The Science Case for GNSS-R

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Workshop on Reflectometry using GNSS and Other Signals of Opportunity

October 11-12

Purdue University

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Outline

- Motivation
- Science drivers
- Eddy characteristics
- Alternative methods
- Discussion
- Summary

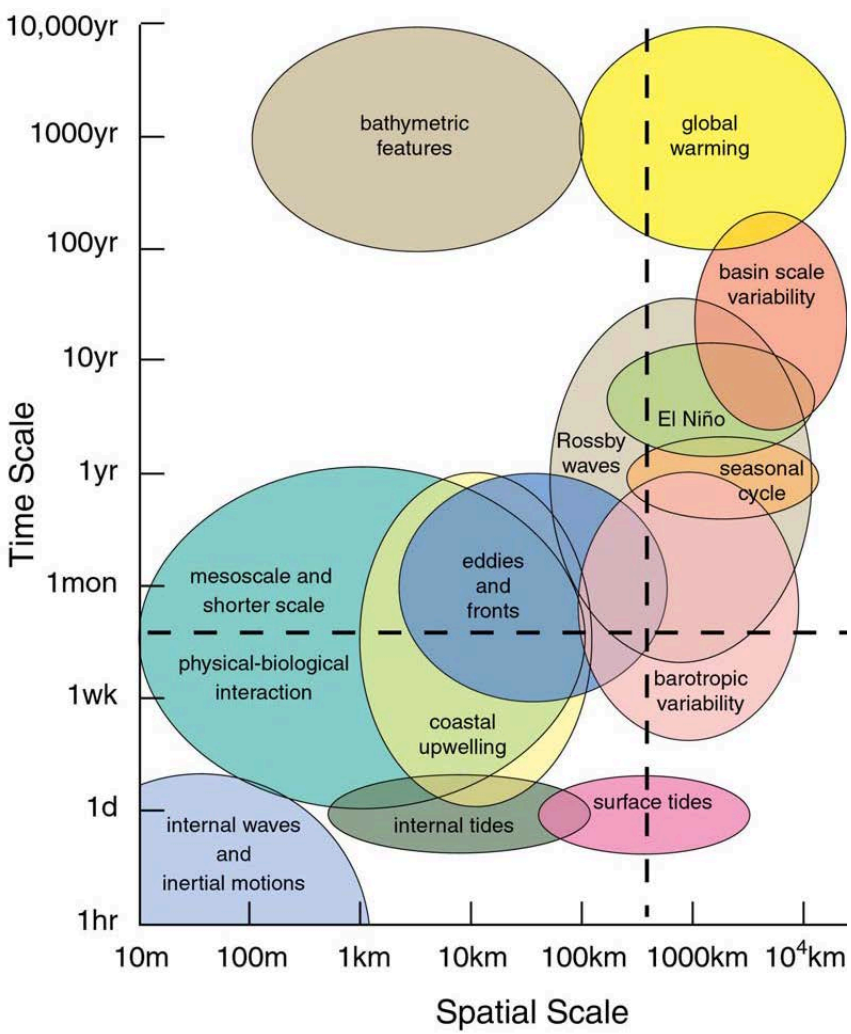
Motivation

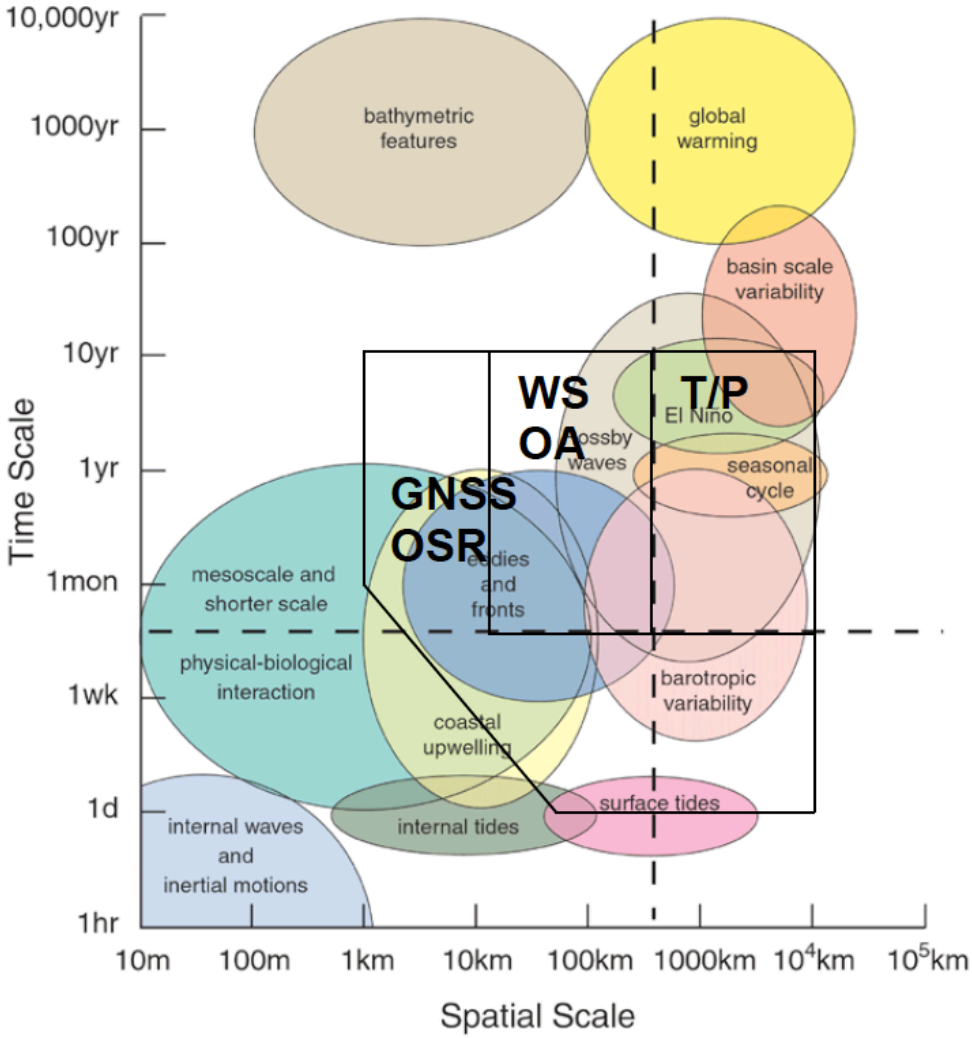
- *Altimetric* GNSS-R will be implemented if the science case is sufficiently compelling and resources are available
  - It can be expensive, but not too expensive
- "Compelling" means uniquely measure an ocean property that is not well measured but that impacts numerous aspects of the Earth system
- Does GNSS-R meet these criteria?
  - Yes, regarding compelling nature
  - "It depends" regarding uniqueness
  - Uniqueness could be "affordable" constellations of instruments
- I am not discussing non-altimetric applications

Compelling Nature of Ocean Eddy Measurement

- **Research in 2000 and after: altimeters have revealed that SSH variability is dominated by westward-propagating nonlinear mesoscale eddies throughout most of the World Ocean**
- **Nonlinear: maximum rotational fluid speeds U that exceed their translation speed c**
  - **They can transport parcels of fluid**
- **The significance of these non-linear eddies is "intuitive"**
  - **Even thought I'm leaving out lots of details…**

Ocean Scales

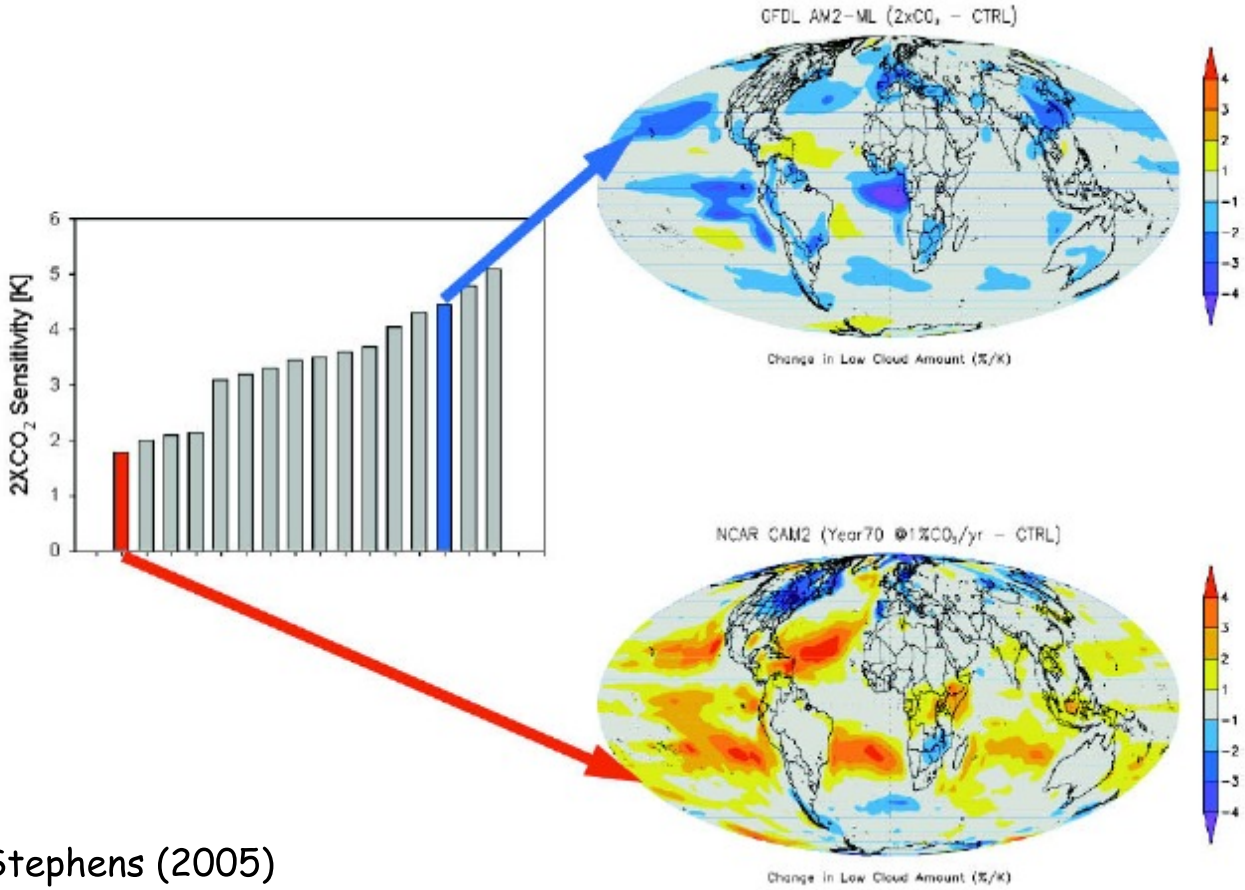




Neither figure is particularly "compelling" *in and of itself*

Radio Occultation (RO) Example of "Compelling"

IPCC 2007: "Cloud feedbacks remain the largest source of uncertainty"



Doubling CO_2 ➔ less low clouds in GFDL ➔ 4 K global warming

Doubling CO_2 ➔ more low clouds in NCAR ➔ 2 K global warming

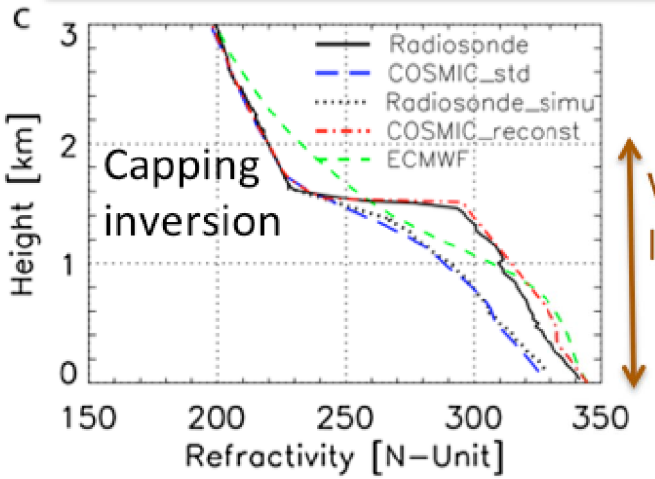
Stephens (2005)

RO: Unique Boundary Layer Data

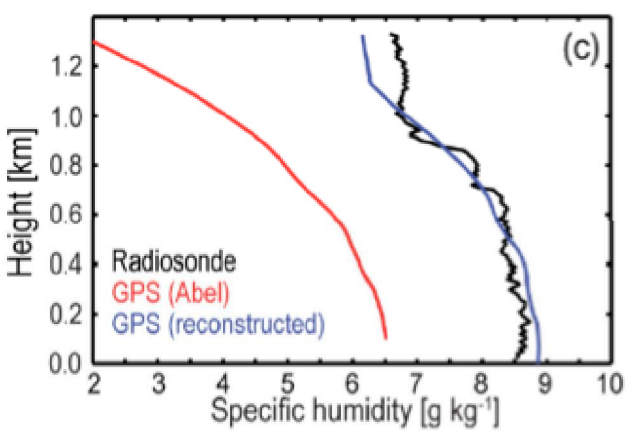
Radio Occultation:
- Cloud penetrating
- High vertical resolution

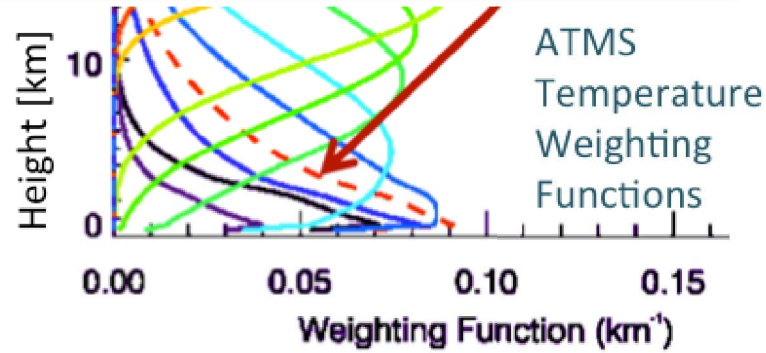
Infrared:
- Blocked by clouds
- Moderate vertical res

Microwave:
- Penetrates clouds
- Low vertical res

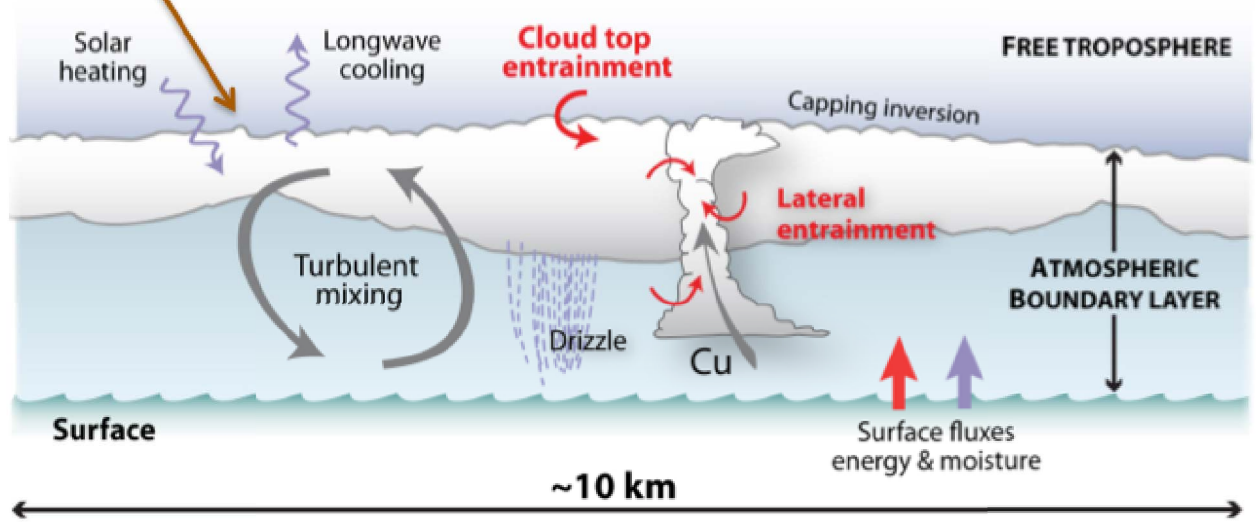


Vertical resolution
IR sounders (~2 km)



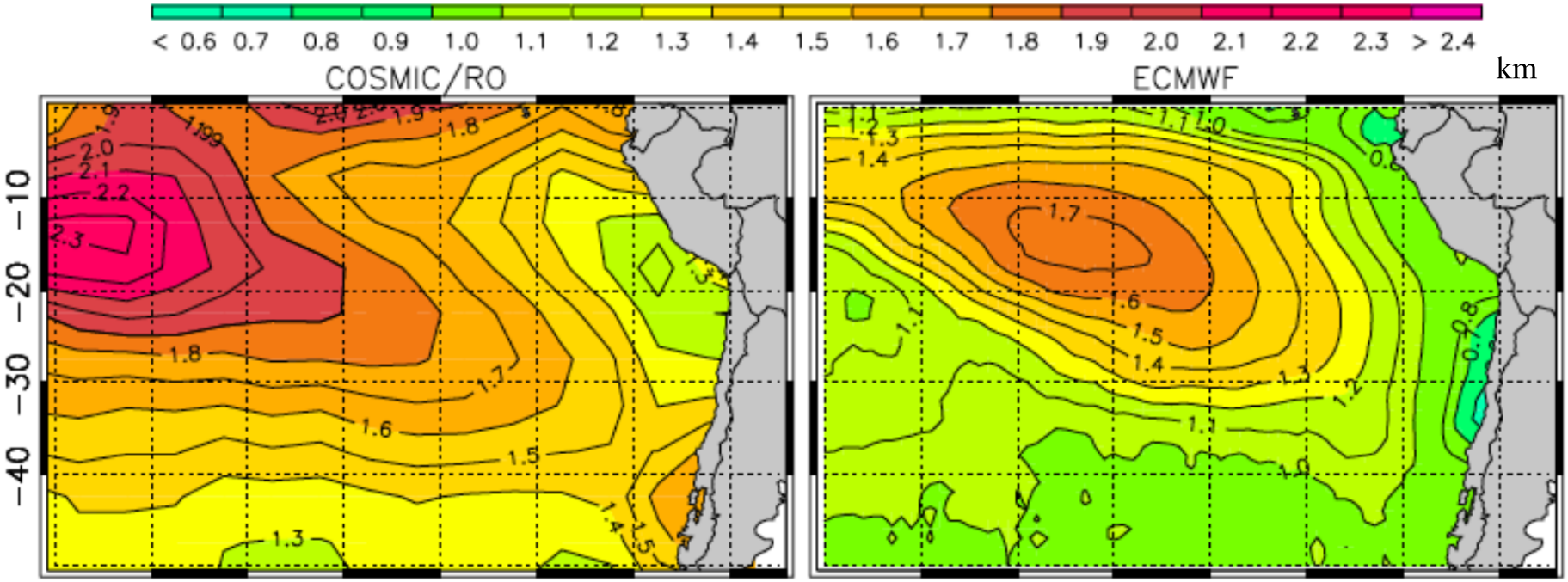


Opaque to IR



Boundary Layer Processes

Validation of "Compelling and Unique"



Maps of the atmospheric boundary layer height
Southeast Pacific Ocean, 2007-2009, Sep-Oct-Nov

- **RO observations differ significantly from the best available model**

The life-cycle of low clouds is the largest remaining uncertainty in climate projections

Xie et al., Atm Chem Phys (2011)

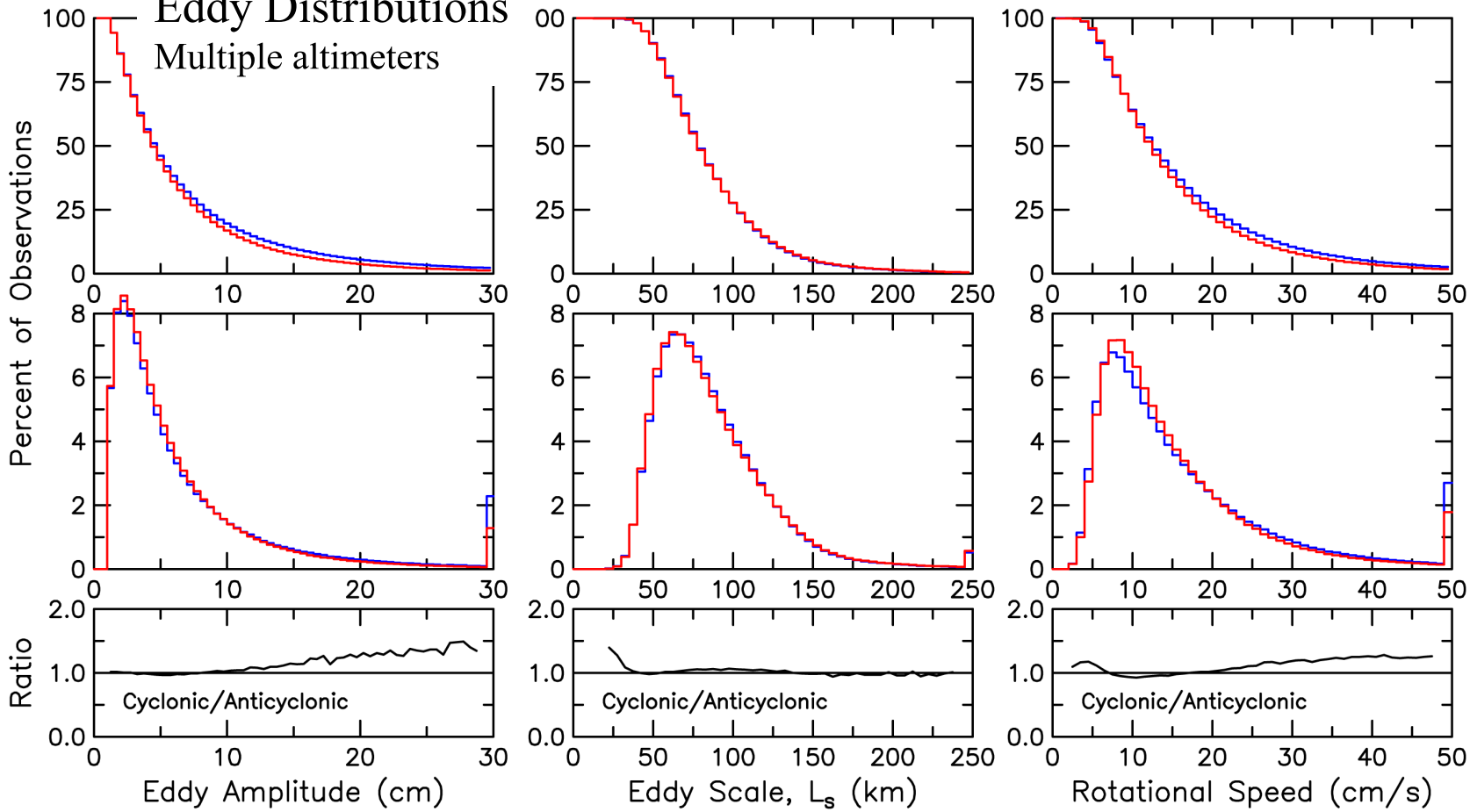
What we want to measure

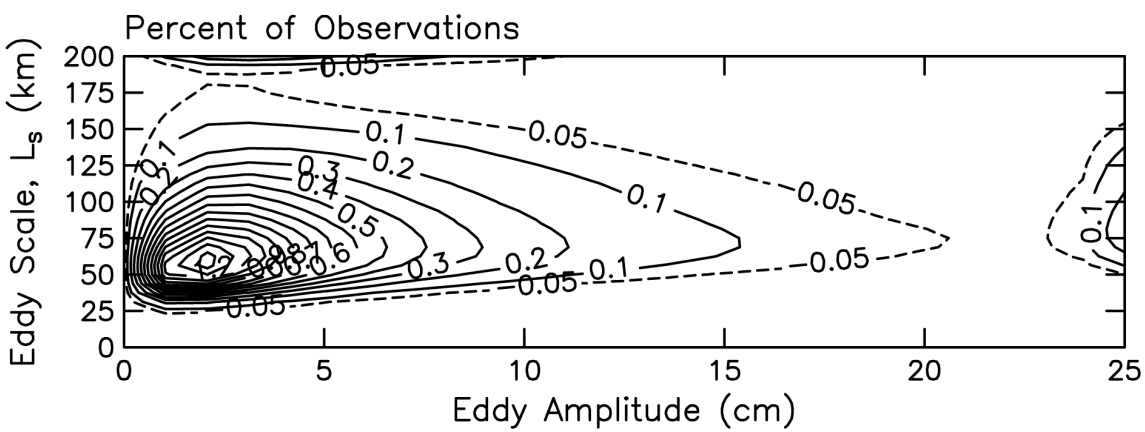
- **Distribution of ocean eddies**
  - **Versus amplitude, speed, size**
- **Basic shape (quadratic?)**
- **How does GNSS-R measure this?**

- **These are the *long-lived* eddies (> 4 weeks)**

Eddy Distributions

Multiple altimeters





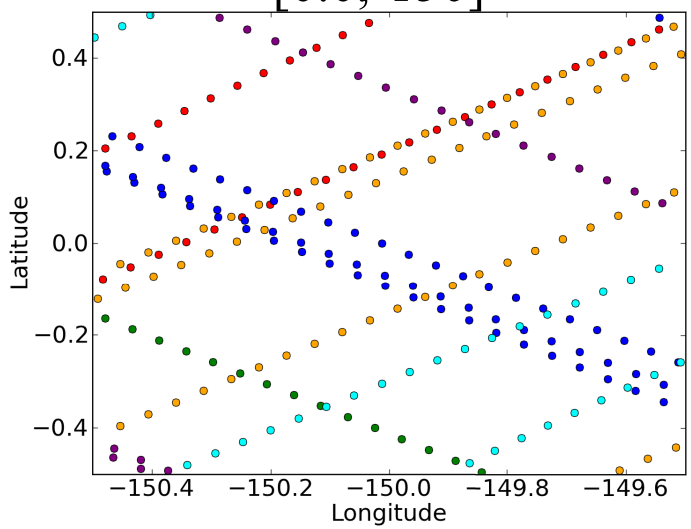
>= 4 weeks lifetime

2° spatial cutoff from mapping approach

Chelton et al., 2011

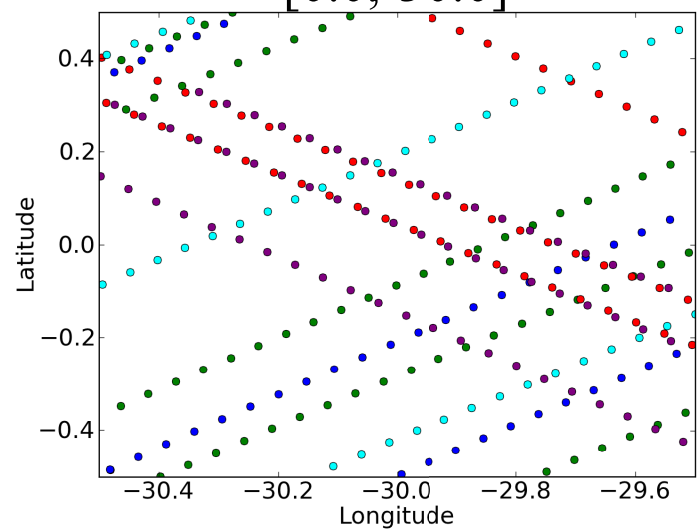
Measuring Eddies With GNSS-R COSMIC-2 Equatorial

[0.0,-150]

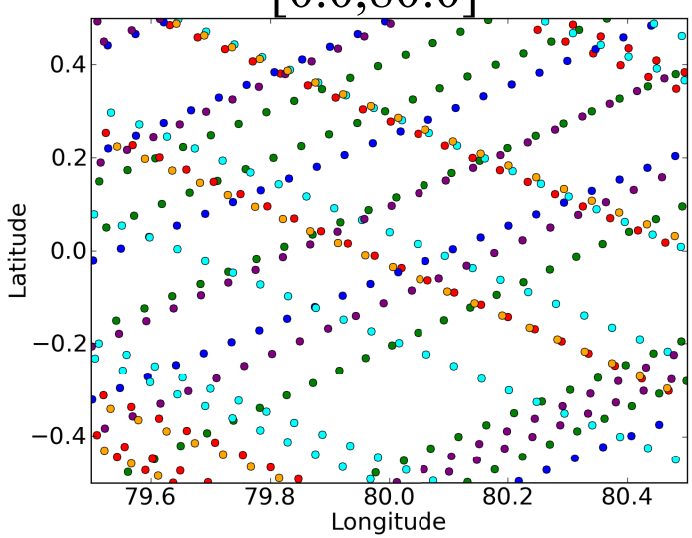


6 satellites
24° incl
3 days
1-sec points
Each color is
12 hours

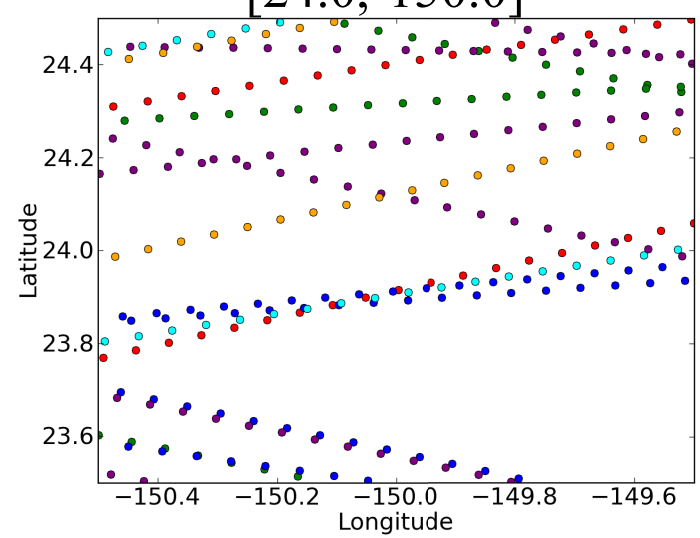
[0.0,-30.0]



[0.0,80.0]

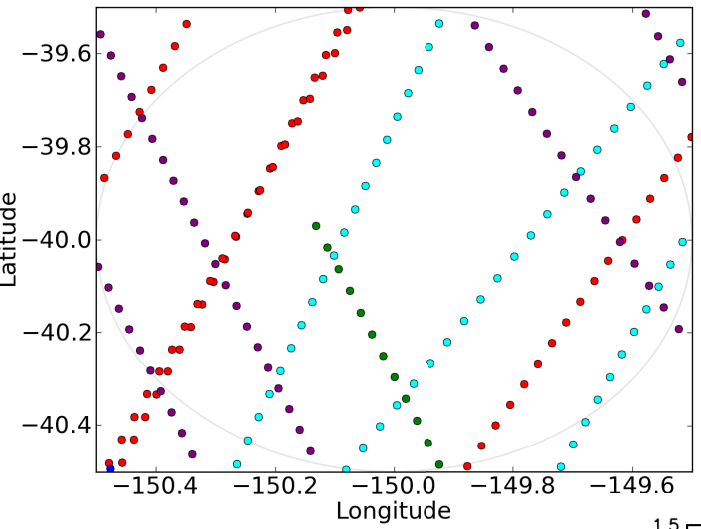


[24.0,-150.0]



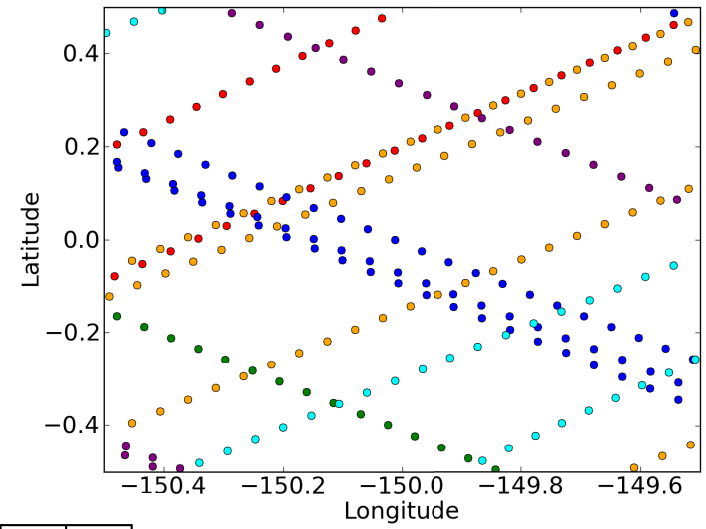
COSMIC-2 Polar

[-150.0,-40.0]

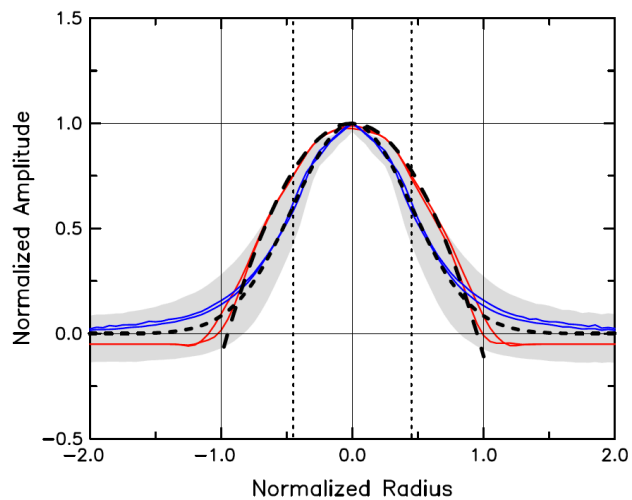


6 satellites
72° incl
3 days
1-sec points
Each color is
12 hours

[-150.0,0.0]



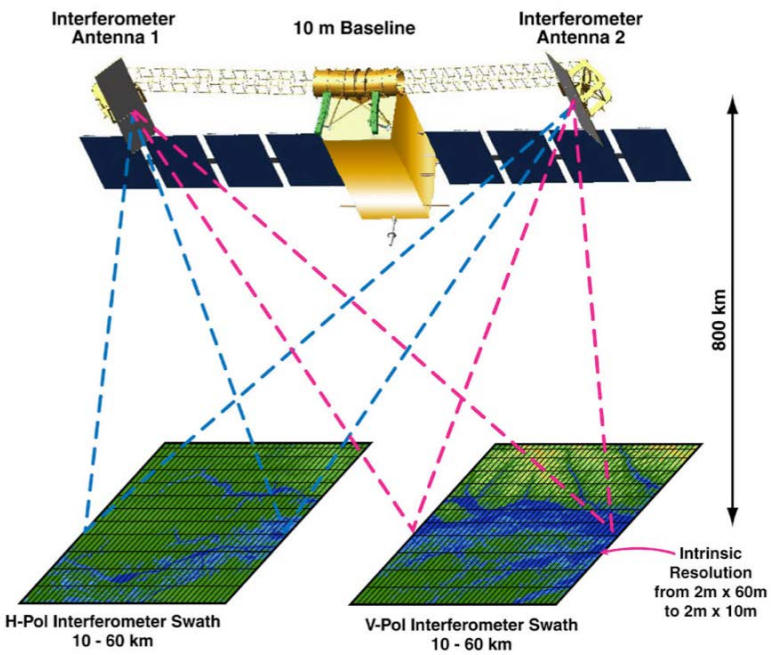
Normalized Eddy Shape

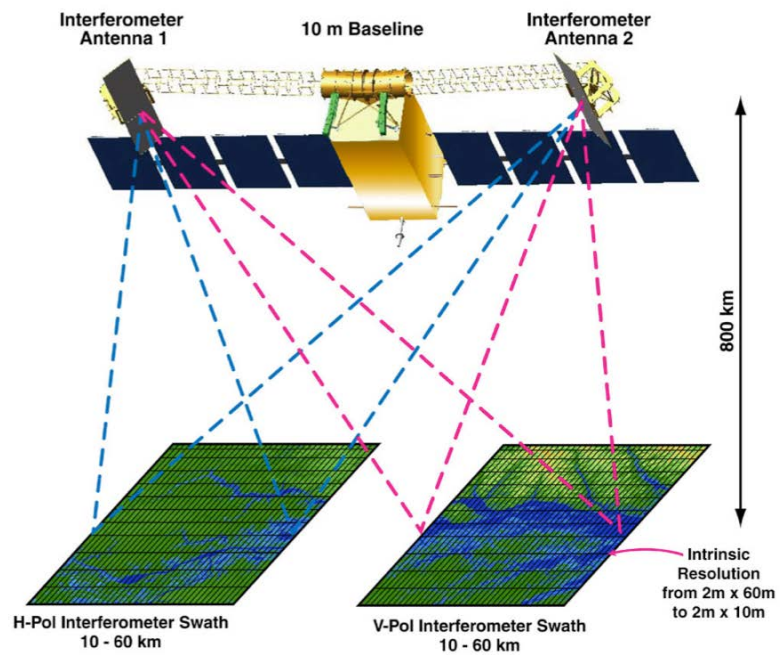


Eddy speeds, ~2 km/day westward

SWOT – Planned NASA Mission

One orbit later
2800 km





10-60 km swaths
1 km resolution

22-day repeat orbit => 127 km displacement/day

Compelling and Unique?

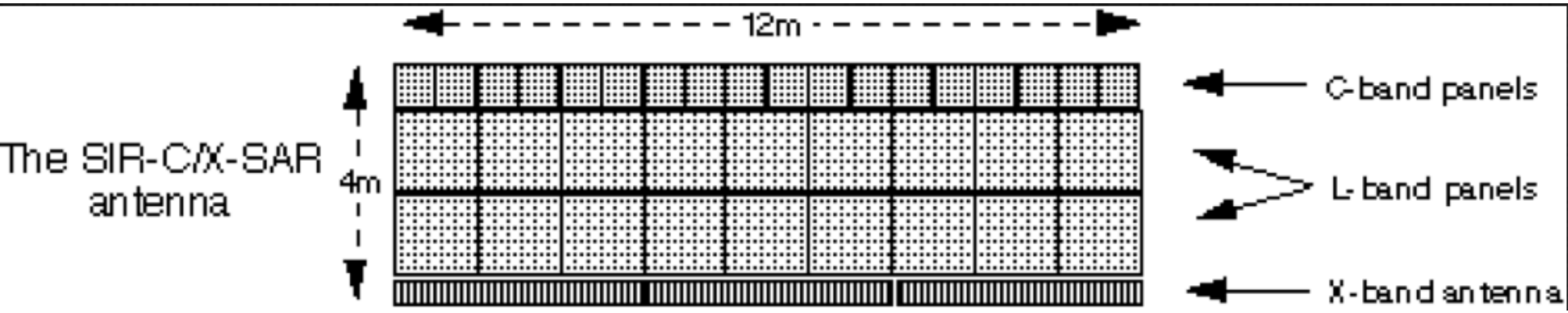
- **Eddies are the dominant source of sea surface height variability**
- **Predominantly non-linear, they have a major influence on transport/advection**
- **Global measurements are lacking**

- **"Unique compared to SWOT" depends on lifetimes of interest**
  - **SWOT will do an excellent job on eddies with lifetimes > 3 weeks or so**
- **GNSS-R is best suited for eddies with shorter lifetimes**

"Not surprisingly, eddies with small amplitude or small scale generally have short lifetimes, while eddies with large amplitude or large scale generally have longer lifetimes."

Not Discussed

- **Altimetric accuracy: how many 1-second points are incoherently averaged?**
  - **Is the 1-sec altimetric accuracy 6 cm (SIR-C) or 42 cm (20 dB gain antenna, approximate)**
- **Doppler technique**
- **Geophysical corrections such as troposphere**
  - **How to minimize impact?**



Summary – Altimetric GNSS-R

- **Recent science suggests there are compelling reasons to characterize eddies at scales ~50-100 km**
  - **There are lots of them and they transport lots of stuff in the ocean**
- **Eddy amplitudes are in the range 5-20 cm**
- **Need an algorithm to retrieve Eddy distributions using GNSS-R – requires oceanographer involvement**
  - **E.g. an "observation system simulation experiment"**
  - **Also, improved estimates of altimetric precision**
- **"Uniqueness" depends on the lifetimes of the eddies of interest**
  - **Planned SWOT mission (2020) will significantly improve resolution of eddies**
- **Strongly endorse CYGNSS, GEROS and PARIS as positive steps**

Web Site

http://gnss-r.jpl.nasa.gov (soon!)

Modify?

GNSS-R

gnss-r.jpl.nasa.gov

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Remote Sensing Using Global Navigation System Satellites Reflections

GNSS-R Science
- Home
- Science Objectives
- Technology
- Platforms

Missions/Mission Concepts
- CYGNSS
- PARIS
- GEROS/ISS
- Other

Institutions
- U Michigan
- Purdue U
- ICE (Spain)
- JPL

Remote Sensing

3 Days (GPS+Galileo)

Introduction Title

Main text goes here

Request to join our email list

Upcoming Workshops
Keep Posted for future workshops...

GNSS-R Documents
- Report 1 + View report →
- Report 2 + View report →
- Report 3 + View report →
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Content 1
+ something here