Nocturnal Thunderstorm Redevelopment Under Synoptic Scale Destabilization in the Northern Sacramento Valley

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INTRODUCTION

Successful forecasts of thunderstorm development in areas with little or no currently observed deep convection presents a challenge. If the period of time under consideration also happens to be overnight, in which stabilization of the boundary layer tends to be at a maximum, the probability for deep moist convection is considered to be relatively low as a rule. Research has shown however, that certain other parameters can serve to overcome what seems to be limiting factors. The combined effects of enhanced low-level moisture convergence and layer destabilization due to upslope flow over mountainous terrain has shown to be responsible for thunderstorm development in an otherwise non-favorable conditions (Tardy 2002, Colman 1990). In the Northern Sacramento Valley, a surface moisture convergence zone has been identified and linked to severe as well as non-severe thunderstorm development in the cool season (Tardy 2002 Staudenmaier 1995). In some cases however, deep moist convection leading to thunderstorms can result from layer destabilization in very moist mid level environments undergoing lift due to upper level divergence forced by a synoptic scale feature (Tardy 2001 and 2002). This type of deep moist convection is often categorized as 'elevated' as it is not linked to any boundary layer or terrain feature. This case of elevated thunderstorms, while not major, had the potential to produce hazards with greater impacts, such as wildfires, due to the fact that they were not anticipated.

CASE SYNOPSIS

On the afternoon of July 21, 2002, significant mid to upper level moisture and upslope flow over Northern California had led to moderate thunderstorm development over the extreme Northern Sierra, the Lassen NF, and the Shasta-Siskyou mountains of the Southern Cascades.

(Fig 1). Another limiting factor among those that are taken into consideration when forecasting thunderstorm development in the Central Valley is the time of year. During the period of June through October, the boundary layer is generally very dry over the Central Valley, and the resulting Convective Inhibition (CIN) is next to impossible to overcome. As Fig 1 shows, July 21 was no exception, with sunny skies over the entire valley. While the low levels were thoroughly mixed, the depth was not great enough for parcels to reach the LFC as is the case with the dry, 'inverted-V' sounding environments associated with microburst thunderstorms over the Rockies and High Plains.

By 0230UTC 22 July, not only was the Central Valley void of thunderstorms, but the mountains in the northern portion of NWS Sacramento's forecast area that had seen thunderstorms just a few hours ago were as well. The strongest and most numerous storms were now near Mt Shasta with a trailing line extending slightly into Shasta County, with another area on the west slopes of the Trinity Alps (Fig 2). This would be about the time a new forecast team on duty would be looking at the current weather and observations and determining if any short term forecast updates are needed. At 0200UTC, GOES water vapor imagery showed plentiful moisture at mid and upper levels north of about Lake Tahoe, and the GFS model initialization at 0000UTC described two maxima of upward vertical motion rotating around a weak closed low centered off the Central CA coast (Fig 3). The northernmost wave near the Oregon border was associated with the mountain thunderstorms seen in Fig2, with another east of Lake Tahoe following on its heels. The second maxima can be seen to be acting on the observed plentiful mid level moisture - with rapid cooling and cloud development observed in the Pyramid Lake area north of Reno NV. This wave was forecast by both the GFS and Eta to continue propagation around the low center, moving into the northeastern zones of the NWS Sacramento forecast area by 06Z. A GFS cross section running north-south from the Mt Shasta area down to south of Sacramento shows these two areas of upward omega, with the weakening, terrain forced maximum in the extreme north and a much deeper layer of lift further to the south from about 700mb up to 350mb (Fig 4). This area, was also forecast to have significant horizontal extent, but would be limited in thunderstorm development due to much less available mid/upper moisture in this layer as one looks toward Sacramento, as well as a strong CIN-increasing area of subsidence below this, centered around 700 mb. Thus, by considering the observed absence of any thunderstorms earlier or currently at around 0200UTC and the increased stabilization of the boundary layer at night, one might have precluded any chance for thunderstorm development over the 0-500 foot elevations of the valley without consideration to synoptic scale layer destabilization forecast to occur during that evening.

A WSR-88D radar mosaic over Northern California at 0440UTC (Fig 5) shows thunderstorms redeveloping over the mountains of western Plumas County above Oroville, but also over the western Sacramento Valley west of Marysville. These were the first of what would become a significant number of nocturnal thunderstorms over the dry and stable valley. As the wave propagating around the upper low rotated northwest, thunderstorm development increased in the northern Sacramento valley, while the areas seeing activity to the south and east earlier began to clear (Fig 6). A time-height profile of winds from the KBBX (Beale AFB) WSR-88D shows this southeasterly steering flow above about 15,000 feet (Fig 7), with weak north to northeast flow in the subsidence layer below it.

A one-hour forecast RUC sounding (Fig 8) constructed for a grid point between Red Bluff and Chico at 0600UTC, the area of the Sacramento Valley and time which saw the most intense thunderstorms showed close to 1000J/kg derived from an area of positive buoyancy, above an LFC of 583mb or approximately 15,000 ft above the valley floor! Note the relatively dry low levels as depicted by the temperature and dewpoint sounding and reflected in the -101J/kg CIN (negative buoyancy). Considering this dry boundary layer, the moisture available in this environment was considerable, with a calculated 1.12 inches of total precipitable water in the column. GOES IR imagery at this time of peak thunderstorm activity shows cloud-top temperatures below -50 C (Fig 9). With an equilibrium level near -40 C (Fig 8), this represents a significant overshooting top due a strongly accelerating updraft. Strong updrafts produced strong charge separations in the cumulonimbus, with numerous cloud to ground lightning strikes associated with these storms detected by the NLDN, mostly between 0500-0700UTC.

CONCLUSION

When thunderstorms form over any area considered to be too stable (marine layer), or too dry (CA Central Valley) it is often unexpected and if so, likely unforecast. Also, in this case, the area that experienced the strongest storms had no prior activity, and areas adjacent to it that had seen convective activity saw rapid dissipation early in the evening coincident with radiative cooling. It is not too surprising then, that these nocturnal events over the Central Valley are a challenge to forecast. Another complicating factor in a nocturnal event is the lack of clues from cloud types at night. The destabilization/cooling in the mid and upper levels likely produced altocumulus with some castellanus, but these would be difficult to observe at night. So the forecaster must rely more on a combination of satellite trends and high resolution model forecasts of stability, moisture, and lift than might be considered for a daytime event where development is moderated more by the amount and location of boundary layer solar heating and moisture convergence.

REFERENCES

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Staudenmaier, M. Jr., 1995: The 10 February 1994 Oroville Tornado A Case Study. NOAA Technical Memorandum. NWS WR-229.

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Figure 1

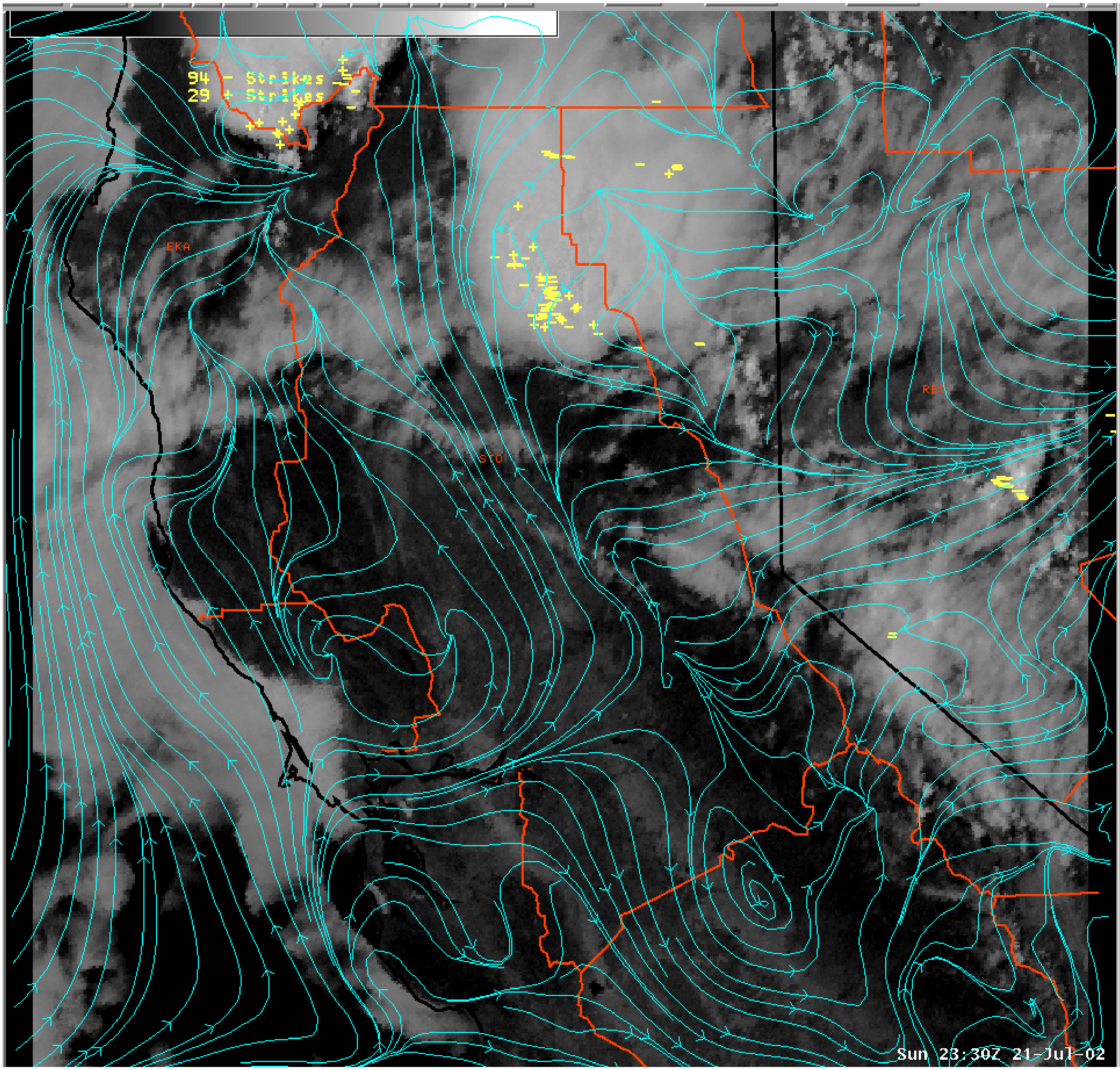

Figure 1 ~ 2030UTC 21 Jul visible image with 1 hour accum NLDN lightning and LAPS sfc streamline analysis

Figure 2

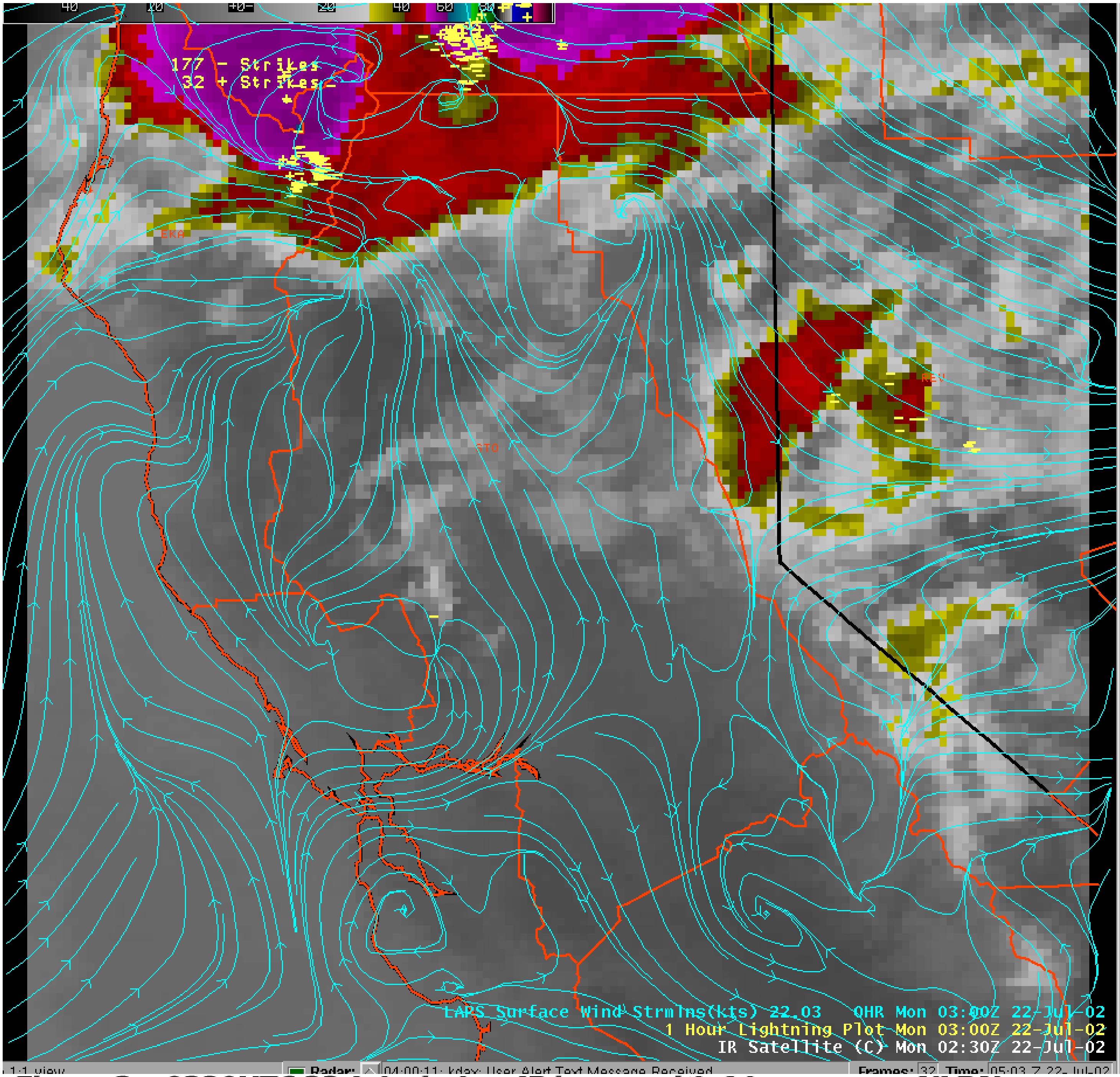

Figure 2 ~ 0230UTC 22 Jul window IR image with 1 hour accum NLDN lightning and LAPS sfc streamline analysis

Figure 3

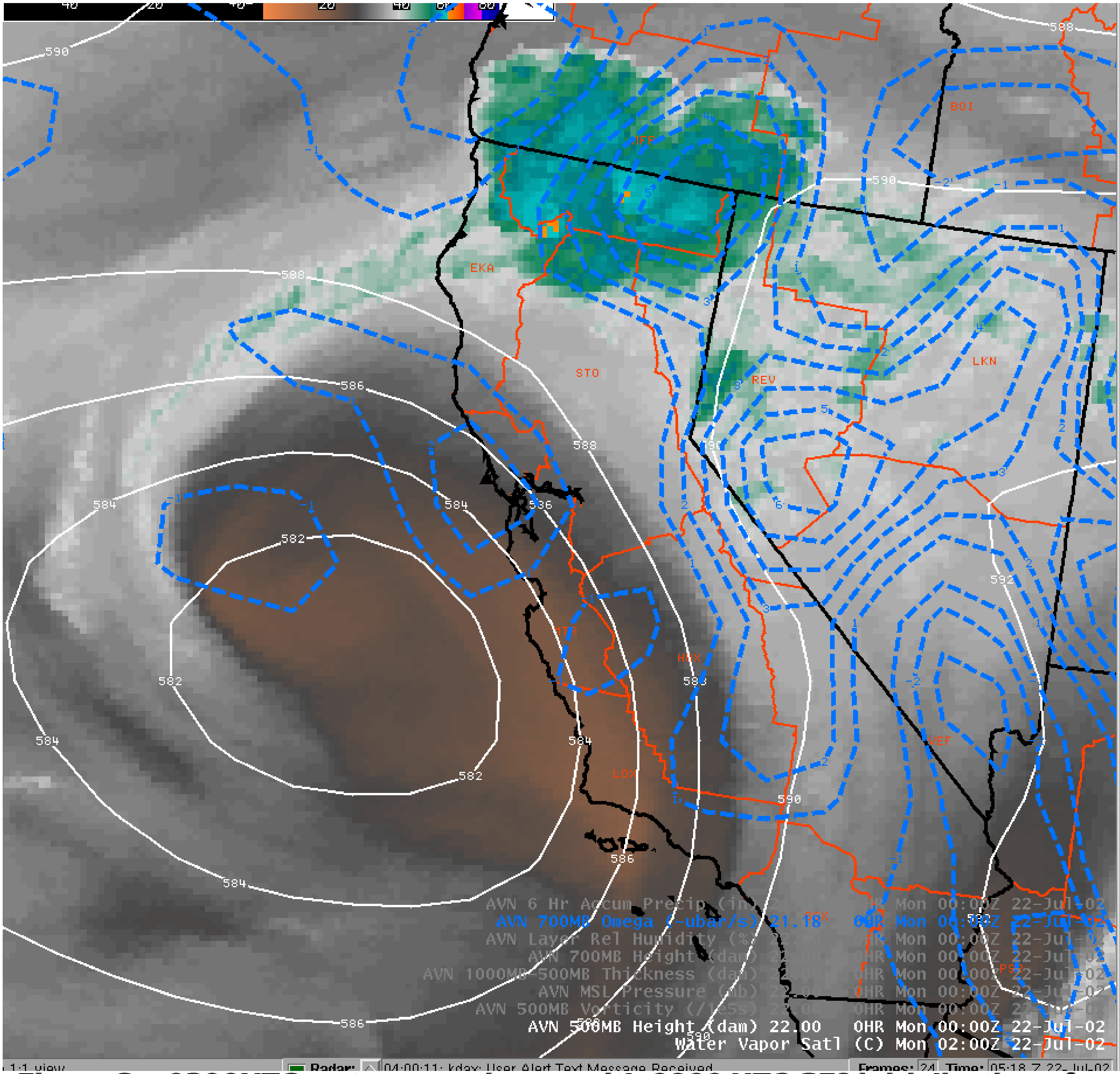

Figure 3 ~ 0200UTC water vapor image with 0000 UTC GFS initialization of 500mb heights(white), and 700mb omega(dashed blue). Note upward vertical motion is positive.

Figure 4

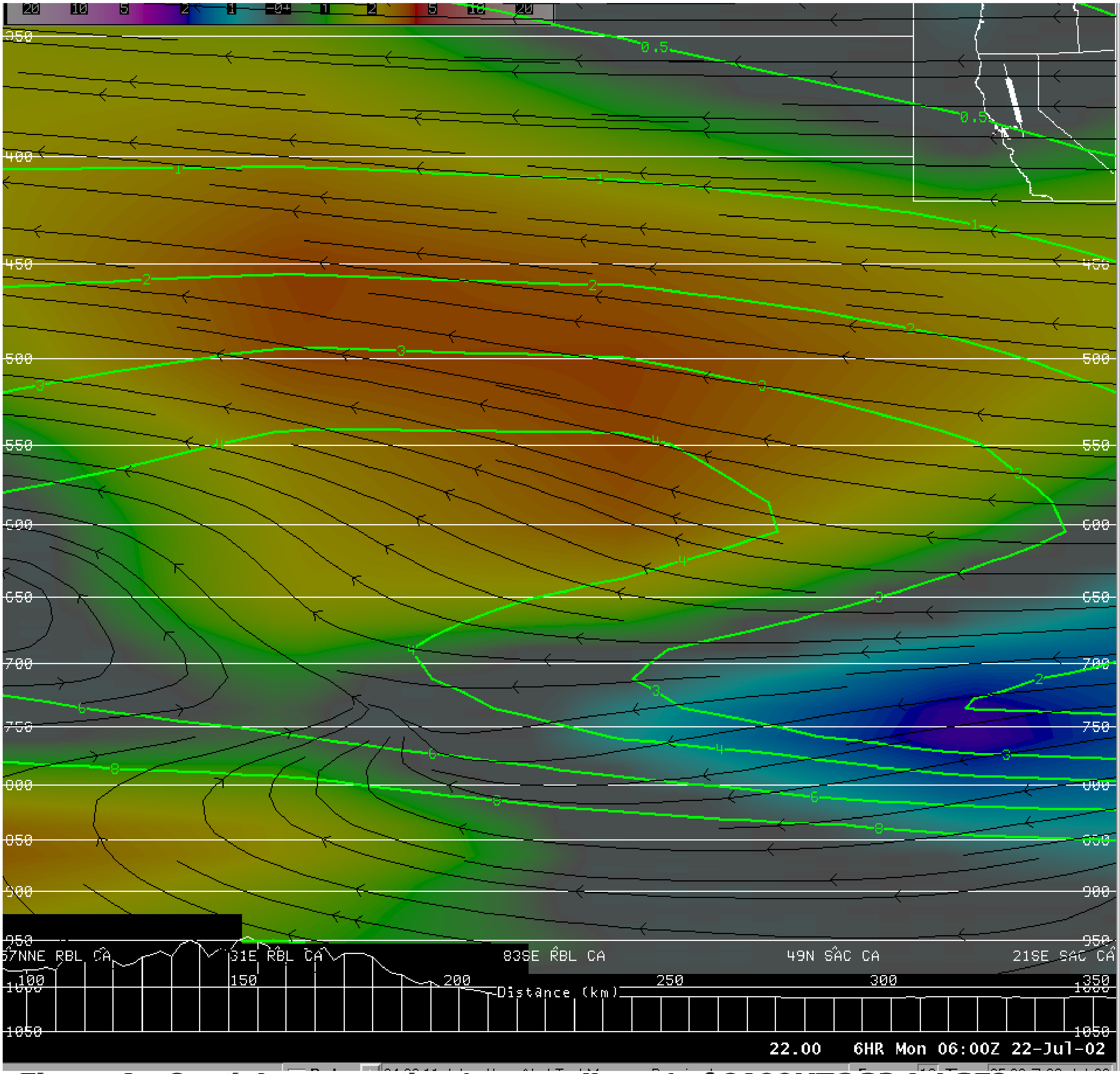

Figure 4 ~ Spatial cross section (see small map) of 0600UTC 22 Jul GFS forecast omega (image - warm/lifting, cool/subsidence), mixing ratio (green), and vertical circulation streamlines

Figure 5

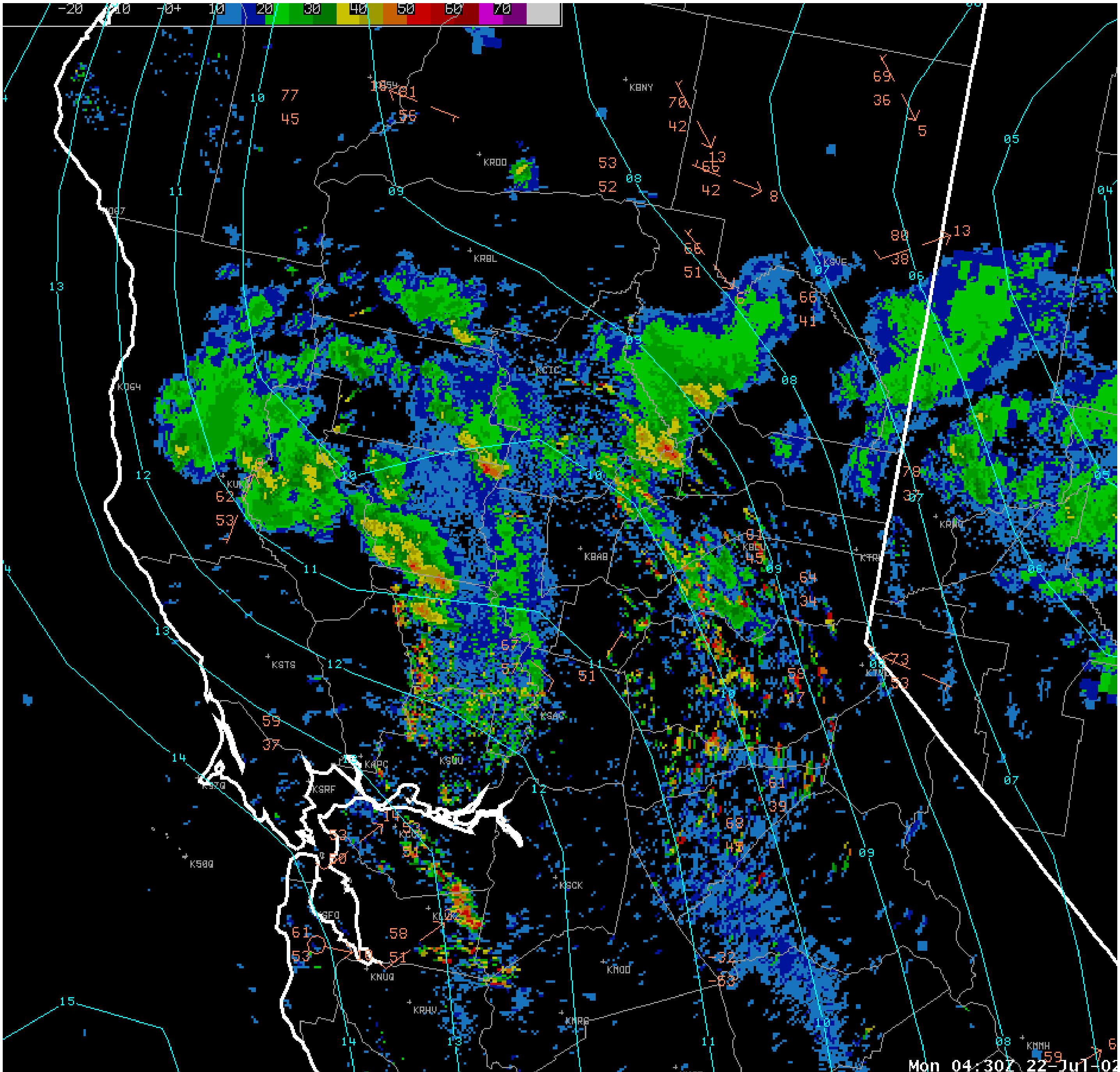

Figure 5 ~ 0430UTC 22 Jul WSR-88D composite reflectivity multi-radar mosaic with 0400UTC LAPS MSL pressure analysis (cyan)

Figure 6

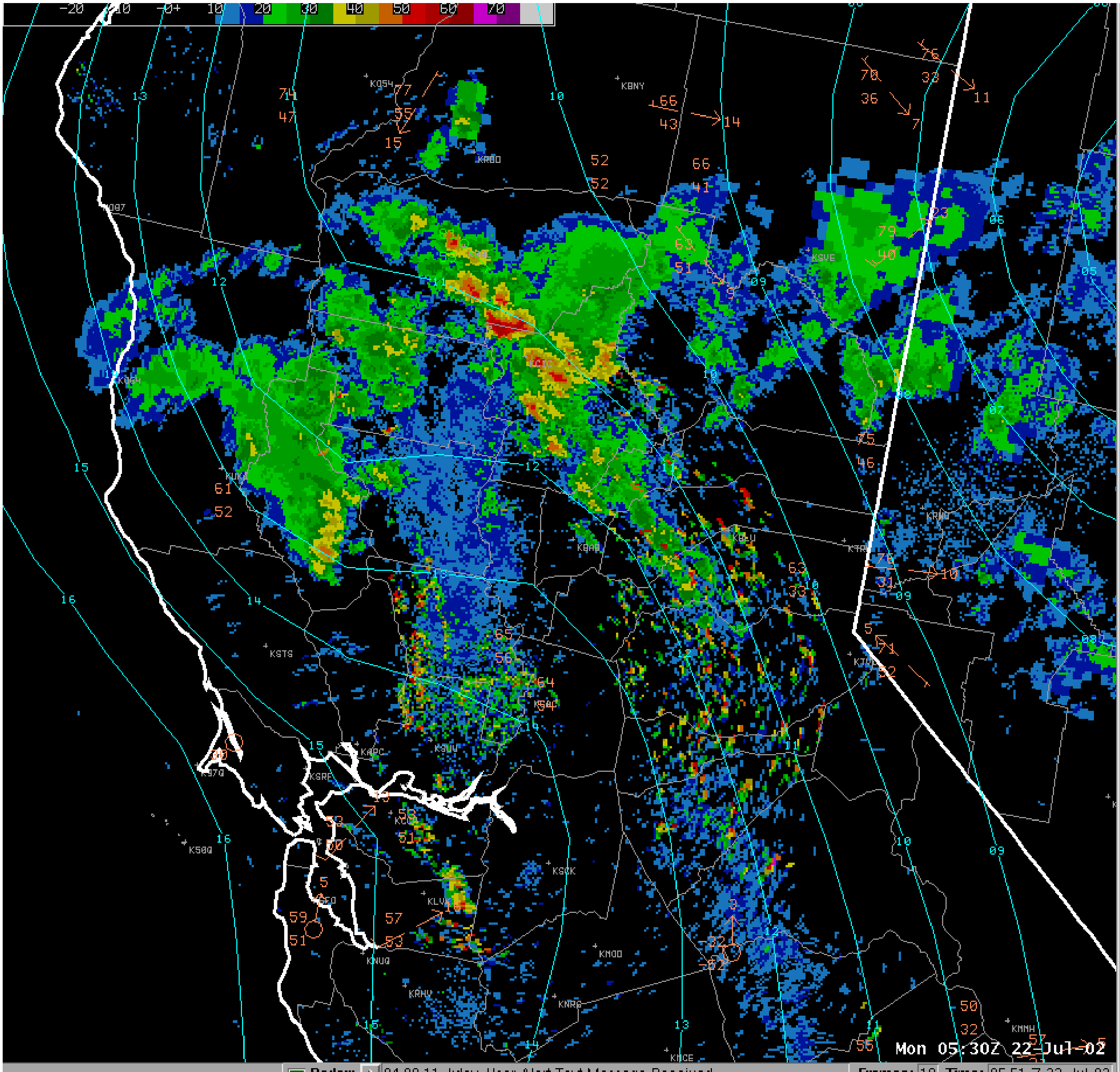

Figure 6 ~ 0530UTC 22 Jul WSR-88D composite reflectivity multi-radar mosaic with 0600UTC LAPS MSL pressure analysis

Figure 7

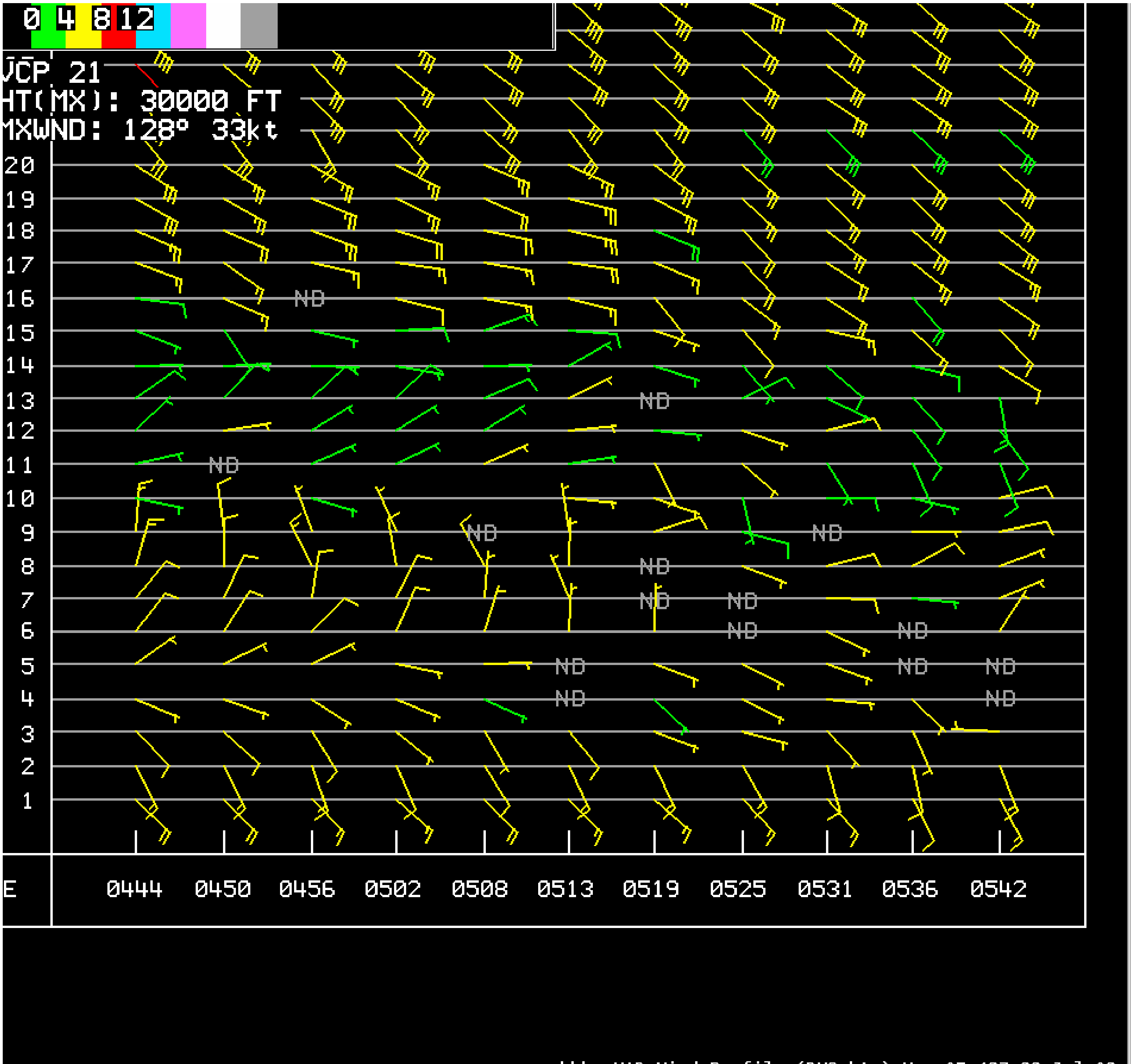

Figure 7 ~ 0542UTC KBBX (Beale AFB) WSR-88D VAD wind profile

Figure 8

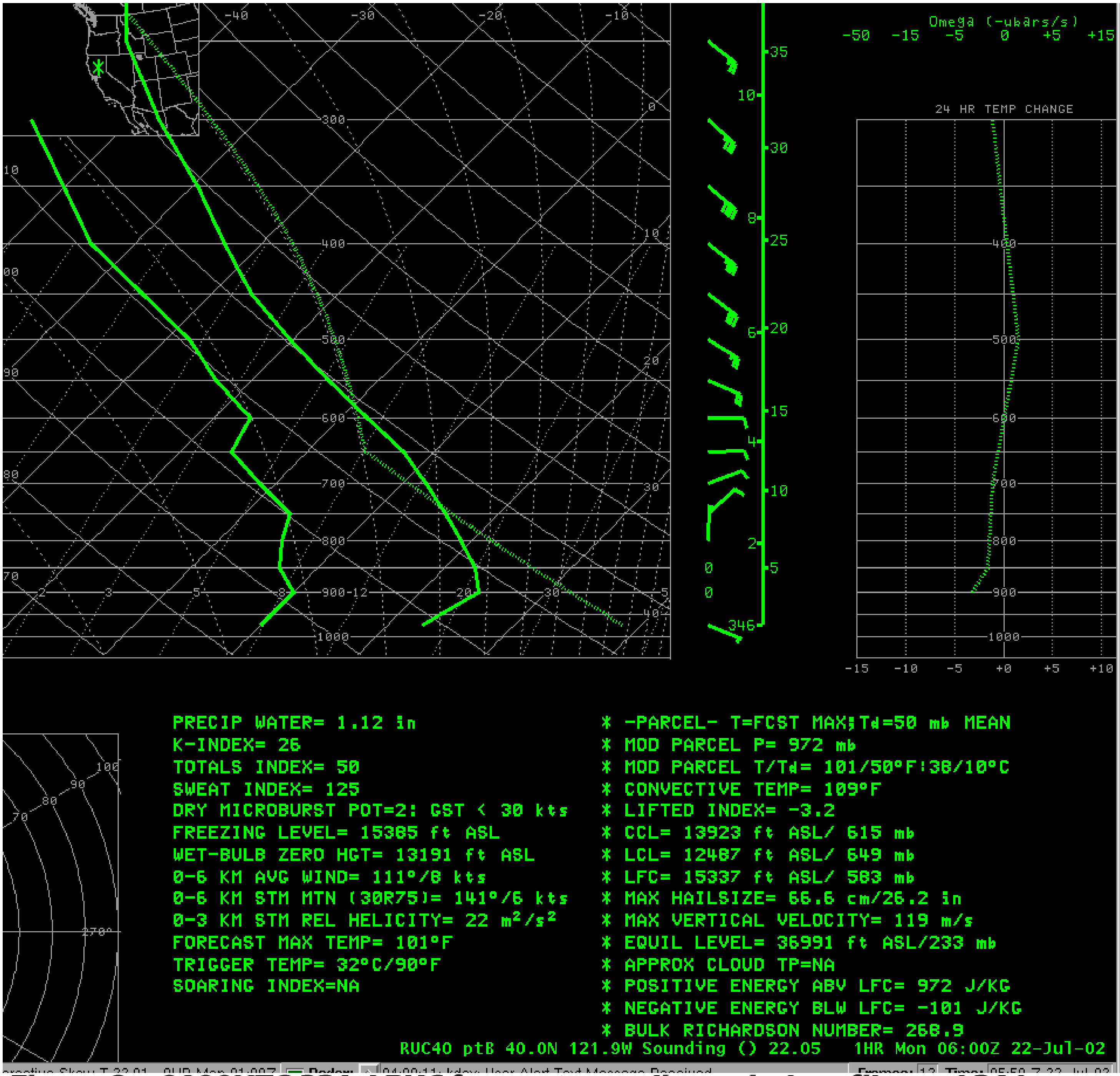

Figure 8 ~ 0600UTC 22Jul RUC forecast sounding, wind profile, and 24 hour change profile for grid point near Tehama/Butte county border

Figure 9

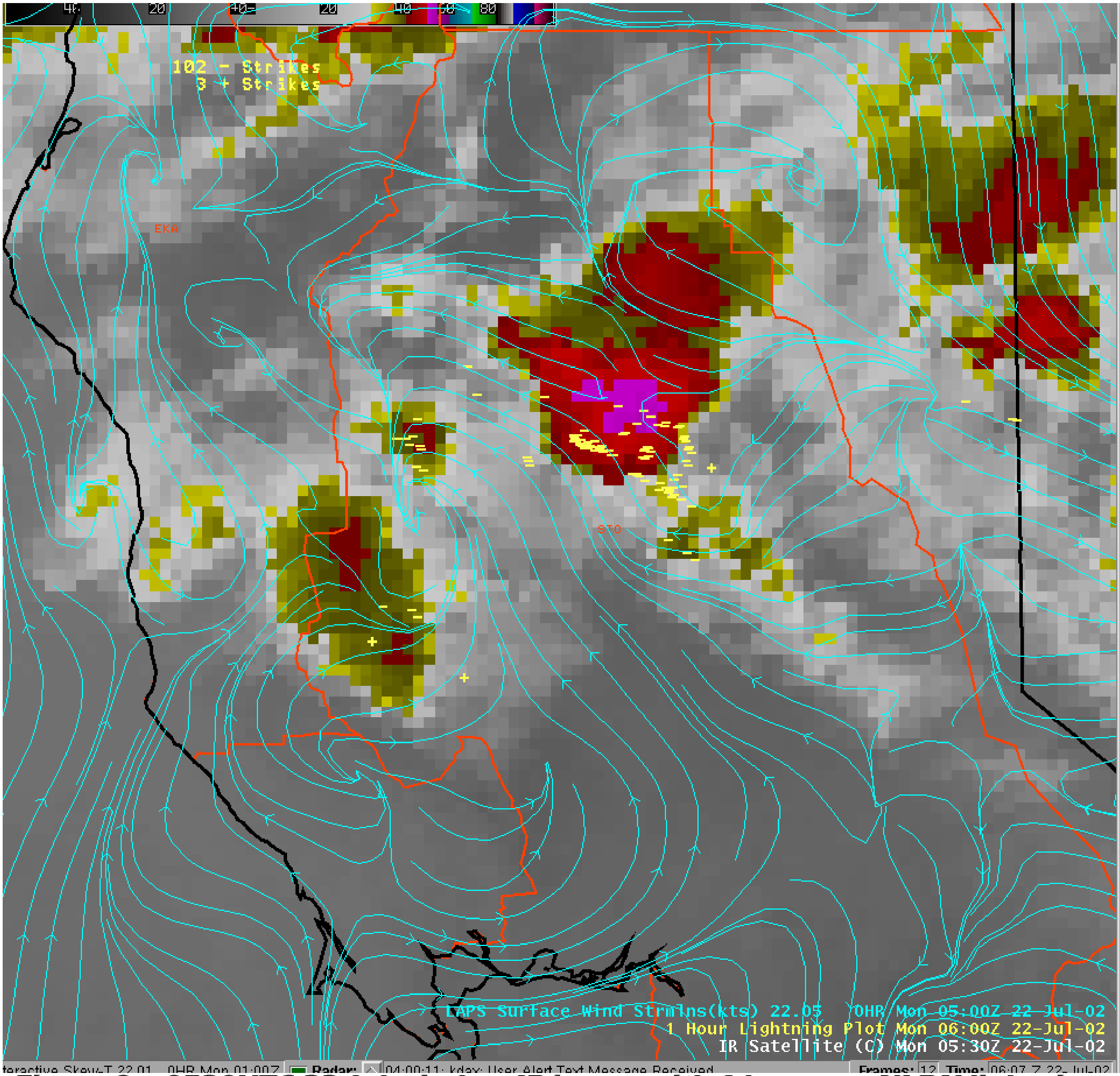

Figure 9 ~ 0530UTC 22 Jul window IR image with 1 hr accum NLDN lightning and 0500UTC LAPS surface streamline analysis