Accuracy and Stability of Satellite Winds for Tropical Climate variability Studies

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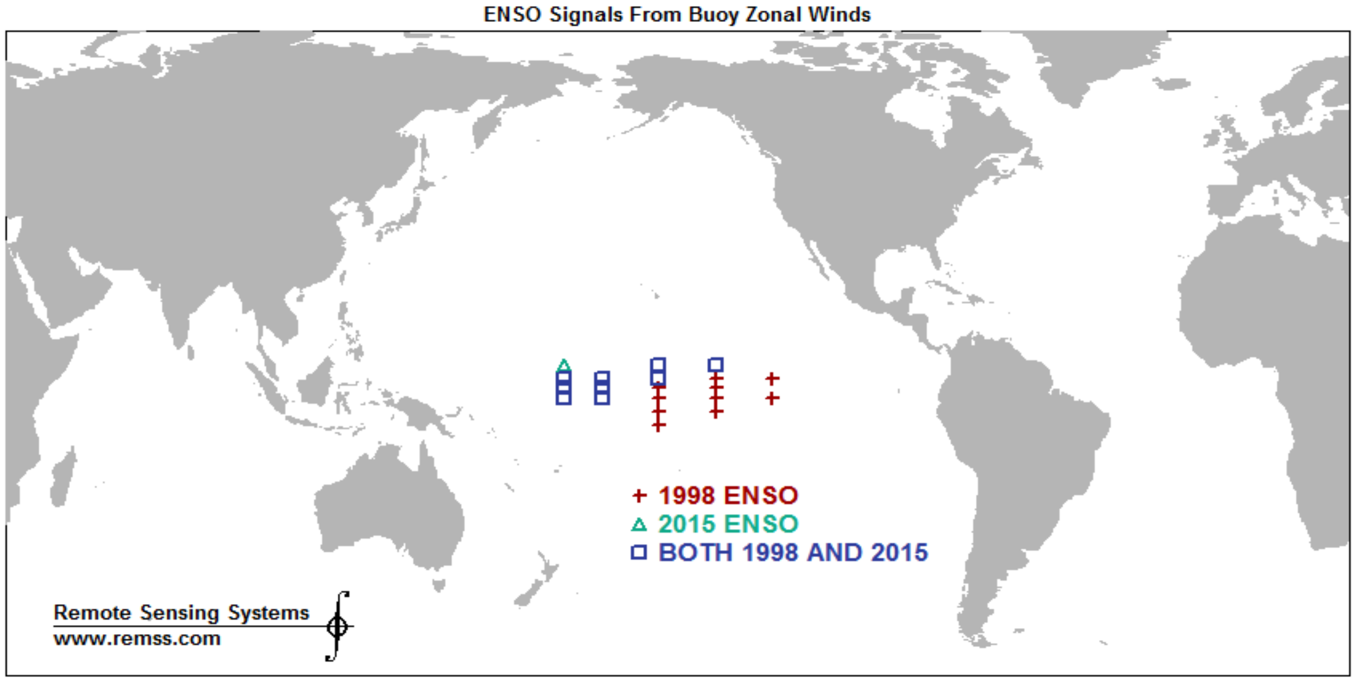

TAO Buoys with strong ENSO signal

Acknowledgements: This work is supported by the NASA OVWST and Phys. Oceanography

Motivation

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- Past years were devoted to achieve consistency for different Ocean Surface Wind retrievals coming from different satellites, scatterometers and radiometers
- Based on two "calibration targets" :
  1. Radiometers intercalibration: Use common radiative transfer model RTM V7/V8 calibrated to buoys, aircraft
     (Meissner and Wentz, 2012; Meissner et al, 2014)
     Tb (1.2-37 GHz)→ Emissivity Model (1K accuracy) → wind retrieval (1 m/s accuracy)
  2. Scatterometers GMF: GMF based on millions of rain-free collocations with radiometers
     (Ricciardulli and Wentz, 2015; Ricciardulli, 2016)
     Backscatter(Ku , C-band)=f(w, dir,Inc angle, pol, SST, freq) →wind retrieval (1 m/s accuracy)
- With this method we achieved a Global Monthly accuracy of ~ 0.1 m/s (Wentz et al., 2017)
- **Yet, studies of tropical climate variability often rely on buoys only, supported by reanalyses used as observations**
- Often this is due to out-of-date information on satellite data accuracy and consistency, and difficulty/misuse with quality control of satellite data

Objective

- Focus on accuracy and consistency study in the TAO buoy array area and prove quality of the satellite wind record
- Summarize results in paper aimed at the climate variability community to increase confidence in satellite data
- Suggest framework for other groups/datasets to verify satellite wind consistency with buoys

BUOY-SATELLITE DATA COLOCATIONS

- Used only TAO array BUOYS, 1988-current
- Buoy data: Hourly averages (from 10-min original data), converted to 10m height, and the actual buoy location (not the nominal) is used here for colocation with satellite data
- Scatterometers and radiometers: 10m EN winds, daily gridded maps, 0.25 deg, asc/desc: 30 min colocations
- Rain flags: Strictly Rain-free only. Very important for consistency study.

SATELLITE MISSIONS	period	Local Time
QSCAT	1999-2009	6 am/pm
ASCAT	2007-current	9:30 am/pm
WindSat	2003-current	6 am/pm
TMI	1997-2014	All
GMI	2014-current	All
AMSRE	2002-2011	1:30 am/pm
AMSR2	2012-current	1:30 am/pm
SSMI/SSMIS F08,F10,F11,F13,F14,F15,F16,F17,F18	1988-current	Varies

Details of analysis

1. For each buoy/satellite dataset: We developed pairs of daily timeseries (U,V, W) for buoy and colocated satellite at each buoy location only when satellite pass occurred
2. We averaged all daily timeseries for all TAO buoy locations
3. Built statistics using daily timeseries for individual buoys
4. Analyzed timeseries of individual buoys and average over TAO array, daily and 30-day smoothed

SAMPLE BUOY 51010 VS QSCAT: ZONAL WIND

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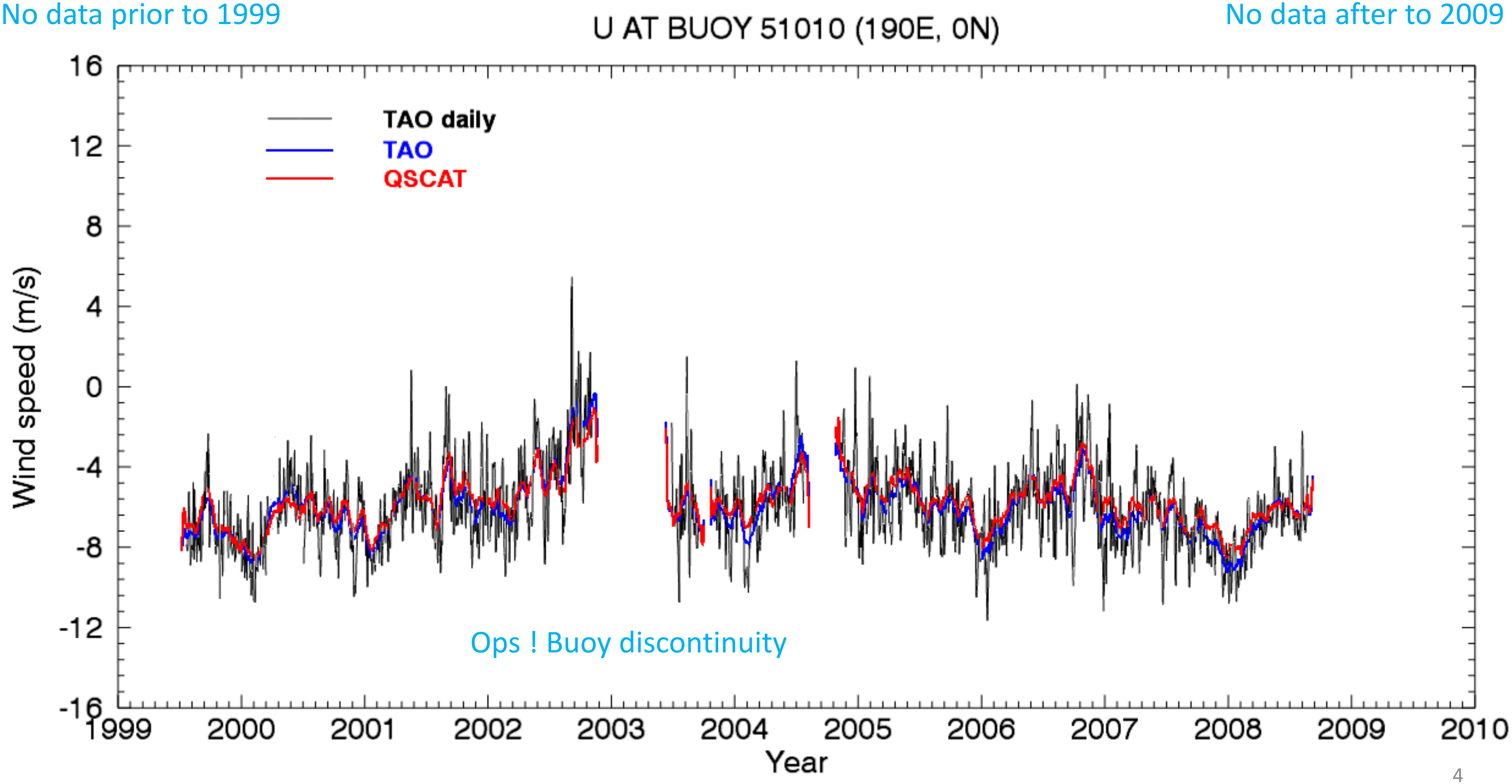
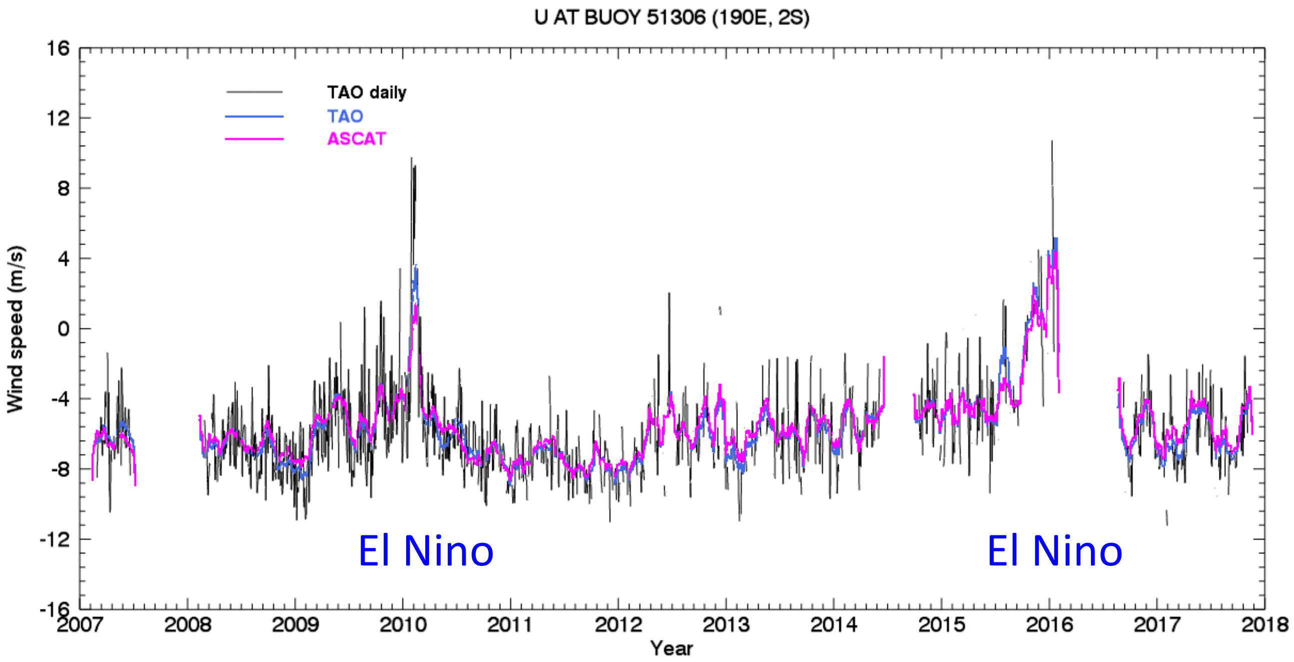
No data prior to 1999

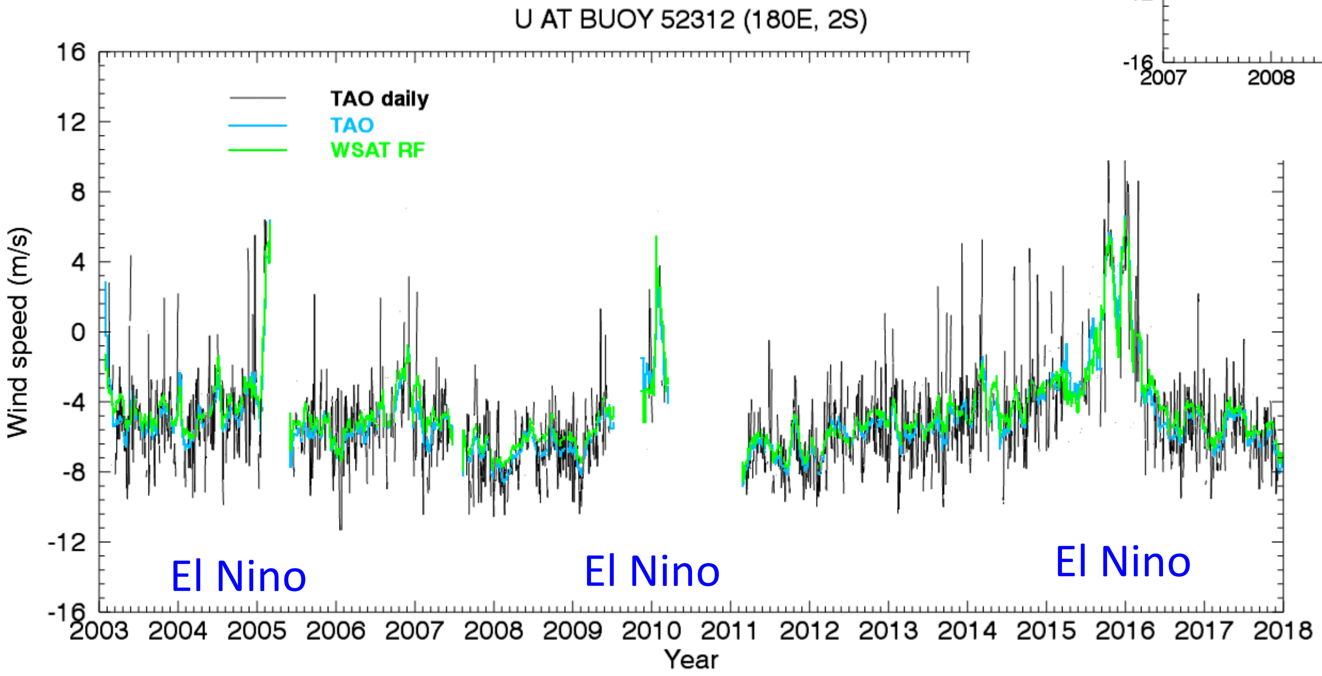
No data after to 2009



U: ASCAT AND WINDSAT VS SAMPLE BUOYS

ASCAT vs 51306





WSAT vs 52312

U, V, W: AVERAGE OVER ALL TAO BUOYS

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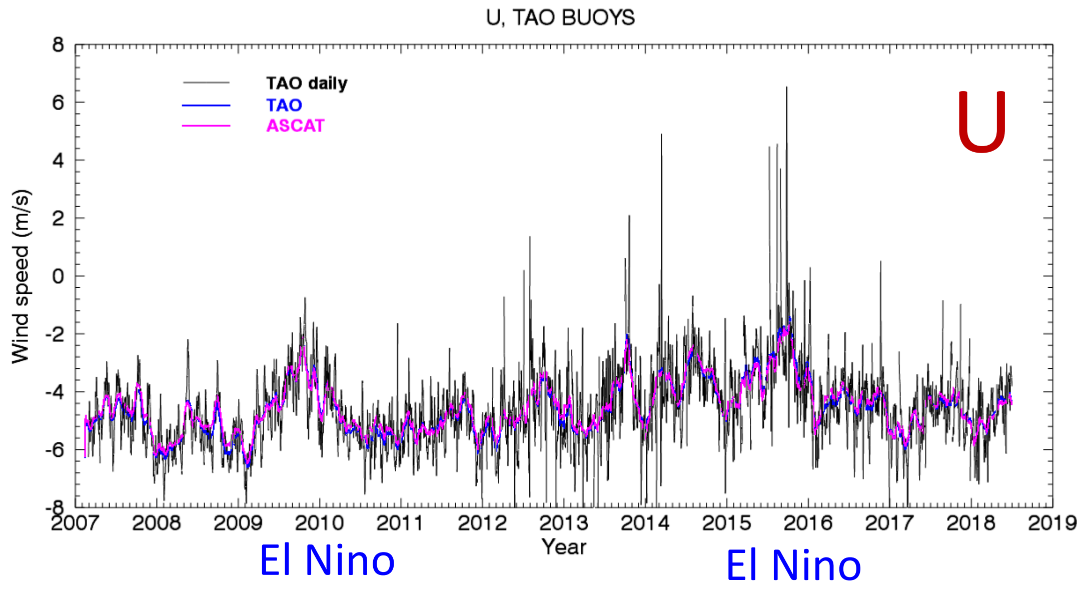
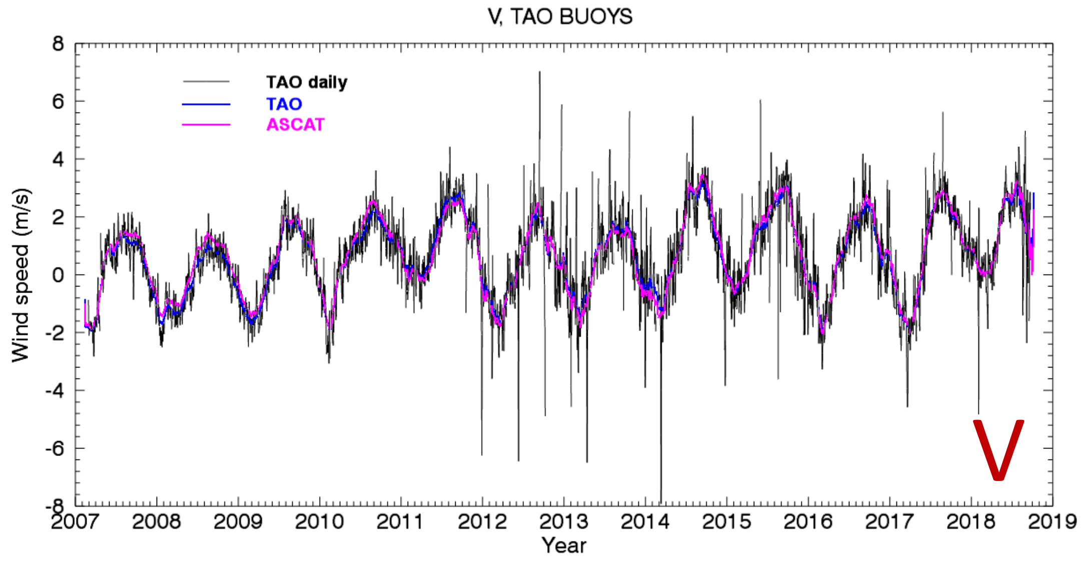
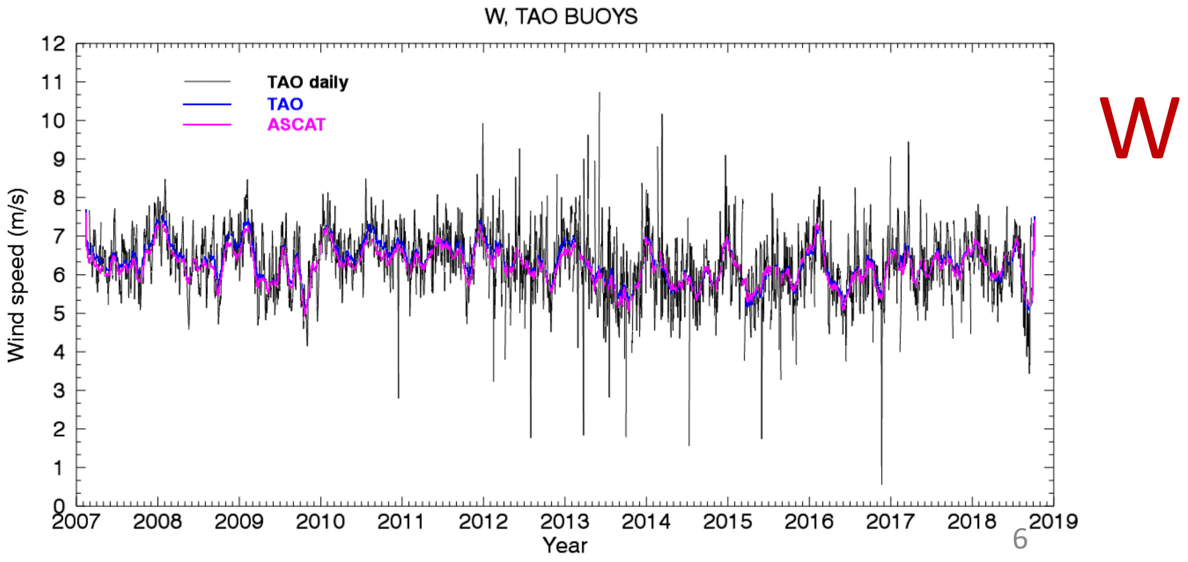


- Working with single buoys/single sensors is challenging
- Issues: discontinuities, noise in measurements, effects of currents…
- Timeseries were created for each buoy of the TAO array (1988-2018) colocated with each sensor: SSMI, SSMIS, TMI, QSCAT, AMSRE, WindSat, AMSR2, ASCAT, GMI.
- For each sensor/TAO buoy colocation set, we averaged all the daily timeseries for U, V, W to produce an average satellite and TAO colocated U, V, W timeseries using all TAO buoys





BUOY-SAT U COMPARISONS: QSCAT, ASCAT, WSAT

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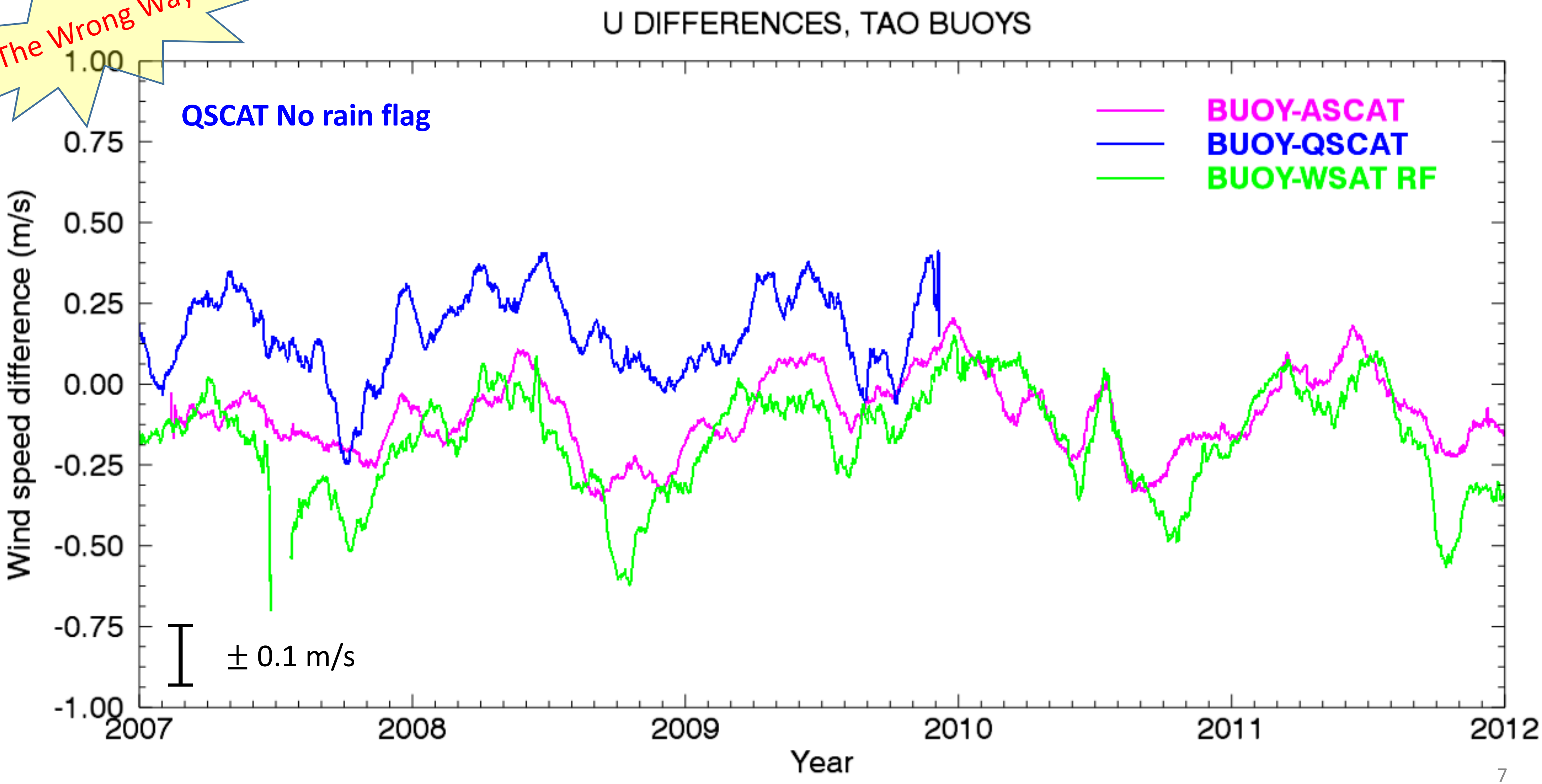
The Wrong Way



BUOY-SAT U COMPARISONS: QSCAT, ASCAT, WSAT

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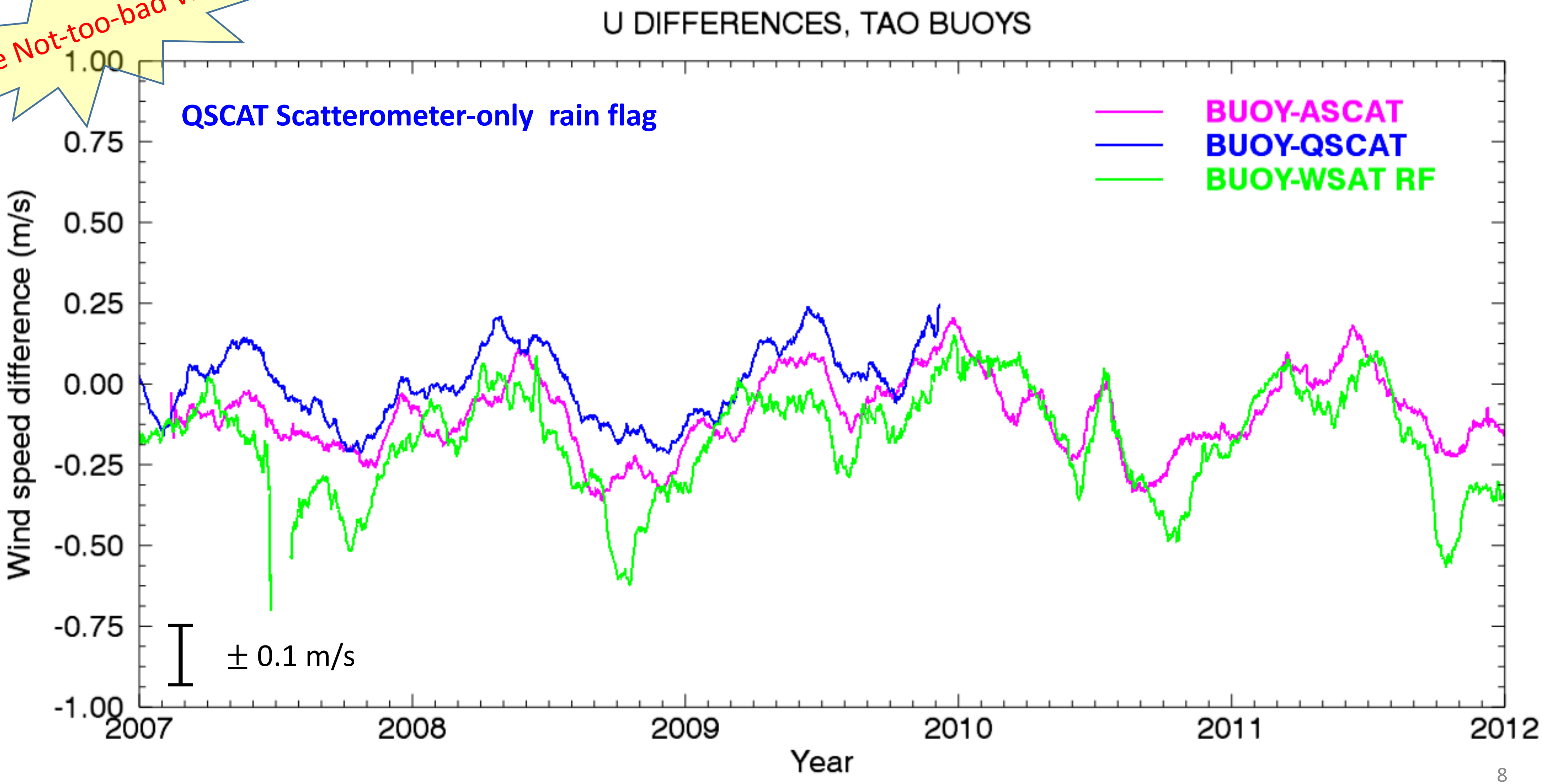
The Not-too-bad Way



BUOY-SAT COMPARISONS : QSCAT, ASCAT, WSAT

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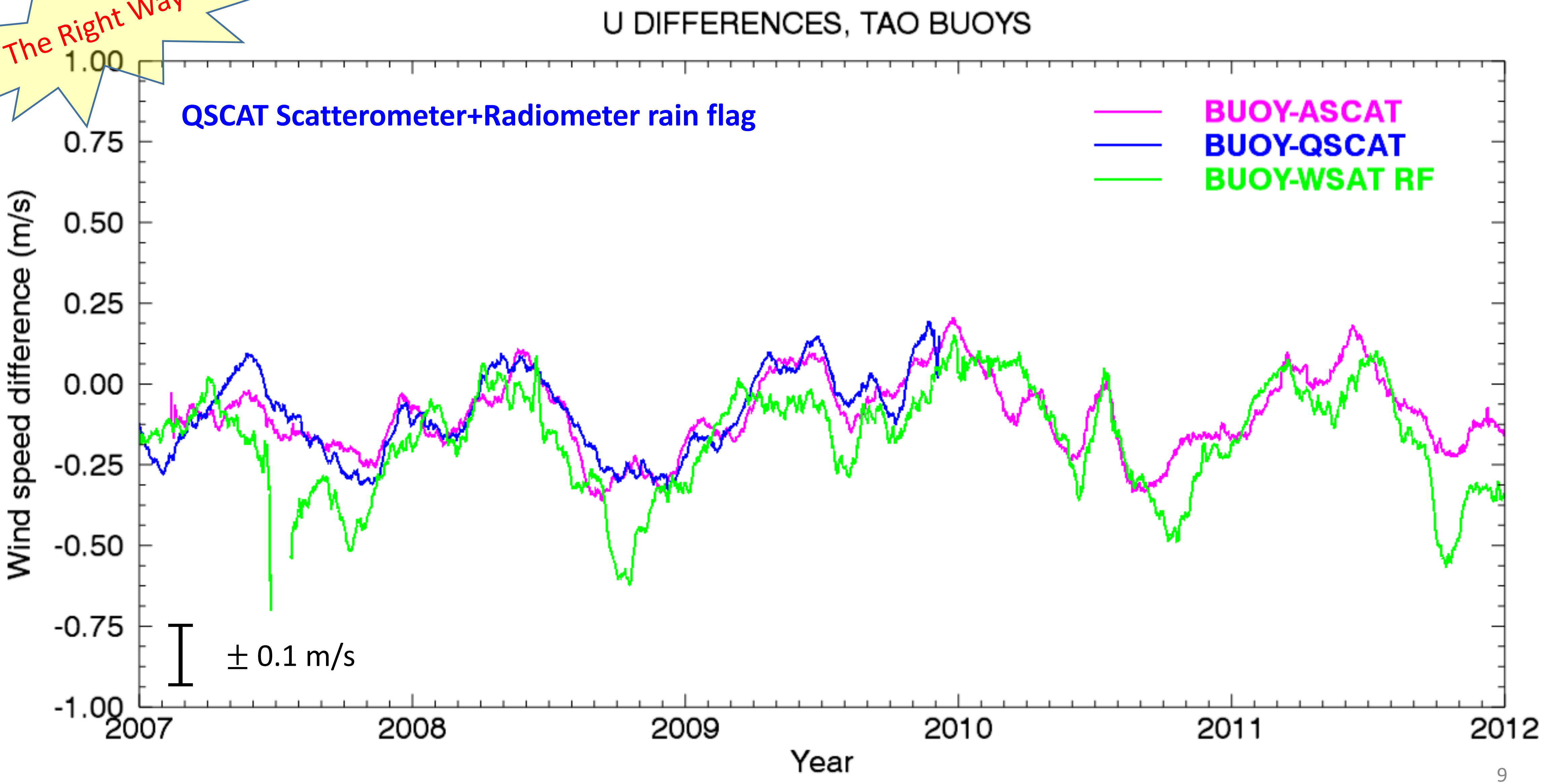
The Right Way



BUOY-SAT W COMPARISONS: 2007-2012

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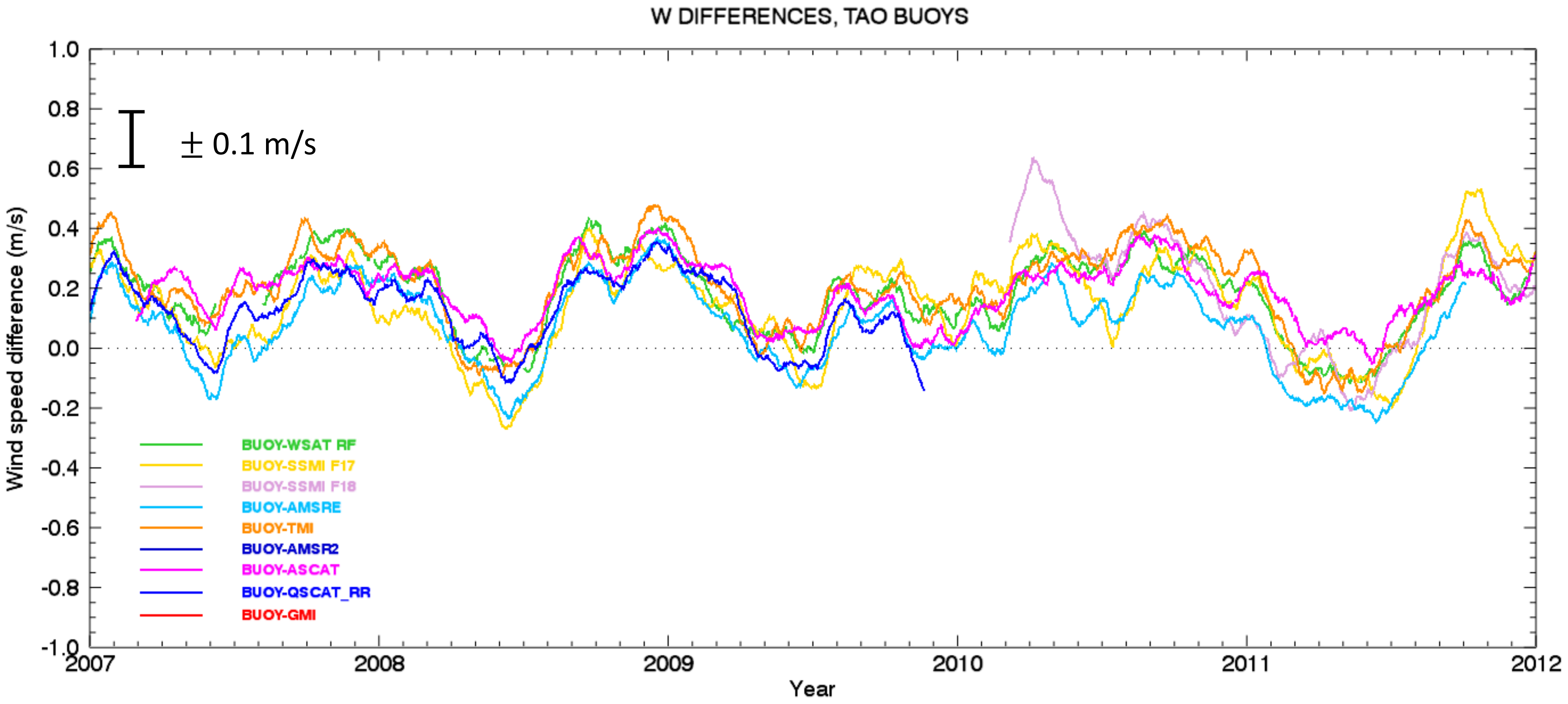

BUOY-SAT W: THE BIG PICTURE 1999-2018

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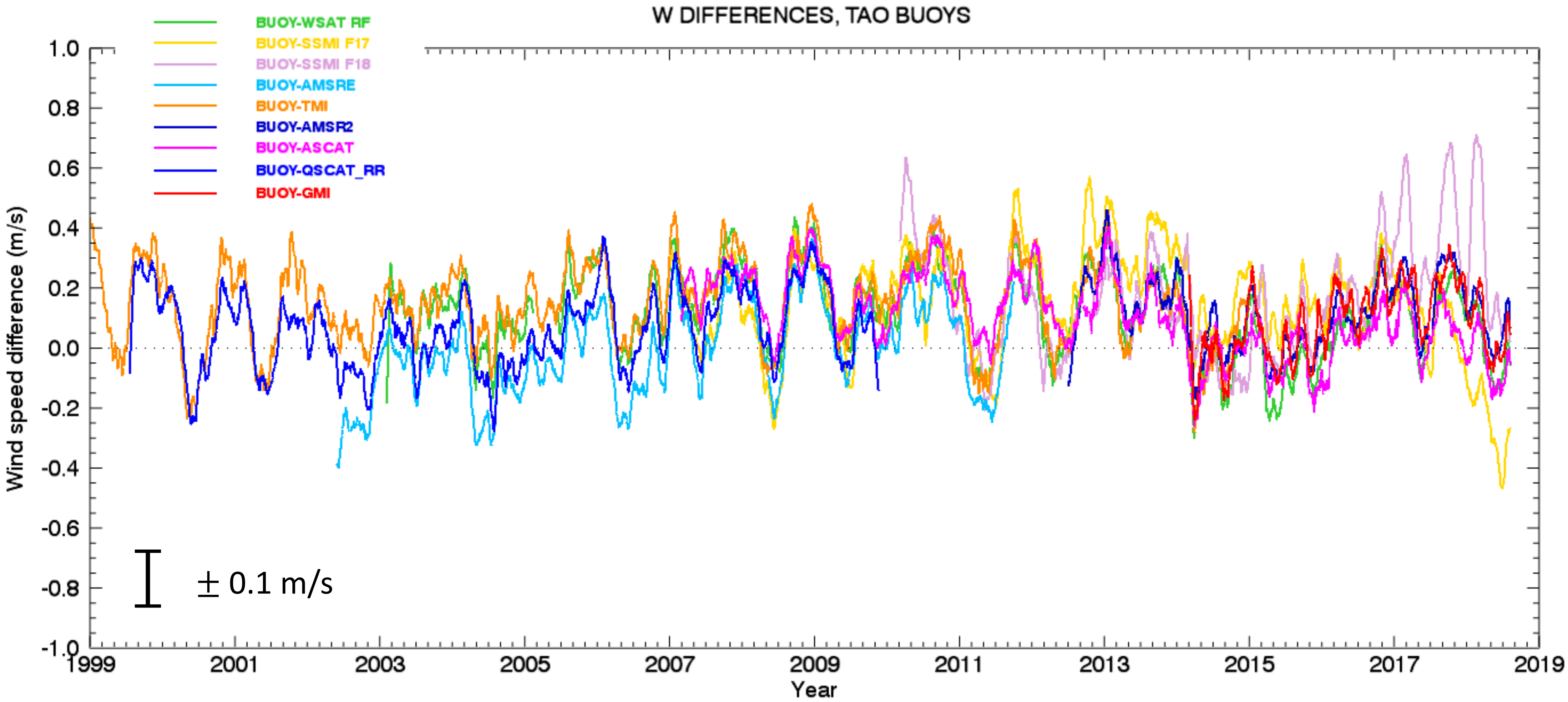
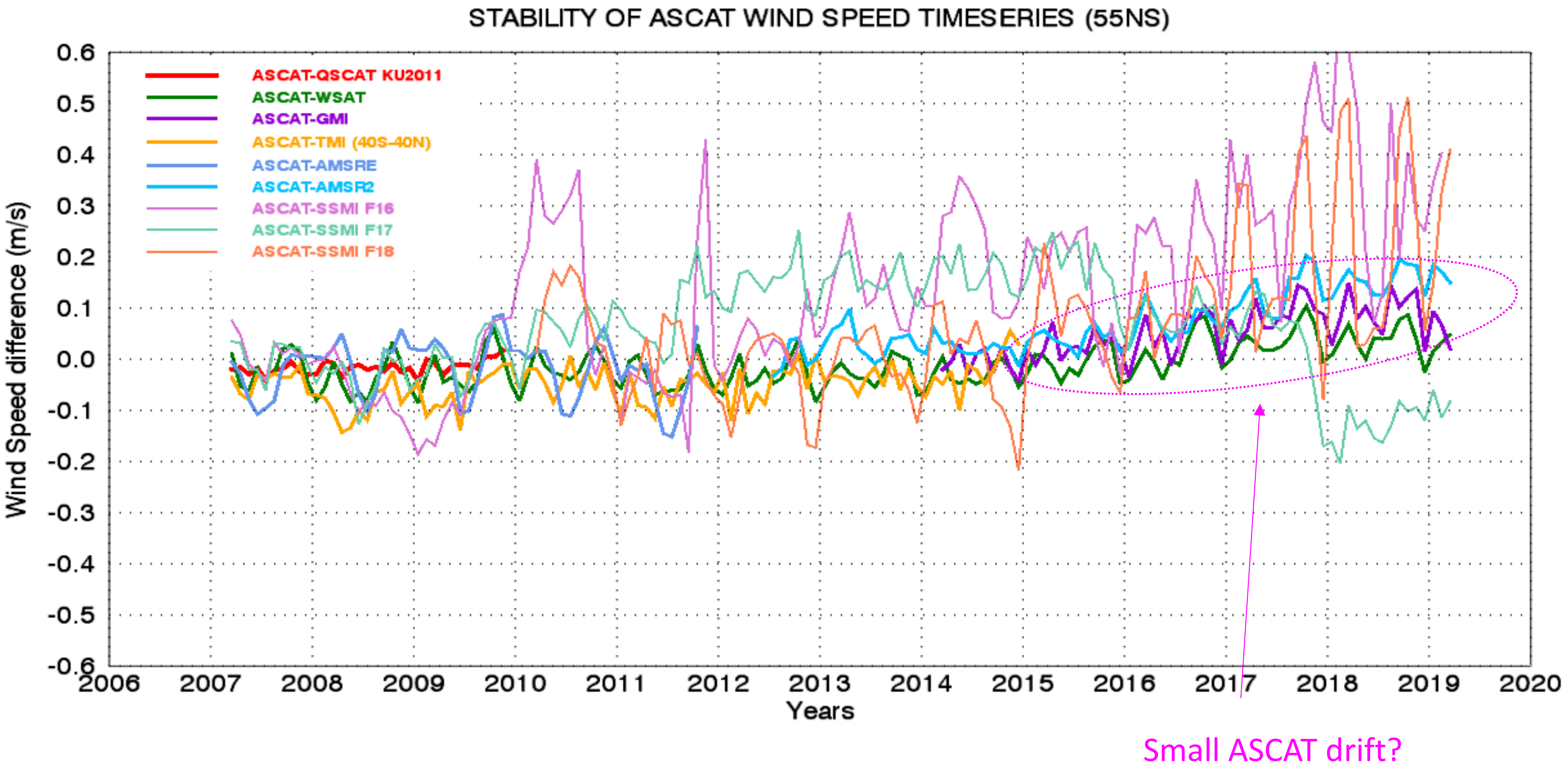


- Mostly within 0.1 m/s within each other.
- Difference with buoys have seasonal cycle, currents et al.
- Instabilities/swings: F18 (pink), F13 (not shown)
- Drifts: F17 (yellow) after 2017; very small ASCAT (magenta) drift, after 2016 (see next slide)

2018 OVWST: ASCAT INTERCALIBRATION ANALYSIS



From GLOBAL comparisons between ASCAT and all other sensors

BUOY-SAT: ASCAT DRIFT?

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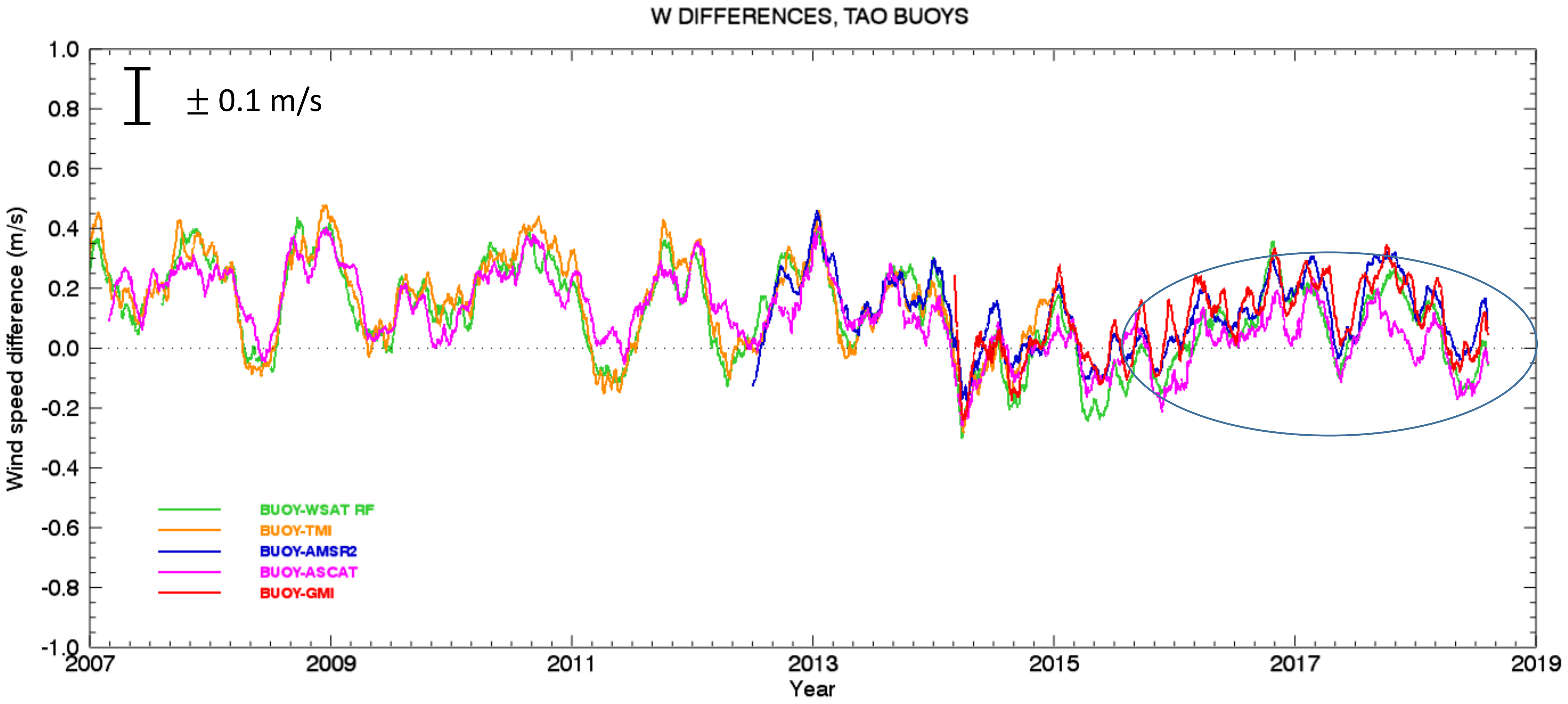

From comparisons between <u>differences with TAO buoys</u>, for ASCAT and all other sensors: Possible drift but harder to detect

What about Accuracy ? |U|, |V| and W

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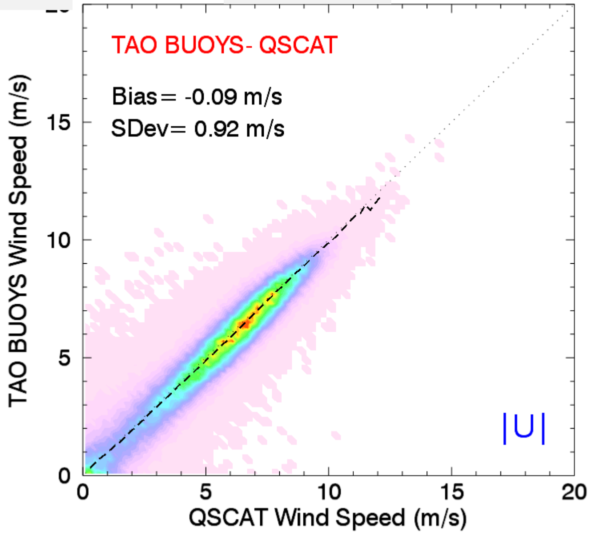
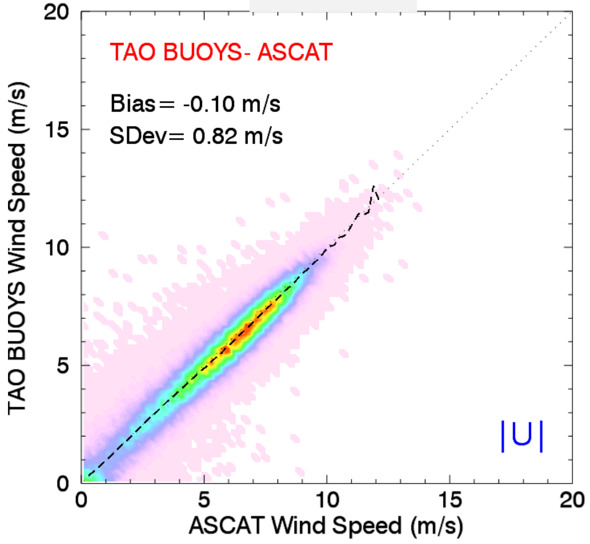
U comp

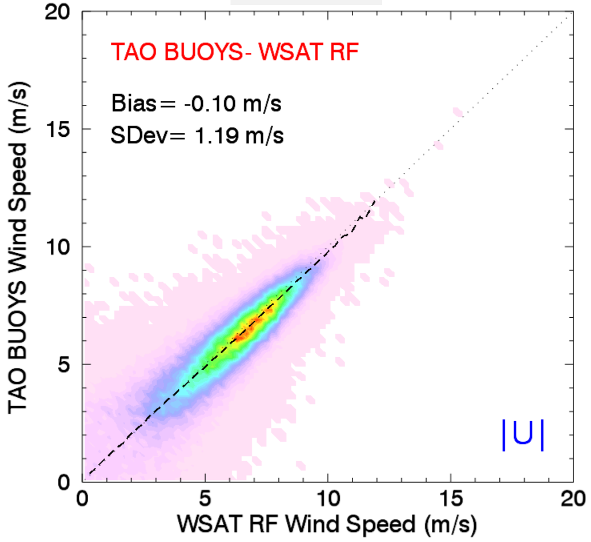
QSCAT



ASCAT

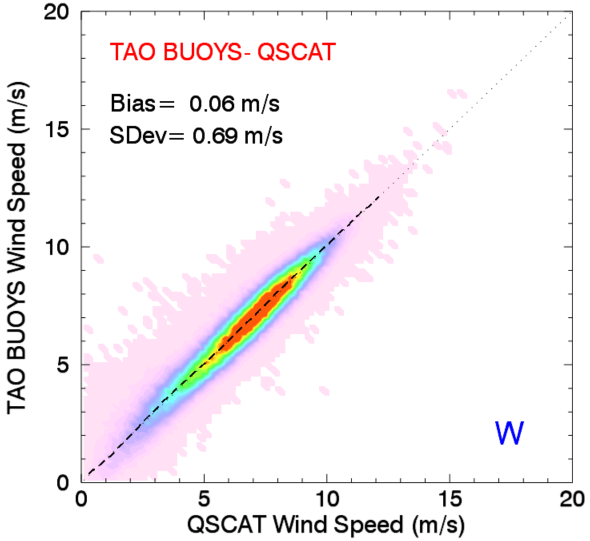


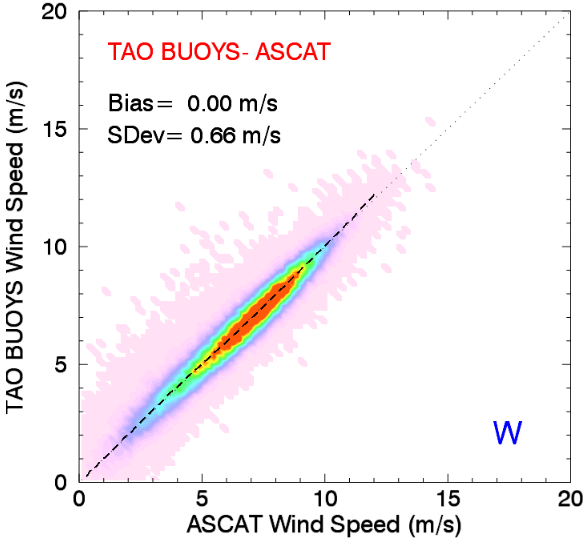
WSAT

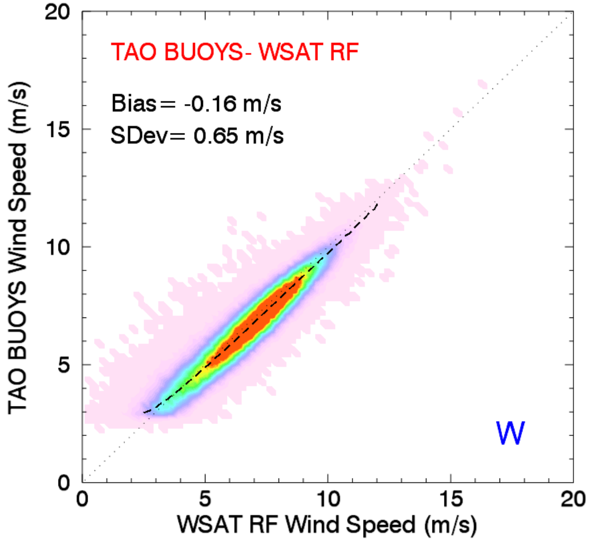


BIAS (m/s)	U	V	W
QSCAT	-0.09	0.06	**0.06**
ASCAT	-0.1	0.01	**0.0**
WSAT	-0.1	-0.06	**-0.16**

WSP







StDev (m/s)	U	V	W
QSCAT	0.92	0.93	**0.69**
ASCAT	0. 82	0.91	**0.66**
WSAT	1.19	1.43	**0.65**

Accuracy for Wind Seed, all Radiometers

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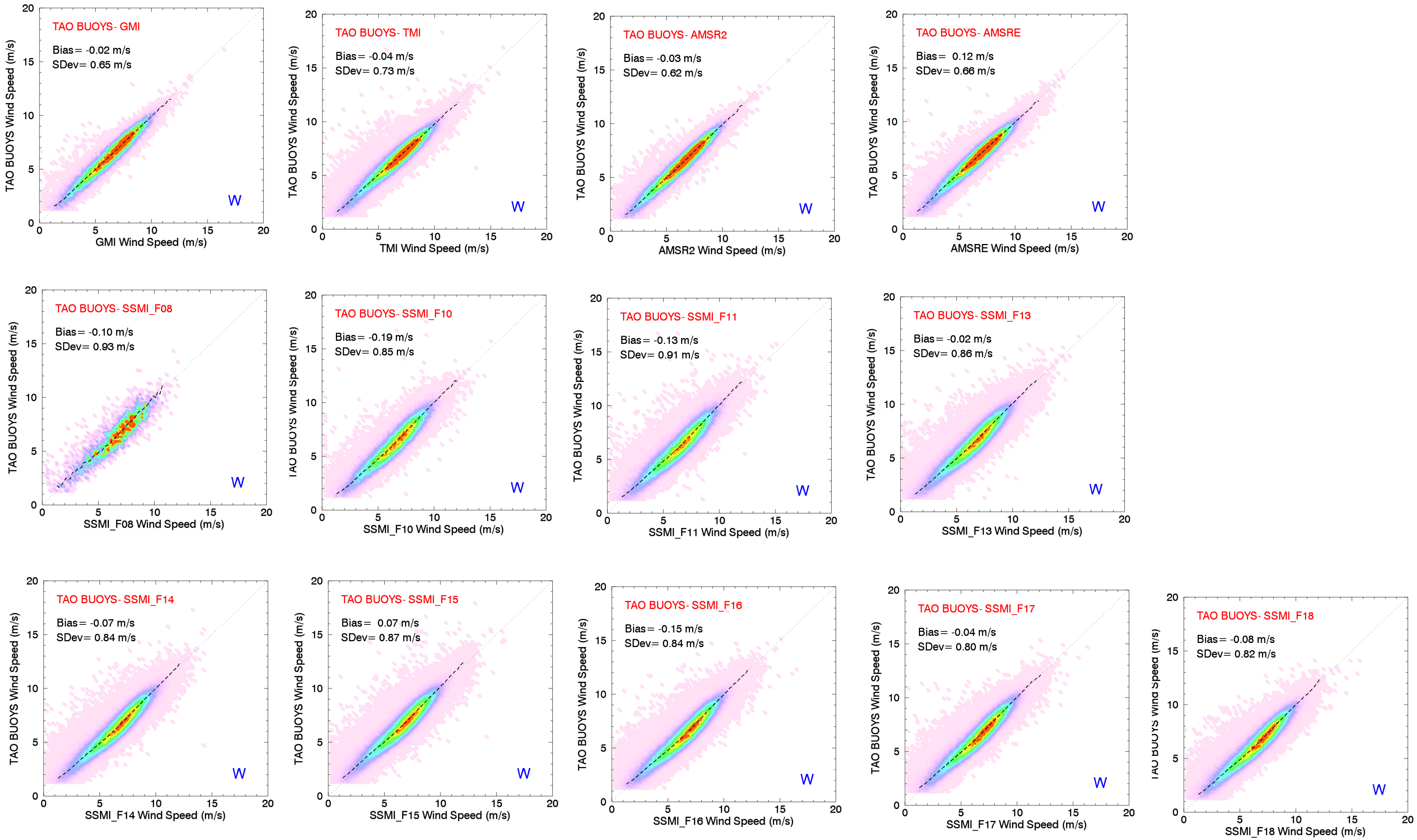


StDev (m/s)	W
GMI	0.65
TMI	0.73
AMSR2	0.62
AMSRE	0.66
F08	0.93
F10	0.85
F11	0.91
F13	0.86
F14	0.84
F15	0.87
F16	0.84
F17	0.80
F18	0.82

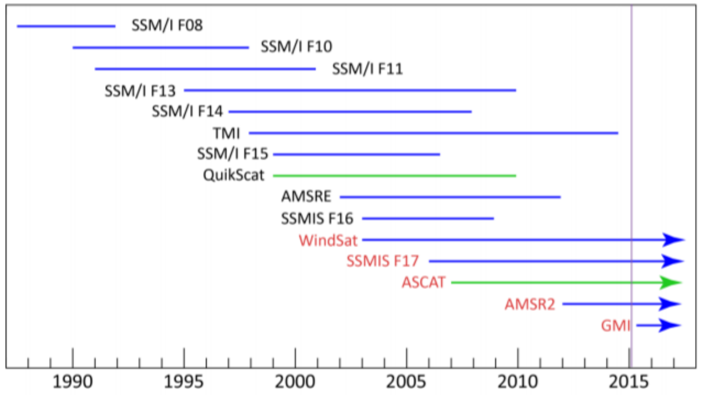
HOW TO USE SATELLITE DATA FOR ENSO STUDIES

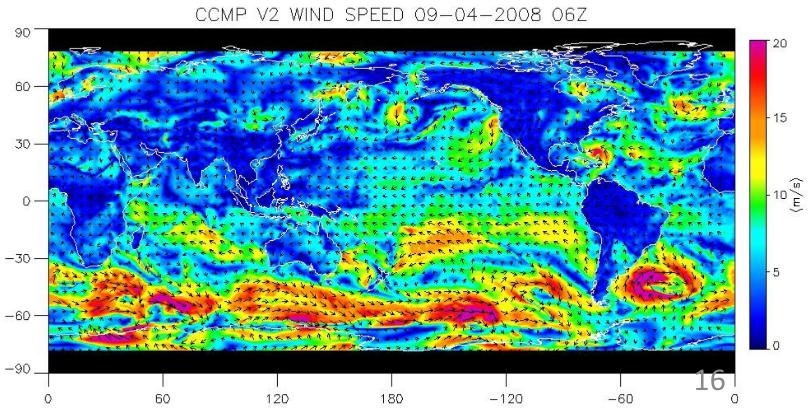
1. Using single sensors, necessary rain-flagging, especially for QuikSCAT
2. Attach timeseries of different sensors: Be aware of small differences due to diurnal cycle, otherwise ok
3. Best option: Use CCMP, satellite-based wind vector analysis; scatterometers+radiometers+ buoys+ model wind (ERA-Interim or NCEP background); (Atlas et al, 2011; Mears et al, submitted)
   - 6-hourly, 0.25 deg gridded wind components, 1988-current
   - Available also in NRT-version, without buoys

Example: Westerly Wind Bursts and El Nino

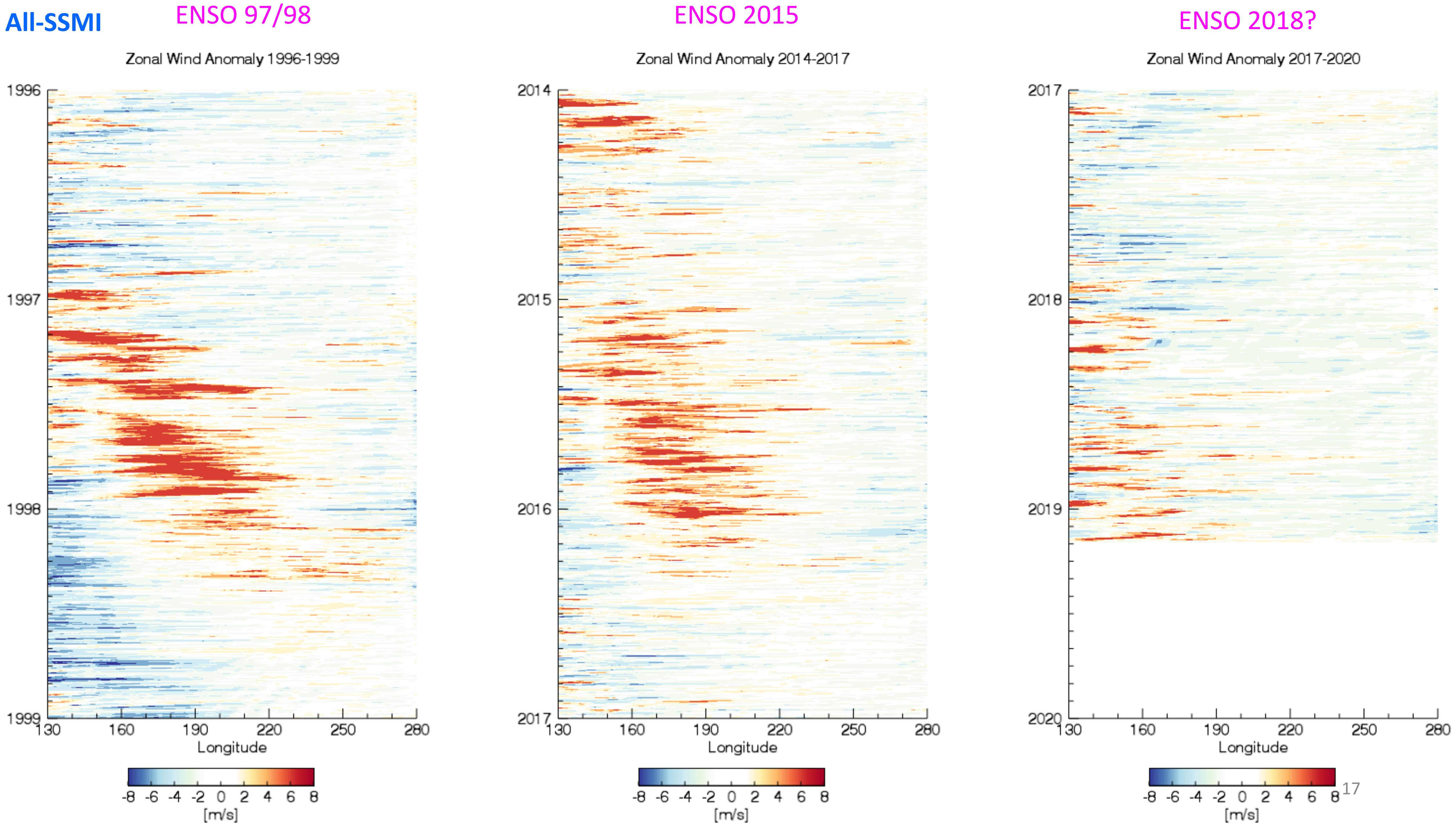
- We studied occurrence of Westerly Wind Bursts (WWB) in the Pacific which contribute to trigger El Nino events.
- WWB are usually defined as anomalies in the zonal winds that exceed 2 m/s for a period longer than 3 days
- Focus on 3 major El Nino events: 1997/98; 2014/15; 2018/19
- Used all-SSMI timeseries, associated CCMP wind direction to determine zonal wind component U_{SSMI};
- Compared to U_{CCMP} itself
- Compared to one reanalysis (20CR)

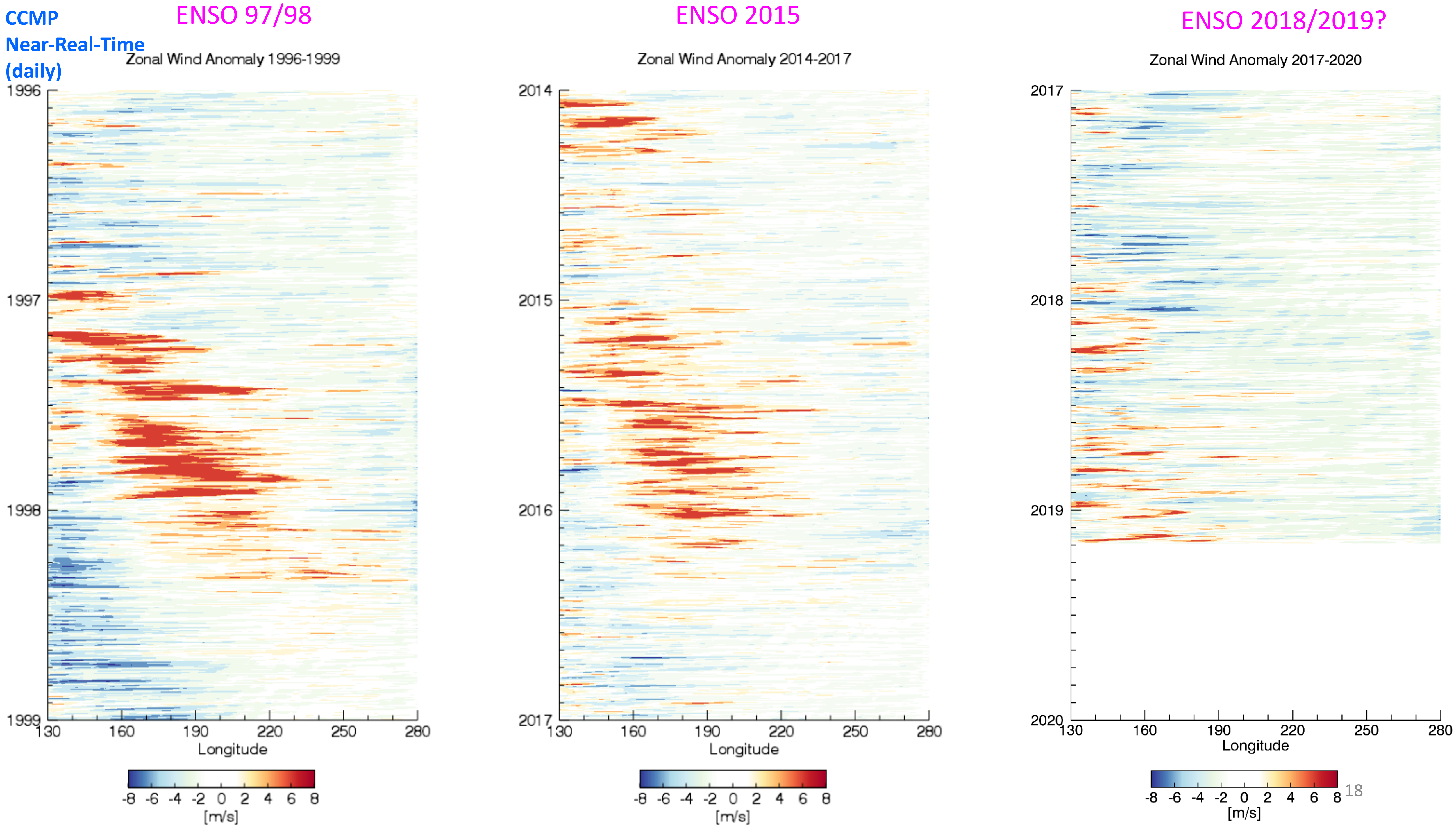
SATELLITE WINDS IN CCMP V2



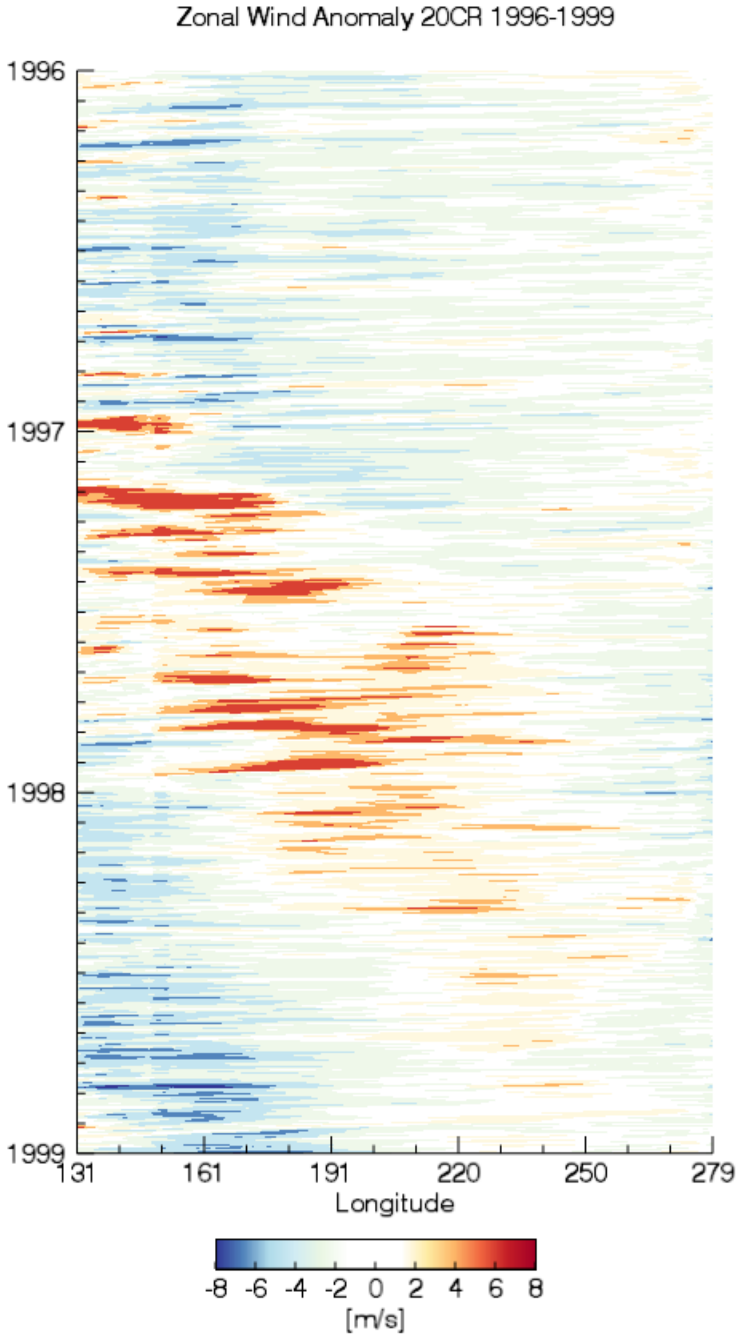


All-SSMI


ENSO 97/98
Zonal Wind Anomaly 1996-1999
1996
1997
1998
1999
130 160 190 220 250 280
Longitude
-8 -6 -4 -2 0 2 4 6 8
[m/s]
ENSO 2015
Zonal Wind Anomaly 2014-2017
2014
2015
2016
2017
130 160 190 220 250 280
Longitude
-8 -6 -4 -2 0 2 4 6 8
[m/s]
ENSO 2018?
Zonal Wind Anomaly 2017-2020
2017
2018
2019
2020
130 160 190 220 250 280
Longitude
-8 -6 -4 -2 0 2 4 6 8
[m/s]


CCMP
Near-Real-Time
(daily)
ENSO 97/98
Zonal Wind Anomaly 1996-1999
1996
1997
1998
1999
130 160 190 220 250 280
Longitude
-8 -6 -4 -2 0 2 4 6 8
[m/s]
ENSO 2015
Zonal Wind Anomaly 2014-2017
2014
2015
2016
2017
130 160 190 220 250 280
Longitude
-8 -6 -4 -2 0 2 4 6 8
[m/s]
ENSO 2018/2019?
Zonal Wind Anomaly 2017-2020
2017
2018
2019
2020
130 160 190 220 250 280
Longitude
-8 -6 -4 -2 0 2 4 6 8
[m/s]

20CR_v2c 97/98



SUMMARY

- While in situ-data will always be considered the absolute ground truth, they are sparse.
- Properly calibrated Satellite data provide uninterrupted global coverage since 1988 (Radiometers) and 1999 (scatterometers; adding ERS would go back to 1991).
- Best way to compare different sensors with different observing time, is using to use the buoy as reference and compare QSCAT-BUOY to ASCAT-Buoy, for example.

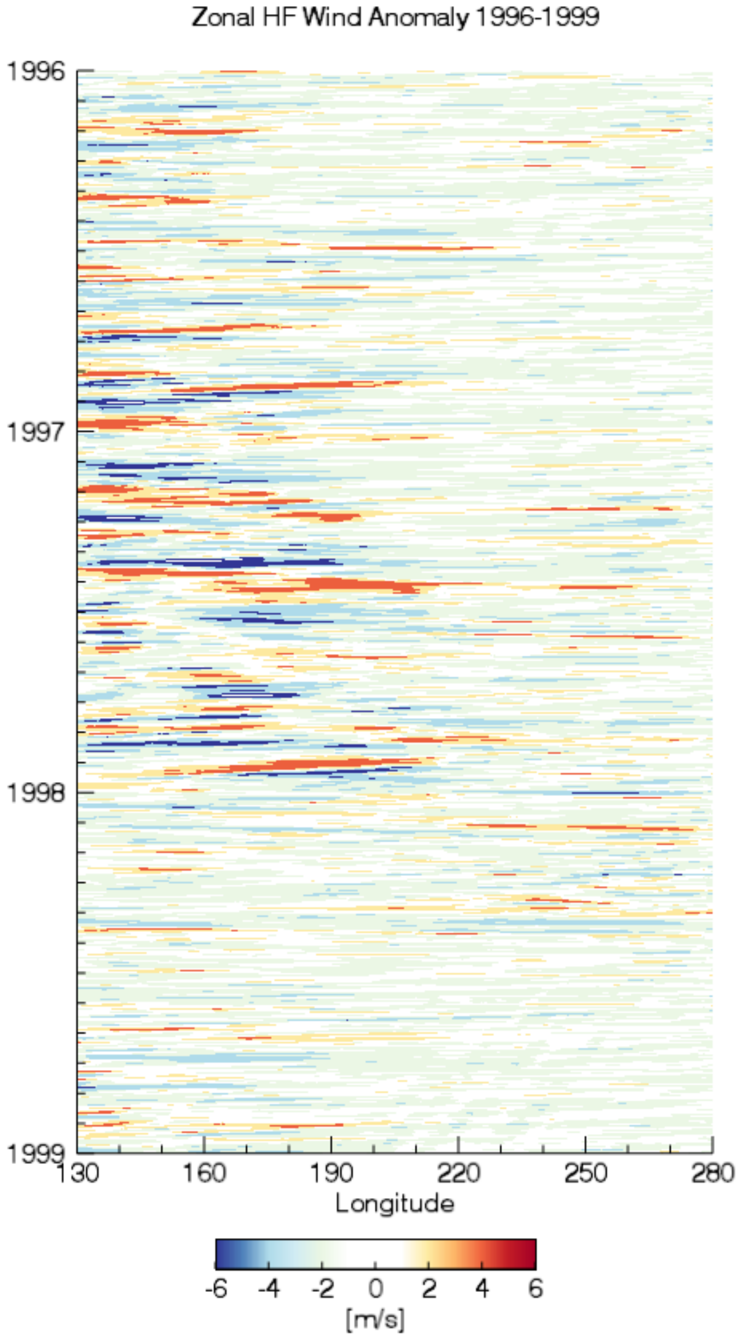
Note:

1) ASCAT and QSCAT are extremely consistent in rain-free over the TAO buoy array
2) Consistent quality control of satellite data is essential
3) WSAT U (and V) are not as closely consistent because the WSAT wind direction error is larger at low winds compared to the scatterometers.
4) ASCAT is less affected by rain than QuikSCAT. For best comparisons is better to make sure QSCAT is only rain-free

CONCLUSIONS

- Satellite wind speeds and components are calibrated over the tropics within 0.1 m/s vs TAO buoys; Uncertainty ~0.6 m/s
- Satellite data or satellite-based analysis CCMP can be used, in addition to in situ, for climate studies.
- Considering the recent degradation/lack of funding for buoys in the TAO array, we believe is important to provide an alternative and prove the accuracy of current satellite data vs buoys to the climate community, for ENSO and climate-related studies → Peer-review paper + stimulate similar analyses for other datasets

extras


Zonal HF Wind Anomaly 1996-1999
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Longitude
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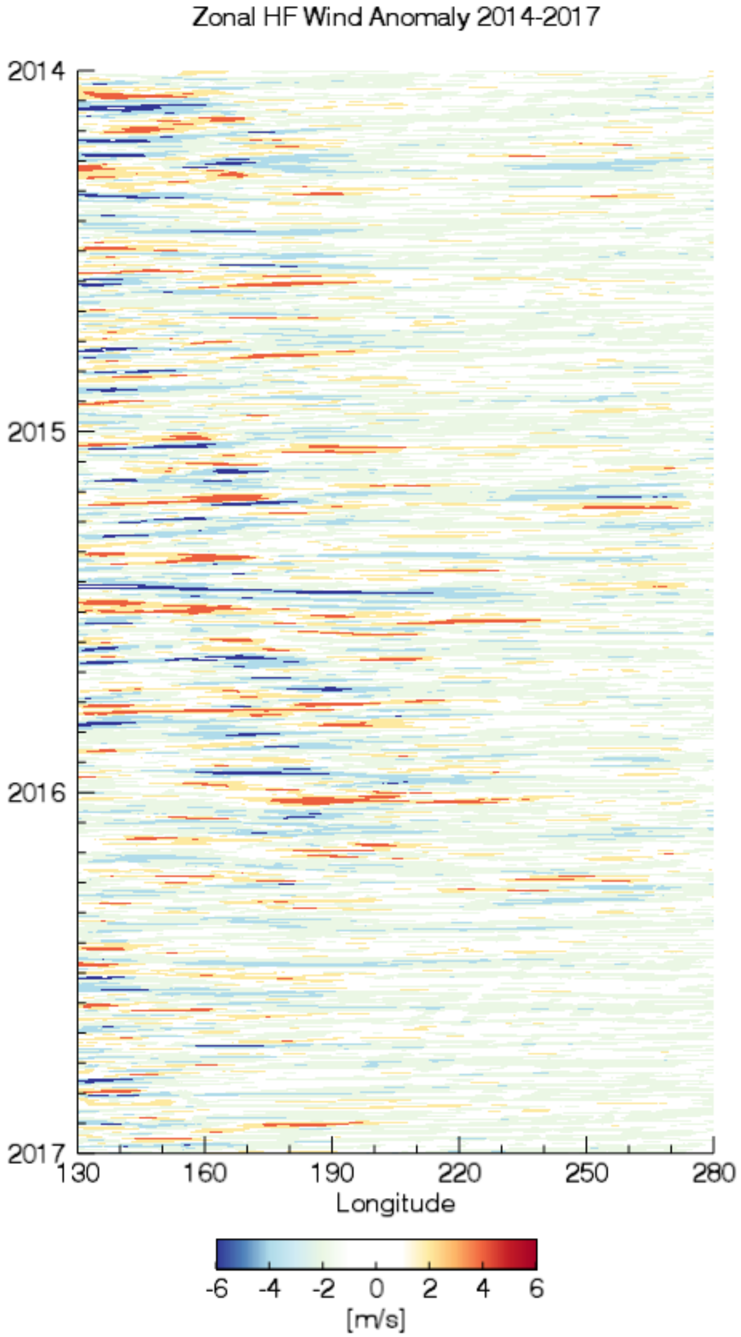
[m/s]


Zonal HF Wind Anomaly 2014-2017
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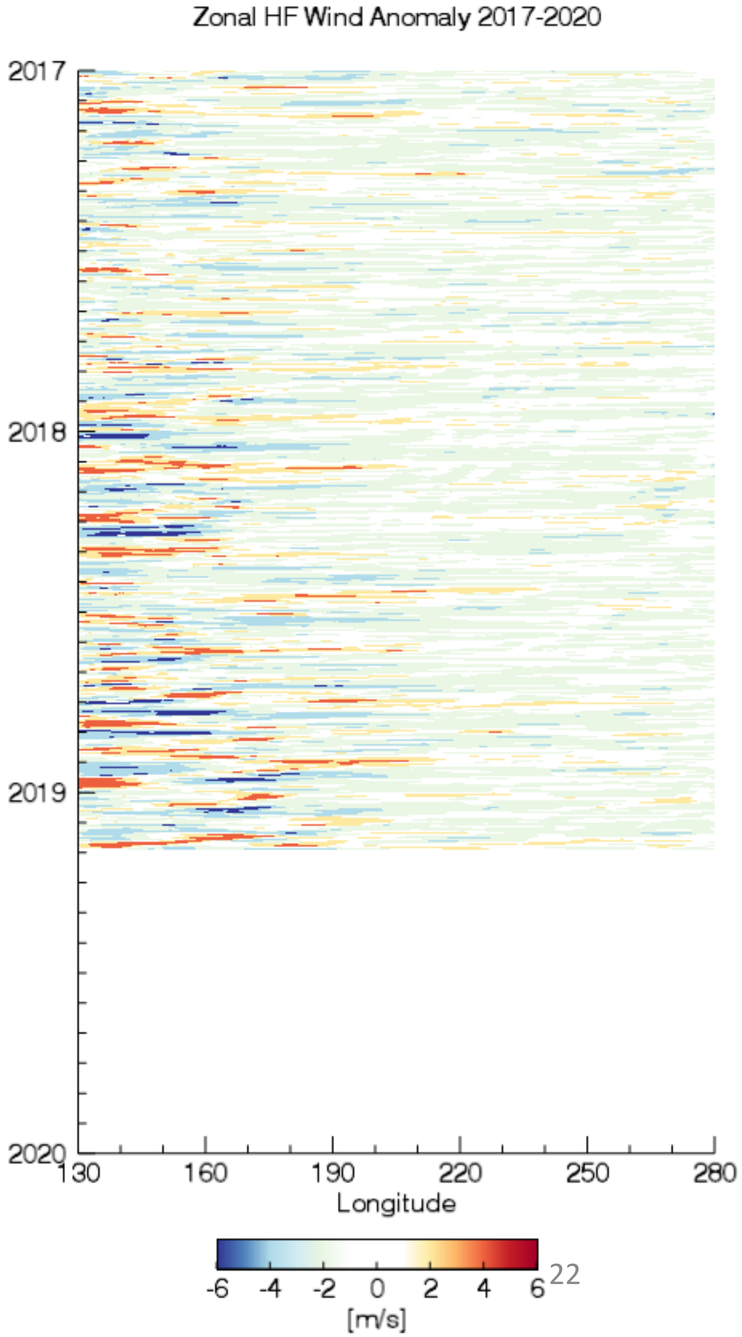
[m/s]


Zonal HF Wind Anomaly 2017-2020
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Longitude
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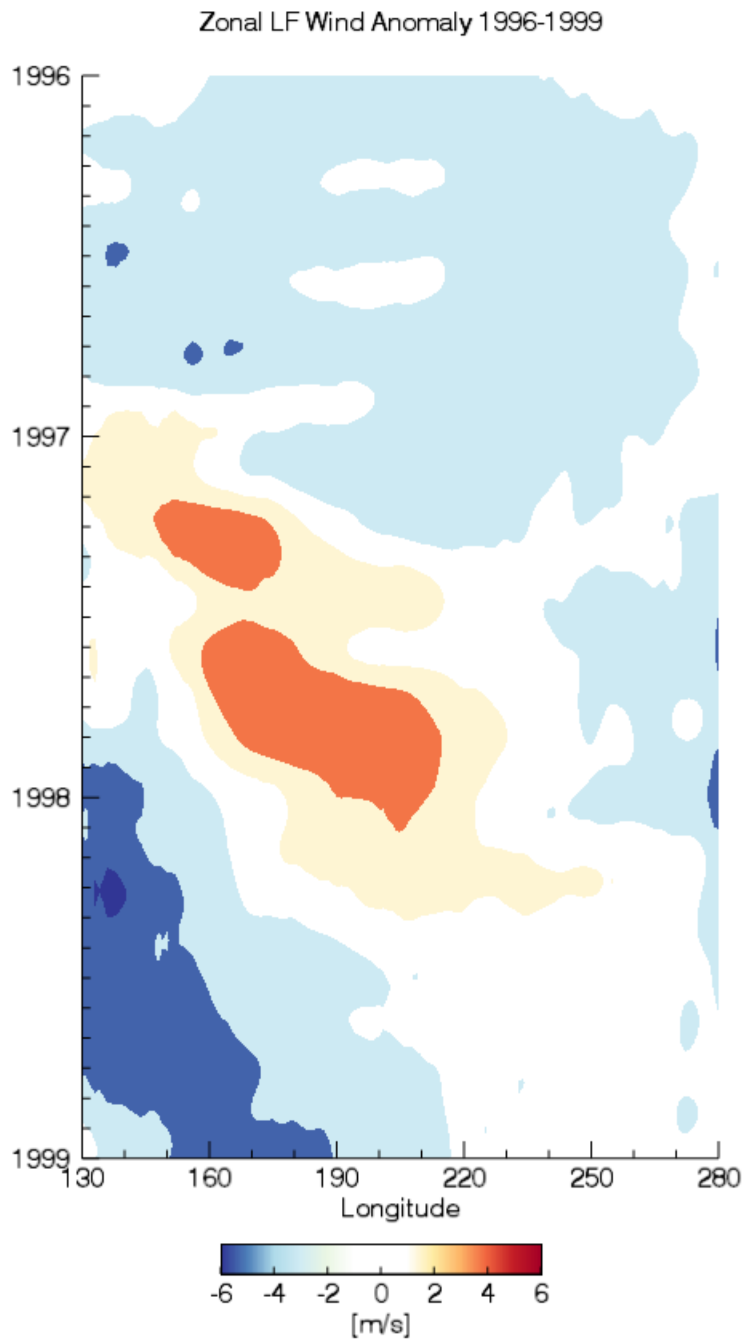
[m/s]


Zonal LF Wind Anomaly 1996-1999
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Longitude
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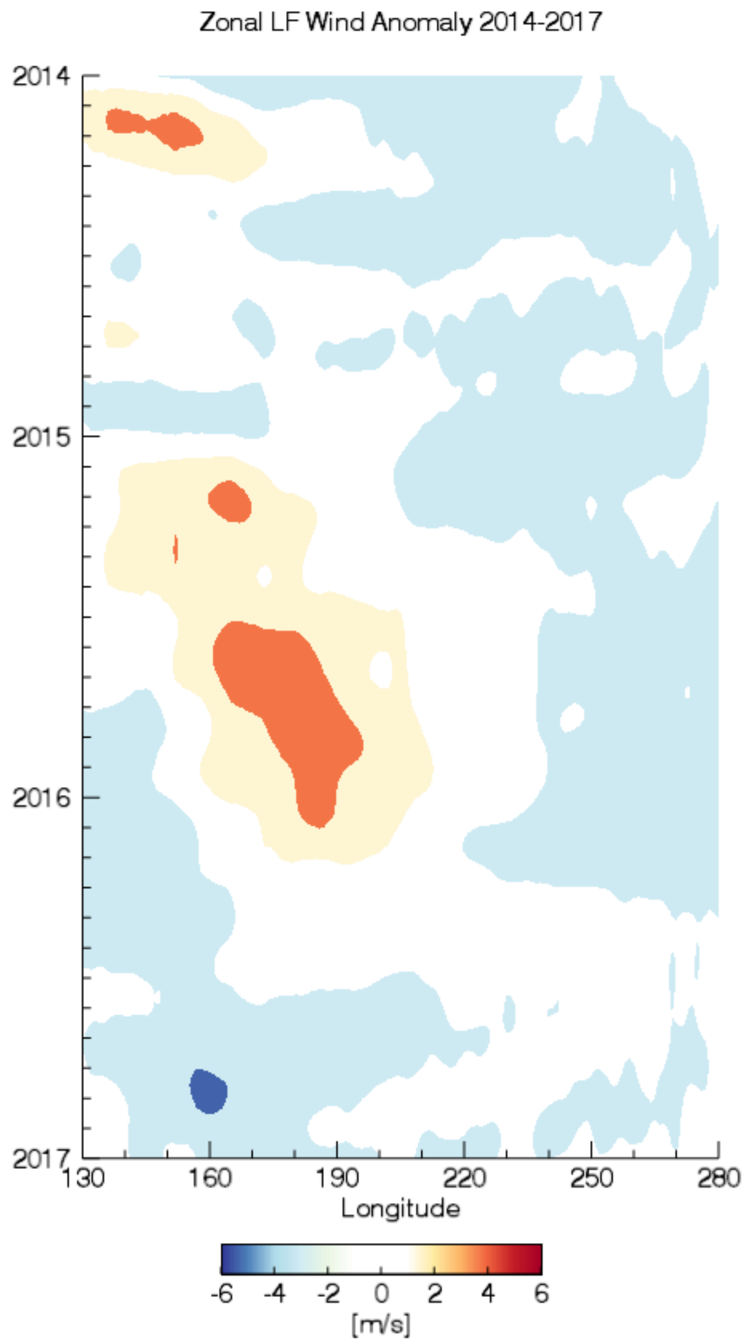
Zonal LF Wind Anomaly 2014-2017
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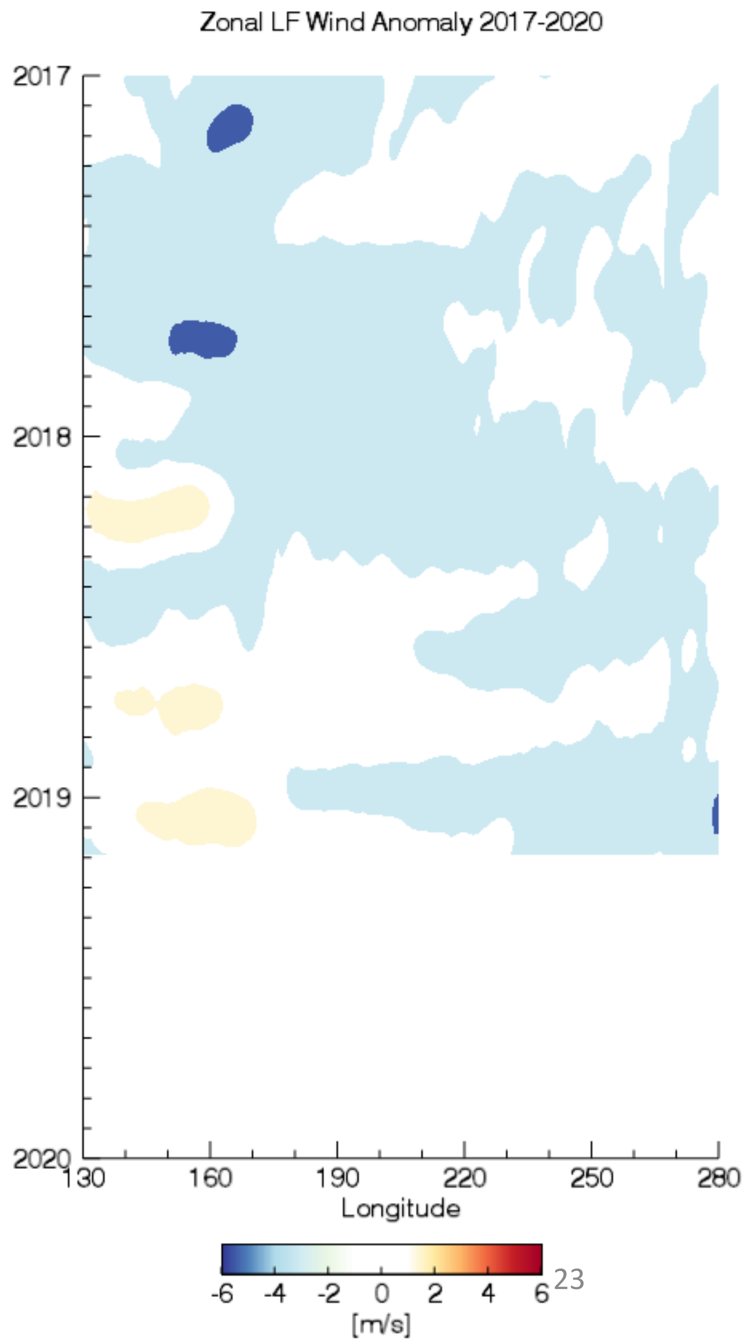
Zonal LF Wind Anomaly 2017-2020
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Longitude
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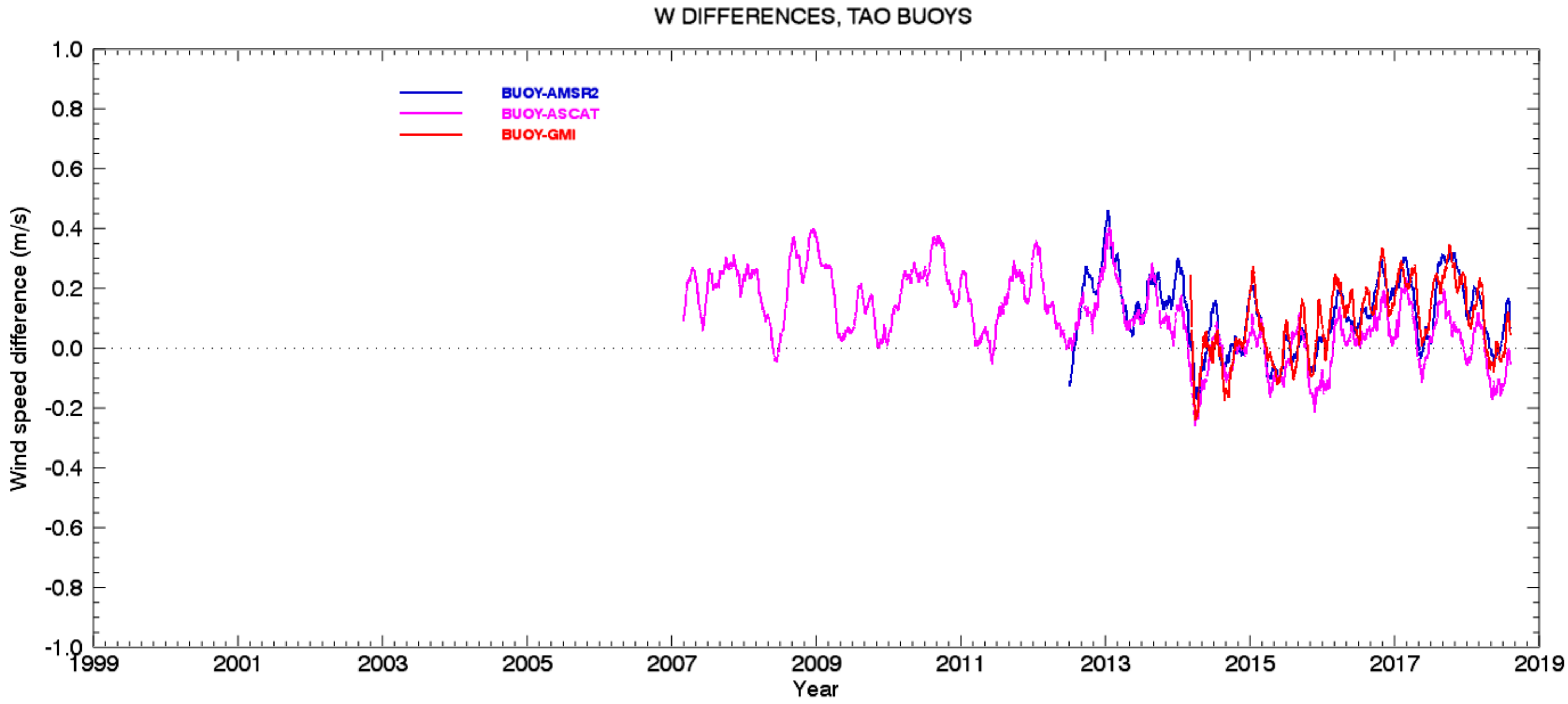
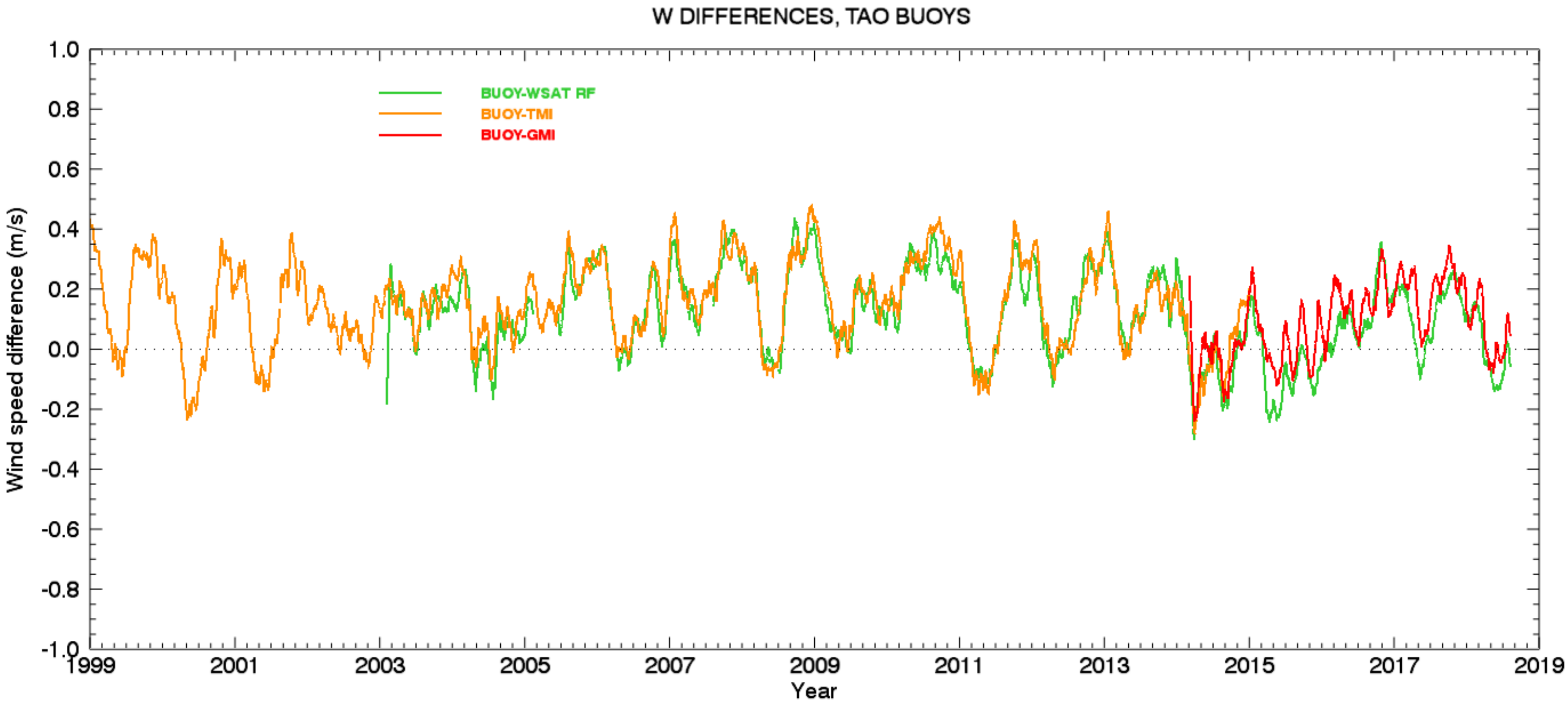
[m/s]

ASCAT/AMSR2 aligned well
Possible ASCAT drift after 2016



Consistency of TMI/GMI
Very small WSAT drift possible after 2014



ASCAT/TMI aligned well
Possible ASCAT drift after 2016