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Twelve hours in the life of a snowstorm (explainer)

BY JEFF HALVERSON January 22 at 2:22 pm

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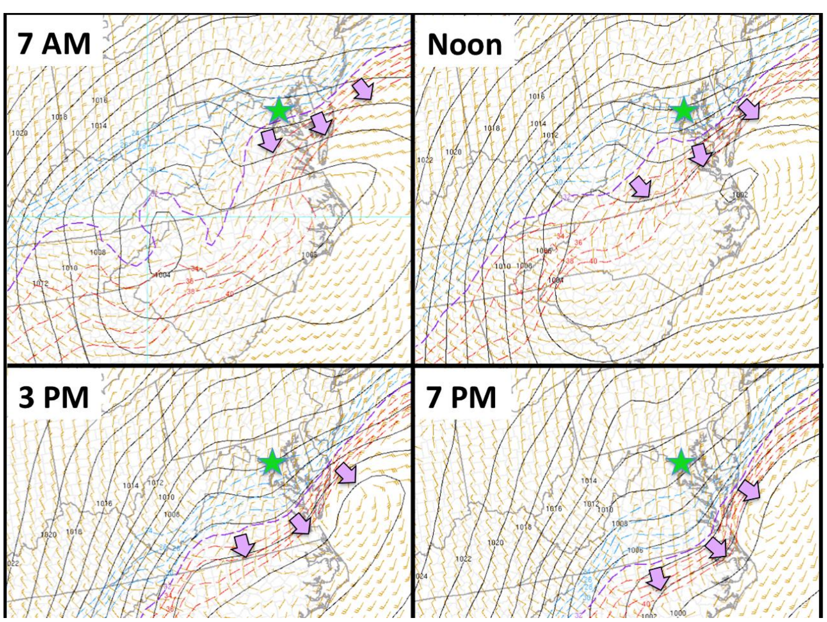
Here is the tale of how key elements interacted to produce the Washington region's most significant snowfall in three years.

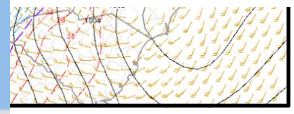
The importance of refrigerated air

This was not a juicy storm, in terms of moisture feeding into it, but an unusually deep layer of subfreezing air more than compensated for snow production. The temperatures in the cloud layer, above 5,000 feet, were in the exact range needed to produce snow very efficiently, e.g. -12 to -16 C. This is the so-called "dendritic growth" temperature range.

When vigorous uplift of moist air coincides with these temperatures, a type of multi-pronged, six-sided ice crystal called a dendrite is generated. Jostled by wind currents in the cloud, dendrites very effectively hook together – like microscopic Velcro – rapidly building to snowflake size.

A deep front of advancing, subfreezing air – called an arctic front – pushed across the Washington region during the mid-late morning hours on Tuesday. This is shown in Figure 1.





curve, 0 C isotherm) at the surface

Meanwhile, low-level moist air off the Atlantic was streaming into the developing storm over the Tennessee Valley from the east-northeast. The moist air was lifted along the arctic front, freezing into all those countless trillions of dendrites.

15:1

Mid-to-late Tuesday morning, once temperatures at the surface fell below freezing, the character of the snow changed. A brief period of moderate-sized, semi-wet flakes quickly morphed to granular powder. When meteorologists attempt to predict snow accumulation (to the very inch), we must decide on a conversion factor between snow and its liquid water equivalent.

The reason for this is the models output total precipitation as inches of liquid. The commonly used 10:1 snow:liquid ratio (10 inches of snow for every one inch of liquid precipitation) is predicated on a layer of freshly fallen snow, which by volume contains much more air than actual water.

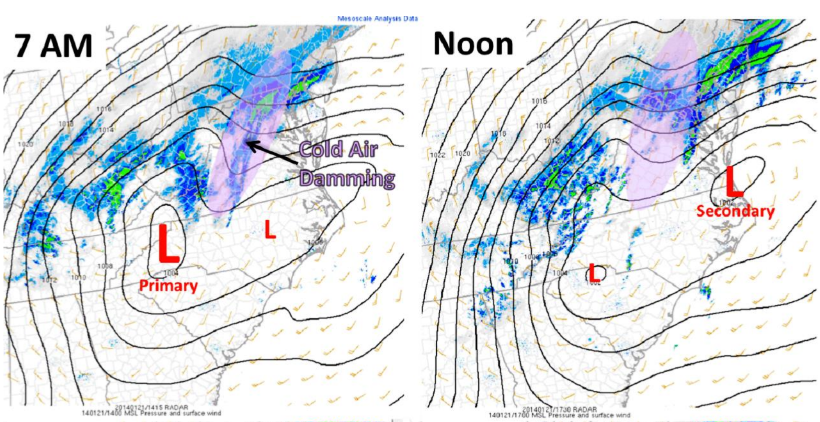
However, a layer of wet flakes that clump into a sticky snow has greatly reduced air fraction, dropping ratios to as low as 5:1. To get such a wet snow, you need either temperatures very close to melting (0 C) and/or exceptionally high cloud liquid water content (i.e. buku water vapor rising into the cloud layer).

In air far below freezing, and in a moisture-limited storm, the manufactured snow is going to pile up quite dry and fluffy. CWG meteorologists realized that this would be the case for Tuesday's storm, and 15:1 became the ratio du jour for our snow accumulation predictions. A 15:1 ratio was also adopted by both the National Weather Service and Weather Prediction Center for its forecasts.

Choosing a 20:1 ratio was probably too dry for this storm. This high ratio is more typical of extremely moisture-starved storm systems, such as Alberta Clippers crossing the Upper Midwest. 20:1 produces an extremely dusty, talcum-like snow.

Currents of rising air

In spite of subfreezing cold and moisture, without rising air, there would be no clouds to manufacture snow. In Tuesday's storm, ascending air came from three sources: The jet stream, the developing coastal low, and forced uplift along the nose of the arctic front.



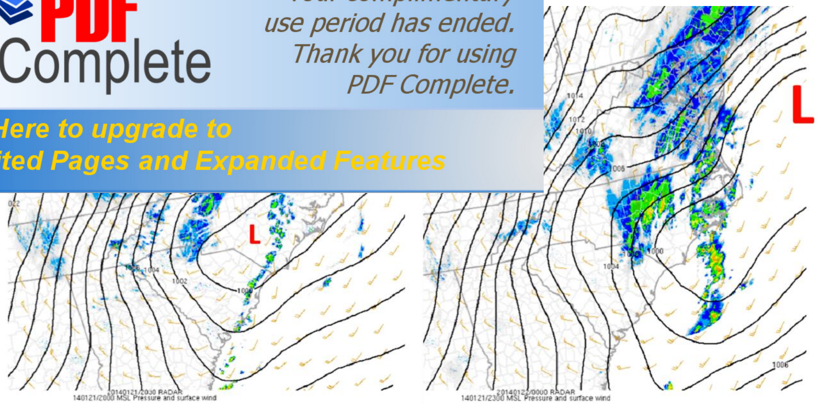
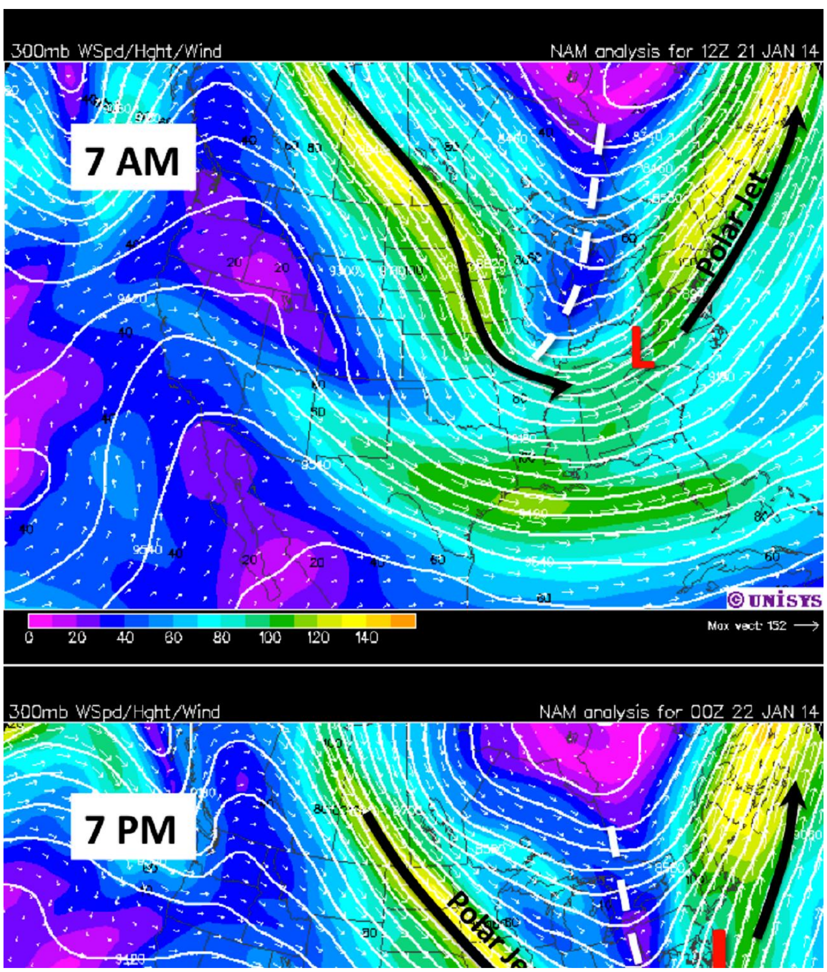


Figure 2: Progression of surface weather features through the day on Tuesday, including formation of a coastal low (red ñLò) and region of cold air damming (purple shaded region). Adapted from NOAA. Click to enlarge.

From this 4-panel sequence, note the progressive eastward movement of the low pressure region, its reformation and deepening along the coast. This is classic Miller Type B evolution: The primary low weakens along the Appalachians, then a new secondary center “steals the show” along the coast.

Cold air rushed into this vortex from the north, helping to drive the arctic front to the Virginia-North Carolina border. Part of this northerly current also became channeled into the all-too-familiar cold air dam or “wedge” over the Piedmont (purple shaded region). Atlantic moisture was streaming westward into the low at 5,000 feet and higher.

What caused this coastal storm to develop so rapidly? Concentrated uplift in the core of jet stream, at 30,000 feet. A vigorous wave in the jet stream, called a shortwave trough, was approaching the region from the Ohio Valley. This is shown in Figure 3.



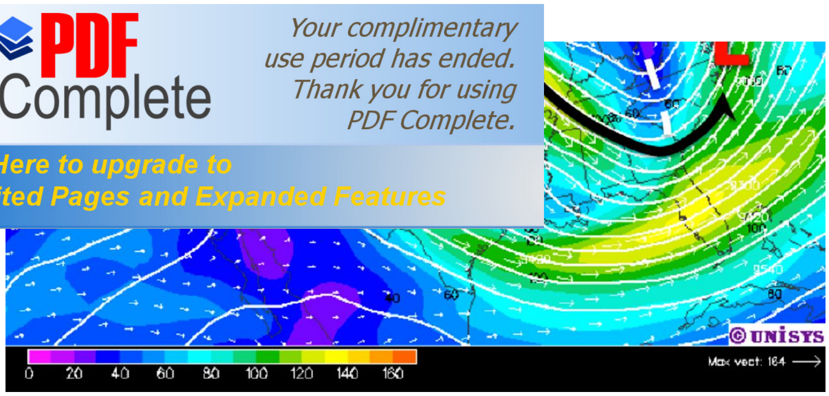


Figure 3: Dynamical processes in the polar jet stream leading to formation of coastal low (red ﬁLﬂ) and its intensification. Note the change in orientation of the shortwave trough (white dashed line). Adapted from Unisys Corp.

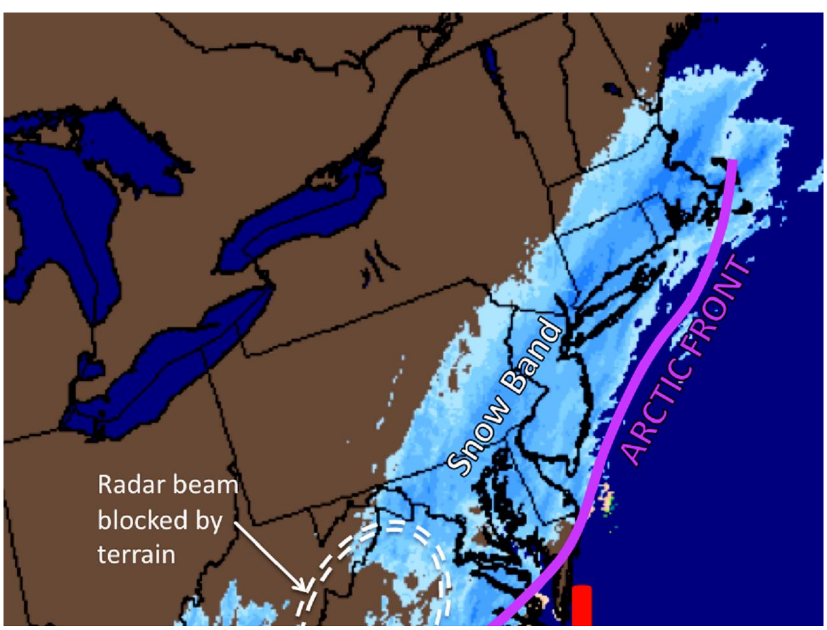
On account of some fairly advanced fluid dynamics, air ascends just ahead of the axis of a shortwave trough. Like a vacuum, the trough draws up air from the surface, dropping the pressure in the center of the low.

But the character of the shortwave changed through the day on Tuesday. The tilt of the trough axis became re-oriented from northeast-southwest to northwest-southeast. When a trough acquires this “negative tilt” configuration, air is exhausted from the top of the surface low much more rapidly. As a result, the low began to intensify along the coast Tuesday afternoon through the overnight. The heaviest snow tends to fall during these intensification phases. This was consistent with the burst of heavy snow across our region around 6 p.m.

Snowband

All the elements that conspire to create heavy snow – cold air and ascending moisture – tend to concentrate into band or streak-like features on the backside of a developing vortex. Predicting the occurrence, location, timing and duration of bands is the essence of a snowstorm’s nowcasting phase.

Meteorologists know about the preferred regions for these bands, and you may hear jargon such as “frontogenetic region” or “deformation zone”. Fluid dynamics aside, Tuesday’s storm had all this. Figure 4 shows a very prominent, elongated band that developed during the late afternoon on Tuesday – stretching from Washington to Boston.



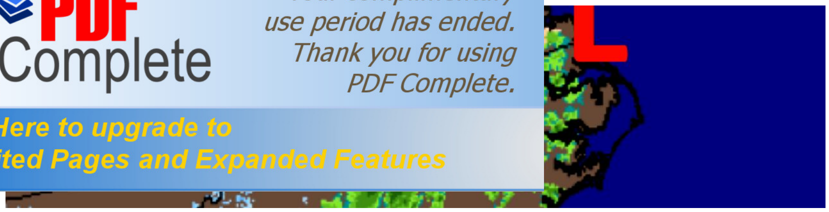


Figure 4: Large, persistent snow band that became established to the northwest of the coastal low (red ñLò), and extending northeastward along the arctic front (solid purple line). Adapted from Weathertap.com.

This band actually became aligned along the arctic front encroaching on the storm system from the north and west. A very large temperature and moisture gradient developed along this front, and uplift was enhanced by sinking cold air and rising milder air. The band was a persistent, quasi-stationary feature for many hours. The snowfall rate tended to pulse on and off during the course of this band's activity, but it did develop in the location and timeframe as advertised by the models.

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spf130 wrote:
7:13 PM EST

I'd like to know more about the radar image above where it notes that, over SW VA and parts of WV, the "radar beam blocked by terrain." Is that a common issue and does that mean there likely was precip falling in that area that was missed by radar? Everyone was fired up about the apparent dry slotting going on yesterday, but was that just a bad radar feed? Lastly, if it was in fact dry slotting, how common is that with similar storms and how do you take that into account when forecasting? Thanks!

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Jeff-CapitalWeatherGang responds:
10:01 PM EST

The Sterling radar suffers from beam blockage toward the southwest, due to the Appalachians. It was also overshooting the snow falling from shallower layer clouds to its south on Tuesday. This is a common occurrence.

The dry slot was a mid-level feature, noted in water vapor imagery, in the mid-tropospheric vapor channel. It moved through during the late-morning on Tuesday. This was a distinct entity from radar beam issues, but it may have contributed to a reduction in snow rate for several hours - until the main snowband kicked into action.

The dry slot is a dynamic feature induced by sinking of upper- and mid-level tropospheric air, usually behind a cold front, but also seen in connection with shortwaves in the jet stream.

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BobMiller2 wrote:
5:34 PM EST

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bob909 responds:
5:41 PM EST

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