EASTERN REGION TRAINING AND EVALUATION MODULE NO. 4
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COLD AIR DAMMING: AN INTRODUCTION

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This module is the first in a series which will explore cold air damming. This installment will define cold air damming, explain its importance to operational forecasting, and introduce the three damming types and the two "lookalike" types.

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1. Objectives

Upon successful completion of this module, the reader will meet the following objectives (without reference to this module):

a. Describe the relative roles of synoptic scale forcing and diabatic processes in each of the damming types.

b. Given a surface analysis of a real weather event, identify the likeliest damming type indicated.

c. Cite the major differences between damming events and "lookalike" events.

d. Given a cold air damming scenario, list the most important weather elements of greatest concern for the forecast, and describe how these elements would change during the forecast period.

2. Introduction

Cold air damming (CAD) has long been a great challenge for operational forecasters. The phenomenon occurs frequently over the eastern slopes of the Appalachians [Bell and Bosart (1988) cited an average of 2 - 3 events per month during the winter months of October through March]. These events can produce a myriad of difficulties in forecasting elements such as temperatures and precipitation type.

Despite the continually improving computer models which now provide data with higher horizontal and vertical resolution than ever before, and mesoscale models which are quickly becoming a more routine source of guidance in the operational forecasting arena, the small scale of the processes that influence CAD development continues to make it a meteorological albatross. Models often accurately depict large-scale signatures of damming, but frequently fail to fully detect small-scale features and processes which so heavily impact CAD development and evolution (Stauffer and Warner 1987; Bell and Bosart 1988). Even high-resolution mesoscale models exhibit some difficulty with these phenomena (Kramer 1997). As such, the forecaster cannot rely solely on computer models for correct CAD solutions. A sound meteorological foundation of CAD processes, and knowledge of existing CAD conceptual models and typical patterns, are imperative for those trying to forecast cold air damming.

This failure of the models to detect key CAD features is particularly important across the mid-Atlantic and southeastern states, which are often at the southern extent of the cold dome, and as such are susceptible to great temperature differences over a short distance during CAD events. In this region, model output statistics (MOS) can overforecast high temperatures by 10°- 20°F or more during a damming event. The forecaster who is not anticipating a damming event can severely "bust" high temperatures in areas along the eastern slopes and adjacent piedmont region of the Carolinas, Virginia, and Georgia (referred to hereafter as the "damming region"). Additionally, small-scale but critical changes in the vertical thermal structure in and near the damming region produced by a damming event can lead to unexpected changes in precipitation type (Keeter et al. 1995).

This TEM in the CAD series will describe the basic meteorological processes at work in cold air damming, based upon past and current research efforts. In addition, the reader will be introduced to a newly developed classification scheme for a spectrum of damming and "lookalike" events, which could serve as a conceptual model that facilitates the forecast process for these events.

3. Defining Cold Air Damming and Identifying the Contributing Processes

a. Primary surface processes

An eastern United States CAD event can be broadly described as a surface-based layer of relatively cold, <u>stable</u> air which has become entrenched against the eastern slopes of the Appalachian Mountains, occurring primarily during the months of October through April. At an event's onset, strong Canadian or Arctic high pressure at the surface [typically 1028 mb or higher (Forbes, personal communication)] to the north of the damming region (most favorably located north of 40°N, centered over the northeastern United States or southeastern Canada) provides the cold air source, and can be termed the "parent" high. As the northeasterly or easterly winds around this high pressure area encounter the mountain chain, the flow becomes blocked and is deflected southward, producing a U-shaped "wedge" of high pressure and a buildup of cool, stable air along the eastern slopes (Richwien 1980). Adiabatic cooling resulting from orographic ascent leads to a hydrostatic pressure rise, which further increases the wedge appearance of the damming ridge and produces an ageostrophic wind response to the modified mass field. The northeasterly or easterly *geostrophic* winds (having a significant component orthogonal to the mountains), and the *ageostrophic* wind flow away from the damming ridge, combine to produce a total wind from the north/northeast--parallel to the mountain slopes--which leads in turn to additional low-level cold air advection from the surface parent high. This process further increases the stability of the surface-based layer, producing a wind flow that is even less able to ascend the mountain barrier.

The idealized CAD development described above can be termed "classical" (Fig. 1), as it is *governed by relatively strong synoptic scale features and processes* at the surface and aloft, and has been studied in depth (Baker 1970; Richwien 1980; Forbes et al. 1987; Bell and Bosart 1988). The role of strong synoptic scale forcing in the development of this damming type is much greater than that of any other contributing surface-based processes, such as diabatic cooling from precipitation in the damming region.

In other damming types, however, precipitation plays a key role in damming development and evolution. If precipitation falls in the damming region into an existing CAD wedge possessing cold, dry air, evaporative cooling can decrease the surface temperatures, further enhancing low-level stability, increasing the blocking of the low-level flow by the mountains, and strengthening the CAD event (Fritsch et al. 1992). Experience has shown that when (a) the parent high is in a favorable location but with a weak central surface pressure (less than 1028 mb), or (b) the parent high movement is progressive (limiting the duration of strong cold air advection into the damming region), precipitation plays a nearly equal role in CAD development as that of the synoptic scale forcing (Fig. 2). Reduced solar radiation due to extensive cloud cover is another diabatic process that can heavily influence CAD evolution. **A CAD event that is produced by *both synoptic scale forcing and diabatic processes* is referred to as "hybrid" damming.**

Precipitation can also instigate a damming event. *In these cases, cool, dry, surface-based air already resides in the damming region, but the surface high is unfavorably located (e.g., off the mid-Atlantic coast) and thus no cold air is initially being advected into the damming region.* The hydrostatic pressure rise produced by evaporative cooling from precipitation into this air mass results in a surface wind adjustment to a north-northeast direction. If these low-level winds now advect cold air into the damming region, a damming event can be initiated (Fig. 3). **These events have been termed "in situ," since damming is produced *almost solely by precipitation* into the pool of dry, relatively stable air already in place over the damming region, with *little or no synoptic scale forcing* contributing to the event's initiation.**

****** PRACTICE***

1) What is the primary distinction between classical CAD, hybrid CAD, and in situ damming?

b. Contributing processes aloft

In addition to the low-level signatures of damming, processes above the mountain barrier affect the near-surface environment significantly and must be included in the conceptual models of damming. For example, the wind flow atop the surface-based stable layer (also called the "cold dome") greatly influences CAD events. Typically, an 850-mb analysis during CAD will show an anticyclone centered off the southeastern United States coast with a ridge extending into the Mid-Atlantic states; this scenario produces a light-to-moderate warm, moist, southeasterly or southerly wind flow atop the cold dome from the Gulf of Mexico or Atlantic Ocean (Fig. 4). This configuration enhances the CAD by strengthening the low-level inversion through warming at the top of the inversion, and by generating cloud cover, which reduces insolation and often causes overrunning precipitation into the cold dome. In the absence of this warm, moist 850-mb inflow, CAD will frequently be weak and short-lived, as the low-level inversion will be susceptible to dissipation by solar heating. An 850-mb flow that is too strong, however, can lead to increased mixing at the top of the cold dome and a faster dissolution of the inversion.

Farther aloft, at 500 mb, a split-flow regime is often observed during a classical CAD event, with a southern stream trough or closed low over the southern Plains states and a northern stream trough over eastern Canada (Fig. 5). The resulting confluent flow and subsidence over the northeastern United States helps to strengthen the parent surface high and anchor it in a favorable location to provide continued cold air advection into the damming region. This regime also allows the surface ridge ample time to spill southward into the damming region without being impeded by coastal cyclogenesis generated in the southern stream (Bell and Bosart 1988).

Evidence also exists that the upper-level (300-250 mb) jet structure can promote CAD development. In a classical event, the entrance region of the (straight) polar jet is typically located above the surface high (Fig. 6). The ageostrophic circulation around the jet entrance region produces downward vertical motion atop the high (Uccellini and Kocin 1987), and northerly ageostrophic winds near the surface produced by this circulation can help drive cold air southward from the parent high into the damming region. The relative role of this complex process in CAD development is currently under investigation.

***** *PRACTICE***
2) Describe the primary damming signature, and resulting processes, of a classical CAD situation at 850 mb, 500 mb, and 300 mb.

4. An Introduction to "Lookalikes"

Certain weather phenomena exist which are often mistaken for cold air damming, as they produce weather conditions over the damming region which are similar to those produced during CAD (such as considerable cloudiness, cool temperatures, and a mesoscale high pressure area over the eastern mountain slopes). **In these cases, *1) the low-level wind flow is NOT blocked by the mountain barrier, as it is during CAD*, 2) the stable air mass over the damming region is not connected to a parent high, and 3) typical damming signatures are often lacking above the boundary layer.**

Two events in particular, called "cool air pooling" and "upslope," have been labeled "lookalikes," in that they can be (and have been) inaccurately labeled CAD events by operational forecasters. Making the distinction between these "lookalikes" and true CAD events is a critical element in the CAD forecast process, since their evolutions differ greatly and have varying impacts on weather conditions in the damming region.

During development of cool air pooling, precipitation falls into a dry air mass residing over the damming region, but the low level flow is not dammed against the mountains, and the air mass *is not connected to or supported by any parent high pressure area*. In other words, there is no cold air advection into the cool pool. A diabatically-induced mesoscale high pressure area results, and it is often contained by a weak thermal-moisture boundary. It is this "meso-high" which can be misinterpreted as a CAD-produced wedge.

Adiabatic lift resulting from upslope flow along the eastern slopes of the Appalachians can lead to considerable cloudiness and, subsequently, cooler temperatures and possibly the formation of a meso-high in the damming region. However, while the low level flow is orthogonal to the mountain barrier, the low levels are *too unstable* for CAD and the *wind flows over the mountains without being significantly impeded*. This configuration and the weather conditions produced can also be confused with a CAD event.

***** *PRACTICE***

3) What are some forecast elements that you would most want to look at in order to distinguish between a true vs. a "lookalike" cold air damming event in the forecast period?

5. Introducing the "Spectrum"

Figure 7 is a graphical representation of the "Spectrum of Cold Air Damming and Lookalike Events."   Encompassed in this table are the basic distinctions among the various CAD events and "lookalikes," including event strength and duration, and the relative roles of diabatic processes and synoptic scale forcing in each type's development.   It provides a quick-look "prompt sheet" for operational forecasters, to help them determine what CAD or "lookalike" type is expected or occurring. One must be aware, however, that the spectrum is not composed of discrete types, since the relative roles of synoptic scale forcing and diabatic processes are somewhat subjective. Rather, an event's classification may (and frequently will) fall *in between* two types.

It is also important to note that an event can change classifications during its lifetime. For example, a "classical" event may evolve into a "cool air pooling" event once the parent high has moved well offshore, leaving a pool of stable air into which there is no longer any cold air advection and which is no longer being impeded by the mountains. Evolutions such as these will be dealt with in more detail in future TEMs.

Finally, in an effort to provide a detailed reference source for cold air damming terminology, a glossary of terms relating to CAD and "lookalikes" has been developed (see Appendix). A primary intention of this glossary was to ensure that particular features and processes were not being mislabeled, and that forecasters at each National Weather Service office were using the same term to refer to the same feature or process, which is critical in these times of expanded coordination efforts among NWSFOs and NWSOs.

6. Conclusion

Eastern U.S. cold air damming and "lookalike" events occur frequently during the months of October through April, and can have a dramatic impact on weather conditions (and hence forecasts) in the damming region, particularly temperatures and precipitation type. Since computer models are often unable to capture the small-scale features of CAD, forecasters must utilize their knowledge of CAD processes, conceptual models, and "lookalike" signatures to assist in the forecast process.

"Classical" CAD is the most recognizable type, as it possesses distinct signatures, and is driven primarily by synoptic scale forcing and strong low-level cold air advection from a cold parent high. "Hybrid" events possess features which are typically weaker than those of "classical" CAD, and diabatic processes such as evaporative cooling from precipitation or reduced solar radiation from clouds can tip the scales toward a damming event. During "in situ" damming cases, evaporative cooling due to precipitation leads to low-level cold air advection from a parent high not in a favorable damming location.

"Lookalike" events resemble CAD in the weather conditions produced, but the flow is not blocked in these cases, as it is during CAD, and the existing stable air mass is not connected to a parent high. "Cool air pooling" is due to evaporative cooling from precipitation, but no low-level cold air advection from a high pressure area results. During "upslope" events, forced ascent produces clouds and precipitation, creating a meso-high over the damming region. The "Spectrum" graphic provides the forecaster with a quick-look reference for CAD and "lookalike" events, and the glossary can assist in improving coordination.

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Appendix

Glossary of Terms for Cold Air Damming and Lookalike Events

Basic Terms

1. Cold Air Damming (CAD) - A shallow, surface-based layer of relatively cold, stably stratified air entrenched against the eastern slopes of the Appalachian Mountains. Physical processes important to the initiation and maintenance of the damming cold air dome include low-level cold air advection; increased low-level stability from differential vertical thermal advection; adiabatic cooling associated with orographic ascent; cooling due to parcel ascent along the slope of the cold air dome; and cooling from low-level *diabatic cooling processes* [6]*. The relative importance and various combinations of these processes varies according to the type of damming event (see *damming spectrum* [5]) and the *event life cycle* [20].

2. Damming Lookalikes - Upslope flow, cool pools associated with clouds and/or precipitation, and surface-based high pressure ridges with only weak stability can all easily be mistaken for *cold air damming* [1], since the weather conditions associated with each are often quite similar.

3. Damming Potential - To a degree, the potential for damming is dependent upon the low-level characteristics of the air mass over the *damming region* [4]. In general, an air mass with good damming potential is characterized by relatively cold temperatures, high dew point depressions, high static stability, and warm air advection above the surface-based cold layer.

4. Damming Region - In the Carolinas and Virginia, refers to the eastern slopes and foothills of the Appalachian Mountains and the adjacent piedmont region.

5. Damming Spectrum - A classification scheme consisting of various types of *cold air damming* [1] and *damming look-alike* [2] events. The spectrum is based upon event differences regarding scale variations, the relative contributions of adiabatic versus diabatic cooling, and the relative degree of favorable synoptic scale support. The events evolve as the synoptic and mesoscale environments change (see *event life cycle* [20]).

6. Diabatic Cooling Processes - Consist of precipitation-induced evaporative cooling in the subcloud layer, and radiative cooling from clear-air effects. These processes can strengthen an ongoing *damming* [1] event and may even initiate *damming*. The <u>direct effects</u> from these processes include a drop in temperature, creating a cool pool; a hydrostatic pressure rise; and an adjustment of the winds to the modified mass field. The <u>indirect effects</u> of diabatic processes may lead to an evolution from *pooling* [7] to *damming* [1] by increasing the low-level static stability, such that the low-level flow no longer crosses the mountains (i.e., is blocked). Additionally, the low-level winds adjust, relative to the terrain, to allow significant adiabatic cooling in the *damming region* [4] from orographic ascent.

7. Pooling - A thin, surface-based layer of relatively cool air generated by *diabatic cooling processes* [6]. While *damming* [1] requires a mountain barrier, pooling does not.

8. Upslope - Orographic ascent from the component of low-level flow normal to the rising terrain resulting in adiabatic cooling.

Types of Cold Air Damming Events

9. "Classical" Cold Air Damming (CD) - Damming events chiefly initiated by highly supportive synoptic-scale features leading to strong, adiabatic upslope cooling from the persistent advection of cold, stable air into the *damming region* [4]. Synoptic-scale features providing the forcing and support to initiate and maintain "classical" damming events include: i) a strong *connecting/supporting surface parent high* [19] centered over the northeast U.S. or southeast Canada; ii) confluent flow at 500 mb above the *parent high* [21]; iii) northerly ageostrophic winds associated with the transverse circulation in the entrance region of a straight polar jet; and iv) a light-to-moderate, warm, moist inflow at 850 mb.

10. "Hybrid" Damming (HD) - The initiation of the *damming* [1] event is due to the combined contributions from both *diabatic cooling processes* [6] and weak horizontal cold air advection (into the *damming region* [4]) provided by the rather limited support from somewhat favorable synoptic features. Given this weak synoptic support, often it is evaporative cooling from precipitation that tips the scales toward the development of a *damming* event.

11. "In situ" Damming (ID) - *Damming* [1] events that are initiated with little or no support from the prevailing synoptic-scale features. As a result, there is no significant advection of cold, stable air into the *damming region* [4]. It is the indirect effects of diabatic cooling on the air mass already in place that leads to "in situ" damming. Specifically, the increase in low-level static stability results in a flow less likely to cross the mountain tops, while the adjustment in the low-level winds, relative to the configuration of the terrain, leads to further cooling from low-level cold, dry air advection and from orographic ascent in the *damming region*.

Signatures: Damming and Damming Lookalike Events

12. Dry Air Ridge (DAR) - In the mean sea level pressure field, refers to an axis or "nose" of high pressure extending down the eastern seaboard from a synoptic scale high centered to the north. The DAR is not adjacent to the mountains as is a *wedge* [17]. The DAR represents a surge of cold, stable air, and often is a precursor to a *cold air damming* [1] event. Surface winds within the DAR generally are not parallel to the mountains (flow from the north and/or northwest).

13. False Wedge - A feature easily mistaken for a *wedge* [17] with "U"-shaped isobars adjacent to the eastern slopes of the Appalachians and an isobaric connection to a synoptic scale surface high centered to the north. Typically, the air mass accompanying a false wedge possesses too much low-level instability for *damming* [1] to occur. In contrast to the *wedge*, surface winds are not persistently from the northeast within the *damming region* [4] , and there is little or no cold air advection into the *damming region*.

14. Mesoscale Wedge - Similar to the *wedge* [17] but much smaller, it is typically the signature of an *"in situ" damming* event [11], but also may be seen in the decay stages of *"hybrid"* [10] and *"classical"* [9] events. It implies little synoptic scale support left to maintain the *damming* event.

15. Piedmont Air Mass - Describes the general conditions of an air mas produced in the *damming region* [4] as a result of a *damming* [1] or *damming look-alike* [2] event, generally including considerable low cloudiness, below-normal temperatures and possibly precipitation.

16. Regional Anticyclone - A local area of high pressure associated with a surface-based cool pool resulting from *diabatic cooling processes* [6].

17. Wedge - A signature of *cold air damming* [1] in the mean sea level pressure field identified by "U"-shaped isobars adjacent to the eastern slopes of the Appalachians. The wedge is connected to a surface high centered to the north, with surface winds paralleling the mountains.

Event Life Cycle and Associated Surface Features

18. Connecting/Non-Supporting Parent High - Though connected in the mean sea level pressure field to a *wedge* [17] or *mesoscale wedge* [14], the *parent high* [21] is not located in a suitable position to provide the advection of cold, stable air into the *damming region* [4]. This feature is typically found in the decaying stages of *"in situ" damming* [11], *"classical" damming* [9], or *"hybrid" damming* events [10], as the supporting cold air high moves well offshore and cold air advection into the *damming region* ends.

19. Connecting/Supporting Parent High - Through the persistent advection of cold, stable air into the *damming region* [4], this *parent high* [21] provides support for a *damming* [1] event. Its center to the north is connected in the mean sea level pressure field to the damming *wedge* [17]. Connecting/supporting parent highs typify *"classical"* [9] and *"hybrid" damming* [10] events.

20. Event Life Cycle - The degree and nature of support provided by synoptic and mesoscale features in *a spectrum* [5] event will vary, and so may change classifications as it evolves, due to various processes driven by the synoptic and mesoscale environment: a *pooling* event [7] may develop into *damming[1]*, or a *"classical" damming* event [9] may, in time, resemble an *"in situ" damming* event [11] as the synoptic conditions become unfavorable for supporting damming.

21. Parent High - The surface high pressure system that originally provided the *damming region* [4] with an air mass of high *damming potential* [3].

22. Thermal Moisture Boundaries (TMB) - Very shallow and strongly topographically influenced boundaries representing discontinuities in temperatures, moisture, and stability. In the Carolinas and Virginia, coastal fronts develop near the coastal waters (in the vicinity of the Gulf Stream), and can move well inland. The term "piedmont front" has been widely used to describe the eastern and southern periphery of the *damming* [1] cold air. Other TMBs include old and decaying synoptic fronts, rain-cooled boundaries, and differential heating boundaries.

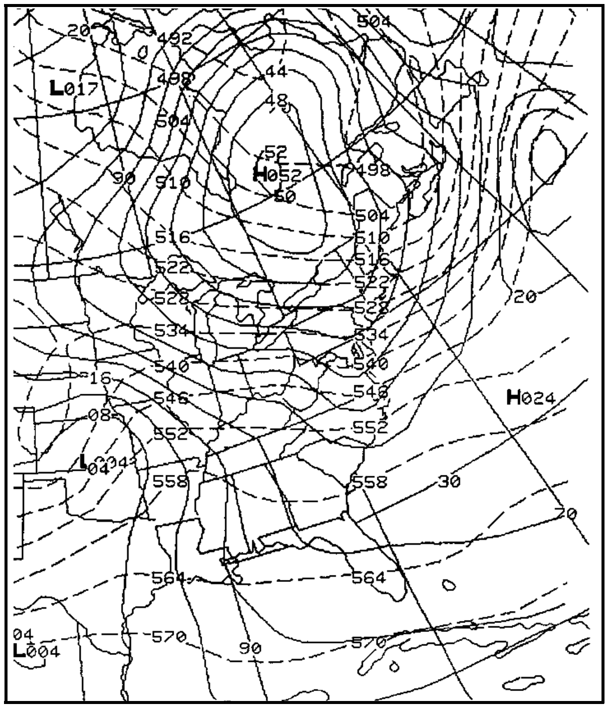

FIG. 1. Example of a surface map showing classical cold air damming (from 00-h LFM model analysis valid 0000 UTC 27 January 1994). Solid lines are MSL pressure (mb), dashed lines are 1000-500 mb thickness (dam).

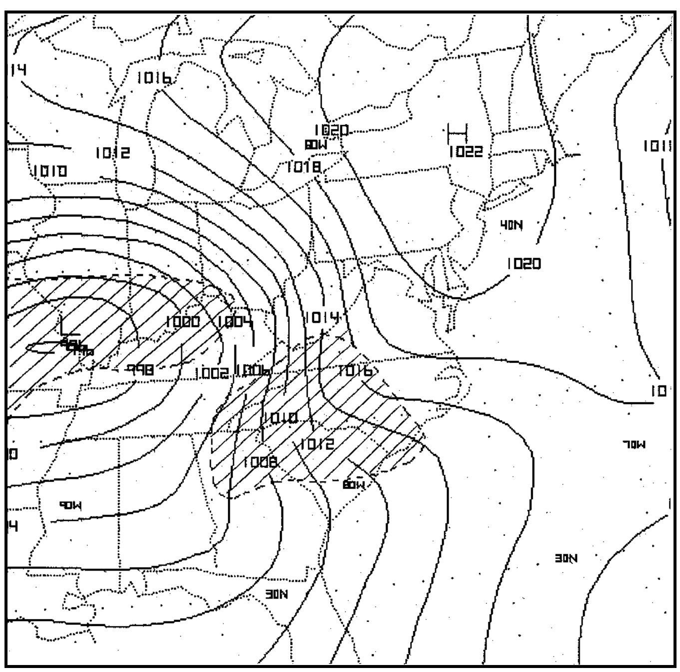

FIG. 2. Conceptual model of a surface map showing hybrid cold air damming. Hatched area represents precipitation. Solid lines are MSL pressure (mb). Note the position and strength of the high pressure area compared to that in Fig. 1.

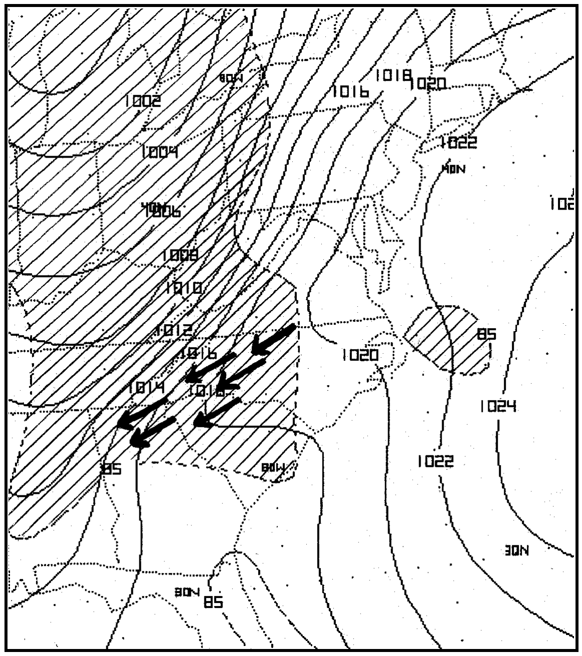

FIG. 3. Conceptual model of a surface map showing in situ cold air damming. Hatched area represents precipitation. Solid lines are MSL pressure (mb); arrows depict surface winds. Note the offshore position of the parent high pressure area.

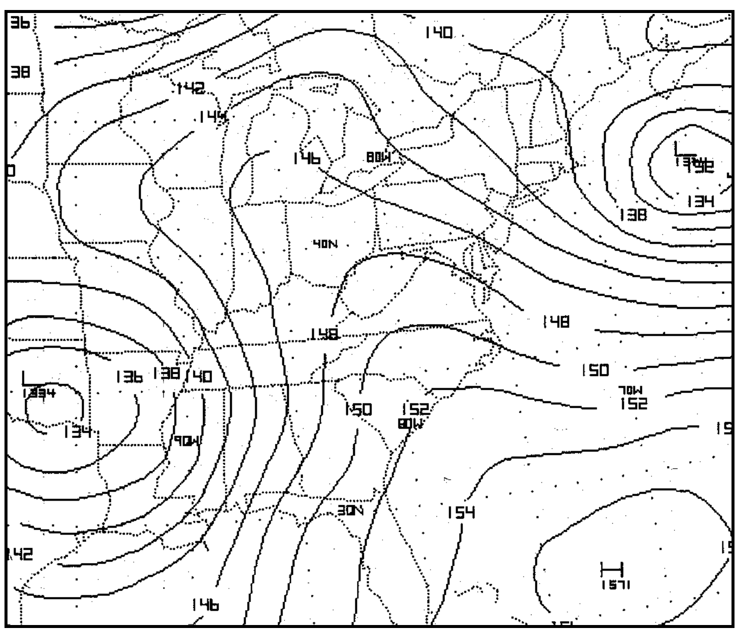

FIG. 4. Example of 850-mb plot during a cold air damming event (from 06-h Eta model forecast valid 0600 UTC 24 December 1997). Height contours are in tens of meters.

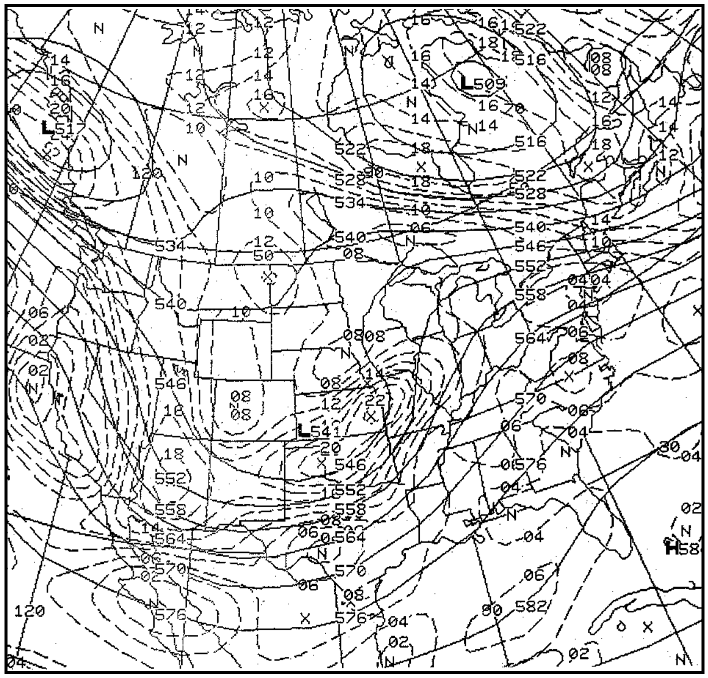

FIG. 5. Example of 500-mb plot during a classical cold air damming event (from 24-h Eta model forecast valid 0000 UTC 23 February 1994). Height contours (solid lines) are in tens of meters. Note the confluent flow pattern over the northeast United States.

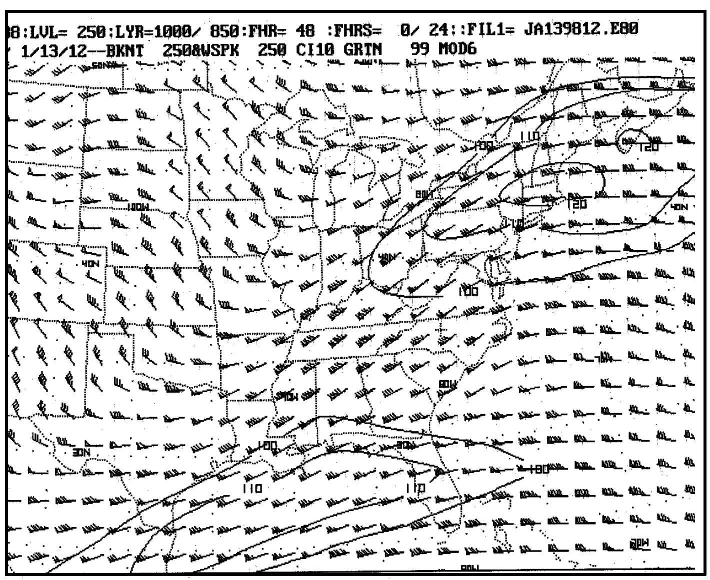

FIG. 6. Example of 250-mb jet structure analysis during a classical cold air damming event (from 48-h Eta model forecast valid 1200 UTC 15 January 1998). Isotachs (solid lines) and winds are in knots.

Spectrum of Cold Air Damming and Lookalike Events

Damming Events

(**Damming events evolve, and can change categories during their life cycles**)

Events are categorized by:

- three-dimensional scale variations
- relative roles of synoptic-scale forcing and diabatic processes

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Classical ----- Hybrid ------ In Situ

<<-----------<<-*increases*--<<---------<<

- Depth of cold air dome
- Wedge's resistance to decay
- Role of synoptic-scale forcing as damming initiator
- Models' capability to forecast

>>----------->>-*increases*-->>--------->>

- Diabatic processes as damming initiator

Lookalike Events

These events:

- produce weather conditions which mimic damming
- will likely lack signatures above the boundary layer
- often occur as a damming event dissolves; may also develop into a damming event

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Upslope -------------- Cool air pooling

<<-----------<<-*increases*--<<---------<<

- Role of orography in development
- Models' capability to forecast

FIG. 7. Graphic of the cold air damming spectrum.

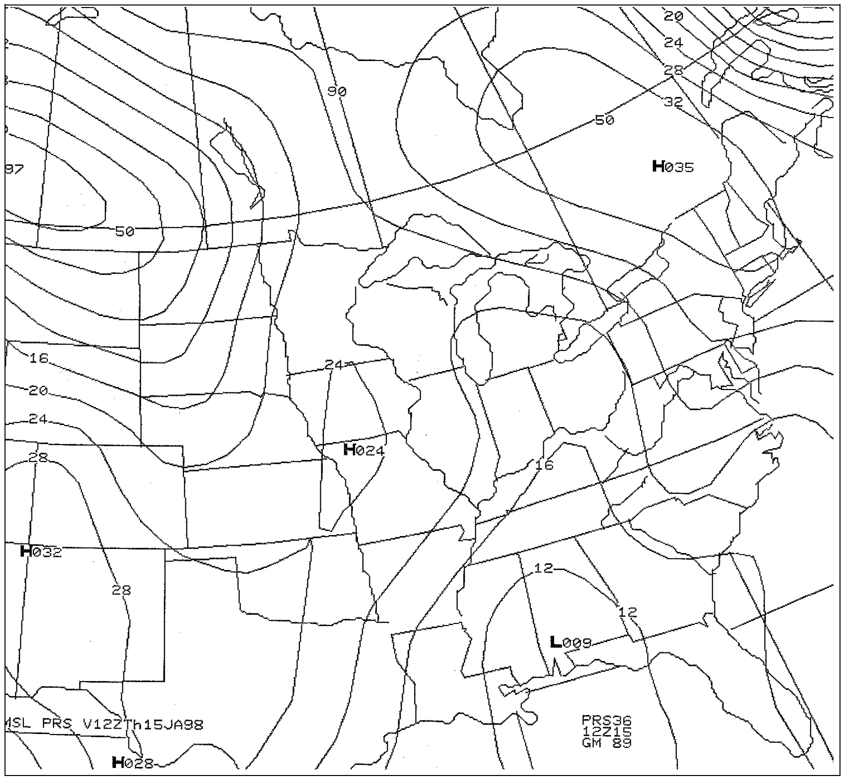

FIG. 8. MSL pressure (mb) from the 36-h Eta model forecast, valid 1200 UTC 15 January 1998.

ANSWERS TO PRACTICE EXERCISES

1. What is the primary distinction between "Classical" CAD and "Hybrid" and "In situ" CAD?

The ongoing support of entrenched, cold surface air in a Classical damming event is provided primarily by a favorably located, slowly moving, and strong synoptic scale "parent" surface high. In contrast, mesoscale diabatic forcing processes, such as precipitation and cloud cover, are a significant source of cold air in "Hybrid" and "In situ" damming events (and are often shorter-lived).

2. Describe the primary damming signature, and resulting processes, of a classical CAD situation at 850 mb, 500 mb, and 300 mb.

850 mb - Typically an anticyclone is centered off the southeastern U.S. coast, with a ridge extending into the mid-Atlantic states. This produces a warm, moist, southerly/southeasterly flow from the Gulf, or Atlantic, atop the cold damming region. This would a) strengthen the low-level damming inversion, and b) likely add clouds and cooling (due to precipitation) into the cold air, preventing solar dissipation of the cold dome. Strong winds would not be favorable, as this could lead to mixing at the top of the cold layer.

500 mb - Look for confluent flow atop the parent surface high, leading to subsidence in the area. This serves to strengthen and anchor the parent high, maintaining a favorable position for cold air advection into the damming region. This also allows the surface ridge time to 'spill' southward into the region without influence of any coastal cyclogenesis generated in the southern stream.

300 - 250 mb - If the front entrance region of a (straight) polar jet is located above a strong surface high in the northeast U.S., the resulting ageostrophic circulations would produce downward vertical motion over the high. In addition, the low-level ageostrophic winds within this region's transverse circulation would help drive cold, surface-based air southward from the high into the damming region.

3) What are some forecast elements that you would most want to look at in order to distinguish between a true vs. a "lookalike" cold air damming event in the forecast period?

Wind flow - During true CAD, the wind flow is blocked, or dammed, against the mountain barrier. During “lookalike” events, the flow is not physically blocked.

Synoptic connection - In "lookalike" events, the relatively stable air mass is not connected to, or supported by, any synoptic-scale, "parent" surface high pressure area.

Low-level stability - In "lookalike" events, there is little or no cold air advection strengthening the existing cool pool, so the surface air mass is not as strongly stable as in true cold air damming.

Processess aloft - Typical damming signatures are often lacking above the boundary layer in "lookalike" CAD events, whereas upper-air processes are critical to the formation and support of classical cold air damming.