Research Interests – Milad Asgarimehr

My research studies are dedicated to the remote sensing of the Earth using Signals of Opportunity. This refers to the exploitation of the heretofore existing signals normally intended for positioning such as those from the Global Navigation Satellite System (GNSS) including e. g. Global Positioning System (GPS). More specifically, I investigate the use of the GNSS signals after reflection from the Earth's surface. The surface properties leave their signatures in the signals and the geophysical information can be obtained through them after being intercepted by a receiver. This technique is called GNSS Reflectometry (GNSS-R) being illustrated in figure 1. This figure also shows one of the eight microsatellites of the U. S. Cyclone GNSS (CYGNSS) constellation launched in late 2016.

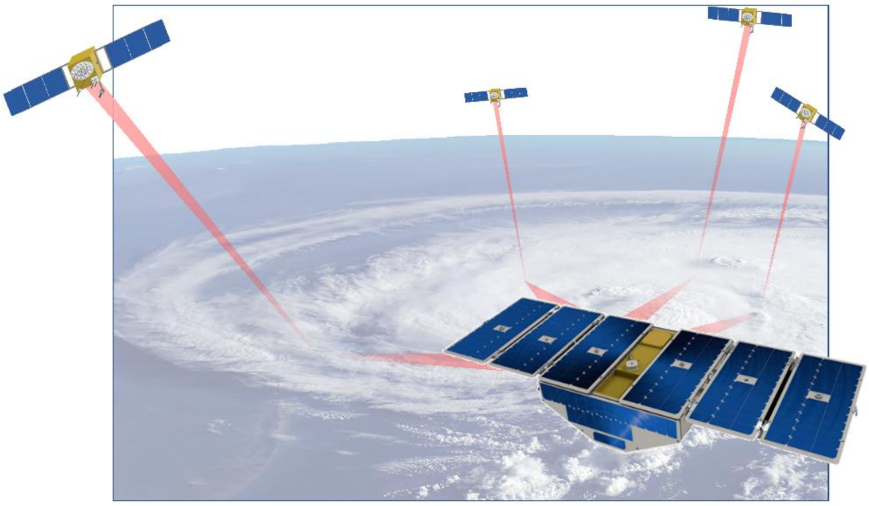

Figure 1 – Illustration of the GNSS Reflectometry technique: One of eight microsatellites of CYGNSS mission tracking four GPS reflected signals from an inner hurricane.

Ocean monitoring is one of the major GNSS-R applications. The pattern of signals scattering from the ocean surface is principally a function of the ocean state, which is, in turn, mainly controlled by the surface wind over fully-developed seas. As a result, GNSS-R receivers can operate as scatterometres tracking the signals simultaneously transmitted from numerous GNSS satellites and reflected from multiple distinct areas. For instance, the GNSS-R receivers onboard CYGNSS can track up to four reflected signals as shown in figure 1. This technique can be therefore considered as a multistatic scatterometry providing geophysical data with an unprecedented sampling rate and high spatial coverage.

My studies develop ocean wind data especially with a high level of robustness during precipitation due to the GNSS operating at L-band frequencies. Such data could accelerate the progress in more efficient severe weather forecasting with closing the data gaps in such atmospheric conditions. My research is followed by the physical characterisation of the observations, not only for a higher quality of the estimates but also for seeking more varied data products. This includes studying rain effects and the altered ocean roughness by the raindrops impinging on the surface. We have demonstrated a rain splash signature in the GNSS-R measurements and provided a plausible physical explanation for this phenomenon based on the recent scattering theories. This study provides a better understanding of the associated physics and potentially could initiate the development of rain detection over calm oceans as a near-future GNSS-R application. Higher spatiotemporal precipitation information could assist the scientists for a better characterisation of the atmospheric patterns and climate change. Besides, the oceanic mechanism of non-wind driven waves (swells) and ocean currents swirling in a roughly circular motion (mesoscale eddies) and their signatures in the GNSS-R measurements are my research interests.

In addition to relying on the theoretical knowledge of radar physics and electromagnetic waves scattering as well as ocean and atmosphere, I have tried to take advantage of data and computer science methodologies. The high number of GNSS-R measurements provides the opportunity for efficient deployment of Artificial Intelligence (AI) techniques. Our interdisciplinary research has recently shown that such a technique could significantly improve the quality of the derived ocean wind speeds. An AI method could be able to capture the highly nonlinear physical interactions dictated by data. This capability also leads to the modelling of a variety of effects on the derived geo-data products. The theoretical models are developed based on simplifying assumptions due to the complexities in the physics of signals scattering from a rough surface and oceanic mechanisms. They are also not yet fully validated for field conditions and might be subjected to refinements. The usage of AI in processing the GNSS-R measurements can additionally enhance the physical understanding of GNSS scattering, in an empirical sense, through an inverse interpretation of the effects and characterising currently hidden geophysical structures in the measurements.

A more significant role of the GNSS-R is expected in the near-future Earth observation. Scientists have been developing a variety of ideas for the exploitation of the cheap and cost-effective receivers on different platforms – from commercial planes to the International Space Station (ISS). I stay committed to promoting the geophysical knowledge using these big datasets requiring novel processing algorithms for practical use. In this sense, I would like to contribute to even more progressed modelling of Earth systems and, consequently, more efficient severe weather forecasts and recognition of the climate change.