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ANALYSIS OF THE NVAP WATER VAPOR DATASET: A TOOL FOR MONITORING EARTH'S WATER VAPOR FROM DAILY TO DECADAL TIME SCALES

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1. INTRODUCTION

Water vapor is Earth's most important variable greenhouse gas. The NASA Water Vapor Project (NVAP) is a NASA Pathfinder project designed to measure the distribution of water vapor from satellite on a daily basis. NVAP data now covers the period 1988 – 1999. The NVAP dataset will be extended into the 21st century with the follow-on NVAP-Next Generation dataset (Forsythe et al, 2003). The Climate Data Records (CDR's) developed by NVAP will give us an increasing capability to monitor Earth's water vapor fluctuations on timescales greater than decades. The NVAP dataset has been reviewed by Simpson et al (2001) and found to possess sufficient accuracy for variability studies.

The original NVAP dataset is described by Randel et al (1996). To summarize, NVAP contains daily, 1 degree resolution maps of total column water vapor (TCWV), cloud liquid water (over oceans), and precipitable water in 4 layers (1000 – 700, 700 – 500, 500 – 300, and < 300 mb). NVAP fields are created by blending retrievals from polar orbiting satellite instruments such as SSM/I and TOVS with rawinsonde measurements. NVAP does not use numerical model input, so it can be compared to general circulation models as an independent source of verification.

NASA has created a list of Earth Science Research Questions which are outlined by Asrar et al. (2001). The selected questions below are particularly addressed by NVAP:

"How are global precipitation, evaporation, and the cycling of water changing?"

"What trends in atmospheric constituents and solar radiation are driving global climate?"

"How well can long-term climatic trends be assessed or predicted?"

NVAP data has been widely used over the past decade in scientific studies to answer these questions. In AMS journals alone, 25 papers cite NVAP data. At least 10 other papers in non-AMS refereed journals were found by a quick search.

In this paper, we present results from the 12 years of NVAP data and examine the interannual and decadal variability of Earth's water vapor.

2. OBSERVED VARIABILITY

Although NVAP is particularly intended for climate studies, it is always worth remembering that climate is a collection of many occurrences of weather. Figure 1 shows Earth's TCWV on July 1 for four years spanning NVAP. Note the particularly strong Asian monsoon on this date in 1998 compared to the other years. By contrast, the tropical Pacific on July 1, 1994 appears much quieter than in the other years. Many of the features that appear in daily fields such as these are the result of atmospheric circulation patterns with a timescale of days to months, such as tropical moisture plumes, monsoons and the poleward progression of moisture in the summer hemisphere. Superimposed on these are atmospheric circulation regimes with timescales measured in years, such as El Nino and La Nina. Now that NVAP data covers twelve years and is being extended forward in time, we can start to address a previously out-of-reach question: Is there a change in total atmospheric water vapor due to anthropogenic climate change?

Mean global TCWV fields from 1988 – 1999 for four months are shown in Figure 2. The major feature is the increase of moisture in the summer hemisphere. The South Pacific Convergence Zone is apparent, especially in October. In every month but July the western United

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State and Siberian regions are quite dry. The type of plot shown in Figure 2 could be replicated with a global climate model for a number of years. This would confirm that the model is properly placing moisture in the correct amounts at the right locations.

Year	N. Hem.	S. Hem.	Global
1988	26.24	23.76	25.00
1989	25.64	23.37	24.50
1990	25.83	23.21	24.52
1991	25.82	23.18	24.50
1992	24.87	23.27	24.07
1993	25.37	22.95	24.16
1994	25.72	22.86	24.29
1995	25.61	23.02	24.32
1996	25.39	22.74	24.06
1997	25.79	22.93	24.36
1998	25.95	23.85	24.90
1999	25.45	22.78	24.12

Table 1. Mean global and hemispheric TCWV (mm) from NVAP.

The most obvious long-term variability in global water vapor is that which occurs with an annual cycle. By removing the annual cycle, longer-term variability becomes visible. Figure 3 shows two plots of the standard deviation of TCWV. In Figure 3a, TCWV is shown with the annual cycle removed. In Figure 3b, the annual cycle is present. The annual cycle manifests itself most strongly in the monsoon regions and in the storm track regions to the east of Asia and North America. There are some modest north-south fluctuations in the tropical oceans associated with the movement of the ITCZ. In Fig. 3a, where the annual cycle has been removed, an entirely different picture emerges. Now we begin to see atmospheric states not directly related to seasonal change. In particular, the strongest changes are in the tropical East and Central Pacific Ocean, the area most strongly reflecting sea surface temperature changes during El Nino and La Nina periods. During the 12 years covered by Figure 3, there was a major El Nino in 1997 – 1998 with a weaker even in 1991-1992. La Nina periods occurred in 1988-1989 and again in 1996 and 1999. The twelve years of the NVAP dataset are now allowing us to characterize the atmospheric water vapor response to these events.

It should be expected that water vapor would be closely correlated with global sea surface temperature fields. In Figure 4, we compare NVAP global moisture anomalies to global sea surface temperature anomalies computed from the dataset of Reynolds et al (2002). The fields correlate well, but the water vapor has some higher frequency variability. The 1997-1998 El Nino manifests itself as a warm global SST anomaly and a high water vapor anomaly. According to the NVAP data, the atmosphere contained more moisture in 1998 than any year since 1988.

3. LONG-TERM TRENDS

Table 1 shows the global and hemispheric averages of TCWV from NVAP for 1988-1999. Note that overall the northern hemisphere contains roughly 2.5 mm more precipitable water than the southern hemisphere.

From Table 1, there is no discernable trend over the twelve year period. What is most interesting is the variability from year-to-year. How much of this is Earth's natural variability is being investigated. During the NVAP time period, there is an ever-changing cast of instruments which might have some effect on long-term climate records. For instance, in 1988 NVAP began with one SSM/I instrument (F-8), but by 1999, there were three SSM/I instruments available, allowing for better global coverage.

4. CONCLUSION

The NVAP dataset continues to grow and now covers the period 1988 – 1999. Additional work in progress will add the years 2000 and 2001, with increased resolution and several new satellite sensors (Forsythe et al, 2003). Atmospheric features with recurrence intervals on a timescale of years, like El Nino, can now be studied with NVAP. The natural variability of atmospheric water vapor can be quantified with NVAP. We are now at a point where we can start to look for decadal variability in Earth's water vapor. Our analysis for 1988-1999 does not detect any systematic long-term trend in total atmospheric water vapor. The continued expansion of the time record of NVAP will allow us to further assess whether any trends are occurring. However, we do find very interesting interannual variability, most likely the result of variability in the large-scale circulation in some regions.

Climate Data Records from NVAP provide a key data point to address critical science questions related to climate and global change. NVAP plays a fundamental role, along with other projects like the Global Precipitation Climatology Project (GPCP) and the International Satellite Cloud Climatology Project (ISCCP), in understanding Earth's hydrologic cycle.

5. ACKNOWLEDGMENTS

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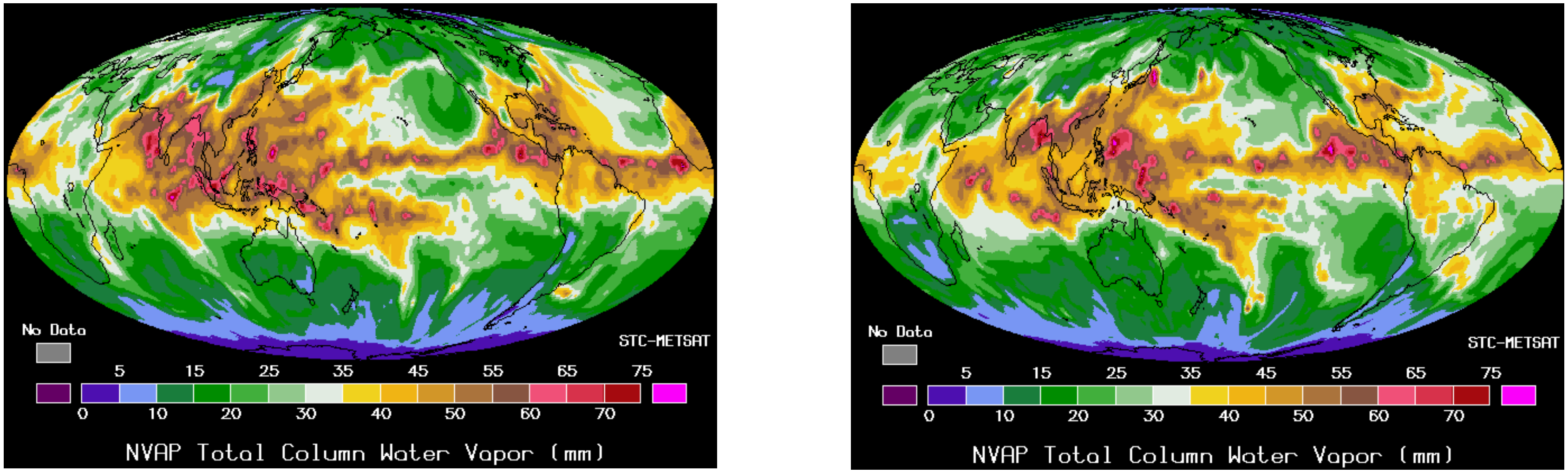
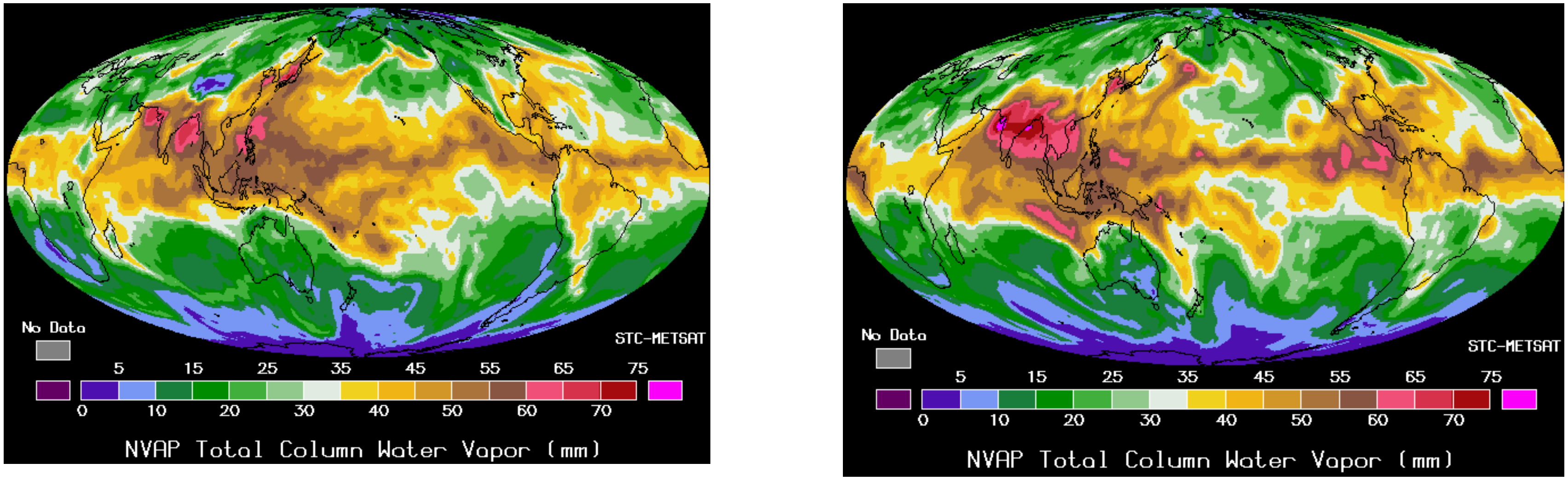


July 1, 1988 **July 1, 1992**



July 1, 1994 **July 1, 1998**

Figure 1. A look at Earth's total column water vapor (mm) on July 1 for 4 different years spanning the NVAP dataset. A finding from NVAP is that the year-to-year variability in the distribution of water vapor is large.

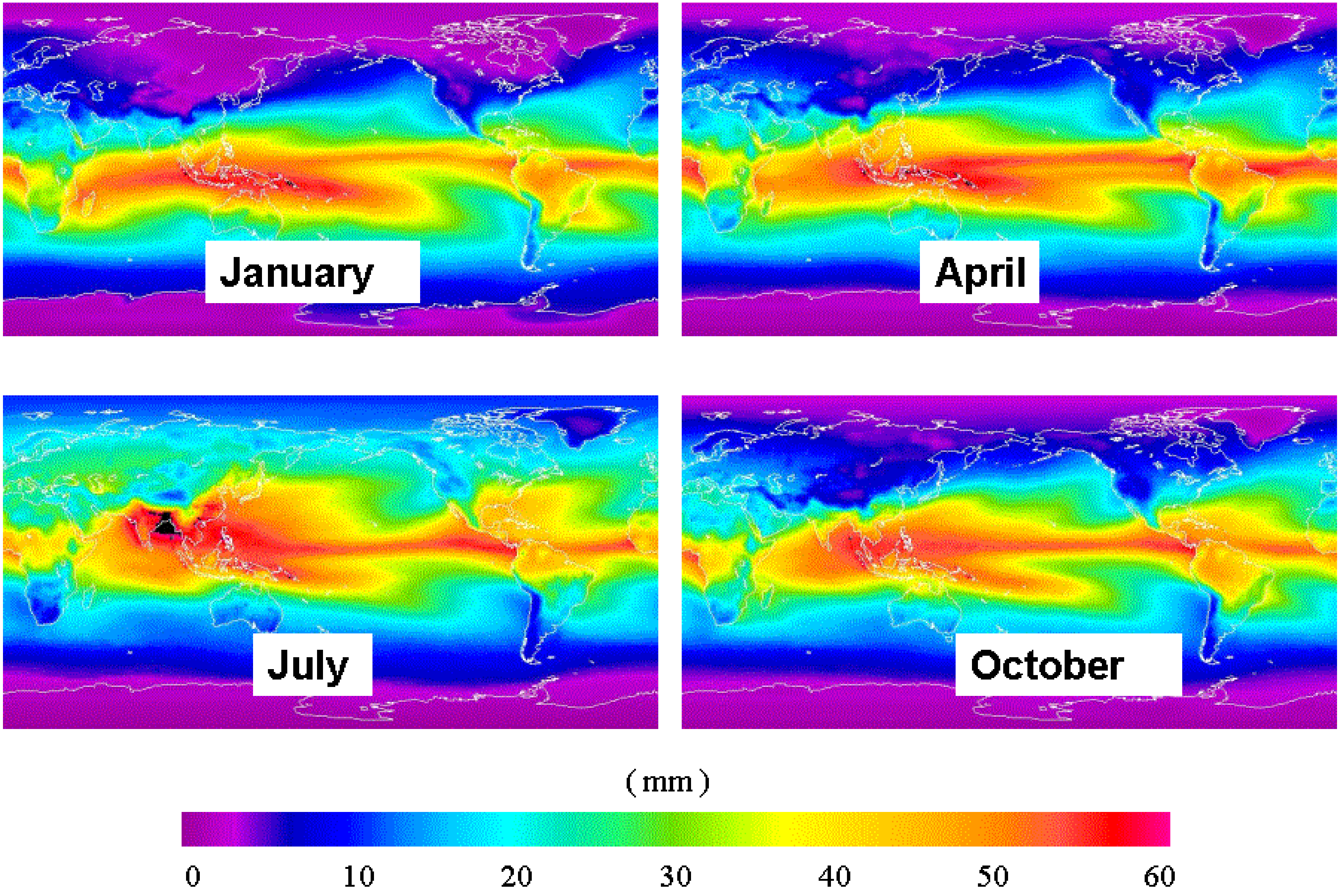


Figure 2. The mean total column water vapor (mm) from NVAP from 1988-1999 for 4 different months.

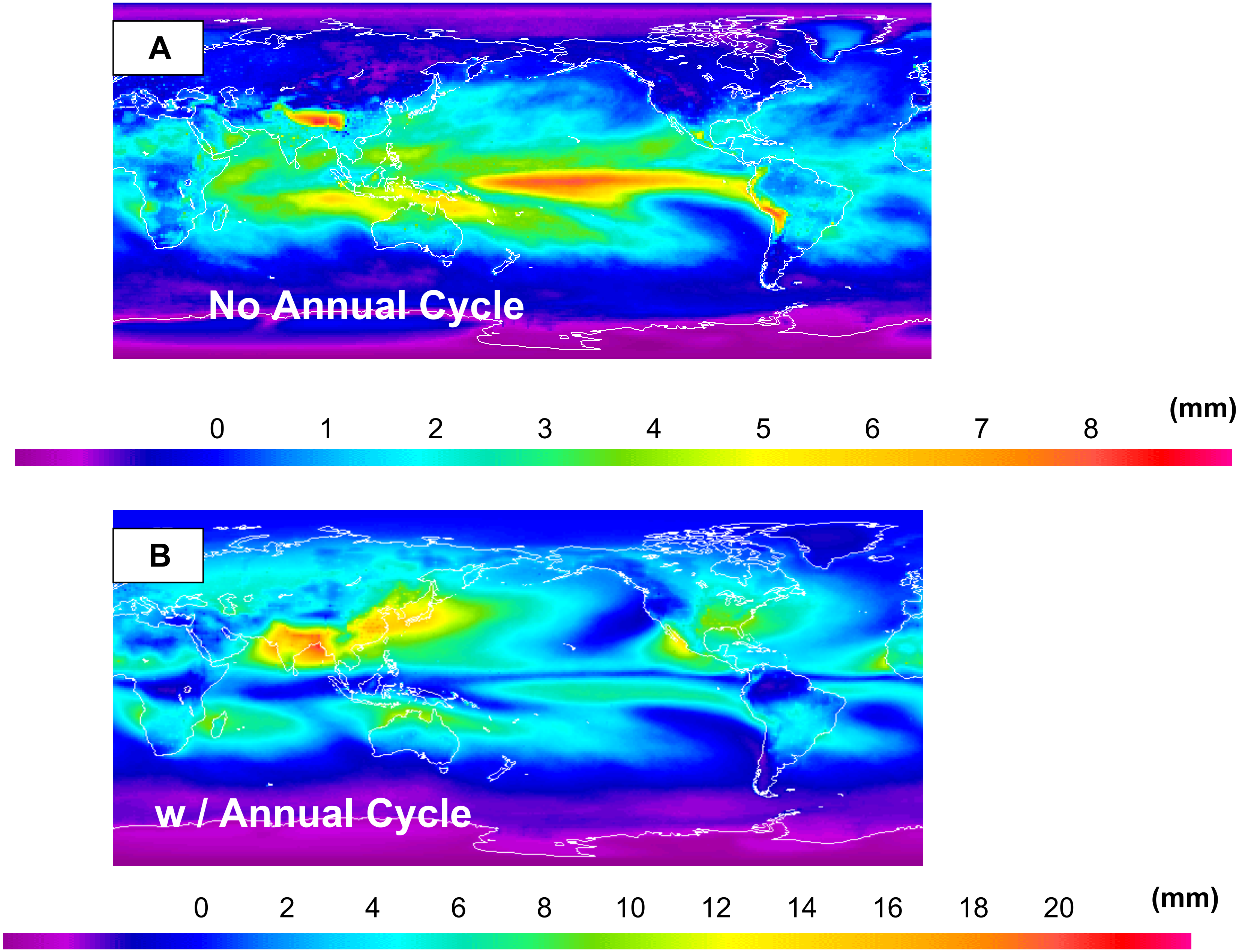


Figure 3. The global standard deviation of total column water vapor for 1988-1999. **A**) The annual cycle has been removed. This reveals phenomena operating on timescales longer than a year, such as El Nino / La Nina. Note the high variability in the Tropical Pacific. **B**) With the annual cycle included. The monsoon and storm track regions are well delineated by their impact on the annual cycle.

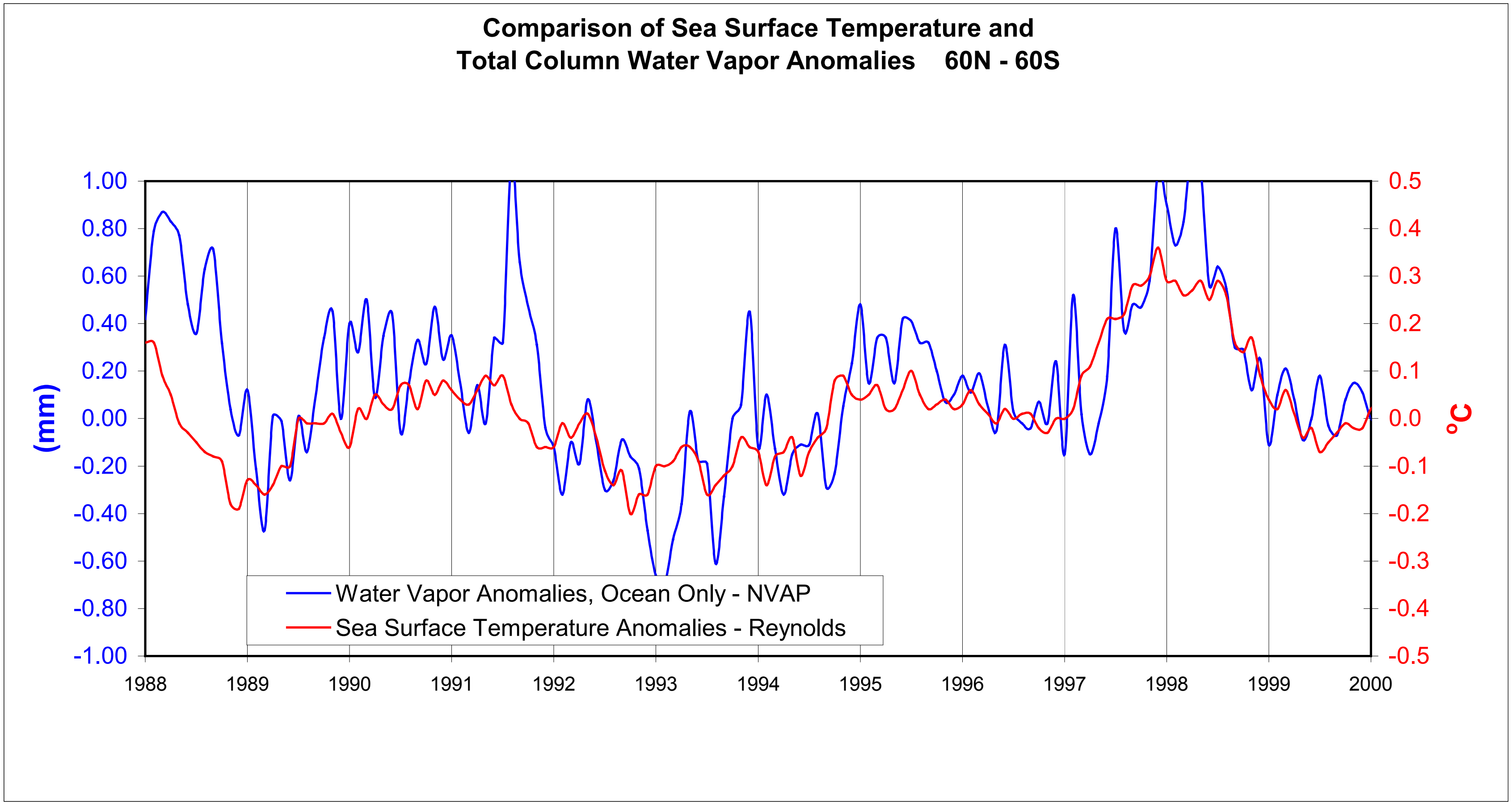


Figure 4. NVAP total column water vapor (TCWV) anomalies (blue) compared to sea surface temperature anomalies (red) derived from Reynolds et al (2002) for 1988-1999. Results are for ocean only. The NVAP water vapor anomaly line is adjusted upwards after January, 1995 to include intersatellite calibration and implementation of the the SSM/I antenna pattern correction normalization of Poe and Colton (1999). The anomalies generally correlate well, although the water vapor anomaly does show some higher frequency variability.