*Proposal for CMIP2+ Diagnostic Subproject*

# The Seasonal Cycle and Length-of-Day: Geodetic Monitoring of Climate Change

Steven L. Marcus, Jean O. Dickey, and Richard S. Gross
Jet Propulsion Laboratory, MS 238-332, Pasadena, CA 91109-8099

## Background

The solid Earth exchanges angular momentum with the fluid components of the Earth system (atmosphere, oceans, and the liquid core) over a wide range of time scales, thereby changing its angular momentum and hence the length-of-day (LOD; e.g., Marcus et al., 2001). Core angular momentum dominates decade-to-century scale LOD variability (e.g., Hide and Dickey, 1991), effectively masking the geodetic signature of longer-term natural or anthropogenic changes in atmosphere / ocean circulation (cf. Dickey et al., 1999). On seasonal time scales, however, the core is effectively decoupled (e.g., Hide et al., 2000), and the solid Earth (i.e. crust and mantle), atmosphere and oceans form a closed dynamical system, which approximately conserves angular momentum. Global measurements, in fact, show that the dominant forcing of seasonal LOD comes from zonal winds (cf. Rosen, 1993, and references therein), with contributions from oceanic currents and ocean / atmosphere pressure changes at a lower level. Thus, knowledge of the changing atmospheric wind fields, as provided in the initial CMIP2+ announcement, will enable us to compute the dominant contribution to changes in the seasonal cycle of LOD, and to judge the extent to which variations in this parameter, accurately measured by modern space geodetic techniques, can be used as a diagnostic for anthropogenic effects on the global-scale circulation of the atmosphere. The effect of changes in oceanic currents and mass distribution, although smaller than the atmospheric seasonal signal (Marcus et al., 1998), will also be investigated as these data become available in subsequent announcements.

## Objectives

Results from CMIP1 show that coupled models produce reasonable simulations of the annual signal in surface temperatures, although non-flux-adjusted models may overestimate seasonal amplitudes in the Southern Oceans (Covey et al., 2000). Previous studies of atmospheric angular momentum (AAM) derived from the NCEP / NCAR reanalysis (Kalnay et al., 1996) and archived LOD (Gross, 2001) have confirmed that the seasonal amplitudes of these two quantities are highly correlated, and that both are strongly influenced by interannual climate variability, in particular the ENSO cycle (Gross et al., 1996; 2001). In our proposed sub-project, we will examine the effects of interannual, decadal and secular (i.e. $CO_2$-induced) climate changes on the seasonal variability of the atmosphere as calculated under the CMIP2 scenario, with particular attention to features that influence the strength of its west-to-east superrotation (e.g., meridional temperature gradients, modifications to the amplitude and extent of the Hadley cell, and the response of the tropical easterlies, subtropical jets, and midlatitude westerlies). Our goal is to understand the different sources of variability in the seasonal cycle of AAM, in order to assess the mechanisms by which ongoing changes in the climate may affect future variations in the size of the annual LOD signal. Changes in the semi-annual cycles of LOD and AAM, which appear to be anti-correlated with the corresponding annual signals (cf. Gross et al., 1996; 2001), will also be investigated.

## Methodology

Calculation of axial angular momentum from general circulation model output is straightforward (e.g., Marcus et al., 1994, 1996), and will enable us to monitor and detect changes in the dominant seasonal forcing of LOD using the atmospheric model history tapes from the initial CMIP2+ announcement. The oceans also contribute to seasonal changes in the Earth's rotation rate (Marcus et al., 1998), and these effects will be examined as ocean data from the coupled model runs becomes available in subsequent announcements. Planned releases of history tapes containing daily data will also enable a rigorous study of phase changes in seasonal AAM, and permit a more detailed examination of the semi-annual AAM cycle, related to changes in the tropical circulation (Huang and Sardeshmukh, 2000). This study will build upon the results of previous and ongoing diagnostic subprojects related to AMIP1 and AMIP2 (Hide et al., 1997; Salstein et al., 2002), and will maintain links with the CMIP diagnostic subproject of de Viron et al. (Effect of predicted global warming on the Earth's rotation). In particular, changes in the seasonal LOD cycle will be related to secular LOD trends predicted by the full suite of CMIP2 models (de Viron et al., 2002), in order to better quantify observable geodetic effects which may be associated with the global warming signal.

## References


Covey, C., et al., The seasonal cycle in coupled ocean-atmosphere general circulation models, *Clim. Dyn. 16*, 775-787, 2000.

de Viron, O., V. Dehant, H. Goose, and M. Crucifix, Effect of global warming on the length-of-day, *Geophys. Res. Lett*., in press, 2002.

Dickey, J. O., P. Gegout, and S. L. Marcus, Earth-atmosphere angular momentum exchange and ENSO: The rotational signature of the 1997-98 event, *Geophys. Res. Lett. 26,* 2477-2480, 1999.

Gross, R. S., Combinations of Earth orientation measurements: SPACE2000, COMB2000, and POLE2000, *Jet Propulsion Laboratory Publ. 01-2*, 25 pp., 2001.

Gross, R. S., S. L. Marcus, T. M. Eubanks, J. O. Dickey, and C. L. Keppenne, Detection of an ENSO signal in seasonal length-of-day variations, *Geophys. Res. Lett. 23*, 3373-3376, 1996.

Gross, R. S., S. L. Marcus, and J. O. Dickey, Modulation of the seasonal cycle in length-of-day and atmospheric angular momentum, in *Proceedings of IAG 2001: Vistas for Geodesy in the New Millennium*, in press, Budapest, Hungary, September 2-7, 2001.

Hide, R., and J. O. Dickey, Earth's variable rotation, *Science 253*, 629-637, 1991.

Hide, R., J. O. Dickey, S. L. Marcus, R. D. Rosen, and D. A. Salstein, Atmospheric angular momentum fluctuations during 1979-1988 simulated by global circulation models, *J. Geophys. Res. 102*, 16423-16438, 1997.

Hide, R., D. H. Boggs, and J. O. Dickey, Angular momentum fluctuations within the Earth's liquid core and torsoinal oscillations of the core-mantle system, *Geophys. J. Int. 143*, 777-786, 2000.

Huang, H. P., and P. D. Sardeshmukh, Another look at the annual and semiannual cycles of atmospheric angular momentum, *J. Clim. 13*, 3221-3238, 2000.

Kalnay, E., et al., The NCEP/NCAR 40-year Reanalysis Project, *Bull. Am. Met. Soc. 77*, 437-471, 1996.

Marcus, S. L., M. Ghil, and J. O. Dickey, The extratropical 40-day oscillation in the UCLA General Circulation Model, Part I: Atmospheric angular momentum, *J. Atmos. Sci. 51*, 1431-1466, 1994.

Marcus, S. L., M. Ghil, and J. O. Dickey, The extratropical 40-day oscillation in the UCLA General Circulation Model, Part II: Spatial structure, *J. Atmos. Sci. 53*, 1993-2014, 1996.

Marcus, S. L., Y. Chao, J. O. Dickey, and P. Gegout, Detection and modeling of nontidal oceanic effects on the Earth's rotation rate, *Science 281*, 1656-1659, 1998.

Marcus, S. L., J. O. Dickey, and O. de Viron, Links between intraseasonal (extended MJO) and ENSO timescales: Insights via geodetic and atmospheric analysis, *Geophys. Res. Lett. 28*, 3465-3468, 2001.

Rosen, R. D., The axial momentum balance of Earth and its fluid envelope, *Surv. Geophys. 14*, 1-29, 1993.

Salstein, D. A., R. D. Rosen, J. O. Dickey, and S. L. Marcus, Assessment of atmospheric angular momentum in AMIP-2 simulations, *AMS Symposium*, Orlando, Florida, 2002.