Field assessment of ocean wind stress derived from active and passive microwave sensors

Doug Vandemark, Marc Emond (UNH)
Jim Edson (UCONN)
Bertrand Chapron (IFREMER)

Motivations

Are there 1st or 2nd order distinctions between τ and U_{10EN_SAT} and amongst the OW sensors?

- Need still exists to address long-standing issue of validating the scatterometer as a wind stress estimator, in large part due to lack of ground truth
- Desire climate data record Ocean Wind (OW) consistency amongst many different passive & active ocean wind configurations– i.e. the remote sensing aspect comes into play
- Support for interpretation of OW as an area-mean stress and clear methods for moving between $U10EN_{SAT}$ and τ_{SAT}
- New L-band data (Aquarius/SMAP/CYGNSS) + CFOSAT is/will provide expanded and alternate view of wind-waves & winds
- Surface current missions envisioned – will open another new window

Outline

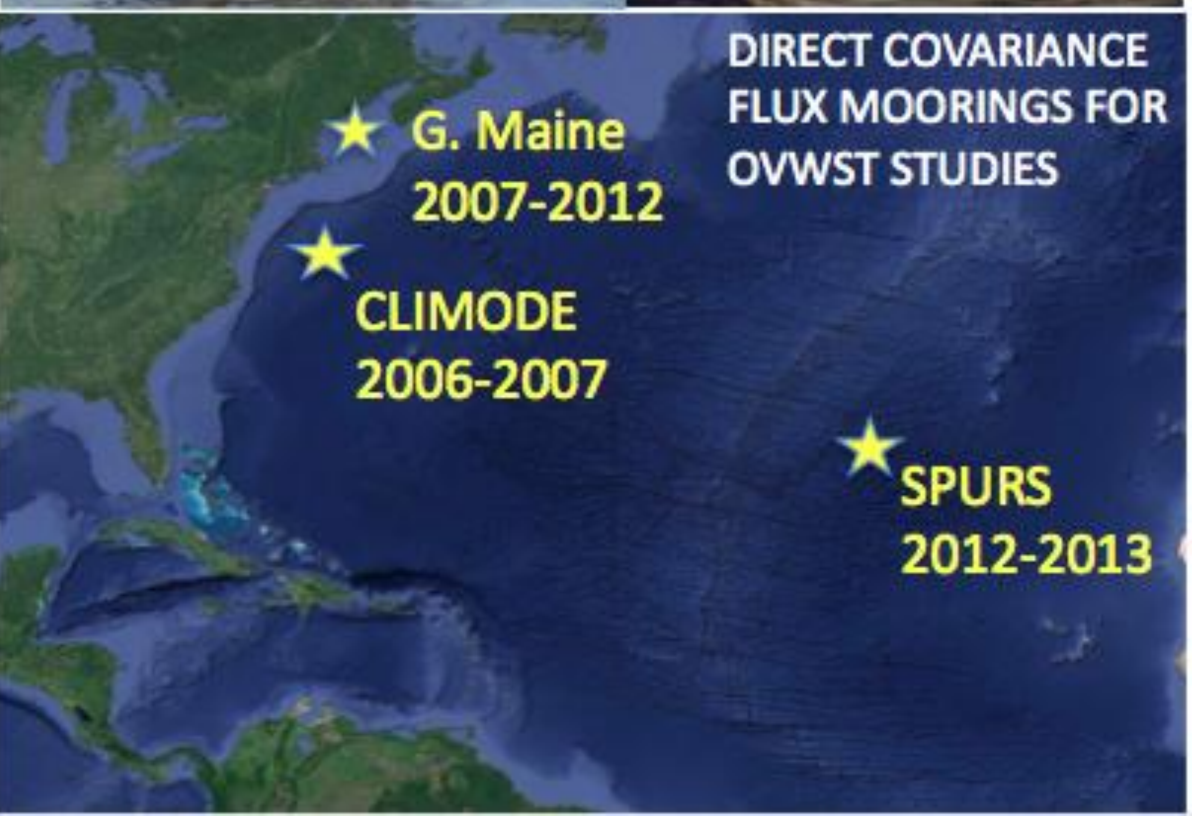
- Approach – provide some complement to the nominal triplet approaches with in situ stress data

$$U(z) - U_s = \frac{u_{*a}}{\kappa}\left[\ln\frac{z}{z_0} + \phi(z, z_0, L)\right]$$

- density
- stability
- drag coefficient
- surface current

A valid assumption,and for all sensors?

$\boldsymbol{\tau_a} = \; < \rho_a \cdot C_{d10EN} > \cdot \, |\mathbf{U_{10EN\_sat}}| \cdot U_{10EN\_sat} = \rho_a \, |\mathbf{u*}| \, u*$



Momentum Flux Met Platforms 2006-2014

Primary sensor –
3D 20 Hz sonic anemometer with motion package (Direct Covariance Flux System DCFS)

Range of Conditions -

marginal sea, tides, short fetch
Gulf Stream & fronts
Subtropical gyre & swell

Hourly data collection for months to years

Ocean wind satellite datasets

- Scatterometer:
  - QuikSCAT: 12km (L2 V3 PO.DAAC);
  - ASCAT-A (L2 KNMI)
  - OSCAT L2B (PO.DAAC)
- Radiometer (all V7 RSS):
  - AMSR-E
  - AMSR-2
  - WINDSAT
  - SSM/I
- Altimeter (GDR)
  - Jason-1
  - Jason-2
  - Envisat RA-2
  - GFO
  - Saral/AltiKa

Creation of quality-controlled satellite ocean wind stress assessment datasets – work in progress

- Consistent in situ data : use of moored direct covariance momentum flux measurements and consistent data processing for motion correction and data QA/QC
- Three differing locations to date and coming soon 4 global-node OOI(NSF) mooring + OOI pioneer array data: ↑DOF and ↑ wind-wave conditions
- Satellite matchups performed in consistent manner with latest version wind products, including scatterometer, radiometers and altimeters
- Open data access for IOVWST

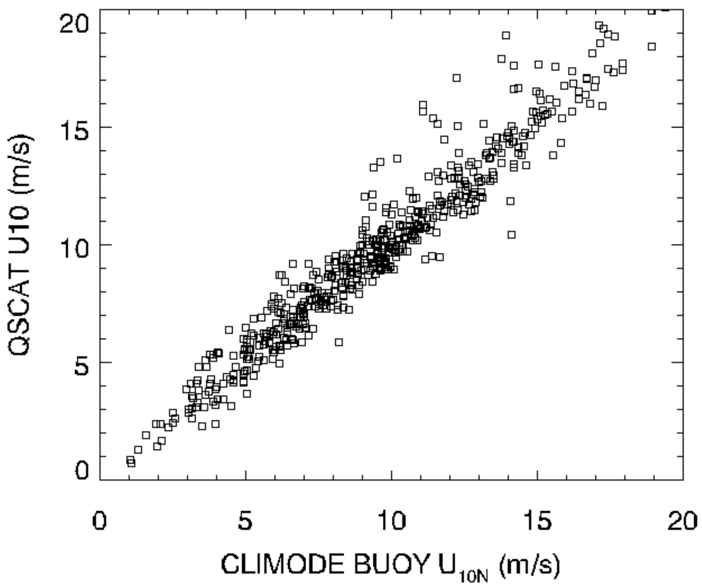
Scatterometer – Flux Buoy Comparison Datasets

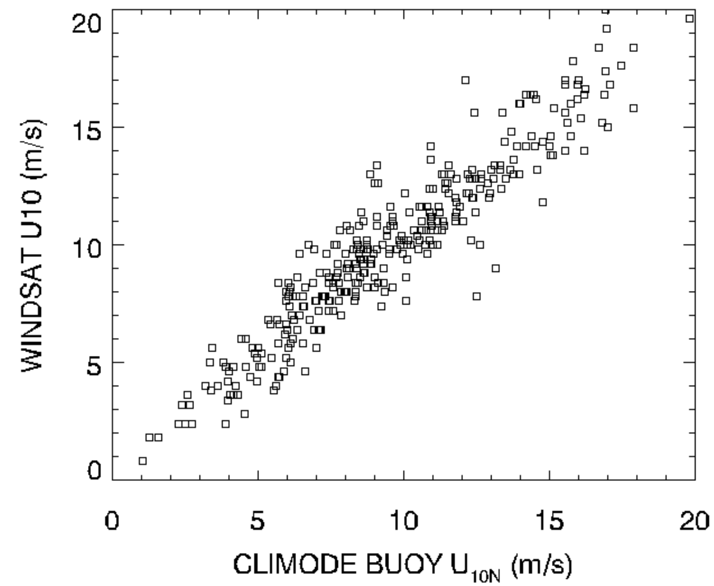
Mission	N	Platforms
QuikSCAT	821	C,J,S
ASCAT-A	710	J,S
OSCAT	847	J,S
Aquarius	051	S

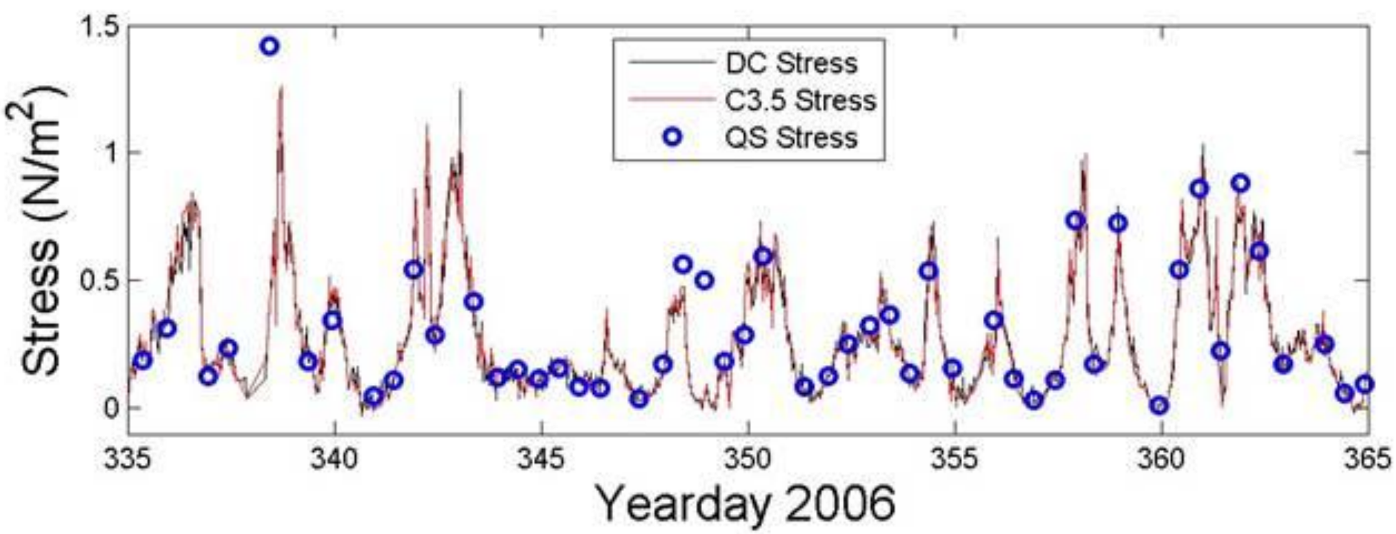
Radiometer – Flux Buoy Comparison Datasets

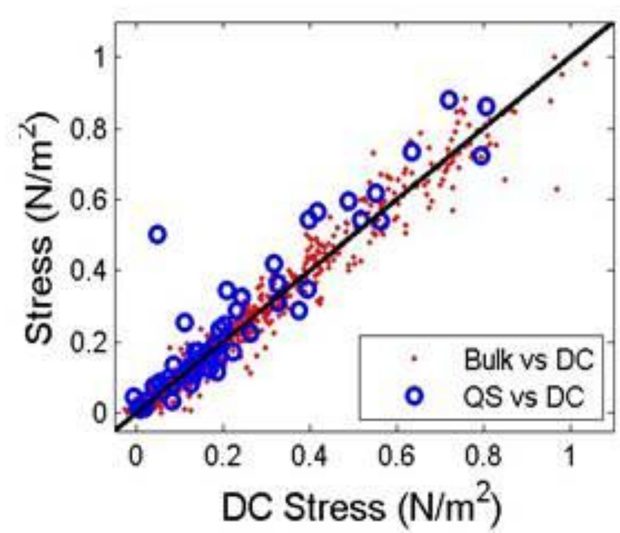
Mission	N	Platforms
SSM/I	4322	C,J,S
AMSR-E	0910	C,J
WINDSAT	1443	C,J,S
AMSR-2	0530	S

CLIMODE examples
QuikSCAT N= 560
Windsat N=335







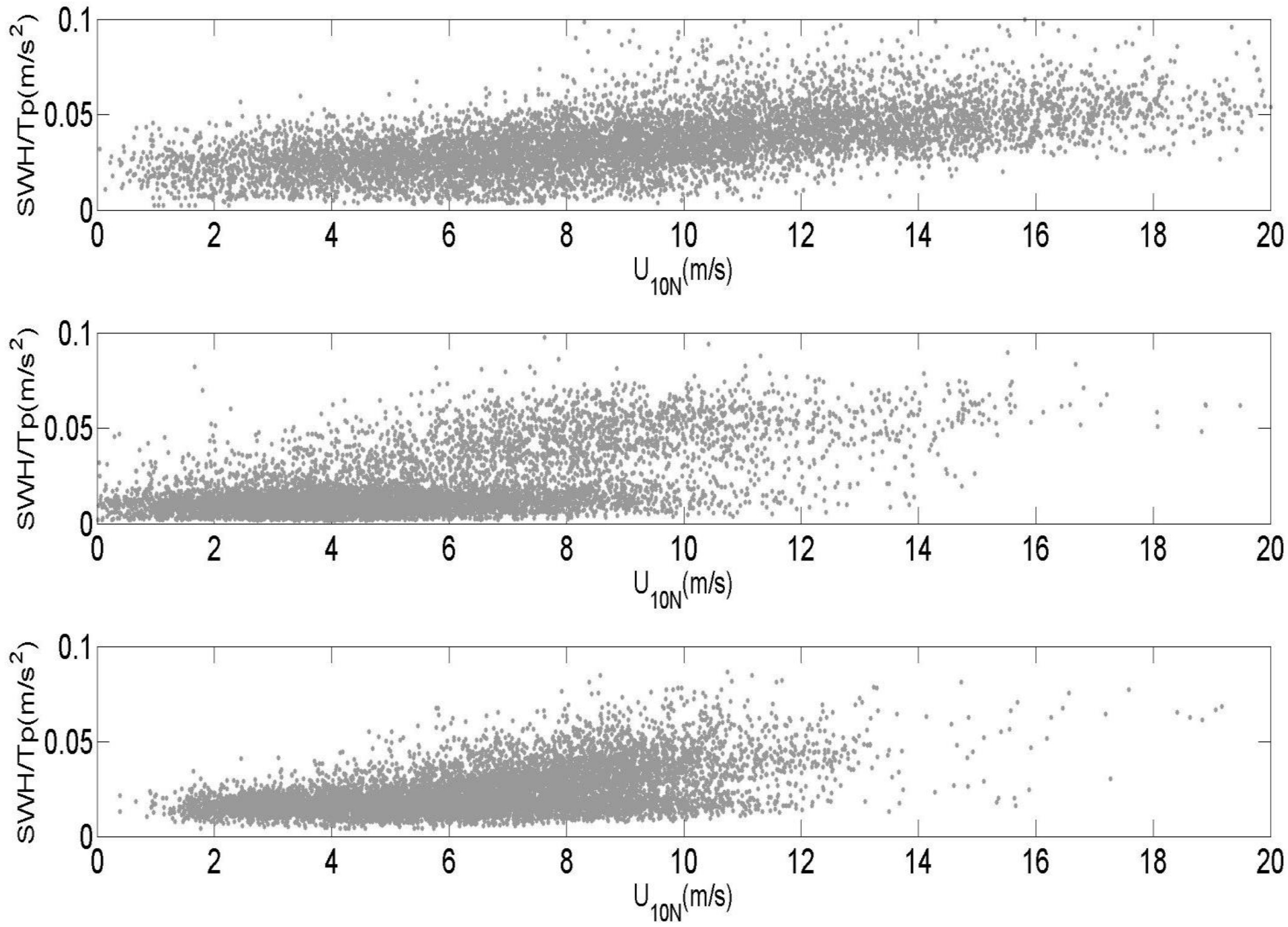


DCFS combined datasets –
expanding wave conditions

CLIMODE

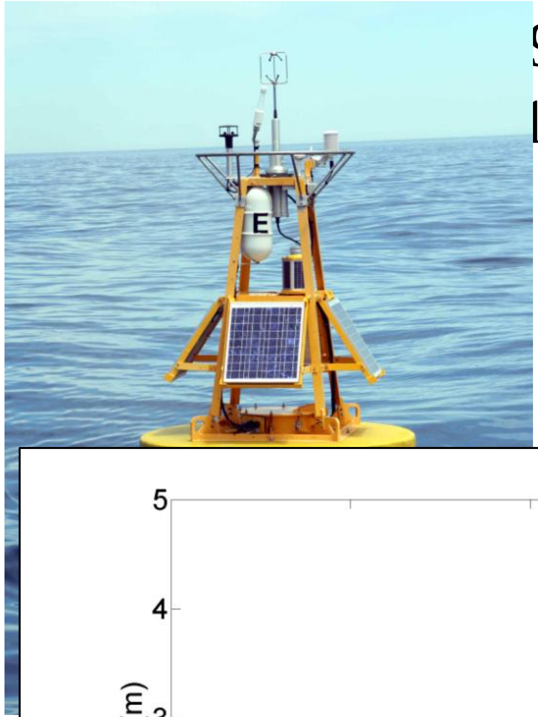
Coastal NE
- bifurcation in
wave climate

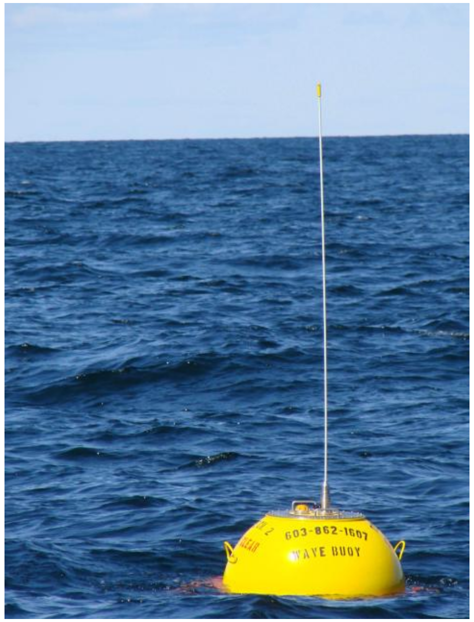
SPURS I
N. Atlantic
24 N



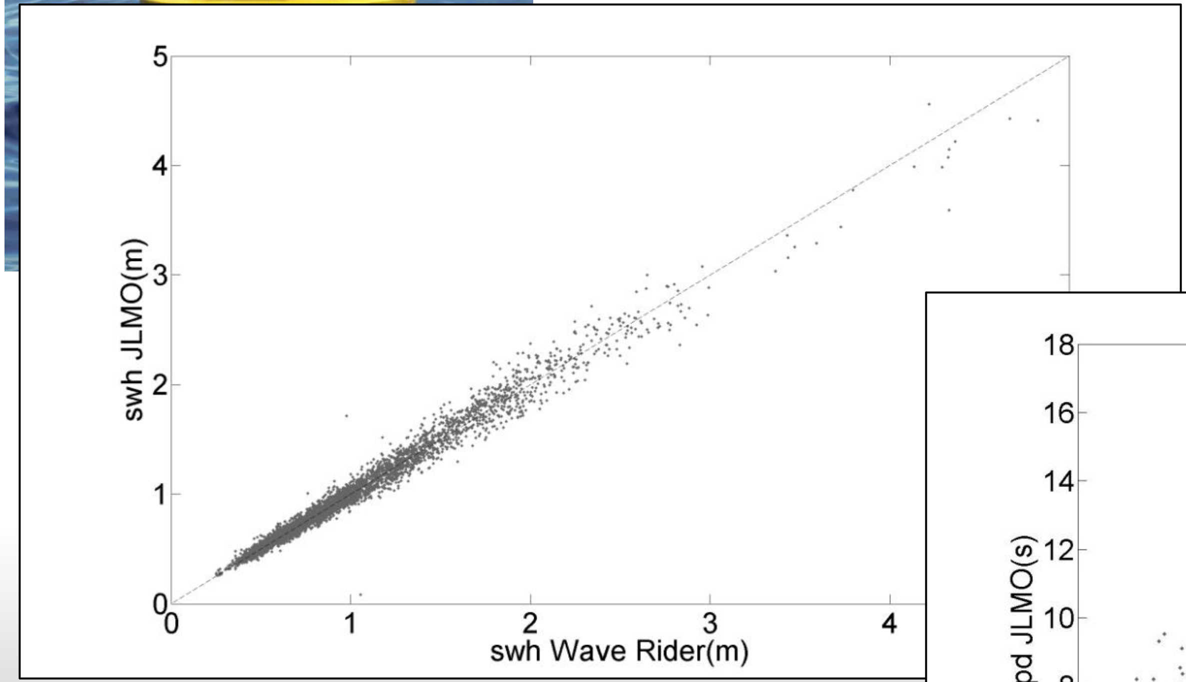
DCFS buoy data quality –

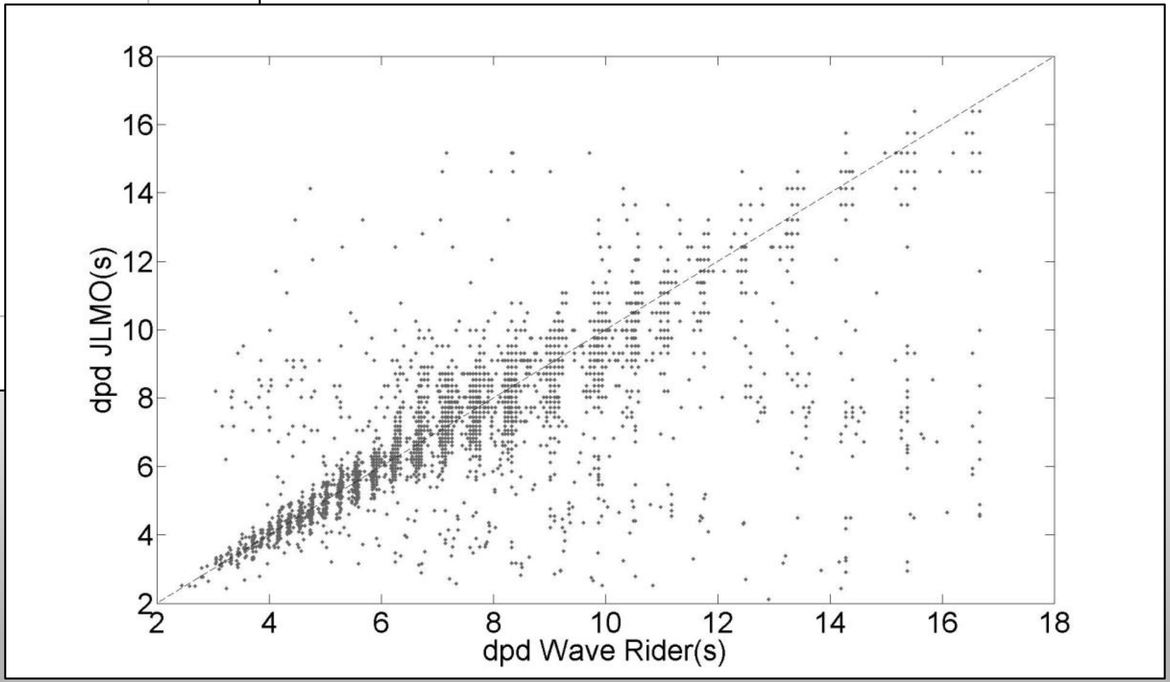
validating derived heave-derived wave statistics against
9-2012 colocated waverider
11 data used here)





- Gravity Wave data central to Cd assessment – DCFS heave approach needs validation





Satellite winds, wind stress, and near-surface density

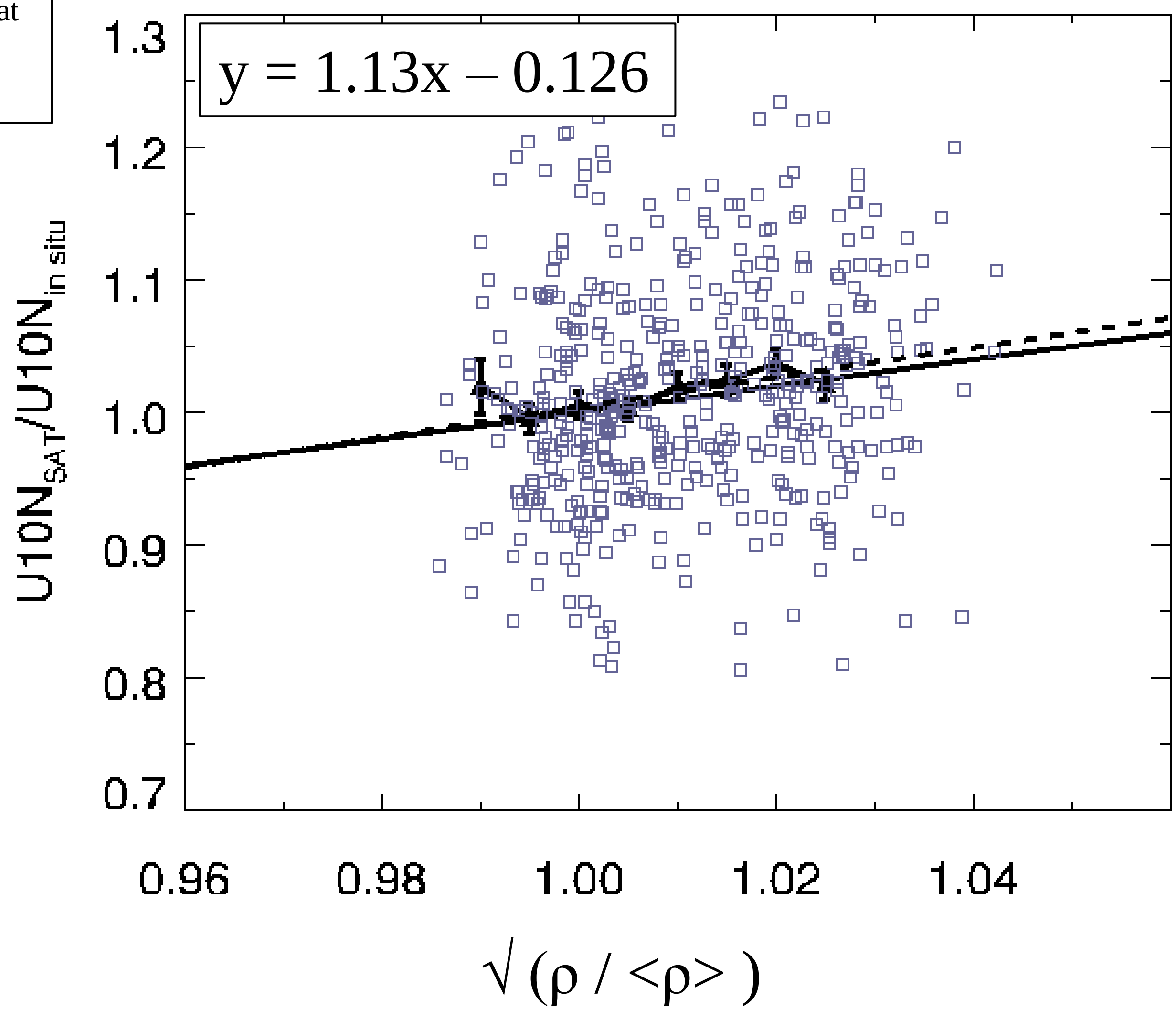
Wentz (stress working group comm.), Hersbach (2010), Bourassa et al. (2010), Grodsky et al. (2012), Pierson and Donelan (1987) and back to Seasat... The assumption: U10N_SAT is not equal to U10N_insitu when near surface air density changes from some nominal density tied to the GMF

$$\tau_a = \langle \rho_a \cdot C_{d10EN} \rangle \cdot |\mathbf{U_{10EN\_sat}}| \cdot U_{10EN\_sat}$$

$$U_{10EN\_sat} / U_{10EN\_InSitu} = \sqrt{[\rho / \langle\rho\rangle]}$$

Data filtering:
<ρ> @ 20degC,
Tair and not SST,
U > 3 m/s,
and deltaU< 3Std,
closest Sat match

QuikSCAT/Buoy

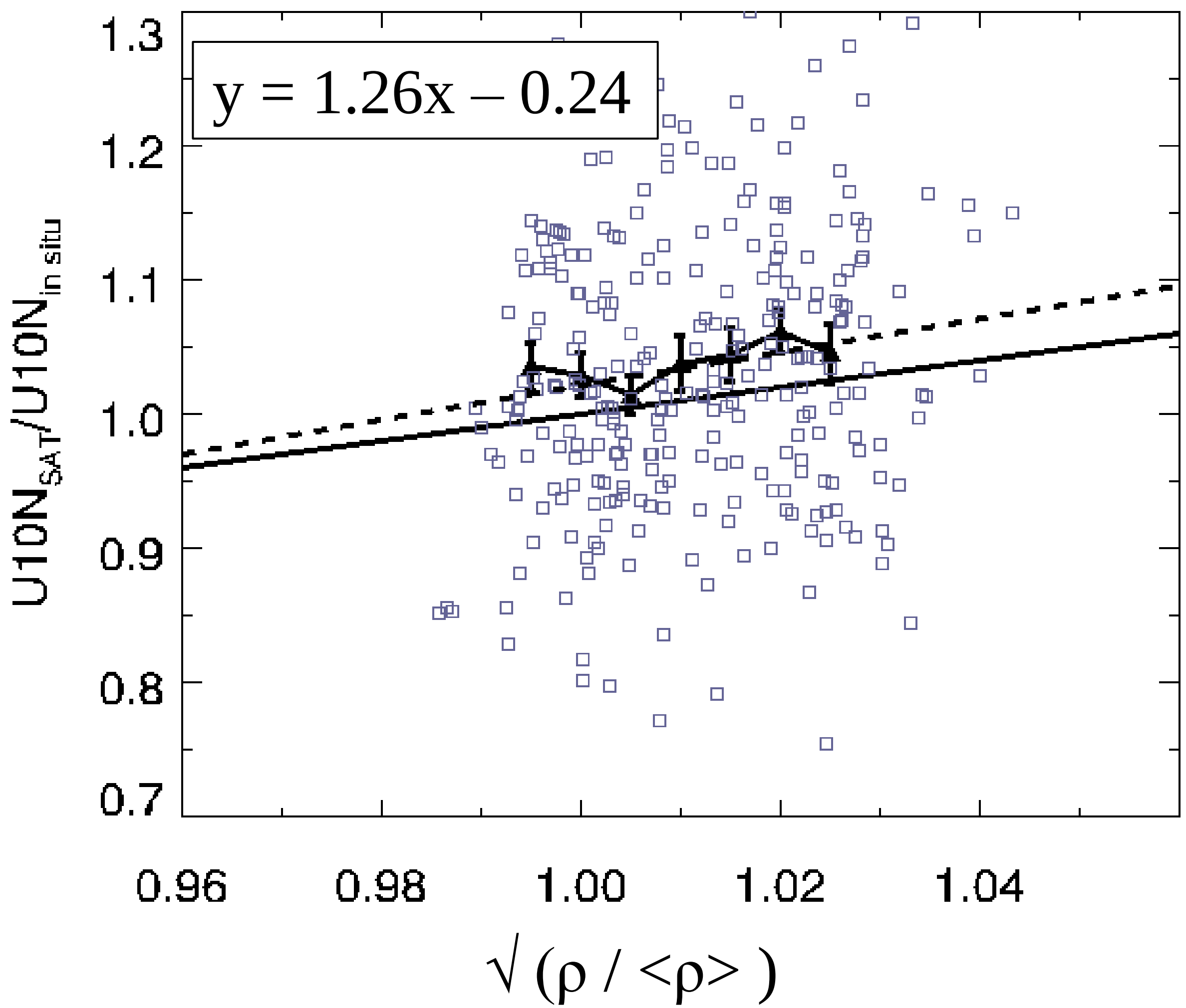


Satellite winds, wind stress, and near-surface air density

We expect same should hold in general for the complement of ocean remote sensors (atmospheric BL, not directly the roughness).

Do we see the same for the radiometers?

Windsat/Buoy



Notes:
< ρ > @ 20degC
U10N > 3 m/s
Climode 2005-7

Fine Point?
< ρ > likely a function of U for each GMF, higher wind tie to lower pressure and temp.

Atmospheric Stability, ocean satellite winds, and equivalent neutral wind

• Evaluated by many against bulk met and other approaches... many in the room.
• Difficult to nail down from many angles including from remote sensing side

Keller et al., 1989

Vandemark, Edson, and Chapron, 1997

Deviations away from bulk estimation when short waves are concerned?

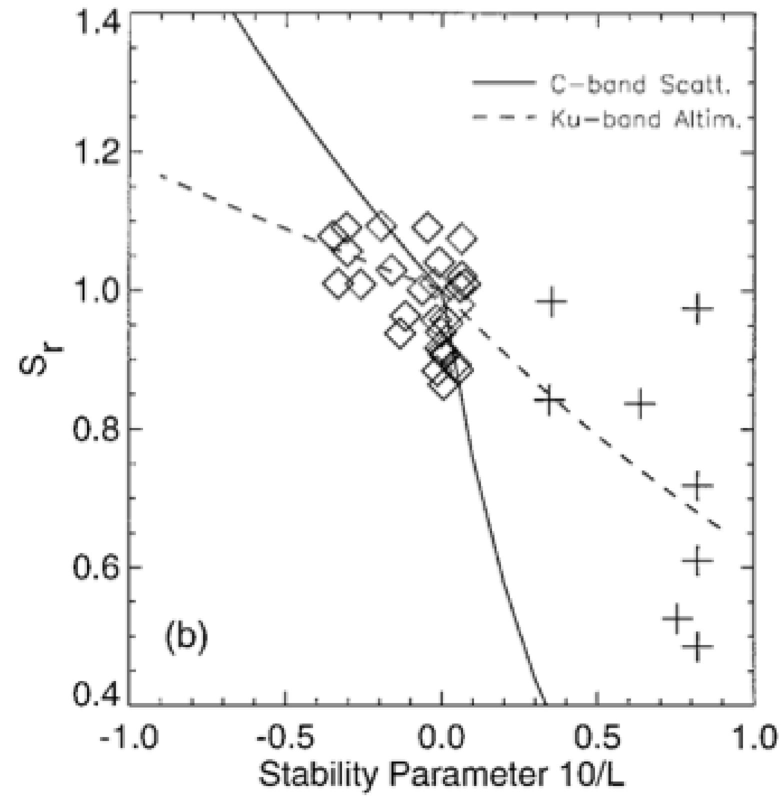
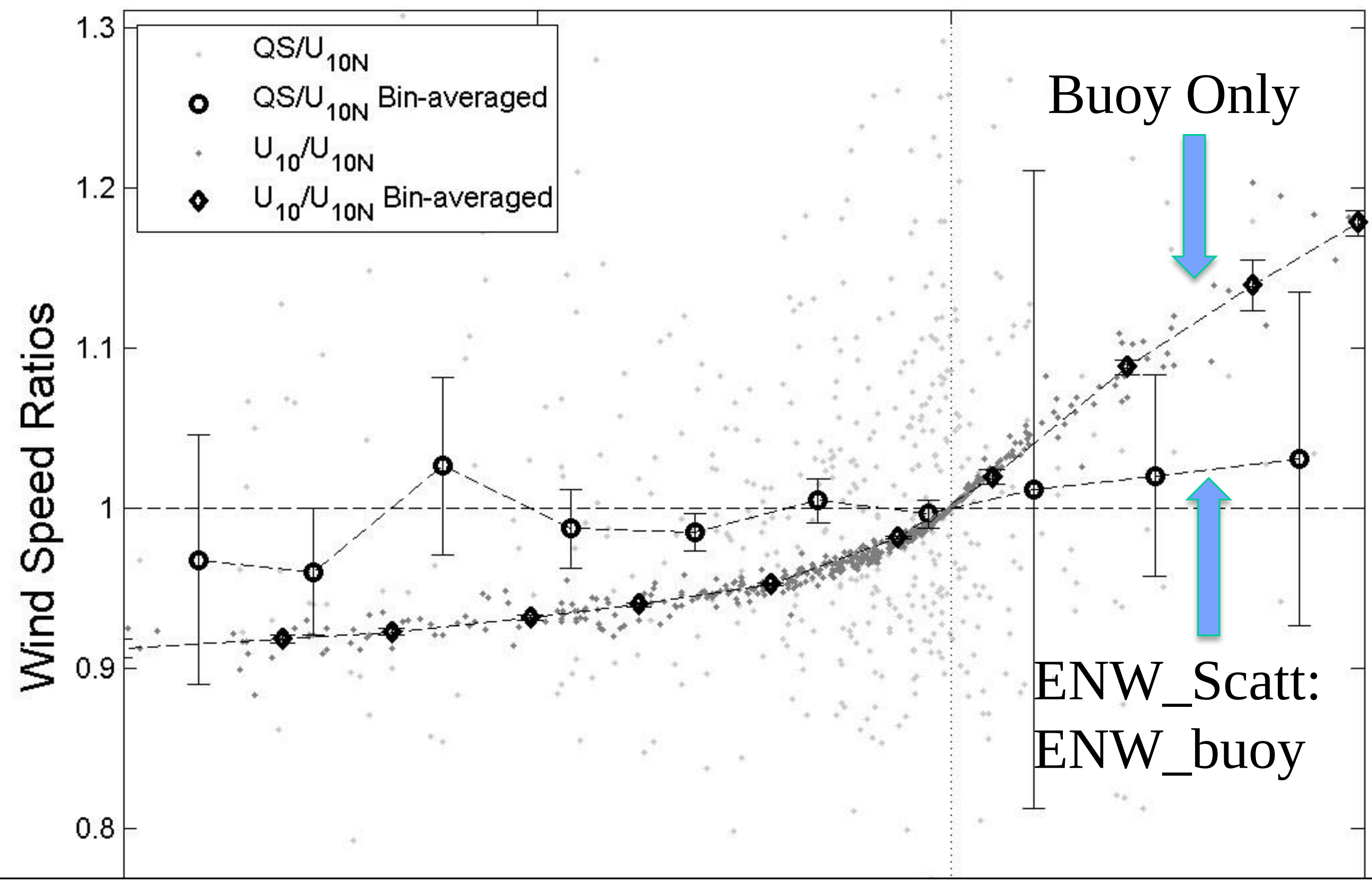


FIG. 4. Environmental parameters (a) effective current, and (b) stability vs altimeter measurement deviation, Eq. (5), from the $u_{*\,MCW}$ algorithm. Measurements in stable stratification are denoted with the "+" symbol. In (a) a linear regression for S_r vs current is shown. In (b), solid curve is (6) and (7) with exponents from the C-band scatterometer. Dashed curve is the present data fit to (6) and (7) giving $\alpha = 0.17$ and $\beta = 0.47$.

QuikScat (Ku-band) wind with change in MO stability length scale

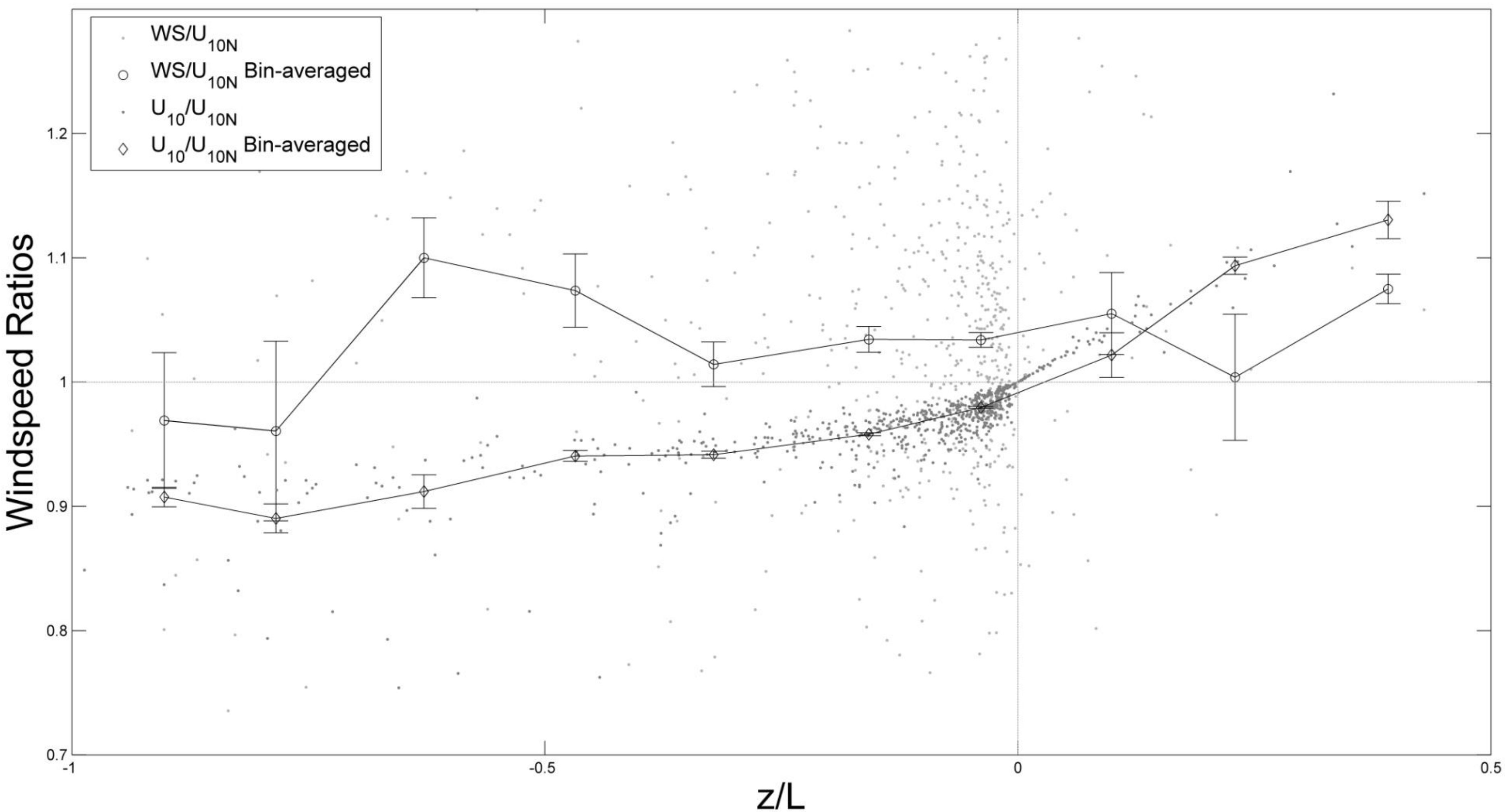


Conclusions: With present DOF (climode analyses), the quikscat data

a) clearly depart from the anemometer 10 m wind
b) follow an ENW (e.g. $\psi(z/L)$ of Coare3.5/LKB) to within a few %
c) some possible over and under shoot hinted at for extremes in z/L

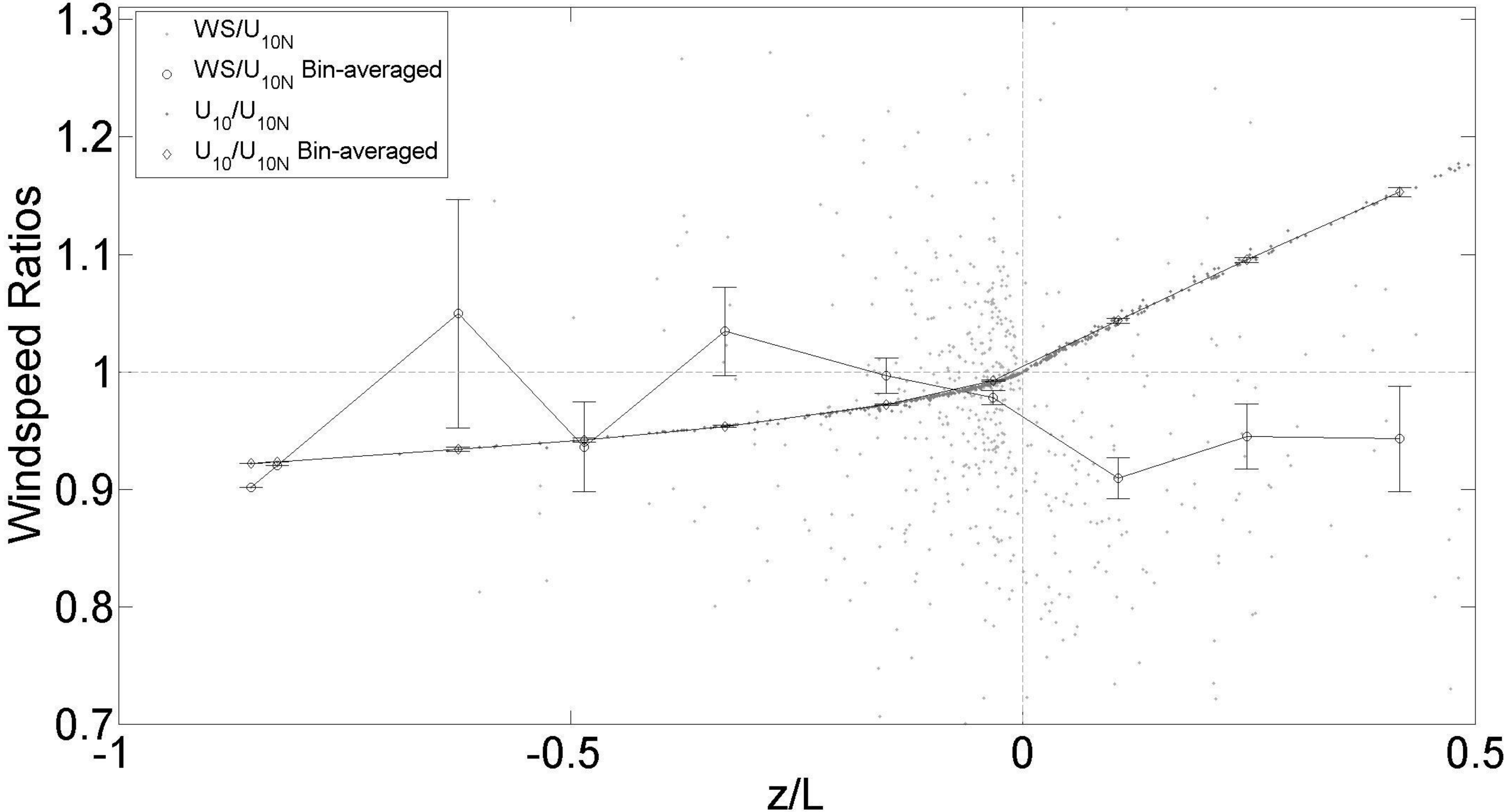
Windsat (MF) wind with change in MO stability length scale

WINDSAT vs. InSitu



ASCAT-A (12km) wind with change in MO stability length scale

ASCAT-A vs. InSitu



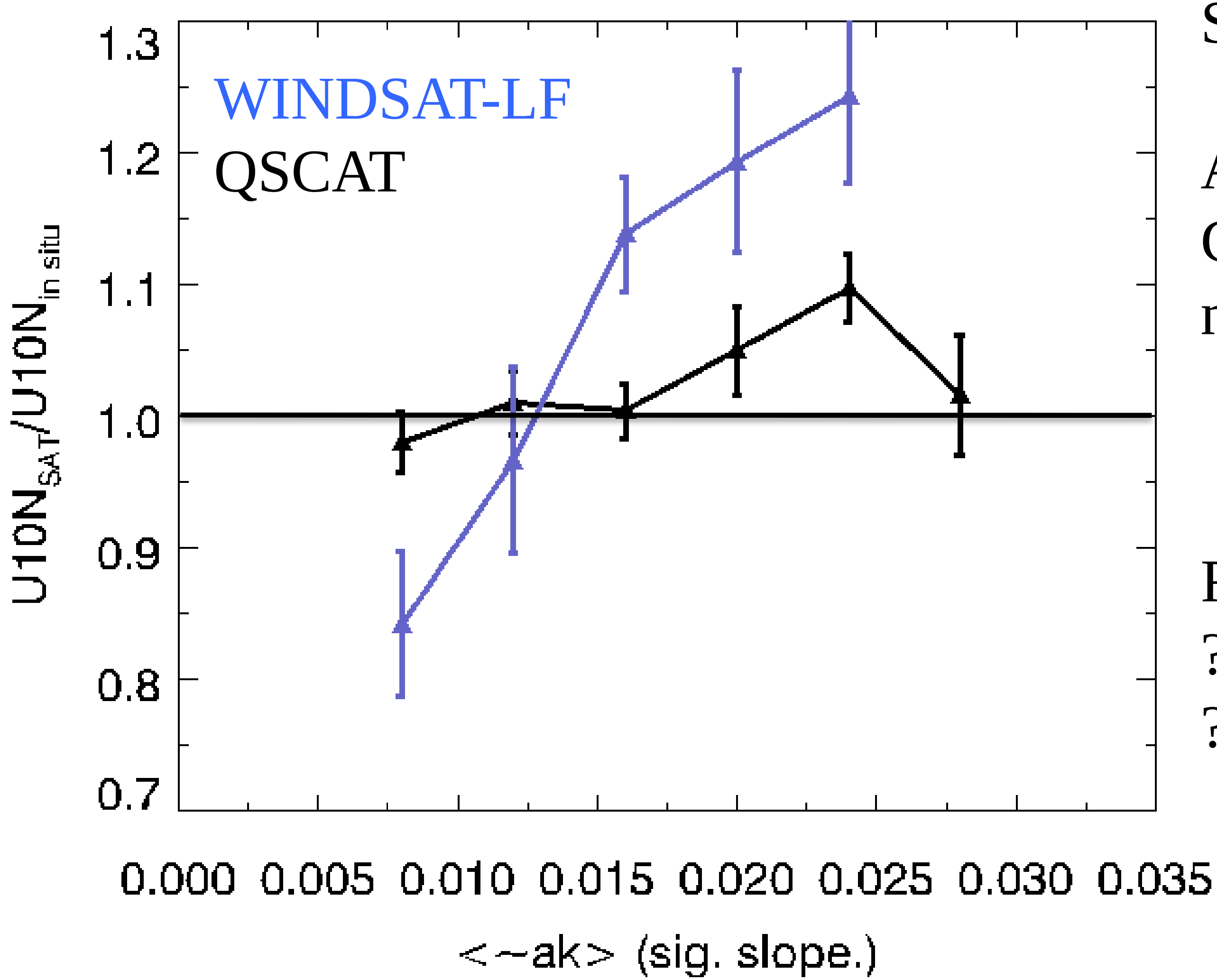
Drag Coefficient

Drag Coefficient

$\boldsymbol{\tau}_{\mathbf{a}} = \langle \rho_a \cdot C_{d10EN} \rangle \cdot |\mathbf{U}_{\mathbf{10EN\_sat}}| \cdot U_{10EN\_sat}$

$U_{10EN\_sat} / U_{10EN\_InSitu} = \sqrt{[\, C_{dN10} / \langle C_{dN10} \rangle \,]} = F\,(\text{sea state?})$

U = 6 +-/ 1 m/s



So a reminder of

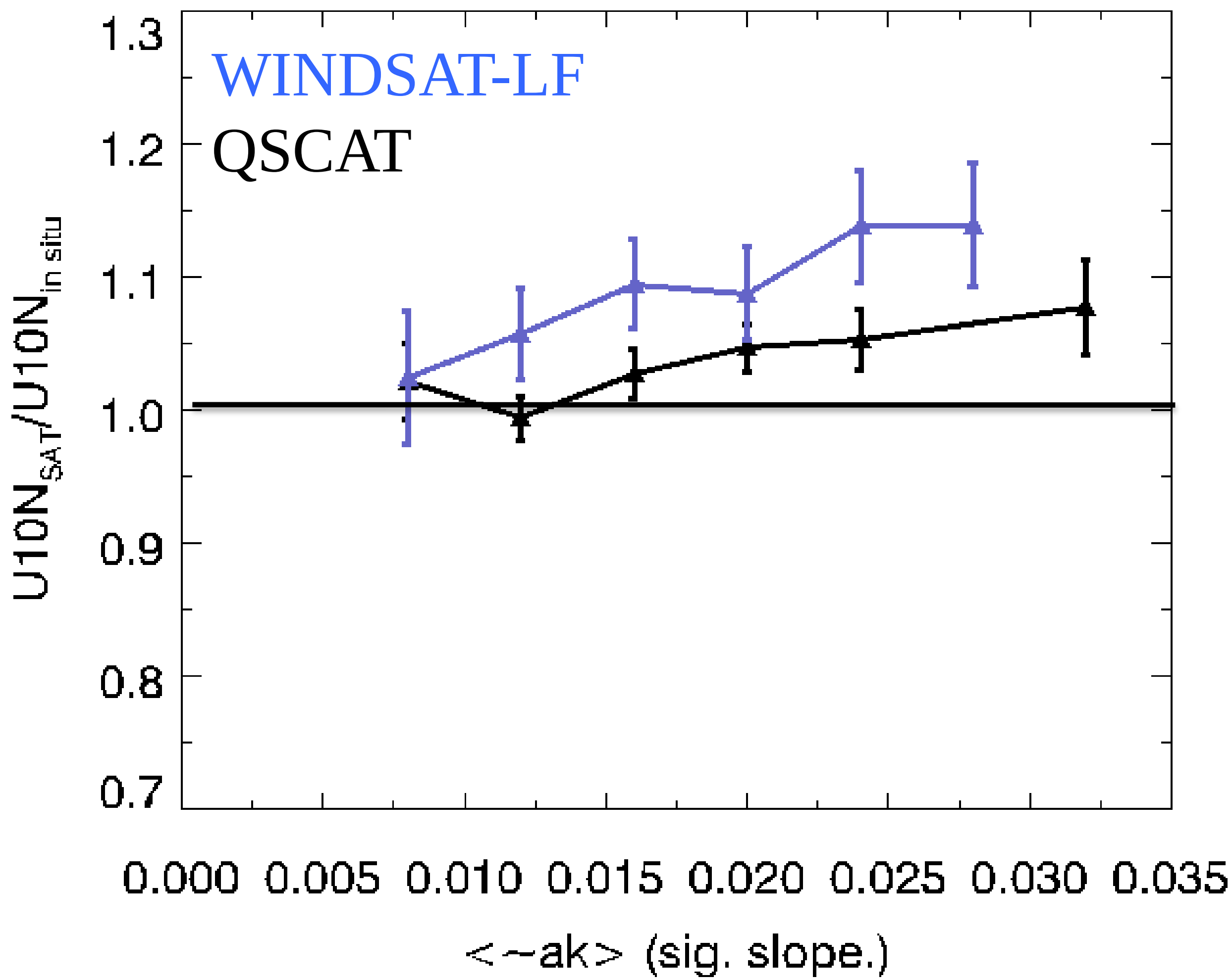
Air-sea flux issue
CdN10 (z_0) = F(u*, u*/Cp, aK, mss)

+

Remote sensing issues:
? $z_{0SCATT} \sim= z_{0Radiom}$?
? $z_{0L\_SCATT} \sim= z_{0Ku\_SCATT}$?

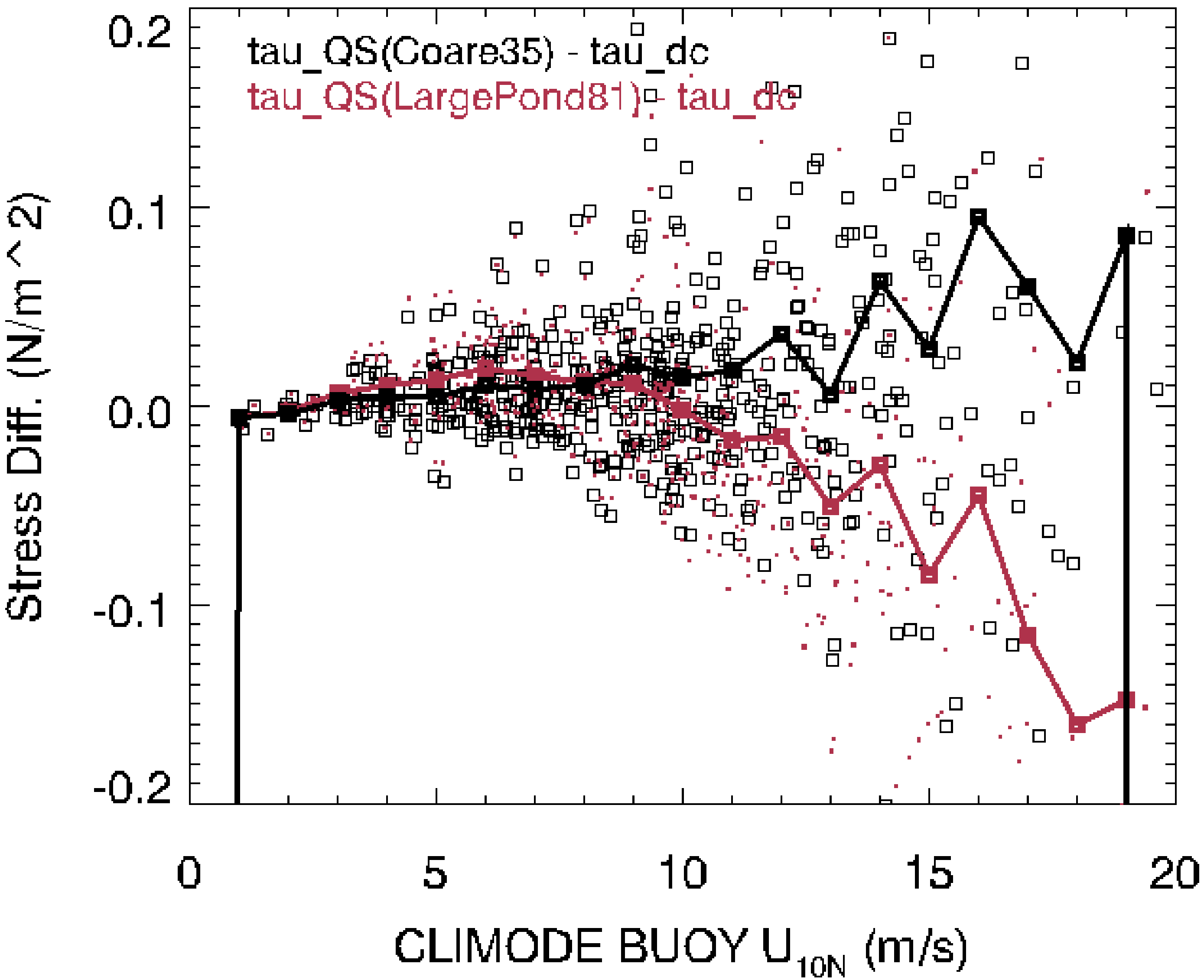
Drag Coefficient

U = 8 +-/ 1 m/s



TRANSLATING U_{10EN_SCATT} to τ

Scatterometer-derived stress with varied Cd(U_scatt) vs. direct covariance stress
- an example using QuikSCAT and the CLIMODE data...



CURRENTS

Scatterometry and currents

- According to surface layer models, we assume that near surface wind should follow the kinematic boundary condition, i.e.:

$$U(z) - U_s = \frac{u_{*a}}{\kappa}\left[\ln\frac{z}{z_0} + \phi(z, z_0, L)\right]$$

surface current

- But:
  - scatterometer winds are derived from short grav.-capillary wind waves – do they obey this form?
  - the few existing scatterometer wind-current studies focus mostly on the equatorial region
  - and/or use only climatological currents & winds
  - or non-surface current measurements (e.g 10m depth)
  - and don't quantitatively validate the assumption

Dickinson et al. 2001; Kara et al. 2007; Kelly et al. 2005; Quilfen et al. 2001

Approach – use Gulf of Maine tides

http://app2.iris.usm.maine.edu/gulfofmaine-censusdev/wp-content/images/circulation/fig4.jpg

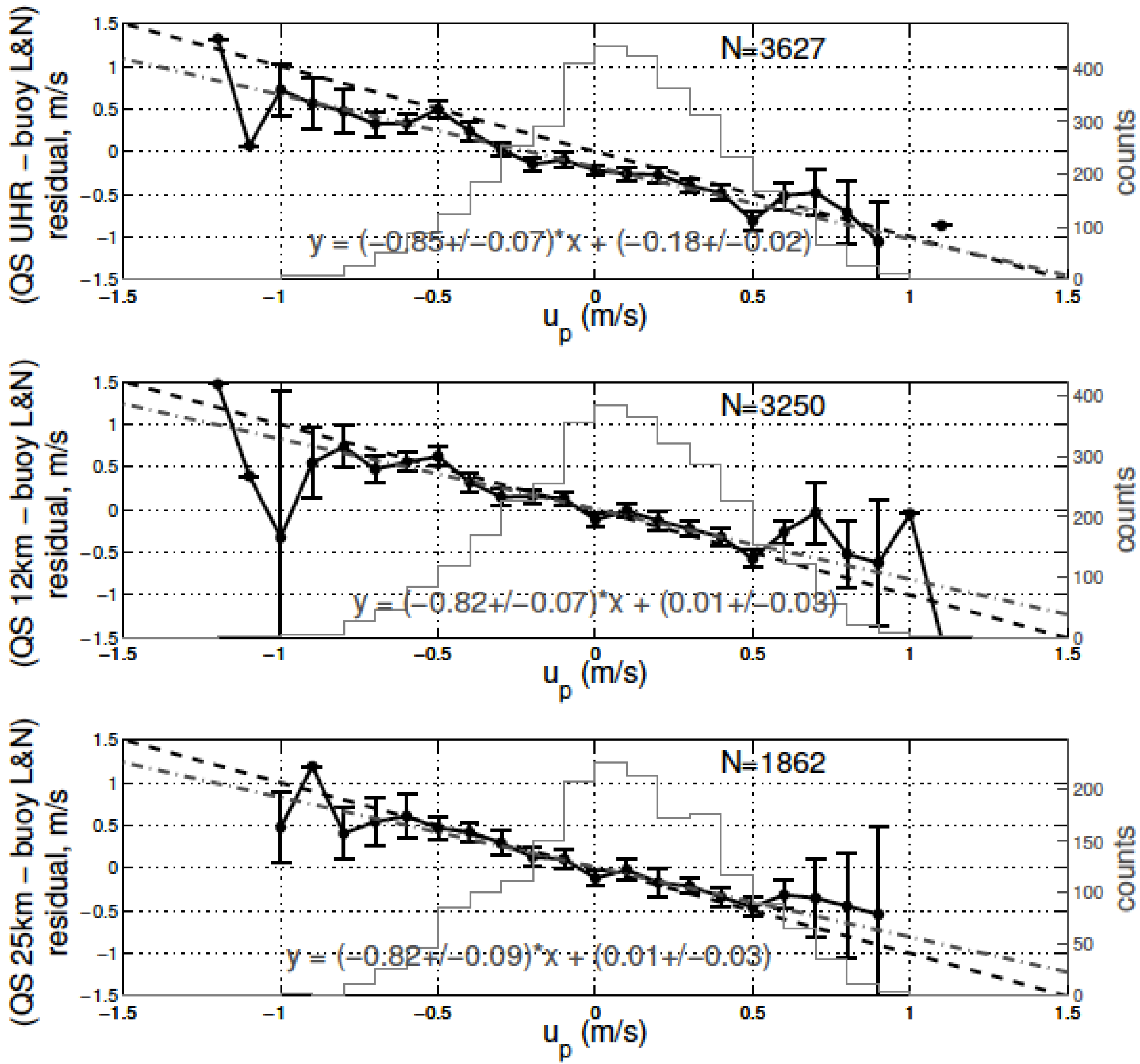
QuikSCAT and buoy wind speed residuals vs. projected current

All data - all wind speeds & conditions

Slope: -0.83 +- 0.07 != 1:1

weighted LS fit

black dashed line indicates *y = -x*

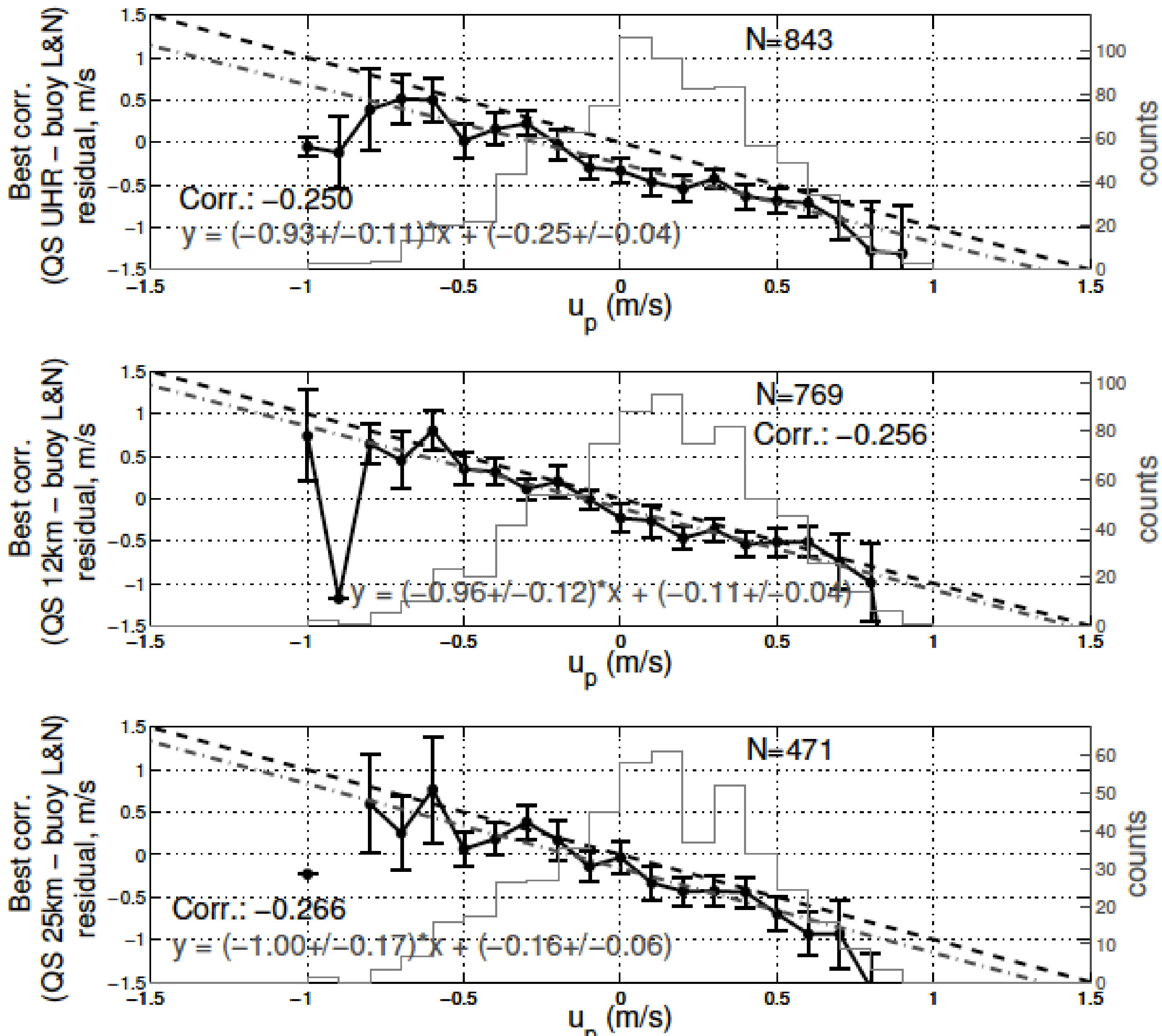


QuikSCAT - buoy wind speed vs. projected current

Conditional filtering:

Moderate wind speed &
near neutral atmos. stability

Slope: 1.0 +- 0.17



weighted LS fit

black dashed line indicates $y = -x$

One Mea Culpa re: ASSCAT-A; Surface currents at C and Ku-band

Plagge et al., Examining the impact of surface currents on satellite scatterometer and altimeter ocean winds, doi: http://dx.doi.org/10.1175/JTECH-D-12-00017.1, 2012

Orig Conclusion: Unexplained earth- vs. current- relative wind difference between the coastal, 12 and 25 km ASCAT wind product. Hypothesis: to do with resolution/smoothing...

Figure from Paper

PLAGGE ET AL.

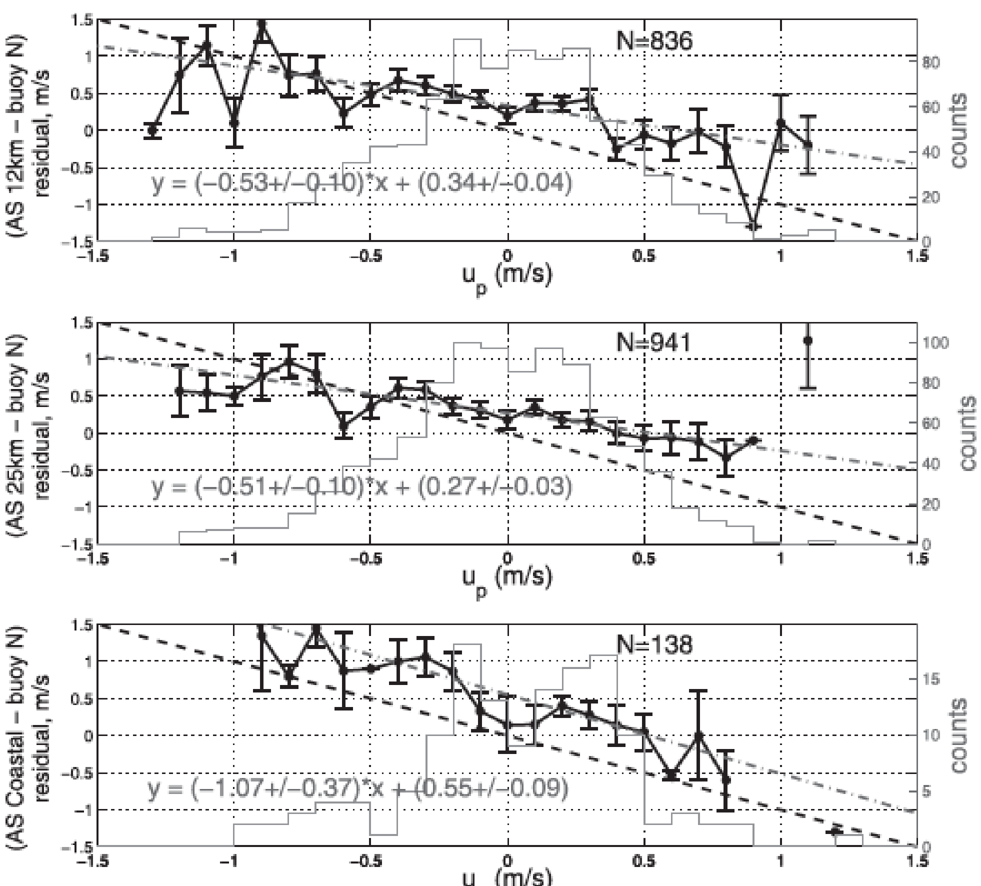
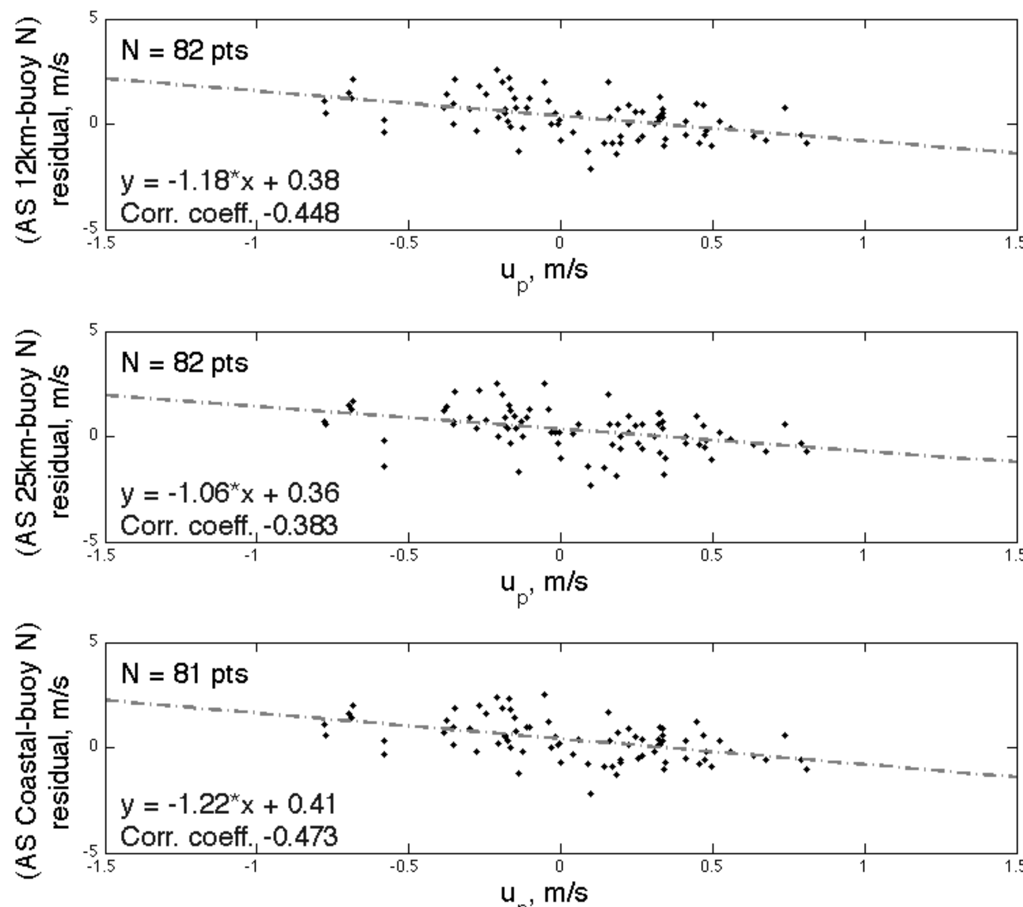


FIG. 10. Wind speed differences (ASCAT − buoy) binned according to u_p (see Fig. 9 for correlations).

New Result, same time and DOF



Source of error: unknown but tied to a time evolving error in colocation of satellite and buoy data 2009-2011 for 12 and 25 km data

New Conclusion: As for Ku-band, we see a trend in earth- vs. current-relative wind that is similar for all three ASCAT resolution products. No difference between the coastal and 25 km product.

PLAGGE ET AL.

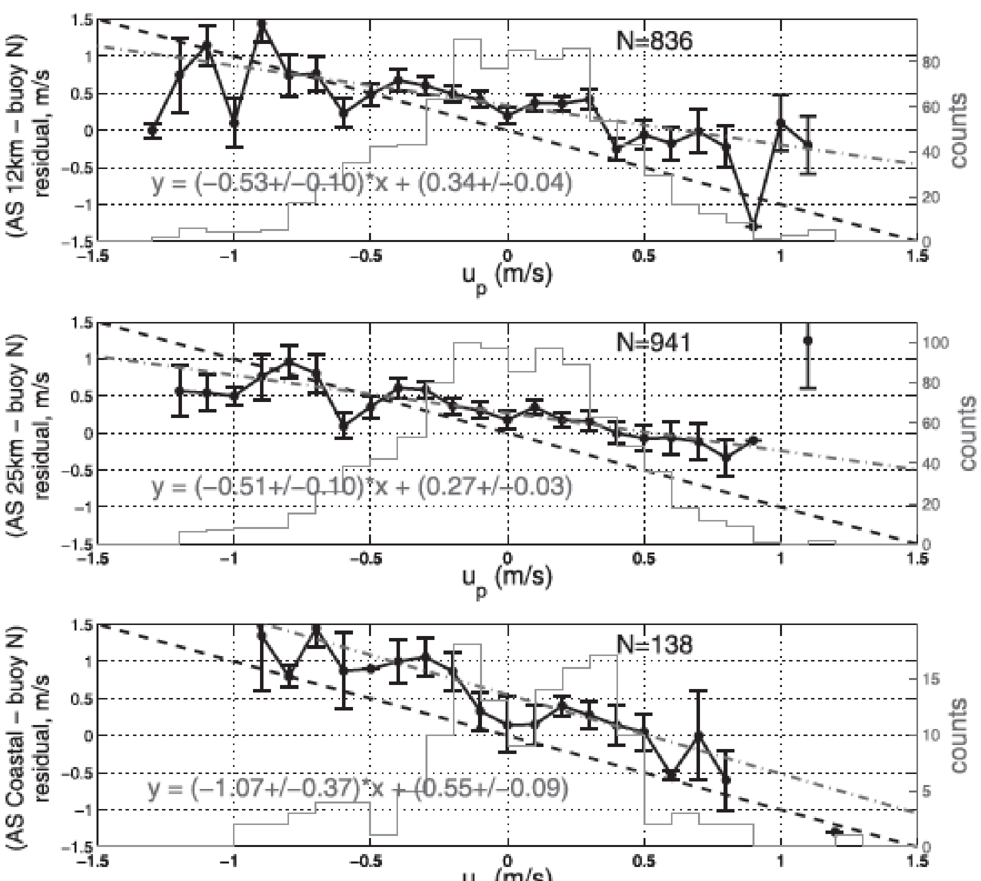
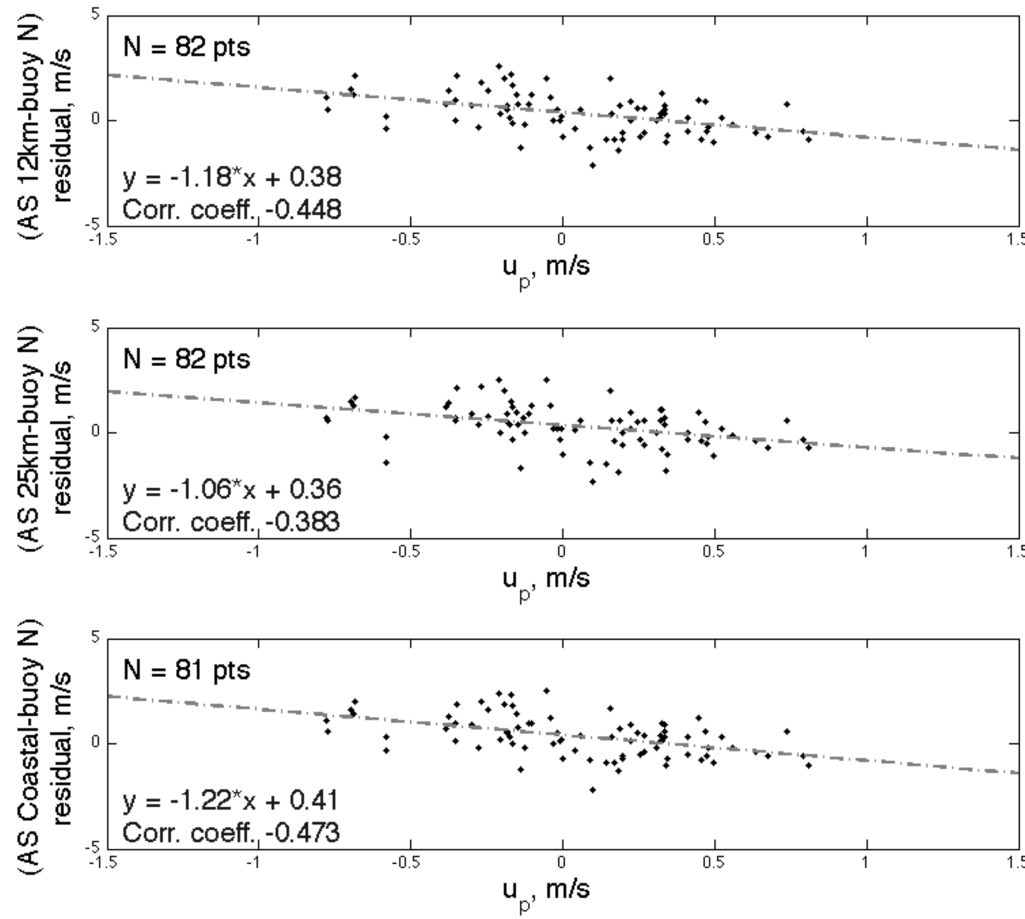


FIG. 10. Wind speed differences (ASCAT − buoy) binned according to u_p (see Fig. 9 for correlations).



Summary

Need exists to further solidify the links between wind stress and ocean satellite winds for all the platforms including scatterometers (C, Ku, L) but also the radiometer and altimeter systems

One approach is via direct validation against direct covariance field datasets

Validation database in development & input welcome on particular satellite products to ingest – open access in next year

First results indicate further evidence and estimate uncertainty related to air density and forward steps re: atmospheric stability (more difficult to isolate)

Drag coefficient 'issue' most likely to divide the sensors

Some next steps

- Fold into the stress and CDR working group goals
- Combination of ASCAT, direct covariance and 7 bulk met buoys in GoMaine region to assess ASCAT under stable MABL condition, for Cd under short fetch, and for SST impacts (e.g. Grodsky et al. 2012)
- Is there a case for more or more targeted (e.g. process/location) platform deployments?
- Guidance for triplet, ship or buoy colocation revisits?
- Expand flux/satellite OW database with known coming DCFS buoy sets including OOI and perhaps SPURS II
- Expand datafields (Tb, sigma0, wavefield statistics)

Thanks to NASA, ESA, and NSF for funding support