NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Satellite Research Centre
School of Electrical and Electronic Engineering

Tropika-1 Pathfinder Mission for Equatorial Weather and Space Weather Forecasting

The aim of this Tropika project is twofold; To build and operate a small satellite capable of delivering high quality Global Navigation Satellite System Radio Occultation (GNSS-RO) and Reflectometry (GNSS-R) data along with in-situ ionospheric plasma density measurements from Low Earth Orbit (LEO). The second objective is to develop from fundamental physics based models to use the GNSS-RO, GNSS-R and ionospheric data for weather forecasting and space weather nowcasting over the Singapore region.

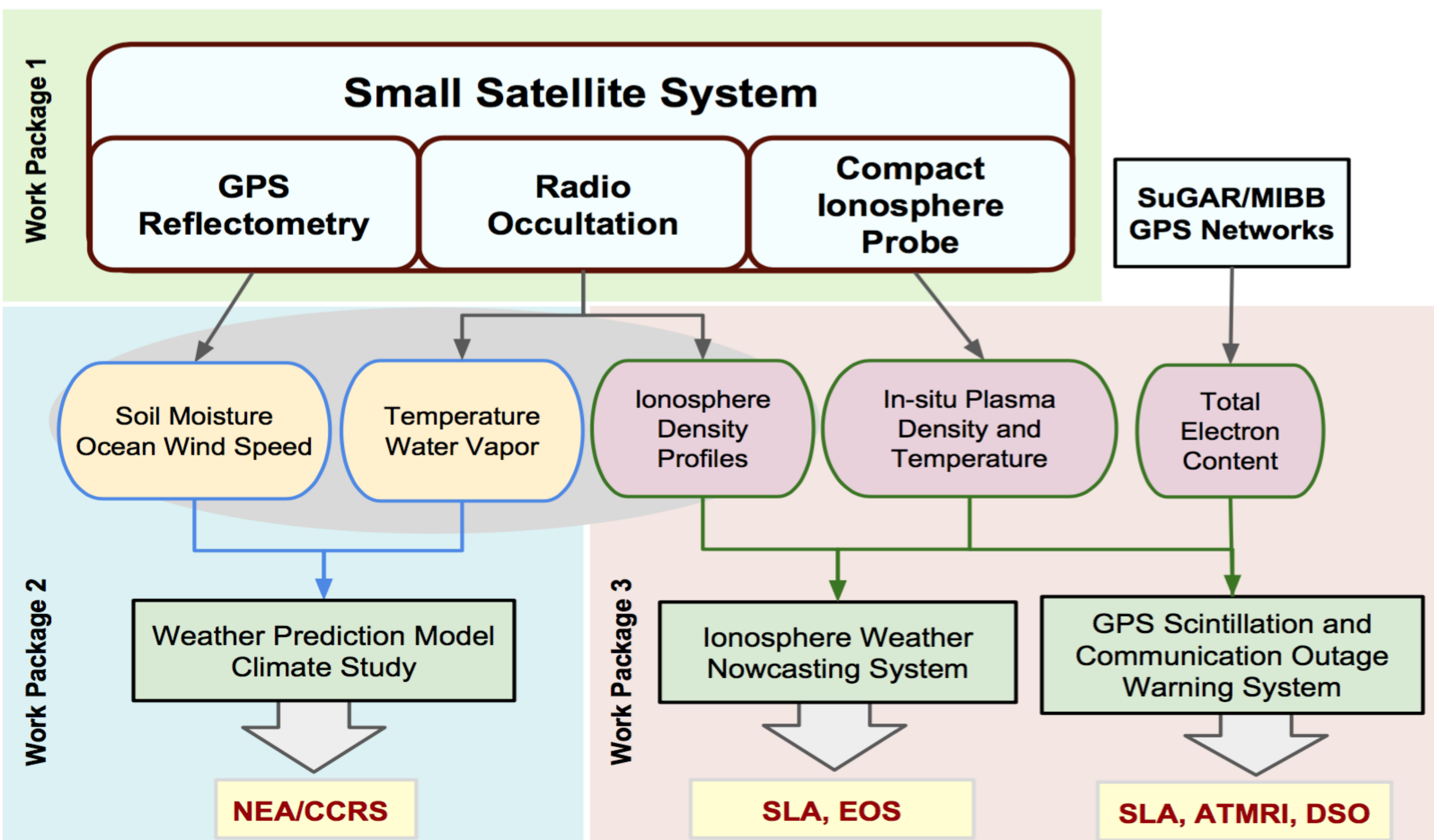


Figure 1. Schematic plot of different work packages of the Tropika Project

The Tropica-1 Pathfinder Mission project broadly aims to:

(1) Take advantage of Singapore's expertise in small satellite technology to build a small satellite platform capable of delivering vertical profiles of temperature and water vapor with the GNSS- RO technique, ocean wind and soil moisture information from GNSS-R signals, and in-situ ionospheric plasma density measurements from a plasma sensor.

(2) Develop advanced techniques for assimilating GNSS RO data into numerical weather prediction (NWP) systems to improve weather forecasting and extracting weather related parameters from GNSS-R signals to better understand our environment.

(3) Develop a data-assimilation (DA) system combining satellite and ground-based measurements for monitoring space-weather conditions in South-East Asia and establish nowcast and forecast products that can be used to mitigate space-weather impacts on communication and positioning systems in the region.

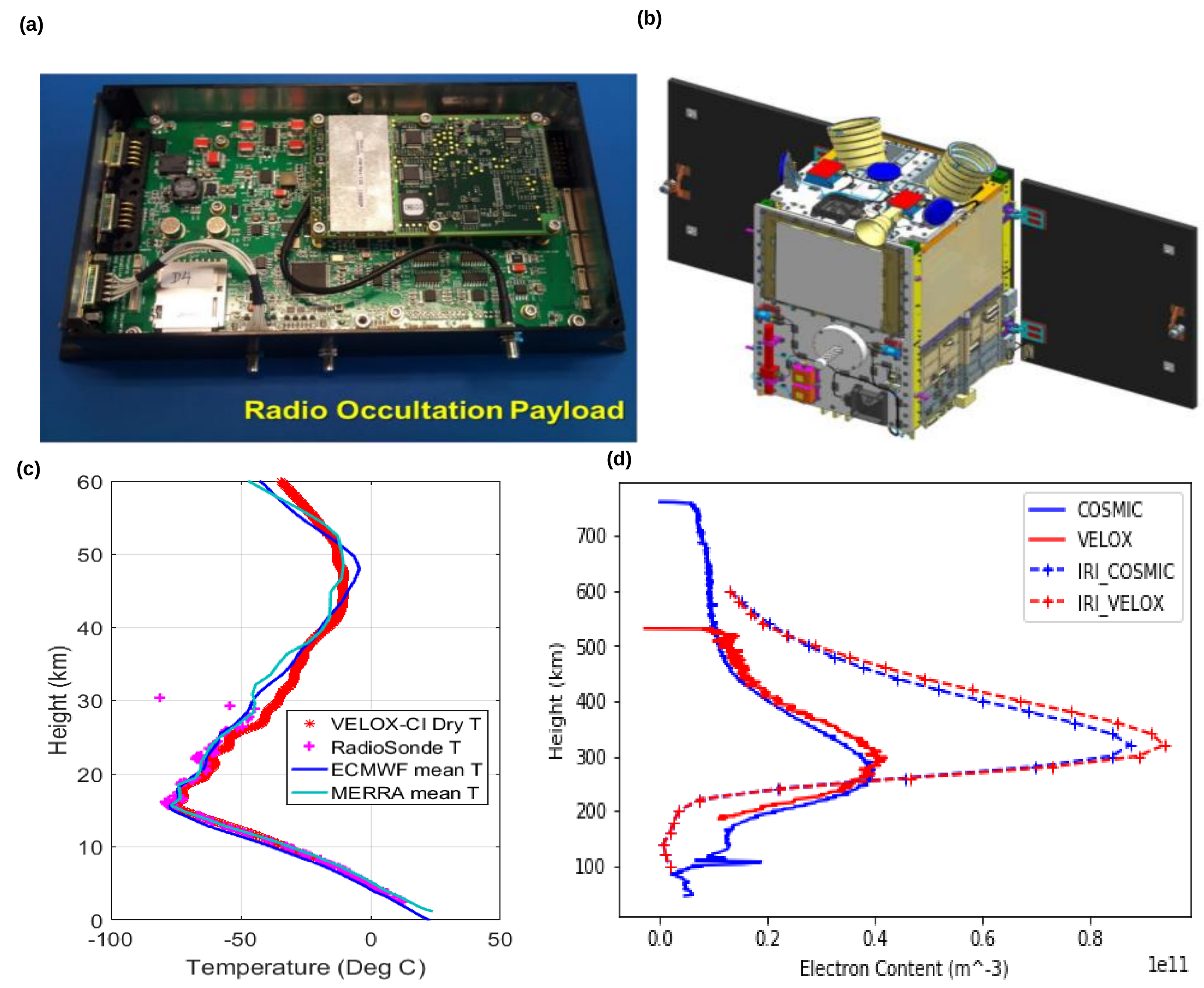


Figure 5: (a) GNSS-RO payload carried on-board VELOX CI satellite developed at Nanyang Technological University Satellite Research Centre (b) The VELOX CI satellite with the GNSS-RO antenna (blue) (c) VELOX -CI atmospheric temperature profile measured with the GNSS-RI payload and compared with Radiosonde, ECMWF and MERRA model vertical profiles. (d) VELOX-CI measured ionosphere electron content compared with COSMIC satellite and IRI profiles. The comparisons show good agreement between the VELOX-CI data and models.

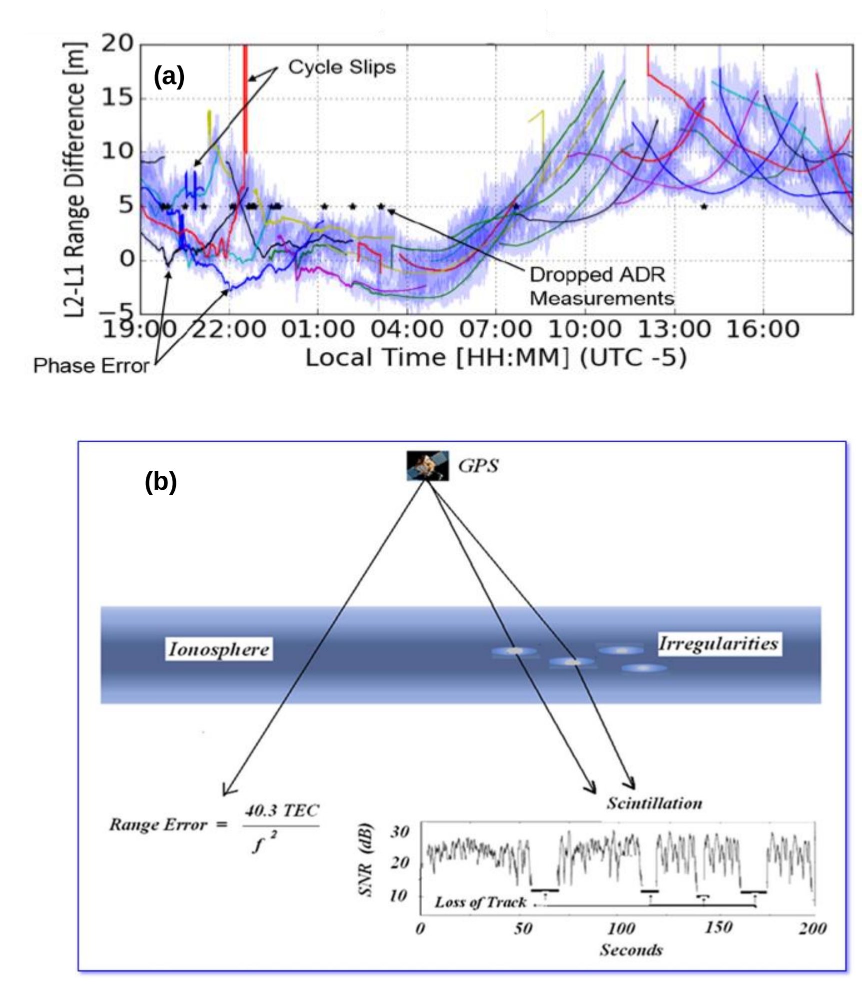


Figure 6. (a) Impact of ionospheric irregularities on GPS signals. Carrier cycle slips, no measurements, and accuracy degradation caused by phase error are demonstrated in the plot. (b) Mechanism of GNSS signal scintillation caused by plasma irregularities in the Ionosphere. Such plasma irregularities are a common feature in the equatorial ionosphere and hence equatorial countries like Singapore are affected more.

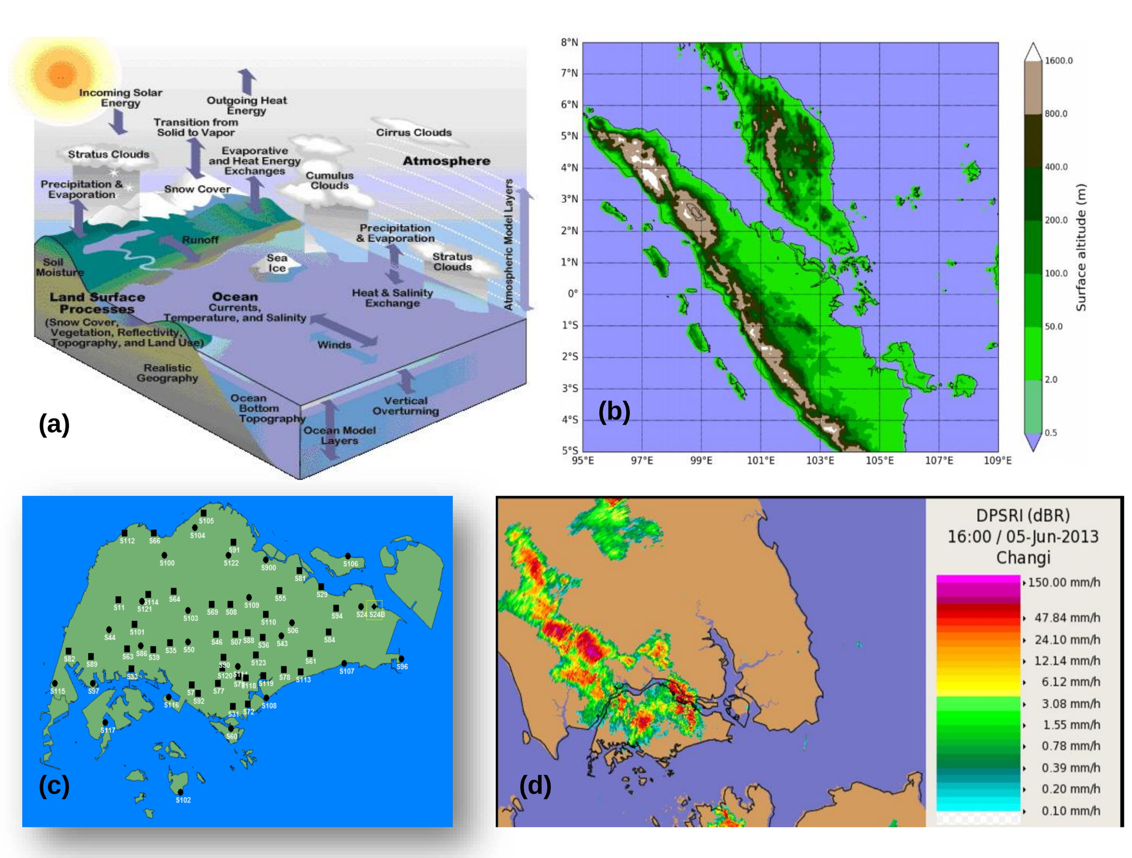


Figure 2. (a) Illustration of different physical processes that affect and are used in Numerical Weather Prediction Models (b) Orographic map of **SINGV** NWP model domain (c) Land based network of automatic weather stations used for data assimilation in SINGV (d) A thunderstorm in Singapore. Note the drastic variability in rainfall that falls across the island. Accurate forecasting of precipitation amount across the island remains a challenge.

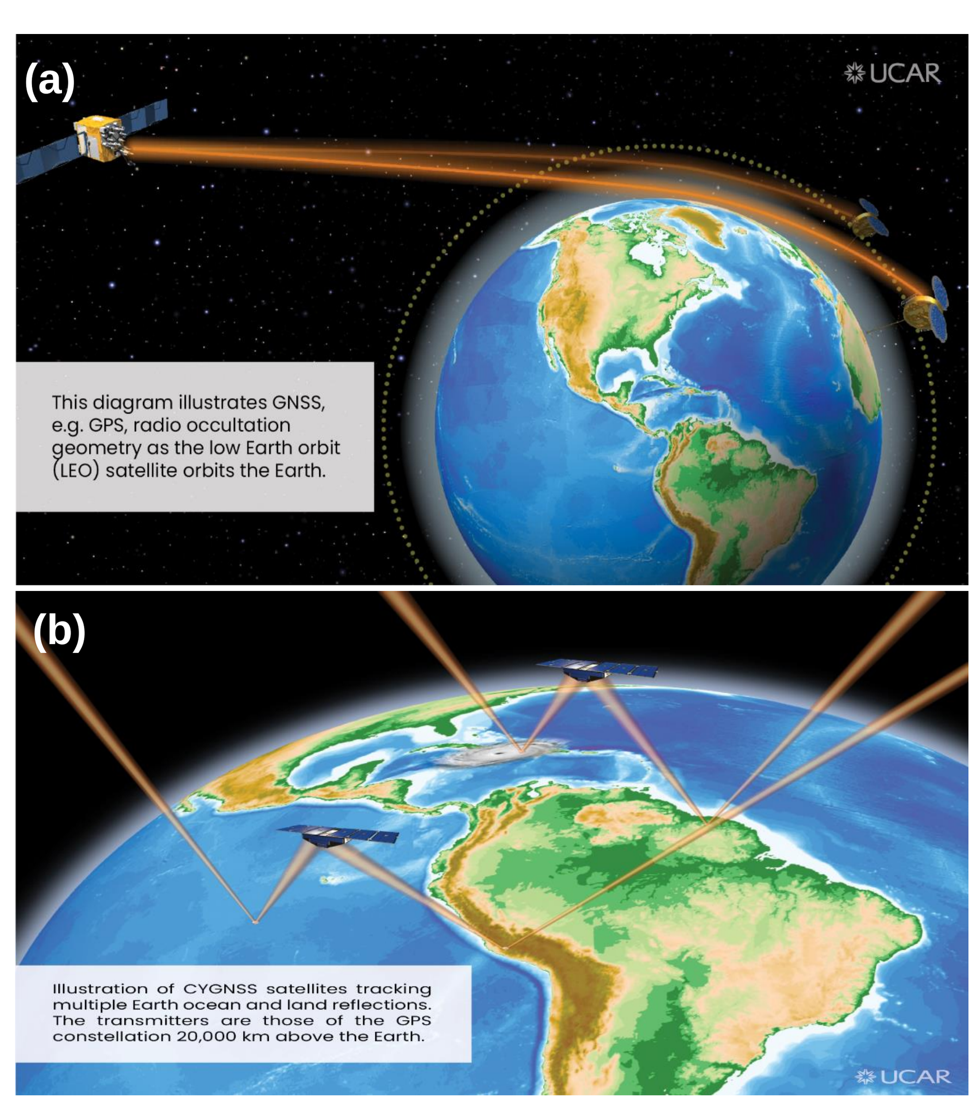
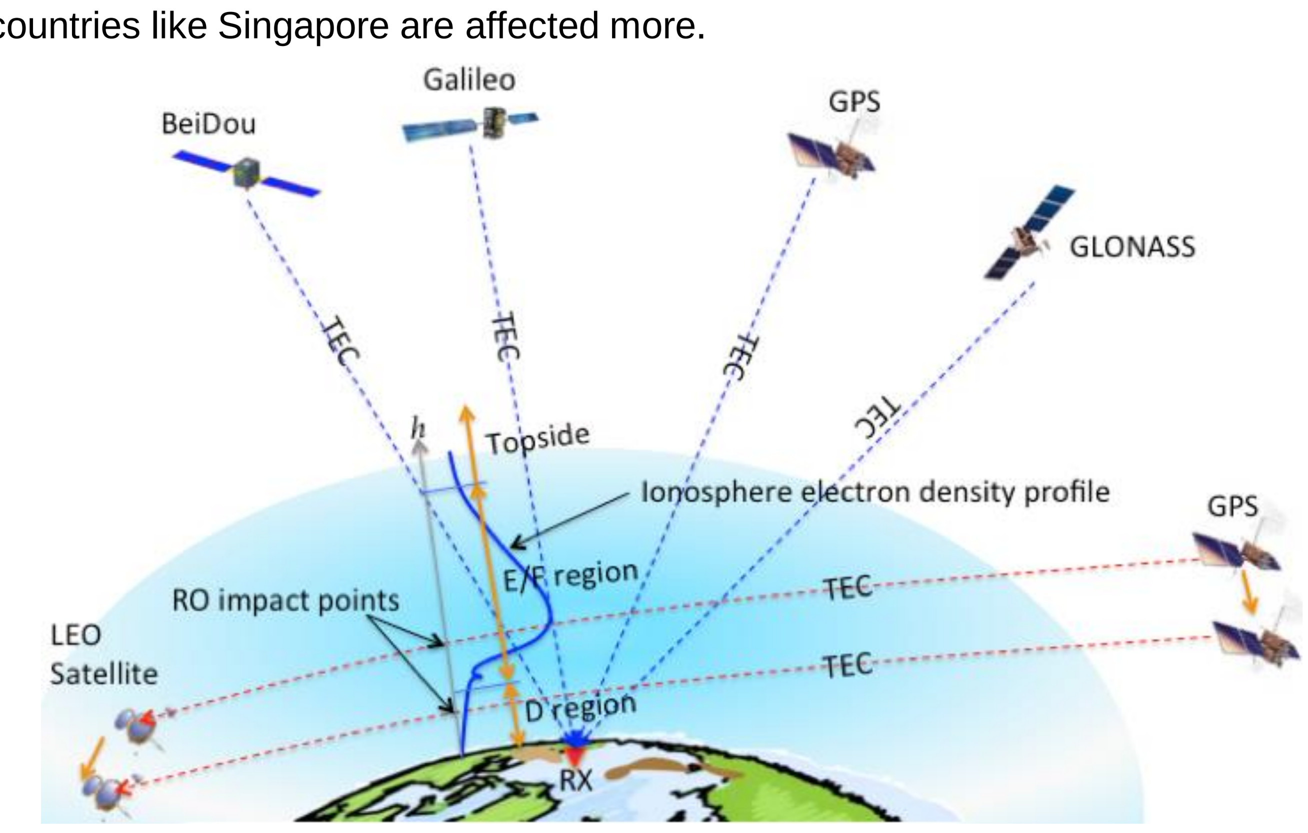


Figure 3: (a) Illustration of GNSS Radio Occultation technique (b) Illustration of GNSS-Reflectometry technique (*Courtesy UCAR*)



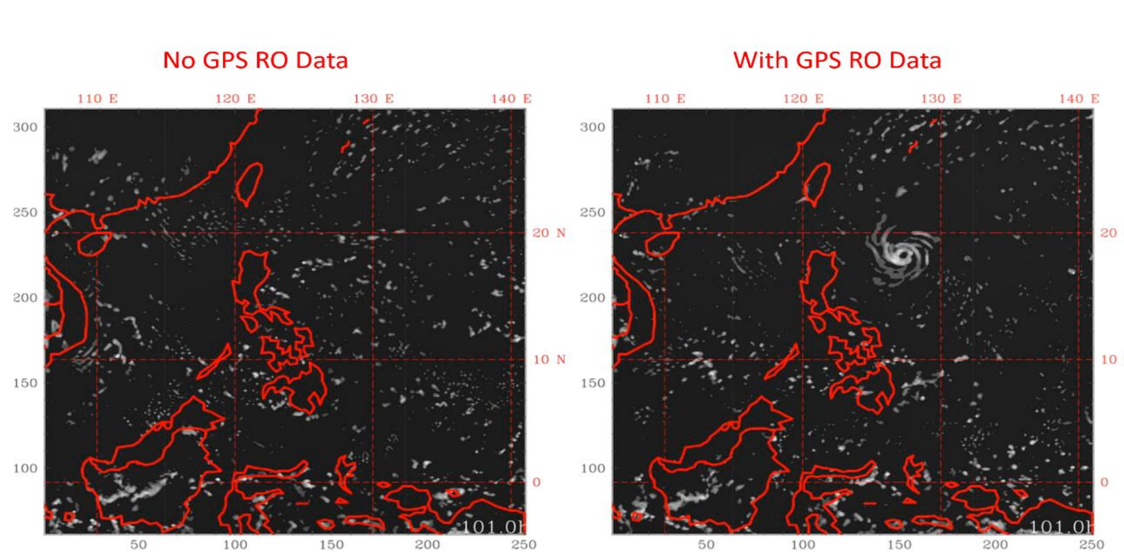


Figure 4. Weather Research and Forecasting (WRF) Model Forecast Starting at 18 UTC 14 August 2008. Following 3-day of GNSS-RO data assimilation showing cyclogenesis for Tropical cyclone Nuri in 2008 in the right panel NorthEast of the Philippines. [*Kuo et al.*, 2016]

Figure 7. Illustration of a ground-based GNSS receiver measurement total electron content (TEC) from multi-constellation GNSS satellites and a LEO satellite performs limb scan of an occulting GPS satellite signal to measure TEC from GPS satellite to LEO satellite. (*Chandran et al., 2018*)