<u>Model-Data Comparisons for Climate Variability</u>

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This communication is to provide input to the WGOMD regarding indices and metrics that could be used to evaluate the performance of ocean models in reproducing observed climate variability. We note that GSOP will be assembling an extensive set of measures suitable for testing the ability of models to reproduce climatological conditions as well as variability about the climatology. We limit the scope of the present note consistent with the following points.

1) We are concerned with measures of the low-frequency, large-scale variability since these are most relevant to climate.
2) We are interested in measures that can be directly compared with observational estimates that can be derived from available historical data sets.
3) We are interested in quantities that are not terribly sensitive to the details of how they are calculated. (Otherwise the model-data comparison will likely be useless because the data won't resolve the details often enough or because the algorithm will be too cumbersome to use.)

Based on the above, at least initially, our proposed comparisons involve integral measures of variability. Thus, we seek a set of ***<u>indices</u>*** that represent large-scale, low-frequency variability in the ocean. The set of ***<u>metrics</u>*** with which we propose to judge the success of models are simply defined in terms of these indices as:

1. $\dfrac{\overline{\left(\left(I_n^o-\bar{I}_n^o\right)-\left(I_n^m-\bar{I}_n^m\right)\right)^2}}{\overline{\left(I_n^o-\bar{I}_n^o\right)^2}}$, a "noise-to-signal" ratio,
2. $\dfrac{\overline{\left(\left(I_n^o-\bar{I}_n^o\right)\left(I_n^m-\bar{I}_n^m\right)\right)}}{\left[\overline{\left(I_n^o-\bar{I}_n^o\right)^2}\;\overline{\left(I_n^o-\bar{I}_n^o\right)^2}\right]^{1/2}}$, the correlation between modelled and observed variability,
3. $\dfrac{\overline{\left(I_n^m-\bar{I}_n^m\right)^2}}{\overline{\left(I_n^o-\bar{I}_n^o\right)^2}}$, the ratio of variances,

for n=1…# of indices. Note that the correlation and ratio of variance together will show if the model variability is strongly correlated with observations but with an incorrect gain; the first measure above won't distinguish this case. If the annual cycle is strong for any particular series, it will be necessary to filter this component to obtain a meaningful comparison of lower frequency variability. Care will be required to avoid aliasing problems.

We offer the following as possible indices (with associated metrics).

a. Florida Strait transports of heat, salt and mass (the interannual signal back to 1982 is on the AOML website)

b. Baroclinic transport through Drake Passage, referenced to the bottom. We have a 30 year time series now and SO winds appear to be increasing. (Contact Harry Bryden for additional information.)
c. Variation in mode waters (LS water, 18 degree water, Greenland Sea deep water, etc; need robust and efficient algorithms). Probably best to focus on major water masses observed at Ocean Weather Stations. The upstream "head" for deep Greenland Sea waters overflowing the Iceland-Faroe-Scotland sills is a particularly important example in this class.
d. Curry and McCartney baroclinic transport index (store the integrated potential energy anomalies for each sight and for heat and salt contributions separately)
e. Sea ice extent (area north of the ice margin). For the satellite era (1978 onward), the best source is the National Snow and Ice Data Center in Boulder, http://nsidc.org/noaa/. Contacts there are Julienne Stroeve, Florence Fetterer, and Mark Serreze. They can put you in touch with the appropriate databases, which originated with NASA. For the longer historical period, e.g., back to 1900, a good contact is Nick Rayner at the Hadley Centre in the U.K. (she is the keeper of the sea ice portion of HadISST, a gridded dataset designed for modelers -- and for the type of application you have in mind.
f. Changes in annual or decadal mean heat and freshwater contents as a function of latitude (above and below 1000m). This may only be possible to estimate between the 60's and the 90's. (Currie, Dickson and Yashayaev, 2003)
g. Integral of tracer concentration as a function of latitude and time (compare basin wide CFC-11,12 inventories and their distributions.) Data available from WOCE DACs and further information can be found in Rhein et al. 97 JPO, Kieke et al. 05, JPO (in press).

Other possibilities of shorter duration include:

h. MOVE transports of heat, salt and mass
i. RAPID transports of heat, salt and mass
j. ASOF transports of heat, salt and mass
k. A measure of Gulf Stream position [perhaps the area north of Cape Hatteras and west of the tail of the Bank that lies between the 1000m isobath and the position of maximum annual mean density gradient at 300m]
l. Altimetric measurements of sea surface height from TOPOEX/POSEIDON and Jason1 1992 - present; metric could be spatial averages over predefined regions, or time series of EOF amplitudes. (Global gridded fields of altimetric sea surface height at 10-day intervals are freely available from e.g. French Aviso system [http://www.jason.oceanobs.com/html/donnees/welcome_uk.html].)