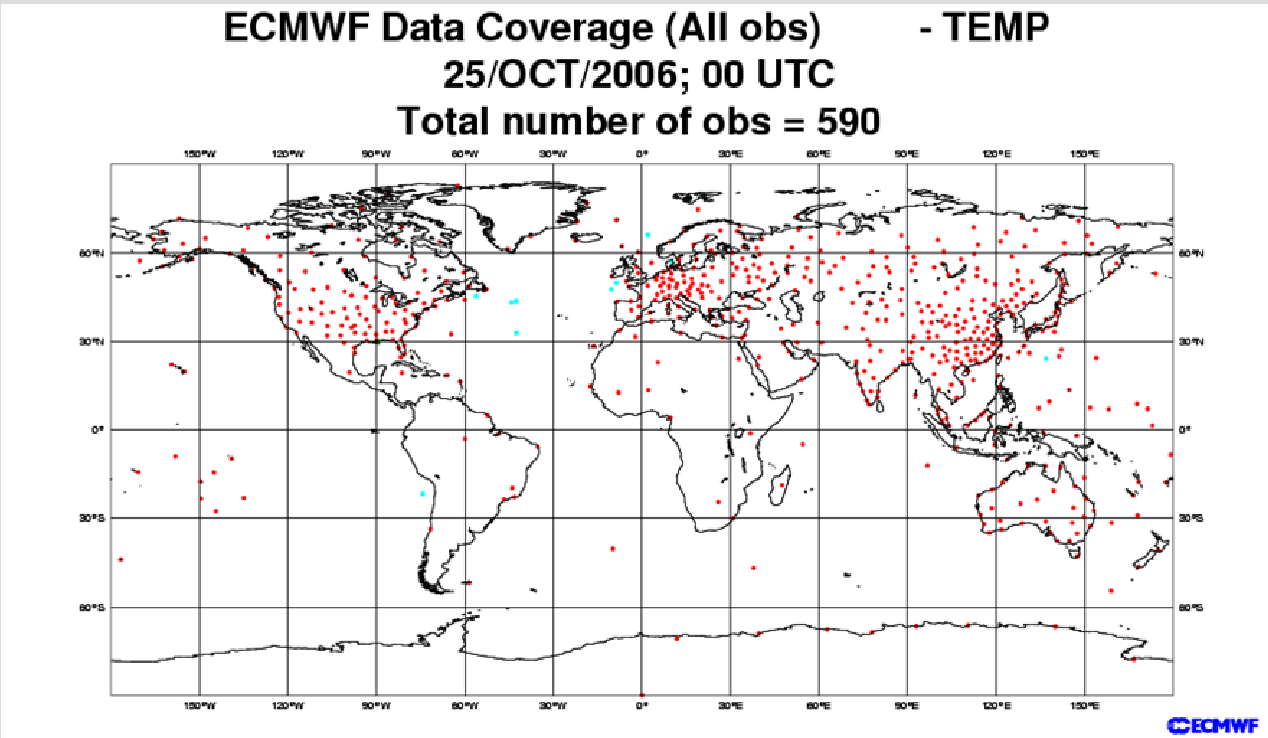
Many observations you see on a surface map are taken from ASOS.

Analysis phase: Ocean data

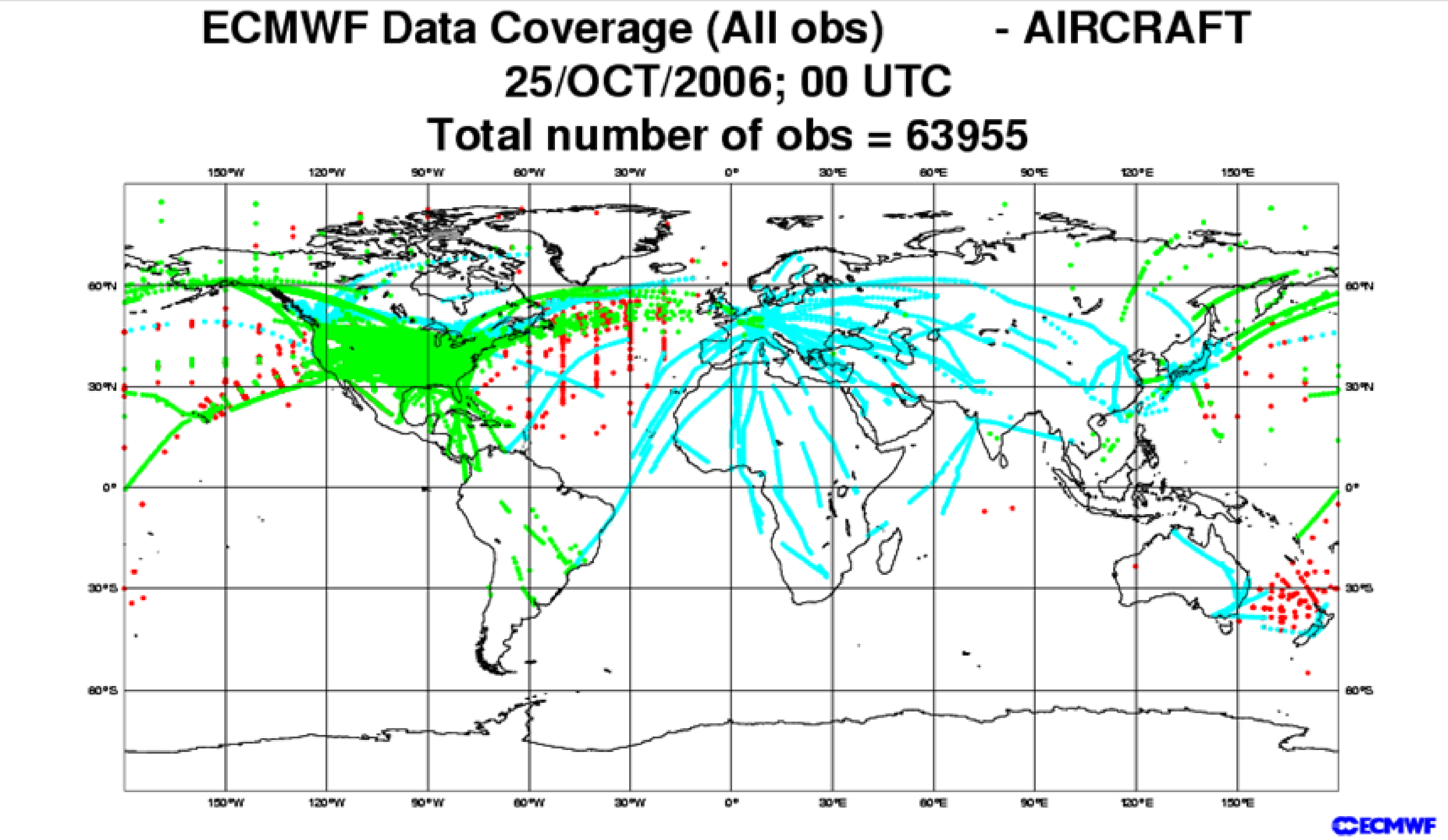


Drifting and moored ocean buoys.

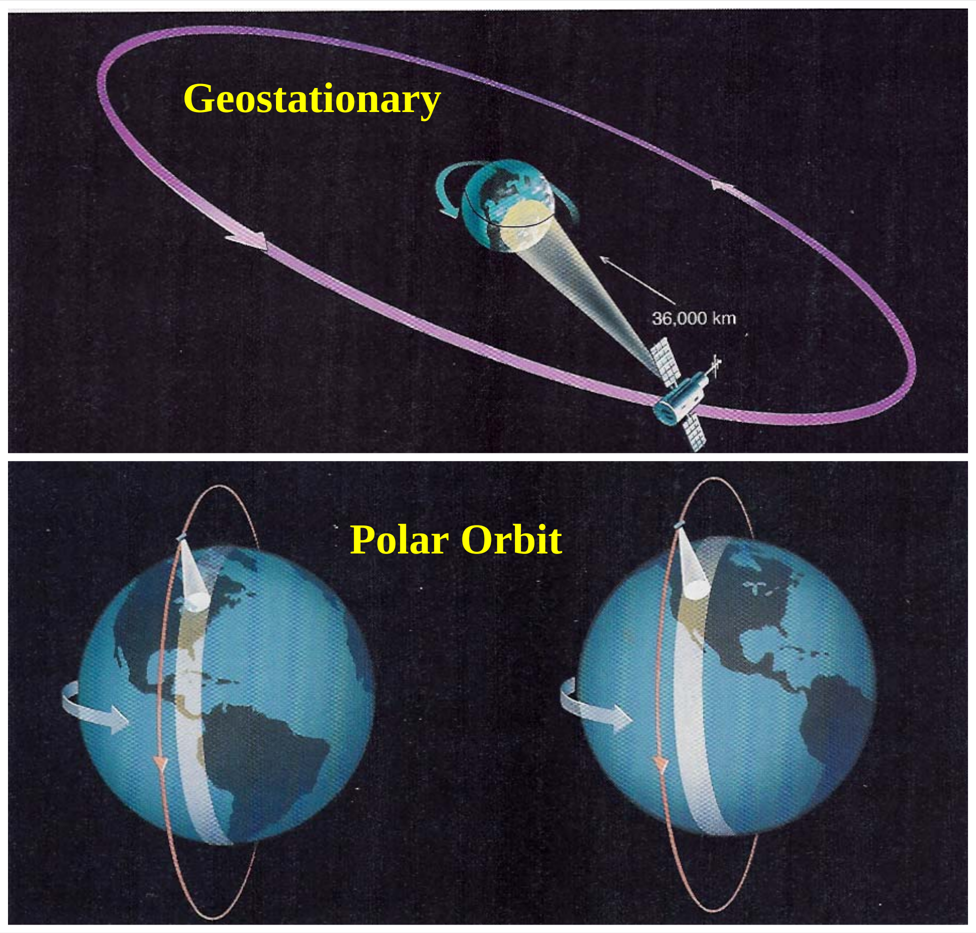
Analysis Phase: Upper air data from radiosondes (weather balloons)



Analysis Phase: Aircraft reports



Analysis Phase: Satellites



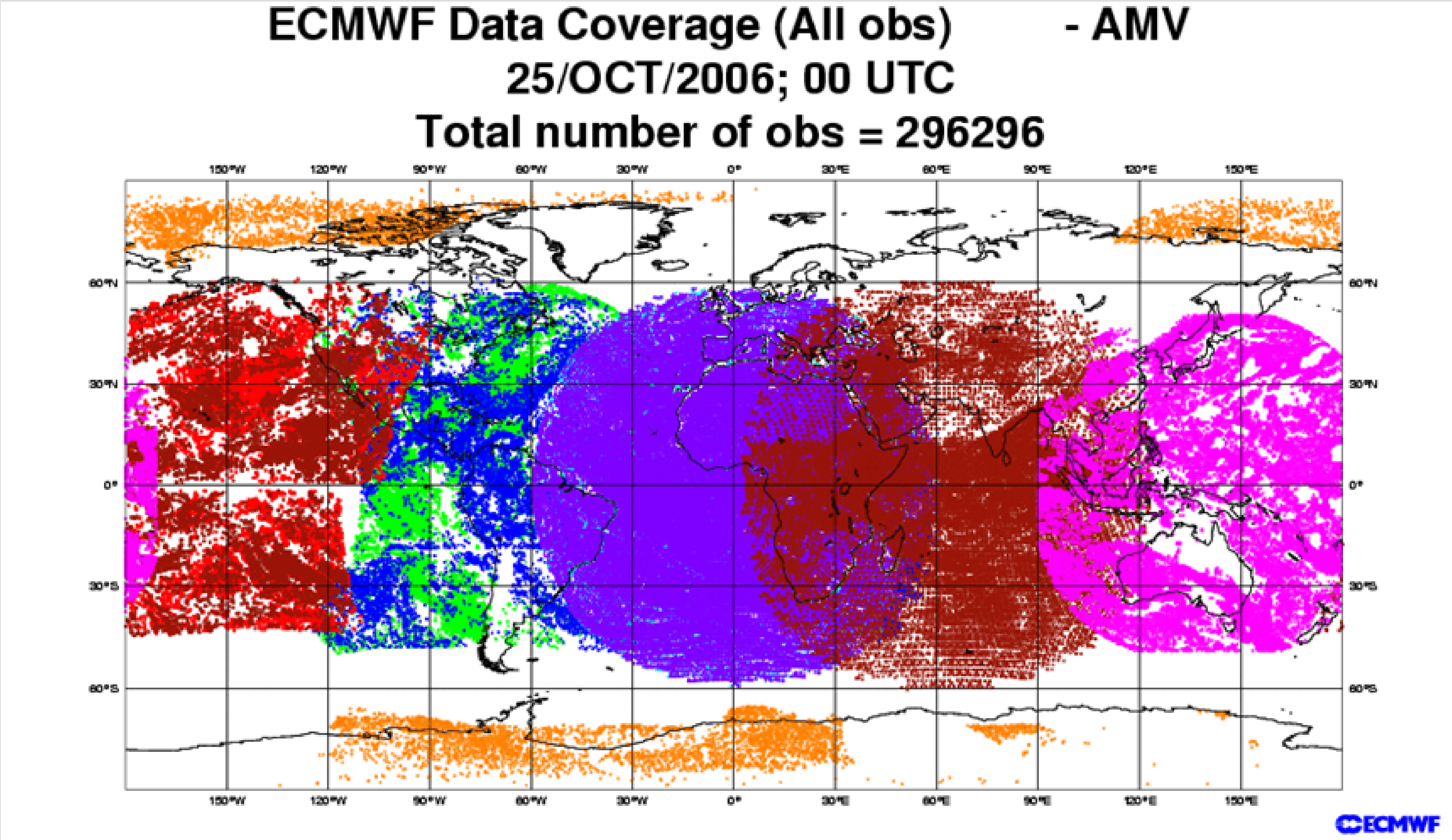
<u>Geostationary</u>:

Fixed over one location at all times directly over equator.

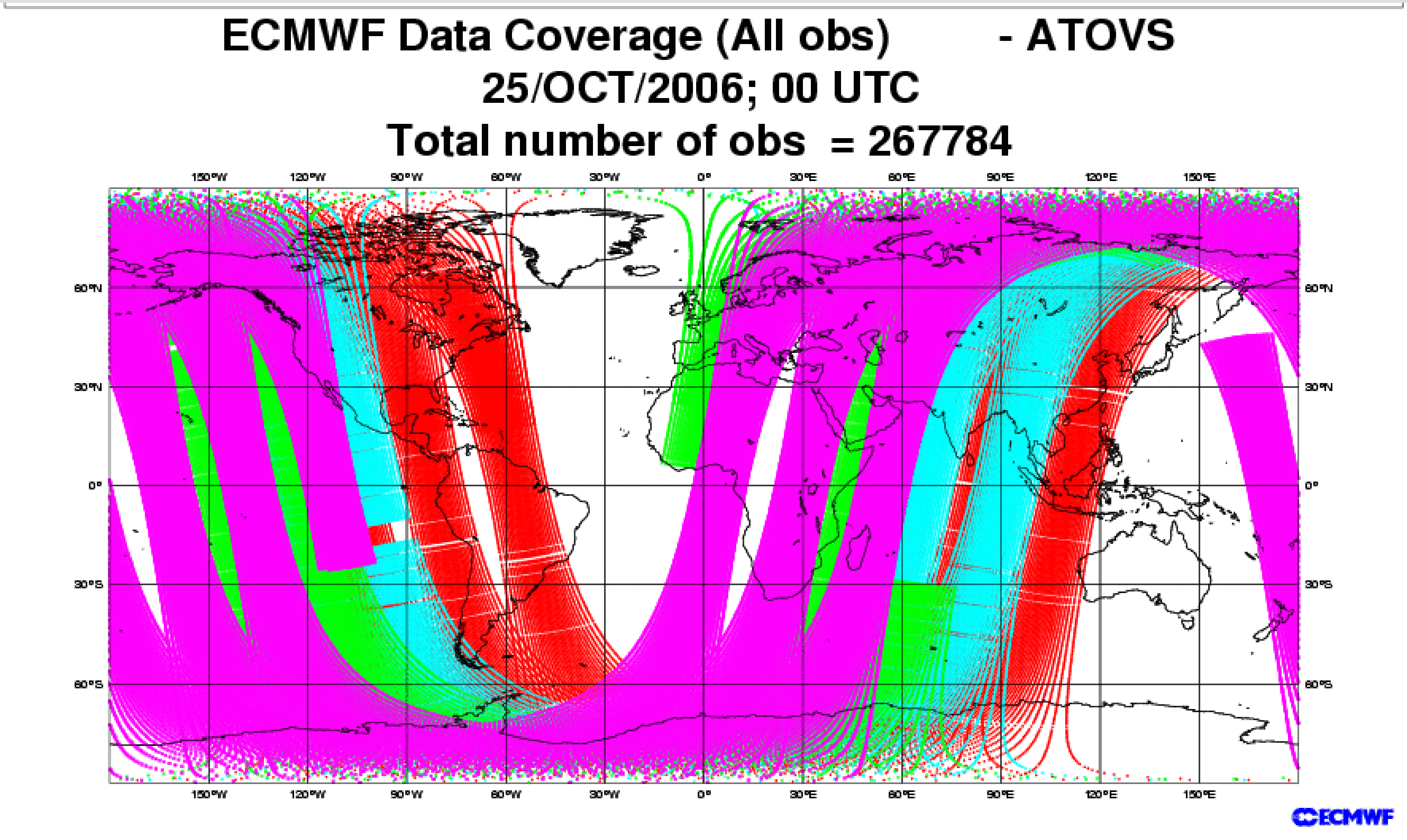
<u>Polar:</u>

Orbit over the poles, covering the Earth in swaths.

Geostationary satellite data coverage



Polar satellite data coverage

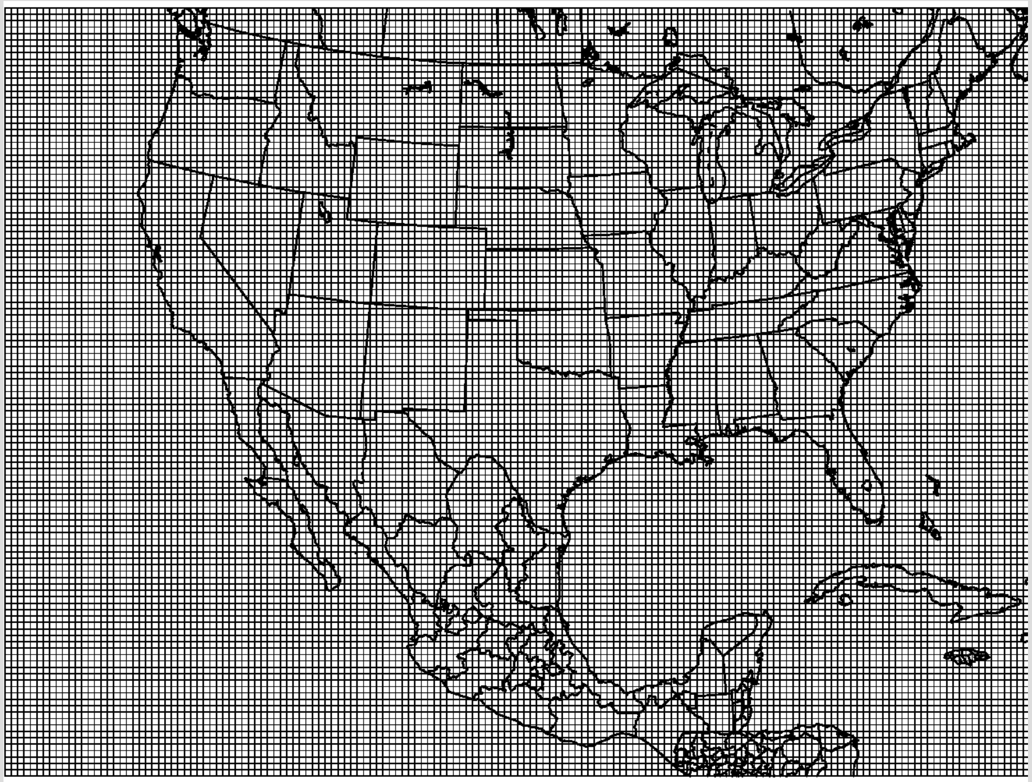


So we get all that data, say about every six hours or so.

Now what?

Objective Analysis

Data must be interpolated to some kind of grid so we can run the numerical weather prediction model—this is called the initial analysis.



Grid spacing = 35 km

For a regional model these are equally spaced points.

Now the “fun” begins—actually running the model to make a prediction!

But how do NWP models work?

Not a simple answer!!

Structure of atmospheric models

Dynamical Core

Mathematical expressions of

Conservation of motion (i.e. Newton's 2nd law $F = ma$)
Conservation of mass
Conservation of energy
Conservation of water

These must be discretized to solve on a grid at given time interval, starting from the initial conditions (analysis).

Parameterizations

One dimensional column models which represent processes that cannot be resolved on the grid.

Called the model "physics"—but it is essentially engineering code.

Equations represented in dynamic core
MUST SOLVE AT EVERY GRID POINT!

MASS CONSERVATION $\partial\rho/\partial t = -(\nabla \cdot \rho\vec{V}),$

ENERGY CONSERVATION $\partial\theta/\partial t = -\vec{V} \cdot \nabla\theta + S_\theta,$

CONSERVATION OF MOTION $\partial\vec{V}/\partial t = -\vec{V} \cdot \nabla\vec{V} - 1/\rho\nabla p - g\vec{k} - 2\vec{\Omega} \times \vec{V}.$

CONSERVATION OF MOISTURE $\partial q_n/\partial t = -\vec{V} \cdot \nabla q_n + S_{q_n}, \qquad n = 1, 2, 3,$

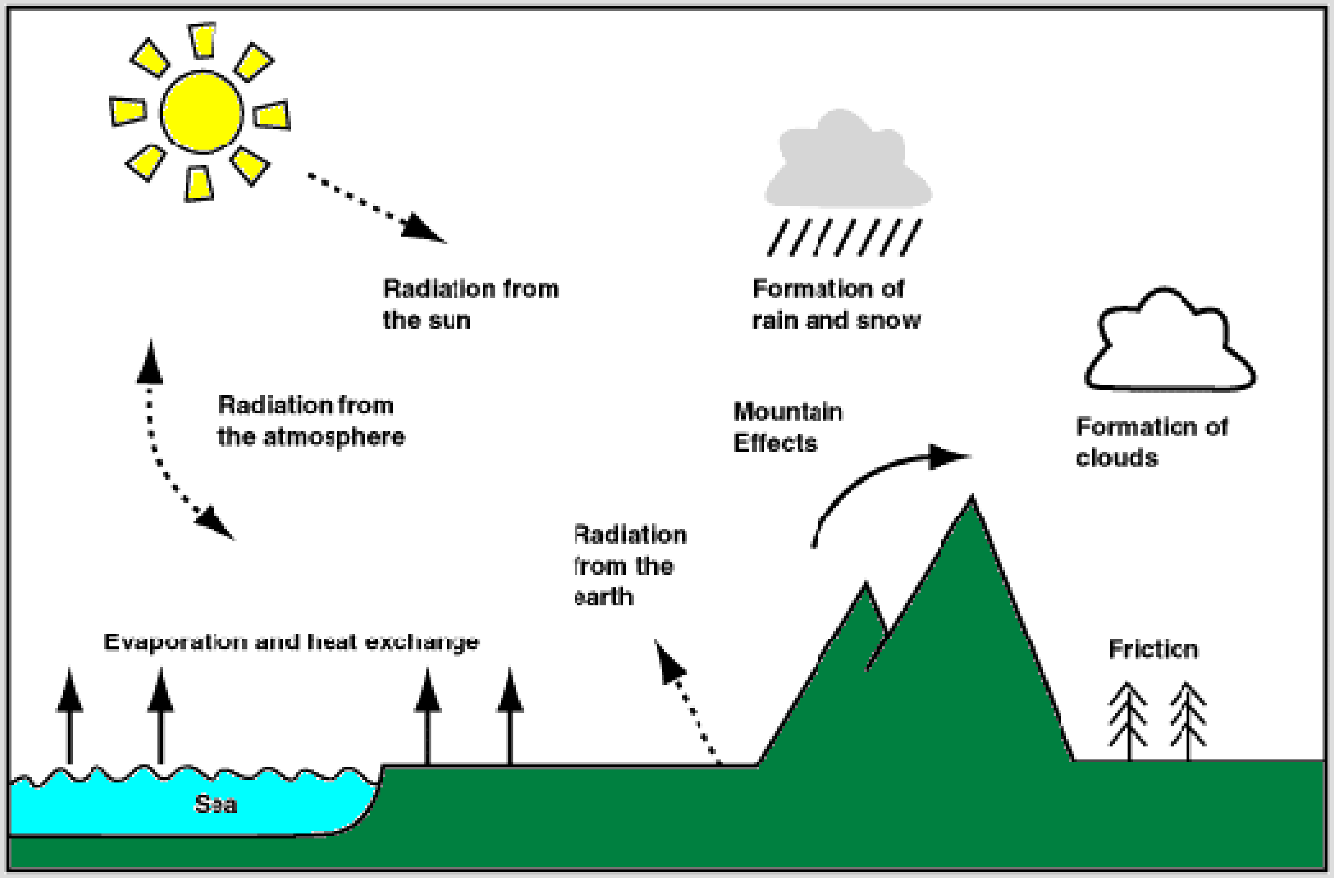
(Pielke 2002)

<u>Why is just doing this REALLY, REALLY HARD?</u>

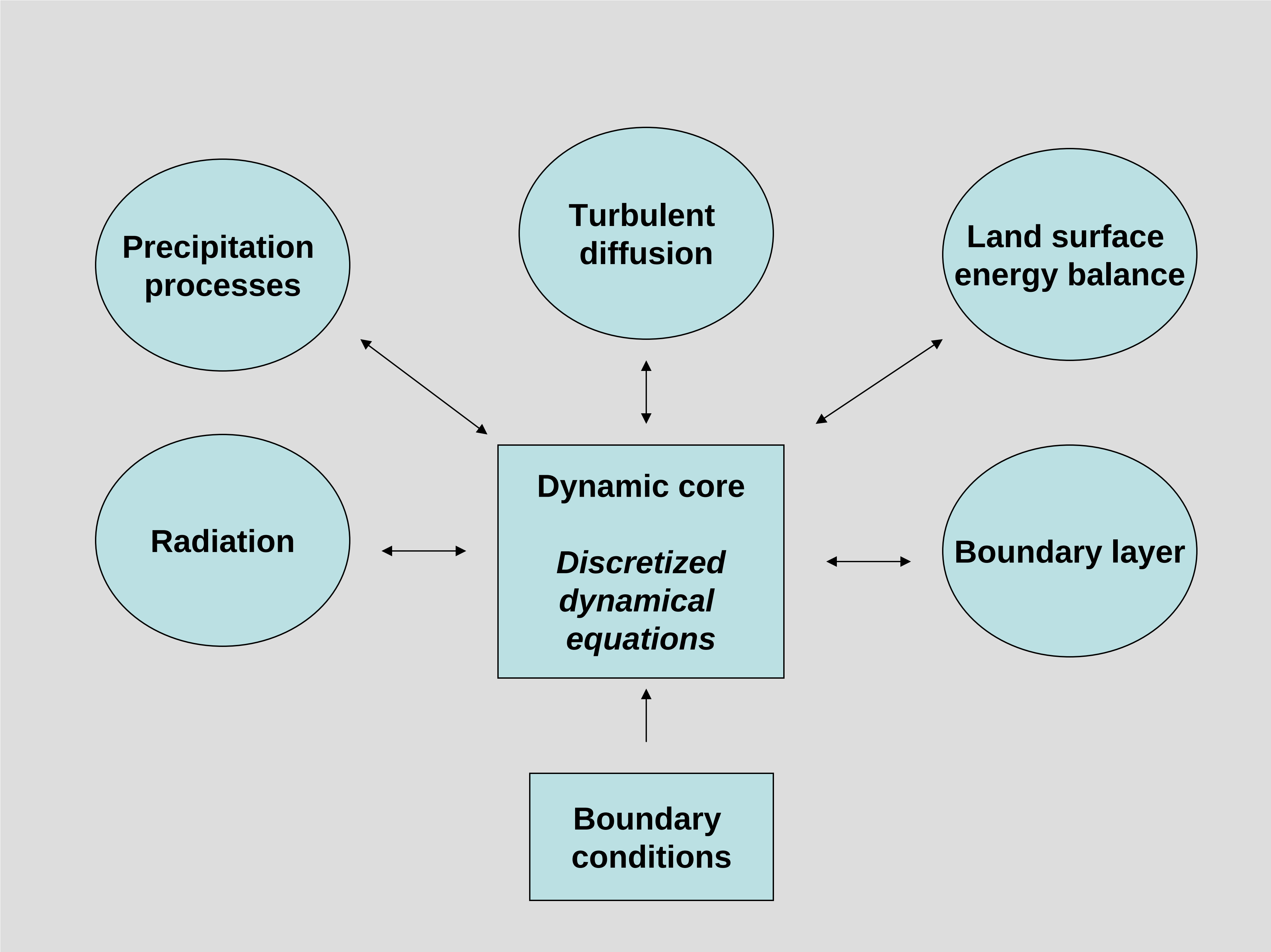
Have to ___________ the equations, so they can be solved on a grid.
Are the equations linear or non-linear?

We haven't even accounted for parameterizations yet!

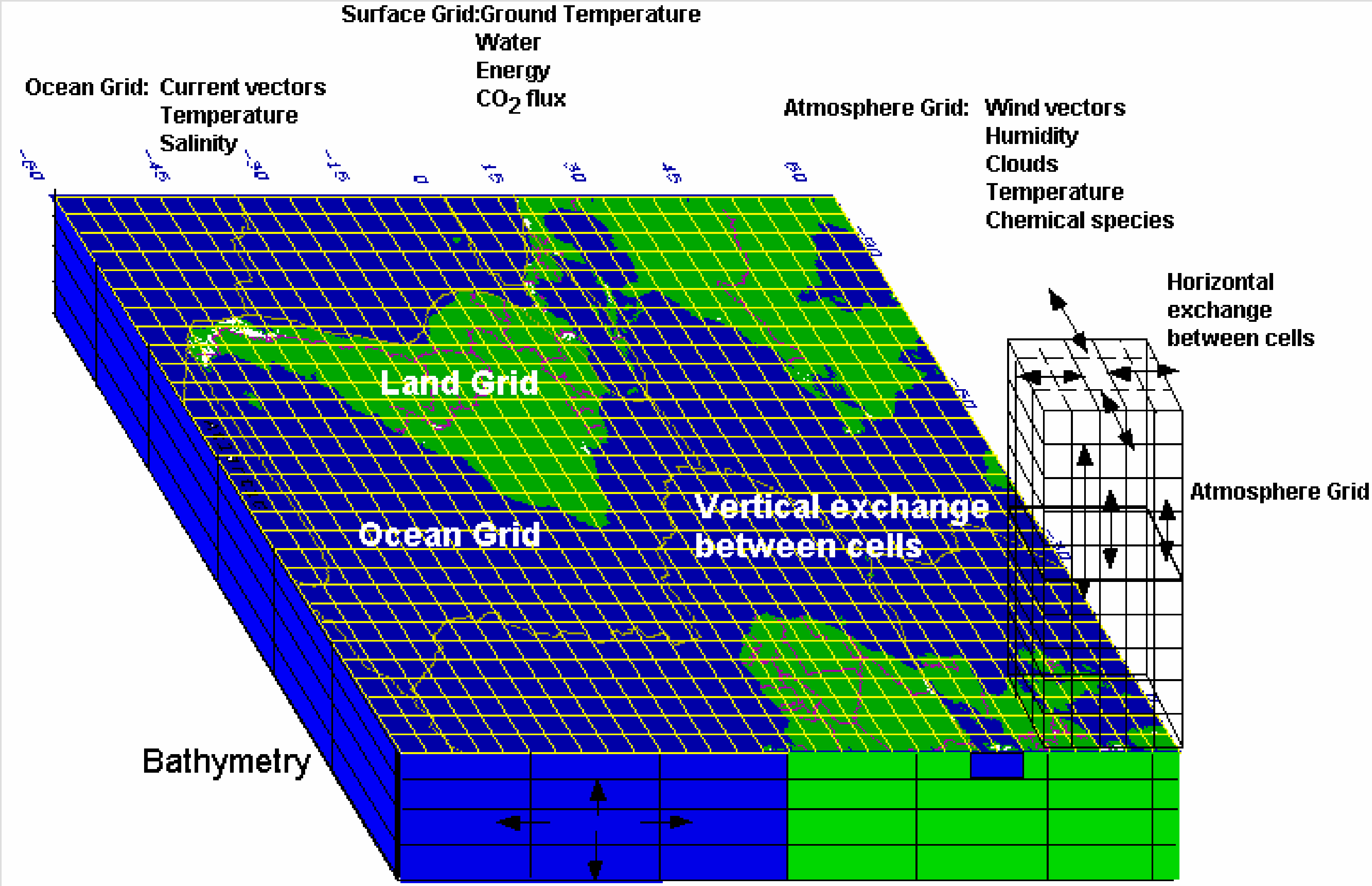
Parameterized processes
One-dimensional models



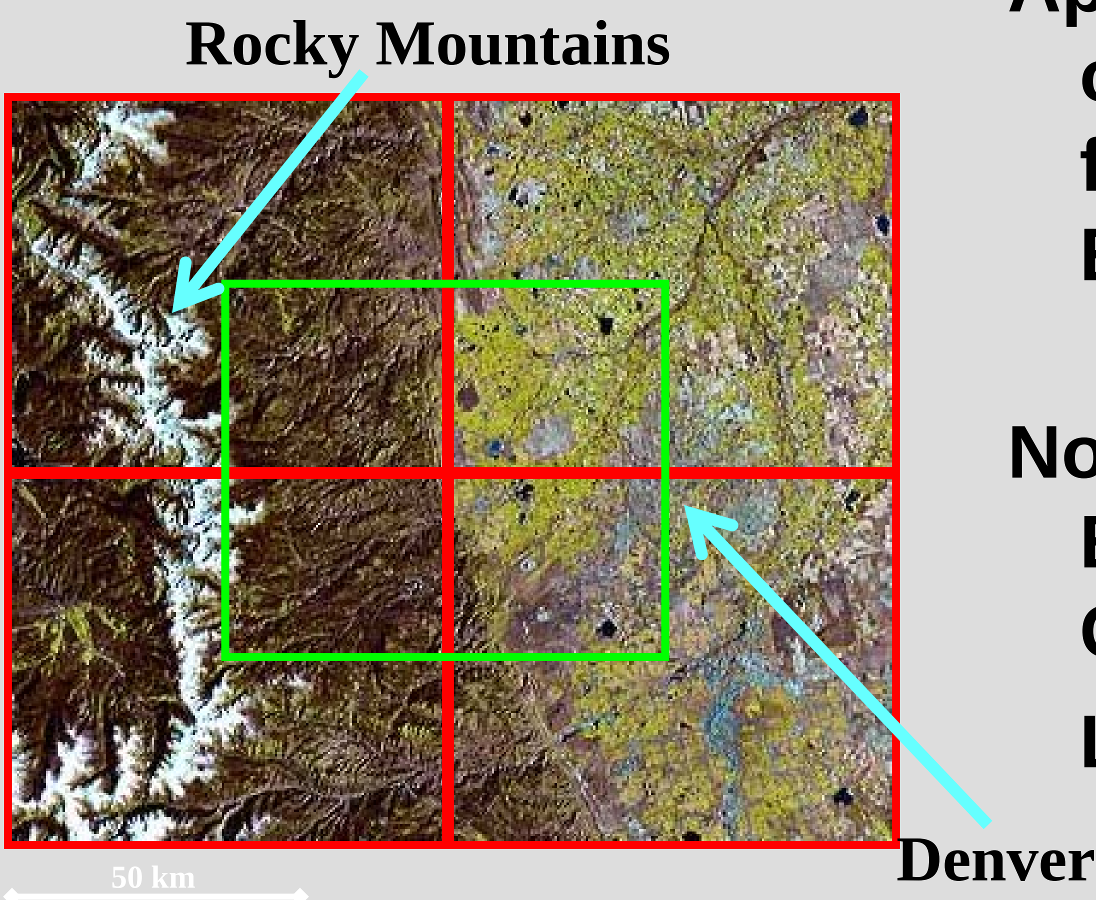
MOST OF THESE REPRESENTED AS 1-D PROCESSES—WITH ESSENTIALLY ENGINEERING CODE.



Precipitation processes
Turbulent diffusion
Land surface energy balance
Radiation
Dynamic core
Discretized dynamical equations
Boundary layer
Boundary conditions


Surface Grid:Ground Temperature
Water
Energy
CO_2 flux
Ocean Grid: Current vectors
Temperature
Salinity
Atmosphere Grid: Wind vectors
Humidity
Clouds
Temperature
Chemical species
Horizontal exchange between cells
Land Grid
Ocean Grid
Vertical exchange between cells
Atmosphere Grid
Bathymetry

“A Lot Happens Inside a Grid Box”
(Tom Hamill, CDC/NOAA)

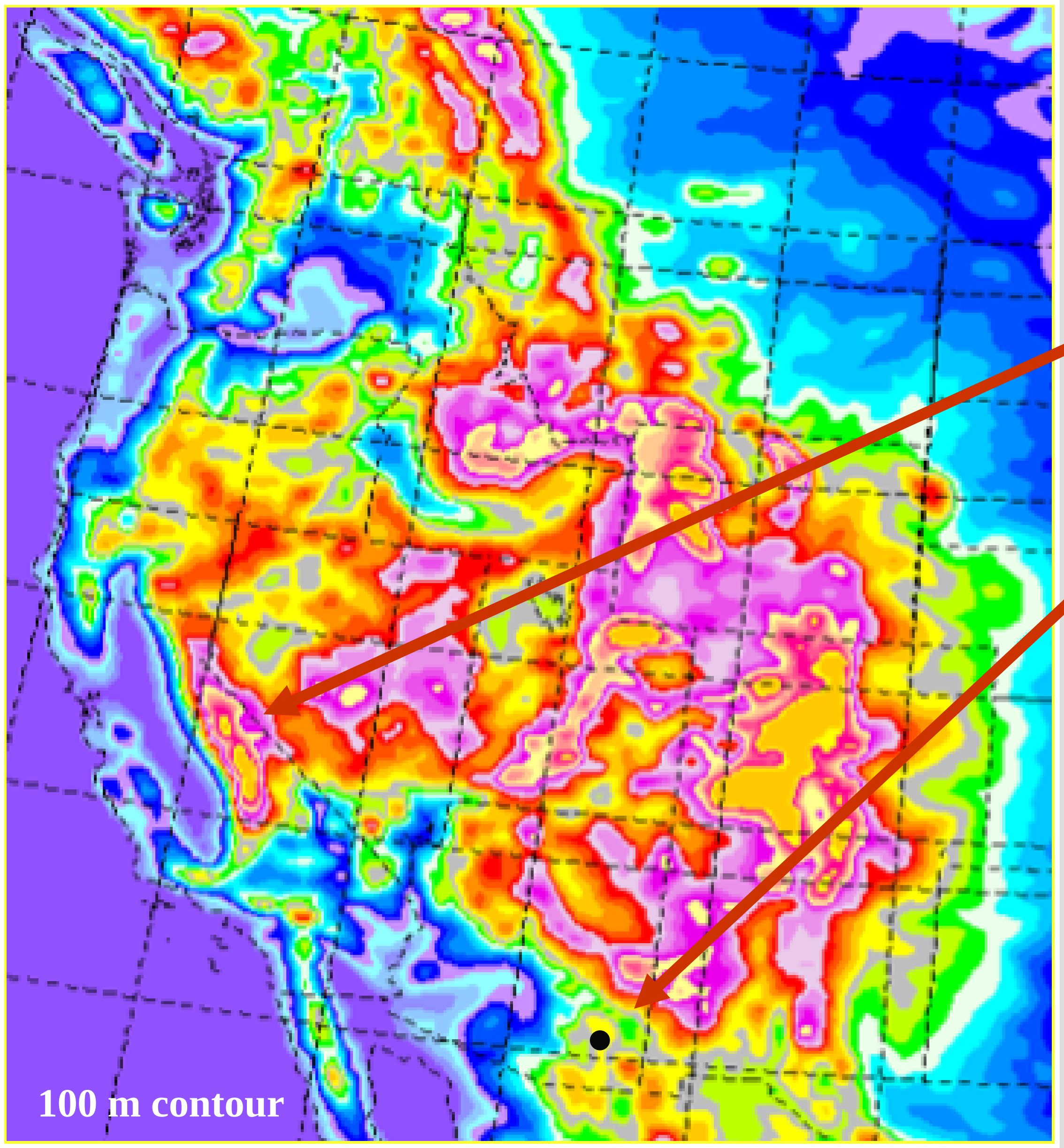


Source: www.aaccessmaps.co

Approximate Size of One Grid Box for NCEP Global Ensemble Model

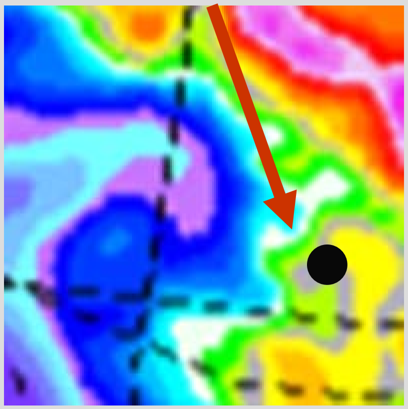
Note Variability in Elevation, Ground Cover, Land Use

13 km Model Terrain



Big mountain ranges, like the Sierra Nevada, are resolved.

But isolated peaks, like the Catalina's, are not evident.



Summary of Lecture 24

Weather and climate forecasting is really important, but a very challenging problem.

Simple approaches to forecasting include: persistence, trend, climatology, and analog. It must be demonstrated that any other forecasting methodology can beat these to show it's useful.

NWP is the use of a physical and mathematical model to represent the atmosphere, starting from an observed state at an initial time.

In the analysis phase of NWP, data is gathered from a variety of sources, such as: surface stations, buoys, radiosondes, aircraft, and satellites. These data are then objectively analyzed to a grid.

A NWP model consists of a dynamical core and (one-dimensional) parameterizations to represent sub-grid scale processes.

"Run" a NWP model by solving the dynamical equations and parameterizations forward in time.