Signals of Opportunity in Earth and Planetary Science

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Planetary Radar and Radio Sciences Group

Communications, Tracking and Radar Division

Jet Propulsion Laboratory
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IEEE Rising Stars Conference

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Outline

1. My Path to Success:

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament de Teoria del Senyal i Comunicacions

Masters
(2005-2006)

Ph.D. Thesis
(2006-2011)

UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament de Teoria del Senyal i Comunicacions

Colorado State University

Postdoc
(2012-2013)

Postdoc
(2013-2015)

PURDUE UNIVERSITY

CYGNSS

CYCLE SciTech

CRG Centre for Genomic Regulation

Entrepreneurship
(2016)

Mom at Home
(2017)

NASA Jet Propulsion Laboratory
California Institute of Technology

JPL Scientist (2018-Present)

2. Summary and remarks

My Path to Success. Masters (2005-2006)

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Departament de Teoria del Senyal i Comunicacions

I studied Telecommunications (equivalent to Electrical Engineering in the US) and I gained:

- Broad knowledge: antennas, signal processing, communications, programming
- Analysis skills: physics, calculus, statistics

But what do I do with all of these?

I wanted to use the knowledge to build technology, but I also wanted to use the technology for an application.

I tried many different options within the broad spectrum of classes offered by UPC… I finally found one I loved, Remote Sensing.

For me, **Earth Remote Sensing** is where technology and science become the perfect couple.

My Path to Success. Masters (2005-2006)

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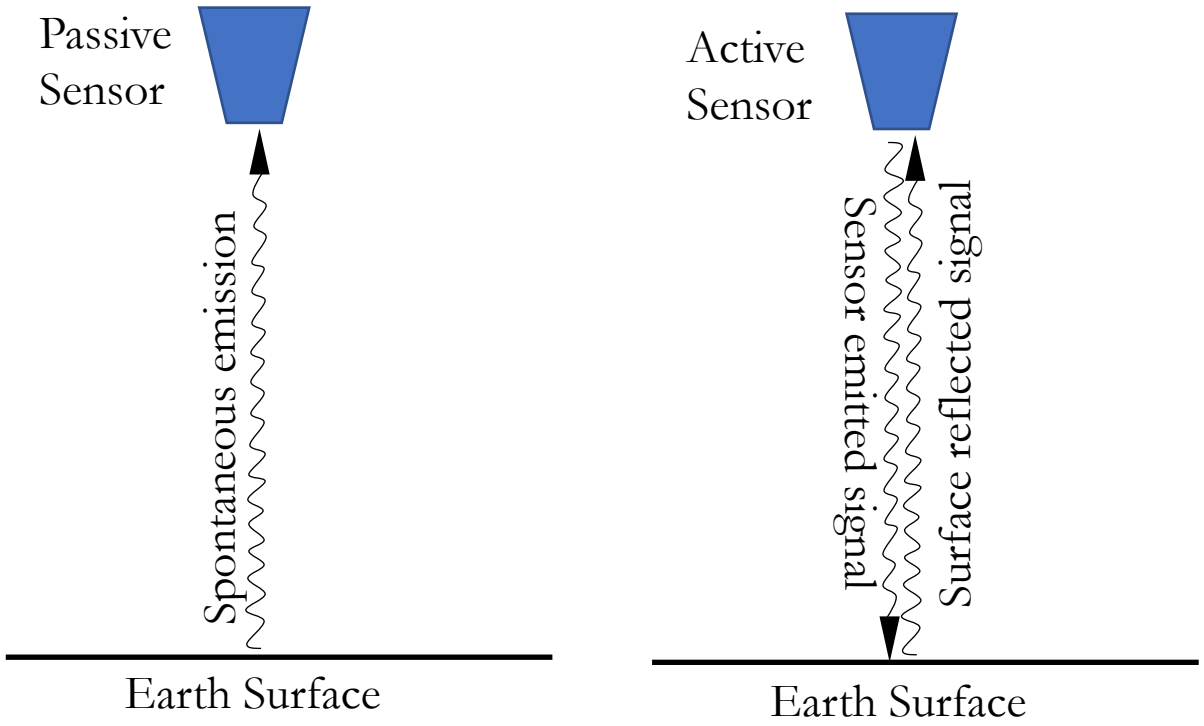
What is Earth Remote Sensing?



I finally joined the Earth Remote Sensing group at UPC: Passive Remote Sensing (PRS) and my adventure started:

My Path to Success. Masters (2005-2006)

Passive Advanced Unit (PAU) Instrument – The 2004 European Young Investigator Awards (EURYI) by the European Science Foundation (ESF) awarded to Prof. Adriano Camps.

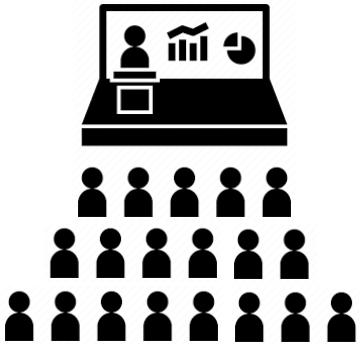
Instrument:

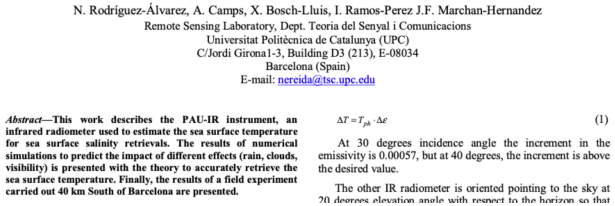
- PAU Radiometer - Measure ocean emissivity from its spontaneous emission (depending on salinity, ocean roughness and temperature).
- PAU Reflectometer – Measure ocean roughness from GPS reflected signals.
- PAU Infrared Radiometer – Measure ocean physical temperature from its thermal infrared emission.

Science: Use all three measurements to improve sea surface salinity retrievals, important to determine ocean circulation.

I successfully led the PAU Infrared Radiometer (PAU-IR)

Went to a conference for the first time!





Sea Surface Temperature Retrieval Using IR-Radiometry and Atmospheric Modeling: Simulation and Experimental Results Using PAU-IR

N. Rodríguez-Álvarez, A. Camps, X. Bosch-Lluis, I. Ramos-Perez J.F. Marchan-Hernandez
Remote Sensing Laboratory, Dept. Teoria del Senyal i Comunicacions
Universitat Politècnica de Catalunya (UPC)
C/Jordi Girona1-3, Building D3 (213), E-08034
Barcelona (Spain)
E-mail: nereida@tsc.upc.edu

***Abstract*—This work describes the PAU-IR instrument, an infrared radiometer used to estimate the sea surface temperature for sea surface salinity retrievals. The results of numerical simulations to predict the impact of different effects (rain, clouds, visibility) is presented with the theory to accurately retrieve the sea surface temperature. Finally, the results of a field experiment carried out 40 km South of Barcelona are presented.**

$$\Delta T = T_{ph} \cdot \Delta\varepsilon \quad (1)$$

At 30 degrees incidence angle the increment in the emissivity is 0.00057, but at 40 degrees, the increment is above the desired value.

The other IR radiometer is oriented pointing to the sky at 20 degrees elevation angle with respect to the horizon so that

I became really interested in the **use of GPS signals to measure properties of the Earth**, that was my first contact with signals of opportunity, and I decided to do my Ph.D. in the so called GNSS-R field.

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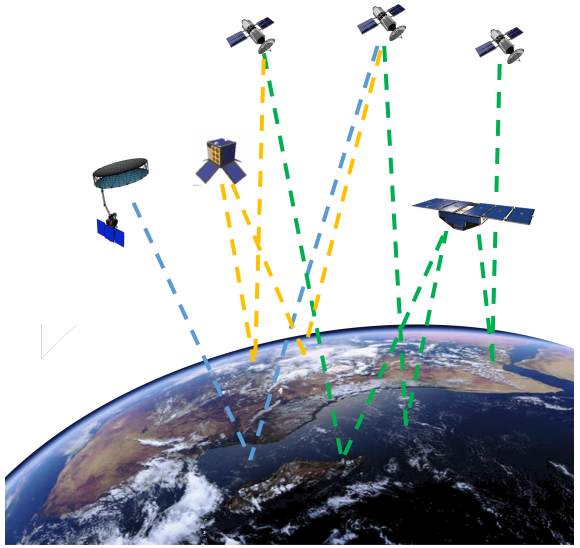
What Is Then A Signal Of Opportunity?

- Signals of Opportunity are signals that, in addition to their intended purpose (i.e. GPS: geolocation), are used to infer properties of the materials or surfaces in which they reflect or go through.
- Examples:
  - Global Positioning System (GPS) – L-band
  - Mobile User Objective System (MUOS) – P-band
  - Digital TV,…
- Signals from the GPS constellations have been broadly used by the scientific community.
- Many bistatic radar ground-based systems were built during years to prove the science.
- Soon after, the first aircraft experiments helped the concept to grow and the technology to mature.
- Finally the first satellite missions became a reality:
  - UK-DMC, 2003 (experiment)
  - TechSemoSat-1, 2014 (in-space test facility)
  - CYGNSS, 2016 (specific mission)
  - SMAP, 2015 (radar rx mode, re-purposed)
- And with those, the global science applications flourished.



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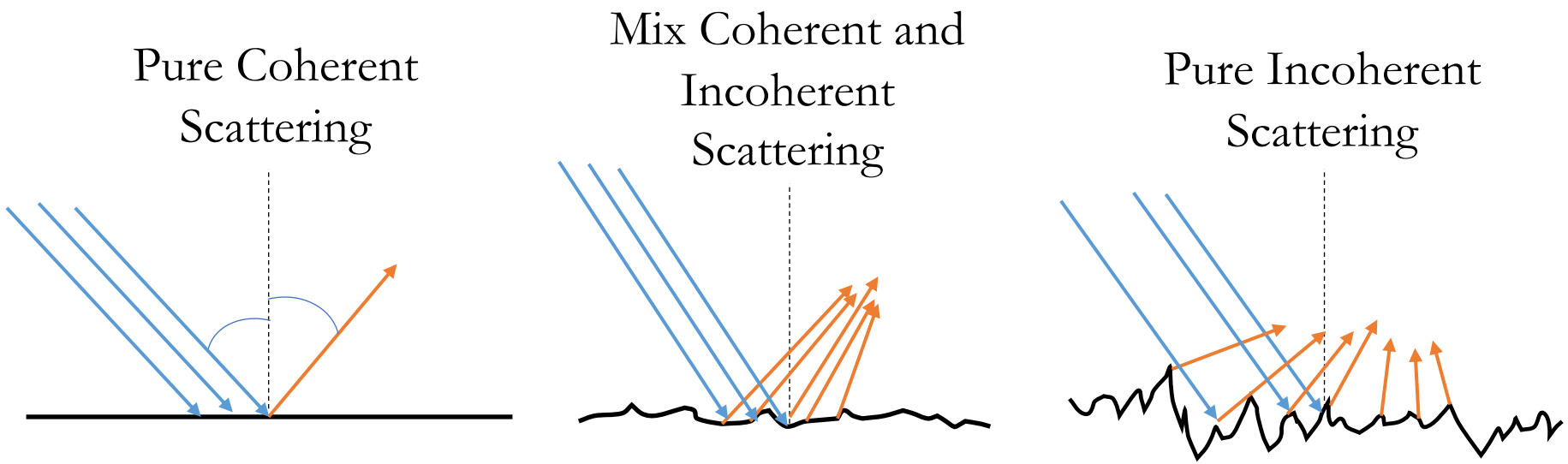
In General, How Do We Measure The GPS Signal?

First, we build a GPS receiver.
Then, the receiver measures different contributions depending on the surface properties



What the receiver sees is the GPS signal reflected from different surface points towards the receiver. The rougher is the surface the wider is the scattering area from where those reflections are coming from.

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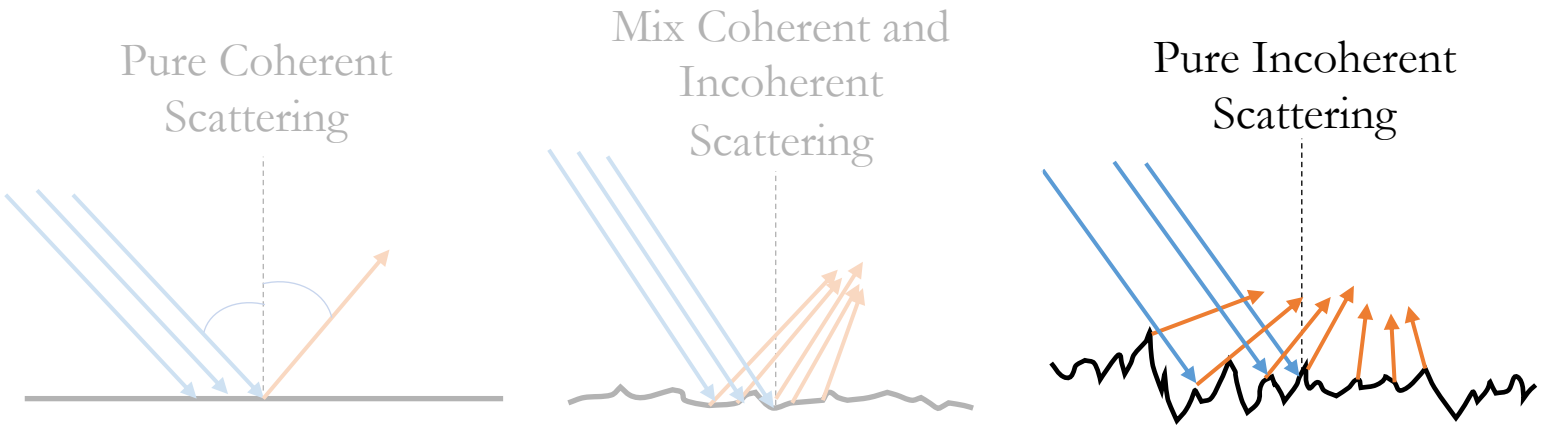
So… The Scattering Properties Depend on The Surface Type!



Ocean surface is dominated by incoherent scattering.
Heavily vegetated landscapes also have a strong incoherent component.

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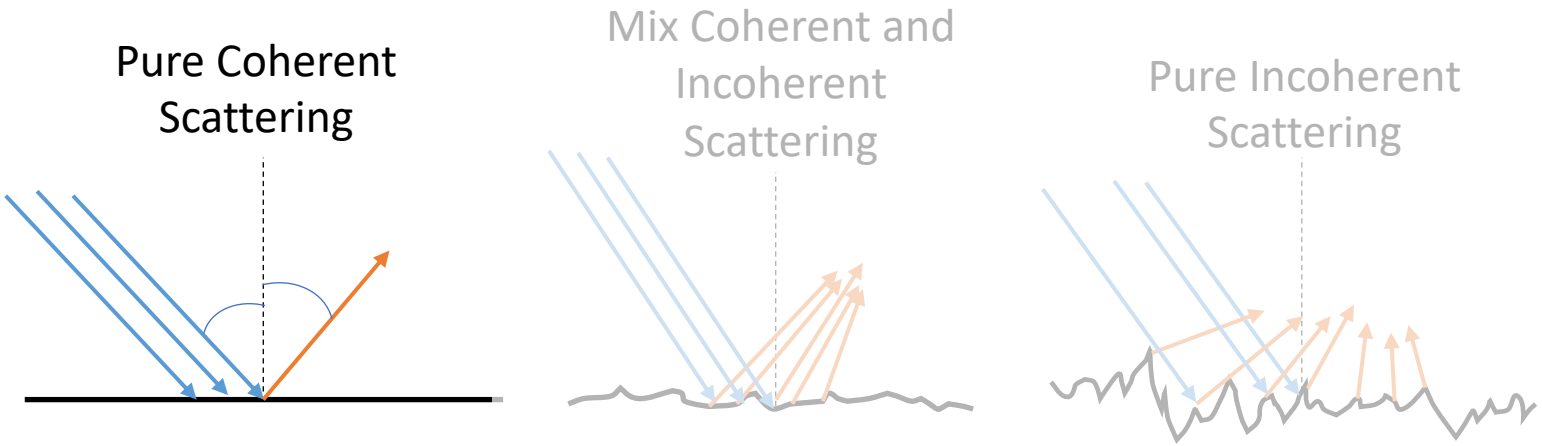
So… The Scattering Properties Depend on The Surface Type!



Lakes, rivers, wetlands and smooth ice surfaces are dominated by the coherent scattering.

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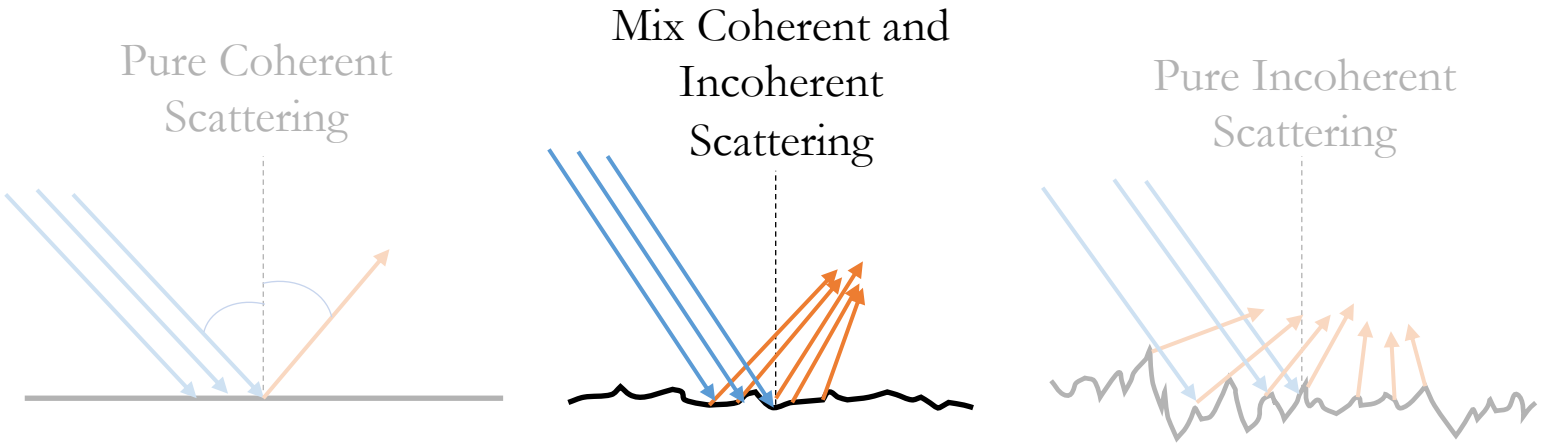
So… The Scattering Properties Depend on The Surface Type!



Land surfaces with low vegetation or no vegetation a mix between coherent and incoherent scattering.

Soil moisture decrease

Vegetation height and Vegetation Water Content increase

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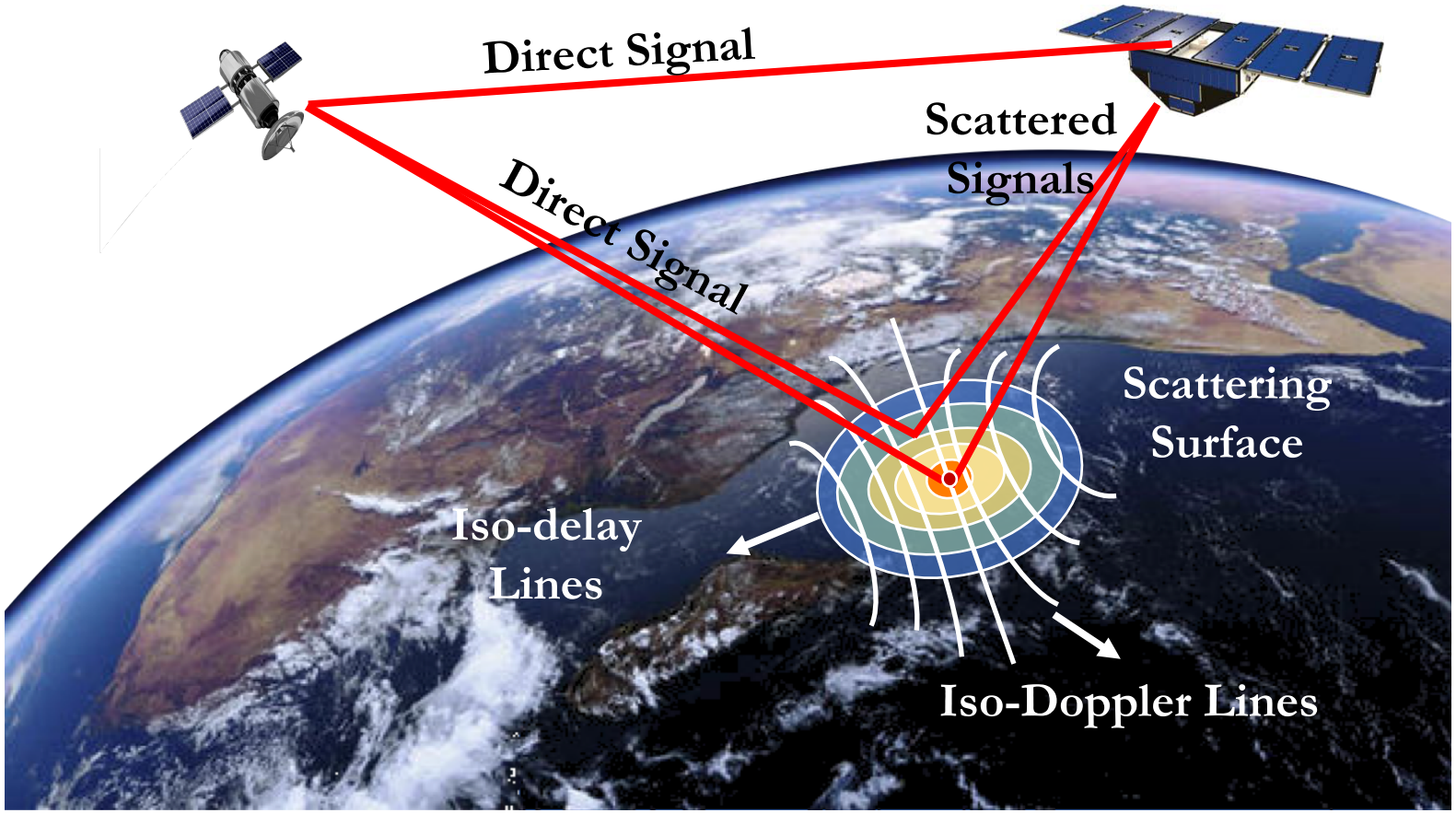
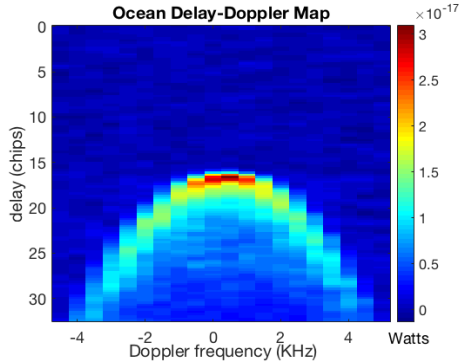
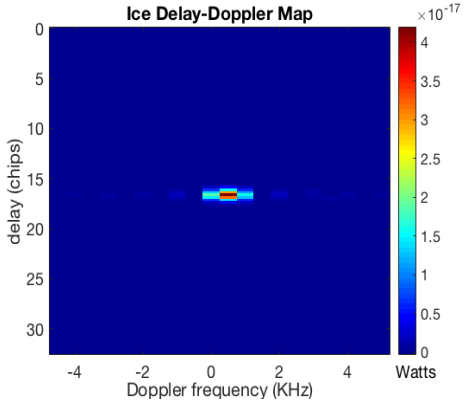
What Do We Measure?







But let's not skip ahead of time: my Ph.D. thesis and the time of ground-based instruments.

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What Do We Measure From a Ground-Based Receiver?

- From a ground-based instrument:
  - There will not be any Doppler spread
  - The received power will be affected by the reflectivity of the surface

- Measure power as a proxy to the reflectivity. We need:
  - Measurement of the variations of the reflected GPS signal
  - Also, the GPS transmitted power is not constant, so let's make sure we get the reference: Measurement of the direct GPS signal.

- At what polarization?
  - GPS transmits right hand circularly polarized (RHCP). Antenna for the direct signal must be RHCP.
  - Signal reflects of the surface of the Earth and becomes left hand circularly polarized (LHCP). Antenna for the reflected signal must be LHCP.

But the Reflectivity is linked to the Soil Moisture… and the Soil Moisture is Well Characterized by the Brewster Angle at V-pol, Right?

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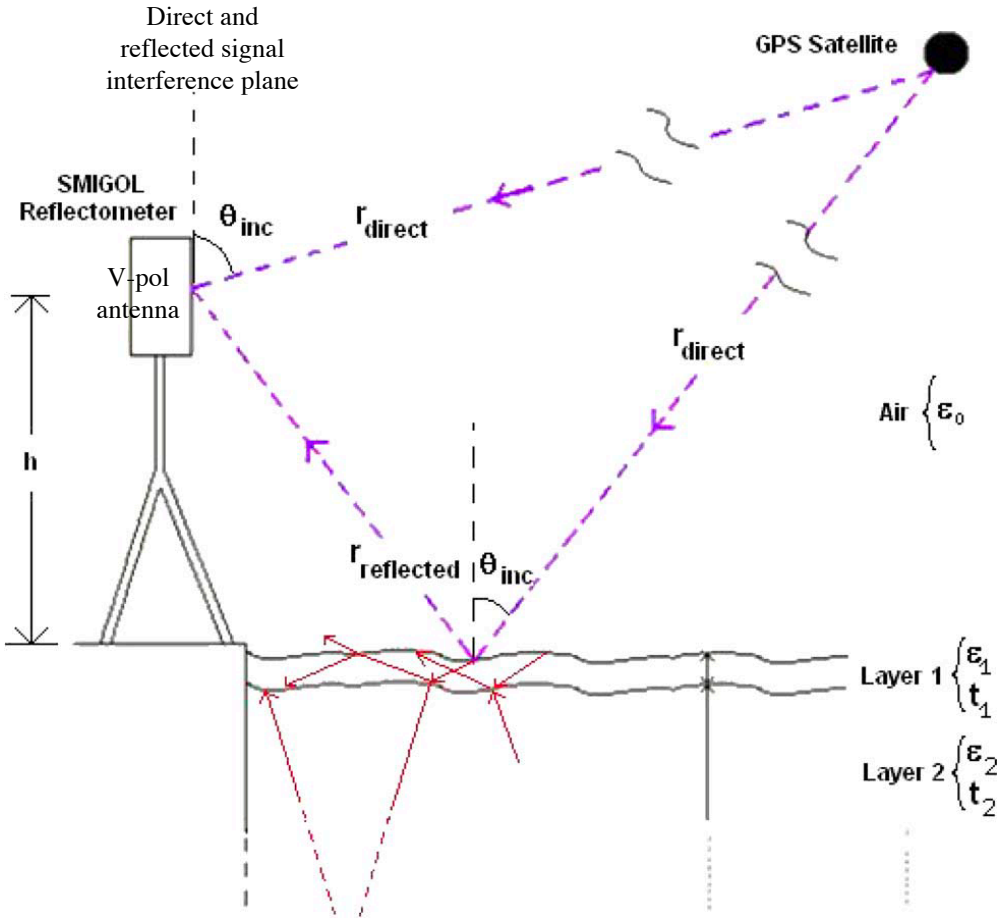
I Got A Ph.D Idea!

- New reflectometer concept (SMIGOL):
  - Implicit calibration of the antenna pattern and the transmitted power
    - 1 single antenna looking at the horizon
    - Symmetric antenna pattern respect the horizon
    - Direct and reflected signal interference at the plane of the antenna
  - Brewster angle estimations
    - Vertical polarization



SMIGOL: **S**oil **M**oisture **I**nterference-pattern **G**NSS **O**bservations at **L**-band.

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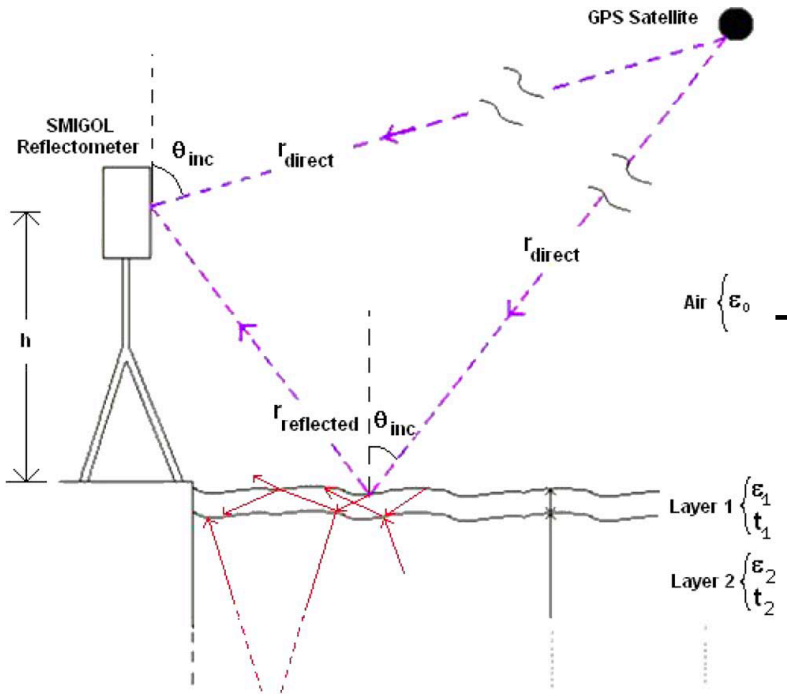
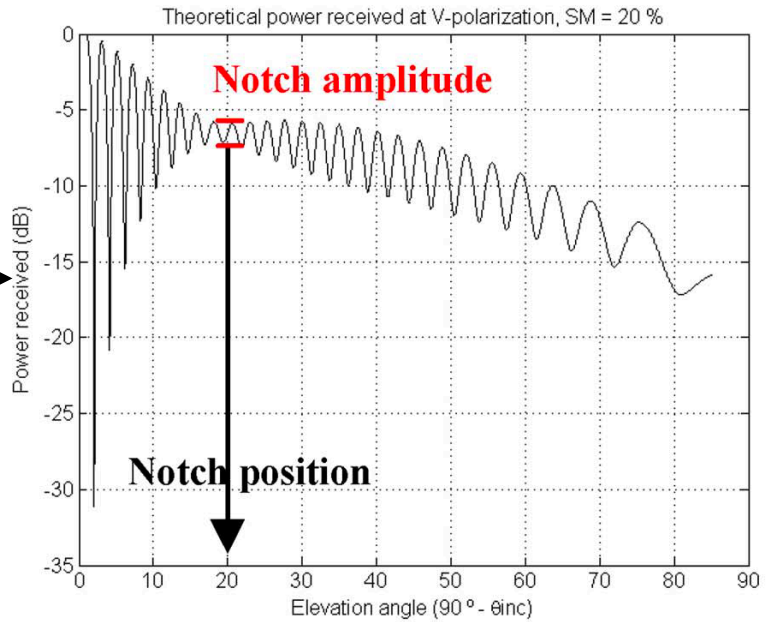
Modelling



Electromagnetic model



- Interference pattern due to the constructive and deconstructive interference of the direct and reflected signals.
- Speed of the oscillations: linked to the height of the instrument respect to the ground => **Surface topography estimations**
- Minimum amplitude of the oscillation (notch) coincident in position with the Brewster angle => **Soil moisture estimations**
- Amplitude of the oscillations => **Soil moisture estimations**

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Scientific Impact

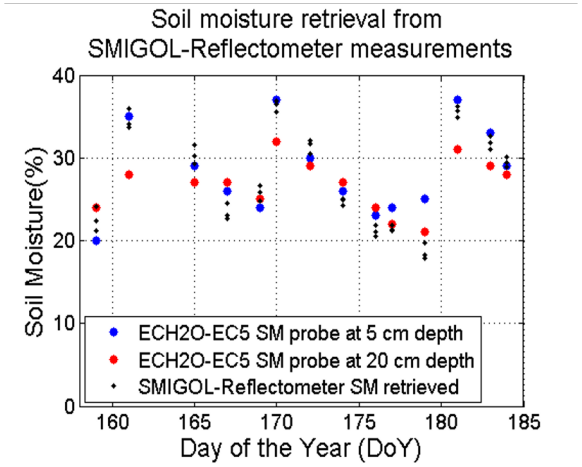
3616 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 47, NO. 11, NOVEMBER 2009

Soil Moisture Retrieval Using GNSS-R Techniques: Experimental Results Over a Bare Soil Field

Nereida Rodriguez-Alvarez, *Student Member, IEEE*, Xavier Bosch-Lluis, *Student Member, IEEE*, Adriano Camps, *Senior Member, IEEE*, Mercè Vall-llossera, *Member, IEEE*, Enric Valencia, *Student Member, IEEE*, Juan Fernando Marchan-Hernandez, *Student Member, IEEE*, and Isaac Ramos-Perez, *Associate Member, IEEE*

***Abstract*—This paper presents a new technique to retrieve soil moisture using global navigation satellite signals reflected over the soil surface using the measurement of the power fluctuations of the signal created by the interference between the direct GPS signal and the one reflected over the soil surface. As a function of the elevation angle, power fluctuations at vertical polarization pass through a notch, which is related to the soil moisture content, while horizontal polarization exhibits a very weak dependence.**

relations for different Doppler shifts). In addition, these global navigation satellite signal (GNSS) reflectometry techniques have been widely used for sea-state retrieval [15]–[18] testing and validating their capability to retrieve surface geophysical parameters. As compared to SAR or radar systems, a GPS reflectometer has the advantage of being a passive instrument, in which the signals emitted by the GPS satellites are taken as



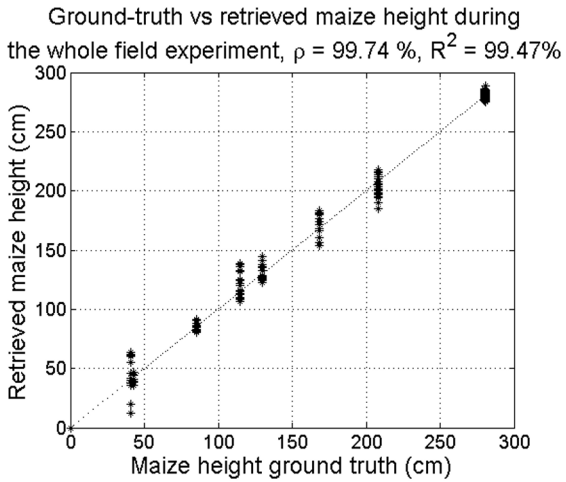
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 49, NO. 1, JANUARY 2011 71

Land Geophysical Parameters Retrieval Using the Interference Pattern GNSS-R Technique

Nereida Rodriguez-Alvarez, *Student Member, IEEE*, Adriano Camps, *Senior Member, IEEE*, Mercè Vall-llossera, *Member, IEEE*, Xavier Bosch-Lluis, *Student Member, IEEE*, Alessandra Monerris, *Student Member, IEEE*, Isaac Ramos-Perez, *Associate Member, IEEE*, Enric Valencia, *Student Member, IEEE*, Juan Fernando Marchan-Hernandez, *Student Member, IEEE*, Jose Martinez-Fernandez, Guido Baroncini-Turricchia, Carlos Pérez-Gutiérrez, and Nilda Sánchez

***Abstract*—In the past years, the scientific community has placed a special interest in remotely sensing soil moisture and vegetation parameters. Radiometry and radar techniques have been widely used for years. Global Navigation Satellite Systems opportunity signals Reflected (GNSS-R) over the earth's surface are younger, but they have already shown their potential to perform these observations. This paper presents a GNSS-R technique, based on Global Positioning System (GPS) measurements, that allows the retrieval of several geophysical parameters from land surfaces.**

ocean salinity retrieval [7]–[10], soil moisture can be retrieved over land surfaces [11]–[15], and ice age or thickness can be retrieved over iced surfaces [16]. The particular GNSS-R technique used in this paper is the Interference Pattern Technique (IPT) that consists of measuring the power fluctuations of the interference of the direct and the reflected electric fields as the Global Positioning System (GPS) satellite moves. The



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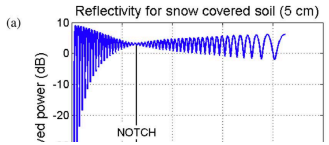
Scientific Impact

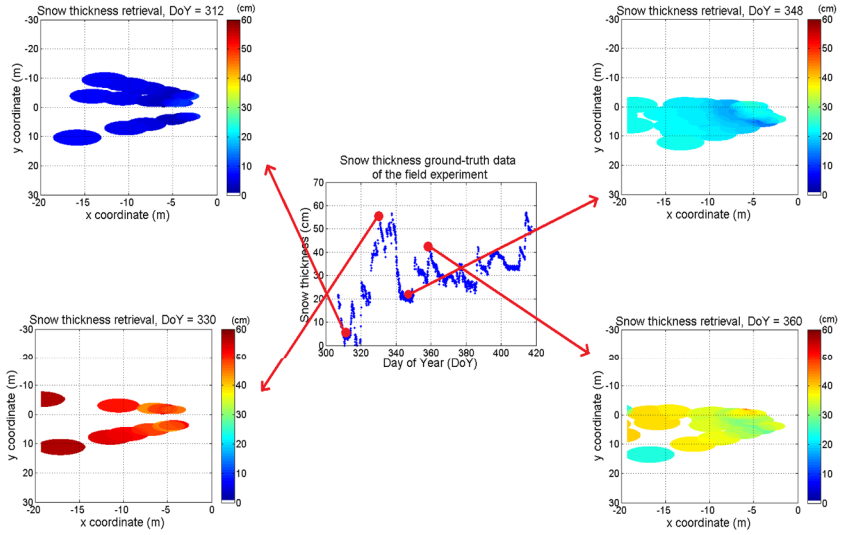
IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 9, NO. 6, NOVEMBER 2012 1109

Snow Thickness Monitoring Using GNSS Measurements

Nereida Rodriguez-Alvarez, *Student Member, IEEE*, Albert Aguasca, *Member, IEEE*, Enric Valencia, *Student Member, IEEE*, Xavier Bosch-Lluis, *Student Member, IEEE*, Adriano Camps, *Fellow, IEEE*, Isaac Ramos-Perez, *Student Member, IEEE*, Hyuk Park, *Member, IEEE*, and Merce Vall-llossera, *Member, IEEE*

***Abstract*—Global navigation satellite system reflectometry has already shown its potential to perform retrievals of a number of geophysical parameters, including soil moisture, vegetation height, etc. This letter focuses on the study of snow-covered soils using the interference pattern technique (IPT) with the Soil Moisture Interference-pattern GNSS Observations at L-band (SMIGOL) reflectometer, a ground-based instrument. Snow effects are analyzed, and an algorithm has been developed for this type of surfaces. From November 2010 to May 2011, a long-term field**





WATER LEVEL MONITORING USING THE INTERFERENCE PATTERN GNSS-R TECHNIQUE

N. Rodriguez-Alvarez[1], *X. Bosch-Lluis*[1], *A. Camps*[1,2], *I. Ramos-Perez*[1], *E. Valencia*[1], *H. Park*[1], *M. Vall-llossera*[1,2]

[1]Remote Sensing Lab, Dept.Teoria del Senyal i Comunicacions, D3, Universitat Politècnica de Catalunya and IEEC CRAE/UPC.
[2]SMOS Barcelona Expert Centre. Pg. Marítim de la Barceloneta 37–49, E-08003 Barcelona, Spain
Tel. +34+934017362, E-08034 Barcelona, Spain.

ABSTRACT

In the last decade GNSS-R techniques have started to be used for Earth remote sensing [1-7]. In previous studies, the Interference Pattern Technique (IPT) was used to observe much simpler IPT is applied to perform a similar study with centimetric accuracy. The IPT consists of the simultaneous measurement of the direct GPS signal and the reflected one over the surface, which add coherently at the receiving antenna (Fig. 1).

Ground truth	SAT	Mean level retrieved	Δh
3.000 m	22	2.982 m	1.8 cm
	31	2.991 m	0.9 cm
3.006 m	28	2.997 m	0.9 cm
3.012 m	19	3.002 m	1.0 cm
	23	3.003 m	0.9 cm
3.024 m	24	3.017 m	0.7 cm
3.036 m	13	3.022 m	1.4 cm
	24	3.028 m	0.8 cm
3.048 m	17	3.052 m	0.5 cm
	8	3.032 m	1.6 cm
	7	3.037 m	1.1 cm

Scientific Impact

282 IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 9, NO. 2, MARCH 2012

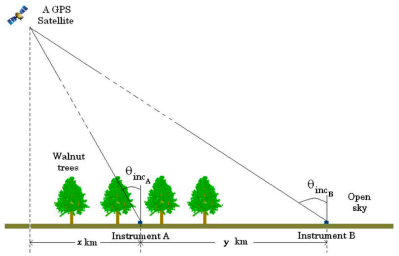
Vegetation Water Content Estimation Using GNSS Measurements

Nereida Rodriguez-Alvarez, *Student Member, IEEE*, Xavier Bosch-Lluis, *Student Member, IEEE*, Adriano Camps, *Fellow, IEEE*, Isaac Ramos-Perez, *Student Member, IEEE*, Enric Valencia, *Student Member, IEEE*, Hyuk Park, *Member, IEEE*, and Merce Vall-llossera, *Member, IEEE*

***Abstract*—Global Navigation Satellite Systems (GNSS) opportunity signals reflected at or near the Earth's surface have already shown their potential to perform retrievals of a number of geophysical parameters. Radio occultations using GNSS signals are also used for atmospheric sensing. This letter presents a GNSS technique to retrieve vegetation water content (VWC). This technique measures the received powers of the GPS signals in open sky and under the vegetation layer. From these two powers, the attenuation due to the vegetation is computed, which is related to the VWC. This letter presents the results obtained after deploying the instrument in a walnut-tree stand for 11 months.**

***Index Terms*—Global Navigation Satellite Systems (GNSS), vegetation, water content.**

I. Introduction



626 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 51, NO. 1, JANUARY 2013

Airborne GNSS-R Wind Retrievals Using Delay–Doppler Maps

Nereida Rodriguez-Alvarez, *Student Member, IEEE*, Dennis M. Akos, Valery U. Zavorotny, *Fellow, IEEE*, Jeffrey A. Smith, Adriano Camps, *Fellow, IEEE*, and Christopher W. Fairall

***Abstract*—Global navigation satellite system (GNSS) reflectometry has emerged recently as a promising remote sensing tool to retrieve various geophysical parameters of the Earth's surface. GNSS-reflected signals, after being received and processed by the airborne or spaceborne receiver, are available as delay correlation waveforms or as delay–Doppler maps (DDMs). In the case of a rough ocean surface, those characteristics can be related to the rms of the L-band limited slopes of the surface waves and, from there, to the surface wind speed. The raw GNSS-reflected signal can be either processed in real time by the receiver or recorded and stored on board and postprocessed in a laboratory. The latter approach leveraging a software receiver allows more flexibility while processing the raw data. This work analyzes DDMs obtained as a result of processing of the data collected by the Global Positioning System (GPS) data logger/software receiver on board the National Oceanic and Atmospheric Administration Gulfstream-IV jet aircraft. Thereafter, the DDMs were used to retrieve surface wind speed employing several different metrics**

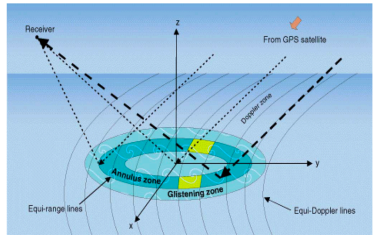
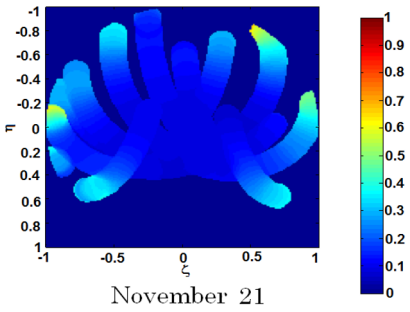
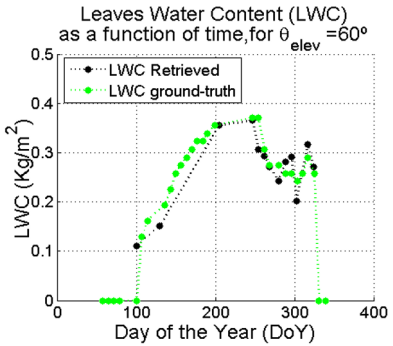
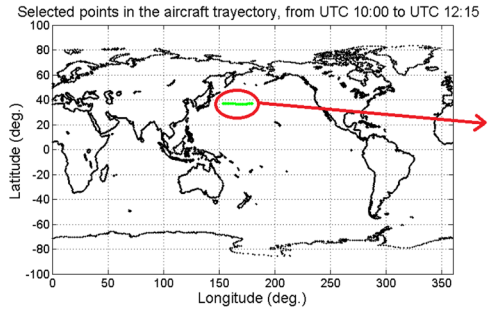
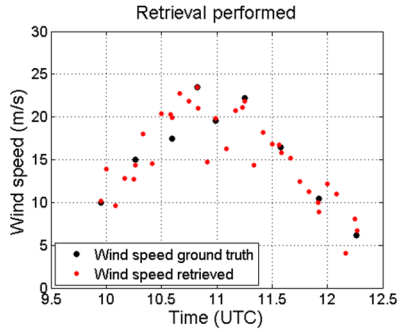


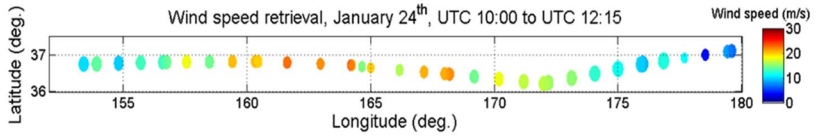
Fig. 1. Geometry of the GPS signals scattered over the ocean surface.











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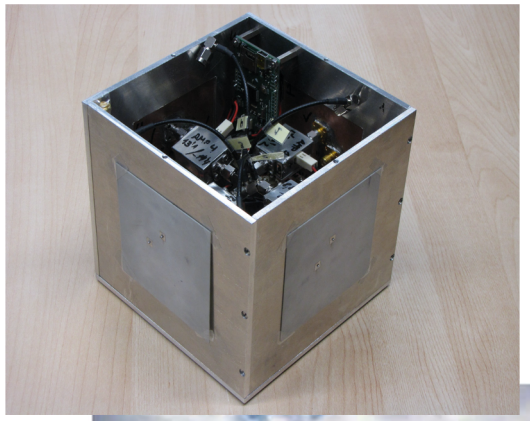
What Did I Learn?

- I learned about Global Navigation Satellite System (GNSS) – Reflectometry
- Built a reflectometer myself – loved the hands-on part of my Ph.D.!
- Understood the physics behind the measurements I was actually gathering myself.
- Build my first retrieval algorithms for: soil moisture, vegetation height, snow depth and reservoir's water level.
- Did my first scientific contributions!



My Path to Success. Post-Doctoral Fellowship (2012-2013)

What Next?

What do I do to keep on expanding my research and my expertise?

Industry (Spain)

Personal growth?	Research?	Salary?	Expertise?
Rare	No	Medium/ Low	Rare

Academia (Spain)

Personal growth?	Research?	Salary?	Expertise?
Maybe	Yes	Low	Yes

Industry (US)

Personal growth?	Research?	Salary?	Expertise?
Yes	Yes, R&D	High	Yes

Academia (US)

Personal growth?	Research?	Salary?	Expertise?
Yes	Yes	High/Medium	Yes

My Path to Success. Post-Doctoral Fellowship (2012-2013)

What Next?

What do I do to keep on expanding my research and my expertise?

I Value Research and Personal Growth → Industry (Spain)

- Personal growth? → Rare
- Research? → No
- Salary? → Medium/ Low
- Expertise? → Rare

No Openings + Scarce Resources → Academia (Spain)

- Personal growth? → Maybe
- Research? → Yes
- Salary? → Low
- Expertise? → Yes

Complicated for Foreign Nationals → Industry (US)

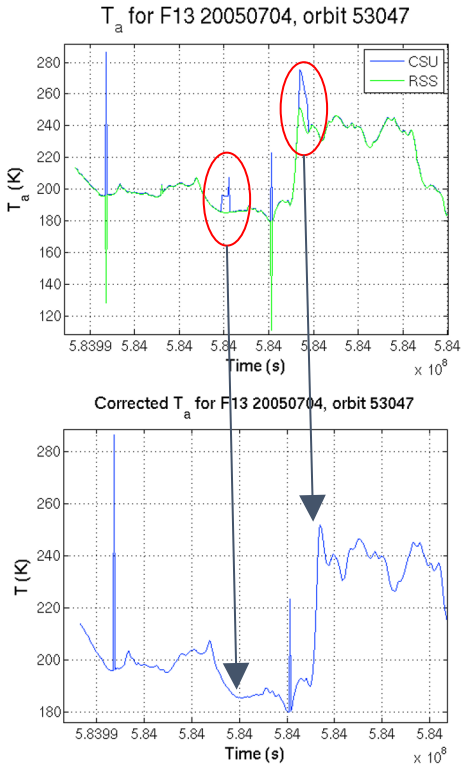
- Personal growth? → Yes
- Research? → Yes, R&D
- Salary? → High
- Expertise? → Yes

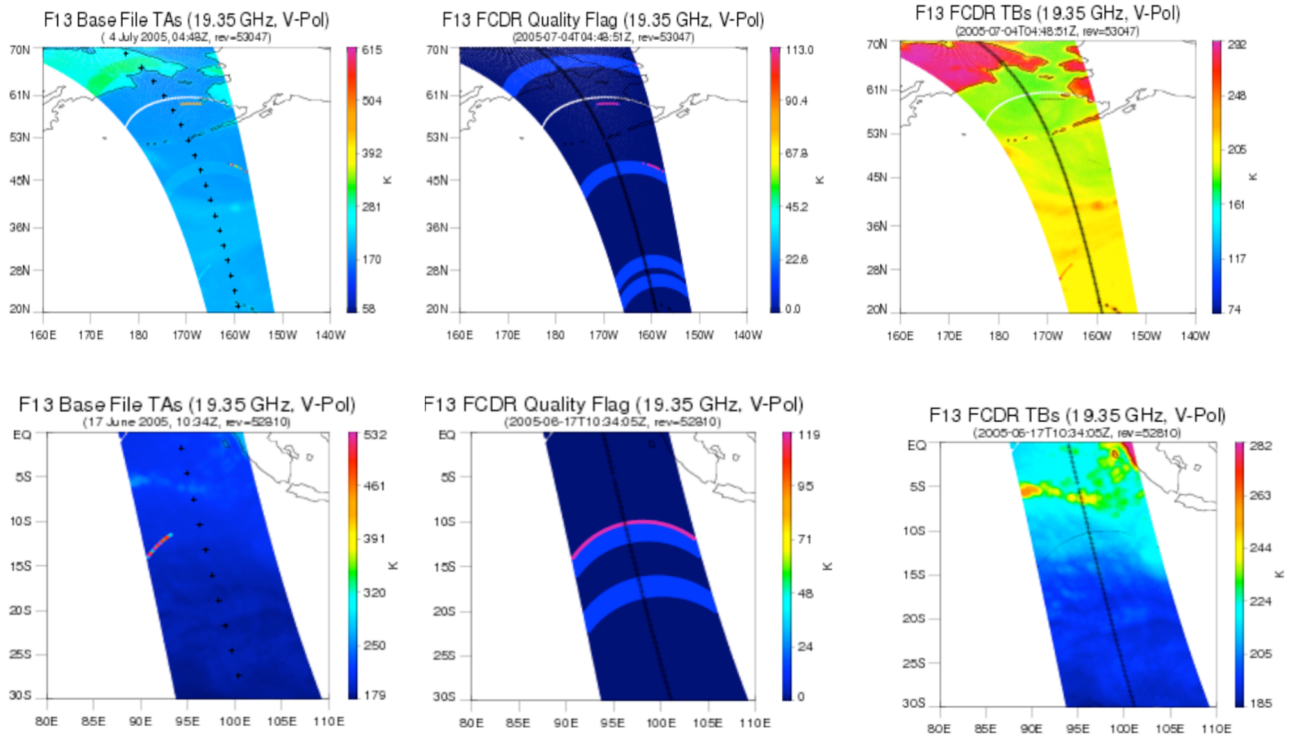
Academia (US)

- Personal growth? → Yes
- Research? → Yes
- Salary? → High/Medium
- Expertise? → Yes

Postdoc in SSMI and SSMI/S calibration

Contributions to the antenna temperature correction from count analysis



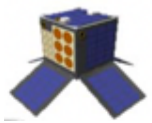


What Did I Learn?

- Expanded my expertise outside the GNSS-R field.
- Passive remote sensing
- Learned high precision calibration of radiometric data.
- Understood the physics behind the radiometric measurements.
- Contributed to a better data product.

Postdoc in CYGNSS Mission

It was the time that satellite missions were getting ready to launch and science teams were forming.



TechDemoSat-1 SGR-ReSI (TDS-1)

SPECIFICS:

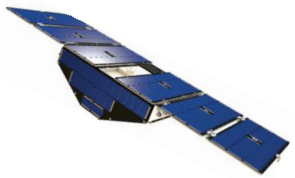
- Launched on July 8, 2014 (ended Dec. 2018)
- Sun-synchronous near-circular orbit, altitude of ~ 635 km, inclination = 98.8º.
- TDS-1 Primary Payload: SGR-ReSI (Space GNSS Receiver – Remote Sensing Instrument).
- Goal: Demonstrate the technology and science required for L1-band GPS Reflectometry through the operation and collection of data over the ocean.

BENEFITS:

- Polar coverage
- Low-cost

LIMITATIONS:

- Intermittent operation: shared platform
- Calibration – Lack of direct reference signal.



CYclone Global Navigation Satellite System (CYGNSS)

SPECIFICS:

- Launched on Dec. 15, 2016 (data available from Mar. 2017)
- Orbit altitude of ~ 520 km, inclination = 35º.
- 8 CYGNSS Spacecrafts, measuring 4 GPS signals simultaneously = 32 meas/sec.
- Goal: Tropical cyclone genesis, intensification and decay

BENEFITS:

- High temporal repeat resolution
- Low-cost
- Ocean and Land Measurements at L-band.

LIMITATIONS:

- Lack of polar coverage.
- Land measurements are yet not well-calibrated.

Postdoc in CYGNSS Mission

- I joined Prof. James Garrison group at Purdue and became a CYGNSS Science Team member.
- Our role was to produce innovative approaches alternative to the main baseline retrieval algorithm.
- Contributed to the group for 2.5 years:

1. Generalized Linear Observable based on Principal Component Analysis

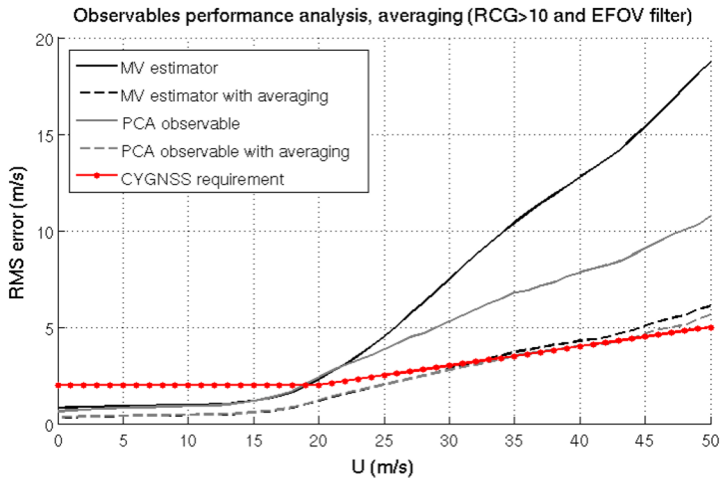
1142 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 54, NO. 2, FEBRUARY 2016

Generalized Linear Observables for Ocean Wind Retrieval From Calibrated GNSS-R Delay–Doppler Maps

Nereida Rodriguez-Alvarez and James L. Garrison, *Senior Member, IEEE*

***Abstract*—The Cyclone Global Navigation Satellite System (CYGNSS) mission will use Global Navigation Satellite System-Reflectometry to measure ocean surface winds in and near the hurricane inner core, including regions beneath the eye wall, which could not previously be measured from space due to intense precipitation. The CYGNSS constellation will consist of eight small satellite observatories in 500-km circular orbits at an inclination of ∼35°. CYGNSS observatories will receive both direct and reflected signals from Global Positioning System satellites.**

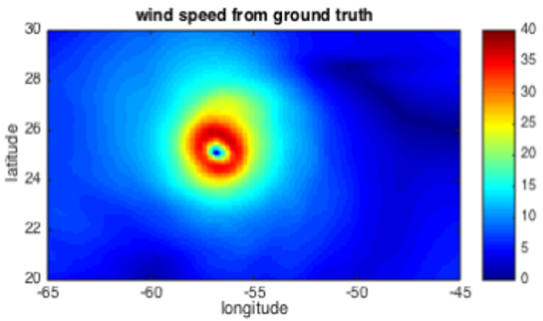
Model assimilation of remote sensing data has contributed to an improvement in the accuracy of TC track forecasts by around 50% over the last two decades. There has not, however, been significant improvement in storm intensity forecasts over this same time period. It is hypothesized that this shortcoming is a result of sparsity in observations of the TC inner core. This lack of observations can be attributed to two causes [1].

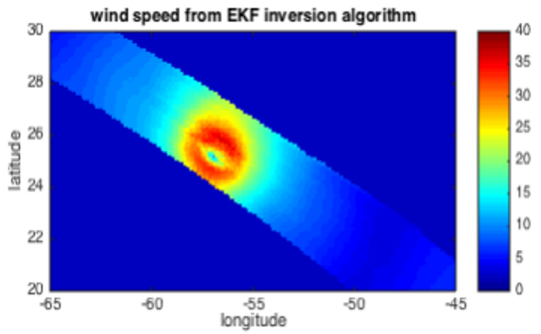


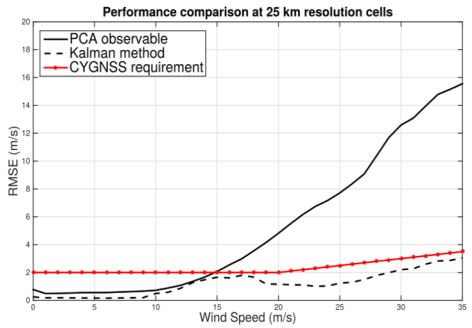
Postdoc in CYGNSS Mission

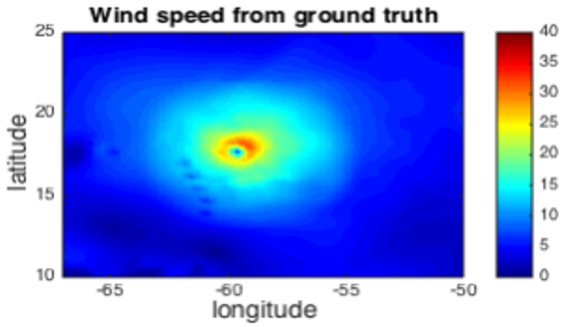
1. Sequential Processing based on Extended Kalman Filter

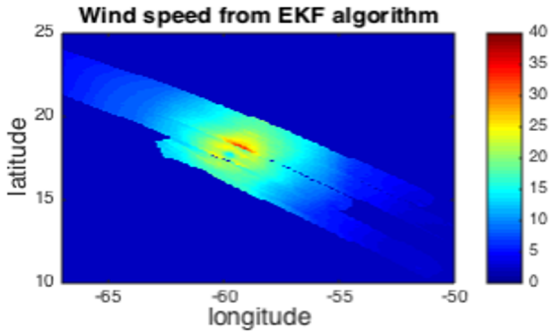
First developments on and tests on synthetic data.

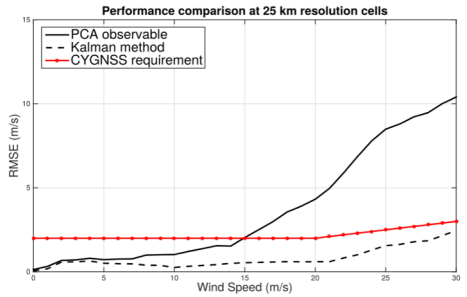












10202 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 57, NO. 12, DECEMBER 2019

Sequential Processing of GNSS-R Delay-Doppler Maps to Estimate the Ocean Surface Wind Field

Feixiong Huang, *Student Member, IEEE*, James L. Garrison, *Senior Member, IEEE*, Nereida Rodriguez-Alvarez, Andrew J. O'Brien, Kaitie M. Schoenfeldt, Soon Chye Ho, *Student Member, IEEE*, and Han Zhang, *Student Member, IEEE*

***Abstract*—Spaceborne Global Navigation Satellite System Reflectometry (GNSS-R) measurements of ocean winds present a challenge because the surface wind speed cannot be assumed homogeneous over the large glistening zone observable from orbit. The 25-km resolution requirement of the Cyclone GNSS (CYGNSS) mission limits wind speed retrievals to using only a small fraction of the delay-Doppler map (DDM) near the specular point. This paper presents a new method to invert a**

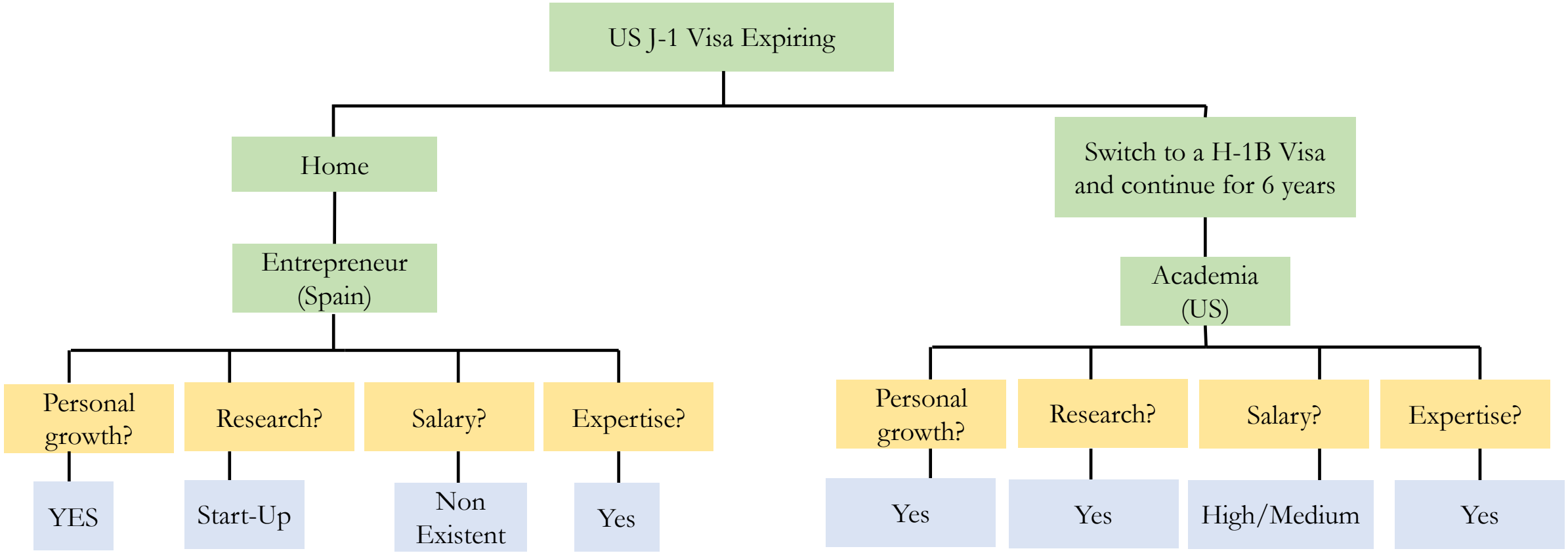
NOMENCLATURE

(R, V)	Coordinates of surface frame in 10-km resolution.
(θ, ϕ)	Coordinates in surface frame.
(n_R, n_V)	Grid dimensions in 10-km resolution.
(n_r, n_v)	Grid dimensions in 1-km resolution.

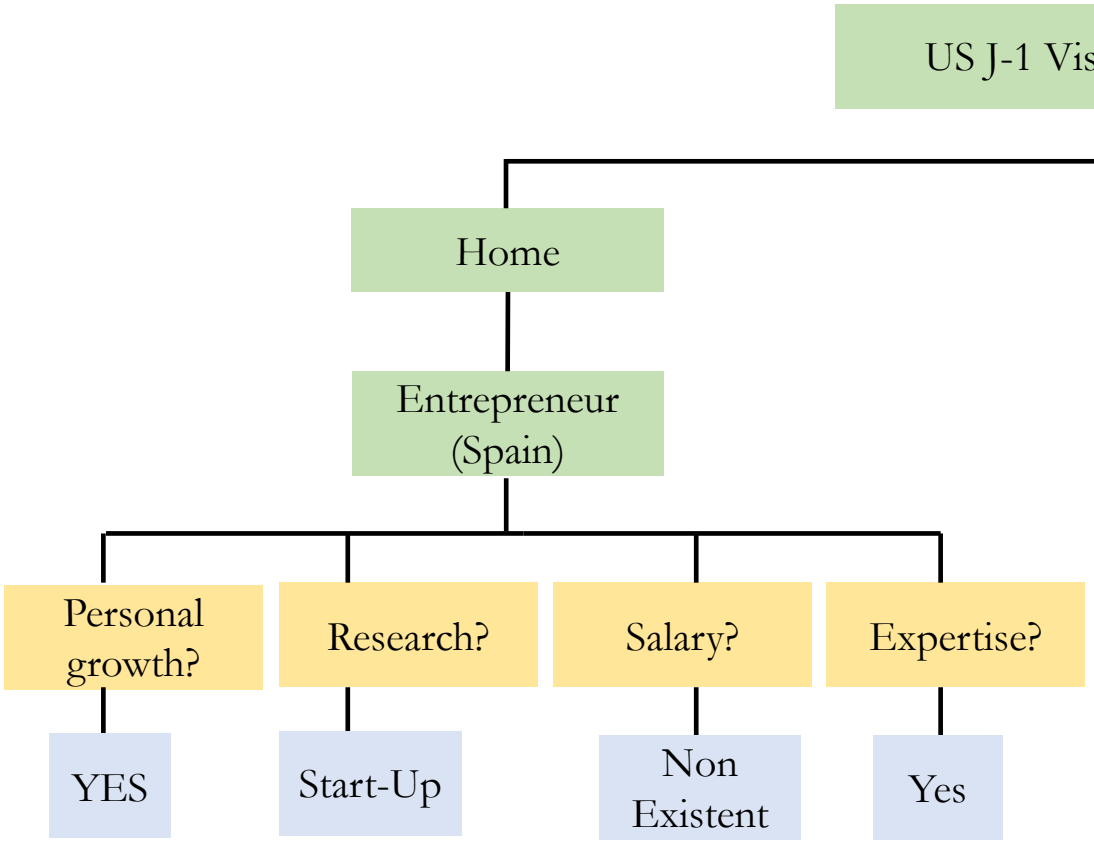
What Did I Learn?

- This was an unique opportunity to learn and work with the fathers of GNSS-R (Dr. Zavorotny, Dr. Katzberg, Prof. Garrison).
- I learned how a science team is organized and what are the different roles necessary.
- I learned how to structure my work and deliver progress on a timely manner.
- I expanded my research to the ocean surface and implemented the techniques necessary for satellite signal processing (different from my Ph.D.), where delay-Doppler maps provide a measurement of surface roughness.
- I implemented retrieval algorithms using statistical analysis and filtering techniques I knew of but I never foresaw they could be used in such applications.
- I understood another dimension of the science generated: ocean wind maps to be used for climatological models.

What Next?


US J-1 Visa Expiring
Home
Switch to a H-1B Visa and continue for 6 years
Entrepreneur (Spain)
Academia (US)
Personal growth?
Research?
Salary?
Expertise?
YES
Start-Up
Non Existent
Yes
Personal growth?
Research?
Salary?
Expertise?
Yes
Yes
High/Medium
Yes

What Next?



- Both my husband and I had visas expiring.
- I was pregnant !!
- We felt we never really tried to be home.
- We always wanted to start a company.
- We met a neuroscientist in need of the expertise of remote sensing techniques.

We decided to be brave and at our own cost (money and precious time), we would spend one full year developing the idea the neuroscientist brought to the table

My Path to Success. Entrepreneur in Residence (2016)

Cycle SciTech

With the support of the Center for Genomic Regulation in Barcelona

X. Gallego, Ph.D.
Neuroscientist
CEO/CSO

X. Bosch-Lluis, Ph.D.
Hardware Engineer
CMO

N. Rodriguez-Alvarez, Ph.D.
Software Engineer
CTO

Applied remote sensing techniques for the tracking of mice, observed with optical and infra-red cameras. We applied statistical approaches and neural networks to classify the behavior of the mice, who suffered from stress, depression, and other similar illness, and were administrated different drugs to alleviate the symptoms.

Developed the software — Gather the Interest of the Market — Follow Mentors Advice — Applied for funding to Caixa Impulse Program — Rejected — Look for other funding or leave the project?

Better product than existent
Time to Market: 10 years

My Path to Success. Mom at Home (2017)

What Next?

1 year goal expired
$0 funding

Home (Spain)

Same economical situation
Not much R&D
Universities with no openings

European Country

New Experience
No contacts

Back to US

Still had contacts
A clear path to grow

Husband applied for a position at Jet Propulsion Laboratory

Moved to California

Mom at Home

My Path to Success. JPL Scientist (2018 - Present)

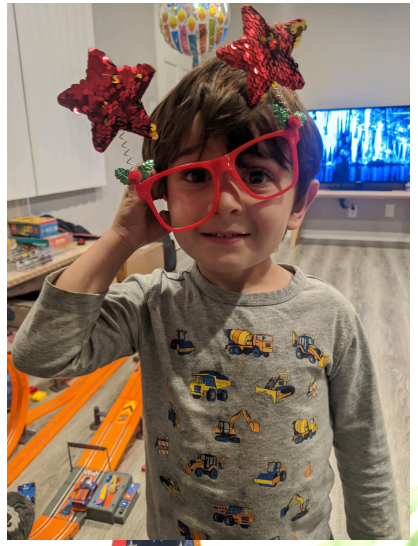
Jet Propulsion Laboratory
California Institute of Technology

What Next?

- Mom at Home
  - Passive
  - Pro-Active
    - Contacted many people from my field in search for a job
      - No Current Funds Not in California
        - Start-up in Colorado, mimicking my Ph.D. Thesis wanted to hire me.
          - I declined
      - Invitation to a GNSS-R workshop from the JPL Associate Chief Scientist
        - Met a colleague looking for someone like me to help with a current JPL R&TD project
          - She partnered with my current Group Supervisor at JPL
            - I was hired as bistatic radar expert by the JPL Planetary Radar and Radio Sciences group
    - Applied convolutional network techniques to the remote sensing of the ocean wind speed with GNSS-R

My Career Exploded!

- Since I started working at JPL I have successfully managed 3 roles:
  - Mom of my beautiful 3 years-old boy.
  - Earth Science : Supported a GNSS-R focused R&TD project by leading the processing, algorithm development and science. Got awarded the NASA Early Career Public Achievement Medal for my role in the GNSS-R field and the accomplishments at JPL.
  - Planetary Science : Wrote a learning manual for the Goldstone Solar System Radar (GSSR), promoted innovative ideas within the group trough numerous proposals, and learned about near-Earth asteroid tracking, orbital debris, and lunar debris. This year I lead a Blue Sky Study and next year I am going to be leading an effort for advanced signal processing techniques for the GSSR.



Earth Science

Wetland inundation detection and monitoring with GNSS-R

remote sensing MDPI

Article

Classifying Inundation in a Tropical Wetlands Complex with GNSS-R

Nereida Rodriguez-Alvarez [1,*], Erika Podest [2], Katherine Jensen [3,4] and Kyle C. McDonald [2,3,4]

1 Planetary Radar Radio Science Systems Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
2 Carbon Cycle and Ecosystems Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA; erika.podest@jpl.nasa.gov (E.P.); kmcdonald2@ccny.cuny.edu (K.C.M.)
3 Department of Earth and Atmospheric Science, The City College of New York, City University of New York, New York, NY 10031, USA; kjensen@ccny.cuny.edu
4 Earth and Environmental Sciences Program, The Graduate Center, City University of New York, New York, NY 10016, USA
* Correspondence: nereida.rodriguez.alvarez@jpl.nasa.gov; Tel.: +1-818-393-7507

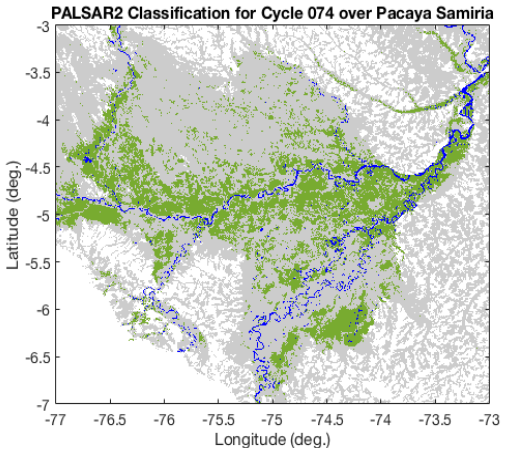
Received: 10 April 2019; Accepted: 2 May 2019; Published: 4 May 2019

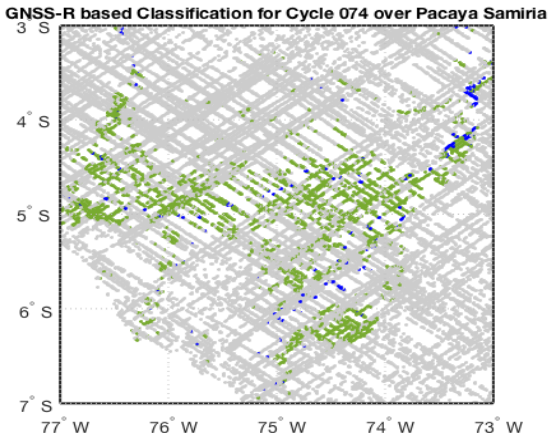
check for updates

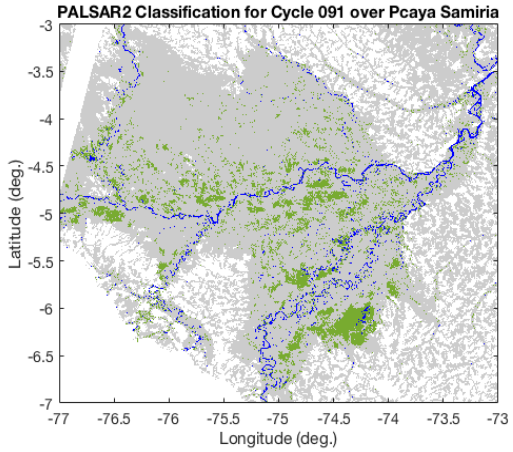
Abstract: The use of global navigation satellite system reflectometry (GNSS-R) measurements for classification of inundated wetlands is presented. With the launch of NASA's Cyclone Global Navigation Satellite System (CYGNSS) mission, space-borne GNSS-R measurements have become available over ocean and land. CYGNSS covers latitudes between ±38°, providing measurements over tropical ecosystems and benefiting new studies of wetland inundation dynamics. The GNSS-R signal over inundated wetlands is driven mainly by coherent scattering associated with the presence of surface water, producing strong forward scattering and a distinctive bistatic scattering signature. This paper presents a methodology used to classify inundation in tropical wetlands using observables derived from GNSS-R measurements and ancillary data. The methodology employs a multiple decision tree randomized (MDTR) algorithm for classification and wetland inundation maps derived from the phased-array L-band synthetic aperture radar (PALSAR-2) as reference for training and validation. The development of an innovative GNSS-R wetland classification methodology is aimed to advance mapping of global wetland distribution and dynamics, which is critical for improved estimates of natural methane production. The results obtained in this manuscript demonstrate the ability of GNSS-R signals to detect inundation under dense vegetation over the Pacaya-Samiria Natural Reserve, a tropical wetland complex located in the Peruvian Amazon. Classification results report an accuracy of 69% for regions of inundated vegetation, 87% for open water regions, and 99% for non-inundated areas. Misclassification of inundated vegetation, primarily as non-inundated area,

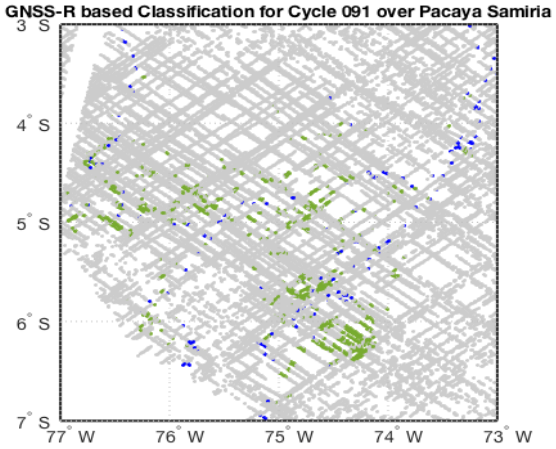
Pacaya Samiria:

- Heavily vegetated area in the Peruvian Amazon.
- Inundates 80% seasonally.
- Field campaign on 2017.









Earth Science

Sea ice detection and classification with GNSS-R

Remote Sensing of Environment 230 (2019) 111202

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

An Arctic sea ice multi-step classification based on GNSS-R data from the TDS-1 mission

Nereida Rodriguez-Alvarez*, Benjamin Holt, Sermsak Jaruwatanadilok, Erika Podest, Katherine C. Cavanaugh

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA

ARTICLE INFO

Edited by: Menghua Wang

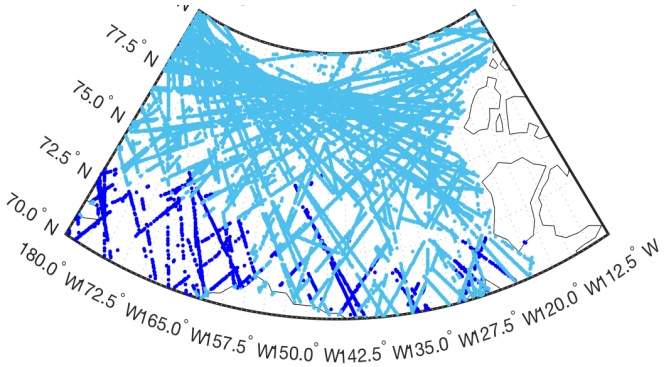
Keywords:
Bistatic radar
GNSS-reflectometry
TDS-1
Sea ice
Open water–ice classification
Ice type classification

ABSTRACT

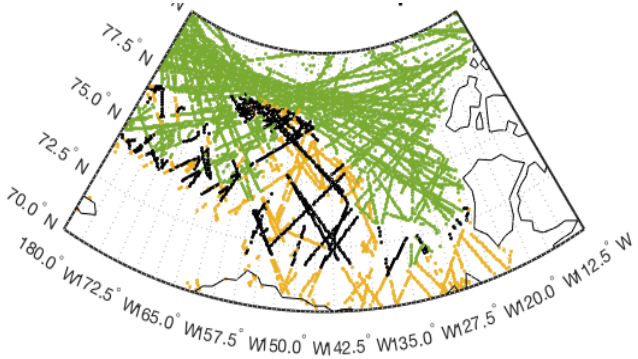
This study examines the potential of using bistatic radar reflections from the Global Navigation Satellite System (GNSS) to classify sea ice types in the Arctic Ocean during the sea ice formation period. For this study, we used data obtained from the United Kingdom (UK) TechDemoSat-1 (TDS-1) satellite mission. The main objective of the TDS-1 mission is to provide L-band radar reflections of the ocean surface in order to infer wind speed through an estimation of the ocean surface roughness. Given the orbit inclination of TDS-1, polar coverage is obtained providing datasets over the Arctic sea ice cover. Recent studies demonstrated the use of TDS-1 data for accurately deriving ocean-ice detection using the shape of the bistatic radar waveforms derived from delay-Doppler maps. We aim to advance this previous research by demonstrating the sensitivity of GNSS bistatic radar signals to sea ice types. The originality of the study presented in this manuscript is the classification of sea ice types, never implemented before with any GNSS-R mission. For this study, we examined the fall period of October 2015 in the Beaufort and Chukchi seas region, when considerable expanses of young ice, first-year ice (FYI), and multi-year ice (MYI) were present. We developed a sea ice multi-step classification approach based on bistatic radar reflections to generate not only an ocean-ice classification but to classify between the three dominant ice types present. The classification was done in multiple steps based on GNSS bistatic radar observations only and includes checks for spatio-temporal consistency with each dominant class. Validation results are based on the comparison of the GNSS classification against SAR-derived sea ice type maps produced at the US National Ice Center. First, we derived classifications of sea ice–open water samples with a success rate of 97%, comparable to previous studies. Next, the sea ice type classification results identified FYI, MYI and young ice with success rates of 70%, 82% and 81%, respectively, indicating a strong sensitivity of the L-band GNSS bistatic radar signals to the different surface scattering properties of these primary ice types.

With this manuscript we demonstrate the potential of the GNSS bistatic radar signals to classify ice types during the sea ice formation period. GNSS bistatic radar signals provide unique forward scattered measurements at L-band, potentially on a daily temporal revisit, that can be used to produce enhanced information on sea ice characteristics, such as those currently generated by other sensors. In order to determine the use of GNSS-R

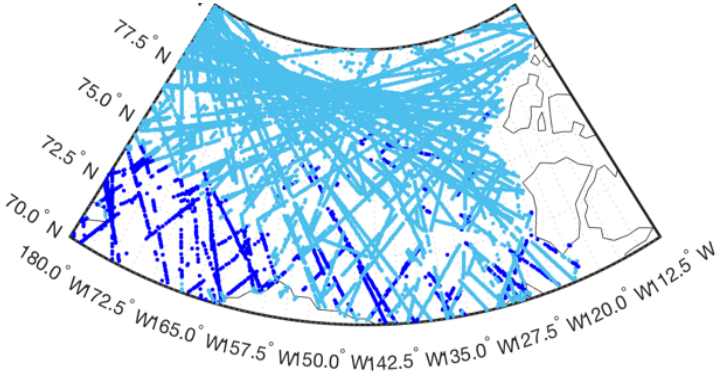
Reference for Open water and Sea Ice Samples



Sea Ice Type Reference Samples

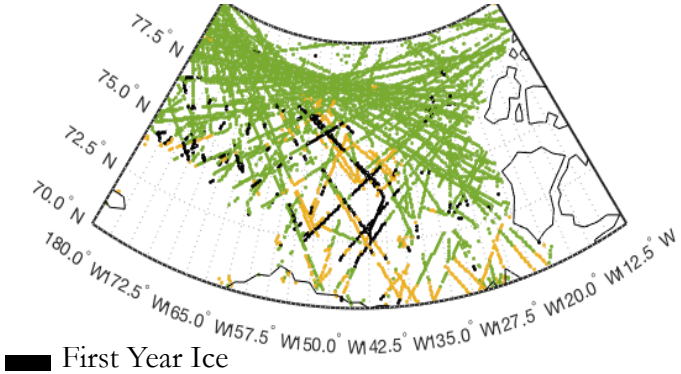


GNSS-R Classification



Open water
Sea Ice

GNSS-R Classification



First Year Ice
Multi Year Ice
Young Ice

Earth Science

Calibration of SMAP radar receiver working as a GNSS-R instrument (SMAP-R)

remote sensing

MDPI

Article

The Use of SMAP-Reflectometry in Science Applications: Calibration and Capabilities

Nereida Rodriguez-Alvarez [1,*], Sidharth Misra [2], Erika Podest [3], Mary Morris [2] and Xavier Bosch-Lluis [4]

1 Planetary Radar Radio Science Systems Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA
2 Microwave Instrument Science Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA; Sidharth.Misra@jpl.nasa.gov (S.M.); mary.g.morris@jpl.nasa.gov (M.M.)
3 Carbon Cycle and Ecosystems Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA; Erika.Podest@jpl.nasa.gov
4 Microwave Systems Technology Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA; javier.bosch-lluis@jpl.nasa.gov
* Correspondence: nereida.rodriguez.alvarez@jpl.nasa.gov; Tel.: +1-818-393-7507

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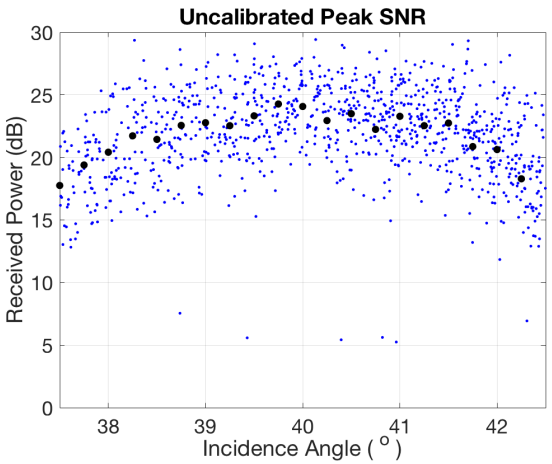
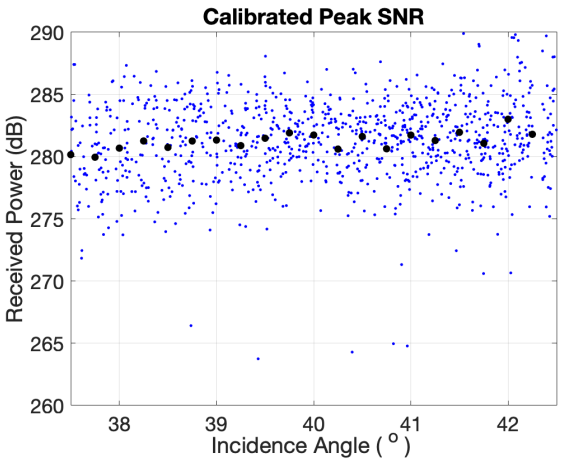
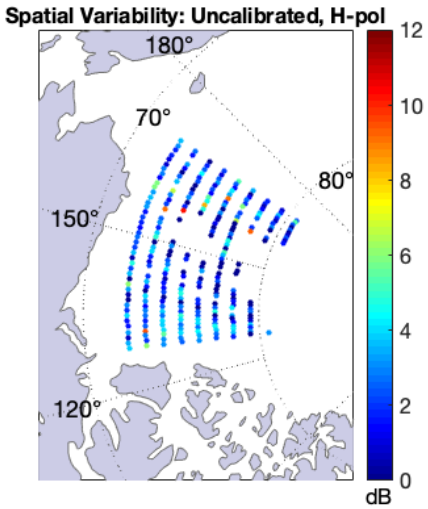
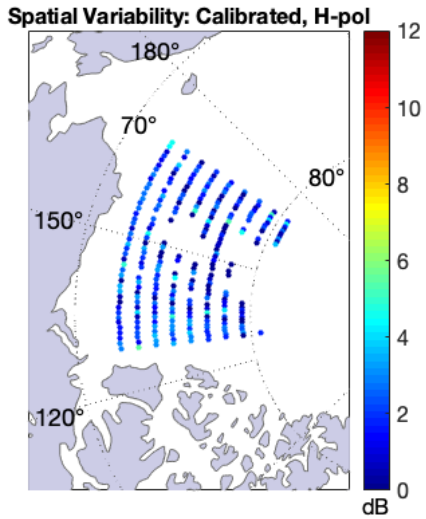
check for updates

Abstract: The Soil Moisture Active Passive (SMAP) mission became one of the newest spaceborne Global Navigation Satellite System–Reflectometry (GNSS-R) missions collecting Global Positioning System (GPS) bistatic radar measurements when the band-pass center frequency of its radar receiver was switched to the GPS L2C band. SMAP-Reflectometry (SMAP-R) brings a set of unique capabilities, such as polarimetry and improved spatial resolution, that allow for the exploration of scientific applications that other GNSS-R missions cannot address. In order to leverage SMAP-R for scientific applications, a calibration must be performed to account for the characteristics of the SMAP radar receiver and each GPS transmitter. In this study, we analyze the unique characteristics of SMAP-R, as compared to other GNSS-R missions, and present a calibration method for the SMAP-R signals that enables the standardized use of these signals by the scientific community. There are two key calibration parameters that need to be corrected: The first is the GPS transmitted power and GPS antenna gain at the incidence angle of the measured reflections and the second is the convolution of the SMAP high gain antenna pattern and the glistening zone (Earth surface area from where GPS signals scatter). To account for the GPS transmitter variability, GPS instrument properties—transmitted power and antenna gain—are collocated with information collected from the CYclone Global Navigation









Earth Science

Crop monitoring using GNSS-R (to be submitted)

remote sensing MDPI

Article

The Polarimetric Sensitivity of SMAP-Reflectometry Signals to Crop Growth in the US Corn Belt

Nereida Rodriguez-Alvarez [1], Sidharth Misra [2] and Mary Morris [2,*]

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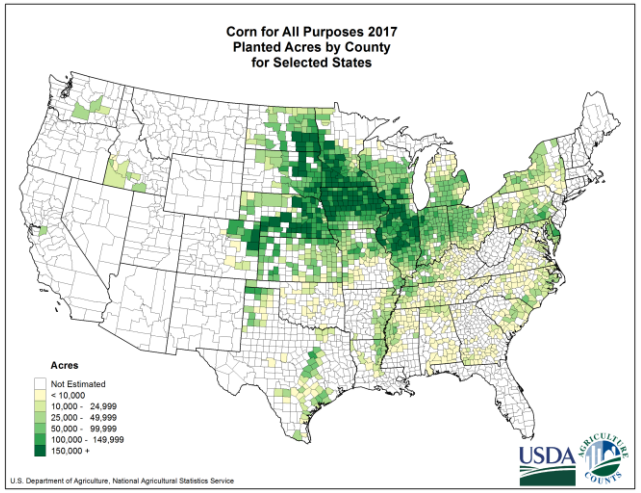
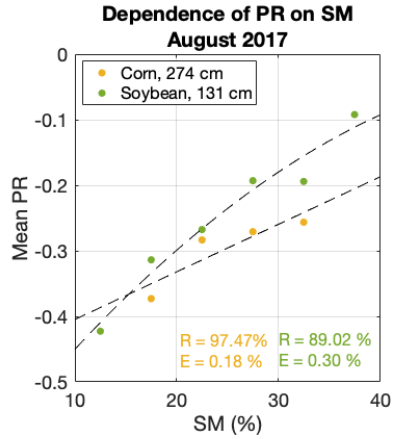
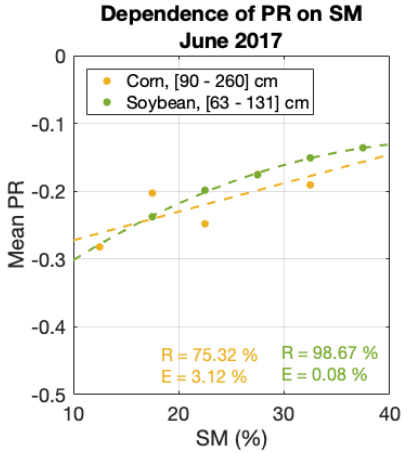
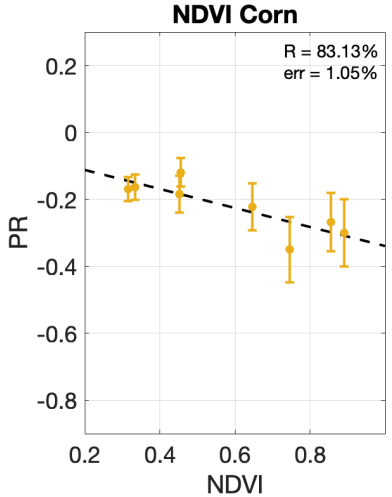
Received: date; Accepted: date; Published: date

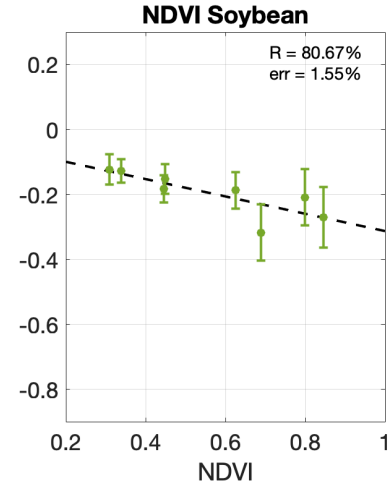
Abstract: The Soil Moisture Active Passive (SMAP) mission has been collecting Global Positioning System (GPS) signals as they reflect off the Earth's surface since August 2015. The L-band dual-polarization measurements cover at this moment a total period of 4 years allowing for studies of the evolution of geophysical parameters during seasonal transitions. This work focusses on the study of the sensitivity of SMAP-Reflectometry signals to crop growth related parameters of agricultural areas, such as type of crop, vegetation water content (VWC), crop height, and vegetation opacity (VOP). The monitoring of the crop growth related parameters is relevant to the scientific community in general to assess better soil moisture products but in particular it is relevant to applications where the availability of health crop information has the potential to aid farmers to increase the productivity and quality of the crops. The study presented is conducted for data over the United States Corn Belt, where a vast extensive area covering several states is planted every year with mostly corn, and areas of soybean and wheat. We explore the potential to regularly generate an alternate source of information, completely independent of current data used in the soil moisture (SM) products developed with SMAP mission. To overcome the low sampling and low repeat of SMAP-R measurements we implement an observational strategy using measurements over long periods of stability in two extremes and average them together. This defines two states that become the reference of the observations. Then, we analyze the variability of the polarimetric ratio (PR) – computed from the peak signal at V-polarization and peak signal at H-pol – during transitional











Earth Science

Urban and Agricultural Flooding Detection using GNSS-R (to be submitted)

remote sensing

MDPI

Article

Flooding Detection Algorithm Using GNSS Bistatic Radar Measurements at Local/Regional Scale Urban/Agricultural Areas

Nereida Rodriguez-Alvarez [1,*], Andrew Kruczkiewicz[2,3], Erika Podest[4], and Kamal Oudrhiri[1]

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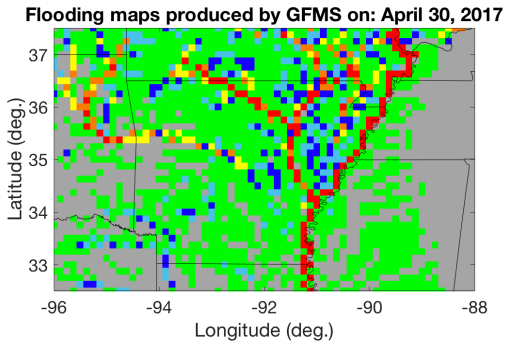
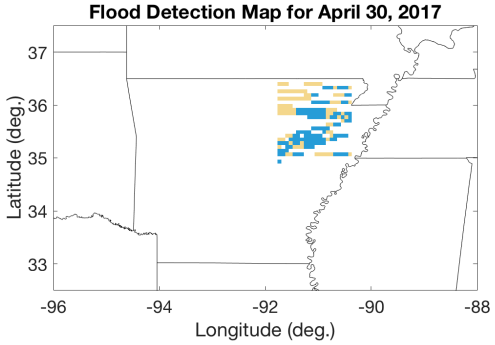
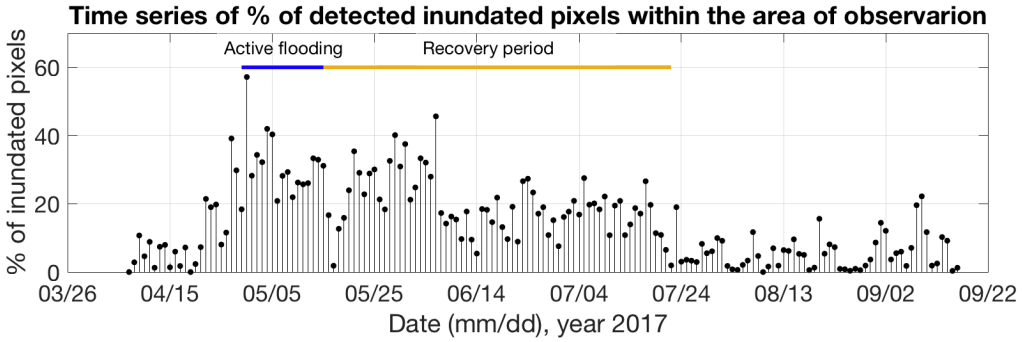
Received: date; Accepted: date; Published: date

Abstract: The use of signals of opportunity for land applications has exploded since satellite observations were made available to the scientific community through missions as TechDemoSat-1 (TDS-1), CYclone Global Navigation Satellite System (CYGNSS) and Soil Moisture Active Passive (SMAP) radar - working in receiver mode-. In particular, the spatial and temporal coverage obtained from CYGNSS mission is unprecedent and allows exploring the use of these signals for monitoring dynamic processes with variations on the order of hours to 2 days. The work presented in this manuscript demonstrates a statistically-based methodology that employs CYGNSS measurements to detect and monitor the dynamics of local flooding at the human-natural interface. The human-natural interface is characterized by urban and agricultural environments, while wetlands refers to flooding at

Midwest Spring floods 2007
(North-East Arkansas)







Earth Science

Freeze and Thaw monitoring using GNSS-R (In preparation)

remote sensing

MDPI

Article

The Use of SMAP-Reflectometry (SMAP-R) Signals to Monitor the Freeze/Thaw State Transition over Alaska

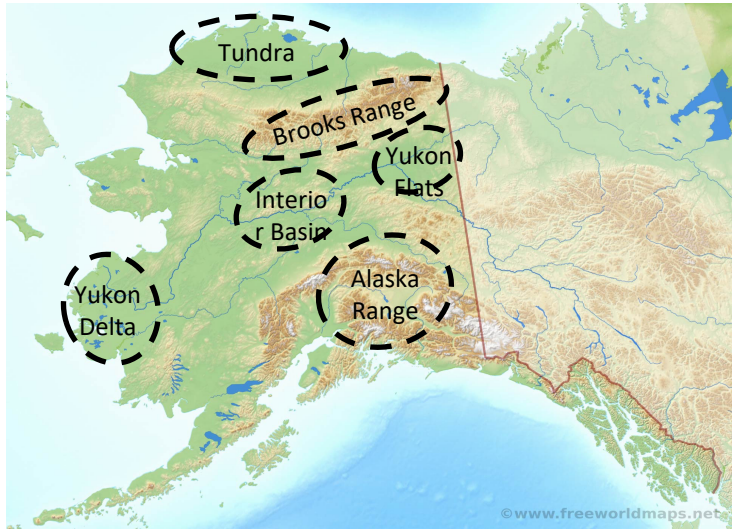
Nereida Rodriguez-Alvarez [1,*] and Erika Podest [2]

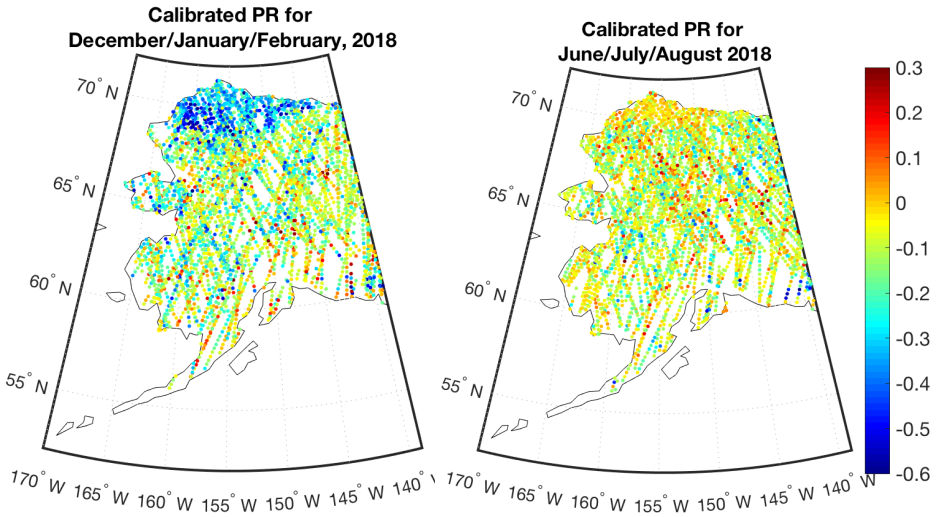
[1] Planetary Radar Radio Science Systems Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, USA; e-mail: nereida.rodriguez.alvarez@jpl.nasa.gov
[2] Carbon Cycle and Ecosystems Group, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109, USA; e-mail: Erika.Podest@jpl.nasa.gov

* Correspondence: nereida.rodriguez.alvarez@jpl.nasa.gov; Tel.: +1-818-393-7507

Received: date; Accepted: date; Published: date

Abstract: The landscape transition between frozen and thawed states has an impact on climate, hydrology and ecology. One of the primary objectives of the Soil Moisture Active Passive (SMAP) mission is to estimates the surface binary freeze/thaw (F/T) state for the region north of 45°N latitude with a classification accuracy of 80% at 3-km spatial resolution and 2-day average intervals. The objective was accomplished by the SMAP radar measurements, but unfortunately, in July 2015 the radar transmitter lost its functionality. The SMAP mission decided to switch the frequency of its radar receiver band pass filter to GPS L2C allowing for the gathering of L-band dual-polarization (H-pol and V-pol) bistatic radar measurements of the Global Positioning System (GPS) signal as it scatters from the Earth surface. The current dataset expands from August 2015 to present (> 4 years) and allows time series studies of the F/T state transitions over the years. This work focusses on the use of SMAP-Reflectometry signals to sense the F/T state transition over Alaska. The monitoring of the F/T state and the timing of the transitions is relevant to the scientific community to understand the impact of these processes in the total surface energy budget. With this work we aim to provide a better characterization of the link between the F/T state and the environmental constraints to the processes of different ecosystems and a better understanding of the time when plants become active after the period of inactivity for different ecosystems. The developed methods use the sensitivity of SMAP-R signals to F/T state together with ancillary products to produce an alternate F/T product based on bistatic radar measurements that can potentially be combined with radiometer measurements to enhance the current products. SMAP-R data is characterized by low sampling and

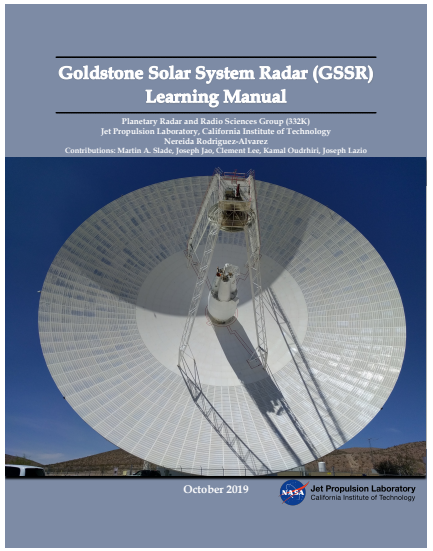




Planetary Science

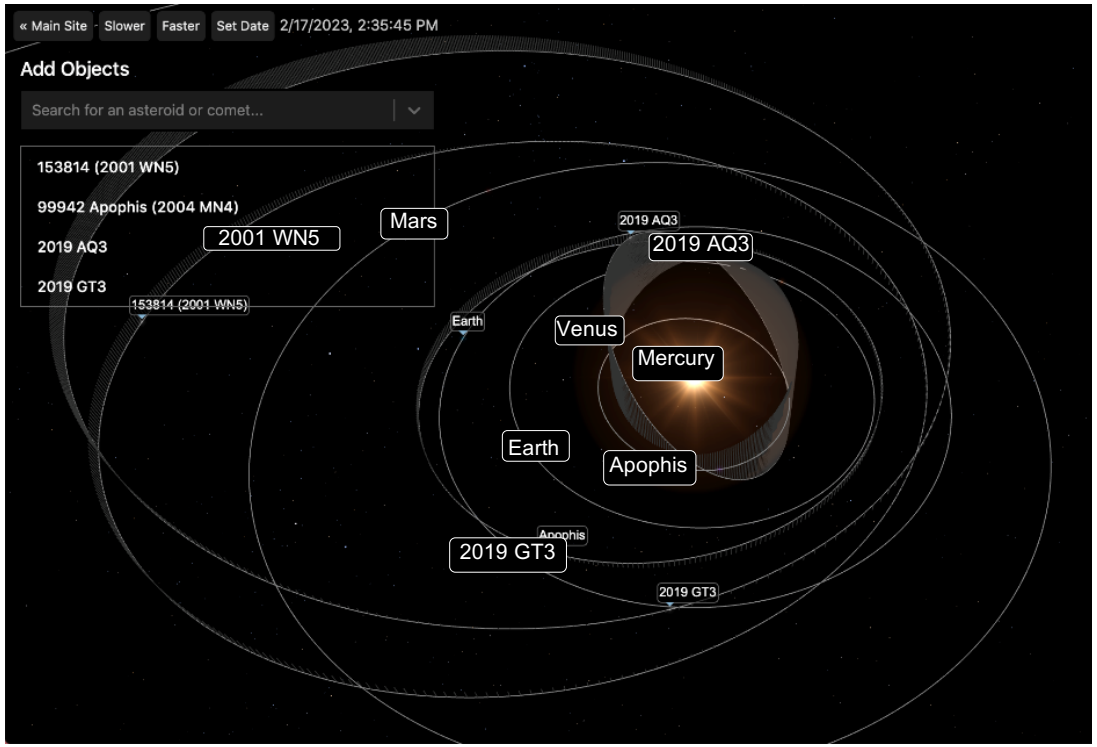
- Learn about Near-Earth Asteroid (NEA) tracking (theory behind the measurements and track support)
- Wrote a manual on the Goldstone Solar System Radar (GSSR).
- Gained experience in the post-processing of NEA radar tracks.
- Learn about orbital debris and lunar orbital debris.
- Got to see a real time track at the Deep Space Network, DSS-14.
- Got involved in the post-processing of pulsars, quasars and FRB.
- Got involved in a project for detecting lightening at Mars.

GSSR Learning Manual



Planetary Science

The Feasibility of Using Near-Earth Objects as Transportation Vehicles for Strategic Low-Cost Sensing Instruments.

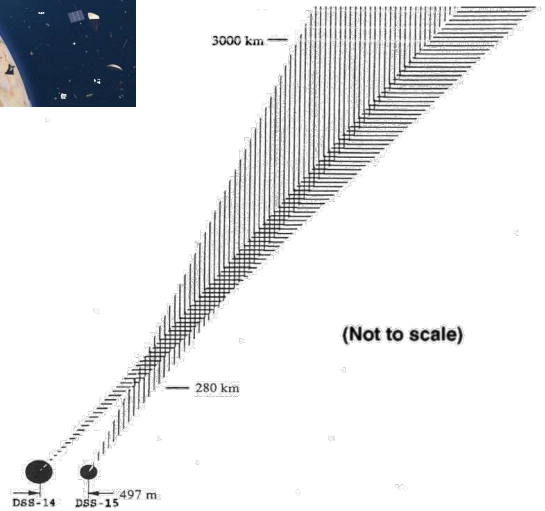


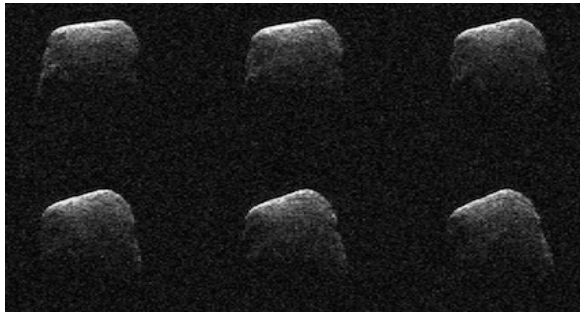
Proposal to NASA Advanced Innovative Concepts (NIAC)
- Phase IA (accepted)
- Phase IB (invited)

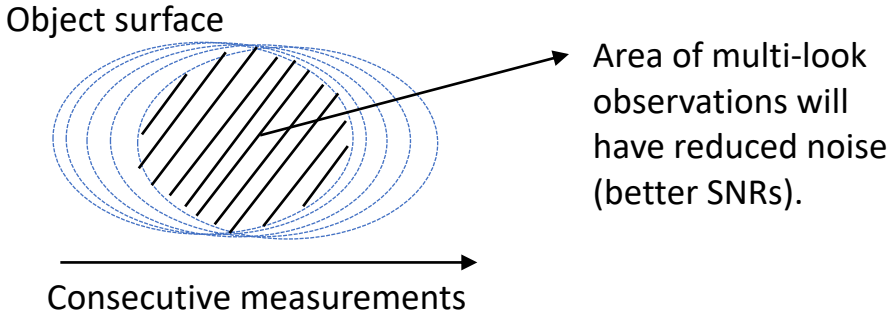
Planetary Science

Next objectives are:

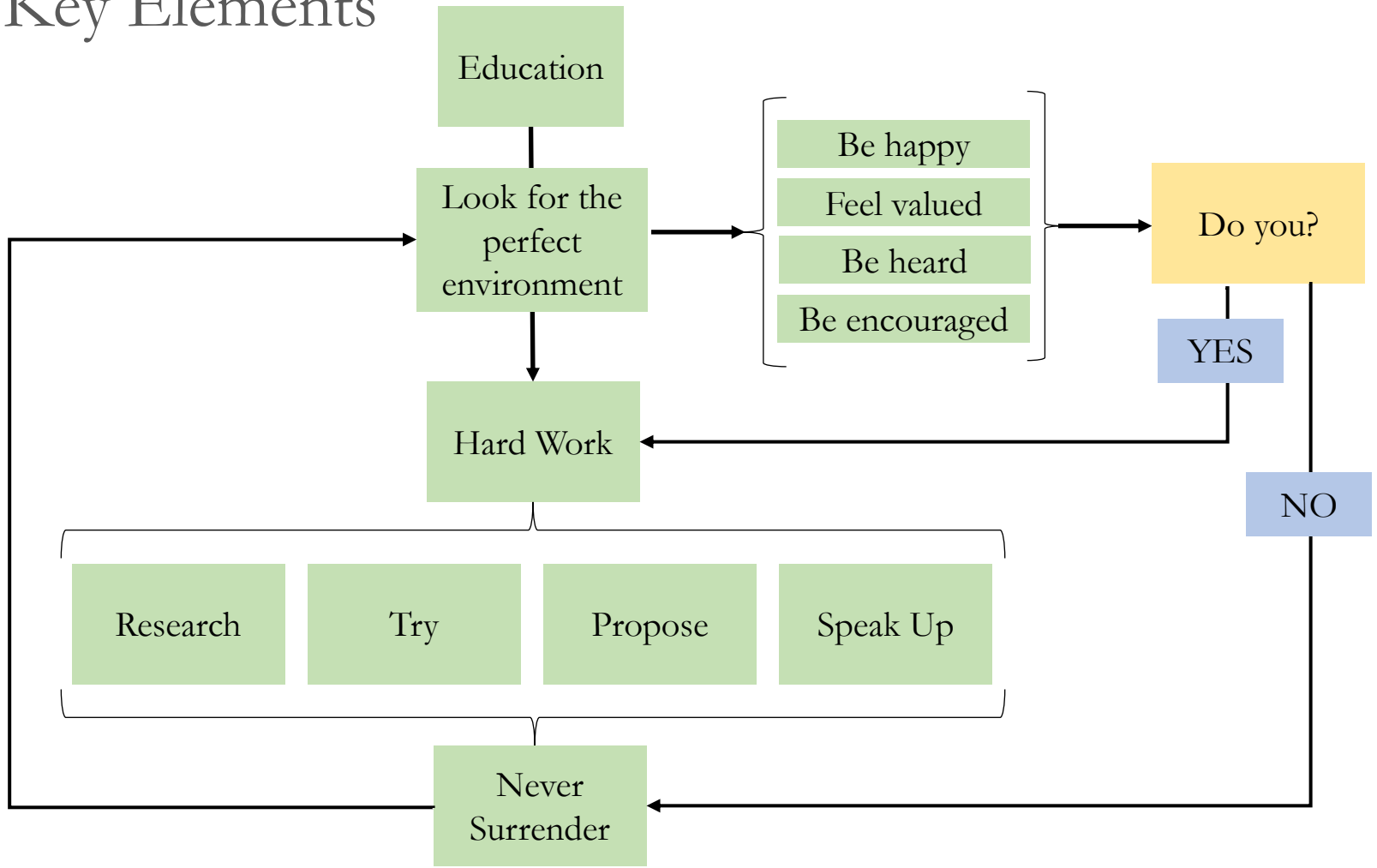
- Expanding my field to planetary science: The use of signals of opportunity in planetary science
- Cis-lunar Space Debris Radar Detection and Advanced Signal Processing for GSSR (JPL Strategic Initiative Proposal) AWARDED



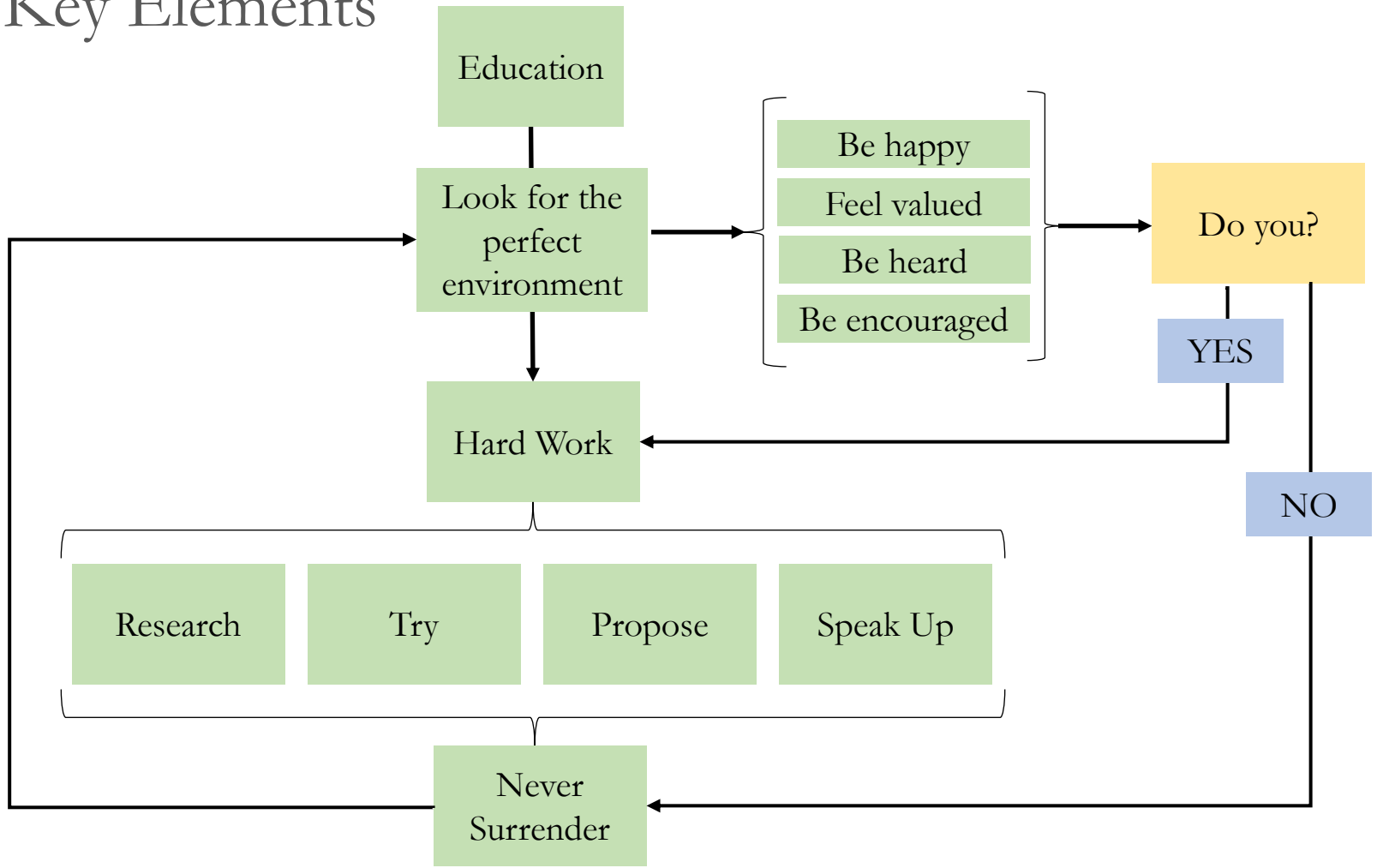




Key Elements



Key Elements



JPL has been for me the perfect environment:

- Dynamic
- Open to new ideas
- Space to grow
- Supportive

I feel so lucky!

But, don't wait for your luck to come… Go find it!

Acknowledgement

The master and Ph.D. research was carried out at Universitat Politecnica de Catalunya, at the Passive Remote Sensing Laboratory.

The first post-doctoral work was conducted at Colorado State University, Atmospheric Science Department.

The second post-doctoral work was conducted ar Purdue University, Department of Astronautics and Aeronautics.

The last Earth Science work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. © 2019. California Institute of Technology. Government sponsorship acknowledged. In particular, it was conducted under the JPL Research and Technology Development Program (Land Surface and Sea Ice State Characterization with GPS Reflections Data: PI - Erika Podest) and the R&A Hydrology & Weather from the Soil Moisture Active Passive (SMAP) project.

All of the Planetary Science work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. © 2019. California Institute of Technology. Government sponsorship acknowledged. In particular it has been conducted under the 106847-DSN O&M project and the SSR Technical Leadership and SSR Signal Processing tasks.

Thank you!

Jet Propulsion Laboratory
California Institute of Technology

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Planetary Radar and Radio Sciences Group - 332K