DEFENCE R&D DÉFENSE

DEFENCE R&D DÉFENSE

The Estimation of Ship Velocity from a SAR Image

James K.E. Tunaley,

Radar Applications and Space Technology Section

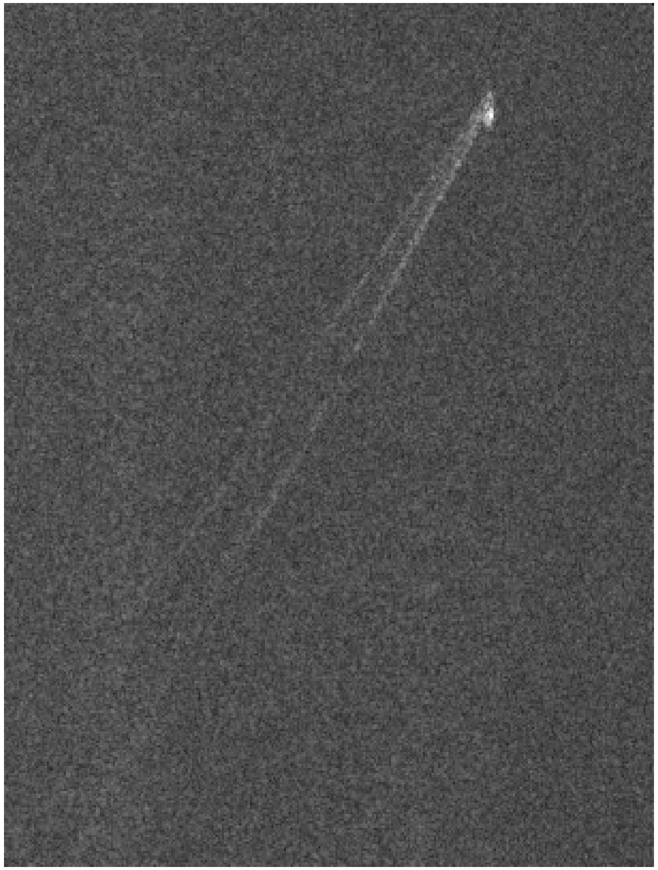
DRDC Ottawa

OBJECTIVES

- Ship velocity vector is important for ocean surveillance:
  - Tracking requires ID maintenance
  - Dense shipping environments
- Study the feasibility of extracting ship velocity vector (heading and speed) from SAR imagery:
  - * Cross-range displacement *
  - Kelvin wake
  - Other wakes
  - Ocean models – internal wave speed (maximum)
- Code software tool (Gayan Abeysundara)

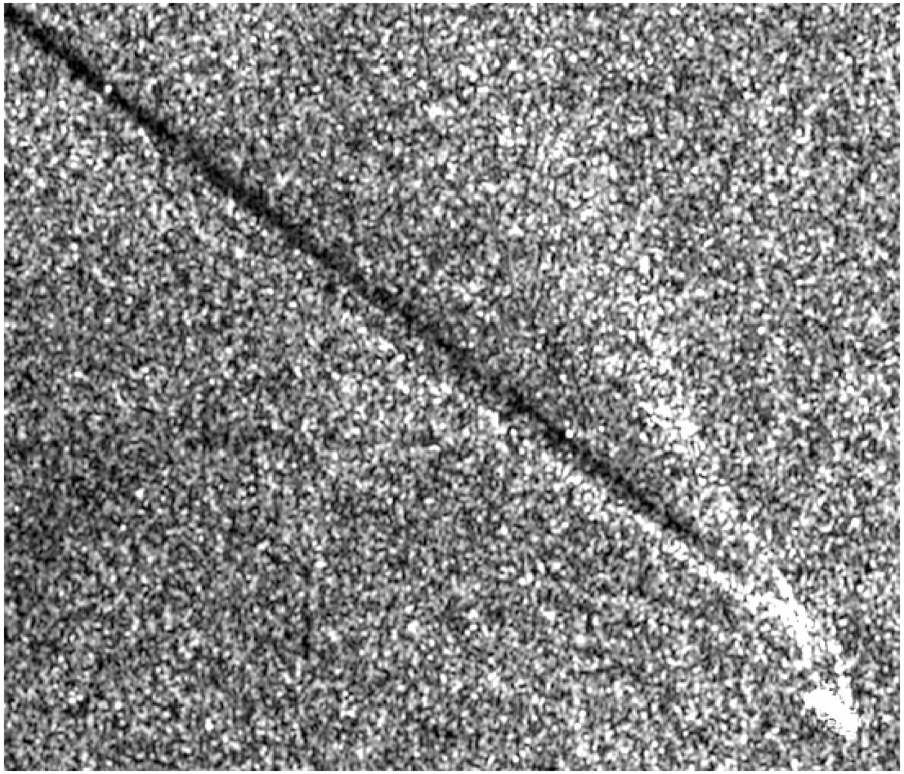
CROSS-RANGE DISPLACEMENT

- Seasat: note offset
- Internal wave wake?
- Unsteady wake?



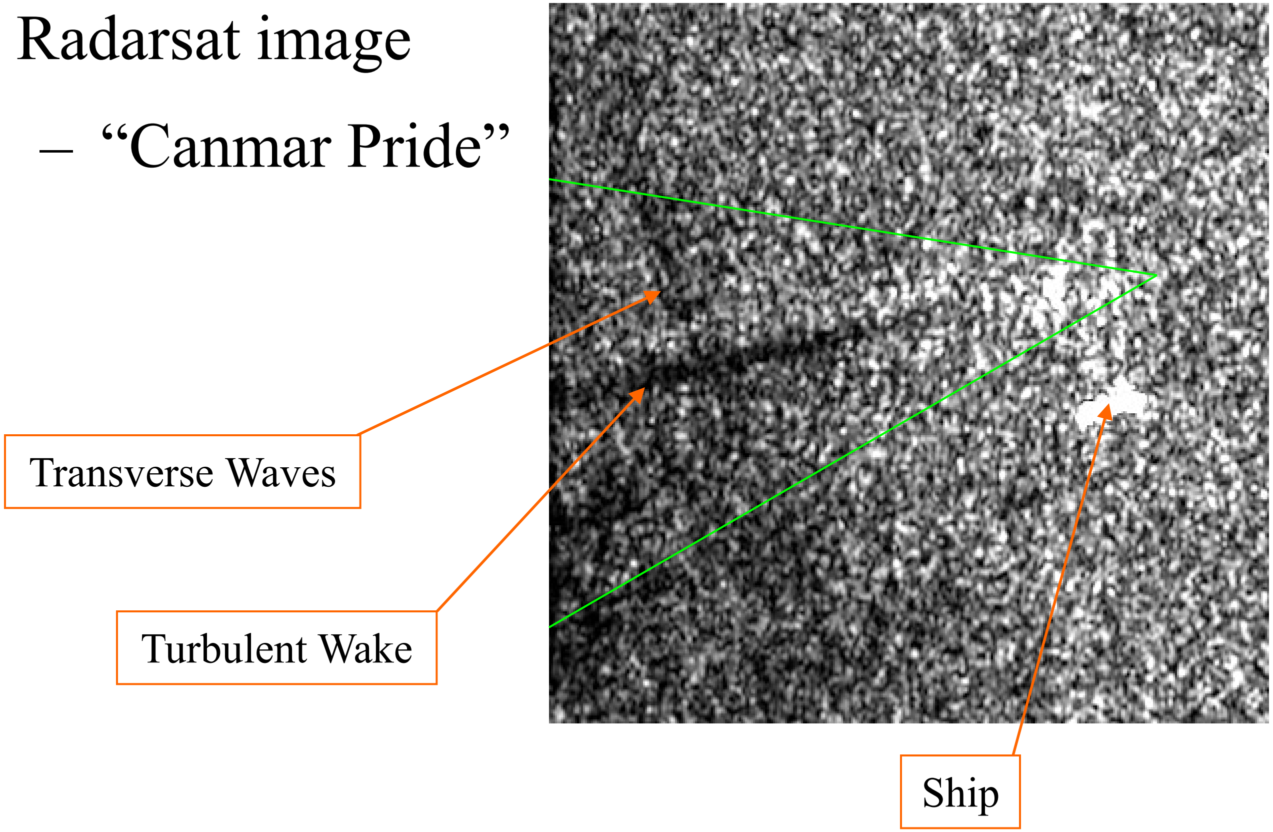
EXAMPLE OF TURBULENT WAKE

- Turbulent wake in Radarsat image

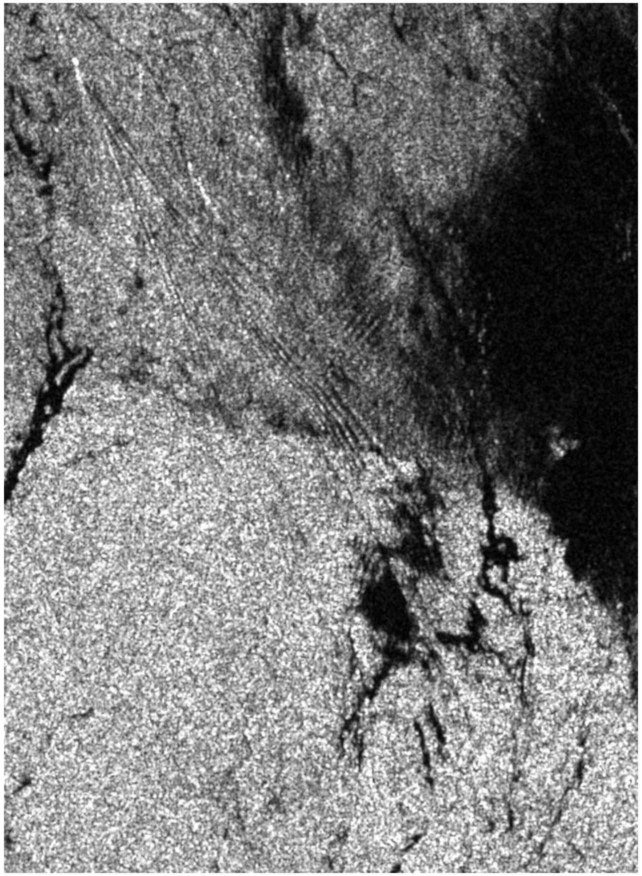


EXAMPLE OF KELVIN WAKE

- Radarsat image
  - "Canmar Pride"



INTERNAL WAKE (ERS)



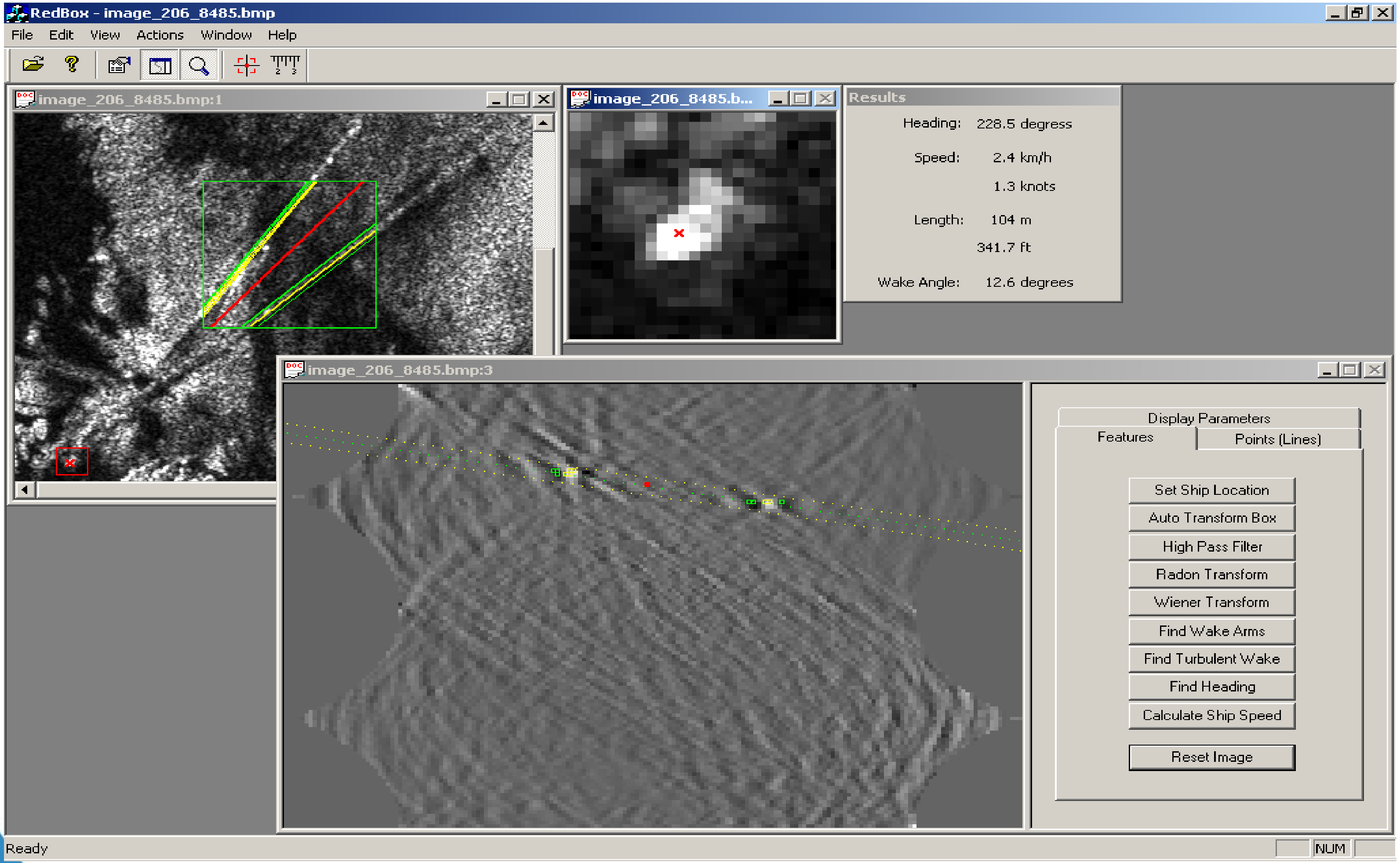
POTENTIAL DIFFICULTIES

- Not always a wake:
  - Turbulent wake usually present for large ships: up to and including SS4
  - Internal waves common in littoral areas when SS<3
- Ambient sea
- Variety of wake types
  - Turbulent
  - Steady Internal
  - Kelvin
  - Unsteady surface and internal wakes
- Some wake arms missing
- Natural internal waves

RADON TRANSFORM

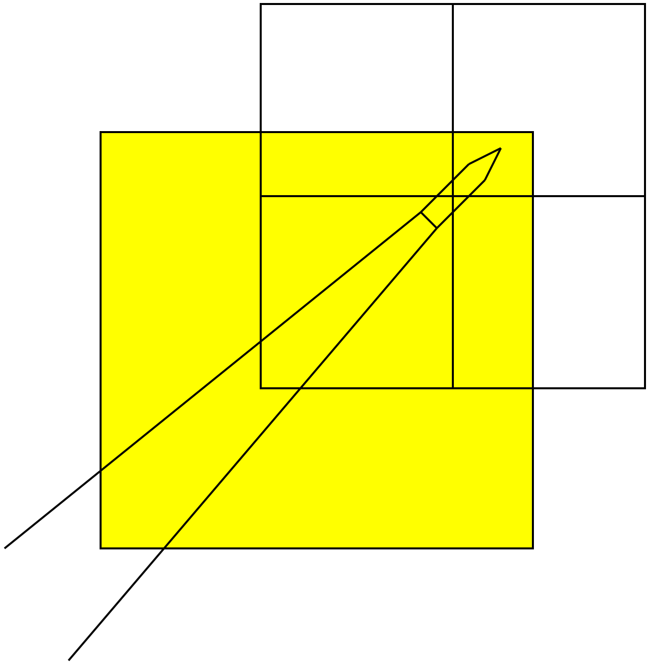
- Maps lines in spatial domain to points in Radon space
- Should be preceded by high pass filter and possibly by a Wiener post-filter (Seasat)

EXAMPLE OF RADON TRANSFORM



WAKE ARM EXTRACTION

- Locate wake using 4 regions
- Extract arms from larger area

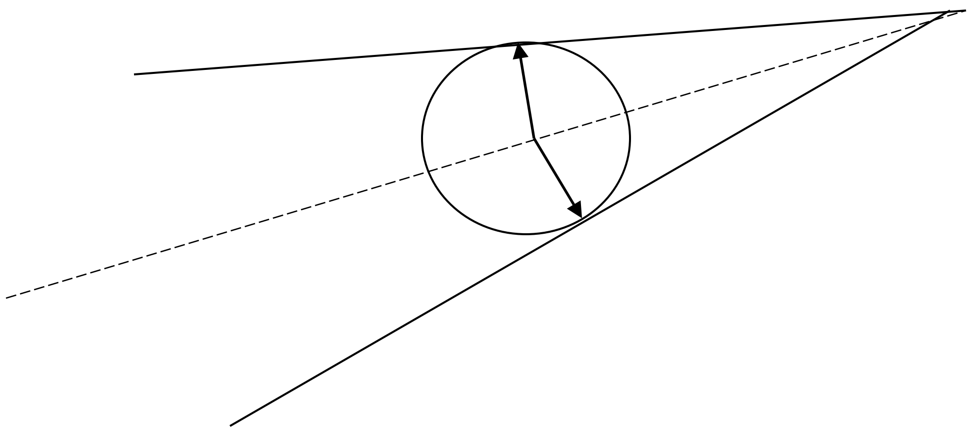


WAKE CLASSIFICATION

- Angle of wake
- Shape of crests; presence of transverse waves
- Width and brightness of lines (important for turbulent wake)

OTHER TECHNIQUES: OCEAN MODELS

- Internal wave wake opening angle



KELVIN TRANSVERSE WAVES

- Ship speed equals phase speed
  - Dispersion relation $\omega^2 = gk$

$$U = c = \omega/\kappa = \sqrt{g\lambda/(2\pi)}$$

PERFORMANCE

- Data from the Canadian Coast Guard
  - Reporting points in Gulf of St. Lawrence

TABLE 1 SHIP PARAMETERS

Name	Type	Length (m)	Service speed (km/hr)	Actual Speed (km/hr)
Canmar Pride	Container Carrier	244	39	41.8±1.5
Hope 1	Bulk Carrier	188	28	20.4±0.7
Turid Knutsen	Chemical Tanker	163	25	18.9±0.7

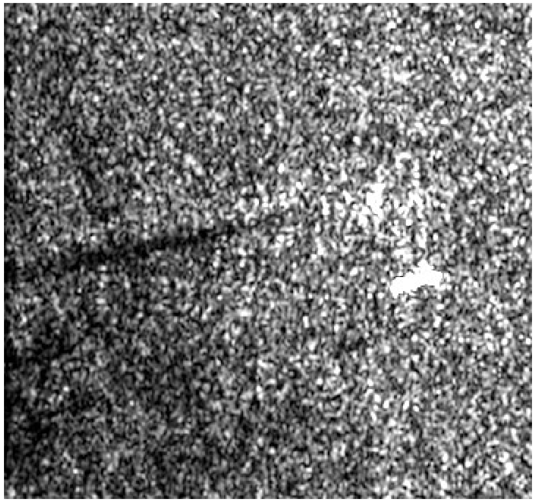
WAKE-DERIVED SPEEDS (TURBULENT)

TABLE 2
IMAGE DERIVED LENGTHS AND SPEEDS

Name	Length (m)	Speed (km/hr)
Canmar Pride	200-260 (244)	36.5-41.7 (41.8)
Hope 1	172-240 (188)	23.2-27.5 (20.4)
Turid Knutsen	200-260 (163)	22.6-28.0 (18.9)

WAKE-DERIVED SPEED (KELVIN)

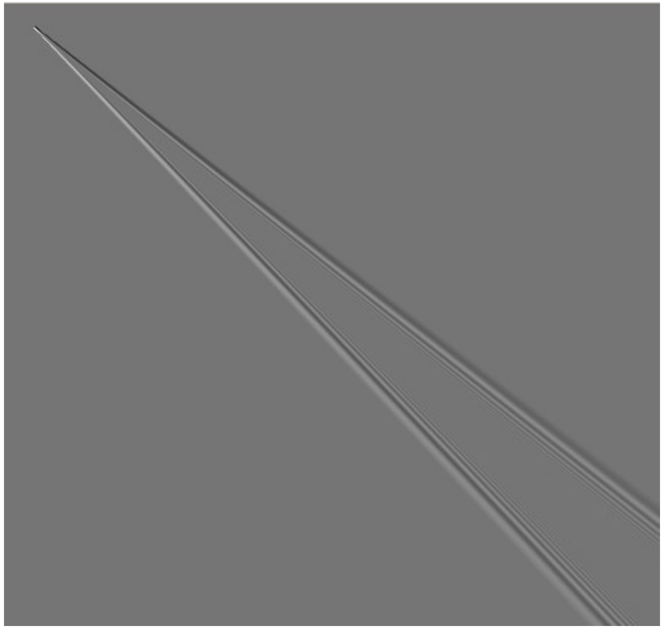
- Canmar Pride speed:
  - Wavelength about 78 m
  - Speed about 40 km/hr (11 m/s, 22 knots)

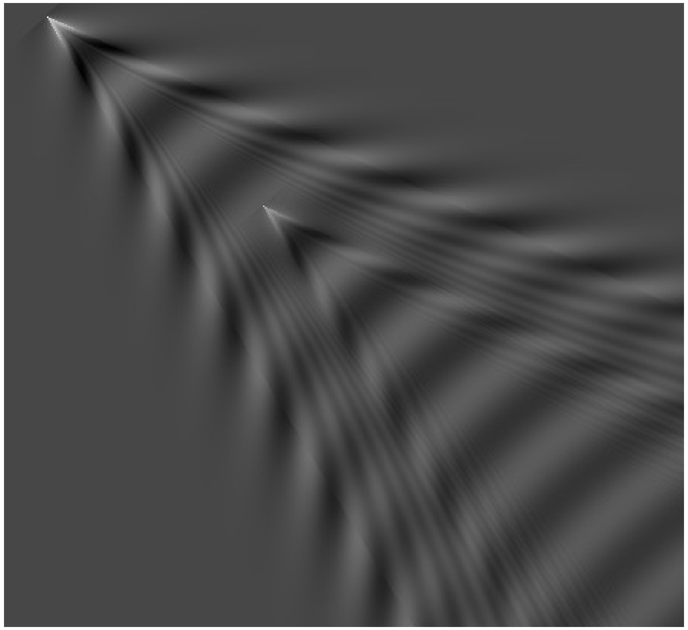


SUPPORTING ACTIVITIES

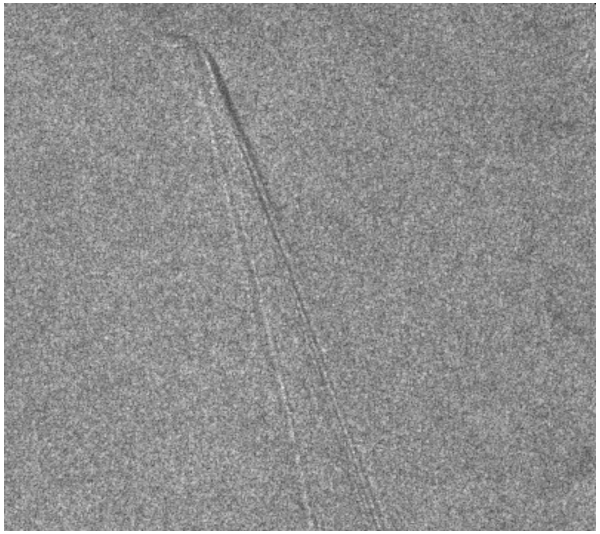
- Wake simulations
  - Kelvin
  - Internal
  - Turbulent
  - Unsteady: ship motion, reflections, propellers
- Breaking wave modeling
  - Ambient sea (short crested)
  - Breaking criteria

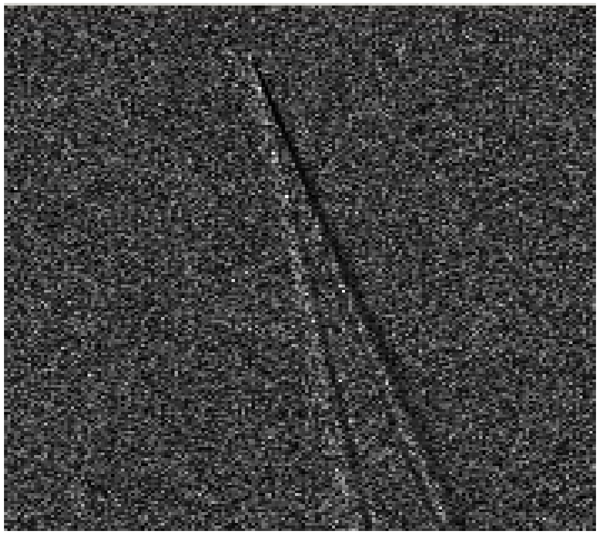
HYDRODYNAMICAL SIMULATIONS





REAL AND SIMULATED RADAR IMAGE

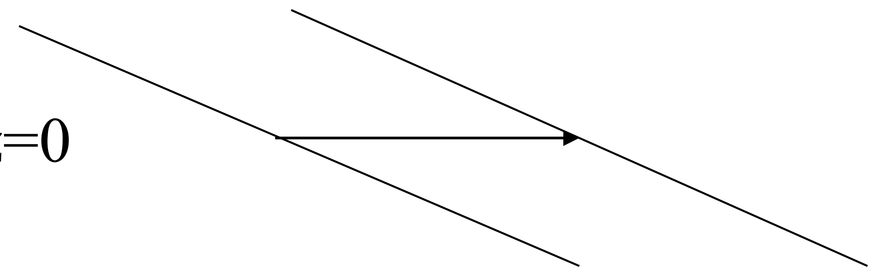




BREAKING WAVE CRITERIA (1)

- Banner and Phillips criterion:

dz=0



$$\frac{dz}{dt} = \frac{\partial z}{\partial t} + \frac{\partial z}{\partial x}\frac{dx}{dt} + \frac{\partial z}{\partial y}\frac{dy}{dt}$$

$$v_z + v_S \cdot \nabla z = 0$$

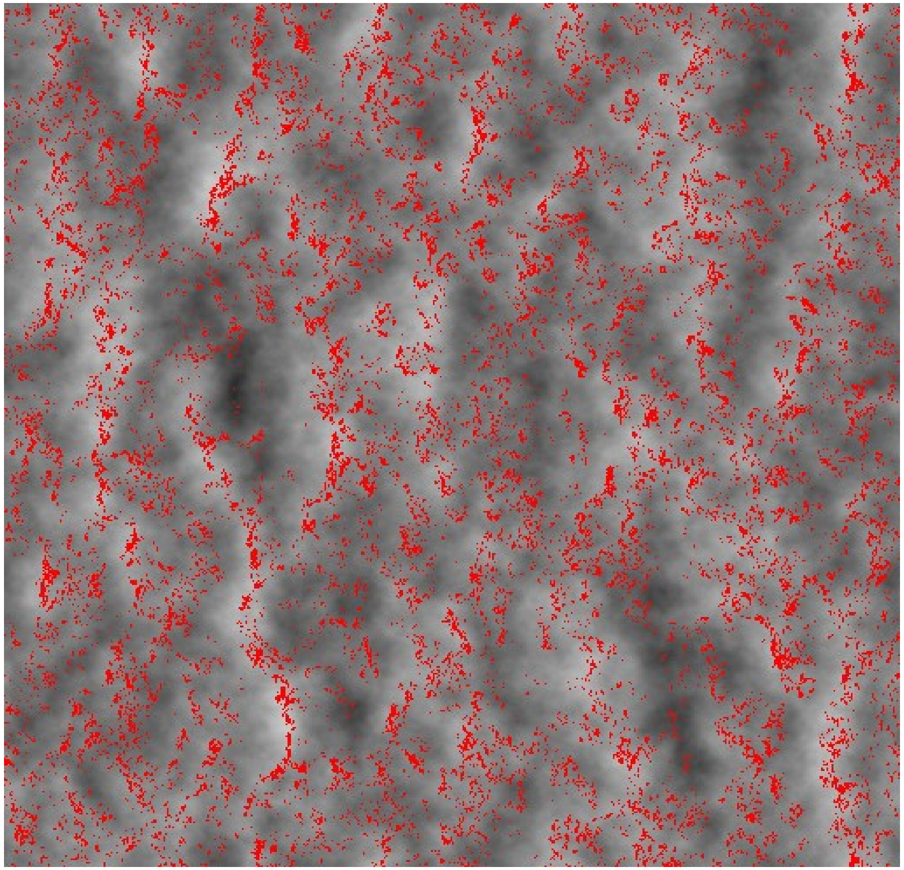
TENTATIVE BREAKING CRITERIA

$$v_z + v_F \cdot \nabla z < 0$$

$$v_S \cdot \nabla z < 0$$

- v_S=fluid surface horizontal velocity
- v_F=fluid particle horizontal velocity
- grad(z)=slope

EXAMPLE OF WAVE FIELD (SS3, V_w=2m/s along x-axis)

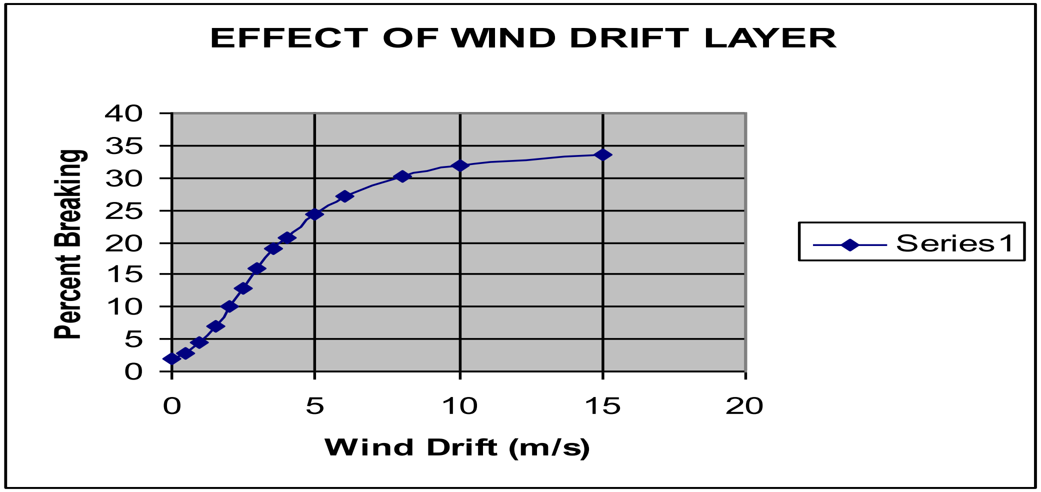


EFFECT OF WIND DRIFT LAYER

- Sea State 3

$$v_{drift} = 0.55u_*$$

$$u_* = \frac{Kv_{wind}}{ln(z / z_0)}$$



DEFENCE R&D DÉFENSE