Chapter 13: Weather Forecasting

Forecasting is like driving a car down the road where you are only allowed to look out the back window.
- Source unknown

Utility of weather forecasts
Weather observations and analysis at surface and aloft
Weather forecasting methods
Accuracy versus Skill
Probability forecasts
Numerical (i.e., computer) forecasts
Ensemble forecasting
You can forecast
Watches, warnings, and advisories

Utility of Weather Forecasts

- Meteorologists can't change the weather, but forecasts can help people prepare for it.
  - What to wear
  - Travel (driving, airlines, shipping)
    - US National Weather Service is in Dept of Commerce
  - Construction
  - Agriculture
  - Forest fires
  - Tourism
- Good forecasts are based on good observations and a good understanding of the underlying science.

ASOS: Automated Surface Observing System

- Most surface observations come from ASOS.
- Roughly 1000 ASOS stations in US, operated by National Weather Service, FAA, and military.
- ASOS automatically and electronically measures temperature, relative humidity, pressure, wind speed and direction, rainfall, visibility, height of cloud ceiling (but not cloud type). Also determines whether precipitation is rain or snow and whether there is freezing rain.
- At airports, people are contracted to take hourly observations of cloud type and weather that may be missed by ASOS (high clouds & weather in area)

US Radiosonde Network

- Roughly 92 stations launching twice daily over US.
- N Hemisphere coverage is good for observing mid-latitude cyclones over land but inadequate in space and time to provide good observations of thunderstorms
- Can reach 100,000 ft during 90 minute ascent
- Equipment: about $100 per launch. Few recovered.
- Next generation sondes with GPS will cost about $160 each, so desirable to increase recovery rate. One possibility: glidersonde (glider the size of model airplane equipped with weather instruments). Takes observations as it is lifted by weather balloon. Released from balloon at preset altitude and glides back to launch point.
- Upper air obs info: http://www.ua.nws.noaa.gov/

US Radiosonde Stations

Other Observing Tools in US

- 2 geosynchronous satellites for E & W of US: www.goes.noaa.gov
- 164 Doppler radars covering US; see www.nws.noaa.gov/ost/88dtech.html
- 35 profilers, most in middle third of US, measure wind speed and direction as a function of height, reporting hourly (www.profiler.noaa.gov)

Other Observing Tools in US

- Roughly 500 commercial aircraft carry weather sensors & report 150,000 observations per day, mostly in the upper troposphere (called ACARS, MDCRS, and AMDAR. http://aviationweather.gov/general/pubs/front/docs/jul-03.pdf, http://acweb.fsl.noaa.gov/)
- Anchored buoys in Caribbean & Atlantic; also in the Pacific Ocean along & near the equator to monitor El Nino. See http://www.ndbc.noaa.gov/

Worldwide Weather Network

- Over 1500 radiosonde observations per day
  - Northern Hemisphere land covered fairly well
  - Oceans, South America, and Africa not well covered.
- Over 10,000 land-based stations reporting surface conditions
- Hundreds of ships help with weather observations

World Meteorological Org. (WMO)

- World Meteorological Org (WMO)
  - branch of the United Nations
  - over 175 nation members (http://www.wmo.ch)
  - facilitates data exchange through "World Meteorological Centers" in Melbourne, Moscow, and Washington, DC and over 25 regional data centers around the world
  - educates meteorologists in developing countries, e.g., workshops at FSU

Weather Analysis: What's the weather like now?

- Wait a few hours after each observation time to collect as many observations as possible before starting the analysis for that time
- Quality control: Discard readings if they are too different from climatology or nearby observations.
- Start analysis using a forecast for the analysis time, so every place has weather values.
- Blend in the new observations, making weighted averages of the forecast with observations to construct a 3-D grid of weather values.
- Adjust values so that they will work smoothly with the equations in the computer forecasting models.

Weather Forecasting Methods (p. 368, 373)

- Forecasting technique depends on how far into the future you want to forecast
- Short range (a few minutes to next day):
  - Persistence: weather will continue "as is" with no change. If it is dry/raining now, it will continue dry/raining forever. Tomorrow's high and low temperatures will be the same as today's. A persistence forecast is often good in tropics, which change little.
  - Trend method (also called "steady-state" method in textbook): present trends will continue, e.g., fronts, lines of thunderstorms, hurricanes, etc., will continue to move, bringing in their associated weather. Often used for "nowcasting": forecast for next few minutes to at most a few hours.

Forecasting 1 or more seasons into future

- Example: What would the weather be like for an outdoor wedding in Jacksonville at 10 am on a day months from now?
- Seasonal forecasting methods
  - Forecast the seasonal average, i.e., climatology. (E.g., the Farmer's Almanac seems to be climatological.)
  - Simple statistical models involving correlations between past and future anomalies (i.e., deviations from the mean). Can be run on a personal computer or fancy pocket calculator.
  - Very complex coupled ocean-atmosphere models. Requires a supercomputer.
  - The simple statistical models are currently about as accurate as the supercomputer forecasts.
  - Supercomputer forecasts are improving, such as advances in ensemble forecasting by FSU's Dr. T. N. Krishnamurti. More about this later in the lecture.

Forecasting 1 day to 2 weeks into the future

Historical ordering of techniques:

- Look at the sky. In middle latitudes, cirrus clouds are often a sign that a front is coming within 12 to 24 hours. See table 13.3, p. 348, and p. 351.
- Study daily weather maps year after year and gain an intuitive understanding how the weather typically evolves: analogue forecasting, weather types.
- Write a computer program using the equations that describe the atmosphere's motion (dynamics) and temperature (thermodynamics): numerical weather prediction. This has become the dominant technique supplemented by human and statistical improvements (Model Output Statistics).

Accuracy versus Skill

- Accuracy measures size of forecast error.
- Tropical weather has little variability, though, so even persistence forecast errors are usually small.
- Mid-latitude weather is more variable and forecast errors are larger.
- By definition, a forecast has "skill" if it is better than a persistence or climatology forecast.
- It is easier to have a skillful forecast for mid-latitudes than for the tropics even though the errors are larger.
- To "verify" a forecast, one checks what actually took place. Many times, one assigns a number that measures the size of the overall forecast error, such as the magnitude of the average error or the largest error anywhere in the forecast region.

Probability Forecasts (pp. 345-346)

- Probability of precipitation: chance of measurable precipitation (0.01 inches or more) at a randomly chosen point in the forecast area during the period covered by the forecast (often 12 hours). Footnote on p. 345 not right. With showers, chance that a random point is hit equals fraction of area hit.
- Randomly chosen point may as well be where you are.
- Question: How can you tell whether a probability forecast (say, a 10% chance of rain) is correct?
  Answer: It is impossible to verify one probability forecast by itself. A whole set of forecasts is needed. Collect all forecasts with 10% chance of rain. Did it rain in 10% of cases? Repeat for 20% chance, 30% chance, etc.

Numerical Weather Prediction

- Most National Weather Service forecasts for several hours to 10 days into the future are based on complicated computer programs.
- Forecasting programs calculate what the weather will be. Specifically, they calculate things like:
  - pressure gradient force, Coriolis force, and friction to compute how the wind speed and direction change with time
  - heating from sun, infrared, and condensation minus heat loss by emission of infrared and evaporation to compute temperature changes
  - condensation from rising air to compute rain and snow

Characteristics of Some Forecasting Models

- Characteristics of 6 different US numerical models: http://meted.ucar.edu/nwp/pcu2/launpcu2.htm (Subject to change! Don't memorize.)
- Schedule of forecast runs: http://www.nco.ncep.noaa.gov/pmb/nwprod/prodstat/
- Computer forecasts at http://www.nco.ncep.noaa.gov/pmb/nwprod/analysis/
- Example: Global Forecast System (GFS) global model
  - Horizontal resolution roughly 55 km (34 miles) in latitude and longitude
  - 64 levels in vertical from surface into stratosphere
  - 7.5 minute time step run out to 16 days
  - Run four times daily, each taking 80 minutes of computer time

Regional models

- Regional "eta" (Greek letter) model over N America
  - Horizontal resolution: 12 km between grid points
  - 60 levels in vertical
  - Run 4 times daily out to 2½ days. Each run takes 1 ¼ hrs.
- Rapid Update Cycle (RUC) model
  - Run out to 12 hours every hour. Takes about ½ hr to do calculations.
  - Horizontal resolution: 20 km between grid points
  - 50 levels in vertical
- Regional models need to get conditions on their boundaries from global forecast models. That allows weather to enter and exit the limited area covered by a regional model.

Ensemble Forecasting (pp. 342,343)

- General definition of ensemble: collection of things, as a musical ensemble or a clothing ensemble
- Ensemble forecast: 2 or more forecasts that all apply to the same place and time. ("2 heads are better than 1.")
- Example: You make an ensemble forecast when you compare forecasts from several different TV stations.
- Theory suggests that skillful detailed forecasts of planetary-scale weather is impossible beyond about 2 weeks because the atmosphere is "chaotic" (p.342). Smaller scale features can be forecast even less than that. Example: small thunderstorms have a forecast limit of an hour or so, tornadoes less than that.
- An ensemble of forecasts considers some of the possibilities. Average of forecast ensemble is usually more accurate than a single high resolution forecast.

Operational Ensemble Forecasting

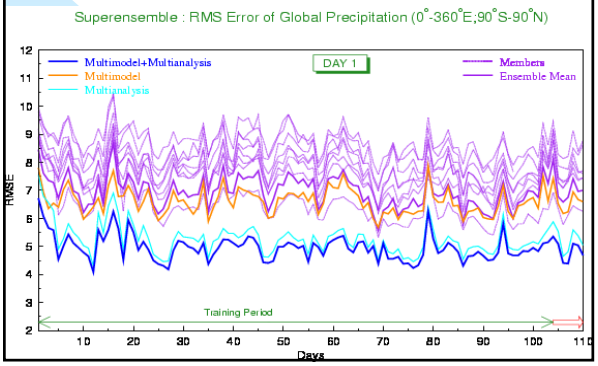
- Example: Forecast for D-Day invasion of France on 6 June 1944 was made by comparing forecasts from 3 separated teams, each using different forecast technique.
- Global ensemble forecasts out to at least 10 days since Dec 1992 at both US & European forecasting centers.
- In US, experimental regional ensemble forecasts since 1995, operational since 2001.
- Currently, US has 15 forecasts in its global ensemble; European Centre has 50. Precise number isn't important because it changes, but European Centre has more & better forecasts.
- Ensemble philosophy is similar to mutual funds: average over the stock market produces a better return than trying the pick the best performing stock.

Ensemble Forecasting Breakthrough at FSU

- Breakthrough improvement in ensemble forecasting by FSU's Prof. T. N. Krishnamurti in spring 1999
  - Don't just average forecasts, remove biases.
  - Requires months of old forecasts to determine biases, so you have to wait months to collect statistics if major changes in model is made.
  - Compute a weighted average forecast where the weighting could be different from place to place and variable to variable.
  - This work by Dr. Krishnamurti has been highlighted on CBS & ABC national evening news & The Weather Channel

Day-by-day errors for global precipitation

Dr. Krish's "Super-ensemble" has lowest error (blue line). Individual forecast errors (purple lines) are much larger.



Operational Ensemble Forecasting: The Future

- Ensemble forecasting will become more common.
  - It provides guidance as to forecast reliability. (You check how well the various forecasts agree.)
  - It provides a direct way of estimating probability of an event by considering the fraction of forecasts that have the event. Example of application: What is the probability of more than one inch of rain in 24 hours?
- Because of limited time to compute a forecast, there will always be a trade-off between the number of forecasts in an ensemble and the complexity of each forecast

Operational Ensemble Forecasting: The Future

- More people will do what Dr. Krishnamurti is doing, i.e., correct biases and allow for a more flexible way to combine the forecasts in an ensemble.
  - Research topic: If forecast model improves, can Krish's technique be applied without having to wait months to gather statistics exist?
- More forecasts with probabilities will be produced.
  - Challenge: How can we educate the public to understand this extra information?
- More businesses will make use of forecasts to maximize profits.

You can forecast! (pp. 350, 351)

- Page 350: Table 13.3 gives forecasting guidelines based on simple observations you can make about the weather.
- Page 351: Watch drifting clouds at two different levels to determine wind direction at different heights. If wind direction turns counterclockwise with increasing height, then cold advection. ("Back in time, it was cold.") If wind direction turns clockwise with increasing height, then warm advection.
- The guidelines on pp 350 & 351 are good. Some will be on the final exam.
- Pages 353-357 apply chapter 12 material to consider forecasts for 6 cities.

Watches, Warnings, & Advisories (p. 337)

- Watch: Alert that hazardous weather (thunderstorm, tornado, hurricane, etc.) is possible
- Warning: Alert that hazardous weather (thunderstorm, tornado, hurricane, etc.) is a reality
- Advisory: Notice of less hazardous conditions caused by wind, dust, fog, snow, sleet, or freezing rain.