INFLUENCE ON SEVERE STORM DEVELOPMENT OF IRRIGATED LAND

R. A. Pielke (1) and X. Zeng (2)

Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado 80523

ABSTRACT

Using radiosonde sounding data collected over an irrigated area and over an adjacent natural grassland region in northeast Colorado, it is documented that larger available buoyant energy exists in the lower troposphere over the irrigated land. This enhanced energy, a result of evapotranspiration from the crops, is suggested as a mechanism for potentially enhanced thunderstorm severity over and near irrigated locations. Low-level convergence that develops as a result of the differential turbulent sensible heating between the two land surfaces can further enhance available buoyant energy.

During recent years, there are anecdotal opinions that tornado frequency in the Colorado Front Range communities has increased significantly. While it is easy to dismiss these perceived increases as due to population growth (such as concluded for south Florida, Pielke, 3), there is circumstantial evidence that the increases could be real.

During the summer of 1987, as reported in Segal et al. (4), aircraft flights that transected irrigated and natural grassland areas showed large differences in thermodynamic properties. The lower troposphere was cooler above irrigated areas. This reduced heating, by itself, would act to reduce convective available potential energy (CAPE) which is the difference between the actual total enthalpy of a given atmospheric mass field and the minimum total enthalpy that could be achieved by rearranging the mass under reversible adiabatic processes. However, at the same heights, the dew-point temperatures were substantially elevated as compared with the natural grassland during the aircraft measurement period. The cumulative effect of the temperature decrease, water vapor increase can be represented by changes in equivalent potential temperature Θ_E). At around 150 m above the irrigated land, up to a 10°C increase in Θ_E was found, while a 5°C rise in Θ_E was measured even at 440 m.

Figure 1 illustrates thermodynamic radiosonde soundings constructed for the dryland area and the irrigated area for one of the flights. Parcel ascents from the surface for both cases illustrate the increase in CAPE over the irrigated areas. For Figure 1, a standard synoptic severe storm index, the Lifted Index (L.I.), is computed. This index is calculated e.g., from Pielke (5).

$$L.I. = T_{500\text{ mb}} - T_{p500\text{ mb}}$$

where $T_{500\text{ mb}}$ is the observed 500 mb temperature and $T_{p500\text{ mb}}$ is the temperature of a parcel lifted dry adiabatically to the level where saturation is achieved and then moist adiabatically to 500 mb.

Using the surface parcels method for the sounding in Figure 1, the *L.I.* values are zero over the dryland area and −2.0 over the irrigated area. Therefore, all other factors being equal, one should expect that thunderstorms, including tornadoes, should be more likely (and more severe) over the irrigated regions.

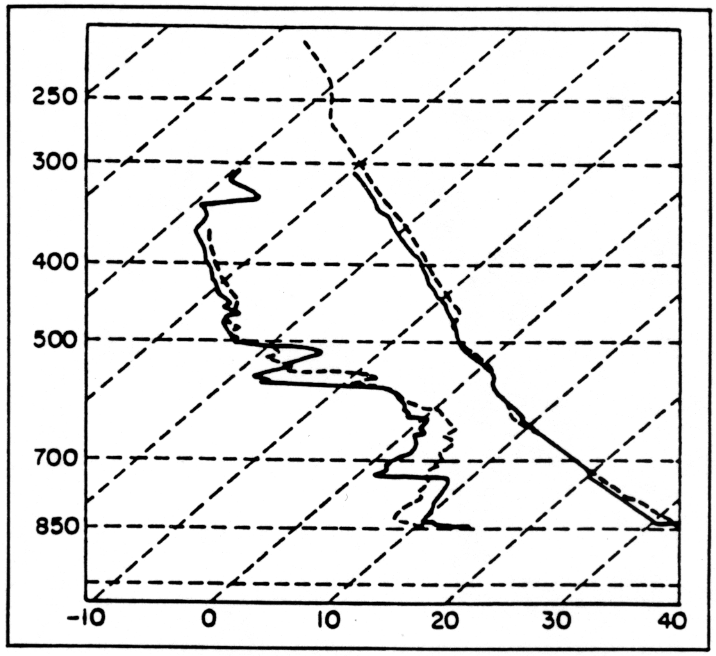

Fig. 1. Radiosonde measurements of potential temperatures (right side) and dew point temperatures (left side) for the dry area (dashed lines) and the irrigated area (solid lines) at 1313 MDST of July 28, 1987.

There is also an additional physical mechanism regarding thunderstorm development that needs to be considered when irrigated areas are adjacent to dry lands. As is well known for sea-breezes (e.g., see Pielke, 6), for wet-soil/dry-soil contrasts (Ookouchi *et al.*, 7), and for cloudy/no cloud area contrasts (Segal *et al.*, 8), significant mesoscale vertical circulations develop. As shown by Pielke *et al.*, (9), the predominate effect of these circulations is to focus moisture and heat into a narrow region, thereby substantially increasing the convective instability (the CAPE), as would be found separately for the irrigated and dryland regions.

Using the idealized experiments reported in Segal *et al.* (10) for irrigated-dryland contrasts, the changes of *L.I.* listed in Table 1 were found.

These values are similar to what Lyons *et al.* (11) found over central Florida where the sea-breeze convergence,

Table 1:

	Well-Removed From Convergence Zone		Convergence Zone Between The Two Land Uses
	Irrigated Area	Dryland Area	
L.I.	−6.8	3.0	−7.5

resulting from the juxtaposition of land and water, was the mechanism which focused heat and water vapor. Lyons *et al.* (11) indicated that typical values of *L.I.* were from −1.0 to −8.0 in the convergence zone.

Therefore, it appears there are two impacts on severe thunderstorm development when irrigated land is adjacent to natural dryland in regions where natural thunderstorm development already occurs. These are:

- elevation of CAPE over the irrigated land;
- even further enhanced CAPE in convergence zones that develop as a result of sensible heat gradients between the irrigated and dryland areas.

ACKNOWLEDGMENTS

The authors would like to acknowledge National Science Foundation (NSF) for providing the support to complete this work, through Grant #ATM-8616662. The aircraft measurements were completed with the University of Wyoming King Air through the allocation of resources by NCAR. NCAR is supported in part by the NSF. Robert Kelly, Wendy Schreiber, J. Garratt, G. Kallos, A. Rodi, J. Weaver, and Peter Hildebrand are acknowledged for their cooperation in this project. Moti Segal is particularly thanked for his insightful and effective development of this research theme. The manuscript was very ably typed by Dallas McDonald and Bryan Critchfield.

NOTES AND REFERENCES

1. Roger A. Pielke is a Professor of Atmospheric Science at Colorado State University in Fort Collins, Colorado. His research focuses on mesoscale meteorology and climatology, and on developing improved techniques for weather forecasting.

2. Xubin Zeng received his M.S. degree in 1987 at the Institute of Atmospheric Physics of the Chinese Academy of Sciences in the People's Republic of China. He is now a visiting scholar at the Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado. He works on mesoscale numerical modeling, chaos, and boundary layer meteorology, and has published three papers in these fields.

3. Pielke, R. A., 1975: The influence of the sea breeze on weather and man. Weather, *30, 208–221.*

4. Segal, M., W. E. Schreiber, G. Kallos, J. R. Garratt, A. Rodi, J. Weaver, and R. A. Pielke, 1988b: The impact of crop areas in northeast Colorado on mid-summer mesoscale thermal circulations. (submitted to Mon. Wea. Rev.*).*

5. Pielke, R. A., 1988: Synoptic Weather Lab notes. Department of Atmospheric Science Paper, Colorado State University, Fort Collins, CO 80523. 195 pp. plus appendices.

6. Pielke, R. A., 1984: Mesoscale meteorological modeling. *Academic Press, New York, NY, 612pp.*

7. Ookouchi, Y., M. Segal, R. C. Kessler and R. A. Pielke, 1984: Evaluation of soil moisture effects on the generation and modification of mesoscale circulations. Mon. Wea. Rev., *112, 2281–2292.*

8. Segal, M., J. F. W. Purdom, J. L. Song, R. A. Pielke and Y. Mahrer, 1986: Evaluation of cloud shading effects on the generation and modification of mesoscale circulations. Mon. Wea. Rev., *114, 1201–1212.*

9. Pielke, R. A., J. L. Song, M. Segal, P. J. Michaels, W. A. Lyons, and R. W. Arritt, 1986: The predictability of sea breeze generated thunderstorms. Proceedings of the WMO International Workshop on Rain-Producing Systems in the Tropics and the Extra-Tropics, July 21–25, 1986, San Jose, Costa Rica, *101–107.*

10. Segal, M., R. Avissar, M. C. McCumber and R. A. Pielke, 1988a: Evaluation of vegetation effects on the generation and modification of mesoscale circulations. J. Atmos. Sci., *45, 2268–2392.*

11. Lyons, W. A. and R. A. Pielke, 1988: Operational forecasting of Florida sea breeze thunderstorms using a mesoscale numerical model. Final Report on NASA Contract NAS10-11321, *small business innovation research (SBIR) solicitation 89-1, Phase II, RSCAN, Minneapolis, Minnesota.*