Interpreting Weather Products

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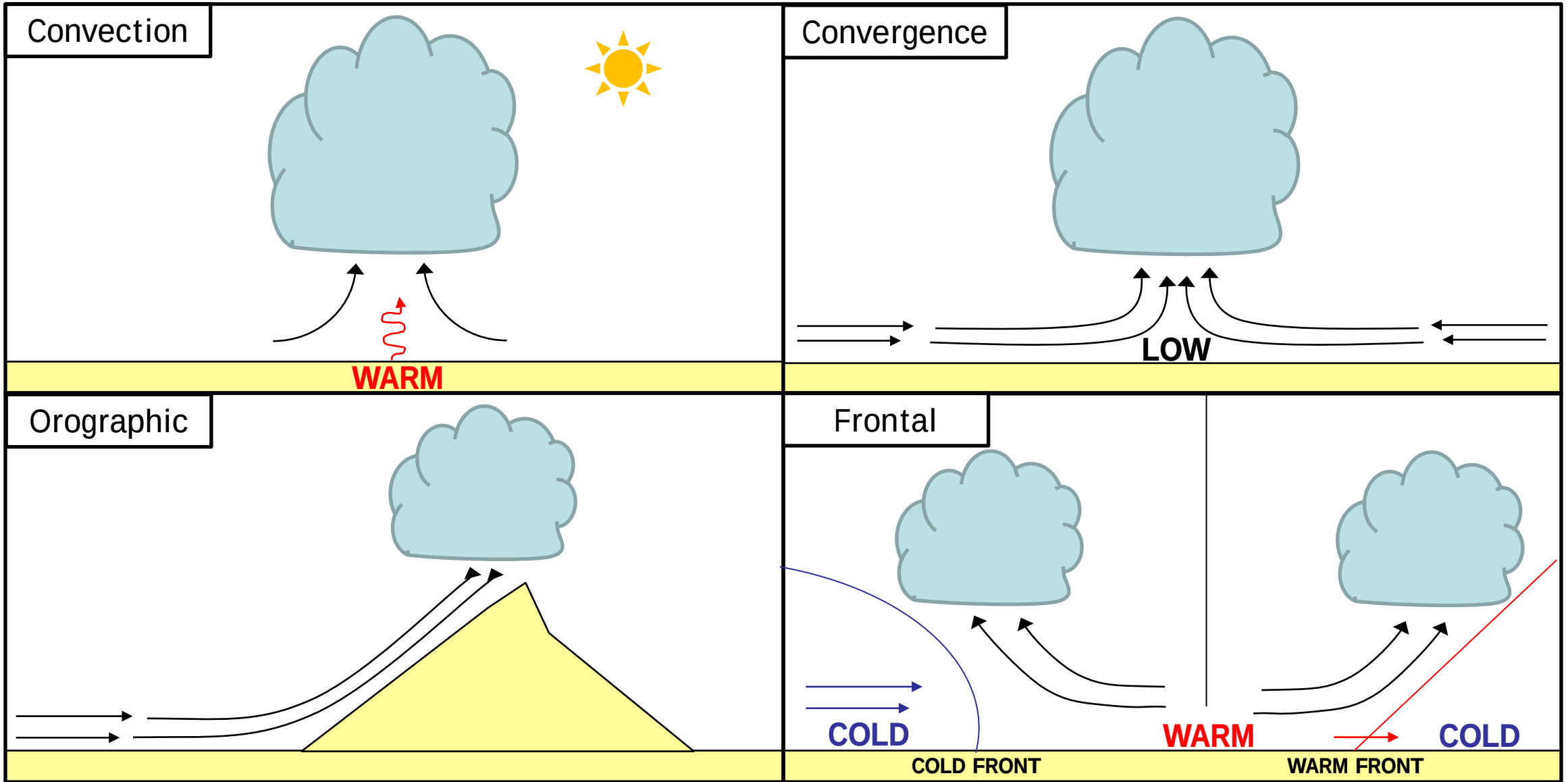
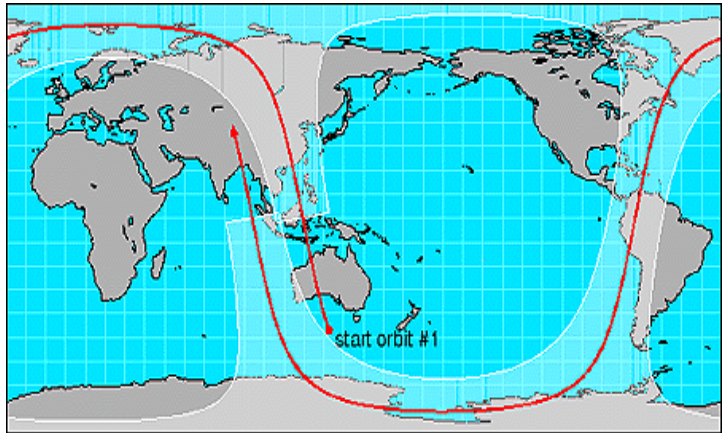
Outline

- Intro/Basics
- Satellite
- Radar
- Surface data & RWIS
- Weather Models
- Forecasting
- Climate

Lifting Mechanisms for Precipitation

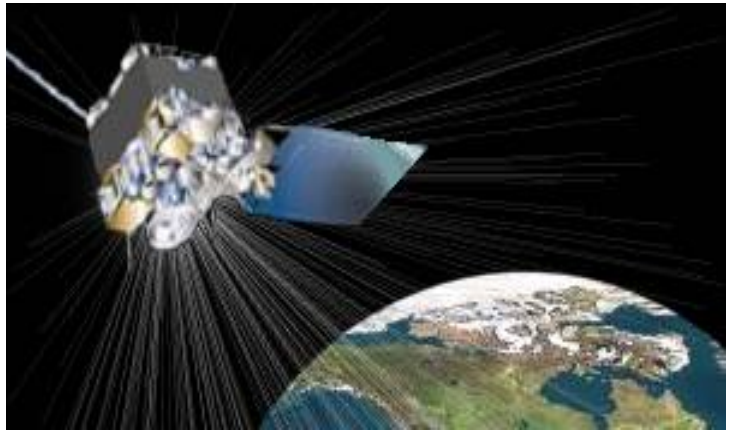


Satellite



POES

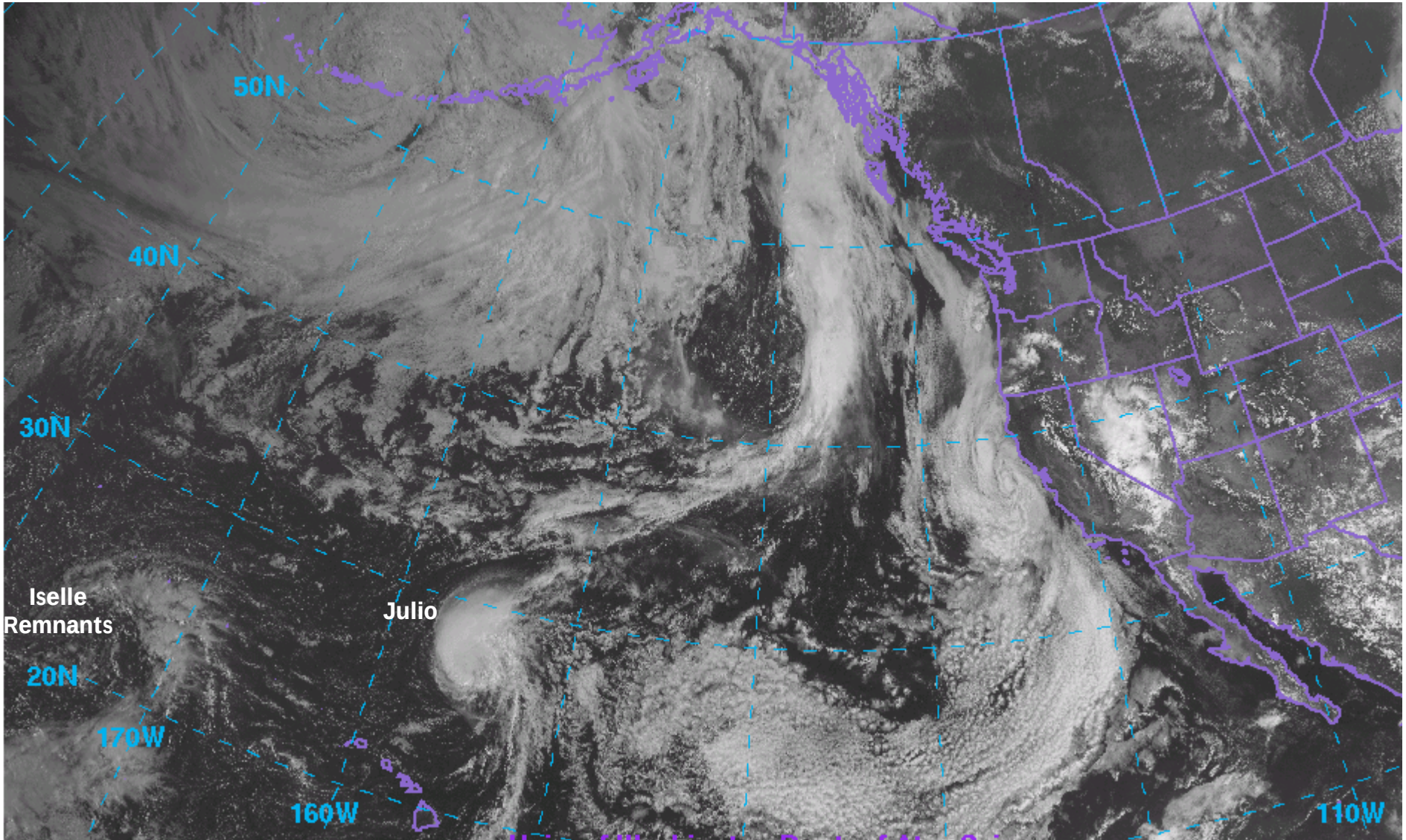
Polar Orbiting Environmental Satellite. 520 miles above the earth



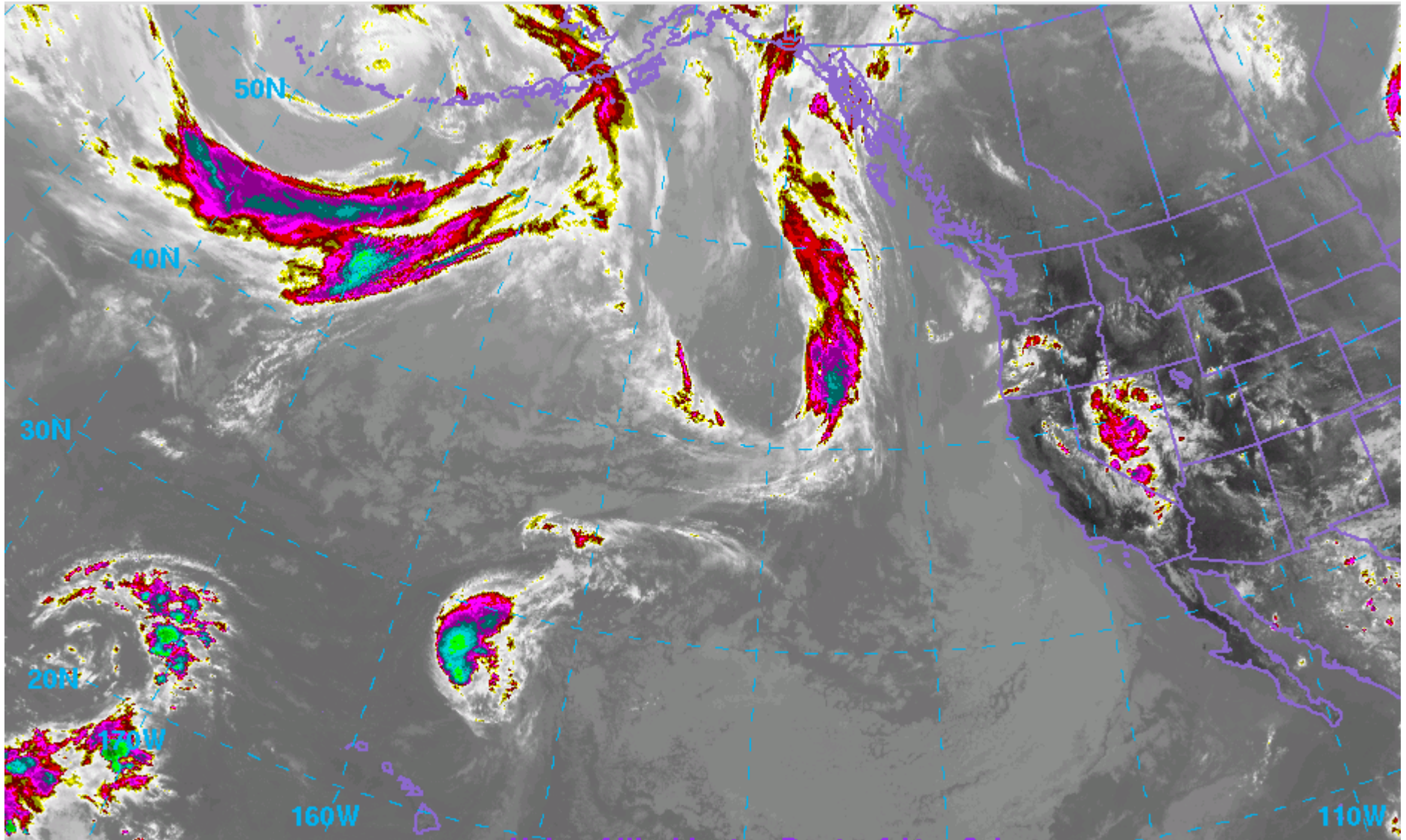
GOES

Geostationary Operational Environmental Satellite. 22,300 miles above the earth

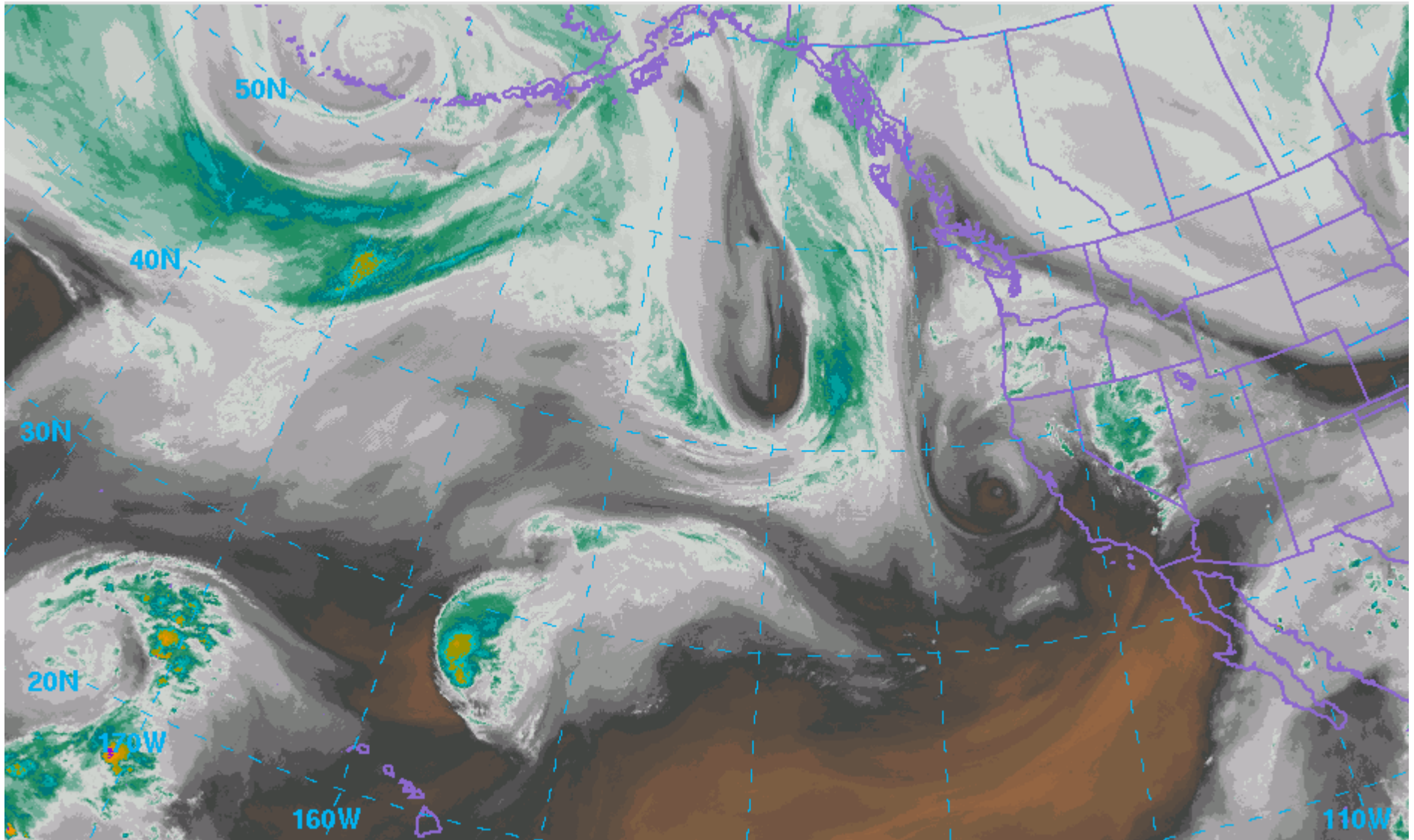
Satellite – Visible



Satellite – IR

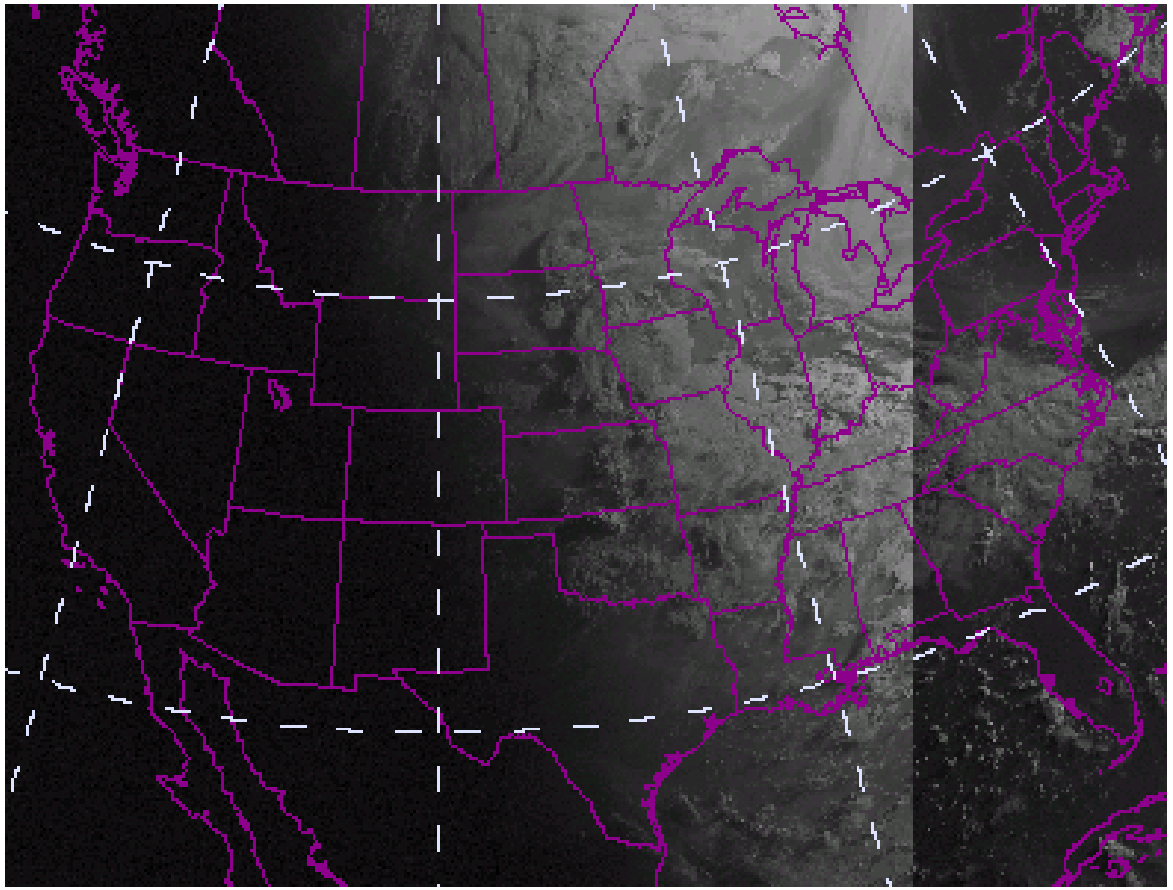


Satellite – Water Vapor



Satellite Imagery Limitations

- Visible imagery doesn't work when there's no light!
- IR only shows cloud-top temperature, not cloud type.
- WV only shows upper atmosphere.



Current Satellite

IR Satellite – Tuesday, August 12, morning

http://www.atmos.washington.edu/~ovens/wxloop.cgi?ir_central_enhanced+12

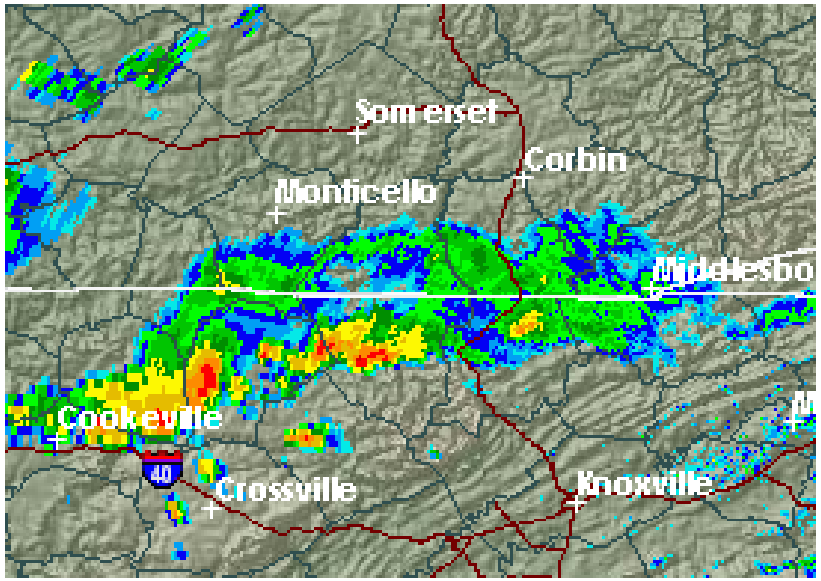
www.atmos.washington.edu/~ovens/loops

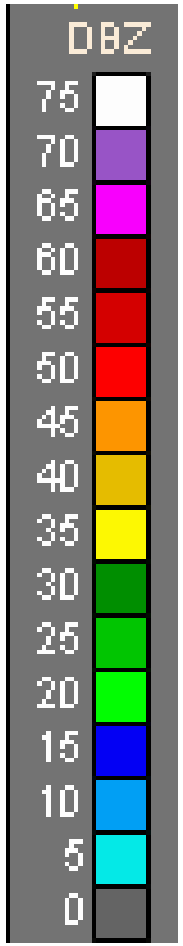
Radar Basics

NOAA

- Energy is emitted by the radar
- Energy is scattered and reflected by precipitation, dust, birds, etc.
- Reflected energy unit is dBZ

Radar Basics





←Extreme/Large Hydrometeors

←Very Heavy

←Heavy

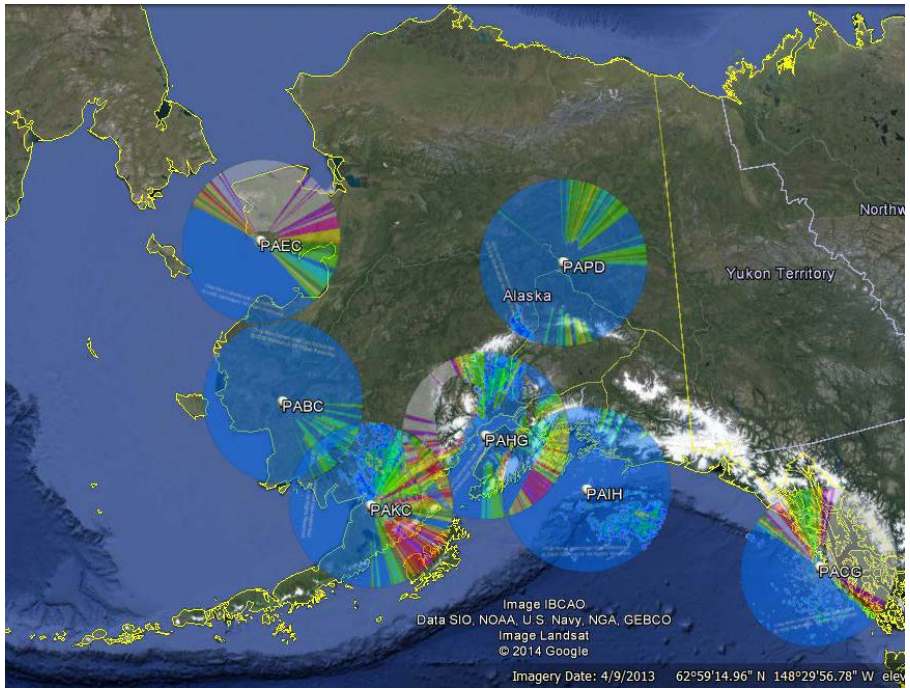
←Moderate

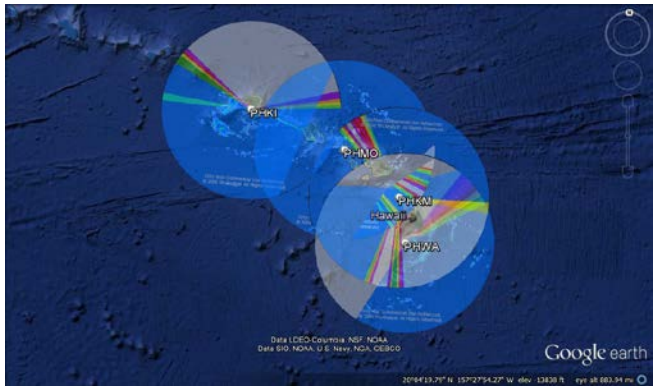
←Light-Moderate

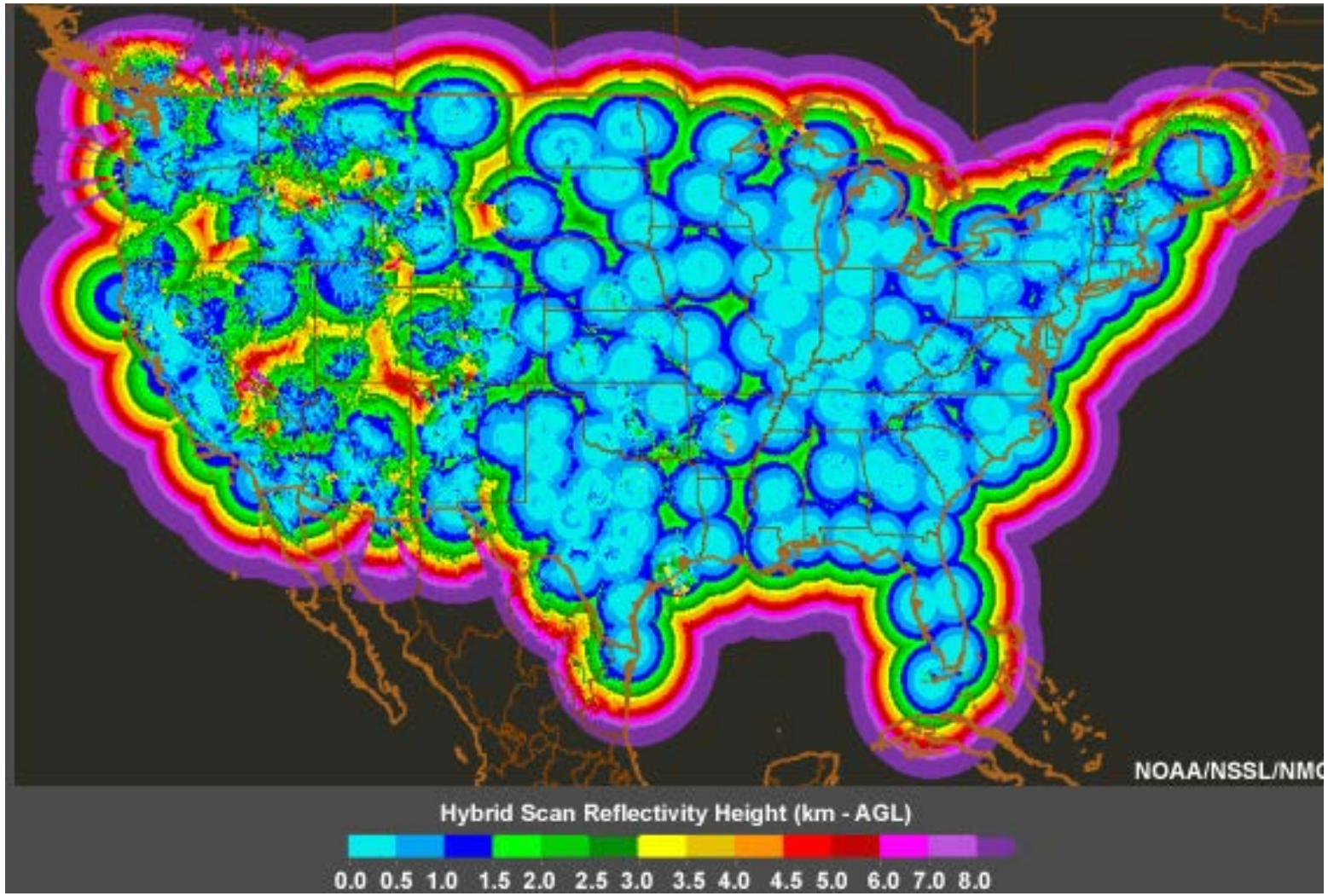
←Light

←Very Light/Mist

US Radar Coverage

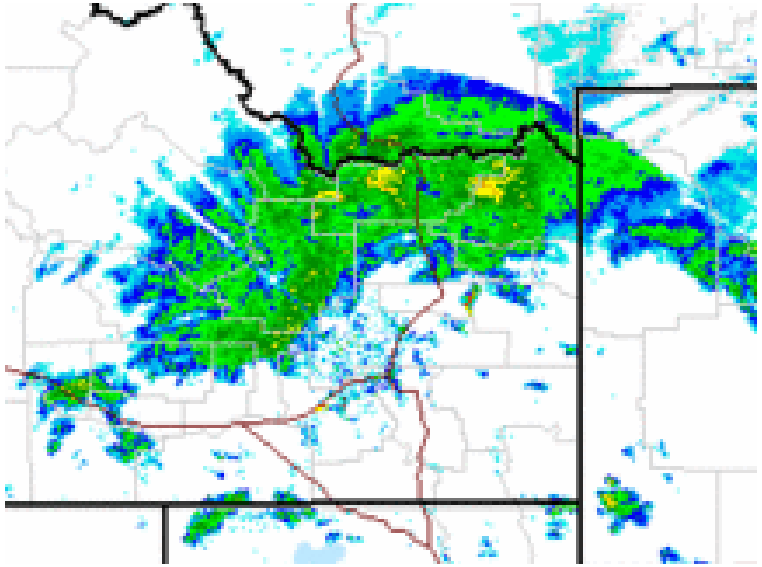


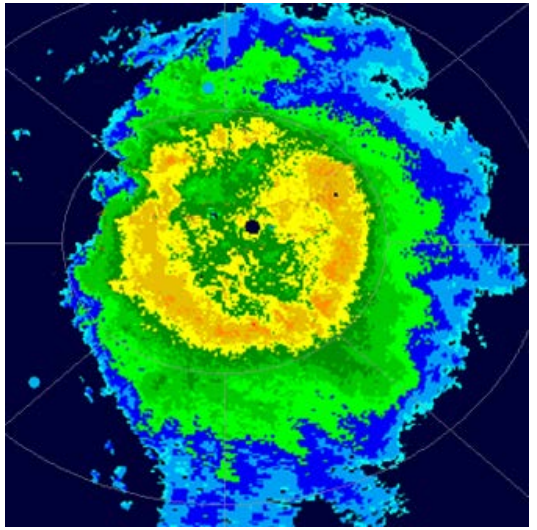


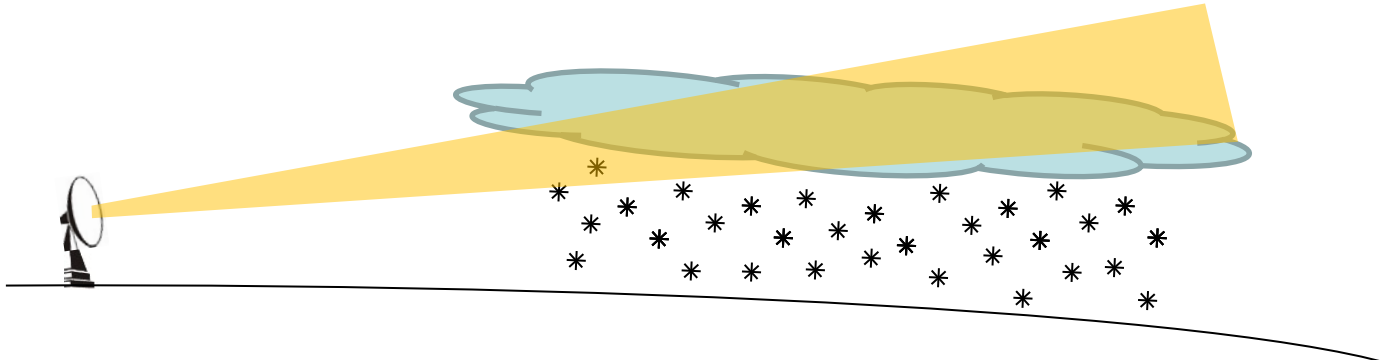


Radar Limitations

- Terrain blockage
- Radar gaps (Western US)
- Beam attenuation
- Beam overshooting
- Reduction of resolution at distance
- Bright band
- Smoke, chaff, debris, birds/bats, ground clutter
- Anomalous propagation (superrefraction of beam downward sees terrain, etc)
- Solar interference







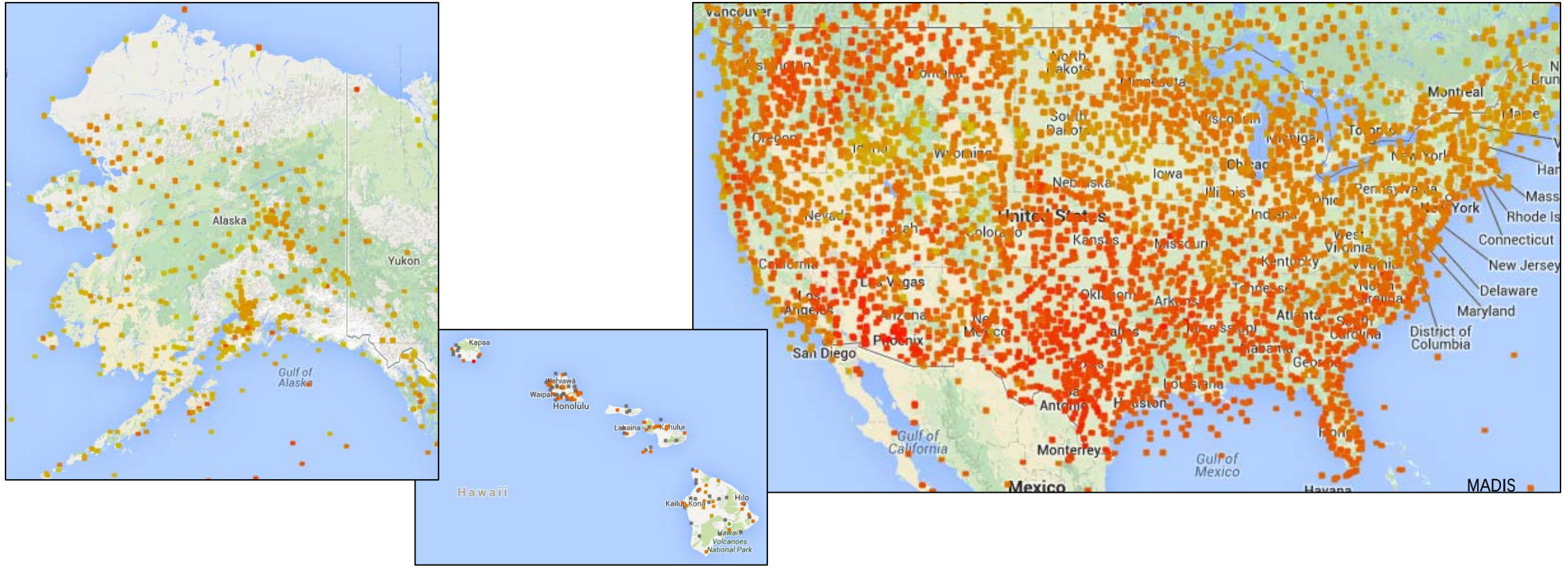
Radar

KMTX (SLC) Radar – Tuesday, August 12, morning

http://www.weather.gov/Radar

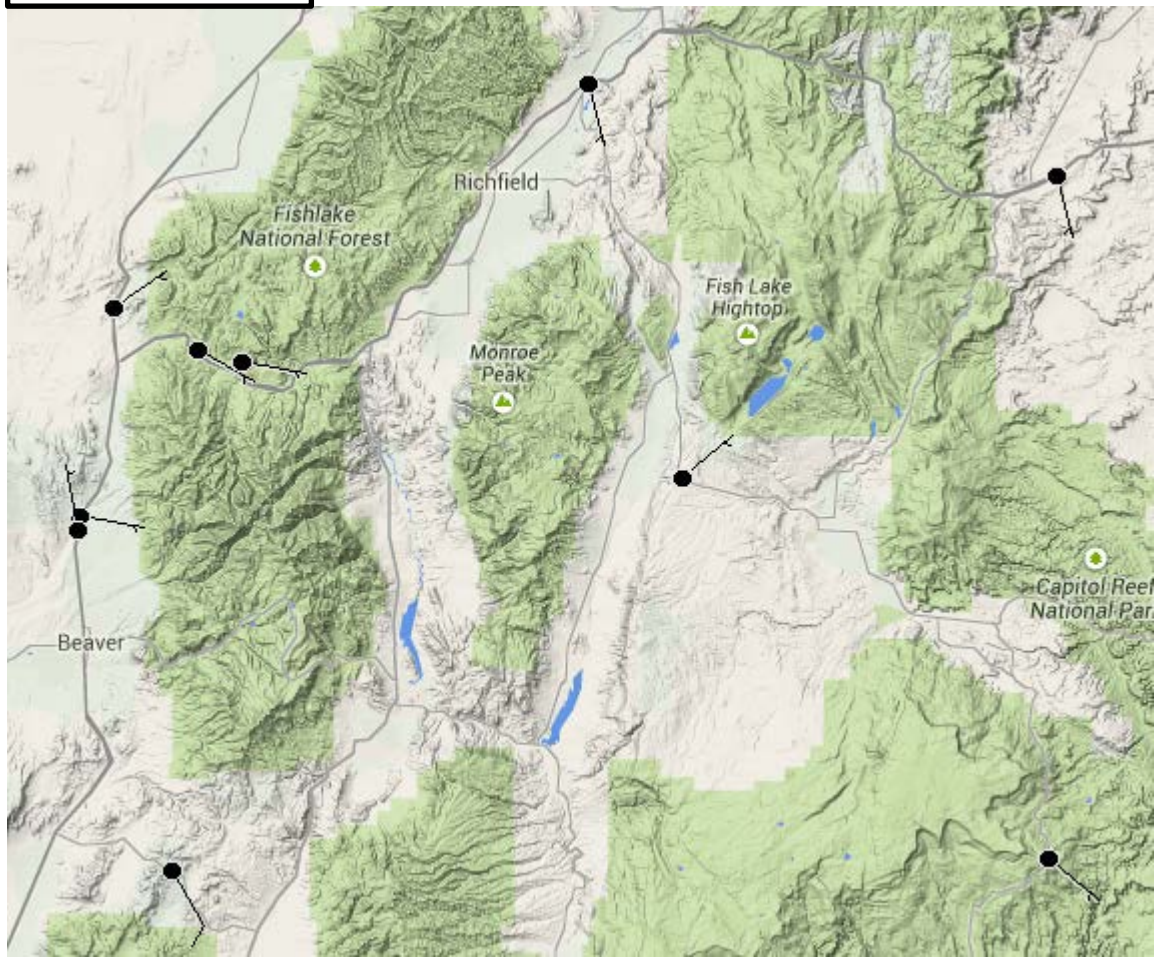
Surface Observations

- The US has multiple networks of observations from government and private sources, and in urban and rural environments.
- RWIS is an important part of the surface data field!

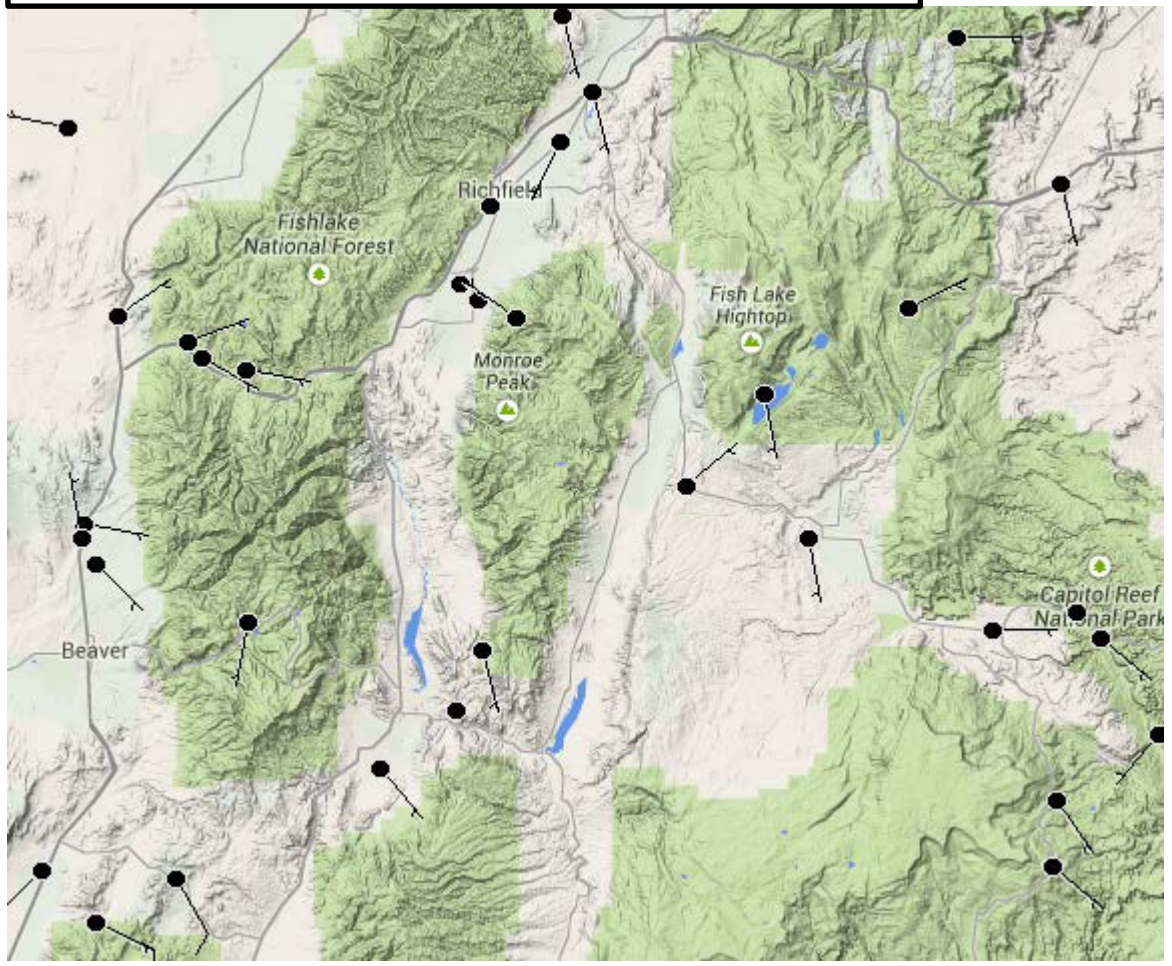


Using Other Observation Networks

RWIS Only

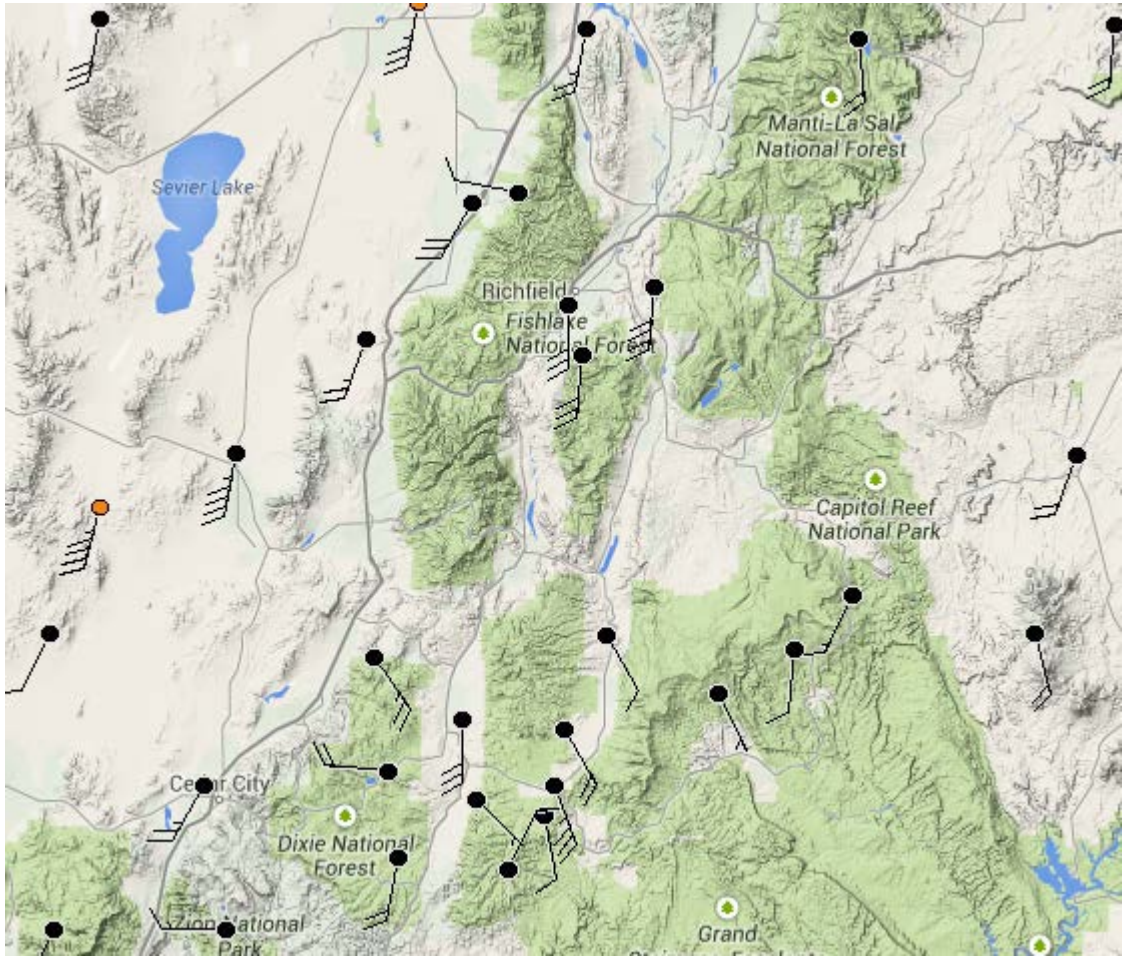


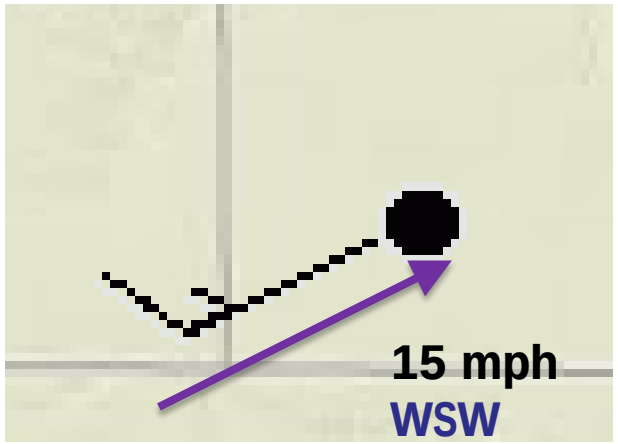
RWIS + NWS, RAWS, COOP, SNOTEL, etc.

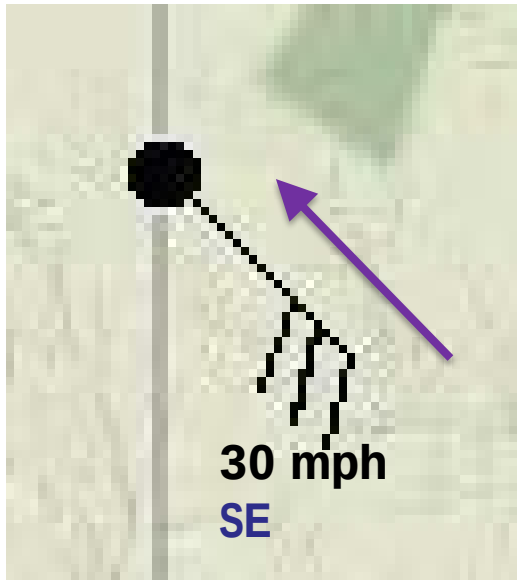


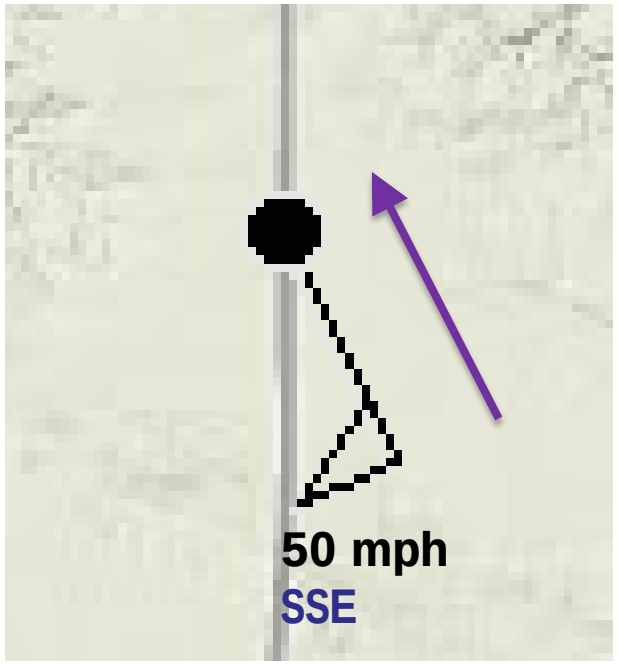
South-central Utah, rural

Wind barbs: speed and direction









RWIS

Temperature
- Air
- Road
- Subsurface

Humidity
- Relative Humidity
- Dewpoint Temperature

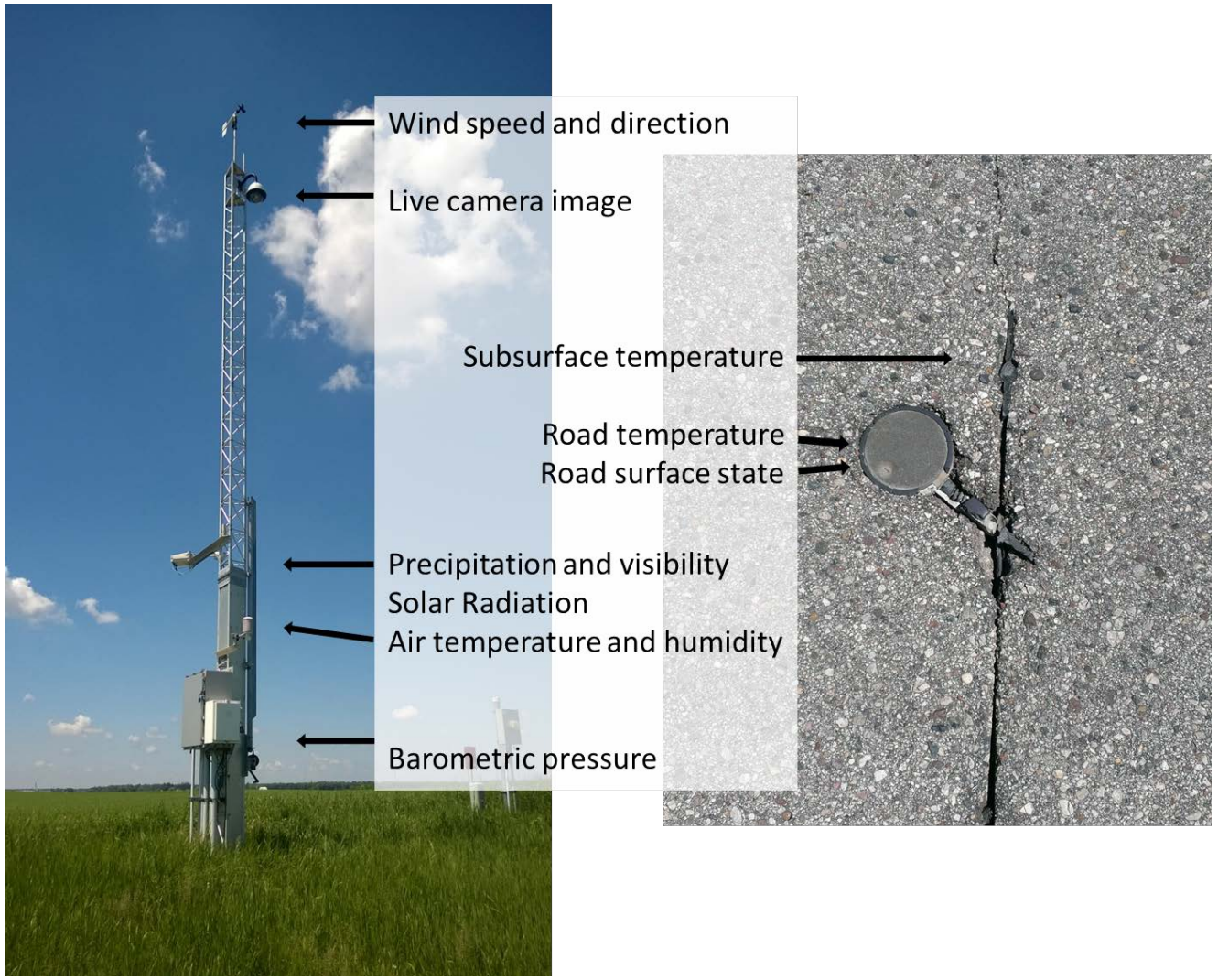
Wind Speed & Direction

Visibility

Precipitation
- YES/NO
- Type
- Amount, snow depth, etc.

Solar Radiation

Barometric Pressure



Moisture Terms

- **Dew Point Temperature**: temperature to which air must be cooled (at constant pressure) for it to become saturated
  - *dew point depression*
  - *collapsing dew point*
- **Wet-bulb Temperature**: temperature the air obtains when liquid water evaporates into it until it reaches saturation
- **Relative Humidity**: ratio of the amount of water vapor in the air compared to the amount required for saturation (at a particular temperature and pressure)
- **Specific Humidity**: the mass of water vapor in a unit mass of air

Use RWIS Data in Context

- Temporal Context

  Rather than viewing data as a snapshot, you need to keep an eye on the trend of the data in time. This will give you a better handle on what the environmental and road conditions were, are and will be.

- Spatial Context

  View each observation in relation to the observations around it. This shows the conditions that may be headed in your direction.

Each data element should be viewed in the context of the other data elements.

It's important to understand how the parameters relate to each other. For example…

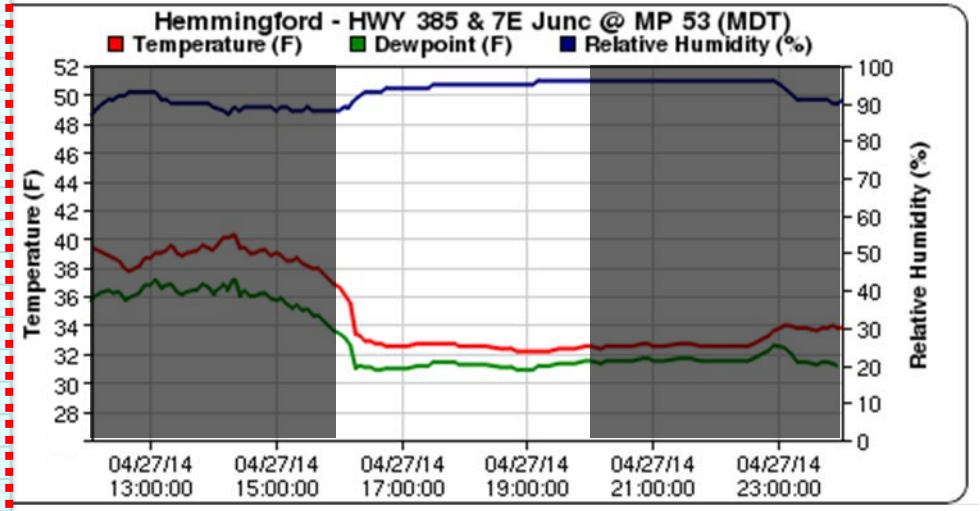
- Temperature and dewpoint (dewpoint depression)
- Dewpoint and road surface temperature (and wind)

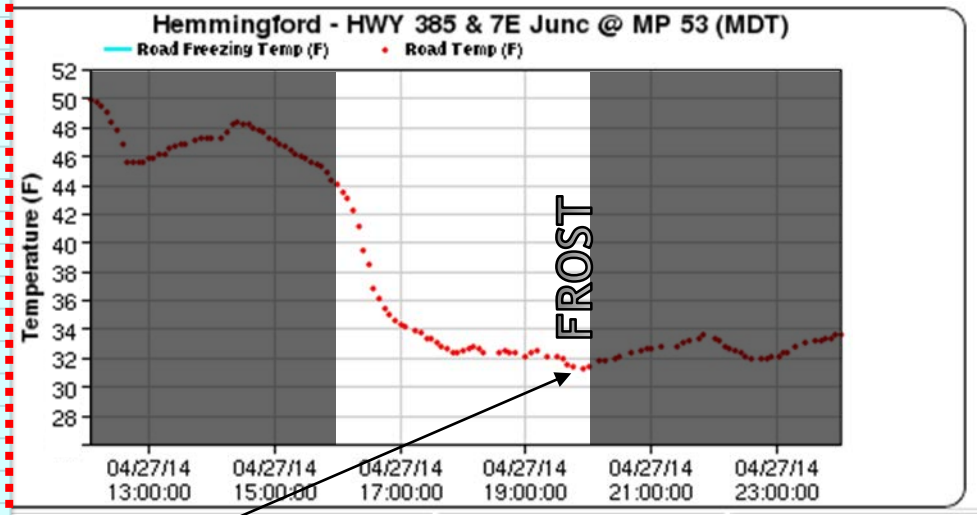
RWIS Data

- Tabular view
- Graphical view
- Parameter relationships

D5-RWIS 385 132.31 E. of Hemingford (NE023)

Time (MDT)	Air Temp (°F)	Dew Point Temp (°F)	Relative Humidity (%)	Wind Speed (mph)	Wind Direction	Road Temp (°F)
16:05	36.1	33.2	89	17.7	NE	43.5
16:10	35.6	32.6	89	19.5	SW	43.1
16:15	33.4	31.1	91	14.5	NW	42.2
16:20	33.2	31.2	92	13.2	NW	41.2
16:25	32.9	31.1	93	11.4	NW	39.5
16:30	32.9	31.1	93	10.5	NW	38.5
16:35	32.7	30.9	93	9.6	NW	36.8
16:40	32.7	30.9	93	7.6	NW	36.1
16:45	32.5	31	94	7.6	NW	35.4
16:50	32.5	31	94	6.9	NW	35
16:55	32.5	31	94	5.8	NW	34.7
17:00	32.5	31	94	5.8	NW	34.3
17:05	32.5	31	94	17.9	NW	34.1
17:15	32.7	31.2	94	18.1	NW	34
17:20	32.7	31.2	94	15.7	NW	33.8
17:25	32.7	31.2	94	16.1	NW	33.4
17:30	32.7	31.4	95	18.3	NW	33.4
17:35	32.7	31.4	95	17.9	NW	33.1
17:40	32.7	31.4	95	17.4	NW	32.9
17:45	32.7	31.4	95	19.7	NW	32.7
17:50	32.7	31.4	95	20.4	NW	32.3
17:55	32.5	31.2	95	17	NW	32.3
18:00	32.5	31.2	95	17	NW	32.5
18:05	32.5	31.2	95	18.8	NW	32.7
18:10	32.5	31.2	95	18.8	NW	32.9
18:15	32.5	31.2	95	18.3	NW	32.7
18:20	32.5	31.2	95	24.8	NW	32.3
18:35	32.3	31.1	95	25.7	NW	32.3
18:40	32.3	31.1	95	24.4	NW	32.5
18:45	32.3	31.1	95	21.3	NW	32.3
18:50	32.2	30.9	95	21	NW	32.3
19:00	32.2	30.9	95	21.5	NW	32.2
19:05	32.2	30.9	95	21.3	NW	32.3
19:10	32.2	31.1	96	19.7	NW	32.5
19:20	32.2	31.1	96	20.6	NW	32.2
19:30	32.3	31.3	96	24.2	NW	32.2
19:35	32.3	31.3	96	24.6	NW	32
19:40	32.3	31.3	96	23.3	NW	31.6
19:45	32.3	31.3	96	22.8	NW	31.4
19:55	32.5	31.5	96	23.5	NW	31.3
20:00	32.5	31.5	96	24.4	NW	31.4





mesowest.utah.edu

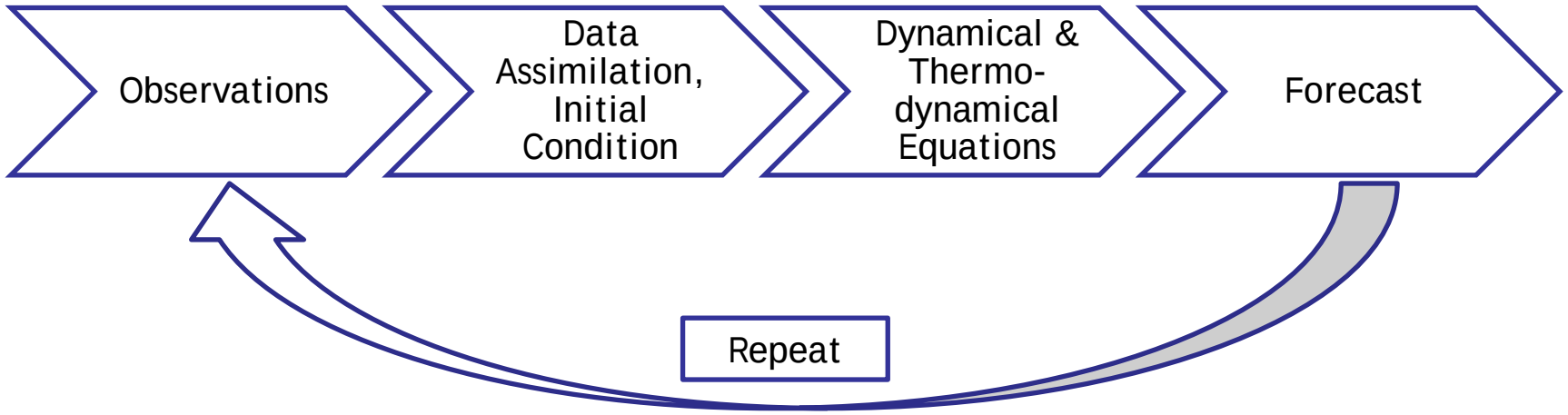
“Snow Level” in Forecasts

- Snow line
- Rain-snow line
- Rain-snow elevation
- Road snow level

Weather and Climate Models

Weather models collect **observations**, creating an **initial state** of the atmosphere, and **project** that state forward in time using dynamical and thermodynamical **equations**.

The output is a series of weather forecasts.

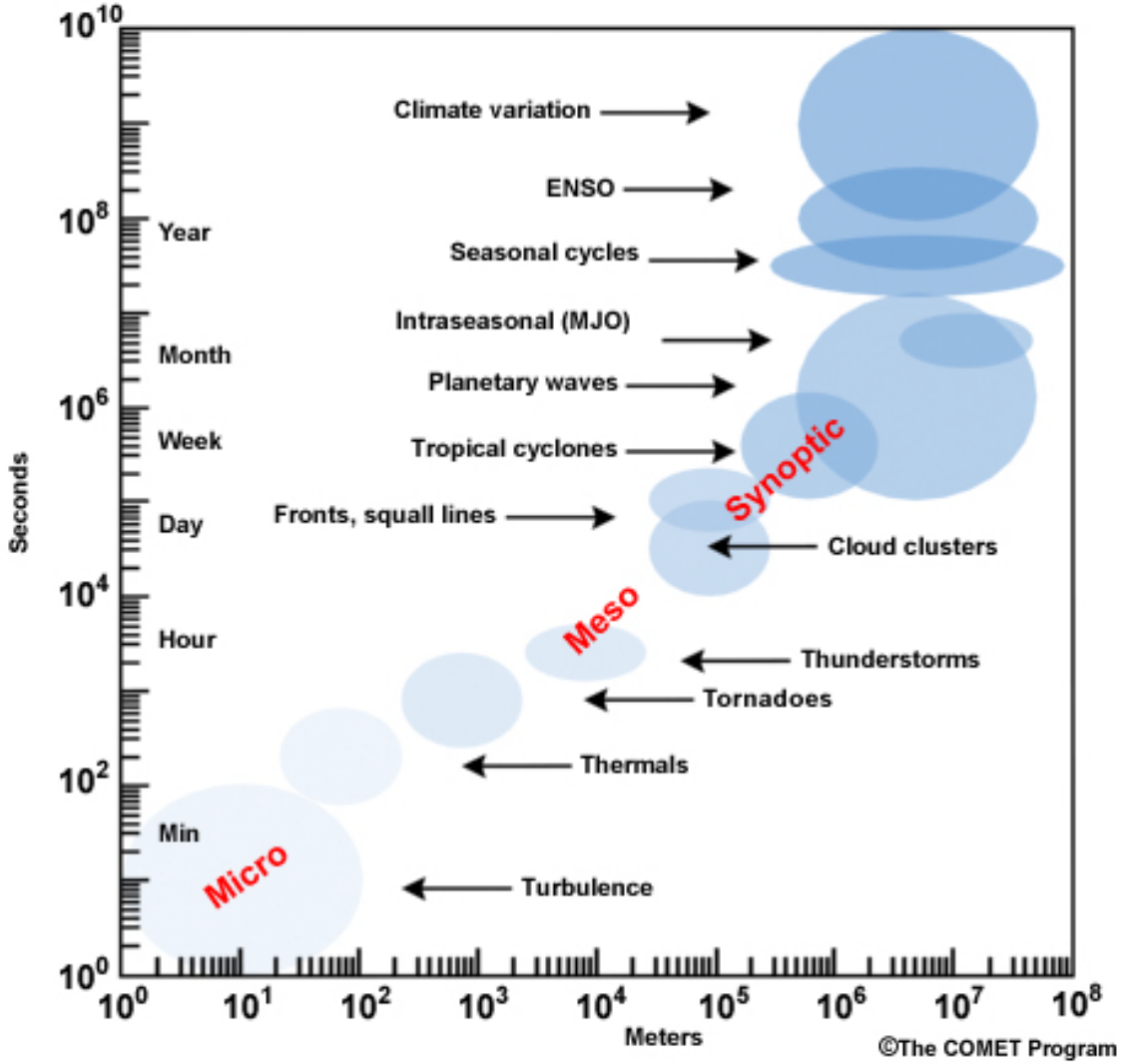


Atmospheric Scales – Time and Space

- Spatial scales in the atmosphere:
  → Micro (mm) to planetary (10,000 km)
- Temporal scales in the atmosphere:
  → Micro (sec) to seasonal or multi-year

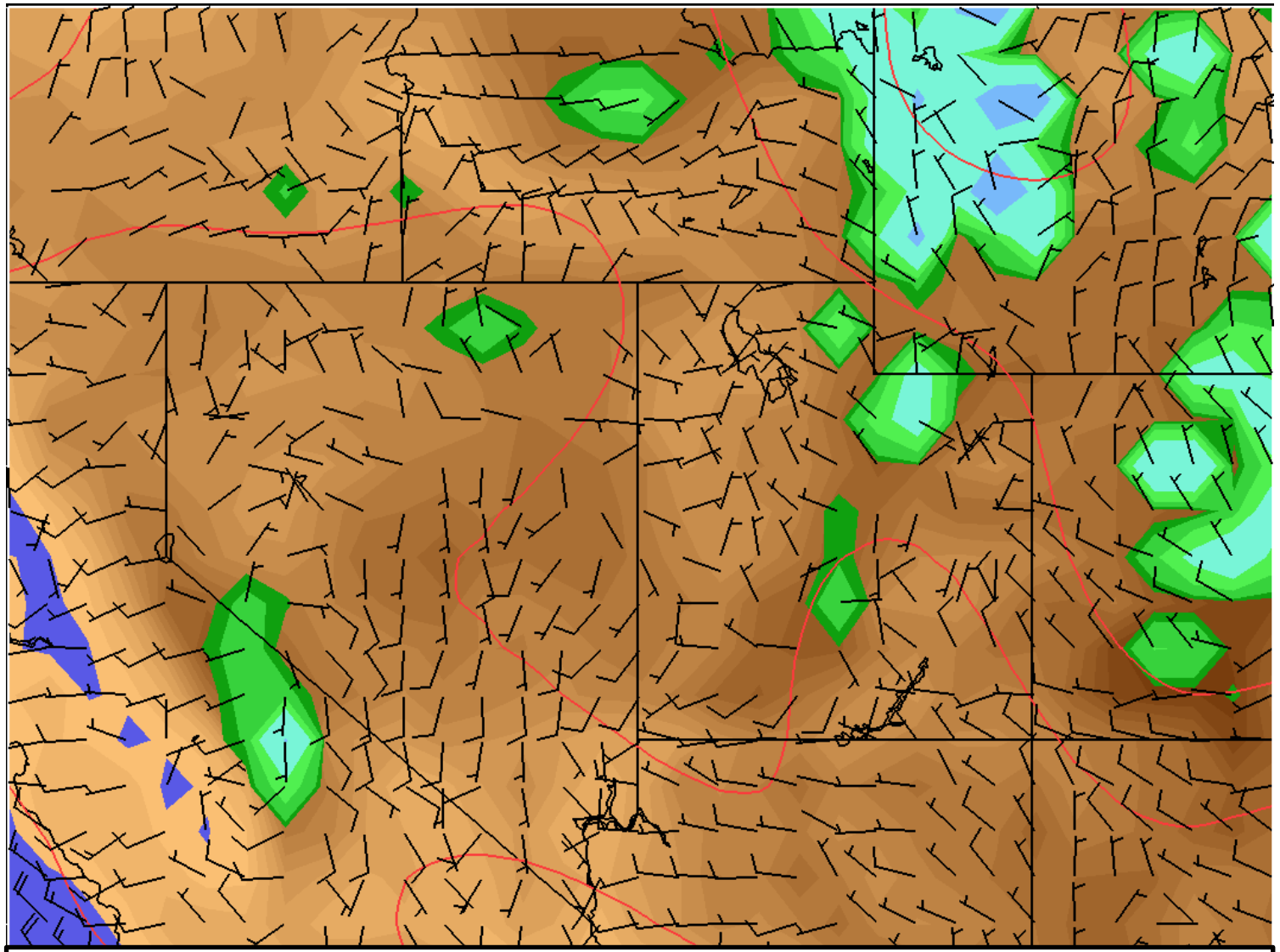
Transportation operations:

- micro (road surface)
- meso (snow squall)
- synoptic (storm system)
- planetary (El Niño)



Weather Models – Resolution

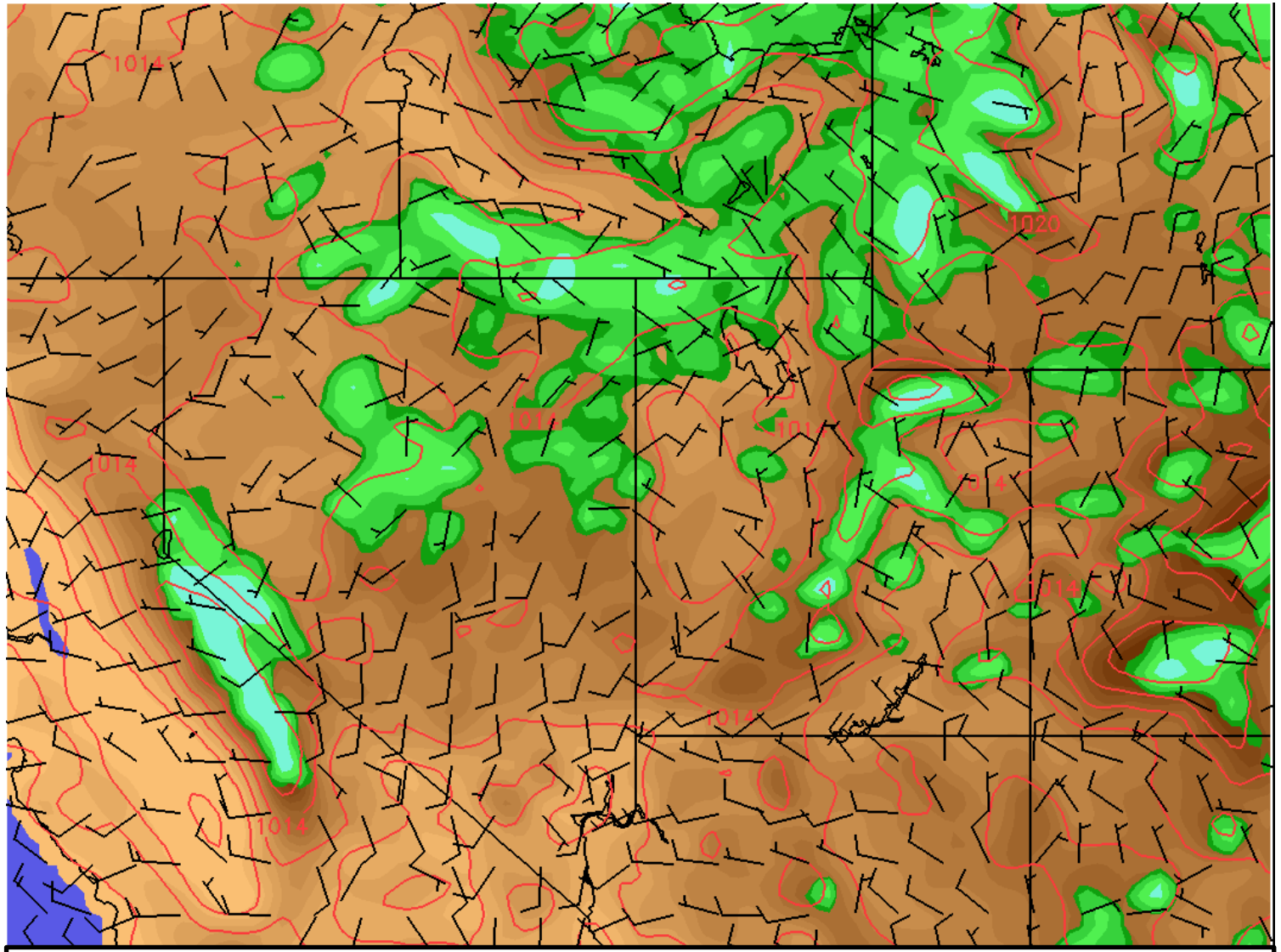
GFS
(Global Forecast System)
Resolution: ~27-km, 6-hr



36-hour forecast valid Sat, Aug 9 @ 6 pm

Weather Models – Resolution

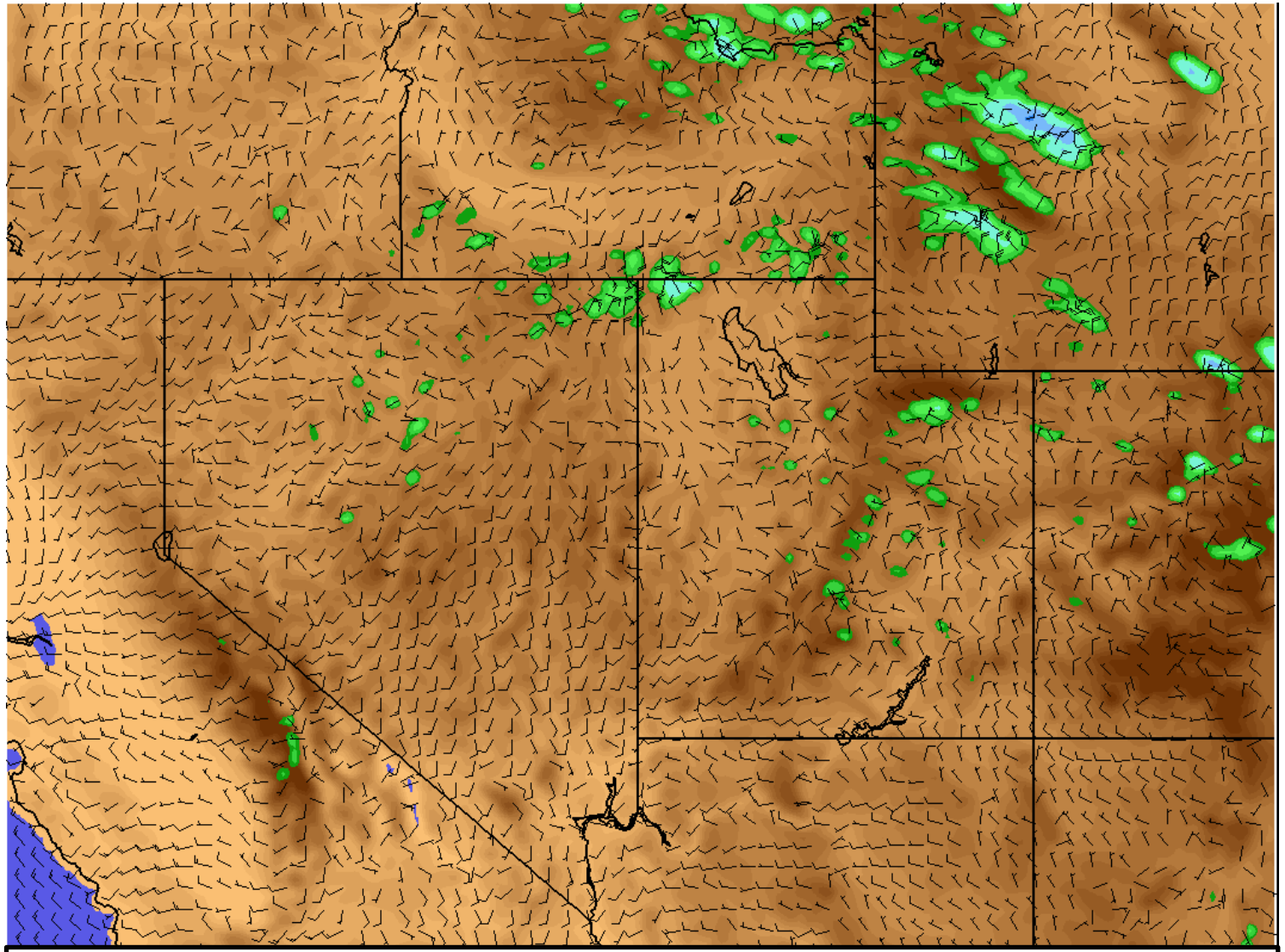
NAM
(North American
Mesoscale model)
Resolution: ~12-km, 3-hr



36-hour forecast valid Sat, Aug 9 @ 6 pm

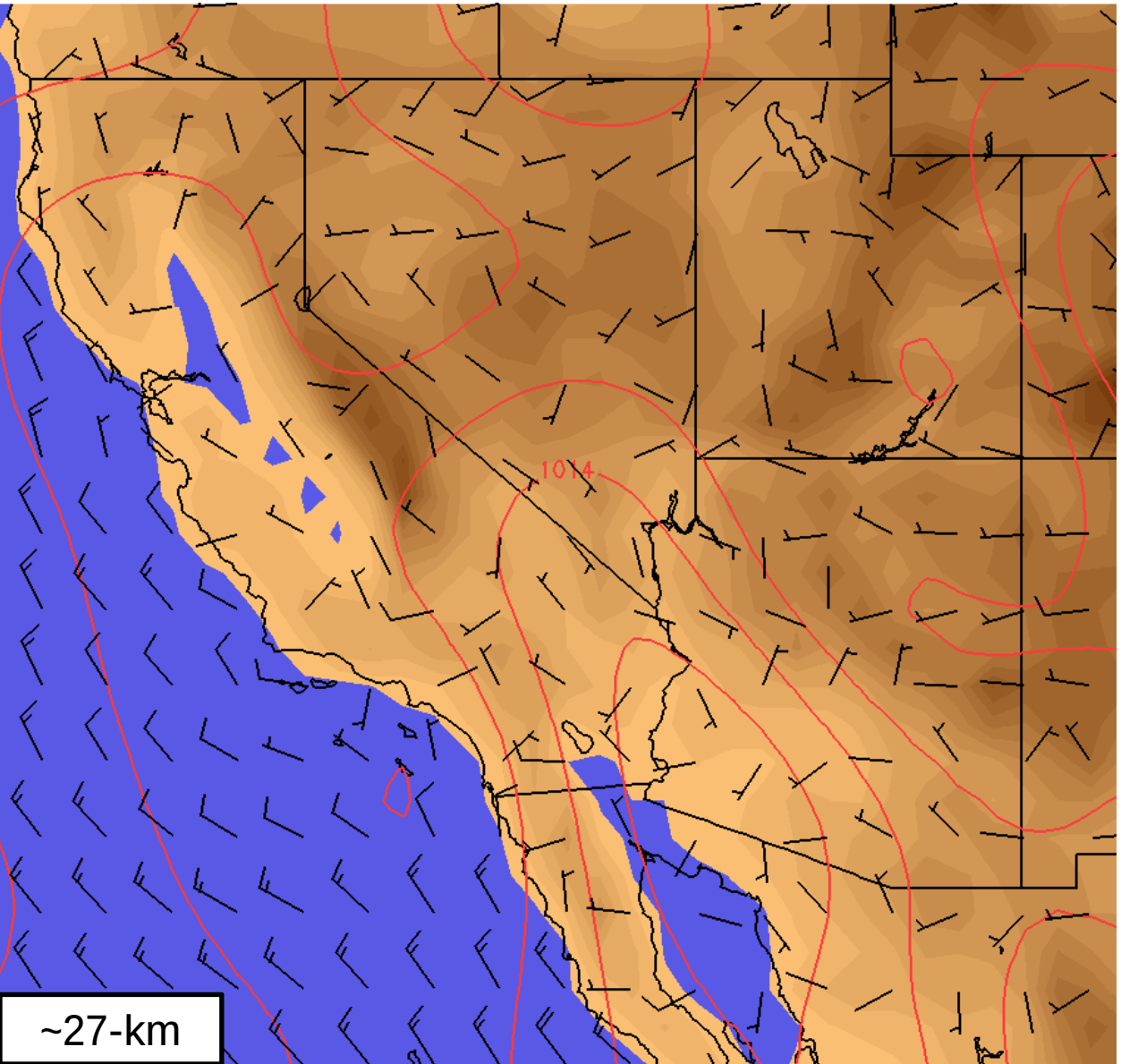
Weather Models – Resolution

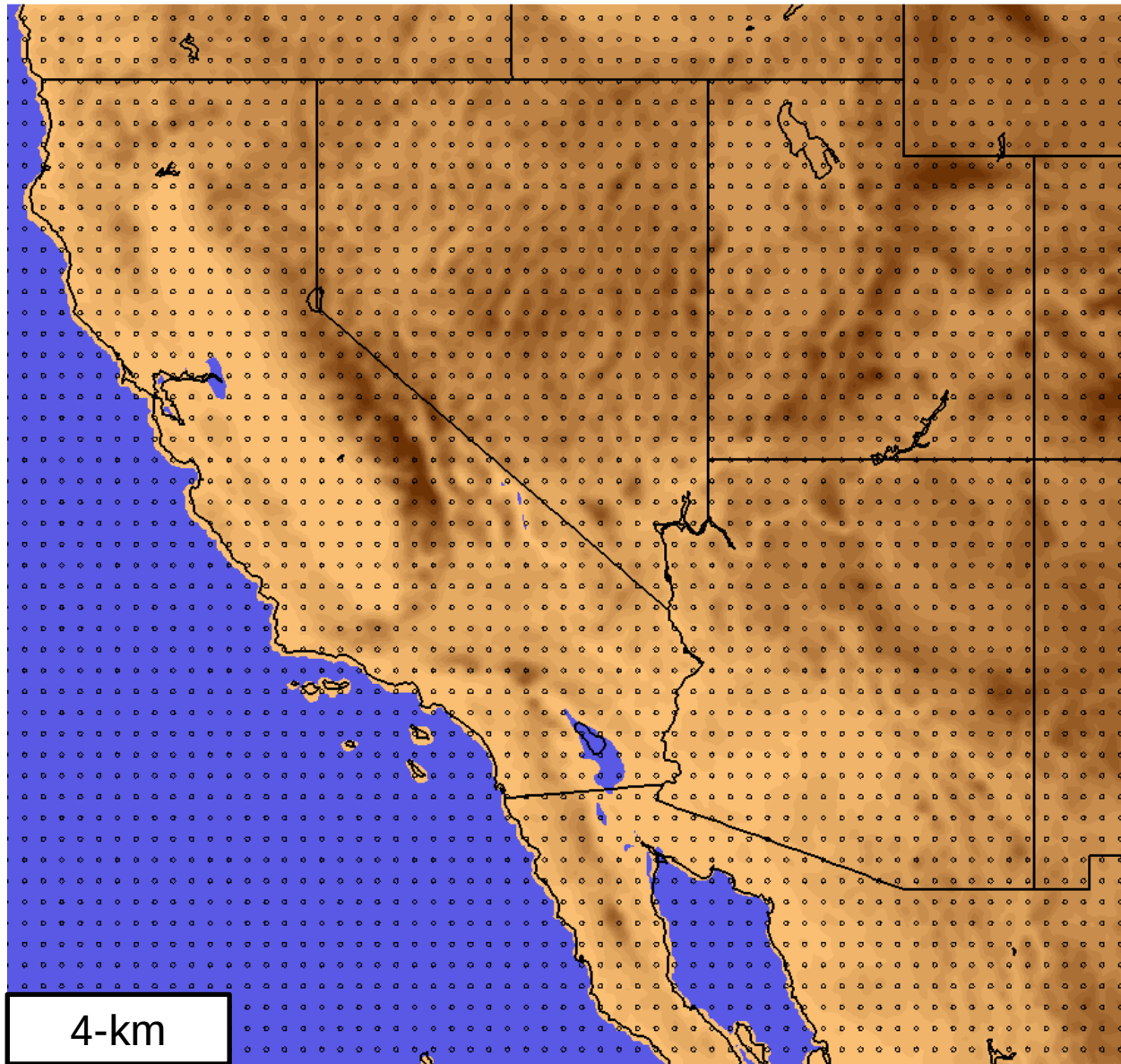
NAM-4km
(North American Mesoscale model)
Resolution: ~4-km, 3-hr



36-hour forecast valid Sat, Aug 9 @ 6 pm

Weather Models – Resolution – Terrain

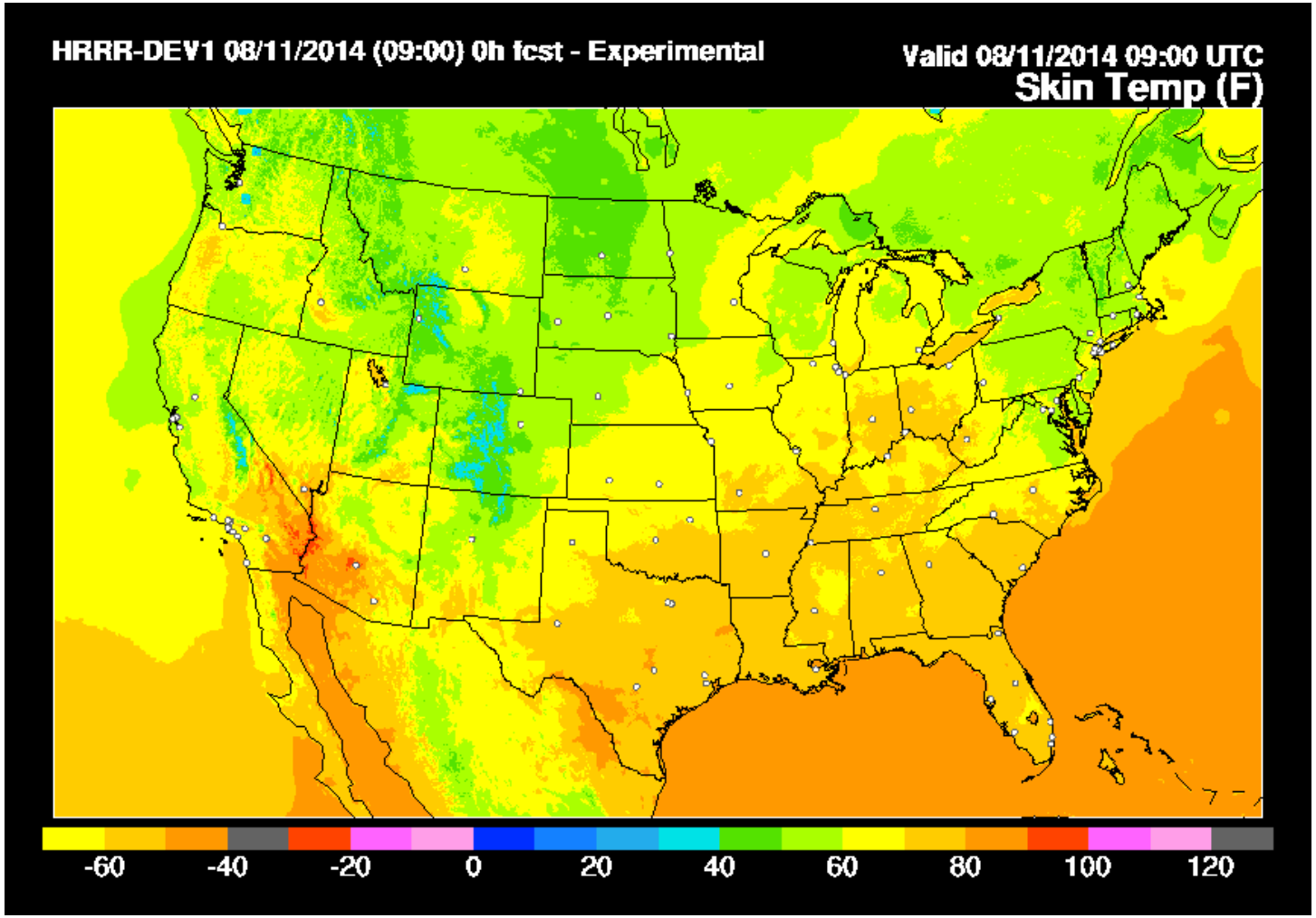




High-Resolution Models

For example, the High-Resolution Rapid Refresh (HRRR) model:

- Real-time
- 3-km resolution
- 1-hr forecast updates



Why making a forecast is difficult

- The better the observations, the better the forecast, but…
- All measurements have errors, and the observation network still needs a lot of work.
- We can never represent the environment perfectly.
- The atmosphere is *chaotic*:
  - Random, non-linear and, at some point, unpredictable.
- At ~7-10 days, forecast certainty is low to nil ("predictability barrier").

Forecast Confidence

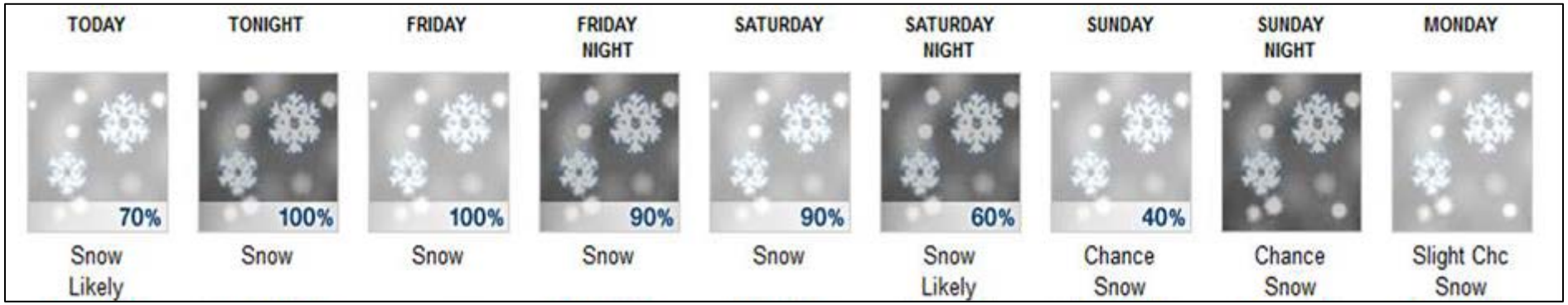
- **Confidence**: A forecaster can get a sense of the models' confidence using an *ensemble* of models.
  - A forecaster can give you a sense of their confidence in the forecast, but there is no direct correlation between a forecaster's confidence and accuracy.
- **Uncertainty**: there is an element of uncertainty in all forecast models
- *Talk to your forecaster.* What does your forecaster's confidence mean to you?
- "Benefit-Cost Ratio"

Operational Forecast:

Deterministic vs. Probabilistic

•YES/NO	•Chance of occurrence
•Single forecast	•Ensemble of forecasts

Probability of Precipitation (POP)



- The likelihood, expressed as a percent, of measurable precipitation (≥ 0.01 inch) at a particular point during a specified time period. (NWS)
- A 60% chance of rain for a specific location means that out of 100 days with the same atmospheric ingredients in place, we believe it will rain/snow on 60 out of those 100 days (or a 60% chance).

POP (%)	Qualifying Term	Areal Term
20	Slight Chance	Isolated
30, 40, 50	Chance	Scattered
60, 70	Likely	Numerous
80, 90, 100	(none)	(none)

How do you verify a forecast?

- **Forecast Verification**: Assessing the quality of the forecast, after the forecast time period.

  (Big business in NWS and forecasting firms.)
- Quantitative or qualitative

  You may be able to use a simple qualitative verification scheme at your DOT for your forecasting services.

  Probability forecasts must be verified against an aggregate.
- Forecast skill vs. value

  Consider what is most important for your operations: the skill of any given forecast may be low by some measure, but the value of that forecast to the DOT may still be high (did the operational decisions you made based on the forecast still optimize DOT time and resources?).

Yearly/Decadal Climate Signals

Teleconnections: Links between weather changes occurring in widely separated regions of the globe.

El Niño/La Niña (ENSO)

Multi-year shifting of sea-surface temperatures and atmospheric pressure in the central Pacific, effectively altering the temperature and precipitation distribution in North America.

Pacific Decadal Oscillation (PDO)

Approximately decade-long shifting of Pacific sea-surface temperatures that affects weather over North America. Positive, or warm phases of the oscillation can produce El Nino-like climate variations, whereas negative, or cold phases of the oscillation can produce La Nina-like conditions.

North Atlantic Oscillation (NAO)

Approximately seasonal shift of the difference between low pressure in the subpolar Atlantic and high pressure in the subtropical Atlantic. High correlation to temperature patterns across Eastern North America.

Arctic Oscillation (AO)

Approximately seasonal shifting of the wind speeds around the Arctic, which affects the circulation of Arctic air southward.

Pacific-North American Index (PNA)

Monthly-to-yearly shifting of upper atmospheric pressure over the northern Pacific and North America. This climate signal is more of an "end product" derived from changes and shifts by other climate signals and oscillations

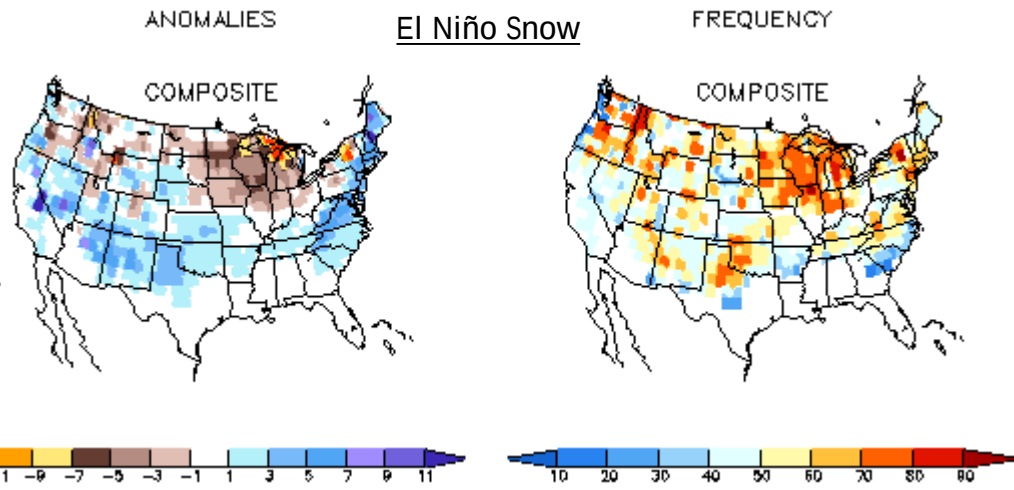
Madden-Julian Oscillation (MJO)

Sub-seasonal fluctuations of thunderstorm activity/rainfall in the tropics. Strong, long-lasting MJO waves will sometimes increase predictability of weather in the 2-3 week timescale, as they are directly responsible for significant alterations to the global upper-level weather pattern.

Eastern Pacific Oscillation (EPO)

Seasonal fluctuations in upper atmospheric pressure across the eastern Pacific and particularly Alaska. A strongly positive phase of this oscillation will lead to very cold and stormy weather over Alaska, with a very mild weather pattern over virtually all of the continental USA.

El Niño Snow



What Is Climate *Change*?

- Climate change:
  - Any systematic change in the long-term statistics of climate elements (such as temperature, pressure, or winds) sustained over several decades or longer (The Glossary of the American Meteorological Society)
  - Climate change may be due to:
    - Natural external forcings (e.g., changes in solar emission or slow changes in Earth's orbit);
    - Natural internal processes of the climate system; or
    - Anthropogenic forcing.

- *Change* is determined using trends in the U.S. Historical Climatology Network (USHCN) data, which go back many decades and are meticulously quality controlled.

- An individual extreme event, in and of itself, is not indicative of a changing climate.
- Climate includes *decades* of extreme events.

- Generally, a changing climate shifts the normal curve in one direction or another, making it more likely that extreme events will happen more often and break more records than ever before.

Questions?