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Sub-Grid Scale Mountain Blocking at NCEP

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1. INTRODUCTION

Atmospheric flow is significantly influenced by orography creating lift and frictional forces. The representation of orography and its influence in numerical weather prediction models, as well as other physical processes, are necessarily divided into the resolvable scales of motion and treated by primitive equations, the remaining sub-grid scales to be treated by parameterization. In terms of large scale NWP models, mountain blocking of wind flow around sub-grid scale orography is a process that retards motion at various model vertical levels near or in the boundary layer. Flow around the mountain encounters larger frictional forces by being in contact with the mountain surfaces for longer time as well as the interaction of the atmospheric environment with vortex shedding which occurs in numerous observations (see the list in Etling, 1989 and O'Connor and Bromwich, 1988) and tank simulations such as Snyder, et. al. (1985). Lott and Miller (1997), incorporated the dividing streamline and mountain blocking in conjunction with sub-grid scale vertically propagating gravity wave parameterization in the context of NWP. The dividing streamline is seen as a source of gravity waves to the atmosphere above and nonlinear sub-grid low-level mountain drag effects below.

Presented in this poster is an augmentation to the gravity wave drag scheme in the global forecast system (GFS) at NCEP which follows the work of Alpert et al (1988, 1996) and Kim and Arakawa (1995). We incorporate the Lott and Miller mountain blocking parameterization scheme with minor changes in the model, including a dividing streamline, where below the flow is expected to go around the mountain, and above the dividing streamline, gravity waves are potentially generated and propagate vertically, depending on the stable stratification.

2. DESCRIPTION

A dividing streamline at some level, $\boldsymbol{h_d}$, as in Snyder et al. (1985) and Etling, (1989), dividing air parcels that go over the mountain from those forced around an obstacle, is used to parametrize mountain blocking effects. As in Lott and Miller (1997) recent studies of model behavior have shown that models underestimate mountain drag. Further, the NWP models generate mountain disturbances which have horizontal scales that are the same as the model truncation. At the time that this Poster is presented a simulation of a 10 km NCEP regional spectral model is shown as a proxy for motion patterns around a barrier represented by the Hawaiian Islands. We do this to get an indication of the effects on the larger scale model with mountain blocking parameterization. In Fig. 1 is a representation of the two types of flow for the mountain blocking paramererization.

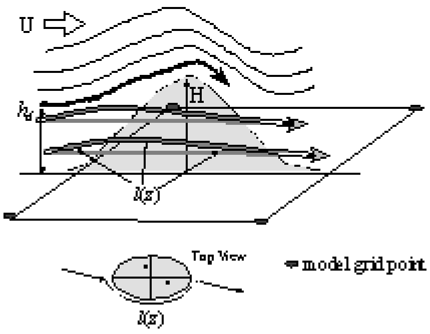

Fig 1. Representation of the low-level flow above and below the dividing stream line.

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The dividing streamline height, of a sub-grid scale obstacle, can be found from comparing the potential and kinetic energies of up stream large scale wind and sub-grid scale air parcel movements. These can be defined by the wind and stability as measured by *N,* the Brunt Vaisala frequency. The dividing streamline height, can be found by solving an integral equation for h_d:

$$\frac{U^2(h_d)}{2} = \int_{h_d}^{H} N^2(z)(H-z)\,dz$$

where ***H*** is the maximum elevation within the sub-grid scale grid box of the actual orography, *h,* form the GTOPO30 dataset from the U.S. Geological Survey. The actual orography is replaced by an equivalent elliptic mountain from the topographic gradient correlation tensor

$$H_{ij} = \overline{\frac{\partial h}{\partial x_i}}\,\overline{\frac{\partial h}{\partial x_j}}$$

and orographic standard deviation, h', used in the gravity wave drag fromulation (Alpert, 1988). The model sub-grid scale orography is represented by four parameters, after Baines and Palmer (1990), h', the standard deviation, and γ, s, Θ, the anisotropy, slope and geographical orientation of the orography form the principal components of H_{ij}, respectively. These parameters will change with changing model resolution.

In each model layer below the dividing streamline a drag from the blocked flow is exerted by the obstacle on the large scale flow and is also calculated as in Lott and Miller (1997):

$$D_d(z) = -\rho C_d l(z) U|U| / 2$$

where ***l(z)*** is the length scale of the effective contact length of the obstacle on the sub grid scale at the height *z* and constant $C_d \approx 1$. The function l(z), following Lott and Miller (1997):

$$l(z) = \max(2 - 1/r, 0) \times$$

Terms (1) (2) (3)

$$\frac{\sigma}{2h'}\sqrt{\left[\frac{h_d - z}{z + h'}\right]}\max(\cos\psi, \gamma\sin\psi)$$

where $r = \dfrac{\cos^2\psi + \gamma\sin^2\psi}{\gamma\cos^2\psi + \sin^2\psi}$

Term (1) relates the the eccentricity parameters, *a,b*, to the sub-grid scale orography parameters,

$$a \approx h'/\sigma,$$
$$a/b \approx \gamma$$

and allows the drag coefficient, C_d to vary with the aspect ratio of the obstacle as seen by the incident flow since it is twice as large for flow normal to an elongated obstacle compared to flow around an isotropic obstacle. Term (2) accounts for the width and summing up a number of contributions of elliptic obstacles, term (3) takes into account the flow direction in one grid region.

3. RESULTS

In addition to a general improvement in northern hemisphere model skill scores using the GFS, at T62, there is a reduction in the number of very poor (busts) 5 day forecasts. The too low bias in geopotential height is somewhat alleviated.

Results have shown the mountain blocking scheme improves forecasts generally in the northern hemisphere with minor degradation in the southern hemisphere. For example, Fig 2, shows a low resolution cycling analysis test of the scheme for the northern hemisphere. Anomaly correlation for the period 14 FEB2003-27FEB2003 are shown, each experiment with its own cycling analysis and he forecasts were compared with their own analysis. The red is the control (operational Alpert , et al., 1996 and Kim and Arakawa, 1995), black is the experiment with mountain blocking and the green line is the operational GFS. At low resolution the mountain blocking appears to be an improvement over the control case. The average scores over the period are .73 for the control, .77 for the mountain blocking and .79 for the operational GFS remain competitive although the small number of separate model runs (14) may not be statistically significant.

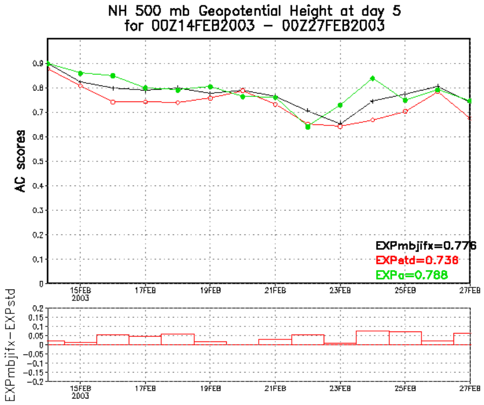

Fig 2. Comparison of 5 day forecasts of anomaly correlation from 20-80 North, mountain blocking experiment in black, control in red and the operational GFS in green.

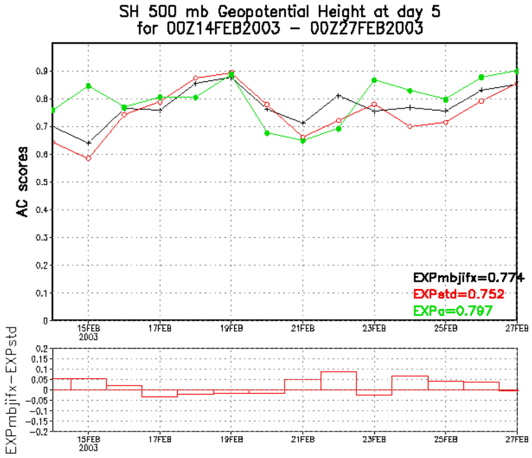

Fig 3. Comparison of 5 day forecasts of anomaly correlation from 20-80 South as in Fig 2.

In addition to an improvement in the skill of the forecast the tropical winds show a small reduction in the bias. In Fig 3, the southern hemisphere skill score is shown. The mountain blocking experiments at low resolution show less improvement but they

4. SUMMARY AND FUTURE WORK

Case studies of the flow around Hawaiian islands with the NCEP 10km regional spectral model (RSM), to simulate atmospheric flow around an obstacle, is used as a laboratory to compare to the larger scale modeled sub-grid scale mountain blocking parameterization at various resolutions. These experiments are underway.

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