Errata

This document provides information about corrections to the AWOC Winter Weather Track FY06 Student Handout document. Most of the changes are fairly minor. All pages with corrections are included in front/back pairs to use as replacement pages.

If you prefer replacing pages over marking corrections, simply print this errata document and replace the existing pages in your printed copy.

IC/Lesson	Page(s)	Content
Table of Contents	i-iv	IC7.2 Part 2, add " - Case Study" to title.
IC3.3	3-47	**FXNET** should be **FXC**
IC4.3	4-141 to 4-156	Images out of synch with instructor notes. A new version of the complete IC4.3 handout is available.
	4-144	**treat** should be **threat**
IC5.1	5-9	Slide 16 Title: **Qn** and **Qs** should be $\mathbf{Q_n}$ and $\mathbf{Q_s}$.
IC5.1 Job Sheet	5-23	**Intructions** should be **Instructions**
	5-23	The fourth paragraph below "Instructions" should read: On the regional map scale, load a NAM 80 tropopause map (use "trop" under the misc. planes menu in the volume browser) with wind vectors, potential temperature and pressure at 3 layers: 700-500 mb, 500-400 mb, and 400-300 mb. Answer the following questions.
	5-23	**"$_e$"** should be **"θ_e"**
IC5.2	5-30 to 5-31	The slide title says "Divergence Always Produces Frontogenesis". It should say "Divergence Always Produces Frontolysis".
IC5.2 Job Sheet	5-45	**"$_e$"** should be **"θ_e"**
	5-46	**"Any any scale"** should be **"At any scale"**.

IC/Lesson	Page(s)	Content
IC5.3 Job Sheet	5-67	**"$_e$"** should be **"θ_e"**
	5-67 to 5-69	**"$_{es}$"** should be **"θ_{es}"**
	5-68	In "Overlay 2-D frontogenesis." paragraph, replace **EPV_g** with **MPV_g**.
	5-68	Replace "in step #4" in the fifth paragraph with "of the NAM analysis valid 12 UTC 15 March 2004".
	5-69	In "Overlay Div-Fn vectors in the same layer you displayed EPV_g." replace **EPV_g** with **MPV_g**.
IC5.3 Job Sheet	5-70	Replace "in step #4" in the fifth paragraph with "of the NAM analysis valid 06 UTC 04 November 2003".
	5-70	**In "**Where, if anywhere, is the EPV_g minimized above the frontogenesis?**"** replace **EPV_g** with **MPV_g**.
IC 5.4	5-75	**500-500** should be **400-500**
IC5.4 Job Sheet	5-95	Under "Instructions" change 00Z **23** Nov 2004 run of the NAM 80 to 00Z **24** Nov 2004 run of the NAM 80
	5-95	In the last paragraph on the page, replace **EPV_g** with **saturated geostrophic equivalent potential vorticity**.
IC5.5	5-113, 5-114	On slides 31 and 33 in the title, **q_e** should be θ_e.
IC5.5 Job Sheet	5-122	In the last paragraph (starts with "Finally"), replace **"K isentropic"** with **"equivalent potential temperature surface map"**.
IC6.4 Job Sheet	6-119	Replace **"This loads EPV_g"** with **"This loads potential vorticity, geostrophic equivalent potential vorticity"**.

IC/Lesson	Page(s)	Content
IC7.1 Job Sheet	7-25	In Item 3, first bulleted paragraph, add "(" before 13 Z.
	7-26	In Item 4, first bulleted paragraph, after "WV image" at the end of the second sentence, add: "by selecting "Prev Run" from the top left drop down menu in D2D before you load the product in the volume browser"
	7-27	Replace the first bulleted item on the page with: "Load a NAM 40 model sounding in the changeover region somewhere near southwest Iowa. Overlay Omaha's sounding and then overlay an aircraft sounding from around 12 UTC (MDCRS in the volume browser, you will need to have "Inventory" selected in the main D2D window before loading the aircraft data, found under upper air menu and heading "Aircraft")."
IC7.1 Job Sheet	7-27	Replace the last bulleted item on the page with: "Swap panes and get to the state scale and set the loading drop-down menu to "previous run". In the volume browser, load the NAM 40 model run snow accumulation product, then overlay 0.5 reflectivity mosaic. (You will only be able to compare a few snowfall graphics to actual radar images because of the way AWIPS loads products). This should have loaded the 15 March 00 UTC NAM 40 model run snow accumulation. You may also examine the 15 March 12 UTC NAM 40 model run snow accumulation in another window to see the latest available snowfall forecast, but you will not be able to overlay any reflectivity images onto that model run."
IC7.2 Part 2	7-64 to 7-74	Images out of synch with instructor notes. A new version of the complete IC handout is available.
IC7.4 Job Sheet	7-115 to 7-120	Replace all with new version. (Mostly formatting and layout changes.)

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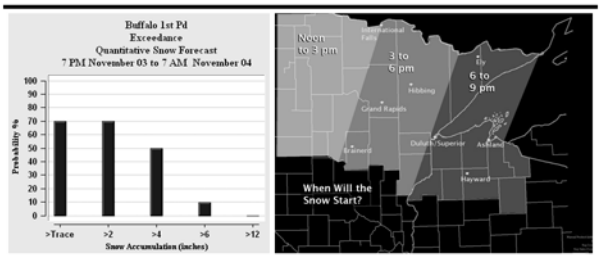
11. Tools for Conveying Forecast Confidence to Users: Graphical Products

Instructor Notes: AFDs are not the only tool available to forecasters to clarify uncertainty. Many WFOs have developed local graphical products, some of which are experimental, to try to communicate forecast threat information to users. Some of the more common ones for winter weather forecasting involve visualizations of probabilistic snowfall totals. Others utilize applications like FXC so that D2D-like displays with simple annotations can be generated quickly with minimal effort on a forecaster's part. Just about any visualization tool can be useful to generate bar charts or other products if that graphic conveys certainty (or uncertainty) in forecast details. The National Academy of Sciences workshop (2003) on communicating uncertainties in weather information encouraged the development of graphical products to convey threat information to the public. Not all graphical products are a "home run", so to speak. "Spaghetti" charts and similar ensemble-type displays can help visually represent the range of values to an expert, but may intimidate the average user and be difficult to interpret. Maps similar to SPC convective outlooks (with low, middle, and high classifications) are more user friendly, but forecasters may be hesitant to label something "low confidence." An effective way to communicate uncertainty can be to display a variable using different color hues or levels of transparency to display probabilities (such as graphics that use filled contours to illustrate ensemble "spread"). Such continuous value displays are more inviting to users and can convey significant details to them.

Student Notes:

Tools for Conveying Forecast Confidence to Users: Graphical Products



- Local, experimental products mostly
- FXNET, other tools useful
- Different ways to convey certainty include varying color hues and transparency levels

12. AFDs: Examples of Effectively Stated Forecast Certainty

Instructor Notes: Forecast certainty issues can be addressed in many ways. Some offices may use language that explicitly states "high confidence" or "low confidence", etc. Others may use different language to convey confidence. Regardless of what system your office uses, what is most important is to clearly state what the key issues are with

the forecast and your expert analysis on those issues. The goal should be for users, especially regular users, to correctly interpret your products. In these examples, you see language that state forecast confidence explicitly and implicitly, as well as discussing how forecast certainty is trending. The last text box is a little different than the others. It presents an example where there is mixed certainty. These situations are not only challenging to forecast, but can also be challenging to communicate. If customer utilization of our forecasts and products is one of our ultimate goals, then it's only natural that we may be apprehensive at times to admit to forecast uncertainty. But these cases are when clarity is most crucial. When you are finished reviewing the text, please push the play button to advance to the next slide.

Student Notes:

AFDs: Examples of Effectively Stated Forecast Certainty

FORECAST CONFIDENCE INCREASING FOR POTENTIAL ICING EVENT ACROSS NORTHERN SECTIONS OF STATE LATE TONIGHT THROUGH WED MORNING.

QUITE A FEW FACTORS IN TODAY/S MODELS AND WITH THE CURRENT ATMOSPHERIC TRENDS ARE FAVORING AN ICE STORM…AND WILL UPGRADE ALL WATCHES TO ICE STORM WARNINGS WITH THIS PACKAGE

THIS IS ONE OF THE FEW WINTER SYSTEMS WHERE CONTROVERSY IN PRECIPITATION TYPE DOES NOT EXIST. ALL FORECAST ANALYSIS SUGGEST THAT ONLY SNOW WILL BE POSSIBLE.

MODELS IN VERY GOOD AGREEMENT WITH MAIN FEATURES OF NOR'EASTER MOVING UP THE COAST.

THIS SYSTEM HAS A LOT THAT IS FAVORABLE FOR SIGNIFICANT SNOW … HENCE…FEEL VERY CONFIDENT THAT MEASURABLE SNOWS WILL OCCUR…HOWEVER…CHANGES IN EXPECTED TRACK COULD HAVE SIGNIFICANT EFFECTS ON AMOUNTS. GIVEN THIS UNCERTAINTY…

13. Examples of Value-Added Text Clarifying Event Impacts and Forecast Certainty Issues

Instructor Notes: There will always be a bit of conflict between saying more is more (say, adding a sentence to further illustrate your thinking) and less is more (being concise so that your thought process is clearer). When considering using value-added wording in discussions and other products, be specific and concise. Also, make sure the text, in fact, adds the desired value. You want the additional text to be informative, but not seem like a tangent. These examples add value by discussing details of forecast techniques, event impacts, model diagnosis, conceptual models, and even where to get important information on road conditions. When you are finished reviewing the text, please push the play button to advance to the next slide.

1. IC4.3: Microclimates: Interaction of Synoptic Patterns with Local Terrain

Instructor Notes: Welcome to IC 4, Lesson 3, “Microclimates” or “How Synoptic Patterns Interact with Local Terrain to Impact Winter Weather.”

Student Notes:

Microclimates: Interaction of Synoptic Patterns with Local Terrain

Eric Stevens, WFO Fairbanks, Alaska
AWOC Winter Weather Track:
IC 4, Lesson 3

2. Microclimates—Why do We Care?

Instructor Notes: You may ask why microclimates are important. After all, we are meteorologists, not climatologists. The reason microclimates are worth your time is that microclimates modify the meteorology in your CWA. Microclimates are a constant consideration—they impact your routine day-to-day forecasts, and they can be a deciding factor in your warning/no warning decision. This IC contains descriptions of the broad categories of microclimates. Then to illustrate how these microclimates really impact our jobs on the forecast desk, some examples of microclimates in action will be presented. Microclimates are highly localized phenomena, and the specific examples presented in this lesson will come from Alaska, since I am most familiar with that area. Please don’t take the message that microclimates are only important in Alaska—they are not, microclimates impact the weather all across the country. These are just some examples from Alaska. As we go through this lesson, think of how these concepts might apply to your forecast issues in your CWA. At the end of this lesson there will be an exercise to document a microclimate in your CWA.

Student Notes:

Microclimates—Why do We Care?

- Microclimates modify meteorology
  - Microclimates impact your routine forecasts
  - Microclimates can be a deciding factor in your warning/no warning decision
- Microclimates are at work in all CWAs
  - This IC contains examples from Alaska
  - Think of examples in your CWA
  - Exercise: document a microclimate in your CWA and how it impacts your forecasts

3. Outline

Instructor Notes: This will be a very qualitative IC. We will present these concepts broadly and briefly. Section 1: Microclimate defined. Section 2: Identify major categories of terrain that produce microclimates. Section 3: Utility of NWP Models. Section 4: Apply these concepts to your CWA and your forecasts. This last point is the real point—learning more about microclimates in our CWAs and applying this knowledge to our forecasts.

Student Notes:

Outline

- Section 1: Microclimate defined
- Section 2: Identify major categories of terrain that produce microclimates
- Section 3: Utility of NWP models
- Section 4: Apply these concepts to your CWA and your forecasts

4. Learning Objectives

Instructor Notes: By the end of this lesson you will be able to… Define microclimate; Identify terrain features impacting winter weather; Identify strengths and weaknesses of NWP models.

Student Notes:

Learning Objectives

- Define microclimate
- Identify terrain features impacting winter weather
- Identify strengths and weaknesses of NWP models

5. Performance Objectives

Instructor Notes: We have three performance objectives with this IC. Identify microclimates in your CWA. Demonstrate how specific synoptic patterns interact with your CWA's terrain. Apply knowledge of microclimates to your forecasts, both routine day-to-day forecasts as well as warning decisions. Again, note the emphasis on YOUR CWA and your forecasts. This IC presents general concepts and a few examples from Alaska, but the performance objective we are all hoping for is in reference to your CWA and your forecasts.

Student Notes:

Performance Objectives

- Identify microclimates in your CWA
- Demonstrate how specific synoptic patterns interact with your CWA's terrain
- Apply knowledge of microclimates to your forecasts
  - Account for microclimates in your routine forecasts
  - Account for microclimates in your warning decisions

6. Section 1: Microclimate Definition

Instructor Notes: That is all for section 1, the definition of microclimate Here is the definition from American Heritage Dictionary of the English Language, Fourth Edition. …Online. This American Heritage definition is useful to consider. Building on that definition, the idea I have kept in mind while developing this IC is that a microclimate is the result of interaction between the synoptic pattern and local terrain, with the outcome being sensible weather on the local scale that may at first glace appear to be unex-

pected. But upon further study, we see that such localized weather occurs regularly under certain synoptic regimes and is actually a micro climate. For the purposes of our discussion here, we will not limit the term “terrain” to mean only mountains. The Rocky Mountains certainly are a terrain feature, but we also need to consider bodies of water as terrain features which impact microclimates. Your soil type can be a factor, the degree of vegetation can be a factor. Terrain here is anything underneath the sky. Microclimates are primarily a boundary layer issue. For example, under a quiet high pressure scenario, the 500mb height field and 850mb temperature field may be nearly devoid of gradients over your CWA, but nighttime temperatures down at the surface, where the people are, may vary considerably over hilly or mountainous terrain due to the development of shallow surface-based radiation inversions. The spatial scale of a microclimate can vary widely, depending on terrain. For the purposes of this IC we will limit our focus to the spatial scales which impact NWS forecasts. Now in the digital age, the spatial resolution of IFPS is a consideration. We’ll focus on scales of single kilometers to tens of kilometers in the horizontal. This upper end of such scales may be encroaching into the mesoscale, but for the sake of our quick discussion here we will refer to all these terrain-driven modifications of weather as microclimates. One could also argue that there are microclimates of very small scales—for example, different climates immediately to the north or south sides of a single building. But we will not consider those fine-scale influences as important to this discussion. That is all for section 1, the definition of microclimate

Student Notes:

Section 1: Microclimate Definition

- Microclimate: climate of a small, specific place within an area as contrasted with the climate of the entire area *(American Heritage Dictionary of the English Language, Fourth Edition)*
- Result of interaction between synoptic patterns and local terrain
  - “Terrain” doesn’t just mean mountains
- Primarily a boundary layer issue
- Spatial scale can vary, depending on terrain
  - We focus on scales that impact NWS forecasts: from single km to tens of km in the horizontal

7. Section 2: Terrain and Microclimates

Instructor Notes: Here is section 2 of the IC, the kinds of terrain that can interact with the synoptic pattern and produce microclimates. For the purposes of our discussion here, “terrain” doesn’t just mean mountains. Terrain does include mountains, but also forests, farm fields, lakes, basically anything under the sky. Here are the three major categories of terrain features that produce microclimate: Mountains and valleys; Land cover: trees, soil types, etc.; Bodies of water, lakes and oceans. Now we will look at each of these categories more closely and see some examples of how these terrain features affect day-to-day weather and even watch/warning decisions.

Student Notes:

Section 2: Terrain and Microclimates

- Major categories of terrain features that produce microclimates
  - Mountains and valleys
  - Land Cover
  - Bodies of Water

8. Mountains and Valleys

Instructor Notes: The first of the three major types of terrain features that produce microclimates is mountains and valleys. Mountains and valleys impact the wind. --Wind speeds can be accelerated. Examples include gap flow and Chinook winds. --Winds can be steered down a valley. One could also loosely define “valley” enough to include narrow marine channels where winds blowing either up channel or down channel are favored. --Sometimes the terrain prevents much wind of any kind from being realized at a location. For example, the bottom of a valley that is frequently under a radiation inversion and is effectively decoupled from the flow above the inversion. Mountains and valleys also impact precipitation. This is the old rule of enhanced precipitation on the windward, upslope side of a mountain barrier, and a downslope precipitation shadow on the lee side of the barrier. This topic is covered in more depth elsewhere in AWOC Winter Weather track. Temperatures are also affected, and not simply because it’s colder on a 15,000 ft. mountain top than it is at sea level. Even with much less extreme relief than that, radiation inversions will develop in valleys and lead to sometimes striking stratification of temperatures in the vertical, even down in the inhabited elevations. A mountain barrier can also constrain the movement of air masses in the horizontal, particularly a cold surface-based air mass. One classic example of this effect is when a topographic barriers constrains the advection of cold air at the lower levels and produces a cold air damming event.

Student Notes:

Mountains and Valleys

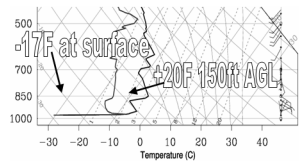
- Wind
  - Acceleration
  - Steering
  - Shadowing
- Precipitation
  - Upslope enhancement
  - Downslope shadowing
- Temperature
  - Vertical stratification
  - Separation of airmasses in the horizontal
  - Cold air damming

9. Vertical Temperature Stratification

Instructor Notes: Here's an example of how rough terrain, be it mountains and valleys or less extreme terrain like rolling hilly country, can produce significant temperature variations near the surface. In Alaska's interior, strong surface-based temperature inversions are common in the winter. This example is extreme, but it is fun to look at because it so dramatically illustrates the issue. Through the bottom 150 ft. of the atmosphere temperature rises 37F. The surface-based inversion is established as long-wave radiation escapes during the long clear nights, and density currents then allow the coldest air to pool down in the valley bottoms. Once established, the inversion can be tough to remove if the surrounding higher terrain hinders the ability of a new airmass to scour out the cold air down in the valleys. Not to say that the inversion will NEVER leave. If clouds move in, the radiative balance will change, and surface temperatures can rise substantially. Also, if a puff of wind comes along, a sharp but shallow inversion like the one in this sounding will be mixed out and surface temperatures can rise substantially. Since these inversions develop down in the inhabited elevations, they are an important forecast issue. Such inversions occur many times during a winter season, and they contribute to the microclimate where valley bottoms are much colder than the surrounding higher terrain—this is a variation on the "thermal belt" theme associated with fire weather forecasting.

Student Notes:

Vertical Temperature Stratification



- Fairbanks Sounding, 00Z January 17, 1995
  - An extreme example
  - Lapse rate of 37F/150ft
- Topography's role:
  - Density currents establish inversion in valleys
  - High terrain can inhibit scouring out of inversion
- Sharp lapse rates at inhabited elevations

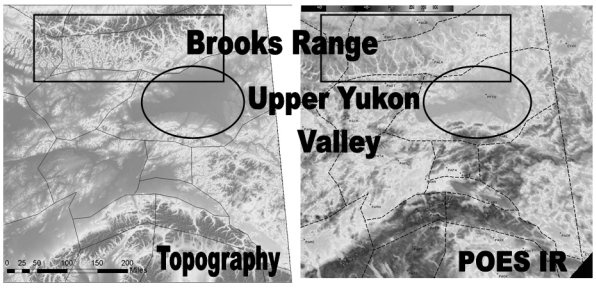
10. Vertical Temperature Stratification

Instructor Notes: Having looked at an extreme example of this effect on a single point basis, let's switch to a more routine example, but this time in the plan view. Here are two images of Alaska's interior: on the left is a topographic map where low elevations are green and high elevations progress from yellow to brown. On the right is a polar orbiter IR image from a clear day in February 2005. Since skies were totally clear when this picture was taken, all we are seeing here is surface temperatures. The images are labeled, because at first glance it is difficult to tell them apart—that's how strong the relationship is between temperature and height in this case. In this case, temperatures down at inhabited elevations, where the towns and roads are, range from 50 below to near zero Fahrenheit, with the coldest temperatures down in the valley bottoms. This type of temperature distribution is common in Alaska's interior when skies are clear during the winter—this is no once-a-decade extreme example, this is a routine microclimate. Note that cold temperatures have pooled in the broad, roughly bowl-shaped Upper Yukon Valley. Cold air settles in broad valleys and in narrow valleys alike. Note the narrow valleys draining out of the Brooks Range near the top of these images—the cold air settles into the narrow valleys here just as easily as it does in the broad Upper Yukon Valley. This example comes from Alaska, but the concepts apply everywhere: colder air will settle into valley bottoms. Most CWAs don't have large mountains, but there can still be river valleys where this kind of microclimate may play a role. Even slightly rolling terrain can be impacted. As part of this IC you will do an exercise in which you document a microclimate in your CWA. Is there a vertical stratification of temperature in your CWA that you could document?

Student Notes:

Vertical Temperature Stratification

- Cold air pools in valleys
- Valleys can be broad or narrow



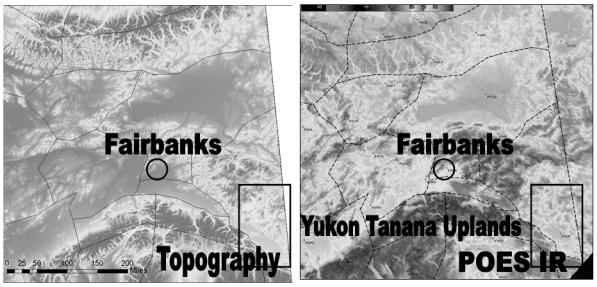
11. Vertical Temperature Stratification

Instructor Notes: As the size of the area under consideration increases, the relative nature of elevation becomes evident. That is, no single elevation above mean sea level separates the cold air in the valleys from the milder air in the hills across this entire domain. For example the Yukon Tanana Uplands in Alaska's southeastern interior could generally be described as elevated terrain. In this area, an elevation of 1500 ft. mean sea level is in the valley bottoms and thus is in the bitterly cold air, as we see in the satellite picture. But in the greater Fairbanks area, within the circle, the same absolute elevation 1500 ft. MSL is up in the hills with the milder air. So the lesson here is that cold air settles into valleys, but valleys are relative to the local surrounding terrain--you can't simply query elevation in the GFE to assign cold air across the entire domain below a single elevation MSL.

Student Notes:

Vertical Temperature Stratification

Valleys and hills become relative over broader distances



12. Vertical Temperature Stratification

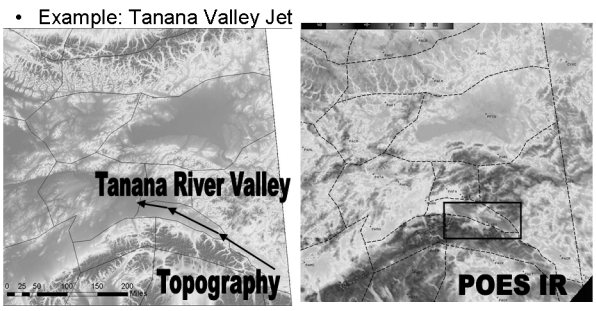
Instructor Notes: As we saw in the sounding on slide 9, the depth of the surface-based inversion can be quite shallow. Wind can mix the boundary layer and eliminate the sharp

stratification of temperature in the vertical. There is an example of this wind-induced mixing phenomenon at work in this same case we have been looking at over the last couple of slides. On the topographic map note how the Tanana River flows down the Tanana Valley from the southeast to the northwest. A down-valley wind known as the “Tanana Valley Jet” is common here and can mix away the surface-based inversion. Note the more smeared-out homogenized look to the temperatures in the windy area on the IR image. This satellite image allows us to make only a binary qualitative assessment of the wind speed here: in areas where there is at least “some” wind the IR imagery shows milder temperatures, even down in the valley bottoms. In areas where there is little or no wind the highly detailed dendritic pattern is evident in the IR temperatures as the cold air quietly settles into the lower elevations. In the windy areas we can’t correlate specific temperatures to specific wind speeds, rather we simply know that the wind speeds in these warmer homogeneous areas are non-zero. We will return to the Tanana Valley Jet later in this IC during our discussion of NWP models and their strengths and weaknesses in accounting for microclimates.

Student Notes:

Vertical Temperature Stratification

- Wind can mix boundary layer and eliminate stratification
- Example: Tanana Valley Jet



13. IC 4.3 Interactive Quiz

Instructor Notes:

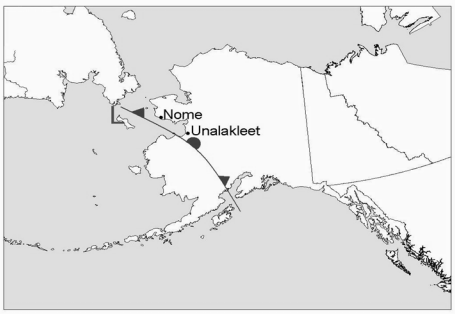
Student Notes:

14. Downslope Flow

Instructor Notes: Now we're going to look at how mountains and valleys produce downslope flow which makes hazardous weather less likely at one location. On this simple cartoon we see a surface low with an occlusion stretching to the southeast. On the synoptic scale, the villages of Nome and Unalakleet appear to be in the same situation: these villages are about 150 miles apart, but both are coastal villages ahead of an approaching occlusion, and they both can expect gusty easterly winds and some snow. Blowing snow may reduce visibility down to blizzard levels. This is a common winter storm pattern for Alaska's west coast. However, it turns out that under this kind of scenario Unalakleet actually verifies blizzard conditions only about half as often as Nome does. And if Unalakleet does have a blizzard, the blizzard is often comparatively brief, while Nome may have many hours of blizzard conditions. Why the difference?

Student Notes:

Downslope Flow

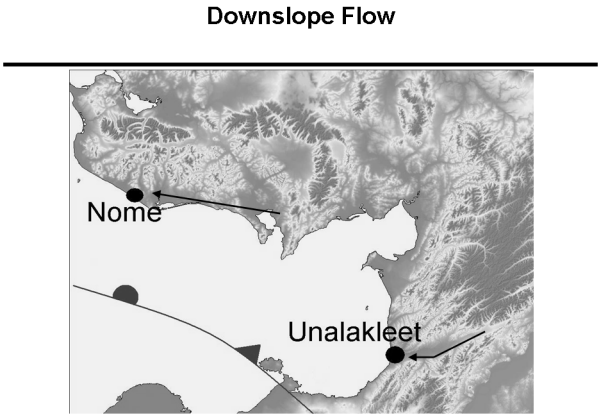


15. Downslope Flow

Instructor Notes: We zoom in to look at the topography around Nome and Unalakleet. Again, these villages are about 150 miles apart. Notice how the village of Unalakleet is at the western end of a river valley that cuts through higher terrain. When a winter occlusion is approaching from the south, the flow at Unalakleet is out of the east, down the river valley, and is a downslope flow out of the higher terrain. Up at Nome an easterly flow is roughly parallel to the coastline where there is no downslope component. The downslope flow at Unalakleet makes precipitation associated with the approaching occlusion less likely than at Nome where there is no downslope. This is not to say that blizzards cannot happen at Unalakleet when an occlusion is approaching from the south…the blizzards are just less likely than at other communities in the area such as Nome. As the occlusion passes directly over Unalakleet the synoptic scale dynamic forcing can overcome the downslope and produce some snow and possible blizzard conditions…but this blizzard is not usually very long-lived. Nome is not protected by downslope and can begin getting blizzard conditions while the occlusion is still comparatively far to the south. So this is an example of how the terrain produces a microclimate that actually makes

severe winter weather less likely at a location. Microclimates can just as easily protect an area from severe winter weather as make an area more vulnerable. This kind of information can be useful in our WSWs, since it may allow us to specify locations where conditions are likely to be more or less severe during a winter weather event. This is the end of our discussion of the first category of terrain that produces microclimates, mountains and valleys.

Student Notes:



16. Land Cover

Instructor Notes: The second of the three major types of terrain features that produce microclimates is land cover: trees, stubble in a plowed field, bare rocks, a built-up urban area, snow, etc. The land cover effects radiation from and into the surface. A great example of this is the impact of an insulating cover of fresh snow. All other things being equal, newly snow-covered ground will radiate much more effectively under clear skies at night than snow-free ground. Snow-covered ground will also reflect incoming short-wave raditaion during the daytime and limit the diurnal rise in temperatures. It is important to keep in mind that snow's albedo and radiative properties can change as the snow pack ages-the snow can compact over time, become "dirty," etc. Different types of soil, such as sand, dirt, or rocks-all have their own radiative properties and albedos which can impact your temperature forecast, both at night and during the day. The degree of urbanization can produce a "urban heat island" and alter the local radiative properties of the landscape as compared to rural areas. Land cover will impact the magnitude of the wind, and consequently the potential for blowing snow. It's very difficult to achieve a zero-visibility white-out due exclusively to blowing snow in the middle of a thick forest. Even less prominent land cover, such as a farm field of corn or sunflowers, can diminish the magnitude of the wind, compared to wind blowing over a field that has been harvested and is bare except for ankle-high stubble. Again the age and condition of the snow cover can be an issue here. A fresh fluffy snowpack is more available to being picked up by the wind and reducing visibility as blowing snow than is an older snowpack which may already be wind-sculpted or crusted over from previous thaw/freeze episodes. Compared to mountains and valleys, land cover is very changeable in time. Snow cover comes and goes, forests may be cut down or replanted, forests can also

burn down and regrow over time. Advancing urban sprawl can mean the urban heat island will have an increasing effect in an area.

Student Notes:

Land Cover

- Radiative properties
  - Snow vs no snow
  - Age and condition of snow
  - Soil type
  - Urban vs rural
- Wind and blowing snow regimes
  - Absence/presence of trees
  - Agriculture
  - Age and condition of snow
- Changeable
  - Snow comes and goes
  - Deforestation and Reforestation
  - Urbanization

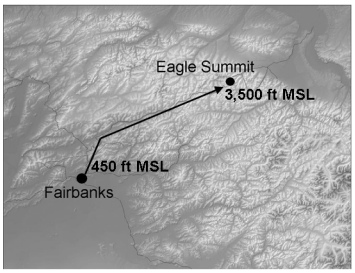
17. Land Cover

Instructor Notes: Here's an example of how ground cover can influence the likelihood of blowing snow events. In the area around Fairbanks, there is a "tree line" at about 2000 ft. mean sea level, with trees below this elevation and much shorter types of vegetation above. This map shows the road system around Fairbanks. You can drive from Fairbanks, at 450 ft. MSL, up to Eagle Summit, at 3500 ft. MSL. In the high terrain northeast of Fairbanks there is extensive area above tree line. When the wind kicks up, blowing snow can reduce visibility throughout these uplands, even to the point of blizzard conditions. Down at elevations below tree line, some locations can become very windy—like the wind down the Tanana River Valley we saw earlier—but the territory surrounding these low-elevation windy locations is usually covered by trees, so less blowing snow is produced and blizzard conditions are almost unheard of. So in the northern Alaska CWA, you can't simply use the GFE query tool to select all grid boxes for winds greater than some value and then assign a visibility restriction due to blowing snow. Instead you might need to query for wind speed and then also query for elevations above tree line. Only in areas where there is both sufficient wind speed and also sufficient surface area devoid of trees can enough blowing snow be kicked up to introduce a treat of legitimate blizzard conditions. This is an Alaskan example. Can this concept be applied to your CWA? Are there differences in land cover across your CWA that could impact the likelihood of blowing snow? Are some areas thickly wooded and other areas which are more open? Again, keeping in mind your exercise to document a microclimate in your CWA as part of this IC, are there any land cover issues which impact forecasts in your CWA?

Student Notes:

Land Cover

- Different blowing and drifting snow regimes above and below tree line
- Sufficient tree-free area needed to allow generation of significant blowing snow



18. Bodies of Water

Instructor Notes: The third of the three major type of terrain features which produce microclimates is bodies of water, where the body of water in question can be large, like an ocean or one of the Great Lakes, or even smaller, but still significant lakes and major rivers. The classic impact here is lake effect snow, as shown in this visible satellite image of the upper Great Lakes. LES is covered in more detail in Winter Weather AWOC IC5 Lesson 7. Also, temperatures can be impacted along a coast within the marine layer, and the degree of inland penetration of the marine layer can be somewhat variable. Impacts will include temperature, dewpoint, cloud cover, precipitation. Coastal flooding isn't just for tropical storms. Wintertime extratropical cyclones can also ravage a coastline, both with pounding waves and with a storm surge. As in the case with tropical storms, different coastal communities have differing degrees of vulnerability to coastal flooding depending on the immediate terrain. This picture is from the coastal community of Nome, on Alaska's west coast, during the great storm of October 2004. That's ocean water flooding the village. The storm surge during this event was eight to ten feet high. As in the case with land cover, the impact from bodies of water can change over relatively short periods of time. For example, LES in the lee of the Great Lakes will become less of a factor if the lake ices over. In northern Alaska, the coastal flood season effectively ends as the ocean ices over. That is it for Section 2 of this IC, identifying the three major categories of terrain features that produce microclimates: Mountains and Valleys, Land Cover, and Bodies of Water.

Student Notes:

Bodies of Water

- Enhanced snowfall
  - Lake Effect Snow
- Inland penetration of marine layer
- Coastal floods
- Changeable
  - Water can ice over and diminish these effects

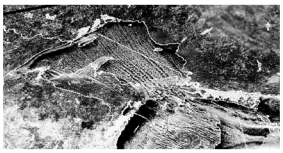


Photo Credit: City of Nome

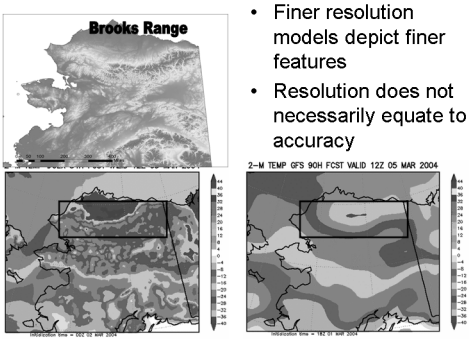
19. Utility of NWP Models: Gridded Fields

Instructor Notes: Now on to Section 3, NWP models and their strengths and limitations when it comes to depicting microclimates. We're going to look at both the gridded NWP output as well as MOS. We will look at an example of how two different models depict 2-meter temperatures, in a case where temperatures are highly influenced by topography, per our discussions earlier in this IC. Here's another map of topography over northern Alaska. Note the Brooks Range, an east-west oriented mountain chain extending across northern Alaska. Elevation decreases sharply to the north of the crest. Here again is the roughly triangle-shaped bowl of the Upper Yukon Valley. With ever increasing computer power, the spatial resolution of NWP models is constantly becoming finer and finer. A model with finer resolution can depict finer-scale features. Here's a picture of the DGEX model 2-meter temperatures. The DGEX, which is basically a tight-domain version of the 12km eta forced by the GFS for the boundary conditions, is able to show a fair amount of topographically forced detail in the temperature field. For example, note the sharp temperature gradient the DGEX depicts from the crest of the Brooks Range down to the purple puddle of cold air on the flats to the north. This is the vertical stratification of temperature in complex terrain microclimate at work again, and the DGEX depiction is conceptually very reasonable. The DGEX also has a less pronounced cold pool here in the Upper Yukon Valley. Now here is the DGEX's parent the GFS with a depiction for the same time, 12z March 5th, 2004. The GFS is a much coarser model than the DGEX, so it's depiction looks very different from the DGEX. The GFS' 2-meter temperature field has the same idea in putting a cold pool on the flats north of the Brooks Range, but is not able to resolve the sharp temperature gradients along the crest of the mountains as well, and in this case does not have as extreme a minima on the flats either. The GFS also has a local cool spot in the Upper Yukon Valley, but again differences appear between the models regarding the sharpness of the temperature gradients and in the magnitude of the extrema. So we see here that finer resolution models can depict finer features. Now we just need a 1 km model that goes out seven days and IFPS can take care of itself and everything will be perfect. Or maybe not. Keep in mind that fine resolution doesn't necessarily mean the forecast is more accurate. Remember that microclimates are the result of synoptic patterns interacting with local terrain. If the model's long wave

synoptic-scale forecast is wrong, then no degree of fine resolution of terrain will be enough by itself to yield an accurate solution. In this sense, relying on a model simply because of its fine resolution can be like watching an outrageous daytime talk show on high-definition television-it looks sharp, but the underlying substance may be questionable and the overall result may be garbage. There are still plenty of other pitfalls for any model aside from the issue of resolution, such as accounting for radiation processes and proper depiction of snow cover, etc, but, in general, if a model's synoptic-scale solution is good, and if the model has a very fine resolution, then it **should** provide a better depiction of these kinds of terrain-influenced microclimate effects than that of a coarser model, all other things being equal.

Student Notes:

Utility of NWP Models: Gridded Fields



- Finer resolution models depict finer features
- Resolution does not necessarily equate to accuracy

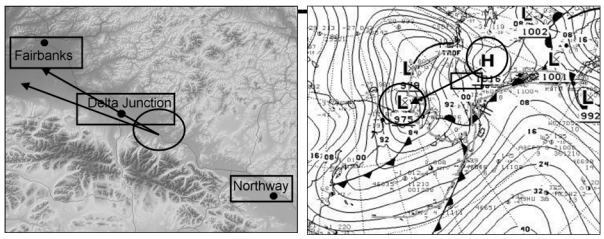
20. Utility of NWP Models: MOS

Instructor Notes: Now we'll take a look at how MOS, even if its parent NWP model is comparatively coarse, has the potential to account for microclimates on a point by point basis. To illustrate this point we'll look at part of the Tanana Valley in Alaska's interior, and at a microclimate called the "Tanana Valley Jet." Fist we set the stage on the synoptic scale. On the right is NCEP's sea level pressure analysis at 06Z November 28, 2003, a typical Tanana Valley Jet scenario. A 1016mb high is centered over northwestern Canada and is centered north of the arctic front. Surface temperatures in northwest Canada and over the eastern half of Alaska's interior associated with this high range from about 35 below zero up to the single digits above zero. The low near on Alaska's west coast has a central pressure of 975mb, so the sea level pressure gradient across mainland Alaska is around 40mb. Under these conditions, the pressure gradient force will produce the Tanana Valley Jet, but the winds will not be realized everywhere. Some locations become very windy, and other locations have little or no wind at all. We are going to consider the portion of the Tanana Valley from Northway downriver to Fairbanks, which we've zoomed into on the topographic map. Just to get you oriented, here is, roughly speaking, this same section of the Tanana Valley on the broader NCEP analysis. On the topographic map of the Tanana Valley the road system in red, and we see the communities of Fairbanks, Delta Junction, and Northway are all located down in the valley bottom. When the Tanana Valley Jet develops, high pressure is to the southeast, and the wind

accelerates due to pressure gradient force. But the wind doesn't develop in the uppermost reach of the valley. It starts between Northway and Delta Junction where the Tanana Valley begins to widen. The wind then follows the valley northwestward and eventually spreads out and weakens over the broader valley to the south of Fairbanks. The Tanana Valley Jet is a routine event at Delta, and it almost never is realized at Fairbanks or Northway—these wind regimes occur several times a year and are microclimates. Roughly speaking, when the SLP contrast from Northway to Delta exceeds 10mb, peak wind gusts up to 50 m.p.h. at Delta are possible, all while winds are calm or light and variable at Northway and Fairbanks. So, how did the numerical weather prediction models handle this event? As we will see in this example, the gridded output from the GFS model, and the MAV MOS from the GFS model account for this wind microclimate very differently.

Student Notes:

Utility of NWP Models: MOS



- Tanana Valley Jet: November 28, 2003
  - Cold high pressure centered over northwest Canada
  - Low pressure centered on Alaska's west coast
  - PGF pushing across mainland Alaska

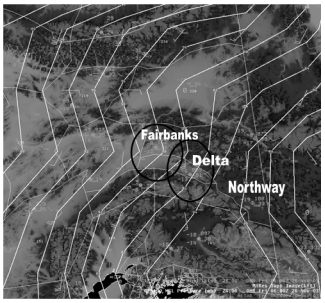
21. Utility of NWP Models: MOS

Instructor Notes: Here's an AWIPS D2D screen capture zoomed into the southeastern part of mainland Alaska. The image is the "hi res topo image," and overlayed on this image is the GFS forecast of sea level pressure in white, the GFS surface winds in blue, and the actual METARs in green, all valid at 06z November 28, 2003. These fields are from the 06z run of the GFS, so it is the initialization of the model. To get you oriented, Northway is here, Delta Junction is here, and Fairbanks is here. The low valley bottom of the Tanana Valley runs from southeast to northwest here, so we can see that the pressure gradient force is pointed straight down the valley. The lower terrain is purple and pale pink. The mountains are blue, green, and yellow and red. At this time the wind at Northway is 12006kt, wind at Delta is 10022g30kt (with temperatures of -6F), and wind at Fairbanks is calm. So how does the GFS wind field compare to the METARs in the Tanana Valley? To the GFS' credit, it depicts a maximum of wind speed near Delta Junction, although the direction is off by almost 90 degrees. If we look around this image, we can see that in locations where the METAR shows at least some wind, that is, no calm or light and variable, the magnitude of the GFS wind is within the ballpark, although the direction often is not. So one of the GFS grid's big weaknesses here is wind direction. Also, the grids fail to depict calm winds at Fairbanks—the GFS has winds at Fairbanks in

the 15 to 20 kt range. In general, the GFS's coarse depiction fails to capture the discontinuities in the wind field that are associated with these microclimates. The GFS's solution may be accurate with regard to the synoptic-scale features, but the resolution of the model is simply too coarse for it to identify these microclimates or even to identify the terrain that helps produce the microclimates. The lesson here is not that we should never use the GFS model. Rather, we just need to consider that the model is not designed to depict microclimates. The GFS' long wave synoptic-scale solution may be of very high quality, and it should be used in a way that maximizes this strength. But if we are going to produce a highly detailed forecast for specific points that are influenced by microclimates, the GFS grids alone will not be sufficient. The GFS grids may be an adequate starting point, but additional details would have to be introduced to account for microclimates.

Student Notes:

Utility of NWP Models: MOS



- GFS grid strengths
  - Depicts speed max near Delta
  - Magnitude of GFS winds are near observed magnitude in non-calm areas
- GFS grid weaknesses
  - Directions often do not match METARs
  - Fails to identify areas of calm winds such as Fairbanks
  - Resolution is too coarse to depict discontinuities associated with microclimates

22. Utility of NWP Models: MOS

Instructor Notes: Here is a table showing the actual winds from the METARs at Northway, Delta Junction, and Fairbanks, as well as the MAV MOS forecast, at 18 hour projection, and the initialized winds from the GFS initialization. One caveat here, is that the GFS grid winds are estimated, since the GFS didn't have data points exactly at the sites we are interested in, some subjective interpolation has been done. So what are the results? We see here that the MAV MOS wind forecast is closer to the METAR winds than the GFS grid winds are. This is especially true with regard to wind direction at Northway and Delta Junction—see that the GFS grids show southerly flow while the MAV MOS improves on the grids by nudging the wind direction to the southeast. The MOS also did very well with the wind speed at Fairbanks, where the MOS correctly identifies that winds will basically be calm. Again, the GFS grids did a good job with the wind speed at Delta Junction, and so did the MAV MOS. This example illustrates how the MAV MOS can account for microclimate effects on a point-by-point basis that its parent model, the coarse GFS, cannot identify. The MOS doesn't physically model these microclimates, but it has "learned" in a statistical sense that each of these locations have their own distinct wind microclimates, and so the MOS is able to account for the microclimates in its forecasts. One weakness of MOS is that it is not complete in space—there is only MOS

guidance for specific points. Fortunately, these points are where most of the people live, but in the digital age we have to produce grids that are complete in space. At the time this IC was recorded, there was work ongoing to develop a viable gridded MOS that could be use in IFPS. One last note…remember a few slides ago when discussed ground cover, and the impact of being above or below tree line with regard to blowing snow? Here at Delta Junction winds of 30kt or greater occur several times a winter--this climatologically normal. But blizzard conditions almost never occur at Delta despite having snow on the ground and very windy conditions. Delta Junction is down in the Tanana Valley, well below tree line. So while the immediate Delta Junction area is commonly very windy, most of the surrounding terrain is forest, so there isn't much square mileage of highly exposed snow for a significant blowing snow event to get going. Above tree line there is widespread bare terrain, and it is those areas which are much more prone to significant visibility reduction from blowing snow.

Student Notes:

Utility of NWP Models: MOS

	METAR	MAV MOS	GFS Grid
Northway	12006kt	12002kt	~20010kt
Delta Junction	10022g30kt	14023kt	~18025kt
Fairbanks	00000kt	14001kt	~18018kt

- GFS' MAV MOS outperforms the GFS grids
  - Particularly with regard to wind direction in this case
  - Particularly at Fairbanks
- MOS can account for microclimates that a coarse gridded NWP model cannot
- MOS is point based…for now

23. Utility of NWP Models: MOS

Instructor Notes: There is no single tool that works best in all situations, and that same caveat applies to MOS. MOS's ability to incorporate the climate record into its forecasts can become a weakness during an unusual event, especially further out in time. To illustrate this point we can consider the great Alaskan high-amplitude meridional flow event of November 2002. During this event a very persistent southerly flow brought unusually mild temperatures to much of Alaska, including Fairbanks, through almost the entire month of November. The MRF grids (as it was known in those days, today the GFS) did a fairly good job with the longwave forecast—that is, the MRF grids usually kept the strong southerly flow in place over Alaska out through days 4 to 7. The temperatures from the corresponding MEX MOS runs for Fairbanks, however, routinely cooled down toward climatology out at days 4 to 7. This kind of divergence between the grids and the MOS happened run after run, basically through the entire month of November. It turns out that the grids were right and the MOS was wrong. This table shows the dismal verification scores for the MEX MOS at Fairbanks during the entire month of November, 2002. Again, this verification if for the entire month, not just for one bad run. The vertical axis is time, going out to day 7. The horizontal axis contains verification statistics

for both the max and min temperatures: There is the RMSE, or “root mean square error,” and the ideal number here is zero. Bias is the measure of skewedness in the distribution, and again the ideal number here is zero. A negative bias means the MOS forecast is too cold. A positive bias means the MOS forecast is too warm. All of these values are degrees Fahrenheit. We can see that for both the max and min temperatures the root mean square error increases as we go further out in time, up to around 17 degrees by day 7. Error increases with time, which is not surprising, but the magnitude of this error is unusually high. Bias also gets worse with time, so that the bias is around 13 degrees too cold by day 7. Again, the ideal bias is zero, so the MOS is forecasting way too cold. Max and min temps were off by 10 degrees or more two thirds of the time out at days 6 and 7. Despite the persistent mild southerly flow depicted by the MRF grids, which turned out to be a pretty good forecast, each run of the MOS advertised a cooling trend with time, a trend toward climatology. The result was a very rough month for the mid-range MOS. I think we can attribute the MOS’s poor performance to its being constrained by the climate record, or more precisely the microclimate record in Fairbanks. In effect, the MOS was saying, “This is November in Fairbanks--it should be cold, I don’t care what the long wave pattern is.” Again, this has been an Alaskan example used to illustrate the broader point. In your CWA, are there situations in which the NWP gridded data and/or MOS routinely perform particularly well or particularly poorly? Does the MOS identify microclimate effects on a point basis that the gridded fields fail to depict? What role would microclimate play a role in such situations?

Student Notes:

Utility of NWP Models: MOS

- Example: MEX MOS for Fairbanks, November 2002
  - Persistent warm southerly flow well depicted by MRF grids
  - MEX MOS temperatures for Fairbanks drifted toward climatology
- MOS can be constrained by climate record

	Max Temperatures			Min Temperatures		
	RMSE	Bias	%=>10F	RMSE	Bias	%=>10F
Day 2	8.9	-4.7	21	9.1	-6.1	33
Day 3	10.4	-7.3	38	10.6	-8.0	43
Day 4	12.1	-8.2	35	12.5	-10.1	50
Day 5	14.7	-9.9	54	14.7	-11.7	53
Day 6	15.3	-11.7	68	15.0	-12.7	60
Day 7	16.7	-13.5	67	15.7	-12.4	63

24. The MOS Glass

Instructor Notes: This leads us to our final NWP slide: the MOS Glass. One of MOS’s greatest strengths is that it learns from the past and thereby can account for microclimatic effects. As we saw in this example at Delta Junction, Alaska, MOS, on a point basis, can replicate local weather that is produced by microclimatic mechanisms, in this case it is the unique wind microclimate at Delta. These are local weather effects that a coarse NWP model cannot explicitly depict. But this influence of the climate record on MOS is also a weakness for MOS. MOS can have difficulty depicting a radical event, such as record-breaking temperature that is several standard deviations away from “nor-

mal." This tendency is especially prominent at the further time projections, such as days four to seven. This is the problem we saw illustrated on the last slide, when the MEX MOS numbers consistently cooled down toward climate normals at Fairbanks, despite the parent MRF model's depiction a persistent warm pattern. So MOS is both trained and constrained by the climate record, specifically the microclimate record for specific points. The MOS glass is either half full or half empty, or both, depending on the weather scenario at hand. We have come to the end of section 3, the utility of NWP models, both gridded data and MOS, in accounting for microclimates.

Student Notes:

The MOS Glass

- Strength: MOS is trained by the climate record
- Weakness: MOS is constrained by the climate record
  - Especially further out in time

25. IC4.3 Interactive Quiz

Instructor Notes:

Student Notes:

26. Summary

Instructor Notes: Let's step back and do a brief summary of the IC to this point. We have described the basic concepts of microclimates and have seen some specific examples of how microclimates impact a forecast. These examples came from Alaska, but the underlying concepts are potentially applicable across the NWS. Why we care: We are meteorologists, not climatologists. We care because microclimates modify the meteorology. Microclimates are a frequent consideration. Microclimates can play a role in your routine day-to-day forecasts as well as during a the "storm of the decade." Microclimate defined. The major categories of terrain features which modify synoptic scale winter weather, again grouped together very roughly Mountains and valleys, which modify winds, modify precipitation through upslope enhancement and downslope shadowing, and modify temperatures through stratification in the vertical as well as affecting the flow of airmasses in the horizontal. Land cover. The ground's cover can impact temperatures due to radiative properties and albedo. Land cover also helps determine the wind and blowing snow regime at specific locations. Unlike mountains and valleys, some kinds of

land cover, such as the presence or absence or condition of a snow pack, can change on time scales we care about. Bodies of water. Can produce LES. The marine layer will influence a number of parameters as far inland as it penetrates. Coastal flooding due to extratropical cyclones is also an issue. The Utility of NWP models There is more to a good model than fine spatial resolution, but a fine-resolution model at least has the **potential**, all other things being equal, to depict a microclimatic phenomenon, such as terrain channeled winds. MOS can account for microclimates on a point basis, even when the MOS' parent model has a spatial resolution too coarse to explicitly resolve the phenomena in question. However, keep in mind that MOS can also be constrained by the climate record, and can have difficulty portraying unusual events—this is especially true further out in time, such as in the days four to seven range.

Student Notes:

Summary

- Why we care: microclimate modifies meteorology
  - Impact day-to-day forecasts and warning decisions
- Microclimate defined
  - climate of a small, specific place within an area as contrasted with the climate of the entire area
  - result from interaction between synoptic patterns and local terrain
- Terrain which modifies winter weather
  - Mountains and valleys, land cover, bodies of water
- Utility of NWP models
  - Finer resolution models have potential to resolve finer features
  - MOS can account for microclimates on a point basis
  - MOS can be constrained by climate record, especially in mid-range

27. Section 4: Apply Concepts to Your CWA

Instructor Notes: Now on to section 4, the most important, and most difficult, part: applying these concepts to your CWA and your forecasts. Here again are the "performance objectives" mentioned earlier in this IC: Identify the microclimates in your CWA. Demonstrate knowledge of how specific synoptic patterns interact with your CWA's terrain. Apply knowledge of microclimates to your routine forecasts and your warning decisions. Here are some ways you can meet the first performance objective, identifying microclimates in your CWA. You can consult existing documentation, such as NCDC's climate data and storm data. There may also be local studies done at your WFO, perhaps your station duty manual or focal point manuals addresses your CWA's microclimates. Secondly, you can consult the "human capital" of your WFO. Some of the most important knowledge about microclimates in your CWA may not even be written down, but could rather be part of the shared knowledge of the forecast staff. You can learn a lot about microclimates in your CWA by asking other forecasters to share their thoughts and experiences. It is likely we can learn something from everyone. The veteran forecasters have the advantage of years of experience to draw on. Newer forecasters bring a fresh perspective and may notice things no one else has considered yet. You can also zero in on the forecasters in your office who are the true "experts" and try to absorb as much knowledge from them as you can. Consider revisiting AWOC IC Core 3,

lesson 1, “Expertise” for more information on “experts.” Lastly, you can learn by doing, by working the forecast desk, and in so doing you become one of your WFOs experts with regard to microclimates. Increased knowledge does not come automatically from working the forecast desk, however. There is a difference between someone who has 20 years of experience and someone else who has one year of experience repeated 20 times. To truly gain expertise we need to be able to learn from our successes and failures and apply this learning to our forecasts in the future. This IC, like all ICs in Winter Weather AWOC, has a quick on-line quiz to test your learning of the basic concepts. But since these performance objectives deal specifically with your CWA, and there is no way a single quiz can account for this across the entire NWS, there is also a quick exercise to help you meet the second and third performance objectives.

Student Notes:

Section 4: Apply Concepts to Your CWA

- Performance objectives
  - Identify microclimates in your CWA
  - Demonstrate knowledge of how specific synoptic patterns interact with your CWA’s terrain
  - Apply knowledge of microclimates to your routine forecasts and your warning decisions
- Identify microclimates in your CWA
  - Documentation: NCDC’s CDs and storm data, local studies, etc
  - Learn from your coworkers
    - Especially the experts. Revisit AWOC IC Core 3, lesson 1, “Expertise”
  - Learn by doing: your own experience on the forecast desk

28. Section 4: Exercise

Instructor Notes: The exercise is for you to produce a one or two page document that describes a microclimate in your CWA. This is not a graduate school dissertation. Keep it short and simple, just one or two pages. It should take just an hour or so to complete--this is nothing overly formal or thorough. Ground breaking research is not required here. Ideally, you can draw on things you have learned about a microclimate in your CWA but have never had the opportunity to document before. Consider the basic categories of microclimates described in this IC as a template of how to identify a microclimate. Then draw upon your own experience on the forecast desk at your WFO. Focus on a microclimate that impacts your forecasts. Perhaps the phenomenon in question is an issue for your routine forecasts, or maybe it has an impact on your warnings. Include any helpful hints or rules of thumb that will help a forecaster make the right decision when dealing with this microclimate. How do the numerical models and MOS handle this microclimate? You may also want to consider the GFE—are there any SmartTools or grid editing techniques that make depicting the effects of this microclimate in the GFE easier? A more complete guide to doing this exercise, including examples from the northern Alaska CWA, are on the Winter Weather AWOC Internet site. Each WFO has unique microclimates and unique circumstances. Your SOO or AWOC facilitator will be in the best position to help shape your WFO’s approach to this exercise. This exercise is optional—you

will still be able to meet the national requirements for passing Winter Weather AWOC without doing the exercise. Individual WFOs may place different amounts of emphasis on this exercise—the upshot is to coordinate with your SOO or AWOC facilitator for the exact approach to be used at your WFO. Individual WFOs may offer unique approaches to this exercise to better meet their unique circumstances. Perhaps you will be asked to work in teams of two or more, or to model your exercise after a specific template or even as a PowerPoint slide show.

Student Notes:

Section 4: Exercise

- Exercise: Describe a microclimate in your CWA
  - One or two pages
  - Draw on your experiences
  - Address the impact on your forecasts, routine or warning
  - Provide "rules of thumb," qualitative or quantitative
  - Any tools or techniques to depict this microclimate in the GFE?
  - A guide to this exercise is on the Winter Weather AWOC Internet site
- Coordinate with your SOO or AWOC facilitator
  - Local needs at your WFO may require a different approach
  - This exercise is optional
  - May work in teams of two or more

29. Section 4: Exercise

Instructor Notes: There are three motives in doing this exercise. As forecasters across the NWS complete this exercise, we as an agency will take a step toward documenting the institutional knowledge of microclimates that may until now have only been held in people's heads. Such documentation will be helpful for new forecasters who come to your WFO in the coming years. Also, the sharing of expertise could help neighboring WFOs make better forecasts for your CWA during service backup. Assume that your exercise will be read by a meteorologist who is a good forecaster but who is simply not yet familiar with the specific microclimates unique to your CWA. Consulting your exercise should help this person get a quick and practical introduction to how this microclimate impacts forecasts in your CWA. These exercises will be collected by Winter Weather AWOC Headquarters at the Warning Decision Training Branch so that they can be made readily available to new forecasters and to neighboring WFOs.

Student Notes:

Section 4: Exercise

- Motivation
  - A step toward documenting the institutional knowledge of microclimates possessed by NWS forecasters
  - Helpful for new forecasters at your WFO
  - Helpful for neighboring WFOs during service backup
- Exercises will be collected by WDTB

30. The End

Instructor Notes: This is the end of Winter Weather AWOC IC4.3, Microclimates: the interaction between synoptic patterns and local terrain. Regarding references, there aren't many generalized references on microclimates. There is considerable literature concerning specific microclimates, such as lake effect snow regimes and wind regimes in complex terrain, however. Concerning NWP models and their strengths and limitations, please consider these two MetEd modules… Concerning microclimates at your own CWA…per the earlier slide there may be some documentation produced by NCDC, or produces locally at your WFO. AWOC IC Core 3, lesson 1, "Expertise" deals with how we can acquire new expertise about microclimates from our coworkers and from our own experiences on the forecast desks. A number of people provided vital assistance in the development of this lesson and should be acknowledged. Rick Thoman, lead forecaster at WFO Fairbanks, is a microclimate expert and supplied frequent guidance throughout the construction of this lesson. Ed Plumb, Service Hydrologist at WFO Fairbanks and former NOAA Employee of the Month, used his GIS skills to produce the topographic maps used in this lesson. And of course all the team at the Warning Development Training Branch and the AWOC developers across the Weather Service helped build this lesson.

Student Notes:

The End

- References
  - NWP: MedEd website http://meted.ucar.edu
    - "Intelligent Use of Model-Derived Products"
    - "Ten Common NWP Misconceptions"
  - NCDC, local references
  - AWOC IC Core 3, Lesson 1, "Expertise"
- Acknowledgements
  - Rick "Microclimates R Us" Thoman, WFO Fairbanks
  - Ed Plumb, WFO Fairbanks
  - WDTB and AWOC Developers

16. Q_n and Q_s Vectors Question

Instructor Notes: And finally, here's your last question. Q_n vectors are related to the change in "blank" of the temperature gradient. The Q_s vector is related to the change in "blank" of the temperature gradient.

Student Notes:

Q_n vectors are related to the change in _____ of the temperature gradient. The Q_s vector is related to the change in _____ of the temperature gradient.

- A. magnitude, orientation
- B. orientation, magnitude
- C. propagation speed, orientation
- D. orientation, propagation speed

17. Q-Vectors & Temperature Gradients

Instructor Notes: Interactive quiz question.

Student Notes:

18. Answer to Quiz Question 4

Instructor Notes: A is the correct answer. Q_n and Q_s do not tell you anything about the movement of a frontal boundary. However, they do provide information on whether a thermal gradient is frontogenetic or frontolytic and which way the isotherms are rotating. In most cases, forecasters are concerned with Q_n and whether a thermal gradient is frontogenetic. When the Q-vector points from warm air to cold air then the gradient is fron-

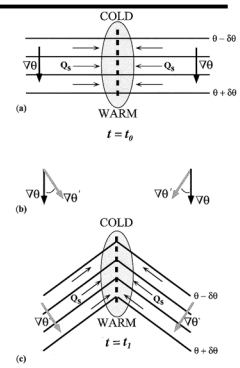
tolytic. When pointing from cold air to warm air, then it is frontogenetic. In addition, the magnitude of the Q_n vector is equal to the geostrophic frontogenesis. We'll discuss geostrophic frontogenesis in more detail in Lesson 2. The Q_s vector is showing changes in orientation to the thermal gradient. While used less often in operational forecasting, the diagram from Martin (1999) shows that the Q_s forcing plays a role in reorienting isotherms to produce a trowal structure within the occlusion of a cyclone. This will be discussed in lesson 5. What is also seen is that, when Q_s is convergent along a thermal gradient, it will act to rotate the isotherms in such way that a thermal ridge will develop on a front where the convergence is maximized. When Q_s is divergent along a thermal gradient, the geostrophic wind is acting to rotate the isotherms so that a thermal trough will develop on the front. The thermal trough will develop where the divergence is maximized along the gradient.

Student Notes:

Question 4 Short Answer

- ***Q***$_n$ points Warm → Cold ***Frontolysis***
- ***Q***$_n$ points Cold → Warm ***Frontogenesis***
  - $|-Q_n|$ is equal to the QG frontogenesis
- The temperature gradient vector will rotate toward the Q_s.
  - ***Q***$_s$ points with cold air on left ***Q*** rotates cyclonically
  - ***Q***$_s$ points with cold air on right ***Q*** rotates anticyclonically

Click here to hear explanation.
Click here to go to potential vorticity.



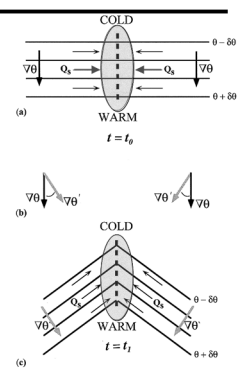
19. Long Answer to Quiz Question 4

Instructor Notes: The instructor provides a more detailed explanation for the answer to the quiz question in the presentation.

Student Notes:

Question 4 Long Answer

- ***Q***$_n$ points Warm → Cold ***Frontolysis***
- ***Q***$_n$ points Cold → Warm ***Frontogenesis***
  - $|-Q_n|$ is equal to the QG frontogenesis
- The temperature gradient vector will rotate toward the Q_s.
  - ***Q***$_s$ points with cold air on left ***Q*** rotates cyclonically
  - ***Q***$_s$ points with cold air on right ***Q*** rotates anticyclonically



IC5.1: Optional Job Sheet

A Review of QG Theory and Potential Vorticity

Objective: Apply the knowledge gained from the winter weather AWOC IC 5 Lesson 1 training module to a case study.

Data: 15 March 2004 winter storm event in the Midwest. You will be using your WES machine in case review mode.

Instructions:
On your WES machine, load the 15 March 2004 case, DMX localization, and set the clock to 15 March 2004, 13:00 UTC.
On the regional map scale, load NAM 80 500mb Height, geostrophic wind, and ageostrophic wind
Where are the QG assumptions valid and invalid? (location detail such as "northern Missouri" would suffice) Explain why.

On the regional map scale, load a NAM 80 tropopause map (use "trop" under the misc. planes menu in the volume browser) with wind vectors, potential temperature and pressure at 3 layers: 700-500 mb, 500-400 mb, and 400-300 mb. Answer the following questions.
Focusing on each layer, where is the upward forcing located? If there is no upward forcing, answer "None".

700-500 mb layer forcing:_____

500-400 mb layer forcing:_____

400-300 mb layer forcing:_____

In which layer does the Q_s pattern favor the development of a thermal ridge?

On the regional map scale, load a NAM 80 1.5 PV map (tropopause map) with wind vectors, θ_e, and pressure.

Where are the jets, trough, ridge?

Jets located:_____

Trough located:_____

Ridge located:_____

Where is air of stratospheric origin being lowered into to the mid-troposphere?

Stratospheric Air: _____

Will the trough **strengthen** or **weaken?** (circle one) Explain your answer.

Will the jet **progress east** or **remain nearly stationary** over the next 6 hours? (circle one)

Are there any areas where a low-level front (or frontogenesis) could be enhanced due to the influence of the PV anomaly? (You'll have to load a pane displaying low-level thermal gradients to answer this one)

An answer key is available for this job sheet. Please see your local AWOC Winter Weather facilitator to obtain a copy.

IC5.2: Optional Job Sheet

Diagnosing Mesoscale Internal Forcing—Frontogenesis

Objective: Examine a winter weather event and apply frontogenesis concepts discussed in the IC 5 Lesson 2 training module.

Data: 15 March 2004 winter storm event in the Midwest. You will be using your WES machine in case review mode.

Instructions:
On your WES machine, load the 15 March 2004 case, DMX localization, and set the clock to 15 March 2004, 13:00 UTC.
Take a vertical cross section perpendicular through the low-level thermal gradient from MN south to MO and load NAM 80 $_e$, omega, wind vectors, 2-D frontogenesis, and Div Q.

Where would you expect to find a secondary ageostrophic circulation?

Is there any sign of such a circulation, and if so, where is it located?

What do you think is causing the vertical motion over southern Iowa?

Where are the upper- and lower-level circulations coupled? (list a vertical layer and a general geographic location)

In a plan view pane and regional scale, load NAM80 750mb wind divergence, wind, total deformation and $_e$.
Does this appear to be **frontogenetic** or **frontolytic**? (circle one)

Where is the convergence maximized?

At any scale of your choosing, load a satellite image over surface obs and NAM 80 850mb 2-D frontogenesis.
Do you expect any enhanced frontogenesis from diabatic effects?

At the regional scale, load NAM80 500-300mb PV and overlay 700mb frontogenesis.
Where and at what forecasted time might the PV anomaly strengthen and/or couple with the frontogenesis?

Load a 4 panel plan view of NAM 80 Div-Q from 700-500 mb, with 2-D Frontogenesis at 4 different heights making up the 4 panels.
At what height are frontogenesis and Div-Q coupled to produce maximum forcing?
Where geographically is this coupling located?

An answer key is available for this job sheet. Please see your local AWOC Winter Weather facilitator to obtain a copy.

IC5.3: Optional Job Sheet

The Effect of Stability on the Response to Internal Forcing in the Atmosphere

Objective: Demonstrate how to assess Equivalent Potential Vorticity (EPV) fields and their effect on winter weather precipitation through a case study.

Data: You will examine 2 different cases to show how EPV or lack of EPV affects the scale and magnitude of the precipitation. As with job sheets for IC 5 Lessons 1 and 2, you will first re-examine the 15 March 2004 winter storm event in the Midwest, then a contrasting event from 4 November 2003, also across the Midwest. You will be using your WES machine in case review mode.

Instructions:

Case #1

On your WES machine, load the 15 March 2004 case, DMX localization, and set the clock to 15 March 2004, 13:00 UTC.

Load surface metars and RUC or NAM40 surface θ_e.

Take a cross section northeast to southwest from southeast Minnesota to eastern Kansas, normal to the surface front across southern Iowa. Load NAM 80 wind vectors, and ageostrophic vertical circulation streamlines. Focus on the NAM analysis at 12 UTC 15 March 2004.

Based on the shape of the circulation and pattern of the vertical motion streamlines, what would you infer about the static stability and inertial stability?

Overlay geostrophic momentum and θ_{es}. Does this agree with model's assessment in #1 of the vertical circulation and thus the inertial and static stability? Why or why not?

Next, overlay Saturated EPV_g (MPV_g). How does this compare with what you saw with momentum surfaces and θ_{es} regarding static stability?

Where is the strongest conditional or symmetric instability in this cross section? Is it deep?

Along the same cross section but in a different window, load NAM80 θ_{es}, saturated equivalent geostrophic potential vorticity (MPV_g), and RH. Shade only the PV values less than +0.25 PV units. Focus on the NAM analysis valid 12 UTC 15 March 2004. What is the likely cause of the MPV_g minimum in the 700-300 mb layer across the southern end of the cross section?

Overlay 2-D frontogenesis. Where is the smallest vertical separation between the maximum in frontogenesis and MPV_g minimum located?

Where would the north and south extents of the heavy snow band likely occur? (Hint, examine the horizontal distance from the maximum frontogenesis at 600 mb to the northeast and at 900 mb to the southwest)

Based on your analysis of the NAM analysis valid 12 UTC 15 March 2004, load a plan view 2-D frontogensis near the level of maximum frontogenesis over Iowa, and overlay MPV_g in the layer 100 mb above the front you discovered in the cross sections. Where, if anywhere, is the MPV_g minimized above the frontogenesis?

Based on your answer to the above, where do you expect the heaviest snowfall to occur and what is the primary forcing mechanism in that region?

Overlay Div-Fn vectors in the same layer you displayed MPV_g. How do the Fn convergence fields compare to the stability above the frontal zone? Is this surprising? Why/Why not?

Case #2—A different perspective

If you have extra time and want to examine a case with different stability and frontogenesis coupling, give this event a try. Load the 04 November 2003 case, FSD localization, and set the clock to 04 Nov 2003, 07:00 UTC.

Determine the location of the surface front at 6 UTC on 4 November 2003.

Take a cross section normal to the surface front across southern North Dakota to southeast Kansas (essentially normal to the thermal wind) and load NAM80 wind vectors, and ageostrophic vertical circulation streamlines. Focus on the NAM analysis at 06 UTC 04 November 2003.

Based on the shape of the circulation and pattern of the vertical motion streamlines, what would you infer about the static stability and inertial stability?

Overlay geostrophic momentum and $_{es}$. Does this agree with model's assessment in #11 of the vertical circulation and thus the inertial and static stability? Why or why not?

Next, overlay MPV_g. How does this compare with what you saw with momentum surfaces and $_{es}$ regarding static stability?

Where is the strongest conditional or symmetric instability in this cross section? Is it deep?

Along the same cross section but in a different window, load NAM80 saturated equivalent potential temperature, MPV_g, and RH. Focus on the NAM analysis valid 06 UTC 04 November 2003.
Where do you see the potential for deep convection to develop?

Overlay 2-D frontogenesis. Where is the smallest vertical separation between the maximum in frontogenesis and MPV_g minimum located?

Where would the north and south extents of the precipitation band likely occur?

Based on your analysis of the NAM analysis valid 06 UTC 04 November 2003, next load a plan view 2-D frontogensis near the level of maximum frontogenesis over southern Nebraska/central Kansas, and overlay MPV_g in the layer 100-150 mb above the front you discovered in the cross sections.
Where, if anywhere, is the MPV_g minimized above the frontogenesis?

Based on your answer to the above, where do you expect the heaviest precipitation to occur and what is the primary forcing mechanism in that region?

Overlay Div-Fn vectors in the same layer you displayed EPV_g. How do the Fn convergence fields compare to the stability above the frontal zone? Is this surprising? Why/Why not?

An answer key is available for this job sheet. Please see your local AWOC Winter Weather facilitator to obtain a copy.

IC5.4: Optional Job Sheet

Examples of Frontal Precipitation Bands

Objective: To apply the diagnostics shown in the IC 5 Lesson 4 training module to a winter weather event.

Data: 24 November 2004 winter storm event in the Midwest. You will be using your WES machine in case review mode.

Instructions:
On your WES machine, load the 24 November 2004 case, ILX localization, and set the clock to 24 November 2004, 01:00 UTC. You will be looking at the 12 hr forecast from the 00Z 24 Nov 2004 run of the NAM 80 across Illinois valid **12Z 24 Nov 2004**.
On the regional scale, load a plan view of NAM 80 400-500mb layer Q vector divergence and Q vectors.
Where is the Q-vector convergence strongest at the 12 hr forecast valid 12 UTC on 24 November?

Step forward 6 hrs to the 18 UTC forecast. At this time where is the upper level forcing strongest?

Load a plan view of NAM 80 700, 850 mb 2-D frontogenesis and 700, 850 mb omega. Where is the low to mid level forcing due to frontogenesis strongest at the forecast valid at 12 UTC? How about the forecast 18 UTC on 24 November?

Is the low- to mid-level forcing collocated with the upper tropospheric forcing at 12 UTC and/or 18 UTC? (Circle the appropriate one(s))
12 UTC 24 November Forecast: **YES/NO**
18 UTC 24 November Forecast: **YES/NO**

Take a cross section perpendicular to the maximum in frontogenesis across Illinois and examine the forecast valid at 18 UTC on 24 Nov 2004. Load NAM 80 omega, 2-D frontogenesis, RH, and saturated geostrophic equivalent potential vorticity.

Do you expect any convection across Illinois, either via conditional instability or slantwise instability?

Describe all the different forcing mechanisms that may be in play to result in the > 20 µb/sec rising motion over central Illinois.

An answer key is available for this job sheet. Please see your local AWOC Winter Weather facilitator to obtain a copy.

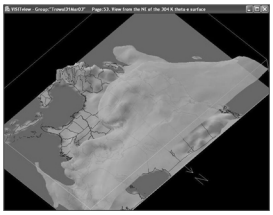
29. Trowal Identification…Best

Instructor Notes: Further information on this specific approach may be found in the VISITView module on trowal identification.

Student Notes:

Trowal Identification… *Best*

- Choose θ_e contour that exists at the leading edge of the warm air of both fronts (Lindstrom et al. 2003)
- Construct a surface of θ_e for this value
- Create trowal trajectories from model output
- Parcels follow trowal axis as the "trowal airstream"



30. Section 4

Instructor Notes: Now let's move onto Section 4, title A Trowal Cast Study.

Student Notes:

Section 4

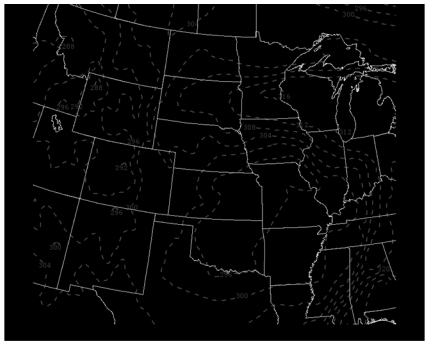
A Trowal Case Study

31. Identify the Trowal from 700 mb θ_e

Instructor Notes: Here is a map of 700 mb theta-E given by the red dashed contours on 03 UTC on the 29th. On the map, indicate where you think the TROWAL would be located. The quiz responder coming in the next slide will allow you to answer this item.

Student Notes:

Identify the Trowal from 700 mb θ_e



Indicate on the map where you think the trowal is based upon the 700 mb analysis.

Dashed red lines are equivalent potential temperature.

32. Interactive Quiz #2

Instructor Notes: Please take a moment to complete this interactive quiz question.

Student Notes:

33. The Trowal is Within the θ_e Ridge

Instructor Notes: As shown earlier, a good first guess for the location of the trowal is the examine equivalent potential temperature on a pressure surface, typically 700 mb although any level from 850 mb to 500 mb would be acceptable. The presence of a thermal ridge indicates that a trowal may be present within the cyclone. In the above diagram the theta-e ridge extends from Wisconsin into western South Dakota.

IC5.5: Optional Job Sheet

The Structure of TROWALS

Objective: Examine a winter weather case, and using the knowledge gained from the IC 5 Lesson 5 training module, identify a TROWAL and predict its evolution.

Data: 1 March 2004 winter storm event in the High Plains. You will be using your WES machine in case review mode.

Instructions:

On your WES machine, load the 1 March 2004 case, GID localization, and set the clock to 07 UTC March 1, 2004. **You will be examining the NAM 80 06 UTC initialization**. On a plan view at the regional scale, load NAM 80 mslp, surface isotherms, and surface winds, then toggle between overlays of wind vectors and $_e$ at three pressure levels: 925mb, 850mb, and 700mb.
Where is the TROWAL located?

TROWAL Location:_____

Is there a surface occluded front? **YES/NO** (Circle one) If so, where is it located?

Swap panes and load a plan view at the regional scale of NAM 80 pressure on a 305K equivalent potential temperature surface, overlaid with winds and saturated equivalent geostrophic potential vorticity (MPV_g) from 700-500 mb.
Where is the trowel in this image?

TROWAL Location:_____

How are the placement and/or structure of the TROWAL different from what you saw with the constant pressure plot?

Where within the TROWAL is the strongest upward forcing signal, and qualitatively how strong is it?

Is there any instability present in the TROWAL? If so, where?

Cut a cross section through the TROWAL, roughly from E. Nebraska north-northwest into southwest Manitoba. Load NAM 80 $_e$ and 2-D frontogenesis.
Explain what the TROWAL looks like in the cross section. Mention if the $_e$ gradient is larger on one side or the other.

Finally, load a NAM 80 plan view on the regional scale of the 305 equivalent potential temperature surface map with pressure, overlaid with 925 and 850 mb Petterson frontogenesis.
Where would the heaviest snow fall? Explain your reasoning.

An answer key is available for this job sheet. Please see your local AWOC Winter Weather facilitator to obtain a copy.

IC6.4: Optional Job Sheet

Ingredients-based Method for Forecasting Heavy Precipitation

Objective: Examine AWIPS procedures designed to assist in the ingredients-based methodology of forecasting heavy precipitation, as discussed in the IC6 Lesson 4 training module. Specifically, you will be able to find areas of potential symmetric instability (PSI) or conditional symmetric instability (CSI), and determine a lifting mechanism that may release the instabilities.

Data: 24 February 2003 winter weather event across Texas. You will be using D2D for this exercise.

Background: Since CSI is almost always released by frontogenetical forcing, you'll notice in this procedure we are using divergence of $\overrightarrow{F_n}$ vectors to assess forcing, saturated geostrophic equivalent potential vorticity to assess instability, and condensation pressure deficit and/or relative humidity to assess moisture. The main difference between CSI and PSI is the use of saturated equivalent potential temperature (CSI) vs. equivalent potential temperature (PSI). The potential in PSI is because the parcel is not saturated. At saturation PSI = CSI.

Instructions: (Instructions numbered 1., 2., … questions numbered 1), 2), …)

1. Load the 24 February 2003 Winter Weather AWOC case on your WES machine in case review mode, using the FWD localization. Set the D2D clock to 24 February 2003 18 UTC. You will be examining the 24 February 18 UTC NAM 40 model initialization, 6 hr NAM 80 forecast valid at 18 UTC, and observational data. So when answering the questions below, ensure that your answers are based on the 24 February 18 UTC initialization run.
2. With these procedures, always feel free to modify and save them as your own. How to visualize D2D data is subjective, and picking colors, products, and overlays that are comfortable to you is what is most important.
3. First, assess the potential for lift. Open the procedure "CSI_PSI" and load "Synoptic Forcing". This loads potential vorticity, geostrophic equivalent potential vorticity both saturated and unsaturated at 4 different layers, Divergence of Q vectors at 3 different layers, and tropopause pressure.
    1) Where geographically is Q vector convergence strongest?

    _____

    2) In which layer is Q vector convergence strongest?

_____mb to _____mb layer

3) Where geographically is potential vorticity at a maximum?

_____

4) In which level or layer is potential vorticity strongest?

_____mb

5) Which layer is moist EPV_g at a minimum?

_____mb to _____mb layer

4. Examine areas where PV anomalies or Q vector convergence is coupled with frontogenesis. Load from the CSI_PSI procedure "Frotogenetic Forcing, Stability".

   This procedure loads NAM 40 2-D frontogenesis and Divergence of $\overrightarrow{F_n}$ at 25-50 mb increments up to 650 mb. It also loads Saturated EPV_g (MPV_g)at 5 different layers.

   6) Where and at what level is frontogenesis strongest? If several strong areas and levels of frontogenesis, list them all.

   _____

   7) Is there potential instability above the strong areas of frontogenesis? If so, which layers are potentially unstable within 50-100 mb above the level of frontogenesis?

   _____

   8) Using the information from questions 1-4, where geographically are the frontogenetical forcing and synoptic forcing coupled?

   _____

5. Next step is to see if 'upright' convection is a concern. If the atmosphere is unstable to both upright and slantwise convection, the upright will be released first. In your uncluttered pane, load the procedure "Upright Convection". This loads NAM 40 ThetaE lapse rates at 800-700 mb, 700-600 mb, 600-500 mb, 750-700 mb, and 700-650 layers. Because the volume browser does not have *saturated* ThetaE lapse rates, the procedure contains RH at those same levels. You'll be looking for RH values greater than 80%. Load each ThetaE lapse rate as an image as you step through them, and shade only negative values.

   9) Circle the appropriate choices for 80% RH and negative lapse rates

IC7.1: Optional Job sheet

Monitoring Model Accuracy

Objective: Examine model data from a winter weather case to assess the pitfalls of numerical weather prediction as discussed in the winter weather AWOC IC 7 Lesson 1 training module.

Data: 15 March 2004 winter weather event across the Midwest. You will be using AWIPS D2D for this exercise.

Instructions:

1. Load the 15Mar2004 Winter Weather AWOC case on your WES machine in case review mode, using the DMX localization. Set clock to 13 UTC 15 March 2004.
2. Assessing Pitfall #1: Upper Trough merger, phasing
   - Overlay a water vapor loop with NAM 80 500 mb absolute vorticity and heights on the CONUS scale. Monitor the progression of short-wave troughs vs. model solution, especially in this split flow.
     1) Are there any short wave troughs in the model output that are merging or phasing with the deep long wave trough over the Great Lakes?
     2) Does the NAM have the short wave trough well analyzed?
3. Assessing Pitfalls #2, #3 and #7: Surface cyclone intensity and track, convection/ diabatic effects
   - Load and examine hourly obs and MSLP objective analyses (MSAS) with IR satellite over the last 24 hours (13 Z 14 March through 13 Z 15 March) on the regional scale. Overlay NAM 40 MSLP and 1-hour lightning. You are looking for unexpected lightning strikes and IR showing significant cloud top cooling near the surface low, or significant departures in the current data from the progged surface cyclone track or intensity.
     3) Is there any evidence that the surface cyclone is more intense or taking a different track than the models predicted? Explain your reasoning.
     4) Where is the convection located relative to the surface cyclone?

5) How might the convection affect the surface cyclone track or intensity?

4. Assessing Pitfall #4: Dry slot

- Load WV imagery on the regional scale, overlay the NAM 40 700-300 mb RH fields. Focus on the 12 hr NAM forecast valid at 12 UTC and the 12 UTC WV image by selecting “Prev Run” from the top left drop down menu in D2D before you load the product in the volume browser. In another pane, load the DDC, DVN, OMA, TOP Raobs and overlay corresponding NAM 40 model soundings at those same areas (i.e. load points over those cities, then use volume browser to load point soundings)

6) Where is the dry slot?

7) How did the NAM 40 12 hr forecast handle the location and movement of the dry slot?

5. Assessing Pitfall #5: Precip transition zones

- Examine the surface obs once again on the regional scale and overlay surface temperatures from the RUC and NAM 40

8) Where is the changeover to snow occurring over the last hour or two?

9) How are the models handling surface conditions? Too cold? Too warm? Bad timing?

- Load a NAM 40 model sounding in the changeover region somewhere near southwest Iowa. Overlay Omaha's sounding and then overlay an aircraft sounding from around 12 UTC (MDCRS in the volume browser, you will need to have "Inventory" selected in the main D2D window before loading the aircraft data, found under upper air menu and heading "Aircraft").What is the primary cause of the changeover to snow?

10) Will you have to worry about sleet or freezing rain anywhere across Nebraska or Iowa? Why or why not?

- Load a nearby lowest tilt radar reflectivity loop.

12) Where is the radar bright banding occurring, and at what height?

6. Assessing Pitfall #6: Mesoscale banding

- Swap panes and get to the state scale. In the volume browser, load the NAM 40 model run snow accumulation product, then overlay both KDMX and KOAX 0.5 reflectivity. (You will only be able to compare a few snowfall graphics to actual radar images because of the way AWIPS loads products)

13) Is the NAM accurately depicting the nature of the mesoscale snow band across Nebraska/Iowa? Be specific.

An answer key is available for this job sheet. Please see your local AWOC Winter Weather facilitator to obtain a copy.

1. IC7.2 Part 2: WSR-88D Winter Precipitation Estimation - Case Study

Instructor Notes: This is part 2 of a lesson on WSR-88D winter precipitation estimation. This is a case study of a New England snow event and should last about 20 minutes.

Student Notes:

WSR-88D Winter Precipitation Estimation – Case Study

James G. LaDue
AWOC Winter Weather Track:
Instructional Component 7, Lesson 2
Part 2

2. This Lesson

Instructor Notes: This lesson is an exercise and an extension of Lesson 2, Part 1 in IC7, titled “WSR-88D Winter Precipitation Estimation”. I suggest you take lesson 2 part 1 before starting this case study.

Student Notes:

This Lesson

- Is an exercise and an extension of Lesson 2, Part 1 in IC7, “WSR-88D Winter Precipitation Estimation”
- I suggest you take Lesson 2, Part 1 before starting this case study

3. Learning Objective

Instructor Notes: By the end of this lesson, you will understand a process to analyze the locations in the radar domain three major errors of radar derived precipitation: over-

shooting precipitation generation, overshooting sub-beam evaporation, and bright banding.

Student Notes:

Learning Objective

- You will understand a process to analyze the locations in the radar domain three major errors of radar derived precipitation
  - Overshooting precipitation generation
  - Overshooting sub-beam evaporation
  - Bright banding

4. Performance Objectives

Instructor Notes: After completion of this lesson, you will be able to apply a methodology to analyze on a radar map three major sources of radar-based winter precipitation estimates. These error sources include: overshooting precipitation generation, overshooting sub-beam evaporation, and bright banding.

Student Notes:

Performance Objectives

- After completion of this lesson, you will be able to apply a methodology to analyze on a radar map three major sources of radar-based winter precipitation estimates.
- These error sources include
  - Overshooting precipitation generation
  - Overshooting sub-beam evaporation
  - Bright banding

5. Review of Part 1

Instructor Notes: As a review of Part 1 of this lesson duo, remember that the radar overestimates precipitation rates where the beam overshoots evaporating precipitation and bright banding occurs. The radar underestimates precipitation where the beam overshoots precipitation production layers. There are system errors, too, that affect precipitation rate estimations such as beam blockage and calibration. You do have the option of adjusting the ZS algorithm coefficients but you would have to keep changing them over

small horizontal distances. We cannot adjust the ZS algorithm without an automated real-time correction scheme and good ground truth data. Instead we choose to draw areas where the precipitation will be over or underestimates of a fixed ZS relationship.

Student Notes:

Review of Part 1

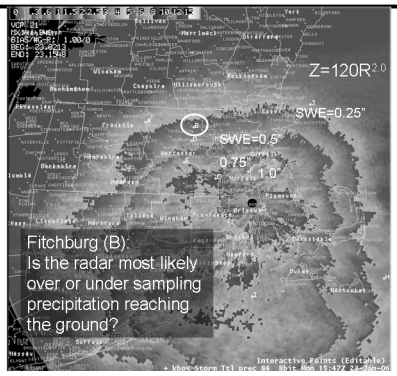
- Radar overestimates precip rate where
  - Beam overshoots evaporating precip
  - Brightbanding occurs
- Radar underestimates precip rate where
  - Beam overshoots precip
- Other errors
  - Beam blockage
  - Calibration errors

6. Case: Range Limitations in New England

Instructor Notes: Let's try an example and take a look at how well the radar is estimating precipitation at Fitchburg, MA (in the circle). We ran the ZR algorithm using the default ZS coefficients that are planned for the Northeast U.S. and the minimum dBZ set to 10. However the results will not replicate the actual implementation of the ZS algorithm because there is no range correction applied here and a lower minimum dBZ setting. Given the criteria I set, do you think the precipitation is likely to be over or underestimated for Fitchburg?

Student Notes:

Case: Range Limitations in New England

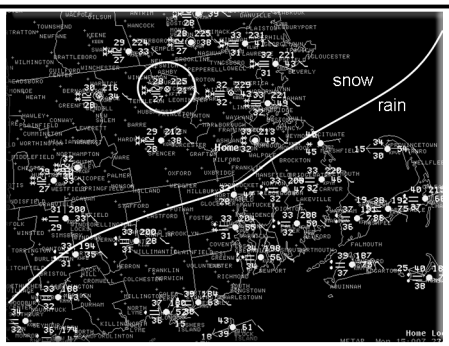


7. Surface Map – New England

Instructor Notes: Fitchburg is well north of the rain snow line. The near saturation around the area also corresponds to relatively low cloud bases. Light winds in the area suggest that any bucket gauge should be able to be pretty efficient at capturing falling snow.

Student Notes:

Surface Map – New England



8. New England Topography

Instructor Notes: Fitchburg is in an area of relatively high terrain (600' MSL) and with the light easterly winds, there should be some upslope component to the flow. Upslope flow in subfreezing air means a greater possibility of low-level feeder clouds. Let's see what the morning sounding on Cape Cod shows. Let's see what you think about the sounding with the question coming up.

Student Notes:

New England Topography

9. Quiz 1

Instructor Notes:

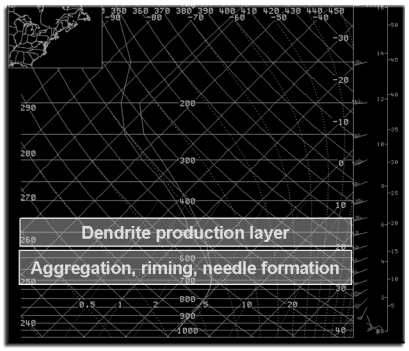
Student Notes:

10. Eta Sounding New England Case

Instructor Notes: That was a tough question. Let's assume that we need to have the lowest beam entirely below the dendrite production layer. Well, that's below about 560 mb layer or 15 kft. MSL. But it's not sufficient to be below just the dendrite production layer. We need to capture ice multiplication, aggregation, riming and needle formation. Most of these processes occur at temperatures colder than -4 degrees C. You'll need to have the beam top below 10 kft MSL to capture most of those processes. Given the deep saturated layer below, there may still be some additional aggregation as snow flakes become coated with thin films of water and get "sticky". So, reflectivity may go up a bit more. As a word of caution, thin films of water also increase the dielectric constant; therefore, reflectivity increases with no corresponding increase in actual liquid precipitation rate. Also, this sounding is not quite as far north as Fitchburg so the cold precipitation generation layer may be a little bit lower.

Student Notes:

Eta Sounding New England Case



11. Calculate Elevation of the 0.5 Degree Beam Top

Instructor Notes: It is difficult to tell where in the sounding precipitation generation ceases and precipitation falls to the ground in its final form and intensity. We do know that below the dendrite production zone, frozen precipitation continues to develop. Even in warmer temperature you still have needle formation, riming and aggregation. We'll take temperatures warmer than -4 to -5 degrees C to be the point where most frozen precipitation growth will have already occurred. The soundings in the previous page show that temperature to be roughly 7400' MSL. We'll take that height and use the beamwidth tool.

Student Notes:

Calculate Elevation of the 0.5° Beam Top

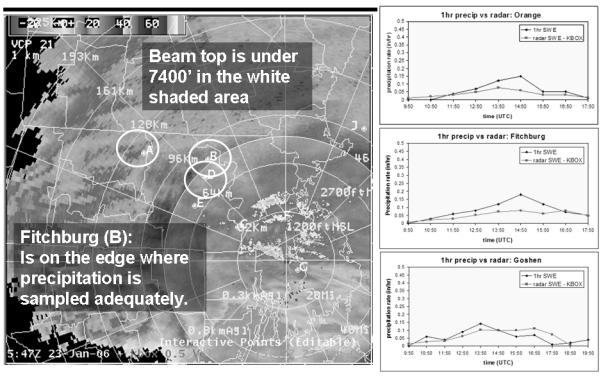
- We will use 7400' as the top of the beam where it reaches above the LCL in -4° C temperatures for the cooler area near Fitchburg
- Click on the link button below or enter http://wdtb.noaa.gov/tools/misc/beamwidth/index.htm
- You'll have to modify the range until the beam top reaches 7400' for 0.5° beam angle.
- What is the range?

12. Adequate Radar Sampling Range?

Instructor Notes: It would be ideal if the beam was hugging the ground and there was no ground interference. Instead, it appears that perhaps we can adequately sample most precipitation if the entire beam remained below 7400' AGL. The white shaded circle satisfying this condition extends out about 53 nm from the radar. The Fitchburg observation is right on the outer edge of good radar sampling. Is 7400' AGL enough or do we need to be lower? As it turns out, the Fitchburg ASOS is reporting higher hourly precipitation rates than the radar using the $Z=120S^{2.0}$ relationship. Going to the town of Orange, MA, which is further away, the same problem reveals itself. The radar is underestimating the hourly reports. Going a little closer to the town of Goshen, MA, the comparison is different. The radar is showing better agreement, perhaps even a bit of an overestimate. If we believe the surface COOP station, then the radar beam is more accurately sampling the precipitation at Goshen than at Fitchburg. That is quite possibly because the beam is extending above some significant precipitation generation as one goes to Fitchburg and points beyond relative to the radar. I could make the argument that the COOP station is underestimating its precipitation and that would be a valid argument. However, I will show later in this lesson that there is nothing indicating that there is enough instrument error to change the conclusions that the radar beam over Fitchburg and beyond is overshooting generating precipitation.

Student Notes:

Adequate Radar Sampling Range?

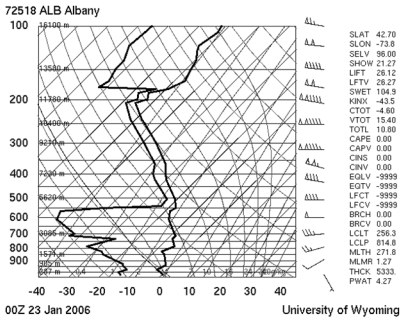


13. The 00 UTC Sounding – Before Precipitation

Instructor Notes: At 00 UTC on the 23rd, the Albany, NY sounding showed a very dry airmass below the midlevel moisture streaming in ahead of a short-wave trough. Let's take a look at the radar 4-panel image next.

Student Notes:

The 00 UTC Sounding – Before Precipitation

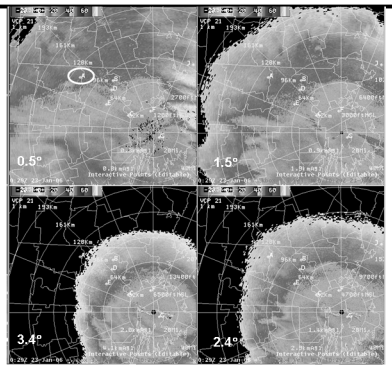


14. Reflectivity 4 panel 0946 – 1029 UTC

Instructor Notes: Take a look at this loop and given the previous sounding and the nature of the reflectivity echoes, determine the type of radar-based precipitation error you may observe here. Orange, in the white oval, is reporting a 9 degree dewpoint depression. I'll pop up a quiz page next so you may answer.

Student Notes:

Reflectivity 4 panel 0946 – 1029 UTC



09:46 –
10:29 UTC

15. Quiz 2

Instructor Notes:

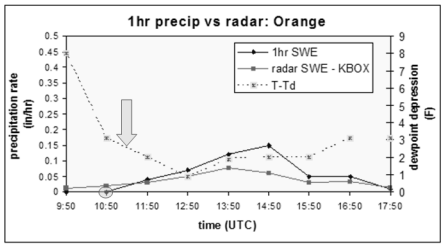
Student Notes:

16. Orange, MA Precip Rate and Dewpoint Depression Time Series

Instructor Notes: When you look at the dewpoint depressions, the dewpoint depressions correlate well with the propensity of the KBOX radar to overestimate precipitation rate at Orange. We're using Z=200S2, but we could raise the coefficient to 220 or 230 and I bet that wouldn't help because no precipitation is being recorded at Orange. Even if there was, note how the errors switch signs later on. You'd have to adapt by changing the ZS coefficients again. The error sign flipped as a large flux in moisture from above quickly saturates the air at Orange. I believe this is a common evolution for many sites that are located well away from the nearest radar.

Student Notes:

Orange, MA Precip Rate and Dewpoint Depression Time Series

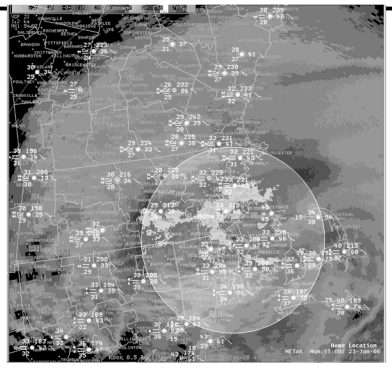


17. Add Any 1501 UTC Evaporation Errors?

Instructor Notes: At this time, most everyone's saturated (at least with respect to ice). I doubt sub-beam evaporation is an issue now. Let's not include it in our considerations. So we still consider where the radar may overshoot precip outside the white shaded circle.

Student Notes:

Add Any 1501 UTC Evaporation Errors?



1501 – 1530 UTC

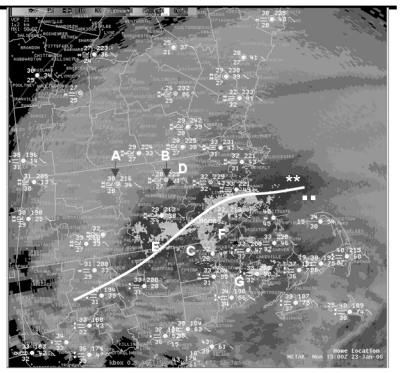
18. Bright Banding Errors?

Instructor Notes: Let's try out your skill at locating bright band contamination. I have seven sites, some are ASOS, some are COOP sites. I am going to trust these sites as being relatively accurate. Understand that ASOS buckets are heated with poor shielding so some losses may occur due to evaporation and wind. Fortunately the wind is light and temperatures are fairly warm so it won't take much to melt snow into the bucket. The METARS tell me that the rain/snow line should be along the blue contour. The sites are, Orange, Fitchburg, Goshen, Worcester, Milford, Norwood, and Taunting. We'll go to a quiz.

Student Notes:

Bright Banding Errors?

- Which sites will be subject to bright band contamination?
  - Site A: Orange
  - B: Fitchburg
  - D: Goshen
  - E: Worcester
  - C: Milford
  - F: Norwood
  - G: Taunton



19. Quiz 3

Instructor Notes:

Student Notes:

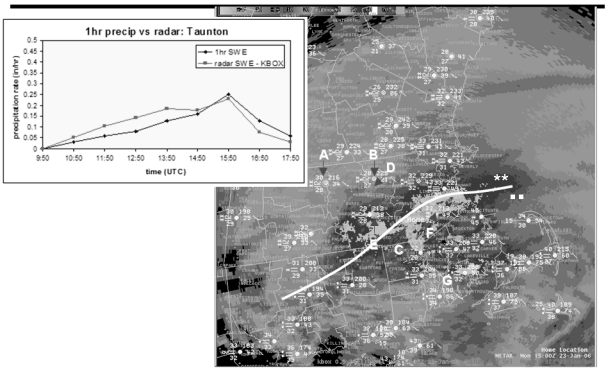
20. New England Bright Band

Instructor Notes: Let's go through the answer to the last question. We start off with Orange (A) and see the problems with underestimation because of overshooting. The same goes with Fitchburg (B). When we get to Goshen (D) we see the radar transition from underestimate to overestimation around 15 UTC. It could be either wet snow, sub-beam evaporation, change in precipitation particle shapes, or an error with the gauge. If we just talk about adequate precipitation coverage, it is doubtful there is sub-beam evaporation given the saturated conditions. I suggest that we are looking at wet snow aggregates with a larger than normal reflectivity factor than the liquid equivalent present. In other words, perhaps some bright banding is beginning even though it is all snow. Going to Worcester (E), shows the same effect and here it is also snow. Recall from lesson 1 that snowflakes near freezing often have a thin film of liquid resident on the ice surfaces resulting in a high dielectric constant and a high radar reflectivity cross-section. Going to

Milford (C), and especially Norwood (F), we are looking at large waterlogged flakes with a huge reflectivity cross-section as the melting layer is fully sampled by KBOX. Finally, the radar is sampling completely melted precipitation at Taunton and there is better agreement there. Note, though, that earlier in the day there is some potential bright banding.

Student Notes:

New England Bright Band

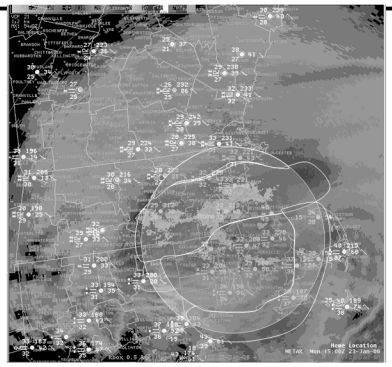


21. Overshooting + Evaporation + Bright Banding

Instructor Notes: Beam overshooting problems exist outside the white shaded circle. There are likely no significant evaporation errors given the saturation across the radar domain. The most likely areas of bright banding appear in purple. The northern area is where the rain snow line exists at the surface but the errors leach into the wet snow areas to the north. Thus, the only areas of good precipitation sampling most likely exists in the orange areas. The northern orange area is the only area where snowfall is adequately sampled for the 15 UTC time frame.

Student Notes:

Overshooting + Evaporation + Bright Banding



1501 – 1530 UTC

22. Summary

Instructor Notes: Outline radar precipitation underestimation errors where the radar is not overshooting precipitation generation. Outline radar precipitation overestimation errors areas where sub-beam evaporation may exist. Outline radar precipitation overestimation errors where bright banding exists. Consider horizontal drift in a few areas. Consider technical errors (beam blockage, calibration). Precipitation particle shape and density is the final error source that cannot be directly accounted for except when after considering the first 5 errors. If there is a consistent bias in the precipitation where sampling is good, you may consider the ZS algorithm coefficient to be in error because of precipitation particle shape.

Student Notes:

Summary

1. Outline radar precipitation **underestimation** errors where the radar is <u>**not**</u> overshooting precipitation generation
2. Outline radar precipitation **overestimation** errors areas where sub-beam evaporation may exist
3. Outline radar precipitation **overestimation** errors where bright banding exists
4. Consider horizontal drift in a few areas
5. Consider technical errors (beam blockage, calibration)

23. Have any Questions????

Instructor Notes: If you have any questions about this lesson, first ask your local AWOC facilitator. If you need additional help, send an E-mail to the address provided. When we answer, we will CC your local facilitator and may consider your question for our FAQ page. We strongly recommend that you take the exam as soon as possible after completing this lesson.

Student Notes:

Have any Questions????

If you have any questions about this lesson:

1. First ask your local facilitator (i.e., SOO)
2. If you need additional help, send an e-mail to icwinter7@wdtb.noaa.gov (Instructors group – answers will be CC'd to your local facilitator and considered for the FAQ page)

We recommend that you take the exam as soon as possible after completing this lesson!

IC7.4: Optional Job Sheet

Diagnosing Unexpected Precipitation Areas

Introduction:

Objective: Building off knowledge gained in the IC 7 Lesson 4 training module, examine a winter weather precipitation event and diagnose the reasons for higher than expected snowfall amounts.

Data: 13 February 2004 winter weather event across northwest Texas and southern Oklahoma. You will be using AWIPS D2D for this exercise. **Procedures are available with this case if you wish to use them.** All procedures will be listed in bold in the instructions of this jobsheet.

Instructions:

Load the 13Feb2004 Winter Weather AWOC case on your WES machine in case review mode, using the OUN localization. Set clock to 06 UTC 14 February 2004

Synoptic Overview and Review of Current Forecast:

Load the procedure set called **"IC7Lesson4"** and load in the first entry **"4panel Syn Overview"**. If you choose to load the products on your own, load the following into a 4-panel regional scale layout:

1. 500 mb height and winds;
2. 700 mb height and omega;
3. 850 mb height, wind, temp; and
4. mslp and surface winds.

In another pane, load the procedure from IC7Lesson4 called **"QG forcing Precip accum"** which loads in a 4-panel display:

1. NAM80 500 mb height and 1000-500 mb RH;
2. 700 mb height and 700-500 mb Div-Q;
3. Select isentropic surface that is just below or near 700mb, and load Pressure, Wind, and specific humidity on that isentropic surface; and
4. MSLP and 6 hr accumulated precip.

Question 1. Where is the strongest QG upward vertical forcing located over the next 24 hours (through 00 UTC on the 15th)?

The fictitious graphical snowfall advisory you inherited is shown in Figure 1, valid for 2 AM-6 PM local time (08-00 UTC). Warning criteria in this CWA is 4 inches in 12 hours, or 6 inches in 24 hours. The previous shift felt the snowfall would be just below this threshold, but could be close to exceeding 3 inches in 12 hrs across the extreme southern part of the CWA along the Red River counties.

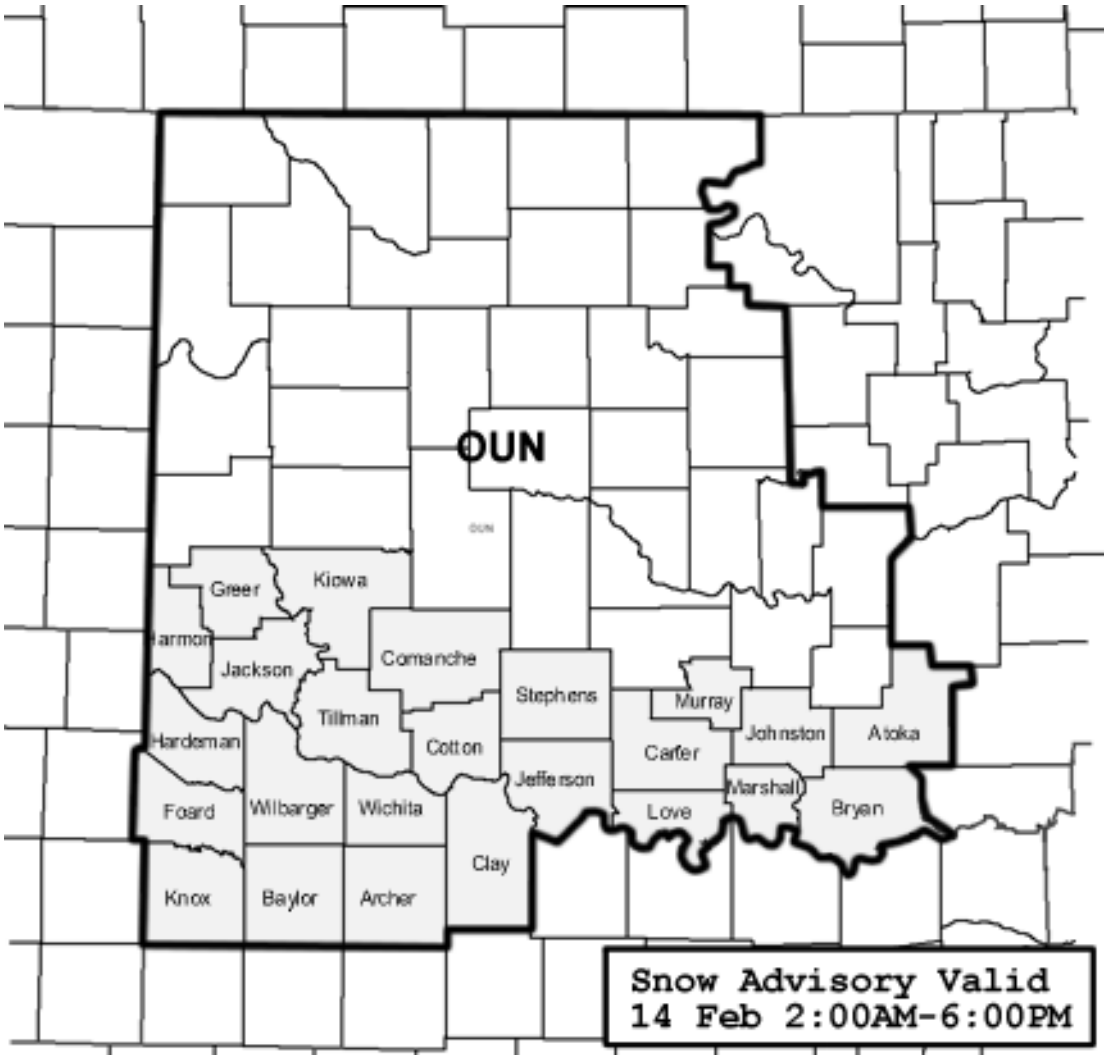


Figure 1. The snow advisory for the OUN CWA, valid 08-00 UTC on 15 February 2004.

Precipitation Diagnosis Methodology

Step 1: Monitor Surface Conditions

Following the methodology in the training module, you will move ahead to a time period during the snow advisory and evaluate the conditions to see if the snow advisory is still the proper product for this event. Set the clocks to 13 UTC 13 February 2004.

Load from the IC7Lesson4 procedure the set named **"NAM MSLP Metars"**, which loads in a single pane layout on the state(s) scale, load NAM40 MSLP and overlay metars.

Load from the IC7Lesson4 procedure the set named **"IR 500mb Heights"**, which loads IR satellite and overlay NAM40 500 mb heights.

Next, load from the IC7Lesson4 procedure the set named **"TLX, FDR and Metars"**, which loads 32-frame KFDR 0.5 reflectivity and toggled with KTWX 0.5 reflectivity and overlaid metars (since it was VCP32/31 with a 32 frame loop you can view ~5 hours of radar data). For a closer examination of the metars in hourly increments, load the set named **"METAR 6 radar frames"**. This loads metars first and overlays the reflectivity images in 1 hr increments.

Question 2. Does the location and intensity of the precip agree with what you saw in the 12 hr forecast from the NAM 80 in the previous step?

Step 2: Recognize Forecast Departure

Figure 2 shows the spotter reports that came in at 7:00 AM local time (also current D2D time), for snowfall totals since the current snowfall began overnight.

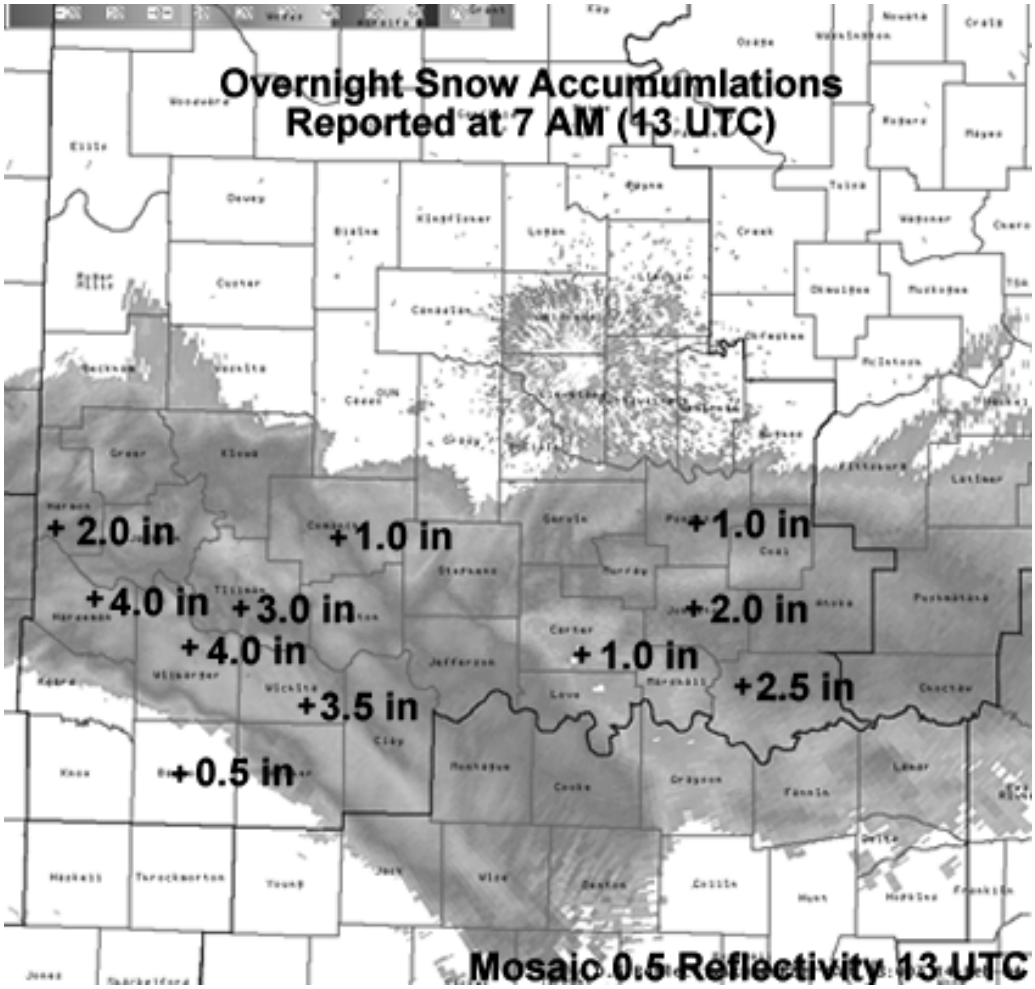


Figure 2. 14 February 2004 13 UTC 0.5 degree mosaic 8-bit reflectivity with overnight snow accumulations reported around 13 UTC overlaid.

Question 3. Are these snowfall totals consistent with the snow advisory currently in effect?

Question 4. Given current trends in radar, which counties will likely see additional snowfall exceed (or likely already has exceeded) warning levels?

Step 3: Diagnose Cause for Forecast Departure

Load from the IC7Lesson4 procedure the set named **"Meso Lift"**, which loads NAM 80 500 mb height, saturated EPV from 700-300 mb, 700-500 mb Div-Q, and 700 mb 2-D Frontogenesis in a state scale plan view window.

To aid in answering question #5 below, you may want to load in a separate window the same products but in a different manner, using the set named **"dprog-dt Meso Lift"**. This loads all available model runs valid at 12 UTC on 14 February 2004. The data are NAM 80 500 mb height, saturated EPV from 700-300 mb, Div-Q 700-500 mb and 2-D Frontogenesis at 700 mb just as you did in the step above.

Question 5. Where is strong QG forcing coupled with frontogenesis, and is it stronger and/or positioned differently than previous model runs?

Using baseline A, set up a cross section through the maximum frontogenesis and along the region of strongest Q-vector convergence, roughly from central Texas north to north central Oklahoma. Then you can load from the IC7Lesson4 procedure the set named **"Xsection Line A"**. This set will load NAM 80 geostrophic momentum, θ_e, saturated equivalent potential vorticity, RH, 2-D Frontogenesis, Omega, and temperature ***along Line A only***, thus the importance of positioning Line A where you want it. You'll have to toggle on and off combinations of products to answer the questions below.

Question 6. What do you notice about the location of the rising motion vs. area of frontogenesis?

Question 7. Is this cross section favorable for efficient snowgrowth in the dendritic growth zone? Where are these conditions most favorable?

Question 8. Is there any instability, and if so, is it favorably coupled with frontogenesis? Where is the instability greatest?

Step 4: Forecast Persistence

Using radar trends, metars, and the cross section analysis, analyze how long you expect the snow to continue across northwest Texas and southern Oklahoma, and which counties will be affected the most or longest. You'll need this information for the final step below.

Question 9. Snow likely to continue through _____UTC.

Step 5: Update forecast

On the original CWA Snow Advisory map provided, indicate where you would upgrade to a Heavy Snow Warning by drawing an **"X"** through the county. Then, draw total expected snow fall accumulation contours on the map. If you upgrade to a heavy snow warning, when will you set it to expire?

Question 10.HSW Expires at: _____ CST