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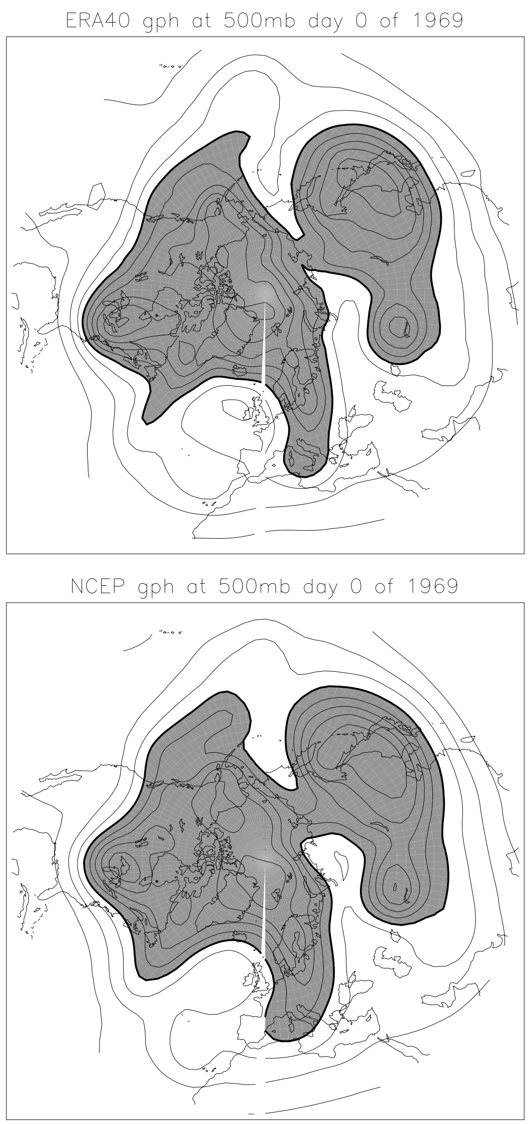
Vorticity Area Index: comparing ERA40 values with NCEP

Peter Thejll



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Contents

1. Dansk resumé

Værdier for vorticity area index (VAI) udregnet på grundlag af re-analysedata fra NCEP/NCAR, i USA, sammenlignes med VAI data udregnet på grundlag af den europæiske re-analyse ERA40. VAI anvendes i analysen af solens mulige indvirkning på dannelsen af lavtryk. De udledte værdier for VAI kan bruges i evalueringen af eksterne forcerinsgmekanismer såsom Brian Tinsley's hypotese om det elektriske kredsløbs rolle i de mikrofysiske processer omkring skydannelse [Tinsley, 1996], [Zhou and Tinsley, 2007], [Burns et al., 2008], [Kniveton et al., 2008]. I sammenligningen mellem nye og gamle datasæt for VAI vises der blandt andet at værdierne fra ERA40 udviser betydelige forskelle på dag-til-dag niveauet, medens årstidscyklus gengives omtrent som før. På den sydlige halvkugle ses en klar ændring i datasættet for VAI i årene omkring indførelsen af satellit-data i ERA40 reanalysen, hvilket bør have en konsekvens i brugen af disse data til forcerings-analyser.

2. Abstract

We compare vorticity area index (VAI) values based on data from the NCEP/NCAR reanalysis with VAI data based on data from the ERA40 re-analysis. VAI is used in the analysis of external forcing by the Sun of low-pressure formation and evolution processes. The presented values of VAI can be used in evaluation of such mechanisms as Brian Tinsley's hypothesis of the role played by the global electric circuit in the micro-physical processes surrounding clouds [Tinsley, 1996], [Zhou and Tinsley, 2007], [Burns et al., 2008], [Kniveton et al., 2008]. In our comparison of old and new values of VAI we show amongst other things that the ERA40-based values show large changes on the day-to-day scale compared to previous NCEP-based values while seasonal cycles are captured about as before. On the Southern Hemisphere we show a very large change in the VAI near the years when satellite data were introduced, which should have consequences for data analysis of purported external forcing.

3. Introduction

Atmospheric relative vorticity is a measure of the strength of circulation, and therefore a representative of strengths of low-pressure and high-pressure systems. Various research in the solar-terrestrial field has in the past utilised indexes derived from vorticity data to analyse questions related to how solar geophysical events related to changes in storminess etc. - see e.g. [Wilcox et al., 1974], [Bhatnagar and Jakobsson, 1978], [Larsen, 1978], [Bochnicek et al., 1996], [Tinsley, 1996], [Bochnícek et al., 1999], [Veretenenko and Thejll, 2004a], [Veretenenko and Thejll, 2004b], [Veretenenko and Thejll, 2005] [Zhou and Tinsley, 2007], [Burns et al., 2008], [Kniveton et al., 2008], and see the reviews of the field in [Herman and Goldberg, 1978]. Originally ([Wilcox et al., 1974]) relative vorticity maps from the NMC grid were used to obtain an index called the Vorticity Area Index (VAI) which indicates in units of square kilometres the area of regions with absolute vorticity above a specified level.

We have previously [Thejll, 2002] reported on the update of such a dataset for VAI using NCEP reanalysis data. We now wish to further update this dataset for VAI using relative vorticity data from the ERA40 reanalysis.

Absolute vorticity is the sum of relative vorticity and the Coriolis parameter. Relative vorticity can be calculated in a number of ways - it is the direct output from the reanalysis system in that the fundamental equations are cast in a way that make relative vorticity and divergence the basic variables; or it can be calculated from geo-potential heights surfaces using a gradient operator; or from winds using the curl operator. In [Thejll, 2002] we compared some of these methods. As we now have direct access to ERA40 relative vorticities it is convenient to use these directly rather than calculate relative vorticity from secondary output such as gph surfaces.

In this report we chiefly inter-compare relative vorticities calculated in the NCEP and ERA40 from gph surfaces with the directly provided relative vorticity from ERA40.

We also calculate several datasets for VAI, based on the ERA40 relative vorticity.

4. Relative vorticity

Figure 4.1 shows the height of the 500 mb surface in NCEP and ERA40 for the first day of 1969. The NCEP data is a daily average while the ERA40 data is the first of 4 four that day. We note the great similarity between the two surfaces. Using the gradient operator discussed in [Thejll, 2002] we can calculate relative vorticity directly from these surfaces. The results are shown as a contour plot in Figure 4.2 in the upper row of panels. The relative vorticity surfaces are certainly not identical, but by looking for strong features we note that there is some similarity - e.g. the activity centres off Africa's northwest coast, over Italy and East of the Aral Sea, as well as by the Asian coast near Korea, over the Great Lakes in the USA and in the North-East Pacific. This shows that the same method applied to two different reanalyses' gph surfaces gives similar results.

Comparing these to the lower panel in Figure 4.2 which is the directly downloaded ERA40 relative vorticity we note the more granular appearance - the daily-average NCEP field is rather smooth (also compared to the ERA40 gph-based relative vorticity). Inspection reveals some of the same features as extracted above, although not as clearly. Despite this we do not suggest that the relative vorticity directly from ERA40 is erroneous in the gross sense - the differences are due to differences in methods used.

5. VAI

The vorticity area is defined ([Wilcox et al., 1974]) as the area of the Earth on which the absolute vorticity is above certain limits. Historically the index VAI is calculated as the sum of the areas where absolute vorticity is above the canonical values of 20×10^{-5} and 24×10^{-5}. Figures 5.1 and 5.2 show the evolution of similarity in the two reanalyses - the 1967 data are quite different while the 1987 data are more similar. This may be due to the introduction of satellite data making the 1987 data more similar than the 1967 results that were probably more sparse and hence more model and method dependent. We note that a seasonal cycle is realistically captured - stormy winters and calmer summers, but that only few rapid excursions are captured, implying that areas of low pressure systems are differently expressed in the NCEP and ERA40 datasets.

We wish to provide several VAI datasets based on the ERA40 relative vorticities from ECMWF. We calculate for both the Northern and Southern hemispheres at the 500 mb surface, and we provide datasets for three different cutoff levels 0.95 1.0 and 1.25 times the limits above.

Figure 5.3 shows the NH and SH VAI calculated between 40 and 80 degrees on each hemisphere, and for the three cutoff factors 0.95, 1.0 and 1.25 times the canonical values. We note some data inhomogeneity in the SH plot near the end of the 1970's. We also calculate VAI for the areas between 20 and 80 degrees North (and South) at 500mb for consistency with [Prikryl et al., 2009], and show the result in Figure 5.4. Again we note the data inhomogeneity in the SH data.

Figure 5.5 shows the same, for 300 mb.

6. Discussion

It is evidently possible to create lists of VAI data that are similar to what has previously been presented, but the values seem to differ on the day-to-day scale when ERA40 values are compared to NCEP values. This was essentially also found when NCEP values were compared to published values (see [Thejll, 2002]). The field of analysing VAI data on short time scales (such as superposed epoch analyses surrounding key dates) should therefore be aware that significant changes occur in the basic data used when new bodies of data are taken into use. This may not be good news for SPEA efforts!

However, in making these lists of VAI data available we have moved from bad data sources to better, and in using the ERA40 relative vorticities directly we have omitted processing steps that may have affected data quality. We therefore see some scope in using ERA40 VAI values based on relative vorticities, but suggest caution in interpreting results based on particularly the short time-scale analyses.

Acknowledgements. ECMWF ERA-40 data used in this study have been obtained from the ECMWF data server.

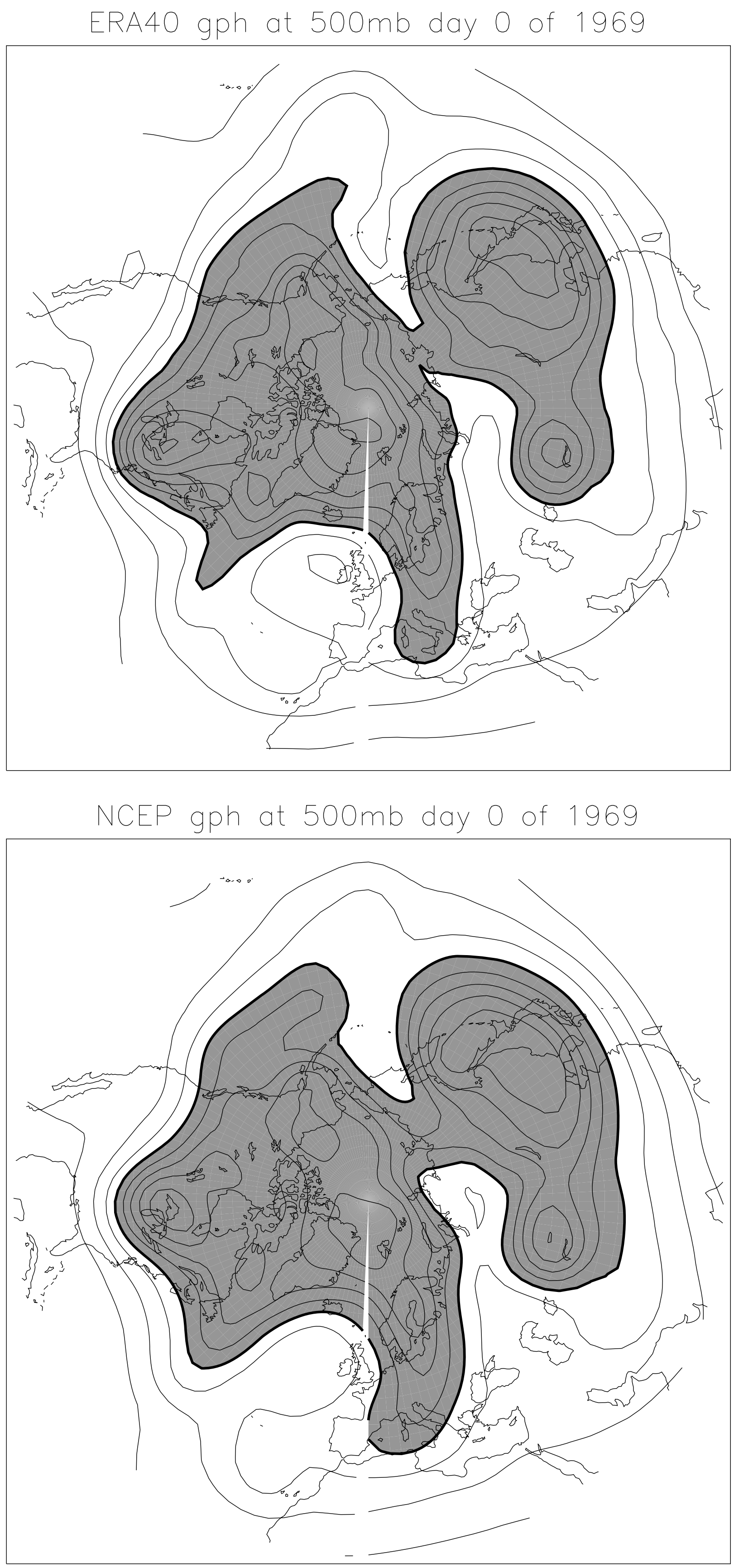


Figure 4.1: Height of the 500 mb surface in ERA40 and NCEP for the first day of 1969 for the Northern Hemisphere. The NCEP field is a daily-average field while the ERA40 field is the first of four fields for that day. Contours are spaced by 100m and grey areas are heights below 5500m.

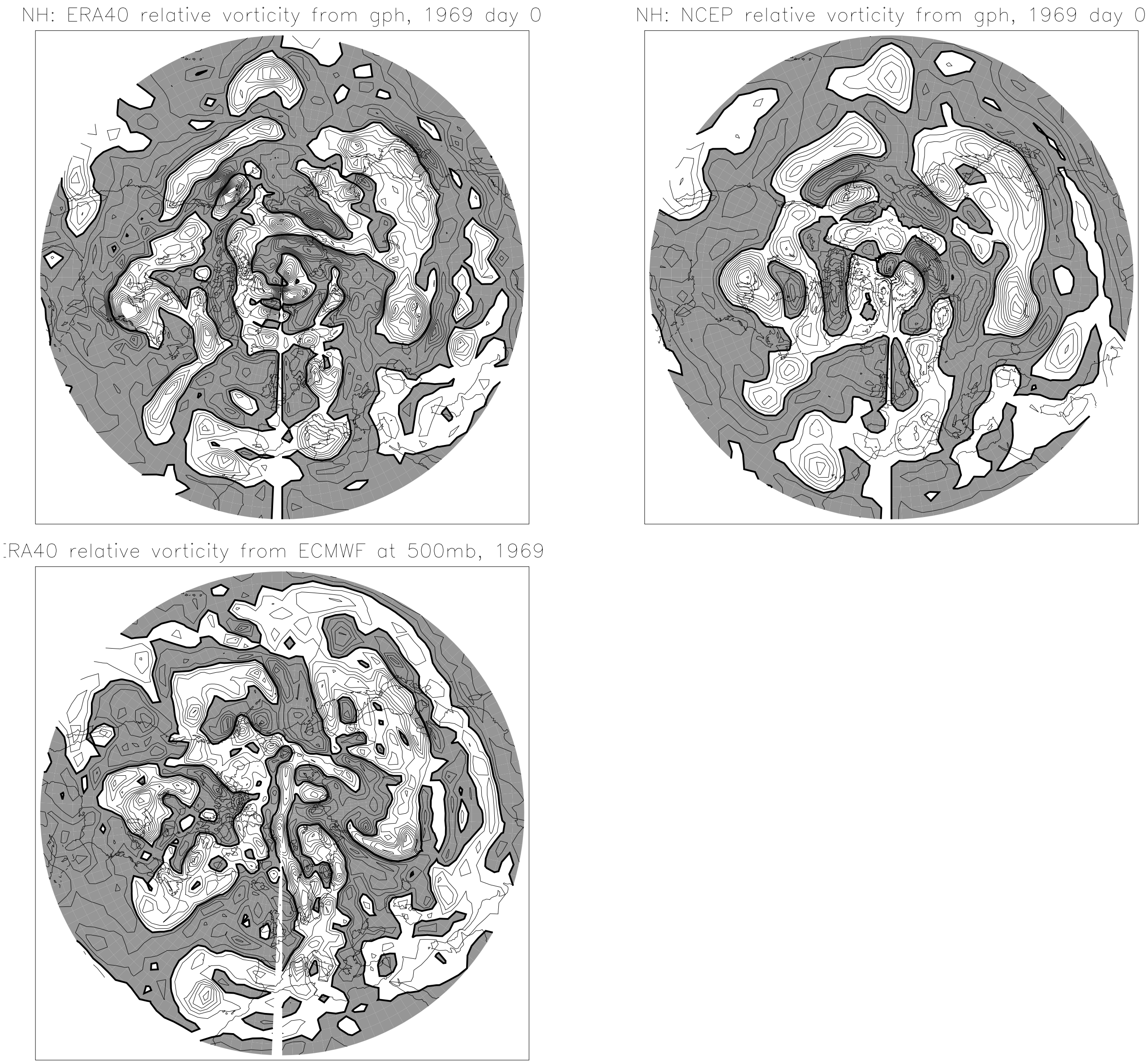


Figure 4.2: Relative vorticity maps from ERA40 and NCEP for the Northern Hemisphere. Top left panel shows the relative vorticity for the 500 mb surface on the first day of 1969, calculated from the ERA40 gph field shown in Figure 4.1, using the spatial operator. Top right is the same field calculated from NCEP gph data. Note that the ERA40 data is one of 4 for that day, while the NCEP data is a daily average field. Bottom left is the ERA40 relative vorticity field downloaded from ECMWF.

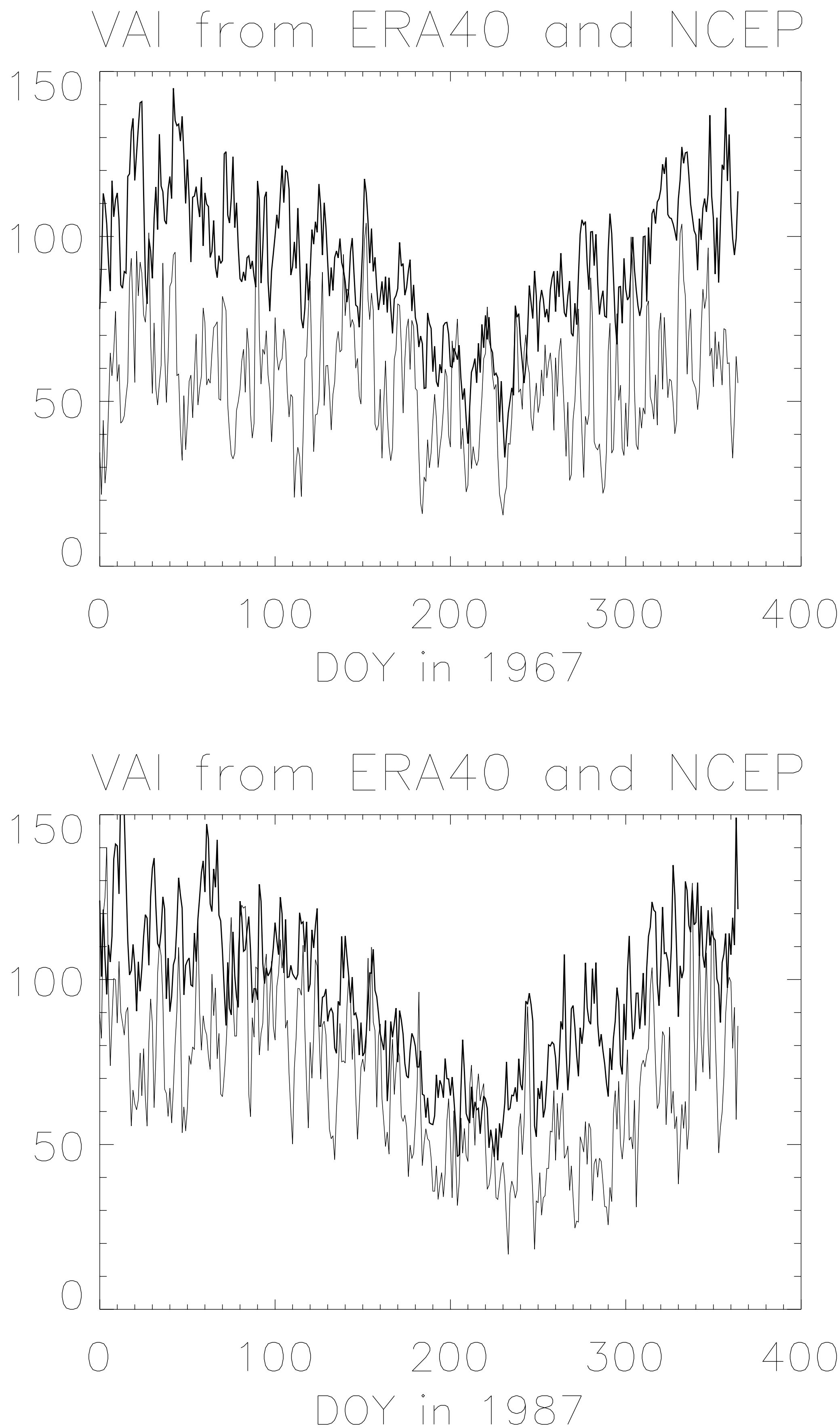
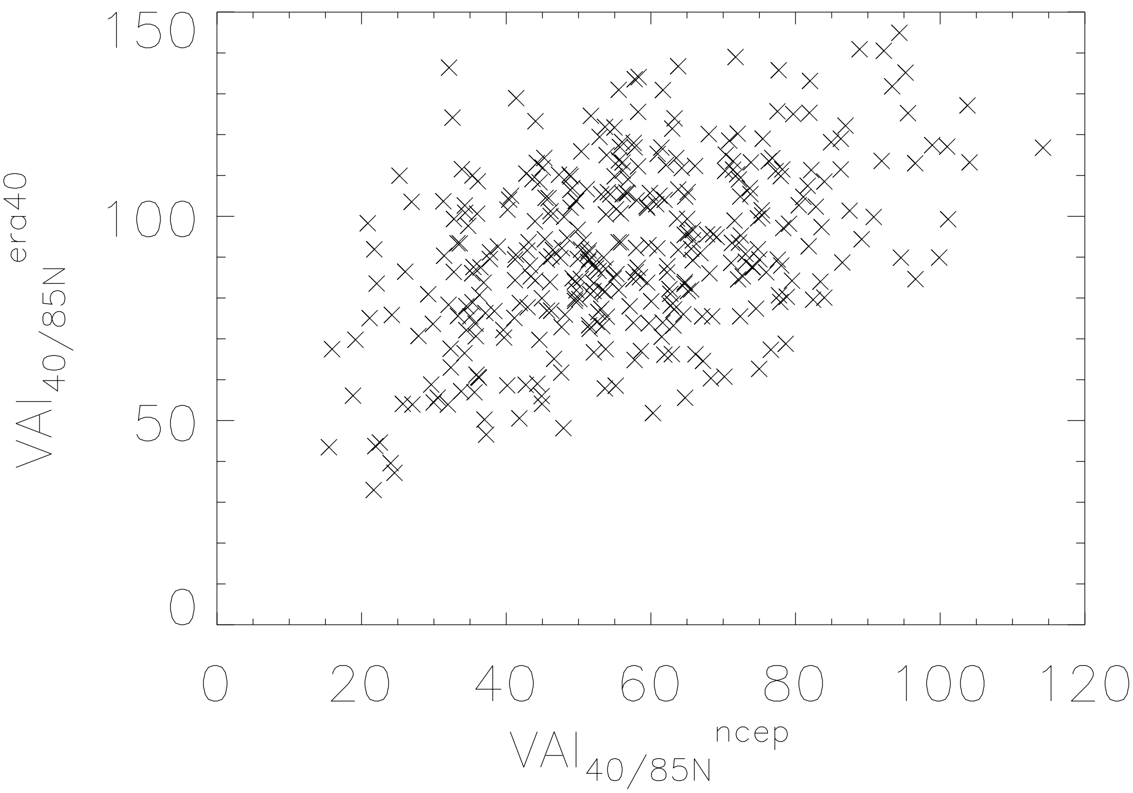


Figure 5.1: NH VAI calculated for 1967 and 1987, from NCEP geo-potential surface heights at the 500 mb level, and from ECMWF relative vorticities (i.e. not calculated from gph data). The thick lines are the ERA40 data.



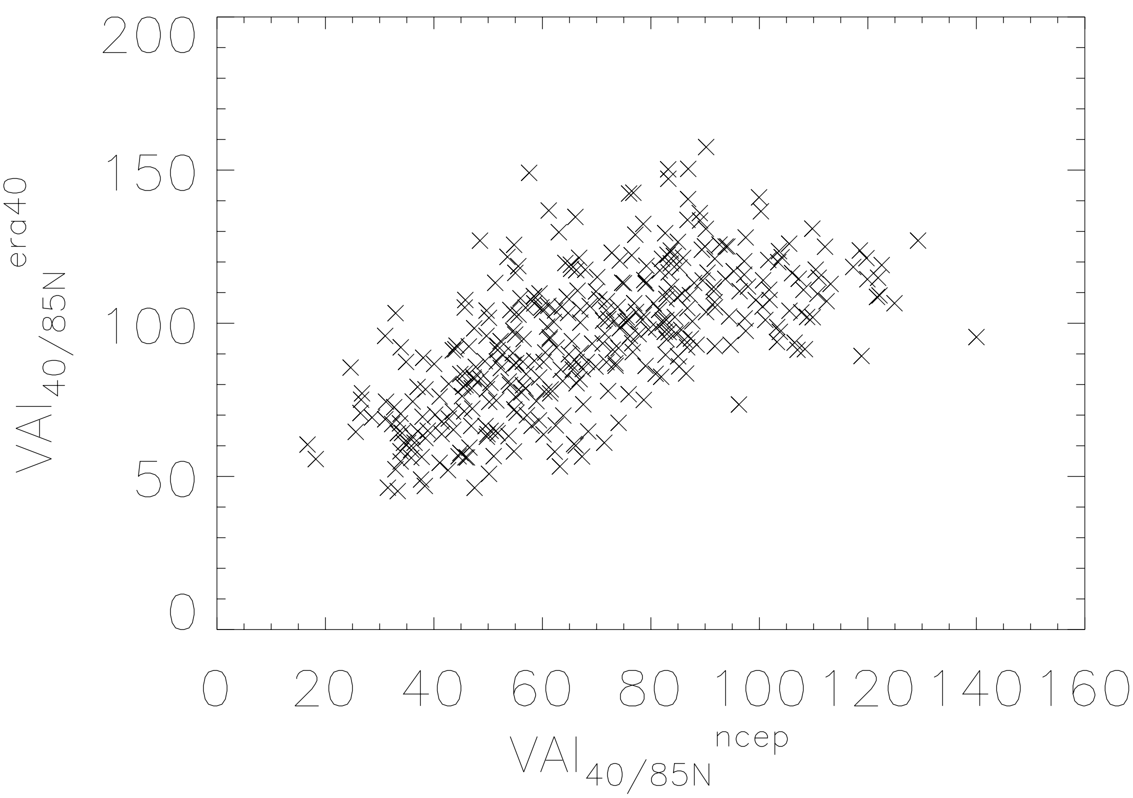


Figure 5.2: As Figure 5.1, but shown as scatter plots. Upper panel is for 1967 and lower is for 1987.

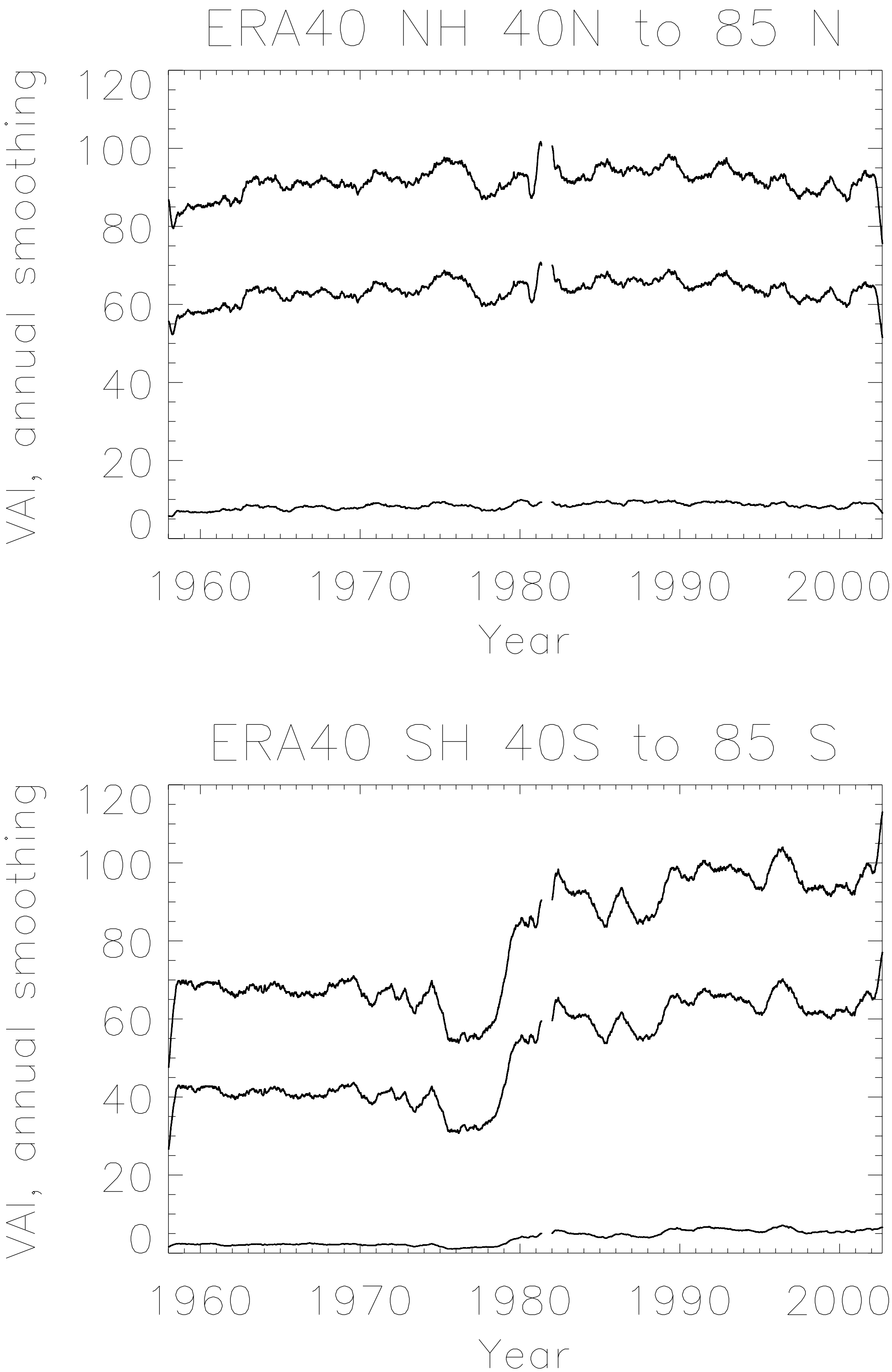


Figure 5.3: 500mb VAI calculated for NH (upper panel) and SH (lower panel), annually smoothed. In each panel there are three curves - this is for the vorticity cutoffs 0.95, 1.0 and 1.25 times the canonical limits of [Wilcox et al., 1974]. Note that there is a data gap near 1980. Note also the offset in SH VAI between pre- and post-satellite times.

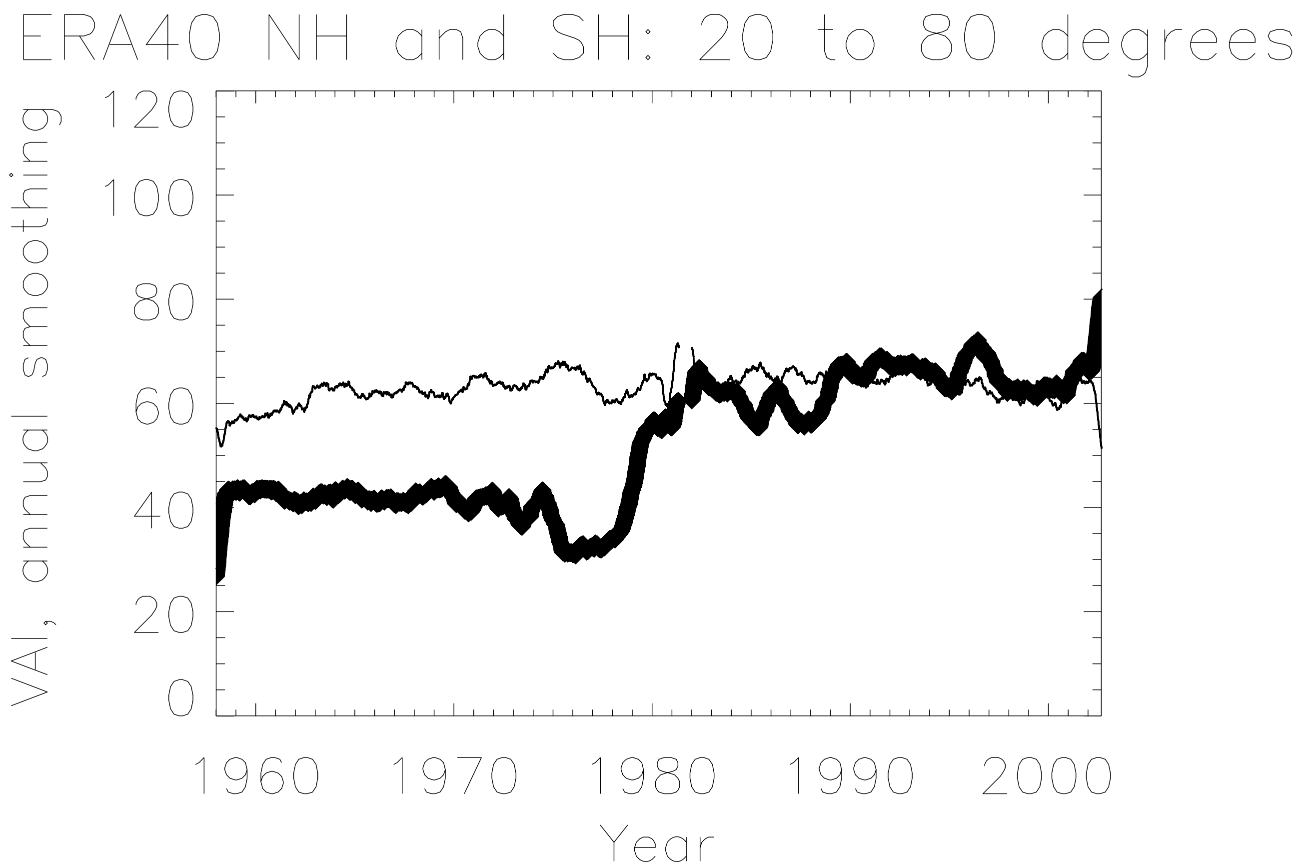


Figure 5.4: As Figure 5.3 but for areas between 20 and 80 degrees North (and South). Heavy line is for the SH.

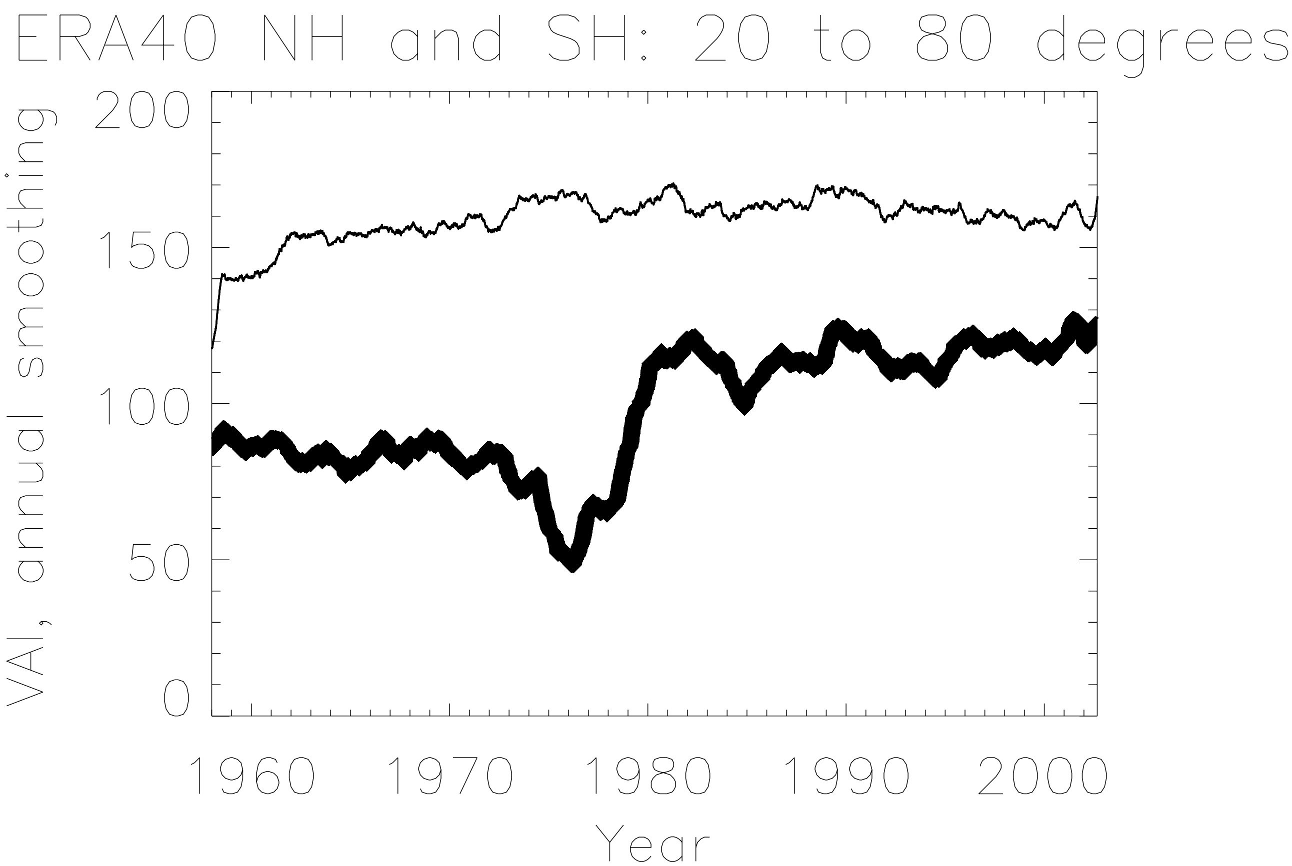


Figure 5.5: As in Figure 5.4 but for 300mb.

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