Surface Fluxes: Challenges for High Latitudes

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Improved estimation of Arctic air-sea CO_2 fluxes from QuikSCAT and shipboard measurements of surface wave slope

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Overview

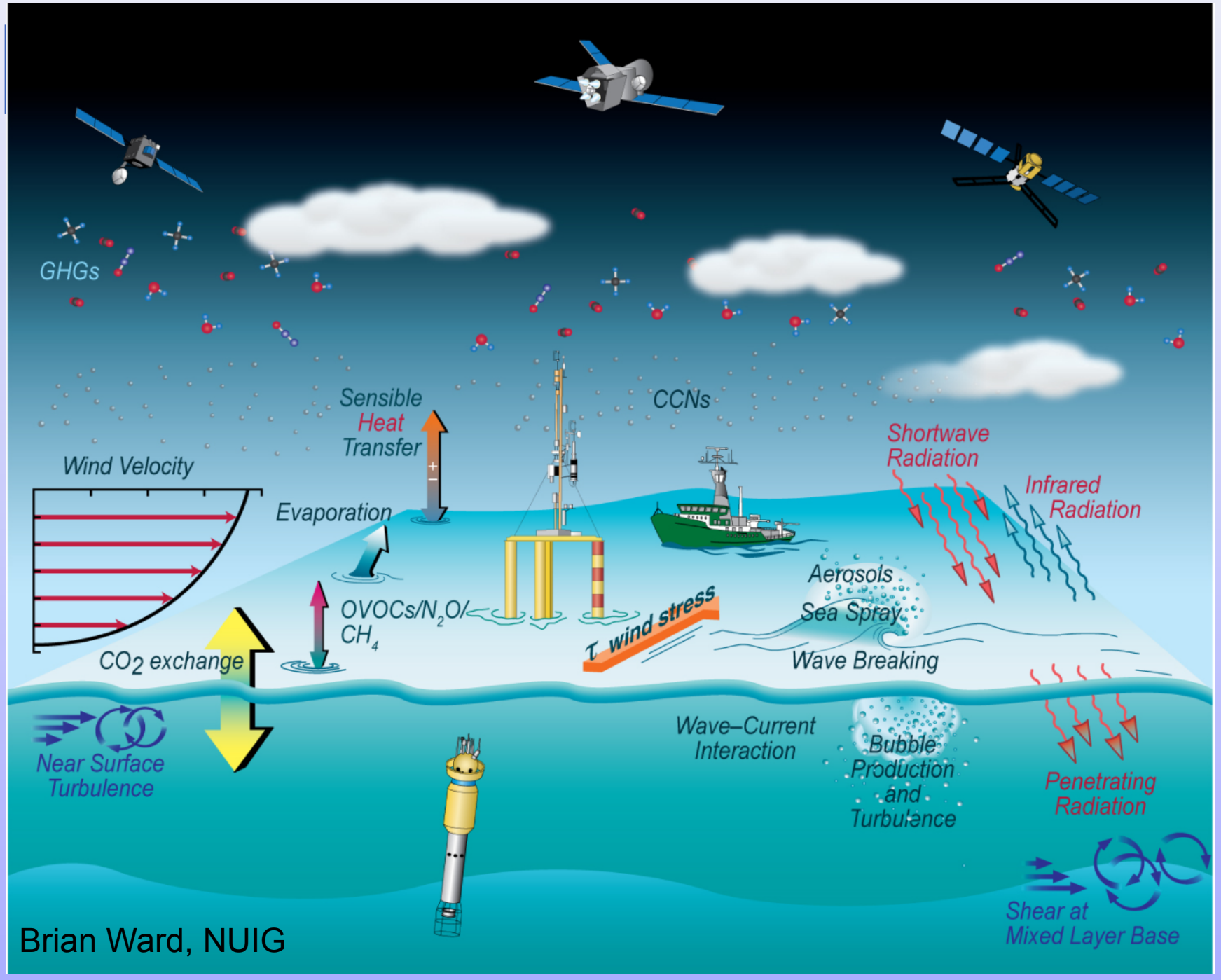
- Motivation
- IPY CFL Study
  - Laser wave slope gauge
  - QuikSCAT
- Mean Square Slope (mss) parameterization of CO_2 gas transfer velocity
- Summary/Remarks

Motivation

$$F = k \cdot \alpha \cdot [(pCO_{2sw}) - (pCO_{2air})]$$

- Conventional parameterizations of gas transfer velocity, k_{660}, (*wind speed, whitecap coverage, physically based models*) contain large uncertainty

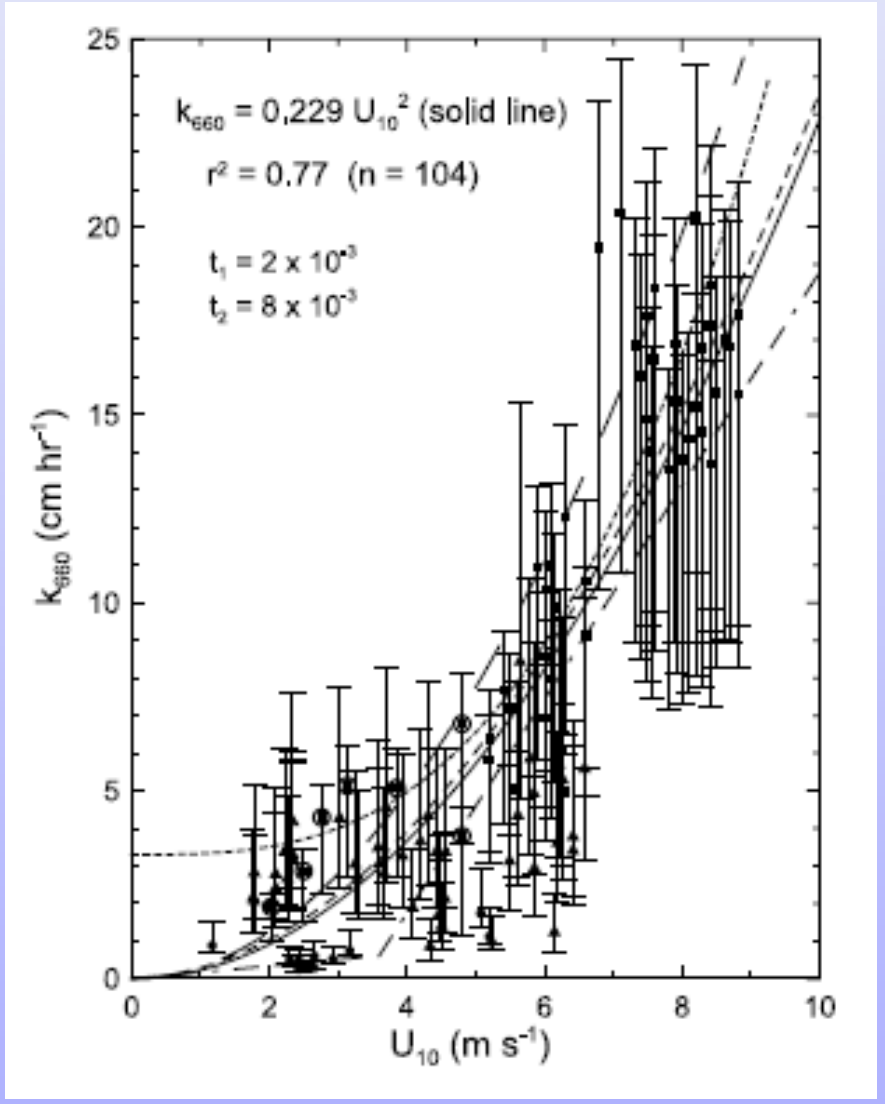
- Turbulence-enhanced gas exchange affected by many factors

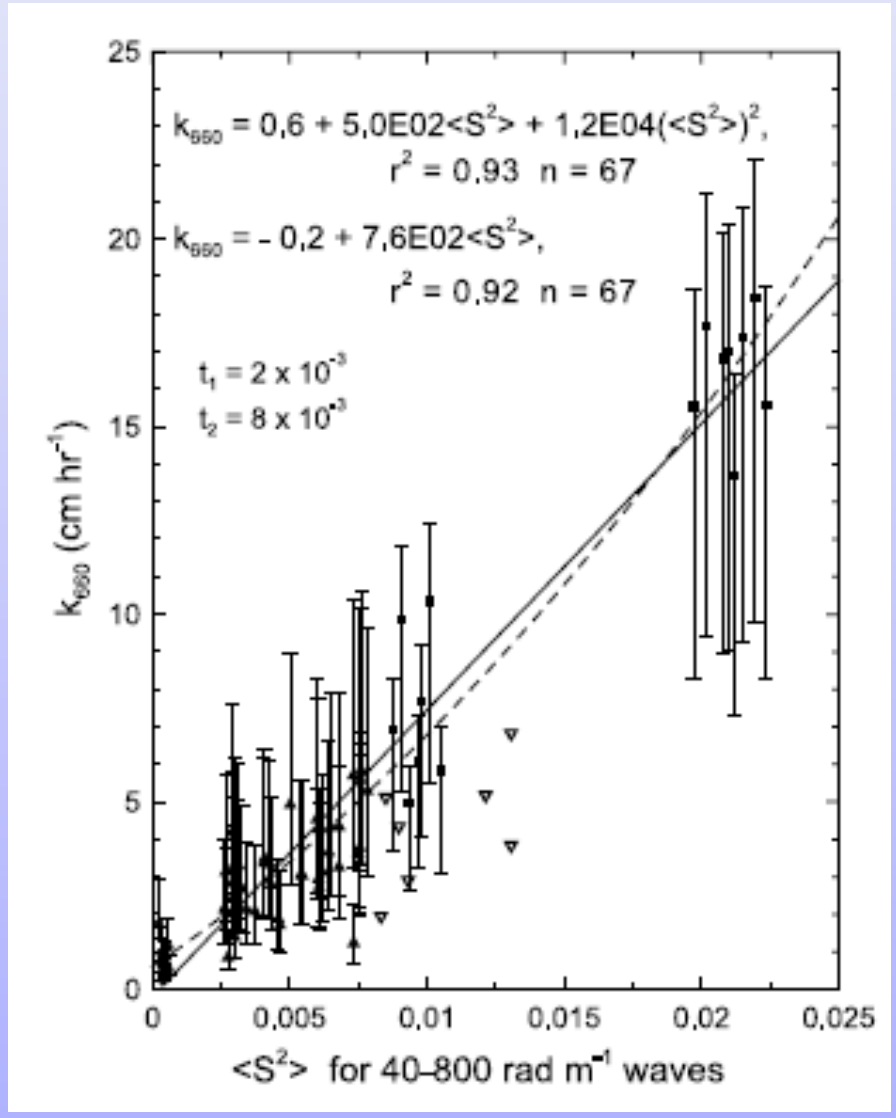

GHGs
Sensible
Heat
Transfer
CCNs
Shortwave
Radiation
Infrared
Radiation
Wind Velocity
Evaporation
Aerosols
Sea Spray
OVOCs/N_2O/
CH_4
τ wind stress
CO_2 exchange
Wave Breaking
Near Surface
Turbulence
Wave–Current
Interaction
Bubble
Production
and
Turbulence
Penetrating
Radiation
Shear at
Mixed Layer Base
Brian Ward, NUIG

Motivation

- How do we improve parameterization of CO_2 flux estimates?
  - Turbulence-enhanced gas exchange affected by many factors (*wind stress, wave-age, wave and current interactions, surface films*) => surface roughness
  - Correlation between gas transfer velocity and mean square slope stronger than correlation between gas transfer velocity and wind speed (Frew et al. 2004)

Motivation – Improved Parameterization



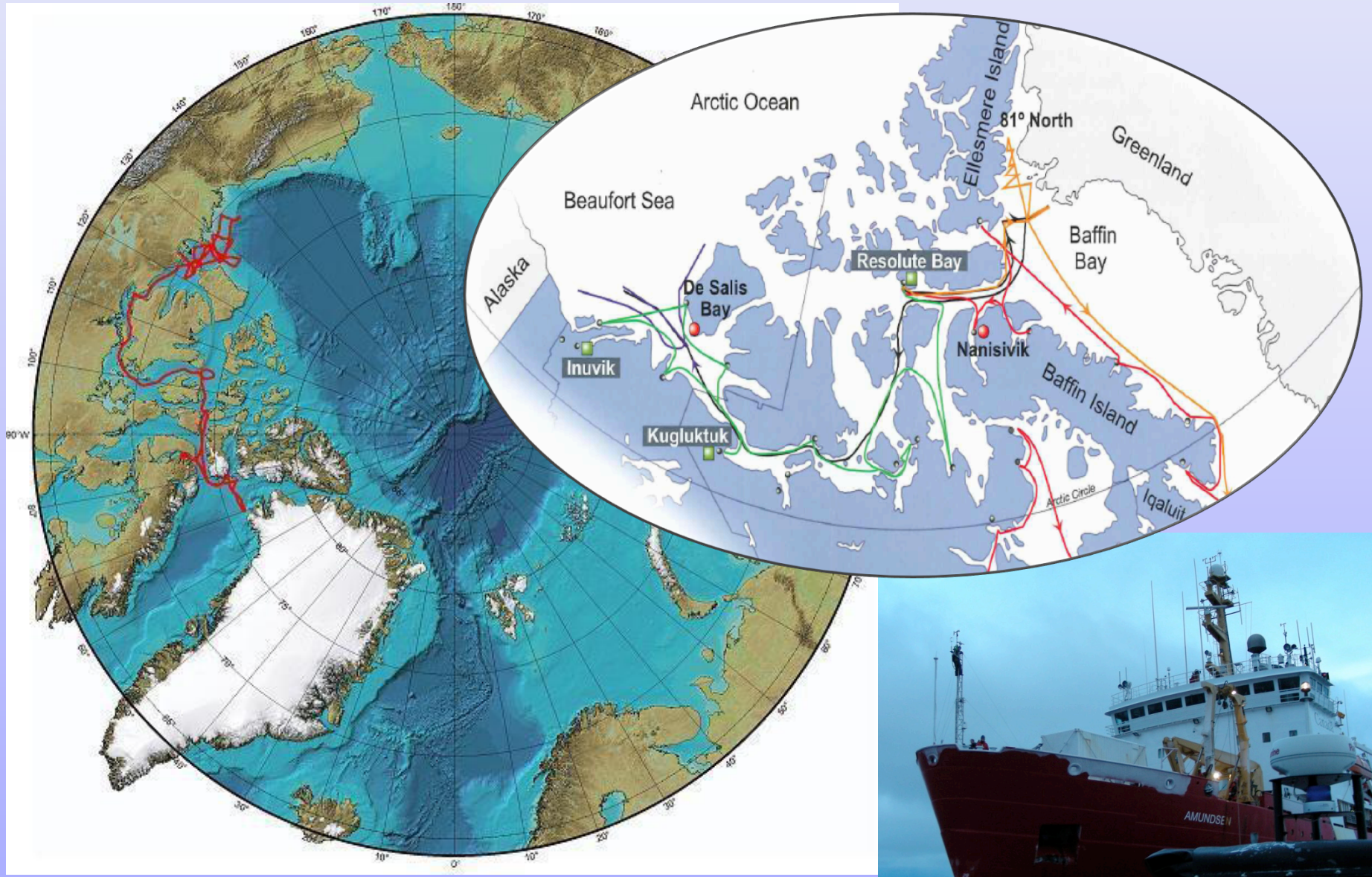


Frew et al. 2004

Motivation

- How do we improve parameterization of CO_2 flux estimates?
  - Wave slope parameterization of gas transfer velocity (Frew et al. 2004)
- Remotely sensed parameters (wind speed, surface roughness)
  - Coverage – temporal and spatial
  - Limited concurrent measurements of relationship, both in laboratory and field, high latitude validation

IPY 2007-2008 CFL System Study

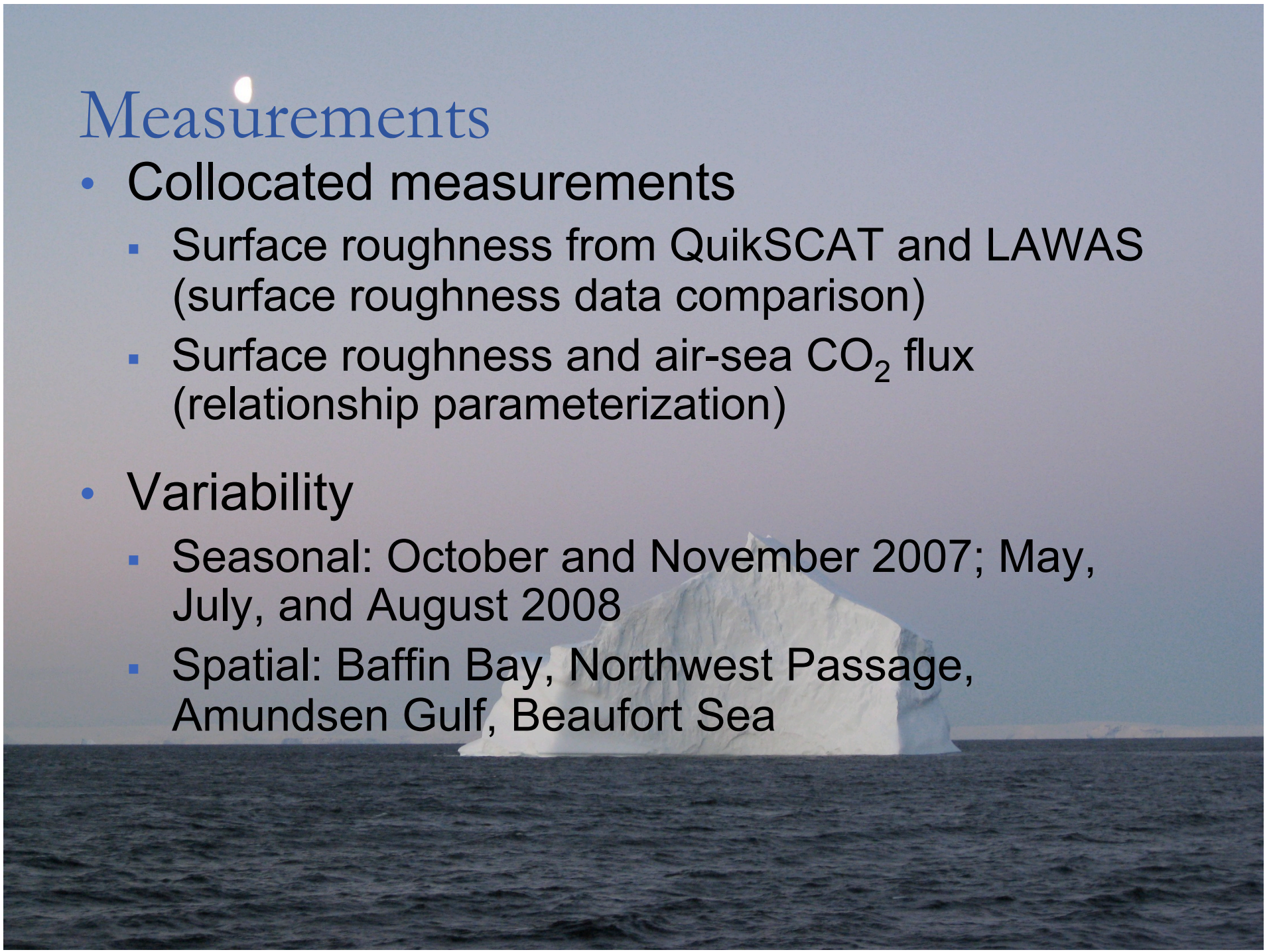


IPY 2007-2008 CFL System

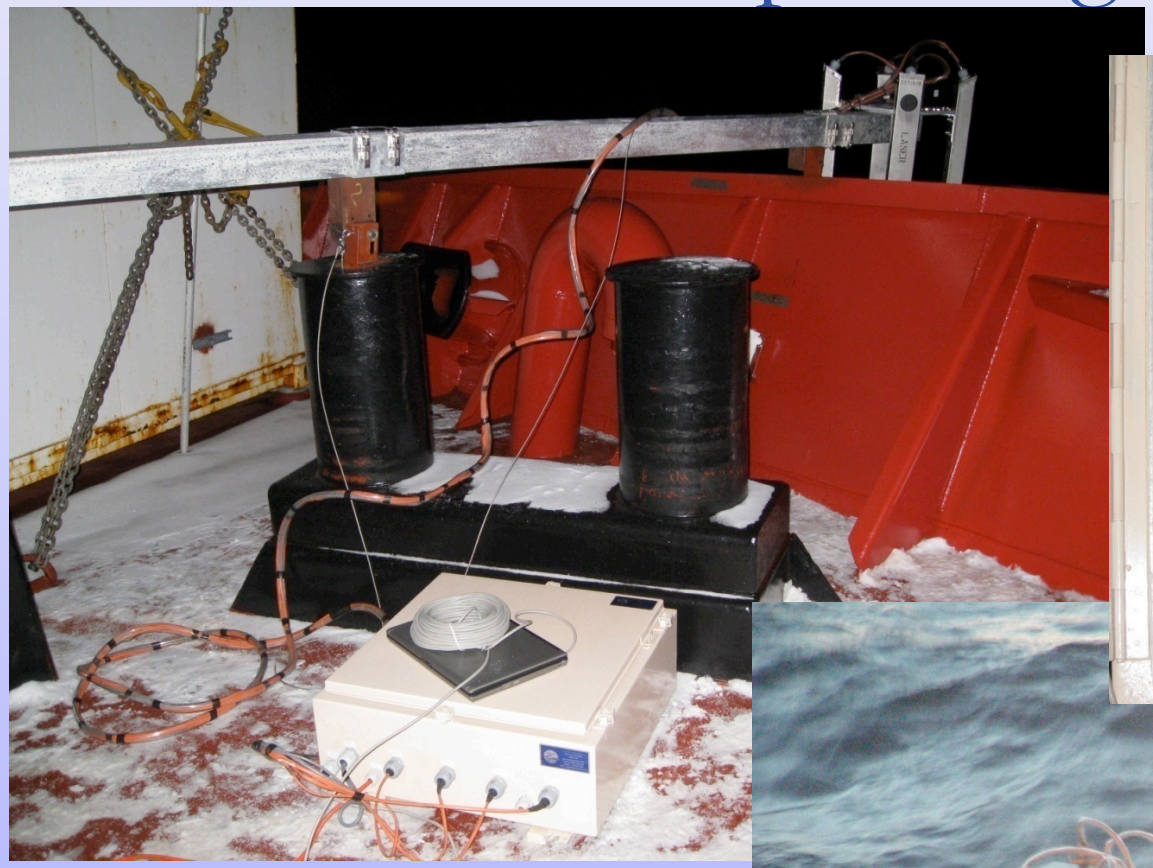
- Instrumentation
  - Flux tower
  - CO_2 sampling system
  - LAser WAve Slope gauge (LAWAS)

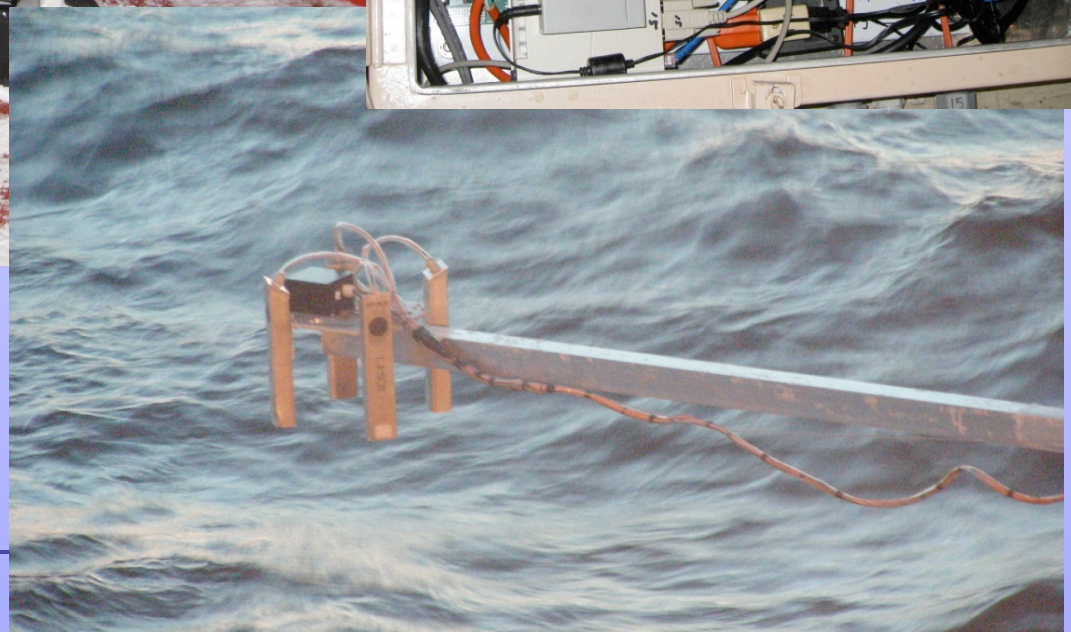
Measurements

- Collocated measurements
  - Surface roughness from QuikSCAT and LAWAS (surface roughness data comparison)
  - Surface roughness and air-sea CO_2 flux (relationship parameterization)
- Variability
  - Seasonal: October and November 2007; May, July, and August 2008
  - Spatial: Baffin Bay, Northwest Passage, Amundsen Gulf, Beaufort Sea



Laser Wave Slope Gauge (LAWAS)

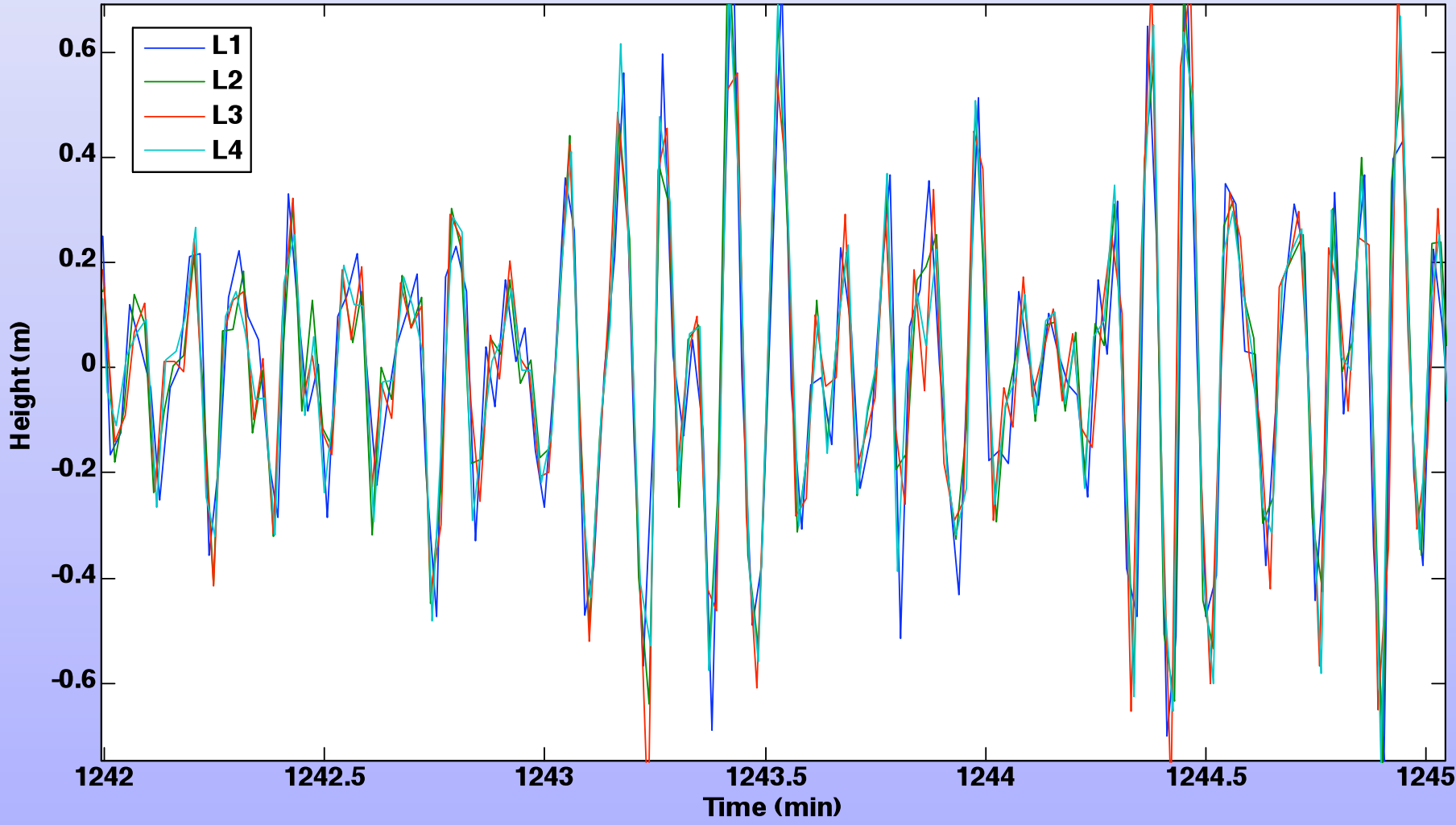




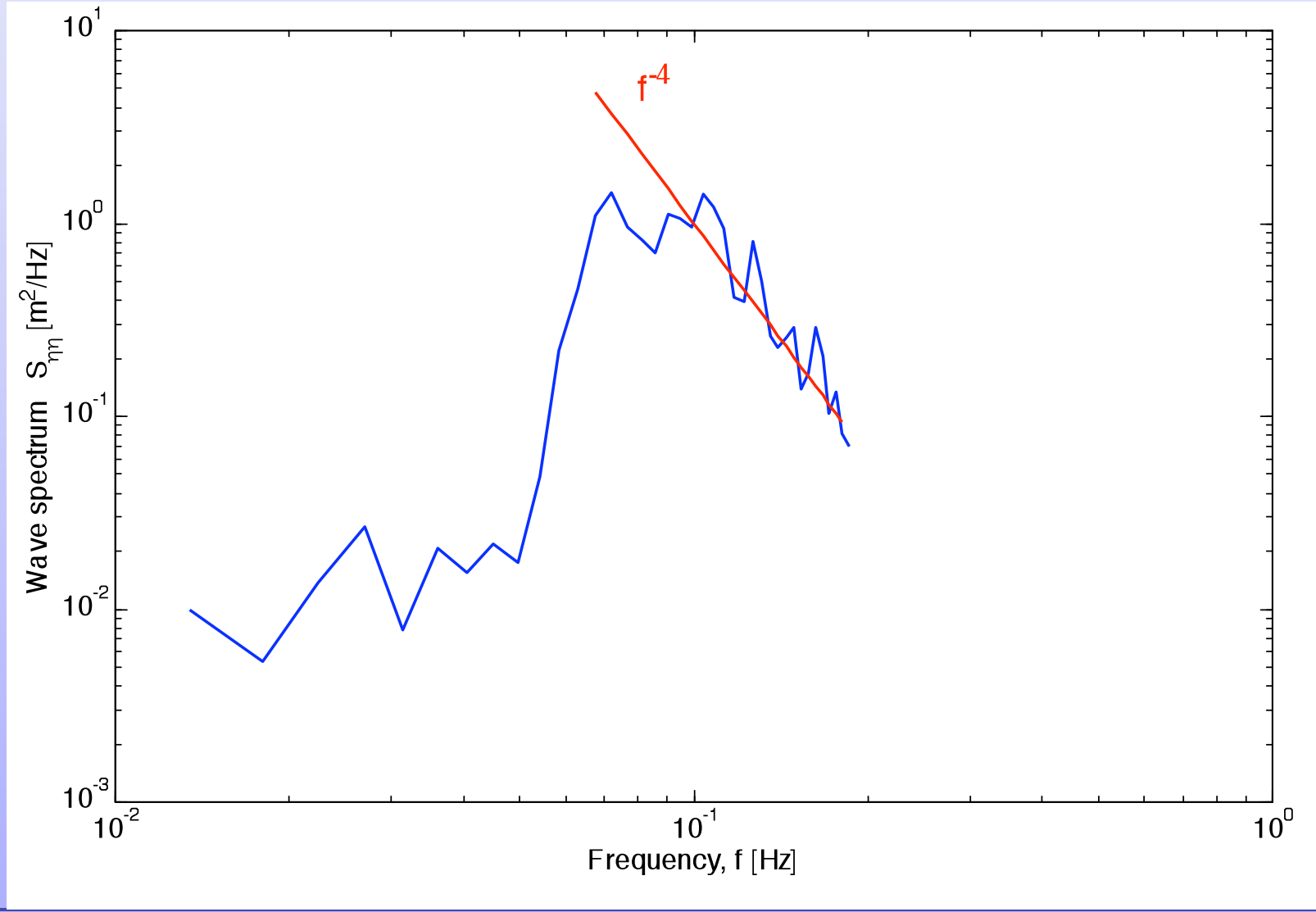
- Mean square surface slope (mss):

$$\left\langle s^2 \right\rangle = \int_0^\infty S(\kappa)\kappa d\kappa$$

LAWAS Time Series

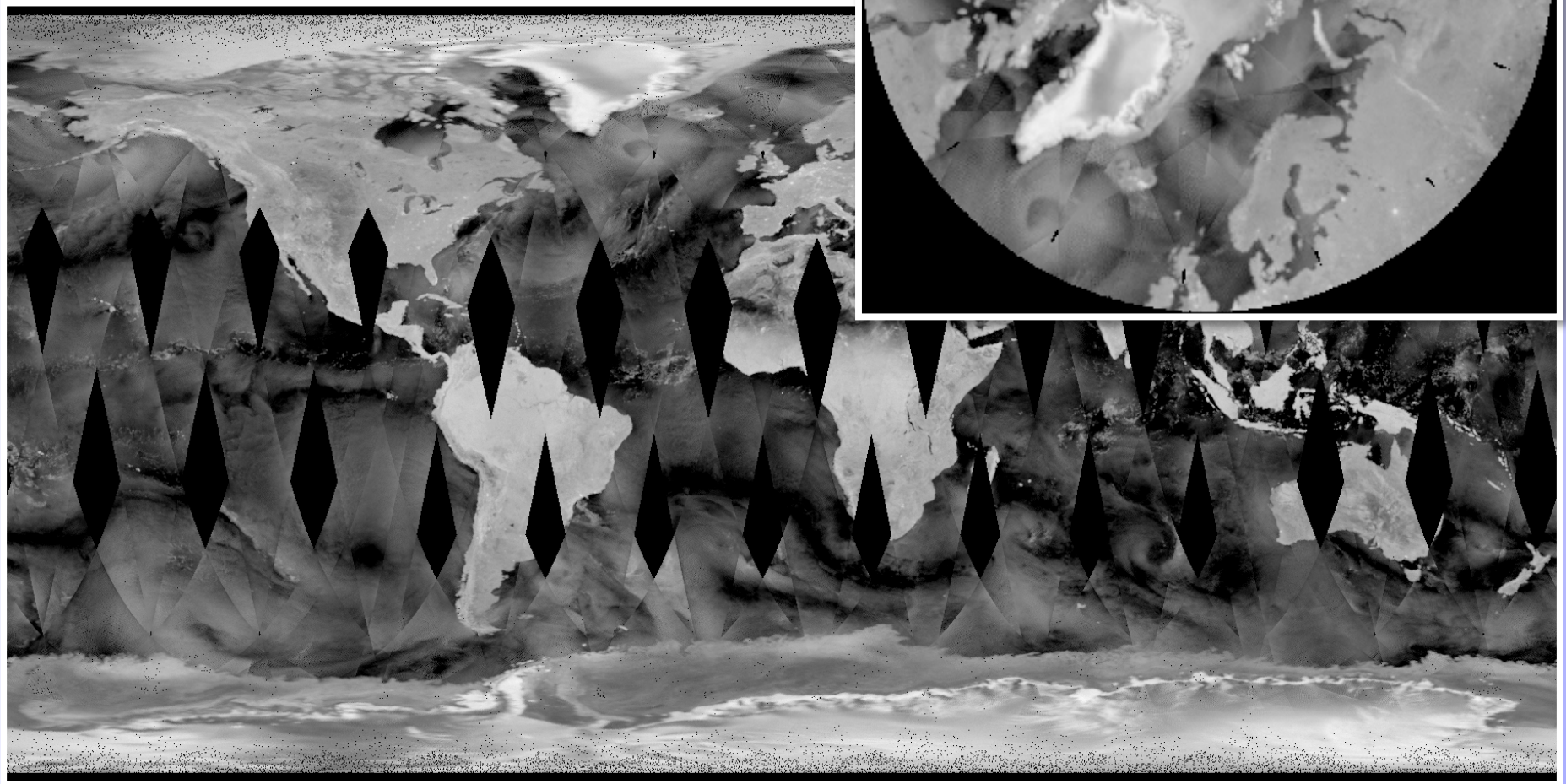


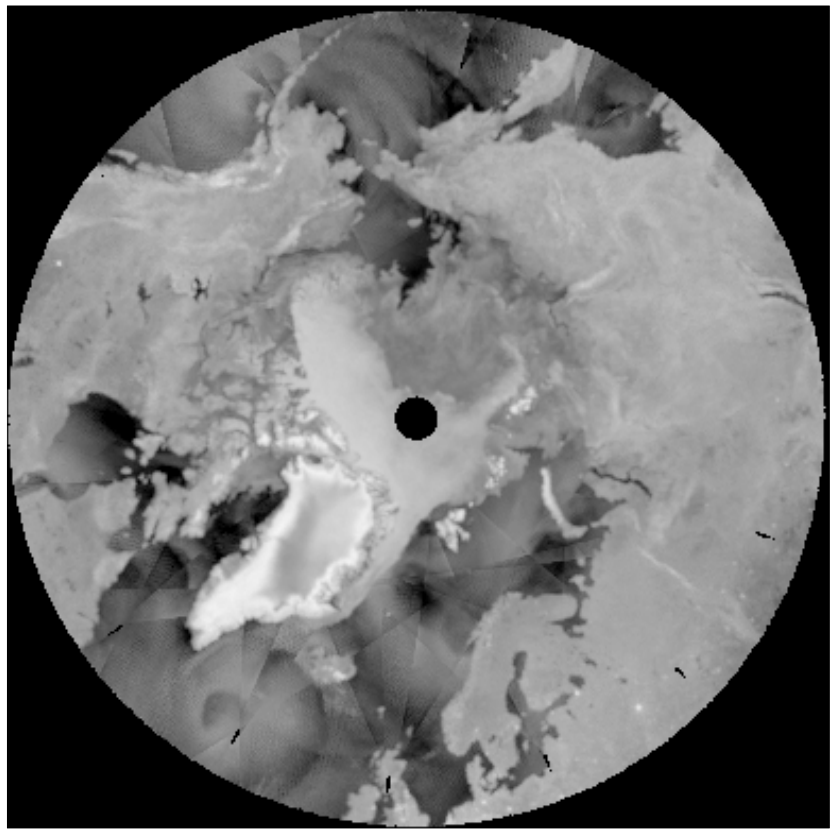
LAWAS Wave Spectrum



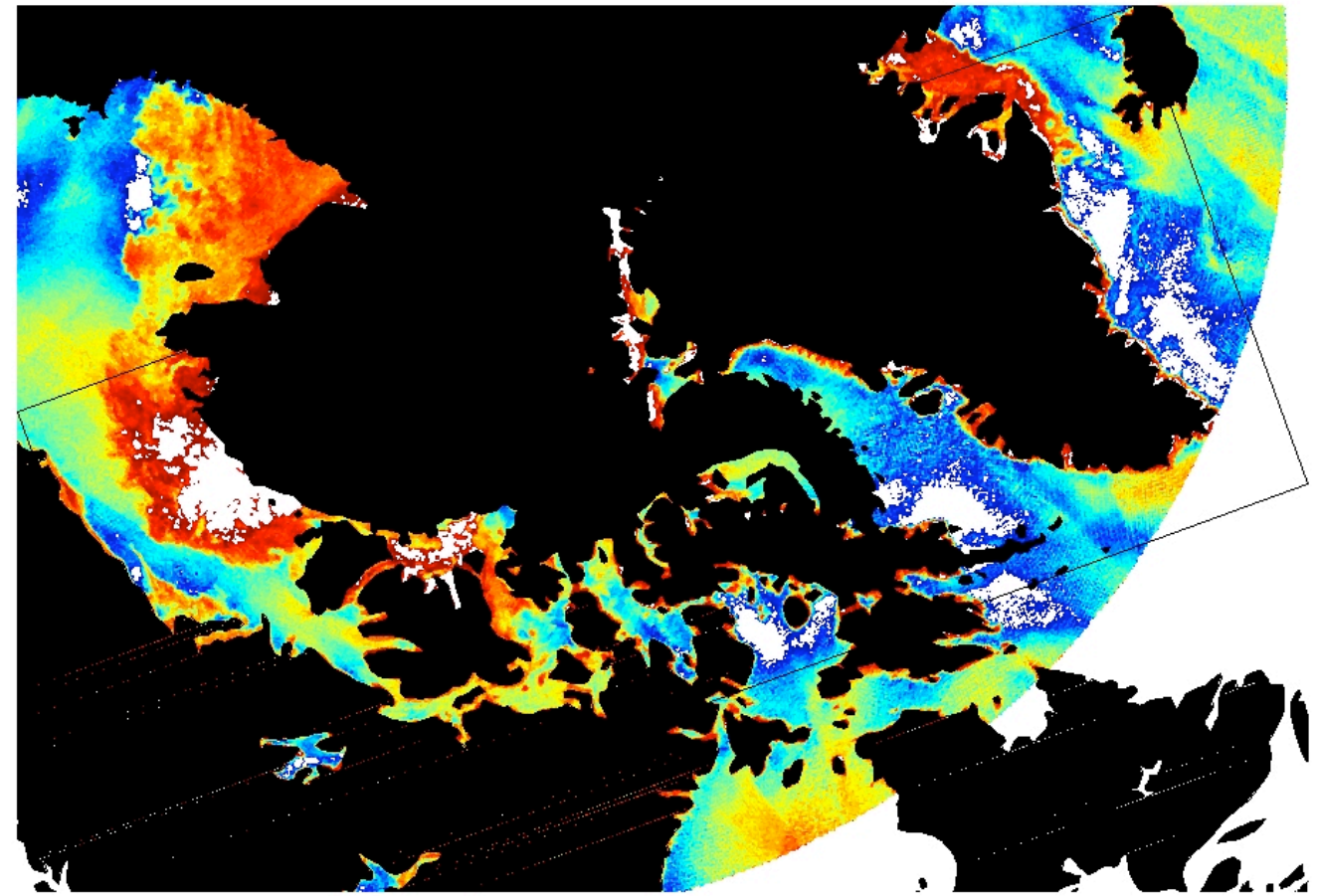
QuikSCAT

- Ku-band radar (13.46 GHz)
- 90% daily global coverage
- h- and v- pol





QuikSCAT σ_0

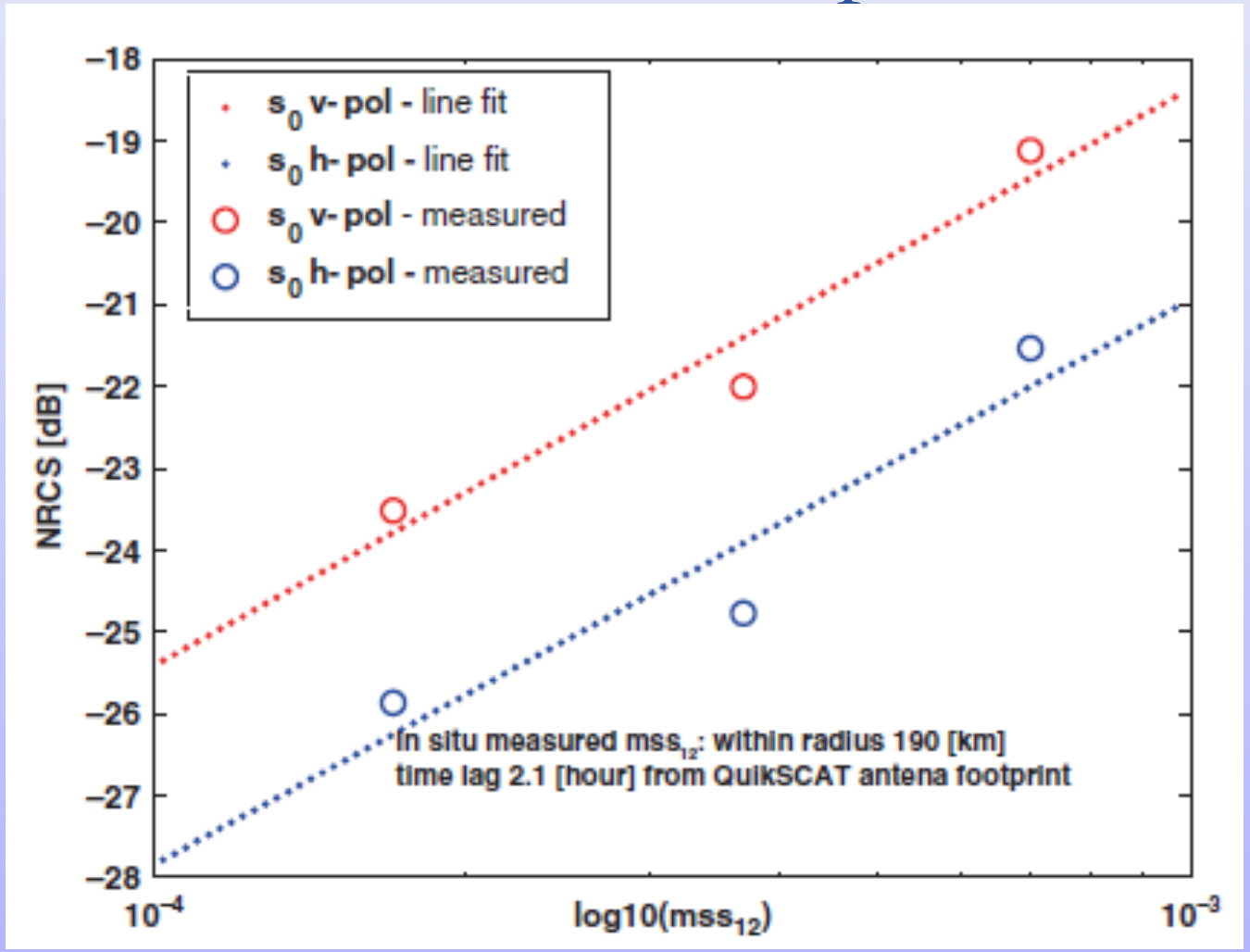


H-pol, high-res L1B data with nominal 2.225 km, available from Long, BYU

Gas transfer velocity from QuikSCAT

- Conventional remote sensing gas transfer estimates:
  - NRCS (σ_0) => wind speed => gas transfer velocity
- Bogucki et al. 2010:
  - NRCS => mss => gas transfer velocity, k_{660}
  - GasEx2001
    - Small set of collocated data points in tropical Pacific:
      - Gas transfer - ASIS
      - mss (laser slope gauge)
      - NRCS - QuikSCAT

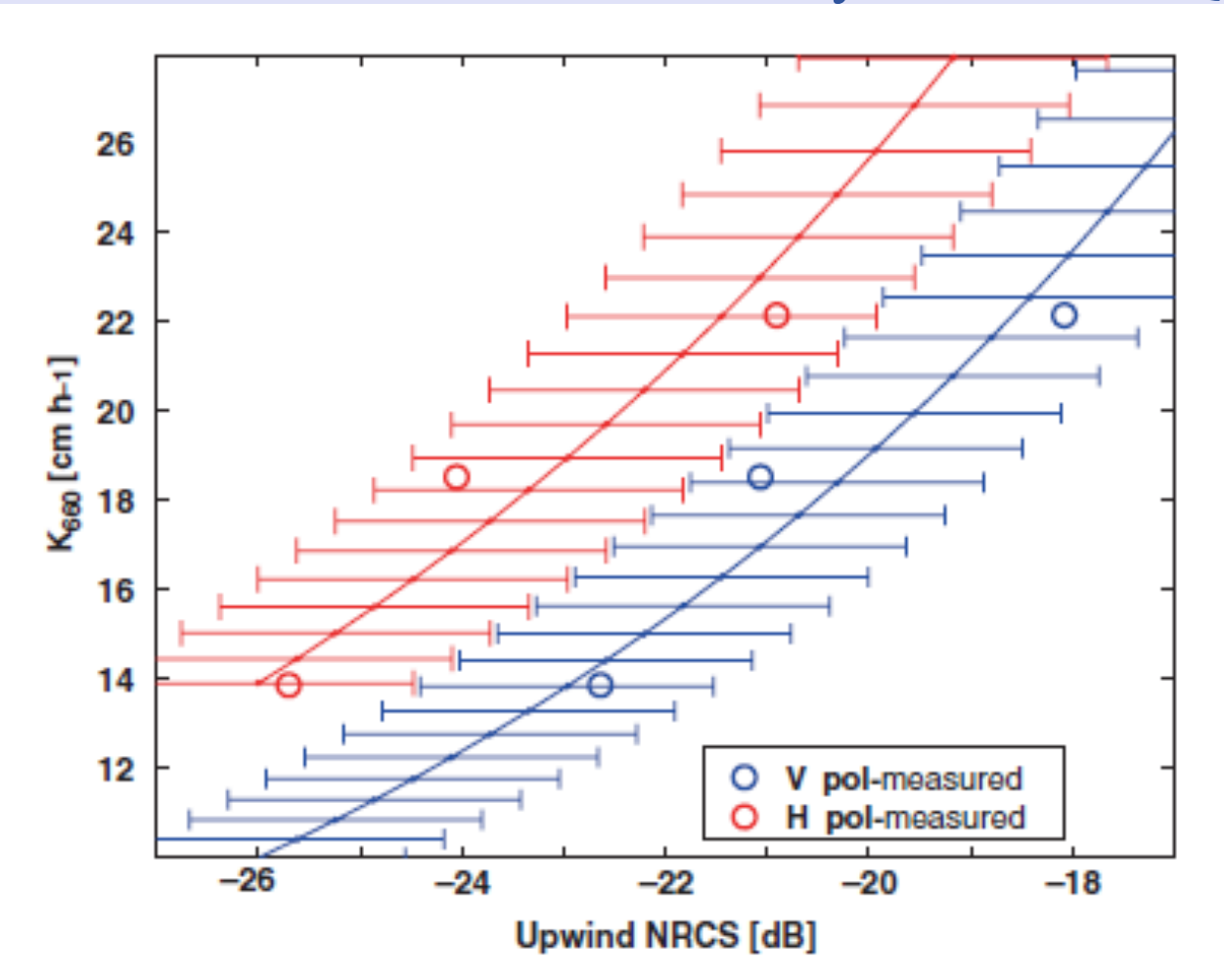
QuikSCAT NRCS vs. shipboard mss



$$\log\left(NRCS(\theta_o)\right) = A\log\left(mss\right) + B(\theta_o)$$

- *A, B* are polarization dependent constants Bogucki et al. 2010

Gas transfer velocity from QuikSCAT

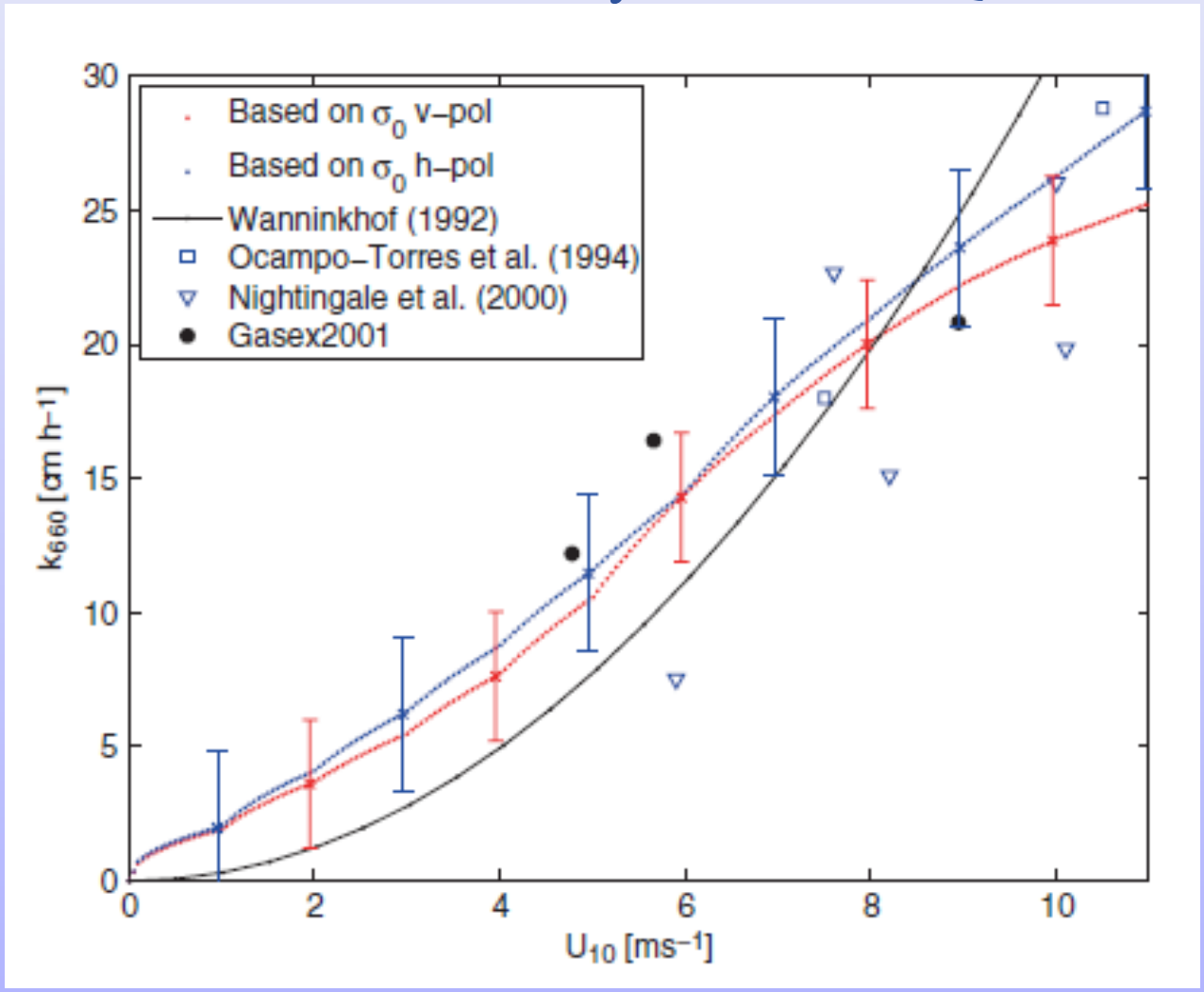


$$\log(k_{660}) = C(\theta_o)\log(NRCS(\theta_o)) + D(\theta_o)$$

- *C*, *D* are polarization dependent constants

Bogucki et al. 2010

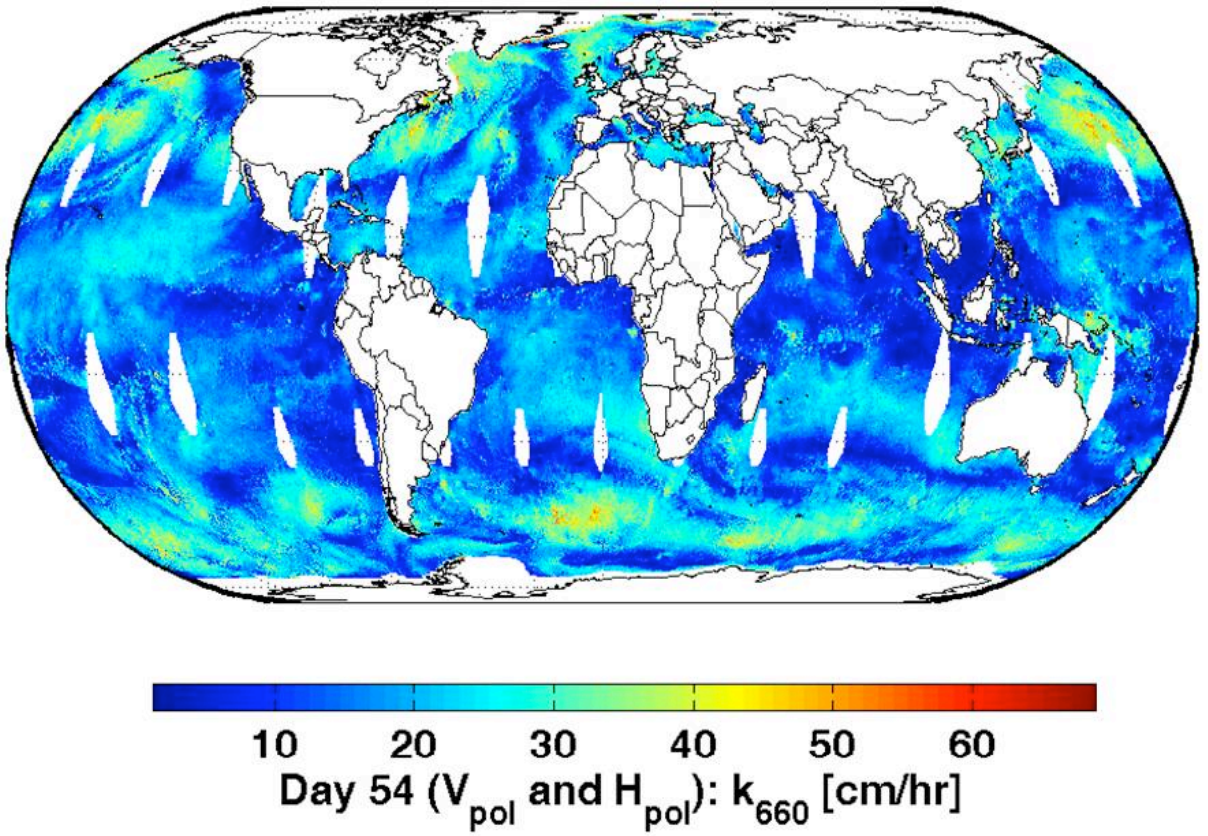
Gas transfer velocity from QuikSCAT



- k_{660} vs roughness, converted to u for comparison with classic approach

Bogucki et al. 2010

QuikSCAT global distribution of k_{660}



The global distribution of CO_2 transfer velocity obtained from QuikSCAT data for day 54 of 2001 using the matchup derived in the GasEx 2001 region. (based on *Bogucki et. al. 2010*)

Summary and Future Directions

- Conventional parameterizations of gas transfer velocity, k_{660}, are associated with large uncertainties
- k_{660} has been shown to correlate well with mean square slope
- Parameterization of k_{660} with surface roughness holds potential for reducing uncertainties in gas transfer estimates
- Additional collocated measurements of NRCS, mss, and air-sea CO_2 fluxes (including spatial and temporal variation) are needed to test and improve parameterization
  - QuikSCAT, SASS, NSCAT, ERS-1, ERS-2, ADEOS-II/Midori2

- D. Bogucki, M.-E. Carr, W. Drennan, P. Woiceshyn, M. Schmeltz, and T. Hara, Preliminary and novel estimates of CO2 gas transfer using satellite scatterometer during the 2001GasEx experiment, *International Journal of Remote Sensing*, 31, 1, 10 January, 75-92, 2010.

- N. Frew, E. Bock, U. Schimpf, T. Hara, H. HauBecker, J. Edson, W. McGillis, R. Nelson, S. McKenna, B. Uz, B. Jahne, Air-sea gas transfer: Its dependence on wind stress, small-scale roughness, and surface films, *Journal of Geophysical Research*, 109, C08S17, 2004.