1. 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."

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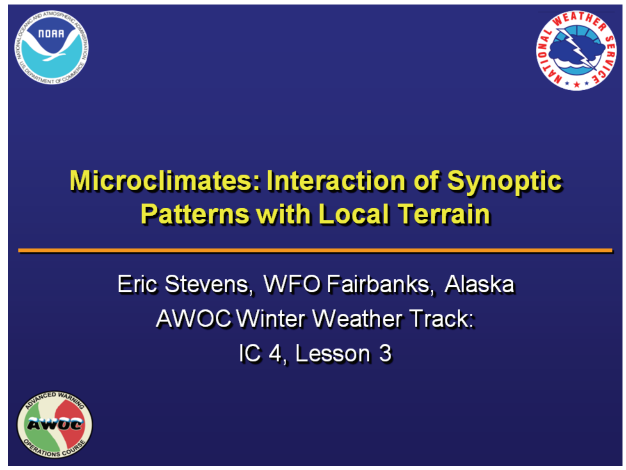

2. Microclimates—Why do We Care?

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.

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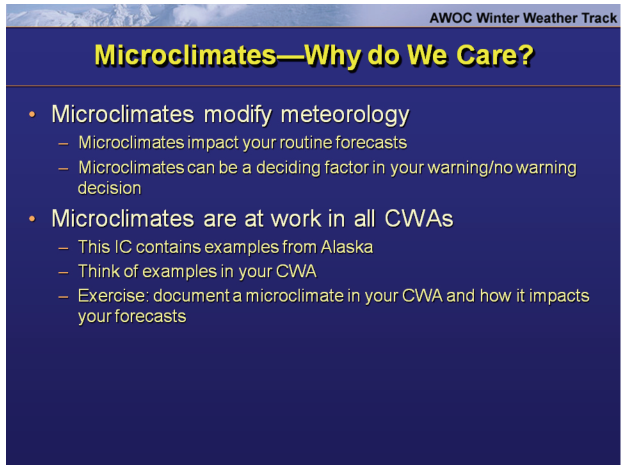

3. Outline

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.

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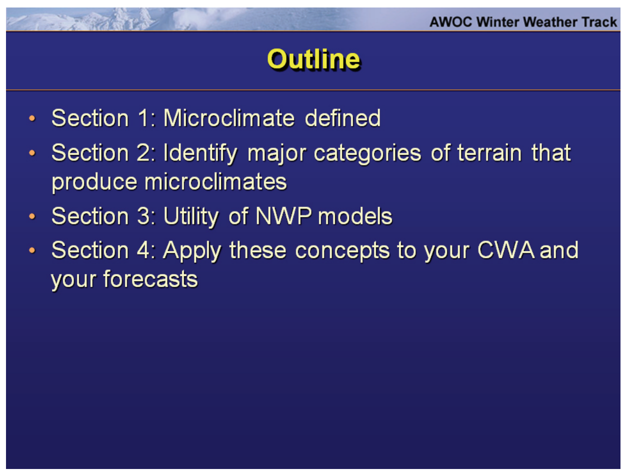

4. Learning Objectives

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.

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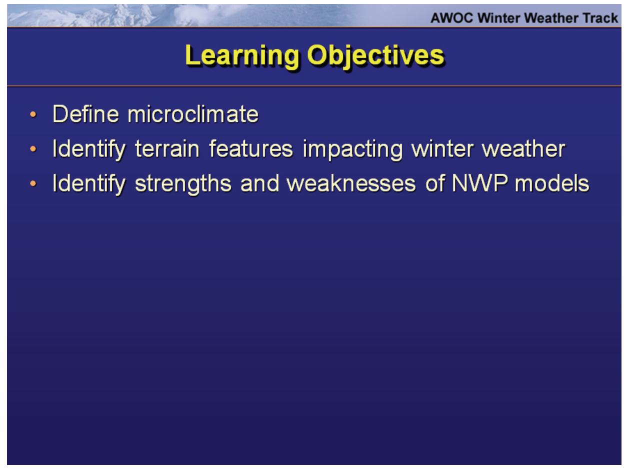

5. Performance Objectives

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.

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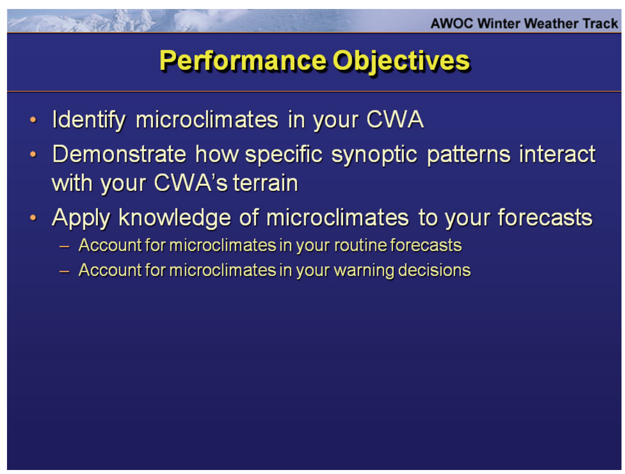

6. Section 1: Microclimate Definition

Instructor Notes: 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 unexpected. 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

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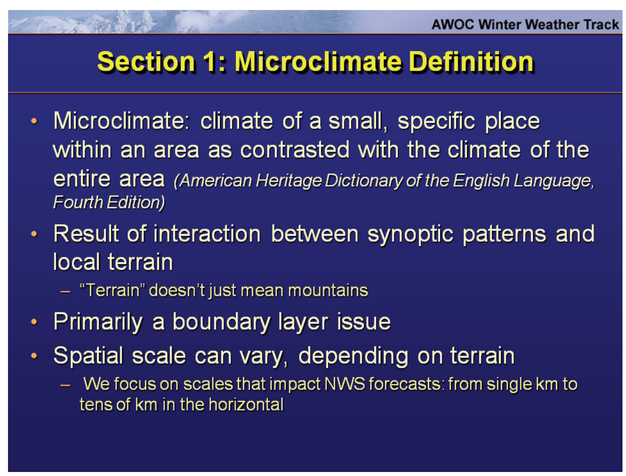

7. Section 2: Terrain and Microclimates

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.

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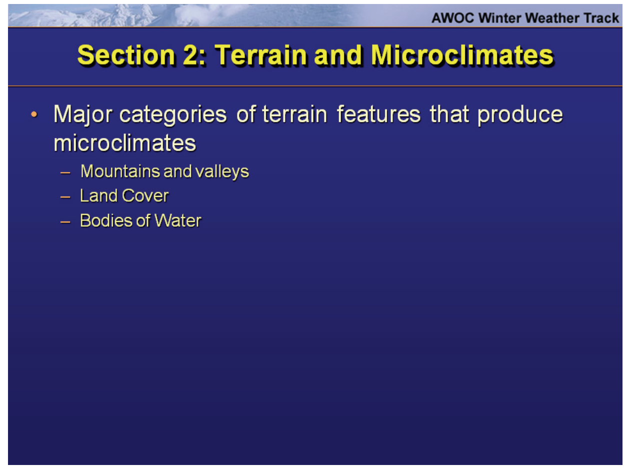

8. Mountains and Valleys

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.

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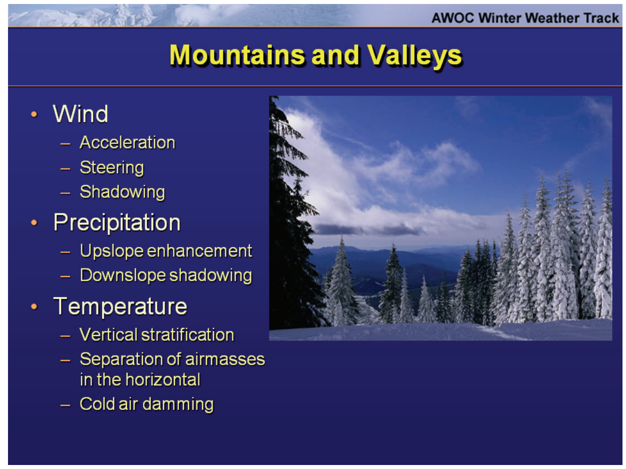

9. Vertical Temperature Stratification

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 substantiallly. 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.

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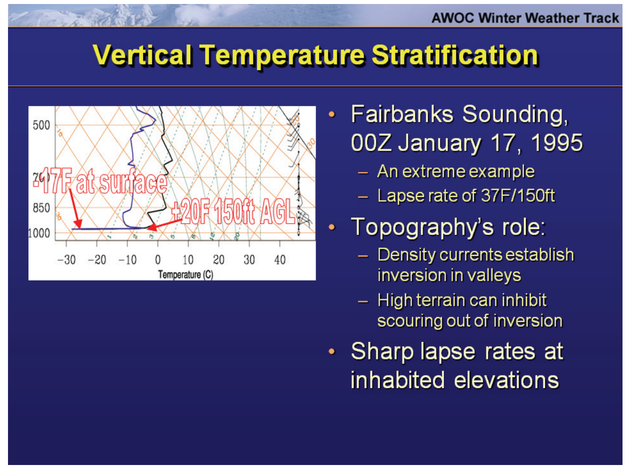

10. Vertical Temperature Stratification

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?

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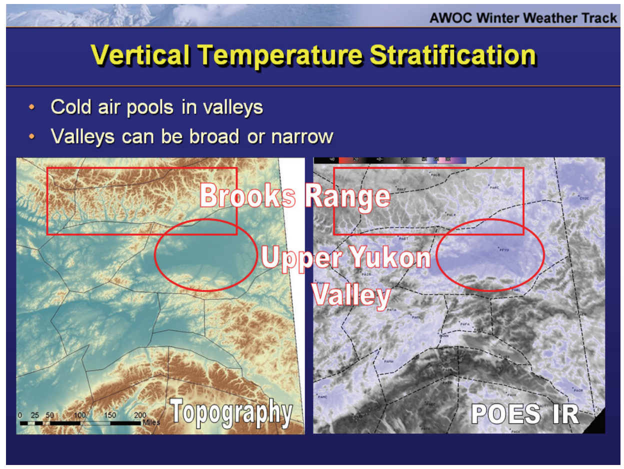

11. Vertical Temperature Stratification

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.

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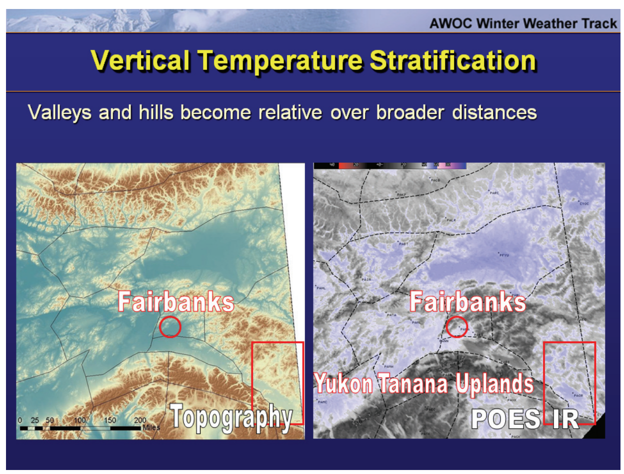

12. Vertical Temperature Stratification

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.

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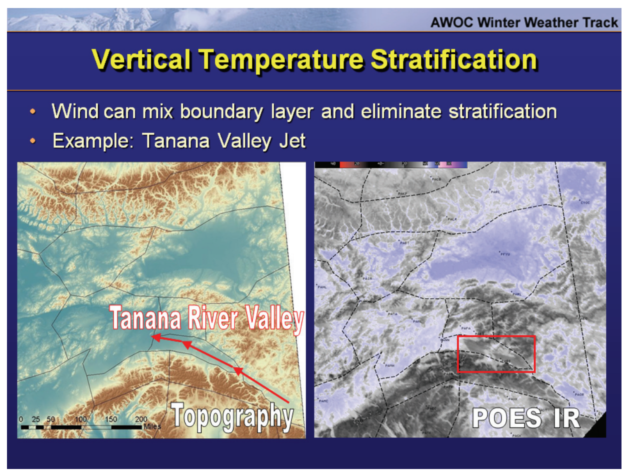

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14. Downslope Flow

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?

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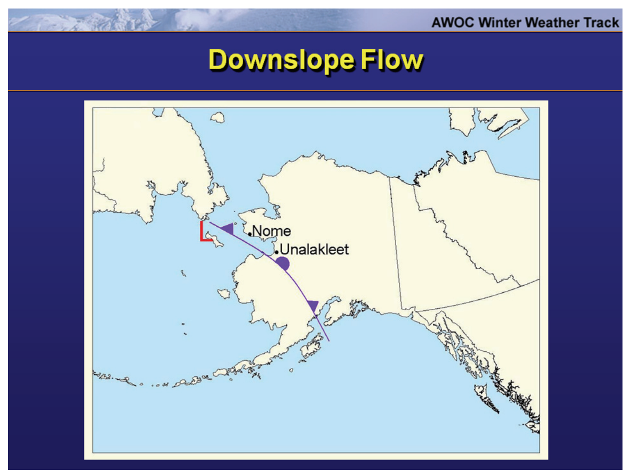

15. Downslope Flow

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.

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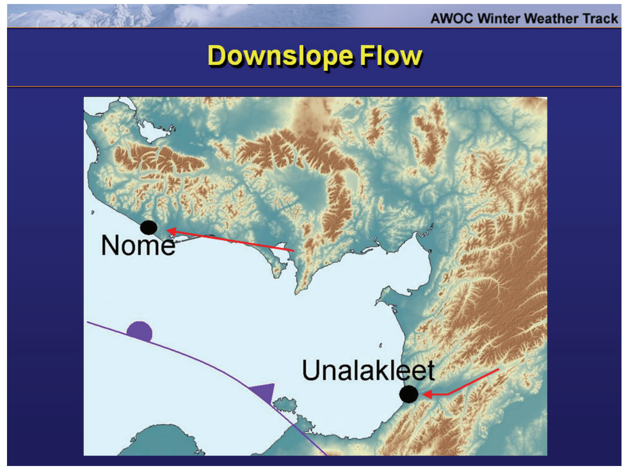

16. Land Cover

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 shortwave 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.

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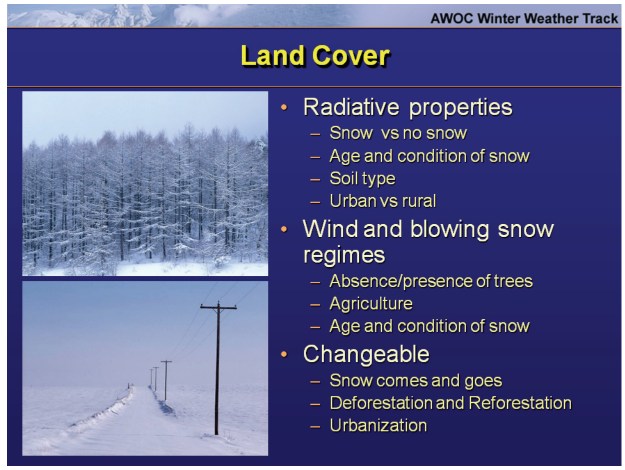

17. Land Cover

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?

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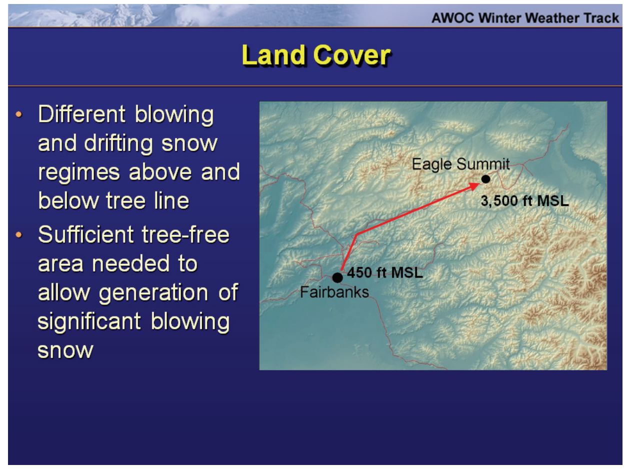

18. Bodies of Water

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.

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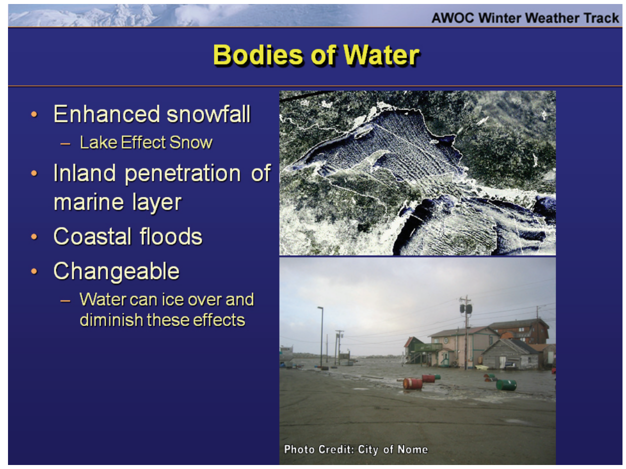

19. Utility of NWP Models: Gridded Fields

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 the Jerry Springer 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.

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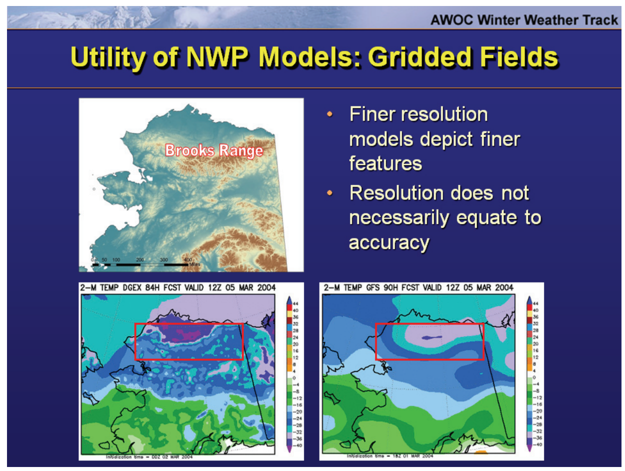

20. Local Modeling

Instructor Notes: With increasing computing power, local modeling is becoming more common at WFOs, and for good reasons. Local models can resolve very fine-scale topography, and thus they have the *potential* to better depict finer-scale terrain-influenced weather. The domain and resolution of a local model can be customized to meet a particular need at the WFO, for example, to serve as a first-guess option for producing grids in the GFE, with model output at the same spatial resolution as the GFE. Output from these models can also help us develop more complete conceptual models concerning microclimates. Consider the case of having only a single observing platform in an area of complex terrain—a local model might reveal processes at work in that area more completely than the point observation could, and thereby help us develop a better conceptual model which we can use on the forecast desk.

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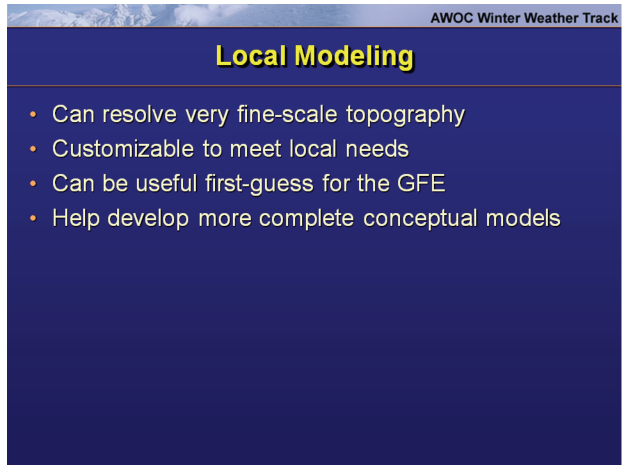

21. Local Modeling

Instructor Notes: Let's look at an example of how a locally-run WRF model handles the wind blowing through a narrow mountain pass, and how important it can be to find the right model resolution to fit the phenomenon in question. The area of concern is Isabel Pass in the Alaska Range. Southerly Chinook winds commonly blow through the pass here. There is a point observation in the pass at Trims Camp, a State of Alaska Department of Transportation maintenance facility . In general, southerly winds are strong through the pass, but the exact wind speed can vary quite a bit by location. It turns out that Trims Camp is not the windiest point in the pass. Can a local mesoscale model depict this?

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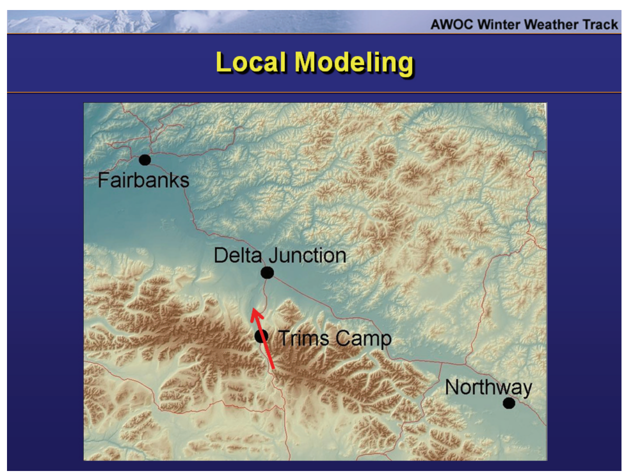
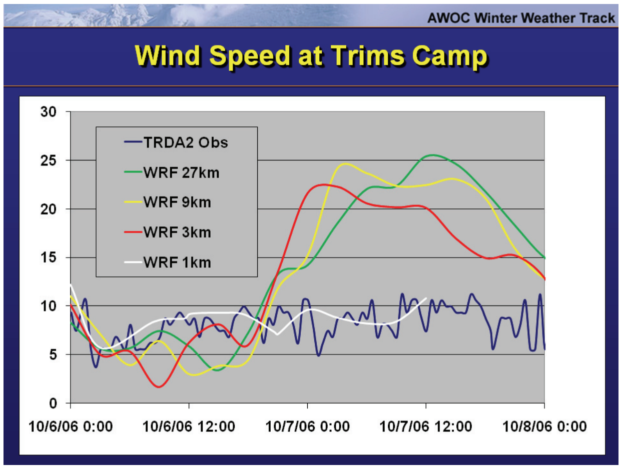


22. Wind Speed at Trims Camp

Instructor Notes: This graph shows wind speed at Trims Camp in mph on the vertical axis, with time during the October 2006 event on the horizontal axis. As a research project, a local WRF model was run four different times for this event, with the only difference between the runs being the model's resolution. The WRF was run at resolutions of

27km, 9km, 3km, and 1km. This graph shows the wind speed obs from Trims Camp in blue—it's actually not very windy at Trims Camp during this event, with winds of just 5-10 mph, although stronger winds speeds did occur elsewhere in the pass. Notice how the 27km, 9km, and 3km runs of the WRF (shown as the green, yellow, and red curves) all depict too little wind early in the event and then too much wind later in the event. And what is really striking is how these three runs are not qualitatively very different from each other, despite the substantial change in resolution between these three runs. It is only when the resolution drops from 3km down to 1km (the white curve on this graph) that the model suddenly seems to "get it," and the model's forecast changes in a quantum sense and is much more accurate than the three coarser runs.

Student Notes:



23. Wind Direction at Trims Camp

Instructor Notes: Here is a similar graph, but for wind direction. Again, the three coarser runs of the local WRF are all roughly equally wrong in their depiction of wind direction at Trims Camp. And again, the 1km run is fundamentally different than the other three runs, and is much more accurate. We can presume that since Isabel Pass is so narrow at Trims Camp, that only when the model's resolution drops down to around 1km can the model begin to accurately account for the pass' modification of the broad-scale wind field at Isabel Pass. The lesson I took from this experiment was that if you can't get the local model to recognize a given microcliamte, maybe playing with the resolution will be helpful. Fine-scale terrain-features can only be accounted for by a fine-scale model, and in this case for Trims Camp changing the model's resolution from 3km to 1km made all the difference.

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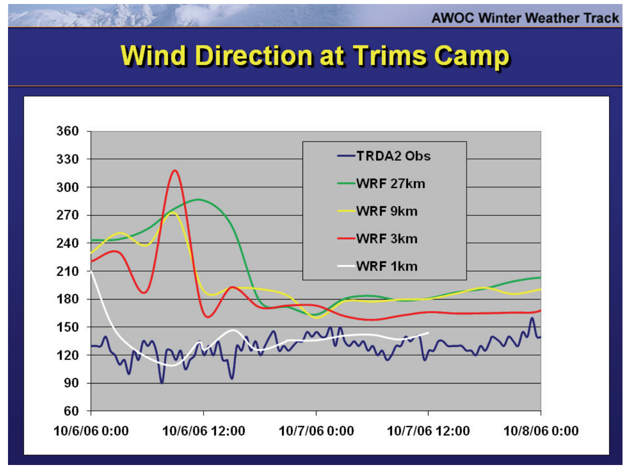

24. Utility of NWP Models: MOS

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 mph 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.

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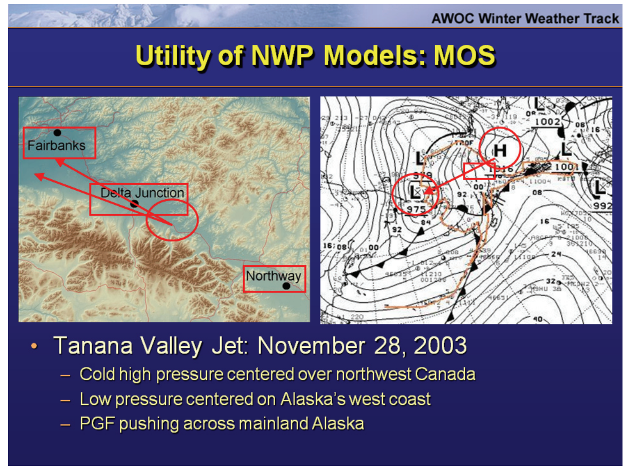

25. Utility of NWP Models: MOS

Instructor Notes: Here's an AWIPS D2D screen capture over the southeastern part of mainland Alaska. I apologize that this image is too small to see clearly--to help mitigate that problem I will describe any feature I refer to here. The image is the "hi res topo image," and overlayed on this image is the GFS forecast of sea level pressure in white contours every 2mb, with high pressure to the east and low pressure to the west, the GFS surface winds in blue, and the actual METARs in tiny illegible green font, 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 Northway to Fairbanks, so the pressure gradient force is pointed straight down the valley. The METARs are too small to read in this figure, so I'll just read them for you, but all we really care about in this case is the wind--At this time the wind at Northway is 12006kt, wind at Delta is 10022g30kt , and wind at Fairbanks is calm. So how does the GFS wind field, the blue wind barbs, compare to the METARs? To the GFS' credit, it does depict a maximum of wind speed near Delta Junction, although the direction is off by almost 90 degrees. The general trend here is that in locations where the METAR shows at least some wind, that is, not 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 toss out 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. 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.

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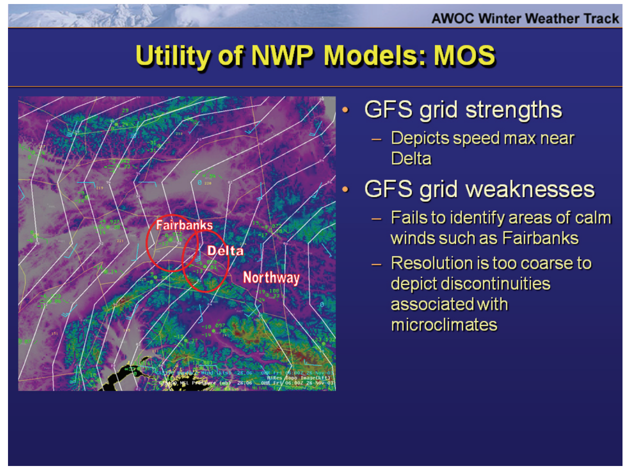

26. Utility of NWP Models: MOS

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 point-based MOS like the MAV is that it is not complete in space. Fortunately, the points that have MOS are where most of the people live. Now in the digital age we produce grids that are complete in space, and MOS has also been making the transition into gridded guidance. 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.

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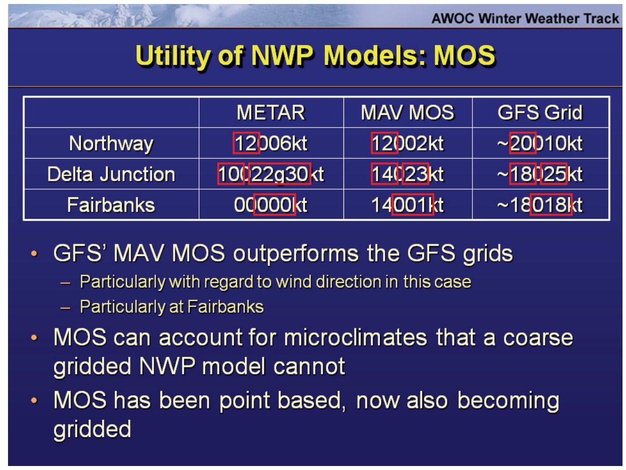

27. Utility of NWP Models: MOS

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?

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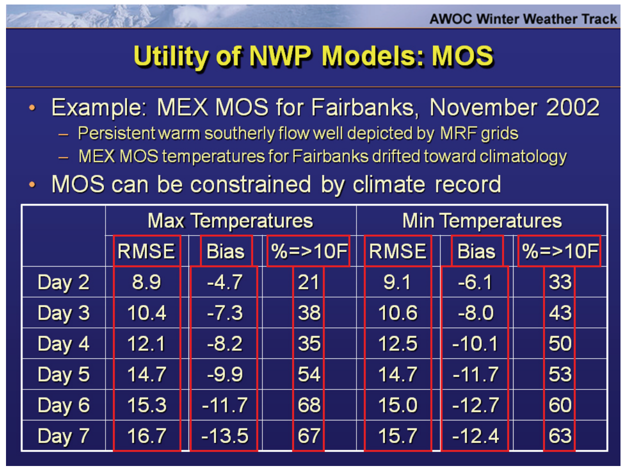

	Max Temperatures			Min Temperatures		
	RMSE	Bias	%=>10F	RMSE	Bias	%=>10F
Day 2	8.9	-4.7	21	9.1	-6.1	33
Day 3	10.4	-7.3	38	10.6	-8.0	43
Day 4	12.1	-8.2	35	12.5	-10.1	50
Day 5	14.7	-9.9	54	14.7	-11.7	53
Day 6	15.3	-11.7	68	15.0	-12.7	60
Day 7	16.7	-13.5	67	15.7	-12.4	63

28. 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 "normal." 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.

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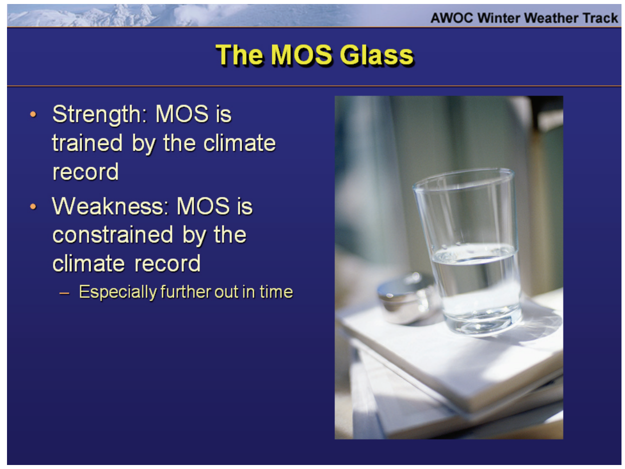

29. ic4-l3-q2

Instructor Notes:

Student Notes:

30. 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. Local models run at the WFO offer the advantage of having very fine resolution, and sometimes it can beneficial to customize the resolution of the local model to meet the requirements of a given terrain-affected phenomenon. 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.

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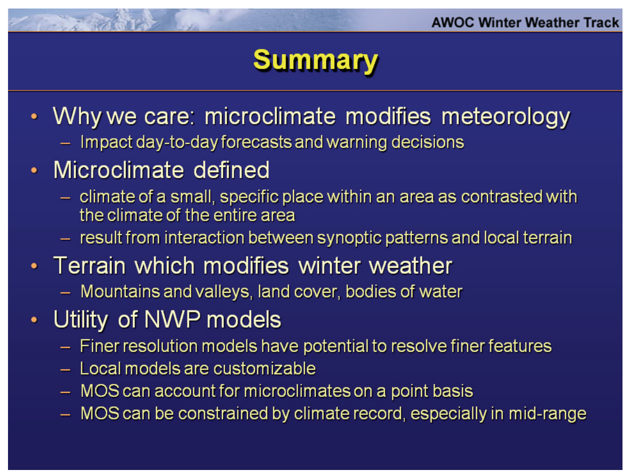

31. Section 4: Apply Concepts to Your CWA

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.

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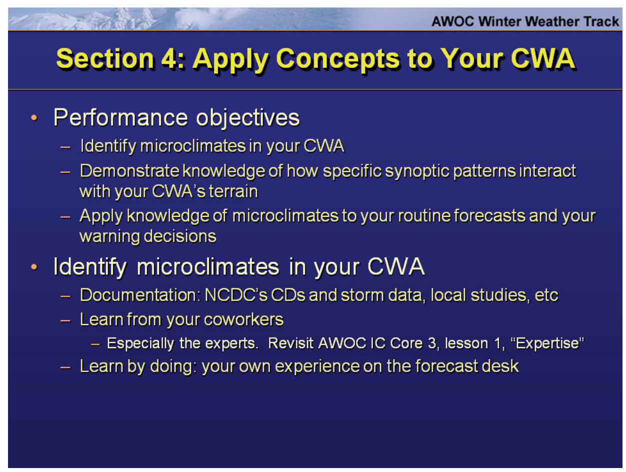

32. Section 4: Exercise

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. Groundbreaking 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. 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.

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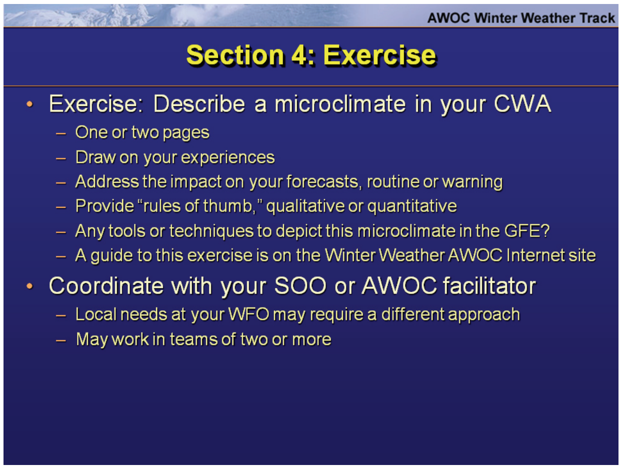

33. Section 4: Exercise

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.

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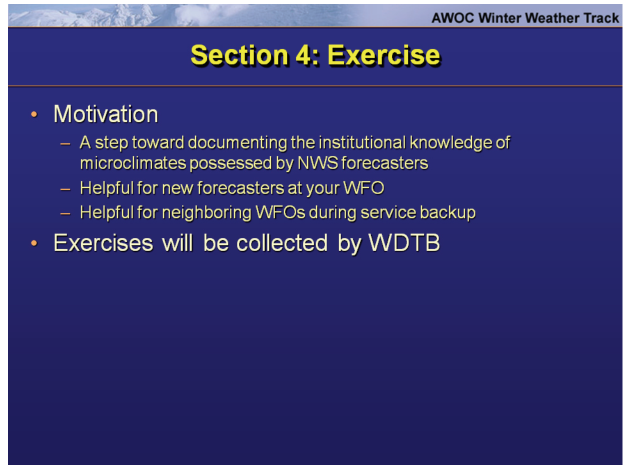

34. The End

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. Don Morton at the Arctic Region Supercomputing Center has been the facilitator for local modeling at WFO Fairbanks. 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: