Spurious Moisture Source

In the polar latitudes, one expects precipitation to be uniform as most of it is the direct result of propagating synoptic-scale disturbances. However, the Reanalysis precipitation has many quasi-stationary small-scale features whose relationship to orography seems quite obvious. Prevailing wisdom was that this precipitation was the so called "spectral rain", an artifact of the Gibb's phenomenon in spectral models.

In August 1996, R. Kistler, M. Iredell and H. Pan decided to to figure out the reason for this "spectral rain". They found that by shutting off the horizontal diffusion of moisture in the boundary layer, the "spectral rain" can be reduced or eliminated. That is when S. Moorthi pointed out, what he had discovered a few months earlier while applying horizontal diffusion in his semi-Lagrangian model (MWR, Moorthi 1997), that the culprit is not the diffusion itself, but the approximation of the correction term and that the resulting rain is not "spectral rain" but "spurious rain". He also showed that the observation made by Kistler, Iredell and Pan can be easily explained. Subsequently, it was confirmed that by eliminating the correction term, this "spurious rain" indeed disappeared.

All models have diffusion of quantities such as vorticity, humidity and temperature. One would expect the diffusion to be anisotropic; different diffusion constants/parameterizations for the vertical and horizontal directions. Ocean modelers have long considered that diffusion takes place more easily on isentropic surfaces than for other directions. As a result, they parameterize diffusion along the the isentropic surface differently than the diffusion in the direction perpendicular to that surface. Originally the MRF considered two types of diffusion, vertical diffusion and diffusion along the sigma surfaces. Later the diffusion was divided into vertical diffusion and diffusion along the pressure surfaces. Since the exact evaluation of diffusion on pressure surfaces is a costly operation, an approximation was made,

$$\nabla_p^2 q \approx \nabla_\sigma^2 q - \frac{\partial \overline{q}}{\partial \ln \sigma} \nabla_\sigma^2 \ln P_s \qquad (1)$$

where P_s is the surface pressure and $\overline{q}$ is the global average of q, the specific humidity.

This approximation (1) is very cheap as both terms can be evaluated spectrally. This is very important as one does not want to use a large number of CPU cycles on a small term such as diffusion. This change was found to improve the model in regions of strong orography.

At high latitudes and elevations, q, the specific humidity, is much smaller than the global average of specific humidity, $\overline{q}$. As a result, the horizontal diffusion is dominated by the second term; i.e.,

$$\nabla_p^2 q \approx - \frac{\partial \overline{q}}{\partial \ln \sigma} \nabla_\sigma^2 \ln P_s \qquad (2)$$

The above equation (2) shows that the first approximation (1) can lead to unreasonable errors in the specific-humidity diffusion. This spurious moisture source/sink can cause unrealistically large or small amounts of precipitation.

A more accurate approximation of the moisture diffusion is planned for the next Reanalysis; however, no change will be made to the current Reanalysis. The operational forecast model was "fixed" by removal of last term in equation 1 (NWS Office of Meteorology, Technical Procedures Bulletin 443, http://www.nws.noaa.gov/om/tpb/443.htm, note equation 1 of the bulletin is incorrect). A post-processing correction may be done. In this case, the some of the excess precipitation associated with this spurious moisture source may be removed. Of course, this correction will be crude as it is impossible to recover the precipitation that would have occurred if a better moisture diffusion were used. Other terms such as precipitable water, 2 meter relative humidity, latent heat release, were also affected by the spurious moisture source/sink but the no bias removal is planned.

As always, the Reanalysis precipitation is based on the model physics and is not based not rain gauge, radar or satellite estimates of precipitation. In general, model parameterizations of clouds and precipitation are often considered to be two of the weakest areas in atmospheric modeling. (This situation may change with high-resolution models which can use "micro-physics".) For people who need the actual precipitation, rain gauge data is the most accurate, followed by radar and then satellite estimates of precipitation. The Party line is that the anomalies in the Reanalysis precipitation are more similar to the observed anomalies than the Reanalysis precipitation is to the total rainfall.