Atmospheric profiling using GPS radio occultation and radiosonde observations in the Australian region

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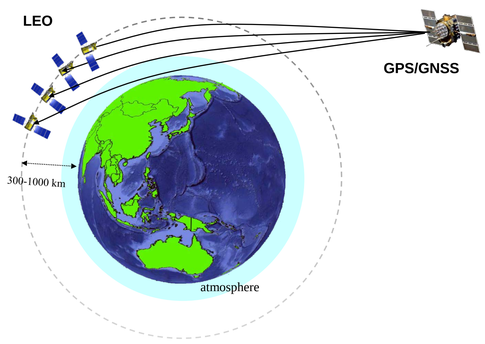
GPS Radio Occultation

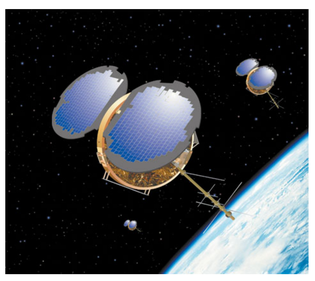
The GPS radio occultation (RO) is an emerging robust, space-based Earth observation technique, with the potential for atmospheric profiling, meteorological and climate applications. The GPS RO technique uses GPS receivers on-board Low Earth Orbit (LEO) satellites to measure the received radio signals from GPS satellites so that ionosphere electron density profiles as well as atmospheric profiles, such as temperature, pressure and water vapour etc., can be obtained using complicated atmospheric retrieval processes. GPS RO has the unique features of long-term stability, all weather and global coverage, unbiased and drift-free measurements and high resolution. GPS RO has recently been incorporated into multiple global numerical weather forecasting systems.

The Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) was launched in April 2006. GPS RO data from this constellation of six LEO micro-satellites has provided a new observation type for operational meteorology and significant information on the thermodynamic state of the atmosphere with the demonstrated potential to improve atmospheric analysis and prognosis. The plenitude of applications of COSMIC RO data reinforce that it is important to know and understand the accuracy and limitations of the COSMIC GPS RO measurements. In this study COSMIC RO measurements are compared to radiosonde (RS) measurements.

The COSMIC GPS RO data have recently been employed in some analysis centres around the globe where they have been shown to improve operational global numerical weather prediction. Recently RO data was assimilated into the global ACCESS (ACCESS-G) forecast system at the Australian Bureau of Meteorology producing improved forecasting over the Southern Hemisphere and in particular in the Australian Region (J. Le Marshall et al., 2010).



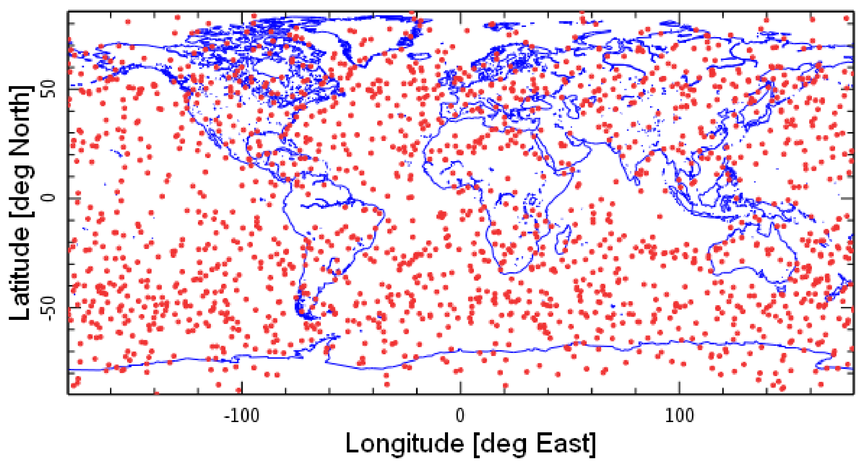
Occultation geometry



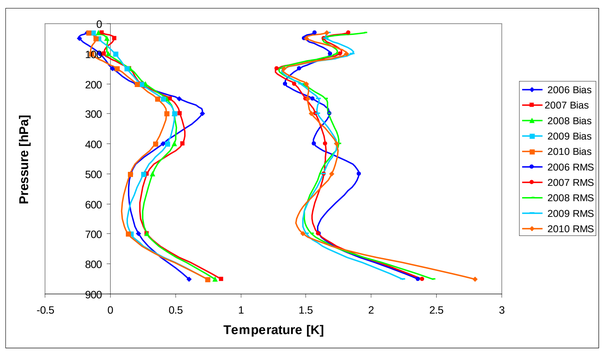
COSMIC satellites

GPS Radio Occultation and Radiosonde Comparisons

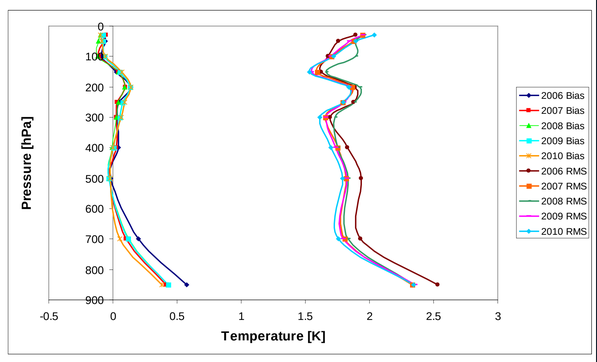
The distribution of GPS RO events for a period of one-day on 15 March 2009 (~50 in the Australian region (courtesy of UCAR).



The distribution of world radiosonde (RS) weather stations (38 from Australia) (courtesy WMO).



Australian region from 2006 to 2010 COSMIC RO – RS temperature bias from 2006 to 2010. Using a spatial and temporal buffer of 2 hours and 200 km.



Global COSMIC RO – RS temperature bias from 2006 to 2010. Using a spatial and temporal buffer of 2 hours and 200 km.

Tropopause

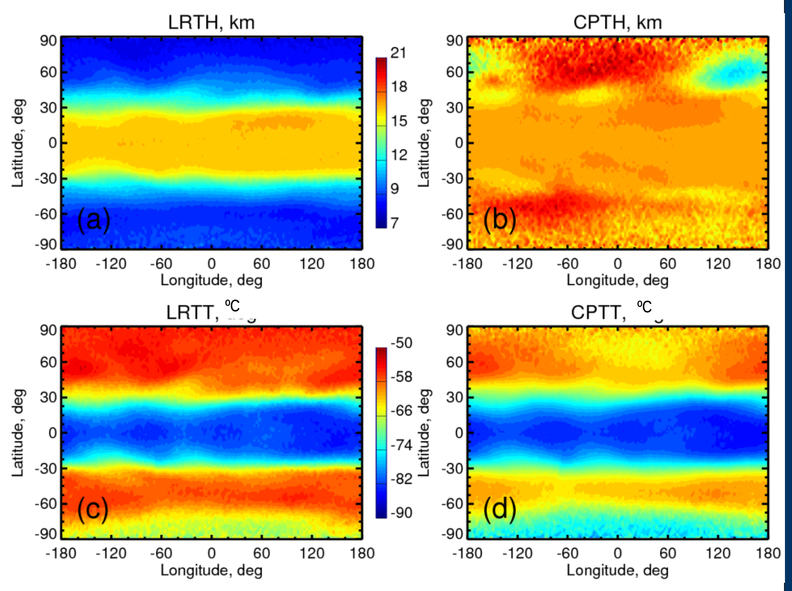
The tropopause is the atmospheric boundary between the troposphere and the stratosphere. The height of the tropopause varies from about 17 km above the equator to about 6 km above the Polar Regions

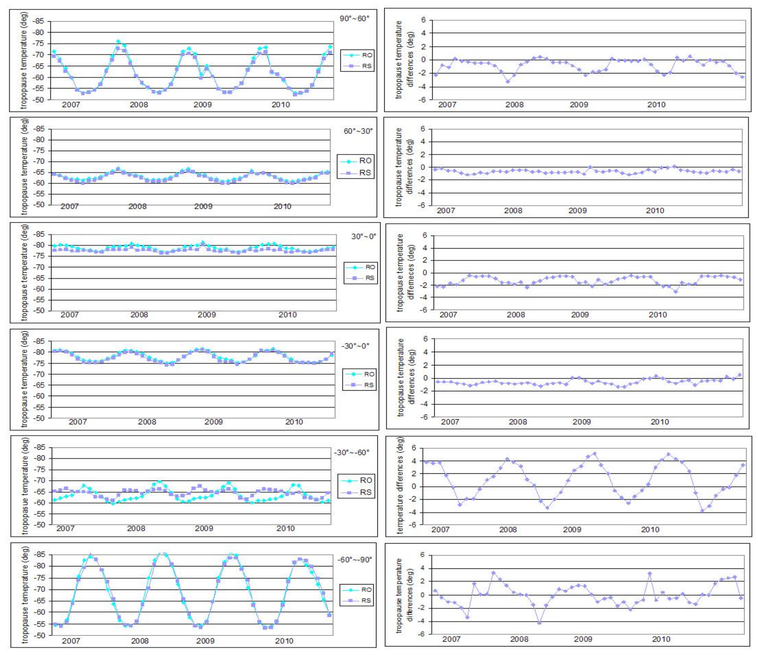
The lapse rate tropopause (LRT) is defined as the lowest level at which the lapse rate decreases to 2K/km or less, with the average lapse-rate from this level to any higher levels within the next 2 km not exceeding 2K/km.

The cold point tropopause (CPT) is located at the minimum vertical temperature in the stratosphere.

The figure to the top right shows the spatial variations of tropopause parameter values derived from COSMIC data.

The figure to the right highlights the RO and RS CPT temperatures in six latitude bands over the four the year period from 2007 to 2011.



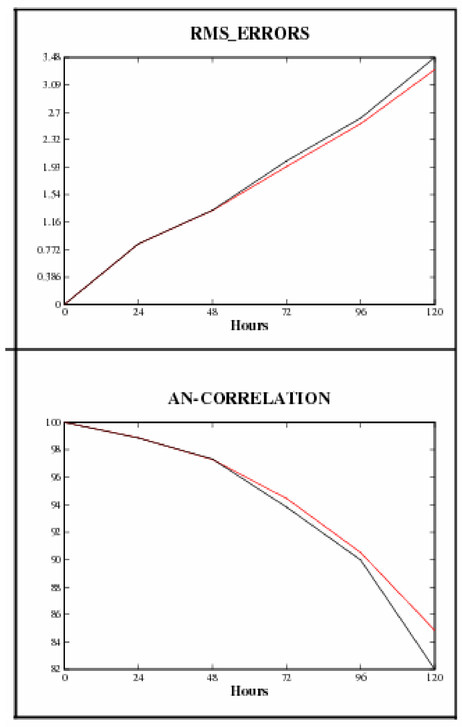


Weather Forecasting using GPS RO

These two figures show the positive impact on MSLP Forecasts (red lines) in the Australian region (65.0S,-17.125N, 65.0E,-184.625E) when GPS RO data is assimilated into the ACCESS-G numerical weather prediction system.

This is a significant finding which demonstrates that the addition of GPS RO data in the ACCESS-G forecasting system can improve weather forecasting in the Australian region (J. Le Marshall et al., 2010).

GPS RO data is now an operational data type used by the Australian Government Bureau of Meteorology's real-time operational systems.



Conclusion

The temperature profiles determined using the COSMIC GPS RO technique compare well with the RS measurements. The high vertical resolution and unbiased nature of RO measurements can be used to improve the bias tuning/calibration schemes used in numerical weather prediction (NWP) and in climate reanalysis, and in conjunction with their direct usage, to potentially reduce biases in the analysis process. This improves the absolute accuracy of reanalyses and the vertical resolution of features such as the tropopause. Thus GPS RO is becoming an increasingly important data type in weather forecasting and climate studies.

As a result of this research, GPS RO data has been incorporated into the operational Australian NWP model – the Australian Community Climate and Earth-System Simulator (ACCESS) system.

This research is primarily supported by a 3-year (2010-13), $8m Australian Space Research Program Platform Technology project and the Australian Research Council project (ARC) awarded to international research consortium sled by SPACE. The key references include:

[1] Zhang K., Wang CS, Bennett J., Carter B., Norman R. and Wu S., The Australian Space Research Program Project – Platform Technologies for Space Atmosphere and Climate: Progress and Preliminary Results, IAG Symp. 139 (CPCI-S indexed), Springer- Verlag, 2012.

[2] Le Marshall J., Xiao Y., Norman R., Zhang K., Rea A., Cucurull L., Seecamp R., Steinle P., Puri K. and Le T., The beneficial impact of radio occultation observations on Australian region forecasts, Australian Meteorological and Oceanographic Journal 60, pp. 121-125, 2010.