

The Importance of short waves

CARTHE All-hands 4/30/2014

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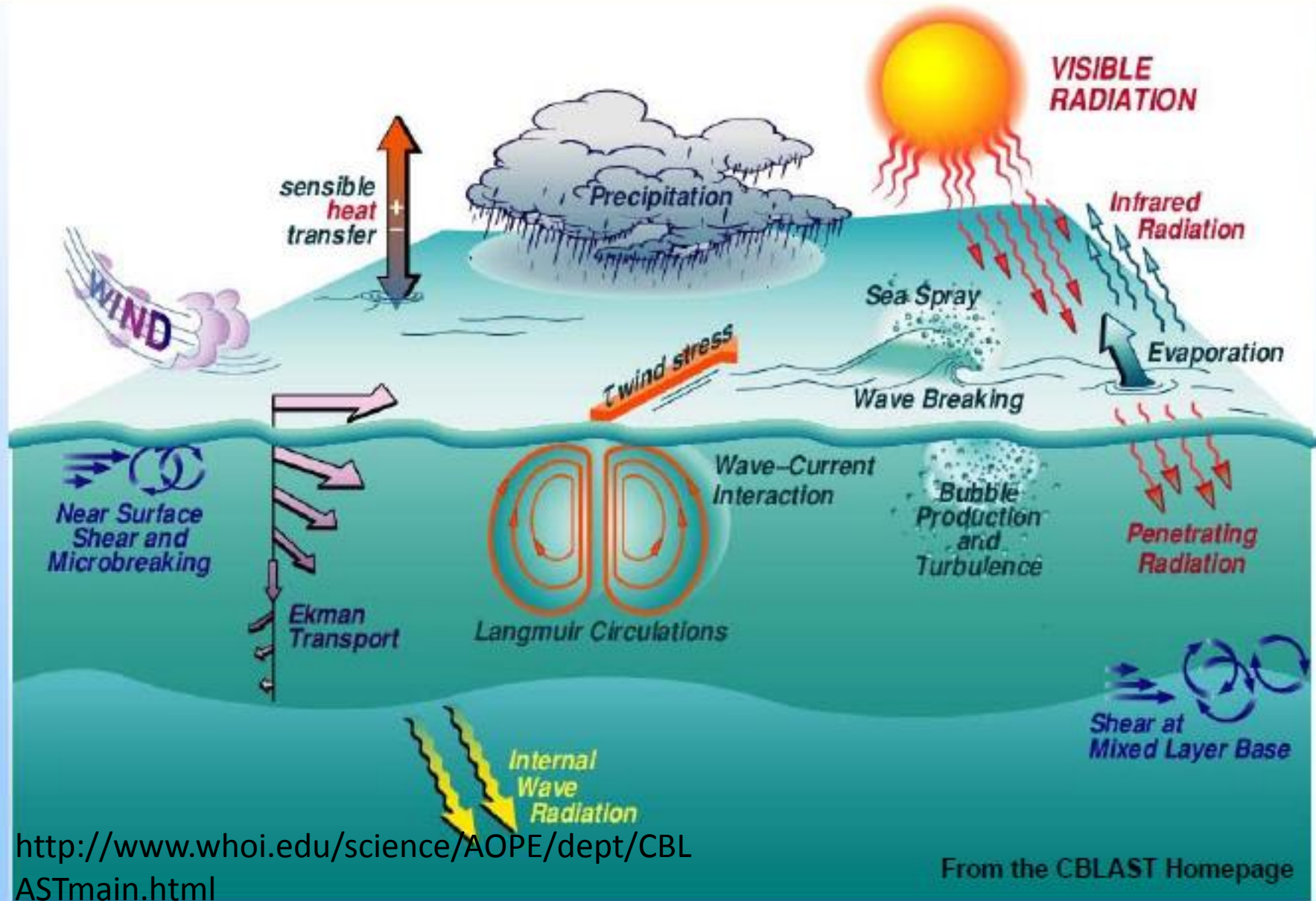
GULF^{OF}
MEXICO
RESEARCH INITIATIVE

The logo for the Gulf of Mexico Research Initiative. It features the text "GULF OF MEXICO" in a bold, blue, serif font, with "RESEARCH INITIATIVE" in a smaller, blue, sans-serif font below it. To the right of the text is a circular emblem containing a stylized map of the Gulf of Mexico region.

Thanks to:

- GoMRI, CARTHE, ONR, CSTARS
- Nathan Laxague, David Ortiz-Suslow
- Neil Williams, Mike Rebozo
- Tamay, Alex Soloviev, Darek Bogucki , NPS (Jamie, Tom Herbers) and the rest of the CARTHE team.

Air-Sea Interaction: Multi-Scale Processes



What do I mean by short?



SUSTAIN Laboratory, 4/17/2014

Wave generation and damping

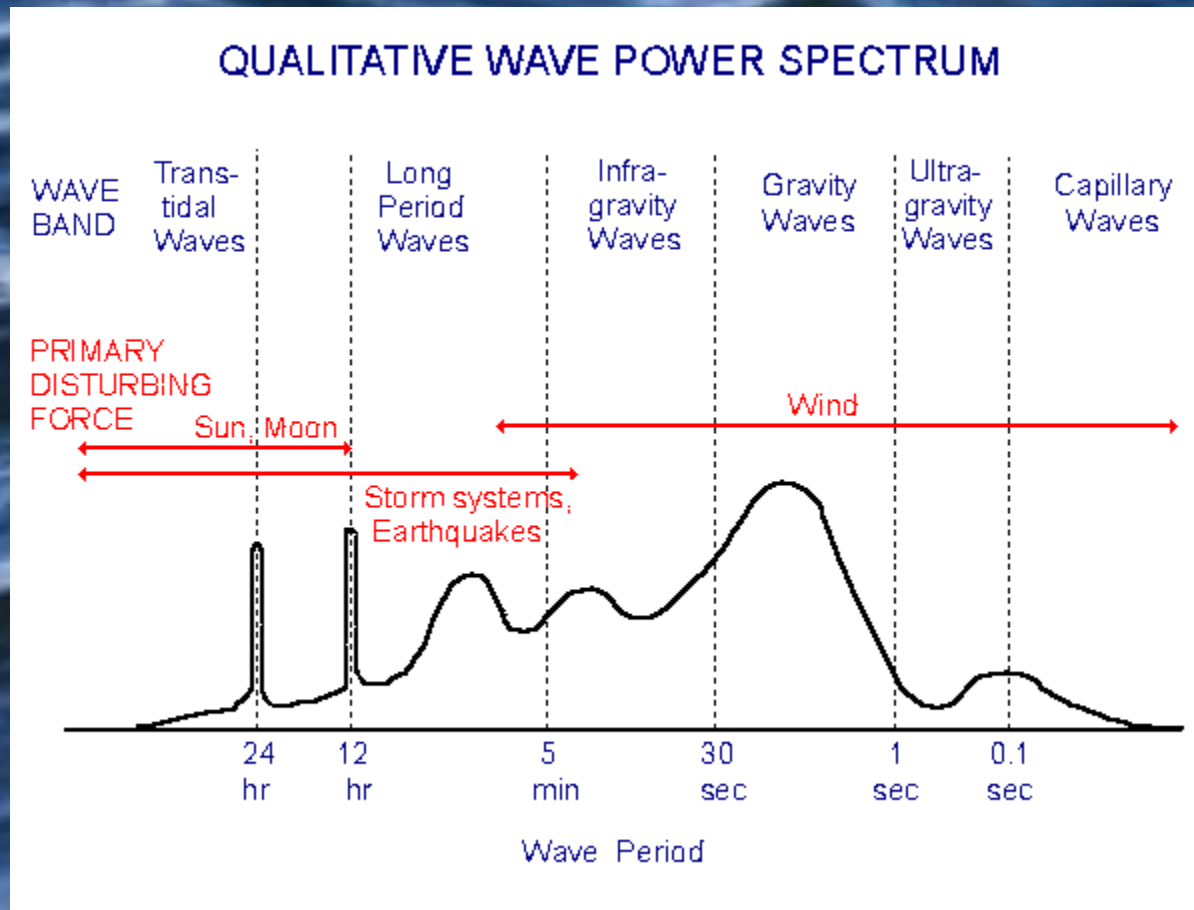


Figure source:

<http://tidesandcurrents.noaa.gov/levelhow.html>

Gravity-Capillary waves

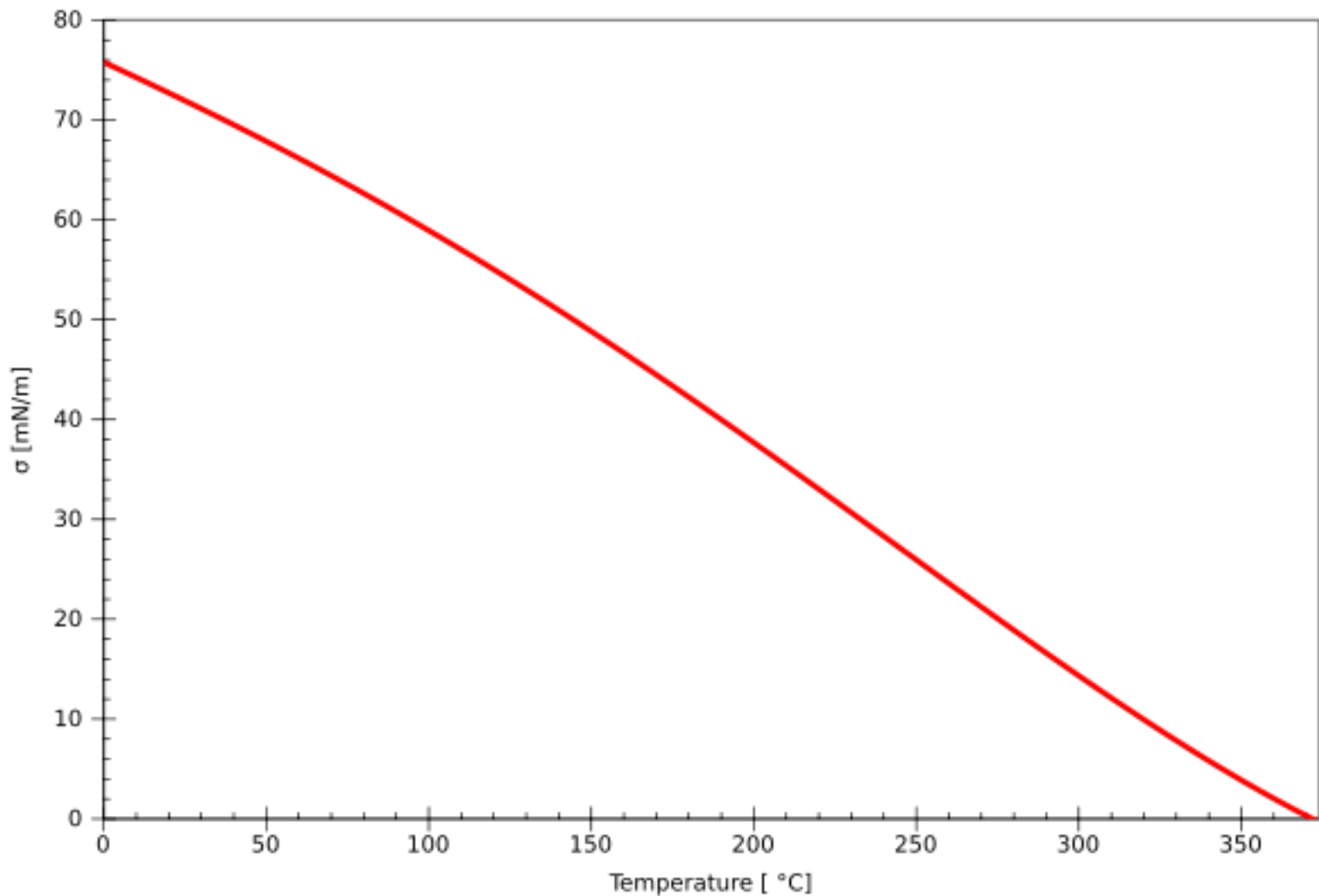
- Both gravity and surface tension act as restoring forces
- Linear dispersion relation

- $$\omega^2 = gk + \frac{\sigma k^3}{\rho}$$

- Phase speed minimum at $\sim k = 354$

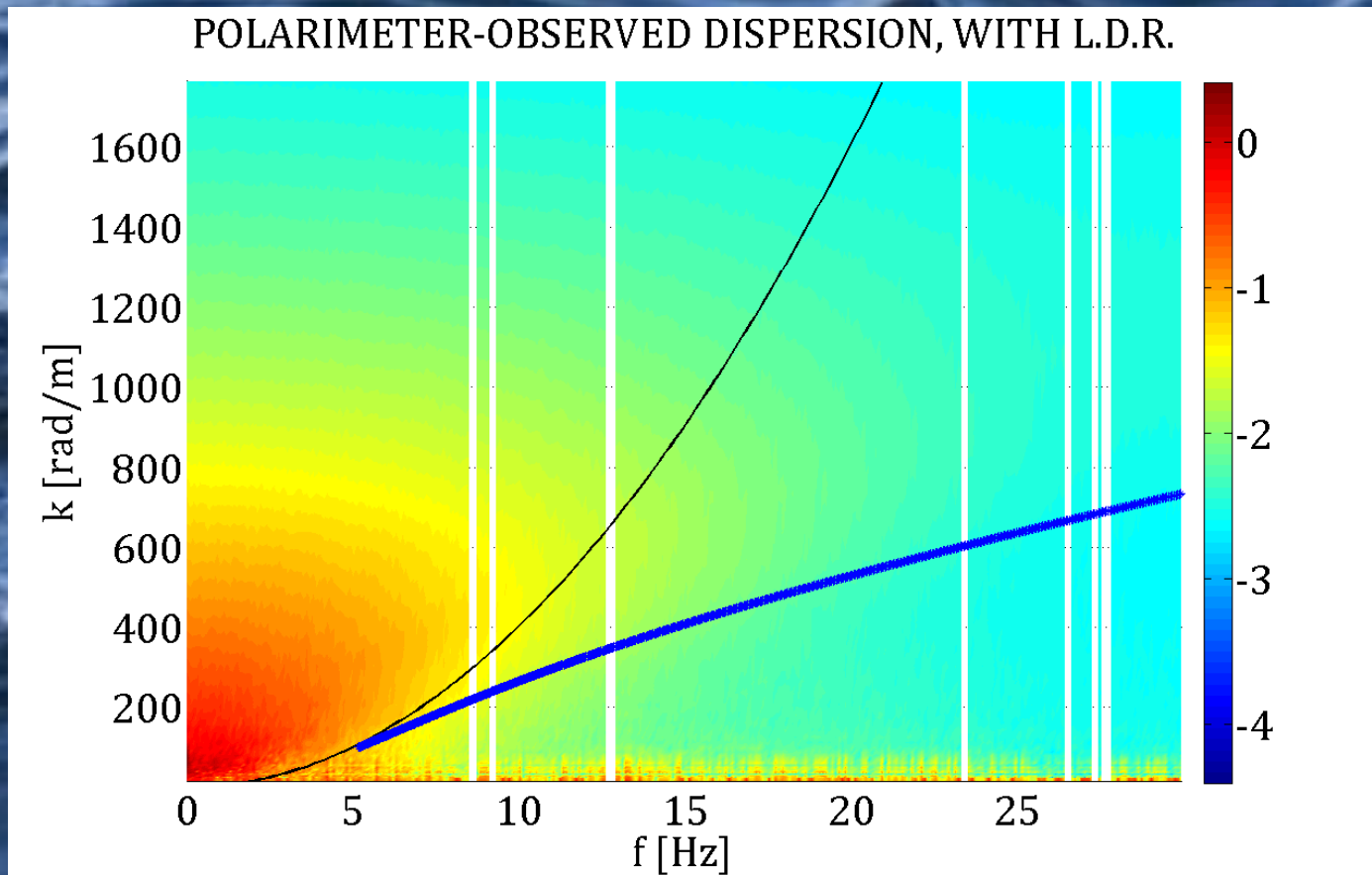
(Seawater, 20 °C, $\sigma = 73 \text{ mN/m}$)

Surface Tension of Pure Water as a Function of Temperature (at Saturation Pressure)

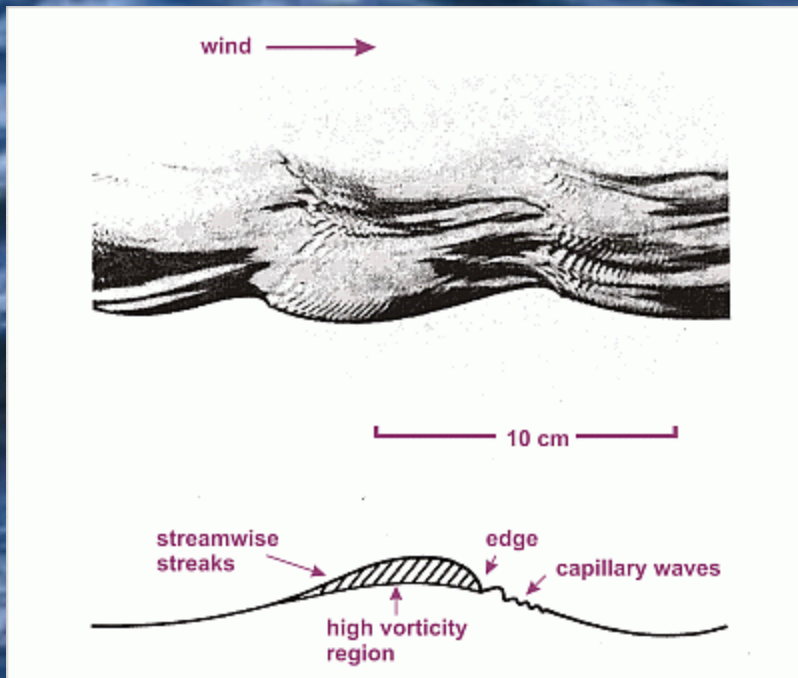


Source:<http://www.wikipedia.org>

In development: Wavenumber-frequency spectra using stacked 10-min series of 2-D slope images.



Bound capillaries



Source: <http://deepseanews.com/2013/10>

Free capillaries



Image Source:[http://www.wikipedia.org/capillary waves](http://www.wikipedia.org/capillary_waves)

So??

- **Scalar Fluxes across the air-sea interface**
 - Gas
 - Heat (sensible and latent)
- **Remote Sensing**
 - Passive
 - Active
- **Momentum flux**
- **Turbulence/dissipation**

Scalar Fluxes

- **Must diffuse across interface**
- **Flux = Force/Resistance**
- **Force = difference between conc. and equilibrium conc.(at given t)**
- **Resistance (either air or water side)**

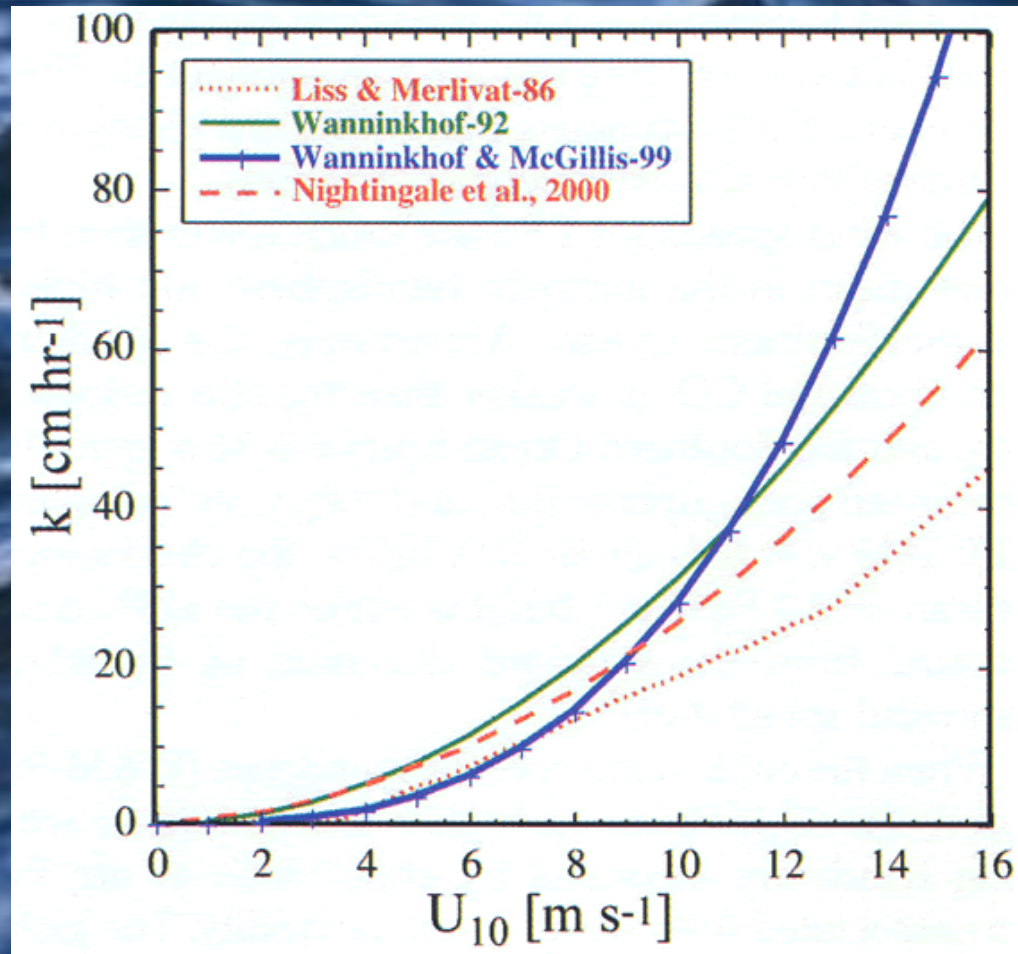
Transfer velocity: Water side resistance

Henry's Law: $S\chi_a = \chi_w$, S = solubility, χ = conc.

Gas flux: $F_i = \frac{\chi_w - S\chi_a}{\sqrt{\frac{\pi t}{D_w}} + S\sqrt{\frac{\pi t}{D_a}}}$, t = time, D = diffusivity

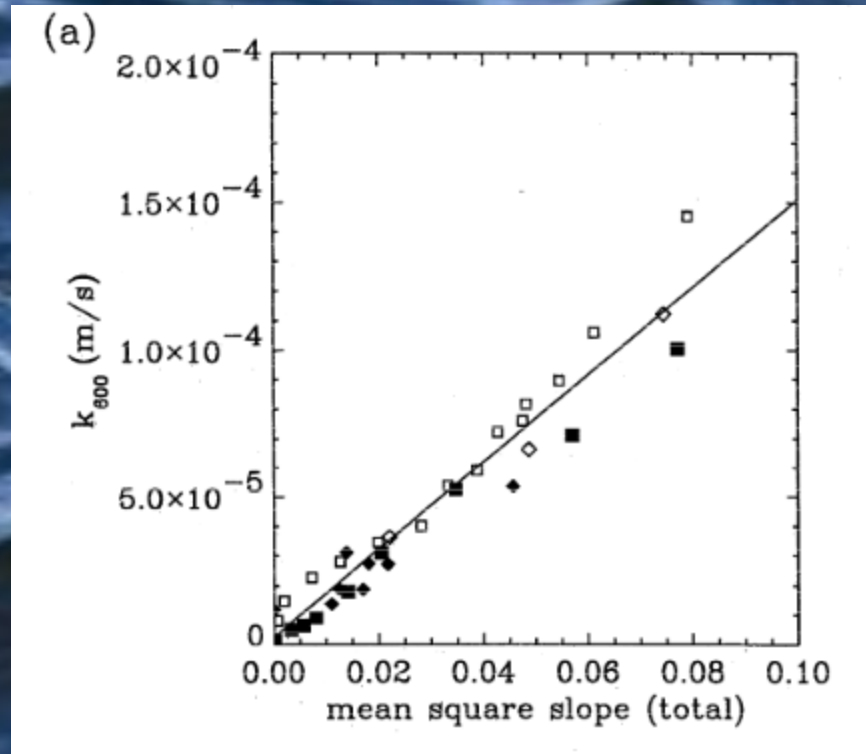
Define transfer velocity k as $\sqrt{\frac{D_w}{\pi t}}$

Wind speed dependence of CO₂ transfer velocity



Source: Feeley et al. 2001

But data collapses better on mean square slope

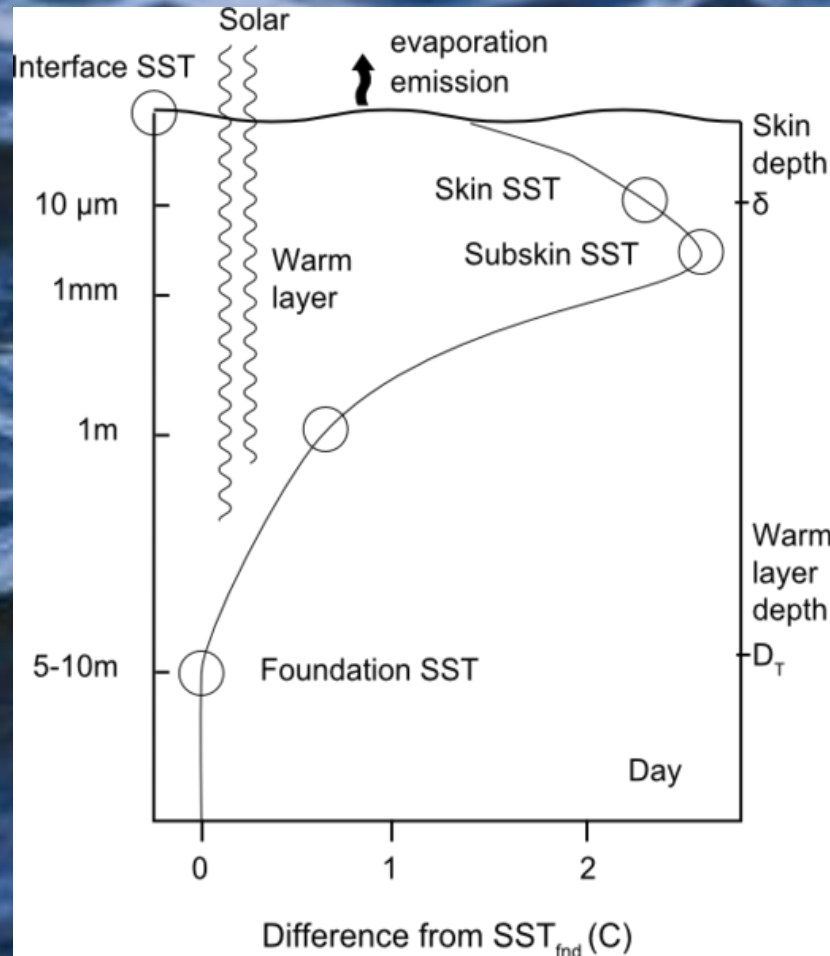


Source: Bock (1999)

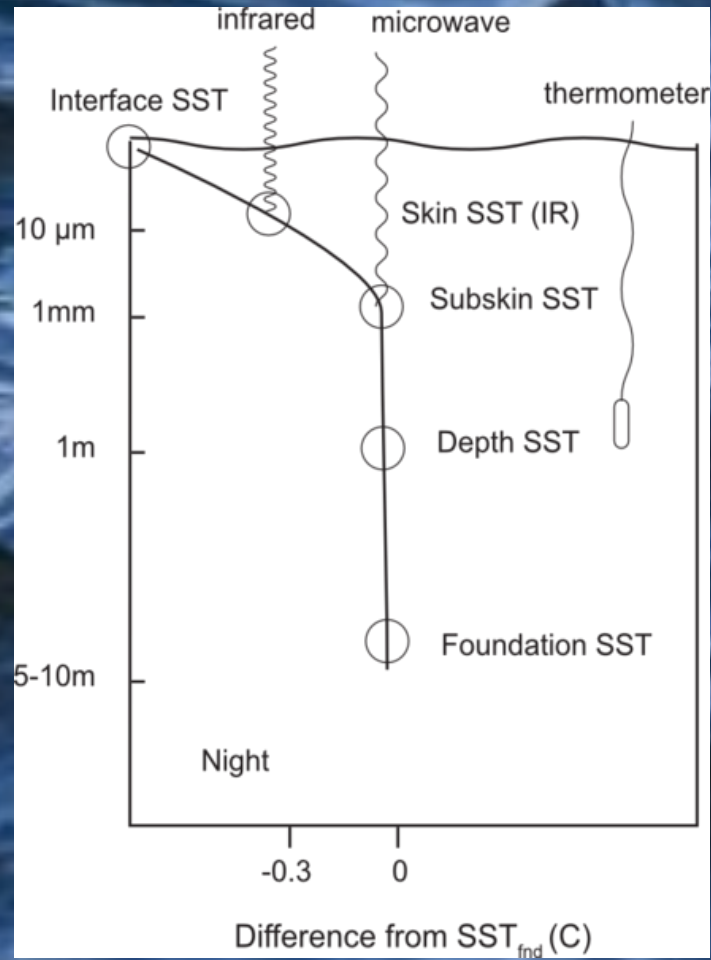
Importance for remote sensing

- **Passive**
- **Active**

Infrared imaging: Surface Skin effects

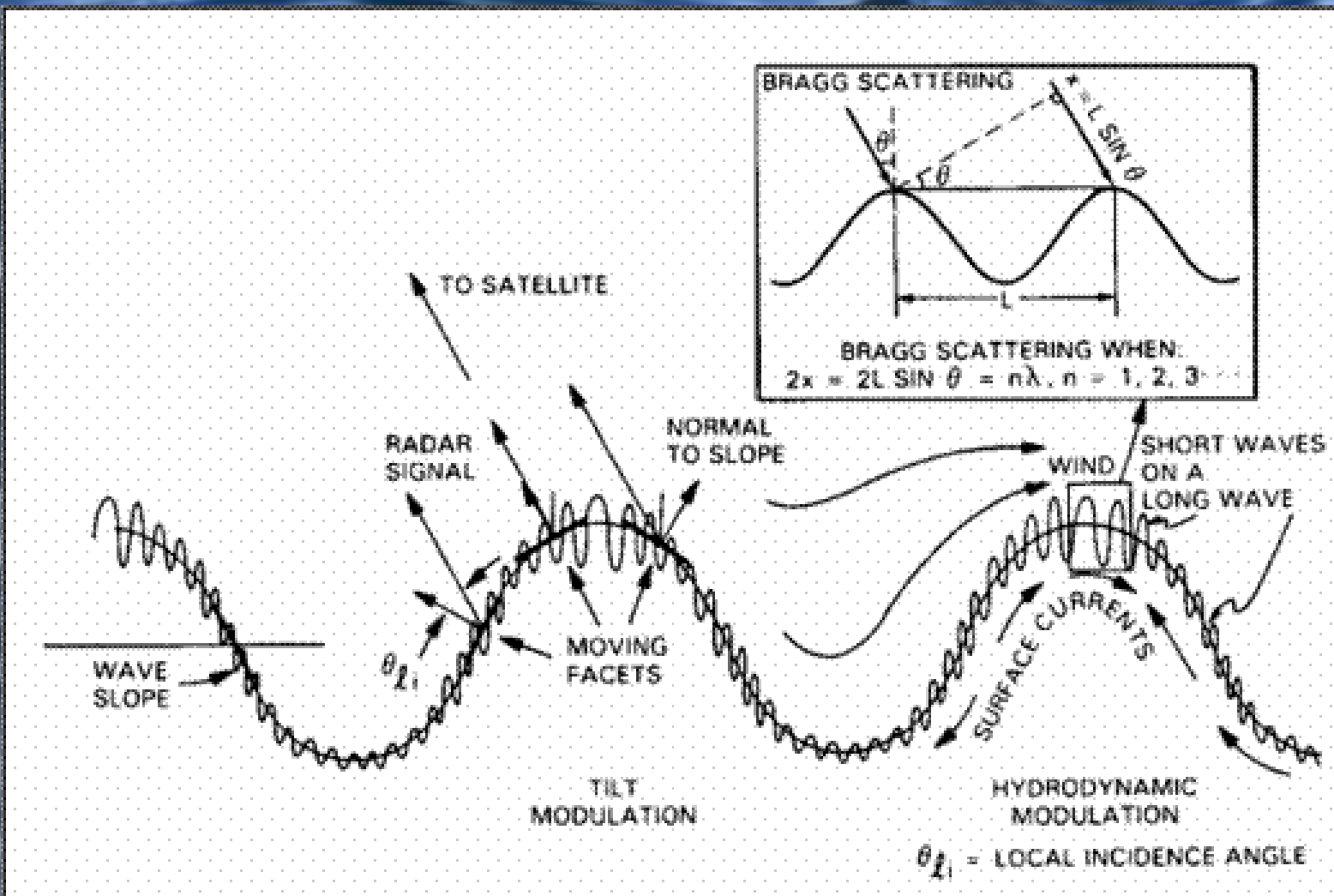


Daylight hours, surface solar heating



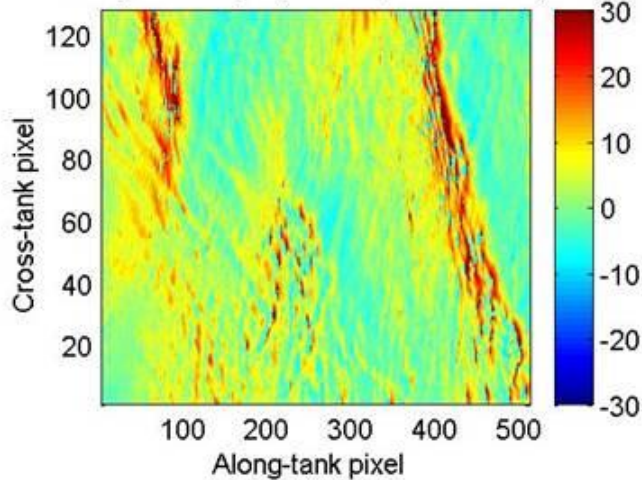
Nighttime hours

Active Remote Sensing: Radar Modulation

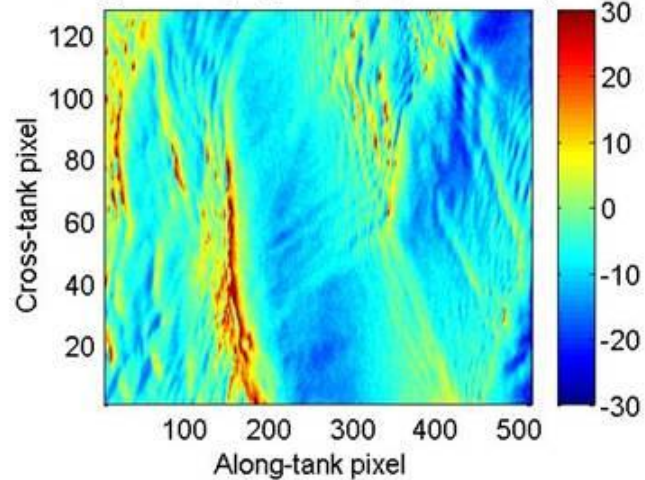


Modulation of short waves by longer waves

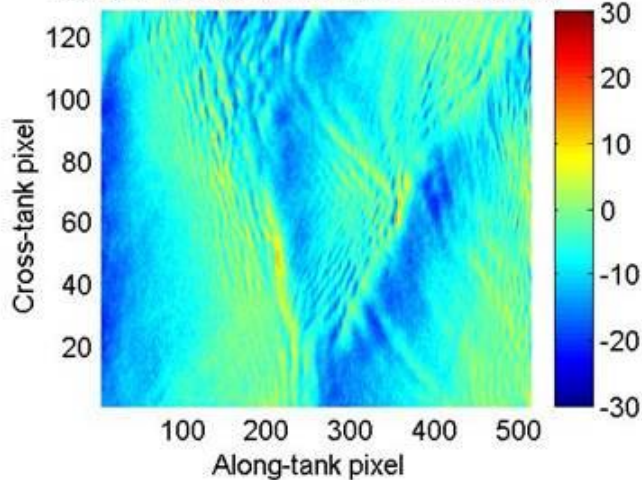
Along-wind slope (phase 0, 1 hz waves)



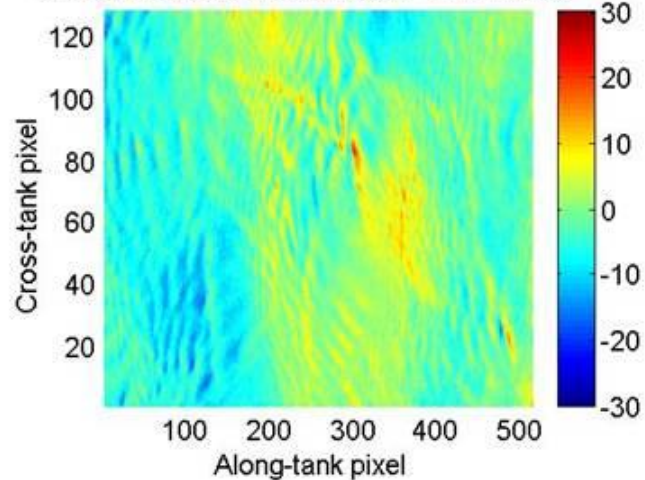
Along-wind slope (phase $\pi/4$, 1 hz waves)



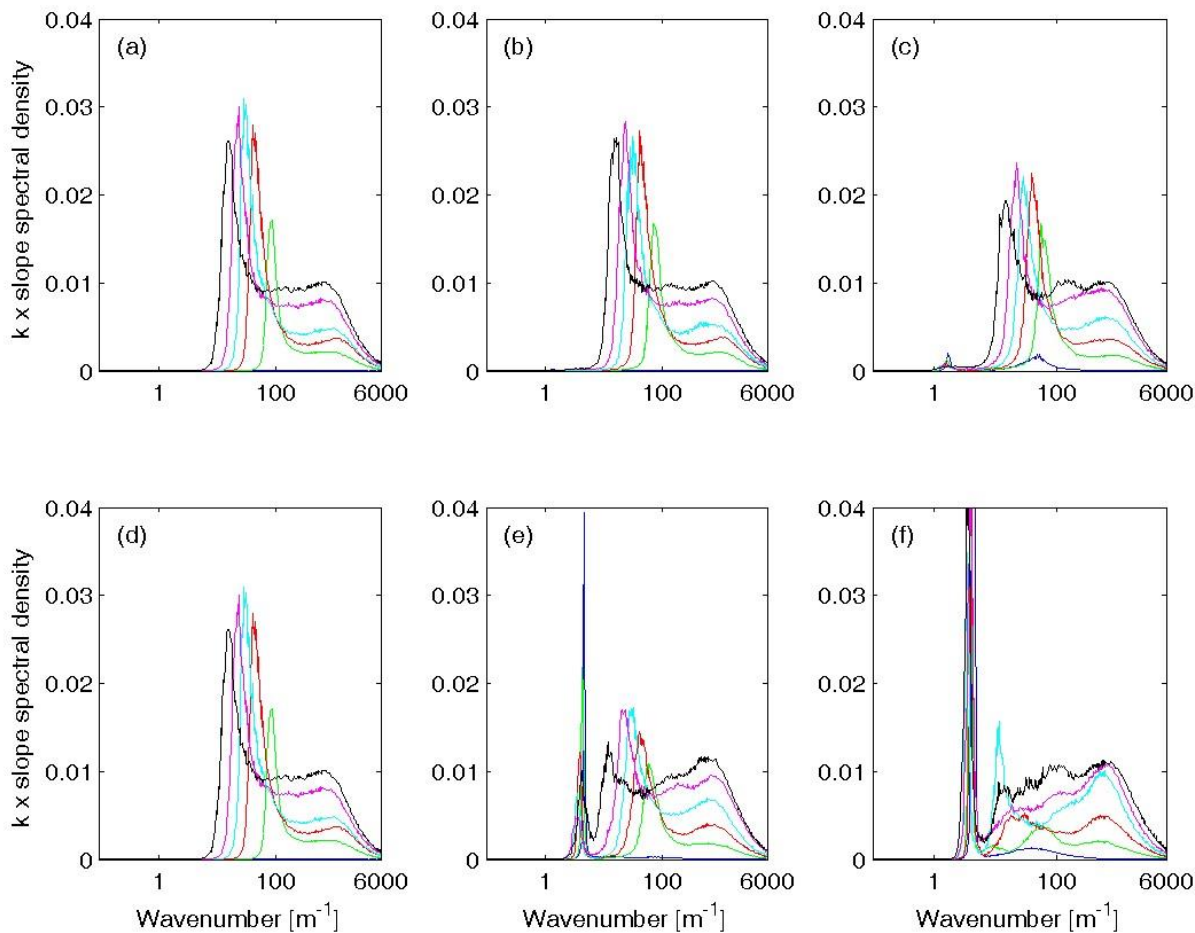
Along-wind slope (phase $\pi/2$, 1 hz waves)



Along-wind slope (phase $3\pi/4$, 1 hz waves)



Hydrodynamic Modulation of Spectra by long waves (a-f) and wind (colored lines)

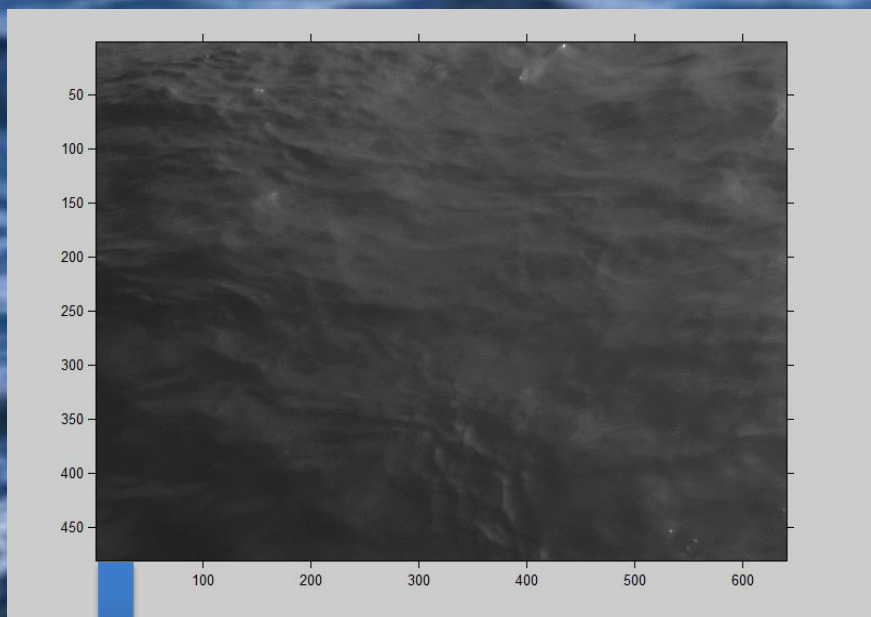


Wind speed
(centerline)

- 0 m/s
- 5 m/s
- 7.5 m/s
- 10 m/s
- 12.5 m/s
- 15 m/s

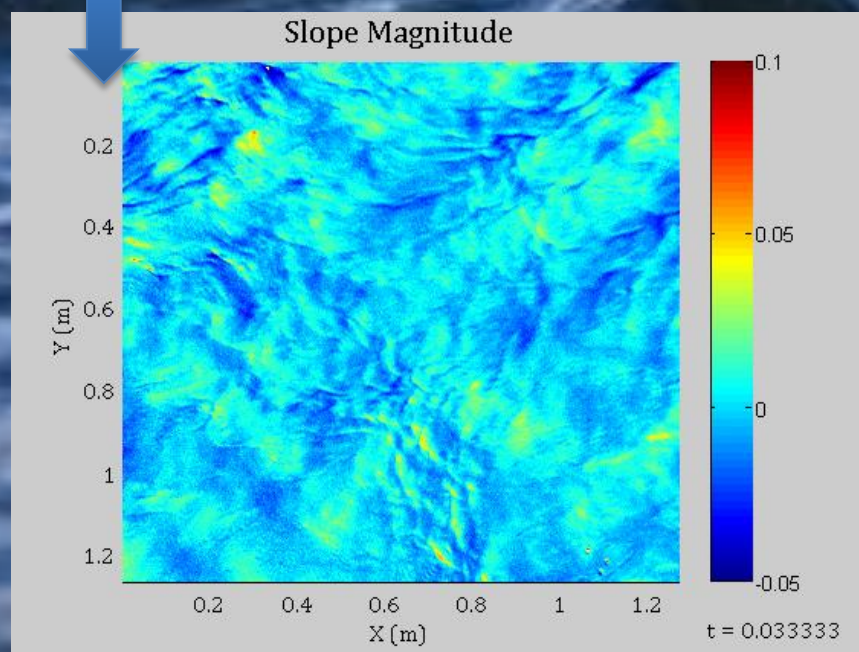
(a,d) wind only, (b) 0.5 hz, 1.1 cm (c) 0.5 hz 2.1 cm (e) 1.0 hz 1.8 cm (f) 1.0 hz 3.0 cm

0 deg. Polarization video from RV, Walton Smith during GLAD,



Shipboard use in 4 field campaigns from 3 ships in last 2 yrs

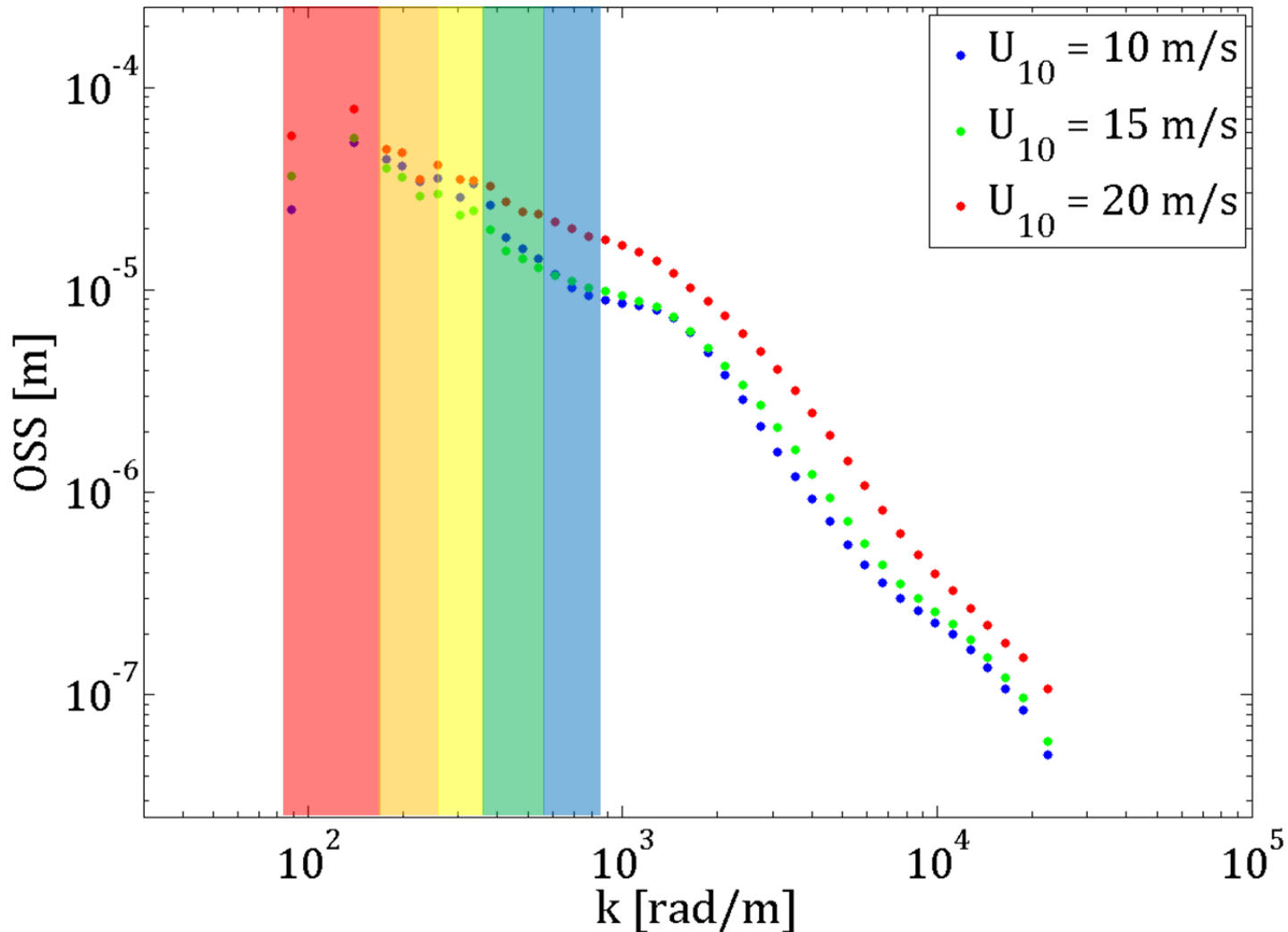
Data from CARTHE- GLAD experiment, see Nathan Laxagues talk



Bottom: Motion corrected, scaled slope field

Polarimetric Slopes over range of wind speeds in ASIST

C X K_u K K_a



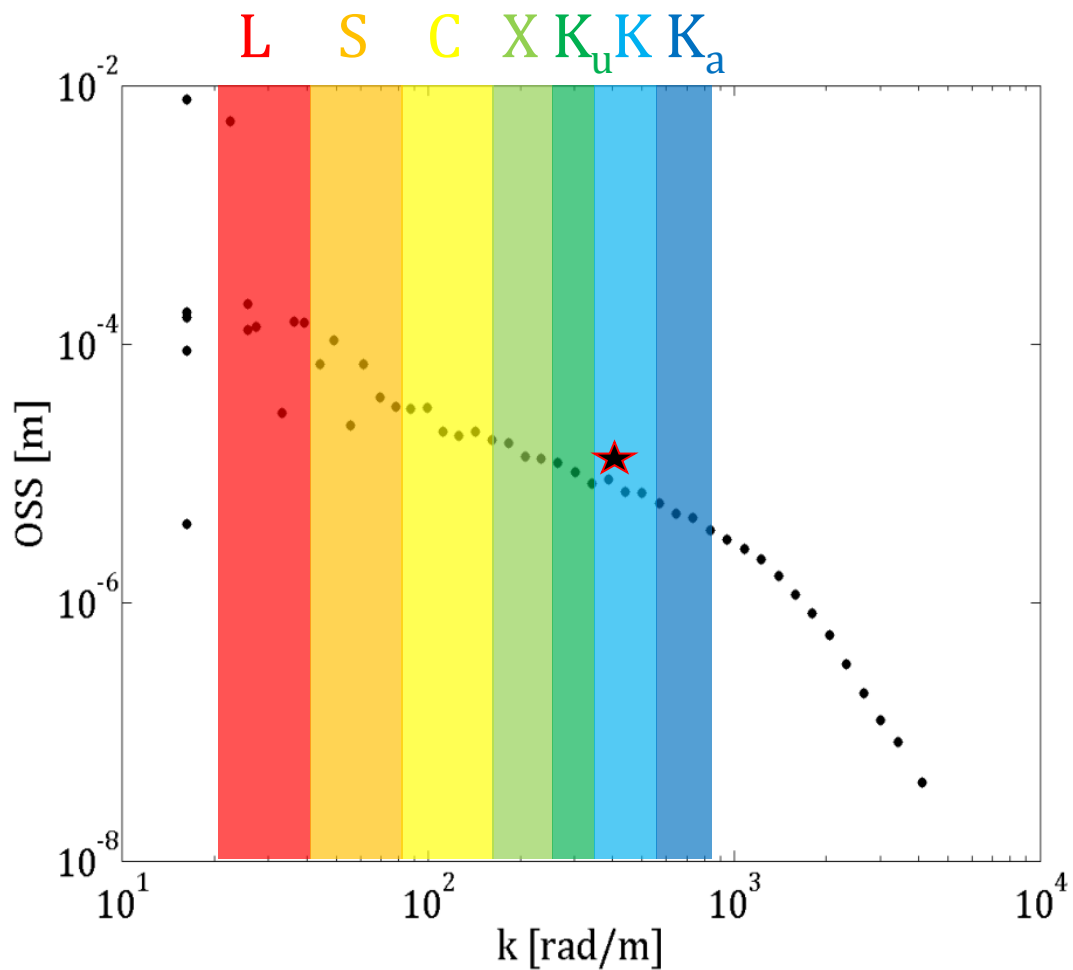
TerraSar-x Spotlight



Measurement of Short Waves



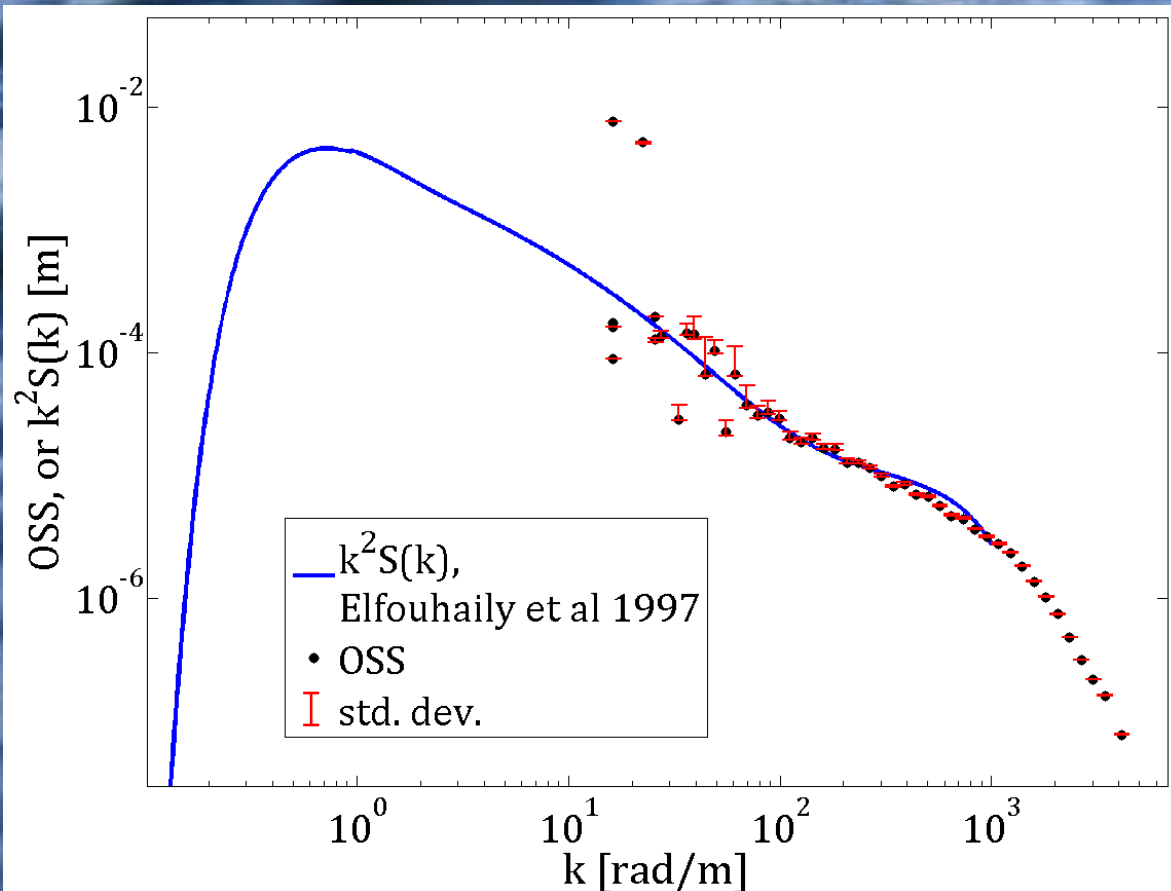
RV SPEC during SCOPE experiment



Common remote sensing wavenumber bands, with Polarimetric slope spectra

RESULTS- COMPARISON TO THEORY

Field data:
omnidirectional
slope spectrum
Theoretical
spectrum: $k^2S(k)$
corresponding to
 $U_{10} = 4$ m/s from
Elfouhaily et al
1997



Flux measurements on RV Point SUR



- 10-20 Hz sampling
- ~9- m elevation
- Unobstructed except from rear
- Motion corrected
- Wind stress, speed, temp-Sonic anemometer
- RM young- mean wind
- Flow through LICOR- CO2, H2O vapor
- Latent, sensible heat flux
- Longwave, shortwave radiation

Direct Covariance Stress

Stress Direction

$$\hat{\tau} = \rho \{ (-\overline{u'w'})\hat{i} + (-\overline{v'w'})\hat{j} \}$$

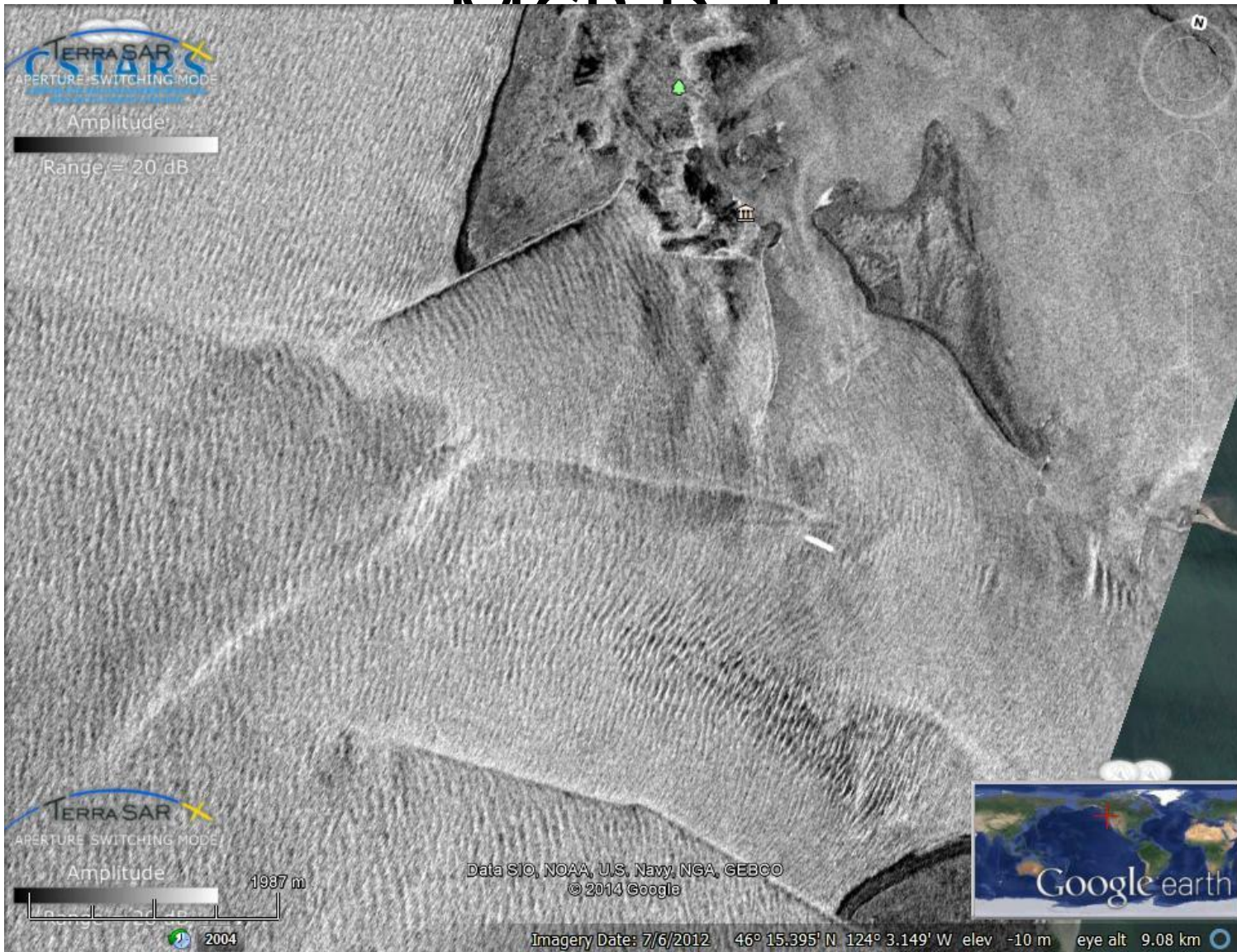
$$\tan \theta = (-\overline{v'w'}) / (-\overline{u'w'})$$

Polarimetric and Infrared sea-surface measurements on RV Point SUR

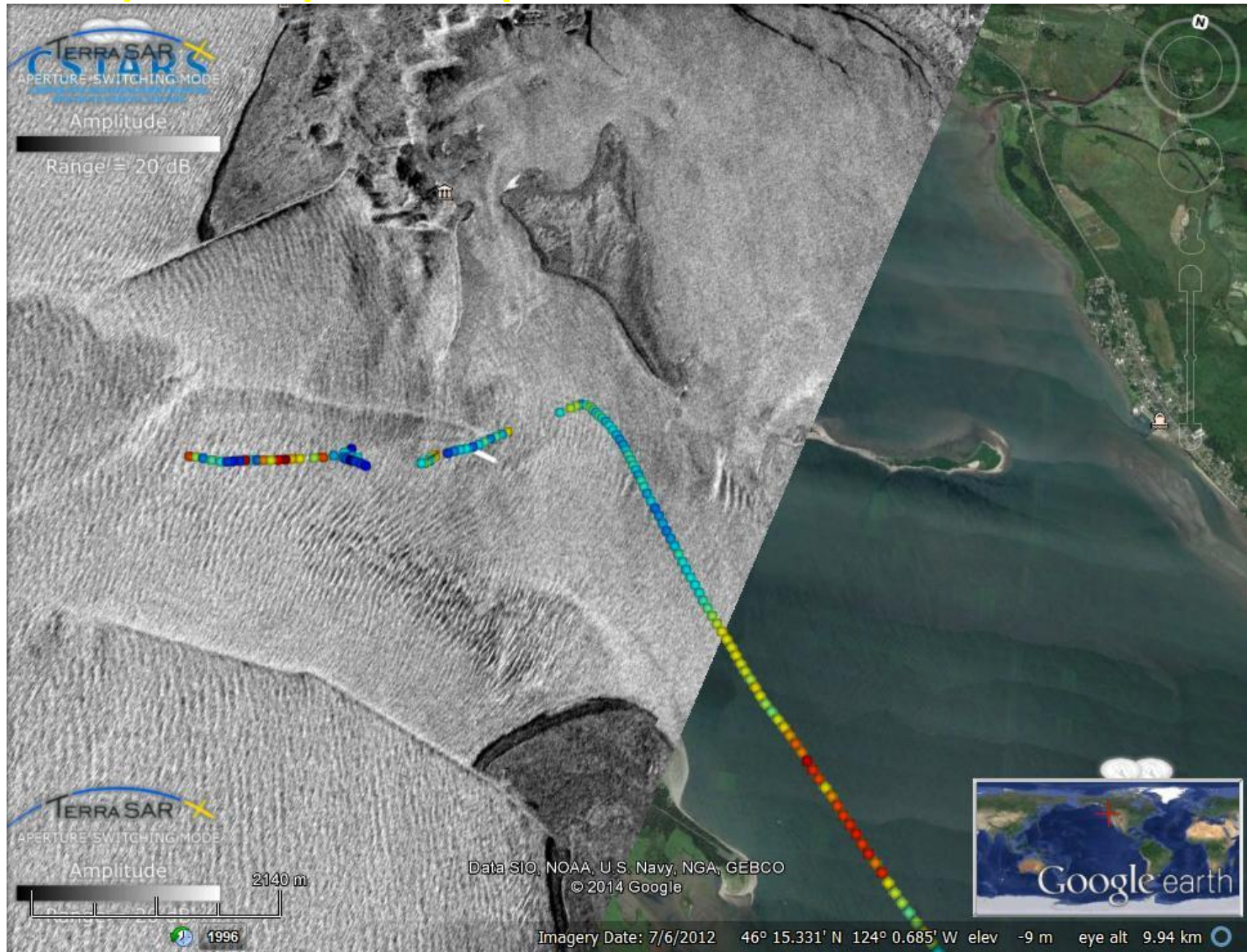


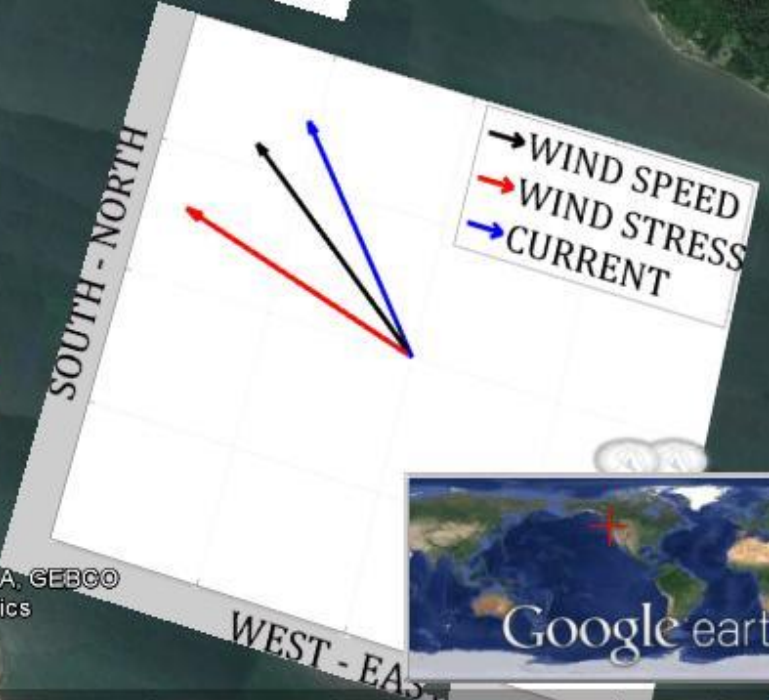
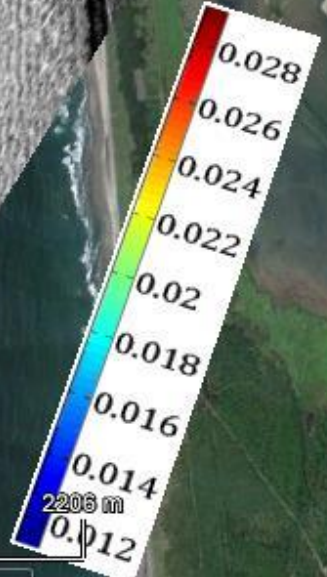
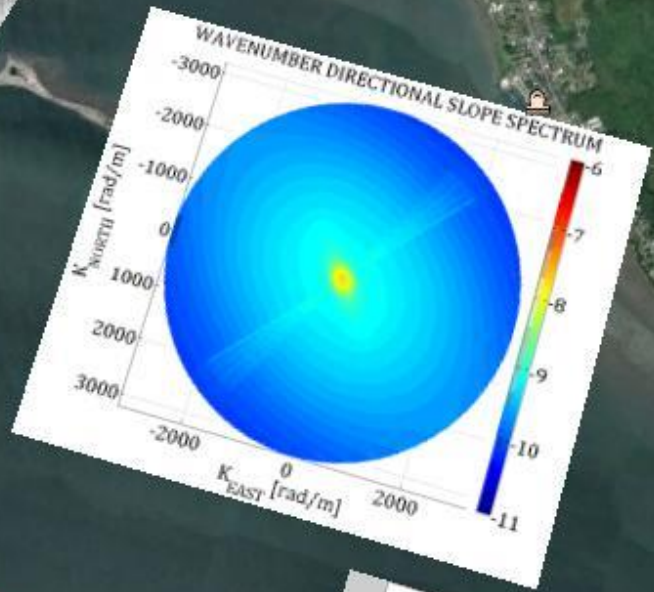
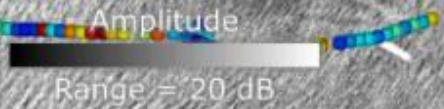
- Up to 54 Hz simultaneous 0,45,90 pol.
- 6Hz infrared sampling
- ~5-m elevation
- Motion corrected
- Usually outside of wake
- ~co-located UDM for 1-D waves

MARSHALL ISLANDS



Mean square slopes from polarimeter

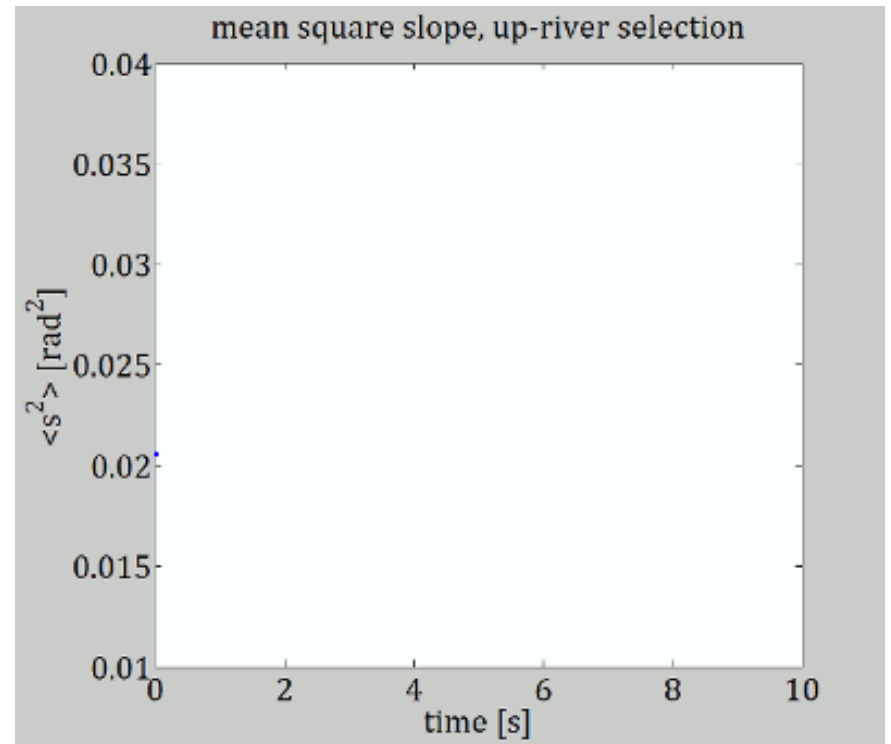
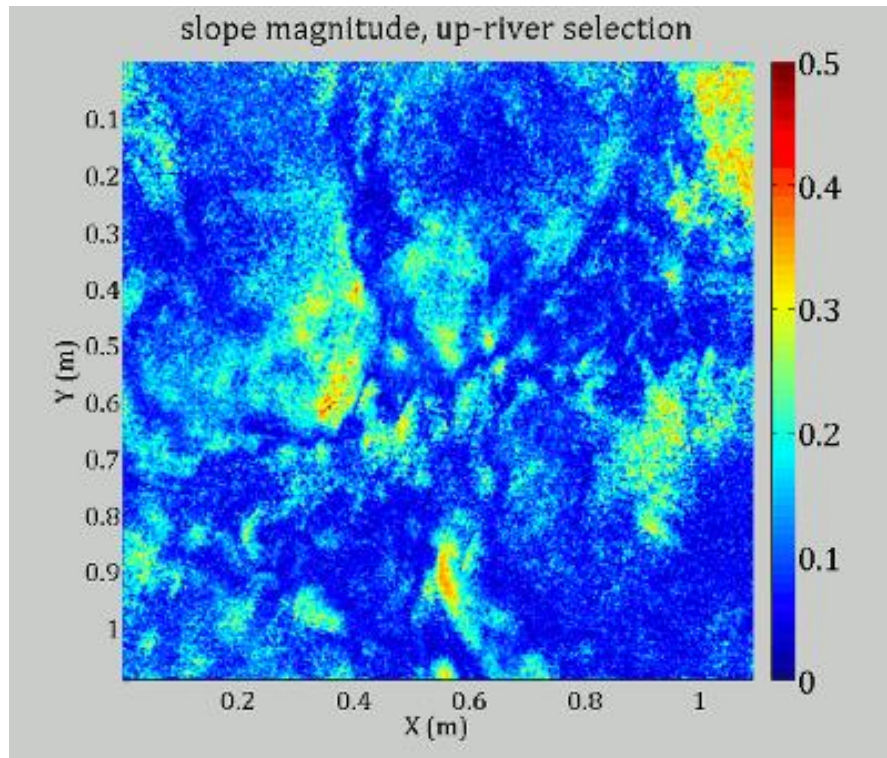


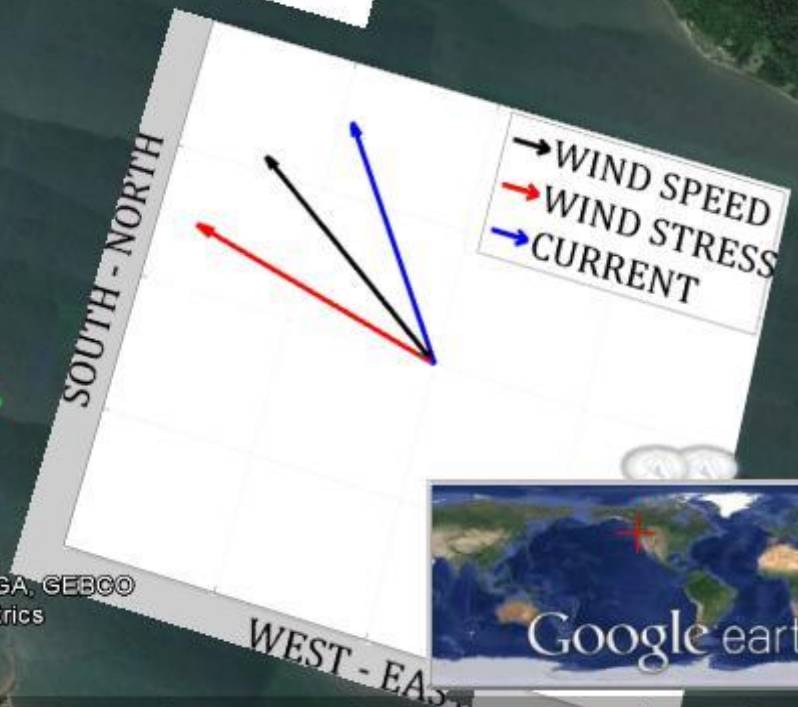
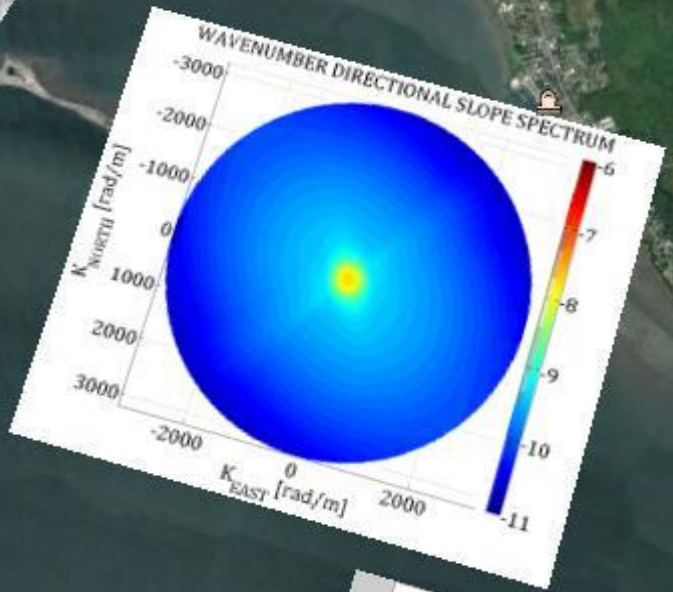
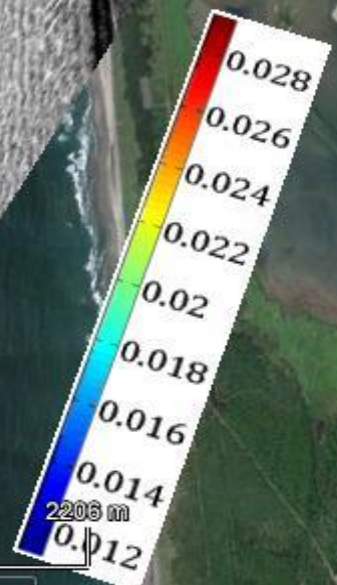
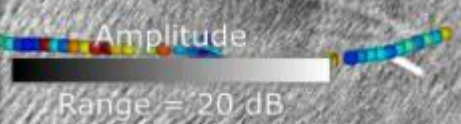


Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2014 TerraMetrics
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In river slope detail



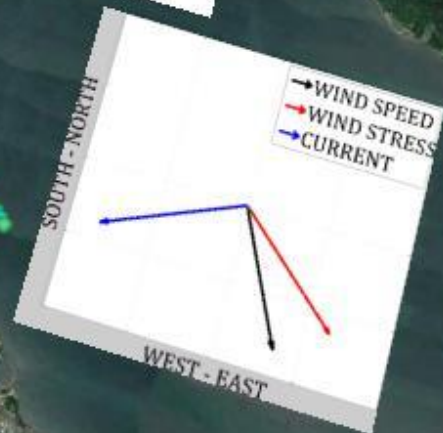
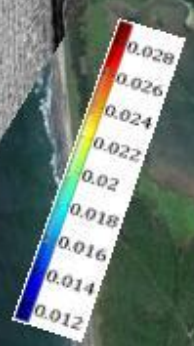
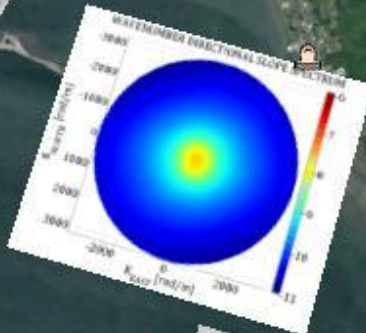
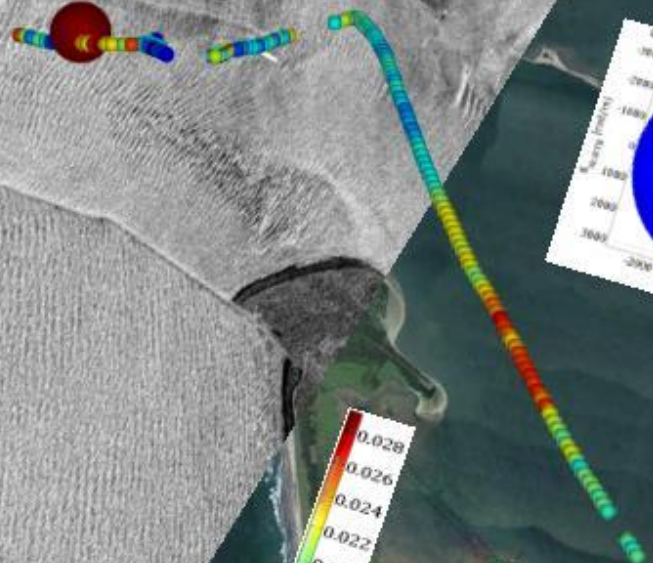


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Amplitude

Range = 20 dB

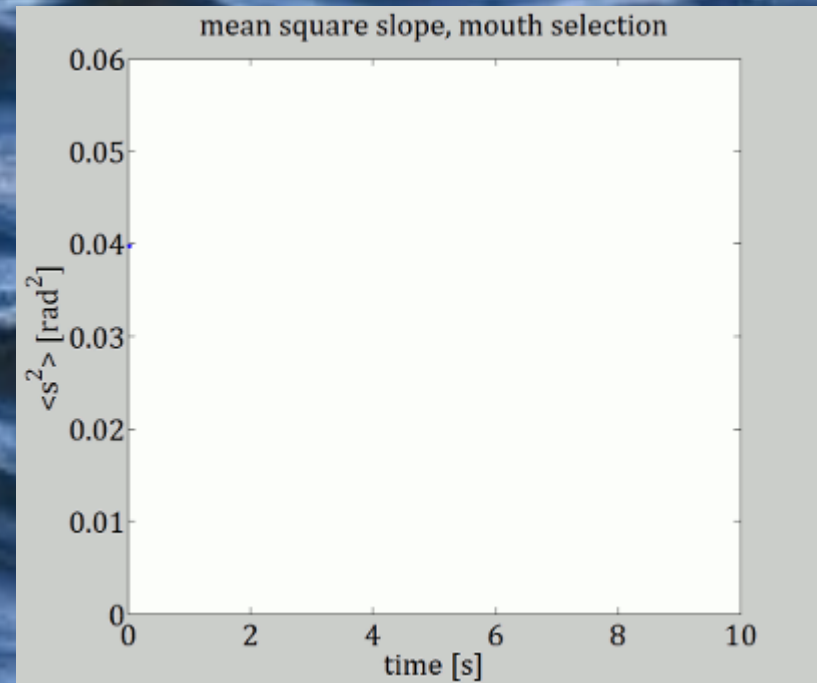
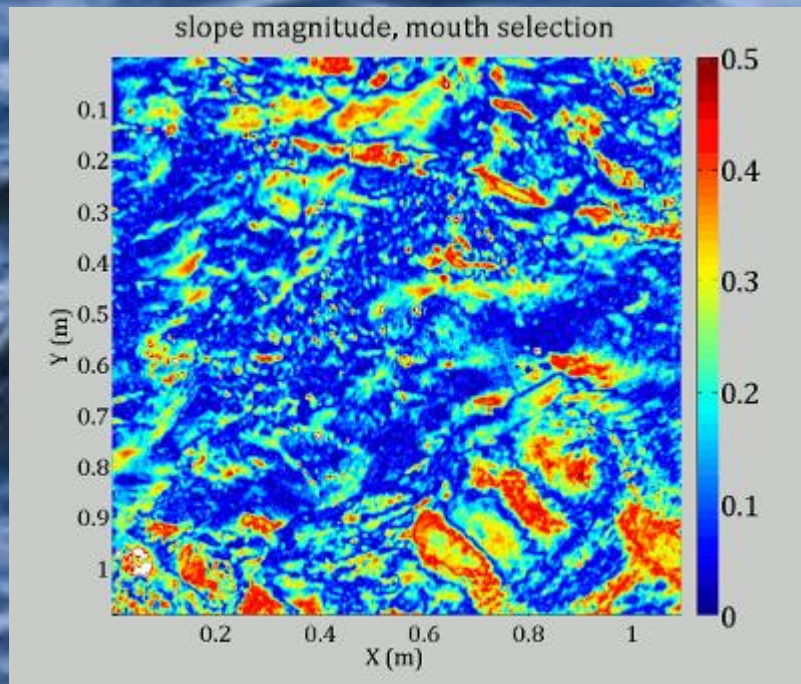


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In mouth slope detail



TERRA SAR
APERTURE SWITCHING MODE

Amplitude

Range! = 20 dB

TERRA SAR
APERTURE SWITCHING MODE

Amplitude

2140 m

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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Imagery Date: 7/6/2012 46° 15.331' N 124° 0.685' W elev -9 m eye alt 9.94 km



1996

SUMMARY

- Although they do not carry significant energy, short waves important for air-sea fluxes and remote sensing
- Mean square slope a key integral parameter
- Polarimetric imaging exciting new tool for sampling MSS