1993

NASA/ASEE SUMMER FACULTY FELLOWSHIP PROGRAM

MARSHALL SPACE FLIGHT CENTER
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

WATER CYCLE RESEARCH ASSOCIATED
WITH THE
CaPE HYDROMETEOROLOGY PROJECT (CHymP)

Prepared by: Claude E. Duchon, Ph.D.

Academic Rank: Professor

Institution: University of Oklahoma
Department: School of Meteorology

MSFC Colleague: Steven J. Goodman, Ph.D. - NASA

NASA/MSFE:
    Laboratory: Space Science
    Division: Earth Science and Applications
    Branch: Earth System Processes and Modeling

I. Introduction

One outgrowth of the Convection and Precipitation/Electrification (CaPE) experiment that took place in central Florida during July and August 1991 was the creation of the CaPE Hydrometeorology Project (CHymP). The principal goal of this project is to investigate the daily water cycle of the CaPE experimental area by analyzing the numerous land and atmosphere in situ and remotely sensed data sets that were generated during the 40-days of observations.

The water cycle comprises the atmospheric branch and the land branch. In turn, the atmospheric branch comprises precipitation leaving the base of the atmospheric volume under study, evaporation and transpiration entering the base, the net horizontal fluxes of water vapor and cloud water through the volume and the conversion of water vapor to cloud water and vice-versa. The sum of these components results in a time rate of change in the water vapor or liquid water (or ice) content of the atmospheric volume. The components of the land branch are precipitation input to and evaporation and transpiration output from the surface, net horizontal fluxes of surface and subsurface water, the sum of which results in a time rate of change in surface and subsurface water mass. The objective of CHymP is to estimate these components in order to determine the daily water budget for a selected area within the CaPE domain.

This work began in earnest in the summer of 1992 and continues. Even estimating all the budget components for one day is a complex and time consuming task. The discussion below provides a short summary of the rainfall quality assessment procedures followed by a plan for estimating the horizontal moisture flux.

II. Daily Rainfall

The first step in any data analysis is to assess the quality of the data. With respect to the precipitation data, a quality assessment program began in June, 1992 and has taken one year to complete. Through this program reliable measurements of daily rainfall are now available for 212 raingages, most of which are in the area bounded by 27° and 29°N and 80° and 82°W. Fig. 1 shows the gage locations that resulted and the associated sponsors. Some of the raingages were operated specifically for the duration of the CaPE experiment and others were (and still are) continuously maintained by federal and state agencies and individual cooperators.

III. Water Vapor Flux

The estimation of atmospheric horizontal water vapor flux requires analyzing both rawinsonde and satellite data. The sounding sites, identified by hexagons in Fig. 1, are located within and around the water budget area (outlined by heavy line). The satellite data come from two sources, AVHRR on the NOAA polar orbiting satellites and VAS (VISSR Atmospheric Sounder) on GOES-7. The objective is to produce estimates of the divergence of water vapor flux every three hours for selected sequences of days. The plan for estimating the water vapor flux is outlined below.

In the early part of the CaPE experiment numerous problems arose with CLASS (Cross-Loran Atmospheric Sounding System) soundings so that only from 20 July to 12 August are

All Raingages – 212
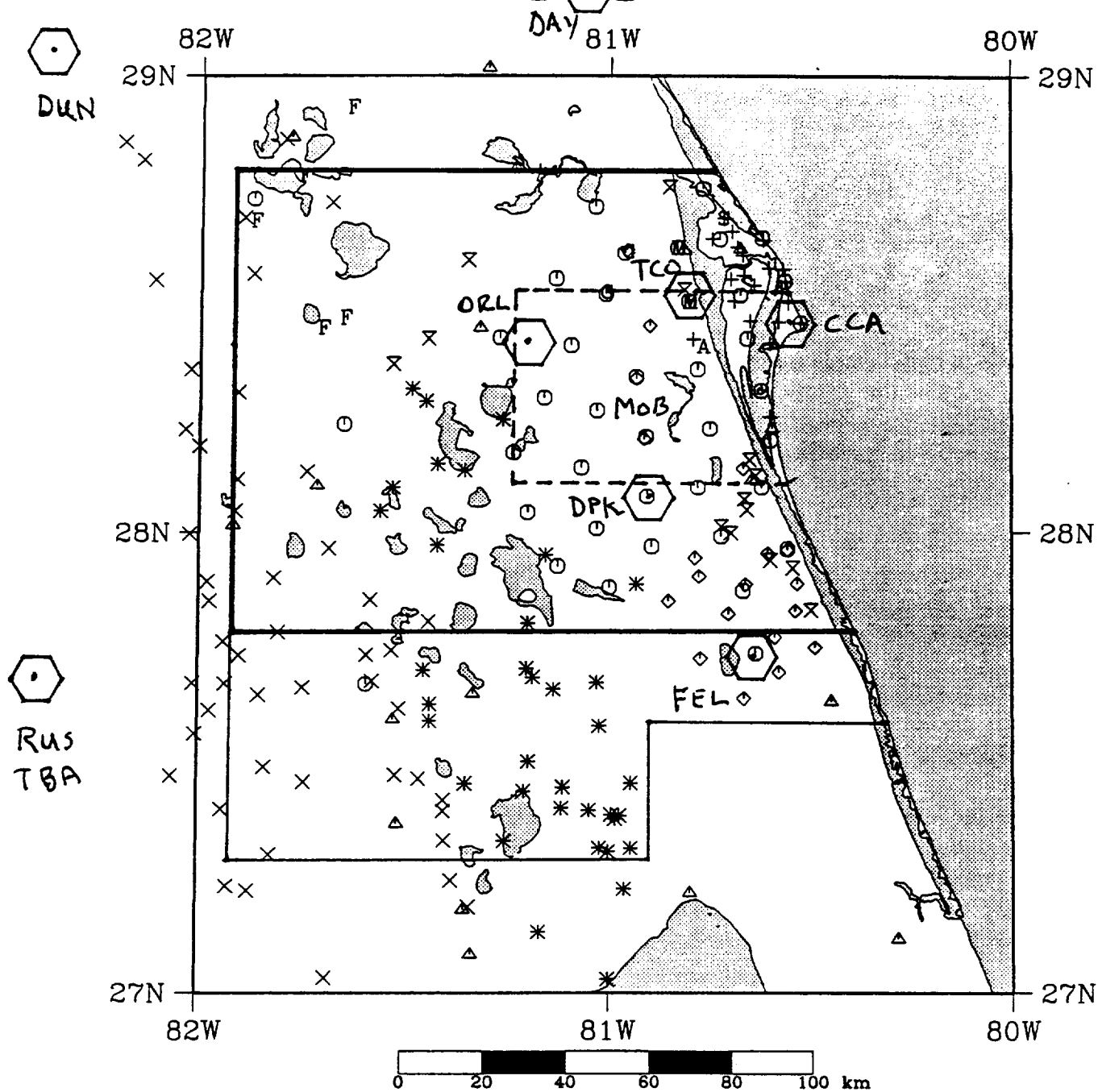
+	KSC/TRMM – 20	×	SWFWMD – 50
⋈	USGS – 14	A	USDA – 1
◇	USJRB – 19	M	MSFC – 2
△	NWS USAF – 20	G	U GA – 2
✳	SFWMD – 3	S	FSU – 2
⊙	PAMII – 40	F	U Fla – 5

IX-2

there an adequate number of high quality soundings available for analysis. The time of soundings is linked to studies of large scale and small scale weather systems. The four outer CLASS sites (Dunnellon, Ruskin, Fellsmere and Daytona Beach) are connected to the large scale with 5 daily soundings taken every 3 hours beginning at 1100 UTC and ending at 2300 UTC. Soundings at Fellsmere and Dunnellon were taken also at 0800 UTC. The Deer Park and Tico Airport locations as well as the mobile CLASS unit were part of the small scale weather system study so that soundings were taken at variable times related to the current daytime storm activity. Cape Canaveral Air Force Station, Orlando and Tampa provided numerous additional soundings, mainly during daytime. During the 24 day period the number of soundings per day ranged from 28 to 48 with the vast majority of the soundings between 1000 and 2400 UTC. The maximum number of soundings between 0000 and 1200 UTC was 5 on one day; typically there were 2. Accordingly, there is a large gap in radiosonde coverage for this 12 hour period.

For many reasons, sondes are not always released at the scheduled time. Also, as noted, some stations have no set schedule. Thus, in order to develop a 3-hourly moisture and wind fields a scheme to incorporate data from surrounding times has to be developed.

Within the 24 day period noted above there are comparatively few days in which data are more or less continuously available from all observational systems--the optimal situation for calculating the daily water budget. Based on the following criteria each day was rated on a scale of 1 (poor) to 5 (good):

a. number of hours of WSI radar coverage given that it is raining (based on gages).

b. percent cloud cover around 1200 UTC derived from visual inspection of GOES visible imagery.

c. total number of atmospheric soundings and the number between 0000 and 1000 UTC.

d. number of times data from the 11μm and 12μm split-window channels on GOES-7 VAS (VISSR Atmospheric Sounder) are available.

e. number of hours of profiler winds.

The larger the value for each criterion, the higher the rating for that day. At this writing the split-window criterion has not been invoked because the selection of data to be ordered is in progress. Based on the remaining criteria the best periods are 26-30 July and 7-9 August.

A rawinsonde provides vertical profiles of wind and water vapor content which begin at a specific time and location at the surface. As the balloon rises its horizontal position changes in response to the wind field. If we consider 400 mb (about 7.5 km) to be the upper level of moisture calculation, which corresponds to about 98% of the integrated water content (IWC), and a balloon rise rate of 5 ms^{-1}, it will take 1400 seconds (23 minutes) to reach that altitude. With an average wind speed of 10 ms^{-1}, the drift will be 14 km. This is a significant fraction of the water budget analysis area so that, in general, balloon position must be taken into account. In addition, an accounting of time differences between soundings must be made.

The first step in rawinsonde data reduction is a vertical interpolation of each sounding to evenly spaced σ levels ($\sigma = P/P_{sfc}$). A resolution of $\Delta\sigma = 0.01$ (≈ 10 mb) will provide 40 levels of wind and water vapor content. Next, the data at each level are linearly interpolated in time and horizontal distance with data from the previous or following ascent to a common time. The result of the interpolations in space and time should be that all data for each level are valid at a single time.

The next step is to perform an objective analysis of the wind and water vapor content on each of the 40 σ-surfaces such that the gridded analysis extends beyond the water budget area. At this point information from VAS and AVHRR will be incorporated into the analysis. Gridded fields of IWC will be obtained using the physical split-window (PSW) technique developed by Dr. Gary Jedlovec at MSFC. The idea is to vertically distribute the VAS- and AVHRR- derived IWC at the same grid points as above according to the water content profile at those grid points derived through linear interpolation from the rawinsonde locations, as discussed above. The reason for incorporating satellite-derived IWC is to provide improved estimates of water content between rawinsonde stations. This may be especially important if there are significant spatial variations of IWC.

The final step is to integrate the moisture flux normal to the boundary around the exterior of the water budget at each level. The summation over all levels is equal to atmospheric water vapor divergence for that time. Assuming that 3-hourly estimates are available they are then summed to obtain the divergence for that day.

IV. Conclusion

After one year of quality assessment, a credible 42 day set of daily rainfall data for 212 stations has been produced. Thus the daily area-average precipitation component of the atmospheric branch has been essentially completed.

A strategy has been formulated to analyze the horizontal flux of water vapor employing rawinsonde and satellite data. Priority time periods have been selected so that satellite data can be now ordered. It is anticipated that the creation of a 3-dimensional grid of moisture and wind will be developed at OU and coordinated with Dr. Bill Crosson at MSFC. IWC data files will be produced by Drs. Jedlovec, Guillory and Crosson at MSFC.

V. Acknowledgments

Many thanks to Dr. Crosson and Joni Brooks for their major contributions to the raingage quality assessment and stimulating discussions on the water vapor analysis.