AN IMPROVED INLAND WATER DETECTOR USING STANDARD L1 DATA: APPLICATION TO CYGNSS

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ABSTRACT

Earth's inland water detection under thick biomass remains unresolved. Optical sensors are limited by night, clouds and upwelling biomass. The SWAMPS product (active + passive microwave sensors) has a coarse spatial resolution ~ 25 km. C-band Sentinel-1 radar is limited by the upwelling biomass and has a high revisit period. In this work, a new retrieval algorithm based on L1 Cyclone Global Navigation Satellite System (CYGNSS) mission data is developed and results show the capability of water detection under thick biomass ~ 450 ton/ha. The use of the recent IEEE Global Navigation Satellite Systems Reflectometry (GNSS-R) Standard would enable the application of this algorithm by all the present and future GNSS-R missions, and thus generating an unbeatable spatio-temporal sampling by this "virtual" constellation of SmallSats. The capability to accurately resolve surface water extend has an important impact on estimating global methane emissions to the atmosphere.

Index Terms— CYGNSS, GNSS-R, inland water bodies, biomass, coherent scattering

1. INTRODUCTION

Future GNSS-R missions will generate unprecedented amount of standard L1 data [1,2]. It is expected that the number of GNSS-R missions, including constellations, will keep increasing in the near future. On the other hand, more traditional remote sensing missions based on Synthetic Aperture Radar (SAR) and microwave radiometry are limited by the required power consumption, instrument size and mission cost. GNSS-R is a good example of success within the so-called New Space Era, thanks to the improved capabilities of SmallSats platforms and the and long-term plan for deployment and maintenance of GNSS systems (USA Global Positioning System or GPS, Russian GLObal'naya NAvigatsionnaya Sputnikovaya Sistema or GLONASS, European Galileo, Chinese BeiDou).

This significant amount of standard GNSS-R L1 data will cover the Earth's surface with very high spatio-temporal sampling, enabling to further understand Earth's surface dynamic processes. In particular, inland water bodies monitoring will benefit from the high spatial resolution under the coherent scattering regime and the high vegetation & clouds penetration depth at L-band. GNSS-R takes advantage of these two characteristics, and it could synergistically work with other sensors such as the recent Surface Water and Ocean Topography (SWOT) mission.

Standard L1 data include reflected power Delay Doppler Maps (DDMs), however they lack phase information. Reflected phase information can be used to accurately classify the surface: inland water vs. land. This approach is further exploited in a companion paper ["In-orbit real time inland water detection by a future spaceborne GNSS-R receiver"]. Here, the goal is to develop an improved inland water detector using just L1 data. In so doing, the NASA CYGNSS raw Intermediate Frequency (IF) data product is used for development and validation [3]. This procedure provides a more reliable validation than using the Pekel water mask as ground truth, which suffer from weather conditions and clouds.

2. METHODOLOGY

The reflectivity Γ and the power ratio P_{ratio} [4] can be used separately for inland water detection. The reflectivity Γ is more related to the surface permittivity while the power ratio P_{ratio} is an indicator of the surface roughness. If the surface is flat, the power ratio P_{ratio} is high, while it gradually decreases as the surface roughness increases. Both detectors are here combined in a single detector with improved capabilities for water detection. A 2-D Boolean algorithm is used to combine 2 Receiver Operating Characteristic (ROC) curves (Γ and P_{ratio}) using a common inverse Cumulative Distribution Function (CDF) parameterization. A ROC curve shows the capability of diagnosis of a binary classifier as a function of the selected system threshold.

This new improved water detector is applied to one full dry-rainy cycle with CYGNSS L1 data for accurate inland water

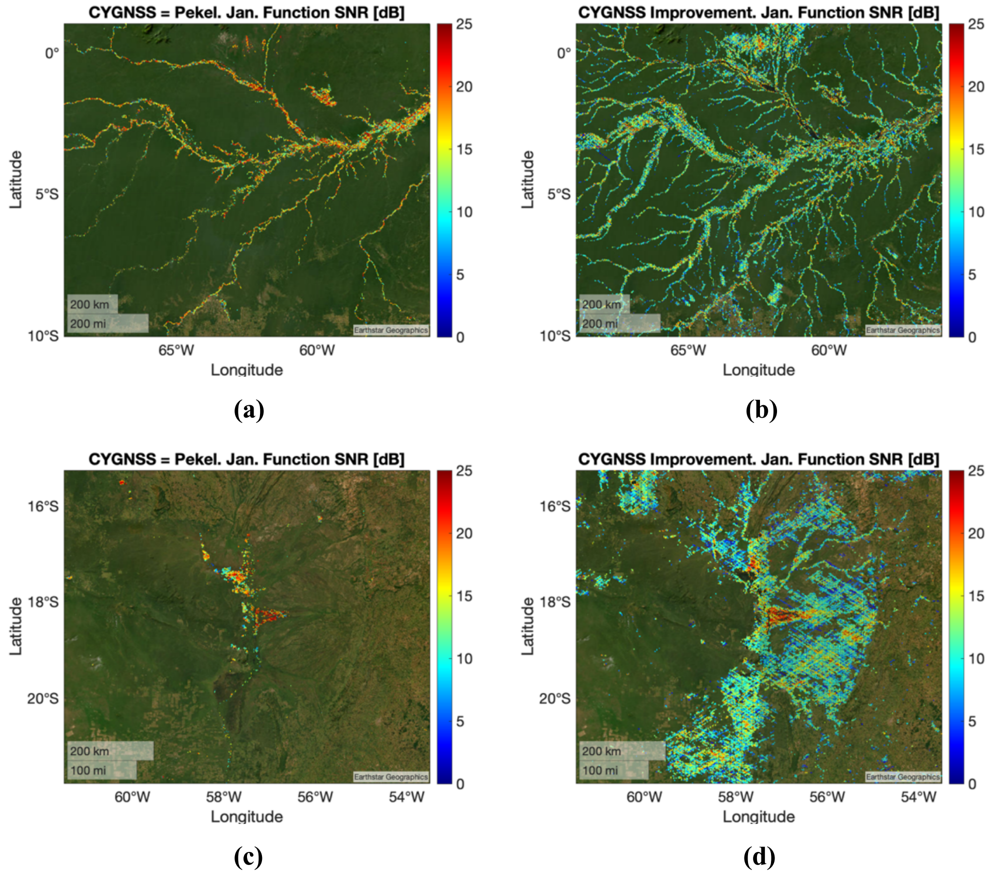

Fig. 1. New CYGNSS L1 water detection algorithm improves Pekel water mask. CYGNSS = Pekel (a,c). CYGNSS improvement as compared to Pekel (b,d). Maps are represented as a function of the signal-to-noise ratio SNR.

monitoring in sub-tropical regions. It is also worth to comment that the method here presented can be applied to other present and future GNSS-R missions including the current constellation of private satellites operated by Spire [5] and the upcoming Hydrology using GNSS reflections (HydroGNSS) mission by European Space Agency [6].

3. RESULTS

The new CYGNSS L1 water detection algorithm improves Pekel water masks. In regions with high biomass this algorithm is able to detect surface water while Pekel does not (Fig. 1). Earth' surface reflected signals are coherently scattered but they are attenuated by biomass and thus the SNR is low. Final results will be presented at the conference.

4. CONCLUSION

The NASA CYGNSS mission resolves surface water extension under thick biomass. CYGNSS provides accurate characterization of surface water extend independently of weather e.g. clouds and day/night transitions.

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