Atmospheric Rivers and Enhanced Integrated Vapor Transport Probability Forecasts as seen During Frontal Passages in Southern California with an Emphasis on Strong Winds

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Introduction

Atmospheric rivers (e.g., *Ralph et al. 2004;)* are not infrequent visitors to the west coast, but they only occasionally slip far enough south to affect Southern California (Fig. 1). The main impact is typically heavy rain, and when cold enough, heavy snow at the higher elevations in the mountains, but another significant impact is strong winds and severe weather. Integrated water vapor transport (IVT) is a good parameter for determining moisture advection into the region and mainly consists of imbedded strong flow combined with significant amounts of moisture. It has been associated with very moist air masses that invade Southern California with wind damage (Small, 2016). With or without much instability, this can result in the generation of damaging frontal passages and strong wind shear, both from a convective standpoint (possible supercells) and a synoptic scale wind standpoint. Major airport traffic delays, flash flooding, and power outages can occur. In order to look at how well these events are forecast in advance, this study makes some brief comparisons of IVT from the perspective of probability forecasts to damaging impacts in the region using the National Center for Environmental Prediction (NCEP) GFS Ensemble Prediction System. The focus will be on the more damaging frontal passages during the 2015-2016 cool season.

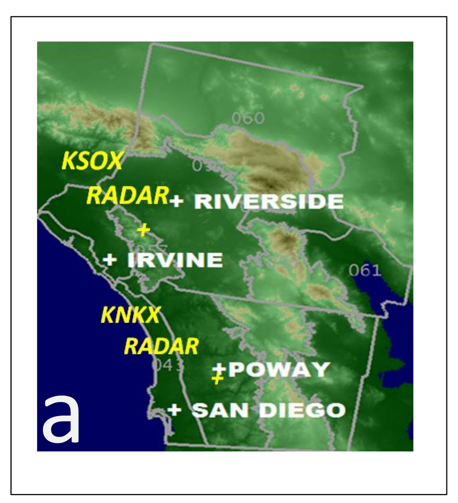

Fig. 1. Terrain map of the WFO SGX Forecast Area. Color coding in the legend is in thousands of feet MSL.

Strong Cold Frontal Passage Case on 6-7 January 2016

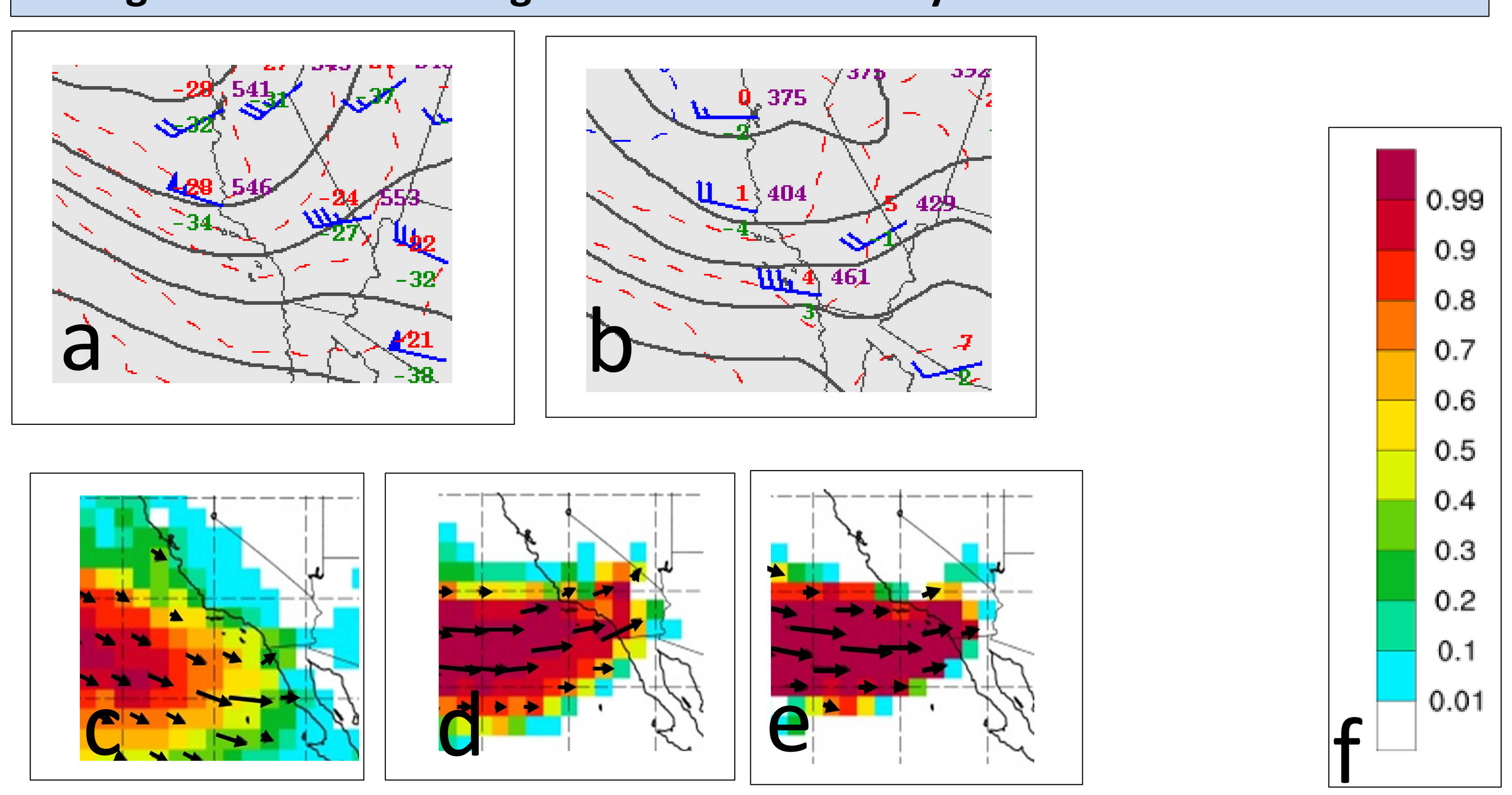

Fig. 2. The upper images are the 0000 UTC 7 January 2016 heights, winds, and temperatures at (a) 500 hPa and (b) 850 hPa. The lower images are the NCEP GFS IVT Probability > 250 (kg m^{-1} s^{-1}) and IVT vector forecasts valid at 0000 UTC 7 January 2016. The images are the (c) 96 hour forecast (d) 48 hour forecast, and (e) 00 hour forecast respectively. The far right image (f) is the probability image scale.

Initially (Fig. 2), on the 96 hour forecast only the very edge of the 0.5 touches the beaches, indicating that the best chance of reaching 250 kg m^{-1} s^{-1} was over the coastal waters. However, by the 48 hour forecast the values of 0.6 and higher had moved over the coastal areas. By the 00 hour forecast solid areas in the 0.99 or higher category extend inland. [Note that this case has no area of 0.99 displaced to the northwest, (as is seen in later cases)]. Below 2500 feet MSL (0.76 km), KNKX radar winds (not shown) peaked around 42 knots (21 m s^{-1}) for numerous trees down in Poway. A side note is that the radar may not have even seen the strongest winds, which may be nearly perpendicular to the radar beam in this case in the Poway area (Small 2016).

Strong Cold Frontal Passage Case on 31 January – 1 February 2016

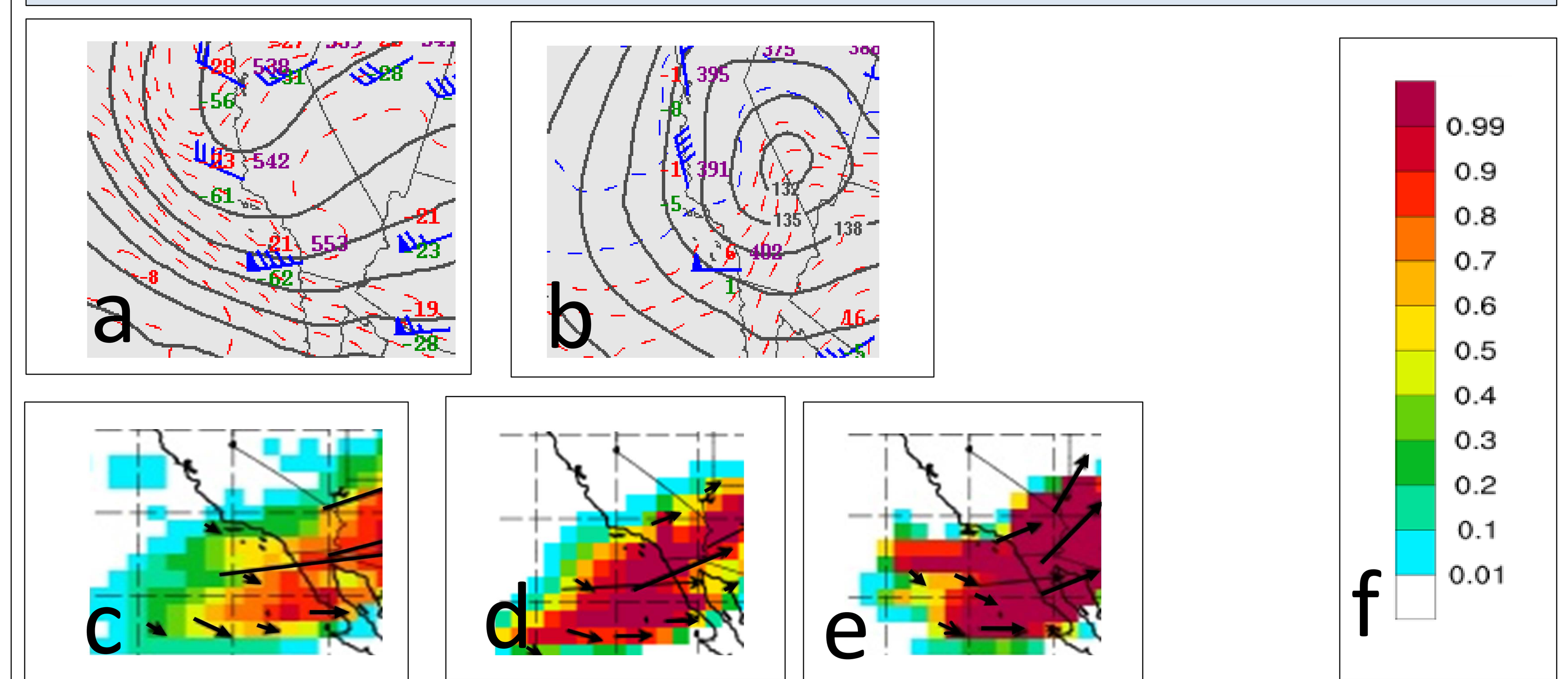

Fig. 3. The upper images are the 0000 UTC 1 February 2016 heights, winds, and temperatures at (a) 500 hPa and (b) 850 hPa. The lower images are the NCEP GFS IVT Probability > 250 (kg m^{-1} s^{-1}) and IVT vector forecasts valid at 0000 UTC 1 February 2016. The images are the (c) 96 hour forecast (d) 48 hour forecast, and (e) 00 hour forecast respectively. The far right image (f) is the probability image scale.

The 96 hour forecast (Fig. 3) showed modest coastal probabilities of about 0.5-0.7. There was a strong increase at 48 hours as values jumped up to around 0.99, and blanket the area by the 00 hour forecast. This case has no area of 0.99 displaced to the northwest, as is seen in later cases. The peak KNKX radar estimated speeds at 2500 feet MSL (0.76 km) or lower (not shown) were in excess of 65 knots (32.5 m s^{-1}). Numerous trees and even power poles were blown down, and there was 1 fatality when a large tree fell on an occupied vehicle in the San Diego area.

Strong Cold Frontal Passage Case on 7-8 March

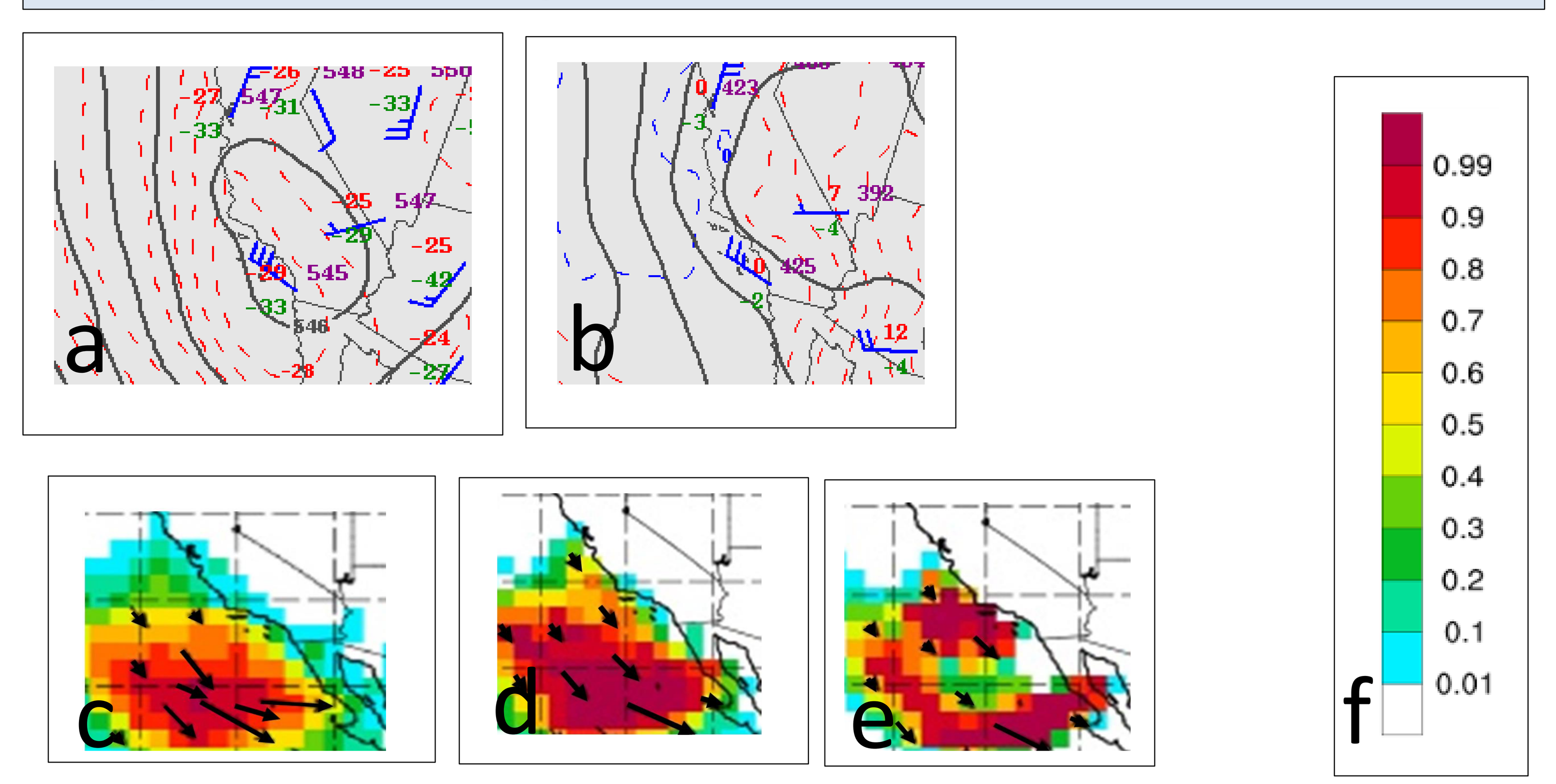

Fig. 4. The upper images are the 0000 UTC 8 March 2016 heights, winds, and temperatures at (a) 500 hPa and (b) 850 hPa. The lower images are the NCEP GFS IVT Probability > 250 (kg m^{-1} s^{-1}) and IVT vector forecasts valid at 0000 UTC 8 March 2016. The images are the (c) 96 hour forecast (d) 48 hour forecast, and (e) 00 hour forecast respectively. The far right image (f) is the probability image scale.

It appears (Fig. 4) that a small area of 0.9 or higher likely swept through the area just prior to the 0000 UTC 8 March 2016 valid time. Note a core of 0.99 in the coastal waters to the northwest, not far from the "cold core" portion of the low, has developed. Downed trees were reported with surface winds gusting to around 43 knots (21.5 m s^{-1}) in the Irvine area. The KSOX radar, located at 3106 feet MSL (around 0.95 km) precludes measurement of wind speeds at 2500 feet (0.76 km) MSL or below, but did indicate 40 knot (20 m s^{-1}) winds near the base of the vertical cross section of the winds (not shown) at the lowest angle of the radar beam.

Strong Cold Frontal Passage Case on 11-12 March 2016

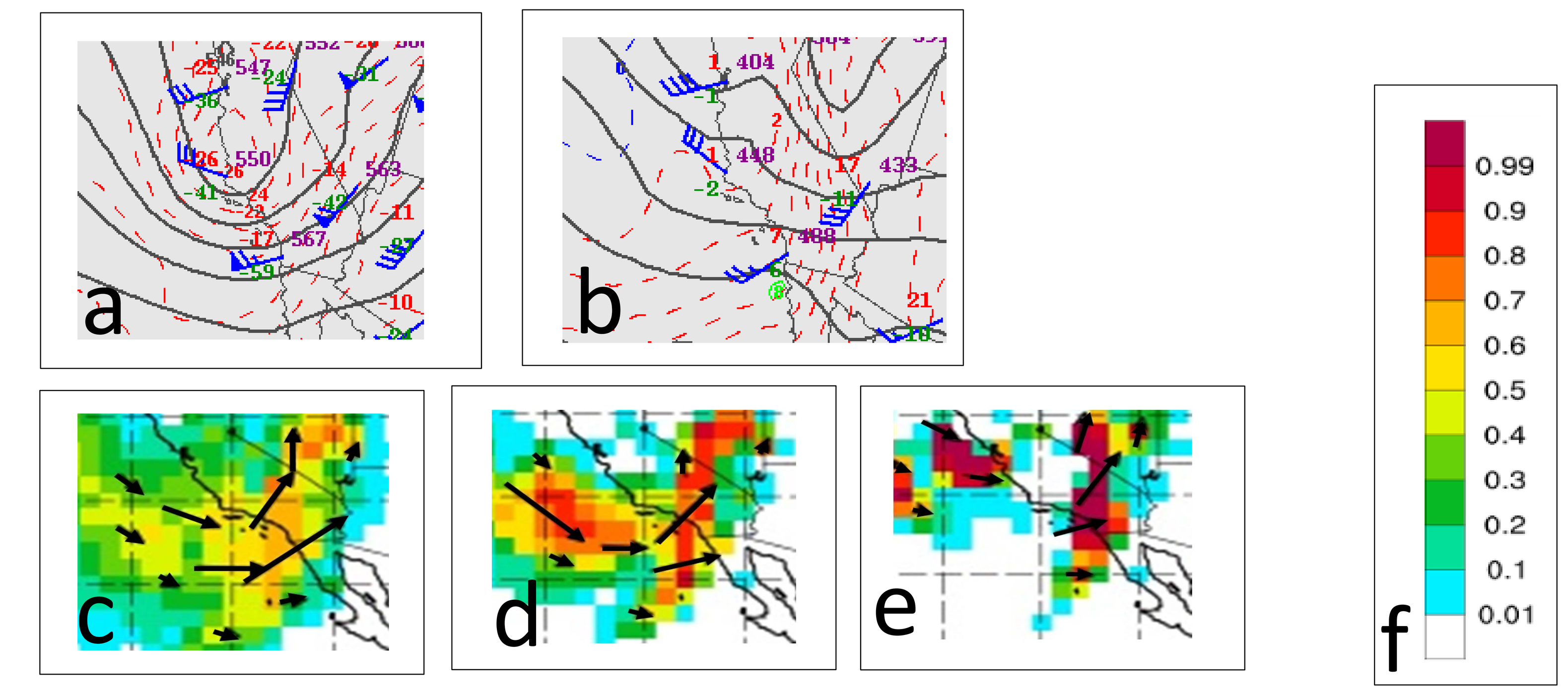

Fig. 5. The upper images are the 0000 UTC 12 March 2016 heights, winds, and temperatures at (a) 500 hPa and (b) 850 hPa. The lower images are the NCEP GFS IVT Probability > 250 (kg m^{-1} s^{-1}) and IVT vector forecasts valid at 0000 UTC 12 March 2016. The images are the (c) 96 hour forecast (d) 48 hour forecast, and (e) 00 hour forecast respectively. The far right image (f) is the probability image scale.

The 96 hour forecast (Fig. 5) showed modest values, but by the 00 hour forecast, values 0.99 and up in a north-south line dominate the coastal areas. Another core of 0.99 and up values was out over the coastal waters to the northwest. Similar to the 8 March 2016 case, this feature is not far from the "cold core" portion of the low. (Note it was not an obvious feature in the 96 hour forecast). Seven power poles and associated power lines were down in Riverside. KSOX radar showed 40+ knot winds (20 m s^{-1}), but at around 3000 feet (0.91 km) AGL.

Summary and Conclusions

Atmospheric rivers with values > 250 kg m^{-1} s^{-1} did develop in Southern California January-May of 2016. Of the seven events detected, 4 events produced wind damage, while 3 events (not shown) did not. Although the dataset is still rather small, some common features with the damaging events are:

1. IVT signatures began to be apparent even out at 96 hours.
2. Negatively-tilted troughs appear to be a common factor
3. Coastal 850 mb winds near 25 knots (12.5 m s^{-1}) or stronger

Among other tools, radar winds around 40 knots (20 m s^{-1}) or stronger about 2500 feet (0.76 km) AGL or lower (AGL closely approximates MSL near the coast) seem to accompany these events. With bowing convective elements, radar winds of only around 35 knots (17.5 m s^{-1}) can be damaging. The 3 events with no strong winds (in contrast to the other 4 cases) had radar-interrogated winds at 2500 feet AGL (0.76 km) or lower that were far weaker than 30 knots (15 m s^{-1}) .

References

Ralph, F.M., P.J. Neiman, and G.A. Wick, 2004: Satellite and CALJET aircraft observations of 1997/98. *Mon. Wea. Rev.*, **132**, 1721-1745.

Small, I.J., 2016: Atmospheric Rivers and Enhanced Integrated Vapor Transport Episodes: Their Role in Damaging Frontal Passages in Southern California with an Emphasis on Strong Winds. 2016 International Atmospheric Rivers Conference, Scripps Institution of Oceanography, Center for Western Weather and Water Extremes (CW3E), 8-11 August 2016, http://cw3e.ucsd.edu/ARconf2016/Presentations/Wednesday/S2_ImpactsofARs2/Small_IARC2016.pdf

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