Lewis, J. M., S. Lakshmivarahan, J. Hu, R. Edwards, R. A. Maddox, R. L. Thompson, and S. F. Corfidi, 2016: Ensemble forecasting of return flow over the Gulf of Mexico. *Electronic J. Severe Storms Meteor.*, **11** (4), A1–A10.

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Ensemble Forecasting of Return Flow over the Gulf of Mexico Supplemental Material

APPENDIX A

A1. Cold/dry intrusion into Gulf of Mexico

This RFE began on 25 and 26 March 2015 with a strong flow of Canadian air southward across the Plains. The surface analysis shown in Fig. A1 is for 1500 UTC on 27 March, after the cold and dry air mass had penetrated well across the Gulf of Mexico (GoM), where surface dewpoints had decreased to the middle 40s F (≈7 °C). The Corpus Christi, TX (KCRP) sounding for 1200 UTC 27 March is presented in Fig. A2. Extremely dry and cool low-level air was present from the surface to 850 hPa and winds in this layer were northerly at about 20 kt (10 m s^{-1}).

The air mass was associated with a polar high that remained to the northeast of the GoM, but the southward intrusion of cold and dry air reinforced a high that had been stagnant over northern Mexico and southwest Texas. The latter high then moved eastward across the GoM. Figure A3 shows a blended precipitable water (PW) analysis for 2200 UTC 27 March 27. PW <25 mm indicated that the dry air had reached to the middle GoM.

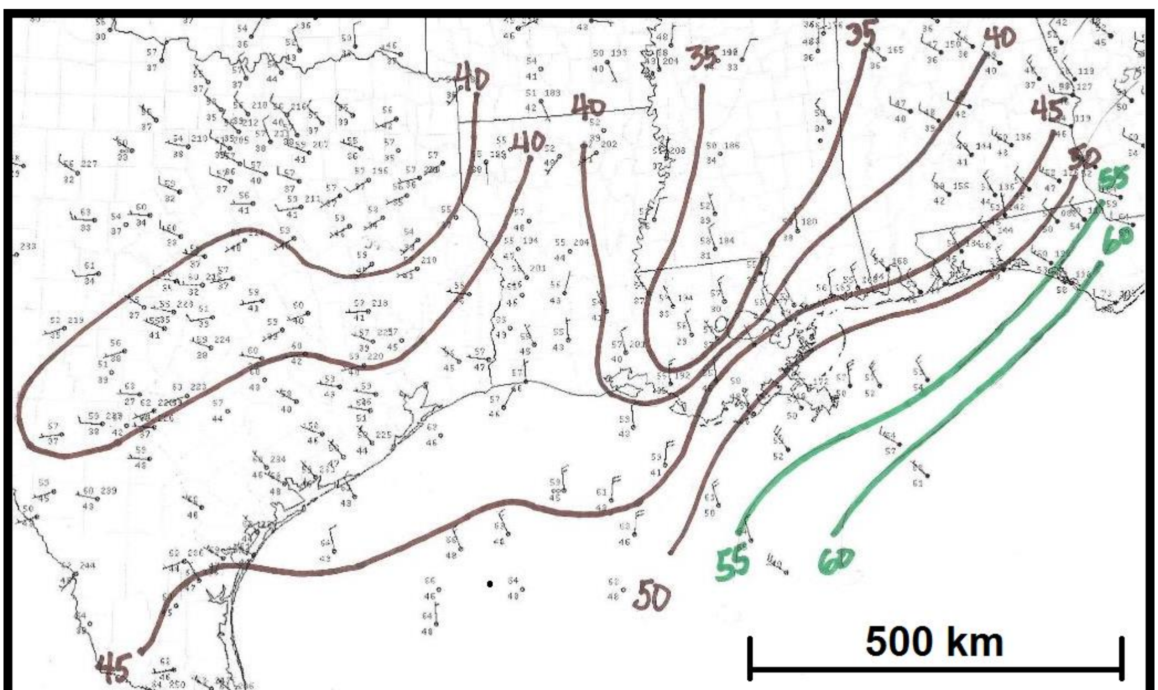

Figure A1: Subjective surface analysis for 1500 UTC 27 March 2015. Thermodynamic data in °F with isodrosotherms drawn every 5°F, and conventional wind plots with full barbs representing 10 kt (5 m s^{-1}).

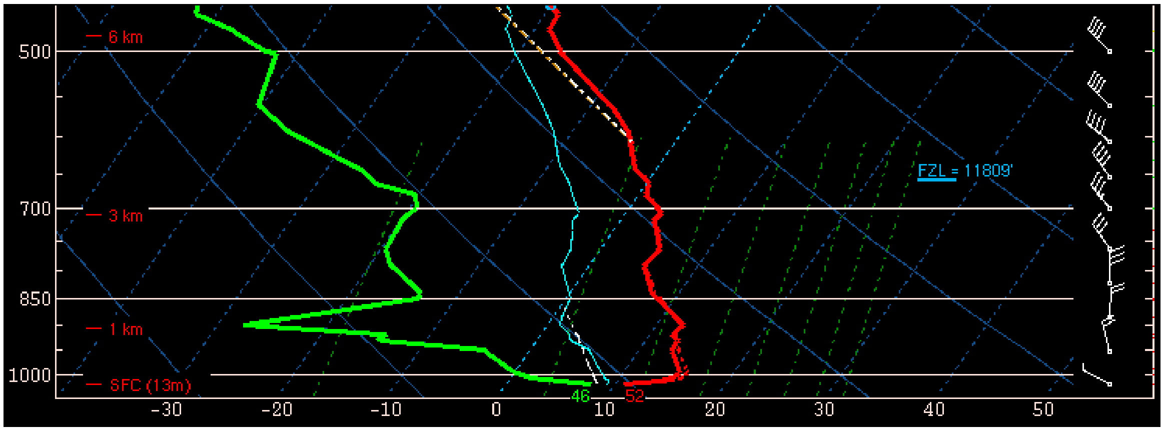

Figure A2: Portion of skew *T*–log*p* plot of sounding data from Corpus Christi (KCRP), TX, for 1200 UTC 27 March [image provided by Storm Prediction Center (SPC)].

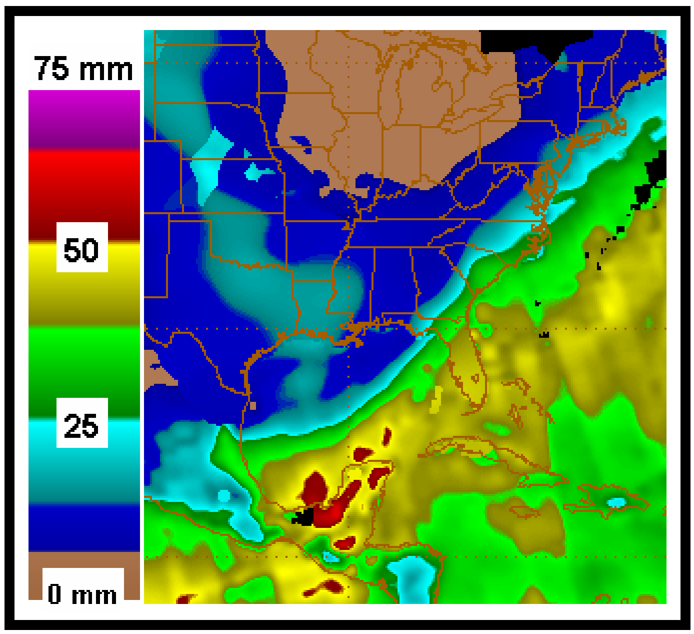

Figure A3: Blended PW analysis for 2200 UTC 27 March, as scaled. This is an experimental product available at http://cat.cira.colostate.edu/btpw2/ from the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University. The analysis blends data from several satellite sounders with estimates of PW derived from GPS measurements.

The 925-hPa analysis shown in Fig. A4 indicates the near-surface high pressure area centered over the western GoM, south of KLCH. This RFE evolved in a similar manner to the one in Figs. 2 and 3 in the main body of this paper. Trajectories from HYSPLIT (Draxler and Rolph 2003) (Fig. A5) illustrate the similarities of the two RFEs, with the 2015 case having longer fetches over the GoM. Figure A5a is an 84-h backward trajectory ending at Lake Charles, LA (KLCH), at 1200 UTC on March 31; while Fig. A5b is a 120-h backward trajectory ending at KLCH at 1200 UTC 1 April.

The blended PW analysis shown in Fig. A6 illustrates two important aspects of this event: 1) the cold front and dry air mass had penetrated south to the Yucatan Channel, and 2) low-level flow and air mass modifications over the waters of the GoM had already led to an area of increased PW located south of Louisiana.

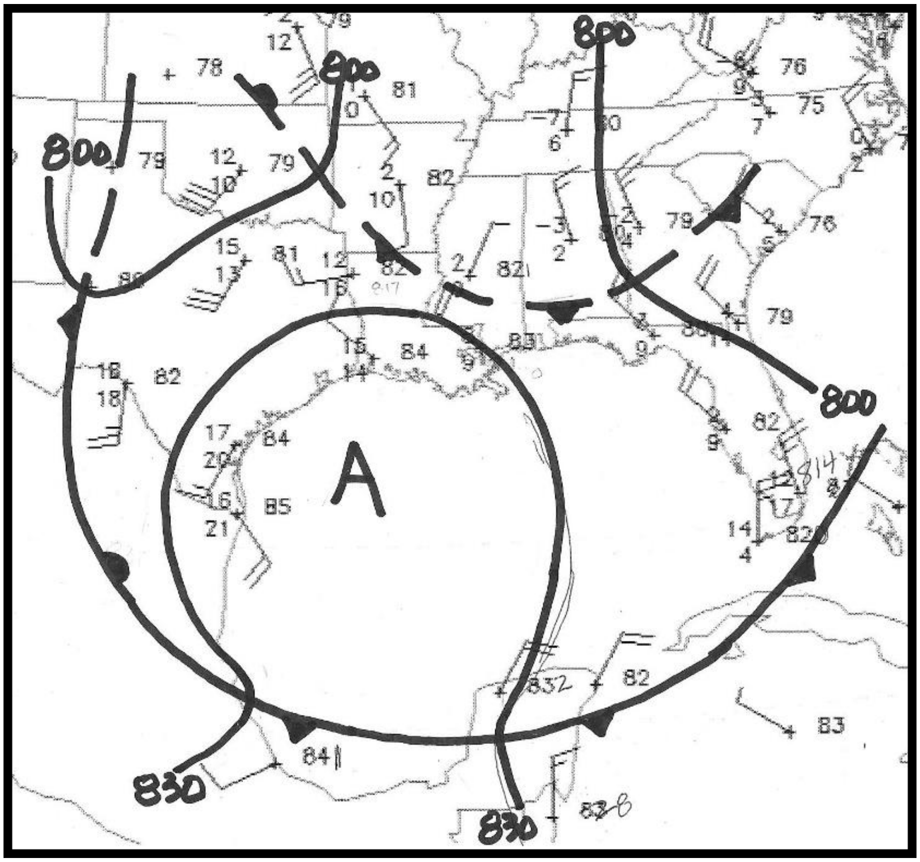

Figure A4: 925-hPa subjective analysis for 1200 UTC 28 March 28. Plotted in standard format are heights (m), temperature (°C), dewpoint spread (°C), and winds in kt (full barb is 10 kt or 5 m s^{-1}). Isohypses every 30 m. "A" denotes anticyclone center.

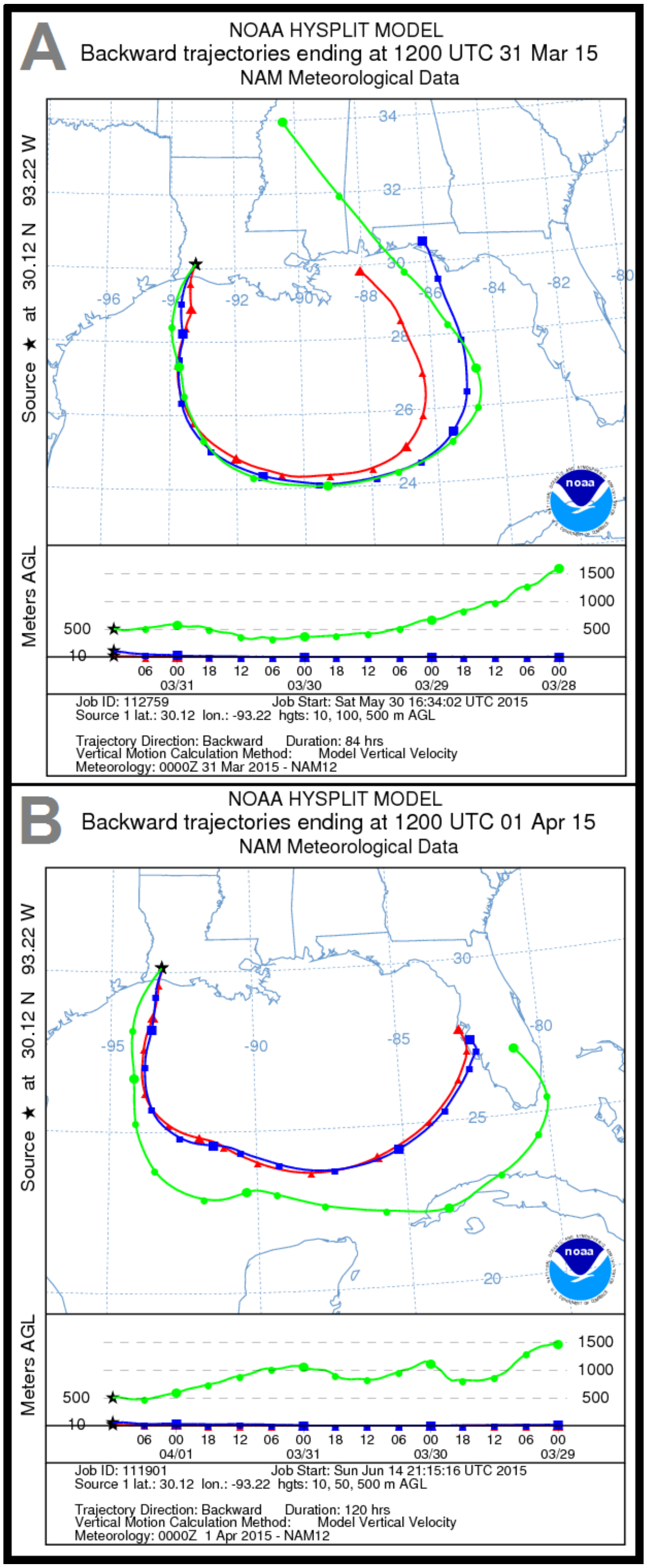

Figure A5: Trajectories generated using archived data from the NAM modeling system on the 12-km grid, with the NOAA ARL HYSPLIT system. Parcels end at 5 (red), 50 (blue), and 500 m (green) AGL at KLCH, for a) 1200 UTC 31 March and b) 1200 UTC 1 April.

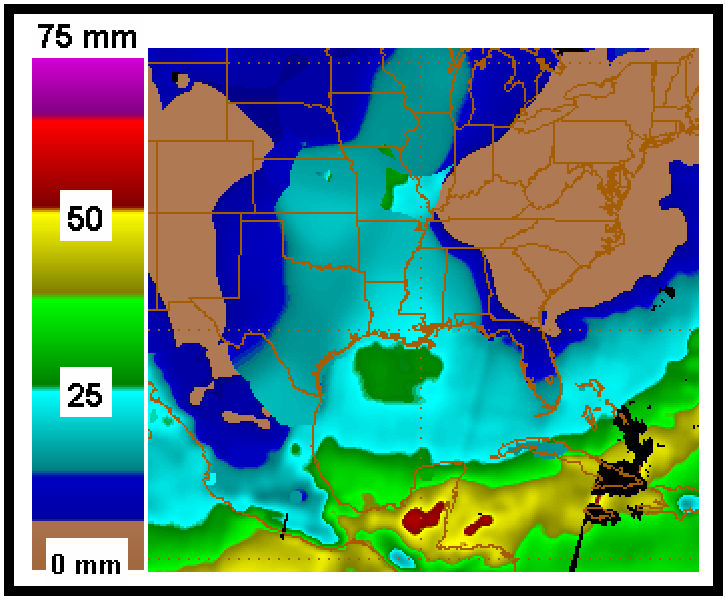

Figure A6: As in Fig. A3 but for 2100 UTC 29 March.

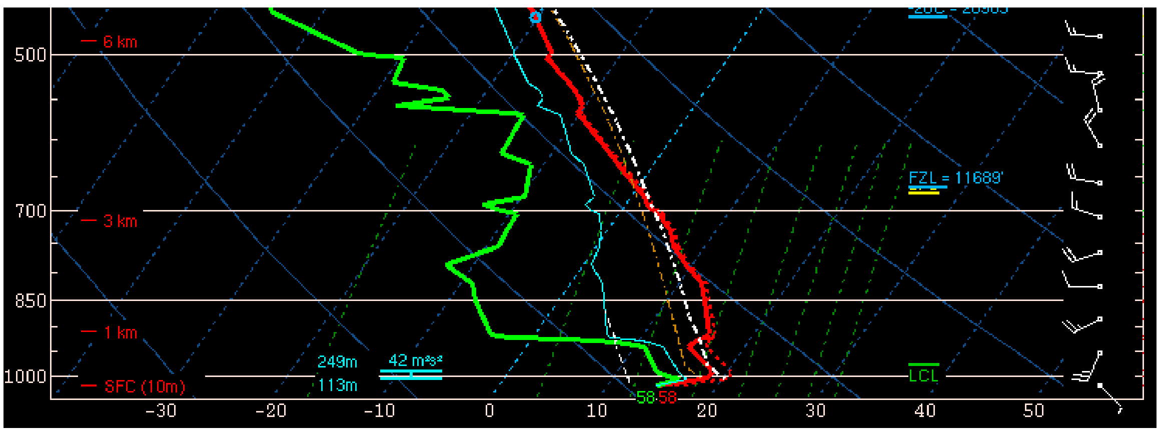

Figure A7: As in Fig. A2 but for KLCH, 1200 UTC 29 March.

A2. Forecast and observed soundings

The focus here is upon the lower- to middle-tropospheric soundings for KLCH; only 1200 UTC soundings are examined to minimize diurnal-heating effects. The sounding shown in Fig. A7 was observed at KLCH at 1200 UTC 29 March—note the cold contact layer (a result of the return flow moving over the cold shelf waters of the GoM).

Model-forecast soundings at KLCH considered here are from operational National Weather Service models: the spectral Global Forecast System (GFS, see http://www.emc.ncep.noaa.gov/index.php?branch=GFS) and the North American Mesoscale Forecast System (NAM on the 12-km grid, see http://www.emc.ncep.noaa.gov/index.php?branch=NAM). Forecast soundings also were obtained from SPC archives. Those presented in Fig. A8 are both 24-h forecasts for KLCH, valid at 1200 UTC 29 March, and are from the GFS (a) and the NAM (b). The GFS forecast appears quite good with respect to the cool contact layer, but is too dry in the layer above. The NAM forecast has a contact layer that is definitely too cool; however, the structure of the modified layer above is quite similar to that observed, but is not deep enough.

The KLCH observed sounding for 12 UTC 30 March is shown in Fig. A9. Note the cold contact layer is now overlain by a layer with nearly well-mixed temperature with significantly increased relative humidity. Modifications over the GoM have apparently extended to ≈900 hPa by this time.

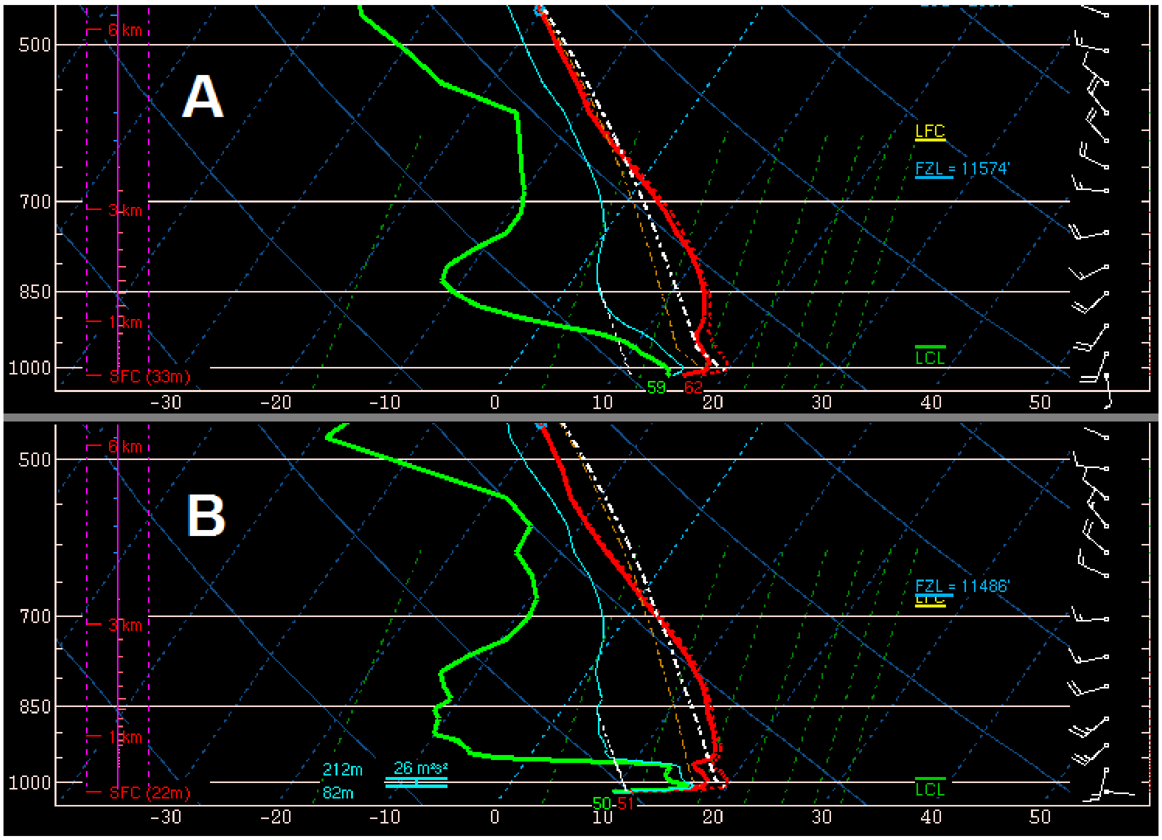

Figure A8: Skew *T*–log*p* representations of model forecast soundings at 24 h for KLCH valid at 1200 UTC 29 March from a) GFS and b) NAM.

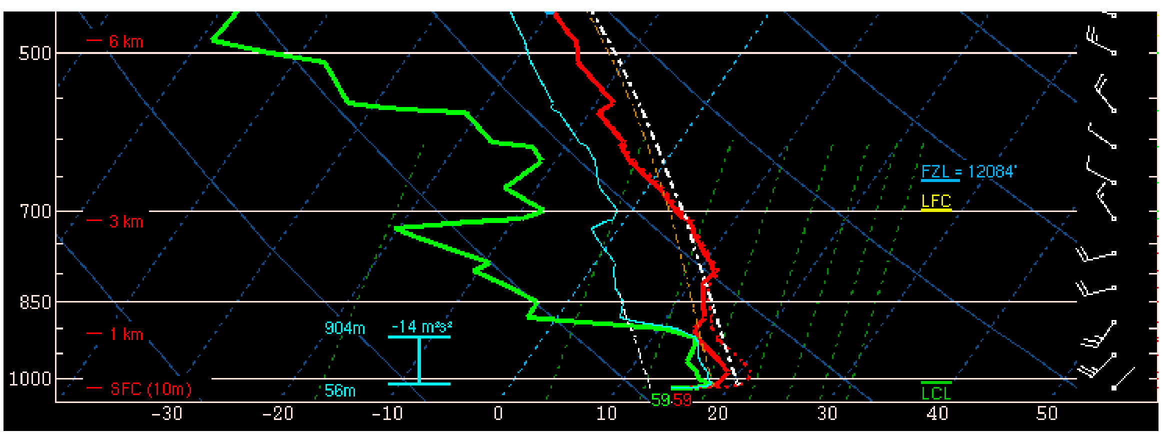

Figure A9: As in Fig. A7 but for 1200 UTC 30 March.

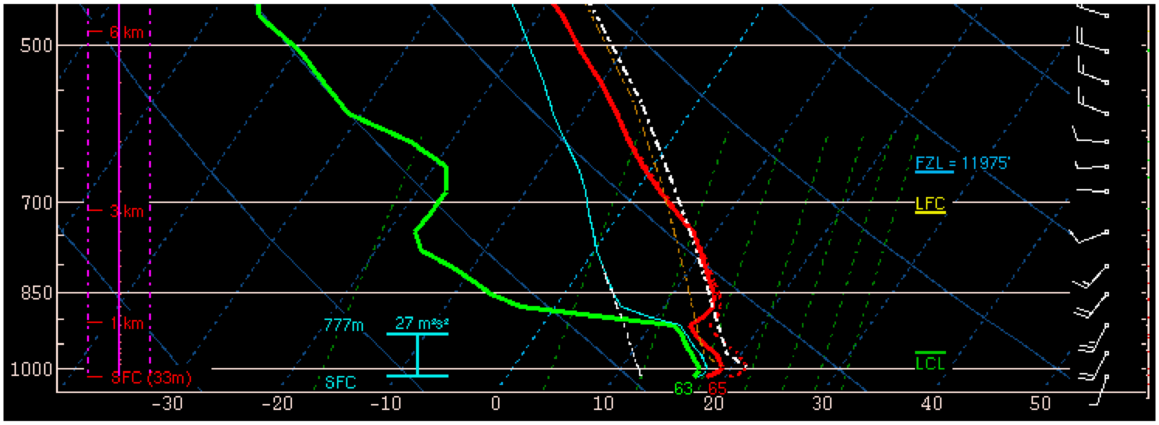

Figure A10: As in Fig. A8 but for GFS 72-h forecast valid 1200 UTC 30 March.

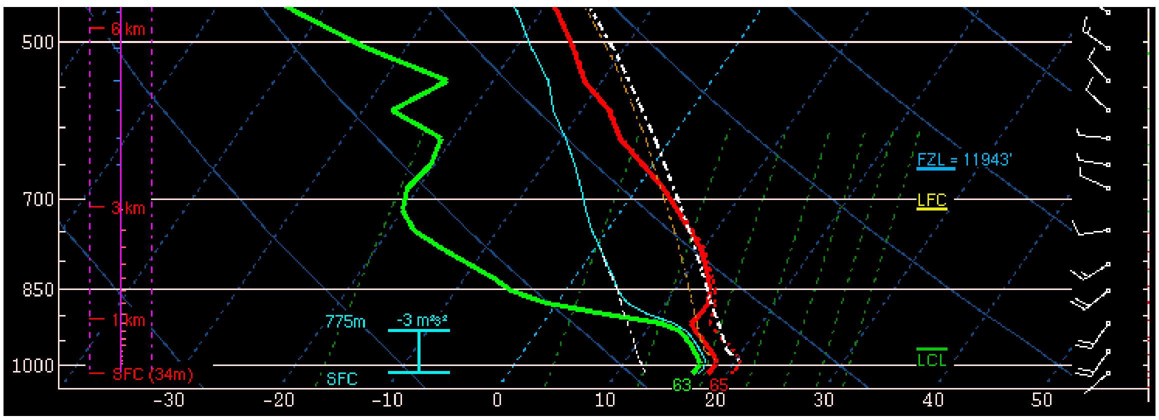

Figure A11: As in Fig. A8 but for GFS 48-h forecast valid at 1200 UTC 30 March.

The forecast soundings in Figs. A10 and A11 are from the GFS—72- and 48-h forecast respectively, both valid at the time of the observed sounding in Fig. A9. These forecasts appear to be reasonably accurate. The strength of the cold, contact layers appear to be too weak, and the lapse rate in temperature forecast above the contact layer at 48 h is a bit too weak.

Two forecasts for KLCH (Figs. A12 and A13) are from the NAM, valid at 12 UTC 30 March; Fig. A12 is the 48-h forecast and Fig. A13, the same valid time for forecasts from the GFS (Figs. A10 and A11) is for 24 h. Problems with the NAM include a contact layer that is also not cold enough, and the layer modified during transit over the GoM is too shallow. The thermal lapse rate above the contact layer is nearly well-mixed, similar to the observed sounding.

The KLCH observed sounding for 12 UTC March 31 (Fig. A14) reveals low-level features similar to the previous morning's sounding, with the cold contact layer overlain by a layer that appears less well-mixed in temperature, but that is now saturated. The 72-h GFS forecast sounding valid at this time is shown in Fig. A15. This forecast clearly has not captured the airmass modification processes well, especially the degree of saturation above the contact layer (reasons are unknown).

The KLCH observed sounding for 12 UTC 1 April is shown in Fig. A16. Features at low levels are similar to the previous morning's sounding, with the cold contact layer that is overlain by a layer that appears less well-mixed in temperature, and that is slightly less than saturated. Modifications over the GoM now extend upward to nearly 850 hPa.

The two forecast soundings in Fig. A17 and A18 are valid at 12 UTC 1 April. Figure A17 is from the GFS at 96 h, a long-range forecast that is capturing the general aspects of the over-GoM air mass modifications but that has obvious problems. Figure A18 is from the NAM at only 24 h, and is pathologically bad (same was true for the NAM forecast for this time for Slidell, LA—KLIX). The forecast sounding is so dry that the model forecast of the low-level flow appears to have a fetch that originated over land in Texas; however the observation was very different. This example shows that the long-term forecasts were capturing airmass modifications over the GoM fairly well, but that at only 24 h out, something went quite awry within the NAM forecast.

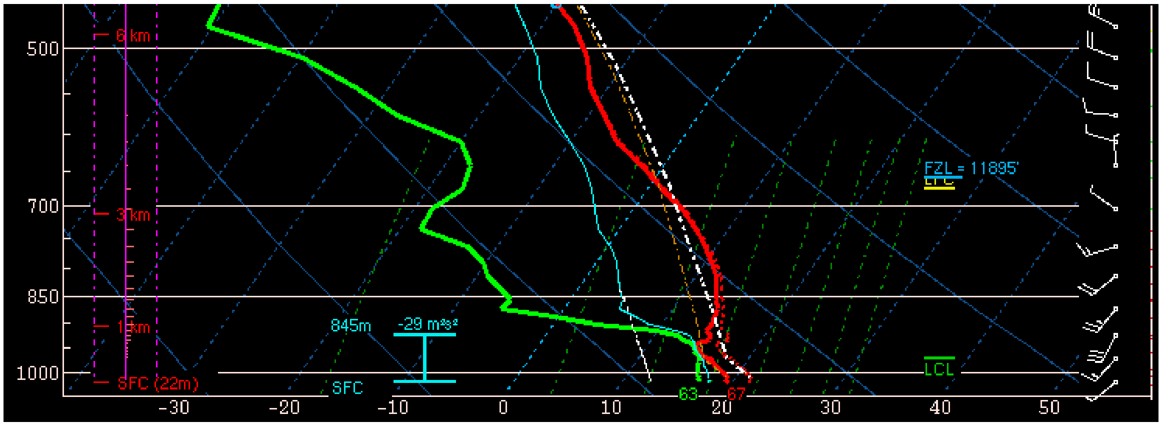

Figure A12: As in Fig. A8 but for NAM 48-h forecast valid 1200 UTC 30 March.

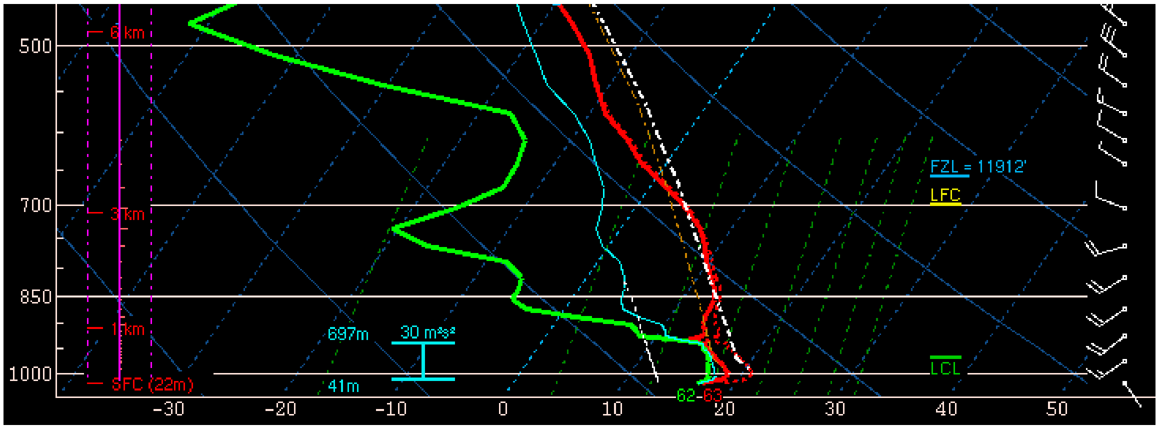

Figure A13: As in Fig. A8 but for NAM 24-h forecast valid 1200 UTC 30 March.

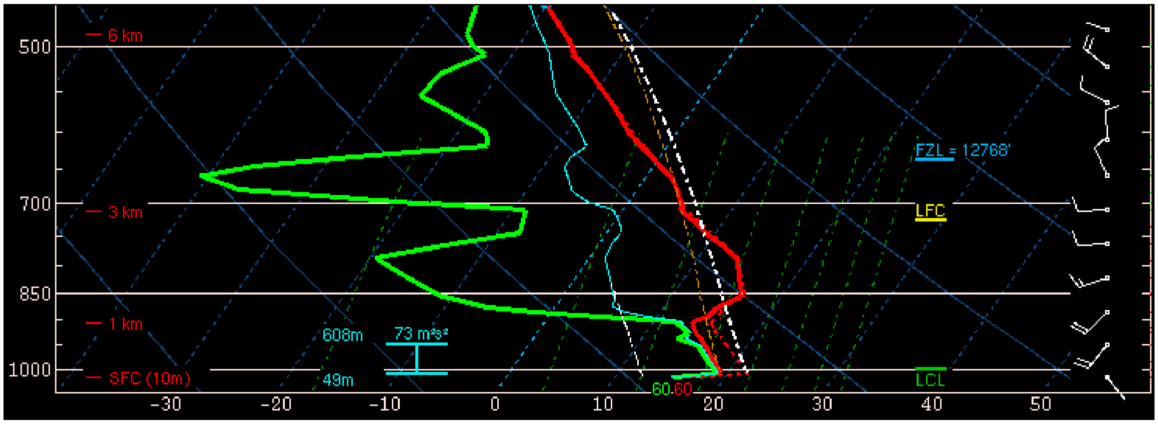

Figure A14: As in Fig. A7 but for 1200 UTC 31 March.

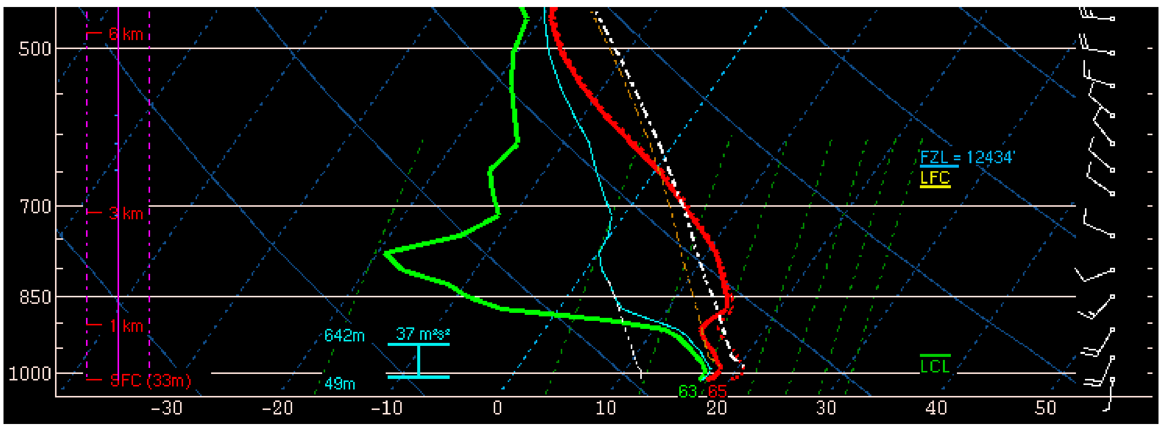

Figure A15: As in Fig. A8 but for GFS 72-h forecast valid 1200 UTC 31 March.

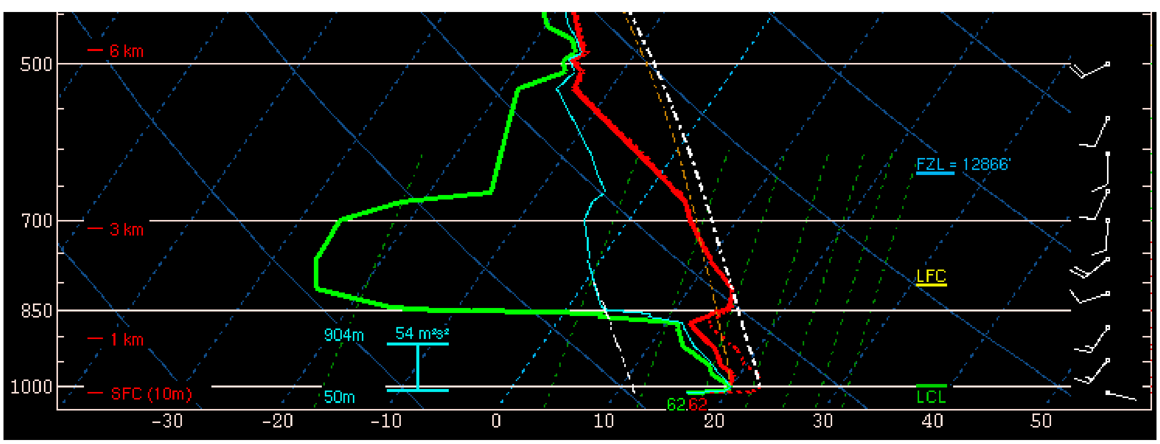

Figure A16: As in Fig. A7 but for 1200 UTC 1 April.

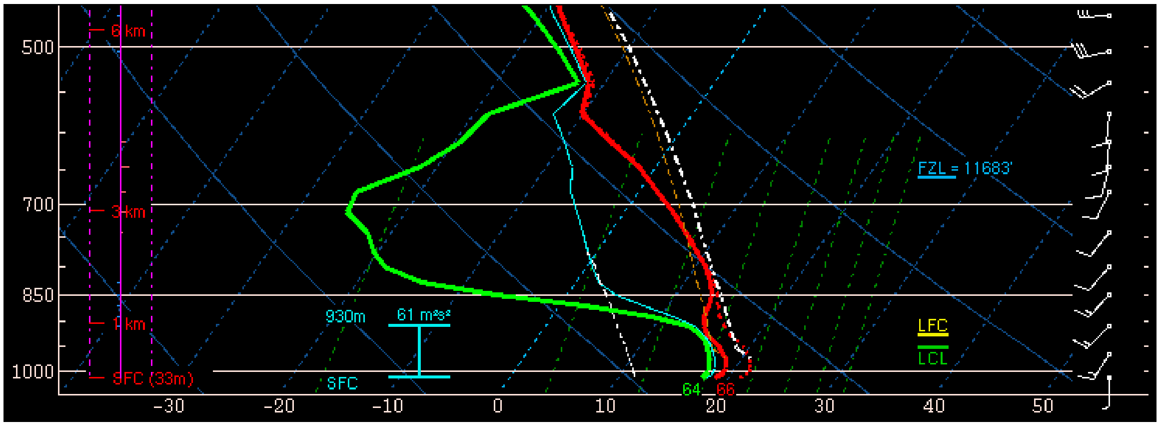

Figure A17: As in Fig. A8 but for GFS 96-h forecast valid 1200 UTC 1 April.

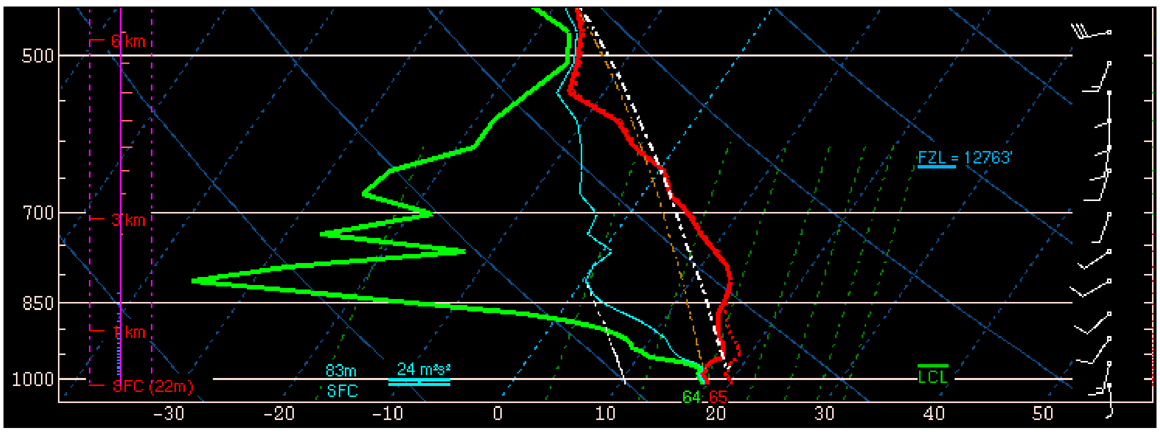

Figure A18: As in Fig. A8 but for NAM 24-hours forecast valid 1200 UTC 1 April.

A3. Summary

The forecast soundings for this event—one that featured substantial low-level airmass modifications during long parcel trajectories over the GoM—have been briefly and subjectively evaluated. Operational numerical forecasts at various lead times demonstrated a number of problems that can perhaps be improved with additional research and use of techniques such as described in the body of this paper. Many of the forecasts were not able to predict the strength of the inversion above the marine layer accurately—a serious problem, especially for forecasting convective development as the airflow from the GoM moves back over the continent. While the current generation of operational numerical forecasts have improved, relative to the older models mentioned in the body of the paper, there are still problems with many aspects of the model forecasts for air mass modification during transits over the warm waters of the GoM.