NOAA Climate Test Bed Joint Seminar Series

A Hybrid Lagrangian/Eulerian View of the Atmospheric Mass Circulation

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In this talk, I will present some preliminary results of an on-going diagnostics study of the seasonal cycle, intra-seasonal, and inter-annual variability of global mass circulation, and its relation with the climate variability in various fields, such as temperature, geopotential height, surface pressure, static stability, wind, potential vorticity and E-P flux using daily NCEP-NCAR reanalysis (1979-present). The primary objectives of our diagnostics analysis are (i) to delineate the simultaneous couplings among diabatic heating, meridional mass transport, meridional angular momentum transport, and form drag associated with baroclinically amplifying waves, (ii) to link the extratropical stratosphere-troposphere coupling to the tropical-extratropical coupling, and (iii) to understand climate variability/changes from global atmospheric mass circulation perspective.

The global mass circulation links the tropics to the extratropics and the stratosphere to the troposphere. Such a global mass circulation consists of a (meridionally) broad Hadley cell in the tropics and a succession of wave-driven cells in the extratropics. Collectively, these circulation systems move warm air poleward aloft and cold air equatorward near the surface. The meridional divergence of warm air mass aloft and convergence of cold air below correspond to adiabatic rising motions whereas the convergence of warm air aloft and divergence of cold air below correspond to adiabatic descending motions. The adiabatically rising air mass is diabatically heated in the tropics and flows poleward where it sinks and loses its heat diabatically. The cold air mass comes back to tropics through the equatorward mass transport and diabatic heating. In the extratropics, the mass circulation is carried out mainly by baroclinically amplifying (or westward tilting) Rossby waves. The westward tilting waves are responsible for a net poleward mass transport aloft and equatorward mass transport below. Accompanied with the wave-driven mass circulation are the accumulation of westerly angular momentum aloft and easterly angular momentum below, giving rise to a poleward shifting or intensification of westerly jet aloft. The westward tilting waves also act to transfer westerly angular momentum downward via form drag. The downward transfer of westerly angular momentum weakens the jet aloft and neutralizes the accumulation of easterly angular momentum below, paving the way for the further poleward advancement of warm air mass and equatorward advancement of cold air mass. The downward transfer of westerly momentum is responsible for prevailing surface westerly flow at the extratropics where the westerly angular momentum is removed by topographic form drag and surface friction.

The temporal and spatial variation of the warm air branch is synchronized with the cold air branch in the troposphere below. Because the pole is the destination point of the warm air branch and the beginning point of the cold air branch, the synchronized poleward warm air advancement and equatorward cold air movement would lead to a strong stratosphere-troposphere coupling over the polar region.