Introduction
Some of the most interesting properties of the climate system are emergent (e.g., sensitivity to external forcings, predictability at the regional scale). By emergent we mean a property that arises from complex interactions between, for instance, dynamics, radiation, cloud formation, and surface fluxes, rather than being a function of a single physical process. Most of the traditional global-scale diagnostics used for climate model evaluation are emergent. Emergence therefore complicates our ability to attribute a systematic model-observation discrepancy to a specific piece of code or model assumption. Indeed, model developers are often left to their experience and trial-and-error when addressing these discrepancies. Unsurprisingly, some notable discrepancies have persisted across multiple generations of climate model development (e.g., the double ITCZ problem). Even with the availability of large archives of coupled GCM output (e.g., CMIP5) and complementary observations to go with them (e.g., Obs4MIP) our ability to address certain questions is limited.

Often these approaches can take the form of a Lagrangian conditional average, which when done correctly, merges a case-by-case perspective of single events with the statistical approach required by climatologists. In this way process-based diagnostics (PBDs) broaden the pool of traditional climate model validation methods.

Use Case - Extratropical Cyclones
Extra-tropical cyclones make excellent candidates for PBDs because: 1) Cyclones are specific, identifiable and well understood phenomena. 2) Cyclone activity shapes the distribution many quantities on both climatic and weather scales (e.g., cloud, temperature, wind). 3) Cyclones have interesting internal and external variability. 4) While today's climate models can in principle resolve basic cyclone features, they are less able to represent smaller key features (e.g., fronts), and questions remain about their ability to capture more subtle changes in cyclone behavior and structure (e.g., variations between seasons, hemispheres). Indeed, mid-latitude cyclone clouds are a key source of inter-model difference in climate sensitivity (Williams and Twifo-Glott, 2007).

An ongoing project led by one of us, “The MAP Climatology of Mid-latitude Storminess” or MCMS, is designed to address just these sorts of questions (see Fig. 2, http://gco-dime.giss.nasa.gov/mcms/mcms.html).

Here we compare the SLP fields from the NCEP Reanalysis II (NRA2) and a climate model (GISS-E2-R) run with complementary historical boundary conditions for the years 1950-2010 (21 years). Fig. 2 depicts the traditional approach of examining the mean fields, which in this case are generally similar except that the GISS result is systematically lower pressure especially over the ocean.

References