Instructions for ENSO Moist Static Energy Process-oriented diagnostics (POD)

This POD package consists of four levels. With a focus on identifying leading processes that determine ENSO-related precipitation anomalies, main module of the POD estimates vertically integrated moist static energy (MSE) budget and its variance diagnostics. In that pursuit, POD is applied to monthly data (climate model or reanalysis products), and budget terms are estimated for “composite” El Niño or La Nina events (either for monthly or seasonal anomalies). To estimate MSE budget, along with surface and radiation fluxes, 3-dimensional atmospheric variables are required. Hence, ERA-Interim is “considered” as “observations” here, and diagnostics obtained from ERA-Interim are used for model validation. In this general README document, brief descriptions of the four levels of the POD are provided but detailed information (e.g., input variables) is provided at each level.

Level 1 – Basic ENSO diagnostics

Composites, regression and correlation etc: Reference index (e.g., Nino3.4 SST)

- Monthly and seasonal averages
- 2 Year life cycle of ENSO: Year(0) and Year(1)
  Year (0) = developing phase and Year (1) = decaying phase

To select Level 1 diagnostics, set: COMP = 1 in the mdtf.py file.
Note: Level 1 diagnostics is required to perform Level 2 diagnostics

Level 2 – MSE (Moist Static Energy) budget analysis (for composite ENSO)

Vertically integrated MSE and its budget are estimated here:

MSE is defined as: $h = C_P T + gz + Lq$

where C_p is specific heat at constant pressure, *T* is temperature, *g* is the gravitational acceleration, *z* is geopotential height, *L* is latent heat of vaporization, and *q* is specific humidity.

The vertically integrated MSE tendency budget is approximately given by

$$\left\langle \frac{\partial h}{\partial t} \right\rangle = -\langle V \cdot \nabla h \rangle - \left\langle \omega \frac{\partial h}{\partial p} \right\rangle + LH + SH + \langle LW \rangle + \langle SW \rangle + R$$

where *SH* is the sensible heat flux, *LH* is latent heat flux, $\langle LW \rangle$ and $\langle SW \rangle$ are net column longwave and shortwave heating rates. $-\langle V \cdot \nabla h \rangle$ and $-\left\langle \omega \frac{\partial h}{\partial p} \right\rangle$ are horizontal and vertical MSE advection terms respectively. *R* is the residual term.

At seasonal time scales considered here, the tendency term $\left\langle \frac{\partial h}{\partial t} \right\rangle \approx 0$.

To select Level 2 diagnostics, set MSE = 1 in the mdtf.py file.

Note: Level 2 requires pre-calculated results (e.g., composites) from Level 1.

Level 3 – MSE variance diagnostics (for composite ENSO)

Vertically integrated MSE variance is estimated here. Outputs are co-variances scaled by MSE variance and given by:

$$s_x = \frac{\left\| x \cdot \langle h \rangle \right\|}{\left\| \langle h \rangle^2 \right\|}$$

where x is a given component of MSE budget, and *h* is MSE.

To select Level 3 diagnostics, set MSE_VAR = 1 in the mdtf.py file.

Level 3 requires pre-calculated results from Level 1 and Level 2.

Level 4 – MSE scatter plots (Metrics).

At this level, results from Level 2 (CMIP-era models) are condensed into scatter plots. Specifically, estimates of each MSE budget term (e.g., $-\left\langle \omega \frac{\partial h}{\partial p} \right\rangle$) is plotted against precipitation. In these plots, also shown are inter-model correlations and best-fit regression line.

To select Level 4 diagnostics, set SCATTER = 1 in the mdtf.py file.

Level 4 requires pre-calculated results from Level 1 and Level 2.

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References:

Annamalai, H., J. Hafner, A. Kumar, and H. Wang, 2014: A Framework for Dynamical Seasonal Prediction of Precipitation over the Pacific Islands. *J. Climate*, **27** (9), 3272-3297, doi:10.1175/JCLI-D-13-00379.1.

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