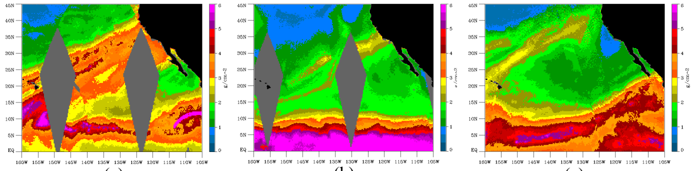
P2.11

UNDERSTANDING THE DYNAMIC LINK BETWEEN TROPICAL CLIMATE VARIATION AND WINTER STORMS ALONG THE US WEST COAST

J.-W. Bao[1] S.A. Michelson[2] P. J. Neiman[1] F. M. Ralph[1] J. M. Wilczak[1]

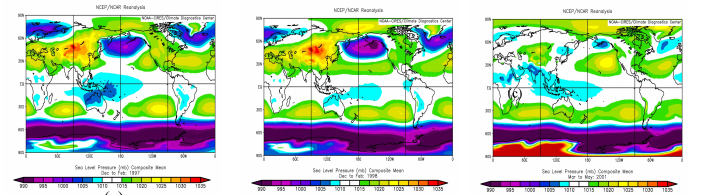
[1]NOAA/Environmental Technology Laboratory, [2]CIRES, University of Colorado and NOAA/Environmental Technology Laboratory, Boulder, Colorado 80305

Motivation: Satellite integrated water vapor (IWV) images over the central and eastern Pacific frequently show bands of enhanced water vapor on the order of 200 km in width and several 1000's km in length (Figs. 1&4). These bands are often associated with the low-level jet of wintertime extratropical cyclones, which produce most of the U.S. West Coast's precipitation. In many cases, these bands extend far enough south that it appears possible that tropical moisture may be transported northeastward by the low-level jet and tapped into by the storm systems that produce heavy precipitation over the U. S. West Coast. However, it is not possible to determine from the satellite images alone whether these bands originate from tropical moisture advection or solely from local low-level moisture convergence. In this study, numerical simulations using a weather prediction model are carried out to (1) address the question of origination of the observed IWV bands, (2) interpret the variation of these bands as a function of tropical climate variation, and (3) better understand the dynamic link between tropical climate variation and moisture sources of wintertime storms along the U. S. West Coast.



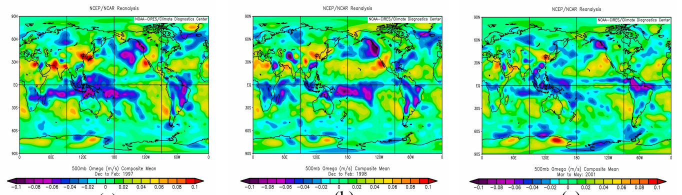
(a) (b) (c)

Figure 1 Composite satellite images of integrated water vapor (IWV, cm) for (a) 2 Jan 1997, (b) 2 Feb 1998, and (c) 1 Mar 2001.



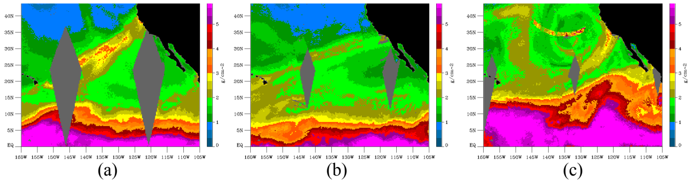
(a) (b) (c)

Figure 2 Seasonal mean sea-level pressure for (a) Dec1996 – Feb 1997, (b) Dec 1997 - February 1998, and (c) Mar - May 2001.



(a) (b) (c)

Figure 3 Seasonal mean vertical velocity (omega) at 500-mb level for (a) Dec 1996 – Feb 1997, (b) Dec 1997 - Feb1998, and (c) Mar - May 2001.

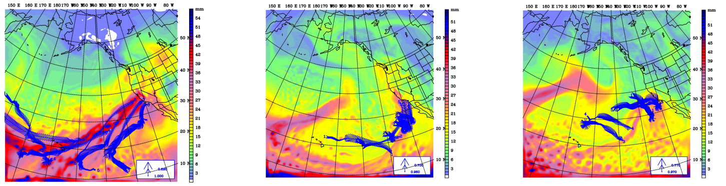


(a) (b) (c)

Figure 4 Additional composite satellite images of integrated water vapor (IWV, cm) for (a) 5 Feb 1998, (b) 22 Feb 1998, and (c) 5 Dec 1997.

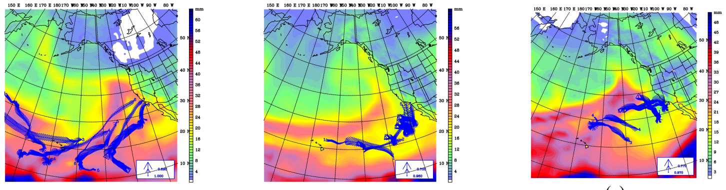
Selected cases: Six cases of land-falling cyclones with observed IWV bands have been selected between 1997-2001, all of which produced significant precipitation in California. The six cases are 1-5 Jan 1997, 4-6 Dec 1997, 2-3 Feb 1998, 5-6 Feb 1998, 23 Feb 1998, and 3-5 Mar 2001. These six cases include conditions of neutral El Nino/Southern Oscillation (ENSO) (the first case), El Nino (the second through the fifth cases), and La Nina (the last case).

Numerical Model: The NCAR/Penn State mesoscale model (MM5) was used to perform numerical simulations and produce the trajectory analyses to physically interpret the satellite IWV images. The model was initialized with both NCEP and ECMWF analyses. Preliminary comparisons show that the simulations initialized with the two different analyses are similar in the evolution of the synoptic flow. The results shown here are initialized with NCEP analyses. The model domain is made of 200 X 200 grid points in the horizontal and 50 vertical levels. The grid resolution is 36 km. The configuration of MM5 physics used in this study includes the mixed-phase cloud physics, the Grell scheme, a 1.5 order planetary boundary layer scheme, and the MM5 simple short-wave and long-wave radiation parameterization schemes.



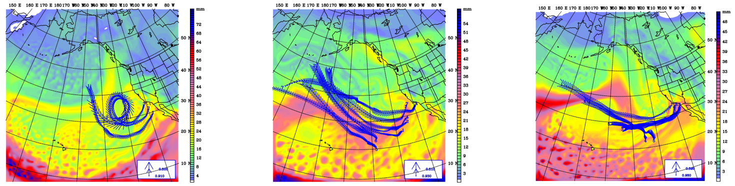
(a) (b) (c)

Figure 5 Integrated water vapor (mm) at the release time of the backward trajectories released at 1-km for (a) the 1-5 Jan 1997 case (neutral ENSO), release at 0000 UTC 2 Jan 1997 for 96 hours; (b) the 2-3Feb 1998 case (El Nino), released at 1200 UTC 3 Feb 1998 for 60 hours; and (c) the 3-5 Mar 2001 case (La Nina), released at 0000 UTC 4 Mar 2001 for 72 hours. The size of the arrowheads in the trajectories represents the elevation of air parcels with bigger arrowheads corresponding to higher elevations.



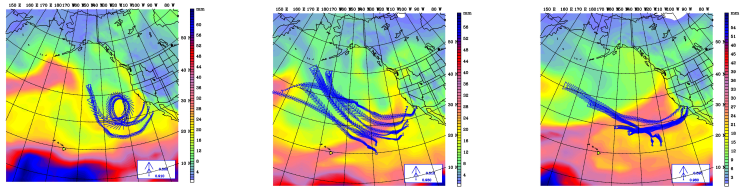
(a) (b) (c)

Figure 6 The same as Fig. 5, except with the integrated water vapor at the end time of the backward trajectories.



(a) (b) (c)

Figure 7 Integrated water vapor (mm) at the release time of the backward trajectories released at 1-km for (a) the 4-6 Dec 1997 case (El Nino), release at 1800 UTC 6 Dec 1997 for 66 hours; (b) the 5-8 Feb 1998 case (El Nino), released at 0000 UTC 8 Feb 1998 for 72 hours; and (c) the 23-25 Feb 1998 case (El Nino), released at 1800 UTC 23 Feb 1998 for 66 hours. The size of the arrowheads in the trajectories represents the elevation of air parcels with bigger arrowheads corresponding to higher elevations.



(a) (b) (c)

Figure 8 The same as Fig. 7, except with the integrated water vapor at the end time of the backward trajectories.

Preliminary conclusions :

All the observed IWV bands are formed within the convergence zone associated with the cold front of extratropical storms. In the neutral ENSO case of 1-5 Jan 1997, the trajectory analyses indicate that there are air parcels feeding into the broad IWV band that originated from the high IWV reservoir in the tropics, indicating the moist tropical low-level air is tapped into and transported northeastward by the storm. However, for the El Nino and La Nina cases, the trajectories of air parcels feeding the IWV plume indicate that they originated from the extratropics and that there is no direct tapping of the tropical low-level moisture into the storm.

Examination of all the results from the simulations of the six cases indicates that the ability of these extratropical cyclones to tap tropical moisture depends on the strength of the Hadley circulation in the eastern Pacific (Figs. 2&3). In the case study from a neutral ENSO year, the flow associated with mid-latitude storms penetrates the sinking branch of the Hadley circulation, creating a break in the sinking branch somewhere between 120ºW and 180ºW. As a result of this, low-level moisture over the tropical ocean feeds into the extratropical storm. On the other hand, during an El Nino year, the sinking branch of the Hadley circulation is enhanced in such a way that the storms cannot penetrate it. This prevents air parcels over the eastern tropical Pacific from moving northward/northeastward and interacting with the mid-latitude storms. Seasonal climate analysis confirms the aforementioned ENSO cycle in the strength of the sinking branch of the Hadley circulation (Figs. 2 & 3).

In this study, it is shown that a regional weather prediction model can be used as an effective tool to provide a detailed picture of how low-level moisture over the eastern tropical Pacific can feed the mid-latitude storms that produce significant precipitation over the US West Coast. They also provide a better understanding of how the transport of low-level moisture from the low-latitudes to mid-latitudes changes with the ENSO cycle.

Acknowledgements: The authors thank Jeff Whitaker at NOAA/Climate Diagnostics Center (CDC) for providing information on how to graph NCEP/NCAR reanalysis data using CDC's online analysis tool. Assistance from Gary Wick at NOAA/Environmental Technology Laboratory in making the composite images of IWV is also appreciated.

Email addresses for further contact:

JWB:	Jian-Wen.Bao@noaa.gov
SAM:	Sara.A.Michelson@noaa.govgov
PJN:	Paul.J.Neiman@noaa.gov
FMR:	Marty.Ralph@noaa.gov
JMW:	James.M.Wilczak@noaa.gov