HMT-West 2008
Summary of IOP 8
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IOP8 Start 23 Feb 18UTC
IOP8 End 25 Feb 06UTC

Non-autonomous Instrument Operations Summary:

- ESRL HYDROX Radar began operations 23 Feb /16UTC and shut down 24 Feb /01UTC. The event was again all snow at BLU and owing to high wind forecasts the radar was shut down early in the event.

- Slough House sondes and special RAOBS from OAK and RNO began at 23 Feb/ 18UTC at three-hour intervals. Goal was to sample the warm advection was occurring with this event. Last sonde at SHS was at 24 Feb/12UTC; last special sondes at OAK and RNO were 24Feb/ 09UTC. All sondes were successful.

- Two weather recon flights were launched for special dropsondes on Feb 22 for NWP support IOP8 with data void dropsondes and on 23 Feb for cross-sections through the IPW river.

Autonomous Instrument Operations Summary:

- Hot Plate at BLU inoperative between 24 Feb 14-22UTC
- Bodega Bay had communications problems
- All other sites appeared to remain up and operative during the event.

Overview: This event was characterized by a very rapidly deepening system in the 24-48 h preceding the storm coming onshore near the OR/CA border around 18z on Sunday 24 February, with the storm occluding and weakening following its rapid deepening phase and eventually passing the ARB as an open trough ~00z/25 Feb. The wave then redeveloped east of the Rockies and became a significant storm moving across the northern CONUS all the way to New England by 26 Feb. The rapid deepening was predicted early on by the GFS model and only somewhat later by the ECMWF, but by the end of the week the forecasts were quite good and consistent amongst the various models. Confidence was very high that significant precipitation would occur in the ARB from the event, but there was considerable difficulty predicting the snow level in the vicinity of the radar.

This write-up will give a brief overview of the case, showing some meteorological fields and forecasts, and some thoughts on some of the forecast issues that occurred.

Synoptic overview: An overview of the upper level conditions preceding the event is given by the collection of GFS analyses in Fig. 1. A fairly broad upper level trough is progressing across the Pacific 19-20 Feb, with another wave coming off of Asia by 0000 UTC/21 Feb. Conditions by 1200 UTC/21 Feb are shown in Fig. 2. The wave of interest is north of Hawaii near 40° latitude, but of importance to the subsequent rapid development was the strong system upstream near 40°N/155°E. This strong system rapidly built an upper-level ridge upstream of the storm approaching the West Coast, resulting

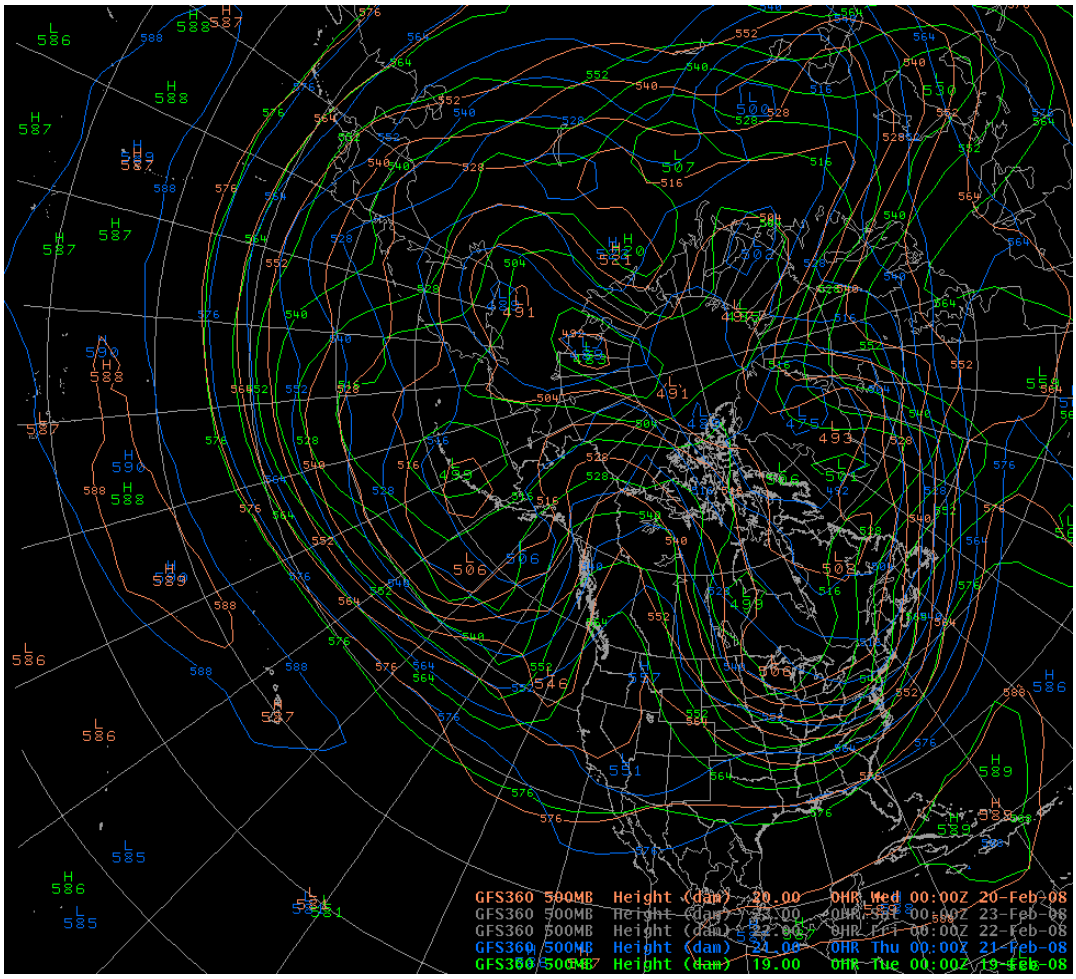


Fig. 1. Set of three 500-mb analyses at 24-h intervals from 0000 UTC 19 Feb to 0000 UTC 21 Feb.

in a very rapid intensification of the system, bottoming out around 12 to 18 UTC on Saturday/23 Feb. Similar satellite imagery at 12-h intervals through 1200 UTC/23 Feb is presented in Figs. 3 and 4, and nicely shows the evolution of the approaching wave. Rapid cloud enhancement of the system is just underway by 1200 UTC/22 Feb (Fig. 3, bottom, seen to the northeast of Hawaii near 30ºN/150ºW). By 0000 UTC/23 Feb (Fig. 4, top) the storm has increased rapidly and displays a nice curl in the satellite imagery, which further tightens by 12 h later (Fig. 4, bottom), when the system is near its peak intensity. The system then lifted to the east-northeast, weakening rapidly on 24 Feb (Figs. 5 and 6).

Fig. 7 shows the storm evolution for a shorter time span using North American scale IR imagery overlaid with 1-h lightning plots at 6-h intervals from 1800 UTC/23 Feb through 0000 UTC/25 Feb. The beginning of this period is when the storm was at its deepest stage. It then slowly weakened as it moved to the east-northeast, reaching the coast near the OR/CA border near 1800 UTC on Sunday 24 Feb. Some lightning was observed, mainly south and then east of the ARB.

The next overview presentation uses NOWRAD radar imagery (basically a composite of the lowest level scan from the various NWS 88-D radars) with observations overlaid (Figs 8-10). Echoes rapidly moved into Northern/Central California by 1800 UTC on Saturday 23 Feb, after there were virtually none present at 1200 UTC. Precipitation began to reach the ground in the ARB by 2100 UTC/23 Feb, and then increased through Saturday night as strong warm advection moved into the area ahead of the now-occluded system. Some upper level cooling moved into the area by Sunday but winds in the lowest few km remained strong out of the SW with strong orographic forcing, resulting in widespread

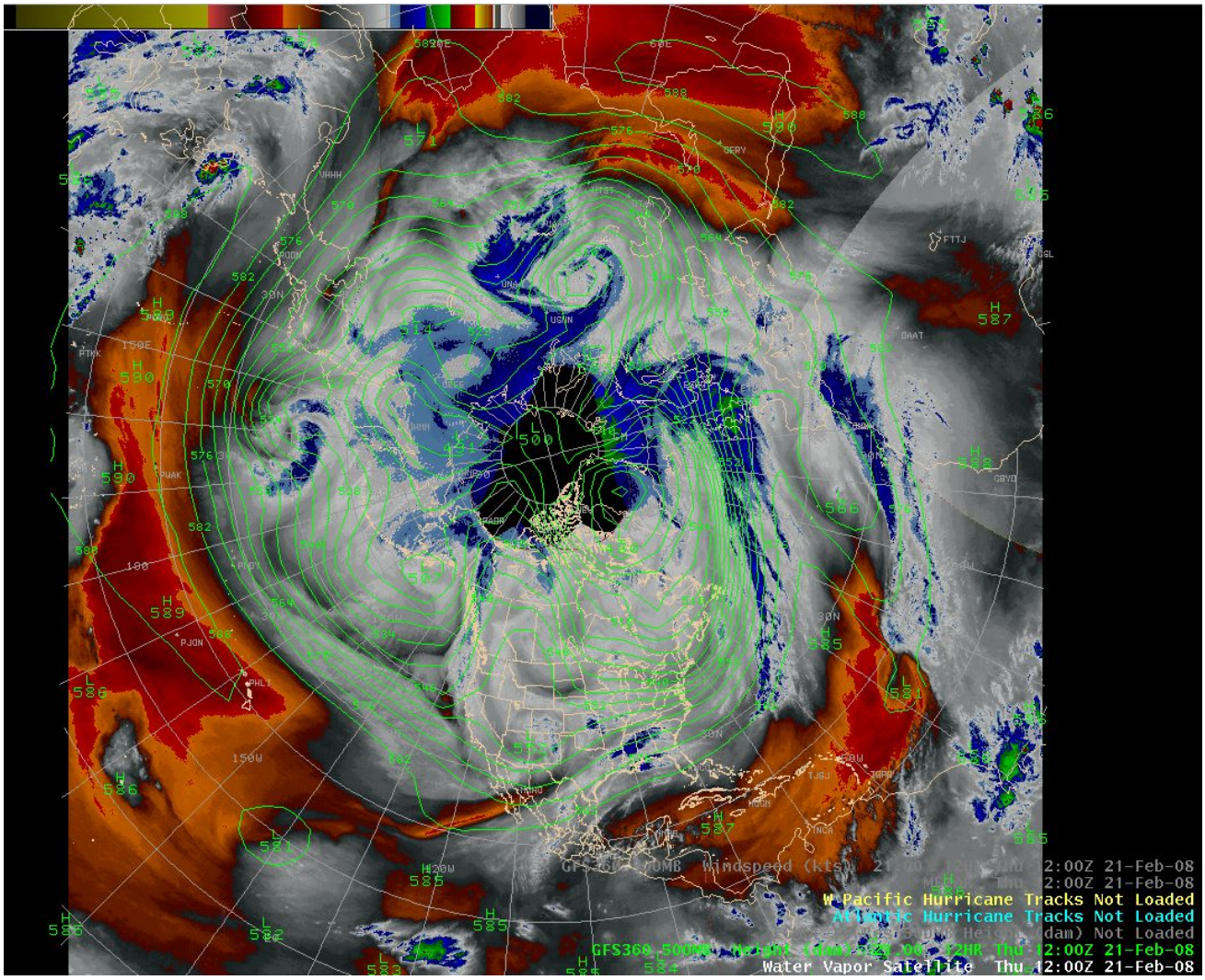


Fig. 2. Water vapor image with GFS 500 mb analysis at 1200 UTC on 21 Feb 08.

echoes across the ARB on Sunday. The surface low is analyzed to come onshore shortly after 0000 UTC/25 Feb, with rapid weakening of the overall system. The precipitation begins to become more restricted to the higher terrain by later in the day on Sunday/24 Feb, and continues there as the upper level trough passes from 0000-0300 UTC/25 Feb, before gradually decreasing. By 0900 and 1200 UTC on 25 Feb only a few echoes are left at the higher elevations, with snow ending at KBLU. The precipitation type and the forecast difficulties with predicting the precipitation type at the elevation of KBLU where the ESRL radar site is located are discussed in more detail later. The warmest temperatures during the event at KBLU, up to 34ºF, occurred during the period 0400-0600 UTC/25 Feb (Fig. 10) near the time of the trough passage, and the precipitation at KBLU may have breifly changed over to rain during this time.

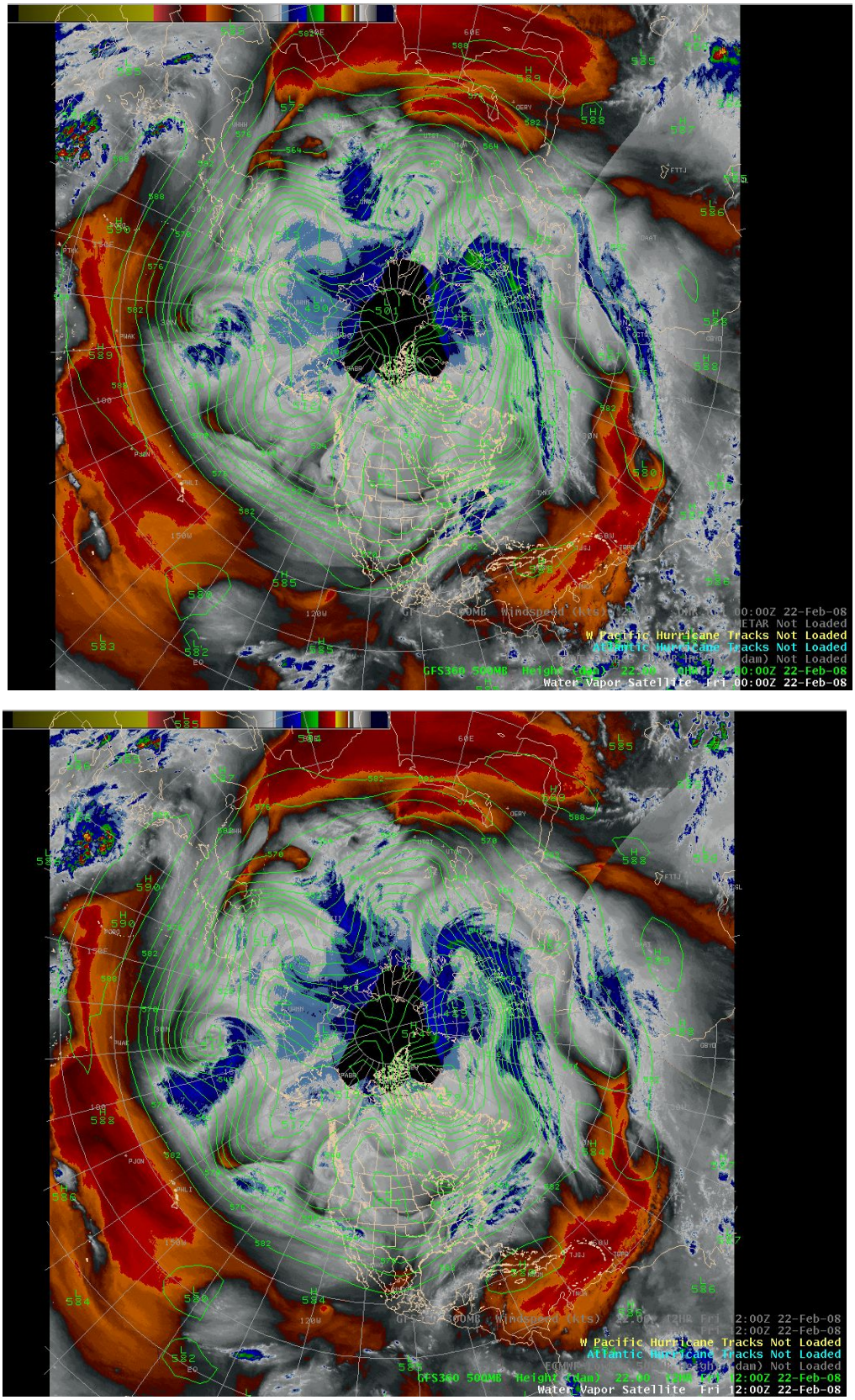


Fig. 3. Water vapor satellite imagery and 500 mb GFS analyses for 0000 UTC/22 Feb (top) and 1200 UTC/22 Feb (bottom).

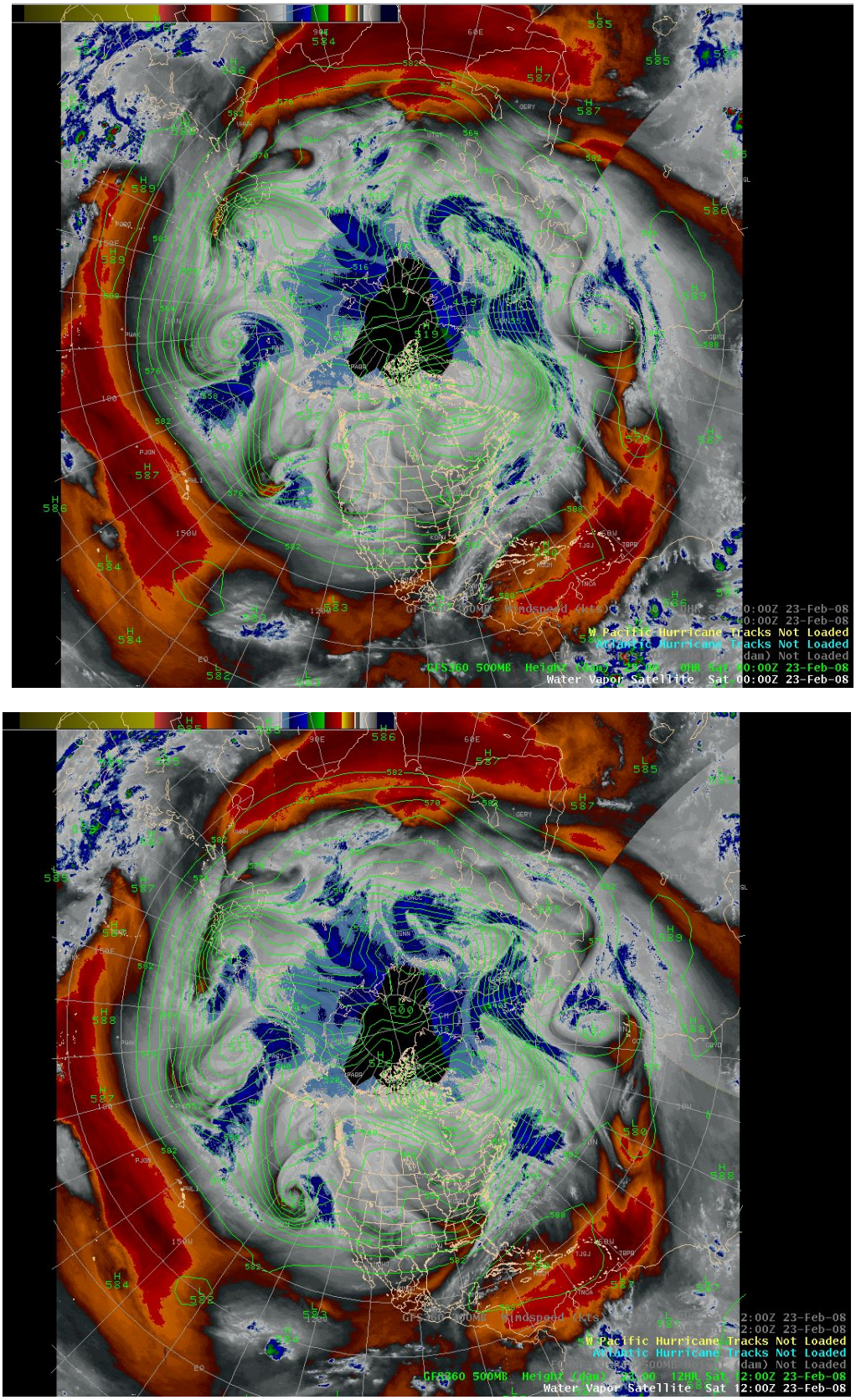


Fig. 4. Water vapor satellite imagery and 500 mb GFS analyses for 0000 UTC/23 Feb (top) and 1200 UTC/23 Feb (bottom).

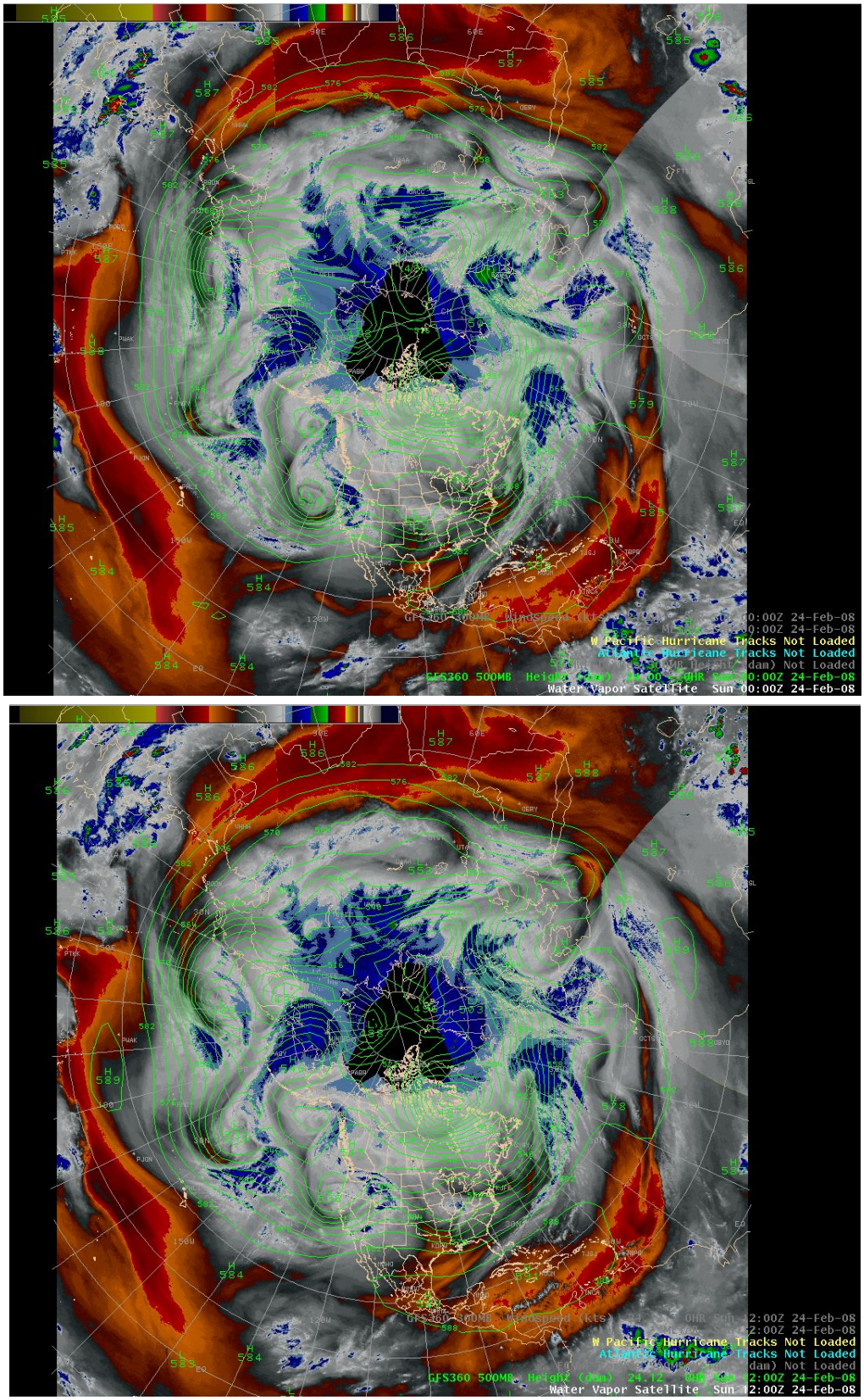


Fig. 5. Water vapor satellite imagery and 500 mb GFS analyses for 0000 UTC/24 Feb (top) and 1200 UTC/24 Feb (bottom).

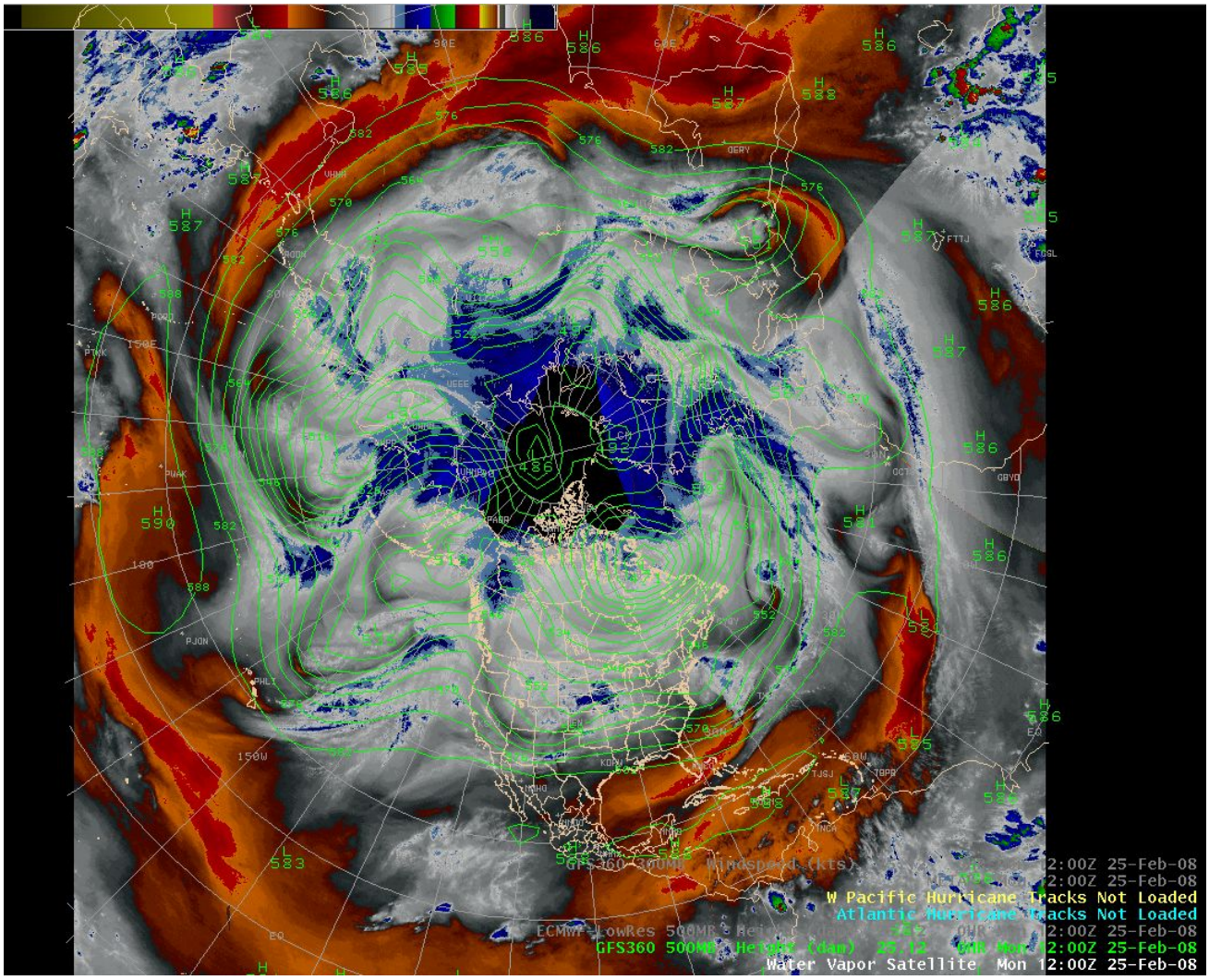


Fig. 6. Water vapor satellite imagery and 500 mb GFS analysis for 1200 UTC/25 Feb.

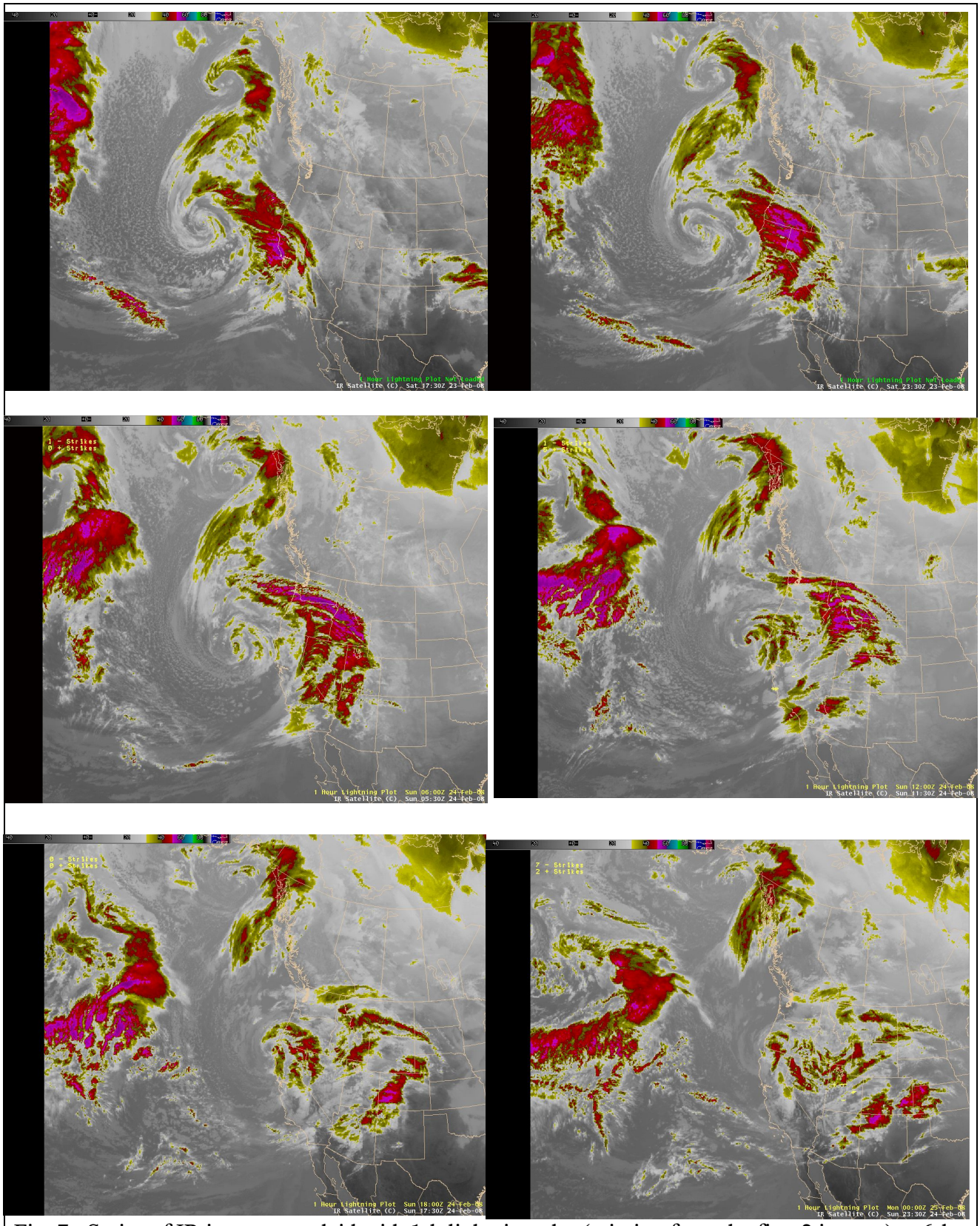


Fig. 7. Series of IR images overlaid with 1-h lightning plot (missing from the first 2 images) at 6-h intervals, from 1800 UTC 23 Feb (top left) through 0000 UTC 25 Feb (bottom right).

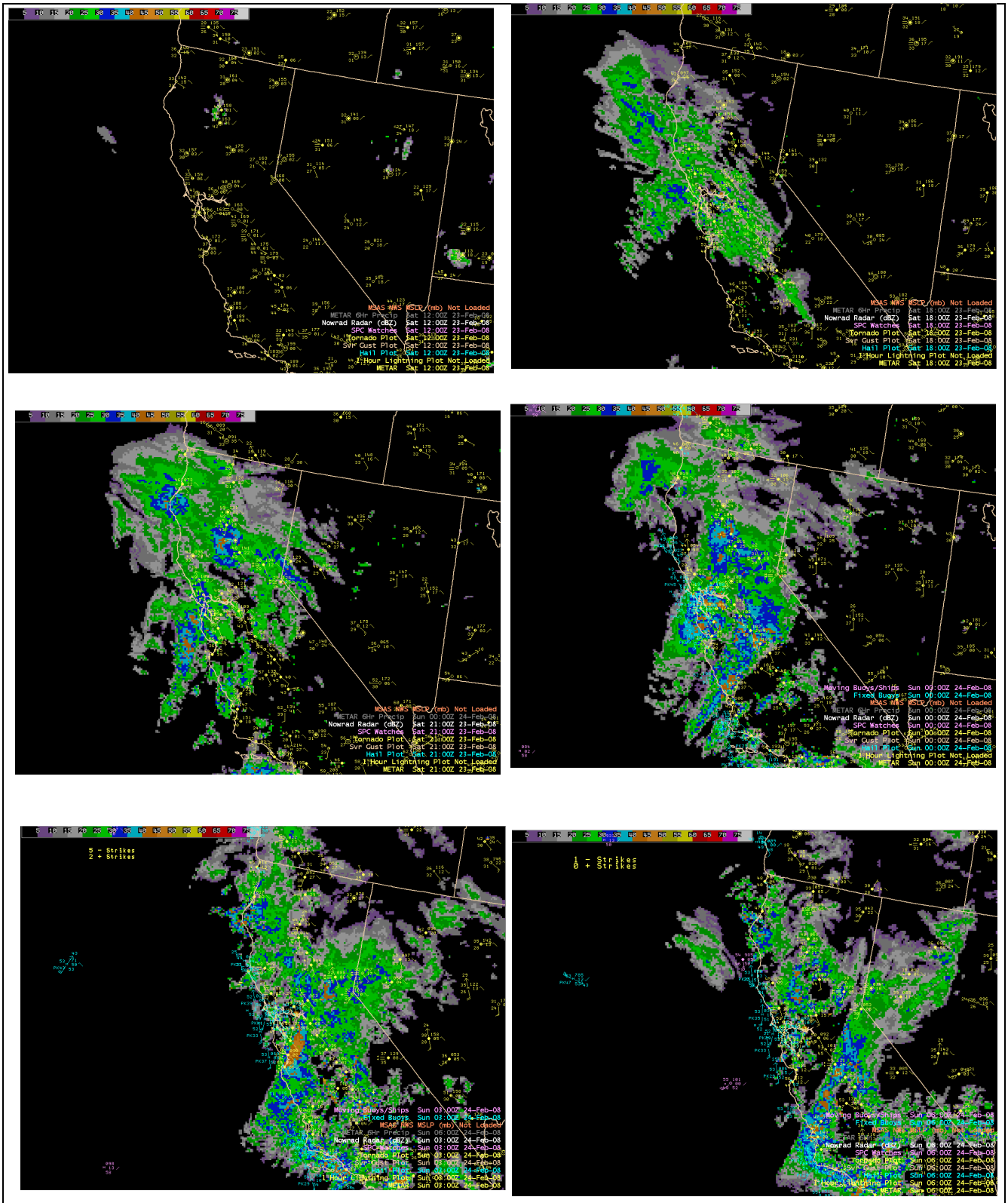


Fig. 8. Series of NOWRAD radar images with METAR and other surface observations, and 1-h lightning plots, beginning at 1800 UTC/23 Feb (top left) through 0600 UTC/24 Feb (bottom right).

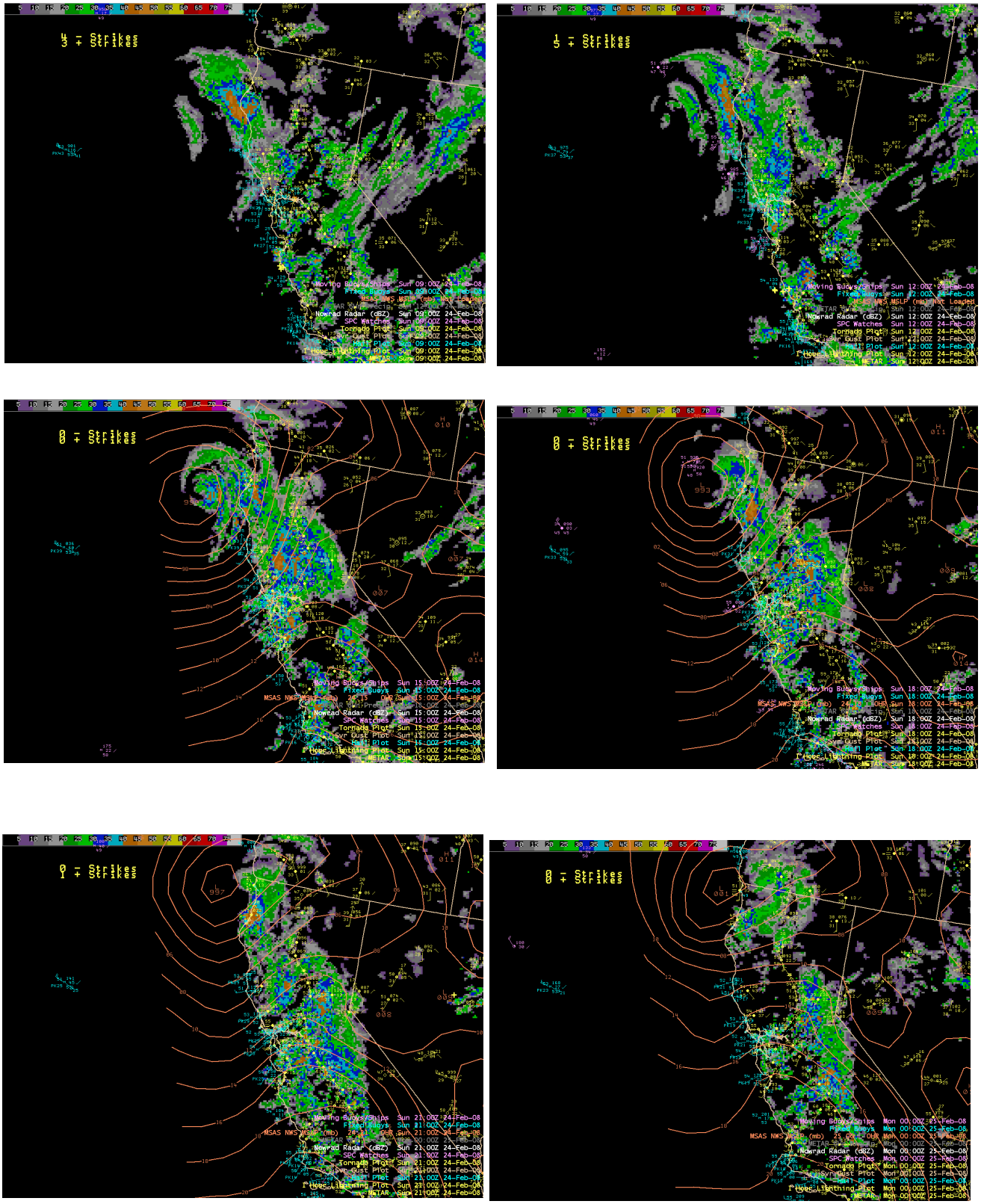


Fig. 9. As in Fig. 8, for the period from 0900 UTC/24 Feb through 0000 UTC/25 Feb.

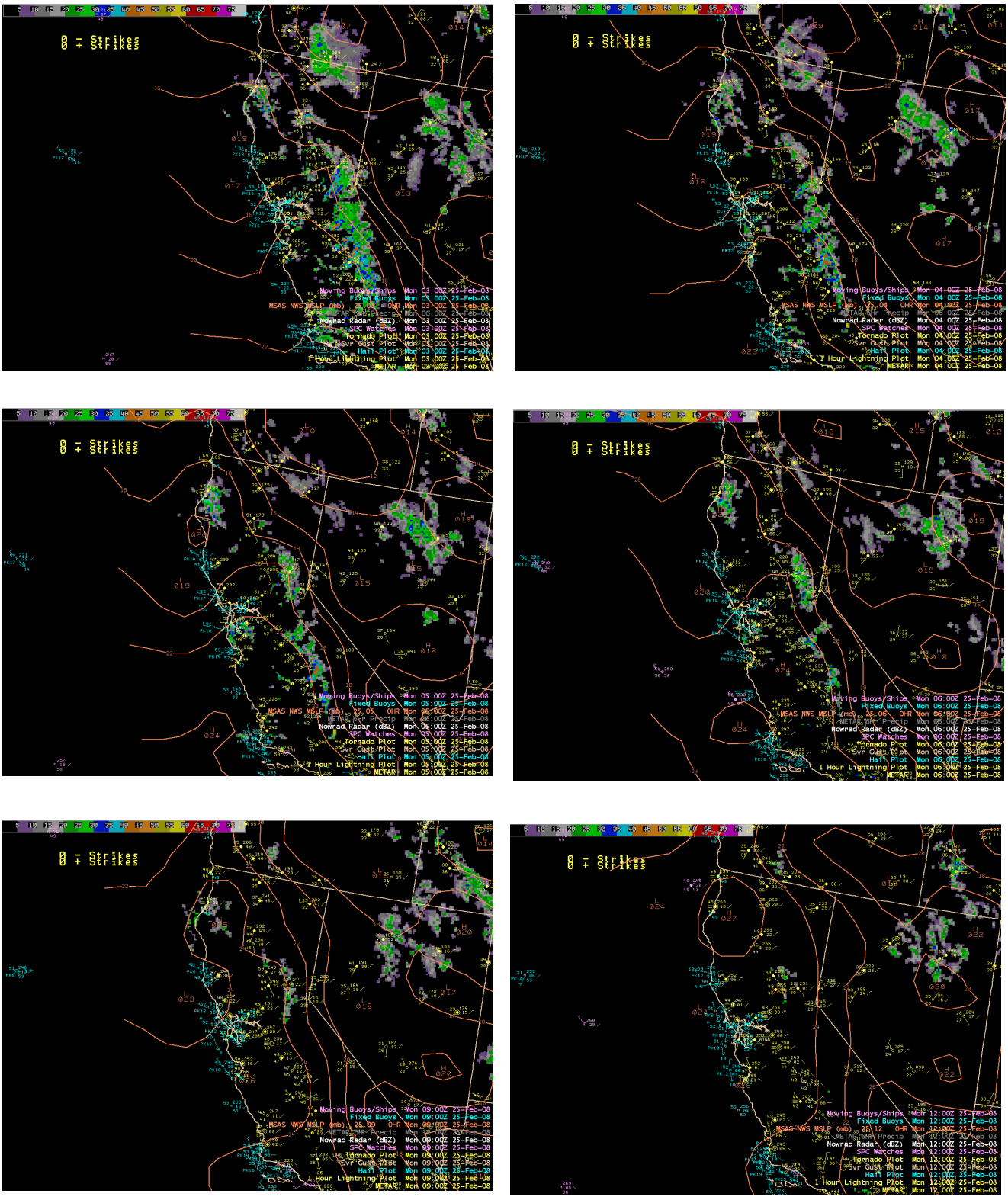


Fig. 10. As in Fig. 8; all data from 25 Feb. Top left 0300 UTC, top right 0400 UTC, middle 0500 and 0600 UTC, bottom left 0900 UTC, and bottom right 1200 UTC.

Forecasts for the event.

Longer range forecasts: Next will be a brief look at some of the longer range forecasts for this event. Attention in the forecast discussions more than a week before the event was on the first system that produced IOP7 near the end of the week of 17-23 Feb (IOP7 occurred on 21-22 Feb). But note was made of a second system in the 16 Feb HMT forecast discussion, with more emphasis in the next couple of discussions on the following two days. A few of the longer range model forecasts are discussed here. In Fig. 11 are some long-range forecasts from a little over a week away from the 0000

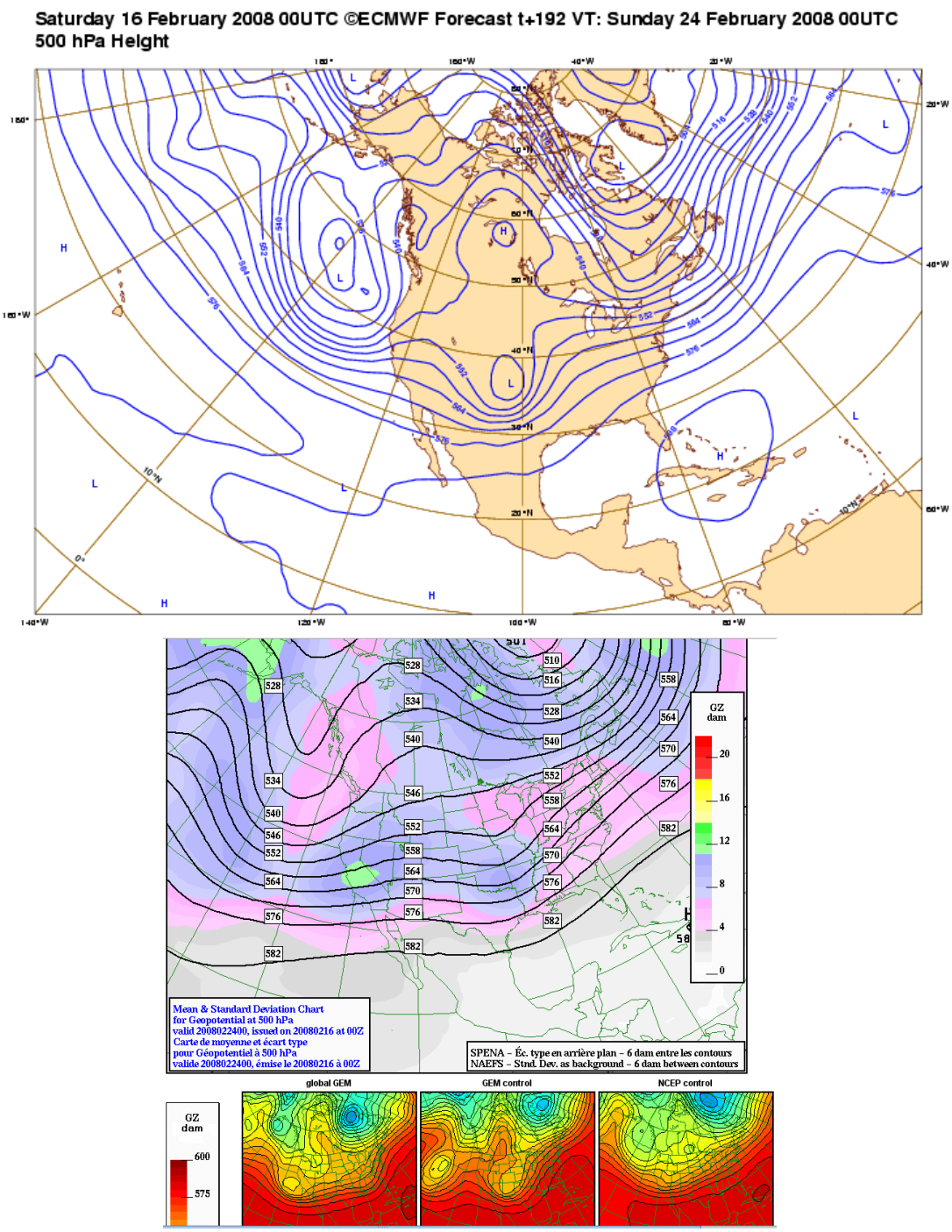


Fig. 11. Long range 500 mb forecasts (see text); 192-h progs valid at 0000 UTC/24 Feb.

UTC/16 Feb ECMWF, Canadian Global, and GFS runs, as well as the mean for the North American Forecast System (NAEFS), which is a combination of the ensemble forecasts from both the Canadian ensemble system and the GFS ensemble system. The presentation shown in Fig. 11 is from the Environment Canada website at http://www.weatheroffice.gc.ca/ensemble/cartes_e.html. A portion of the presentation for each day is shown in Fig. 11, with the three small panels at the bottom showing the deterministic Global Canadian model run ("Global GEM"), the GEM Control run (unperturbed GEM run), and the NCEP control (unperturbed GFS, run at T126 resolution). The 192 h forecasts valid at 0000 UTC/24 Feb from the NAEFS ensemble mean and the individual models have a trough off the CA coast, with quite a bit of variation among the individual model forecasts. Two days later the forecasts valid at the same time were still favorable (Figs. 12 and 13).

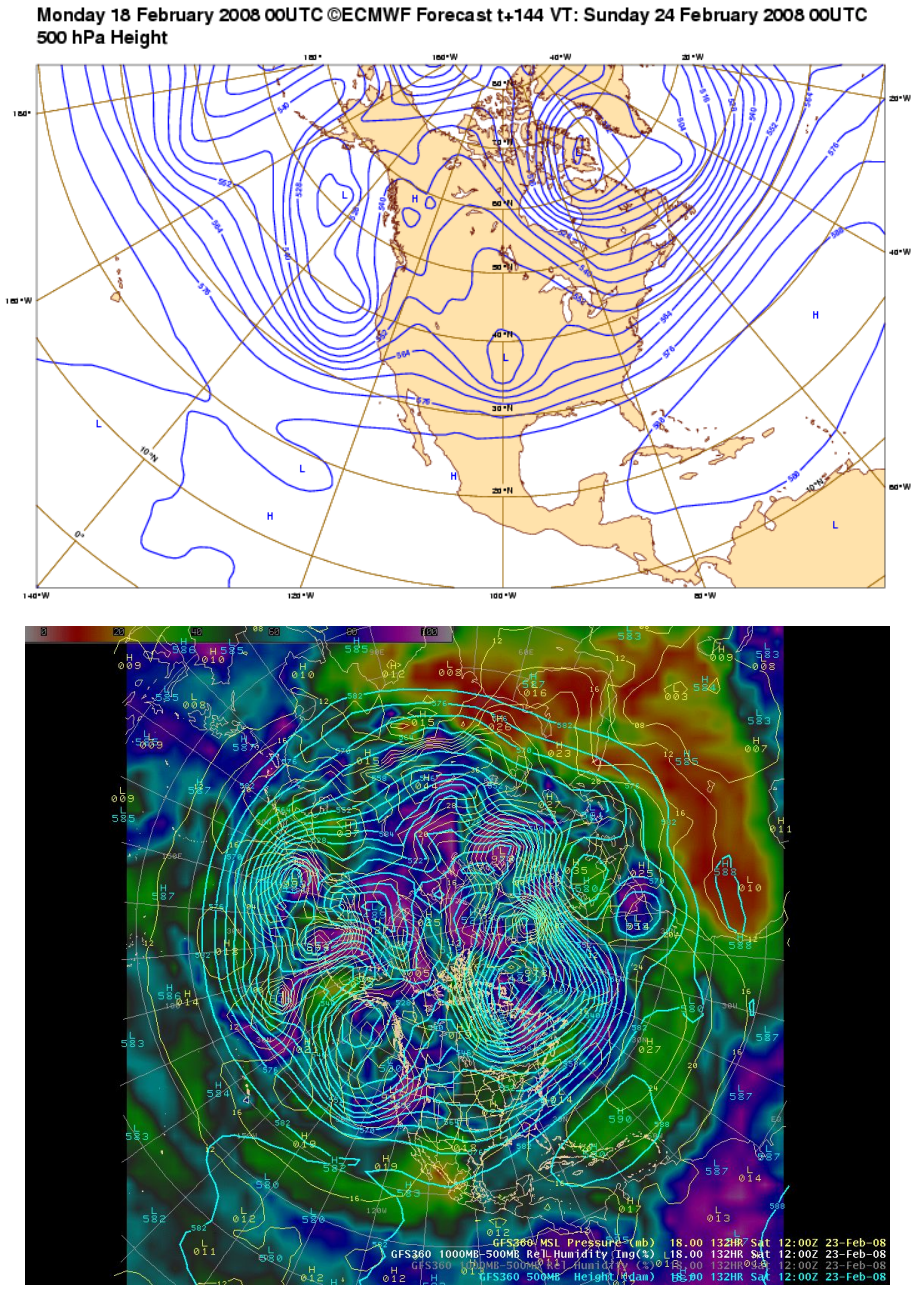


Fig. 12. Deterministic 500 mb forecasts from the 0000 UTC/18 Feb ECMWF (top) and GFS (bottom). Forecast is a 144-h from the ECWMF and 132-h forecast from the GFS.

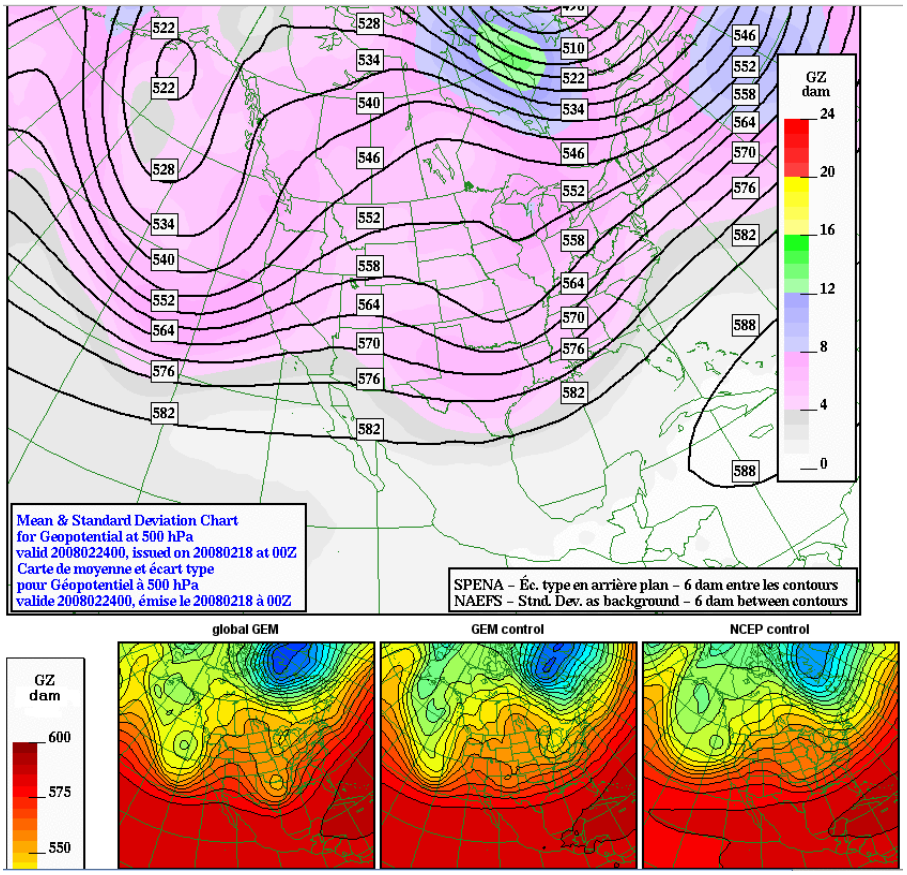


Fig. 13. NAEFS mean and some individual forecasts as in Fig. 11, here 144-h forecasts from the 0000 UTC/18 Feb, valid at 0000 UTC/24 Feb.

Forecasts from the runs 24 h later are shown in Fig. 14 for 500 mb from the ECMWF and GFS deterministic runs, for the surface (mean sea level pressure) for the same runs in Fig. 15, and from the NAEFS system in Fig. 16, all 120-h forecasts valid again at 0000 UTC/24 Feb. Both forecasts predict an intense smaller-scale upper low positioned off the Northern CA coast, with a strong surface low, slightly farther south in the GFS forecast. The ensemble mean 500-mb forecast in Fig. 16 is similar to the one from 24-h earlier. The forecasts from 24-h later (initial time of 0000 UTC/20 Feb) are given in Figs. 17-19. The GFS deterministic run was slightly deeper than 24 h earlier, with a surface low now forecast down to 972 mb and positioned a little farther south as well. The ECMWF run, on the other hand, was not as strong, a trend seen in consecutive forecasts (including the one initialized 12-h earlier). The corresponding surface low is not as strong as in the forecast from the previous day. The ensemble mean forecast (Fig. 19) is a little deeper with the trough, consistent with the deterministic GFS run and the Canadian Global runs shown in Fig. 19.

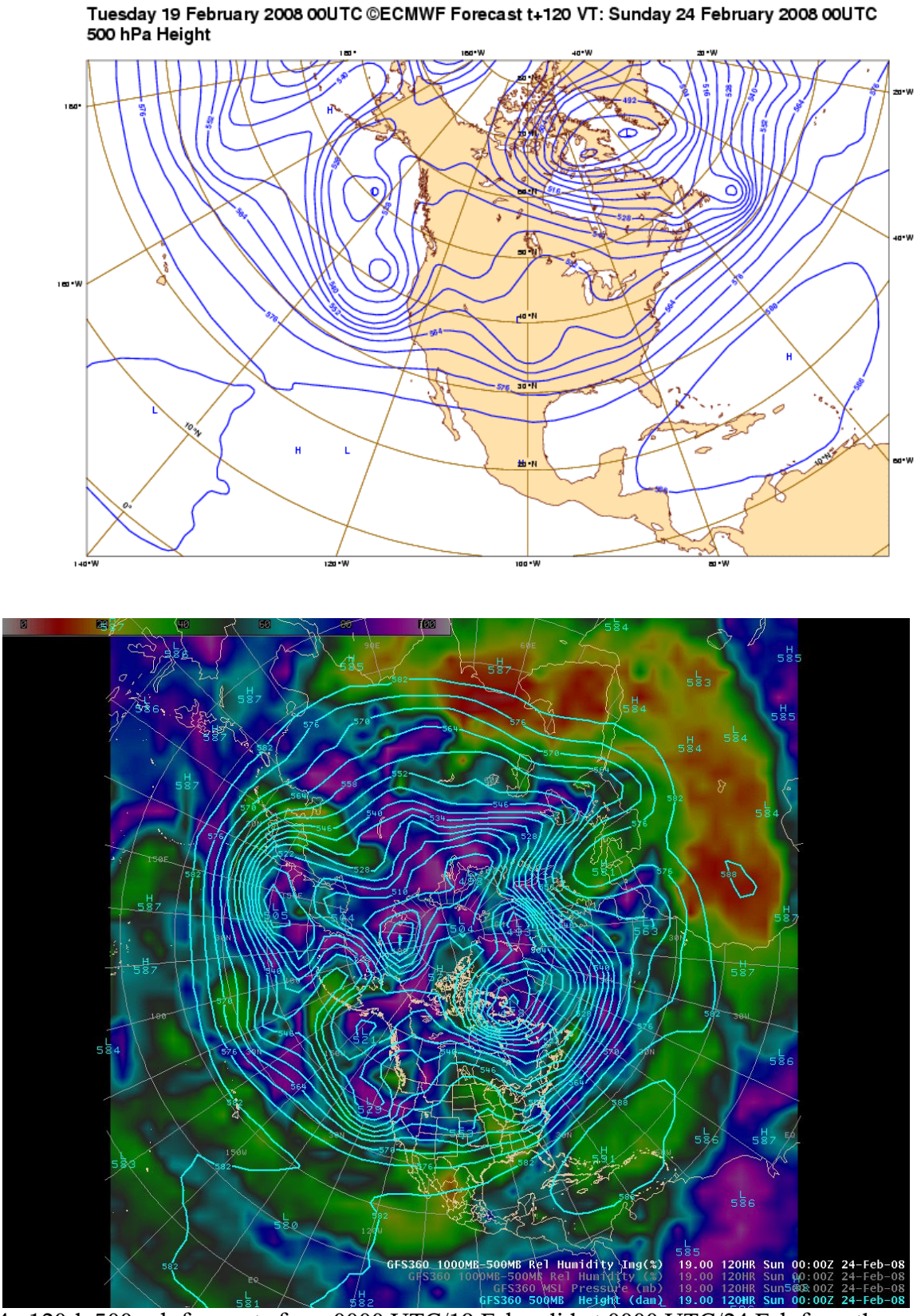


Fig. 14. 120-h 500-mb forecasts from 0000 UTC/19 Feb valid at 0000 UTC/24 Feb from the ECMWF and GFS deterministic runs.

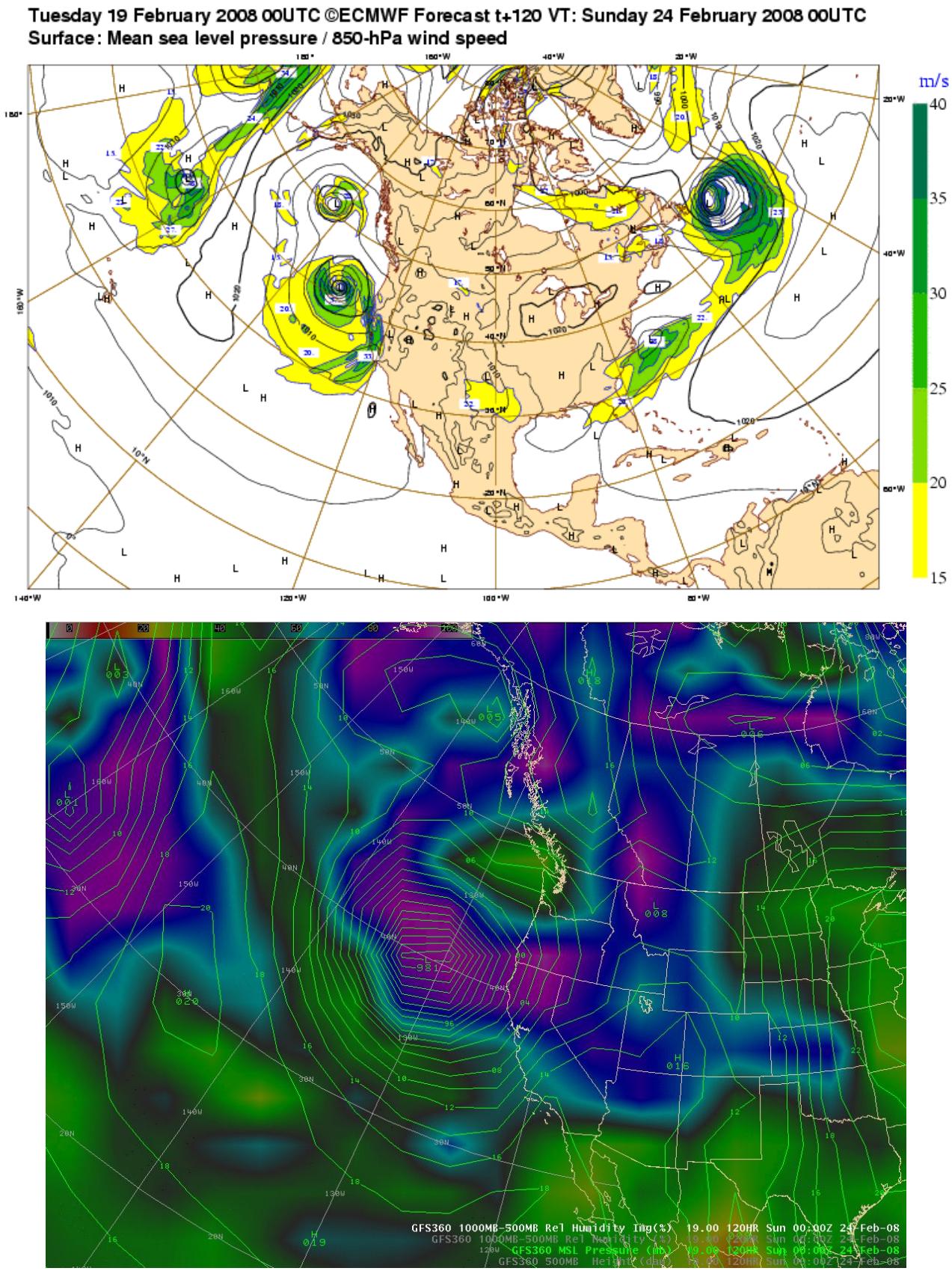


Fig. 15. As in Fig. 14, but for forecasts of mean sea level pressure (along with layer relative humidity as an image for the GFS (bottom), with 850 mb wind speed for the ECMWF (top)).

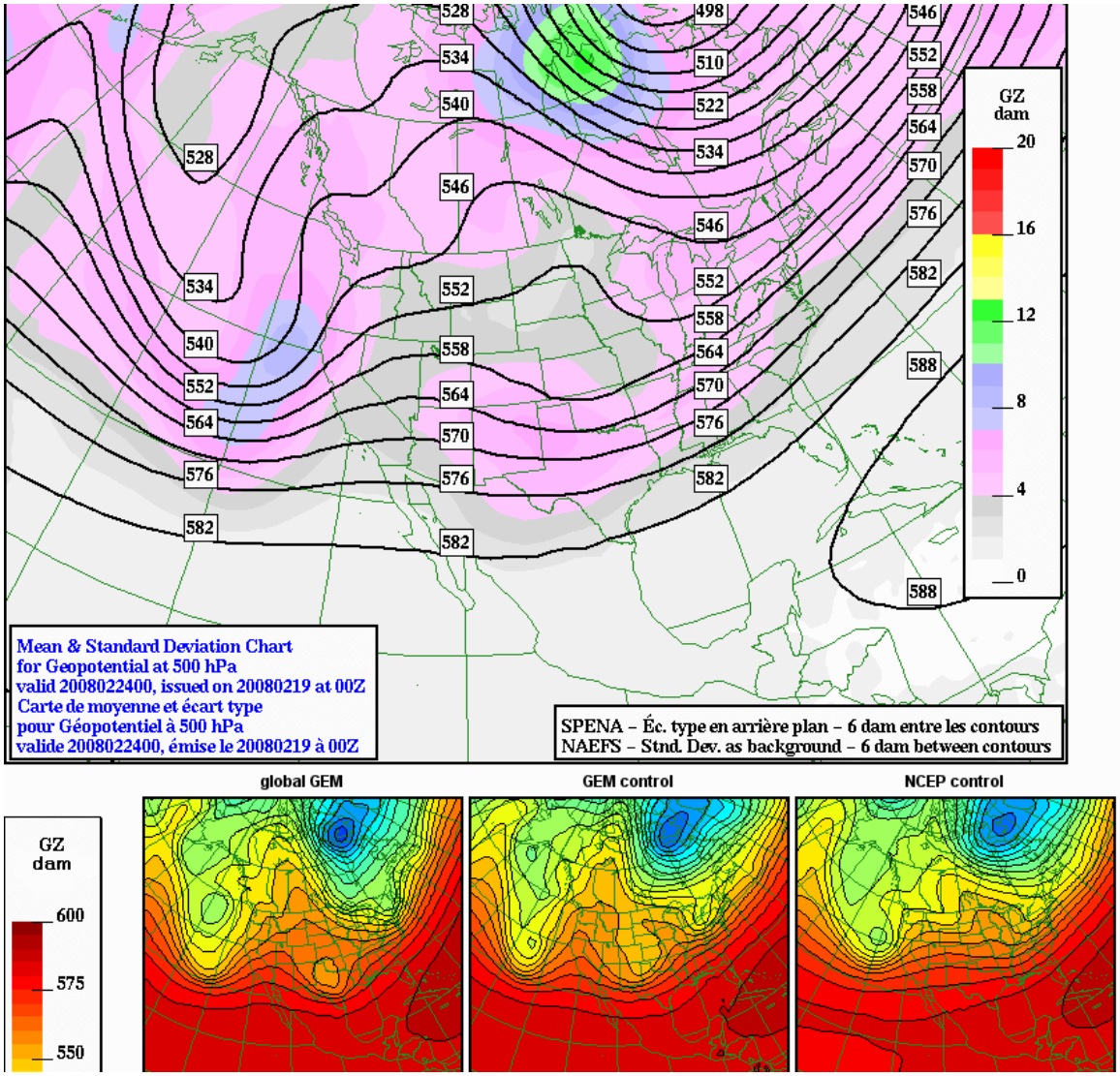


Fig. 16. As in Fig. 13, but 120-h forecasts from 0000 UTC/18 Feb valid at 0000 UTC/24 Feb.

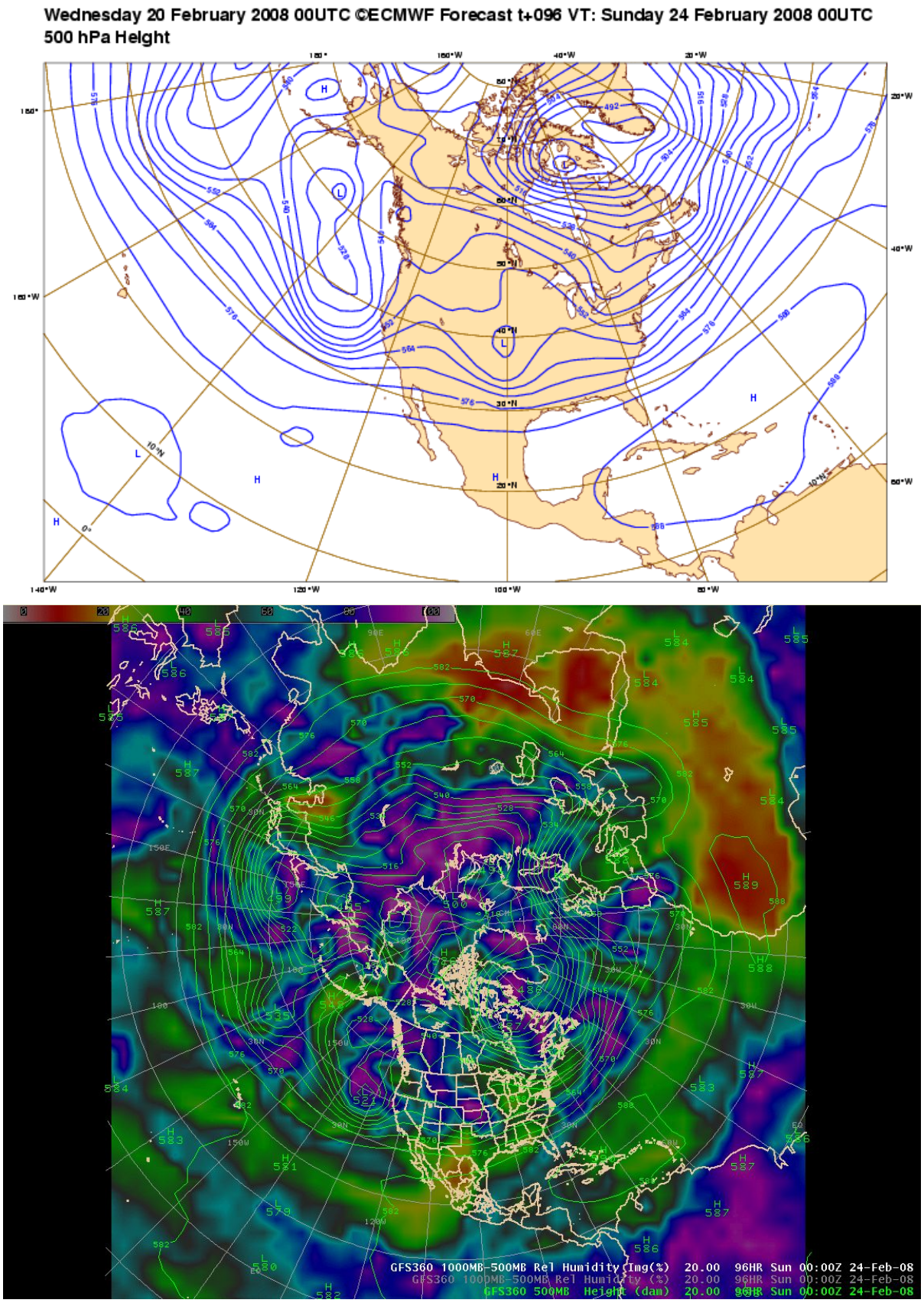


Fig. 17. As in Fig. 14, but for 96-h forecasts from 0000 UTC/20 Feb valid at 0000 UTC/24 Feb.

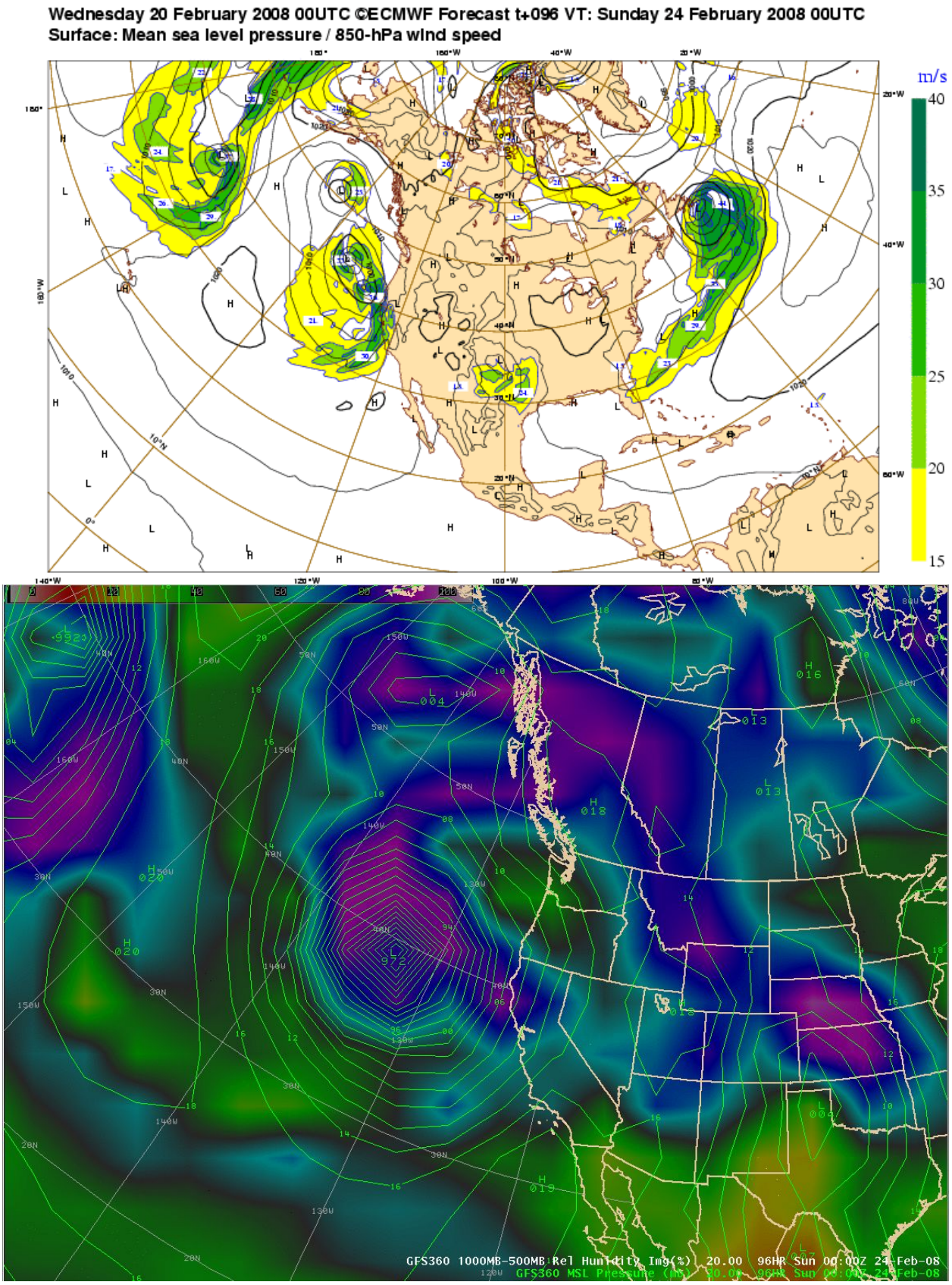


Fig. 18. As in Fig. 15, but for 96-h forecasts from 0000 UTC/20 Feb valid at 0000 UTC/24 Feb.

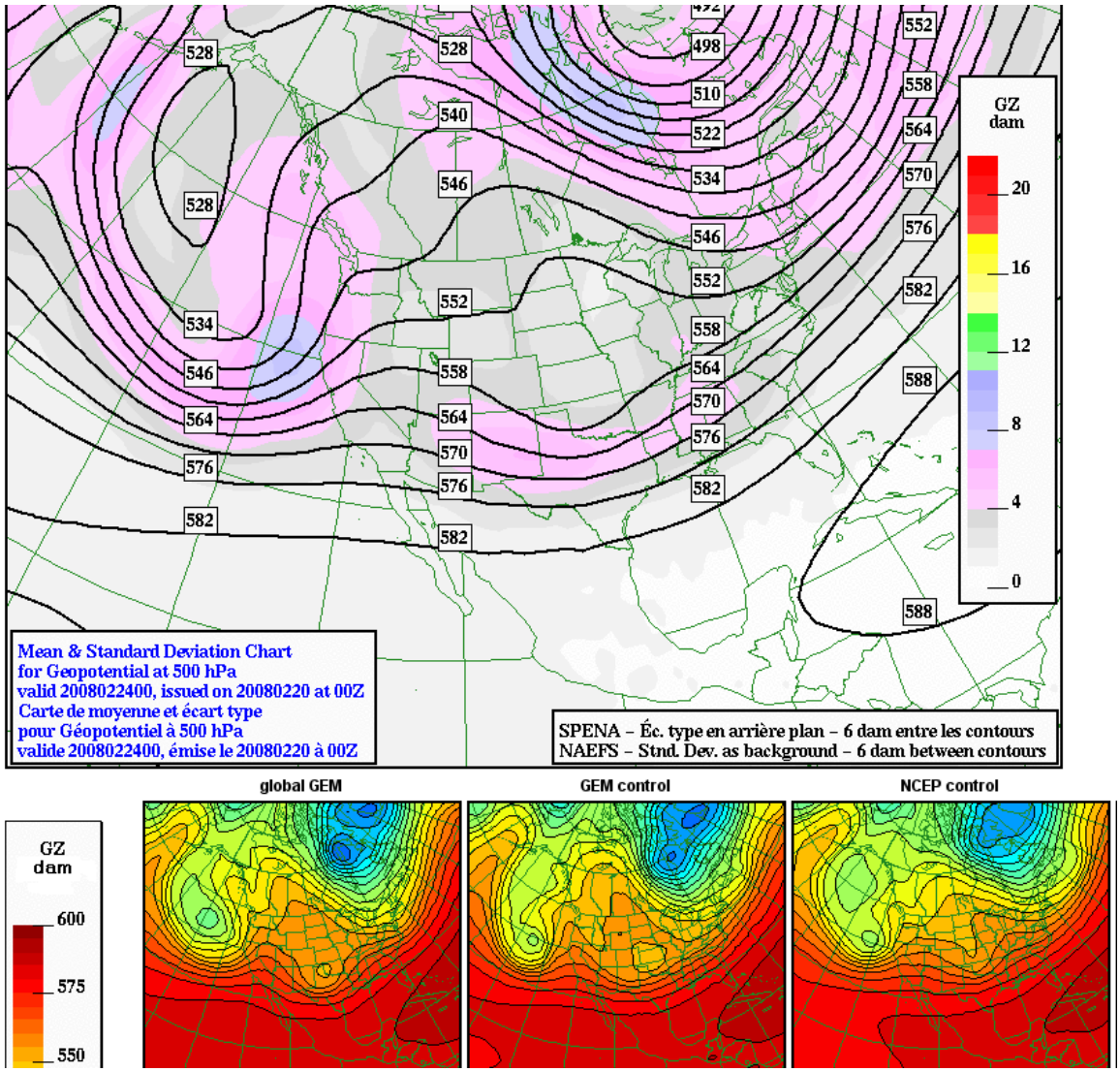


Fig. 19. As in Fig. 13, but for 96-h forecasts from 0000 UTC/20 Feb valid at 0000 UTC/24 Feb.

The final set of forecasts shown are from the next day, 24-h later initialized at 0000 UTC/21 Feb (Figs. 20-22). The GFS forecast is not quite as deep as the one from 24-h earlier, although the forecast 500 mb height of the upper low of 526 dm is closer to the analysis of 528 dm (top image in Fig. 5) than the forecast from the run 24-h earlier. The bigger change is in the ECMWF forecast, which returns to a strong upper and surface low, similar to that forecast by the GFS. The ensemble mean 500 mb forecast (Fig. 22) continued its slight deepening trend as more of the members came into agreement on the strength of the system. Overall there was fairly good guidance from the longer to middle range forecasts.

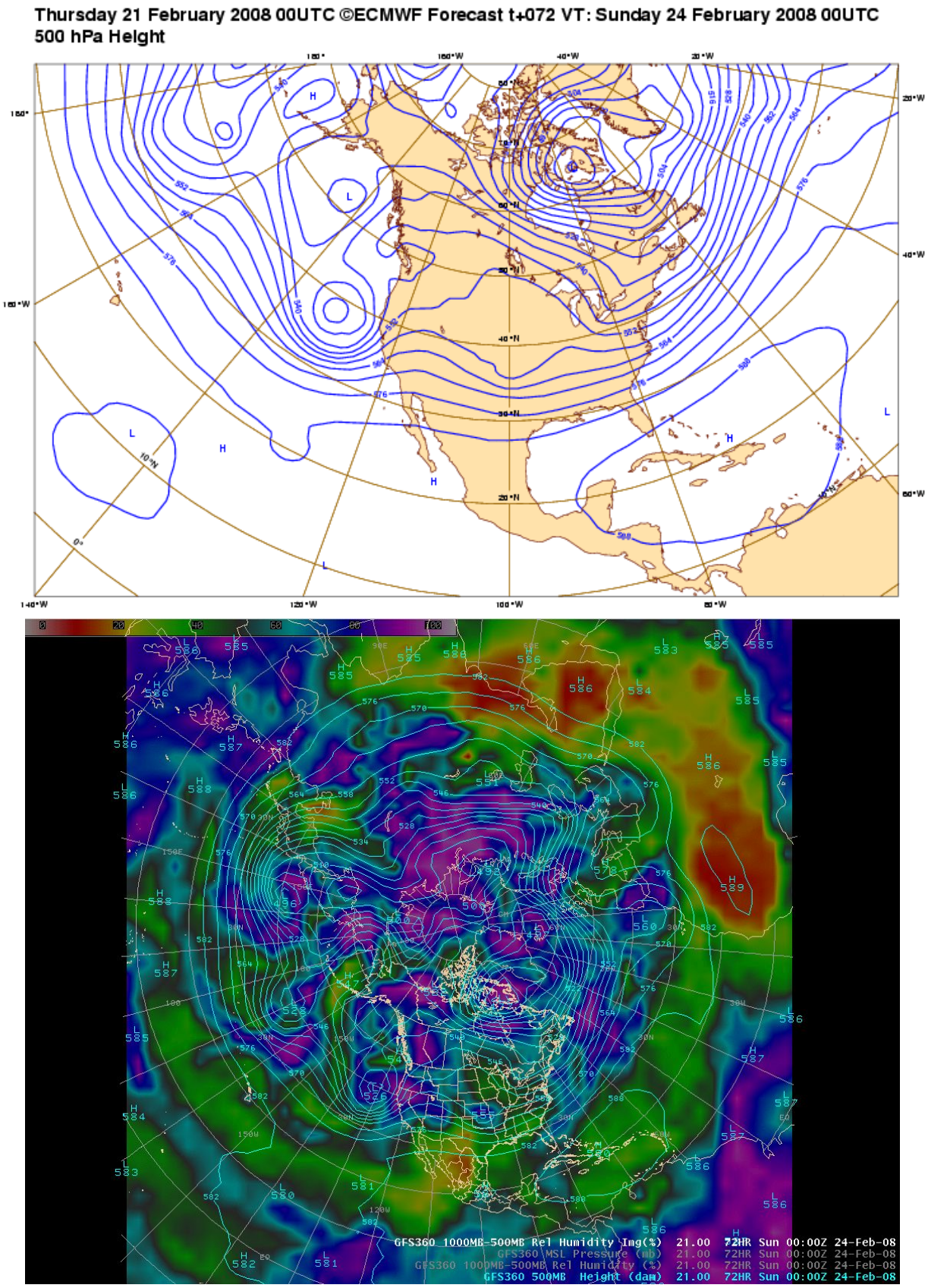
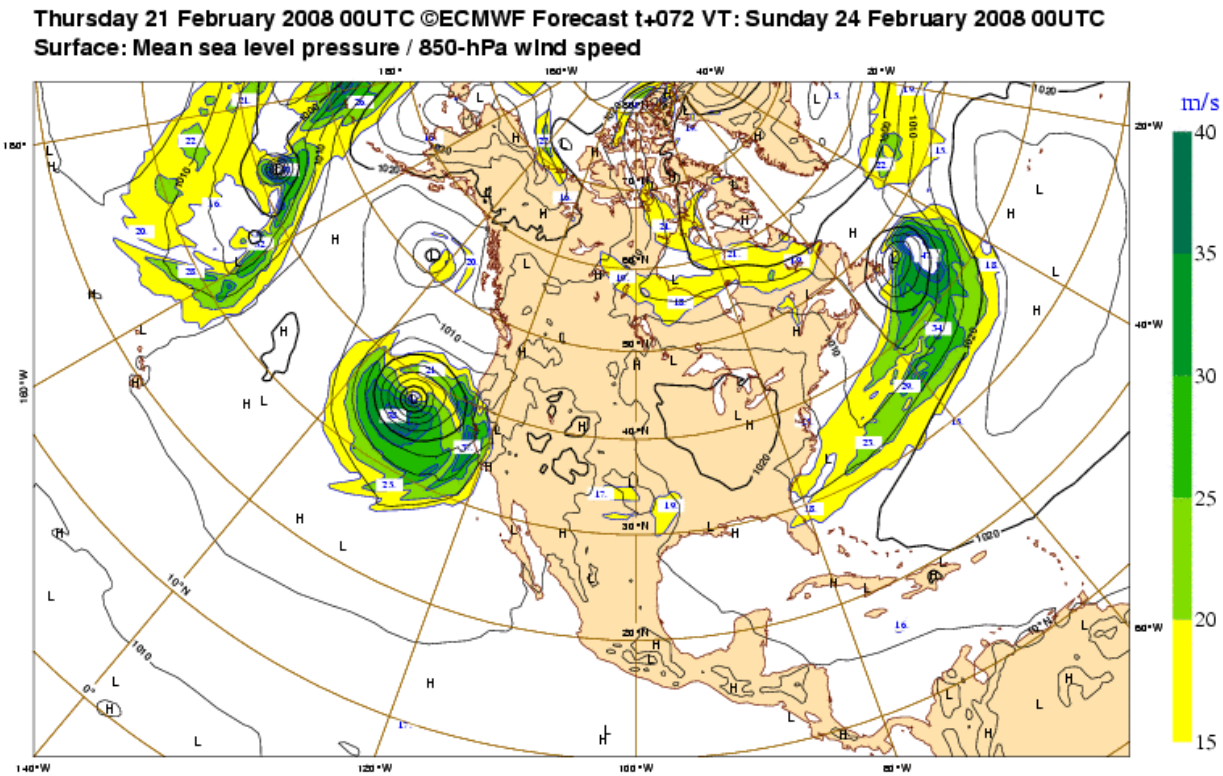


Fig. 20. As in Fig. 14, but for 72-h forecasts from 0000 UTC/21 Feb valid at 0000 UTC/24 Feb.



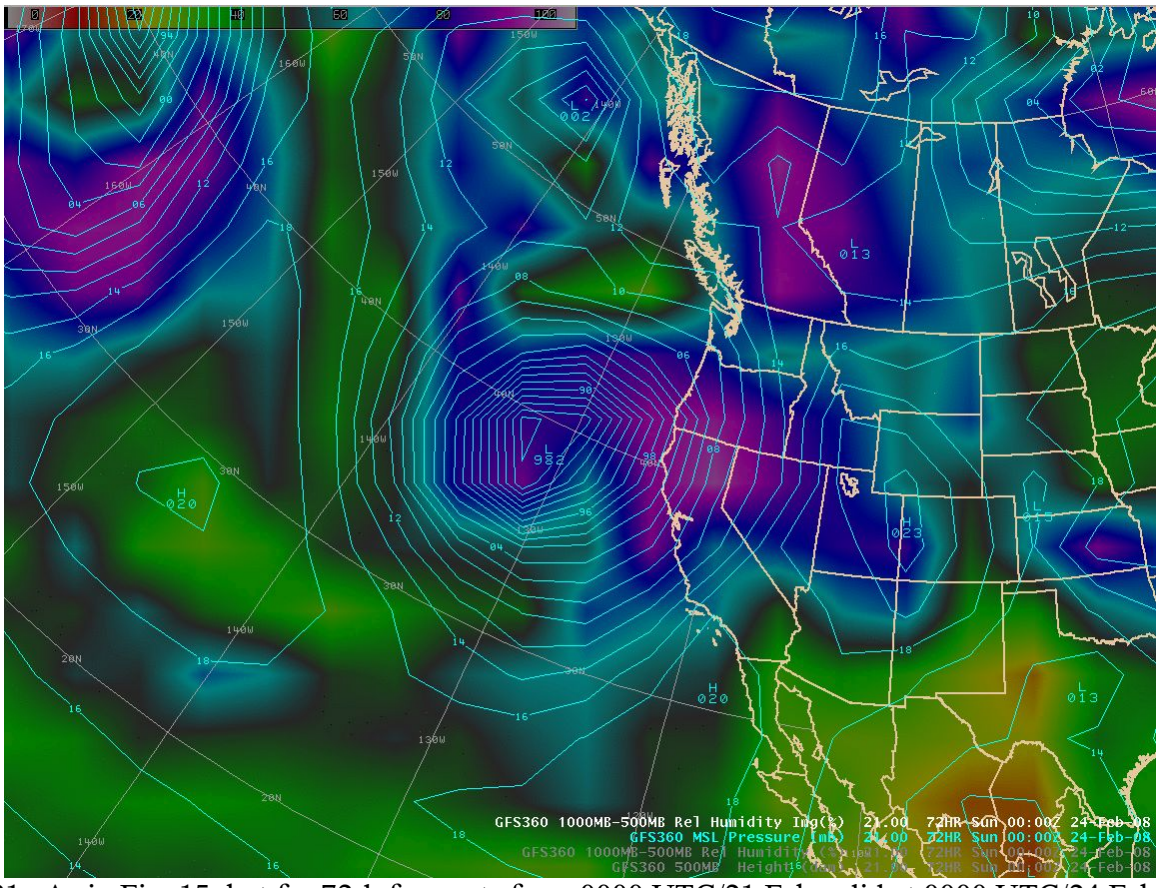


Fig. 21. As in Fig. 15, but for 72-h forecasts from 0000 UTC/21 Feb valid at 0000 UTC/24 Feb.

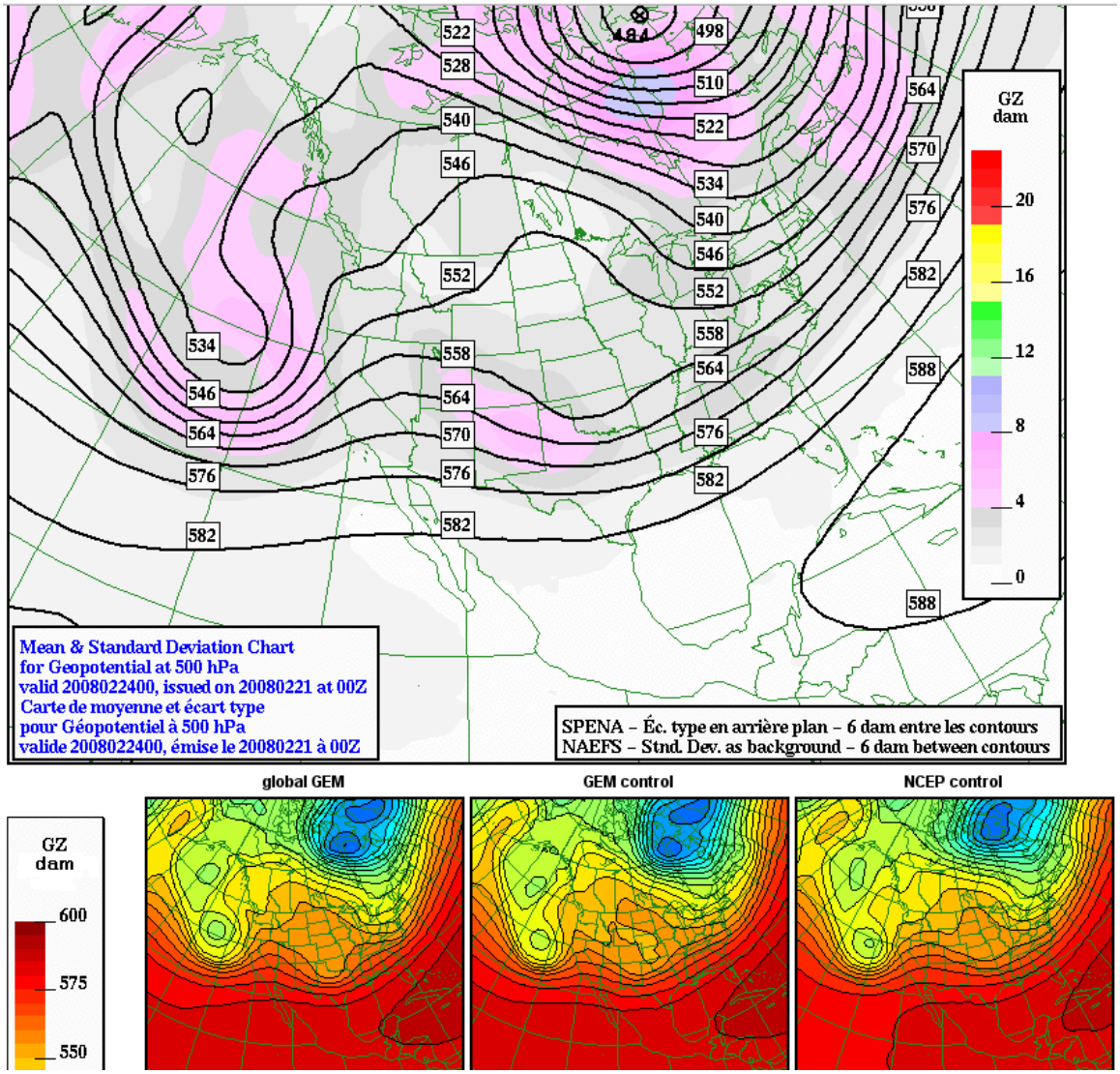


Fig. 22. As in Fig. 13, but for 72-h forecasts from 0000 UTC/21 Feb valid at 0000 UTC/24 Feb.

Shorter range forecasts: The forecasts from the NAM (84-h maximum forecast length) were also generally quite good (not shown), with the precipitation forecasts maximizing the amounts in the higher terrain much more than from the Global models, as would be expected. Forecast total precipitation from the 1200 UTC/Friday/22 Feb NAM included 3.75" interpolated to KBLU and 1.2" for KSAC (Sacramento). This compares to 1.8" and 1.2" respectively from the 1200 UTC ECMWF, and 2.9" and 1.1" from the 1200 UTC GFS. Precipitation totals from the event as compiled by WFO SAC are given in Appendix A, while the time series of obs from the KBLU METAR are in Appendix B. For reference to the forecast amounts, the total precipitation at KSAC was 0.80". At KBLU the ESRL hot plate gage was not functioning properly after recording ~1.4" ending ~1200 UTC/24 Feb. The storm total from the CNRFC was 2.86" (this may be an underestimate given trouble measuring liquid in heavy wet snow). The ESRL hot plate gage farther up the Interstate at Big Bend recorded a storm total of 4.3", which is about the highest total measured within the ARB.

Our high-resolution (3-km horizontal grid resolution) runs that are made every 6-h out to 72 h duration (not shown here) were also forecasting maximum amounts highly tied to the terrain. Individual runs of the local models for the duration of the storm for the 1200 UTC/Friday/22 Feb initialization time had

storm total precipitation amounts in the 4-5 inch range. Our ensemble forecast of the local model runs generally showed about an inch or so less for maximum amounts, closer to what actually occurred. Some precipitation totals from runs initialized 24-h later at 1200 UTC/Saturday/23 Feb include the following: near 4" max within the ARB in the NAM, 2-2.5" in the GFS, about the same from the local models (4-5+ inches) and around 3.5" from the ensemble forecast. So overall relatively good precipitation amount forecasts as the event got closer, with the higher resolution models (NAM through our local runs) correctly predicting a strong gradient tied to the higher terrain. Further discussion of the local model performance for this event is included later under the radar discussion.

Timing of the precipitation was also pretty well forecast, with a starting time of around 2100 UTC for KBLU from both the Friday and Saturday runs. The echo forecasts from our high-resolution models were quite good in showing the evolution of the system, including the rapid increase in echo coverage after 0000 UTC/24 Feb.

Other forecast issues/storm highlights: In this final section some of the other forecast issues and features for this IOP will be briefly discussed. As noted earlier, based on the forecasts there was high confidence of a significant precipitation event, and the timing was generally well forecast. A strong dynamic system was predicted by the models, so strong sw winds were forecast well in advance of the event, a tropical tap that became more diffuse with time, but an event that would have strong orographically forced precipitation.

The biggest forecast problem involved the precip type at the radar location, an issue we have faced often this season. With such a strong surface and upper low forecast to bottom out off the Northern California coast by early Sat/23 Feb strong sw flow would clearly push into the ARB as Saturday went on. With this would be strong warm advection that would not only produce a lot of the initial precipitation, but would also warm temperatures and lower the snow level. The snow level was a point of considerable discussion in the telcons beginning midweek and continuing right up to Saturday, only hours before the precipitation began. Model forecasts had a warm layer rapidly moving to the northeast on Saturday, but whether it would be enough to bring rain to KBLU was tricky. An example of a 24-h GFS forecasts interpolated to KBLU is shown in Fig. 23 for 0000 UTC/24 Feb. Included in Fig. 23 are two analysis soundings from the GFS, to indicate the amount of warm advection that did occur, which was substantial above the surface. Still, the entire temperature profile, according to the GFS analysis, remained below freezing at 0000 UTC/24 Feb. The forecast sounding from the 0000 UTC/22 Feb GFS run was too warm in the lowest ~150 mb, though still not predicted to go above freezing (note that in some of the earlier runs an even warmer profile was predicted by the GFS, while the NAM tended to have a colder forecast). Aloft, the warming was slightly underforecast by the GFS, but still centered near where it occurred.

The potential warming led to considerable discussion of the chance of at least some rain falling at the radar site at Blue Canyon, elevation 5282 ft (1610 m). Initially WFO SAC felt the precipitation would be all snow at KBLU, with a snow level between 4000-5000 ft. Others thought it was likely that the warm advection could raise the snow level to near 6000 ft at least for up to about the first 6 h of the event before a gradual cooling lowered the snow level to below KBLU. Actual observations at KBLU (Appendix B) show that the temperature at KBLU never made it above freezing until very late in the event. Special soundings were launched for IOP8 at Oakland (OAK), Reno (REV), and Sloughhouse (SHS) at 3-h intervals from 1800 UTC/23 Feb through 1200 UTC/24 Feb. The ones from OAK and REV are shown in Figs. 24 and 25.

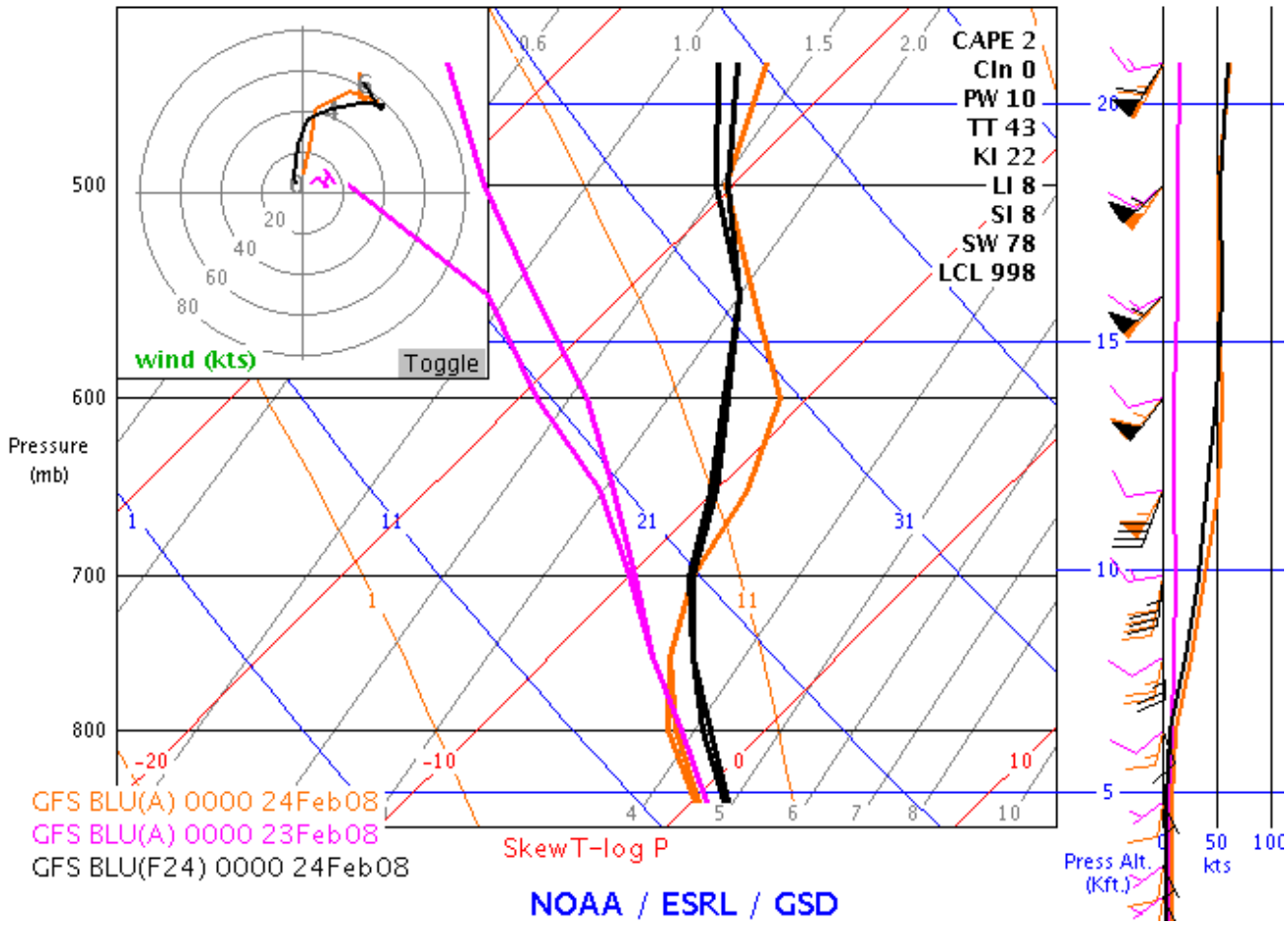


Fig. 23. GFS analysis and forecast soundings interpolated to KBLU. Shown are the GFS analysis soundings for 0000 UTC on 23 and 24 Feb (labeled "A"), and a 24-h forecast valid at 0000 UTC on 24 Feb (labeled "F24"). Note that the soundings extend below the GFS model height of KBLU, which is near 810 mb.

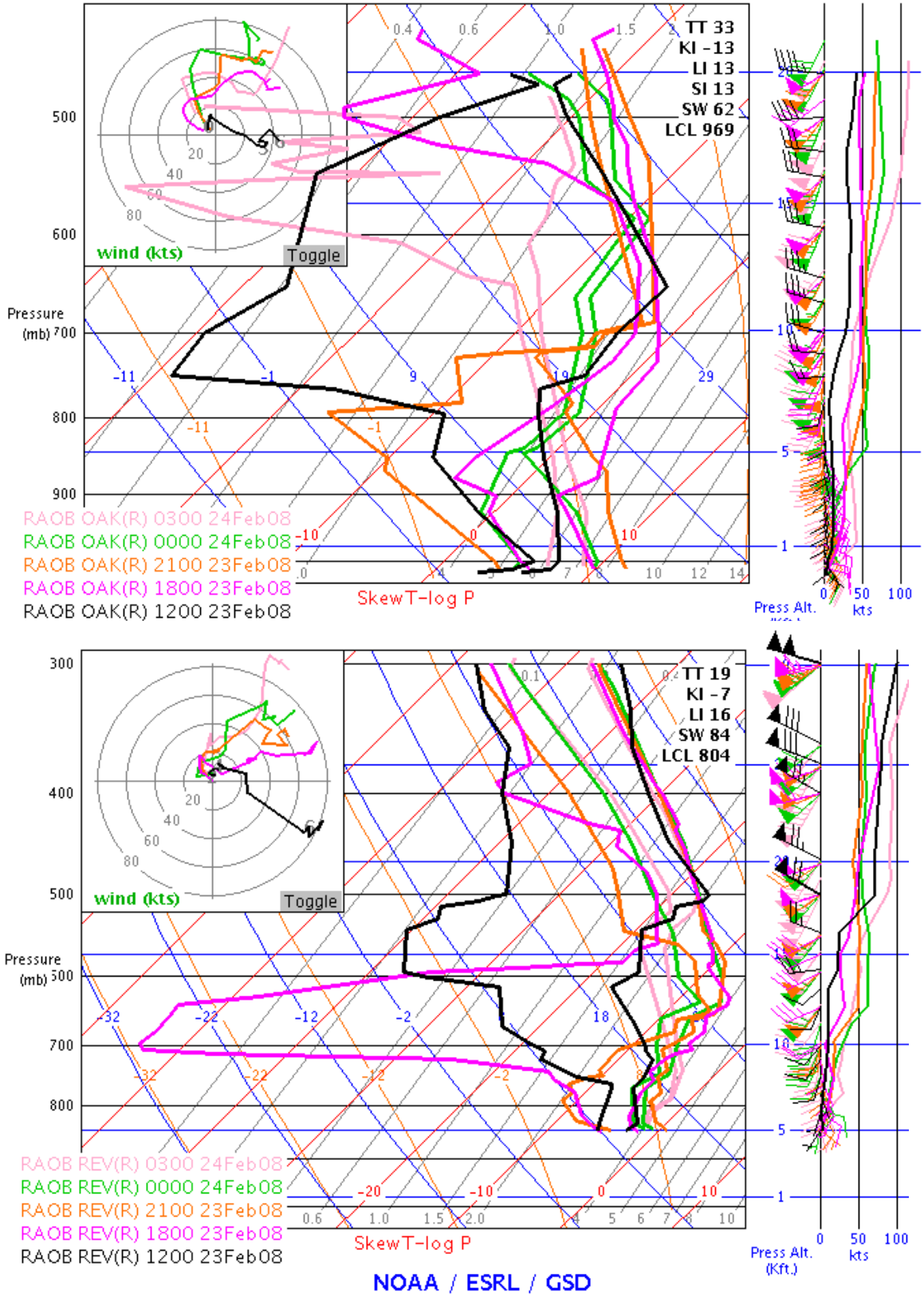


Fig. 24. Standard and special soundings for OAK (top) and REV (bottom) from 1200 UTC/23 Feb to 0300 UTC/24 Feb. The color scheme for the sounding times is the same for both panels.

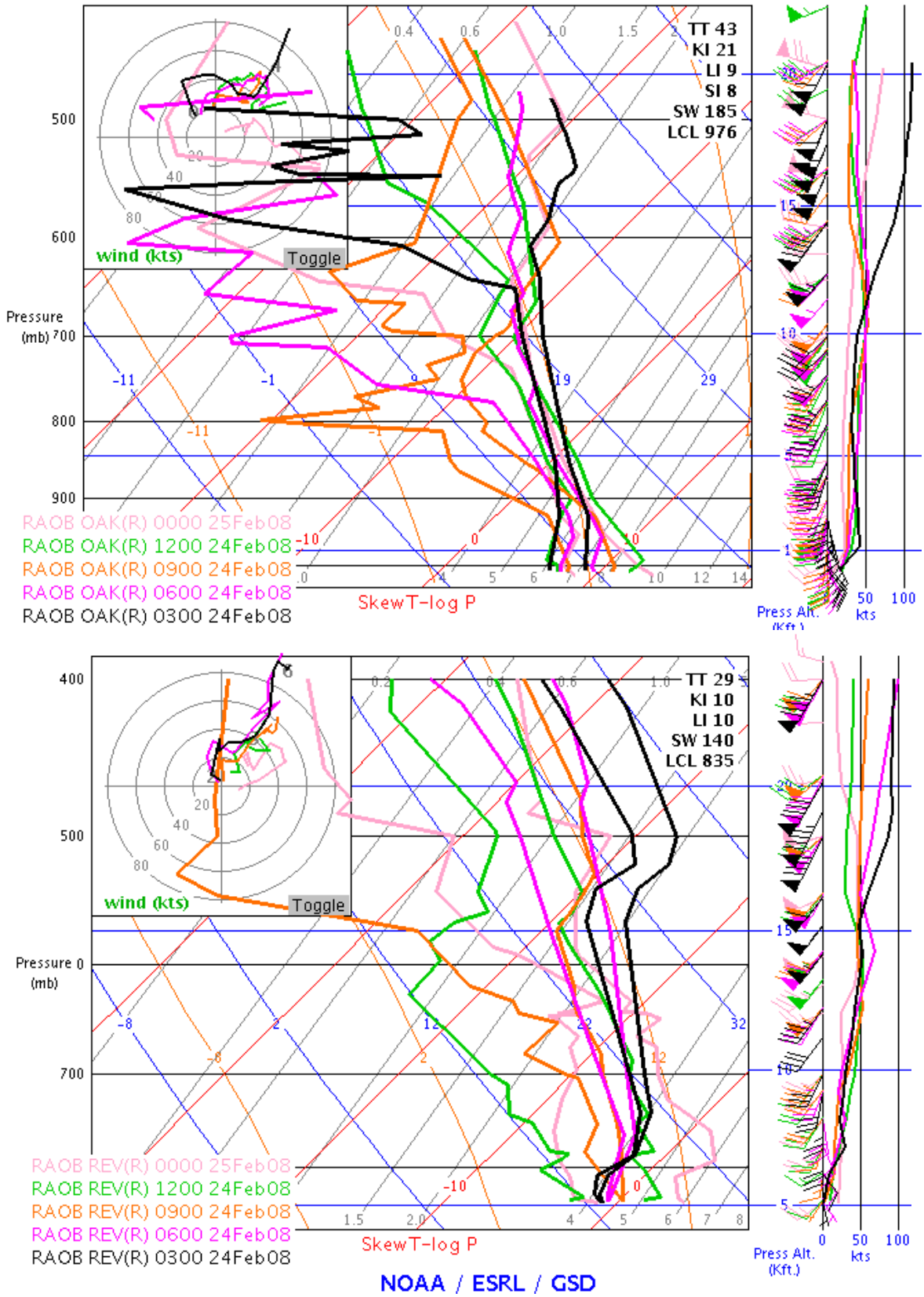


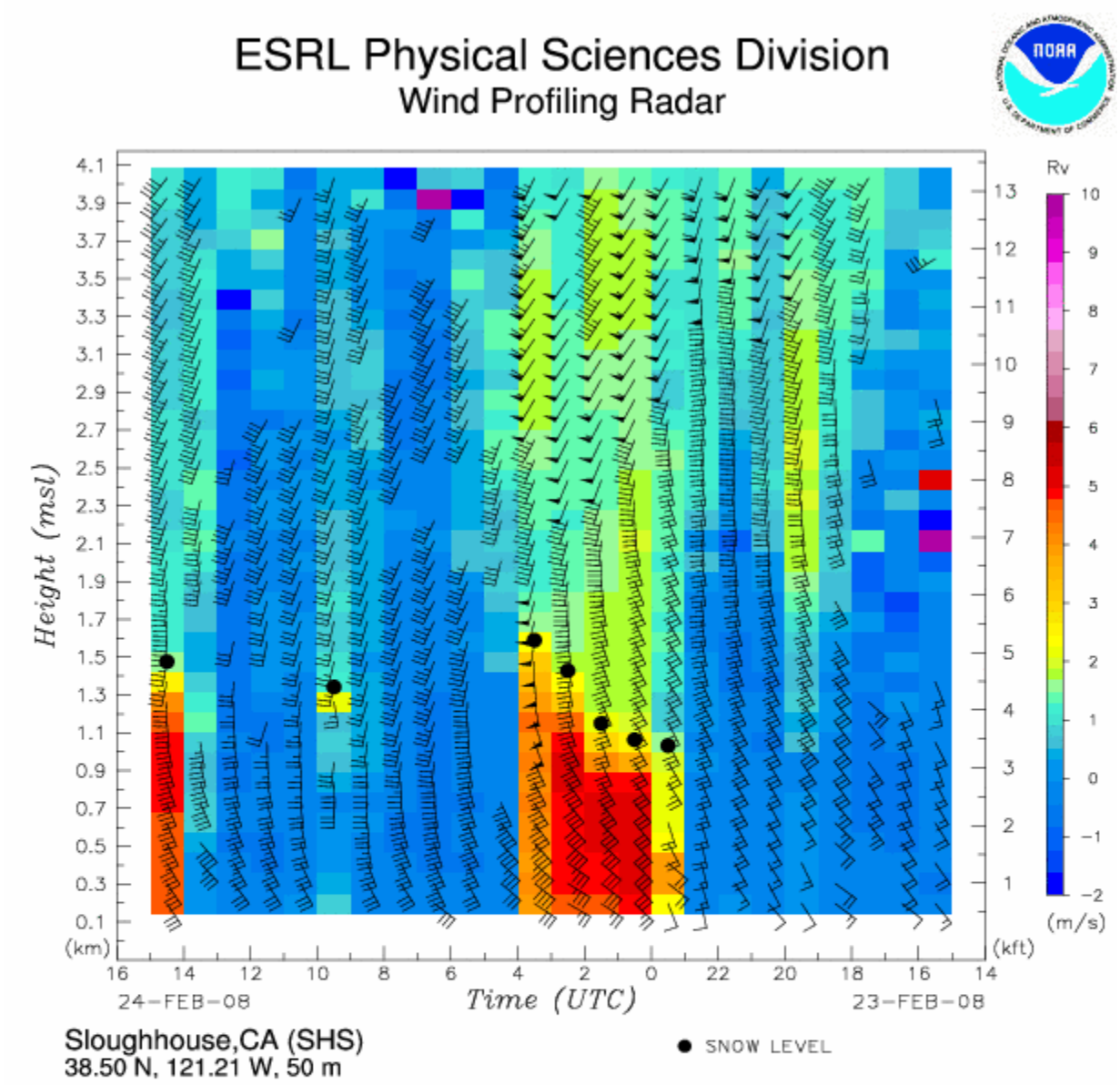
Fig. 25. Standard and special soundings for OAK (top) and REV (bottom) from 0300 UTC/24 Feb to 0000 UTC/25 Feb. The color scheme for the sounding times is the same for both panels.

IOP8 followed quickly on the heels of IOP7 that came to an end from west to east on Fri/22 Feb. Drier air moved in behind this open wave, and this is seen at both OAK and REV at 1200 UTC/23 Feb. In fact, further drying occurs at REV over the next 6 h, with a very dry layer on the 1800 UTC special sounding between 700 and 500 mb. One interesting point mentioned by WFO SAC during the Saturday morning (23 Feb) telcon (at 1930 UTC) was that greater than expected clearing had occurred in the higher terrain at KBLU, resulting in cooler overnight temperatures, which had yet to recover to the freezing level by the time of the telcon. This fact, along with the presence of the dry layer, led the forecasters at WFO SAC to predict that the precipitation would begin at KBLU as snow, and likely remain that way for at least a few hours, before any potential changeover to rain for at least awhile. The previous day or two most of those (including me) believing that some rain would be possible at KBLU felt that it would occur during the early (up to maybe 6 or so hours) portion of the storm. That the storm would begin as snow based on what had occurred overnight and the drying was a good catch by the forecasters at WFO SAC. It was confirmed by observations from the radar site during the telcon of virga that was slowly making its way closer to the ground but that the precipitation nearing the ground looked like snow.

That the precipitation would start as snow at KBLU did not of course preclude the potential for a changeover to rain as the warm advection increased. Indeed, the 1800 UTC REV sounding shows considerable warming above 800 mb, with the warming also at OAK. However, the dry layer at REV would make any changeover more difficult as the atmosphere would be cooling as it saturated, countering any larger scale advection of warm air. The actual soundings after 1800 UTC indicate that the temperature profile actually warmed up a bit despite the wet-bulb cooling as the atmosphere saturated, although some additional cooling did occur by the next sounding time of 0000 UTC/24 Feb as the lower levels became saturated. After 0000 UTC the mid-levels began to cool as the upper level system began to approach the coast, with only slight lower level warming. Similar conditions were revealed by the SHS soundings. The freezing level from these soundings varied as follows:

-1800 UTC/Sat/23 Feb	1478 m/845 mb
-2100 UTC	1961 m/794 mb
-0000 UTC/Sun/24 Feb	1640 m/824 mb
-0600 UTC	1612 m/834 mb
-0900 UTC	1523 m/835.6 mb
-1200 UTC	1498 m/837.7 mb.

The sharpest rise occurred between 1800 to 2100 UTC on Saturday, then things held steady through 0600 UTC before the freezing level lowered through early Sunday morning. The freezing levels above can be compared to the snow level as determined by the SHS profiling radar in Fig. 26. The radar-determined snow level is considerably higher than the freezing level at 0000 UTC/24 Feb, but then the snow level rises dramatically over the next few hours (the 0300 UTC sounding was missing, and it would be interesting to see if the same upward trend was seen in the freezing level for this time period). By the next snow level report at 0930 UTC/24 Feb the snow level has lowered to 1342 m. The upper level data then indicates a valiant effort was made by the warm advection but it was not enough to raise the snow level high enough to change the precipitation to rain at KBLU. Time series from the ESRL gages at Alta (1085 m/3560 ft), Blue Canyon (1610 m/5282 ft), and Big Bend (1739 m/5706 ft) are shown in Figs. 27-30. The temperature rise seen from 0200-0600 UTC/24 Feb in the Alta and BLU time series is consistent with the warming aloft observed, with the surface rise most dramatic at the lower elevation of Alta. Big Bend shows an earlier rise and then conditions remaining steady overnight. The KBLU METAR listing in Appendix B has a brief changeover to freezing rain/ice pellets late Saturday night, but WFO SAC forecasters believed this was most likely snow flakes that became wetter during this period and as a result fell at a faster rate, essentially fooling the automated precipitation sensor into believing this meant a change of precipitation type.



Time (UTC)	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330
Snow Level (m)	1476	none	none	none	none	1342	none	none	none	none	none	1589
Snow Level (ft)	4841	none	none	none	none	4401	none	none	none	none	none	5211
Sfc Temp (C)	10.73	10.78	10.54	10.39	10.69	10.02	9.81	9.77	9.99	10.31	9.61	8.51

Time (UTC)	0230	0130	0030	2330	2230	2130	2030	1930	1830	1730	1630	1530
Snow Level (m)	1428	1149	1063	1032	none	none	none	none	none	none	none	none
Snow Level (ft)	4683	3768	3486	3384	none	none	none	none	none	none	none	none
Sfc Temp (C)	7.86	7.99	8.60	10.52	10.68	10.98	11.38	10.13	9.14	8.72	6.47	5.00

Fig. 26. Wind profiling radar time series from SHS along with snow level output for the period 1400 UTC/23 Feb to 1600 UTC/24 Feb.

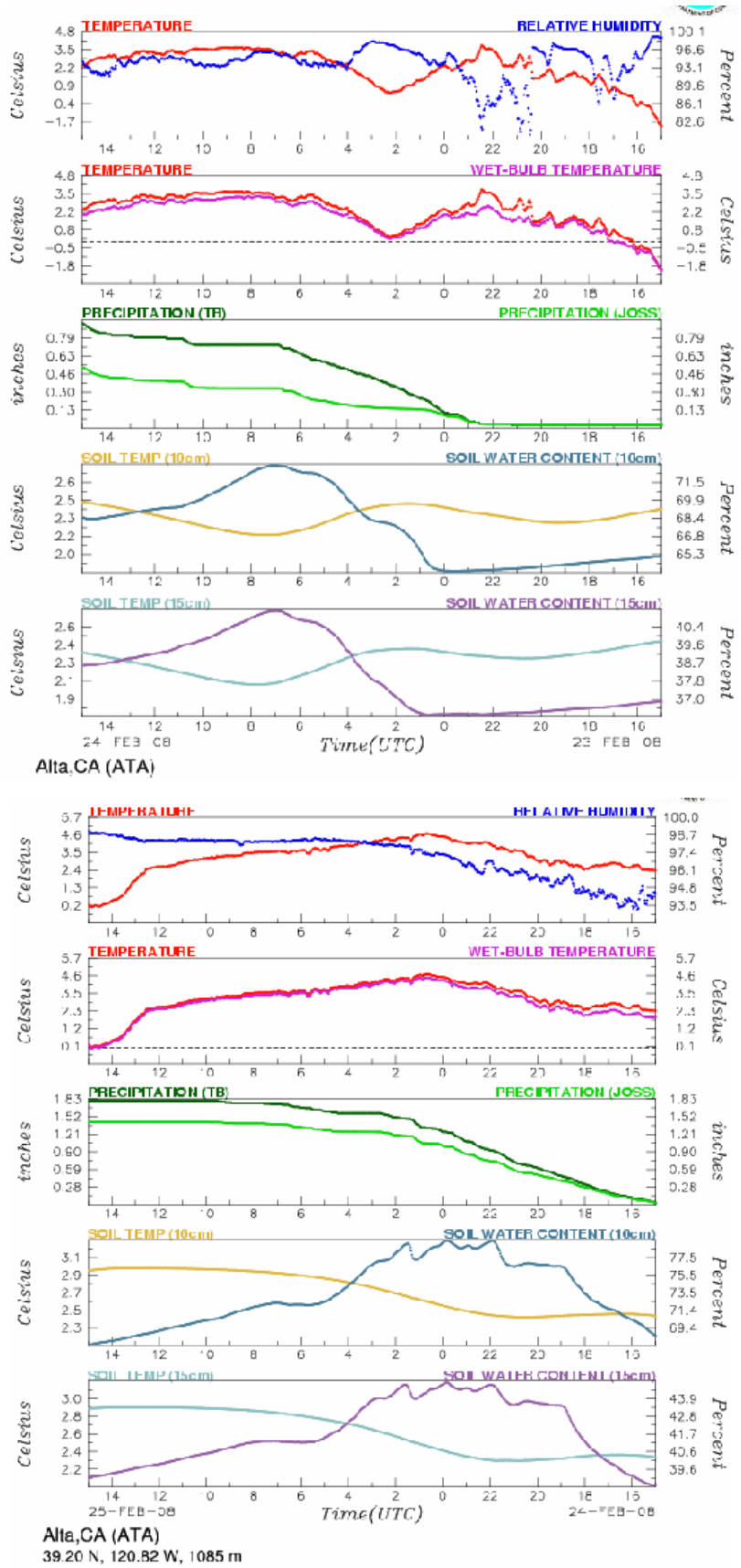


Fig. 27. Time series from the ESRL surface gage at Alta, for two 24-h periods ending 1500 UTC/24 Feb (top) and 1500 UTC/25 Feb (bottom).

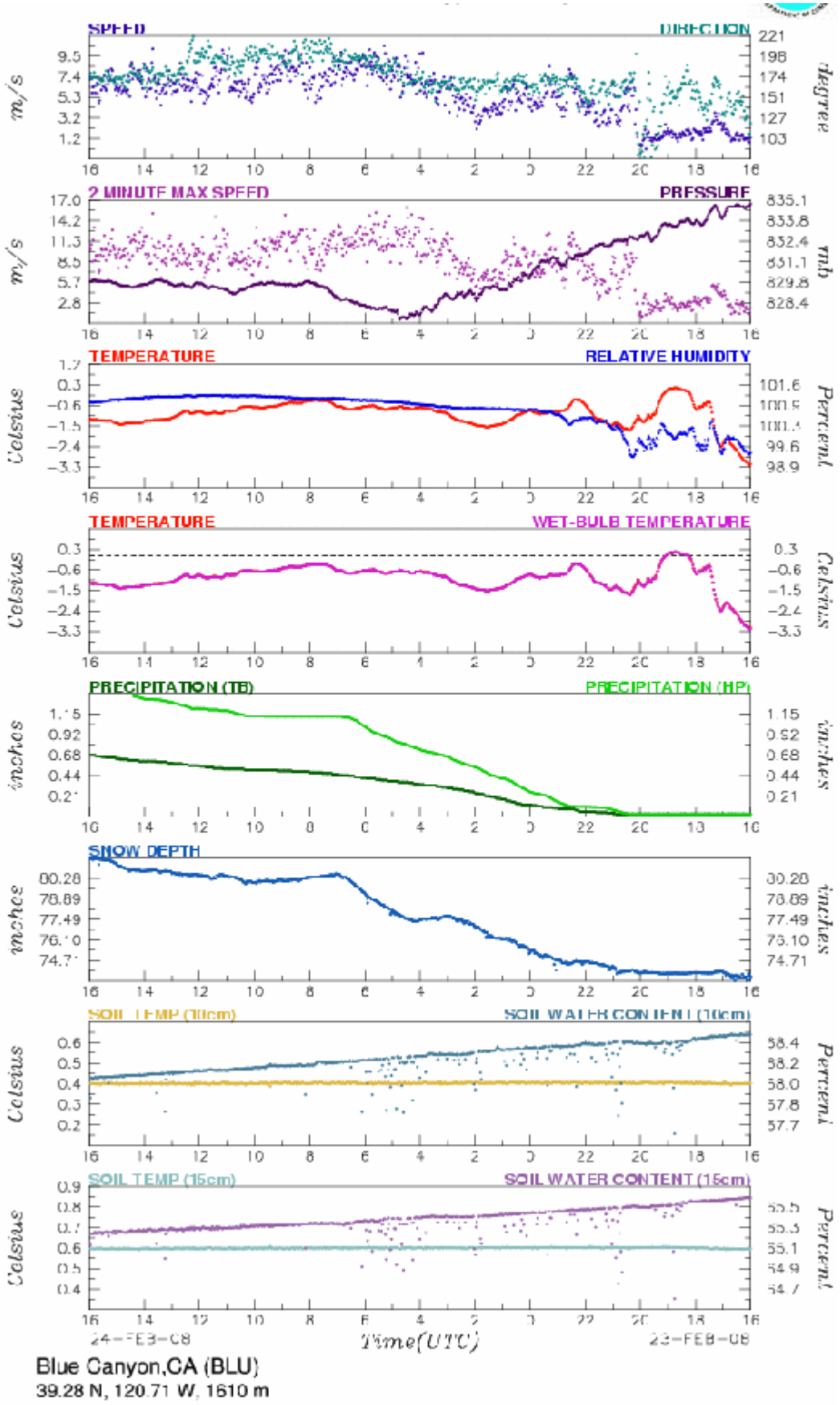


Fig. 28. Time series from the ESRL gage at Blue Canyon, for the 24-h ending 1500 UTC/24 Feb.

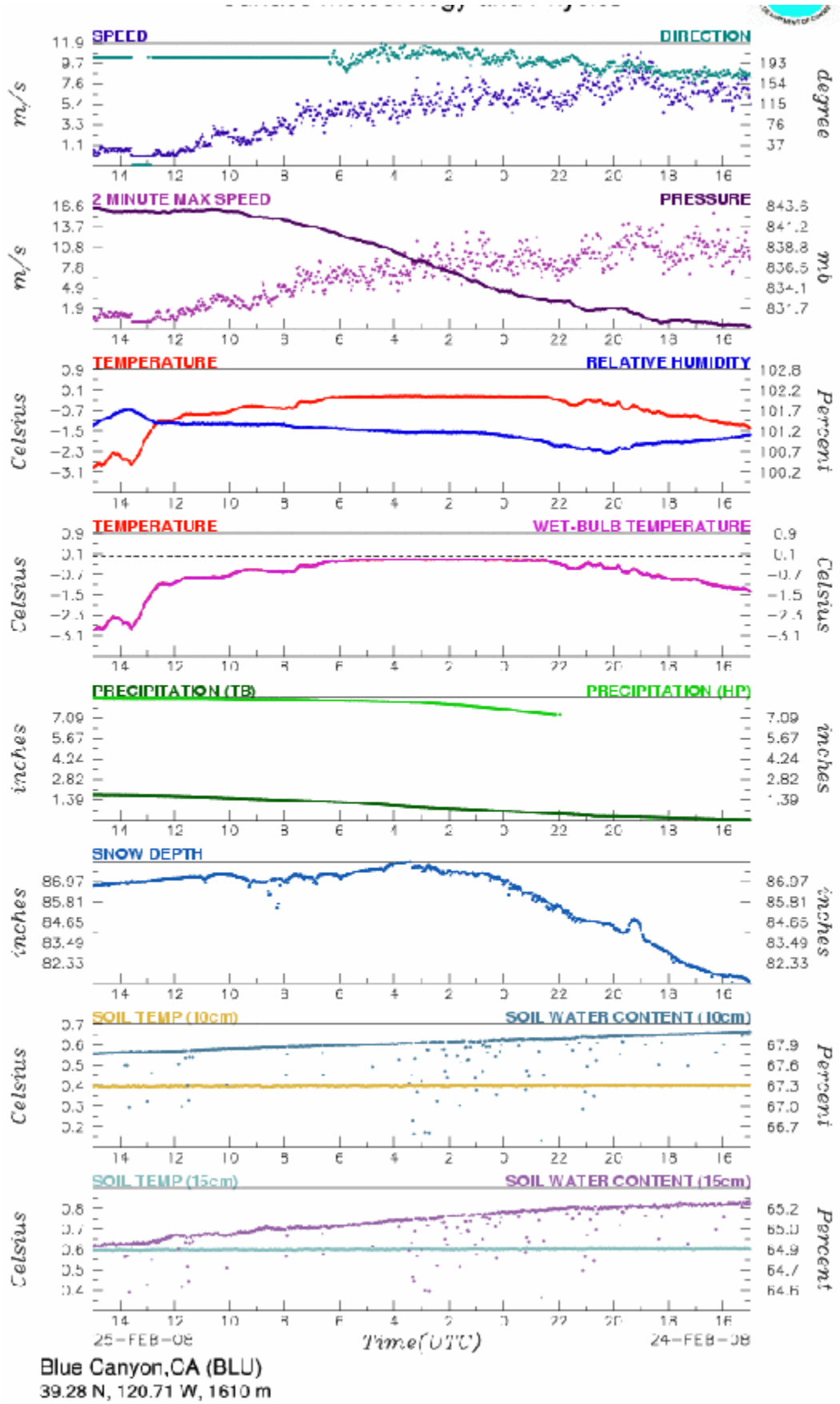


Fig. 29. Time series from the ESRL gage at Blue Canyon, for the 24-h ending 1500 UTC/25 Feb.

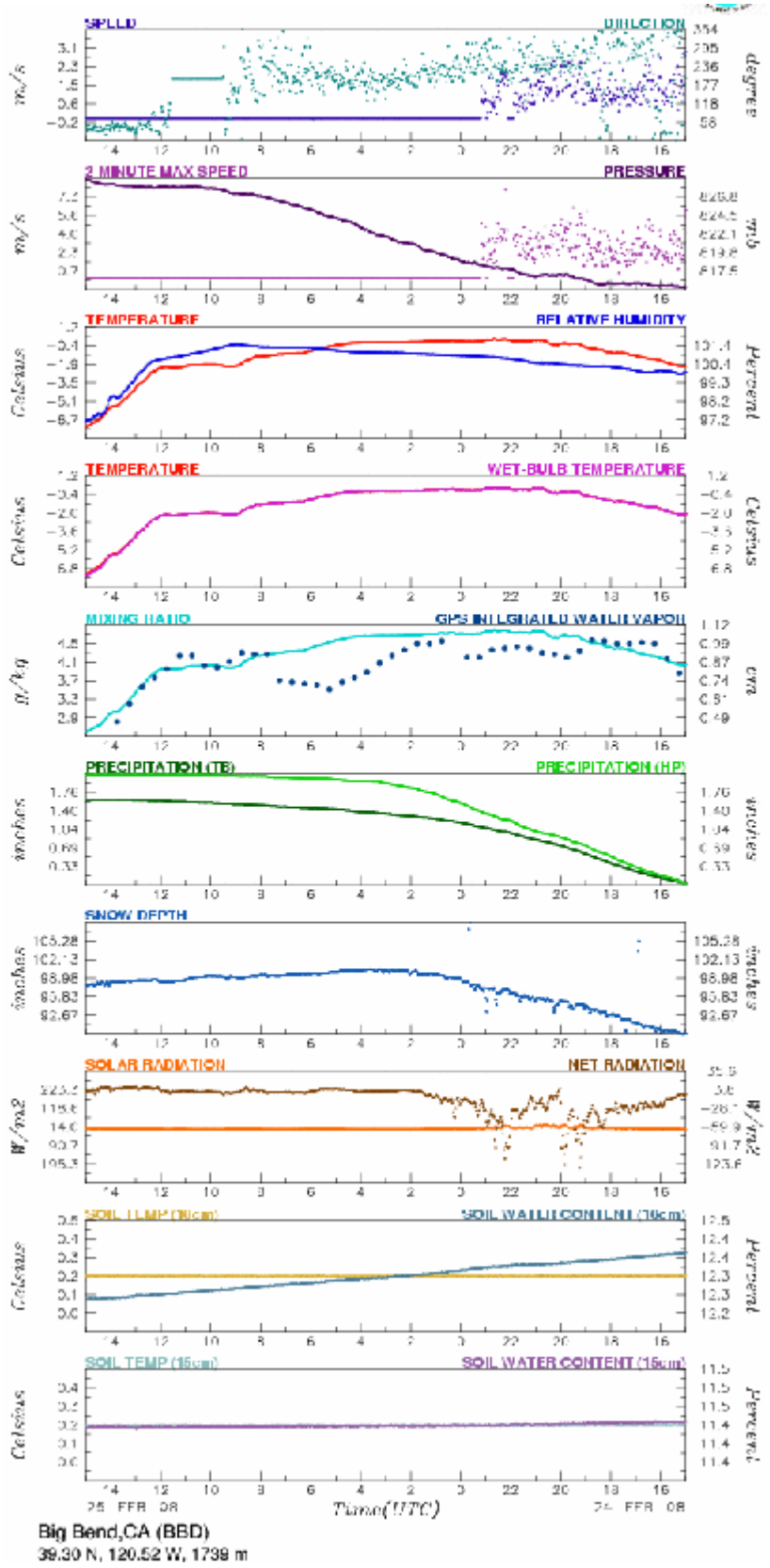
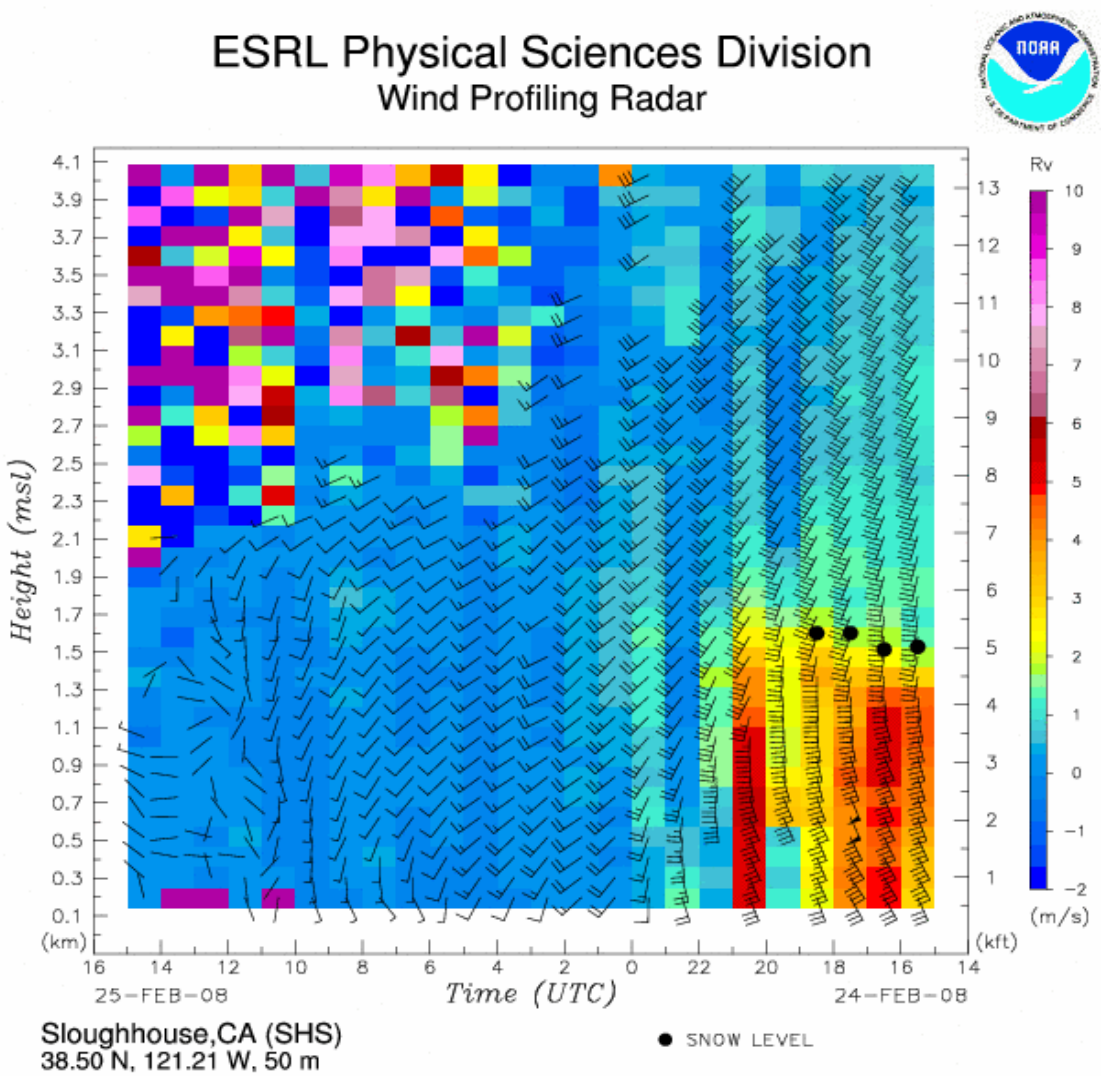


Fig. 30. Time series from the ESRL gage at Big Bend, for the 24-h ending 1500 UTC/25 Feb.

One of the more dramatic aspects of the storm was the rapid increase in southerly flow on Saturday morning into the afternoon. This is seen in the change in the winds (see the hodograph presentation in Fig. 24) at OAK between the 1200 UTC/23 Feb RAOB and the special sounding 6 h later. Similar strengthening is seen in the REV RAOBs. The time series at SHS in Fig. 26 also shows this rapid transition as the upper low approached the far Northern California coast. The actual passage of the system on Sunday was considerably less dramatic as the system weakened rapidly during the day, as seen in the SHS time series in Fig. 31. The winds remained fairly strong during the day on Sunday



Time (UTC)	1430	1330	1230	1130	1030	0930	0830	0730	0630	0530	0430	0330
Snow Level (m)	none	none	none	none	none	none	none	none	none	none	none	none
Snow Level (ft)	none	none	none	none	none	none	none	none	none	none	none	none
Sfc Temp (C)	6.93	8.09	9.00	8.36	8.65	8.58	9.49	9.79	9.83	9.54	9.01	9.94

Time (UTC)	0230	0130	0030	2330	2230	2130	2030	1930	1830	1730	1630	1530
Snow Level (m)	none	none	none	none	none	none	none	none	1601	1601	1514	1528
Snow Level (ft)	none	none	none	none	none	none	none	none	5251	5251	4965	5011
Sfc Temp (C)	10.31	11.05	12.12	12.15	12.70	11.13	11.20	10.99	11.22	11.61	10.73	10.95

Fig. 31. As in Fig. 26, but for the 24-h ending 1600 UTC/Monday/25 Feb.

though weaker than their overnight peak, then decreased near and after the passage of the trough, which is pretty difficult to determine from the lower level winds in Fig. 31, but occurred after 0000 UTC/25 Feb.

Note the rise in the snow level on Sunday in the SHS time series. The RAOB data at OAK and REV indicates this continued through 0000 UTC/25 Feb. The surface sensors in the ESRL time series also showed a temperature rise later on Sunday, and the KBLU METAR time series actually shows the warmest temperatures occurring from 0000-0500 UTC/25 Feb when it reached 34°F and the precipitation sensor again showed a changeover, this time briefly to rain at 0352 UTC. This time it may be real; we discussed this in the Monday telcon but given the warmer temperatures that did occur it was not clear whether or not a changeover did in fact occur. It is certainly possible that some mixing occurred as the weakening trough passed.

Local Radar Observations

The HYDROX radar went into action about 16UTC on 23 Feb. All the precipitation stayed as snow. Figure 32 shows the KDAX Radar the first evening of the event as a very heavy rain/snow band moved up the ARB. The HYDROX site was shutdown and secured at 01UTC on the 24th.

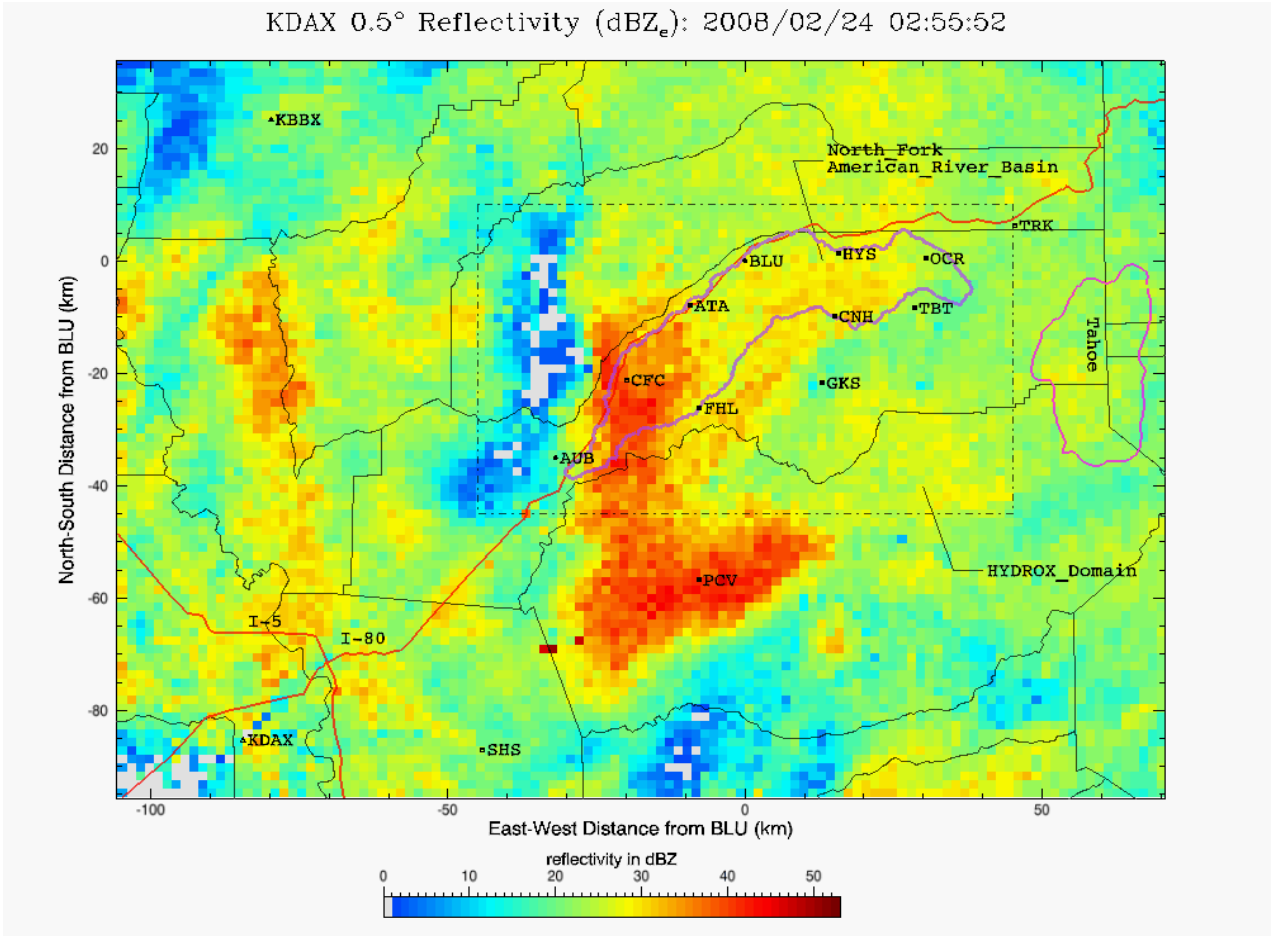


Fig. 32. KDAX radar for 24 Feb 02:55UTC.

Local Model Performance

The 3km ensemble include 3 versions of the WRF-ARW with Ferrier, Thompson, and Schultz microphysics and one version of the WRF-NMM. Fig. 33a shows nearly the entire 48 hour accumulation of one ensemble member the NMM ending at 12 UTC on the 25th. The model was run prior to the onset of precipitation at 12UTC on the 23rd. The green countours indicate that precipitation was forecast to continue up until 12UTC on the 25th. The precipitation ended at BLU at 13UTC. Here are some comparisons between this forecast and observations for IOP8. BBD forecast 5.0" obsv 4.3"; ATA fcst 3.0 obsv 2.7; CFC fcst 2.5 obsv 1.7; TRK fcst 1.5 obsv 0.5; SHS fcst 0.6 obsv 0.4. A slight positive bias was noted. Figures 33 b and c show the ensemble mean forecasts for day 1 (23 Feb 12UTC to 24 Feb 12 UTC; Fig. 33b) and day 2 (24 Feb 12UTC to 25 Feb 12UTC; Fig. 33c). Compare those to the station precipitation amounts and also the AHPS precipitation analysis (shown later in Fig. xxx). Also shown (Figs. 34 a and b) are two cross-sections along the ARB illustrating how the snow level (ice reaching ground – orange contours) descended below BLU and stayed there for the duration of the event. Melting layer was lower to the west over the Central Valley at this time.

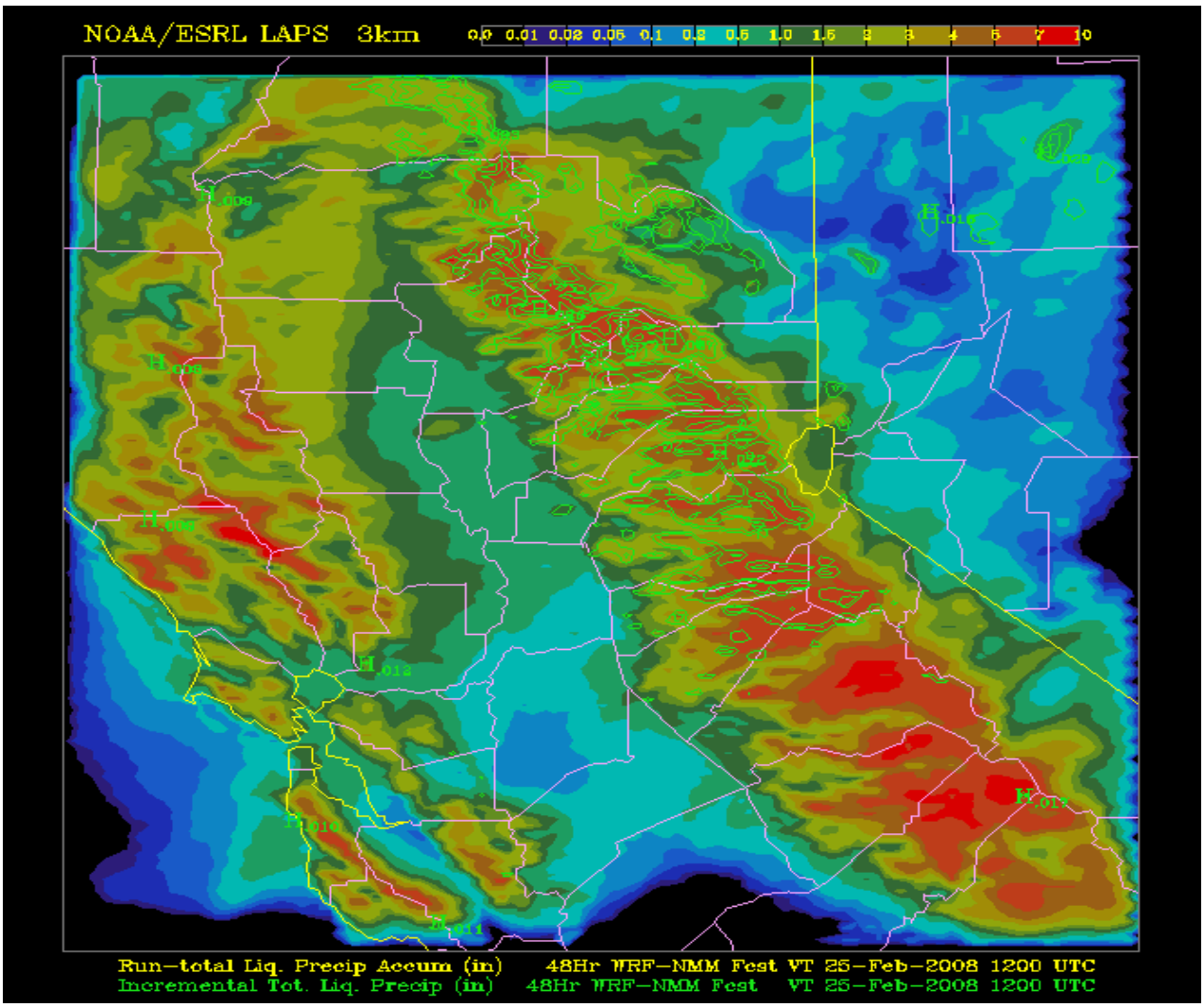


Fig. 33a. NMM total precipitation for IOP 8, in inches.

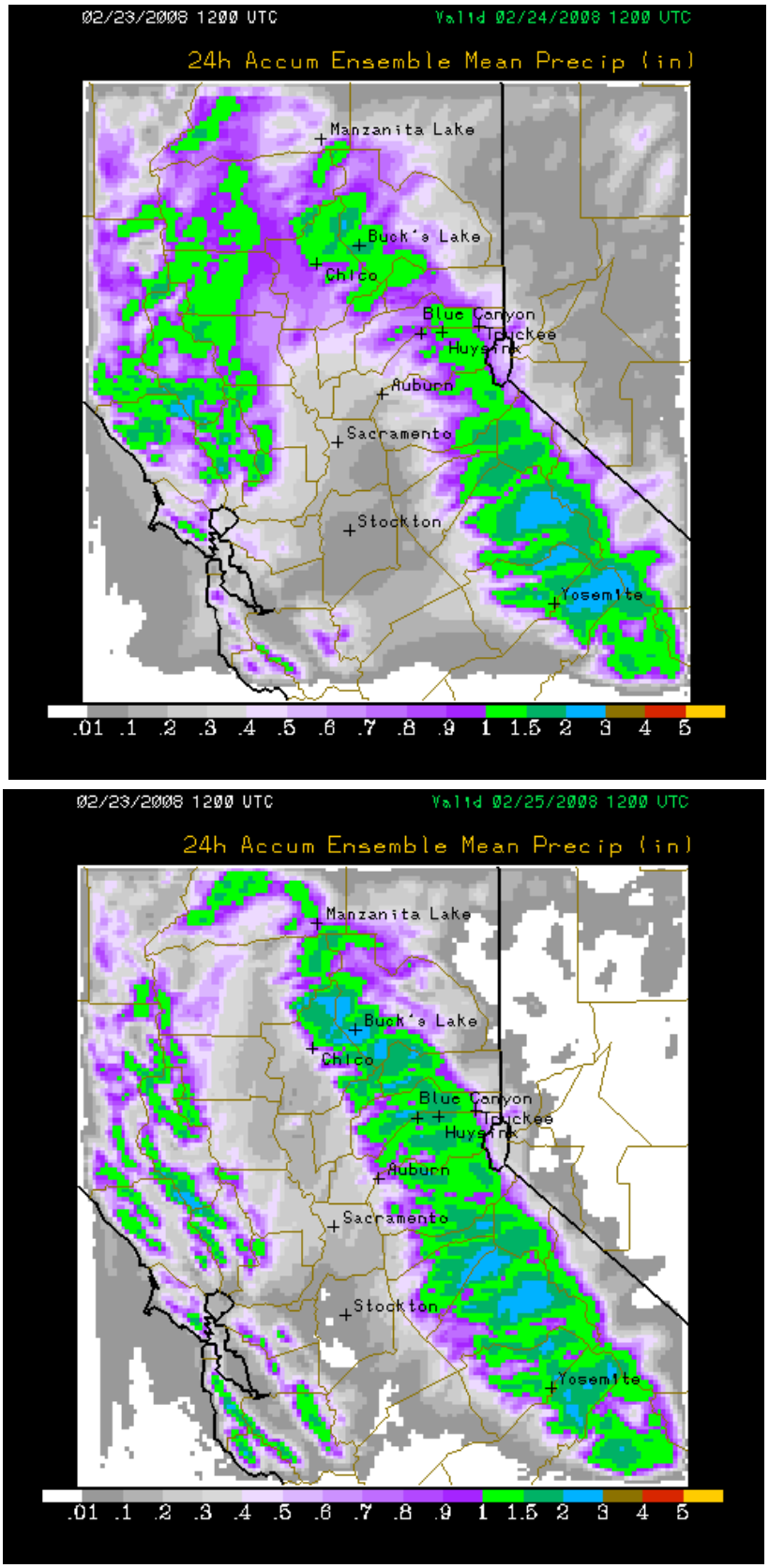


Fig. 33 b and c. b) Day 1 ensemble mean precipitation; c) Day 2 ensemble mean precipitation. Note ensemble mean total precipitation (sum of both b and c) was a little less than single model (NMM, (a)) somewhat adjusting positive bias noted in the latter.

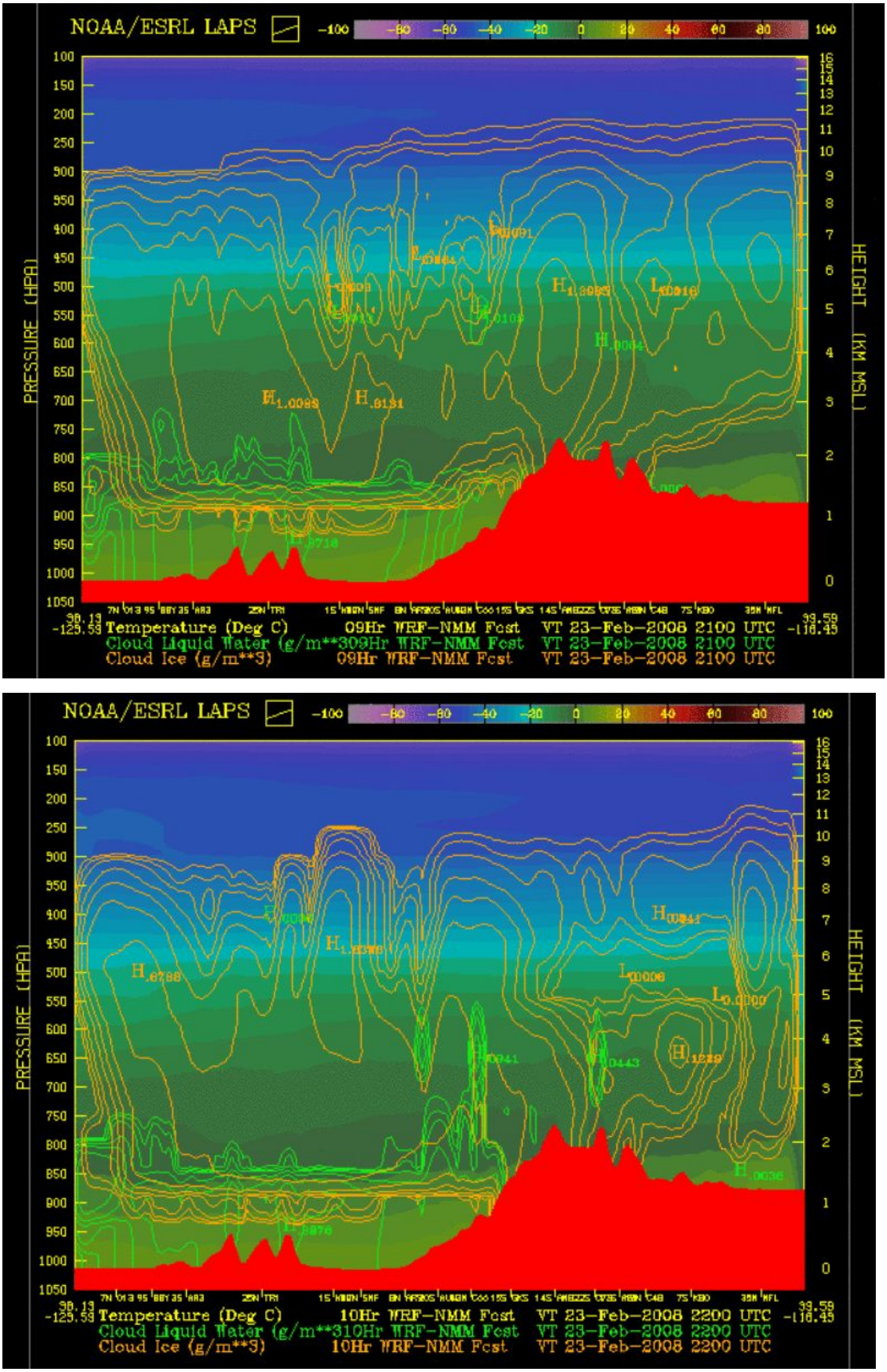


Fig. 34 a, b: Cross-section through ARB for the WRF-NMM run showing snow descending below BLU between 23 Feb a) 21 to b) 22 UTC.

Precipitation Observations

Precipitation observations from 6 stations in and near the ARB are in Fig. 35. Included is the AHPS precipitation analysis for the entire event (Fig. 36).

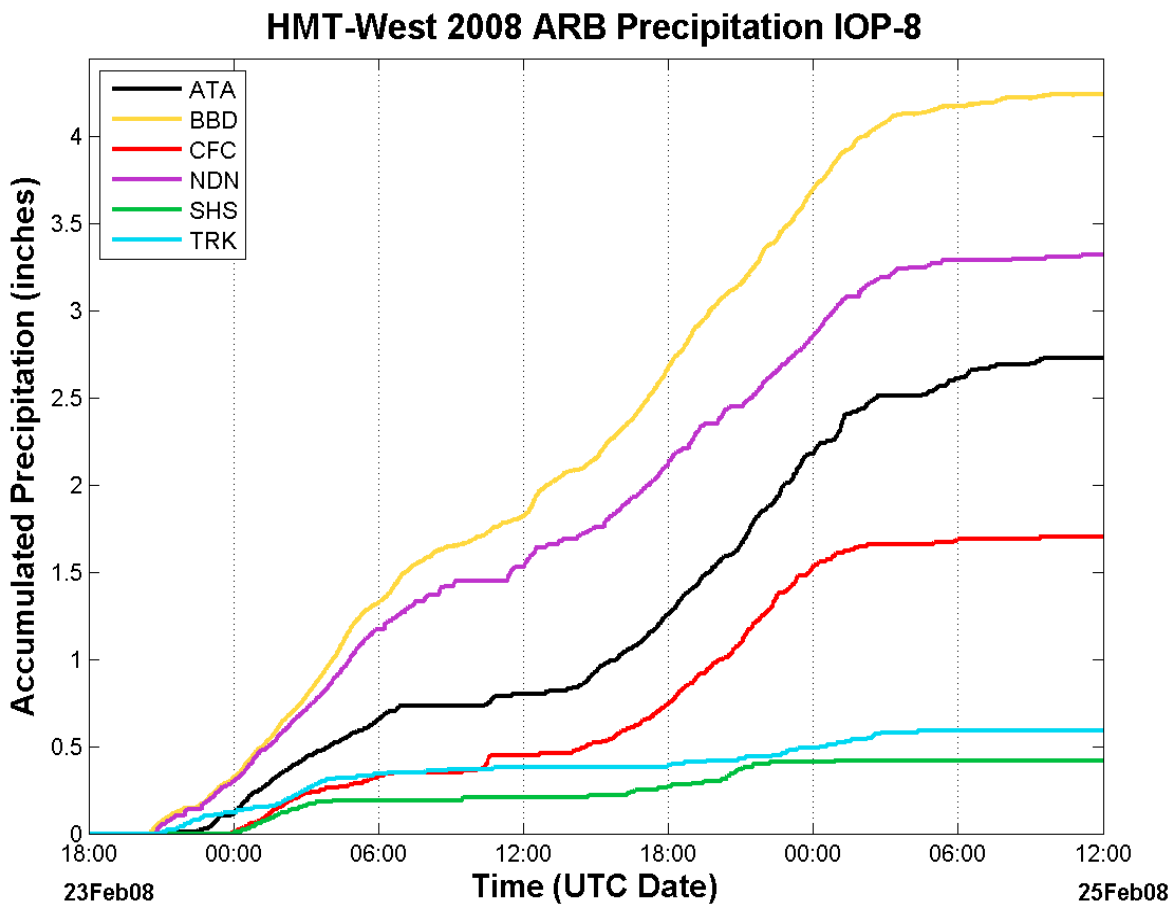


Fig. 35. Multi station precipitation accumulation.

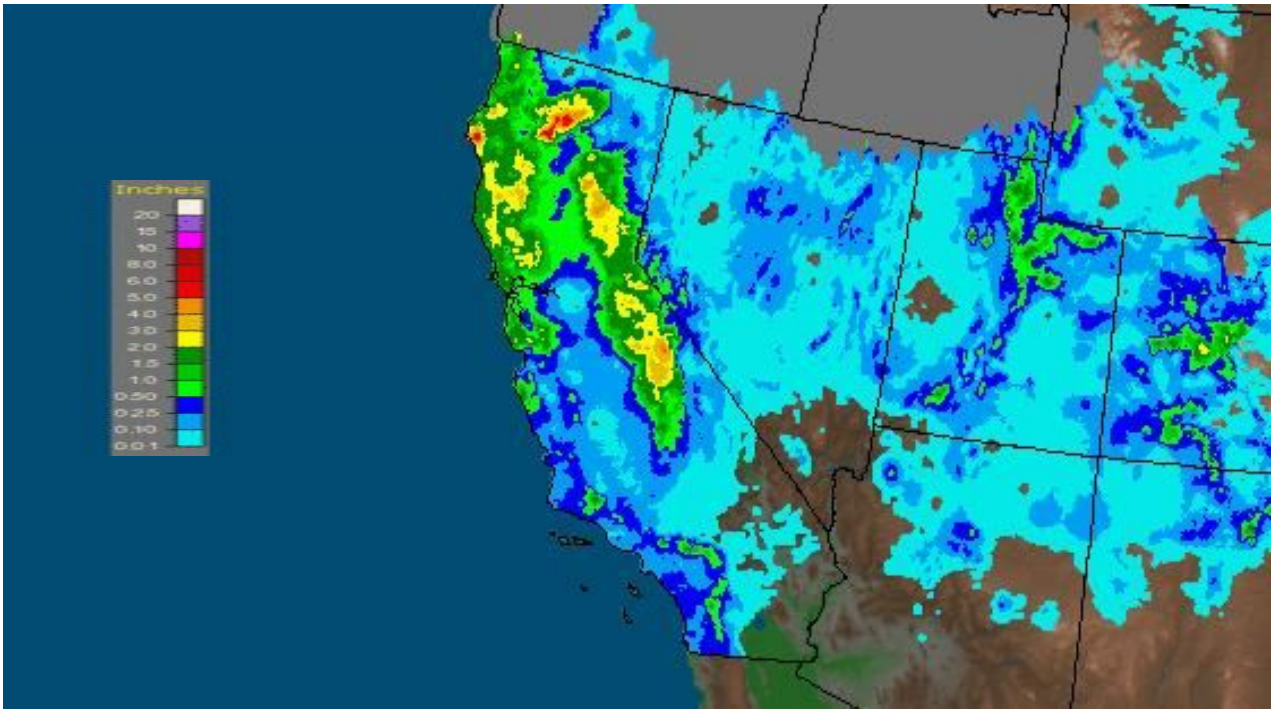


Fig. 36. AHAPS precipitation verification for 24 hrs ending on 25 Feb 12 UTC.

Appendix A lists precipitation and snow totals compiled by WFO SAC for the storm. Appendix B lists the METAR observations from KBLU. Our last figures show the snow report from the ski area closest to KBLU, at Boreal Ridge (Fig. 37) and Tahoe Ski Area (Fig. 38). All in all it was an interesting and at times quite challenging to forecast event.

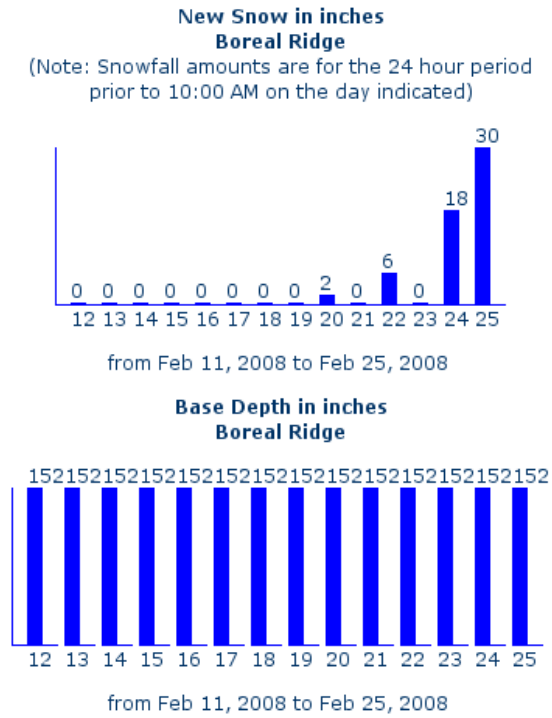


Fig. 37. Snowfall graphic for Boreal Ridge Ski Area, which recorded 48" for the storm (not sure why the snow depth never changes in the second plot).

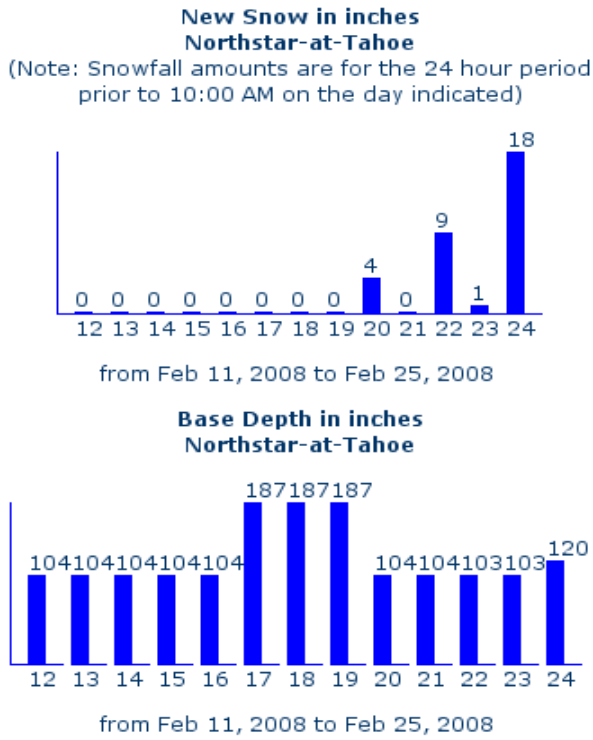


Fig. 38. Snowfall graphic for the Northstar at Tahoe Ski Area. Note that 10 inches of snow fell here during IOP7.

Appendix A. Special Weather Statement issued by WFO SAC on Monday 25 Feb.

PUBLIC INFORMATION STATEMENT
NATIONAL WEATHER SERVICE SACRAMENTO CA
1110 AM PST MON FEB 25 2008

CAZ013>019-063-064-066>069-260600-
SHASTA LAKE AREA / NORTHERN SHASTA COUNTY-
BURNEY BASIN / EASTERN SHASTA COUNTY-NORTHERN SACRAMENTO VALLEY-
CENTRAL SACRAMENTO VALLEY-SOUTHERN SACRAMENTO VALLEY-
CARQUINEZ STRAIT AND DELTA-NORTHERN SAN JOAQUIN VALLEY-
MOUNTAINS SOUTHWESTERN SHASTA COUNTY TO NORTHERN LAKE COUNTY-
CLEAR LAKE/SOUTHERN LAKE COUNTY-
NORTHEAST FOOTHILLS/SACRAMENTO VALLEY-MOTHERLODE-
WESTERN PLUMAS COUNTY/LASSEN PARK-
WEST SLOPE NORTHERN SIERRA NEVADA-
1110 AM PST MON FEB 25 2008

HERE IS A PRELIMINARY SUMMARY OF THIS PAST WEEKENDS PRECIPITATION TOTALS AND PEAK WINDS...FROM THE STRONG PACIFIC STORM. THIS STORM DID WEAKEN BEFORE IT MOVED INLAND...BUT THERE WERE SOME IMPRESSIVE NUMBERS AND TOTALS FROM ACROSS THE REGION.

HERE IS A SUMMARY OF THE PEAK WIND GUSTS ACROSS THE REGION ON SUNDAY FEBRUARY 24TH...

REDDING AIRPORT.....54 MPH FROM THE SOUTHEAST AT 1051 AM
REDDING RAWS.....51 MPH FROM THE SOUTHEAST AT 1049 AM
RED BLUFF AIRPORT.....54 MPH FROM THE SOUTHEAST AT 1003 AM
CHICO RAWS.....49 MPH FROM THE SOUTHEAST AT 948 AM
OROVILLE.....44 MPH FROM THE SOUTHEAST AT 1223 PM
BEALE AFB.....51 MPH FROM THE SOUTHEAST AT 1111 AM
MARYSVILLE.....46 MPH FROM THE SOUTHEAST AT 1112 AM
SACRAMENTO INTL AP.....39 MPH FROM THE SOUTH SOUTHEAST AT 830 AM
SACRAMENTO EXEC AP.....35 MPH FROM THE SOUTHEAST AT 1123 AM
MATHER FIELD.....39 MPH FROM THE SOUTHEAST AT 974 AM
STOCKTON AP.....39 MPH FROM THE SOUTHEAST AT 1031 AM
KONOCTI RAWS.....56 MPH FROM THE SOUTHWEST AT 957 AM
COHASSET RAWS.....52 MPH FROM THE EAST SOUTHEAST AT 951 AM
READER RANCH RAWS.....51 MPH FROM THE SOUTH SOUTHEAST AT 954 AM
MOUNT ELIZABETH RAWS.....56 MPH FROM THE SOUTHWEST AT 1002 PM

HERE IS A SUMMARY OF THE PEAK WIND GUSTS ACROSS THE REGION ON SATURDAY FEBRUARY 23TH...

SACRAMENTO INTL AP.....41 MPH FROM THE SOUTHEAST AT 638 PM
SACRAMENTO EXEC AP.....36 MPH FROM THE SOUTHEAST AT 650 PM
STOCKTON AP.....39 MPH FROM THE SOUTHEAST AT 741 PM
MODESTO AP.....38 MPH FROM THE SOUTHEAST AT 1215 PM

HERE IS A SUMMARY OF THE 48-HOUR SNOW FALL TOTALS...

COOP AND SPOTTERS REPORTS:
SIMS (1650 FT).....3 INCHES *
BURNEY (3154 FT).....4 INCHES *
QUINCY (3408 FT).....3 INCHES *
CHESTER (4525 FT).....16 INCHES *
MINERAL (4875 FT).....14 INCHES *
MANZANITA LATE (5750 FT).....8 INCHES *

SKI RESORTS:
KIRKWOOD.....32-42 INCHES
ALPINE MEADOWS.....28-38 INCHES
HOMEWOOD.....20-29 INCHES
SUGAR BOWL.....25-31 INCHES
SODA SPRINGS.....32-48 INCHES
BOREAL.....32-48 INCHES
SIERRA.....16 INCHES*

*24 HOUR TOTALS THROUGH SATURDAY MORNING

PRELIMINARY SUMMARY OF THE 48-HOUR RAINFALL TOTALS ENDING AT 10 AM...
OAK BOTTOM RAWS (1422 FT)....5.23 INCHES
SIMS RAWS (2400 FT).....3.92 INCHES
SUGARLOAF RAWS (3214 FT).....3.46 INCHES
SHASTA DAM (1075 FT).....3.31 INCHES
STONYFORD (1257 FT).....3.09 INCHES
KONOCTI (2163 FT).....3.14 INCHES
BROOKS (360 FT).....2.22 INCHES
PARADISE (1750 FT).....1.45 INCHES
COHASSET (1733 FT).....1.83 INCHES
GROVELAND (2850 FT).....3.23 INCHES
SONORA (1750 FT).....1.65 INCHES
BUCK MEADOWS (3200 FT).....2.74 INCHES
REDDING AP (502 FT).....1.28 INCHES
RED BLUFF (349 FT).....1.00 INCHES
BANGOR RAWS (803 FT).....1.21 INCHES
CHICO (238 FT).....1.08 INCHES
OROVILLE (192 FT).....1.04 INCHES
BROOKS RAWS (354 FT).....2.22 INCHES
VACAVILLE (113 FT).....1.28 INCHES
WOODLAND (70 FT).....1.35 INCHES
SACRAMENTO INTL AP (25 FT)...1.08 INCHES

Appendix B. Listing of observations from the KBLU METAR from 0420 UTC/23 Feb through 1152 UTC/25 Feb.

KBLU 251152Z AUTO 13003KT 2SM BR BKN001 OVC012 M01/M01 A3023 RMK AO2 SNE39 SLP251 P0001 60009 70118 T10061011 10000 21006 50001 TSNO
KBLU 251147Z AUTO VRB03KT 1 1/4SM BR OVC001 M01/M01 A3023 RMK AO2 SNE39 P0001 TSNO
KBLU 251124Z AUTO VRB03KT 1/2SM -SN FG OVC001 00/00 A3023 RMK AO2 P0001 TSNO
KBLU 251111Z AUTO 16005KT 1/4SM -SN FZFG OVC001 M01/M01 A3023 RMK AO2 P0001 TSNO
KBLU 251052Z AUTO 16005KT 1/2SM -SN FG OVC001 00/M01 A3023 RMK AO2 SLP249 P0001 T00001006 TSNO
KBLU 250952Z AUTO 16006KT 1/2SM -SN FG OVC001 00/M01 A3023 RMK AO2 SNB06 SLP250 P0003 T00001006 TSNO
KBLU 250918Z AUTO 17004KT 1/2SM -SN FG OVC001 00/00 A3021 RMK AO2 SNB06 P0001 TSNO
KBLU 250852Z AUTO 18007KT 1/4SM FG VV001 00/M01 A3021 RMK AO2 SNE18 SLP244 P0000 60004 T00001006 51023 TSNO
KBLU 250817Z AUTO 18007KT 1/4SM -SN FG OVC001 00/M01 A3020 RMK AO2 P0000 TSNO
KBLU 250804Z AUTO 18009G15KT 1/2SM -SN FG OVC001 00/M01 A3020 RMK AO2 P0000 TSNO
KBLU 250752Z AUTO 16010KT 1/4SM -SN FG OVC001 00/00 A3019 RMK AO2 SLP238 P0002 T00000000 400061011 TSNO
KBLU 250652Z AUTO 18012KT 1/4SM SN FG VV001 00/M01 A3017 RMK AO2 SLP230 P0002 T00001006 TSNO
KBLU 250552Z AUTO 19013KT 1/4SM -SN FG VV001 00/00 A3013 RMK AO2 FZRAE0457SNB0457 SLP216 P0002 60045 T00000000 10006 20000 51029 TSNO
KBLU 250516Z AUTO 18012G17KT 1/4SM -SN FG OVC001 01/00 A3011 RMK AO2 FZRAE0457SNB0457 P0002 TSNO
KBLU 250503Z AUTO 19010KT 1/2SM -SN FG OVC001 01/00 A3011 RMK AO2 FZRAE0457SNB0457 P0001 TSNO
KBLU 250452Z AUTO 20011G17KT 1/2SM -FZRA FG OVC001 01/M01 A3011 RMK AO2 RAE27FZRAB27 SLP208 P0005 T00061006 TSNO
KBLU 250443Z AUTO 21009G16KT 3/4SM -FZRA BR OVC001 01/00 A3010 RMK AO2 RAE27FZRAB27 P0004 TSNO
KBLU 250432Z AUTO 20012G21KT 1 1/4SM FZRA BR OVC001 01/M01 A3009 RMK AO2 RAE27FZRAB27 P0003 TSNO
KBLU 250427Z AUTO 21009G17KT 1/2SM -FZRA FG OVC001 01/M01 A3009 RMK AO2 RAE27FZRAB27 P0003 TSNO
KBLU 250352Z AUTO 20007G18KT 1/4SM -RA FG VV001 01/00 A3006 RMK AO2 UPB04E43RAB30SNE04 SLP192 P0003 T00060000 TSNO
KBLU 250326Z AUTO 19010G19KT 1/4SM UP FG OVC001 01/00 A3004 RMK AO2 UPB04SNE04 P0002 TSNO
KBLU 250317Z AUTO 20012G19KT 1/2SM UP FG OVC001 01/00 A3003 RMK AO2 UPB04SNE04 P0002 TSNO
KBLU 250309Z AUTO 20014G21KT 1/4SM UP FG OVC001 01/00 A3003 RMK AO2 UPB04SNE04 P0002 TSNO
KBLU 250252Z AUTO 21011G18KT 1/2SM -SN FG OVC001 01/M01 A3003 RMK AO2 SLP181 P0009 60035 T00061006 53034 TSNO
KBLU 250152Z AUTO 20015G23KT 1/4SM -SN FG OVC001 01/M01 A2999 RMK AO2 SLP165 P0012 T00061006 TSNO

KBLU 250052Z AUTO 20012G23KT 1/4SM -SN FG OVC001 01/00 A2994 RMK AO2 SLP151 P0014 T00060000 TSNO
KBLU 242352Z AUTO 20012G21KT 1/4SM +SN FG OVC001 01/M01 A2991 RMK AO2 SLP136 P0012 60048 T00061006 10006 21006 51022 TSNO
KBLU 242252Z AUTO 18016G23KT 1/4SM SN FG OVC001 01/M01 A2988 RMK AO2 SLP130 P0012 T00061006 TSNO
KBLU 242152Z AUTO 19011G19KT 1/4SM +SN FG OVC001 00/M01 A2987 RMK AO2 PK WND 17027/2100 SLP125 P0011 T00001006 TSNO
KBLU 242052Z AUTO 17016G24KT 1/4SM SN FG OVC001 00/M01 A2983 RMK AO2 PK WND 16031/2033 SLP112 P0005 60013 T00001006 50012 TSNO
KBLU 241952Z AUTO 17018G26KT 1/4SM SN FZFG OVC001 M01/M01 A2984 RMK AO2 PK WND 16034/1907 SLP115 P0003 T10061011 TSNO
KBLU 241852Z AUTO 18017G27KT 1/4SM SN FZFG OVC001 M01/M01 A2981 RMK AO2 PK WND 18033/1840 SLP103 P0005 T10061011 TSNO
KBLU 241752Z AUTO 16013G24KT 1/4SM +SN FZFG OVC001 M01/M01 A2979 RMK AO2 PK WND 16031/1716 SLP097 P0004 60016 T10061011 10000 21011 51007 TSNO
KBLU 241652Z AUTO 17021G30KT 1/4SM SN FZFG OVC001 M01/M01 A2979 RMK AO2 PK WND 16033/1620 SLP096 P0003 T10061011 TSNO
KBLU 241608Z AUTO 16017G27KT 1/4SM SN FZFG OVC001 M01/M02 A2978 RMK AO2 PK WND 18027/1604 P0000 TSNO
KBLU 241552Z AUTO 16014G29KT 1/2SM -SN FZFG OVC001 M01/M02 A2978 RMK AO2 PK WND 17029/1550 SLP092 P0004 T10061017 TSNO
KBLU 241506Z AUTO 16016G23KT 1/4SM +SN FZFG OVC001 M01/M02 A2977 RMK AO2 P0001 TSNO
KBLU 241452Z AUTO 17015G23KT 1/2SM SN FZFG OVC001 M01/M02 A2977 RMK AO2 PK WND 15031/1440 SLP089 P0001 60005 T10061017 50000 TSNO
KBLU 241419Z AUTO 17018G26KT 3/4SM -SN BR OVC001 M01/M02 A2977 RMK AO2 PK WND 15027/1405 P0000 TSNO
KBLU 241412Z AUTO 17017G27KT 1SM -SN BR OVC001 M01/M02 A2977 RMK AO2 PK WND 15027/1405 P0000 TSNO
KBLU 241404Z AUTO 16014G27KT 1 1/2SM -SN BR OVC001 M01/M02 A2977 RMK AO2 PK WND 18027/1401 P0000 TSNO
KBLU 241352Z AUTO 17017G26KT 1 1/4SM -SN BR OVC001 M01/M02 A2977 RMK AO2 PK WND 18031/1342 SLP094 P0001 T10061017 TSNO
KBLU 241342Z AUTO 17025G31KT 1SM -SN BR OVC001 M01/M02 A2977 RMK AO2 PK WND 18031/1342 P0001 TSNO
KBLU 241301Z AUTO 17017G26KT 1/2SM SN FZFG OVC001 M01/M02 A2977 RMK AO2 PK WND 17026/1301 P0000 TSNO
KBLU 241252Z AUTO 16015G24KT 1/4SM SN FZFG VV001 M01/M02 A2977 RMK AO2 PK WND 17028/1241 SLP092 P0003 T10061017 TSNO
KBLU 241234Z AUTO 17016G23KT 1/4SM SN FZFG OVC001 M01/M01 A2977 RMK AO2 P0002 TSNO
KBLU 241218Z AUTO 20010G21KT 1/2SM -SN FZFG OVC001 M01/M01 A2976 RMK AO2 P0000 TSNO
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18029/1110 SNE11 P0001 TSNO
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KBLU 240509Z AUTO 19017G31KT 1/4SM SN FG OVC002 00/M01 A2971 RMK AO2 PK WND 19031/0506 P0001 TSNO
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