Communicating Timely Information on the Evolving Convective Available Potential Energy (CAPE) using Polar Orbiting Hyperspectral Sounders: Application to El Reno Event

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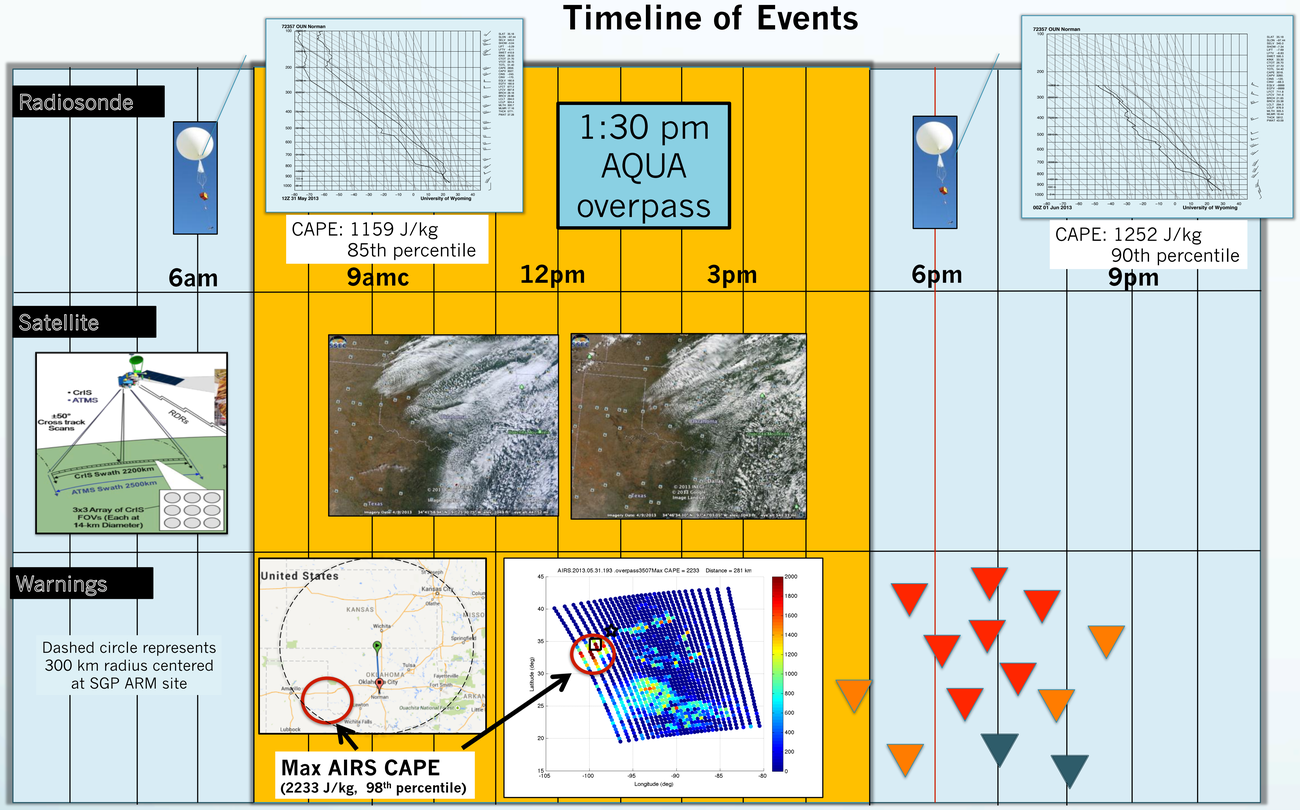
Abstract

A deadly EF5 tornado hit Moore, Oklahoma on May 20, 2013 killing 24 people. Two weeks later on May 31, 2013 nineteen tornados struck central Oklahoma. After hearing a forecast for these tornados, many citizens tried to escape the storm by traveling south to Texas on interstate forty. The interstate soon became traffic jammed for miles. Unfortunately, a massive and unpredictable tornado traveled across the interstate and killed a woman and child in a car near El Reno, Oklahoma in the late afternoon. The most recent prior vertical sounding information from the operational radiosonde network was at 6 am, nearly twelve hours before the tornado touchdown. There are two lessons to consider from these tragedies. One, communication strategies in this scenario need to be analyzed from not only a scientific viewpoint but also from a social perspective. Two, satellite soundings from METOP IASI at 10:30 am and Suomi-NPP CrIS at 1:30 pm combined with hourly data from the GOES Sounder have the potential of providing vertical sounding information that is both timely and accurate.
Using climatology as a guideline, we will analyze how the convective stability of the atmosphere for severe weather differs from typical days in the previous years without severe storms. We will look at the ability of satellite observations to characterize the probability distribution function of CAPE for Oklahoma in the May-June time period for the past decade. A particular focus will be on the ability of the combination of data with high vertical resolution infrared sounders on polar orbiting satellites along with a lower vertical resolution sounder in geostationary orbit to capture the extreme high tail of the CAPE probability distribution. The El Reno event will serve as a case study for showcasing satellite sounding timeliness. It is hoped that assimilation of satellite soundings into numerical models for the analysis and prediction of severe convective weather will prove to be a priority for the future. Understanding how and when satellites can be helpful in providing advance notice for severe events is important for improving the flow of timely information needed for communicating to the public.

Timeline of Events



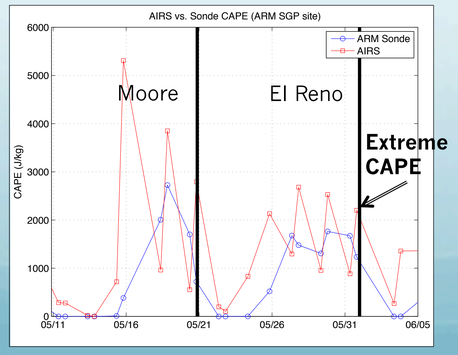
The red line represents the time of the El Reno Tornado (6 pm). The most recent prior vertical sounding information from the operational radiosonde network was at 6 am, nearly twelve hours before the tornado touchdown.

Satellite Sensor and Level 2 Data Product:

The NASA Aqua platform is in a sun-synchronous orbit with local overpass times of about 1:30 pm and 1:30 am. As the satellite orbits from pole to pole the sensor maps out a swath using cross track scan patterns. It measures wavelengths between 3.7 to 15.4 microns. Each of these wavelengths is sensitive to the presence of a specific gas. For example it's possible to acquire information about carbon dioxide, carbon monoxide, ozone and particularly temperature and water vapor. The data product used was the official NASA
AIRS Science Team retrievals downloaded from the NASA Goddard data archive.

Extreme CAPE values just west of El Reno were found in the 1:30 pm AIRS sounder data!

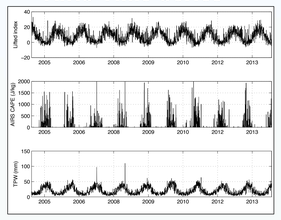
Max AIRS vs. Sonde CAPE



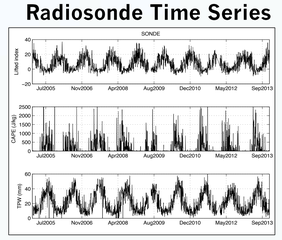
Convective Available Potential Energy (CAPE) Climatology

The climatology of CAPE values in the Southern Great Plains was estimated using radiosonde data launched from the DOE ARM site and interpolated in time to the Aqua overpass times (1:30 pm/am). A time/space coincident matchup was made using NASA AIRS v6 retrievals. The Time Series graphs shown below illustrates the seasonal variation of CAPE, where large CAPE values are more frequent in the summertime than the wintertime. They also show seasonal variations in Lifted Index and PWV. The next set of graphs show the relationship between these three variables: CAPE, Lifted Index and Total Perceptible Water Vapor. It is clear that high PWV is a good indicated of large CAPE values. The histograms are displaying the frequency of CAPE, PWV and Lifted Index values over the nine years. The probability density functions highlight the chance CAPE is greater than 1,000 J/kg. The Cumulative Sum graphs demonstrate the 25th, 50th, 75th, 67th 95th, 99th percentile of CAPE. In general, the radiosonde calculated CAPE values tend to be higher than the time and space coincident AIRS CAPE. However, the maximum AIRS CAPE within a radius of 300 and 500 km was found to have higher CAPE values than the radiosonde CAPE from the ARM SGP site.

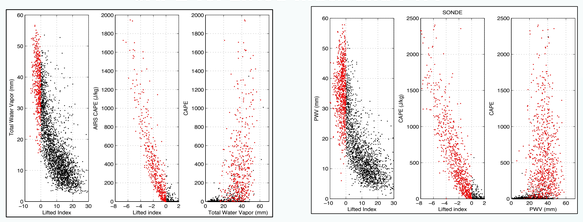
AIRS Time Series



Radiosonde Time Series



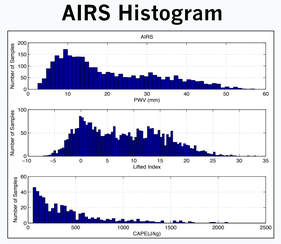
CAPE vs. Lifted Index and PWV



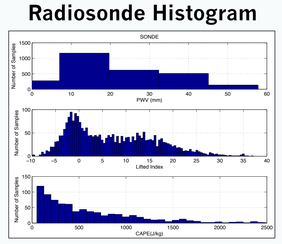
January 2005 – September 2013
(Nine summer seasons at the ARM SGP site)

Red dots represent cases with negative lifted index (unstable thermodynamic profile).

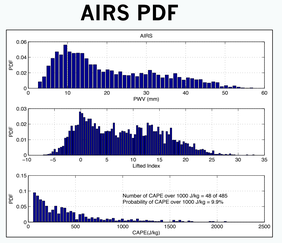
AIRS Histogram



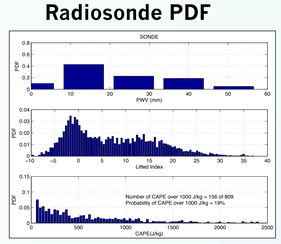
Radiosonde Histogram



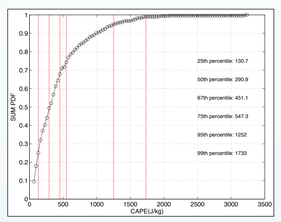
AIRS PDF



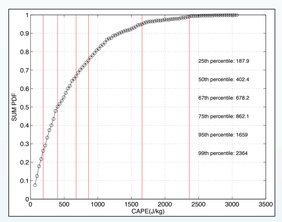
Radiosonde PDF



Cumulative Sum AIRS

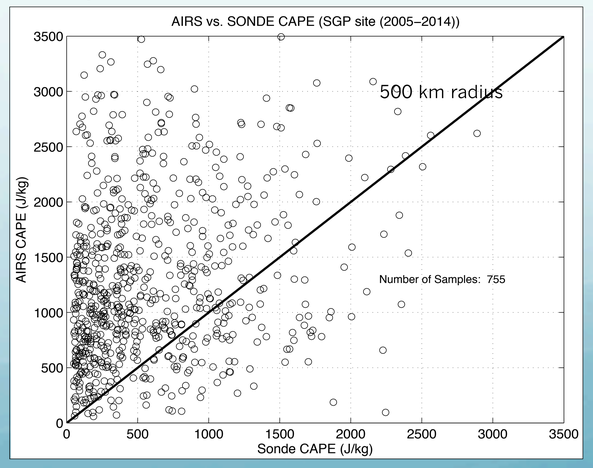


Cumulative Sum Radiosonde



PDF Percentile CAPE >50 J/kg	ARM Sonde Lamont, OK	AIRS Closest CAPE <50 km	AIRS MAX CAPE <300 km	AIRS MAX CAPE <500 km
25	187.9	130.7	225.7	187.5
50	402.4	290.9	655.1	698.2
67	678.2	451.1	967.4	1052
75	862.1	557.3	1202	1287
95	1659	1252	2295	2544
99	2364	1733	2997	3330

Scatterplot of AIRS MAX CAPE vs. ARM SONDE CAPE



Conclusions:

- A sonde climatology at the Lamont Oklahoma ARM site was developed for Jan 2005 to June 2014.
- AQUA overpasses at 1:30 pm local time provide matched AIRS profiles of T and WV for the Oklahoma region.
- The maximum AIRS CAPE value was found within a radius of the SGP ARM site (300km and 500 km).
- Maximum AIRS CAPE values near the SGP site tend to exceed the time coincident sonde CAPE at the ARM site.
- In the El Reno case study, the 6 am sonde at Norman, OK had a CAPE in the 85th percentile (1252 J/kg) .The maximum AIRS CAPE at 1:30 pm was found just West of Oklahoma City with a CAPE exceeding the 98th (2233 J/kg).
- **These results show promise for use of infrared sounder retrievals in the nowcasting of local severe storms!**