The Impact of Upstream Latent Heat Release on Moisture Transport into Extratropical Cyclones along the Southeast U.S. Coast

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The focus of my research is to better understand the impact of latent heat release (LHR) on moisture transport in extratropical cyclones along the southeast coast of the U.S. in the real atmosphere and in NWP models. In particular I'm interested in cases where there is a precipitation feature in the cold sector of the system, such as an instant-occlusion type cyclone. In these synoptic situations, precipitation generated in the cold air can induce impact downstream moisture transport by inducing a cyclonic circulation in the lower troposphere. The exact orientation and strength of this cold air precipitation feature and its attendant circulation can increase or decrease the downstream moisture transport into the developing cyclone, so model representation of these cold air precipitation features is critical to downstream model QPF. Additionally if elevated or slantwise convection are active in these cold air features, models have difficulty representing elevated convective processes in cold air. Overall, if the models are not able to properly forecast the upstream cold air precipitation, this could lead to poor forecasts of moisture transport and QPF downstream.

We have selected this issue for study because of the large impact these features can have on model QPF and the forecast of how far inland the precipitation shield associated with a coastal cyclone will extend. Properly representing the western edge of the precipitation shield is especially critical in situations of frozen or freezing precipitation where a 50 to 100 mile shift of the inland extent of the precipitation can mean the difference between a dry forecast and winter storm warning conditions.

The framework of potential vorticity (PV) is a convenient way to understand how upstream cold air precipitation can impact moisture transport. Since PV is not conserved in the presence of a diabatic process such as LHR. Knowing this it can be used to track the impact of LHR, especially in the lower-troposphere, where background values of PV are typically small. In an area of precipitation, PV is generally generated below the level of maximum latent heating, since LHR both increases the static stability and the absolute vorticity in this area and PV is the product of those two variables. In models the evolution of PV in the lower-troposphere is highly sensitive to the vertical and horizontal distribution of LHR produced by the model's precipitation schemes. The distribution of this heating will determine the size, strength, and orientation of the PV maximum, as well as the strength of the cyclonic circulation associated with it. While these lower-tropospheric PV maxima may not be as strong as PV features associated with the upper trough, the lower-level PV maxima are located where atmospheric moisture content is highest. Previous research has shown that these lower-tropospheric PV maxima have significantly contributed to moisture transport in cyclones and along fronts.

A better understanding of how latent heat is redistributed in models and how this impacts the evolution of lower-tropospheric PV maxima could lead to eventual improvements in the models themselves. Combined with an increased understanding of these physical processes, this would ideally lead to more accurate forecasts for high-impact precipitation events.

Most of the work I've done so far has concentrated on the Jan. 24–25 2000 snowstorm. In this case the operational models failed to predict the development of an area of precipitation that formed early on 24 Jan. over Alabama and Georgia. I've worked to show that this precipitation feature was important to the moisture transport into the Carolinas and Virginia later in the event.

Below is an idealized figure showing a scenario based on the 24–25 January 2000 snowstorm where a region of LHR could enhance moisture transport into the Carolinas and Virginia in a coastal cyclone event.

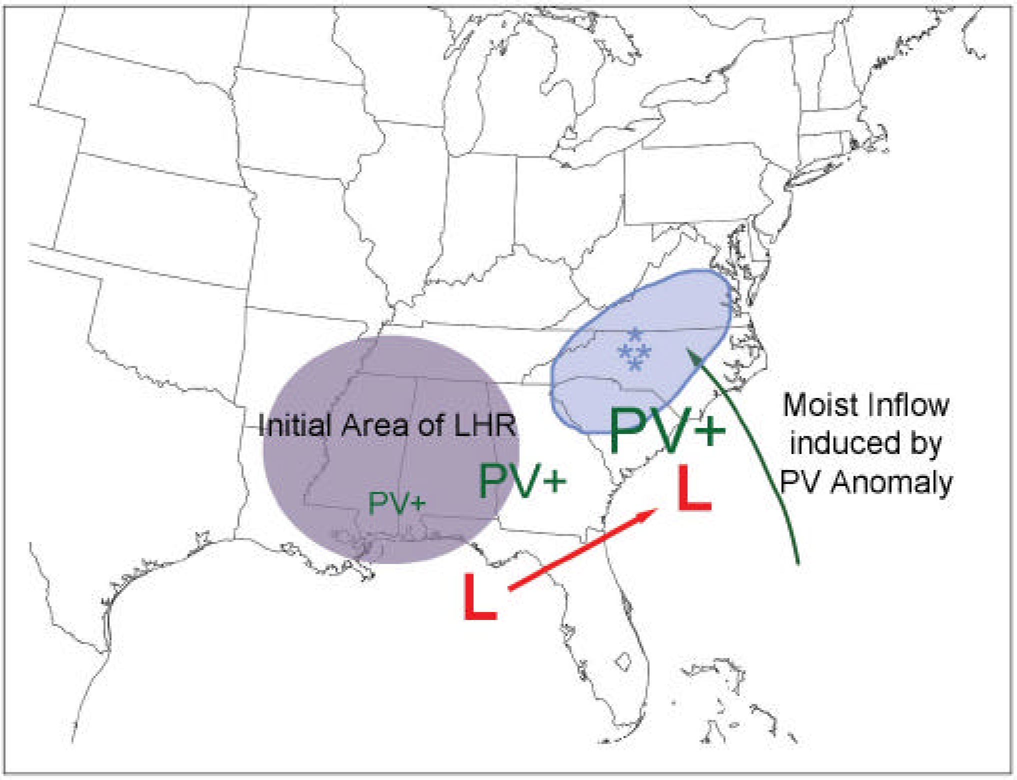

Figure 1. Idealized schematic of evolution of lower-tropospheric PV maximum generated by latent heating, with surface cyclone, and moisture transport into the Carolinas and Mid-Atlantic, based on analysis of 24-25 January 2000 cyclone.

In this scenario, the initial area of LHR forms over the lower Mississippi Valley, generating a positive PV anomaly in the lower troposphere. This PV anomaly strengthens with time and moves northeastward to the coast of the Carolinas as the surface cyclone develops in the Gulf and moves across Florida. The cyclonic circulation induced by the PV anomaly enhances onshore flow in the lower and mid troposphere, providing the necessary moisture to produce heavy snowfall into the Carolinas and Virginia

So far, I've used numerical model simulations to show that this lower-tropospheric PV anomaly was important in driving the moisture transport off the Atlantic into the

Carolinas and Virginia during the period of heavy precipitation. Model simulations that generate the cold air precipitation feature and its PV maximum perform much better with QPF values over the Carolinas and Virginia.

Currently I'm trying to understand how this precipitation over Alabama and Georgia initially formed and why the operational models were unable to predict it. Ongoing work is expanding this research to other cases and exploring the sensitivity of NWP models to the representation of these cold air precipitation features by varying model precipitation physics, grid spacing, and initial conditions.

Most importantly, we are looking for your input into this research, and ways to make it more useful in application to operations.

1.) Are you aware of other cases in which cold-air precipitation features accompanied challenging forecast situations during cyclogenesis? Do you feel that the operational models generally handle the cold air precipitation features well?

2.) To what extent are you comfortable with "PV thinking"? Do you use PV in any operational forecast situations, such as PV AWIPS procedures? Would a "PV tutorial" VISIT session be useful, if we can demonstrate that it would help in the interpretation of synoptic-dynamics case evolutions?

3.) Do you have any of your own interpretations for the mechanisms of cold-air precipitation forcing, in terms of slantwise convection, elevated convection, or non-convective forced-ascent?

4.) Is the "instant occlusion" conceptual model useful for cyclogenesis in the southeast US? Is it employed by NWS forecasters in interpretation of the synoptic pattern? Would background material on this be helpful as well?