Model uncertainty in representing midlatitude atmospheric synoptic variability: a spectral perspective

Alessandro Dell'Aquila [1], Susanna Corti [2]
[1] ENEA, SSPT-MET-CLIM, Italy
[2] CNR, ISAC, Italy
alessandro.dellaquila@enea.it
s.corti@isac.cnr.it

- We present here a **process oriented metric** to evaluate global datasets in terms of their capability in reproducing the midlatitude atmospheric synoptic variability. In particular our analysis focuses on high and low frequency atmospheric variability as represented by propagating and standing waves defined following the spatio-temporal spectral decomposition introduced by Hayashi

- We apply this process oriented metric and ad hoc indices introduced to validate the **ERA-CLIM simulations** and, at the same time, to evaluate signals of multi-decadal variability for planetary and baroclinic waves. The results are compared with a series of different reanalysis products, which assimilate atmospheric observations with increased diversity: from surface-only to surface, upper air and satellite observations **(ERA20C, NOAA 20th Reanalysis, NCEP, Era-Interim, ERA40 Reanalysis…)**

Hayashi Spectra

We follow the Fourier space-time decomposition introduced by Hayashi (1971,1979), assuming complete coherence between the eastward and westward components of standing waves and attributing the incoherent part of the spectrum to real travelling waves. Hayashi spectra allow separation between **travelling vs standing waves** of the 1D+1D field (500 hPa: latitudinal belt 30–75N)

$$Z(\lambda,t) = Z_0(t) + \sum_{k=1}^{\infty}[C_{k_j}(t)cos(k_j\lambda) + S_{k_j}(t)sin(k_j\lambda)]$$

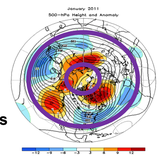
Pω and ***Qω*** are, respectively, the power and the quadrature spectra of the longitude (k) and the time (t) dependent 500 hPa ***Z(λ, t)*** expressed in terms of the zonal Fourier harmonics

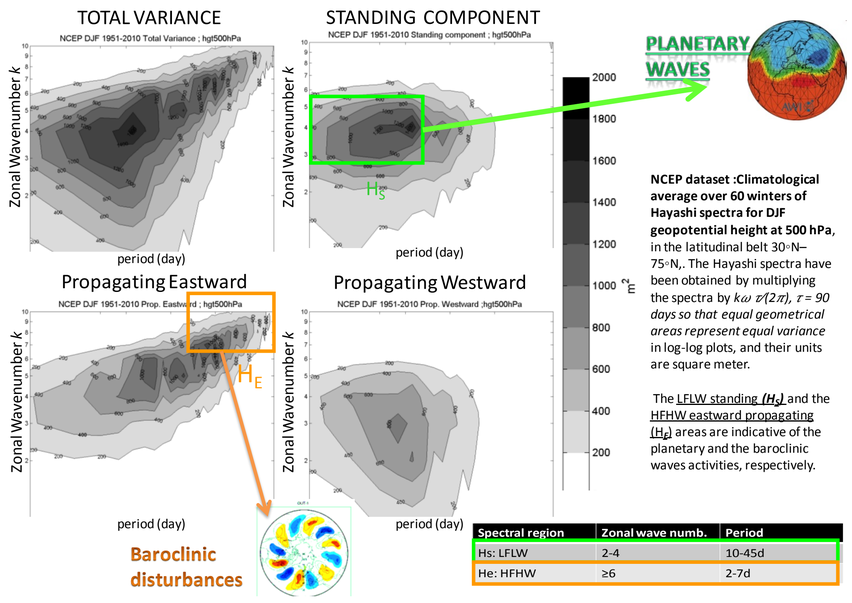
$$E_E(k,\omega) = \tfrac{1}{4}\{P_\omega(C_k) + P_\omega(S_k)\} + \tfrac{1}{2}Q_\omega(C_k,S_k)$$ **Eastward Propagating waves**

$$E_W(k,\omega) = \tfrac{1}{4}\{P_\omega(C_k) + P_\omega(S_k)\} - \tfrac{1}{2}Q_\omega(C_k,S_k)$$ **Westward Propagating waves**

$$E_T(k,\omega) = \tfrac{1}{2}(P_\omega(C_k) + P_\omega(S_k))$$ **Total variance**

$$E_S(k,\omega) = E_T(k,\omega) - |Q(k,\omega)|$$ **Standing waves**





NCEP dataset :Climatological average over 60 winters of Hayashi spectra for DJF geopotential height at 500 hPa, in the latitudinal belt 30◦N–75◦N,. The Hayashi spectra have been obtained by multiplying the spectra by $k\omega\, v/(2\pi)$, $\tau = 90$ *days so that equal geometrical areas represent equal variance* in log-log plots, and their units are square meter.

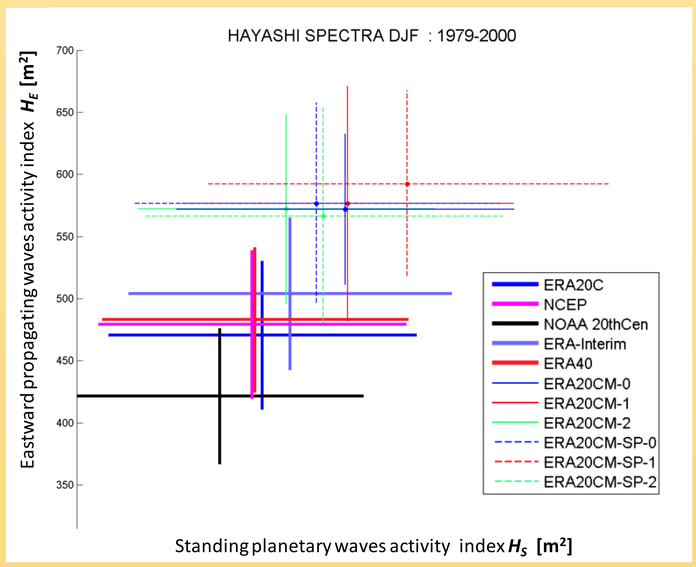
The LFLW standing ***(H_S)*** and the HFHW eastward propagating (H_E) areas are indicative of the planetary and the baroclinic waves activities, respectively.

Spectral region	Zonal wave numb.	Period
Hs: LFLW	2-4	10-45d
He: HFHW	≥6	2-7d

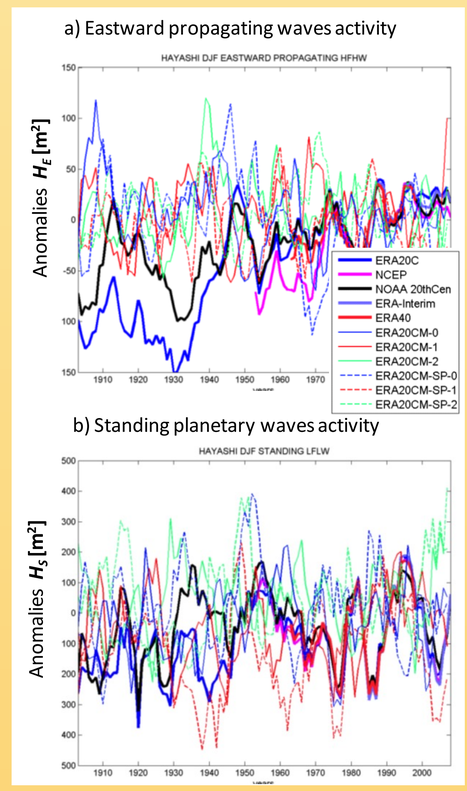
- **Reanalysis Datasets**
  - ✓ **ERA20C** deterministic reanalysis 1901-2010 (*Poli et al 2015)*
  - ✓ **NOAA 20th Century Reanalysis**: 1901-2010: Ensemble mean (*Compo et al 2012)*
  - ✓ **NCEP Reanalysis** : 1951-2010
  - ✓ **ERA-Interim**: 1979-2010
  - ✓ **ERA-40**: 1961-2000

- **ERA-CLIM AMIP runs** *(Hersbach et al 2014)*
  - ✓ **ERA20CM** (members 0, 1, 2): 1901-2010
  - ✓ **ERA20CM-SP,** members 0, 1, 2 with Stochastic Physics: 1901-2010

Spectral process-oriented metrics to measure synoptic waves activity



Scatterplot of index of eastward propagating waves activity H_E (y-axis), for versus the index of the planetary standing waves activity H_S for (x-axis) computed for the Z 500 hPa DJF data averaged in the latitudinal belt 30◦N–75◦N for the overlapping period 1979-2001. The bars stand for +/- 1 temporal standard deviation. The thick lines are for the Reanalysis datasets. The thin solid lines are for the ERA20CM runs while the dashed lines for the corresponding ERA20CM-SP runs with the effects of Stochastic Physics included



1901-2010 Time series of the anomalies (with respect to 1979-2001 period) of index of eastward propagating waves activity H_E (a) and index of the planetary standing waves activity H_S (b), in the latitudinal belt 30◦N–75◦N, by the ERA20C, NCEP, NOAA 20th CEN, ERA-Interim, ERA40, and ERA-CLIM ERA20CM, ERA20CM-SP . We apply a 5-years running mean

DATASETS	TREND H_E (m2/yr)
ERA20C	**1.161**
NCEP	**2.734**
NOAA 20thCen	**0.991**
ERA40	**1.648**
ERA20CM-0	*0.215*
ERA20CM-1	-0.768
ERA20CM-2	*-0.094*
ERA20CM-SP-0	**2.584**
ERA20CM-SP-1	*0.199*
ERA20CM-SP-2	-1.482

Trend for baroclinic activity index H_E in reanalysis datasets and ERA-CLIM runs: in bolds are the statistical significant trend (90% Mann Kendall test) In italics the non significant trends, the shaded area are for negative significant trends (calculated over 1961-2001 DJF period)

- In the second part of the century all the reanalysis datasets exhibit a good agreement in the representation of synoptic atmospheric variability

- **A positive trend in the baroclinic activity index H_E is present in all the reanalysis products over the second part of the century , not present in most of the ERA-CLIM AMIP simulations**

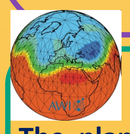
- In the first part of XX century (up to 40s) a clear suppression of high frequency variability is apparent in ERA20C and, to a lesser extent, in the ensembles mean of NOAA 20th Cent. Rean.

- **The same kind of signal, but weaker, is found for the low frequency variability in the 40s**

- High and low frequency variability in ERA-CLIM AMIP simulations do not show a similar suppression of variability during the integrations.

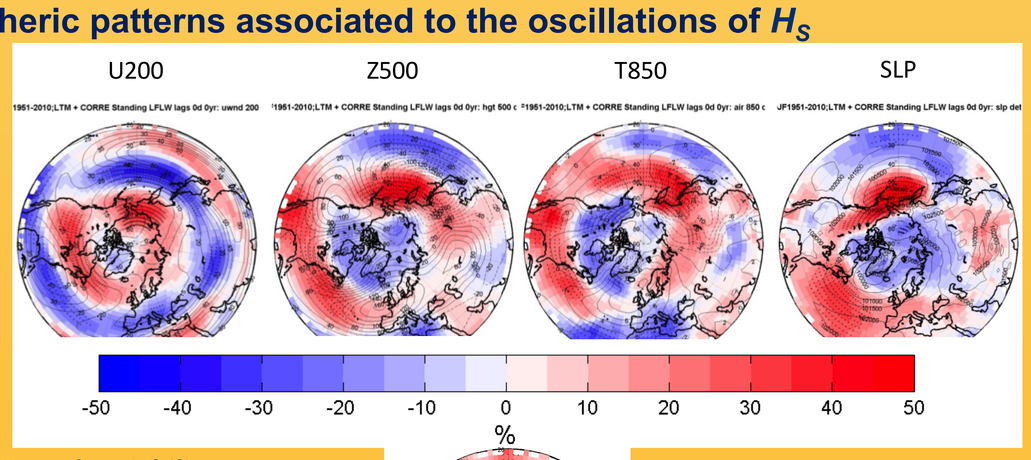
- **The ERA-CLIM AMIP simulations show a general overestimation of synoptic variance**

Atmospheric patterns associated to the oscillations of H_S



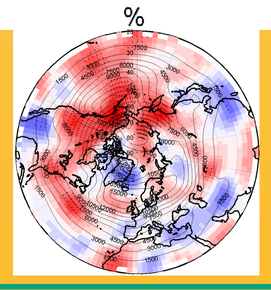
The planetary wave activity index H_S and mean state associated

Correlation between the index of the planetary standing waves activity Hs and mean state of U200, Z500, T850 and SLP for NCEP Reanalysis over the 1951-2010 DJF period. The contour lines are for the corresponding long term mean. In the tippled areas the correlations are statistically significant at 90% (Pearson coefficients)



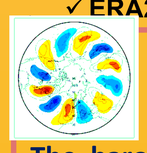
The planetary wave activity index H_S and variability associated

Correlation between the index of the planetary standing waves activity *Hs* and band pass 10-45 days variance of Z500 for NCEP Reanalysis over the 1951-2010 DJF period. The contour lines are for the corresponding long term mean. In the tippled areas the correlations are statistically significant at 90% (Pearson coefficients)



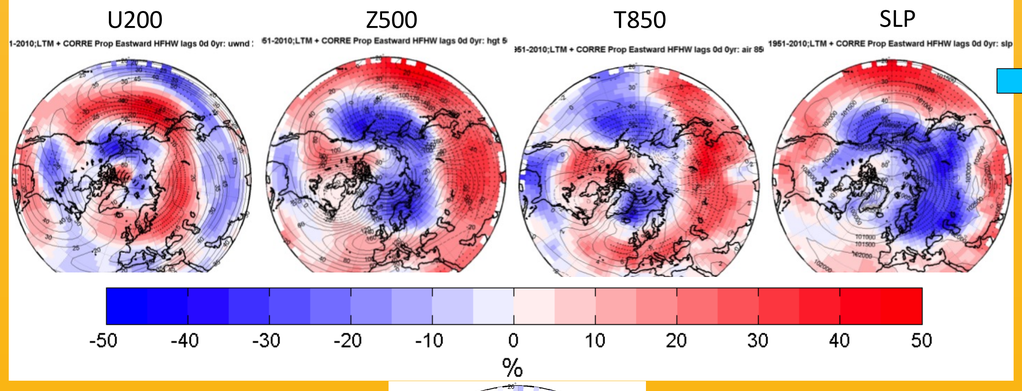
NCEP Reanalysis

Atmospheric patterns associated to the oscillations of H_E



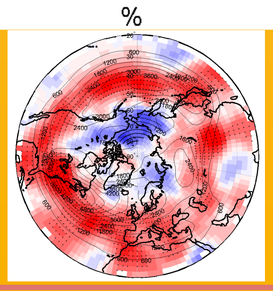
The baroclinic waves activity index H_E and mean state

Correlation between the index of the baroclinic waves activity H_E and mean state of U200, Z500, T850 and SLP for NCEP Reanalysis over the 1951-2010 DJF period. The contour lines are for the corresponding long term mean. In the tippled areas the correlations are statistically significant at 90% (Pearson coefficients)

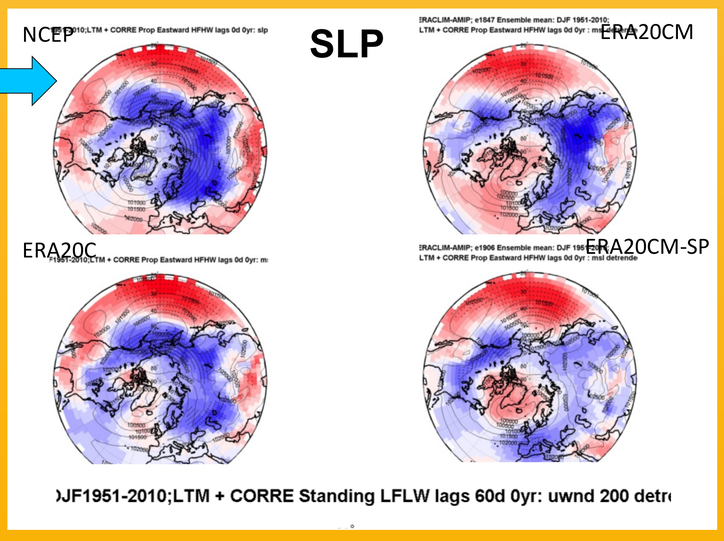


The baroclinic waves activity index H_E and variability associated

Correlation between the index of the planetary standing waves activity HE and band pass 2-7 days variance of Z500 for NCEP Reanalysis over the 1951-2010 DJF period. The contour lines are for the corresponding long term mean. In the tippled areas the correlations are statistically significant at 90% (Pearson coefficients)



NCEP Reanalysis



Correlation between the index of the baroclinic waves activity H_E and mean state of SLP for different datasets over the 1951-2010 DJF period.

The ERA-CLIM simulations show discrepancies in the representation of patterns associated to baroclinic activity mostly over North Atlantic sector

New publications related to this activity

•*Di Biagio V., S. Calmanti, A. Dell'Aquila, P M. Ruti. (2014) Northern Hemisphere winter midlatitude atmospheric variability in CMIP5 models. GRL 41:4, 1277-1282.*

•*Dell'Aquila, A., Corti, S. Weisheimer, A. Hersbach, H., Peubey, C., Simmons A., Poli, P., Berrisford P., Dee, D., (2016) Benchmarking Northern Hemisphere midlatitude atmospheric synoptic variability in centennial reanalysis and numerical simulations .In revision on GRL*