Anticipating a Rare Event Utilizing Forecast Anomalies and a Situational Awareness Display

The Western U.S. Storms of 18–23 January 2010

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In recent years, the use of tropospheric anomalies to anticipate significant weather events has increased across the weather enterprise. Studies have shown the utility of anomalies in a variety of settings, from ranking the meteorological significance of historic events (Hart and Grumm 2001; Graham and Grumm 2010, hereafter GG2010) to identifying anomalous variables associated with specific weather threats, such as East Coast snowstorms and California heavy-precipitation events. Other research has looked at the correlation of anomalies with observed weather and impacts for individual events.

While the use of tropospheric anomalies in the forecast process has been shown to be beneficial, one of the many challenges facing operational forecasters is managing the large amount of guidance data. In recent years, the amount of data available, both from numerical weather prediction output and observational platforms, has increased substantially. This has provided forecasters with a greater breadth of information on which to base their forecasts, but also introduces the potential for data overload and creates a need for tools that aid in effective time and information management.

This paper will document a winter storm cycle that impacted much of the southwest United States during January 2010. In particular, anomalies associated with an extreme precipitation event over Arizona on 21–22 January 2010 will be discussed. This extraordinary event was remarkably well predicted by operational numerical weather prediction models. Standardized anomalies derived from the Global Forecast System (GFS) Ensemble Forecast System (GEFS) indicated a potentially historic storm up to one week in advance. This event demonstrates the utility of using forecast standardized anomalies to heighten awareness that a potentially high-impact—or even historic—event may occur. The event will also be used to demonstrate an anomaly-based situational awareness display, developed at the National Weather Service office in Salt Lake City, which can streamline the identification and analysis of significant forecast anomalies.

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DATA AND METHODS. *Calculating standardized anomalies.* Hart and Grumm (2001) utilized the National Centers for Environmental Prediction/National Corporation for Atmospheric Research reanalysis dataset (NNR) to develop a comprehensive climatology for a variety of atmospheric variables (e.g., geopotential height, temperature, wind) at the standard levels from 1,000 to 200 hPa over eastern North America. The NNR has a horizontal resolution of 2.5° × 2.5° and is available for 17 pressure levels from 1,000 to 10 hPa. GG2010 followed this same methodology to create a climatology (1971–2000) for the western United States. GFS analyses and GEFS forecasts were obtained from the NOAA Operational Model Archive Distribution System (NOMADS) at 1° × 1° horizontal resolution. Observed (forecast) standardized anomalies were calculated by reprojecting the GFS analyses (GEFS ensemble mean forecasts) valid at 0000 UTC 22 January 2010 forecasts to the NNR grid and then subtracting the GG2010 climatology from the observed (forecast) fields. A standardized anomaly (SA) is defined by

TABLE 1. Variables included in the anomaly situational awareness table.

Variable	Available levels (hPa)
Geopotential height	1000, 925, 850, 700, 500, 250
Mean sea level pressure	Surface
Temperature	1000, 925, 850, 700, 500, 250
U-wind	1000, 925, 850, 700, 500, 250
V-wind	1000, 925, 850, 700, 500, 250
Wind magnitude	1000, 925, 850, 700, 500, 250
Specific humidity	1000, 925, 850, 700, 500
Precipitable water	Atmospheric column

$$SA = (F - M)/\sigma$$

where SA is the standardized anomaly expressed in standard deviations from normal, F is the value from the reanalysis data at each grid point, M is the 21-day climatological running mean (i.e., the mean at the specified hour for the 21-day period centered on the specified day), and σ is the value of the standard deviation, at each grid point.

Situational awareness table. Standardized anomalies from model forecasts have increasingly been utilized in recent years by forecasters to identify potential major impact events. SA fields can assist forecasters in wading through the increased suite of available model data. This is critical for assessing model data and making a timely forecast for the customer. Tropospheric anomalies can be readily evaluated in a display framework (available at www.wrh.noaa.gov/slc/projects/anomaly/frames.php) to help direct forecaster attention to anomalous elements that require closer investigation.

This framework organizes the forecast SA values into an anomaly situational awareness table (ASAT), enabling forecasters to quickly identify significant features in the GEFS mean. In all, eight elements (Table 1) are displayed, with the anomalies sorted by element and forecast hour. SA values are calculated for multiple pressure levels (traditional mandatory levels) for all but two of the eight elements. The values in the ASAT (Fig. 1) represent the largest magnitude SA (positive or negative) of all of the pressure levels available for that specific variable and forecast hour (note that in January 2010 the tables displayed only seven elements). To provide context, historic return intervals are available for reference and linked from the ASAT. The cells are shaded based upon the magnitude of the SA, and forecasts are available in 6-h increments out through 180 h. The color coding of the departures by time and element allows forecasters to quickly identify which elements and time frames need further investigation.

While a quick glance at the ASAT will be sufficient to recognize whether an anomalous event is forecast in the GEFS mean, much more detail is available. The SA value displayed in each cell in the ASAT is also a link to images showing the spatial distribution of the SA values for each level available for that particular element. Additional displays are also available from the table, including loops and element-specific

FIG. 1. Anomaly situational awareness table from the 0000 UTC 16 Jan 2010 GEFS forecast cycle (144-h lead time).

Western US Table | January 16th, 2010 | 00z run

	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84
	Sat 16th				Sun 17th				Mon 18th				Tue 19th		
	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z
Height	-4.0	-3.6	-2.5	2.2	-2.4	-2.5	-2.6	-2.7	-2.9	-2.8	-3.1	-4.1	-4.0	-3.7	-3.9
Temp	-3.6	-4.0	-3.0	3.0	2.9	3.1	2.9	2.6	2.8	3.0	3.2	3.1	3.4	3.9	4.3
U-Wind	-3.5	-3.6	-2.8	-3.0	2.8	2.9	3.2	3.1	3.0	3.0	3.0	3.3	3.7	3.4	3.6
V-Wind	-3.7	-3.7	-3.2	2.9	2.8	3.1	2.8	3.2	3.1	3.3	3.3	4.2	4.6	3.7	3.6
SHum	3.9	3.7	4.3	4.2	3.5	2.7	2.9	2.8	3.4	2.9	3.4	2.8	2.6	2.5	3.0
MSLP	-2.2	-2.2	-2.1	-2.0	-2.4	-2.5	-2.6	-2.6	-3.0	-2.8	-3.1	-4.2	-4.1	-3.7	-3.9
PWAT	2.7	3.0	3.4	2.3	2.0	1.7	1.9	1.4	2.1	2.1	2.4	2.1	2.7	2.3	2.3

	90	96	102	108	114	120	126	132	138	144	150	156	162	168	174	180
		Wed 20th				Thu 21st				Fri 22nd				Sat 23rd		
	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z
Height	-3.9	-3.8	-4.5	-5.1	-5.3	-5.4	-6.1	-6.5	-6.3	-6.3	-6.0	-6.1	-5.3	-4.5	-4.0	-3.9
Temp	4.2	3.8	3.6	3.8	3.5	-3.6	-3.9	-4.0	-4.1	-4.0	-4.1	-3.8	-3.5	3.2	3.3	3.4
U-Wind	3.7	3.8	4.0	4.0	4.2	4.3	4.4	4.6	4.9	5.2	5.2	5.1	5.1	5.2	4.4	4.2
V-Wind	3.1	2.5	2.8	4.1	4.6	4.2	4.8	5.5	5.4	5.2	5.5	5.2	4.8	3.7	3.7	2.5
SHum	2.8	3.1	3.0	3.1	2.6	2.7	2.5	2.7	2.6	2.8	2.6	2.8	2.7	2.9	2.4	-2.6
MSLP	-3.9	-3.8	-4.4	-5.2	-5.4	-5.6	-6.1	-6.7	-6.4	-6.2	-5.9	-5.9	-4.9	-4.2	-3.5	-3.4
PWAT	2.0	2.0	2.0	2.2	2.1	2.6	2.5	2.8	2.7	2.8	2.2	2.3	2.3	2.2	-2.1	-2.2

tables (e.g., SA values for all geopotential height levels and forecast hours). There are nine domains (accessible from the bottom of the ASAT) available for subregions across North America. The domains are relatively large because the background climatology is coarse and the focus is on identifying synoptic-scale departures. Information on ASAT functionality can be found at www.wrh.noaa.gov/slc/projects/anomalies/description.html.

EVENT. *Evolution and impacts.* From 18 to 23 January 2010, a series of winter storms impacted the western United States, setting more than 450 daily precipitation records. One of the primary impacts of the series of storms was a heavy precipitation event across Arizona. Rainfall amounts of 125–250 mm were recorded on and just south of the slopes of the Mogollon Rim in central Arizona, with widespread 25–75-mm amounts across Arizona's lower deserts (Fig. 2). The heavy rain produced floodwaters 4–6 m deep in Black Canyon City (Fig. 2), resulting in one fatality and requiring water rescues of more than a dozen individuals. Elevations above 2,100 m in northern Arizona received 100–150 cm of snow, with more than 225 cm falling at Sunrise Mountain. Blizzard conditions (i.e., at least 3 h of sustained wind or frequent gusts of 30 kt or greater, and considerable falling or blowing snow frequently reducing visibility to less than 400 m) were reported at higher elevations in California, Nevada, and Arizona.

The most intense storm during this period (accounting for much of the total precipitation in Arizona) occurred on 21–22 January, producing severe convection (including the first tornado watch in Arizona since 1993), high winds, and heavy rain and snow. The severe weather included two tornadoes in California, prefrontal winds of 20–30 m s^{-1} in southern Arizona, and gusts in excess of 40 m s^{-1} associated with an intense squall line affecting southeast California and Arizona. The heavy snow and high winds resulted in damage to structures, widespread power outages, and paralyzed travel across portions of northern Arizona for several days. Specifically, roads were impassable to the Navajo and Hopi reservations in northern Arizona, which impacted rescue services and resulted in shortages of food and medicine. The event established a new 24-h snowfall record (ending at 1200 UTC 22 January) for Arizona, with 122 cm at Sunrise Mountain (Fig. 2). In all, 17 sites in Arizona tied or set records for the most precipitation for any day in January.

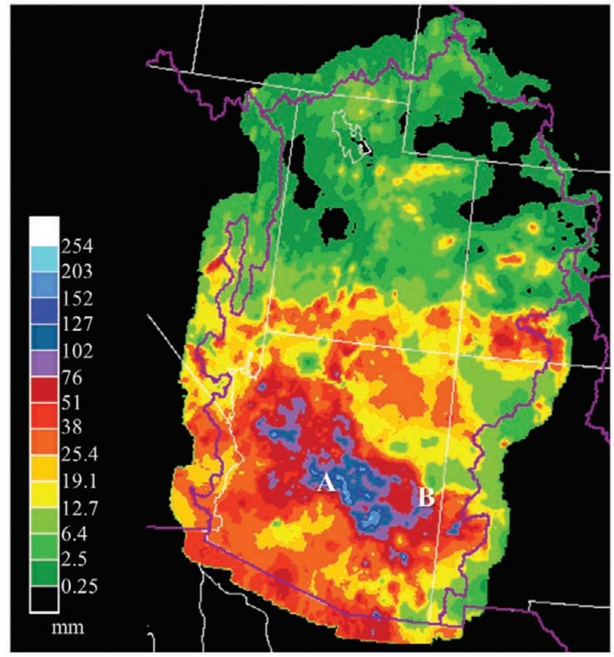

Fig. 2. Quantitative precipitation estimates (mm) from the NOAA/NWS Colorado Basin River Forecast Center for the 24-h period ending 1200 UTC 22 Jan 2012 (image courtesy of NOAA/NWS Hydrometeorological Prediction Center, National Precipitation Verification Unit). "A" indicates approximate location of Black Canyon City; "B" indicates approximate location of Sunrise Mountain. Purple lines highlight River Forecast Center boundaries.

Observed standardized anomalies. The observed SA values associated with this high-impact event were extreme and, in some cases, record-setting. For brevity, only 500-hPa geopotential height, 700-hPa meridional wind, precipitable water, and mean sea level pressure (MSLP) valid at 0000 UTC 22 January 2010 will be addressed, and the anomalies are generally discussed in isolation from each other. However, the juxtaposition of significant SA values is an important consideration in the forecast process. As an example, the collocation of significant positive precipitable water anomalies, large positive meridional wind anomalies, and negative height anomalies provides more information to the forecaster regarding the potential for a significant event than do any of these anomalies individually.

The 500-hPa geopotential height analysis indicated a very deep trough centered off the west coast of the United States. At the base of this trough, an area with an SA of −5 to −6 was analyzed off of the coast of Baja California (Fig. 3a). East of the trough axis,

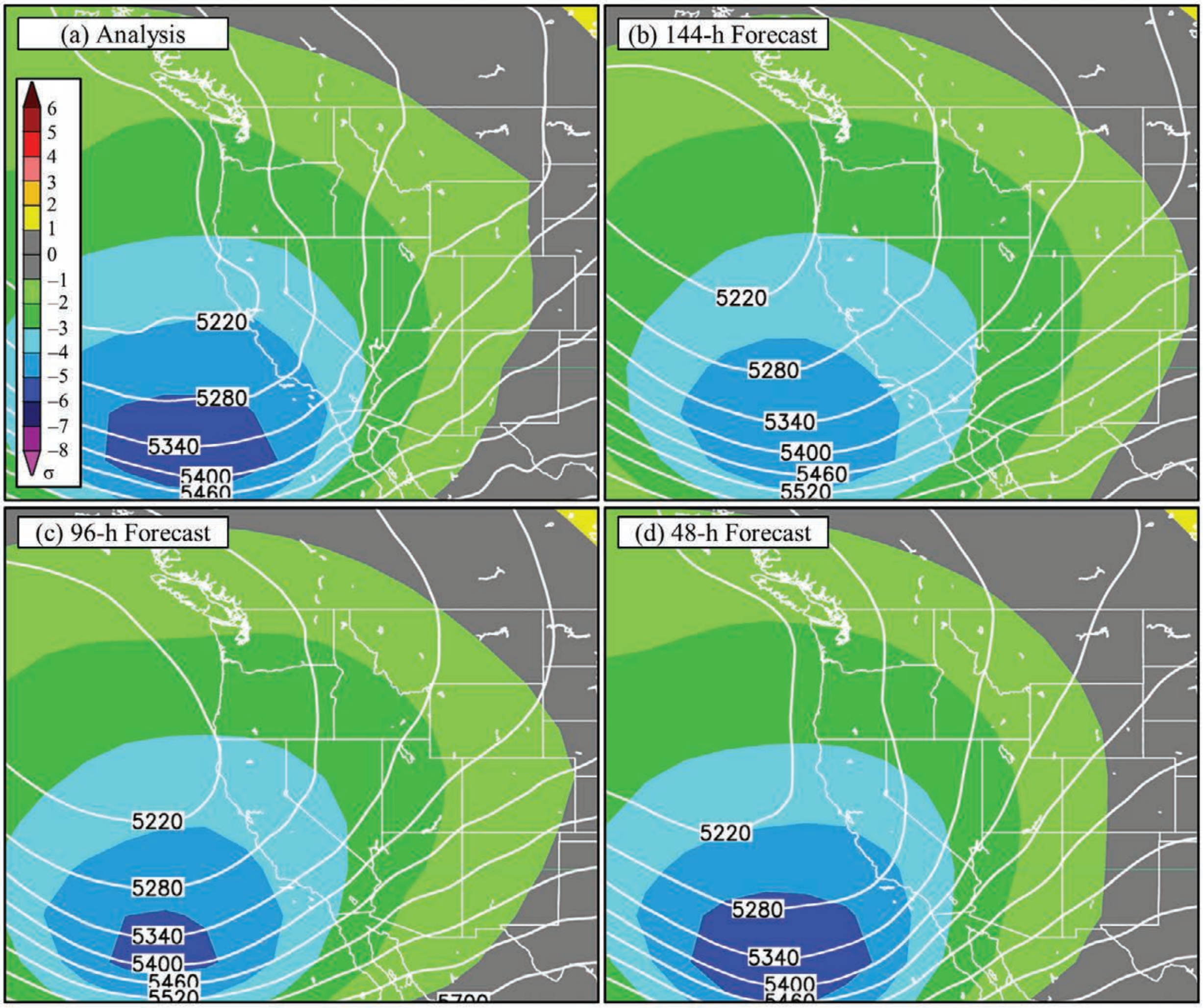

Fig. 3. 500-hPa geopotential height (dm) and SA (σ) valid at 0000 UTC 22 Jan 2010 from the (a) GFS Analysis, and (b) 144-, (c) 96-, and (d) 48-h GEFS forecasts.

the 700-hPa meridional winds were quite strong, particularly over the southern two-thirds of Arizona, where SA values were +5 to +6 (Fig. 4a).

The analyzed precipitable water field (Fig. 5a) also showed a region of significant SA values across the southwest United States, including an area of +3 to +4 over Arizona. These SA values were associated with an atmospheric river impinging on the desert southwest, a feature that has been linked to many western U.S. extreme precipitation events.

One of the most interesting aspects of the storm cycle was the analyzed MSLP SA of −8.7 along the southern California coast (Fig. 6a), which surpassed the largest MSLP SA in the NNR dataset (−8.1). The old record was associated with the 1962 Columbus Day windstorm in the Pacific Northwest, often referred to as the western U.S. "Storm of the Century." Not only was the magnitude of the SA impressive, so too was the areal extent of −3 to −4 values over much of the western United States. This massive MSLP anomaly was associated with numerous all-time minimum pressure records from Medford, Oregon, to Phoenix, Arizona (Table 2). Few of these previous records occurred in the same event, and now many stations across the western United States have a single storm representing their minimum pressure records.

FORECAST ANOMALIES AND THE SITUATIONAL AWARENESS TABLE. The following discussion, focused on the forecast verifying at 0000 UTC 22 January 2010, provides an example of the use of standardized anomalies and the ASAT in anticipat-

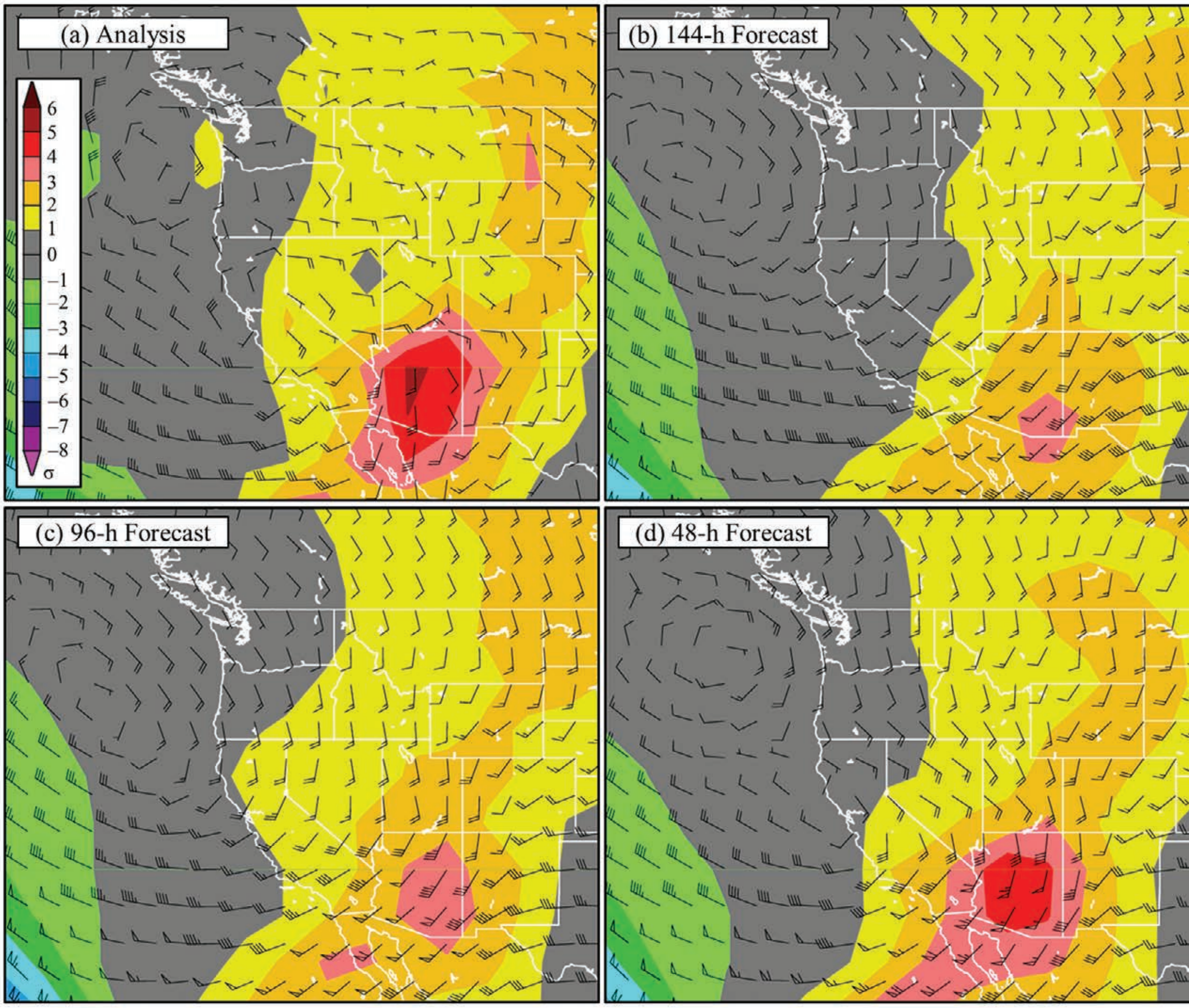

Fig. 4. Same as Fig. 3, except for 700-hPa meridional wind component (kts).

ing extreme events. This time is near the midpoint of the extreme precipitation event occurring in Arizona. For brevity and consistency, only forecasts with lead times of 144, 96, and 48 h will be discussed.

144-h forecast. At 144 h (from the 0000 UTC 16 January 2010 cycle), the GEFS was forecasting significant SA values across the western United States for most elements. A forecaster looking at the ASAT would be drawn to the period of significant SA values around 0000 UTC 22 January (Fig. 1). The largest SA in the western United States domain for the available geopotential height levels was −6.3 (925 hPa). The forecast 500-hPa geopotential height SA values were −4 to −5 in the base of the trough (Fig. 3b). This forecast verified rather well with respect to the analyzed intensity and location (Fig. 3a).

The forecast meridional winds (labeled V-Wind) were also impressive, with a maximum SA of +5.2 (925 hPa) depicted in the ASAT (Fig. 1). The maximum forecast meridional wind SA at 700 hPa was +3 to +4 across southeast Arizona, with a larger area of +2 to +3 extending from eastern Utah to the Baja California coast (Fig. 4b). While the forecast 700-hPa meridional winds across Arizona were underdone (and displaced southeast) relative to the analysis, the strength of the anomalies and extended fetch of the winds from the Pacific indicated the potential for an atmospheric river event (Fig. 4a).

The precipitable water SA values in the ASAT do not immediately stand out, with a domain maximum of +2.8 and an area of +2 to +3 in southern Arizona and northern Mexico (Fig. 1, 5b). This is a considerably smaller departure than what was

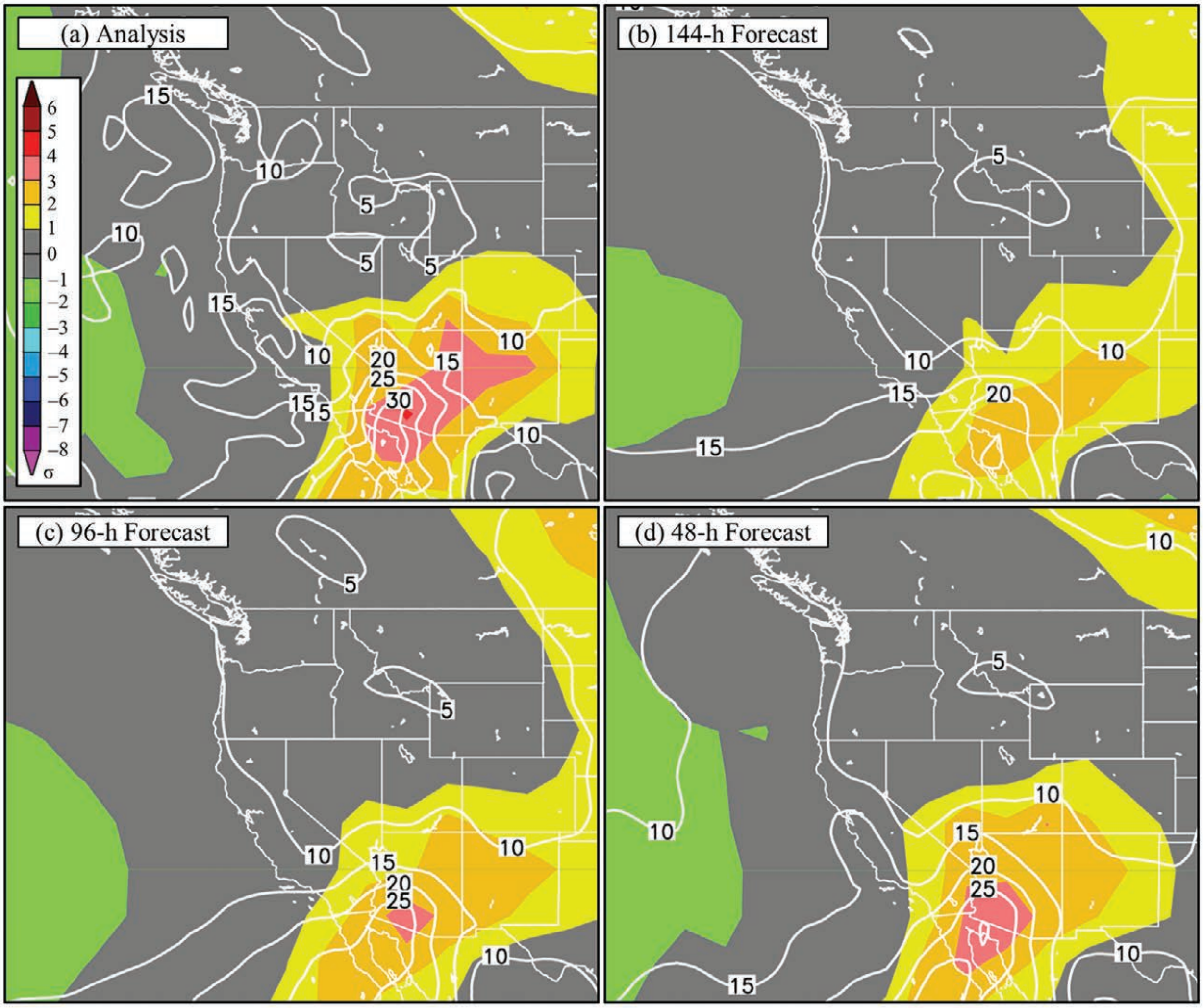

Fig. 5. Same as Fig. 3, except for precipitable water (mm).

analyzed (Fig. 5a), although the forecast improved in subsequent runs. Moreover, the anomalies once again indicated the potential for an atmospheric river event across Arizona.

The ASAT also showed an MSLP anomaly of −6.2 (Fig. 1) off the coast of southern California (Fig. 6b). A forecast anomaly of this magnitude in the ASAT at 144 h should alert forecasters to the potential for a rare event, and may enable them with the opportunity to provide initial decision support services, indicating the possibility of a high-impact event to core customers and partners. Over subsequent runs, this forecast SA was persistent and steadily increased in magnitude (Fig. 6c,d).

96-h forecast. The event looked even more significant in the ASAT in the 96-h forecast (from the 0000 UTC 18 January cycle), with SA magnitudes of at least 3 for every element (Fig. 7). The largest magnitude geopotential height SA was −6.3 (925 hPa) and values of −5 to −6 were found at the base of the 500-hPa trough (Fig. 3c).

The greatest forecast meridional wind SA was +6.1 (925 hPa). At 700 hPa, the SA was still in the +3 to +4 range, but it had expanded to cover much of southern and eastern Arizona (Fig. 4c). The precipitable water SA associated with this core of strong winds had increased to +3 to +4 (Fig. 5c). The collocation of the significant meridional wind and precipitable water SA values could serve to heighten forecaster awareness that a substantial—or even historic—precipitation event was possible in Arizona. The forecast minimum MSLP SA had decreased to −6.4, although the location of this extreme along

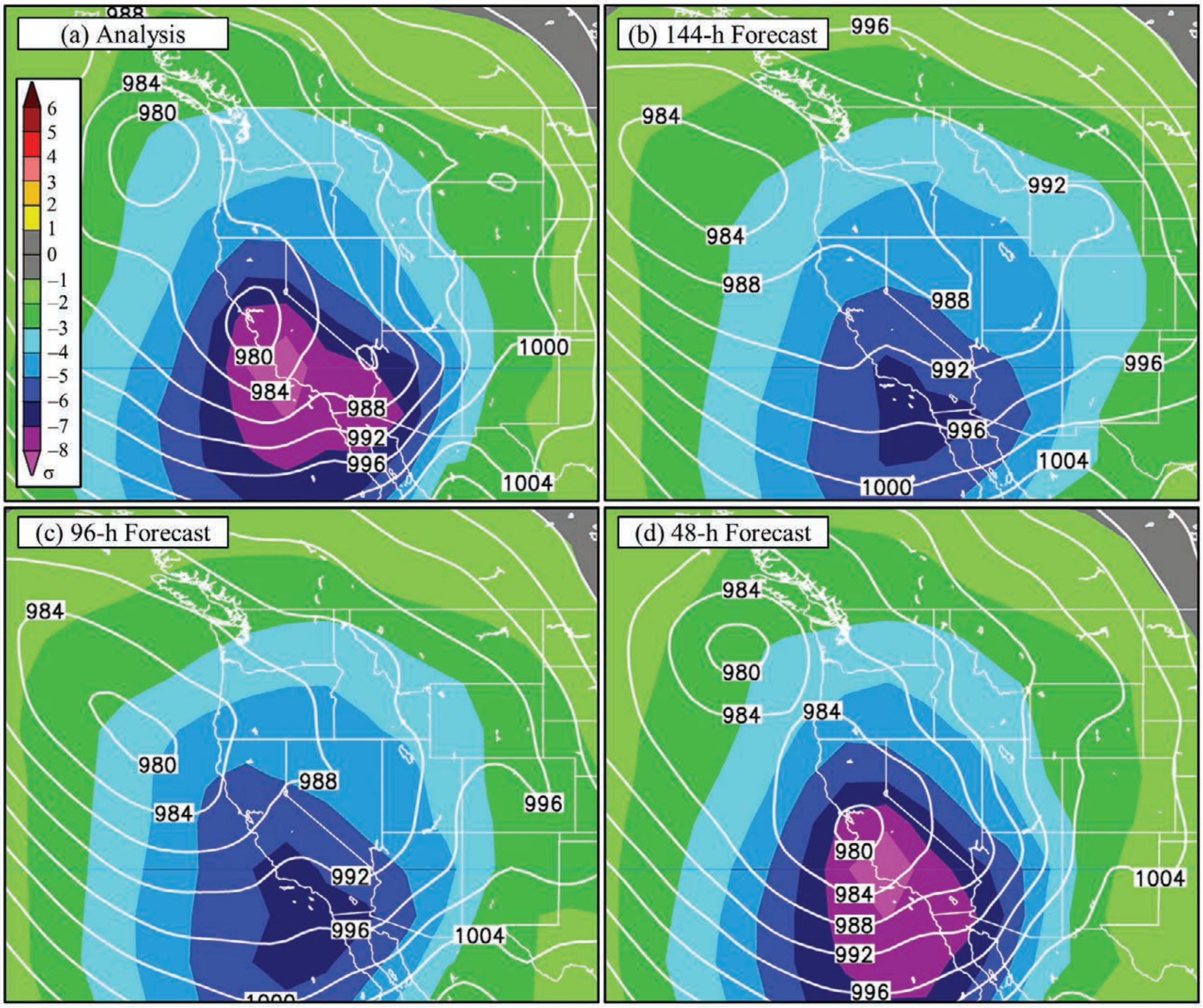

Fig. 6. Same as Fig. 3, except for mean sea level pressure (mb).

the southern California coast was consistent with the 144-h forecast (Fig. 6b,c).

48-h forecast. The 48-h forecast (from the 0000 UTC 20 January 2010 GEFS cycle) provided strong signals that a potentially rare event was possible given the magnitude of the SA values. The 500-hPa geopotential height forecast was similar to the 96-h forecast, although the area of −5 to −6 SA values had expanded (Fig. 3d). The forecast compares well to the analysis (Fig. 3a).

The ASAT indicated the maximum SA for the meridional winds had increased to +7.5 (850 hPa; Fig. 8). To put this forecast in perspective, the NNR dataset (1948–2008) did not contain a single time step with an 850-hPa meridional wind SA ≥ 7.5 anywhere in the western United States. At 700 hPa, the forecast SA had increased to +4 to +5 over much of southern and central Arizona (Fig. 4d). The precipitable water SA remained similar to that at 96 h, showing only a slight increase to +3.7. However, the area of SA values > 3 had expanded and now extended from Baja California to the southern Mogollon Rim (Fig. 5d). This precipitable water SA maximum was collocated with substantial positive meridional wind SA values at 700 hPa, implying a strong upslope component along the northwest–southeast-oriented Mogollon Rim and creating the potential for a heavy-precipitation and high-wind event.

The ASAT indicated that the 48-h forecast MSLP SA was −8.8 (Fig. 8). This forecast anomaly exceeded the largest MSLP anomaly (−8.1) in the dataset examined in GG2010. The 48-h forecast compared very well with the analysis and accurately depicted

Table 2. A selection of all-time minimum mean sea level pressure records (hPa) set across the western United States on 21 Jan 2010.

Site	Minimum pressure (old record)	Date of previous record
Los Angeles	984.4 (990.5)	17 January 1988
San Diego	987.1 (994.6)	3 March 1983
Fresno	980.0 (985.4)	27 January 1916
Eureka	978.7 (979.0)	22 February 1891
Salt Lake City	980.0 (982.1)	15 April 2002
Reno	979.0 (982.1)	27 January 1916
Las Vegas	983.1 (987.8)	December 1949
Phoenix	988.8 (992.2)	22 May 2008

an event that set minimum pressure records across a significant portion of the western United States (Fig. 6a,d; Table 2).

DISCUSSION. The synoptic-scale details of the historic 18–23 January 2010 western U.S. storm cycle and the corresponding SA values were generally well forecast by the GEFS far in advance. The use of the ASAT in this and other events can help alert forecasters to the specific elements, levels, and times where significant anomalies were forecast to occur. This type of display allows forecasters to quickly distill information in an era where attention is divided by a large number of available datasets.

While this event was well forecast, a few caveats need to be considered when utilizing the ASAT or ensemble-based anomalies in general. For large SA values to appear in the GEFS ensemble mean forecast there typically needs to be good agreement (limited spread) among the ensemble members. Limited spread can result from clustering of ensemble members due to a highly predictable pattern or, conversely, from underdispersion, where the ensemble does not capture the full range of possible solutions. Novak et al. (2008) discuss how underdispersion in ensemble prediction systems limits the forecaster's ability to objectively assess uncertainty in the forecast process. Therefore, when large anomalies are forecast from the GEFS in the medium range (days 4–7), forecasters are urged to compare the GEFS to ensemble data from other national numerical weather prediction centers. If there is good agreement, forecasters can more confidently utilize the SA values to provide advanced decision support regarding the potential for a major-impact event.

While the ASAT can be a useful forecast tool, the use of standardized anomalies based on an ensemble mean contains limited uncertainty and probabilistic information regarding the occurrence of an anomalous event. Future development may improve the uncertainty and probabilistic information available to forecasters. A probabilistic approach could be used to compute the likelihood of 2-, 3-, 4-, and 6-sigma events, which would alert forecasters to the potential for an anomalous event while at the same time containing probabilistic information. Cumulative distributions at discrete points, such as major cities, could provide alerts to the forecaster on the

Fig. 7. Same as Fig. 1, except for the 0000 UTC 18 Jan 2010 cycle (96-h lead time).

Western US Table | January 18th, 2010 | 00z run

	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84
	Mon 18th				Tue 19th				Wed 20th				Thu 21st		
	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z
Height	-3.9	-3.8	-3.9	-4.2	-4.5	-4.2	-4.0	-4.1	-3.8	-3.7	-4.8	-5.2	-5.0	-5.8	-6.9
Temp	2.7	2.8	3.1	3.2	3.2	3.7	4.3	4.2	4.1	4.0	4.3	4.2	3.8	-4.1	-4.3
U-Wind	-3.4	3.1	-3.4	3.9	3.7	3.4	3.5	3.7	3.9	3.7	3.9	4.1	4.0	4.5	4.8
V-Wind	3.8	3.7	3.5	3.9	5.5	4.4	3.3	3.1	3.0	3.2	2.8	4.2	3.8	4.1	5.0
SHum	3.2	3.1	3.6	3.3	3.1	3.1	3.6	3.4	3.6	3.4	3.4	3.0	3.1	2.9	3.1
MSLP	-3.8	-3.7	-3.8	-4.2	-4.5	-4.0	-3.9	-4.2	-3.9	-3.6	-4.6	-5.3	-5.2	-5.7	-6.8
PWAT	2.6	2.4	2.8	2.6	3.1	2.7	2.5	2.3	2.4	2.1	2.5	2.2	2.2	2.3	2.6

	90	96	102	108	114	120	126	132	138	144	150	156	162	168	174	180
		Fri 22nd				Sat 23rd				Sun 24th				Mon 25th		
	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z
Height	-6.6	-6.3	-6.0	-6.1	-4.9	-4.4	-4.5	-4.8	-4.3	-3.7	-3.2	-2.7	-2.4	-2.2	-2.6	-3.1
Temp	-4.5	-4.4	-4.3	-4.0	-3.8	3.4	4.0	3.8	3.7	3.4	3.1	3.0	2.7	2.6	2.8	2.7
U-Wind	5.2	5.4	5.6	6.0	5.1	4.6	4.6	4.2	4.3	3.8	3.0	2.8	-2.2	-2.1	-2.2	2.0
V-Wind	6.1	6.1	7.1	5.7	5.5	3.4	3.3	-2.6	-3.0	-2.9	-3.4	-3.3	-3.4	-3.3	-2.9	-2.3
SHum	3.1	3.3	3.0	3.2	3.0	3.2	2.9	-2.9	2.5	2.2	1.9	2.2	2.0	2.8	-2.2	2.3
MSLP	-6.8	-6.4	-5.9	-6.0	-4.5	-3.9	-3.9	-4.0	-3.4	-2.7	-2.2	-2.1	-2.1	-2.0	-2.1	-2.6
PWAT	3.2	3.5	3.1	2.6	2.6	2.8	2.2	-2.5	-2.1	1.9	1.4	1.4	-1.3	-1.4	-1.5	1.6

FIG. 8. Same as Fig. 1, except for the 0000 UTC 20 Jan 2010 cycle (48-h lead time).

Western US Table | January 20th, 2010 | 00z run

	0	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
	Wed 20th				Thu 21st				Fri 22nd				Sat 23rd			
	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z	18z
Height	-4.2	-4.0	-5.1	-5.3	-5.4	-6.0	-7.7	-8.5	-8.5	-7.3	-6.5	-5.4	-4.7	-4.6	-4.9	-4.7
Temp	3.5	3.4	4.0	4.3	4.2	4.5	-4.6	-4.6	-4.6	-4.5	-4.2	-4.0	3.7	4.0	4.3	4.4
U-Wind	4.0	3.7	3.9	4.2	4.1	4.8	5.6	6.3	6.1	6.4	6.2	5.4	5.3	4.5	4.5	4.0
V-Wind	4.3	3.6	3.8	4.5	4.9	4.6	-6.3	7.4	7.5	8.0	7.0	5.4	3.9	3.8	3.0	-2.5
SHum	3.4	3.3	3.4	3.0	3.0	2.7	2.9	3.4	3.6	3.4	3.8	4.3	3.6	3.7	3.7	3.7
MSLP	-4.1	-3.9	-5.0	-5.4	-5.4	-5.8	-7.6	-8.6	-8.8	-7.7	-6.5	-5.6	-4.5	-4.2	-4.2	-3.9
PWAT	2.9	2.0	2.0	2.3	2.1	2.3	3.0	3.3	3.7	3.3	3.1	3.2	3.3	2.8	2.6	2.3

	96	102	108	114	120	126	132	138	144	150	156	162	168	174	180
	Sun 24th				Mon 25th				Tue 26th				Wed 27th		
	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z	18z	00z	06z	12z
Height	-4.2	-3.7	-3.5	-3.2	-2.8	-2.9	-3.2	-2.5	-2.6	-2.6	-2.5	-2.0	1.5	1.5	1.7
Temp	3.8	3.1	3.3	2.9	2.9	2.7	2.4	-1.9	1.7	1.6	1.8	1.6	1.8	1.9	1.9
U-Wind	3.8	3.6	3.6	-3.1	-3.8	-3.6	-3.2	-2.8	-2.9	-2.3	-2.0	-1.6	2.0	2.4	-2.6
V-Wind	2.6	-3.4	-3.6	-3.6	-3.2	-3.4	-3.1	-2.4	-2.1	-1.8	-2.0	-2.4	-2.5	-2.4	2.6
SHum	4.0	2.8	3.3	2.7	2.5	2.0	2.5	2.2	2.5	2.0	2.2	2.0	2.0	1.8	2.2
MSLP	-3.3	-2.8	-2.5	-2.6	-2.6	-2.5	-2.3	-2.2	-2.4	-2.3	-2.1	-1.6	-1.3	-1.5	-1.5
PWAT	2.5	2.0	2.0	1.8	1.9	1.8	1.9	1.6	1.9	1.6	1.7	1.6	1.5	1.5	1.5

potential for a high-impact event at specific sites. Ideally, the climatologically derived anomalies would be used with internal ensemble forecast system climate (M-Climate) to produce extreme forecast indices, providing ensemble-based alerts for a range of severe weather. Forecast system–based quantitative precipitation climatologies are ideal for determining when the system is forecasting a record or near-record event relative to its internal climatology. A record model forecast, when compared to the model climatology, would likely imply the potential for a record or near-record event in the observed atmosphere, which would be valuable information for forecasters.

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