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Title: Synoptic/Planetary-Scale Interactions and Blocking Over the North Atlantic Ocean

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Background of the Investigation:

The central theme of this project has been the diagnosis of blocking anticyclogenesis and the corresponding interactions with synoptic-scale circulations. To that end an extensive investigation of the dynamics and energetics of a major blocking anticyclone and two upstream cyclones, all of which occurred over the North Atlantic Ocean and the United States in January 1979, was undertaken. Data for the study were provided by Goddard Laboratory for Atmospheres (GLA) 4° LAT by 5° LON FGGE analyses. The methodology has primarily focused on the diagnosis of circulation forcing mechanisms using the modified forms (referred to as the extended forms) of the height tendency and Zwack-Okossi equations developed by our research group. Calculations use routine second-order finite differencing with boundary layer friction and sensible heating and latent heat release represented as parameterized quantities. Of particular interest are the latent heat release estimates, which combine convectional parameterized values with estimates derived from satellite IR data. The latter were obtained using an algorithm derived by Dr. Franklin R. Robertson of NASA's Marshall Space Flight Center. Results are contained in project reports, theses and publications identified in previous review summaries and reports, and publications listed at the end of this summary.

Significant Accomplishments in the Past Year

1) The cyclone diagnostic study, using the Zwack-Okossi (Z-O) equation, and the application of these results as lower boundary conditions in the solution of the height tendency equation, both of which were summarized in last year's annual review, have been accepted for publication in refereed journals (Lupo, et al., and Uhl et al.). In addition, the cyclone study was presented at a national conference (Lupo and Smith). Included in this paper was one added feature. Using the 950 geostrophic vorticity tendencies diagnosed by the Z-O equation, predictions of the vorticity fields were made by simply extrapolating these tendencies for 6 and 12 hours. This resulted in remarkably good forecasts for both cyclone cases, thus suggesting that reliable Z-O equation diagnoses can provide the basis for useful short-range predictions and for the evaluation of mechanisms responsible for the predicted states.

2) Undergraduate student David Stettner completed an Honors degree thesis in which he examined the importance of vorticity and temperature advection, two terms that often dominate in the Z-O equation, in seven winter extratropical cyclones. He found that for these two quantities positive correlations with cyclone development occurred for vertically-averaged advections, from 850 to 100 mb for vorticity and from 300 to 100 mb for temperature.

3) The comparison of SAT and NOSAT versions of the GLA FGGE analyses was completed (M.S. thesis, Gregory Lamberty). The comparison strategy was to examine correlation coefficients, RMS differences, and standard deviations first for basic variable fields (sea level pressure, temperature, geopotential height, and wind speed) and then for higher-order derived fields (gradient magnitudes, advections, vorticity, and height tendencies). The comparisons were done over two areas, one encompassing North America and the North Atlantic Ocean and a second encompassing only the ocean region.

Mean value statistics show that the SAT field had a low (high) level cold (warm) temperature bias that resulted in lower, low-level heights and higher, upper level heights. The SAT fields also consistently exhibited, at most levels, stronger height gradients and wind speeds and exaggerated the dominance of cyclonic vorticity and warm air advection in the region by producing a cyclonic geostrophic vorticity bias and a warm air advection bias. Other quantities possessed less consistent differences. Also, differences in the analysis means and standard deviations were larger over the ocean area than over the total domain. The basic variables examined exhibited correlation coefficients (CC) in excess of .90 for both domains. These correlations then decreased for successively higher order parameters. The smallest CC's, with values generally near or below .85, occurred for the horizontal advection quantities. While significant differences were often not apparent in the correlation statistics, such differences did emerge more often in the root mean square differences, which were normalized by dividing by the respective mean standard deviations. Except for the sea level pressure, the normalized root mean square differences (NRMSD) were consistently above 20% of their respective mean standard deviations, with higher-order parameters often in excess of 50%. Furthermore, both the CC and NRMSD statistics revealed that for all variables, the analyses compared most poorly over the ocean area.

Focus of Current Research and Plans for Next Year

We are currently engaged in two studies which will carry through next year.

1) To complete our tests of the Z-O equation, M.S. student Melinda Hunter is diagnosing the evolution of a surface anticyclone that occurred in January 1979 over North America. Data for this study are provided by the GLA FGGE analyses.

2) Ph.D. student Anthony Lupo has began a study of ten blocking episodes that occurred over the North Atlantic and Pacific Oceans. The objective is to examine dynamical relationships between block development and upstream cyclones. While the general dynamics of these cases will be examined, focus will be on

(a) the jet streak link between block formation and upstream cyclone activity, as noted in the single case study of Tsou and Smith (1990, Tellus, 42A, 174-193);

(b) the role of northward warm air advection in block formation;

(c) the importance of cooperative participation of several forcing mechanisms during explosive cyclone development;

(d) the significance of the vertical distribution of forcing processes during cyclone/anticyclone development.

For this study, we expect to use GLA 2° LAT by 2.5° LON analyses. In addition, as in previous studies, GOES satellite IR data will be used to augment conventional latent heat release estimates.

Publications

a. Refereed papers

Lupo, A.R., P.J. Smith, and P. Zwack, 1992: A Diagnosis of the Explosive Development of Two Extratropical Cyclones. Monthly Weather Review, in press.

Smith, P.J., and C.-H. Tsou, 1992: Energy Transformations Associated with the Synoptic and Planetary Scales During the Evolution of a Blocking Anticyclone and an Upstream Explosively-Developing Cyclone. Tellus, in press.

Uhl, M.A., P.J. Smith, A.R. Lupo, and P. Zwack, 1992: The Diagnosis of a Pre-Blocking Explosively-Developing Extratropical Cyclone System. Tellus, in press.

b. Conference preprint

Lupo, A.R., and P.J. Smith: A Comparison of Synoptic-Scale Development Characteristics for Over-Water and Over-Land Cases of Explosive Cyclone Development. Preprint volume of the Symposium on Weather Forecasting, January 6-9, 1992, Atlanta, GA, 72-79.

c. M.S. thesis

Lamberty, G.L.: A Study of the Influence of Satellite Data on Goddard Laboratory for Atmospheres' Analyses. M.S. completed August 1991.