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Convective Radio Occultations Final Campaign Summary

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ARM CLIMATE RESEARCH FACILITY

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Convective Radio Occultation Campaign
Final Campaign Summary

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Executive Summary

Deep convective systems are destructive weather phenomena that annually cause many deaths and injuries as well as much damage, thereby accounting for major economic losses in several countries. The number and intensity of such phenomena have increased over the last decades in some areas of the globe. Damage is mostly caused by strong winds and heavy rain parameters that are strongly connected to the structure of the particular storm. Convection over land is usually stronger and deeper than over the ocean and some convective systems, known as supercells, also develop tornadoes through processes that remain mostly unclear. The intensity forecast and monitoring of convective systems is one of the major challenges for meteorology because in situ measurements during extreme events are too sparse or unreliable and most ongoing satellite missions do not provide suitable time/space coverage.

With this campaign, we propose a new method for detecting the convection intensity in terms of rain rate and surface wind speed by using meteorological surface measurements in combination with atmospheric profiles from Global Positioning System (GPS) Radio Occultation (RO) observations, which are available in essentially all weather conditions and with global coverage. The analysis of models indicated a relationship between the cloud-top altitude and the intensity of a storm. We thus use GPS RO bending-angle profiles for detecting the storm's cloud-top altitude and we correlate this value to the rain rate and wind speed measured by ARM Southern Great Plains (SGP) meteorological station networks.

The initial results suggest that the cloud-top altitude increases with the rain rate and wind speed, despite the small number of co-locations and uncertainties. We conclude that for land convective systems, the cloud-top altitude is connected to the storm intensity and GPS RO observations show encouraging potential to improve the casting and detection of such severe weather phenomena. The future objective is to increase the number of sites and to obtain more co-location in order to develop a statistically relevant number of cases.

Acronyms and Abbreviations

CALIOP	Cloud-Aerosol measurements Lidar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
GPS	global positioning system
RO	radio occultation
SGP	Southern Great Plains
TWP	Tropical Western Pacific
UTLS	Upper Troposphere Lower Stratosphere

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Figures

1.0 Background

This campaign acquired in situ measurements (cloud base, cloud top, profiles of backscatter, temperature, and water vapor) co-located with the GPS ROs tangent point during convective systems in order to assess the contribution of any atmospheric process and parameter to the variation of the RO bending angle. The RO bending angle contains interesting information to detect the convective systems' cloud tops and their thermal structures. A deep knowledge of this parameter allowed:

- development of a good understanding of the role of convection in the climate changes,
- determination of the thermal structure and composition of the Upper Troposphere Lower Stratosphere (UTLS), both in the tropics and in the extra-tropics,
- linkage of the GPS RO signal to the intensity of the storm, and
- characterization of the deep convective cloud top.

Data selection started with the rain rate and wind speed acquired by the weather stations. We selected all the cases with rain rate higher than 4 mm/h and wind speed higher than 15 km/h. We then selected the co-located GPS RO with mean tangent points within 100 km from the location of the weather station and within 60 minutes in time. We have used the GPS RO bending-angle anomaly method for detecting the cloud-top altitude (Biondi et al., 2015) for each single RO event co-located with a weather station. A cloud top is detected if a change of 3% in bending-angle anomaly within 2 km of altitude range occurs; the uncertainty of cloud-top altitude is about 300 m. The cloud-top altitude was then compared to the rain rate and wind speed of the corresponding station, measured by the ground-based rain gauge and anemometers.

Several uncertainties affecting the measurements and the co-locations must be considered:

- horizontal resolution of GPS RPO,
- temporal resolution of weather stations,
- temporal mismatch of GPS RO and weather measurements,
- uncertainty of the cloud-top determination with GPS RO, and
- closeness of co-location between GPS RO, convective systems, and weather stations.

The campaign was developed at the SGP and Tropical Western Pacific (TWP) ARM sites, respectively characterized by deep convection and tropical cyclones. The campaign lasted for 35 months, from February 2012 to December 2014, and the data were analyzed in collaboration with Dr. Stefania Bonafoni (University of Perugia, Italy).

2.0 Notable Events or Highlights

The study and data analysis is ongoing. To date, we have studied and analyzed 35 convective events at the SGP site in the period 2006-2013.

3.0 Lessons Learned

Spatial and temporal co-location of different instruments with convective events is the main issue. For a reliable campaign we should get higher temporal resolution from the ground-based instruments to facilitate comparison of these data with satellite data.

4.0 Results

We selected 35 GPS RO observations co-located with precipitation events within the ARM Southern Great Plains area in the period 2006-2013. We computed the convective cloud-top altitudes by using the bending-angle anomaly technique developed by Biondi et al. (2015). We validated some cloud-top altitudes by co-locating the GPS RO with the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) attenuated backscatter measurements on board of the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO). Finally, we related the cloud-top altitudes with the rain rate (Figure 1) and the wind speed (Figure 2) provided by the ARM stations. The linear fit shows an increase of cloud-top altitude with rain rate and wind speed. However, the temporal resolution of weather stations is unfortunately not adequate for this kind of study to yield scattered rain-rate values.

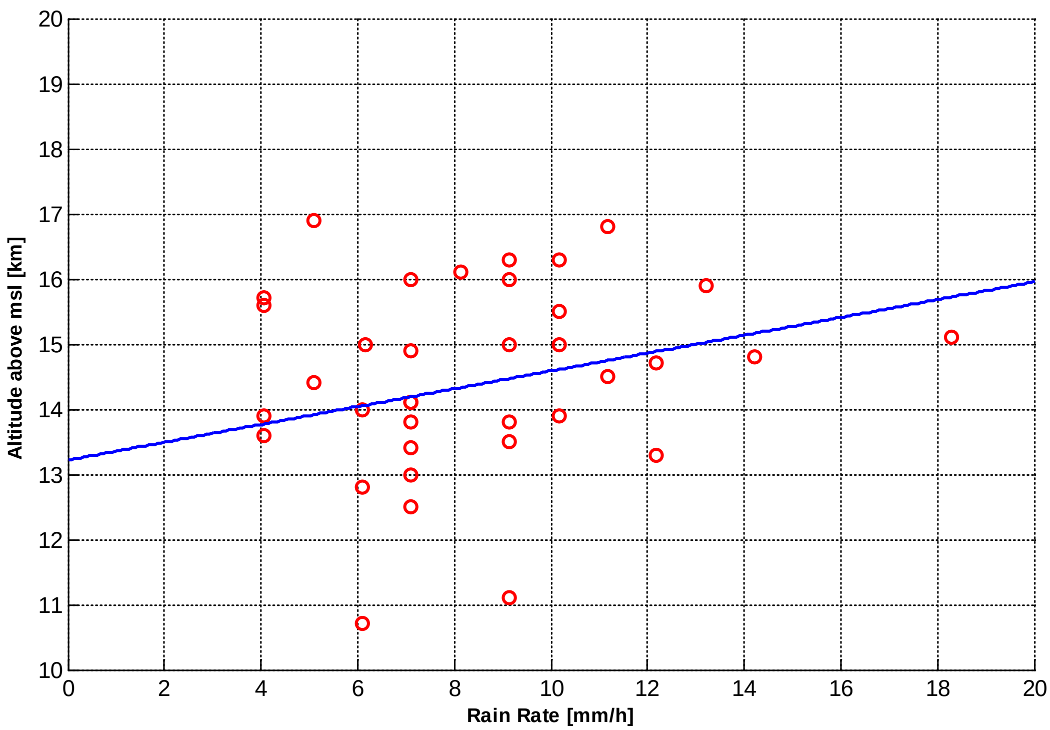

Figure 1: Scatter plot between convective systems cloud-top altitudes computed by using GPS RO bending angle and rain rate measured by the ARM SGP weather stations.

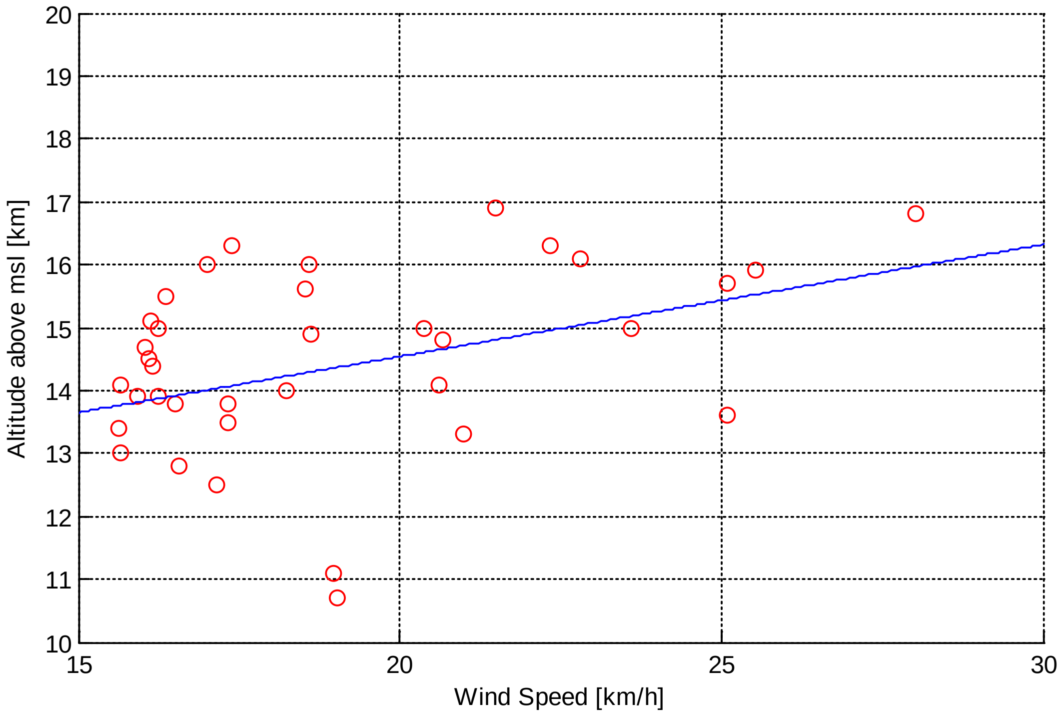

Figure 2: Scatter plot between convective systems cloud-top altitudes computed by using GPS RO bending angle and wind speed measured by the ARM SGP weather stations.

In the near future we will perform the same analyses on tropical cyclones in the TWP area and use additional facilities measurements (such as lidars) to determine if we can retrieve the cloud structure from the GPS RO profiles. A feasibility study for connecting the storm´s cloud-top altitude with storm intensity (in terms of rain rate and wind speed) was published by Bonafoni and Biondi (2015) and the final objective of this campaign will be to develop a reasonable number of storms/ROs co-locations for producing statistically relevant results.

5.0 Public Outreach

http://www.biondiriccardo.it/CONSYDER/indexconsyder.htm

6.0 Convective Radio Occultations Campaign Publications

6.1 Journal Articles/Manuscripts

No journal articles have been published so far with the ARM data.

6.2 Meeting Abstracts/Presentations/Posters

Biondi, R, AK Steiner, G Kirchengast, and S Bonafoni. 2014. "The potential combined use of GPS radio occultations and ground-based GPS receivers for detecting continental storm intensity." Presented at the COST ES1206 GNSS4SWEC Workshop, Munchen (Germany), 26 February-28 February 2014.

Biondi, R, A K Steiner and G Kirchengast. 2015. "Towards evaluating the intensity of convective systems by using GPS radio occultation profiles." Presented at the EGU General Assembly, 2015, Vienna (Austria), 12-17 April 2015.

Biondi, R, and S Bonafoni. 2015. "The synergy of the ground-based GPS measurements and the GPS radio occultations for analysing precipitation events." Presented at the COST ES1206 GNSS4SWEC Workshop, Thessaloniki (Greece), 11-13 May 2015.

7.0 References

Biondi, R, AK Steiner, G Kirchengast, and T Rieckh, 2015. "Characterization of thermal structure and conditions for overshooting of tropical and extratropical cyclones with GPS radio occultation." *Atmospheric Chemistry and Physics* 15: 5181-5193, doi:10.5194/acp-15-5181-2015.

Bonafoni S, and R Biondi. 2015. "The usefulness of the Global Navigation Satellite Systems (GNSS) in the analysis of precipitation events." *Atmospheric Research* 167: 15-23, doi:10.1016/j.atmosres.2015.07.011.