Winter Information to Support Winter Maintenance Decision Making

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Portfolio Product Manager

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2023

PACIFIC NORTHWEST SNOWFIGHTERS CONFERENCE

Agenda

Introductions

Brief DTN Background

How is Weather Information Communicated?

Weather Models

Radar Data

Dew Point and Impact to the Road

Precipitation and Snow Factor

Introductions

- Ben Hershey
- Background in Meteorology
- Portfolio Product Manager

DTN Road Weather for Transportation

28 State DOTs | 465 Munis/Private | 11 European Countries

- Actionable, accurate weather and pavement forecasts allow for *proactive operational planning* year-round.
- Maintenance Decision Support System (MDSS) provides treatment recommendations for *safety and cost efficiency*.
- Road condition risks guide *efficient fleet routing*.
- Road Weather Information System (RWIS) management systems obtain *accurate road conditions for forecasting*.
- Global meteorological consultation services ensure client receive *expert advice for their operational decisions*.

How is Weather Information Communicated?

Rain should switch over to snow around 7pm with 2” of snow accumulation possible

Abandoned cars block a road following a winter storm in Buffalo, New York, Dec. 27, 2022.
Lindsay Dedario/Reuters

Major winter storm with lots of snow!!!

Model Data

Model Differences and Forecast Impact

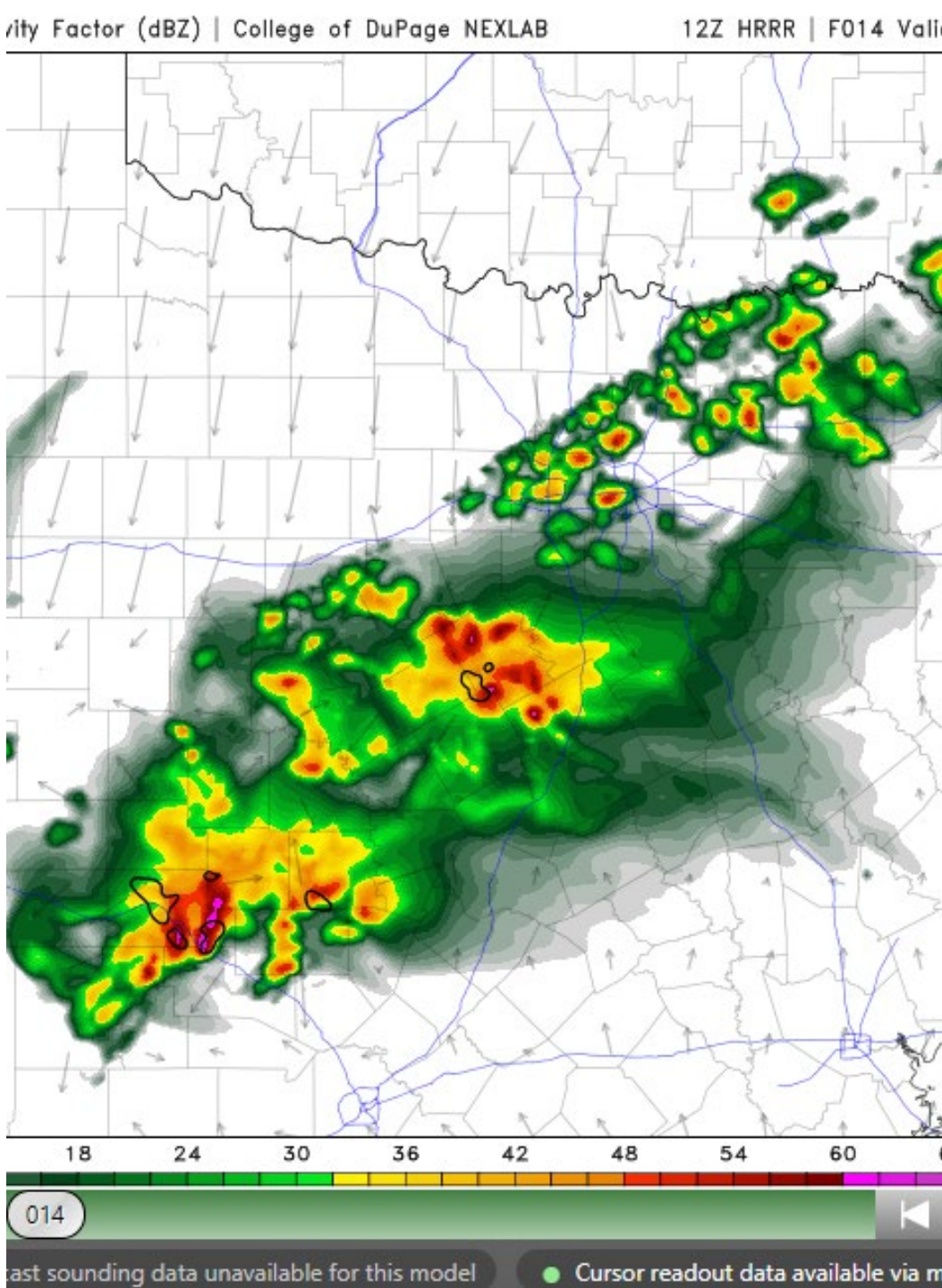
There are many different forecast models. Some of the differences between models include:

Spatial resolution

Temporal resolution

Microphysics schemes

- ✓ (how models deal with cloud/droplet/ice formation), convection allowed/parameterized.



Model Data: The short and long of it

Short Term – Hi Resolution

HRRR – High Resolution Rapid Refresh. Runs every hour with 3km resolution.

RAP – Rapid Refresh. Updated every hour. 13km resolution.

Short to Mid Range

NAM – North American Mesoscale. Every 6 hours. 12km and 3km resolutions.

RGEM – Regional Deterministic Prediction System. Every 6 hours. 12km resolution.

WRF – NAM Weather Research Forecasting model using NAM as background. Run internally every 6 hours.

Mid to Long Range

GFS – Global Forecast System. 0.5 degree resolution. Every 6 hours.

GEM – Global Environmental Multiscale model. 0.24 degree resolution. Every 6 hours

WRF – GFS Weather Research Forecast model run every 6 hours.

ECMWF – European Center for Medium-range Weather Forecasts (aka EURO). 12km resolution. Run 2x daily.

MOS – Model Output Statistics. Site specific forecasts from models based on linear regression.

Ensembles and Others:

GEFS – Global Ensemble Forecast System. 21-member ensemble using GFS.

Seasonal – Models used to predict seasonal weather patterns include **CFSv2**, **CanSIPS**, and **NMME**.

Hurricane – Only run for coastal/tropical regions during hurricane season.

Flood – Flash Flood Guidance based on soil moisture, precip, and streamflow.

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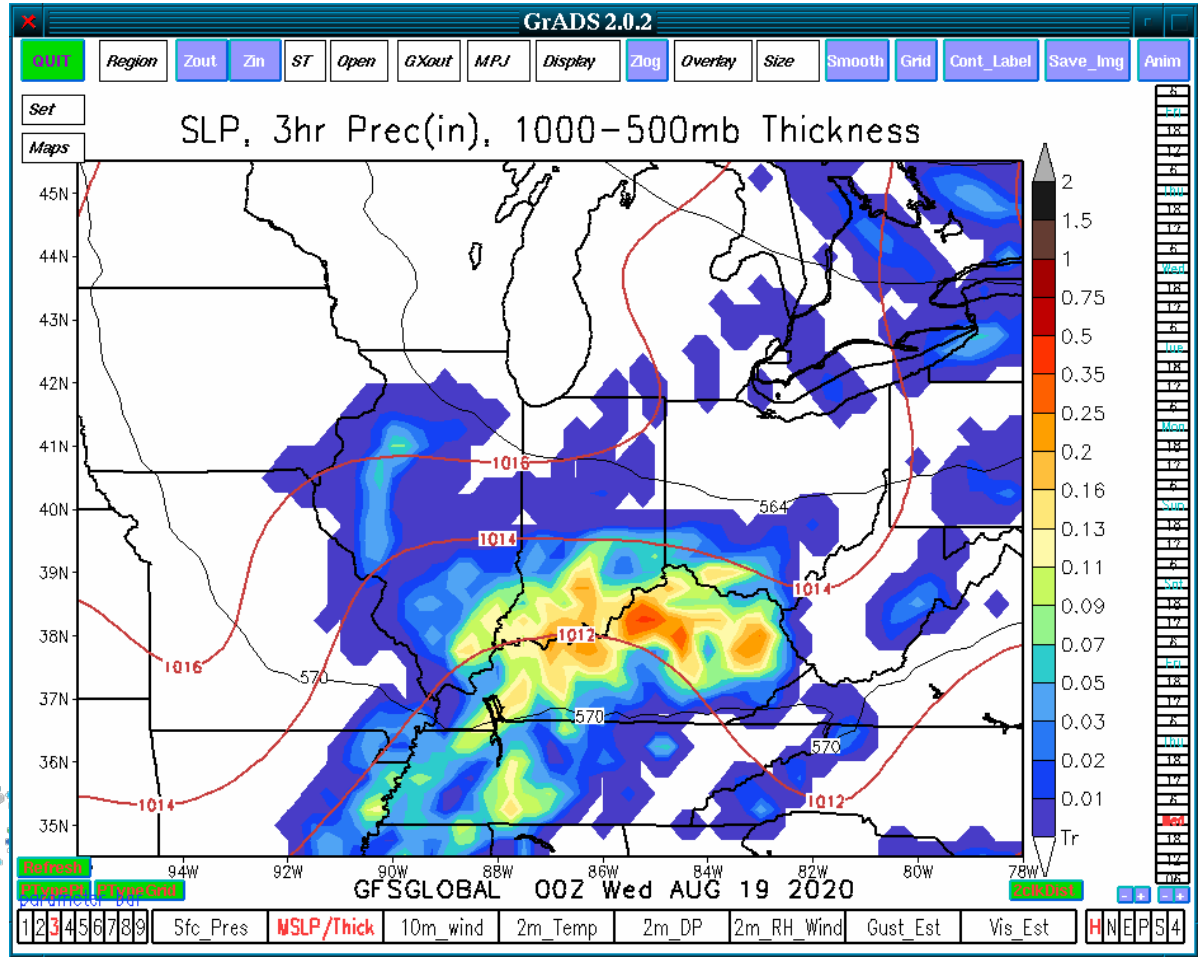
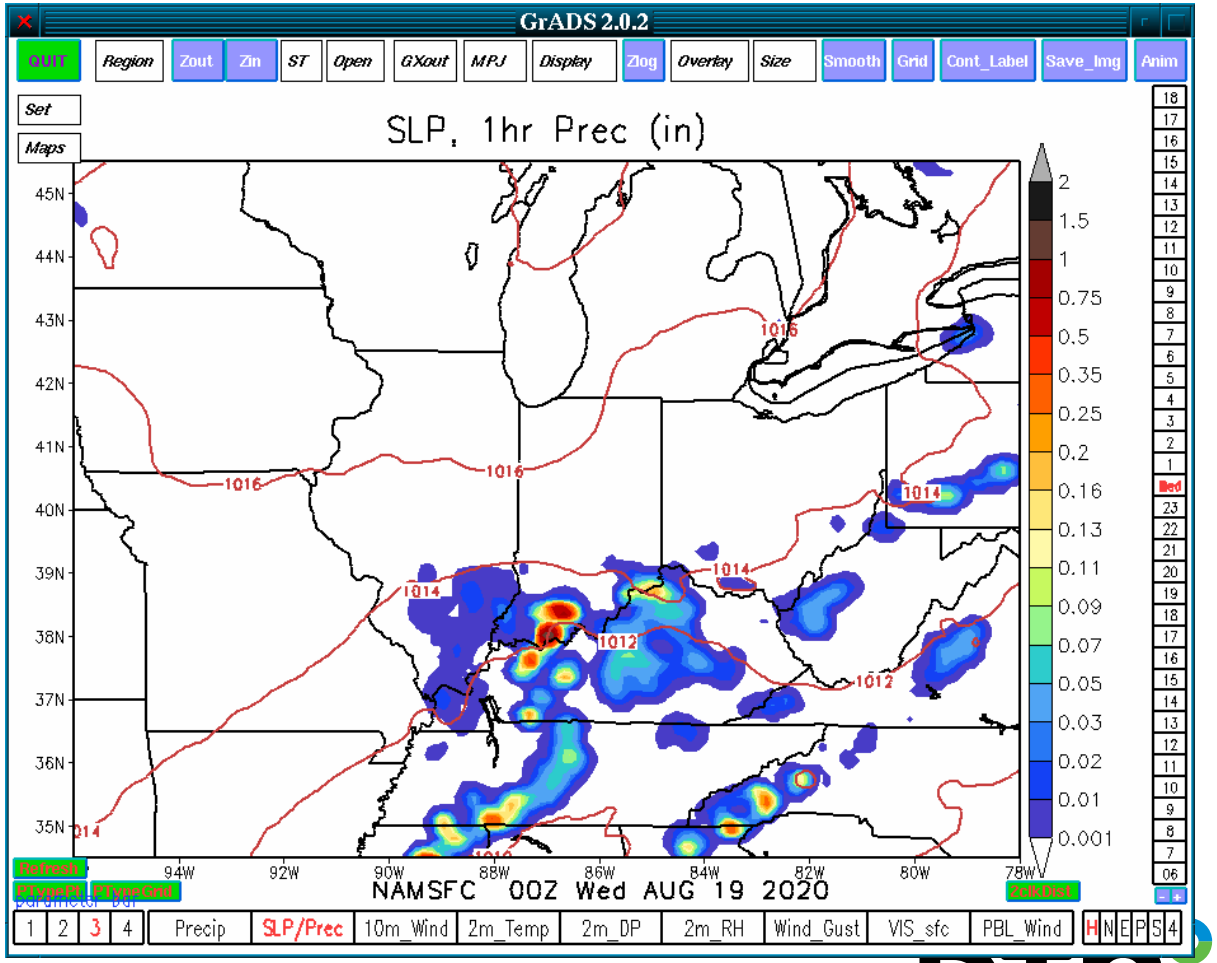
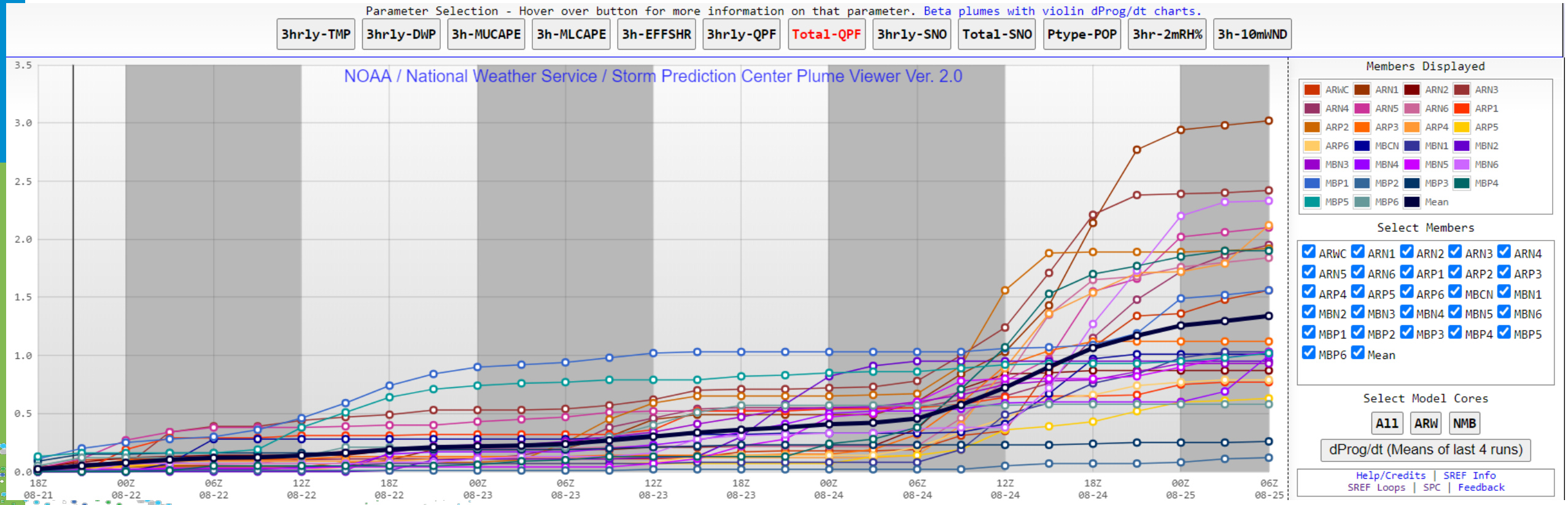
Some models can go out further in time, but have a coarser, less detailed resolution (left) while some others can go out a shorter period of time, but have a finer, more detailed resolution (right).



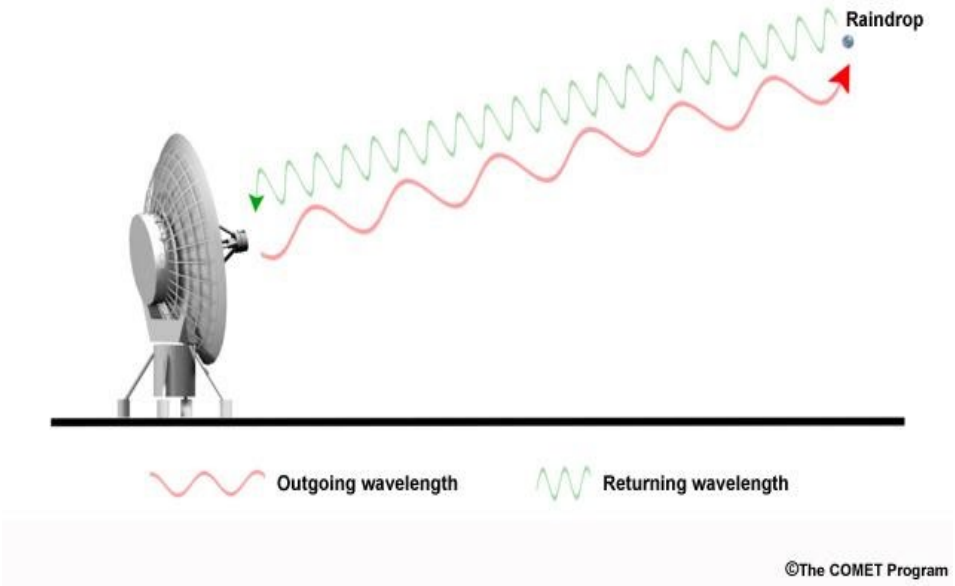


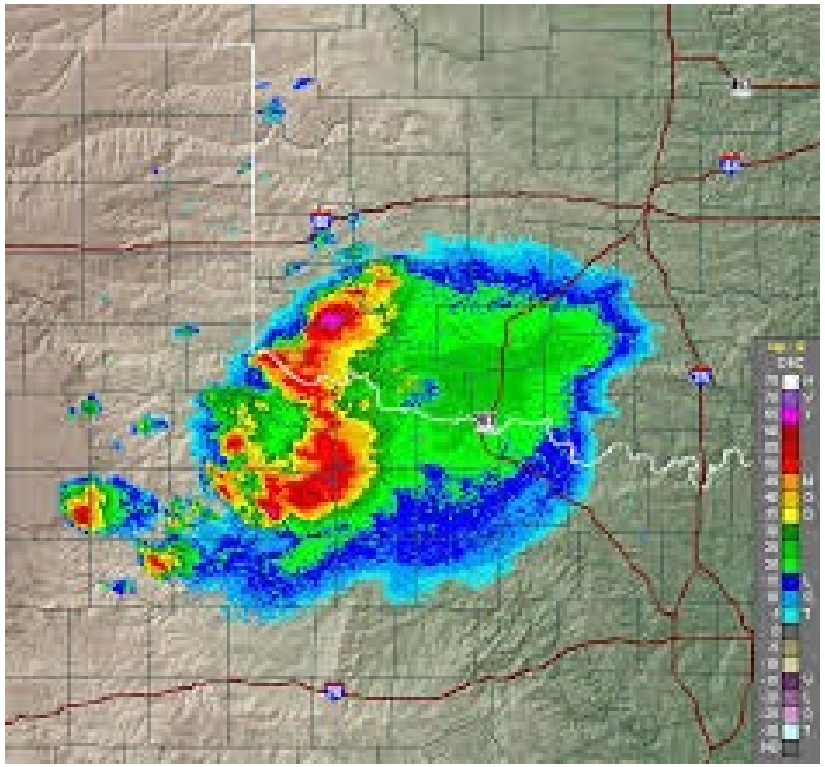
As events get closer, models usually tend to converge on a solution (or sometimes two solutions). As models converge, confidence in the forecast increases, particularly if they converge consistently toward a constant solution.



Radar Data

Radar: How It Works



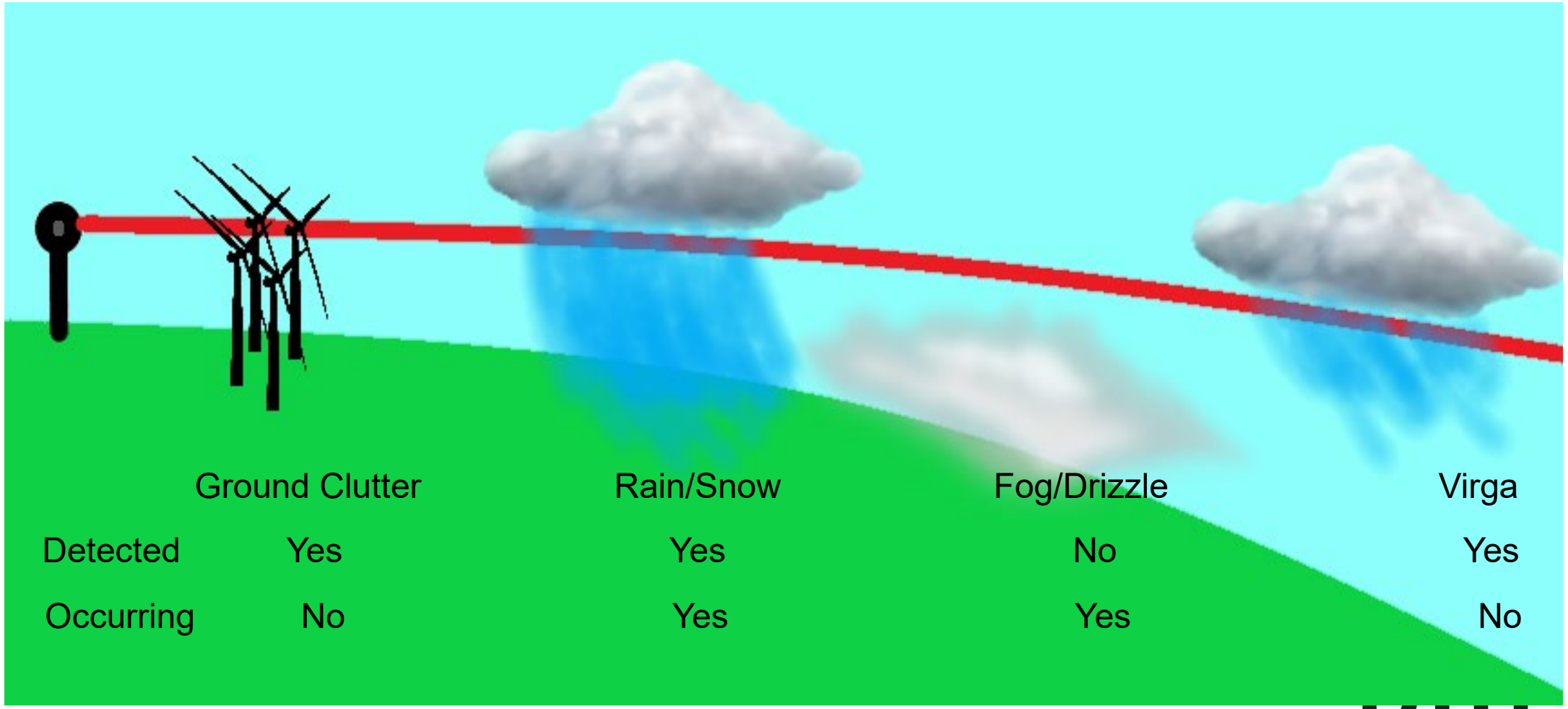


- Radar sends out a signal at a certain frequency that reflects off of precipitation particles.

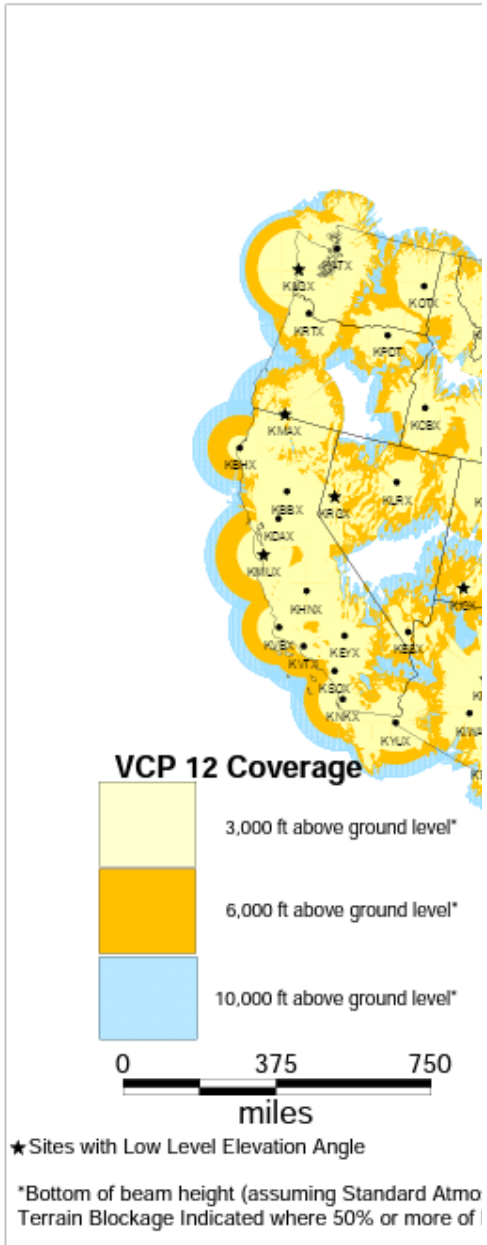
- The amount of signal returned back to the radar site gives information about precipitation intensity (i.e. more signal returned = more intense precipitation)

Radar Limitations

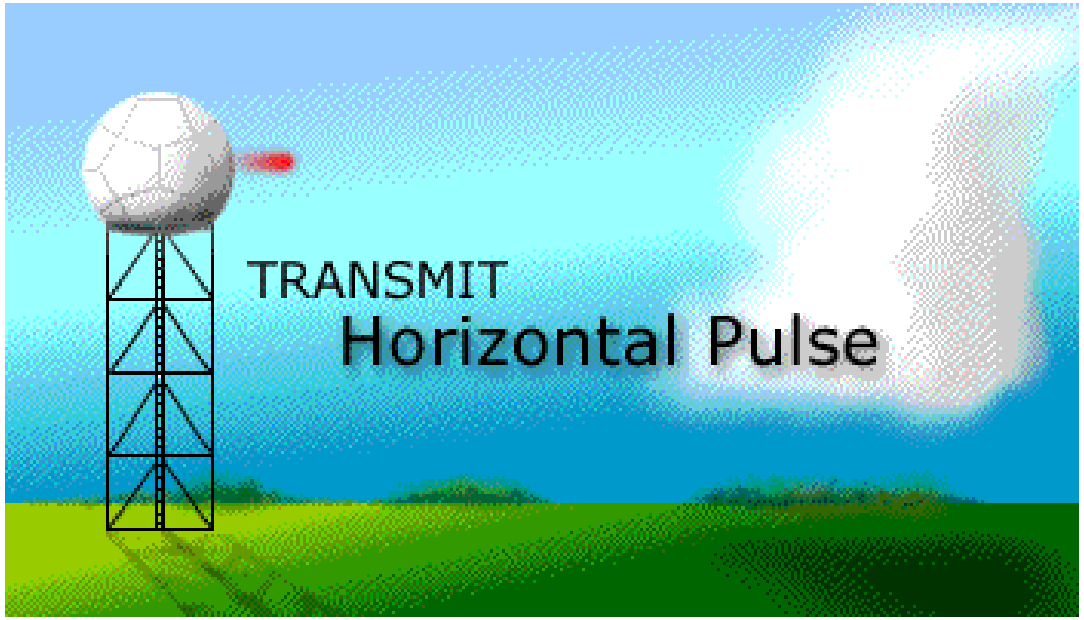
- Due to the curvature of the earth, the radar beam detects objects higher up the further the distance from the radar site



NEXRAD Coverage Below 10,000 Feet AGL



Dual-Pol Radar



Polarimetric Radar (Dual-Pol)
Transmits and receives both horizontally and vertically polarized radio wave pulses. Therefore, they measure the horizontal and vertical dimension of cloud and precipitation particles.

How can this be helpful in winter weather?

We can use this to help determine **precipitation type**!

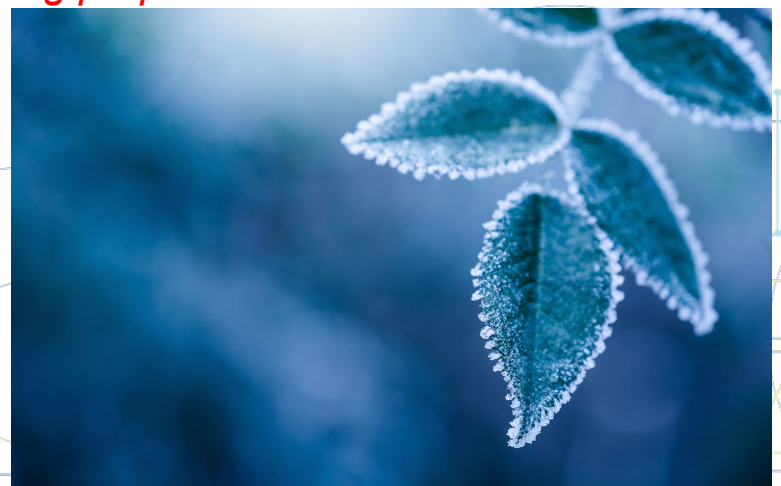
Dew Point and the Pavement

Dew Point and Relative Humidity

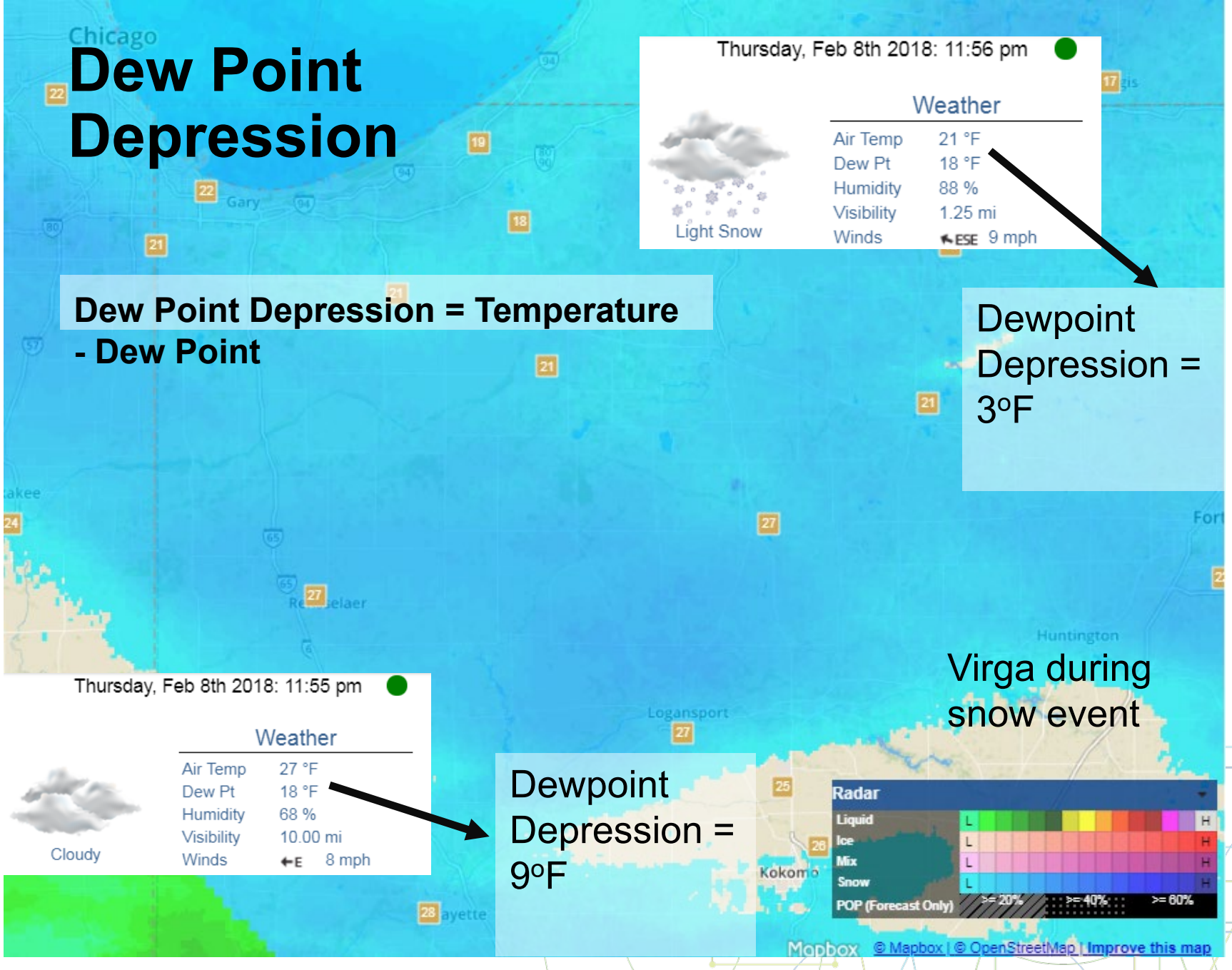
- The dew point is the temperature at which dew (or frost if T< 32 degrees) would form if the air temperature cooled to that point.
- Relative humidity (%RH) is a measure of how saturated the air is (i.e. how much water is in the air compared to how much it can hold).
- These are important for forecasting fog, and road/bridge frost conditions.

To find areas at risk for fog/freezing fog, look for areas where the relative humidity will approach 100%.

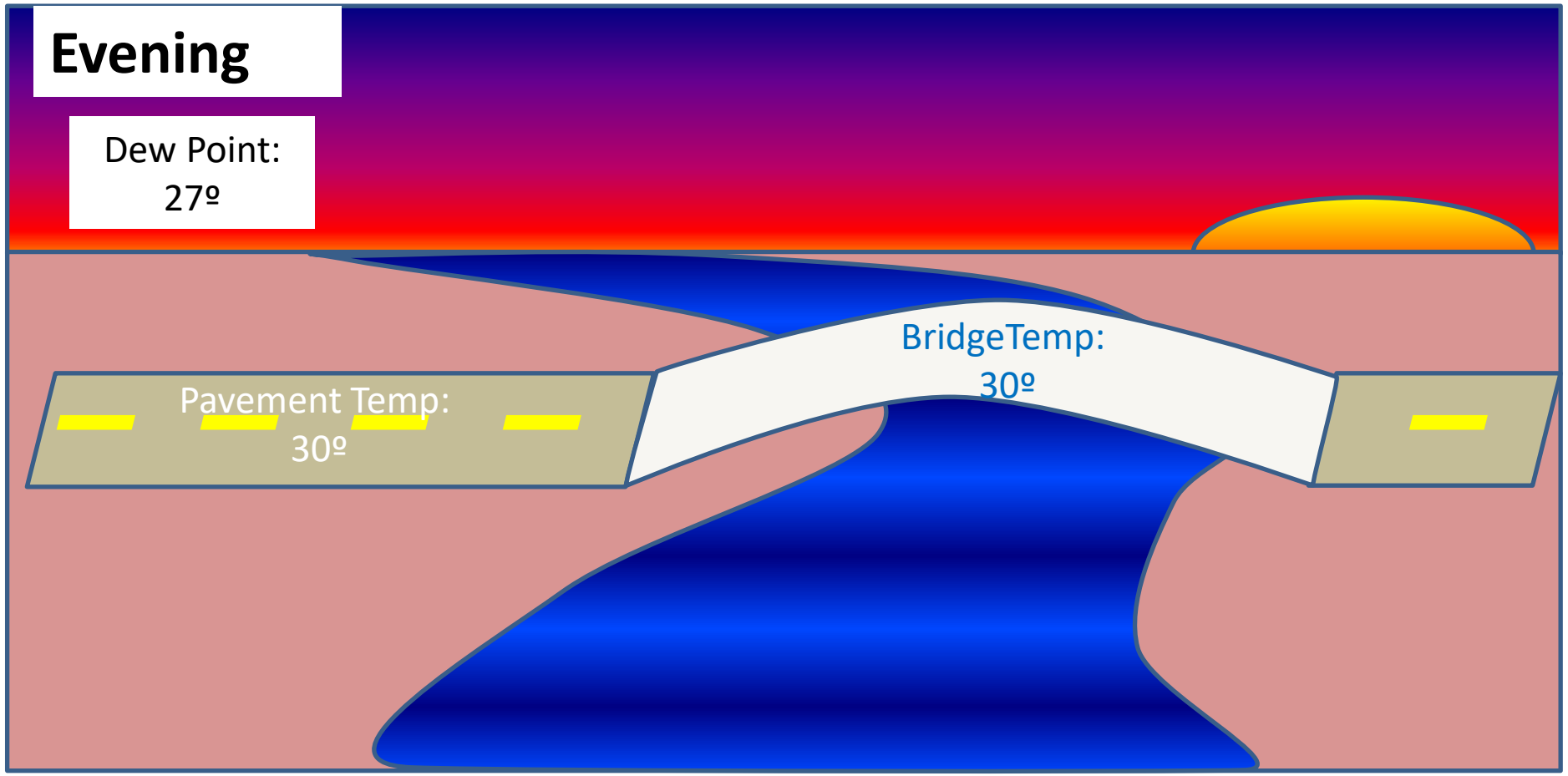
To find areas at risk for road frost, look for areas where the pavement temperature is forecast to be near or below the dew point. Objects such as grass, car windshields, or trees may form dew/frost before or after pavement depending on their individual cooling properties.



Dew Point Depression



Frost: Road VS Bridge



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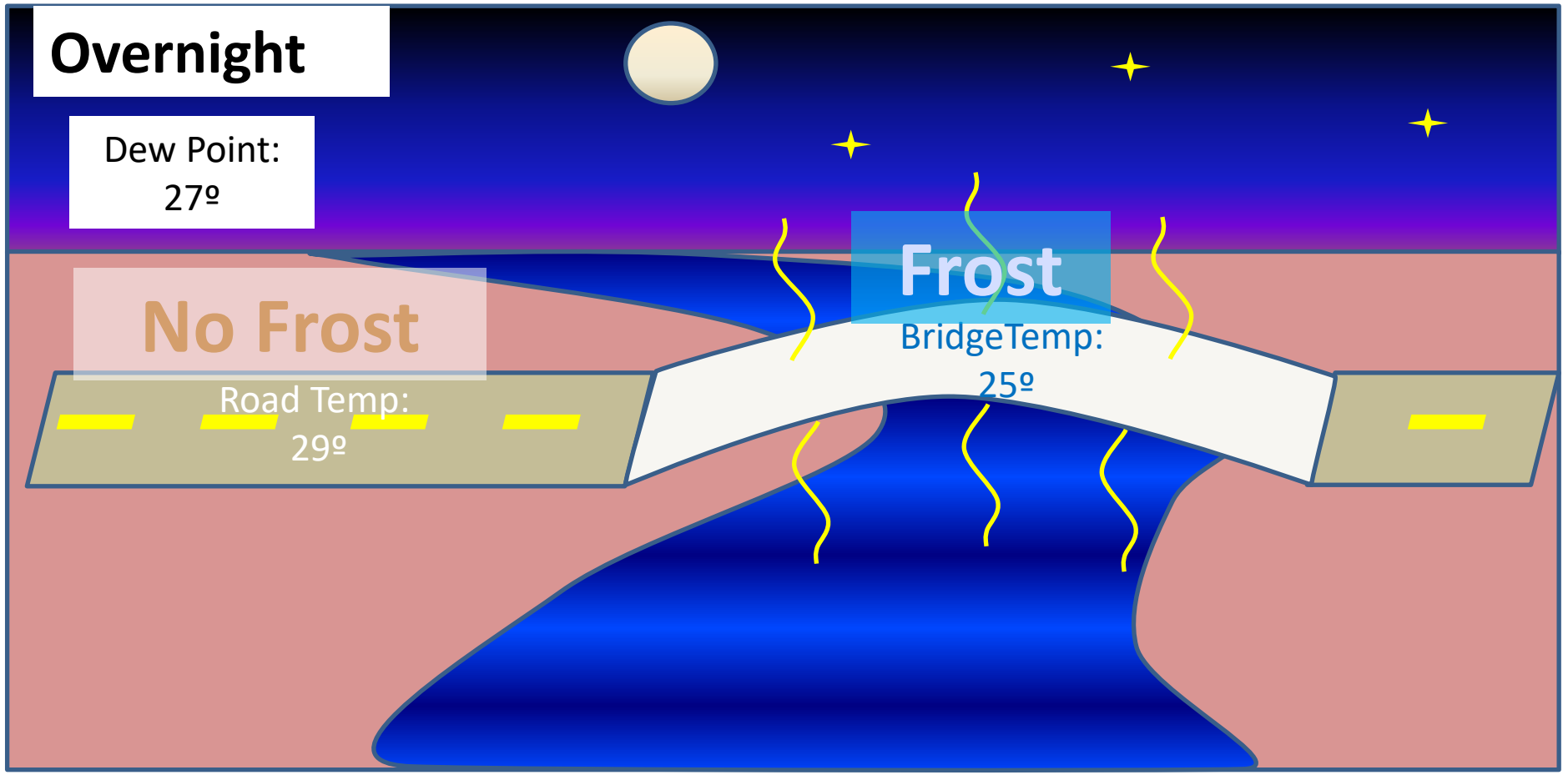
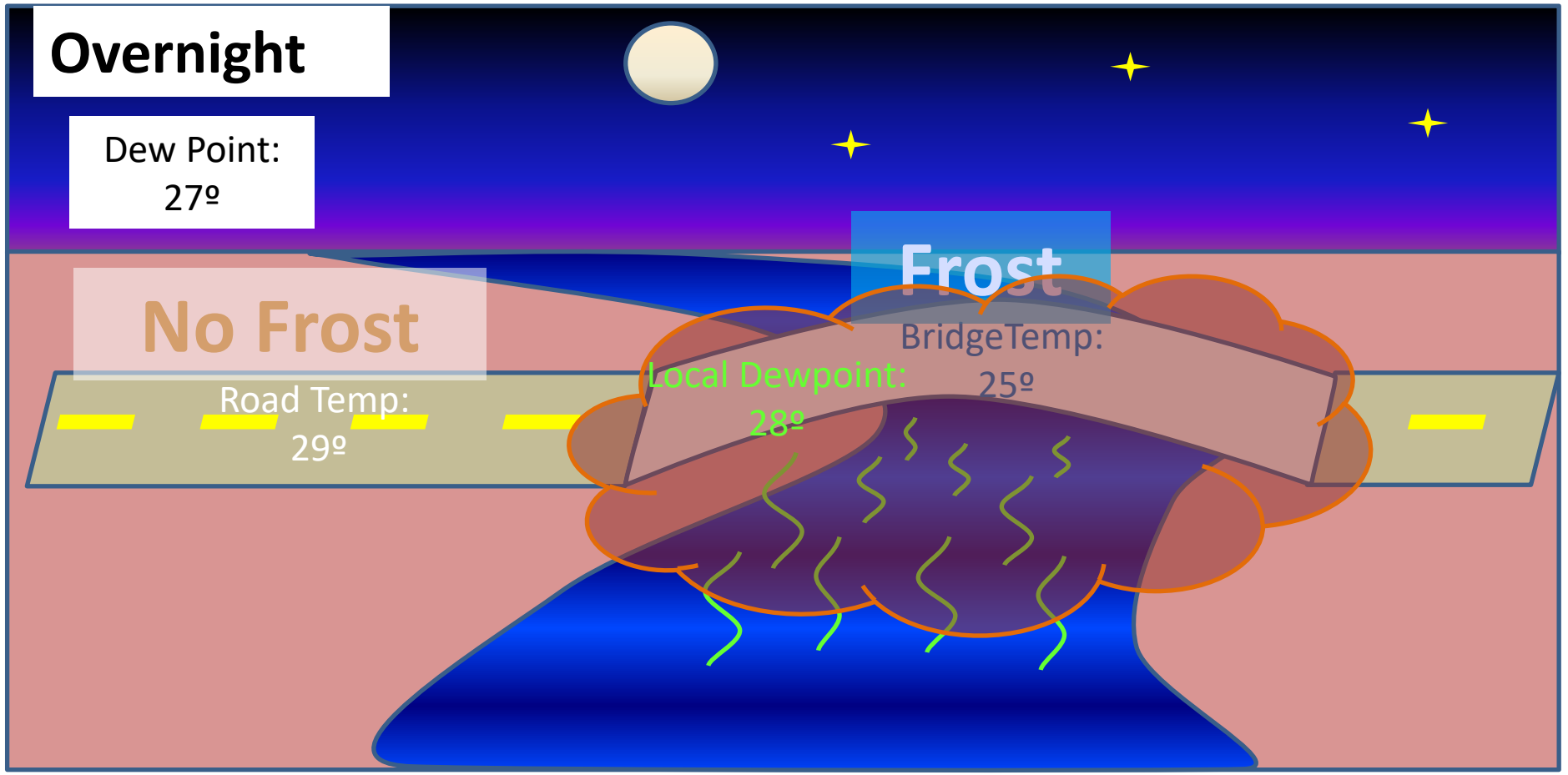


- Bridges typically frost over first due to lack of insulation from underneath.

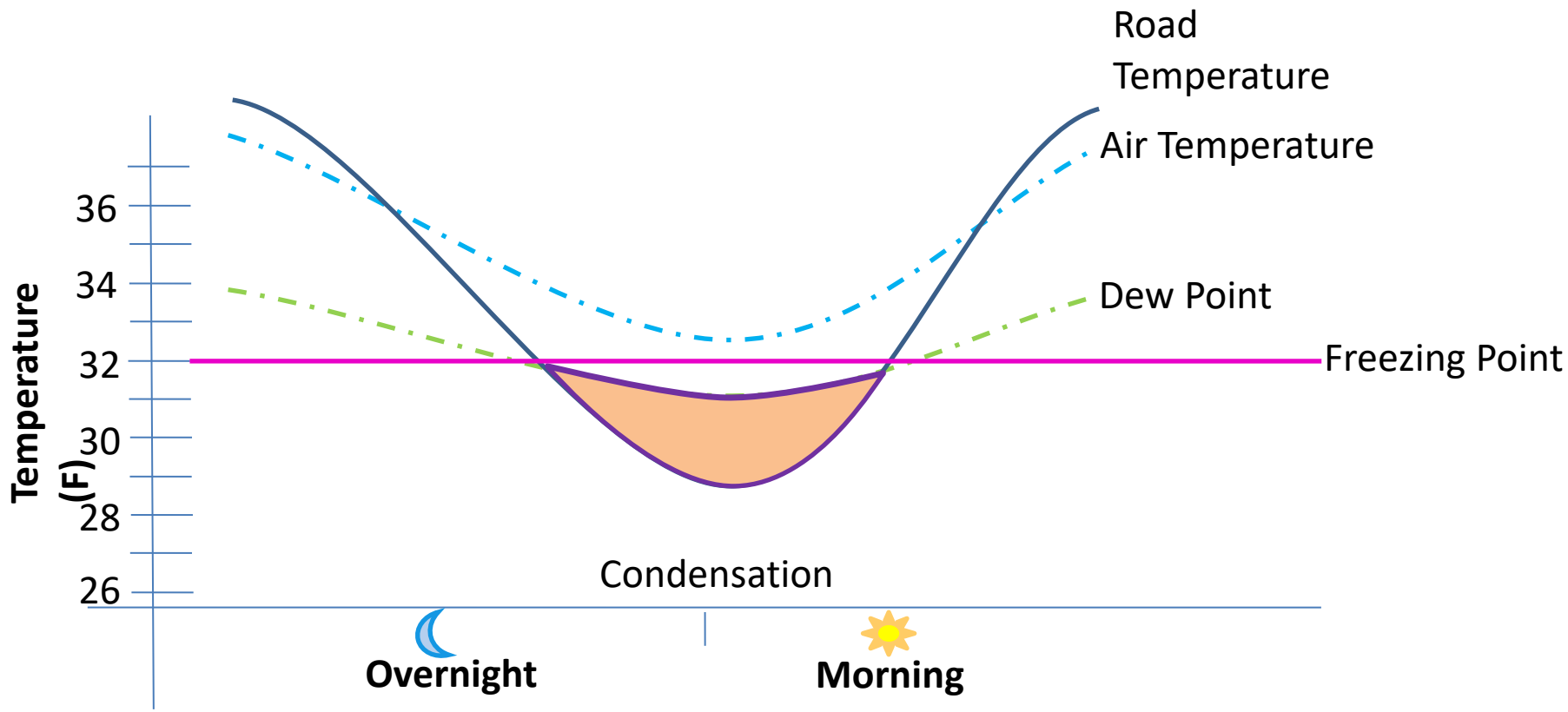
Frost: Road VS Bridge



- Bridges typically frost over first due to lack of insulation from ground.
- Body of water could locally enhance moisture/dew point too.

Frost: How Does It Form?

Scenario: typical loss of heating during a calm, clear, and cool night.



Probabilities: Precipitation vs. Frost

Precipitation Probability

Ranges from 0-100%, with values anywhere in the range used with regularity.

Probabilities above 40% indicate that precipitation is likely in a given area for a given hour.

Impacts possible when precipitation occurs, but not guaranteed

Road/Bridge Frost Probability

Ranges (in theory) from 0-100%, but values above 50% are rare.

Probabilities above around 30% indicate that road or bridge frost is likely in a given area for a given hour.

Impacts almost always occur when road frost occurs.

What does this mean?

Action threshold for road/bridge frost is lower than for snow/ice!

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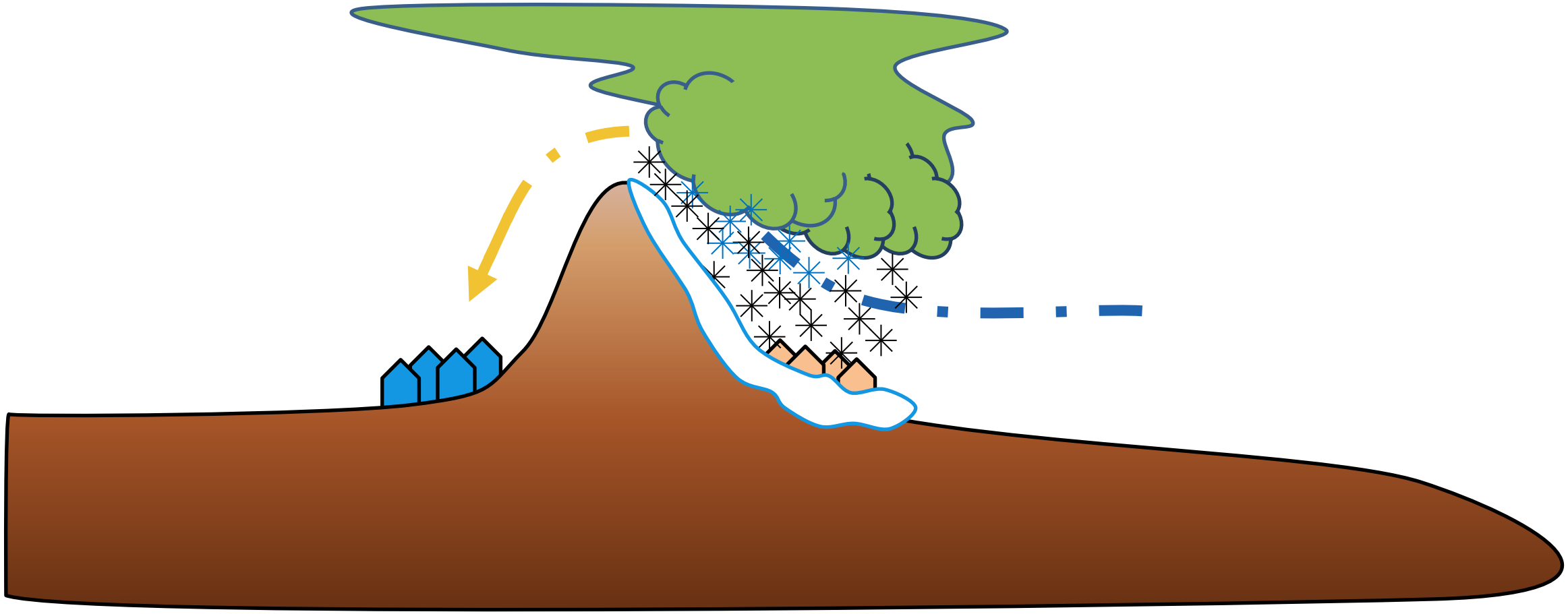
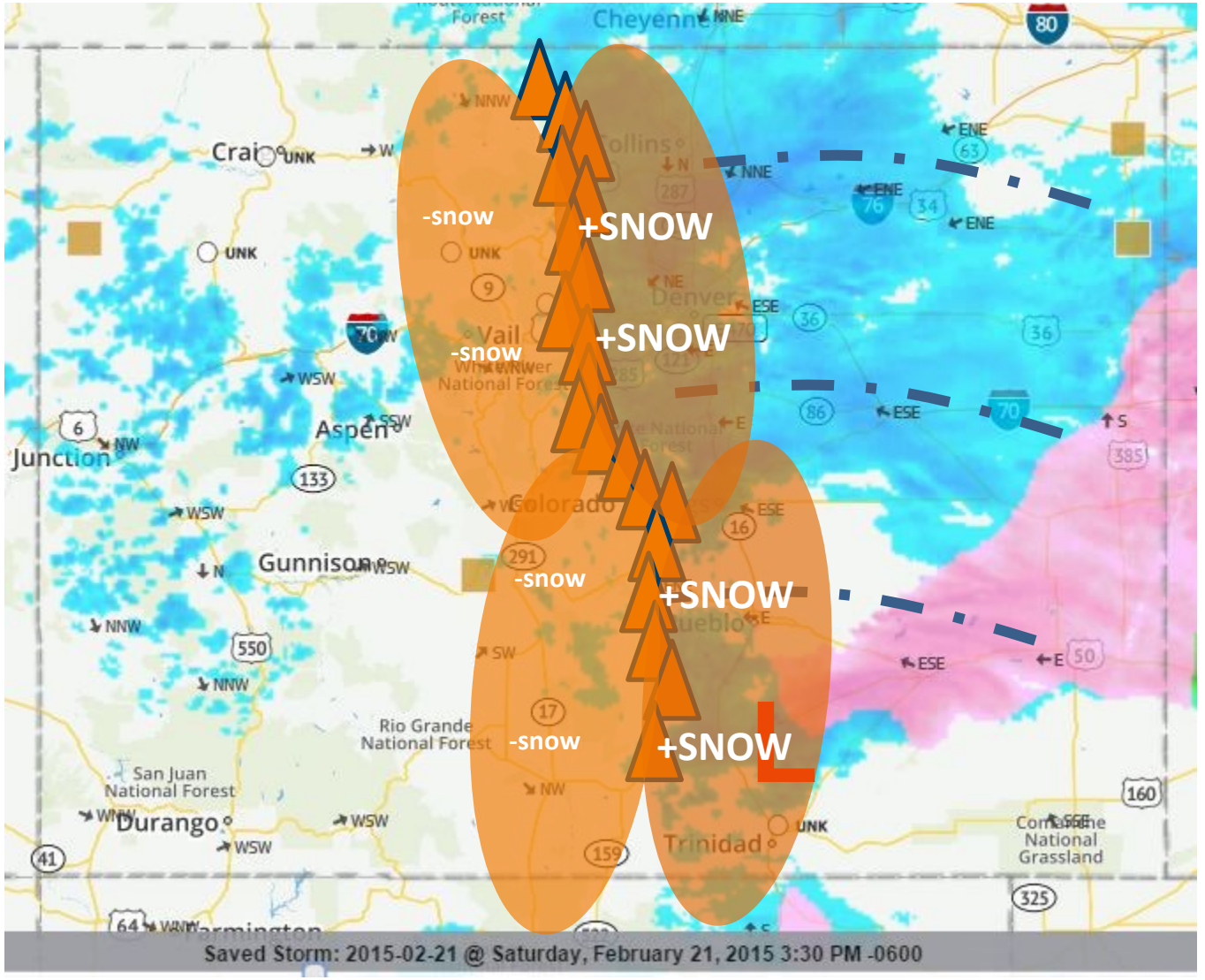
Upslope Precipitation



Upslope Precipitation



Snow Factor

- **Snow Factor** is a variable that multiplied by the **Liquid Rate** to get an approximate snowfall rate (per hour)
- **Snow Factor** x **Liquid Rate** = Snow Fall Rate
- **Snow Factor** is dependent on temperature, ice crystal structure, and wind speed

Snow Fall – Inches per hour

SF (Temp)	Liquid Rate	.01	.02	.05	.10	.15	.20	.25
33 F	6	.06	.12	.30	.60	.90	1.2	1.5
29 F	10	.10	.20	.50	1.0	1.5	2.0	2.5
24 F	15	.15	.30	.75	1.5	2.25	3.0	3.75
16 F	20	.20	.40	1.0	2.0	3.0	4.0	5.0
8 F	25	.25	.50	1.25	2.5	3.75	5.0	6.25
< 0F	40	.40	.80	2.0	4.0	6.0	8.0	10.0

- **Snow Factor** can change throughout a snow event as temperatures and winds change
- **Snow Factor** depends on surface temperature as well as the temperatures aloft

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Pavement Impacts from the Weather

Basics of Pavement Thermodynamics

- With NO precipitation or de-icer chemical present there are THREE modes of heat transfer in pavement:
  - Thermal Convection (Atmosphere Impacts)
  - Thermal Conduction (In Pavement Impacts)
  - Thermal Radiation (Solar Impacts/Pavements Interaction with Air)

Pavement Temperature Balance Equation – Vertical Profile

$$\frac{\partial \vartheta}{\partial t} - \frac{\lambda_\omega}{\rho \cdot c_p}\left(\frac{\partial^2 \vartheta}{\partial z^2}\right) = 0$$

- ϑ = Temperature
- λ_ω= thermal conductivity [W/m*oC]
- ρ = mass density [kg/m3]
- c_p= specific heat capacity [J/ oC*kg]

Comparison of temperature distributions in road pavement obtained in field tests and using transient thermal analysis
Jarosław Górszczyk and Konrad Malicki - https://doi.org/10.1051/matecconf/201926205007

Variables Impacting Pavement Temperature

- Solar Radiation
- Air Temperature
- Wind Speed & Direction

- Precipitation
- Plowing Operations
- Chemical Applications

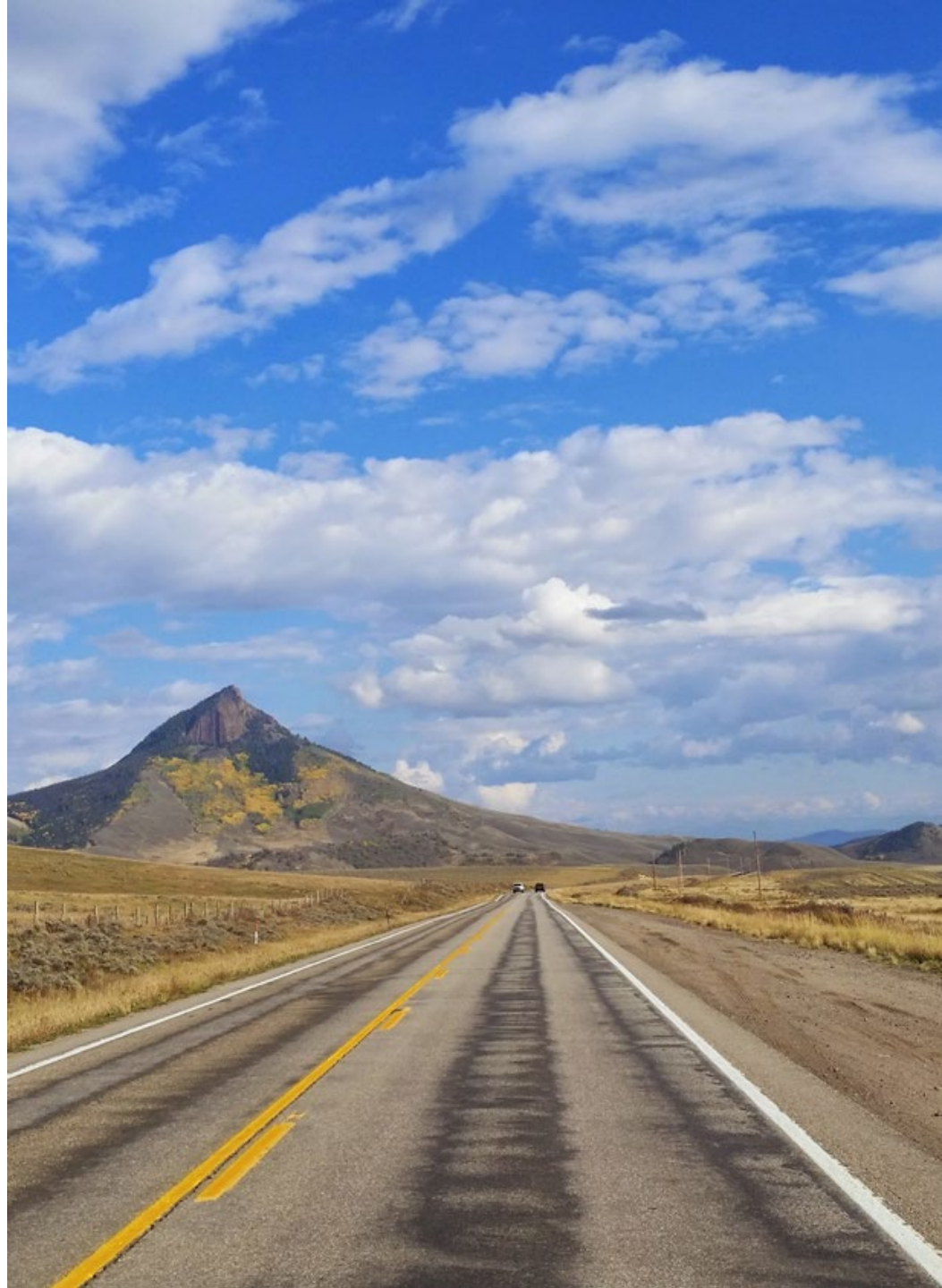
What are Some Differences Between **Asphalt & Concrete**

In YOUR Operations do you consider the difference between pavement and concrete?

SHOULD YOU??

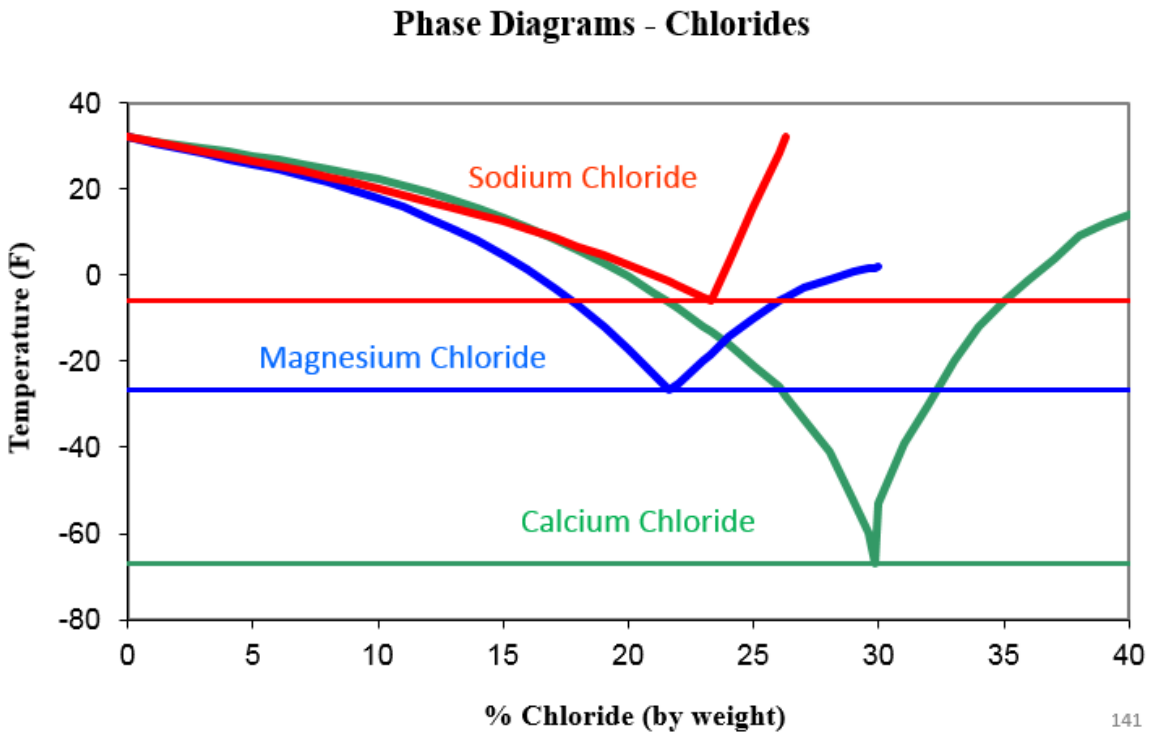
Potential Differences

- Asphalt roads react to radiation changes more quickly
- Concrete roads are slower to react
- Asphalts subsurface temperatures will also warm and cool quicker based on radiation changes
- Residual snow/ice and chemical will respond differently depending on the roads cross-sectional make-up
- In a homogeneous situation asphalt and concrete surface will come to equilibrium after some time



Using Chemicals/Salt for Snow/Ice Removal

- It is a chemistry problem
  - Eutectic Temperature
    - the **Lowest Temperature** a **Concentrated** Solution Begins to **Freeze** or the **Lowest Temperature It Will Melt Ice**



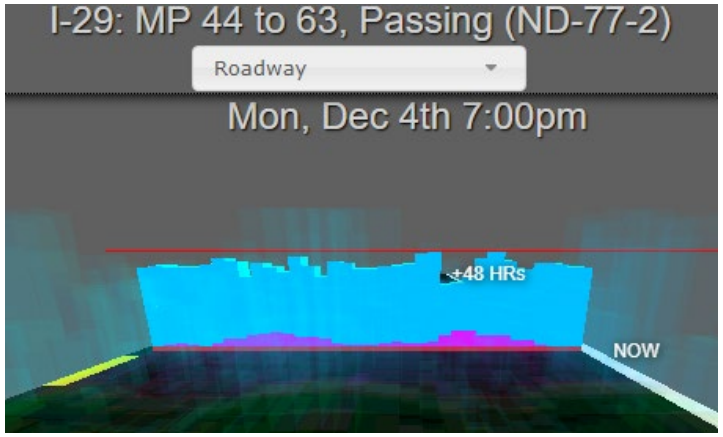
Why Not Use $CaCl_2$ or $MgCl_2$ all the time?

- Price
  - Mag Chloride and Calcium Chloride are expensive
- Corrosive
  - All Chlorides are corrosive; some more than others
- Hygroscopic
  - Meaning “Having the Ability to **Draw Water Vapor from the Air**”
  - Calcium and Magnesium Chlorides pull all available moisture out of the air keeping the road wet/dilutes chemical thus causing ice roads

Black Ice

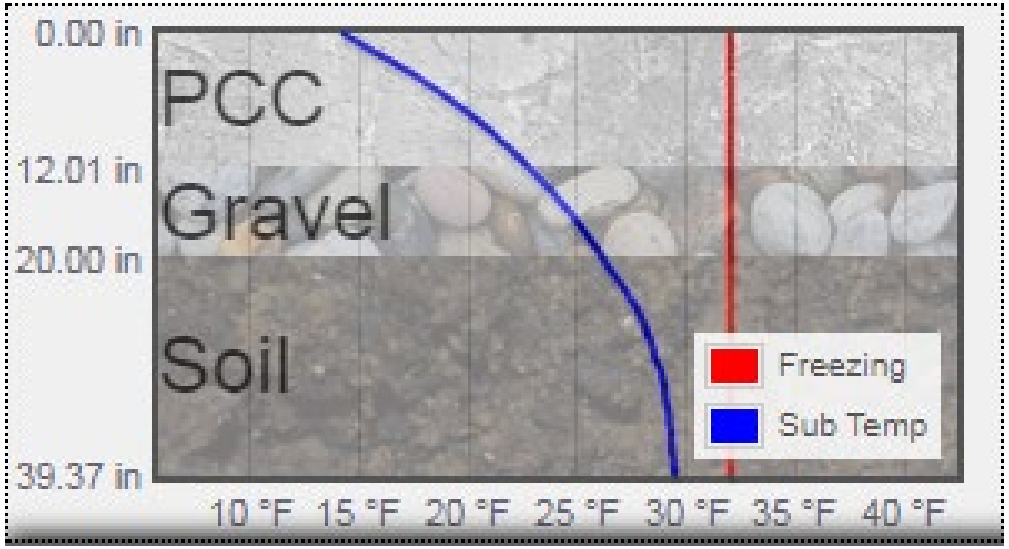
- **Definition**: A thin coat of ice on the pavement. It is transparent and will take on the color of the road, hence the name Black Ice.
- **Cause**: During the day, frozen precipitation can melt onto the pavement due to warmer air temperatures, or rain/drizzle/fog can cause wet roads. Once the air/road temperature drops below freezing, the liquid can refreeze, causing Black Ice.
- **Most Common Time for Formation**: Sunset - Sunrise
- **Common Areas:** Shaded areas, bridges, overpasses
- **How to Spot It**: If the road is mostly dry, look for darker glossy patches on the pavement. If pavement has frozen precipitation, Black Ice is very difficult/impossible to spot.

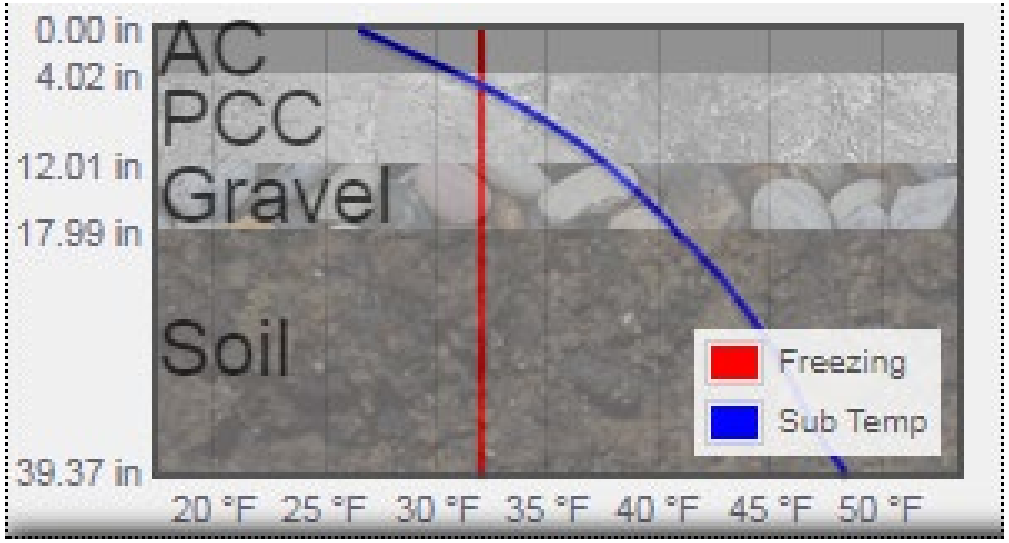
Driving vs. Passing Lane



- Differences in traffic volume result in more packed snow in the driving lane.
- Crews may prioritize the driving lane during heavy snow, allowing more snow to build up in the passing lane.
- Wind direction may cause snow to drift in one lane while blowing off the other.

Sub-pavement





Winter Profile:

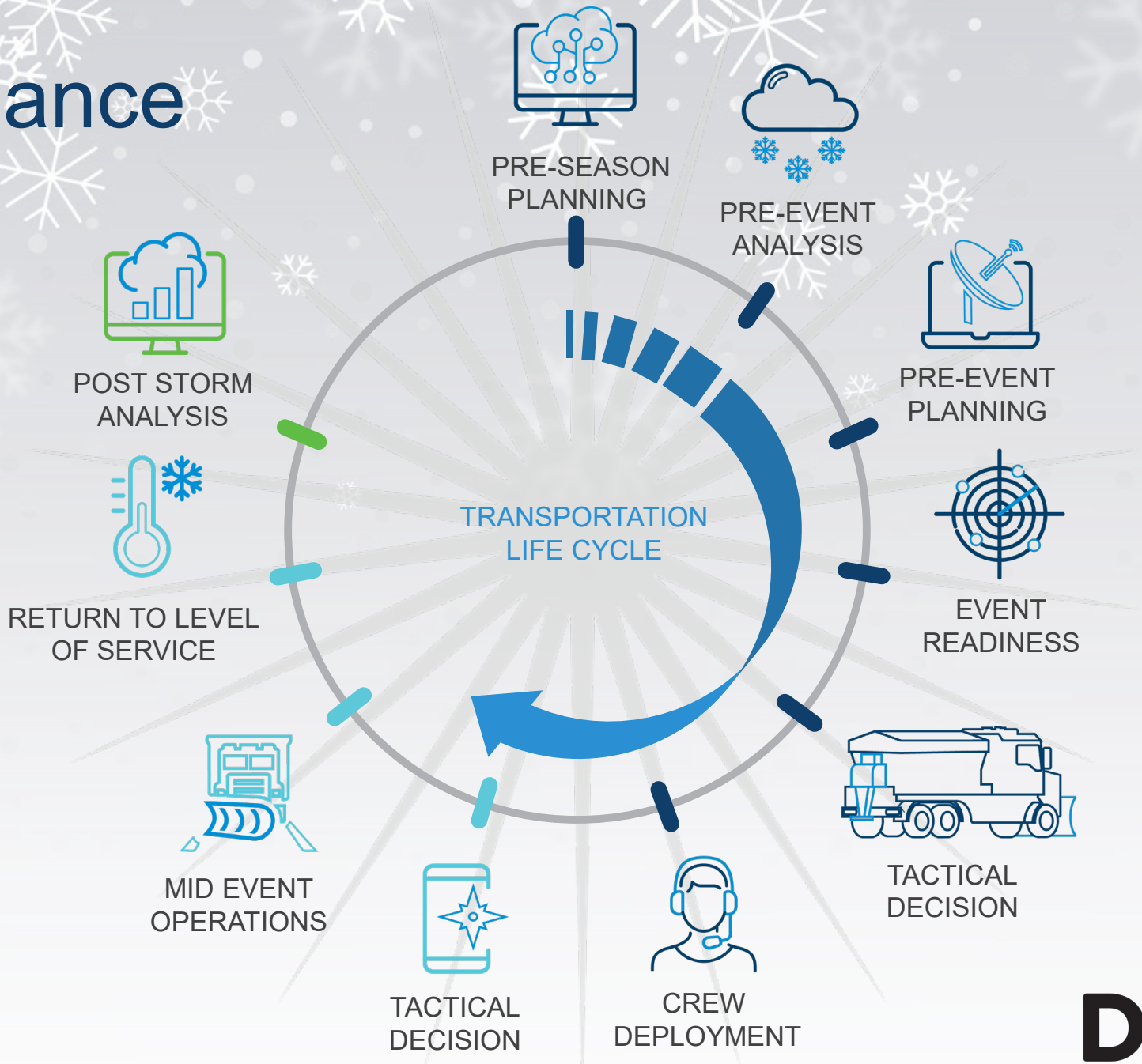
- Entire depth is below freezing.
- Slower post-storm recovery.

Fall Profile:

- Asphalt layer (top) is below freezing, but lower layers are warmer.
- Faster post-storm recovery.

Winter Maintenance Operations

Decisions Making Life cycle



Questions

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