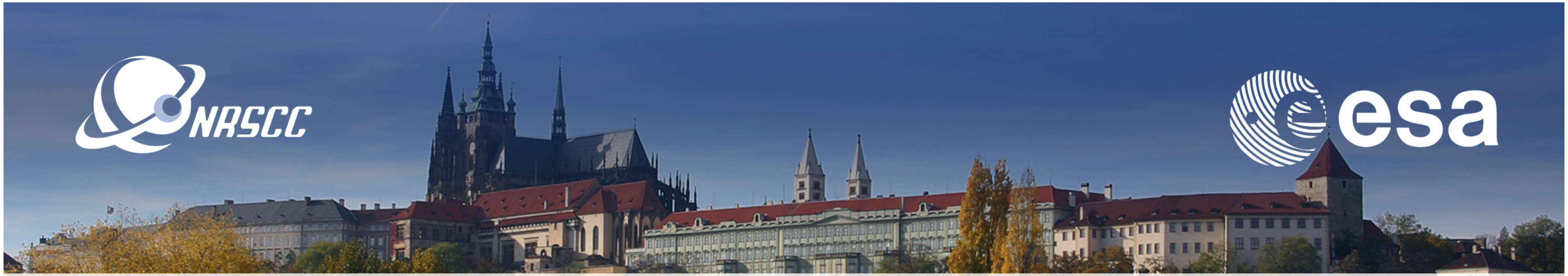

ESA - MOST Dragon 2 Programme

2011 DRAGON 2 SYMPOSIUM

中国科技部-欧洲空间局合作 “龙计划”二期

“龙计划”二期2011年学术研讨会

Progress on Demonstrating SAR Monitoring of Chinese Seas

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Contribution to Dragon project 5316

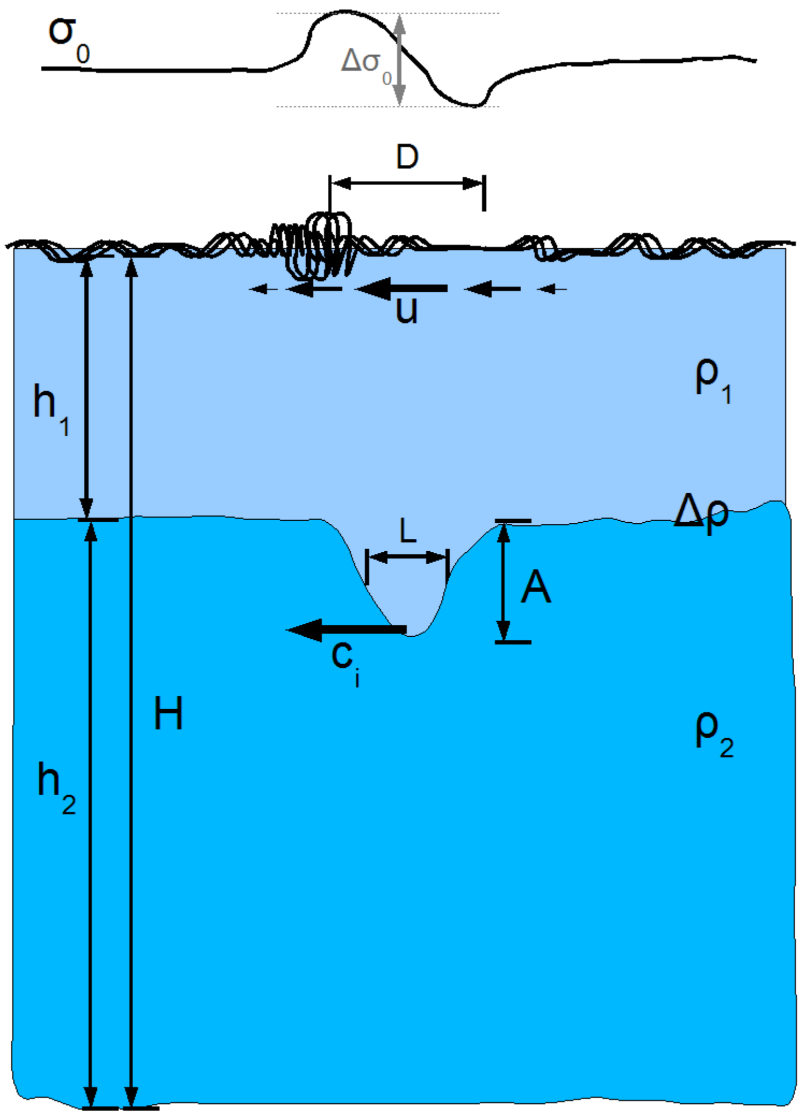
20 - 24 June 2011 | Prague | Czech Republic

捷克 布拉格 2011年6月20-24日

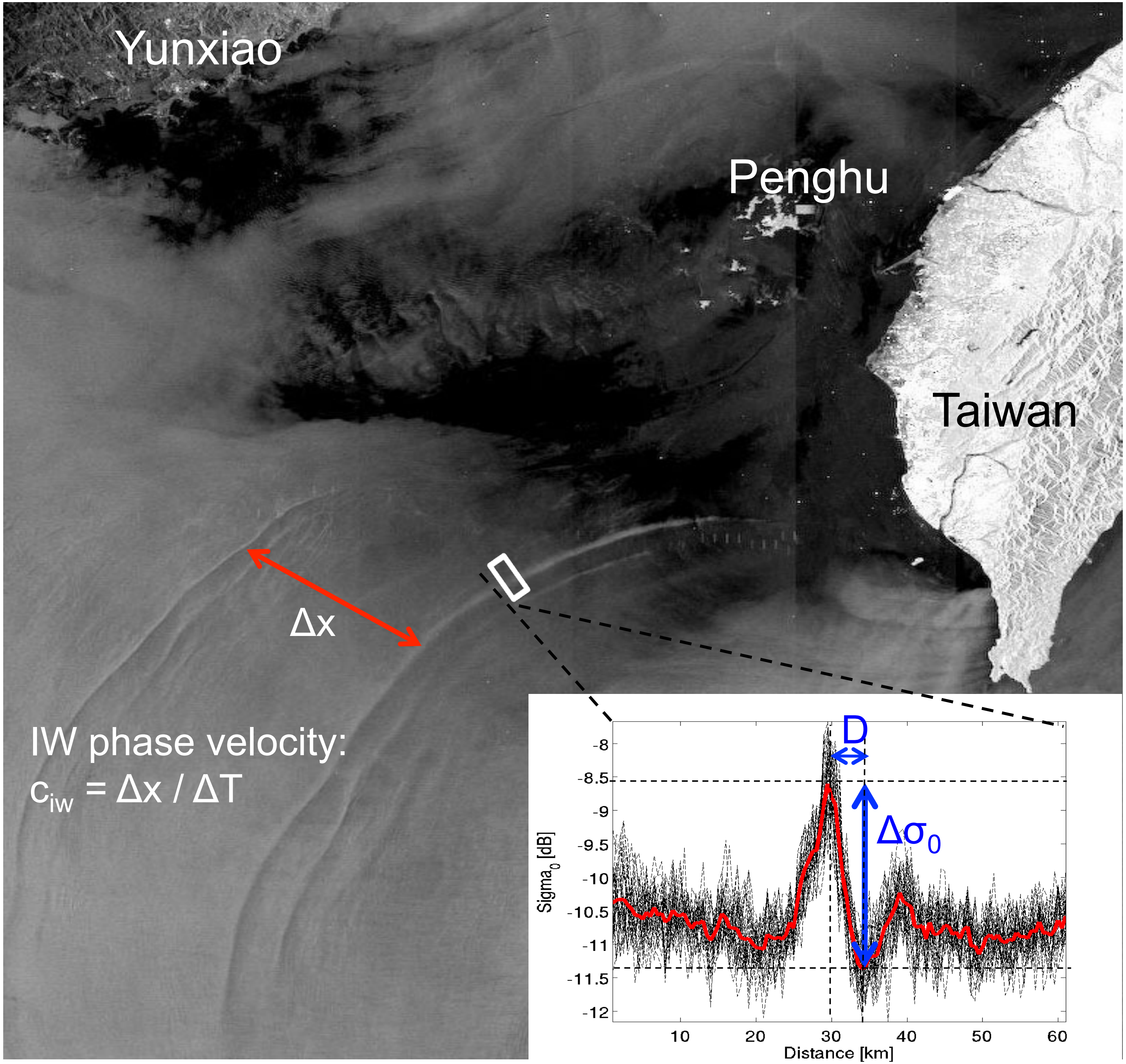
Contents

- Retrieval of internal wave induced surface current from SAR
- Surface current retrieval using ASAR Doppler Velocity

Internal waves



- L = "half width" of IW soliton
  - D = 1.32L
- c_i = phase speed
- u = induced surface current
- h_1 = pycnocline depth
- ρ = mean ocean density
- Δρ = 2 layer density difference
- A = IW amplitude



Yunxiao
Penghu
Taiwan
Δx
IW phase velocity:
c_iw = Δx / ΔT
D
Δσ0
Sigma0 [dB]
Distance [km]
-8
-8.5
-9
-9.5
-10
-10.5
-11
-11.5
-12
10
20
30
40
50
60

- IW-induced SAR roughness modulation $\Delta\sigma_0$ depends on (at least):
  - Wind speed
  - Wind direction
  - SAR look direction
    - Relative to wind direction
    - Relative to IW propagation direction
  - SAR incidence angle
  - IW phase velocity
  - IW characteristic width
  - IW induced surface current

To determine a simple relationship between $\Delta\sigma_{0}$, and the surface current, we will use **dimensional analysis**:

By constructing a set of **dimensionless parameters π_1, π_2, π_3….** from the relevant involved physical parameters, we can seek a solution on the form:

$$F(\pi_1, \pi_2, \pi_3, \ldots) = 0$$

(Buckingham-**π** theorem)

Dimensional analysis

- Two characteristic length scales
  - IW wavelength (soliton width): L
  - Relaxation length of modulated surface waves: λ
  - Dimensionless parameter: $\pi_1 = \dfrac{L}{\lambda}$

- Two characteristic velocity scales
  - Induced surface current velocity: $u_{\max}$
  - Phase (propagation) speed of IW: c_{iw}
  - Dimensionless parameter: $\pi_2 = \dfrac{u_{\max}}{c_{iw}}$

An expression for the surface wave relaxation length

Relaxation length: $\lambda = c_g T$

Relaxation time: $T \equiv \dfrac{1}{\omega\beta}$

Wind growth parameter:

$$\beta = c_\beta \left(\frac{u_*}{c}\right)^2$$

- Bragg waves (~2-20 cm) are normally too short to be modulated directly by current gradients associated with internal waves.
- However, longer waves on meter scale feel current gradient, and generate shorter Bragg waves when they break.
- Hence ω and c_g is here frequency and group velocity of shortest breaking waves

Inserting: $$\lambda = \frac{c^3}{2c_\beta u_*^2 \omega} = \frac{g}{2c_\beta u_*^2 k^2}$$

Forming the dimensionless parameter: $$\frac{\lambda}{L} = \frac{g}{2c_\beta u_*^2 k^2 L}$$

$$\pi_1 \equiv \frac{1}{W^2 L}$$

- Removing constant parameters
- Using wind speed (W) as substitute for U* which is not well known

- Assumption (Buckingham pi-theorem)

$$\Delta\sigma = \alpha(\pi_1)^{x_2}(\pi_2)^{x_2}$$

- Parameters α , x_1 and x_2 to be determined by experiment (or simulation)

Radar Imaging Model

- Wind speed
- Atmospheric stability
- Ocean surface current
- Surface dampening films

Hydrodynamic module

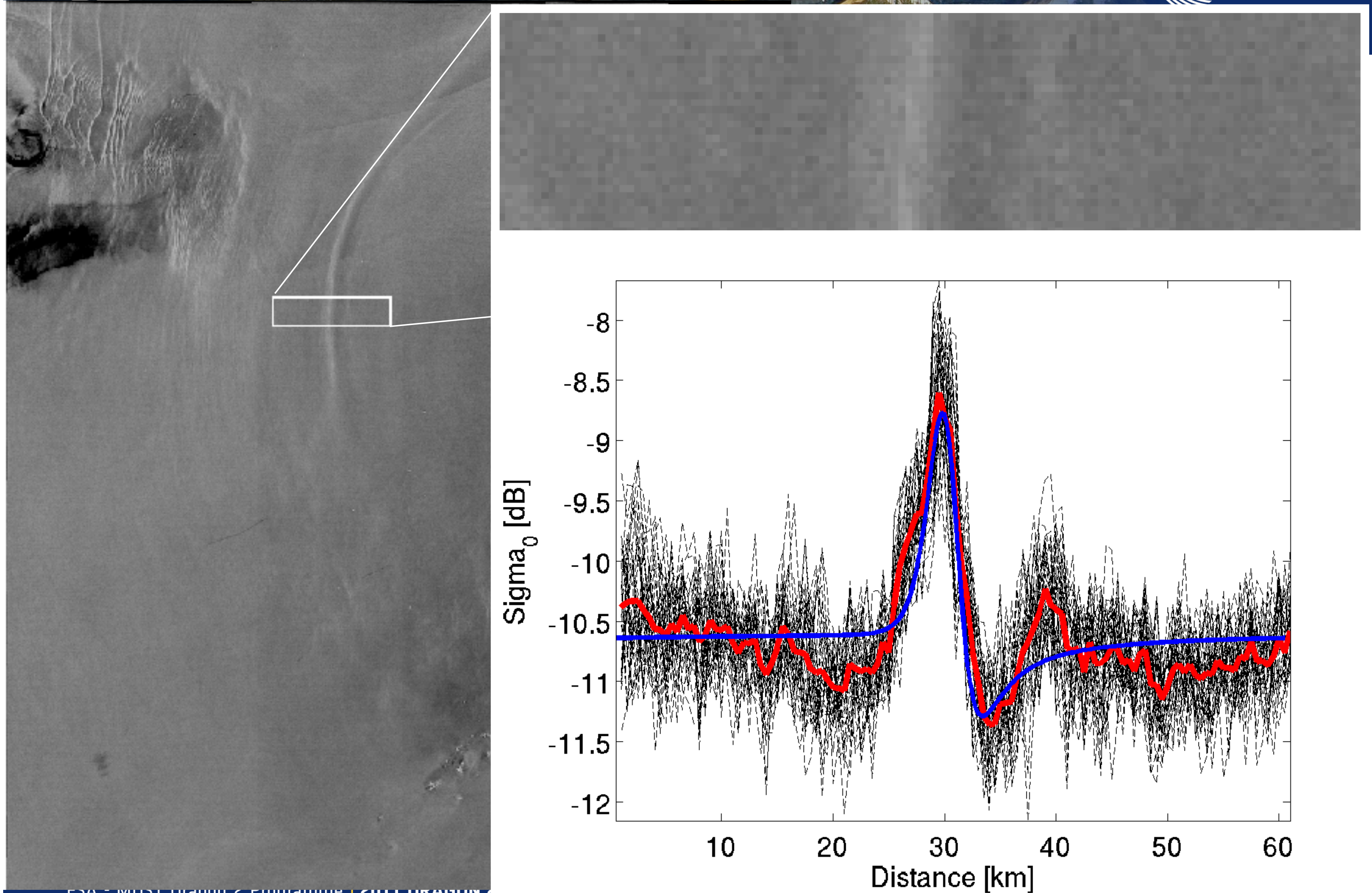
Description of surface waves

Radar parametres:
- Incidence angle
- wavelength
- polarization

Radar module

Bragg scattering
Specular scattering
Breaking waves

σ_0



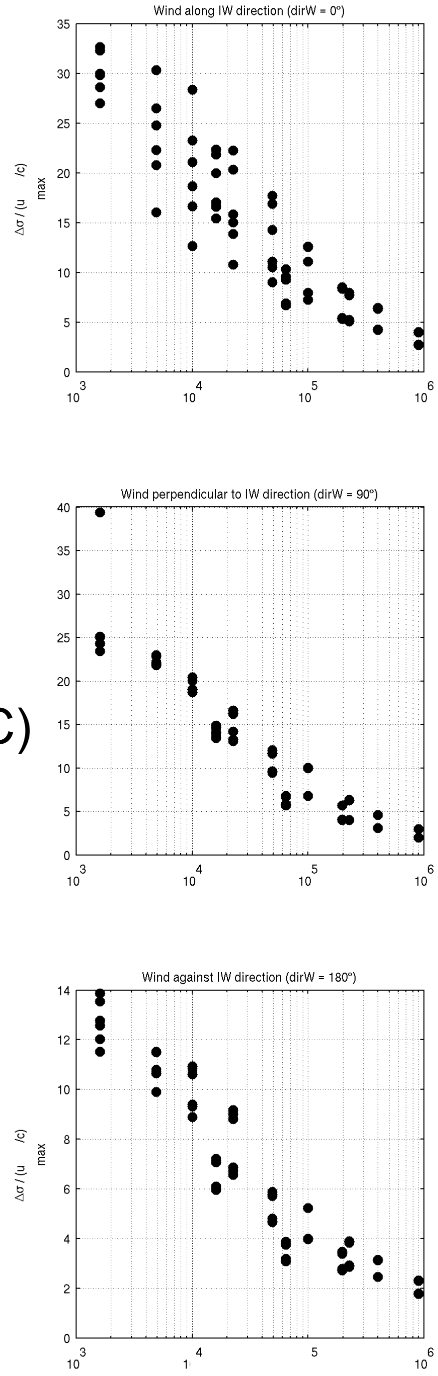
-8
-8.5
-9
-9.5
-10
-10.5
-11
-11.5
-12
$Sigma_0$ [dB]
10
20
30
40
50
60
Distance [km]

The linear relationship found agrees well with RIM-simulations

$$\Delta\sigma_0 = \alpha \frac{U_{max}}{W^2 \ L \ C_i}$$

W = wind speed
L = IW characteristic width
C = IW phase speed

α = parameter which depends on wind direction



$\Delta\sigma$ / (U_{max}/C)

LW^2

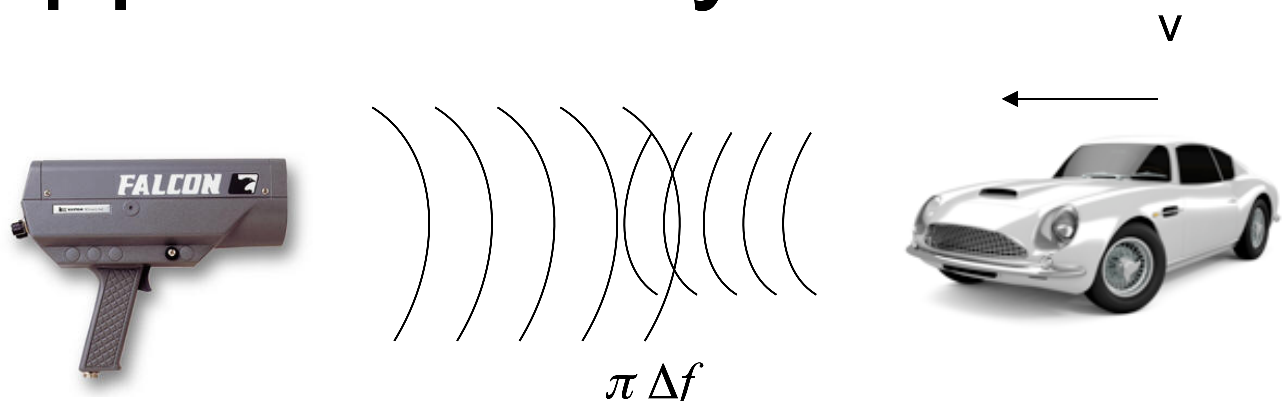
Wind along IW propagation direction

Wind perpendicular to IW propagation direction

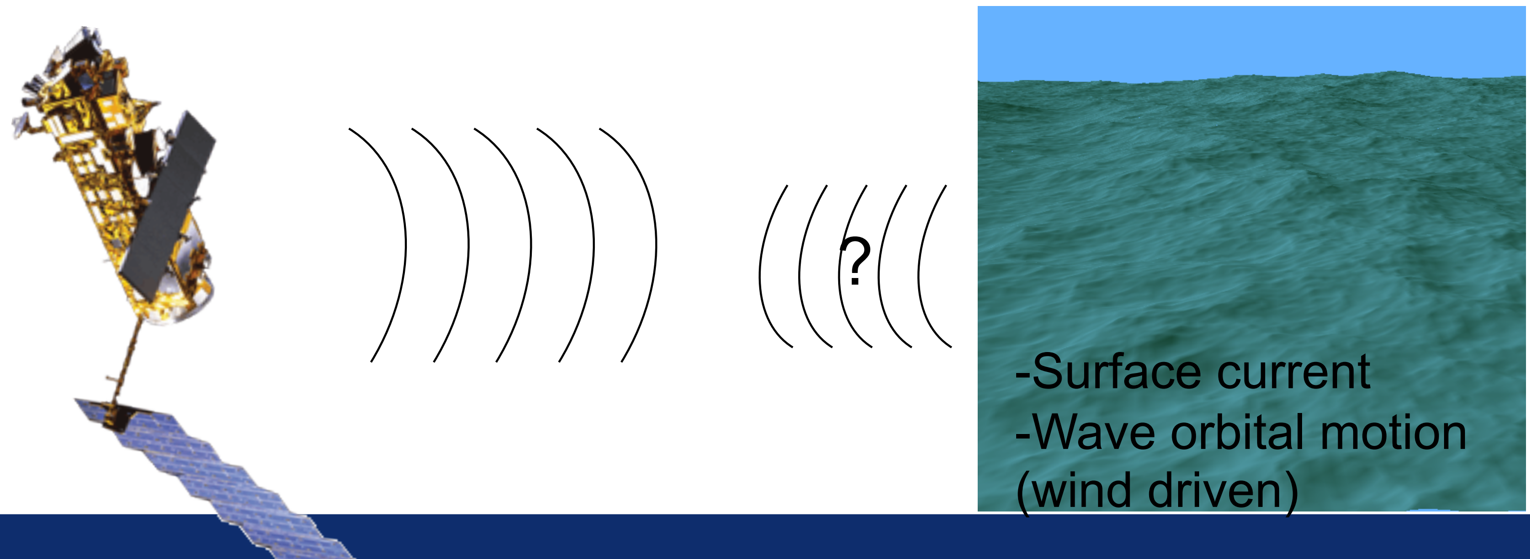
Wind against IW propagation direction

Surface current retrieval using ASAR Doppler Velocity

Doppler velocity measurement



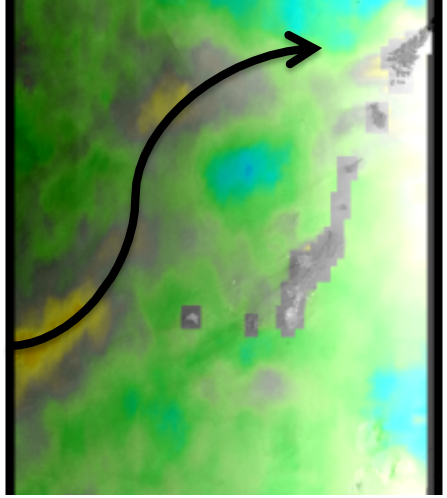
$$v = \frac{\pi \, \Delta f}{k}$$



Typhoon ”Sinlaku”

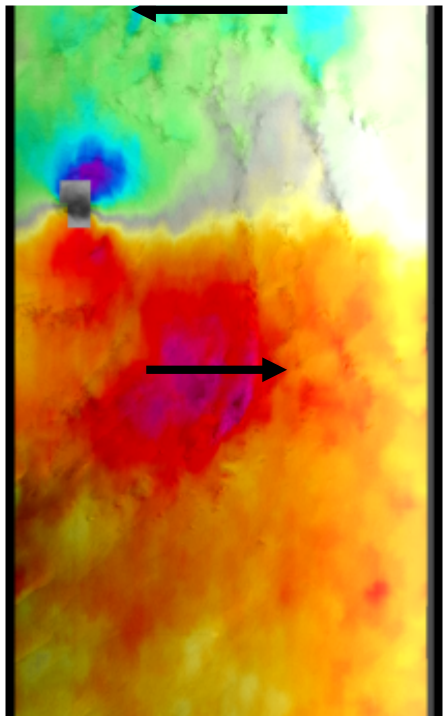
10 Sept 2008
01:30 UTC

Normalised Radar Cross Section



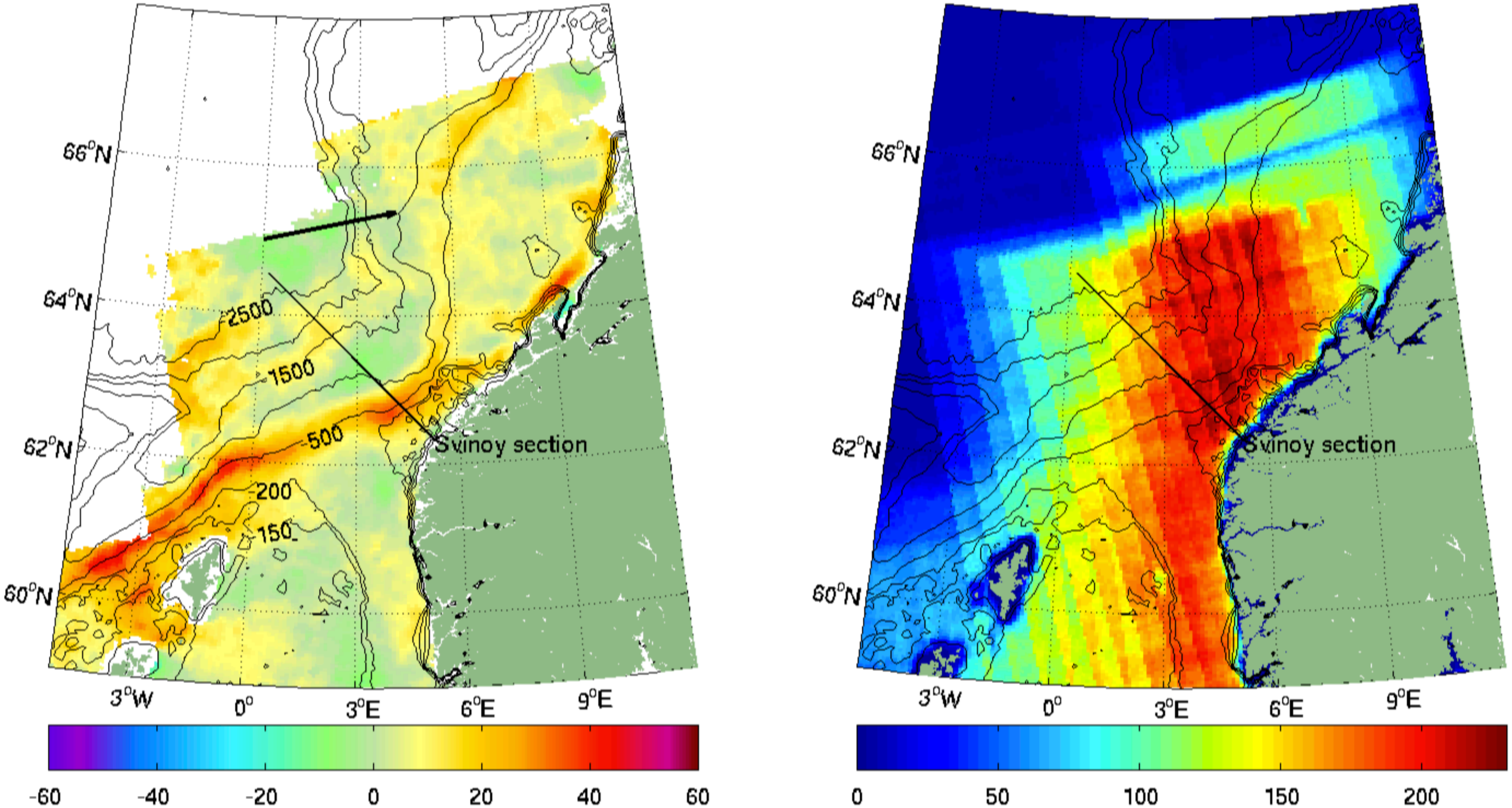
RMS ≈ 20-40 cm/s

Hansen M. W., F. Collard, K.-F. Dagestad, J. A. Johannessen, P. Fabry, and B. Chapron, **Retrieval of Sea Surface Range Velocities from Envisat ASAR Doppler Centroid Measurements**, IEEE TGRS, in print



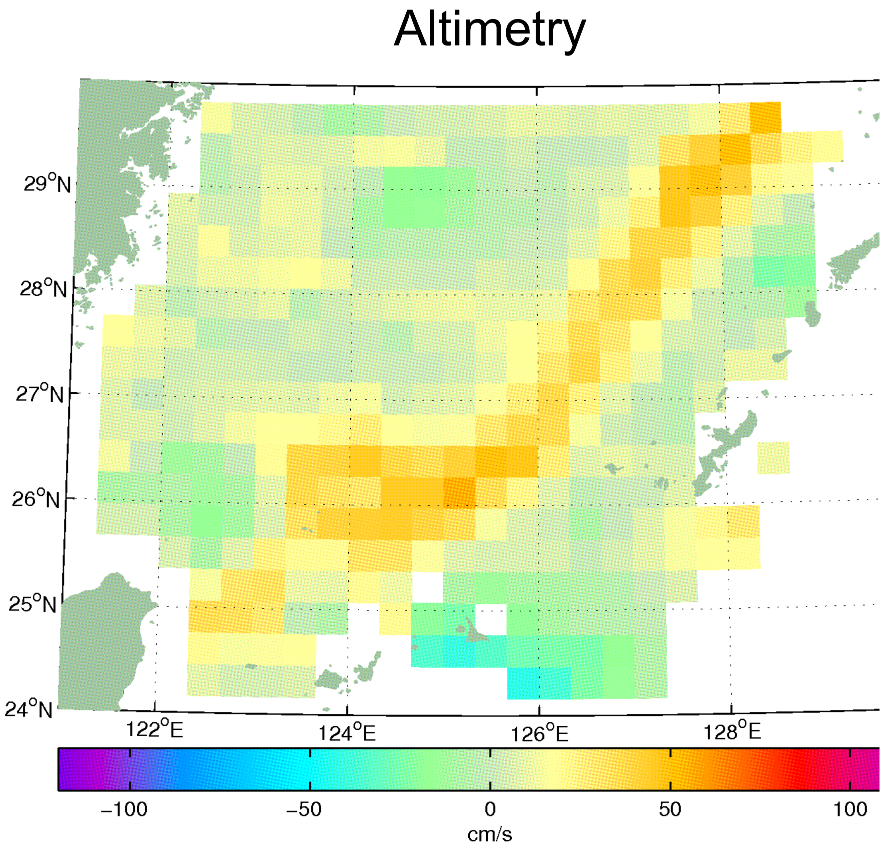
Doppler shift

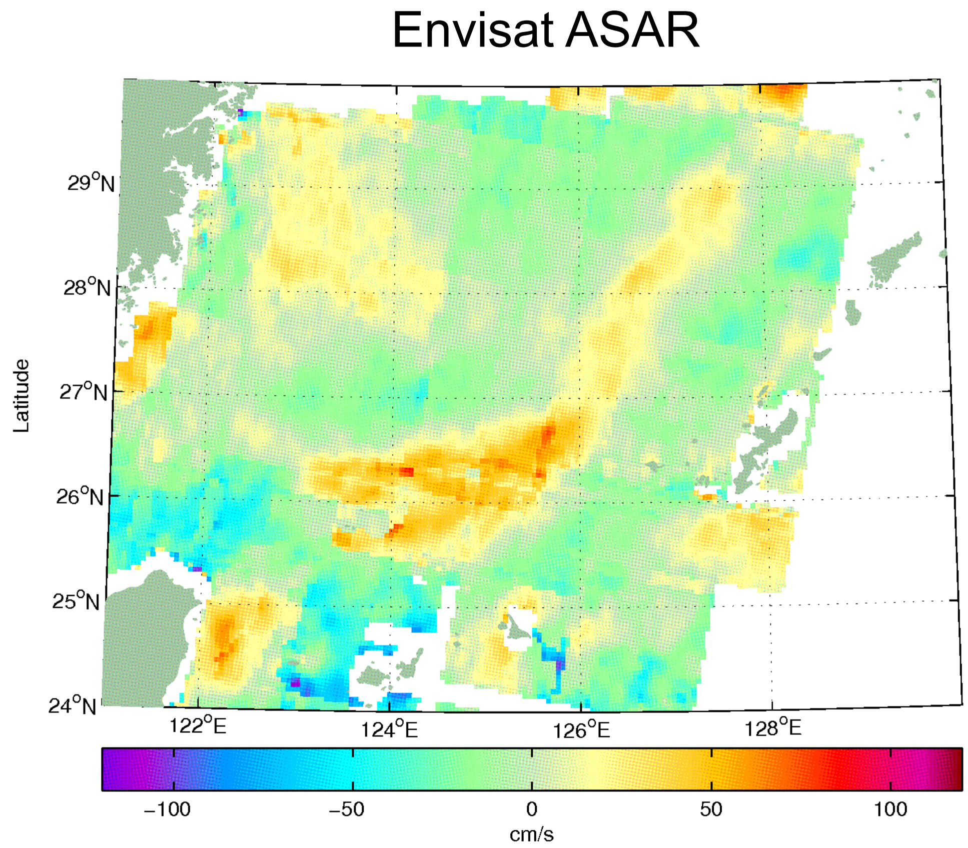
Time-averaged Doppler Velocity



M. W. Hansen, K. F. Dagestad, J. A. Johannessen, F. Collard, A. Mouche, B. Chapron, **Monitoring the Surface Inflow of Atlantic Water to the Norwegian Sea Using Envisat ASAR**, Accepted for publication in Journal of Geophysical Research - Oceans

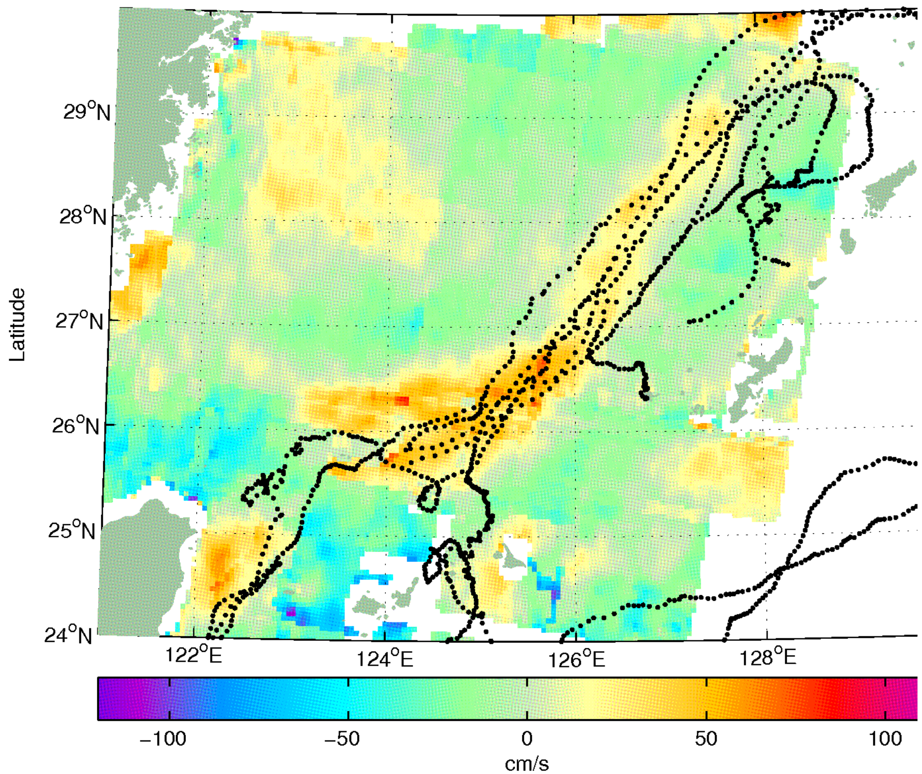
Mean ASAR Doppler velocity of Kuroshio

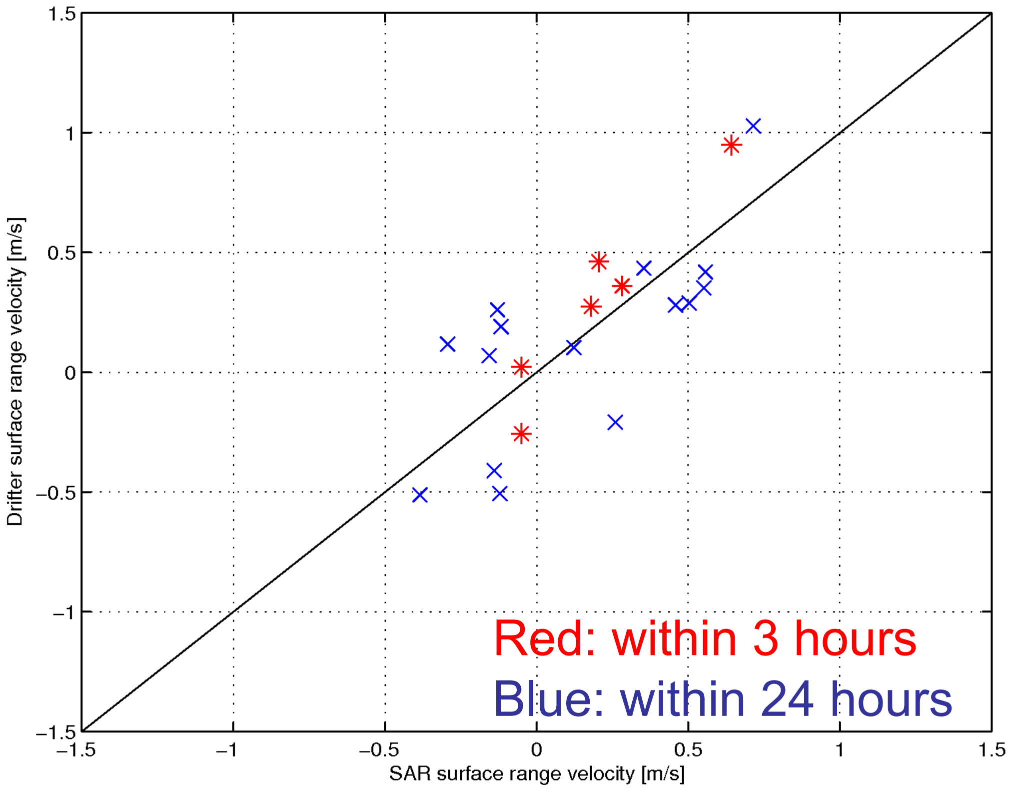




Average of 19 scenes

Comparison with drifters





Conclusion and future work

- Dimensional analysis used to find relationship between internal wave surface current and NRCS modulation
  - Supported by model simulations
  - Future:
    - Need validation against in situ measurements
    - Retrieval of internal wave amplitude and pycnocline depth/strength

- SAR Doppler velocity useful for retrieval of both ocean surface current and wind