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STORM TRACK VARIATIONS AS SEEN IN RADIOSONDE OBSERVATIONS AND REANALYSIS DATA

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1 INTRODUCTION

In this work we compare the interannual variability of the storm tracks for the period 1949-1999, in radiosonde and NCEP/NCAR reanalysis data, in order to determine whether the decadal trends observed in the reanalysis are real.

In a companion paper (8.4: An interdecadal mode of Northern hemisphere storm track variations, see also Chang and Fu, 2001) Chang examined the variability of the storm tracks using the NCEP/NCAR reanalysis data, and found that both the pacific and Atlantic storm tracks intensified by nearly 40% from the 1960's to the late 1980's, early 1990's. The leading EOF of the storm tracks is a mutual intensification of the Pacific and Atlantic storm tracks, and the corresponding PC time series shows a transition from weak storm tracks before 1971 to stronger storm tracks after 1975. Furthermore, even when the component that is linearly correlated with other variability indices like the AO and ENSO are removed from the time series, a considerable positive trend remains. This suggests there is a component of decadal variability that is internal to the storm tracks.

These results should, however, be taken with caution, because the observations which are sparse or nonexistent in the actual storm track regions, do not constrain the reanalysis very strongly. The changes in sonde and aircraft measurement coverage, may have introduced large biases in the analysis (Ebisuzaki and Kistler, 1999). Note that the reanalysis minimizes the RMS difference from sonde observations. This does not necessarily mean that the errors in eddy variance (which is a measure of storm track intensity) are minimized.

2 DATA AND DIAGNOSTICS

We use archived NCEP/NCAR radiosonde data from all stations between 20-80N that reported during 1949-1999, in the latitude range of 20-80N. The data set includes ship reports and land stations.

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To diagnose storm track strength we use the 300mb meridional winds variance, computed using a 24 hour difference filter, which we denote by V1df. Chang and Fu (2001) showed that this measure of storm track strength is comparable to more common diagnostics. We use it because it can be applied to time series with observation gaps.

Our results are for January mean statistics, and we are currently calculating December-February means for comparison. We use the raw data with out any corrections. Bad or missing data is flagged in the raw data set. Most stations report every 12 hours, some report every 6 hours, and occasionally a station report contains missing or bad data. We only use monthly statistics for stations that reported valid meridional winds more than 31 times during January (i.e. half the time, for 12 hourly reports).

To compare radiosonde data with the reanalysis we compile a gridded sonde data set as follows. For each reanalysis grid box (2.5x2.5 degrees) we search the sonde data set for all stations that are located within the grid box. Most of the grid boxes that contain an observing station have only one. When there are more than one station in a grid box, we use data from the station with the largest number of valid reports during the month, and fill in data gaps using other stations. We also repeated some of the calculations using an average of all reports in a grid box and find only tiny differences.

For comparison, we repeat our calculations using two reanalysis data sets, one using only the synoptic times at which we have a valid sonde report (referred to as REAN1) and one using all 124 synoptic times (REAN2). REAN1 and REAN2 are data sets that contain reanalysis data only for the months and grid boxes which have SONDE data.

3 RESULTS

As a measure of the interdecadal variations of the storm tracks, we use the difference between the strongest and weakest decadal means (1986-1995 and 1963-1972 respectively) of V1df (denoted by $\Delta_{10}V1df$). We choose these decades based on the principal component time series of the 1st EOF of V1df (figure 2 of paper 8.4 in this volume). Figure 1 shows $\Delta_{10}V1df$ for the NCEP/NCAR Reanalysis (similar to figure 3c in paper 8.4). We also calculate $\Delta_{10}V1df$ from SONDE, REAN1, and REAN2 data, only using data from grid boxes that have V1df observations for 7 or more years of each decade (marked in figure 1 by filled circles). We divide the main storm track regions into 7 areas (also marked in figure 1), and calculate the mean of V1df and $\Delta_{10}V1df$ for all observations in a given area (a sum divided by the number of observations). Unfortunately, we do not have sufficient sonde observations over the Pacific storm track maximum to calculate $\Delta_{10}V1df$. There are a few ships that reported from that region, which we marked as diamonds on figure 1, but none of these ships reported over a long enough period to determine whether the observed trend is real. Table 1 lists the SONDE, REAN1 and REAN2 $\Delta_{10}V1df$, and the relative (with respect to REAN1) differences between SONDE and REAN1. The reanalysis data shows a storm track intensification in all these areas. The sonde data, on the other hand, shows an intensification in the Atlantic and North America regions (A1-A6), including the Pacific storm track exit in the western US, but essentially no intensification in Japan (A7). The intensification is weaker in the sonde data by 10-30% in the Atlantic regions (A1-A3), by more than 50% in the US (A4), by 30% in Canada (A6), and by 16% in the Pacific exit region (A5). We also tried many other averaging area definitions, and got qualitatively the same results.

To check whether the decadal differences presented here are representative of the evolution during 1949-99, we look at the time evolution of area averages of V1df during this period. Figure 2 shows the 10 year running means for areas A1-A7, for SONDE ($*$), REAN1 ($\bullet$) and REAN2 (o) data. Yearly time series show the same results. A comparison of REAN2 with the area average (latitude-weighted) of the reanalysis using all grid points (not shown) shows sufficient similarity to suggest REAN2 represents the area averages in the boxes shown reasonably well. We see that in the Atlantic and North American regions (A1-A4, A6) there is a trend in SONDE data, but the trend is smaller than in REAN1/2, because of larger differences in the earlier half of the time series. In A6 the actual trend may be even smaller since temporal sampling results in an underestimate of the variance during 1950-70 (compare REAN1 and REAN2). In the western coast of the US, both SONDE and REAN1/2 show that the storm track is weaker during the late 1960s than during the 1980s. However, superposed on this strong interdecadal variation, REAN1/2 also suggest an overall weak positive trend, which is absent in the SONDE data. The most striking difference between SONDE and REAN1/2 data is in Japan (A7), where the strong positive trend in the reanalysis is absent from the SONDE data. This is due to much larger biases in the 50s-60s than during later periods.

4 CONCLUSIONS

To summarize, we find that the intensification of the Atlantic storm track found in the reanalysis data is also found in sonde data, but weaker. The weaker trend is due to the fact that the biases between the reanalysis and sonde data have on the whole decreased with time. Near Japan (area A7), and in the west coast of the US (area A5) the reanalysis shows an interdecadal oscillation superposed on a positive trend. The sonde data only shows the oscillations, but not the trend. It is possible that an intensification of the Pacific storm track did occur, but the sonde data is too sparse to say anything about it. A north eastward shift along with the intensification could, in that case, explain the fact that a positive trend is not observed over Japan and west coast of the US, but is observed over Canada (A6). Currently we are examining aircraft reports over the Pacific and Atlantic to see whether the trend displayed in the reanalysis data can find support in aircraft observations.

5 REFERENCES

Chang, E.K.M., and Y. Fu, 2001: Inter-decadal variations in Northern Hemisphere winter storm track intensity. Submitted to *J. Clim.*

Ebisuzaki W., and R. and Kistler, 1999. An examination of data-constrained assimilation. Proceedings of the Second WCRP International conference on reanalyses, Wokefield Park, UK, 23-27 August 1999, WMO-TD/No 985. pp 14-17.

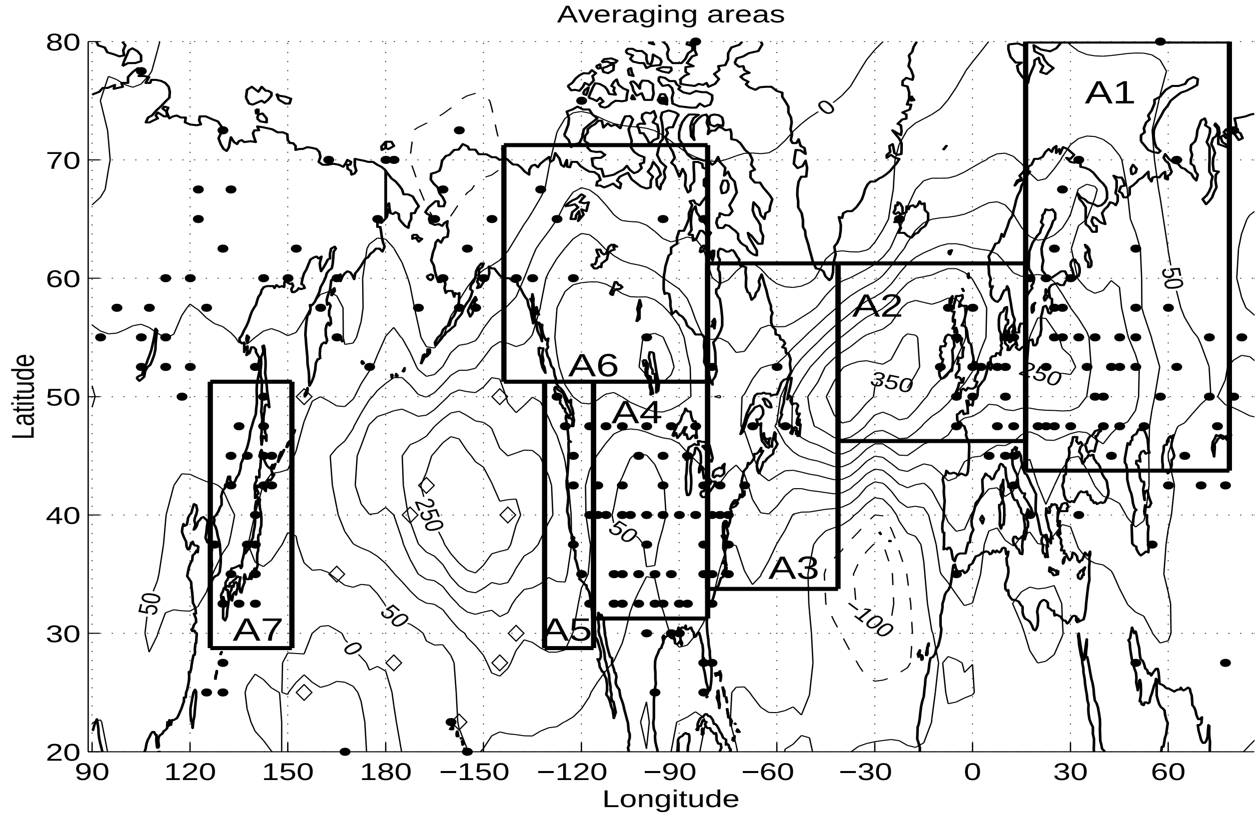

Figure 1: The interdecadal change in storm track intensity, measured by 300mb January V1df 1986-95 mean minus the 1963-72 mean, using the reanalysis data (contours), grid points that have at least 7 years of SONDE V1df observations in each of these decades (filled circles), other Pacific sonde stations (diamonds), and averaging (rectangles). See text for details.

Area	SONDE $\Delta_{10}V1df$	REAN1 $\Delta_{10}V1df$	REAN2 $\Delta_{10}V1df$	$\frac{SONDE-REAN1}{\lvert REAN1\rvert}$
A1	149.6	166.7	162.3	-0.10
A2	169.0	237.0	236.6	-0.29
A3	95.1	107.1	111.9	-0.11
A4	21.6	46.6	67.1	-0.53
A5	72.8	104.0	125.0	-0.30
A6	72.3	85.7	73.0	-0.16
A7	-0.4	32.6	35.6	-1.01

Table 1: Area means of the 300mb January V1df 1986-95 decadal mean minus the decadal 1963-72 mean, for SONDE, REAN1, and REAN2, and the relative (with respect to REAN1) difference between SONDE and REAN1.

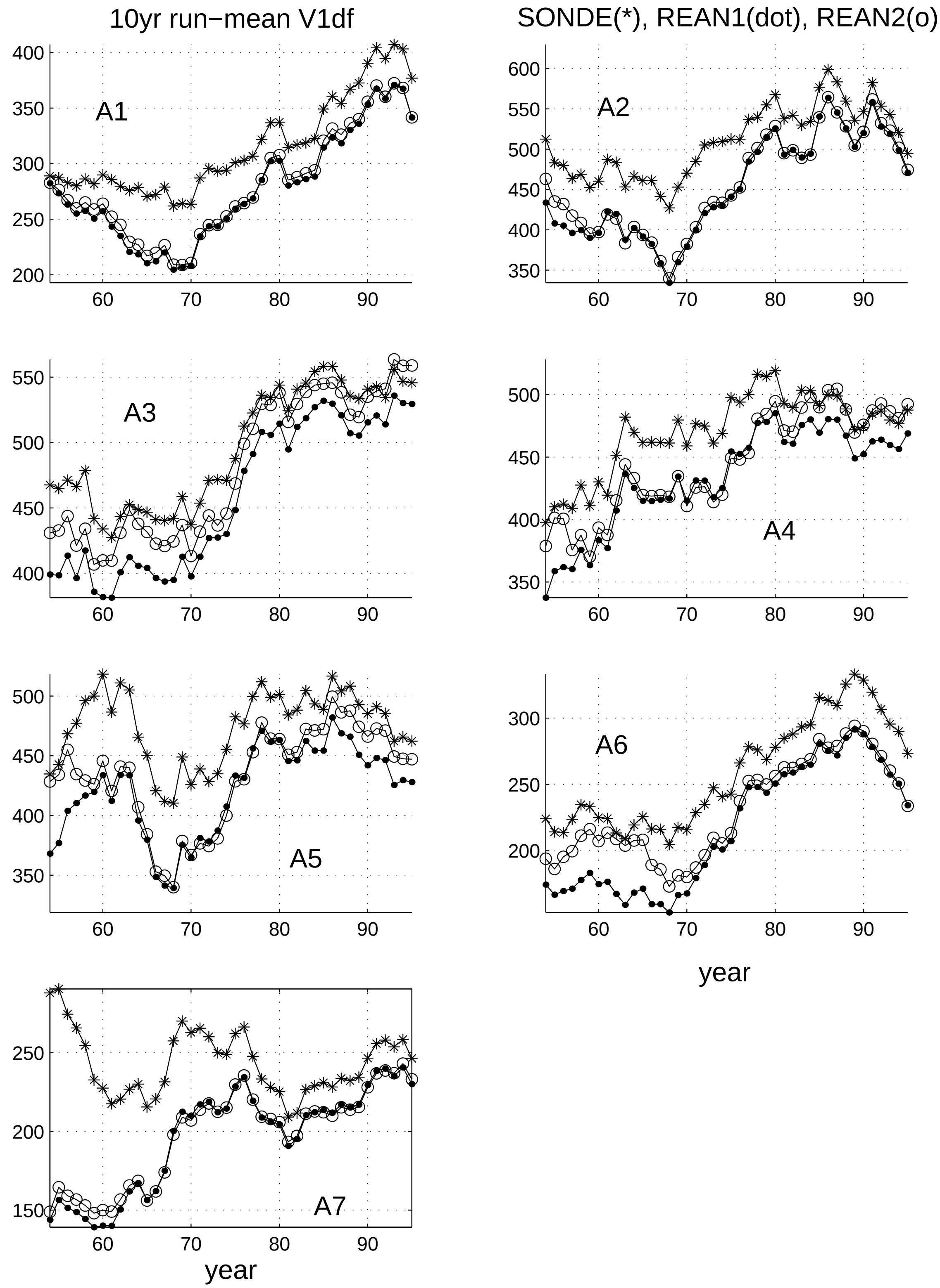

Figure 2: 10 year running means of the area means of 300mb January V1df, for the areas marked in figure 1, using SONDE (*), REAN1 (•), and REAN2 (o) data.