QuikSCAT Calibration and Assessment of Impacts of Spatial and Temporal Variability in Surface Winds

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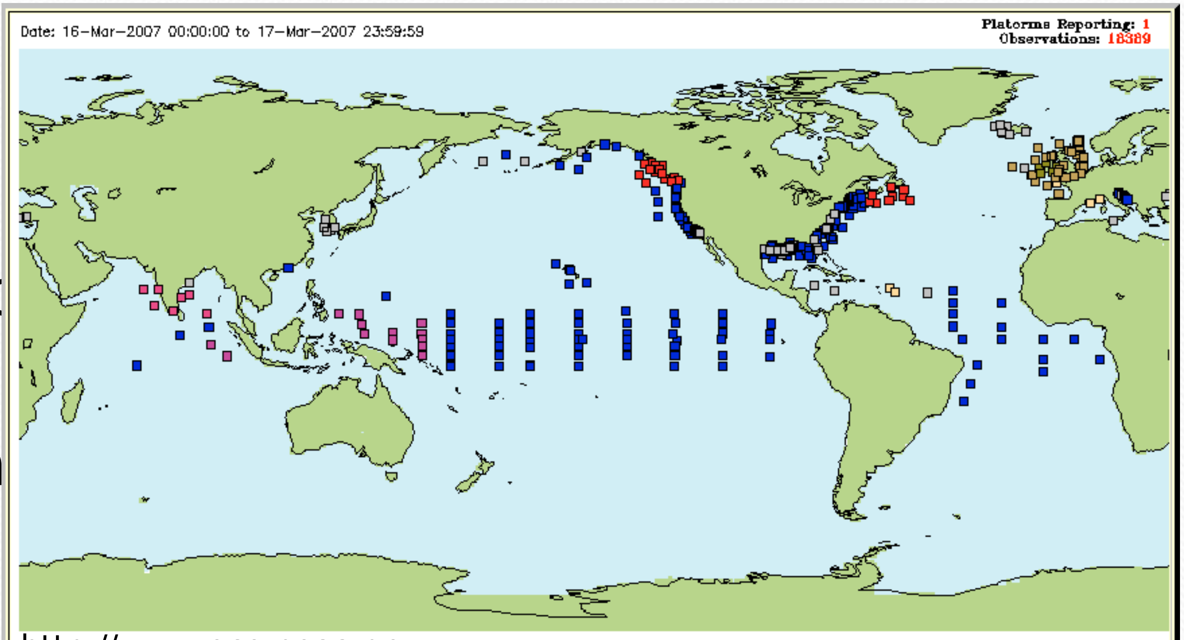
Background/Motivation

- In situ observations (ships and buoys) are used to validate satellite observations
- Problems with comparing data
  - Sparseness of data
  - Large sampling interval of buoy data
  - Spatial coverage of satellite



http://www.oco.noaa.gov

Background/Motivation

- Observations within a certain time and space range to the satellite are used (Ebuchi et al., 2002; Bourassa et al., 2003)
- Total variance when comparing data is a combination of the variance associated with

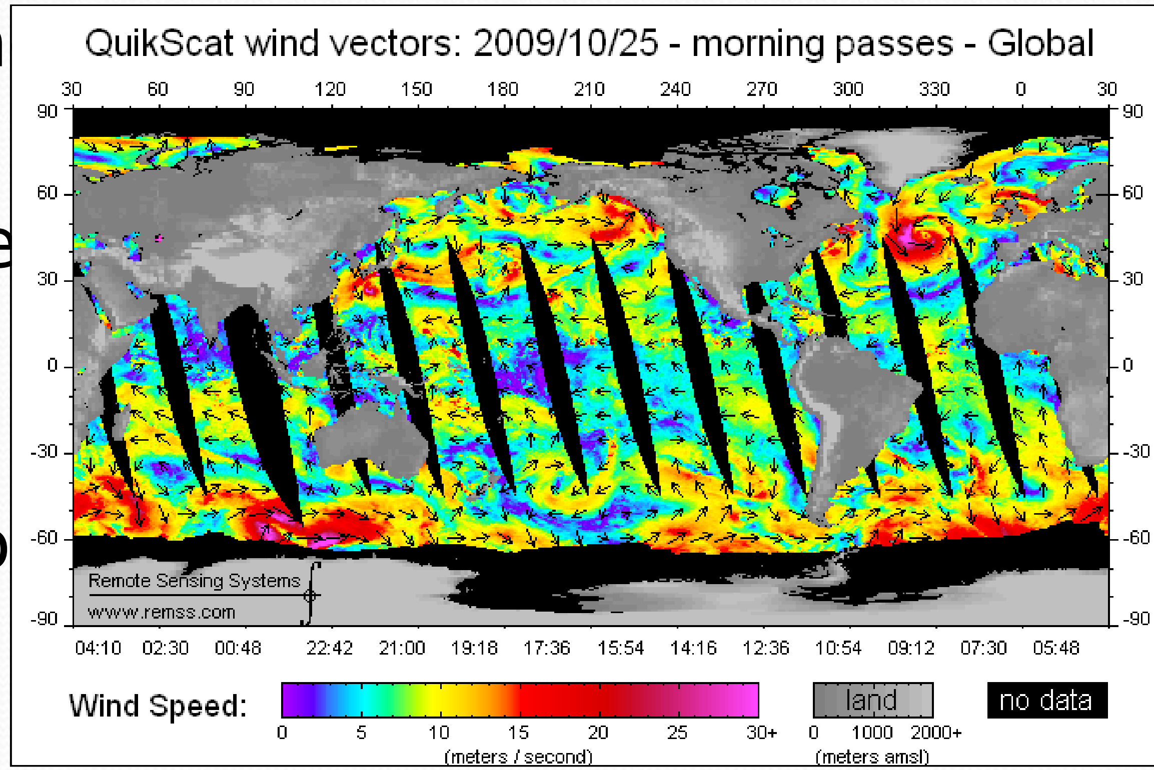
$$\sigma_{total}^2 = \sigma_{sat}^2 + \sigma_{in\_situ}^2 + \sigma_{col}^2$$

  - Data set 1 – satellite observation
  - Data set 2 – in situ observation
  - Temporal and spatial difference

2nd Goal

Data – satellite

- SeaWinds version 3 swath data produced by Remote Sensin
- Ku-2001 geo-physical mode function
- Rain-flagged data are remo



http://www.remss.com/qscat/scatterometer_data_daily.html

Data – in situ

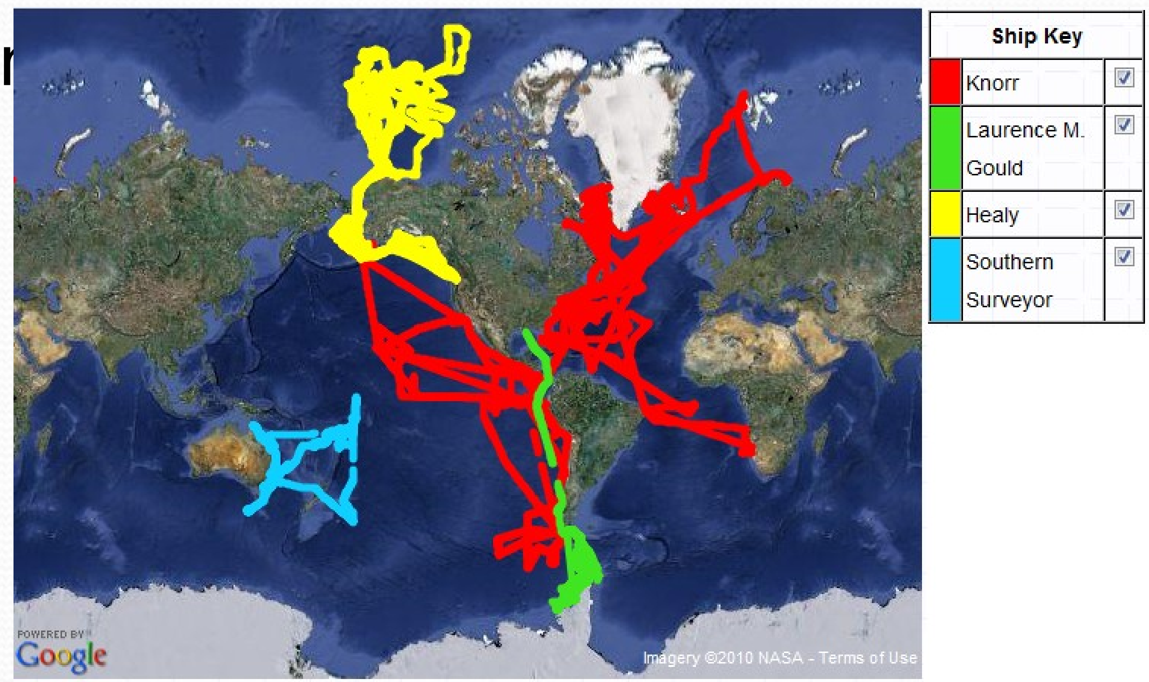
- SAMOS – Shipboard Automated Meteorological and Oceanographic System
- Complimentary to the Voluntary Observing

http://samos.coaps.fsu.edu/html/meta_vessel.php?ship_id=31

- One-minute recorded measurements include: wind speed, air temperature, sea surface temperature, sea level pressure, relative humidity

Data – in situ

- 8 SAMOS equipped vessels are used
- Version 200 data available from 2005 – 2009
- No bias due to ti of year or location since many different geophysical conditions are sampled



http://samos.coaps.fsu.edu/html/ship_tracker.php

Equivalent Neutral Wind

- Equivalent Neutral (EN) wind speeds are calculated by assuming neutral stability, but non-neutral friction velocity and roughness length values

$$U(z) - U_{sfc} = \frac{u_*}{\kappa}\left[\ln\left(\frac{z}{z_0}+1\right) - \varphi\left(z, z_0, L\right)\right]$$

$$U_{10EN} - U_{sfc} = \frac{u_*}{\kappa}\left[\ln\left(\frac{10}{z_0}+1\right)\right]\sqrt{\frac{\rho}{\rho_0}}$$

$$U_{sfc} = U_{current} + 0.8U_{orb}$$

U_{sfc} = mean ocean surface

u_* = surface friction velocity

z_0 = roughness length

κ = von Karman constant

z = reference height

ρ = density of air

ρ_0 = standard density of air (1.0 kg m^{-3})

$U_{current}$ = ocean current

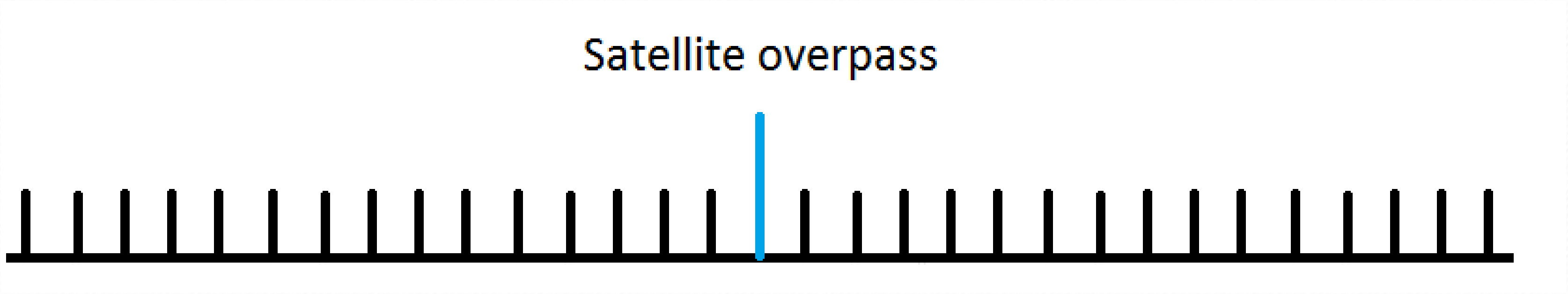
Data – Waves and currents

- Waves
  - NOAA WaveWatch III ocean wave model
  - Spatial coverage: 77° S to 77° N
  - Grid spacing: 1.25° longitude, 1.0° latitude
  - Temporal resolution: 3 hours
- Currents
  - Ocean Surface Current Analyses – Real Time (OSCAR) from NOAA
  - Spatial coverage: 69.5° S to 69.5° N
  - Grid spacing: 1.0° longitude, 1.0° latitude
  - Temporal resolution: 5 days
- Waves and Currents are bilinearly interpolated to ship location

- Part 1 – Idealized Case
  - Examine variability associated with a temporal difference between two observations
- Part 2 – Real World Verification
  - Verify results from idealized case

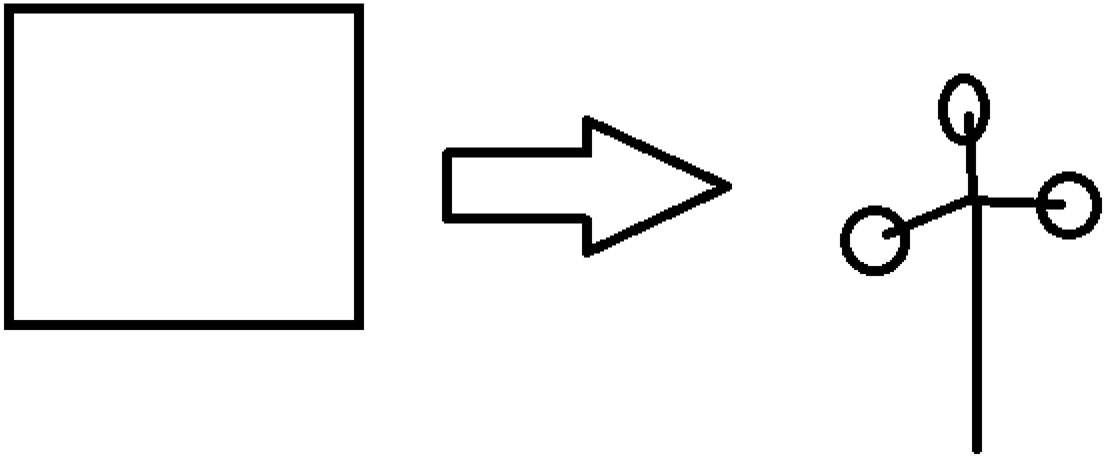
Method – Idealized case

- Assumptions
  - Only using minutely SAMOS data onboard research vessels
  - U_{sfc} term = 0
  - Pseudosatellite is assumed to pass over ship every hour on the hour – no spatial difference



Concepts – Frozen turbulence

- Taylor’s hypothesis: frozen turbulence
  - Characteristics of the turbulence are “frozen” in time
  - Spatial differences converted to a time dif



Method – Idealized case

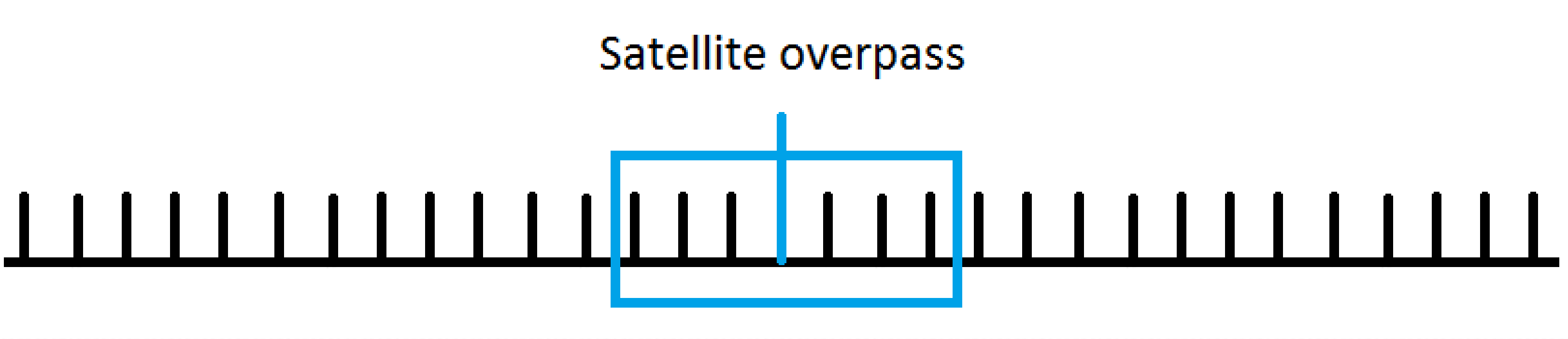
- Define an averaging window (t_{win}) corresponding to an ideal collocation – Taylor's hypothesis

$$t_{win} = \frac{footprint}{\overline{w}} \qquad \left[\frac{m}{ms^{-1}} = s \cdot \frac{\min}{60s} = \min \right]$$

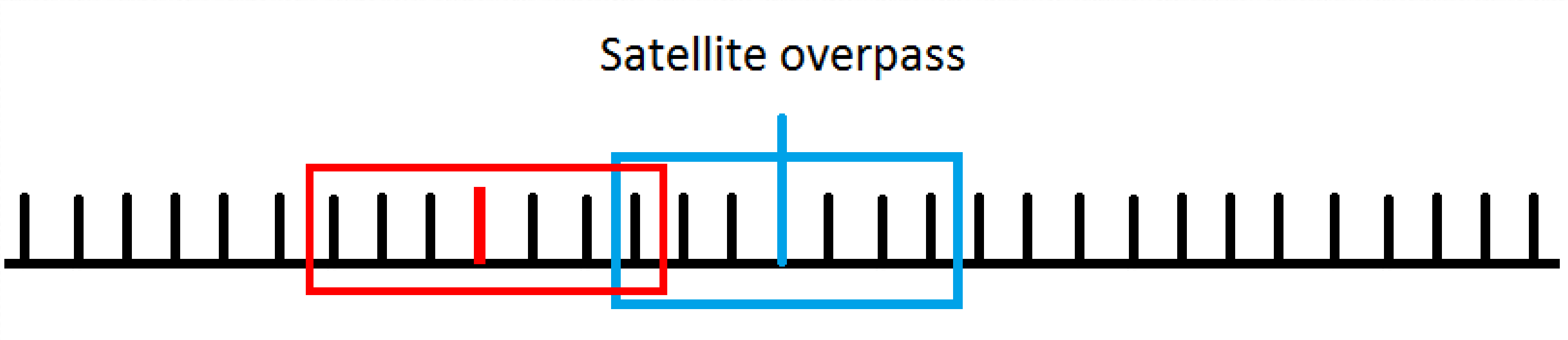
- Footprint = 7 km
  - SeaWinds footprints binned into 25 by 25 km wind cells
  - Bourassa et al. (2003) determined ~ 5 km spatial-temporal scale best matches the balance between signal to noise in research vessel observations
  - Communication with David Long: 7 km more realistic spatial scale for comparisons

Method – Idealized case

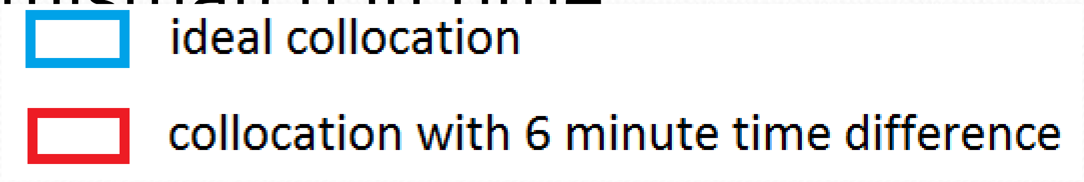
- Size of time-averaging window varies based on the average wind speed and the average wind speed depends on how big the time-averaging window is
- Done for every hour in the SAMOS data set



Method – Idealized case



- Shifts in time from the hourly observation are used to examine error associated with a mismatch in time



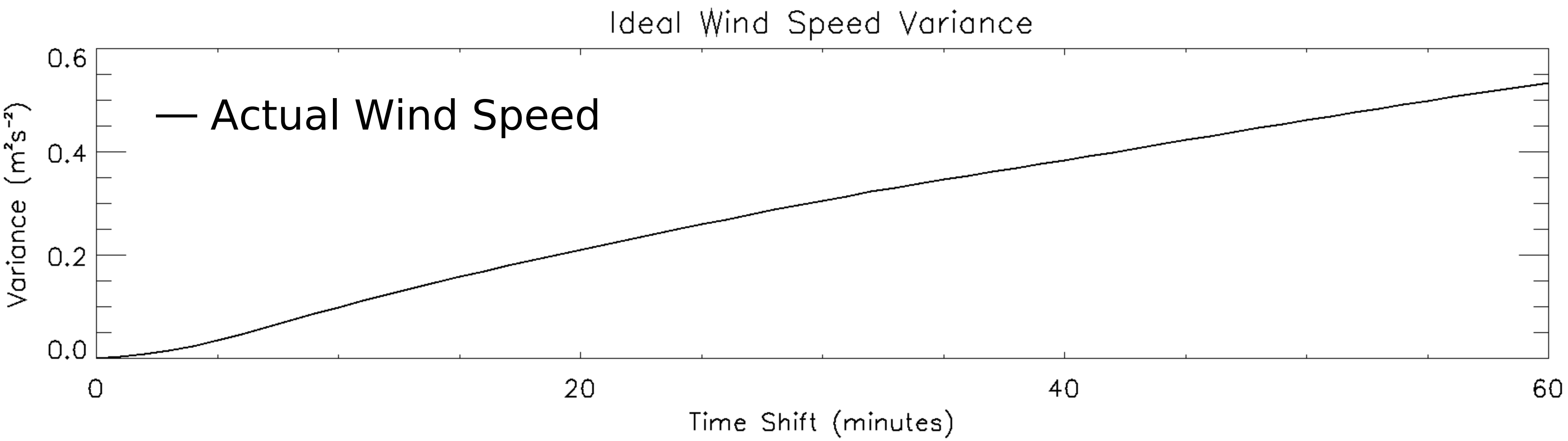
Method – Idealized case

- Variance (σ^2) of the difference between hourly averages ($\overline{w}_{i,j=0}$) and the time-shifted averages ($\overline{w}_{i,j}$) is calculated for each one-minute shift in time

$$\sigma_j^2 = \frac{1}{N_j - 1} \sum_{i=1}^{N_j} (\overline{w}_{i,j} - \overline{w}_{i,j=0})^2$$

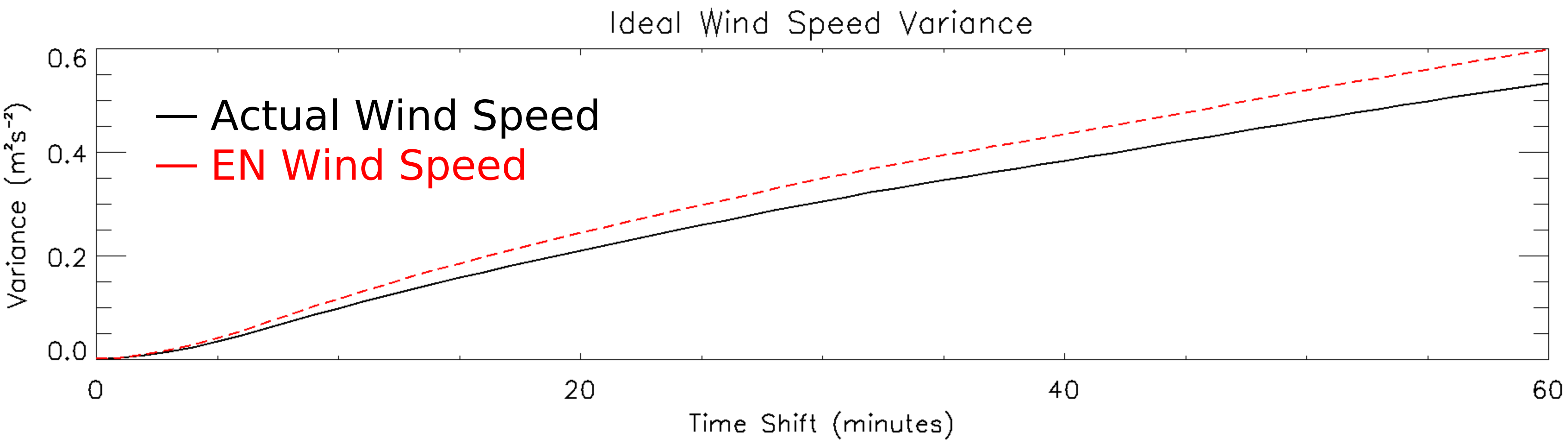
  - *N* = number of observations with j-minute time shift

Results



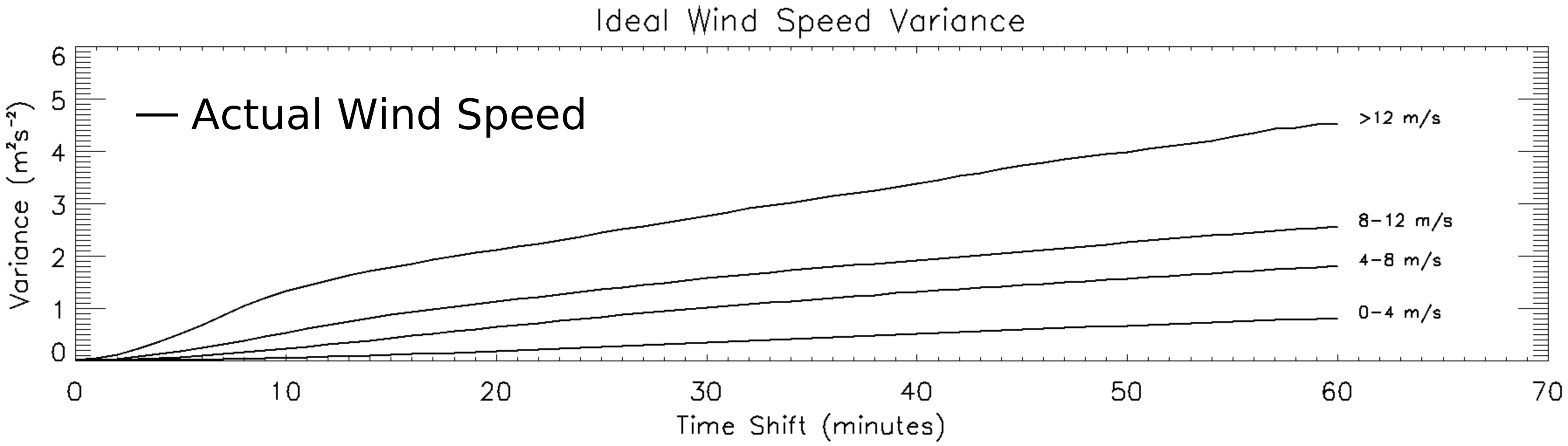
- As the difference in time increases, the variance increases

Results



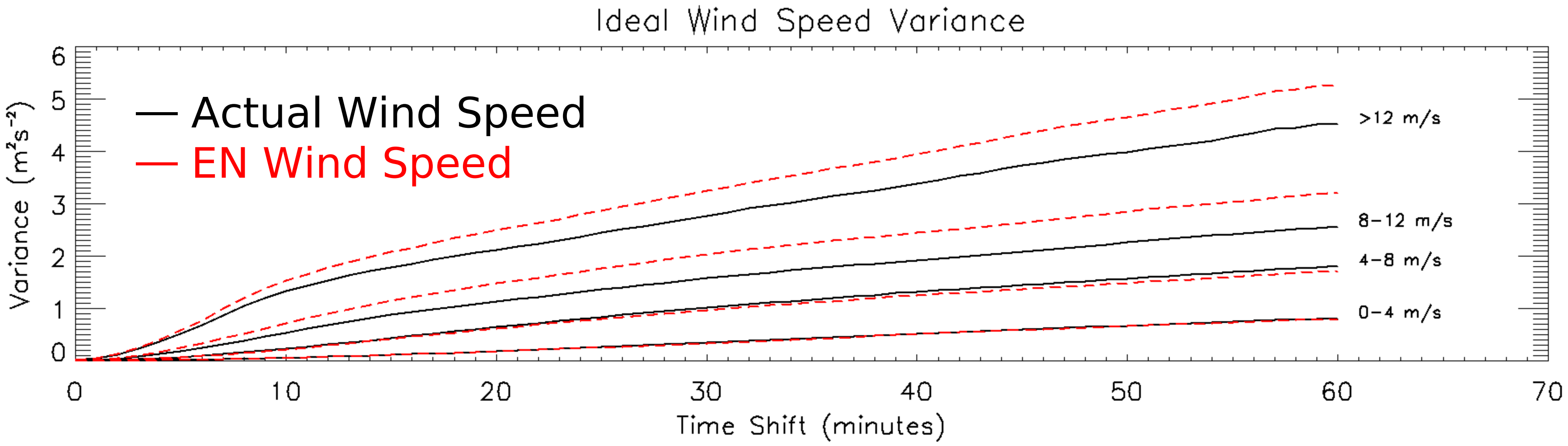
- For unstable atmospheric stratification, EN winds are stronger than actual winds (Kara et al, 2008)

Results



- Higher wind speeds are associated with a larger variance

Results



- Higher wind speeds are associated with a larger variance

Results

- For unstable atmospheric conditions

If wind increases

⇒ More stress

⇒ More mechanical mixing

⇒ More stable stratification

⇒ Lower stress

If wind decreases

⇒ Less stress

⇒ Less mechanical mixing

⇒ Less stable stratification

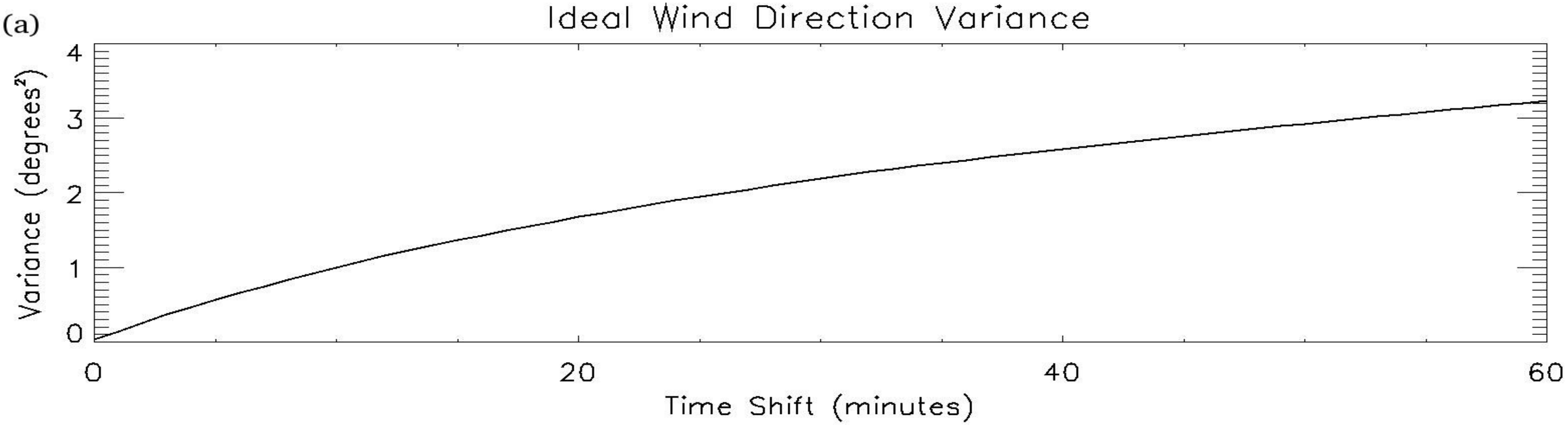
⇒ Greater stress

- At low wind speeds, changes in EN wind speed (i.e., wind shear) are partially compensated by changes in stability

- At higher wind speeds, the atmospheric stability has less influence and cannot compensate for the change in wind speed

Results

(a)


Ideal Wind Direction Variance
Variance (degrees²)
4
3
2
1
0
0
20
40
60
Time Shift (minutes)

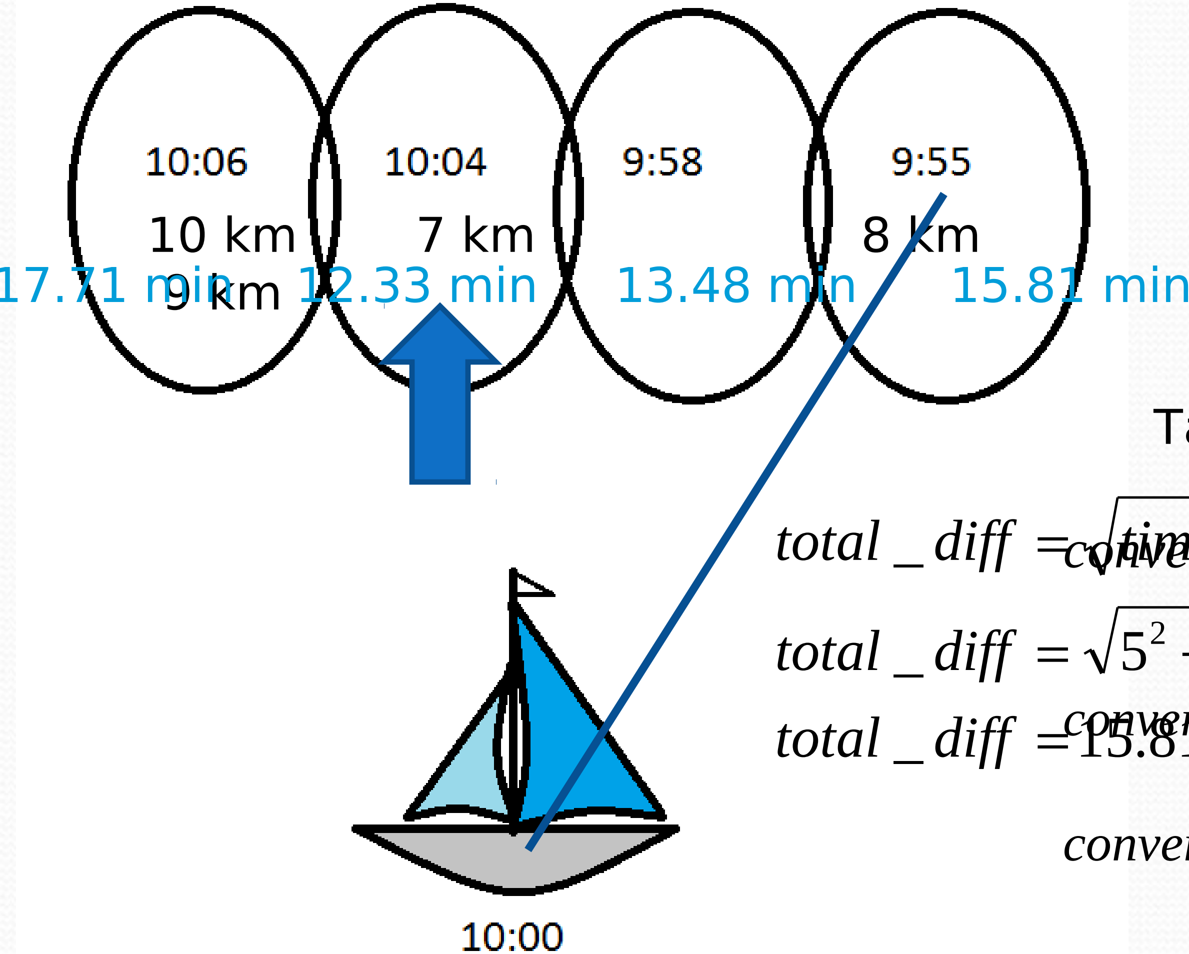
- Part 1 – Idealized Case
  - Examine variability associated with a temporal difference between two observations

- Part 2 – Real World Verification
  - Verify results from idealized case

Method – collocated SAMOS and SeaWinds observations

- Because SeaWinds provides EN wind speed, that is what we will be examining (not actual wind speed)
- Want minimum total difference in both time and space to satellite overpass
- SAMOS and SeaWinds observations with time differences up to 30 minutes and spatial differences up to 30 km of each other were examined

Method – collocated SAMOS and SeaWinds observations



Satellite wind = 10 m/s

Taylor's Hypothesis

$$total\_diff = \sqrt{time\_diff^2 + converted\_space^2}$$

$$converted\_space = \frac{space\_diff}{wspd}$$

$$total\_diff = \sqrt{5^2 + 15^2}$$

$$total\_diff = 15.811 min$$

$$converted\_space = \frac{9000m}{10m/s * 60s/min}$$

$$converted\_space = 15 min$$

Method – collocated SAMOS and SeaWinds observations

- For each collocation, find time-averaging window

$$t_{win} = \frac{footprint}{w_{sat}}$$

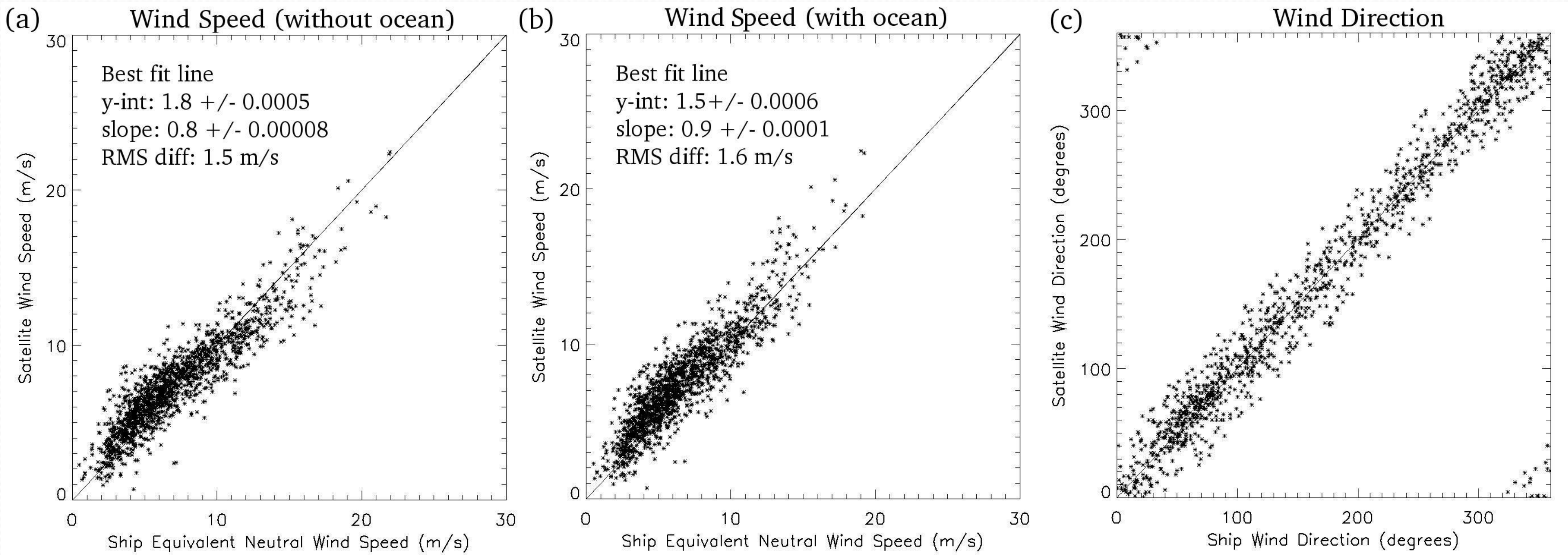
- Calculate 2 average SAMOS EN wind within each window: one with U_{sfc}, one without U_{sfc}

$$U_{10EN} - U_{sfc} = \frac{u_*}{\kappa}\left[\ln\left(\frac{z}{z_0}+1\right)\right]\sqrt{\frac{\rho}{\rho_0}}$$

Method – collocated SAMOS and SeaWinds observations

- Want comparable data sets
  - Only using collocated points that are in both data sets
- Eliminate spurious noise/scatter in data sets due to fronts and incorrect ambiguity selection
  - Remove data with wind speed differences > 5 ms^{-1}
  - Remove data with wind direction differences > 45°

Method – collocated SAMOS and SeaWinds observations



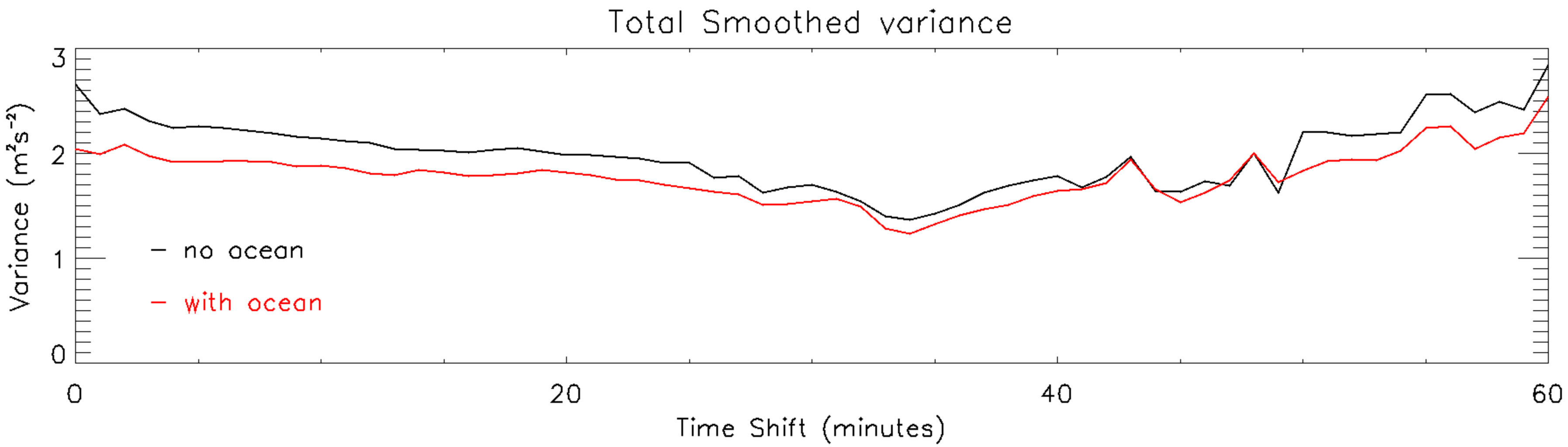
Method – collocated SAMOS and SeaWinds observations

- For each total time difference (*j*), calculate variance (σ_j^2) of the difference of the scatterometer and ship winds ($\Delta w_{i,j}$)

$$\sigma_j^2 = \frac{1}{N_j - 1} \sum_{i=1}^{N_j} (\Delta w_{i,j})^2$$

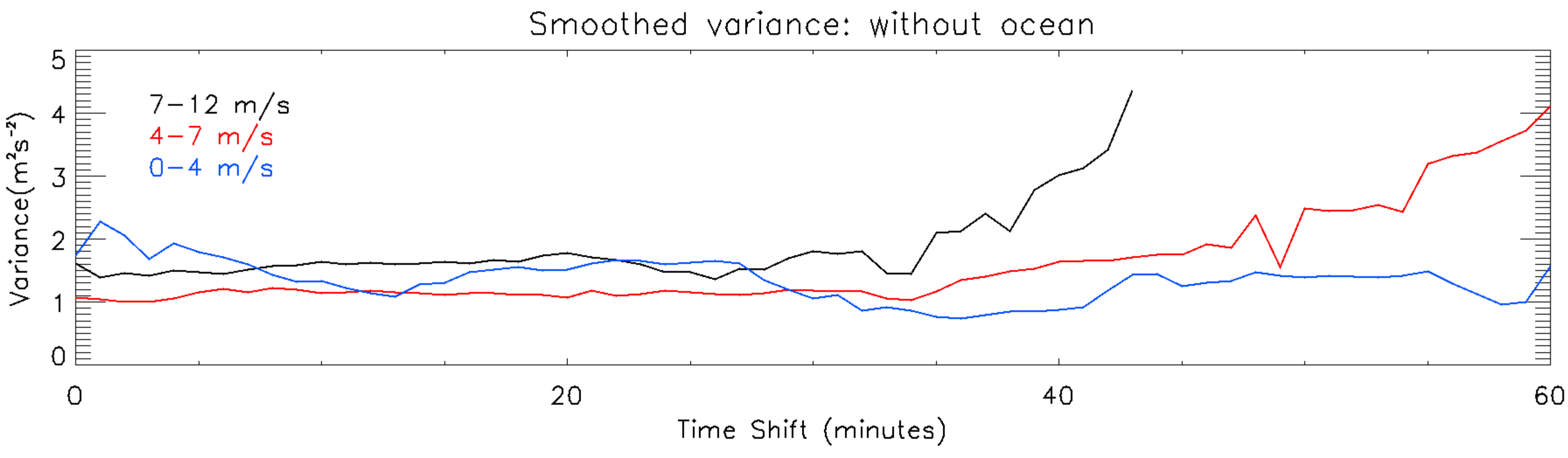
- 15 minute running mean is used to smooth the total variance

Results – collocated SAMOS and SeaWinds observations



- Scatterometers respond to $U(z)-U_{sfc}$ rather than $U(z)$

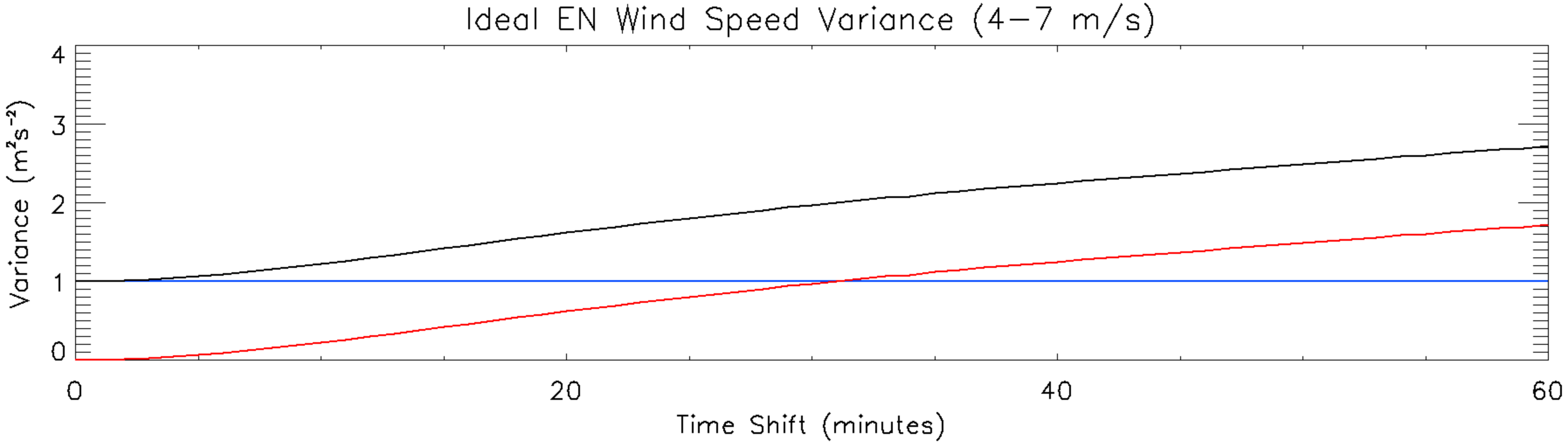
Results – collocated SAMOS and SeaWinds observations



$$\sigma_{total}^2 = \sigma_{sat}^2 + \sigma_{in\_situ}^2 + \sigma_{col}^2$$

Results – collocated SAMOS and SeaWinds observations

$$\boxed{\sigma_{total}^2} = \boxed{\sigma_{sat}^2 + \sigma_{in\_situ}^2} + \boxed{\sigma_{col}^2}$$



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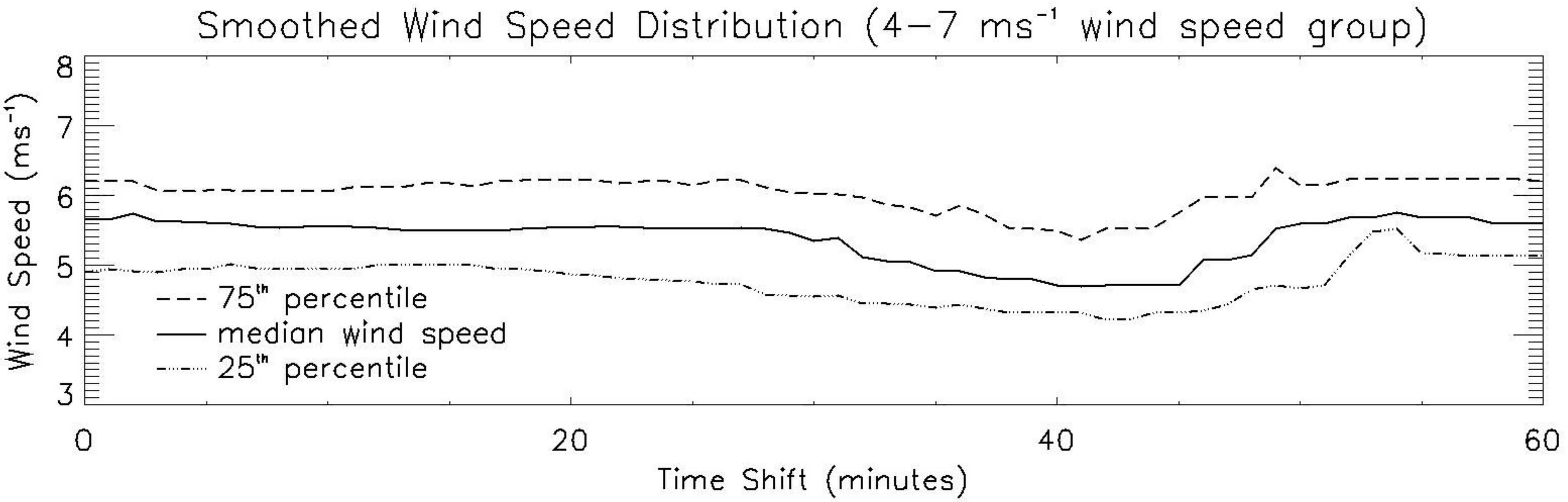

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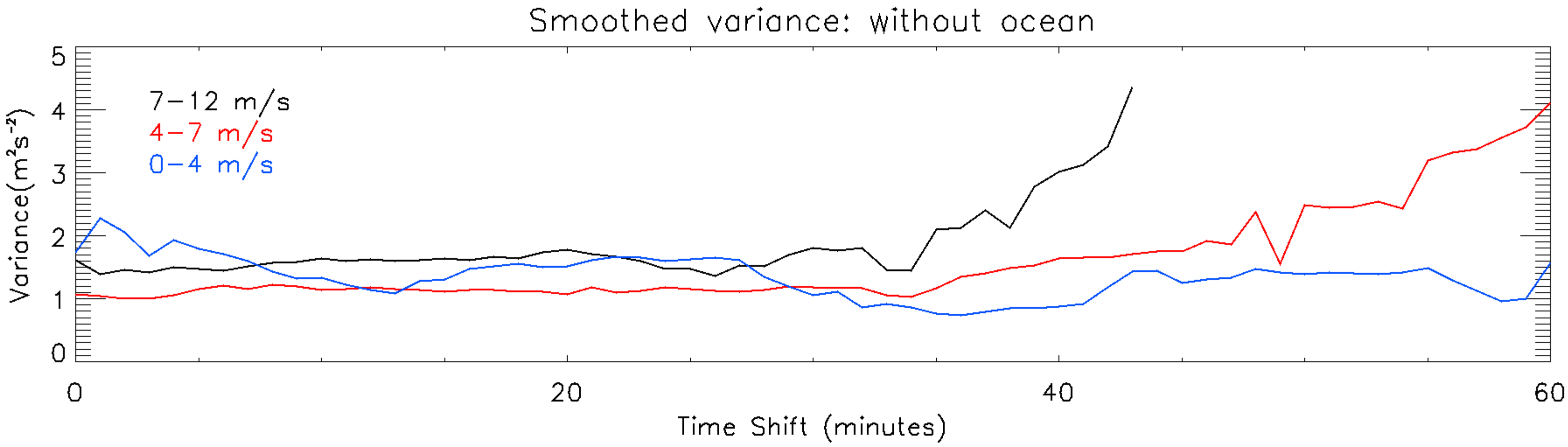
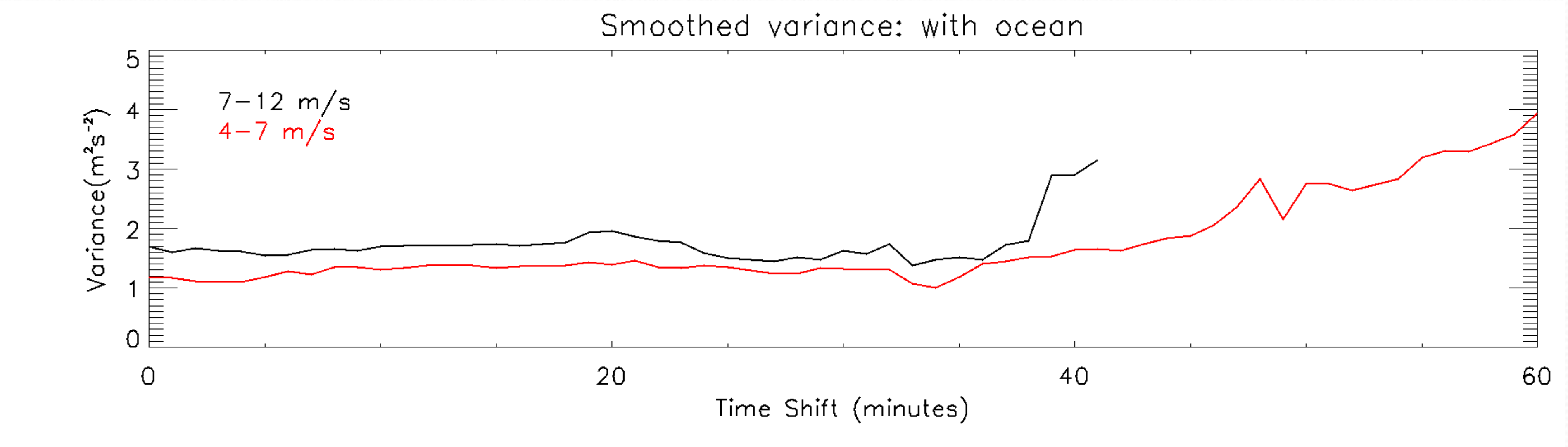


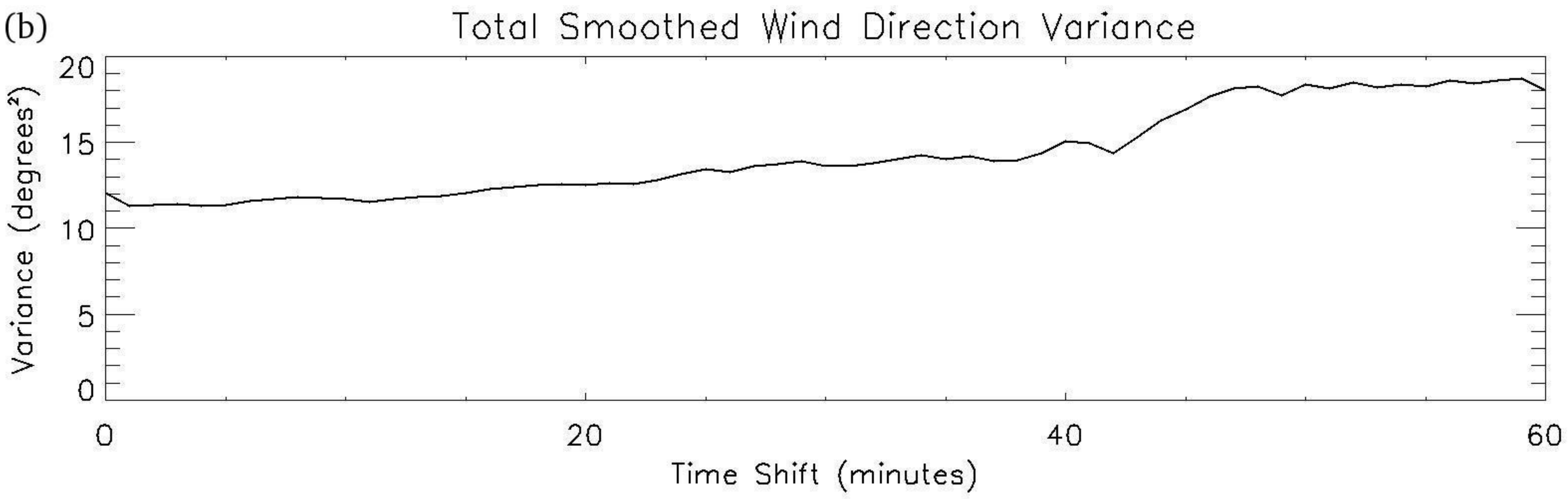
$$\sigma_{total}^2 = \sigma_{sat}^2 + \sigma_{in\_situ}^2 + \sigma_{col}^2$$

Results – collocated SAMOS and SeaWinds observations

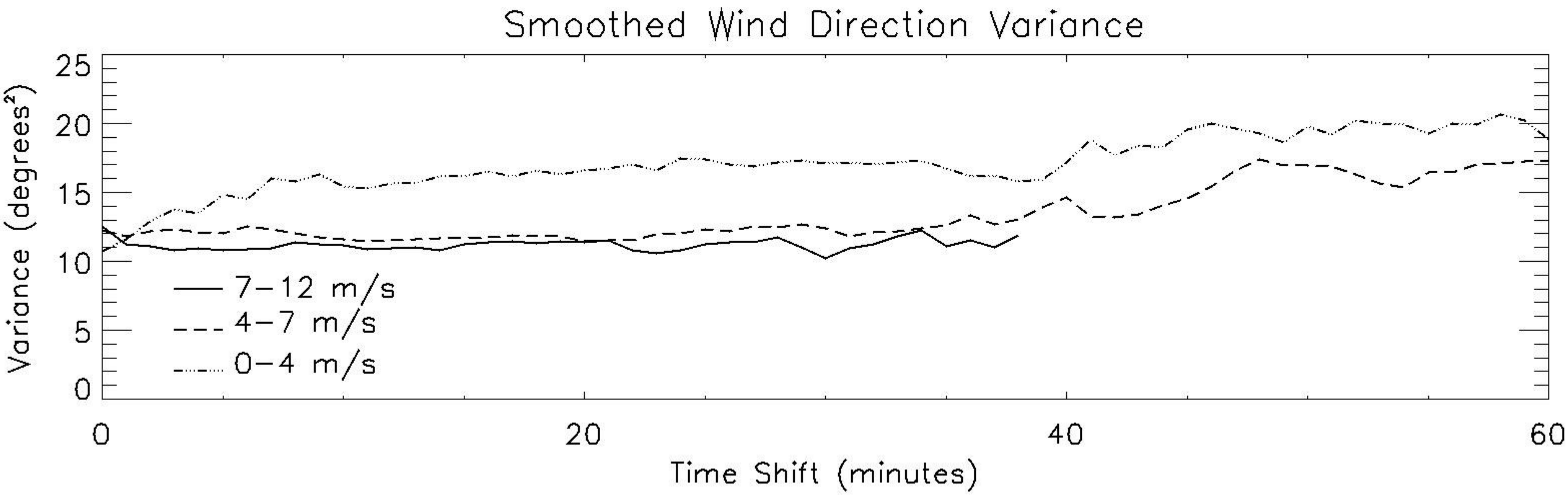


$$\sigma^2_{total} = \sigma^2_{sat} + \sigma^2_{in\_situ} + \sigma^2_{col}$$

Results – collocated SAMOS and SeaWinds observations



Results – collocated SAMOS and SeaWinds observations



Conclusions

- Idealized case
  - EN winds have more total variance than actual winds
  - As the time difference increases, the amount of variance increases
  - Higher wind speeds have a higher amount of variance in wind speed and a lower amount in wind direction
- Real-world
  - EN wind speeds calculated with waves and currents have less total variance than EN wind speeds calculated without waves and currents
    - Scatterometers respond to $U(z)-U_{sfc}$ (wind shear) rather than $U(z)$

Conclusions

- Less than a 25 minute equivalent difference
  - Variance associated with the temporal and spatial difference is negligible compared to variance associated with the data sets

$$\sigma_{total}^2 = \sigma_{sat}^2 + \sigma_{ship}^2$$

$$= 1.5 m^2 s^{-2}; \quad 12 \deg^2 \qquad \text{(7-12 ms}^{-1}\text{)}$$

$$= 1.0 m^2 s^{-2}; \quad 10 \deg^2 \qquad \text{(4-7 ms}^{-1}\text{)}$$

- Greater than a 25 minute equivalent difference
  - Variance associated with the temporal and spatial difference should be taken into consideration with the total variance

Thank you

- Questions / Comments