Weather Forecasting: Lecture 2

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Overview

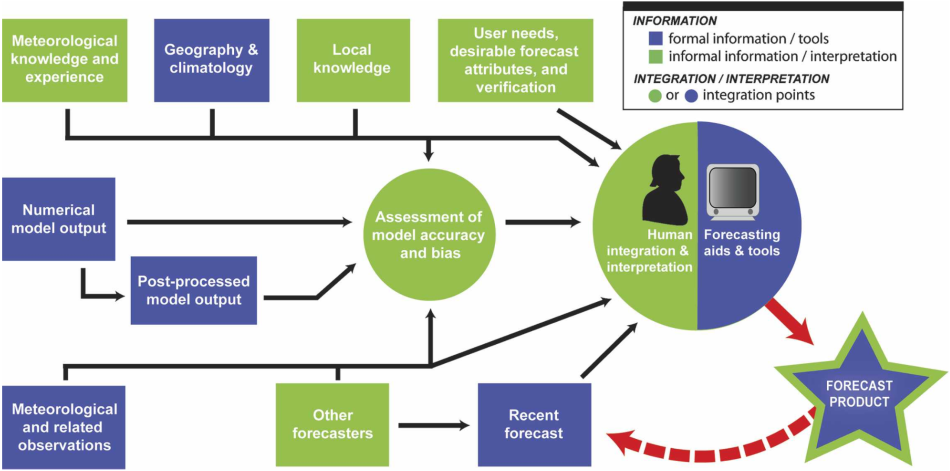
Forecasting Techniques

Forecasting Techniques

Successful forecasting requires:

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

The Forecast Process



Critical Forecast Questions

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

It is easy to only focus on this one question!

Critical Forecast Questions

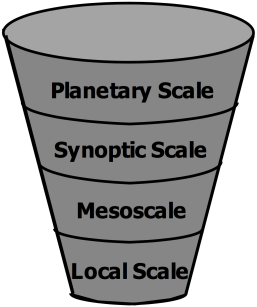
- What has happened?
- Why has it happened?
- Why is it happening?
- What will happen?
- Why will it happen?

These other questions are important when NWP goes awry or cannot resolve local orographic effects

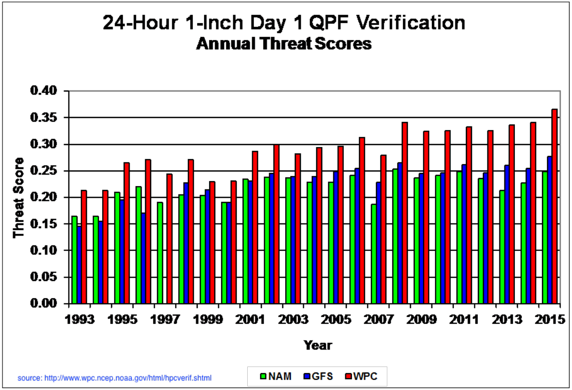
The Forecast Methodology

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



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

> *Forecasters who grow accustomed to letting MOS and the models do their thinking ... are at high risk of "going down in flames" when the atmosphere is in an outlier mode." - Bosart (2003)*

Say No To Autopilot

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

Bottom Line

> *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
- The class is the beginning of that education for you

Forecast Tools

Forecast Tools

- 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"

Forecast Tools

- Climatology
- Persistence
- Observations
  - Your eyes!
  - In-situ and upper-air
  - Wind profiler / RASS
  - Satellite
  - Radar
  - Weather cameras
- Manual analysis
- NWP models
  - Numerical analyses
  - Global and mesoscale models
  - Ensemble forecast systems
- Model output statistics (MOS)
- Scientific analysis and visualization systems

Forecast Tools: Climatology

- 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! For example, not all storms have the climatological precipitation-altitude relationship

Forecast Tools: Climatology

KSLC Climatology

	J	F	M	A	M	J	J	A	S	O	N	D	ANN
Mean Max (F)	37.3	43.4	52.4	61.5	72.2	83.1	92.8	90.4	79.4	65.7	50.0	38.6	63.9
Mean Min (F)	20.3	24.7	31.6	38.3	46.4	54.7	63.2	61.7	51.5	40.2	29.9	22.2	40.4
Mean Precip (in)	1.32	1.28	1.77	2.05	1.69	0.95	0.68	0.78	1.06	1.33	1.37	1.37	15.62
Mean Snowfall (in)	13.5	10.4	9.3	5.1	0.6	0.0	0.0	0.0	0.1	1.4	6.5	13.2	60.1
Mean Snow Depth (in)	2	1	0	0	0	0	0	0	0	0	0	1	0
00Z Dew Point (F)	21.0	22.9	26.7	31.6	37.9	42.3	47.4	46.6	41.0	34.2	26.9	21.1	
12Z Dew Point (F)	23.3	25.1	27.4	31.0	33.8	37.1	41.4	41.5	38.9	35.1	29.8	23.8	
00Z Relative Humidity	74	65	48	42	32	26	20	24	33	49	65	75	
12Z Relative Humidity	81	78	70	67	61	53	45	48	59	67	75	79	
Cloud Cover (Octas)	6.0	5.9	5.5	5.3	4.8	4.0	3.7	3.8	3.4	4.1	5.2	5.8	
12Z Wind Speed (kt)	7.6	7.9	8.2	8.3	7.8	8.0	8.0	8.8	8.0	7.8	7.4	8.0	8.0
00Z Wind Speed (kt)	7.2	7.8	8.8	9.6	9.2	9.5	10.0	9.6	8.4	7.3	6.6	7.1	8.4
12Z Wind Direction	93	71	99	92	103	88	84	93	116	123	90	70	
00Z Wind Direction	317	261	203	220	107	35	40	350	109	197	10	356	
Probability of Trace Precip	46.6%	45.7%	37.2%	41.8%	32.6%	25.8%	21.4%	28.7%	22.1%	27.0%	33.3%	41.1%	33.6%
Probability of 0.01" Precip	32.6%	34.2%	29.8%	34.4%	23.6%	15.8%	10.3%	14.4%	17.3%	20.5%	27.9%	31.7%	24.4%
Probability of 0.10" Precip	14.0%	17.7%	16.4%	19.4%	12.6%	8.8%	3.8%	5.0%	9.1%	14.1%	13.0%	16.4%	12.5%
Probability of 0.25" Precip	5.7%	6.8%	7.5%	10.6%	5.9%	5.5%	2.1%	2.9%	5.5%	6.2%	6.1%	6.2%	5.9%
Probability of TS	0.3%	1.3%	1.8%	7.9%	9.7%	14.8%	16.7%	22.0%	13.6%	6.7%	3.0%	1.5%	8.3%
Probability of SN	35.2%	31.5%	20.8%	9.7%	0.9%	0.0%	0.0%	0.0%	0.3%	2.6%	17.0%	34.9%	12.7%
Probability of RA	20.2%	24.8%	28.2%	38.8%	31.7%	24.2%	17.6%	24.0%	20.9%	25.8%	23.0%	16.4%	24.6%
Probability of VIS < 1 mi	31.4%	22.8%	12.3%	6.7%	0.0%	0.6%	1.5%	0.6%	0.3%	1.5%	10.9%	30.2%	9.9%
TS when precip is falling	0.0%	0.1%	0.6%	3.6%	6.1%	17%	49%	49%	24%	2.9%	1.3%	0.6%	

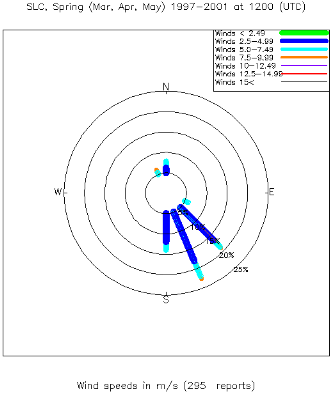
	ANN
Probability of VIS<1 mi given that snow is falling	25.0%
Probability of VIS<1 mi given that rain is falling	0.9%
Probability of VIS<1 mi in TSRA	1.6%
Probability of TS given that snow is falling	0.5%
Probability of TS given that rain is falling	9.1%

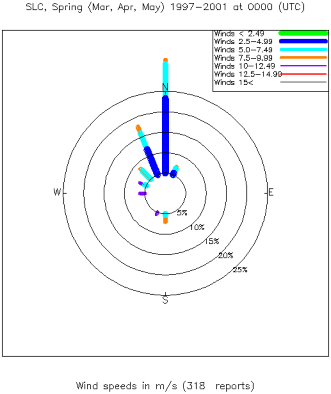
Surface Temperature	Probability of snow given that precip is falling
>40	0.8%
38-40	3.6%
37-38	15%
36	34%
35	59%
34	79%
33	93%

Is this useful?

Means and probabilities for forecast practicum variables

Forecast Tools: Climatology





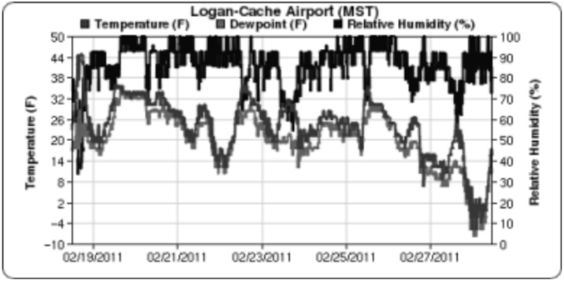
Think beyond the mean!

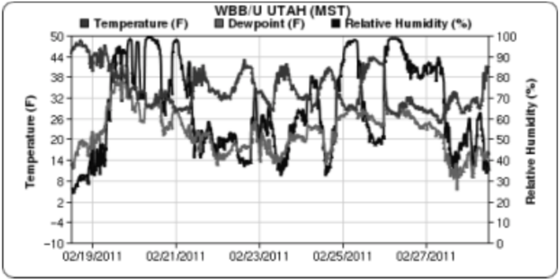
Forecast Tools: Persistence

- 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 and WBB

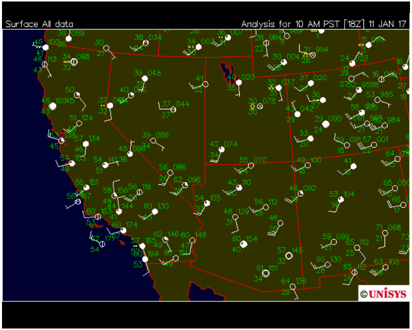


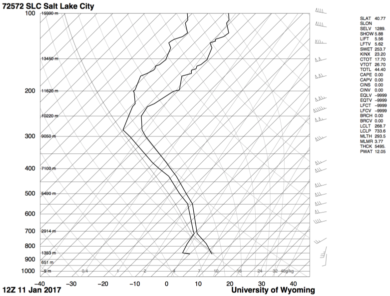


Forecast Tools: Your Eyes

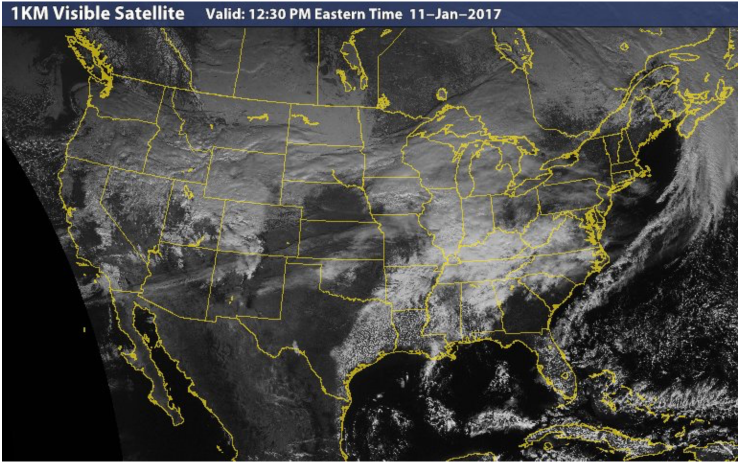
- Never underestimate the value of looking out the window or going outside to feel the weather
- Remember why you became interested in the weather!

Forecast Tools: SFS/Upper-Air



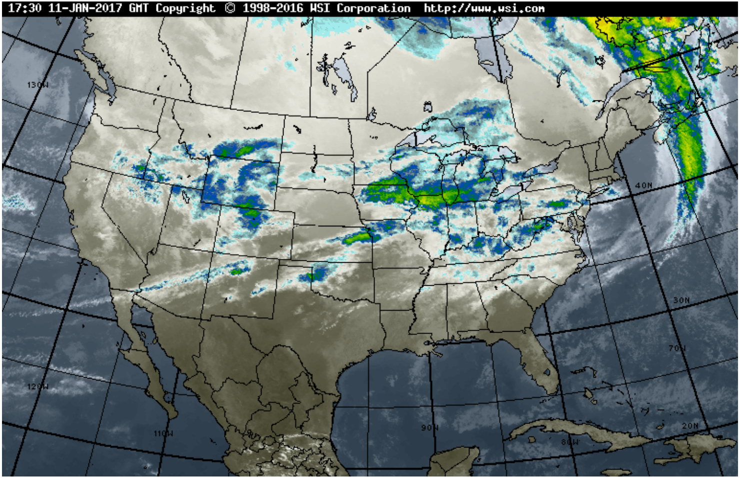


Forecast Tools: Satellite



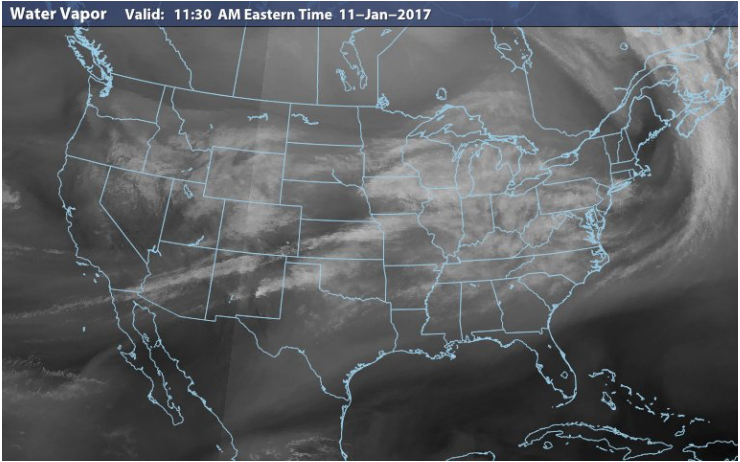
Visible Imagery - Visible radiation reflected back to space by clouds, aerosols, snow, land surface, etc.

Forecast Tools: Satellite



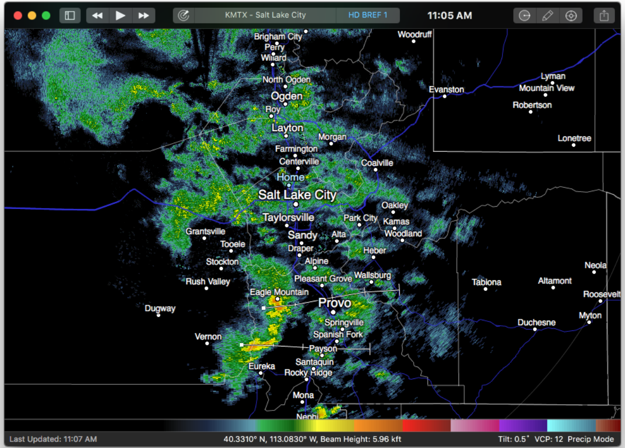
IR Imagery - long-wave radiation emitted primarily by clouds, land-surface, etc. Cloud-top temperature and land-surface temperature

Forecast Tools: Satellite



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

Forecast Tools: Radar

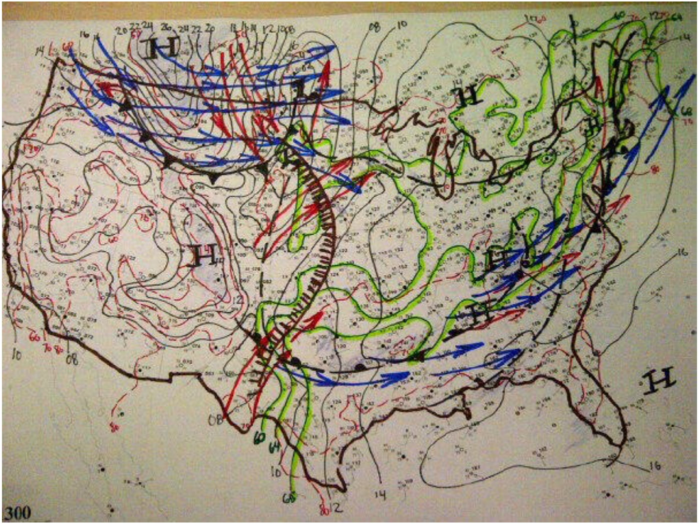


Radar - reflectivity, storm relative velocity, precipitation depiction, rainfall estimates

Forecast Tools: Cameras

Images: Time-Science.com | Data: Utah Dept. of AirQuality

Obvious, but they let you see the environment in action



Above was done recently by an SPC forecaster. A manual surface analysis helps you “feel the weather in your veins”

Useful sites for Observations

- http://mesowest.utah.edu
- http://weather.rap.ucar.edu
- http://spc.noaa.gov/exper
- http://wunderground.com/wundermap
- http://weather.cod.edu/satrad

Forecast Tools: NWP Models

Global Forecast System (GFS)

- Medium range (384 hours) global analyses
- forecasts every 6 h
- Effective spacing of approx 13 km to 192 h
- Compared to other NCEP models, it is relative more accurate for large-scale forecasts
- Weaknesses: terrain and precip

Forecast Tools: NWP Models

North American Mesoscale Model (NAM)

- Based on WRF-NMM
- Short range (84 h)
- Forecasts for N. America every 6 h
- Grid spacing of approx 12 km
- Offers good terrain representation and mesoscale detail
- Weaknesses: limited area, large-scale accuracy

Forecast Tools: NWP Models

Rapid Refresh (RAP)

- Analyses for CONUS every hour
- Very short range (18 h)
- Forecasts for CONUS every 3 h
- Grid spacing approx 13 km
- Offers high-frequency analyses, high-resolution, good 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 elsewhere
- Some offer high-resolutions ($< 10km$) short-range (48 h or less) forecasts
- The WRF model offers great terrain representation, is highly configurable, and can run with very high resolution
- Weaknesses: limited area and often lousy initial condition generation

Forecast Tools: NWP Models

Short Range Ensemble Forecast System (SREF)

- 21 members with 16-km grid spacing
- Each member is based on different models, configurations, and initial conditions
- Forecasts to 87 h every 6 h
- Offers probabilistic information and allows assessment of confidence in large-scale forecast
- Weaknesses: not calibrated and the mean and spread of the ensemble may be biased

Forecast Tools: NWP Models

Global Ensemble Forecast System (GEFS)

- 20 members with approx 55-km grid spacing
- Each member is based on different initial conditions
- Forecasts to 384 h every 12 h
- Offers probabilistic information and allows assessment of confidence in large-scale forecast
- Weaknesses: not calibrated and the mean and spread of the ensemble may be biased, spread slow to develop, and low resolution

Useful sites for NWP Models

- http://weather.utah.edu (GFS/NAM)
- http://weather.rap.ucar.edu (GFS/NAM/RAP)
- http://spc.noaa.gov/exper (SREF)
- http://wunderground.com/wundermap (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
- Available for NAM and GFS

Model Output Statistics (MOS)

Advantages

- Cheap and easy
- Corrects for systematic bias in models
- Blends best of NWP and statistics
- Does well in generic weather systems

Disadvantages

- Doesn't handle model changes very well
- Doesn't handle outlier or unusual events well
- Forecaster over-reliance on MOS leads to rigor mortis of skill

Model Visualization

- Websites
- AWIPS II
- IDV
- Python (MetPY)

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