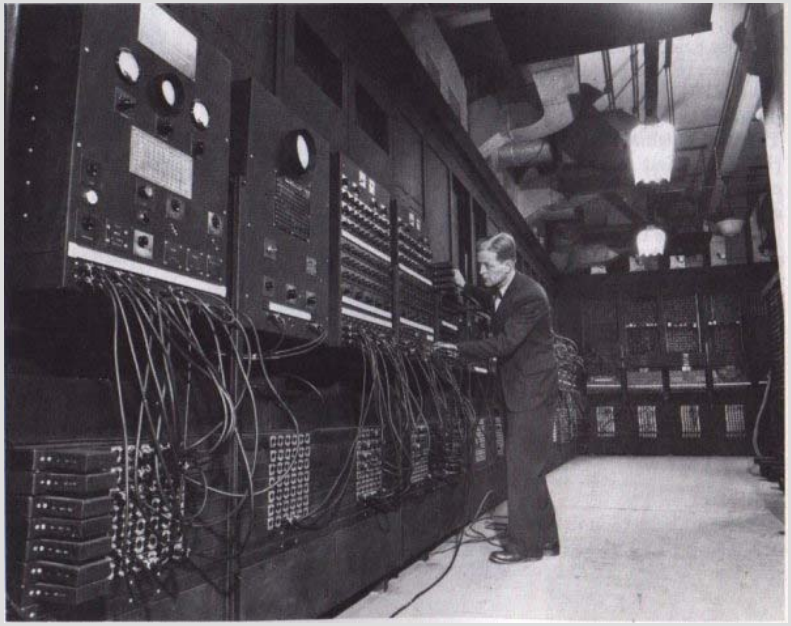
NATS 101
Section 13: Lecture 25

Weather Forecasting
Part II

NWP's First Baby Steps: Mid-Twentieth Century



ENIAC
One of the first computers

It wasn't until the development of computers in the 1940s and 1950s that NWP could be even attempted.

Even at that, the very first NWP models were pretty basic (simple dynamical core, no parameterizations)

Hardware unstable: vacuum tubes in the giant computers often blew.

How were weather forecast made before this time??

Modern NWP

NCAR SUPERCOMPUTER
(Millions of $$)

LINUX PC CLUSTER
(Tens of thousands of $$)

Today, NWP models are typically run on supercomputers or networked clusters of PCs.

We use a Linux PC cluster within the UA Atmospheric Sciences Dept. to generate forecasts during the monsoon season.

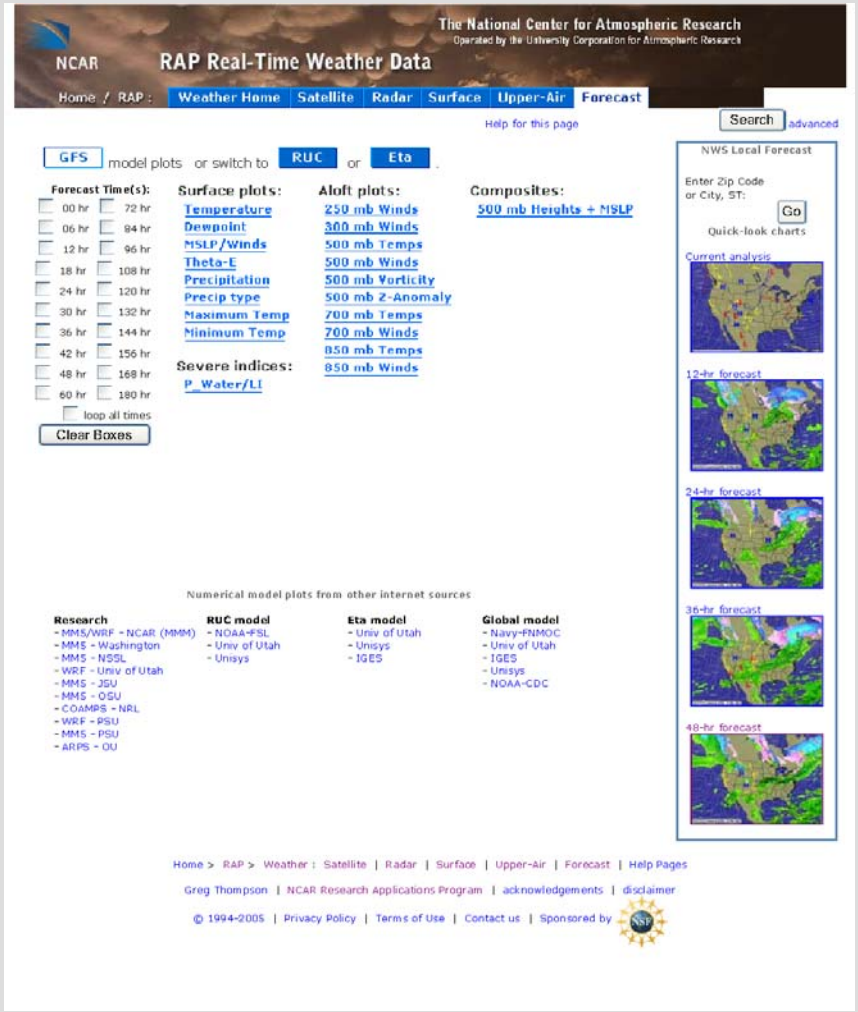
Steps in Numerical Weather Prediction

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

2. PREDICTION: Run the NWP model

3. POST-PROCESSING: Display and use products

Post-Processing
Data Transmission and Display



Model runs executed at a major center (e.g. National Center for Environmental Prediction)

Computer produces forecast maps of the projected state of the atmosphere.

Model data disseminated to the public and the National Weather Service Offices (primarily via the internet now).

Post Processing:
Making the forecast

Advanced Weather Interactive Processing System (AWIPS) at Tucson NWS Office

Experienced meteorologists at the National Weather Service use computer forecasts and knowledge of local weather and model performance to make the forecast.

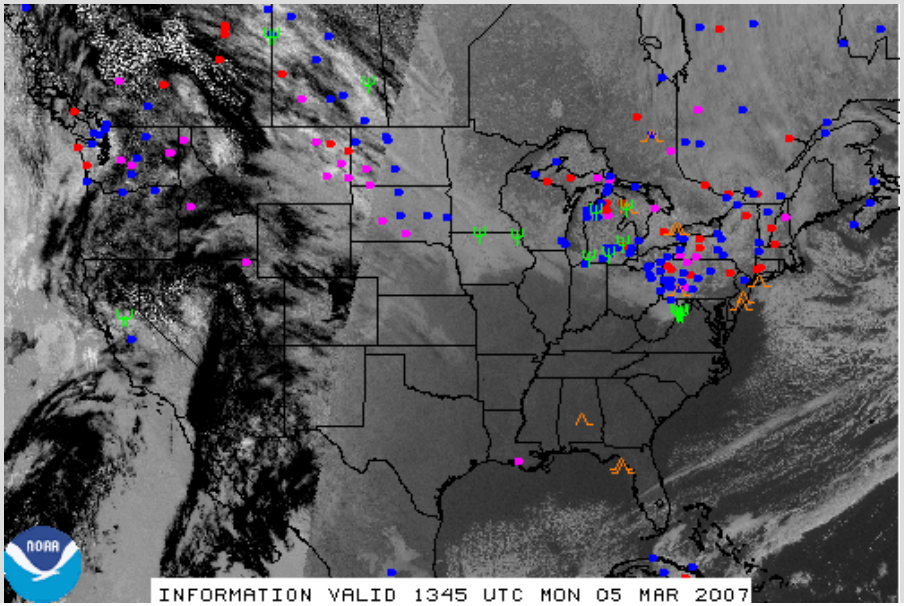
NWS Responsibility (from Erik Pytlak)

- Public forecasts
  - Temperatures
    - Max
    - Min
  - Precipitation
    - Snow
    - Rain
    - Probability
    - Amount
  - Wind
  - Types of Weather
    - Rain
    - Snow
    - Extreme Temperatures
  - Sky Cover

- Fire Weather Forecasts
  - All Elements of Public
  - Relative Humidity
  - Fire Weather indices
    - Haines
    - LAL
    - Fuel Moisture

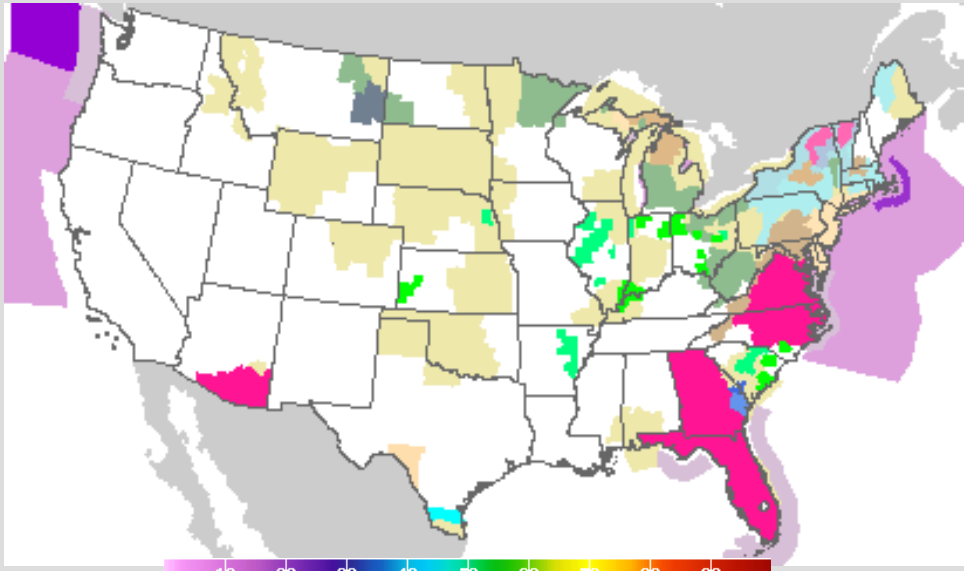
NWS Responsibility

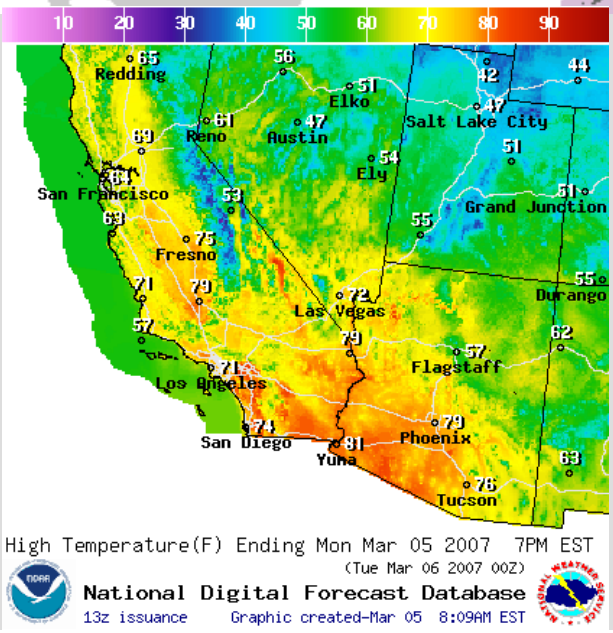
- Aviation Forecasts
  - Terminal Aerodrome Forecast (TAF)
    - By the minute forecast for pilots
  - Transcribed Weather Broadcast (TWEB)
    - Route forecast for pilots
  - Outlook briefings for pilots
  - National Air Traffic Management System support



NWS Responsibility

- Digital forecasts
  - County, “zone” and lat/lon (GIS) coordinate watches, warnings and advisories
  - 2.5km x 2.5km grid forecasts
  - Eventually will to replace “text”





Post Processing
Forecast to news media and public

Finally, news media broadcast the forecasts to the public.

What happens if there is a weather warning?

The TV weather person is likely a credentialed meteorologist too. *If not, I suggest change the channel!!*

Weather vs. Climate Forecast

Weather Forecast

Run NWP model for a period up to two weeks (synoptic timescale)

***Objective*: Forecast relatively precise weather conditions at a specific time and place**

Example*: *NWP model suggests it will likely rain tomorrow afternoon because mid-latitude cyclone will occur over the U.S.

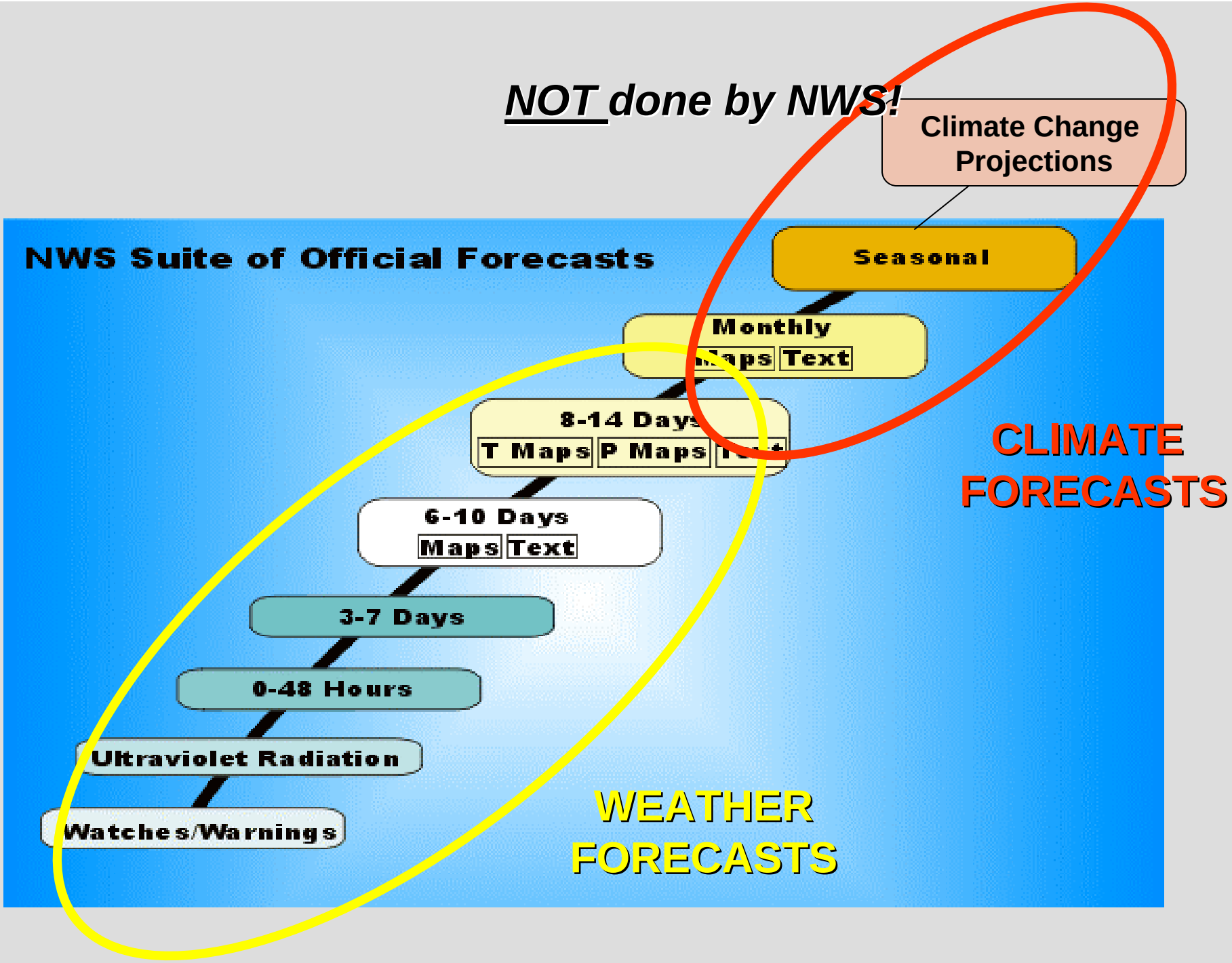
Climate Forecast

Run NWP model for a period longer than two weeks.

***Objective*: Forecast probability of deviation from average conditions, or climatology.**

Example*: *In the fall before an El Niño winter, a NWP model forced with warm sea surface temperatures in eastern tropical Pacific projects a circulation pattern favorable for above-average winter precipitation in Arizona.

NOT DESIGNED TO PREDICT EXACT WEATHER FOR SPECIFIC PLACES/TIMES MONTHS IN ADVANCE.


NOT done by NWS!
Climate Change Projections
NWS Suite of Official Forecasts
Seasonal
Monthly
Maps
Text
8-14 Days
T Maps
P Maps
6-10 Days
Maps
Text
3-7 Days
0-48 Hours
Ultraviolet Radiation
Watches/Warnings
CLIMATE FORECASTS
WEATHER FORECASTS

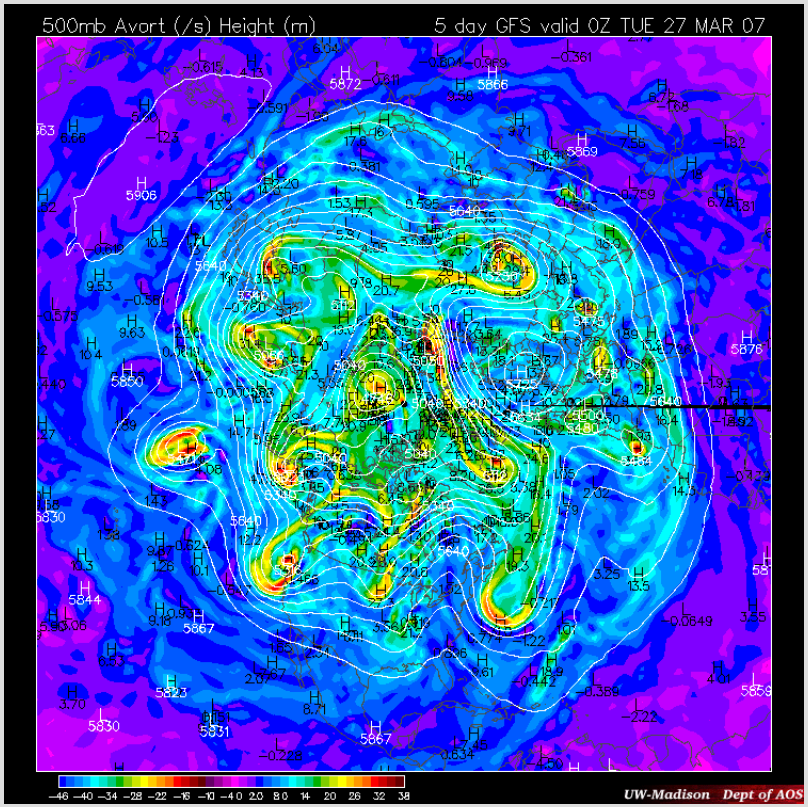
NWP model types to generate weather and climate forecasts

General Circulation Model

Vs.

Limited Area Model

General Circulation Model (GCM)



NCEP Global Forecast System (GFS) Model
Grid spacing = 100s of km

NWP model run over the entire globe

<u>Utility</u>:

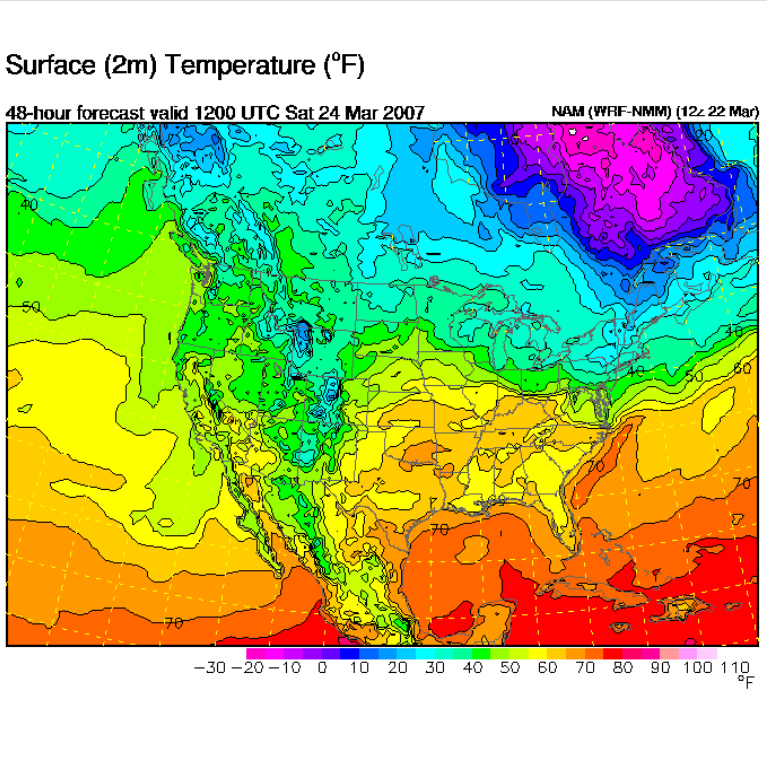
Forecast the evolution of large-scale features, like ridges and troughs.

Use to generate long-range weather forecasts (beyond three days), climate forecasts and climate change projections.

<u>Disadvantage</u>:

Can’t get the local details right because of course resolution and model physics.

Limited Area Model (LAM)



Weather Research and Forecasting (WRF) Model

NWP model run over a specific region

<u>Utility</u>:

Very good for short-term weather forecasting (up to 3 days)

Provides high enough spatial resolution for a detailed local forecast (like thunderstorms in AZ).

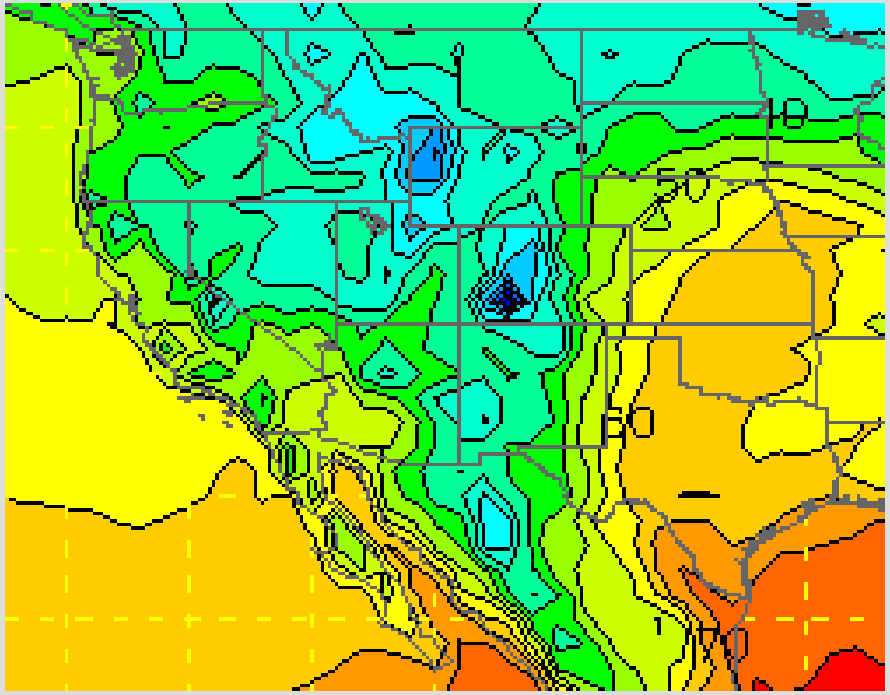
May also be useful for climate forecasting.

<u>Disadvantage</u>:

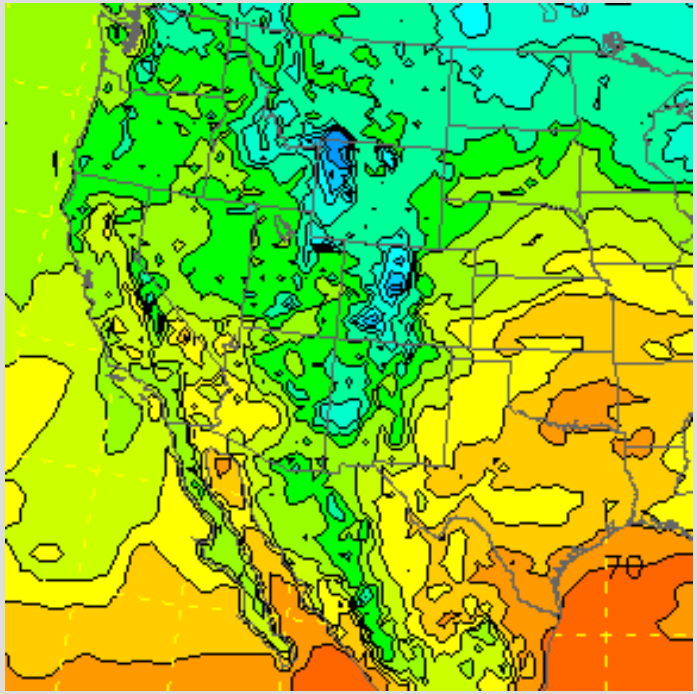
Dependent on a larger-scale model (GCM) for information on its lateral boundaries.

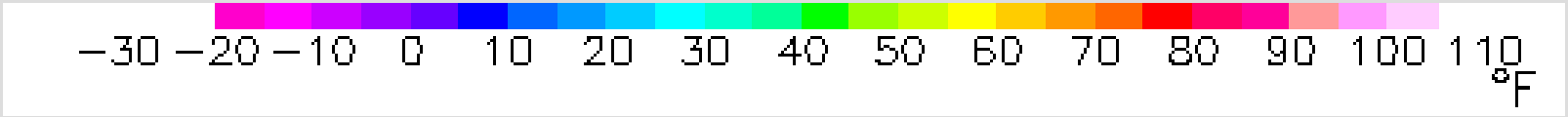
Forecast Surface Temperature
GCM vs. LAM

General Circulation Model

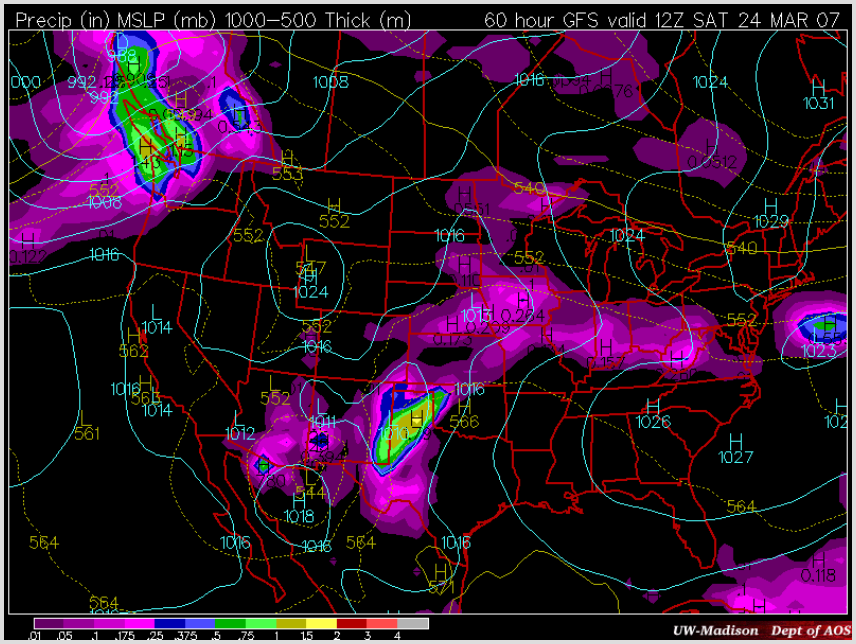


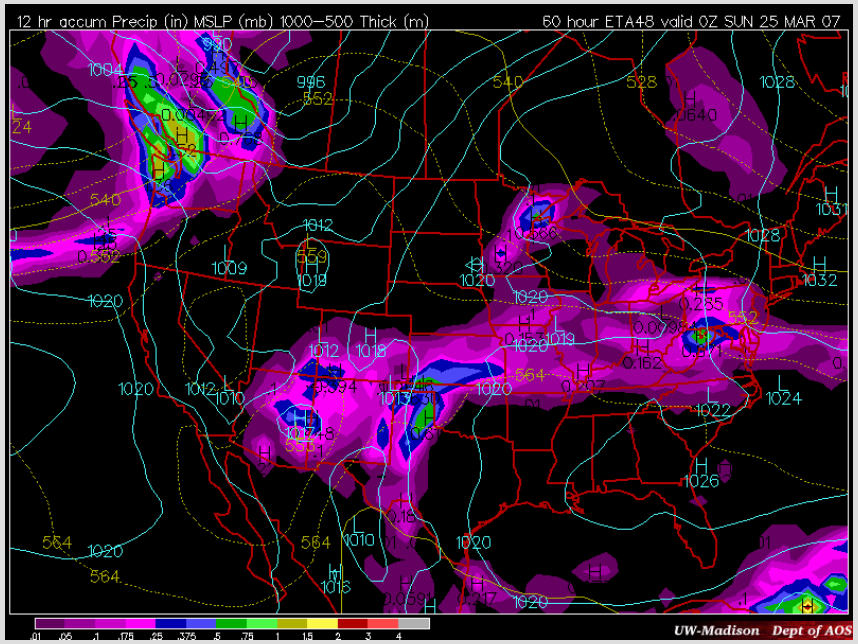
Limited Area Model





Different Models, Different Forecasts!

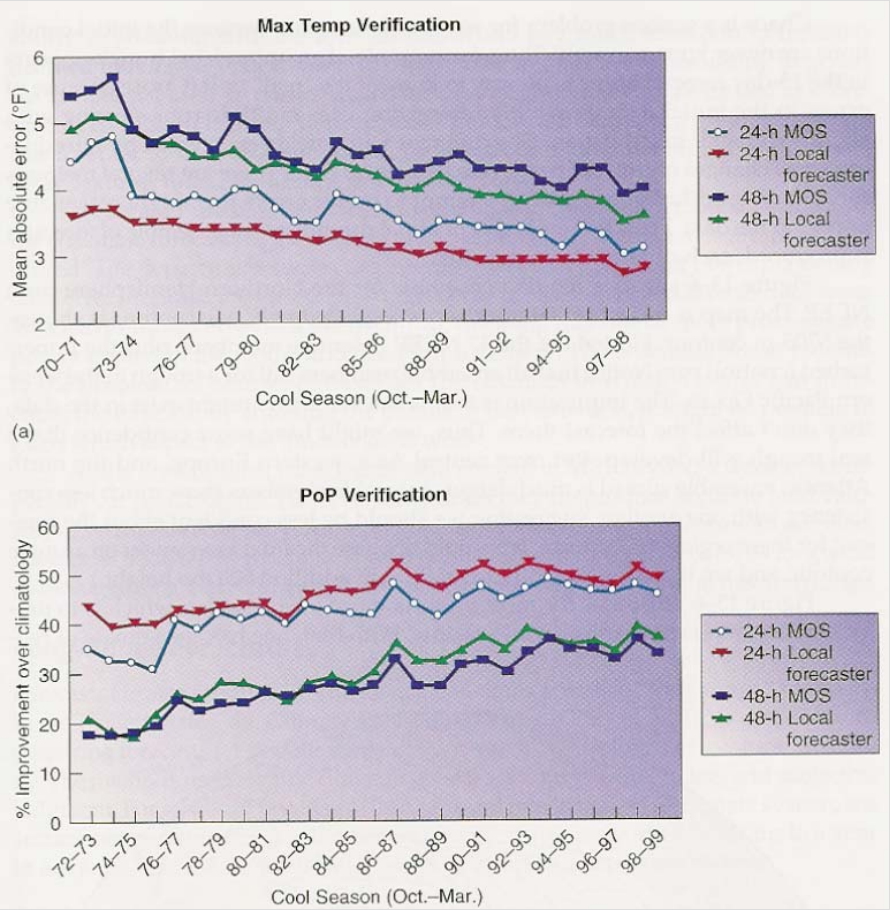




Why different?

Due to all of the various components of the specific modeling system. What are those?

Value Added of the Meteorologist



(Agudo and Burt)

Knowledge of local weather and climate

Experience

Can correct for model biases

Knows how the model works and realizes it isn't just a black box!

<u>MOST IMPORTANT</u>:

ISSUE WATCHES AND WARNINGS WHEN SEVERE WEATHER THREATENS PUBLIC SAFETY.

So why do forecasts go wrong?

***Think about ALL the possible caveats we've already discussed*:**

Model sensitivity

Inadequate data to specify the initial state (analysis)

Unresolved scaled scales and physical processes

Still is a lot about processes in weather and climate we don't understand

An inexperienced meteorologist

EVEN IF WE COULD "FIX" ALL OF THE ABOVE, IT WOULD STILL BE IMPOSSIBLE TO MAKE SKILLFUL AND ACCURATE WEATHER FORECASTS USING A NUMERICAL MODEL BEYOND ABOUT TWO WEEKS.

Chaos: A Fixed Limit to Weather Forecasting—Independent of the specific model

Chaos: **System exhibits erratic behavior in that small errors in the specification of the initial state lead to unpredictable changes sometime in the future.**

In NWP, there will ALWAYS uncertainty in the specification of the initial state—no way around it!

Bottom line: After about two weeks, can't rely on NWP to provide an accurate and skillful weather forecast.

Sometimes called the "butterfly effect"

Dr. Ed Lorenz
Professor, MIT
First one to describe chaos

Beyond the two week limit, any forecast with a NWP model is a climate forecast because it has lost the sensitivity to the initial state.

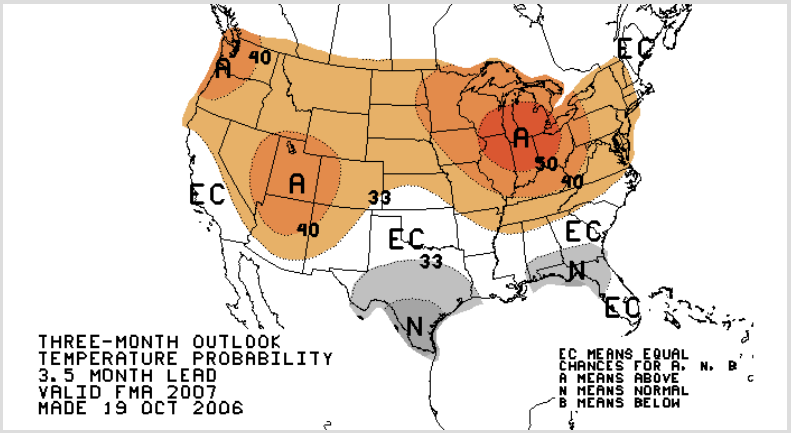
Why is there STILL is value in the climate forecast?

These can project the probability of departure from average conditions due to factors that vary on a long-time scale

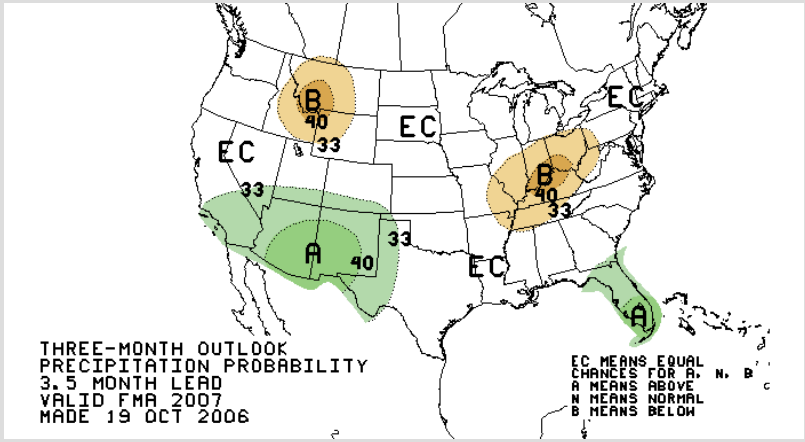
Examples of long term forcing:
ocean temperatures, soil moisture, increase in CO_2

CPC Winter Climate Forecast vs. Obs.

Temperature forecast



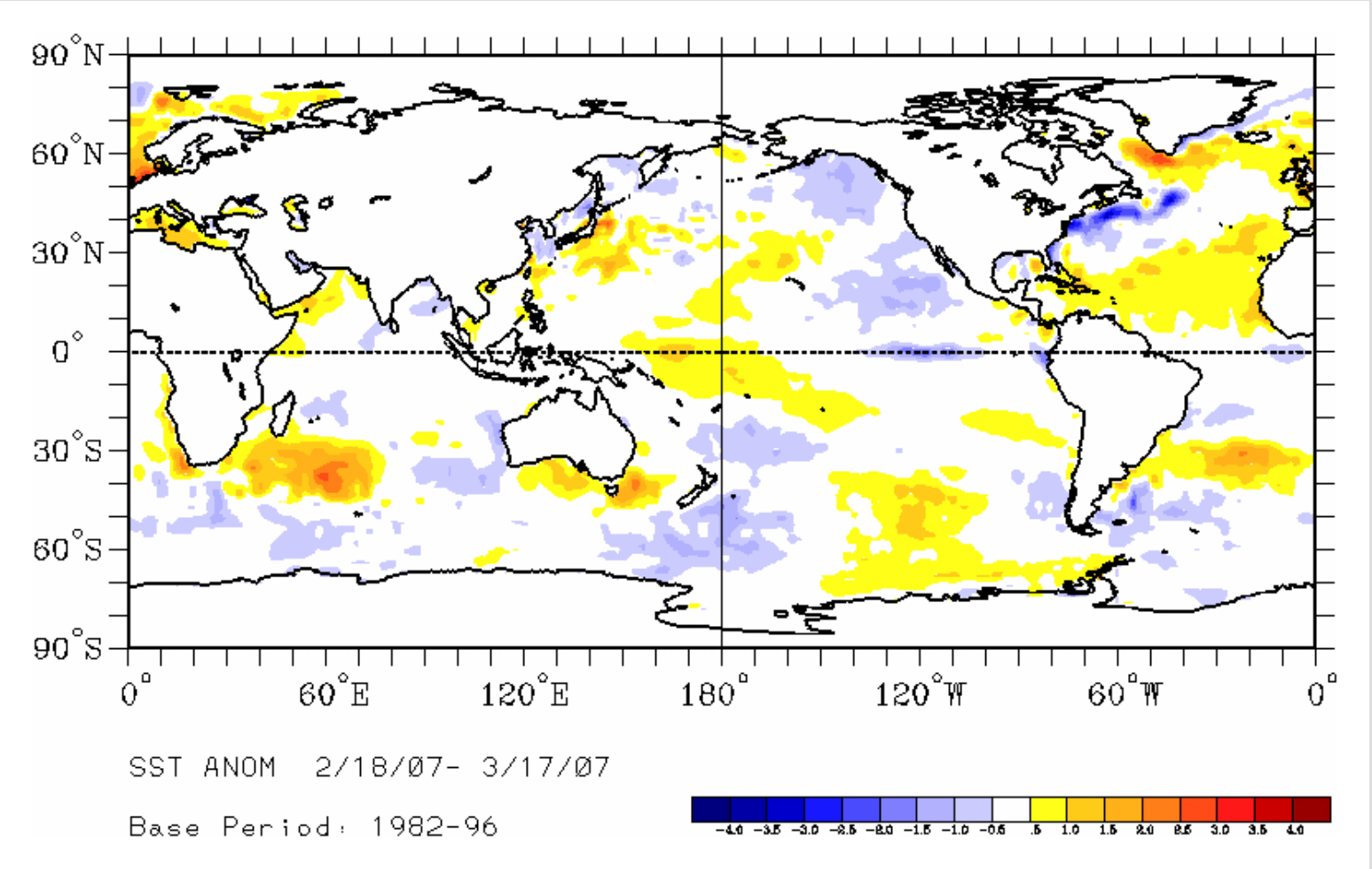
Precipitation forecast



Observed precipitation anomalies

Why was this 2007 forecast a bust in Arizona?

Because no more El Niño!



• TABLE 13.3

Forecast at a Glance–Forecasting the Weather from Local Weather Signs: A few forecasting rules that may be applied when making a short-range local weather forecast.

OBSERVATION	INDICATION	LOCAL WEATHER FORECAST
Surface winds from the S or from the SW; clouds building to the west; warm (hot) and humid (pressure falling)	Possible cool front and thunderstorms approaching from the west	Possible showers; possibly turning cooler; windy
Surface winds from the E or from the SE, cool or cold; high clouds thickening and lowering; halo around the sun or moon (pressure falling)	Possible approach of a warm front	Possibility of precipitation within 12–24 hours; windy (rain with possible thunderstorms during the summer; snow changing to sleet or rain in winter)
Strong surface winds from the NW or W; cumulus clouds moving overhead (pressure rising)	A low-pressure area may be moving to the east, away from you; and an area of high pressure is moving toward you from the west	Continued clear to partly cloudy, cold nights in winter; cool nights with low humidity in summer
Winter night		
(a) If clear, relatively calm with low humidity (low dew-point temperature)	(a) Rapid radiational cooling will occur	(a) A very cold night
(b) If clear, relatively calm with low humidity and snow covering the ground	(b) Rapid radiational cooling will occur	(b) A very cold night with minimum temperatures lower than in (a)
(c) If cloudy, relatively calm with low humidity	(c) Clouds will absorb and radiate infrared (IR) energy to surface	(c) Minimum temperature will not be as low as in (a) or (b)
Summer night		
(a) Clear, hot, humid (high dew points)	(a) Strong absorption and emission of IR energy back to surface by water vapor	(a) High minimum temperatures
(b) Clear and relatively dry	(b) More rapid radiational cooling	(b) Lower minimum temperatures
Summer afternoon		
(a) Scattered cumulus clouds that show extensive vertical growth by mid-morning	(a) Atmosphere is relatively unstable	(a) Possible showers or thunderstorms by afternoon with gusty winds
(b) Afternoon cumulus clouds with limited vertical growth and with tops at just about the same level	(b) Stable layer above clouds (region dominated by high pressure)	(b) Continued partly cloudly with no precipitation; probably clearing by nightfall

Summary of Lecture 25

Post processing steps to NWP include: data transmission and display, making the forecast and disseminating the information the media and public.

A weather forecast is any forecast up to two weeks, before the NWP loses the sensitivity to the initial conditions.

A climate forecast is any forecast beyond two weeks, and depends on long-term forcing factors (ocean, land, CO_2)

The two types of NWP models are:

- **General circulation: coarse resolution, global coverage**
- **Limited Area: fine resolution, regional coverage**

The function of the meteorologist is to 1) make forecasts based on the evaluation of model data, observations, and experience and 2) issue watches and warnings.

Forecasts go wrong because of all of the caveats involved in NWP. Chaos imposes a hard limit to weather prediction.

Reading Assignment and Review Questions

Reading: Chapter 14

Chapter 13 Review Questions

Review: 3,4,5,6,7,9,10,12,16

Thought: 4,5