An Introduction to Modern Weather Prediction:
Is it going to rain, or maybe snow?

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OUTLINE

• Introduction: what is weather prediction?
• Why do we need weather prediction?
• Types of weather forecasts, and where do we get them.
• What is the ‘science’ of weather prediction?
• What are the limits, i.e. how good can forecasts be?
• Significant weather events in Forks history, with some personal anecdotes
• Questions and discussion
What is weather prediction?

- There is a big difference between weather and climate
- Mark Twain: “Climate is what we expect, weather is what we get”.
- Weather predictions are typically classified by length in time.
  - “nowcasts”: few minutes or hours
  - “forecasts”: a few hours to about a week
  - “outlooks”: more than a week
- Also, by area covered, e.g. global vs regional
- I will discuss each of these categories
Why do we need weather prediction?

- Almost every day we make decisions based on what we think the weather will be
- Enormous economic impacts
  - agriculture
  - power utilities
  - transportation
  - recreation
- Military
  - WWII: Admiral ‘Bull’ Halsey ignored typhoon forecasts, lost several ships
HERE IS WHY

2 EXAMPLES OF SERIOUS WEATHER EVENTS

Hurricane Sandy

Major PNW Winter Storm
Sources of weather forecasts

• When you look out the window to check on the weather: you are making a nowcast
• The Langley Hill coastal radar
• Local TV weather
• National TV weather: Weather Channel, Weather Nation
• Internet: National Weather Service, Weather.com, Weather Underground, WXMAP, UW Atmospheric Sciences
  National Weather Service - NWS Seattle
  National Weather Forecast - weather.com
  Forks, WA Weather Forecast from Weather Underground
  FNMOC WXMAP: E Pacific
  Pacific Northwest Environmental Forecasts and Observations
• Farmer’s Almanac
  Long Range Weather Forecast | Farmers' Almanac
Weather Radar

- **Langley Hill**
  - **coastal radar:** Sept 2011

- A “nowcast” tool: 2-3 hours, 100 miles offshore

- A high tech way of “looking out the window”

**National Weather Service - NWS Seattle**
Weather forecasts

- Few hours to about 1 week
- ‘Deterministic’: If we can describe the atmosphere now, we can predict it into the future
- You often hear a TV weather person refer to what the ‘models’ are saying
- These models are the source of numerical ‘guidance’, i.e. numerical weather prediction (NWP)
- Without exception, modern weather forecasting is based on this guidance.
- So, what are these models, and who has them?
How do we ‘model’ the weather?

• A few things about the atmosphere
  - The atmosphere (air) is a fluid
  - The atmosphere is very thin (like the skin of an apple
  - The Earth is a sphere
  - The Earth rotates
  - There is water in the atmosphere

• With these facts, along with other physical processes, we have a mathematical problem.
A model: The primitive equations of atmospheric motion

\[ \frac{\partial V}{\partial t} = -V \cdot \nabla V - (p_s \dot{\sigma}) \frac{\partial V}{\partial p} - \nabla \phi - \frac{RT}{p_s} \nabla p_s - f(k \times V) + F_v \]

\[ \frac{\partial \theta}{\partial t} = -V \cdot \nabla \theta - (p_s \dot{\sigma}) \frac{\partial \theta}{\partial p} + H_\theta \]

\[ \frac{\partial q}{\partial t} = -V \cdot \nabla q - (p_s \dot{\sigma}) \frac{\partial q}{\partial p} + Q_q \]

\[ \frac{\partial p_s}{\partial t} = -\nabla \cdot (p_s V) - \frac{\partial (p_s \dot{\sigma})}{\partial p} \]

\[ \frac{\partial \phi}{\partial \sigma} = -\frac{RT}{\sigma} \]

• These equations are ‘hard’ to solve
• I spent my career working on solution methods
• What do we need to solve them?
First, we need one of these
Also, we need observations (data)

- Conventional data (in situ)
  - Radiosondes
  - Ships
  - Aircraft

- Remotely sensed data
  - Satellites
  - Radar

- Weather data is almost universally shared
  - Even at the height of the Cold War
  - Dedicated Global Telecommunications System (GTS)

- The daily volume of observations taken globally is immense
  - 100’s of millions
  - Overwhelmingly from satellites

- Problems
  - Weather data is very ‘perishable’ (nobody cares about yesterday’s weather)
  - What do we do with all this data?
Radiosondes

• The most traditional weather observation device
  - ‘weather balloons’
  - more than 100 years

• Launched twice daily
  - 00Z (4 PM PST)
  - 12Z (4 AM PST)
  - Synoptic observations

• Quillayute (KUIL)
  - Moved from Tatoosh Island in 1966
  - Arguably the most important upper air station in the US.
Radiosondes
Radiosondes
Radiosondes
Radiosondes
Radiosondes
Radiosondes
Radiosondes

ECMWF Data Coverage (All obs DA) - Temp
06/Jan/2014; 00 UTC
Total number of obs = 611
Ships and Land Stations

ECMWF Data Coverage (All obs DA) - Synop-Ship-Metar
06/Jan/2014; 00 UTC
Total number of obs = 66885
Buoy

ECMWF Data Coverage (All obs DA) - Buoy
06/Jan/2014; 00 UTC
Total number of obs = 7319
Aircraft

ECMWF Data Coverage (All obs DA) - Aircraft
06/Jan/2014; 00 UTC
Total number of obs = 96403
Satellite

ECMWF Data Coverage (All obs DA) - Microwave imager
06/Jan/2014; 00 UTC
Total number of obs = 63179
Satellite

ECMWF Data Coverage (All obs DA) - AMV IR
06/Jun/2014; 00 UTC
Total number of obs = 151988
Weather prediction (guidance)

• So; all you need is a model, a supercomputer, and observations?
  - Yes, but it isn’t easy

• Who does it?
  - National Weather Services
  - Large Laboratories
  - Universities
  - Private companies

• Forecast domains
  - Global (needed for predictions > 3 days)
  - Regional (higher resolution, more detail, e.g. quantitative precipitation)

• International cooperation (data exchange) is between weather services
  - Others depend on their weather services
  - Official forecasts are reserved for the national services
Weather prediction (guidance)

• Operational weather prediction is ‘big’ science

• What is big science?
  - Dependence on complex, expensive facilities
  - Usually lots of international cooperation
  - Source of national prestige

• Other examples:
  - Theoretical and experimental particle physics
  - Astronomy and Astrophysics

• Weather prediction is unique
  - Application of fundamental science with direct, immediate benefit to society
  - This is often a burden because weather is part of our everyday lives, and therefore lacks the mystic of the other examples
The Limits of Numerical Guidance

• If anything can go wrong, it will
  - Chaos theory
  - The butterfly effect
  - Favorite theme of Science Fiction
  - The meteorological term for this is ‘deterministic predictability’

• Applies to numerical predictions
  - Small initial errors inevitably will grow
  - Theoretical deterministic limit is 10-14 days
  - Currently the best models are ‘skillful’ to about 8 days
  - Definition of ‘skill’ at 8 days must be qualified
  - The more specific a forecast the shorter the skillful time will be

• Beyond this we must depend on climatological outlooks
Climatological Outlooks

Farmer’s Almanac Regions
Forks Climatology

- Daily weather records for more than 100 years
  - Since 1927, Jerry King, his mother and grandmother
  - January 17: measurable rain 72 times in 100 years
  - Therefore climatological chance of rain = 72%
  - On Monday of this week the chance of rain today was 10%, based on numerical guidance from the National Weather Service
  - Which was the best forecast?
Weather for the Super Bowl

- 16 Days from now, i.e. beyond range of numerical guidance
- Farmer’s almanac: Cold, snow
- Weather 2020: Unseasonably warm, no snow
- Who to believe
- Shows the perils of climatological outlooks
- Better wait until next week at this time
How good can forecasts be?

• As I said earlier, there are theoretical limits
  - If you want a sure thing, look at a tide table
• There is no substitute for brute force
  - bigger computers allow better models
  - More observations allow better description of the atmosphere
• Currently the ‘best’ model/forecasts come from the European Centre for Medium-range Weather Forecasts (ECMWF)
  - The biggest supercomputer available
  - The best scientific talent in Europe
  - A very specific goal of 10 day skill (currently 8-9 days)
  - They believe they will achieve 10 days within 10 years.
Significant Events in Forks Weather History

- January 29, 1921 Windstorm
- January 13, 1950 Blizzard
- September 20, 1951 Forks Fire
- November 3, 1955 Flood
- October 12, 1962 Windstorm
- February 13, 1979 Windstorm
- December 29, 1996 Ice Storm
QUESTIONS?