## GSA Data Archive

The numerical model used in this study is the Weather Research and Forecast Model (WRF) version 2.2, a numerical weather prediction model that integrates the fully compressible, nonhydrostatic Euler equations for atmospheric motions [Skamarock et al., 2005]. The idealized configuration used here is similar to that used in previous studies [Galewsky, 2008, 2009]. The 2D simulations are run in a channel of 700x50 gridpoints in the horizontal with open boundaries upstream and downstream and periodic lateral boundary conditions. The 3D simulations are run on a domain of 500x500 points in the horizontal with open boundary conditions. All simulations use a 2-km grid spacing and 50 unevenly spaced vertical points, with greater resolution near the surface, in a 30km high domain.

The idealized topography for all of the experiments takes the form of a smooth ridge oriented with its long axis perpendicular to the x direction and is shown in Fig. A1. The topography for the ridge is given by:

$$h(x,y) = \begin{cases} \frac{h_0}{16}[1+\cos(\pi r)]^4, & r \leq 1; \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

where

$$r^2 = \begin{cases} \left(\frac{x}{4a}\right)^2 + \left(\frac{|y|-(\beta-1)a}{4a}\right)^2, & |y| > (\beta-1)a; \\ \left(\frac{x}{4a}\right)^2, & \text{otherwise} \end{cases} \tag{2}$$

where $h_0$ and $\beta$ are the mountain height and horizontal aspect ratio, respectively, and $a$ is the length scale for the terrain width. In this study, the terrain height varies between 1 km and 6 km, in 1 km intervals, with an orogen width of 160 km. $N$ is initialized to be uniform throughout the domain and is defined relative to a moist static stability using the technique of Miglietta and Rotunno [2005], with an initial relative humidity of 98% and a surface temperature of 16 C. The flow is initialized by gradually accelerating the basic wind from rest over the first hour of integration. The wind speeds are varied between 10 and 15 m/s. The results presented here are from $t = 6$ h and $t = 12$ h, where $t$ is the time in hours.

Cloud and precipitation processes are parameterized using the WRF Single Moment 6-phase microphysics (WSM6) scheme. Isotope physics is incorporated using a 'perfect precipitation' (PP) model, which has been used in previous studies of orographic precipitation [e.g. Jiang, 2003] and water isotopologues [Galewsky et al., 2007]. In the PP model, two tracers are added to WRF in addition to the fields used by the WSM6 scheme. One tracer represents all of the water vapor in the system and is initialized to be equal to the initial water vapor mixing ratio. Another tracer represents the mixing ratio of the heavy isotopologue of water vapor and is initialized so that the starting $\delta^{18}O$ ratio of the water vapor -13 ‰ relative to SMOW. These additional tracers are advected with the flow, which is modified by the latent heating associated with condensation from the full microphysics scheme. Upon gridpoint saturation, the excess passive water tracer condenses and falls out as precipitation. Isotopic fractionation takes place upon condensation according to standard temperature-dependent equilibrium fractionation factors [Majoube, 1971; Merlivat and Nief, 1967]. As shown in previous studies [Jiang, 2003], the perfect precipitation (PP) model shifts precipitation maxima upstream owing to the absence of hydrometeor advection, and PP precipitation amounts are greater than the WSM6 amounts owing to the immediate fallout of all condensate (not shown). The PP model simulates the dynamical effects of stratified flow over topography, but does not capture isotopic exchange between condensate and vapor phases or kinetic effects associated with, for example, subcloud evaporation of hydrometeors. Diagnosis of subcloud evaporation from the WSM6 scheme (not shown) indicates that this process is limited to cases with higher terrain (¿ 3km) and in no case exceeds a 6-hour cumulative total of 106 kg/kg, suggesting that such effects should not impact the main results presented in this study.

**References**

Galewsky, J., M. Strong, and Z. Sharp, 2007: Measurements of water vapor D/H ratios from Mauna Kea, Hawaii, and implications for subtropical humidity dynamics. Geophysical Research Letters, v. 34, doi:10.1029/2007GL031330.

Jiang, Q., 2003: Moist dynamics and orographic precipitation. Tellus, v. 55A,p. 301–316.

Majoube, M., 1971: Fractionation of oxygen 18 and of deuterium between water and its vapor. Journal of Chemical Physics, v. 68, p.1423–1436.

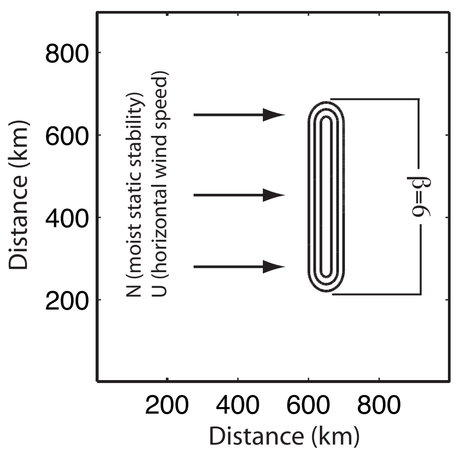
Merlivat, L. and G. Nief, 1967: Isotopic fractionation of the solid-vapor and liquid-vapor changes of state of water at temperatures below 0 c. Tellus, v. 19, p.122–127.

Miglietta, M. and R. Rotunno, 2005: Simulations of moist nearly neutral flow over a ridge. Journal of the Atmospheric Sciences, v. 62, p.1410–1427.

Skamarock, W., J. Klemp, J. Dudhia, D. Gill, D. Barker, W. Wang, and J. Powers, 2005: A description of the advanced research WRF Version 2. Tech. Rep. TN-468, NCAR.

**Figure Captions**

Figure A1. Map view of the idealized model configuration used in this study. Contour interval 1500m.



Distance (km)
800
600
400
200
N (moist static stability)
U (horizontal wind speed)
β=6
200
400
600
800
Distance (km)