CLOUD SYSTEM MODELING WITH A QUASI-LAGRANGIAN VERTICAL COORDINATE

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Motivation and background

There are advantages of using the quasi-Lagrangian (QL) system of equations in atmospheric models over the traditional Eulerian systems such as geometric height. One of these is an improvement of the representation of vertical transport processes. Figure 1 shows the QL framework, as formulated by Starr (1945), in which the vertical coordinate is potential temperature which represents material surfaces for adiabatic processes. In this system, the vertical velocity is virtually eliminated, which greatly reduces the numerical dispersion error associated with vertical transport.

The QL system has been employed in large-scale hydrostatic atmospheric models with much success. However, material (isentropic) surfaces become very irregular when they are used in nonhydrostatic models that simulate the fine-scale, turbulent motion characteristic of cloud-scale flow. We have overcome these difficulties and have developed a model which can simulate such turbulent motion within the QL framework. The model has been extensively tested with dry atmospheric processes such as mountain wave breaking and there is a dramatic improvement in the vertical transport of a passive tracer over the Eulerian framework as shown in Figure 2.

Our proposal is to build on the success of the dry model to develop the first QL cloud system resolving model. We believe that there will be an improvement in the simulated vertical cloud distributions compared to traditional height-coordinate cloud models currently used in the multi-scale modeling framework (MMF). We anticipate that this will lead to a more accurate representation of the effect of clouds on the global climate.
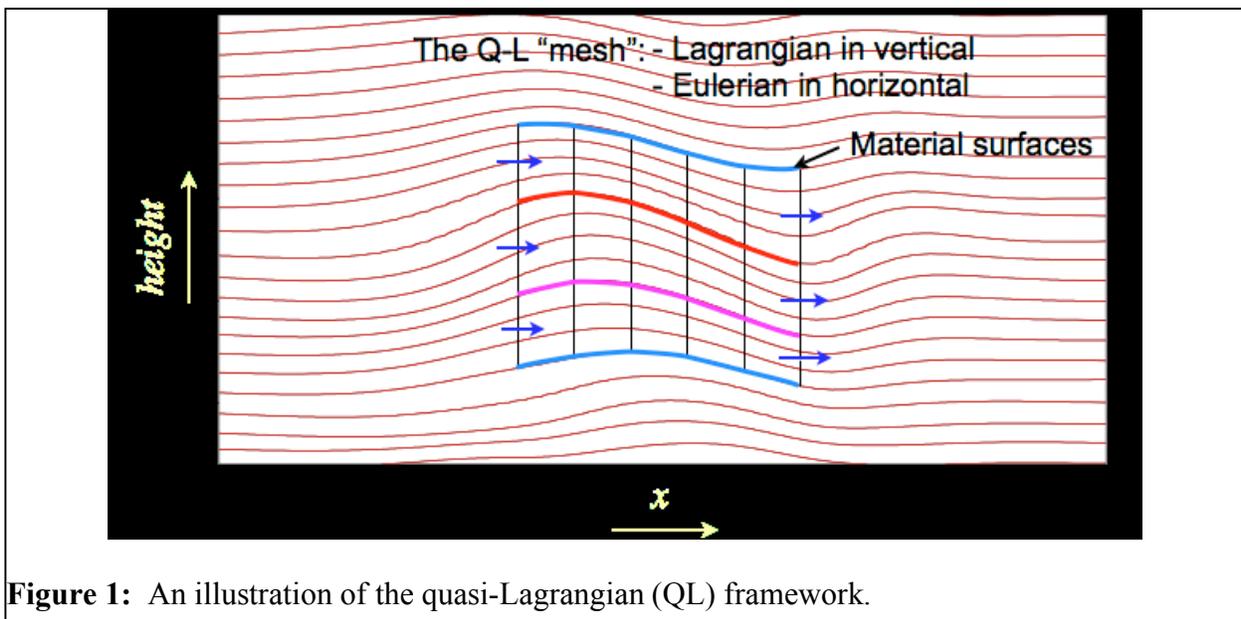

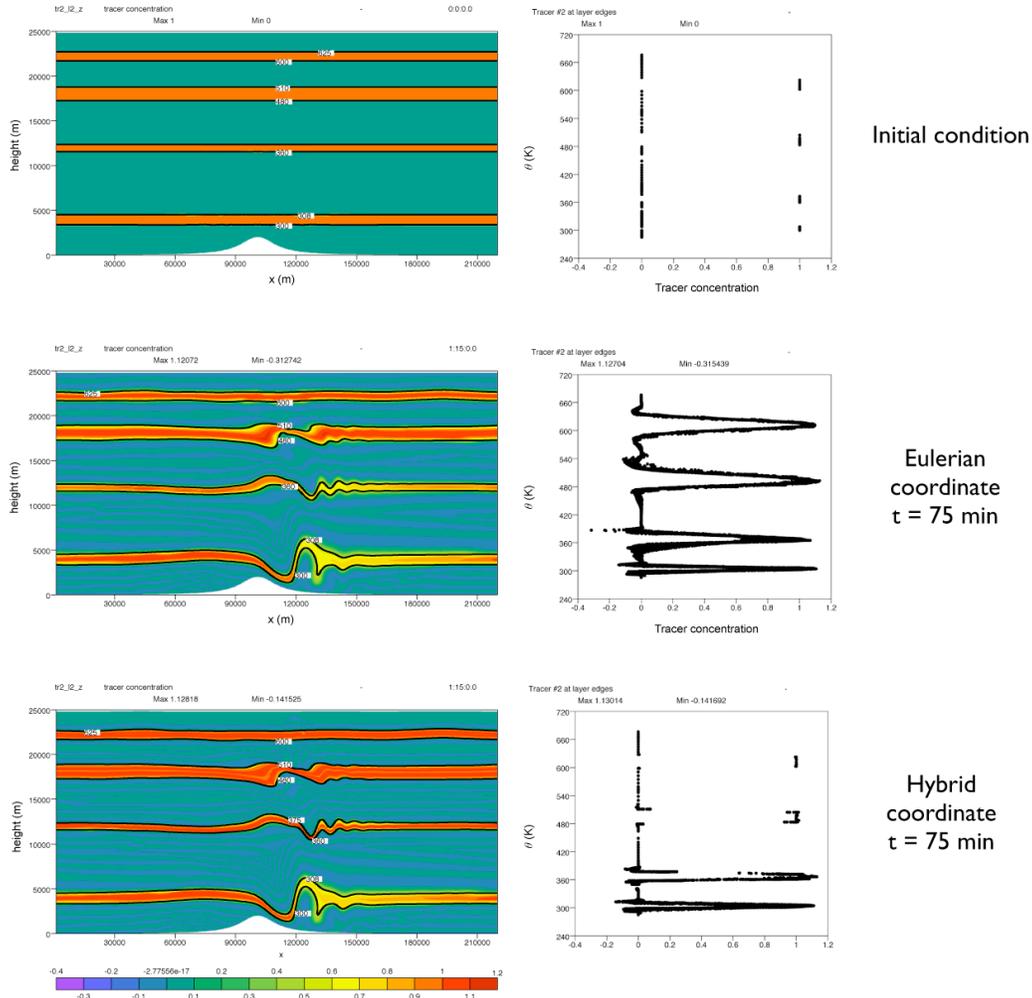**Figure 1:** An illustration of the quasi-Lagrangian (QL) framework.

Figure 2: Tracer transport: Eulerian vs. hybrid coordinate.

Proposed work

The first step toward converting the QL nonhydrostatic model to a cloud system resolving model (CSRM) is to introduce moisture as a tracer and perform the idealized tests of moist condensation in a saturated environment as in Konor and Arakawa (2000). This will test the model's response to diabatic heating, which, in the isentropic coordinate framework, represents a vertical mass flux. The second step will be to explicitly represent cloud processes by coupling the model to an existing cloud physics parameterization, most likely that of the SAM model currently used in the MMF.

We will then test the QL-CSRM and compare cloud simulations with the hybrid versus the Eulerian vertical coordinate to gain an understanding of the effect of the QL framework on predicting the relationship between cloud processes and climate. Test cases we will draw from include the tropical cloud experiments of the TOGA (Tropical Ocean Global Atmosphere) program.