Successful Forecasting Requires

- Knowledgeable, well-trained, & engaged forecasters
  - Meteorological knowledge and experience
  - Local weather & climate knowledge
  - User need recognition
  - Model strength, weakness, and bias assessment
  - Human cognition and interpretation
- Skillful & reliable NWP guidance, forecast tools, and other aids

AKA: The Human-Machine Mix

The Forecast Process

Critical Forecast Questions

- What has happened?
- Why has it happened?
- What is happening?
- Why is it happening?
- What will happen?
- Why will it happen?

Source: Bosart (2003)
Critical Forecast Questions
- What has happened?
- Why has it happened?
- What is happening?
- Why is it happening?
- What will happen?
- Why will it happen?

Important when NWP goes awry or cannot resolve local orographic effects

Source: Bosart (2003)

The Forecast Methodology
- To answer these questions, use the forecast funnel
  - Begin at planetary scale
  - Focus attention on progressively smaller scales
  - In complex terrain, build in orographic effects

The Forecast Methodology
- Answer the what and the why in the past, present, and future
- Avoid "meso-myopia"
  - Understand larger scales before progressing to smaller scales
  - When using high-resolution models, evaluate confidence in large-scale forecast before progressing to smaller scales
  - Expect limited local skill if large-scale is not well forecast
- Beware when the atmosphere is in outlier mode
  - Generalizations break down

Forecast Funnel in Practice
- Evaluate past, current, and future planetary scale setting

Forecast Funnel in Practice
- Evaluate confidence in synoptic-scale forecast

Funnel to synoptic scale
The Forecast Funnel in Practice

Funnel to mesoscale
Consider mesoscale, orographic, and land-surface processes

Adjust for local effects

Real-Time Example Using IDV

Humans Make a Difference

“This continuing skill advantage [indicates] that dedicated and trained forecasters can extract maximum advantage from improvements in operational weather prediction models” - Bosart (2003)

On the other Hand....

Don’t be on Autopilot

“Forecasters who grow accustomed to letting MOS and the models do their thinking...on a regular basis...are at high risk of “going down in flames” when the atmosphere is in an outlier mode” - Bosart (2003)

Although NWP is important, basic understanding, pattern recognition and climatology continue to play an essential role because of limitations in current NWP systems, including inadequate terrain representation, initial condition uncertainty, and parameterization uncertainty
"Forecasters have a clear role in the forecast process, by contributing a wealth of knowledge, tools and techniques that cannot be duplicated by computers or NWP."

McCarthy et al. (2007)

But forecasters need to be engaged and increasingly need an advanced education to extract maximum benefit from today's sophisticated forecast tools.

This class begins that education.

"The problem isn't your eyesight. The problem is you didn't know the alphabet."

A meteorologist knows their tools, including their strengths and weaknesses.

"All observations are bad, but some are useful."

"All models are wrong, but some are useful."

The statistics of weather

- More than just long-term mean
  - Mean, variance, extremes, probabilities
  - Impacts of ENSO and modes of climate variability
  - PDO, NAO, etc.

- Local and mesoscale effects
  - Complex terrain results in large climatological gradients
  - Often poorly resolved by computer models
  - Climatology to used "downscale" or bias correct model forecasts for local effects.

Can be overused

- e.g. Not all storms have the climatological precipitation-altitude relationship.

Forecast Tools: Climatology

<table>
<thead>
<tr>
<th>KSLC Climatology</th>
<th>Means and Probabilities for Forecast Practicum Variables</th>
<th>Is this useful???</th>
<th>Means and Probabilities for Forecast Practicum Variables</th>
<th>Is this useful???</th>
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Forecast Tools: Climatology

Think Beyond the Mean

Forecast Tools: Persistence

- Persistence: What has happened recently
  - Including trends
- Provides context for forecast
- Relevance for forecast varies from high to low
  - High during slowly evolving patterns
  - Low during major pattern shifts

Forecast Tools: Persistence

Context for forecast
During this period is different at LGU & WBB

Forecast Tools: Your Eyes

- Never underestimate the value of looking out the window or going outside to feel the weather

Source: cartoonstock.com, collaborativejourneys.net

Forecast Tools: Sfc/Upper-Air Data

Wind profilers provide more than wind!

Forecast Tools: Satellite

Visible Imagery
Visible radiation reflected back to space by clouds, aerosols, snow, land surface, etc.
**Forecast Tools: Satellite**

- "Window" IR Imagery
  - Long-wave radiation emitted primarily by clouds, land-surface, etc.
  - Cloud-top temperature and land-surface temperature

- Water Vapor Channel (IR) Imagery
  - Long-wave radiation emitted primarily by upper-tropospheric clouds and water vapor
  - Upper-level flow, troughs, etc.

- Forecast Tools: Satellite
  - Precipitable Water from Polar-orbiting microwave sensors
  - GOES IR Detection
  - Longwave IR (11.2 micron)/Shortwave IR (3.9 micron)

**Forecast Tools: Radar**

- NEXRAD Doppler Radar
- NEXRAD vs. TDWR
- Now: Polarimetric NEXRAD

**Forecast Tools: Weather Cameras**

- Click for Animation

**Forecast Tools: Manual Analysis**

- A manual surface analysis helps you "feel the weather in your veins"

Sources: Bosart and Seimon (1988); Neiman et al. (1988)
Useful Sites for Observations
- http://mesowest.utah.edu
  - Surface observations & time series
  - Radar overlays
- http://weather.rap.ucar.edu
  - Satellite, radar, surface maps, upper-air maps
- http://www.spc.noaa.gov/exper
  - Upper-air soundings, upper-air maps, surface mesoanalysis
- http://www.wunderground.com/wundermap/
  - You name it
- http://weather.cod.edu/satradv/
  - Satellite and radar

Useful IDV Bundles for Obs
- Real-Time-WX>Radar>
  - KMTX-3DTopo
  - KMTX-2D-Obs+Anal
- Real-Time-WX>Analyses>
  - Global-10day
  - Global-2day
  - SuperNational
  - Conus-East
  - Conus-West

Forecast Tools: NWP Models
- Global Forecast System (GFS)
  - Medium range (out to 384 hours) global analyses and forecasts every 6 h
  - Effective grid spacing of ~13 km to 192 h (lower resolution thereafter)
  - Available on lower-resolution grids
  - Strengths relative to other NCEP models
    - Accuracy of large-scale forecast
  - Weaknesses
    - Terrain representation
    - Precip structure

Forecast Tools: NWP Models
- North American Mesoscale Model (NAM)
  - Based on the "WRF-NMM"
  - Short-range (out to 84 hours) forecasts for North America every 6 h
  - Grid spacing of ~12 km
    - Higher resolution 4-km CONUS nest available
    - Supposed to be upgraded to 3-km soon
  - Available on lower-resolution grids
  - Strengths relative to other NCEP models
    - Terrain representation, mesoscale detail
  - Weaknesses
    - Limited area, large-scale accuracy

Forecast Tools: NWP Models
- Rapid Refresh (RAP)
  - Analyses for CONUS every hour
  - Very-Short-range (out to 18 hours) forecasts for CONUS every 3 h
  - Grid spacing of ~13 km
  - Available on lower-resolution grids
  - Strengths relative to other NCEP models
    - High frequency analyses and forecasts
    - Resolution, terrain representation, mesoscale details
  - Weaknesses
    - Limited area, large-scale accuracy

Forecast Tools: NWP Models
- High Resolution Rapid Refresh (HRRR)
  - Analyses for CONUS every hour
  - Short-range (out to 18 hours) forecasts for CONUS every hour
  - Grid spacing of ~3 km
  - Strengths relative to other NCEP models
    - High frequency analyses and forecasts
    - Resolution, terrain representation, mesoscale details
  - Weaknesses
    - Limited area, large-scale accuracy
**Forecast Tools: NWP Models**

- **Weather Research and Forecast Model (WRF)**
  - Run in various configurations at NCEP and other locations
  - Some configurations provide high resolution (<10 km) short-range (48 h or less) forecasts
  - Strengths:
    - Resolution and terrain representation
  - Weaknesses:
    - Limited area, often lousy initial condition generation

- **Short Range Ensemble Forecast System (SREF)**
  - 26 members @ 16-km grid spacing based on differing models, model configurations, and initial conditions
  - Forecasts out to 87 h every 6-h (0300 UTC, etc.)
  - Strengths:
    - Probabilistic information, allows assessment of confidence in large-scale forecast
  - Weaknesses:
    - Not calibrated, mean and spread of ensemble may be biased

- **Global Ensemble Forecast System (GEFS)**
  - 20 members @ an effective grid spacing of 55 km based on different initial conditions
  - Forecasts out to 384 h every 12-h
  - Strengths:
    - Probabilistic information, allows assessment of confidence in large-scale forecast
  - Weaknesses:
    - Not calibrated, mean and spread of ensemble may be biased
    - Spread slow to develop
    - Low resolution

**Useful Sites for Model Data**

- [http://weather.utah.edu](http://weather.utah.edu)
  - GFS/NAM
- [http://weather.rap.ucar.edu](http://weather.rap.ucar.edu)
  - GFS/NAM/RAP
- [http://www.spc.noaa.gov/exper](http://www.spc.noaa.gov/exper)
  - SREF
  - ECMWF
Model Output Statistics (MOS)

- Based on statistical relationships between model forecast variables and actual weather in the past
- Relationships then applied to latest model run
- Usually based on stepwise multiple linear regression
- Performs better than NWP or Statistics alone
  - Blends the best of both worlds
- Available for NAM and GFS

Model Output Statistics

- Advantages
  - Cheap and easy
  - Corrects for systematic model biases
  - Blends best of NWP and Statistics
  - Does well in generic weather patterns
- Disadvantage
  - Doesn't handle model changes well
    - i.e., shifts in biases
  - Doesn't handle outlier or unusual events well
  - Forecaster overreliance on MOS leads to rigormortis of skill

Sources: NOAA/MDL, weather.unisys.com
Forecast Tools: Scientific Visualization

- AWIPS/AWIPS-II
- IDV

Advantage: Integration of Diverse Atmospheric/Earth Data

Concluding Thoughts
- Learn to sip from the firehouse
- Find what sites/products you like, bookmark them, and develop a system
- Use IDV or similar software to integrate products when possible
- Time management is a critical aspect of forecasting

Sources: Wikipedia Commons, Unidata