7D.5

Meridional moisture transport by tropical synoptic scale disturbances over the Pacific and Atlantic basins

Chia-chi Wang* and Gudrun Magnusdottir

University of California, Irvine, California

1. Introduction

Water plays an important role for the energy transport on Earth. Energy is stored as water transforms from liquid to vapor phase and then water vapor is transported by the atmosphere circulation. Energy is released as latent heat to warm the atmosphere when water vapor condenses to liquid phase.

There have been many studies regarding the global moisture transport, such as Chen (1985), Heta and Mitsuta (1993), and Liu and Tang (2005) using analysis or satellite data. However, they all focused on the "mean" component of moisture transport, or so-called "stationary mode" and de-emphasized the transient component. Many studies have concluded that the mean flow causes convergence of the moisture into the ITCZ, and the transient mode transports some of the moisture poleward. Their results indicate that the transient mode is only important in mid-latitudes, but not in the tropics. However, we believe that their conclusions about the transient mode may be incorrect. Wang and Magnusdottir (2006) have showed that in the tropical eastern Pacific, tropical synoptic scale disturbances are generated continuously in summer and fall seasons. Moisture is suggested to be carried and transported out of the tropics by the disturbances when the disturbances move toward high latitudes (C. Zhang 2004, personal conversation). The goal of this study is to estimate the amount of moisture that has been transported by these disturbances.

The common flaws of previous studies are that the area extent and time period were not chosen properly, and thus did not show the signal of transient mode of moisture transport at all. Chen's study (1985) uses global zonally averaged First Global GARP Experiment (FGGE) III-b analysis data. However, the water vapor distribution varies greatly in different spatial domain and time period. As the synoptic scale disturbances are only dominant in limited regions, the signal may be smoothed out after the global zonal average. Heta and Mitsuta (1993) and Liu and Tang (2005) both used satellite data. However, Heta and Mitsuta (1993) only have one month of data (July 1980), which is too short to

*Corresponding author address: Chia-chi Wang, Earth System Science, Croul Hall, Irvine, CA 92697-3100. Email: chiachw@uci.edu

represent the general aspect of moisture transport. Liu and Tang (2005) only discuss the global seasonal mean and say nothing about the transient component. Therefore, in this study, we will focus on the tropical eastern Pacific and Atlantic where synoptic scale disturbances are prevailing, and focus on summer and fall seasons (May–Oct) which are the active seasons of synoptic scale disturbances.

2. Datasets

In this research, we use two high resolution analyses data, NCEP and ECMWF, to estimate the meridional moisture transport.

NCEP Global Tropospheric Analyses: This dataset is of $1^\circ \times 1^\circ$ horizontal resolution, 26 vertical levels, and recorded four times per day. It is available for the time period from Sept. 1999 to the present. The disadvantage of this dataset is that it contains model assumptions that sometimes affect the accuracy of the data. However, this dataset is the most comprehensive and high resolution of its kind. NCEP model starts to assimilate AIRS data from May 31, 2005.

ECMWF TOGA Global Advanced Operational Spectral Analysis: This dataset is the output from ECMWF's daily operational global numerical model. Horizontal resolution is T106 spectral resolution in spherical harmonics. All fields are output four times a day.

3. Meridional moisture transport

The moisture flux integrated over an atmospheric column (Θ) can be written as:

$$\Theta = \frac{1}{g}\int_0^{P_s} q\mathbf{v}dp,$$

where g is the acceleration due to gravity, p is the pressure, p_s is the surface pressure, and q and $\mathbf{v}$ are the specific humidity and wind vector ($\mathbf{v} = (u, v)$) at a certain pressure level, respectively.

The moisture flux can be divided into stationary term and transient term, $\overline{q\mathbf{v}} = \bar{q}\bar{\mathbf{v}} + \overline{q'\mathbf{v}'}$, where bar indicates long-term mean (May–Oct mean in this study) and prime indicates the deviation from the mean. We would like to focus on the meridionl moisture transport and the vertical integral of the stationary term and the transient term of the meridional moisture transport, indicated as $\overline{\Theta_v}$ and Θ_v', are calculated for year 2000–2004.

Another approach to isolate the moisture transported by synoptic scale disturbances is to do 2–10 day bandpass filter on v and q, and compute the moisture flux.

4. Results

The stationary term ($\overline{\Theta_v}$) and transient term (Θ_v') of meridional moisture transport during May–Oct, 2004 are shown in The regions shown here are in the eastern Pacific and eastern Atlantic. Generally, the moisture is transported to the tropics by the stationary component, and some of the moisture is brought back to subtropics by the transient component. The transient component in the tropical eastern Pacific and eastern Atlantic appears to have significant contribution on transporting moisture back to subtropics. Similar feature can be found in 2000–2003 (figures not shown). figure 1(NCEP) and figure 2(ECMWF).

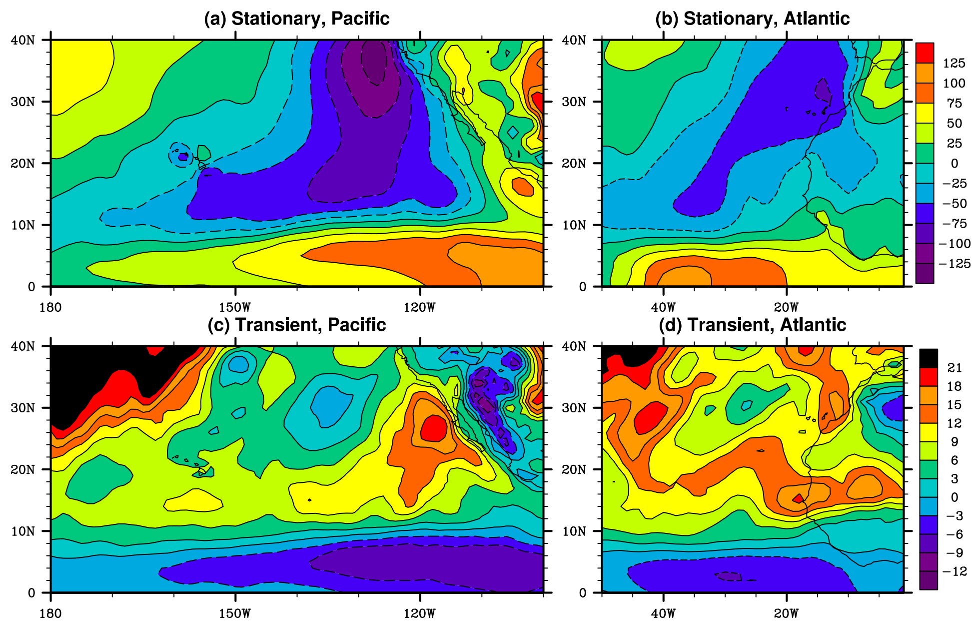

FIG. 1: Stationary ($\overline{\Theta}_v$) and transient (Θ_v') terms of May–Oct, 2004 for the eastern Pacific (domain shown from 180° to 100° W) and eastern Atlantic (domain shown from 50° W to 0°). Unit for the contour is $kgs^{-1}m^{-1}$. Negative (positive) value means southward (northward) moisture transport.

The meridional profiles for the zonally averaged meridional moisture transport over the eastern Pacific and eastern Atlantic oceans estimated from NCEP data are shown in figure 3. We found that the meridional moisture transport by stationary term has obvious interannual variability in summer time. This behvior was not noticed in Liu and Tang (2005) because they did zonally average over the whole ocean domain and the signal in the eastern oceans is damped out. We do not think this is related to ENSO since the we are not focusing on winter and there is no corelation to ENSO activities. Although we did not see interannual variability in the activities of synoptic scale disturbances (Wang and Magnusdottir, 2006), we do notice that there is interannual variability in the moisture transport by the transient term in the eastern Pacifc while in the eastern Atlantic, the interannual variability is smaller. The profiles of the transient term (figure 3 (c) and (d)) also show that the local maximum value in the tropics (around 15° N) is comparable with the

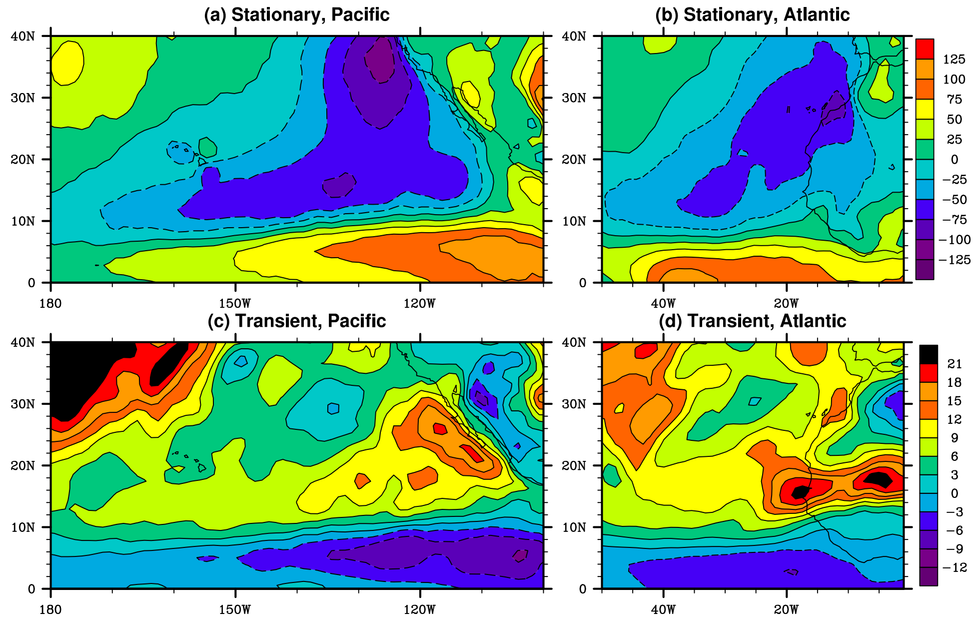

FIG. 2: Same as figure 1, but for ECMWF data

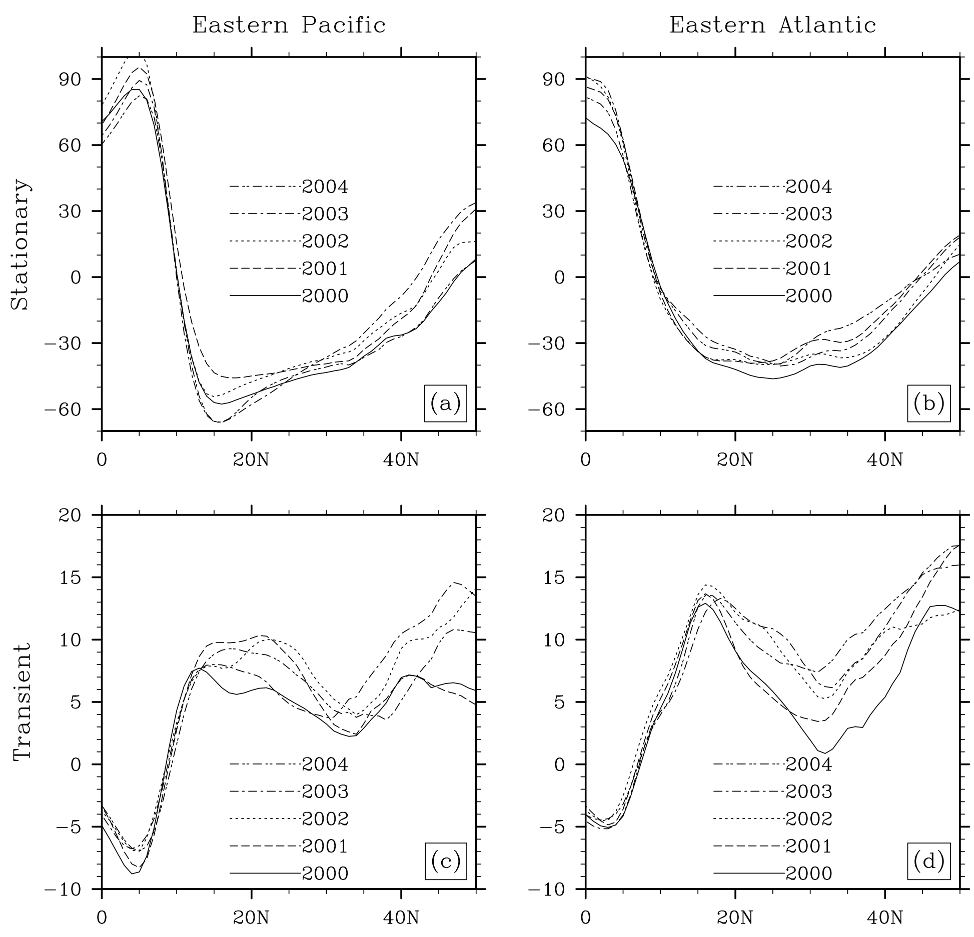

FIG. 3: Meridional profiles of zonally averaged $\overline{\Theta}_v$ and Θ'_v from 2000–2004. Values are estimated using NCEP data. (a) is $\overline{\Theta}_v$ for the eastern Pacific (150° W to 110° W) and (b) for the eastern Atlantic (40° W to 0°). (c) is Θ'_v for the eastern Pacific and (d) for the eastern Atlantic. Unit is $kgs^{-1}m^{-1}$.

maximum value in the mid-latitudes.

Figure 4 and 5 show the 2–10 day filtered Θ_v of 2004 for NCEP and ECMWF data, respectively. This approach separates the synoptic scale disturbances from all other disturbances in longer timescales. Therefore, it can indicate synoptical timescale disturbance better. These figures clearly show the main regions of meridional moisture transport contributed by the synoptic scale disturbances are in the tropical eastern ocean basin around 10–20° N.

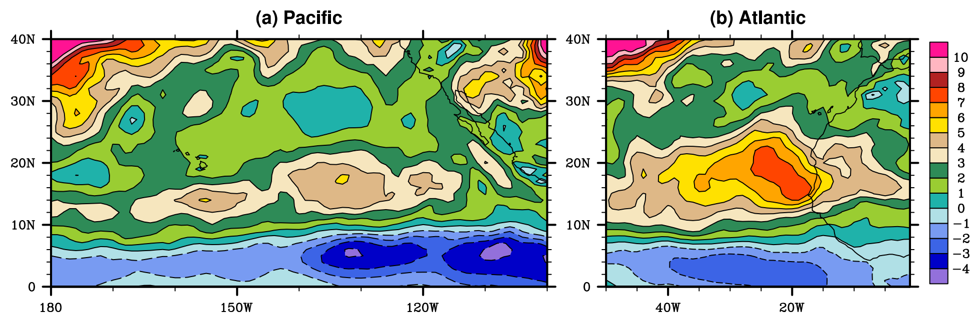

FIG. 4: 2–10 day filtered Θ_v, May–Oct 2004, NCEP data

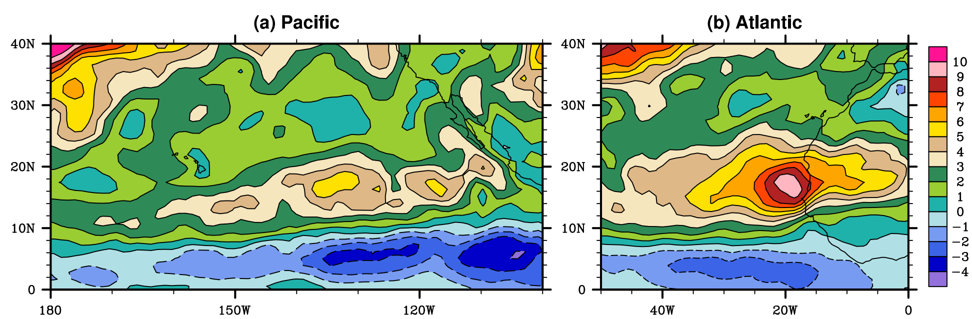

FIG. 5: 2–10 day filtered Θ_v, May–Oct 2004, ECMWF data

Table 1 lists the average $\overline{\Theta_v}$ and Θ_v', estimated from NCEP data, in the area where the synoptic scale disturbances are dominant, 150° W–110° W, 10° N–20° N for the eastern Pacific, and 40° W–0° , 10° N–20° N for the eastern Atlantic. In the eastern Pacific, the ratio of Θ_v' to $\overline{\Theta_v}$ is about 13%–25%, while in the eastern Atlantic, this ratio is one third to almost half, which is a quiet large portion. The same area average for 2-10 day filtered moisture transport is computed and listed in Table 1 as well. We would like to point out that this amount is comparable to that in the mid-latitudes though the value is low.

5. Concluding remarks

The meridional moisture transport by synoptic scale disturbances is estimated by using NCEP and ECMWF analyses for the period of May–Oct from 2000–2004. The results from the two datasets are highly similar which give us more confidence that these results are trustworthy. Our results show that in the eastern ocean basins, a significant portion of

Table 1: The area mean of stationary term and transient term of meridional moisture transport, and area mean of 2-10 day filtered meridional moisture transport in each year. The domain for Pacific is from 150° W to 110° W, 10° N to 20° N, and for Atlantic is from 40° W to 0° , 10° N to 20° N. The unit is $kgs^{-1}m^{-1}$. Negative (positive) value means southward (northward) transport.

	Eastern Pacific			Eastern Atlantic		
	stationary	transient	2-10d	stationary	transient	2-10d
2000	-44.7	6.3	2.66	-29.22	9.71	4.53
2001	-31.98	8.40	3.19	-29.49	10.31	4.69
2002	-42.03	7.29	3.02	-29.67	11.38	4.60
2003	-51.45	6.97	2.95	-21.98	9.64	3.62
2004	-49.54	7.45	3.02	-24.45	10.04	4.40

moisture is transported out of the tropics by the synoptic scale disturbances, especially in the eastern Atlantic ocean. The maximum portion can be as high as half of the amount transported by the stationary term. The moisture transport has larger interannual variability in the eastern Pacifc than it does in the eastern Atlantic. This is probably because the synoptic scale disturbances in the eastern Atlantic (i.e., African eastern waves) are more organized and controlled by the land-ocean contract better than those in the eastern Pacific.

Acknowledgment

This research was supported by the National Science Foundation grants ATM-0530926.

REFERENCES

Chen, T.-C., 1985: Global water vapor flux and maintenance during FGGE. *Mon. Wea. Rev.*, **113**, 1801–1819.

Heta, Y. and Y. Mitsuta, 1993: An evaluation of evaporation over the tropical Pacific ocean as observed from satellites. *J. Appl. Meteor.*, **32**, 1242–1247.

Liu, W. T. and W. Tang, 2005: Estimating moisture transport over oceans using space-based observations. *J. Geophys., Res.*, **110**, D10101, doi:10.1029/2004JD005300.

Wang, C.-C. and G. Magnusdottir, 2006: The ITCZ in the Central and Eastern Pacific on synoptic timescales. *Mon. Wea. Rev.* in press.