A SYNERGISTIC APPROACH FOR STOKES DRIFT ESTIMATION

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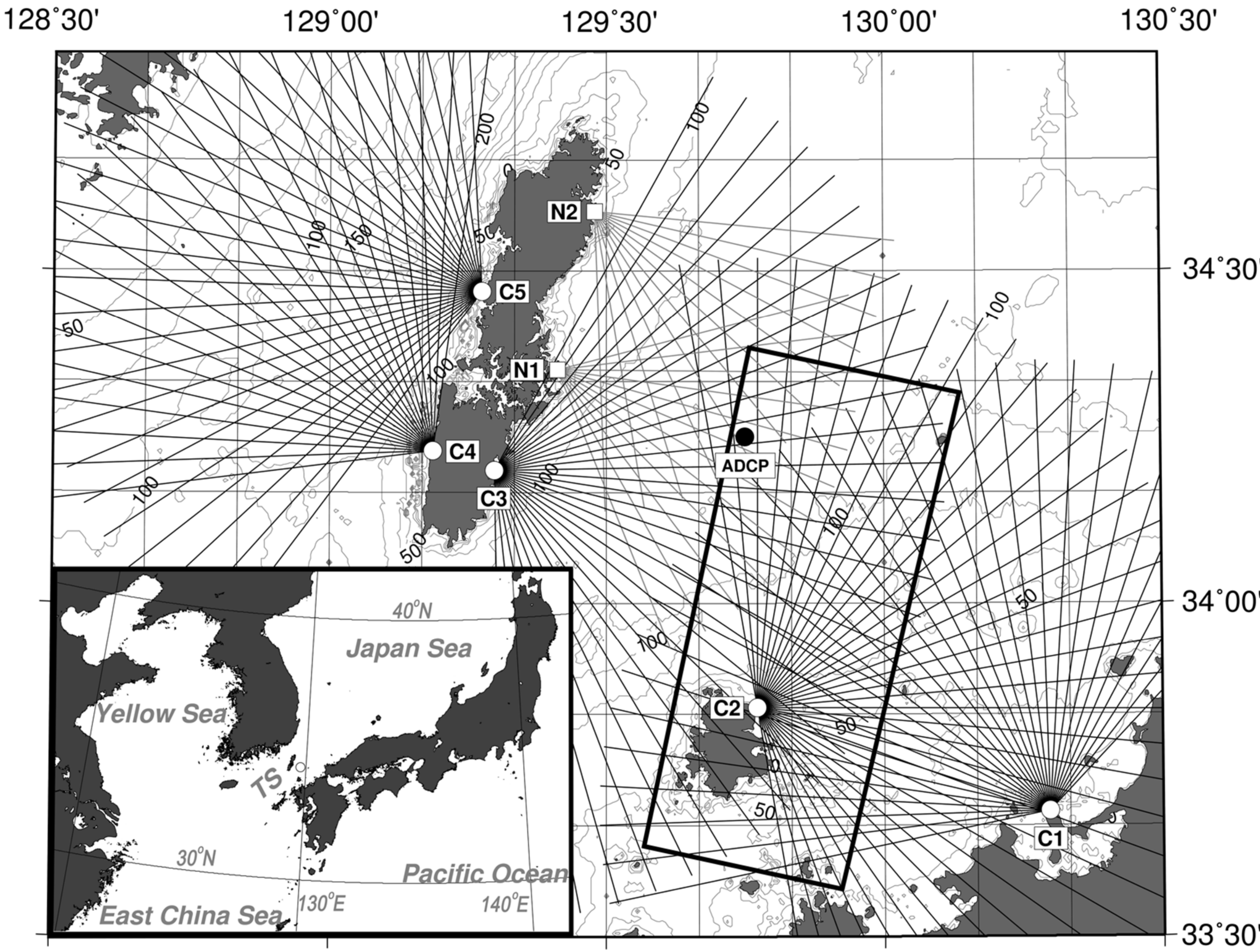
“SYNERGISTIC” ($\rightarrow$ MULTI-INSTRUMENT) APPROACH FOR 13 AUGUST 2006 IN THE TSUSHIMA STRAIT

- HF radar observations covering the Strait (both NJRC and CODAR systems operated)
- Moored ADCP data within radar coverage
- Along Track Stereo Sun Glitter (ATSSG) surface current data from PRISM images on 13/08/06

PRISM = Panchromatic Remote sensing Instrument for Stereo Mapping

(a sensor on ALOS)



128°30'
129°00'
129°30'
130°00'
130°30'
34°30'
34°00'
33°30'
N2
N1
C5
C4
C3
C2
C1
ADCP
200
100
50
Yellow Sea
Japan Sea
TS
Pacific Ocean
East China Sea
40°N
30°N
130°E
140°E

HISTORY OF THE ATSSG TECHNIQUE

- ATSSG:

  "The Along Track Stereo Sun Glitter Technique"

- First attempted during early ocean remote sensing experiments:

- Matthews et al., 1988: Remote sensing of shelf sea currents by HF radar, *Journal of Geophysical Research.*
- Matthews, 1990: Synergistic use of satellite infrared and HF radar near a shelf sea temperature boundary, *International Journal of Remote Sensing*
- Matthews et al., 1993: (HF) Radar observation of an along front jet and transverse flow convergence associated with a North sea front, *Continental Shelf Research.*
- Matthews et al., 1997: The observation of the surface roughness characteristics of the Rhine plume frontal boundaries etc… *International Journal of Remote Sensing.*

CONCEPT OF THE ATSSG TECHNIQUE

- Relies on differential inter-comparison of 2 or 3 Sun glitter images from along-track data takes
- Adjacent image pairs are normally separated in time by about 1 minute

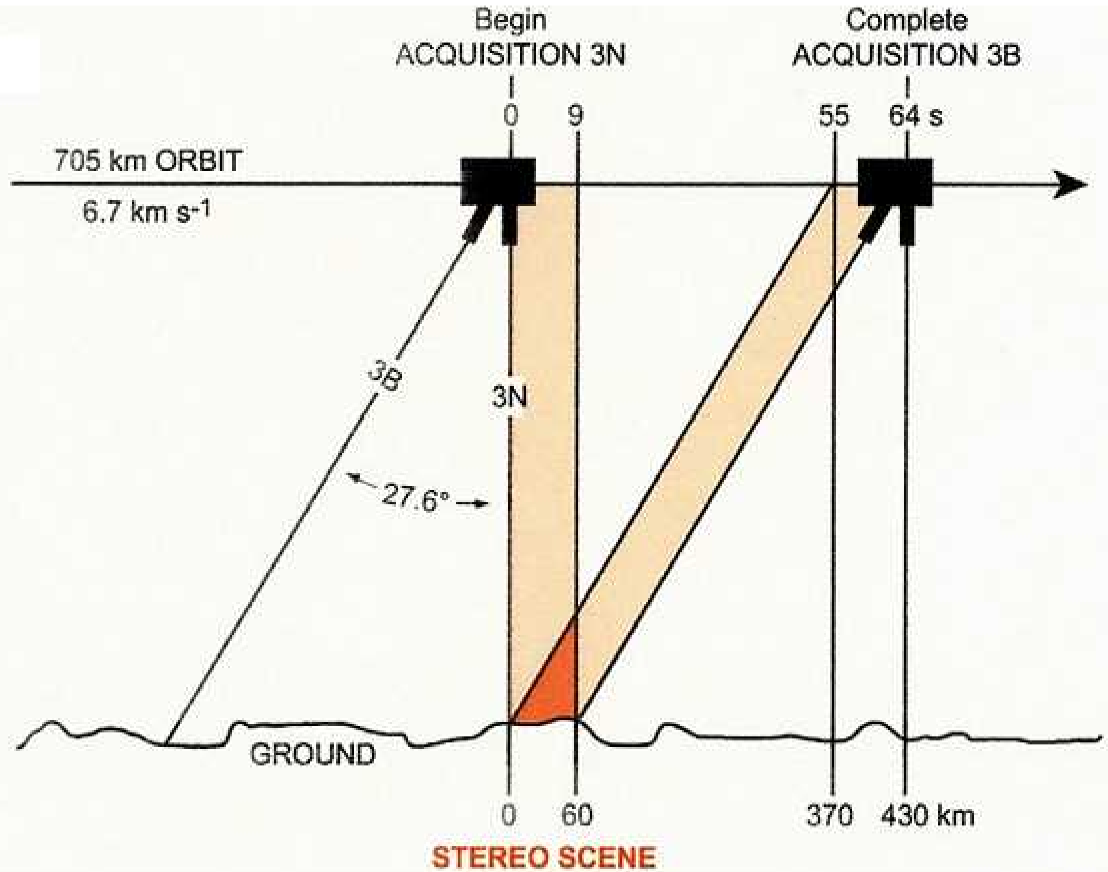


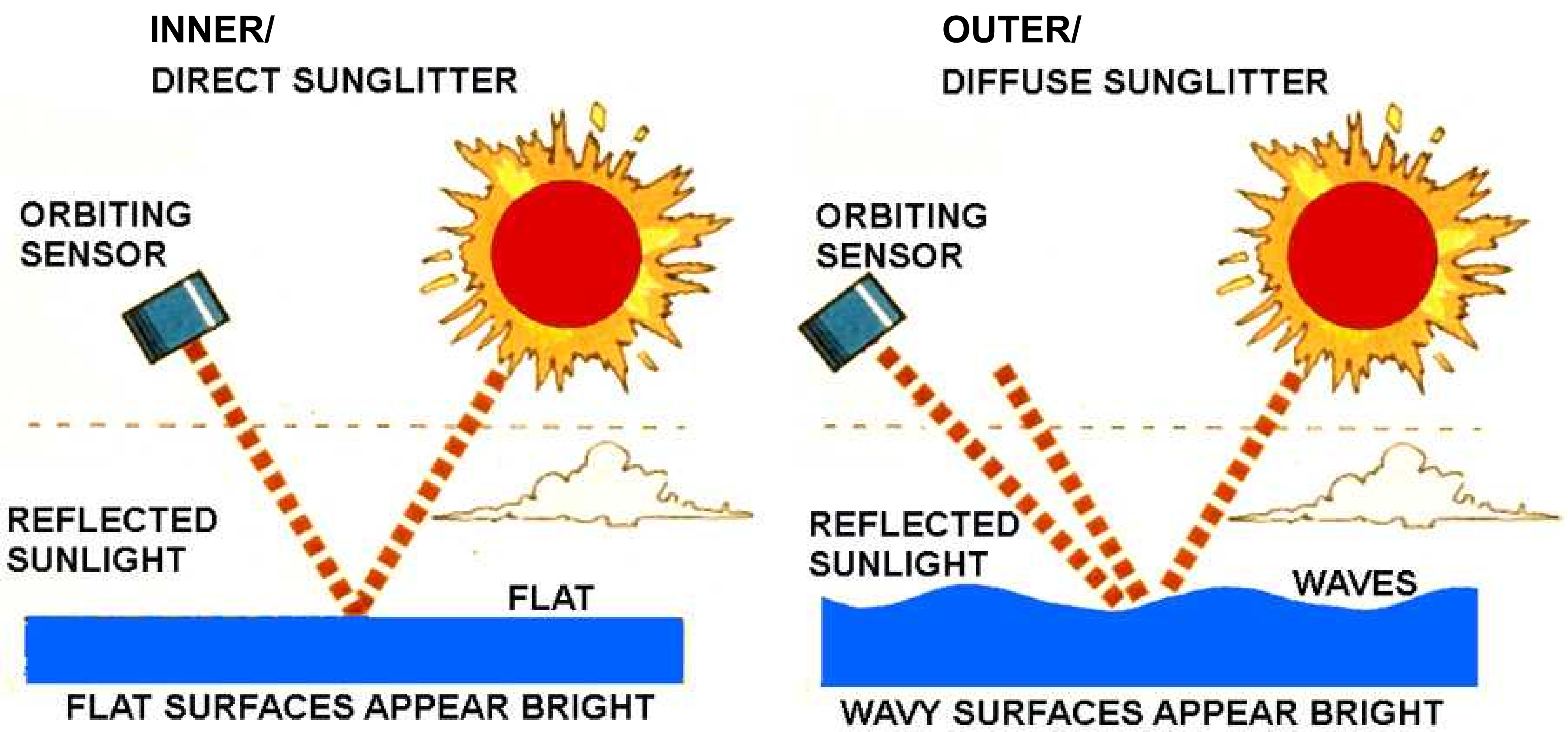
Figure 2: ASTER stereo geometry and timing of the nadir-band 3N and the back-looking sensor 3B (after 8). An ASTER nadir scene of approximately 60 km length, and a correspondent scene looking back by 27.6° off-nadir angle and acquired about 60 seconds later, form, together, a stereo scene.

SUN GLITTER (SG)

The direct reflection of sunlight from a water (ice) surface

Early Sun glitter research → key advances in Satellite Oceanography

SUN GLITTER brightness reversal



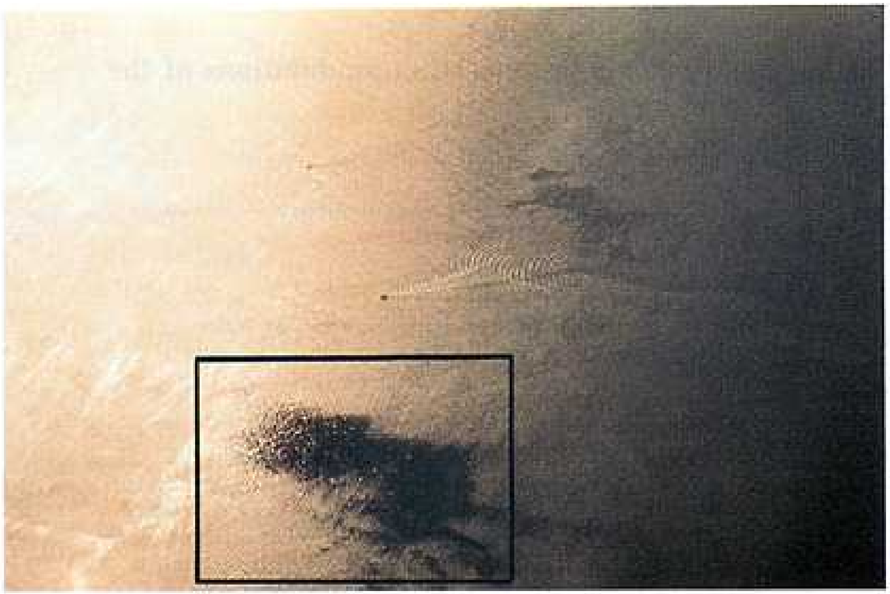


Plate 1a. A surface slick imaged as a sun glint feature (rectangle) of the Atlantic Ocean off the French coast near Brittany. Photograph taken from an aircraft (Dornier 228) of the Deutsche Forschungsanstalt für Luft- und Raumfahrt (DLR) at an altitude of 3200 m on November 27, 1987, 1043 UTC (wind speed 2-3 m/s; courtesy of A. Viola, Consiglio Nazionale delle Richerche, Rome).

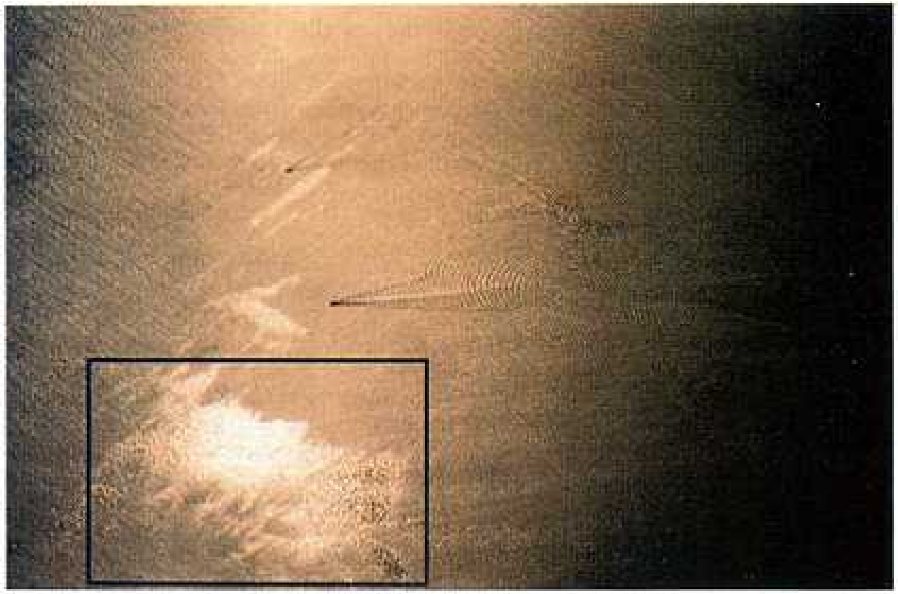
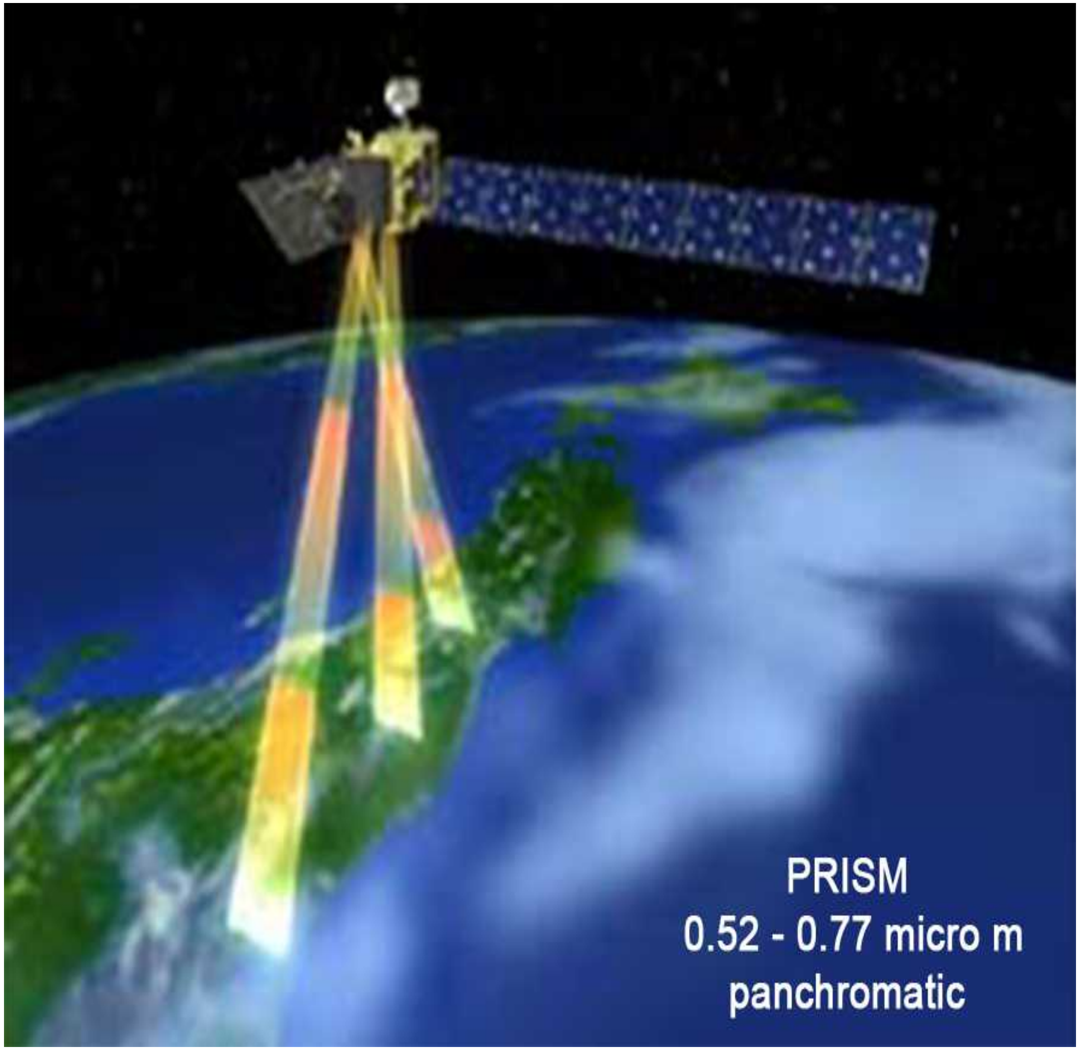
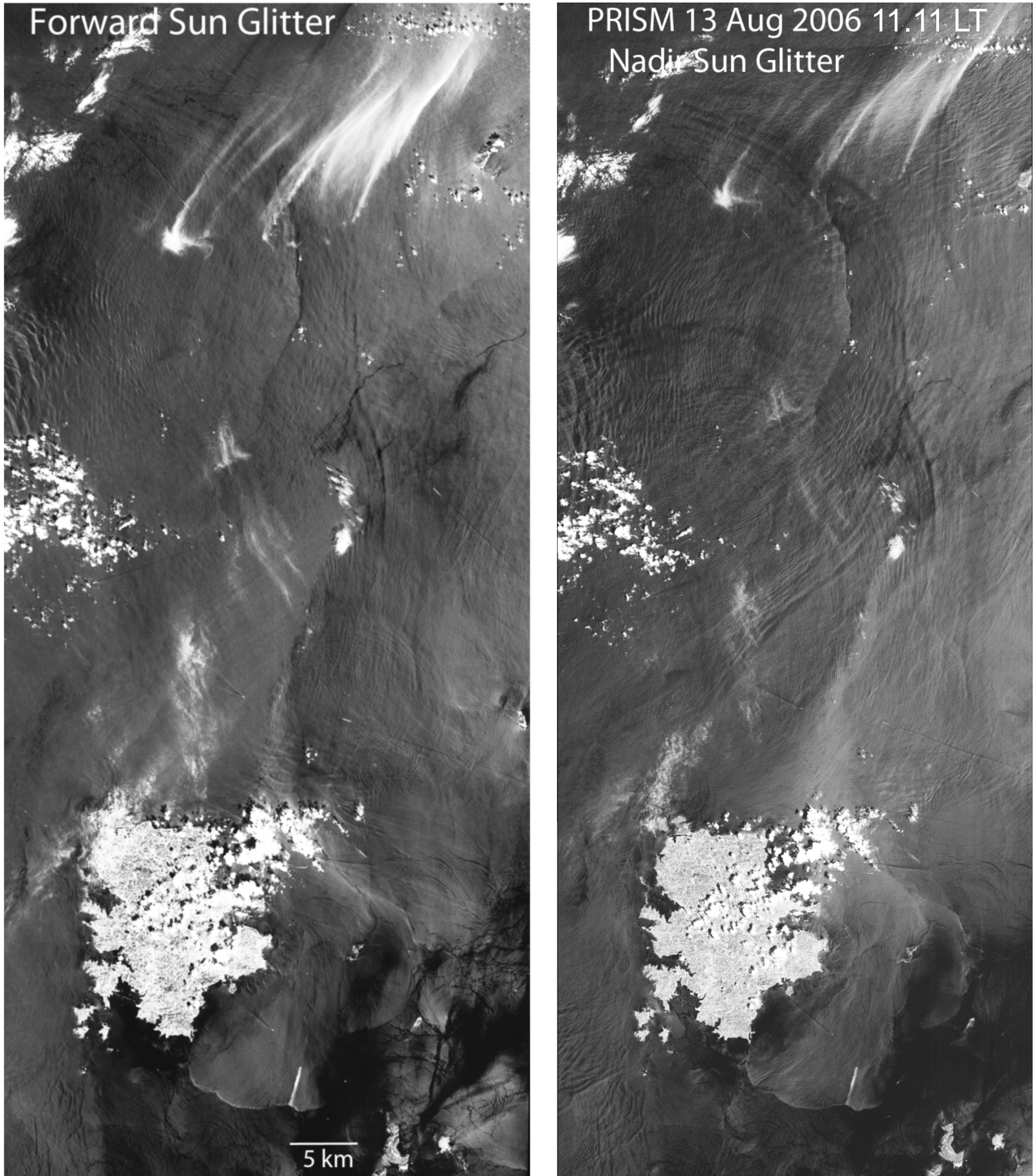


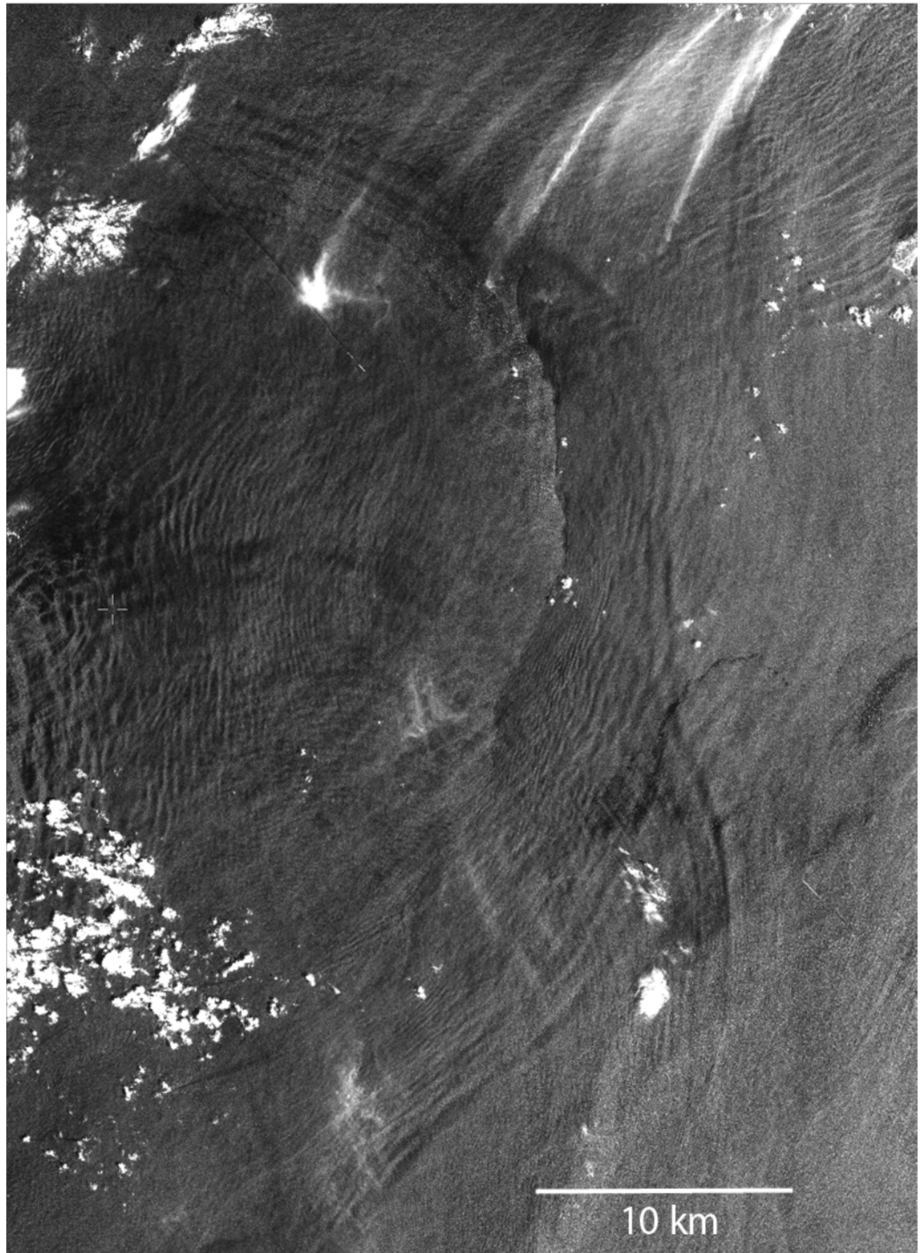
Plate 1b. Same as Plate 1a, some seconds later.

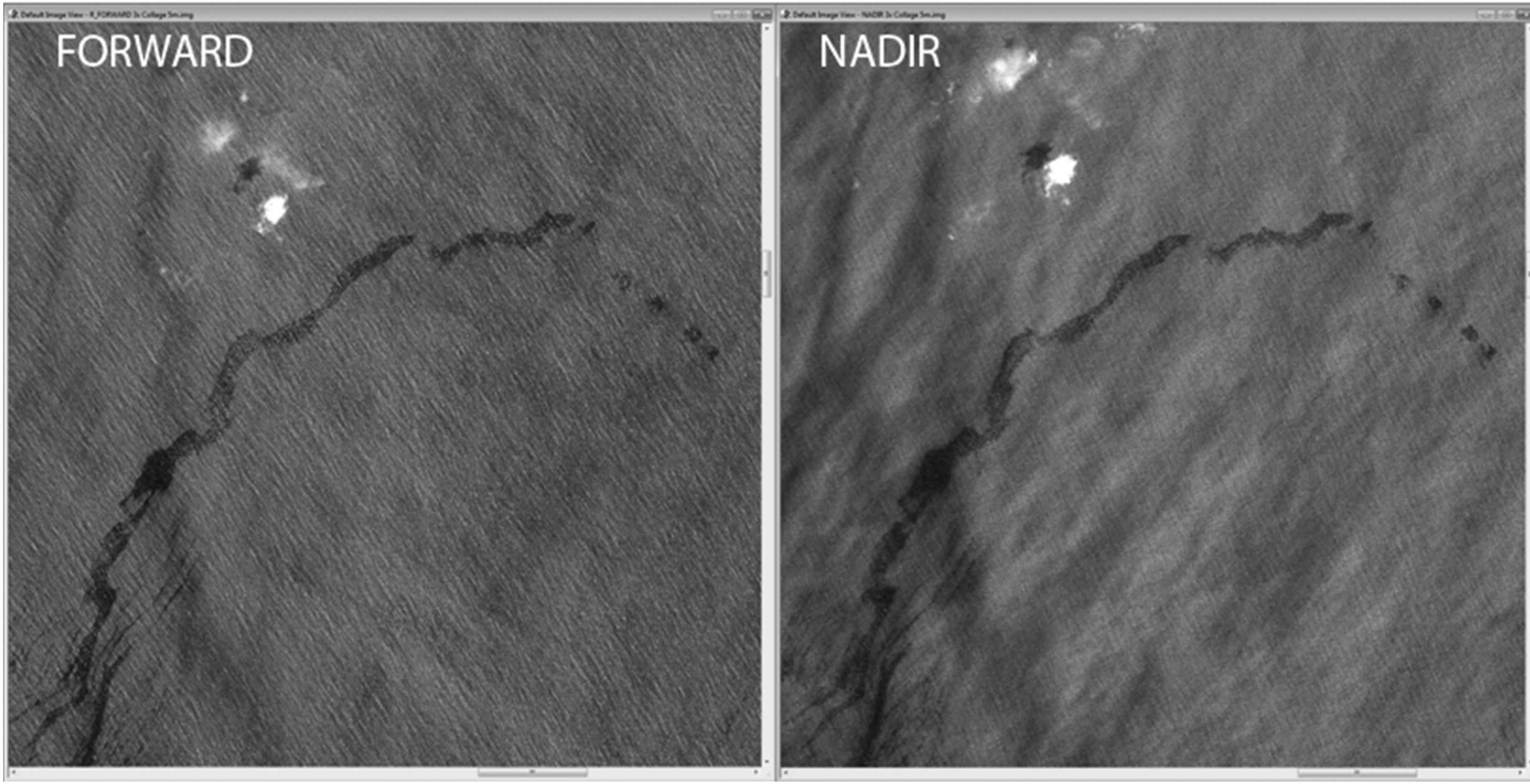
PRISM – launched in 2006 on ALOS provides a new opportunity for ATSSG applications

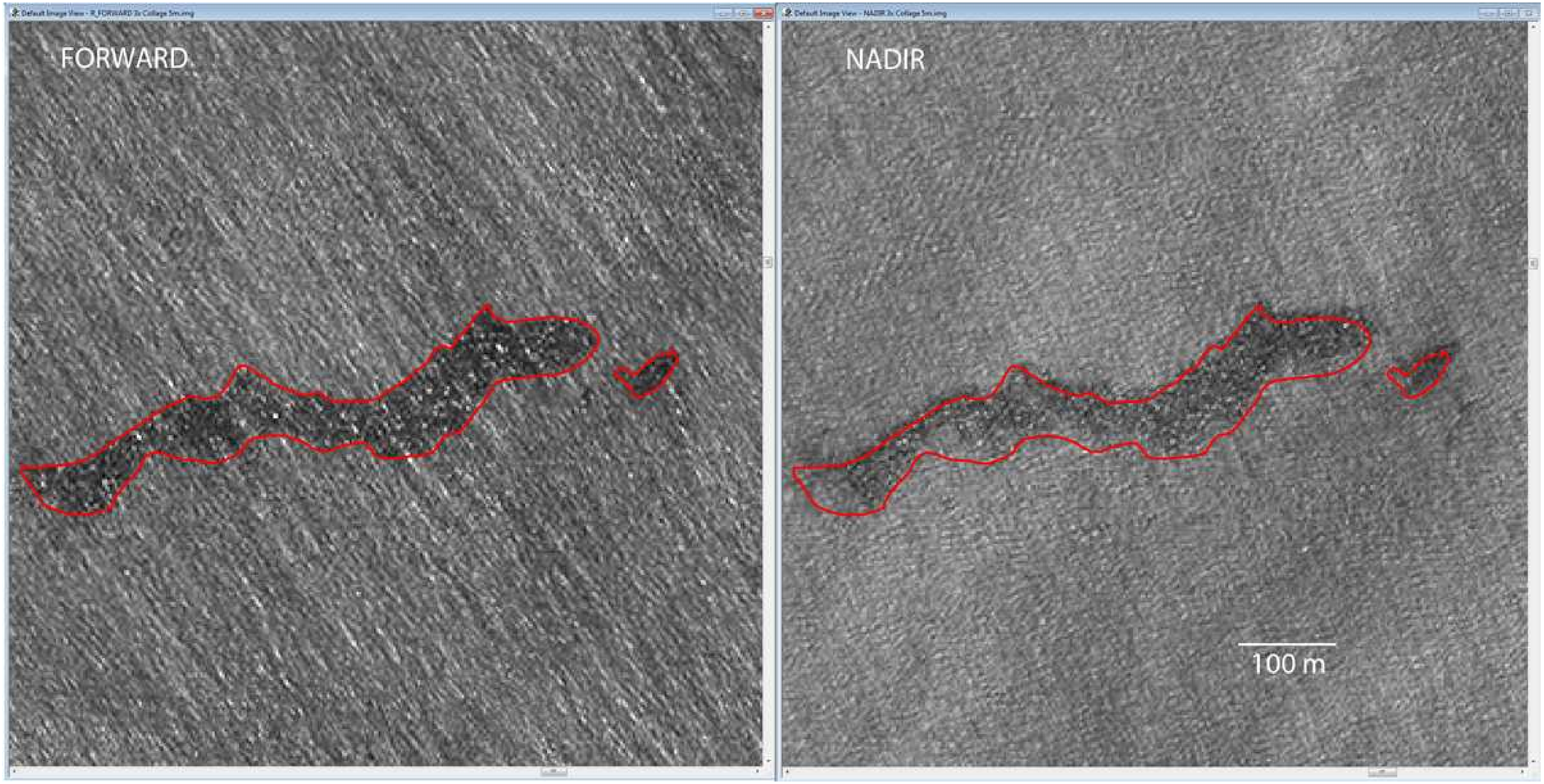



Forward Sun Glitter
5 km
PRISM 13 Aug 2006 11.11 LT
Nadir Sun Glitter

“Front” + Abundant Internal Waves in Tsushima Strait!!!




FORWARD
NADIR


FORWARD
NADIR
100 m

RESOLUTION OF MOTION DETECTION IN PRISM SUN GLITTER

PRISM spatial resolution = 2.5 m

Time between Back and Nadir images (or Nadir and Forward images) = 45.3 s

Basic Motion Resolution without averaging = 2.5/45.3 = 0.055 m/s

ATSSG → Wind Speed from Cloud Shadow Motions

Data near the ADCP mooring on 13/08/06

- ATSSG wind at cloud height (11.11 LT)

speed = 3.9 m/s, direction = 31.2 deg wrtE

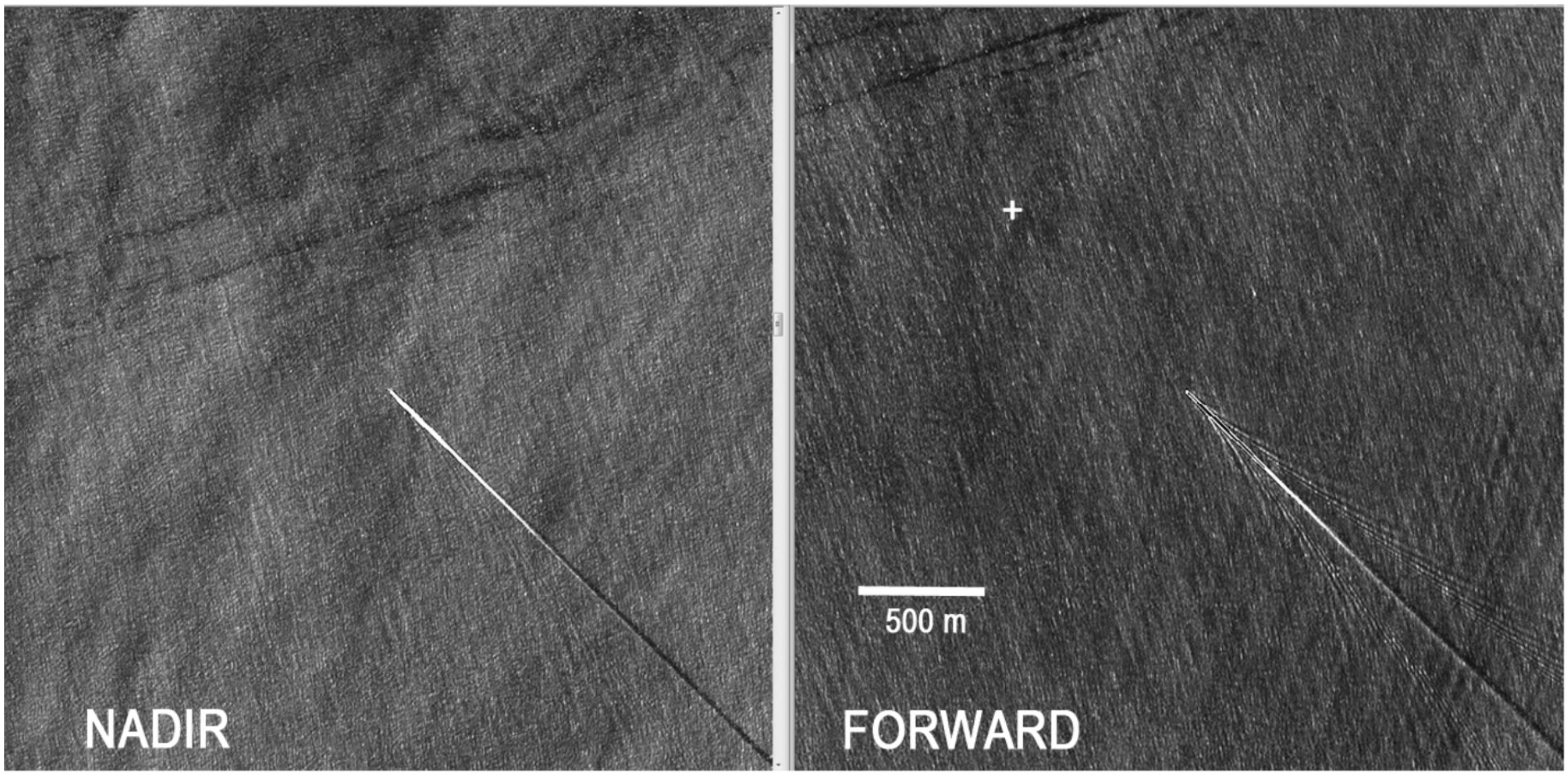
- Predicted 11.00 LT 10-m wind based on assimilation at 09.00 LT

speed = 2.8 m/s, direction = 27.7 deg wrtE

(ENE)

Calibration of ATSSG currents

- Calibrate by comparing to known velocity of Hakata-Pusan jetfoil ferry



Calibration

- Logged ferry speed = 41 knots = 21.1 m/s
- Logged ferry bearing = 332 deg.

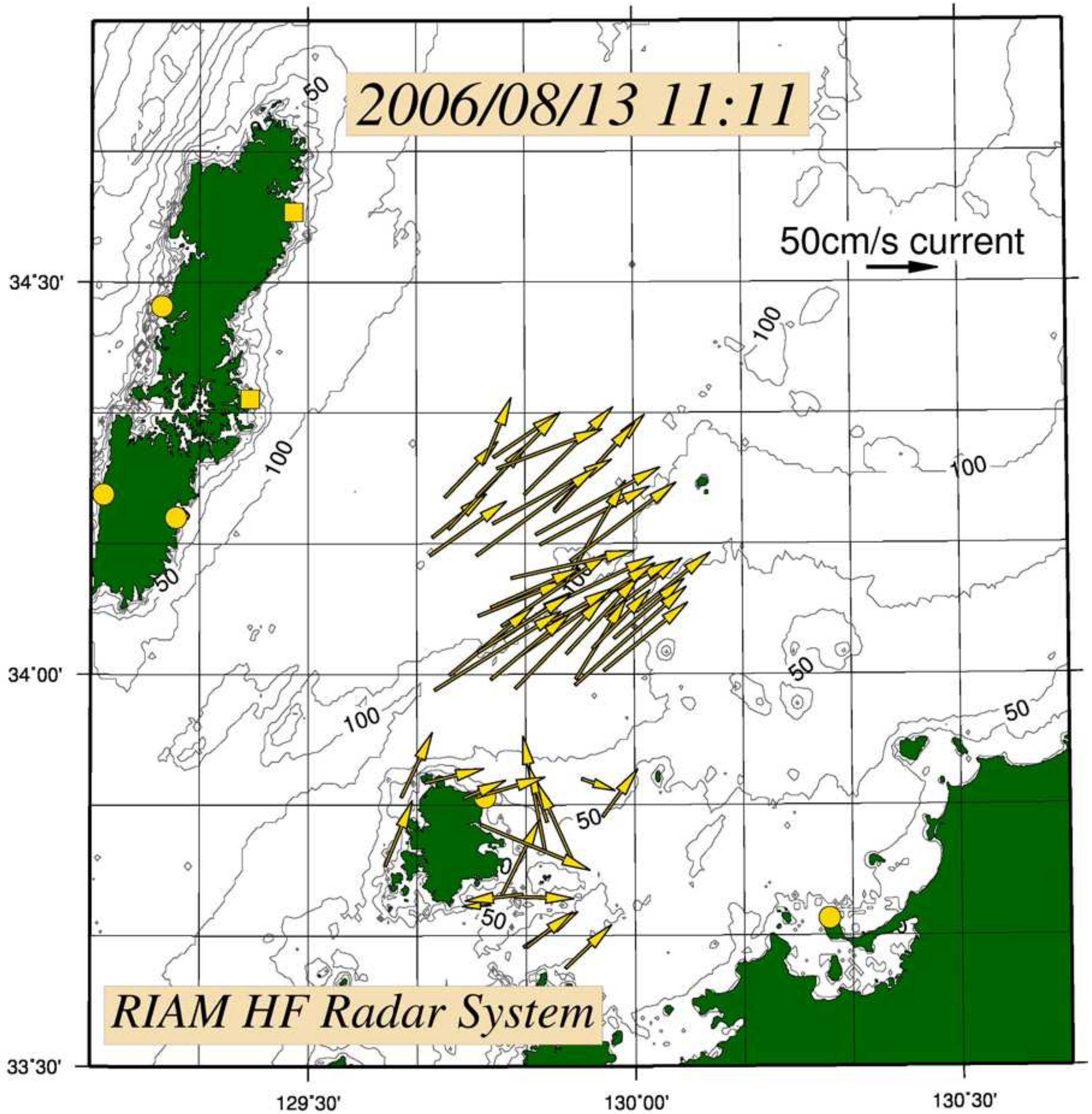
- ATSSG ferry speed = 21.9 m/s
- ATSSG bearing = 330 deg

(with revised pixel sizes of 2.46m)

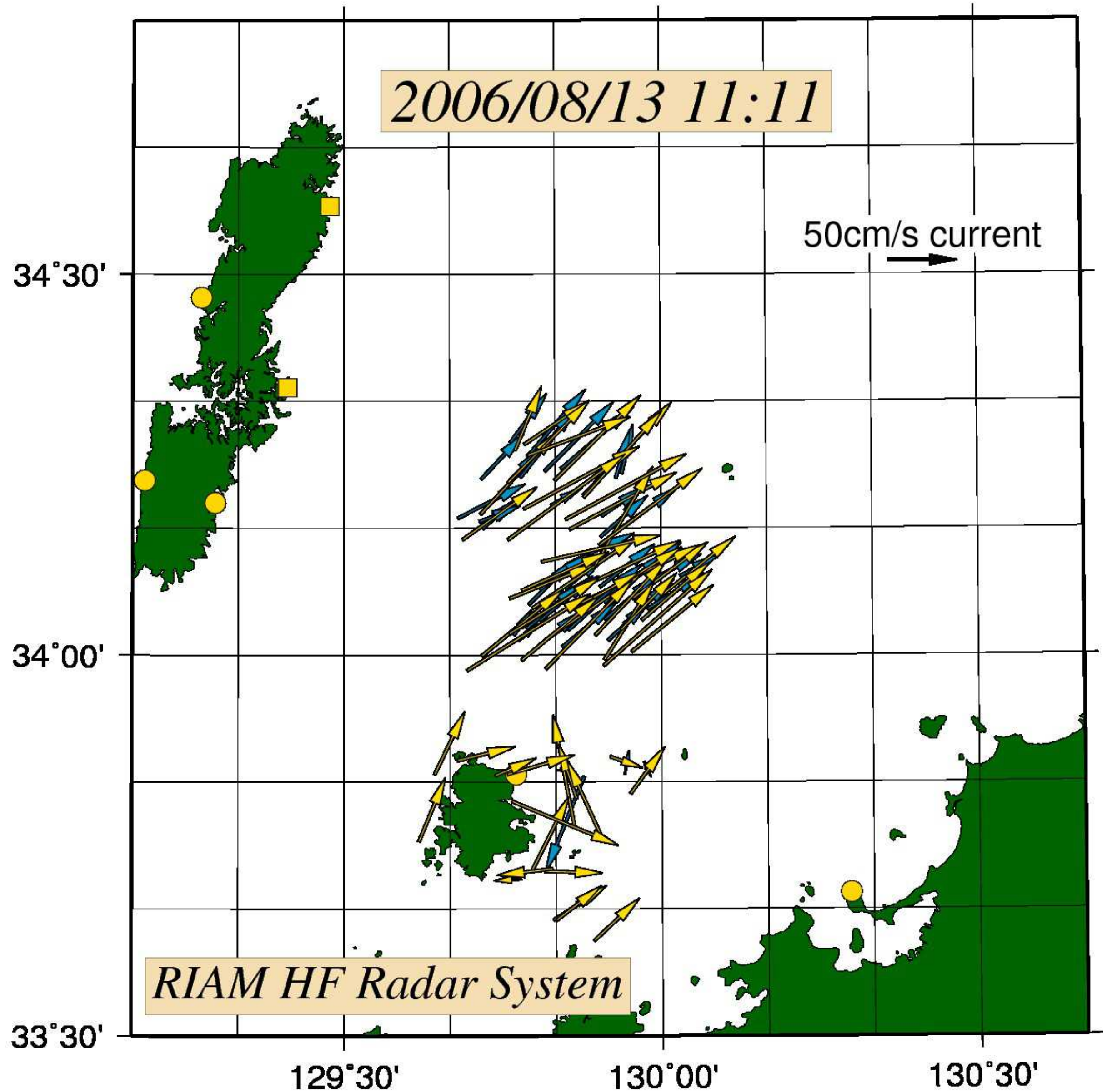
VALIDATION

Compare:

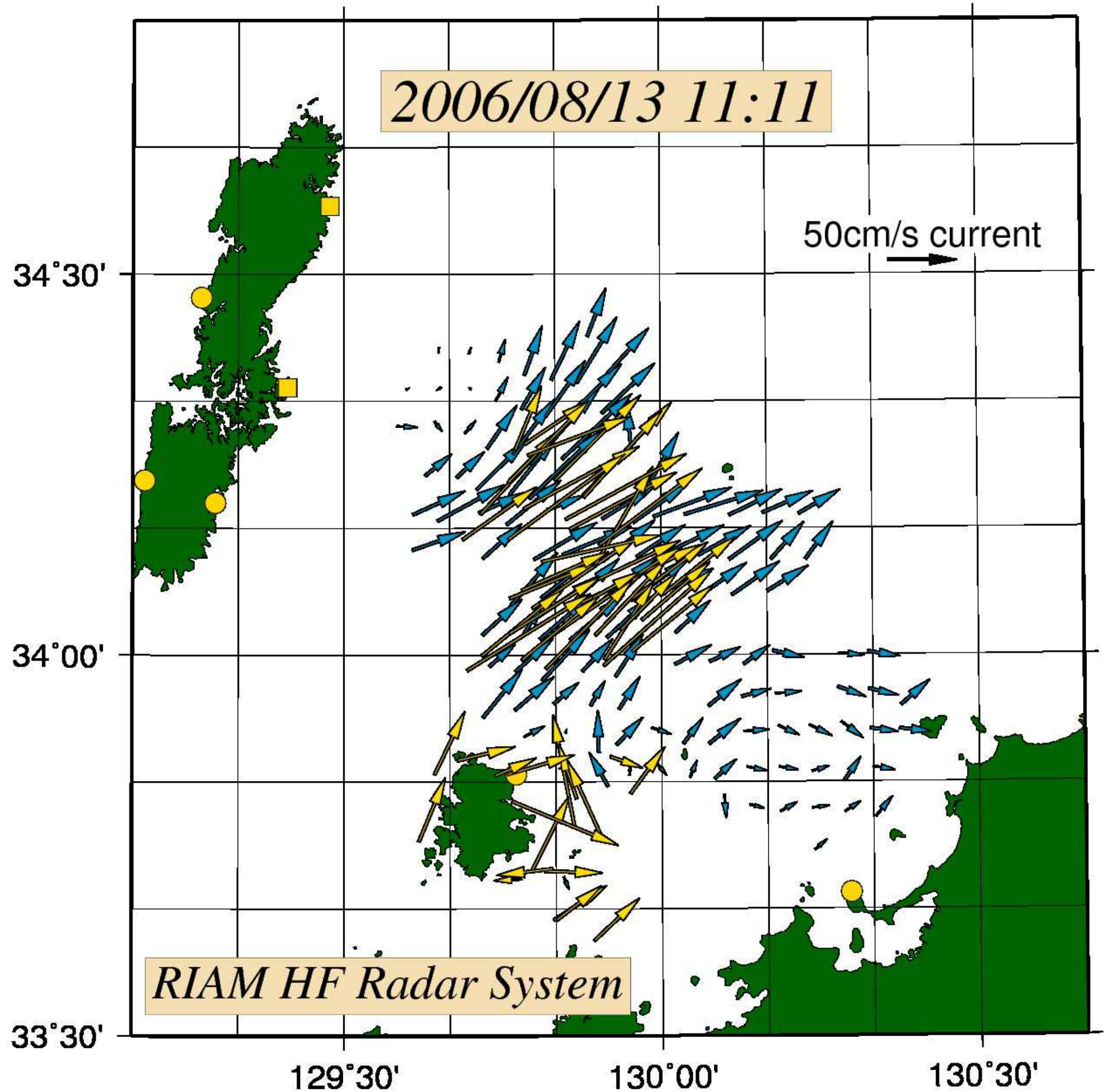
ATSSG currents ←→HF radar currents



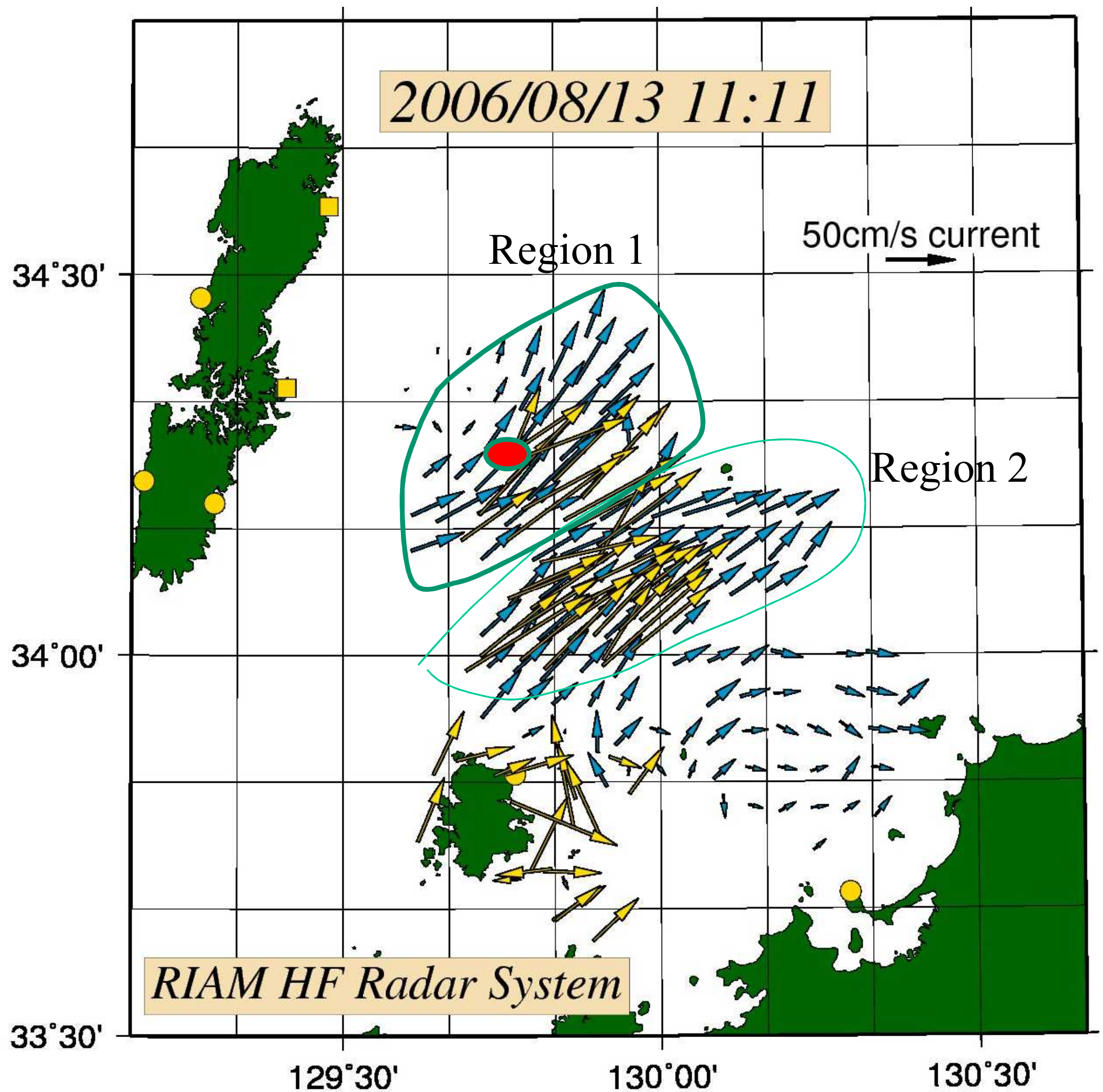
yellow = ATSSG

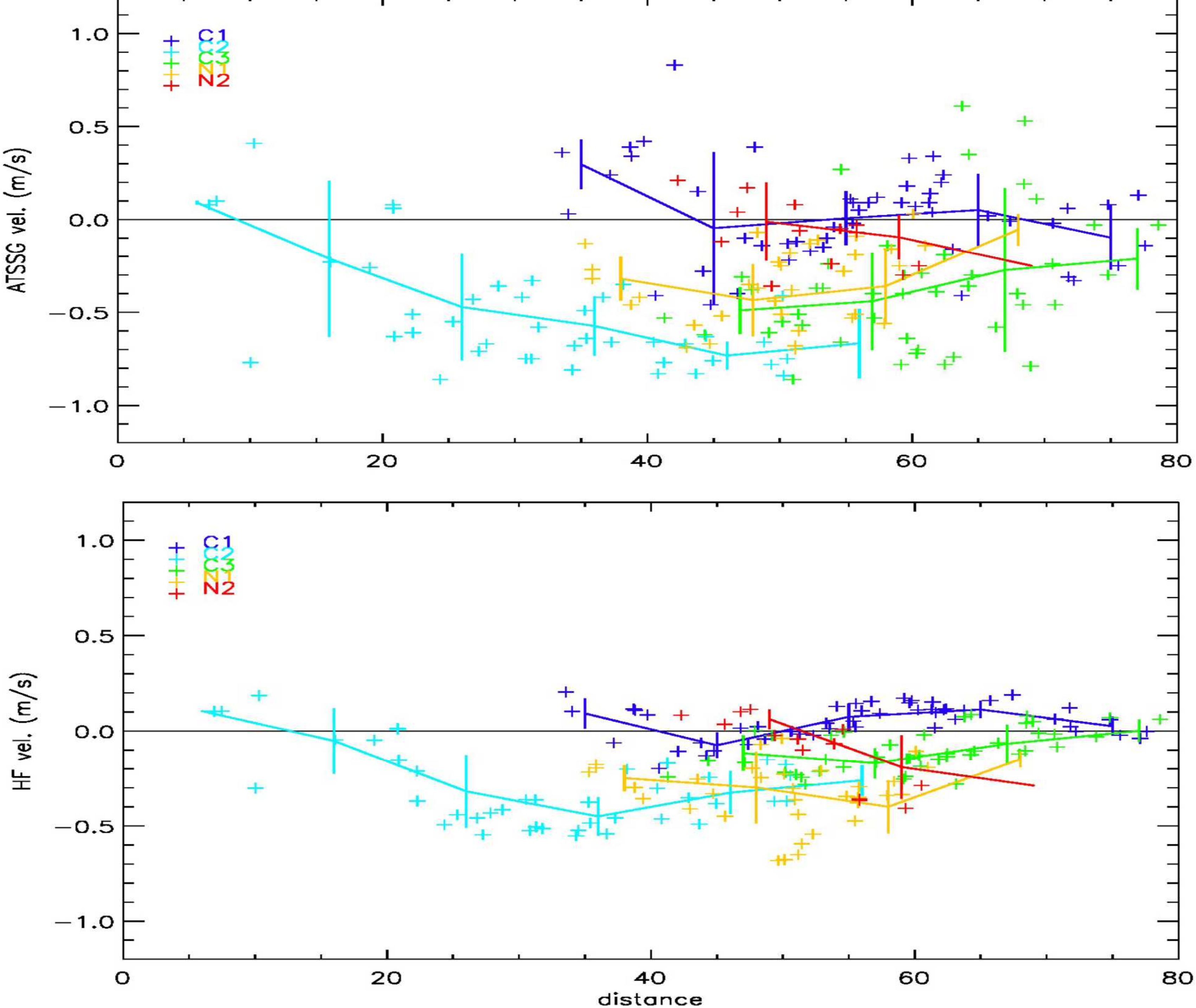


yellow ATSSG blue HF



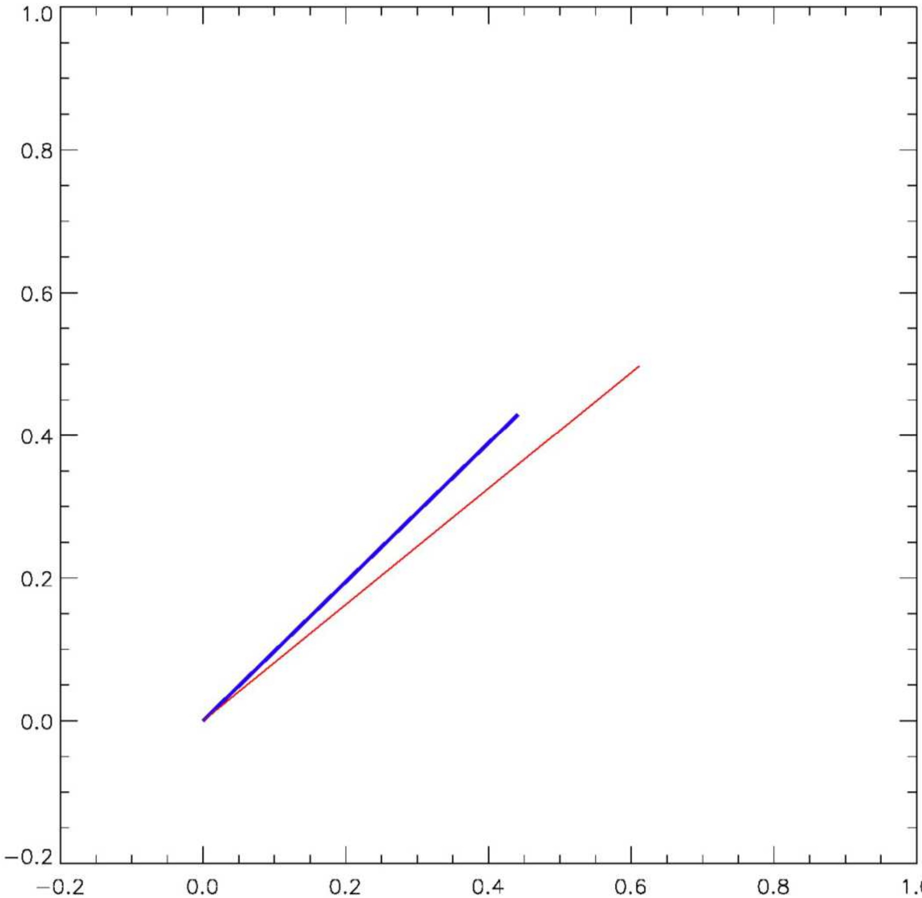
yellow ATSSG   blue HF


2006/08/13 11:11
50cm/s current
Region 1
Region 2
34˚30'
34˚00'
33˚30'
129˚30'
130˚00'
130˚30'
RIAM HF Radar System

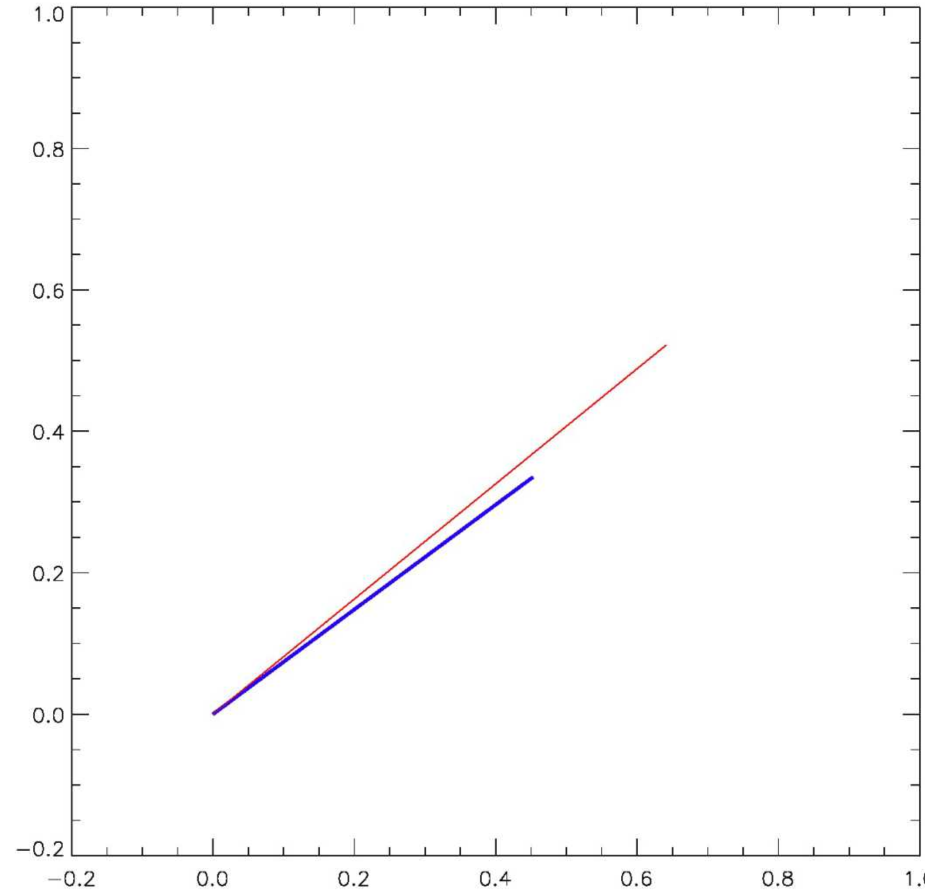


C1
C2
C3
N1
N2
ATSSG vel. (m/s)
1.0
0.5
0.0
−0.5
−1.0
0
20
40
60
80
HF vel. (m/s)
distance

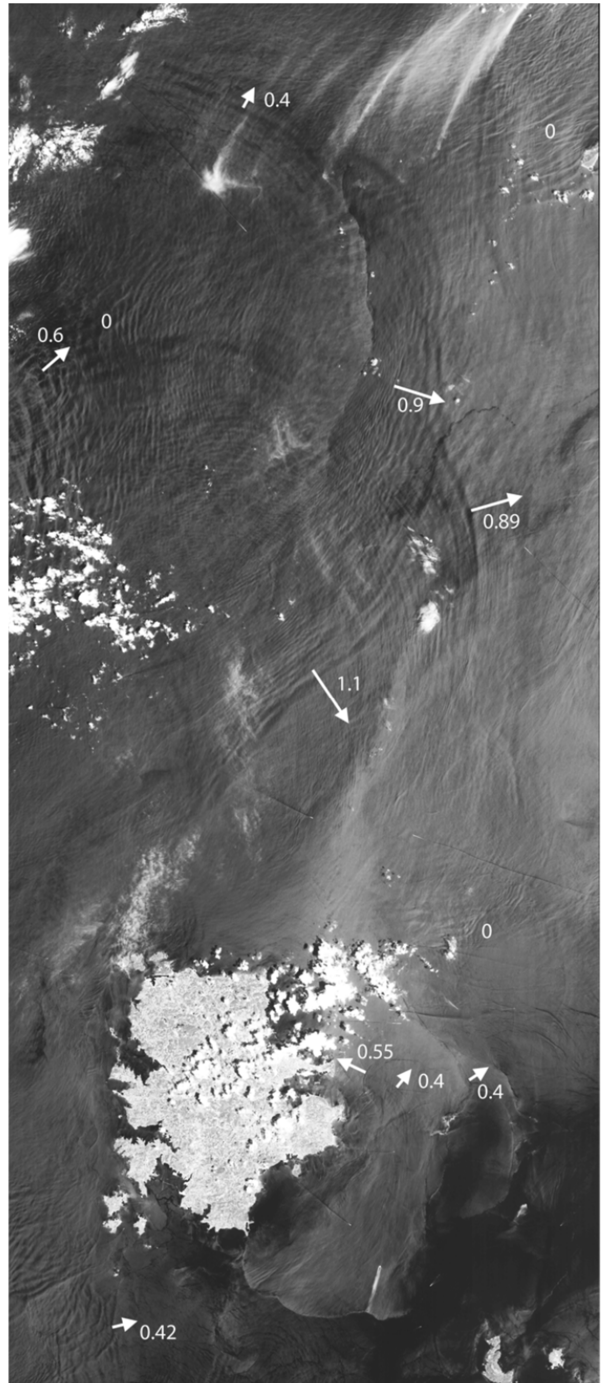
PCA ATSSG vs NJRC data



PCA ATSSG vs CODAR (unc. =0.1m/s)



ATSSG-derived internal wave speeds (provisional)



internal waves on 13 Aug 2006 generally rather slow → moribund?

SENSING DEPTHS

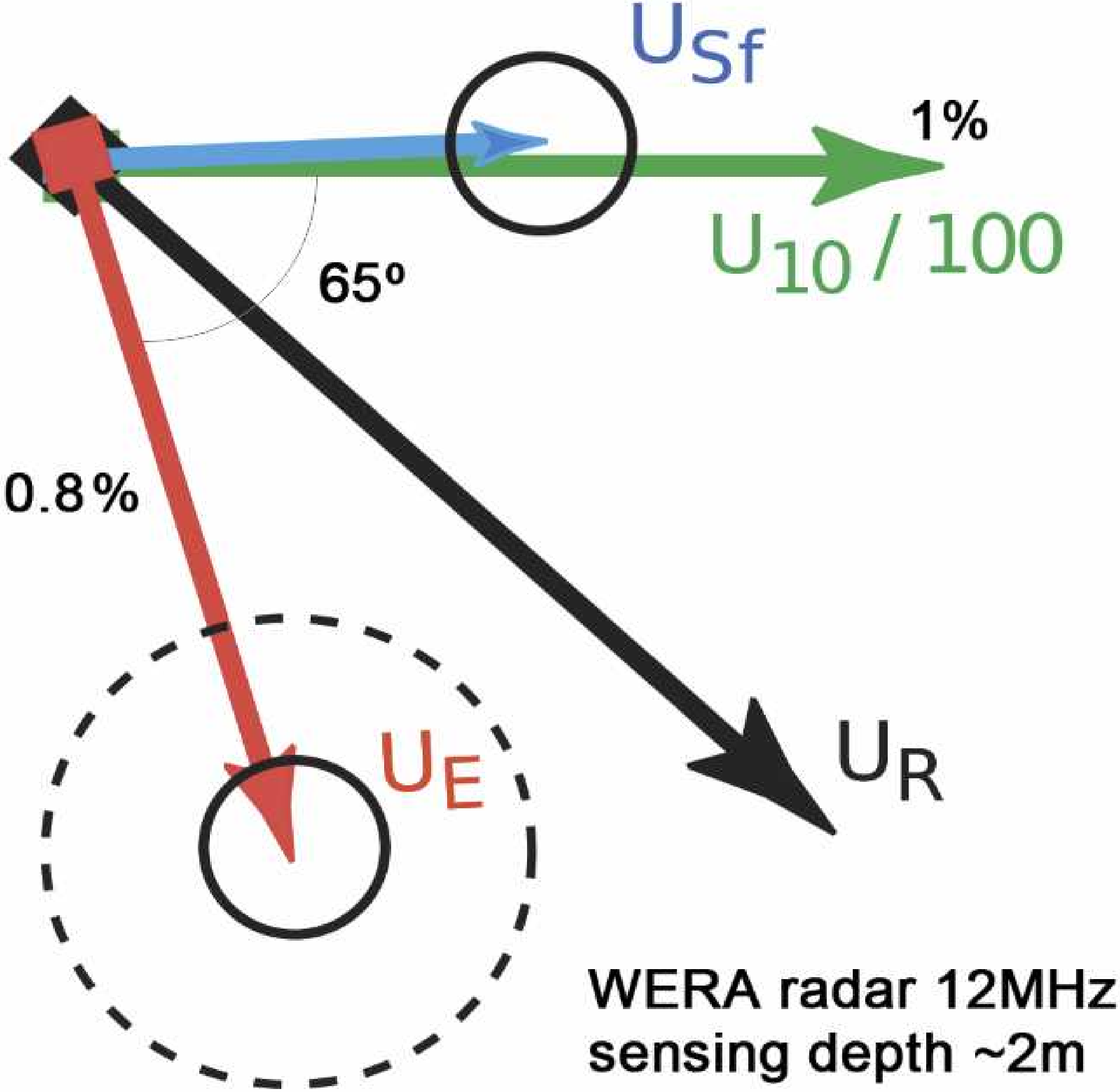
- ATSSG → surface
- NJRC HF radar → 0.97 m
- CODAR HF radar → 1.72 m
- ADCP current meter → 12.8 m

METHOD USED TO DERIVE STOKES DRIFT (downwind direction)

- Remove underlying tidal and geostrophic components using ADCP data at 12.8 m.
- Subtract along-wind contribution from “Quasi-Eulerian” response using estimate based on Ardhuin et al. (2009)
- Assume Q.E. term ~uniform in upper 2m

Stratified (Ardhuin et al., 2009)

Low wind conditions (U_{10} ~ 3m/s)



Using Ardhuin's data (stratified, low wind case)

- For a wind of 2.8 m/s (13 Aug 2006)

→downwind QE component ~ 0.01 m/s

(small!)

In fact: we assume a downwind QE component of ~0.015 m/s for shallower r.s. depths (+higher stratification in Tsushima)

SURFACE STOKES DRIFT (SSD) ESTIMATE

downwind direction

$$SSD \sim ATSSG_{down} - ADCP_{12.9m} - QE\ term_{down}$$

(→ can do the same in the crosswind direction, using QE crosswind estimate of 0.022 m/s)

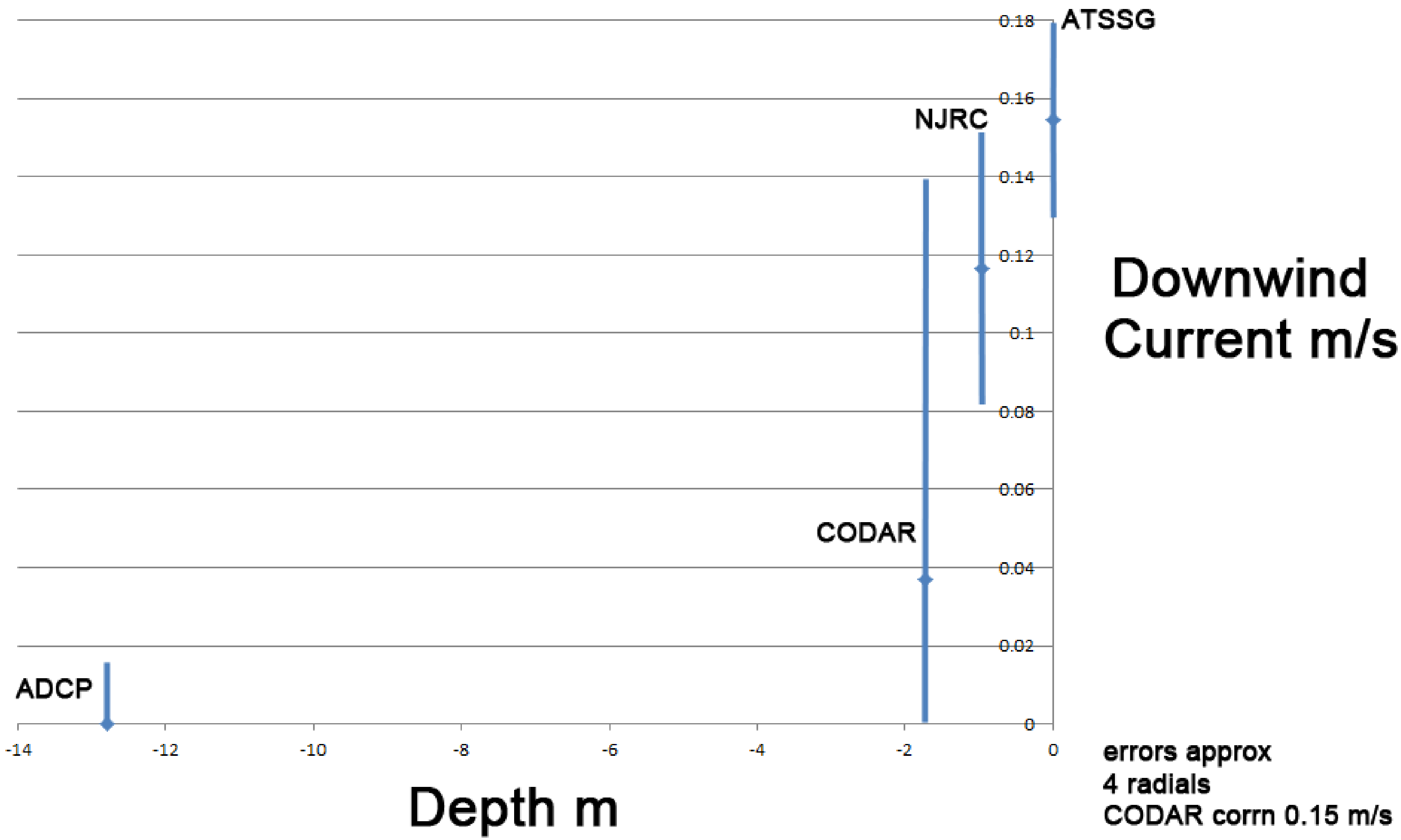
CURRENT MEASUREMENTS AT ADCP LOCATION

SUBTRACT QE TERMS FROM CODAR UPWARDS
ALSO SUBTRACT UNDERLYING FLOW AT 12.79m

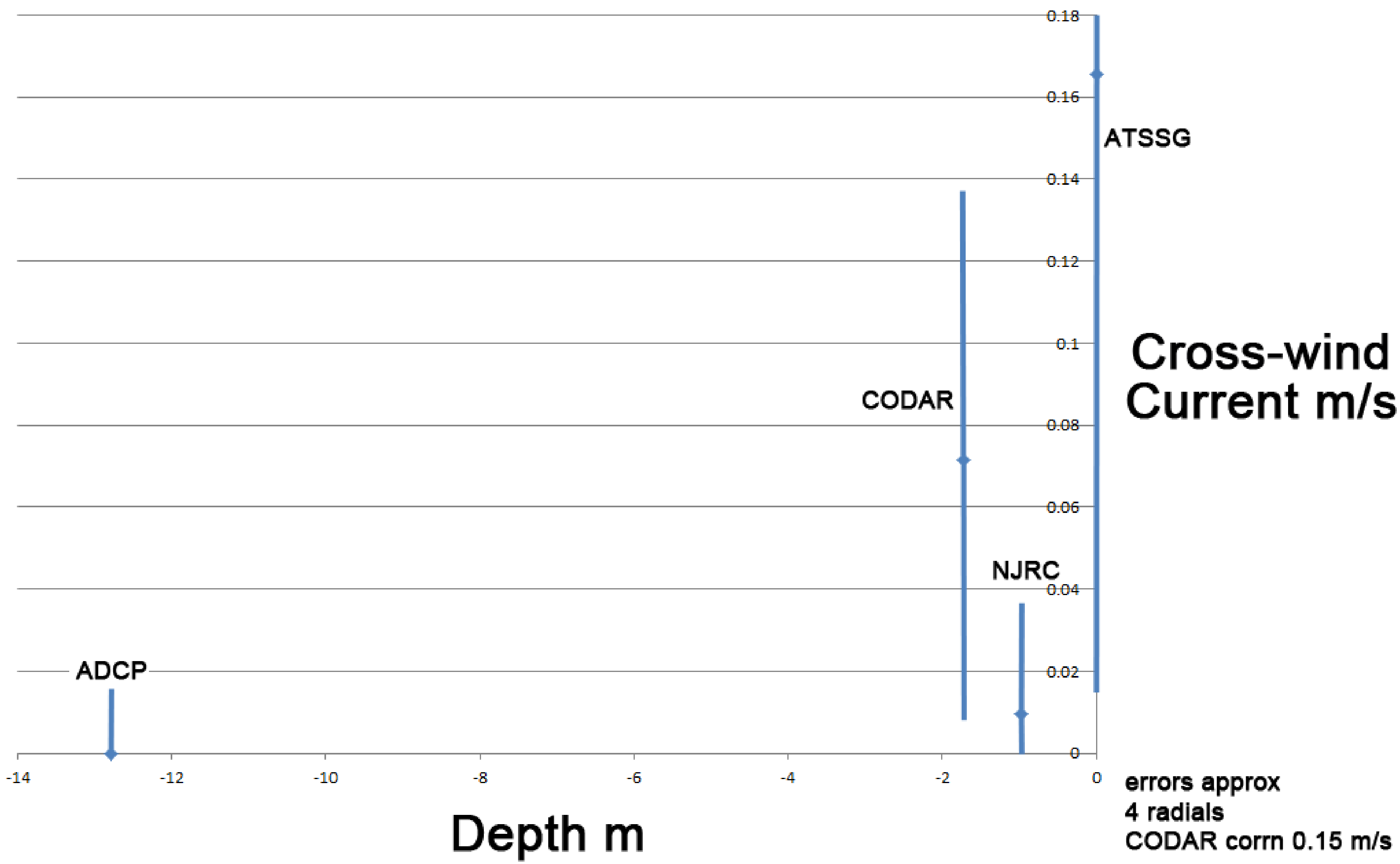
				RESIDS	
	MEASURED CURRENTS	downwind	crosswind	downwind	crosswind
depth		m/s	m/s	m/s	m/s
0	ATSSG data (2.5m res)	0.516279978	0.287765503	0.1547971	0.165517894
-0.97	NJRC	0.477932894	0.131855645	0.11645	0.009608037
-1.72	CODAR*	0.39855754	0.193896078	0.0370746	0.07164847
-12.79	ADCP 12.79m	0.346482925	0.100247608	0	0

				postv right
*CODAR correctn = -0.15 norwd		uniform QE	downwind	crosswind
for 4 radials		in top 2m	0.015	0.022
wind dirn	wind speed			
wrt E 27.74 degrees	2.8 m/s			

STOKES DRIFT ESTIMATES



errors approx
4 radials
CODAR corrn 0.15 m/s

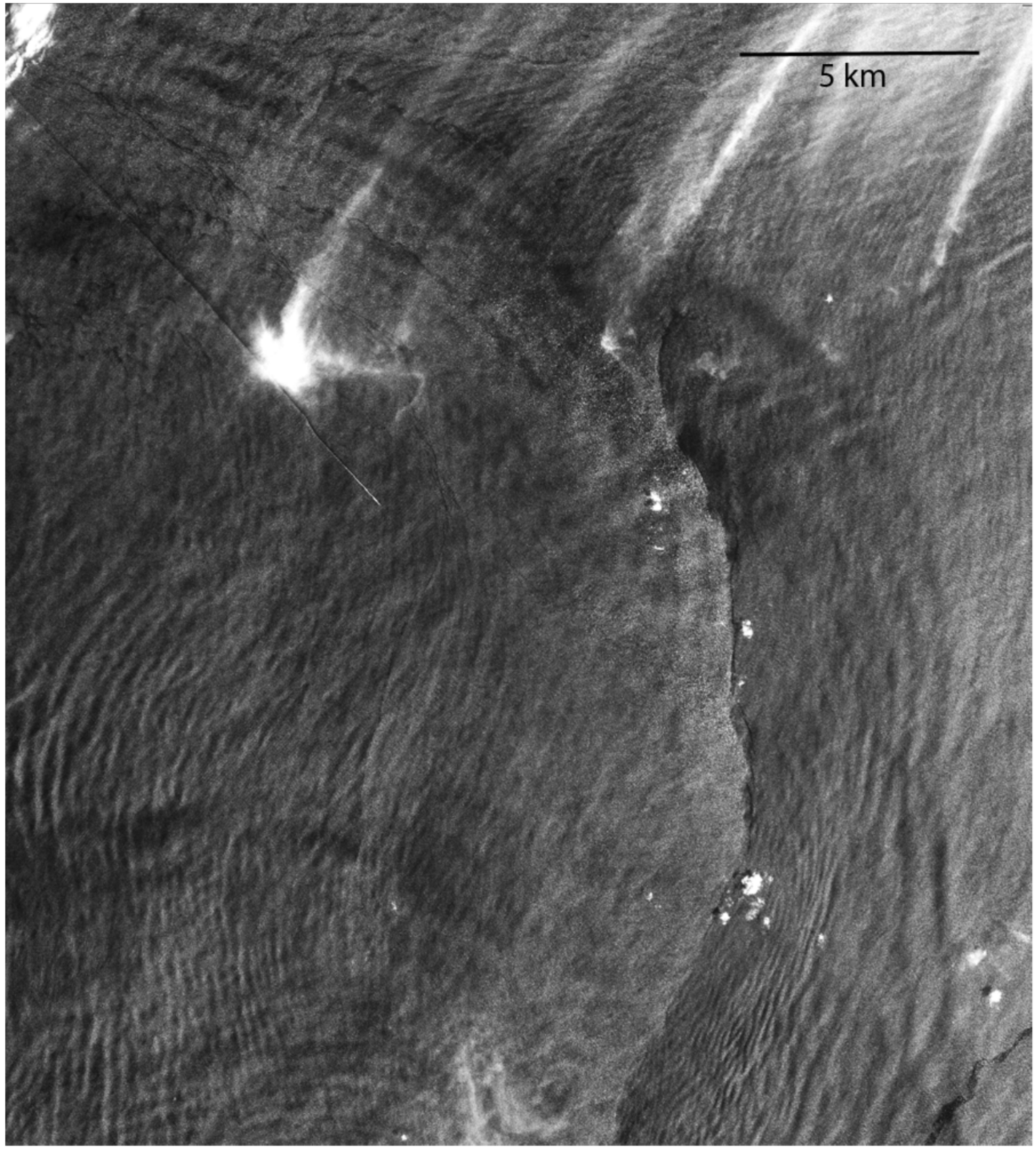


0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
ATSSG
CODAR
NJRC
ADCP
Cross-wind
Current m/s
-14
-12
-10
-8
-6
-4
-2
0
Depth m
errors approx
4 radials
CODAR corrn 0.15 m/s

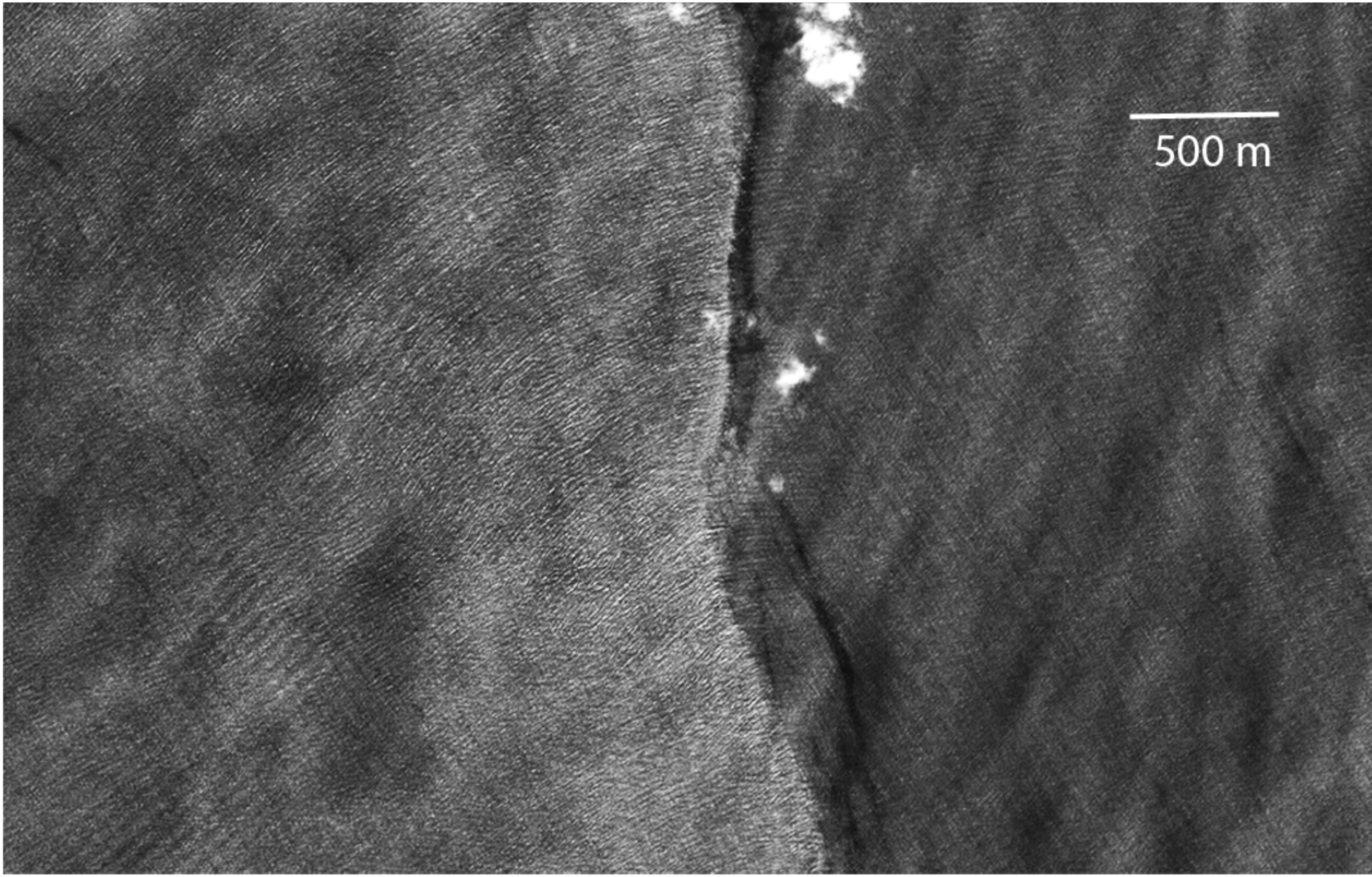
RESULTS FROM THE 13 AUGUST 2006 STUDY

- Calibration + Validation of ATSSG surface currents
  → new derivation of shear in uppermost layer
  → first Stokes Drift vertical profile
- Demonstration of abundant IWs in T.S.
- Discovery of “front”-like features in mid-channel T. S.
- Identification of a small coastal front at Ikishima

“Front” and Internal Waves near Pusan → Hakata jetfoil



Gravity Wave Refraction at mid-channel “frontal” Boundary



Tsushima Internal Waves: Questions

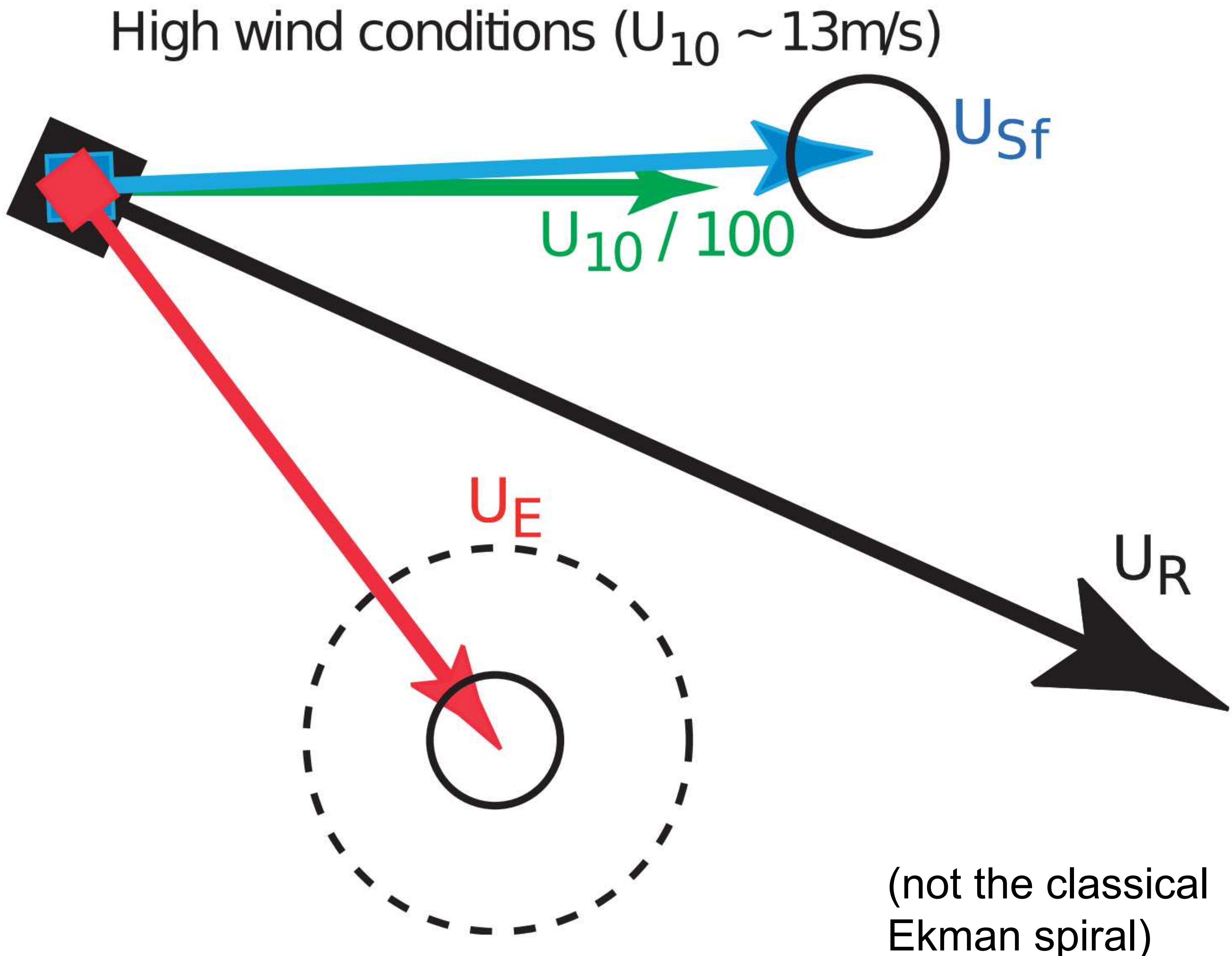
- Where are the waves generated?
- How much energy do they transfer?
- How much mixing do they produce?
- What is the relation waves←→"front"?
- Relation to the Tsushima surface spiral-gyre?
- Influence of IWs and gravity wave field change at "front" on ATSSG and HF radar surface currents?

Measurement of Internal Wave Speeds by the ATSSG technique

- ATSSG delivers total IW speed

i.e. total speed = phase speed + “tidal” advection

- For 13 Aug 2006 IW phase speeds generally little different from surface slick speeds


High wind conditions (U_{10} ~13m/s)
U_{Sf}
U_{10} / 100
U_E
U_R
(not the classical
Ekman spiral)