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Evaluating pre-1979 polar cap variability

1. Motivation

The stratospheric polar vortices in both hemispheres exhibit considerable intra-seasonal and inter-annual variability. Individual events such as sudden stratospheric warmings also exhibit considerable event-to-event differences. Our understanding of the dynamics of this variability, and our ability to validate models, depends strongly on our ability to characterize the observed variability. However, due to the limited observational record, climatologies and composites of this variability is still significantly affected by issues of sampling. The time period between 1958 and 1979 represents a significant fraction of the observational record, but the quality of reanalyses in this period is not clear given the absence of global satellite observations.

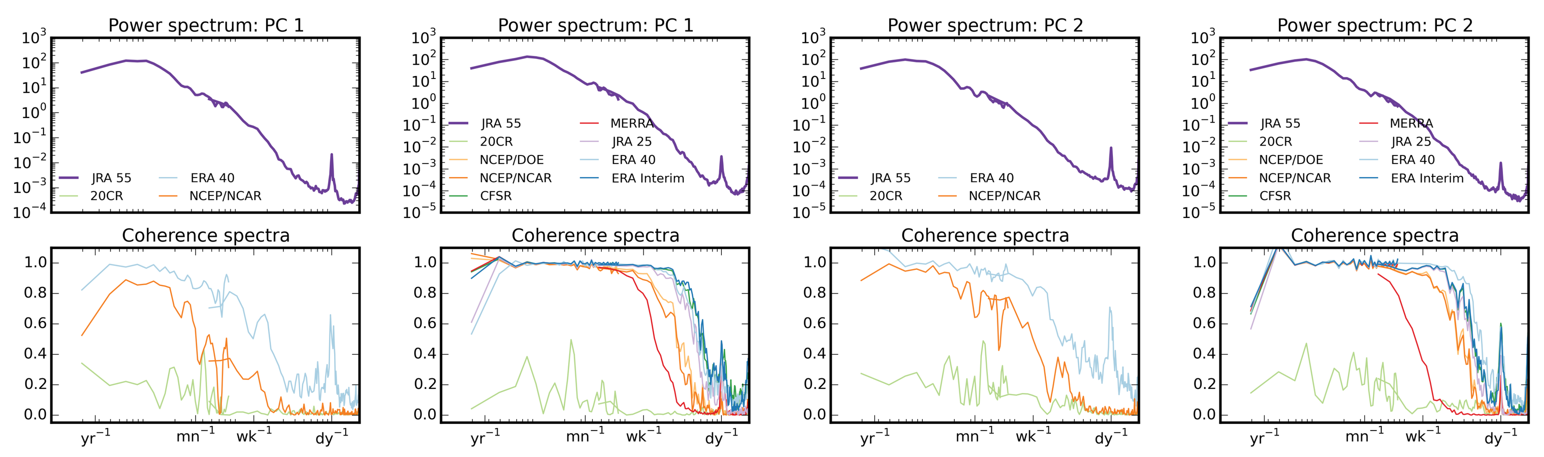
The goal of this work is to evaluate variability relevant to stratosphere-troposphere coupling during this time period by comparing the consistency between reanalyses of a number of quantities. If the spread between reanalysis is comparable during the pre-satellite era to the spread after satellite observations begin to be assimilated, we infer that the model state is determined significantly by observations and can therefore be considered more reliable.

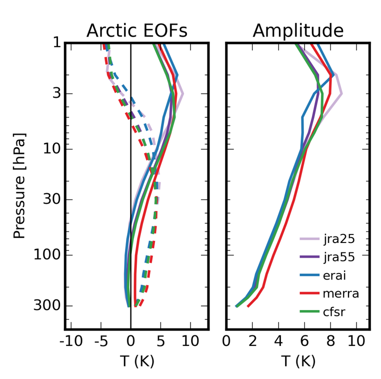
2. Method and Conclusions

Of the nine reanalyses considered here, only four (JRA 55, ERA 40, NCEP/NCAR, 20CR) cover the period from 1958-1979. This time period is compared with the period 1979-2010, except in the case of ERA 40 which ends in 2002. When necessary, JRA 55 is used as a reference reanalysis. Time series characterizing the large-scale variability of the vortex are correlated between each reanalysis for both hemispheres. Some tropospheric quantities are also considered. Coherence spectra are also computed.

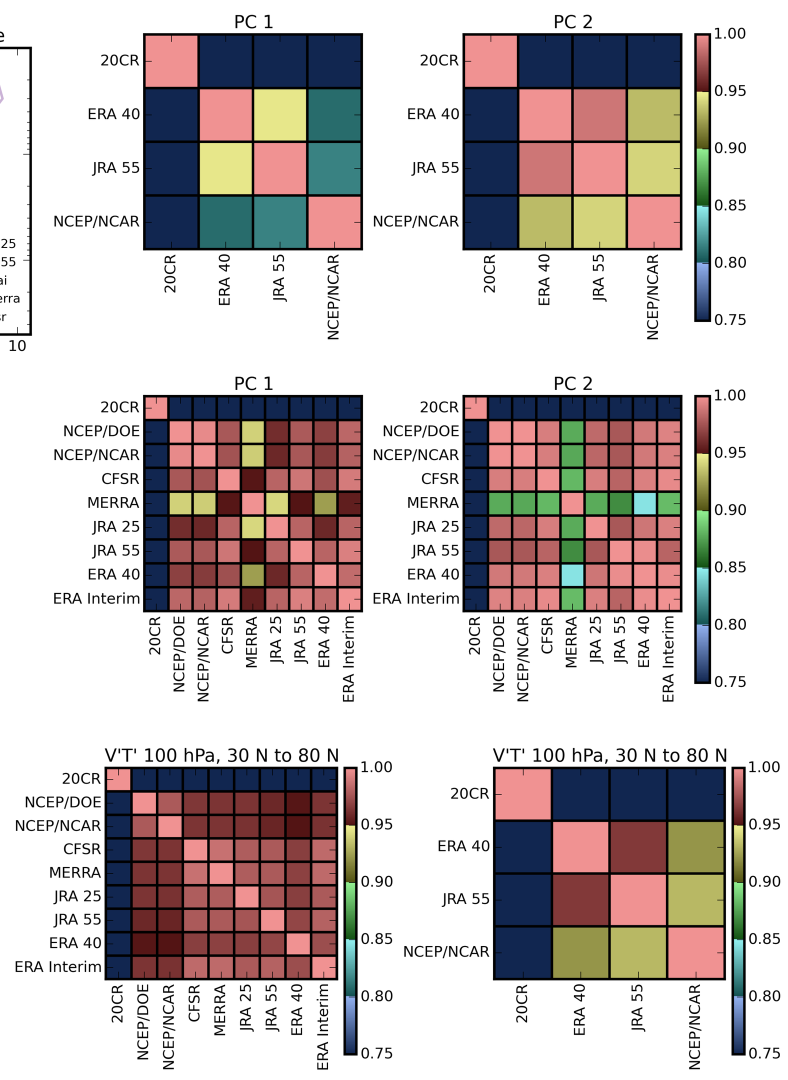
As might be expected, the Northern Hemisphere quantities are significantly better constrained than their Southern Hemisphere counterparts. The 20CR reanalysis captures some aspects of the tropospheric flow but its stratospheric representation is essentially uncorrelated with other reanlayses. ERA 40 and JRA 55 are better correlated with each other in the pre-satellite era than they are with NCEP/NCAR. Variables that capture the basic, zonal mean flow are better constrained in the pre-satellite era than are the fluxes that drive the variabiliity, suggesting that while there is likely reliable information in the pre-satellite era describing the large-scale variability itself (at least in the Arctic), the fluxes which drive the flow are unlikely to be reliable.

3. Arctic Polar Vortex



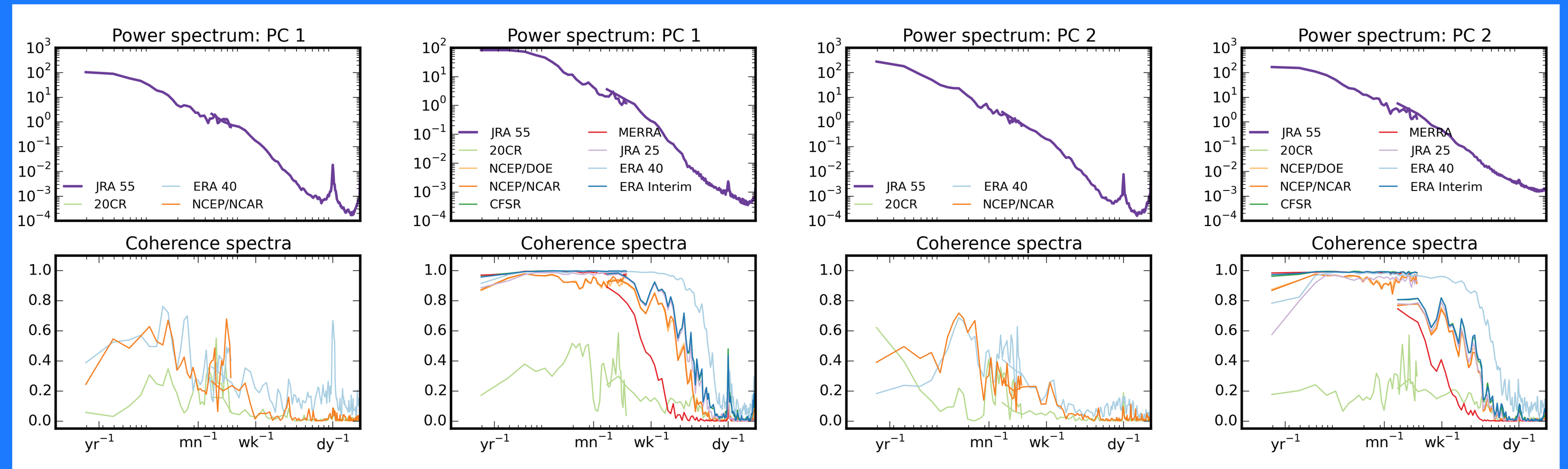


The large-scale variability of the vortex is described here by the first two EOFs of polar cap averaged temperatures, sometimes used to describe the Polar-night Jet Oscillation [1,2]. These capture roughly 85% of the total variance of the anomalous temperatures, including most of the stratospheric annular-mode-type variability. PC time series for each reanalysis are obtained by projecting temperature anomalies computed from the respective reanalyses (using their own climatologies) onto the EOFs computed from JRA55 over the period 1979-2001.

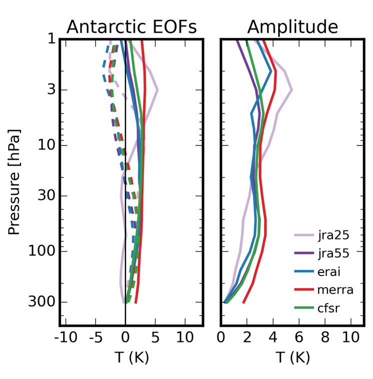


Correlations are generally very close to one in the satellite era though MERRA appears to be a moderate outlier, and as mentioned above, 20CR does not capture the correct stratospheric variability at all. The coherence is generally weaker at periods less than a week, though the total power at these timescales is lower than at inter-annual timescales. Meridional heat-fluxes (vertical EP-fluxes) are also highly correlated in the satellite era, and this high correlation is largely still present in the pre-satellite era between JRA 55 and ERA 40.

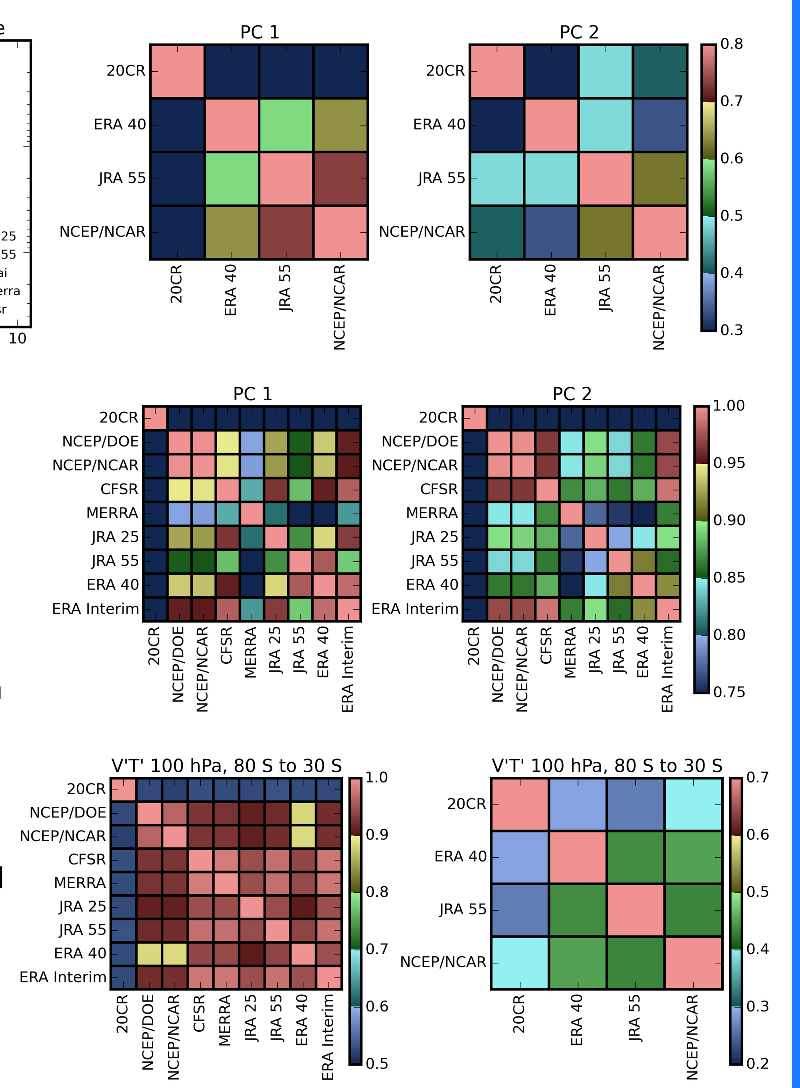
4. Antarctic Polar Vortex



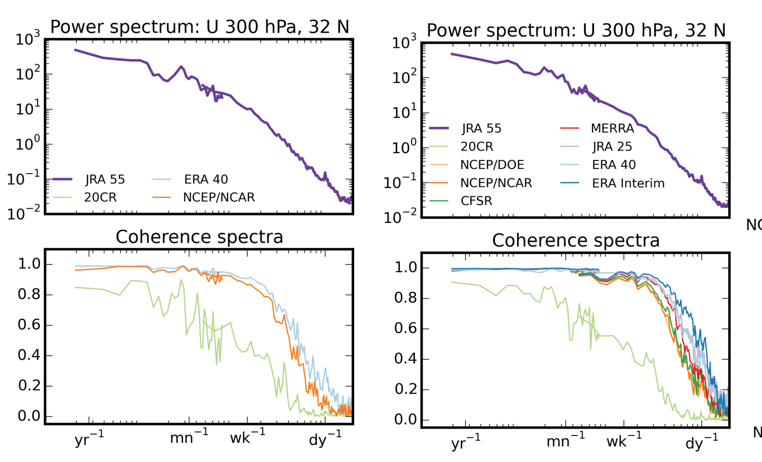
EOFs defined in the same fashion over the south polar region are used to describe Antarctic vortex variability [1]. They capture roughly 70% of the total variance of the temperature anomalies, though the EOF structures are less consistent across reanalyses. Time series are computed as in the Arctic case.



Correlations are generally above 80% between reanalyses in the satellite era, although MERRA again appears to show somewhat weaker correlations with other reanalyses in these metrics. As with the Arctic, 20CR does not capture the correct stratospheric variability at all. The coherence is generally weaker than the Arctic case at periods less than a month, with higher correlations at longer timescales. Correlations fall off sharply in the pre-satellite era. The meridional heat-fluxes gneerally show better correlations in the satellite era than those of the PC timeseries, though they are still weaker than the NH case (note the different colorbar). Somewhat weaker correlations are seen between ERA40 and the NCEP reanalyses, though both are less correlated with more recent reanalyses. Heat-fluxes in the pre-satellite era show much weaker correlations.

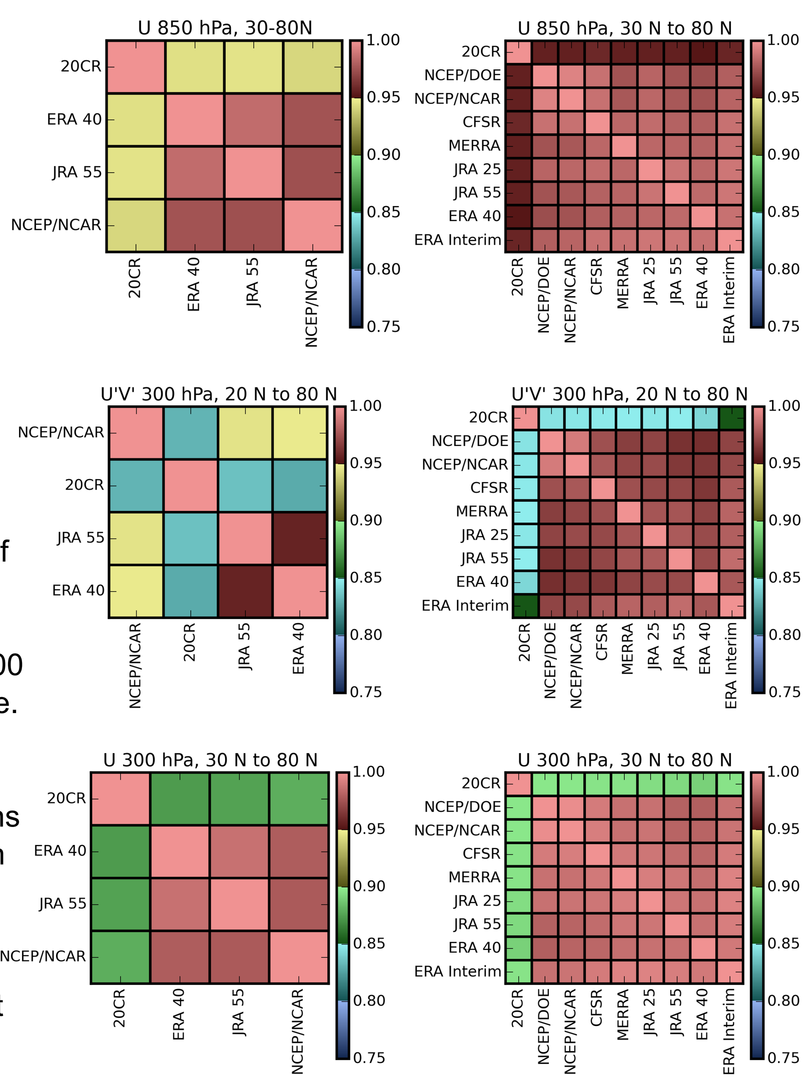


5. NH Troposphere

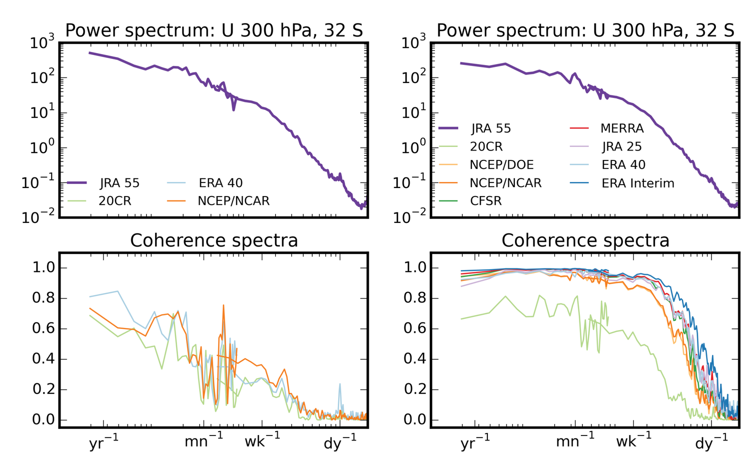


Upper tropospheric winds in the subtropics (roughly in the low-latitude maximum of the annular mode) are used as a time-series representing some component of the tropospheric flow of interest to strat-trop coupling. Correlations are also computed for zonal mean zonal wind over a broad range of latitudes at 850 hPa and 300 hPa, as are momentum fluxes in the upper troposphere. In general correlations in the satellite era are very high (above 95%) for all quantities and all reanalyses with the exception of 20CR which shows weaker correlations for the upper tropospheric mean winds and momentum fluxes, a deficiency which arises at lower frequencies.

The pre-satellite era shows correlations that are only somewhat degrated for the zonal fields, and somewhat more weakened for the momentum fluxes, but remain above 95% at least for ERA 40 and JRA 55.

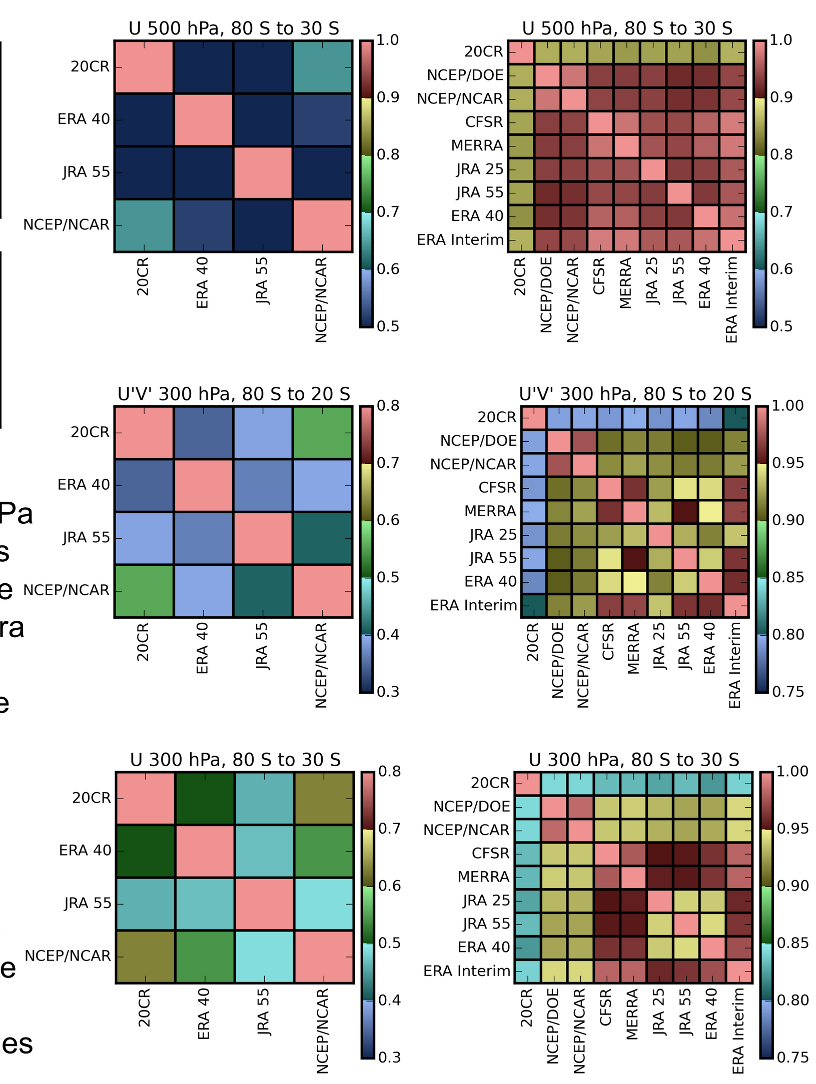


6. SH Troposphere



Similar time series are used to characterize the southern hemisphere tropospheric flow, though 500 hPa winds are considered instead of 850 hPa. Correlations in all cases are weaker than their northern hemisphere counterparts, though correlations during the satelite era are largely above 90%. 20CR in particular shows singificantly weaker correlations in all fields than in the northern hemisphere. The coherence spectra for the upper tropospheric winds during the satelite era looks very similar to the northern hemisphere case as well.

The pre-satellite era however shows significantly degraded correlations between all reanalyses, though as in other cases, JRA 55 and ERA 40 tend to be more closely correlated than other reanalyses. The degradation of the correlations is seen at all frequencies in the coherence spectra.



[1] Y. Kuroda and K. Kodera (2001) J. Geophys. Res., 106:20703-20713.
[2] P. Hitchcock, T. G. Shepherd and G. L. Manney (2013) J. Clim., 26:2096-2116.

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