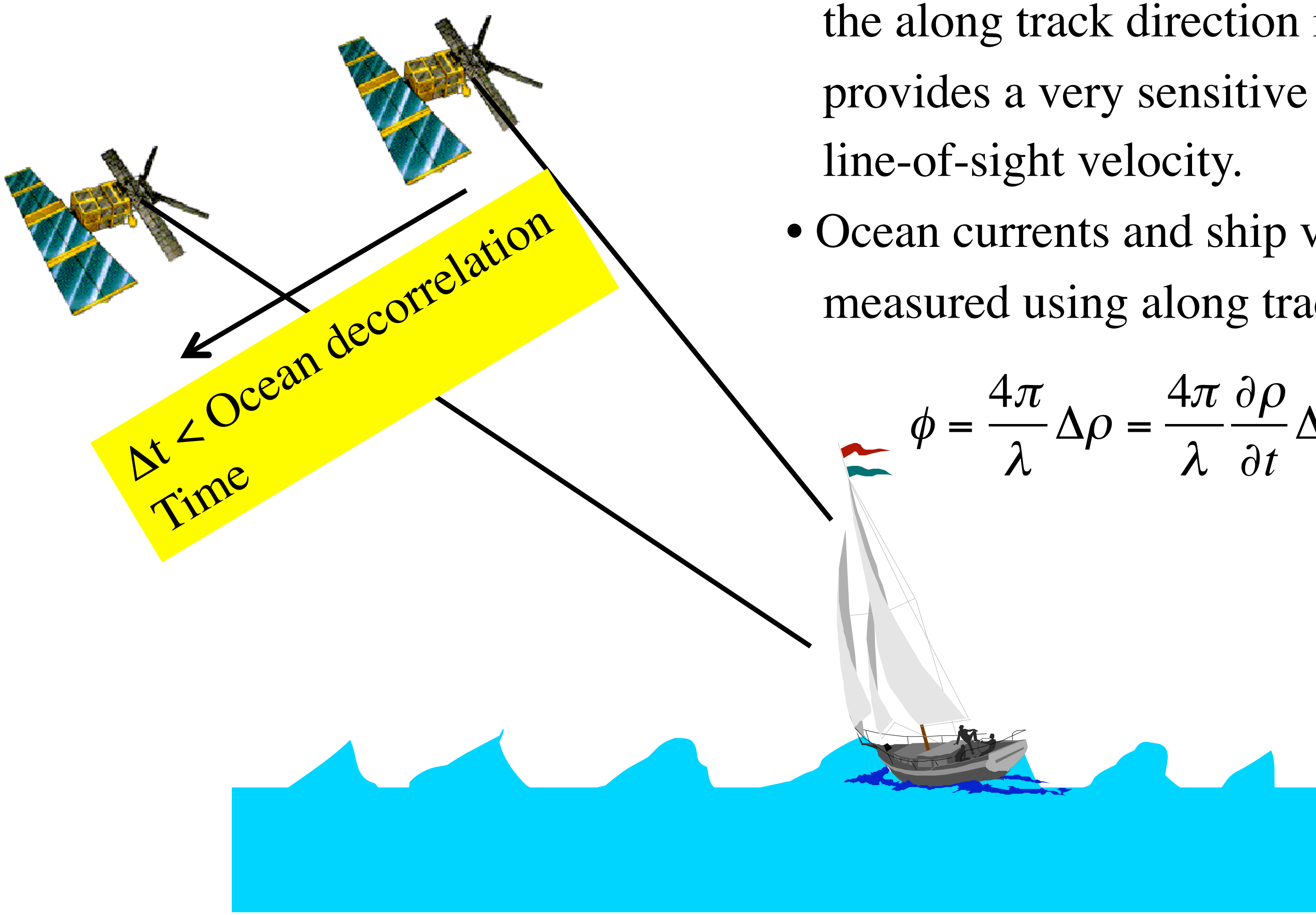
Along Track Interferometry (ATI)

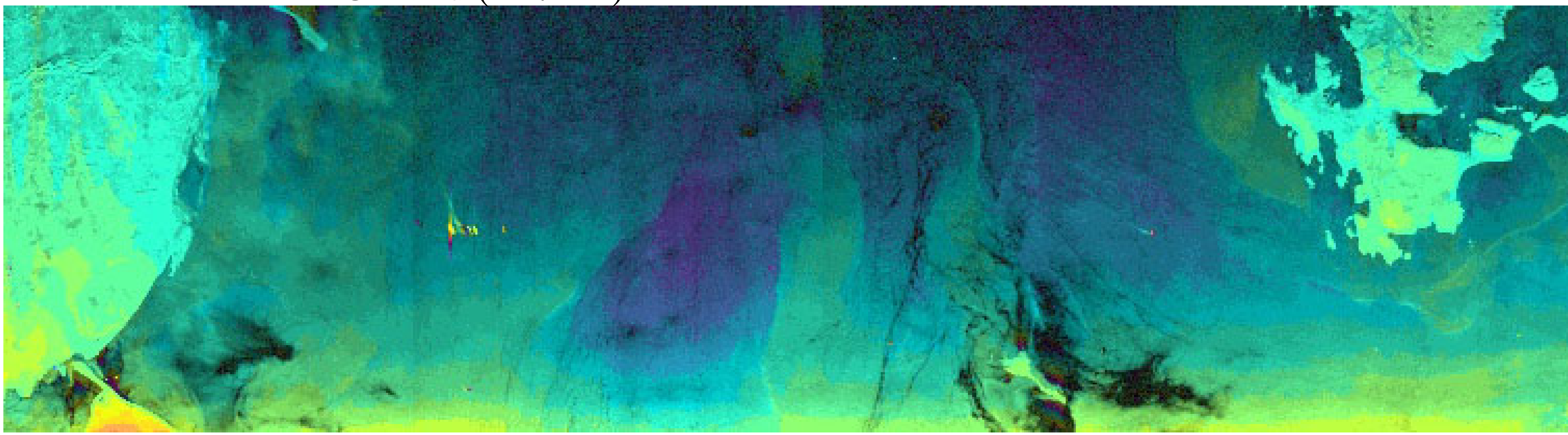


- By having antennas separated in the along track direction interferometry provides a very sensitive measure of the line-of-sight velocity.
- Ocean currents and ship velocities can be measured using along track interferometry.

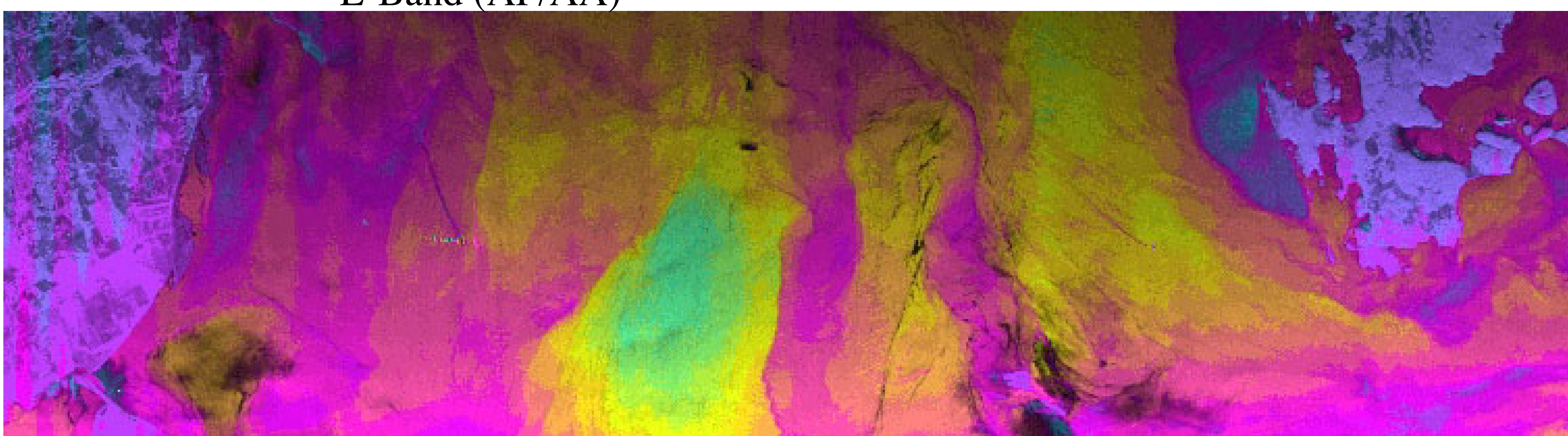
$$\phi = \frac{4\pi}{\lambda}\Delta\rho = \frac{4\pi}{\lambda}\frac{\partial\rho}{\partial t}\Delta t = \frac{4\pi}{\lambda}V_{los}\frac{D}{V_{spc}}$$

ATI Experiment: Straits of Juan de Fuca

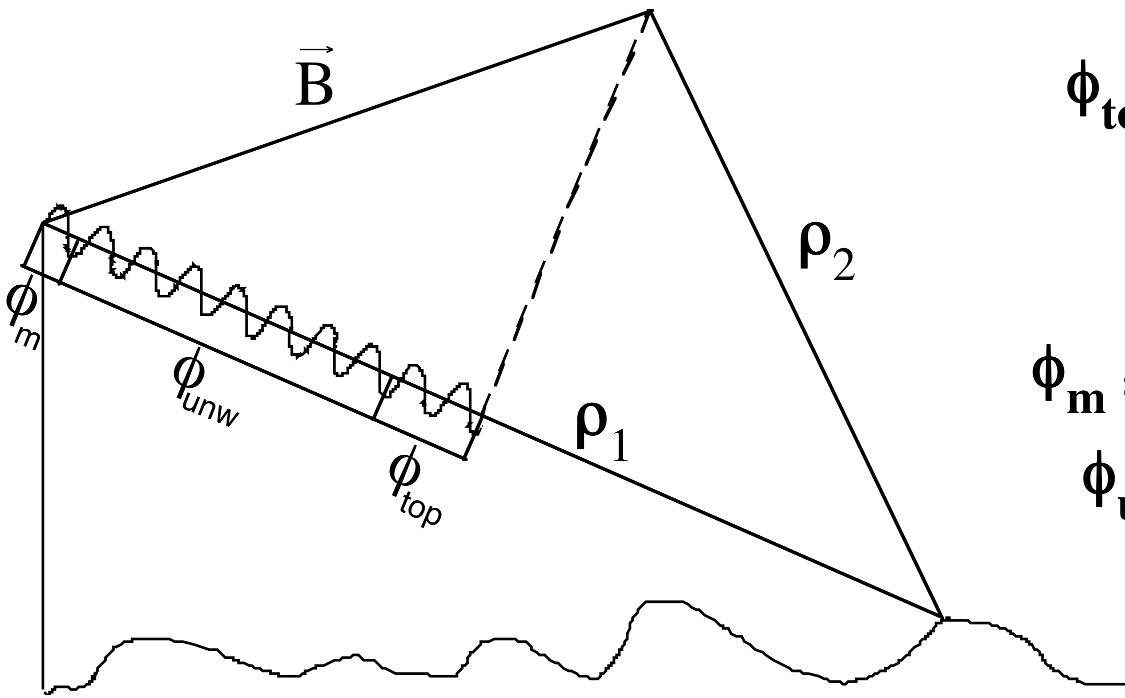
C-Band (AF/AA)



L-Band (AF/AA)



Phase Measurements in Interferometry



$$\phi_{top} = \frac{4\pi}{\lambda}(\rho_1 - \rho_2)$$

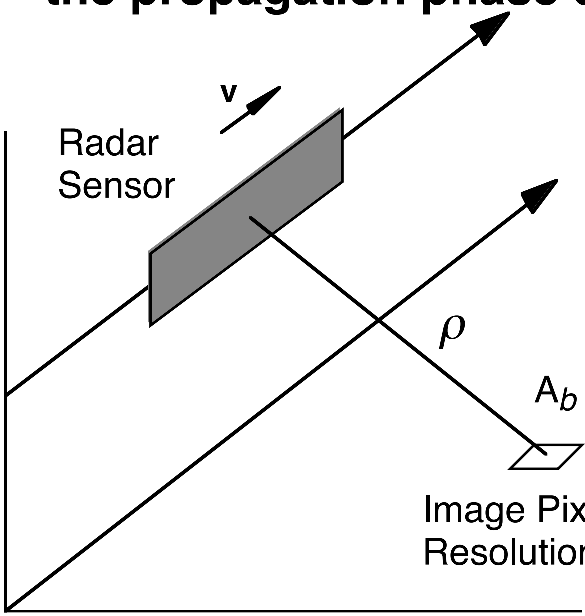
$$\phi_{top} \approx \frac{4\pi}{\lambda}\vec{B}\cdot\vec{L}$$

$$\phi_m = \mathrm{mod}\,(\phi_{top}\;,\;2\pi)$$

$$\phi_{unw} = \phi_{top} + \phi_c$$

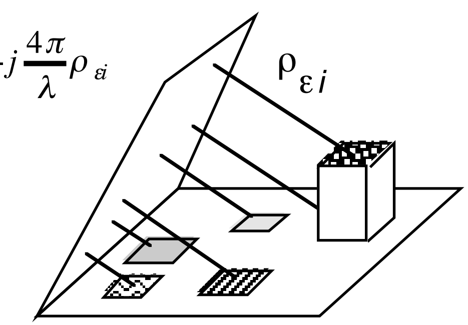
Radar Coherent Backscatter

Pixels in a radar image are a complex phasor representation of the coherent backscatter from the resolution element on the ground and the propagation phase delay



$A_b \, e^{j\phi_b} \longrightarrow \sum_i A_{\varepsilon i} e^{j\phi_{\varepsilon i}} e^{-j\frac{4\pi}{\lambda}\rho_{\varepsilon i}}$

Image Pixel/Resolution Element

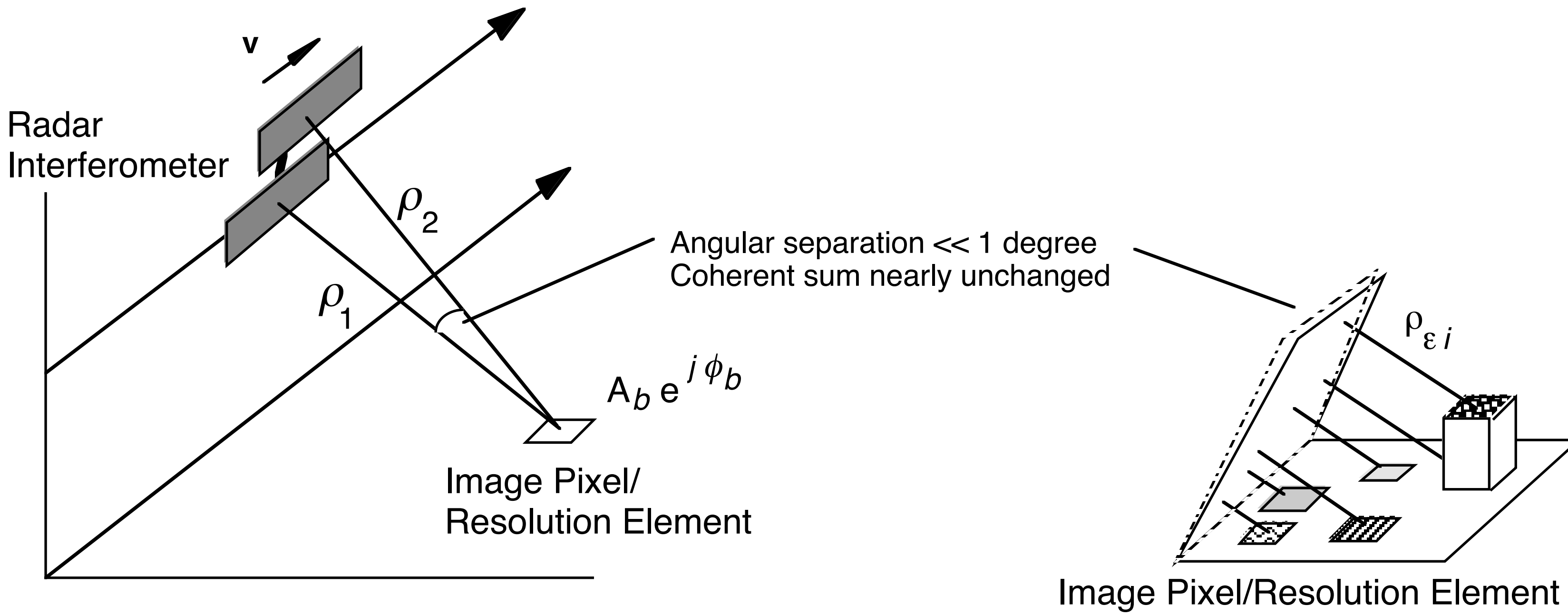


Propagation Phase Delay $\phi = -j\dfrac{4\pi}{\lambda}\rho$

Backscatter phase delay is coherent sum of contributions from all elemental scatterers in the resolution element with backscatter $A_{\varepsilon i} e^{j\phi_{\varepsilon i}}$ and their differential path delays $\rho_{\varepsilon i}$

Interferometric Phase Characteristics

Pixels in two radar images observed from nearby vantage points have nearly the same complex phasor representation of the coherent backscatter from a resolution element on the ground but a different propagation phase delay



$$s_1 = A_b e^{j\phi_b} e^{-j\frac{4\pi}{\lambda}\rho_1} \qquad s_2 = A_b e^{j\phi_b} e^{-j\frac{4\pi}{\lambda}\rho_2}$$

Correlation Theory

SIGNALS DECORRELATE DUE TO

- Thermal and Processor Noise
- Differential Geometric and Volumetric Scattering
- Rotation of Viewing Geometry
- Random Motions Over Time

DECORRELATION OBSERVED AS PHASE STANDARD DEVIATION

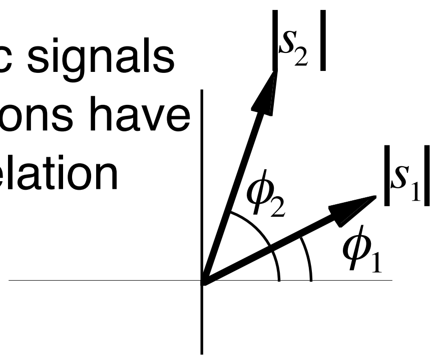
- Affects height and displacement accuracy and ability to unwrap phase
- Can define an effective SNR as thermal SNR degraded by other decorrelation effects

Correlation Definition

For signals s_1 and s_2 observed at interferometer apertures 1 and 2, the correlation γ is given by

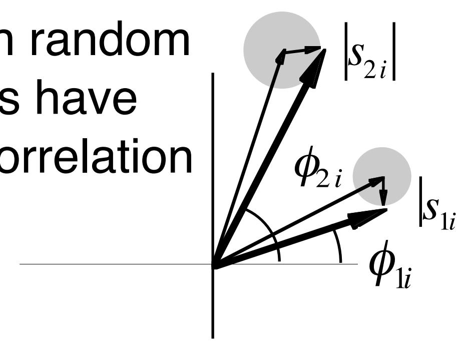
$$\gamma \equiv \frac{\left|\left\langle s_1 s_2^* \right\rangle\right|}{\sqrt{\left\langle s_1 s_1^* \right\rangle \left\langle s_2 s_2^* \right\rangle}}$$

Deterministic signals or combinations have perfect correlation



$$\gamma = \frac{\left| |s_1| e^{i\phi_1} |s_2| e^{-i\phi_2} \right|}{\sqrt{|s_1|^2 |s_2|^2}} = 1$$

Signals with random components have imperfect correlation



$$\gamma = \frac{\left| \left\langle |s_{1i}| e^{i\phi_{1i}} |s_{2i}| e^{-i\phi_{2i}} \right\rangle_i \right|}{\sqrt{\left\langle |s_{1i}|^2 \right\rangle_i \left\langle |s_{2i}|^2 \right\rangle_i}} \neq 1$$

Expectation Estimator

Expectation over the ensemble of realizations s_{1i} and s_{2i} cannot be calculated from a specific realization, that is, the observations s_1 and s_2 . In general, an estimator derived from the image data must be devised.

The maximum likelihood estimator (MLE) of the interferometric *phase difference* between images forming an interferogram that have homo-geneous backscatter and constant phase difference is

$$\hat{\phi} = \arg \sum_{l.m}^{N,M} s_{1l,m} s_{2l,m}{}^{*}$$

where *l* and *m* are image indices relative to some reference location and the sum is computed over a *N* x *M* box. *N* and *M* are known as the number of looks in their respective image dimensions.

Correlation Estimator

The standard estimator of the interferometric correlation between images forming an interferogram that have homogeneous backscatter and constant phase difference is

$$\hat{\gamma} = \frac{\left| \sum_{l.m}^{N,M} s_{1_{l,m}} s_{2_{l,m}}^{*} \right|}{\sqrt{\left| \sum_{l.m}^{N,M} s_{1_{l,m}} s_{1_{l,m}}^{*} \right| \left| \sum_{l.m}^{N,M} s_{2_{l,m}} s_{2_{l,m}}^{*} \right|}}$$

This estimator is biased. As an example, consider *N* = 1, *M* = 1. Then

$$\hat{\gamma} = \frac{\left| s_{1_{x,y}} s_{2_{x,y}}^{*} \right|}{\sqrt{\left| s_{1_{x,y}} s_{1_{x,y}}^{*} \right| \left| s_{2_{x,y}} s_{2_{x,y}}^{*} \right|}} = 1$$

where *x* and *y* are the coordinates of a particular image pixel. Other biases arise when backscatter homogeneity and phase constancy are violated.

Correlation Estimator Characteristics

A general set of curves of reveals the nature of the estimator bias when backscatter is homogeneous and phase is constant.