Theory and numerical simulations to understand / simulate SKIM measurements concept

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Outline

- Wave bias in near-nadir Doppler measurements
  - Theoretical
  - Experimental
- Numerical simulation
  - Objectives

Motivation

SKIM does not measure currents

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SKIM measures Doppler

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SKIM does not measure currents → **SKIM measures Doppler**

- Sources of the backscattered Doppler signal

✓ **« Non-geophysical » Doppler**
- Platform velocity & Antenna rotation
- Earth rotation speed
- ...

✓ **« Geophysical » Doppler**
- Wave contribution
- Current contribution

- Objectives of theoretical and numerical approaches

✓ **Theoretical : understand what's going on**

✓ **Validate consistency between the two approches**

✓ **Describe & quantify known contributions**
- biais
- Variability

✓ **Discover unknown contributions**
- Instrument processing
- Geophysical (inhomogeneities in the footprint, ...)
- Coupled sensor-surface bias

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Wave Doppler (bias)

✓ **Origin (rough approach):**

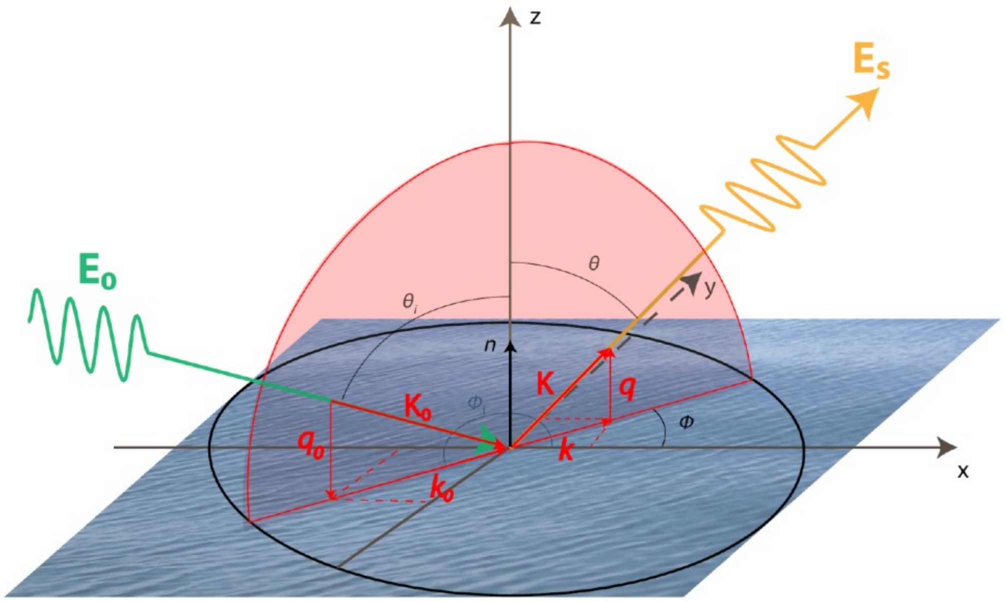

Figure 5: Diffraction (S. Guimbard)

Backscattered signal

Magnitude ← Ocean waves slope

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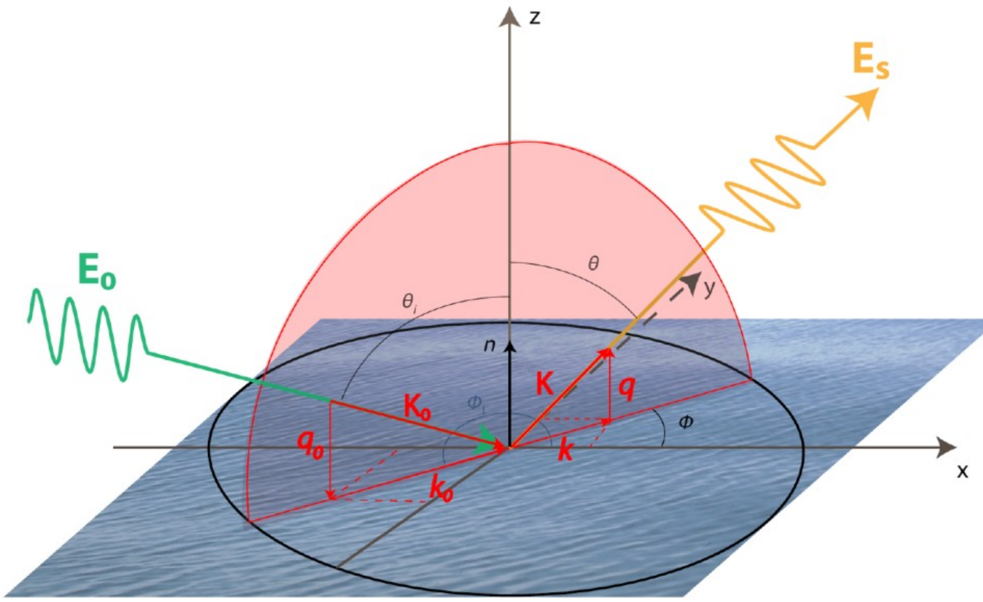

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Magnitude ⟵ Ocean waves slope

Doppler ⟵ Ocean waves (vertical) velocities

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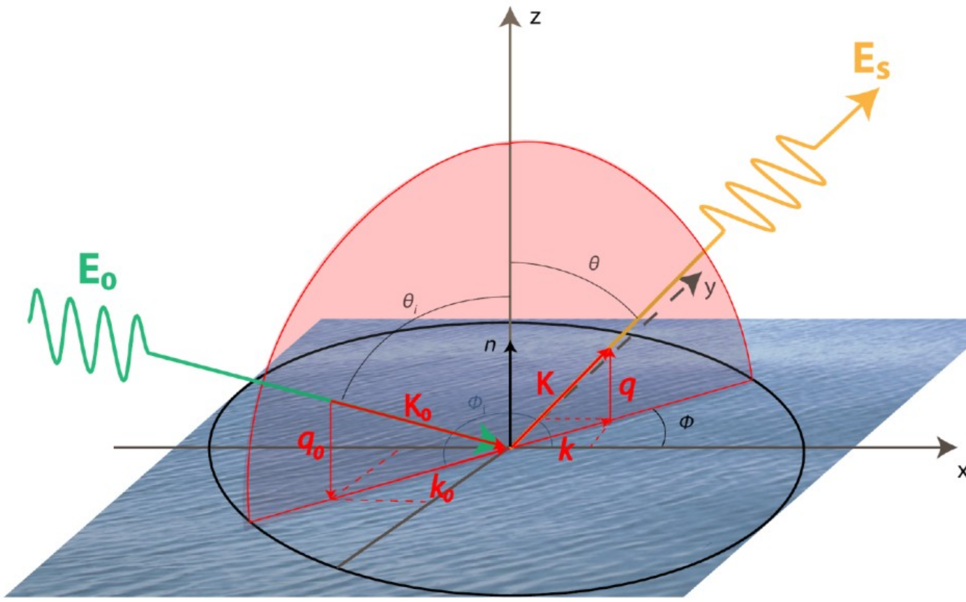

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Backscattered signal

Magnitude ← Ocean waves slope
Doppler ← Ocean waves (vertical) velocities

Waves bias : slope-velocity correlation coefficient

Wave Doppler (bias)

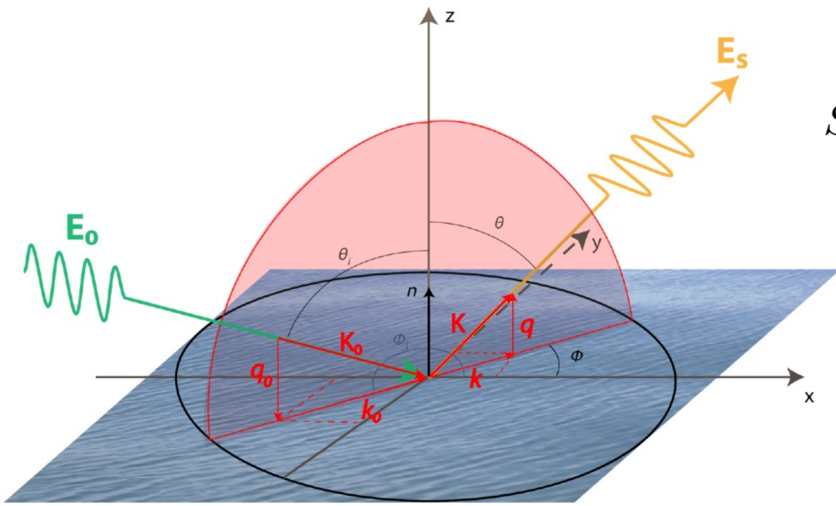


Figure 5: Diffraction (S. Guimbard)

$$S_{KA}(t) \propto \frac{\mathcal{K}e^{iK(R-ct)}}{Q_z(2\pi)^2}\int_A d\boldsymbol{r}\ e^{i\boldsymbol{Q_H}\cdot\boldsymbol{r}}\ e^{iQ_z\eta(\boldsymbol{r},t)}$$

$$\boldsymbol{Q_H} = \boldsymbol{k} - \boldsymbol{k_0}$$
$$Q_z = q + q_0$$

✓ **Sea-state Doppler frequency**

$$f_{\mathrm{GD}} = \frac{Q_z}{2\pi}\left(\mathrm{mss_{xt}}\frac{\partial_{\tan\theta}\psi^0}{\psi^0} + \frac{\mathrm{mss_{yt}}}{\tan\theta}\frac{\partial_\varphi\psi^0}{\psi^0}\right)$$

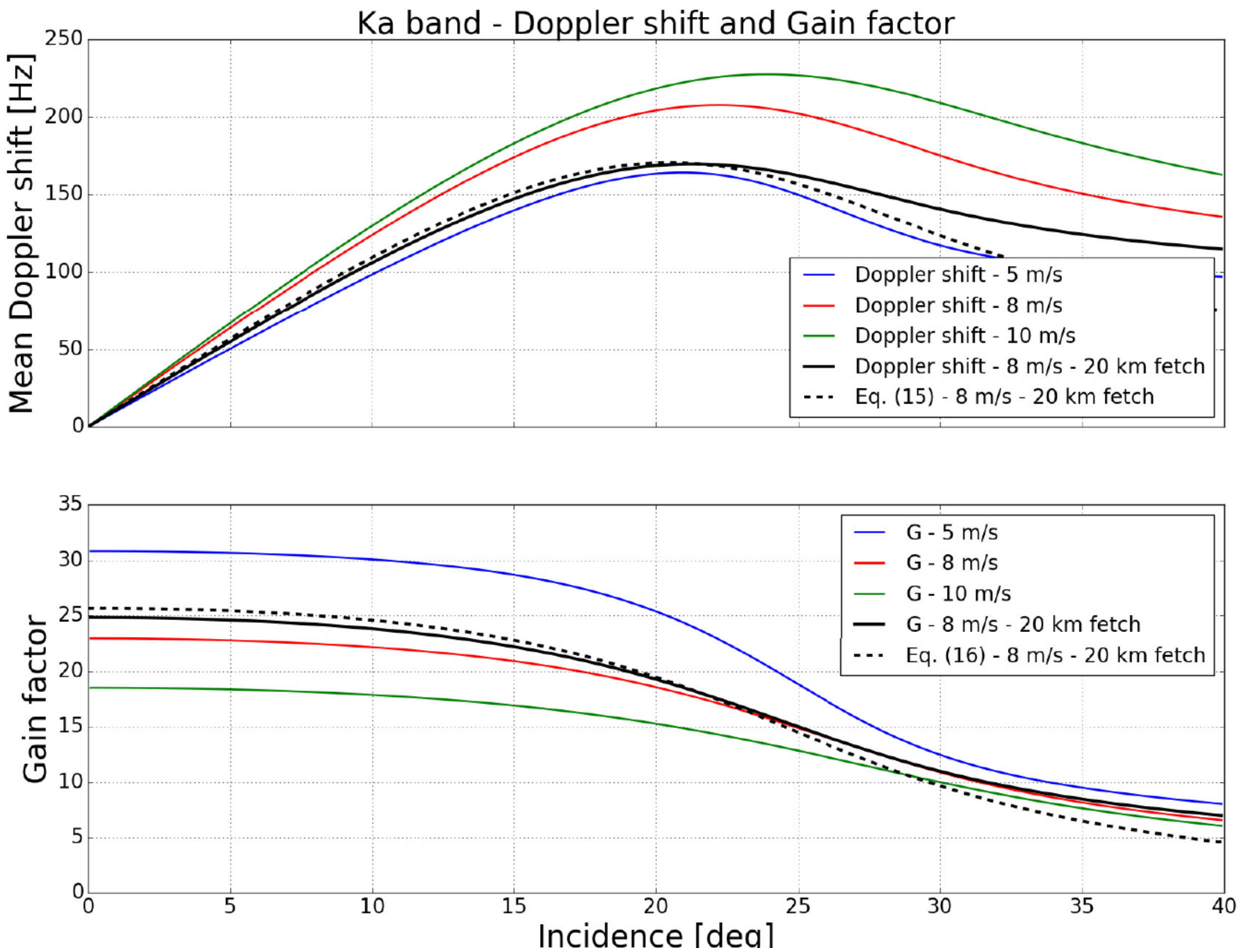
Mean range slope-velocity cross-correlation

NRCS incidence rate of variation

Mean azimuth slope-velocity cross-correlation

NRCS azimuthal rate of variation

Wave Doppler (bias)



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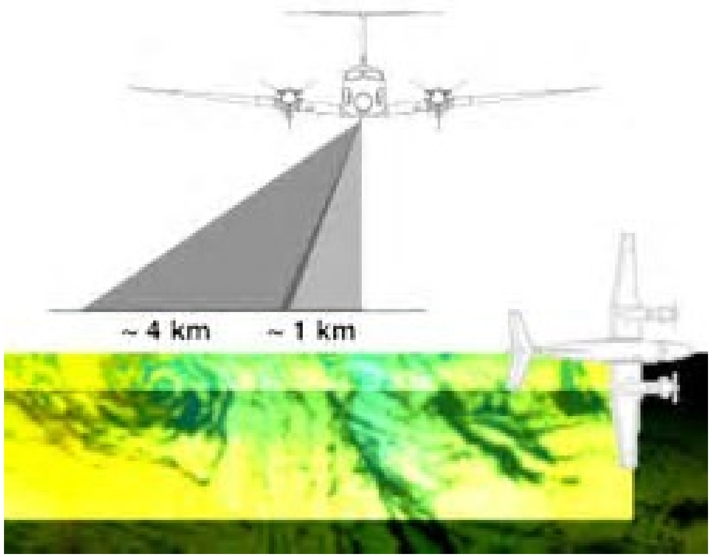
$$G = -\frac{1}{2}\frac{2\pi f_{\mathrm{GD}}}{Q_H \mathrm{mss}_{\mathrm{xt}}}$$

Experiment : AirSWOT Ka-Band

Airborne Surface Water and Ocean Topography



- Ka-band SAR (KaSPAR)
- Operated by NASA Jet Propulsion Laboratory (JPL)
- flying aboard a King Air B220 Aircraft

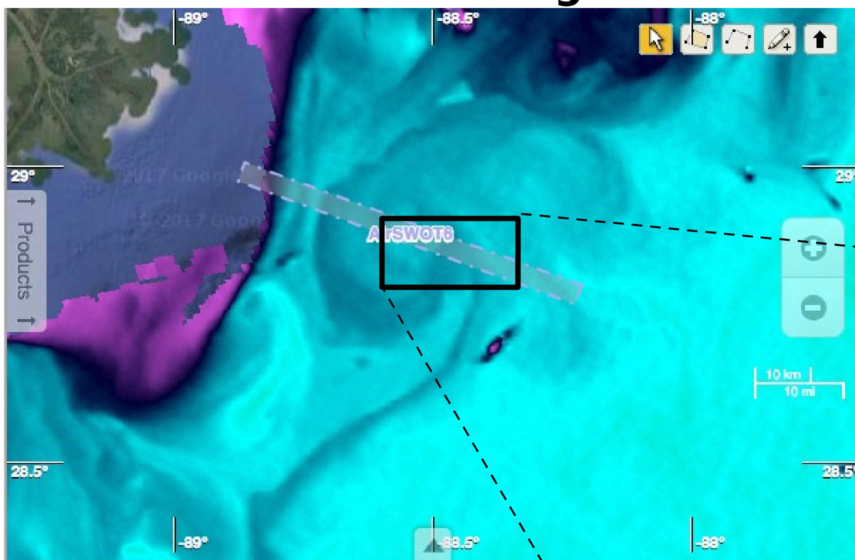
- Interferometric SAR
- ~ 5m range resolution
- Incidence [0°, 23°]

Data were provided by NASA – JPL (Thanks Ernesto)

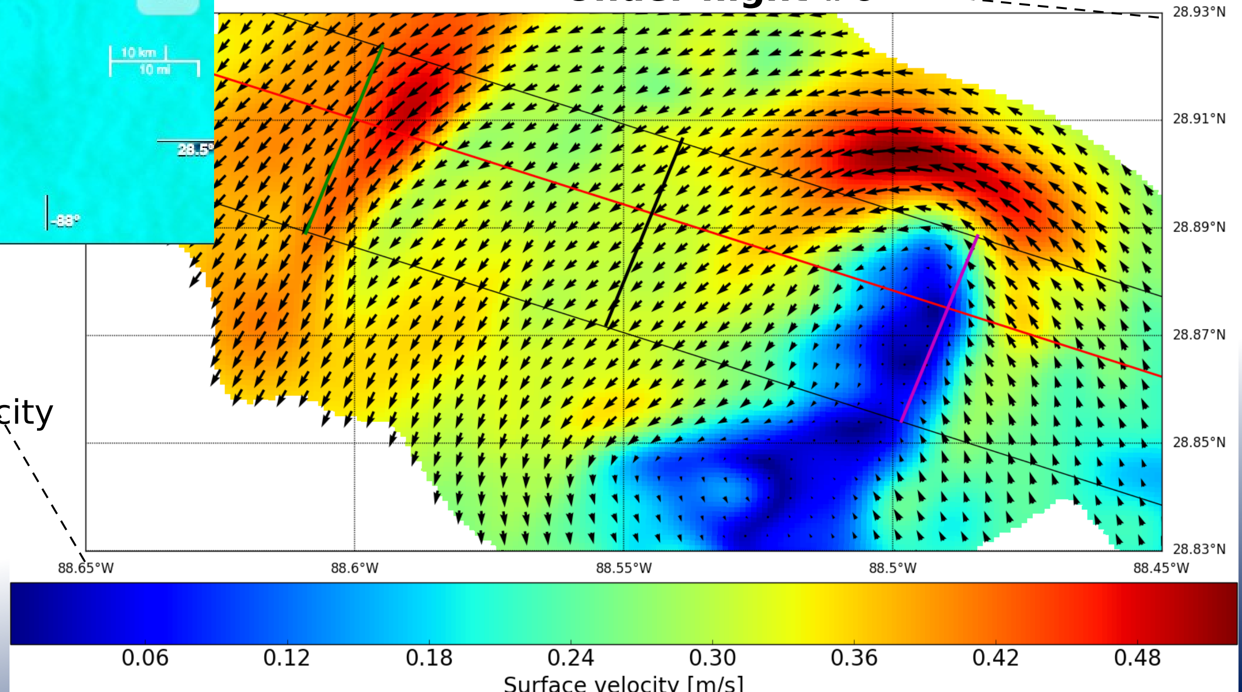
LAgrangian Submesoscale ExpeRiment : 2016/02/07

- Gulf of Mexico
- Hundreds of drifters deployed
- Obs : drifters, cameras, aiborne, SAR, lasers, satellite sensors, ...

SST field under flight #6



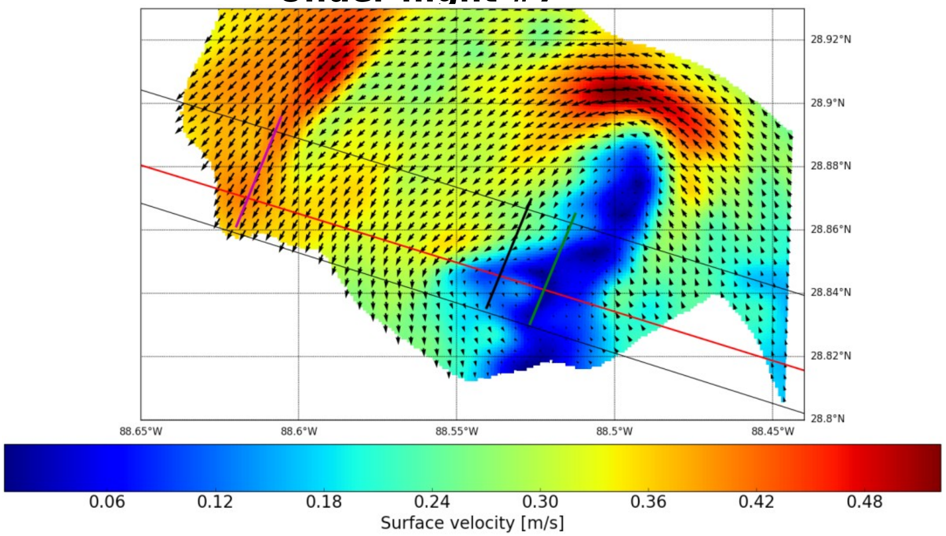
Interpolated surface drifter velocity field Under flight #6



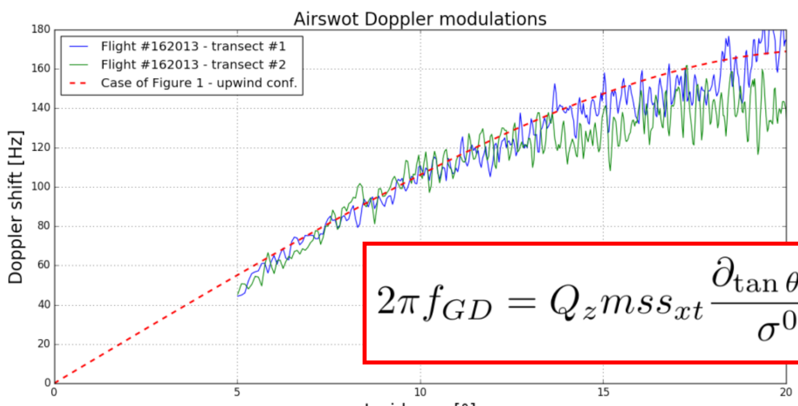
- Colors : in-situ surface current velocity
  Arrows : surface current direction
- Black lines : AirSWOT swath boundaries
- Red line : 12 degrees incidence transect.

Data analysis : Incidence sensibility

Interpolated surface drifter velocity field
Under flight #7

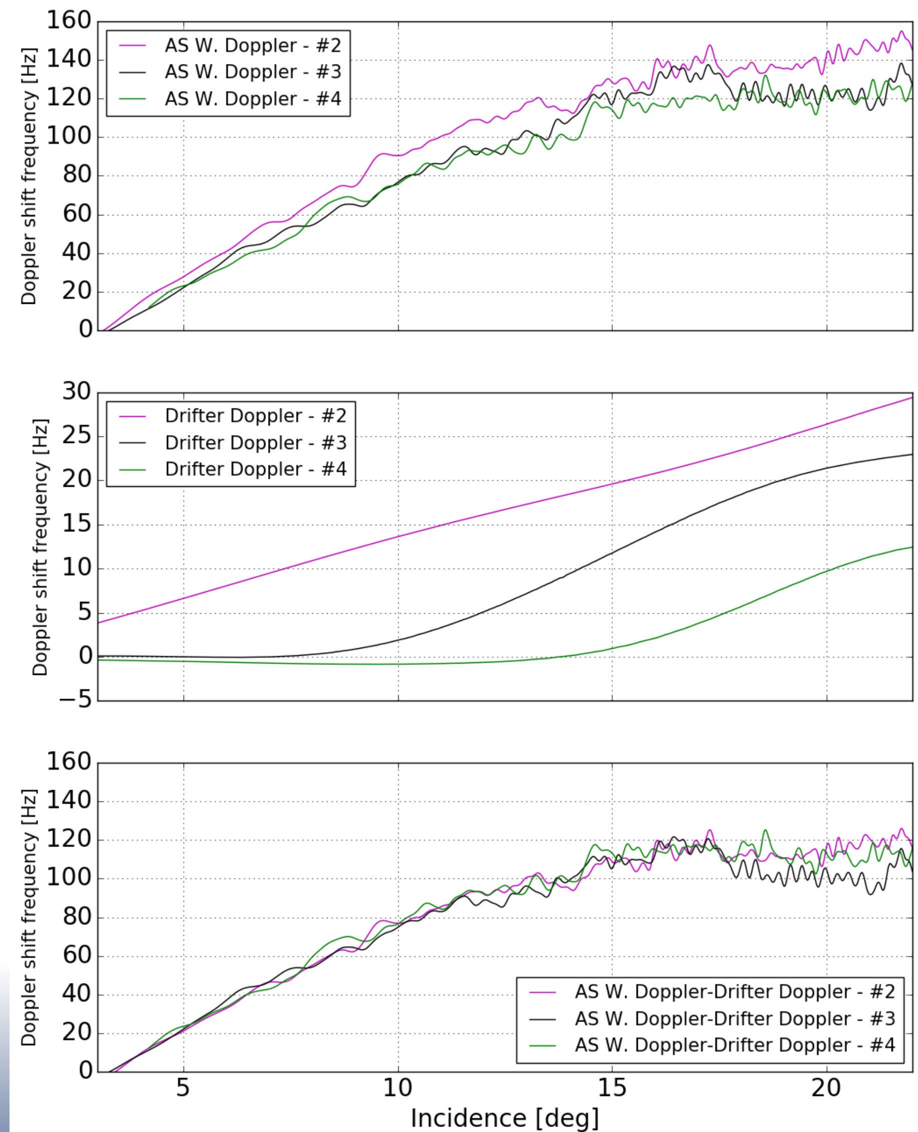


- Upwind/upwave conditions
- Wind speed : 8 m/s
- 45 m peak wavelength



$$2\pi f_{GD} = Q_z mss_{xt} \frac{\partial_{\tan\theta}\sigma^0}{\sigma^0}$$

Doppler Incidence variation



Partial conclusions

- We are confident with our theoretical approach
  - EM modelisation (Ku Band)
  - Sea surface description (“mean” geophysical conditions)

- Experiments confirm the Doppler order of magnitude
  - Sensibility to wave / current

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SKIM concept and configuration is unique.

Few previous concept/experiments can be used to demonstrate SKIM full possibilities

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SKIM concept and configuration is unique.

Few previous concept/experiments can be used to demonstrate SKIM full possibilities

- Dedicated Drift4SKIM Campain (see L. Marié presentation)
- Numerical “End-to-end simulator”

Needs of numerical simulations

- Validate stochastic approach
- Simulate existing signal
  - SWIM/KuROS –like signals
  - Validate closed-form of Doppler wave bias

    (see SKIMulator presentation by L. Gaultier)
- Test SKIM configuration possibilities (optimization)
  - Antenna rotation, altitude, number of beams, define and scale OBP,...
- Evaluate sensitivity to parameters:
  - Geophysical : wind, waves, current, ...
  - Instrumental : antenna pattern, noise, ...
  - Configuration : altitude, PRF, macrocycle, rotation rate, ...
- Investigate non-linear instrument effects (range-bunching, ...)
- Investigate non-linear wave effects
- Develop algorithms
  - Forward model =>Sketch of reconstruction
  - Processing (Wave spectrum restitution, Pulse-pair, ...)
  - ...
- Validate SKIM concept :

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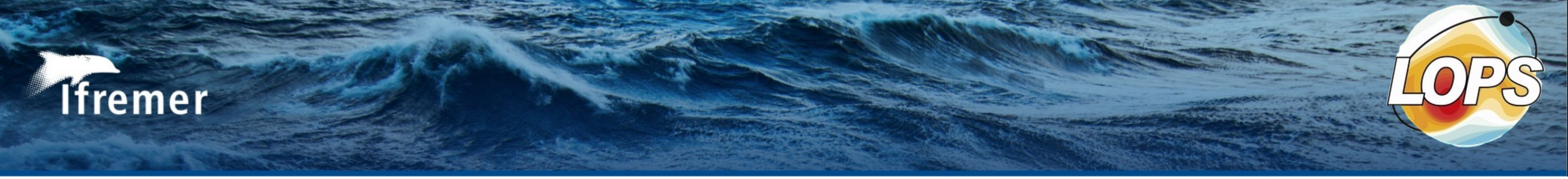
Turn Doppler measurements
into
Surface current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