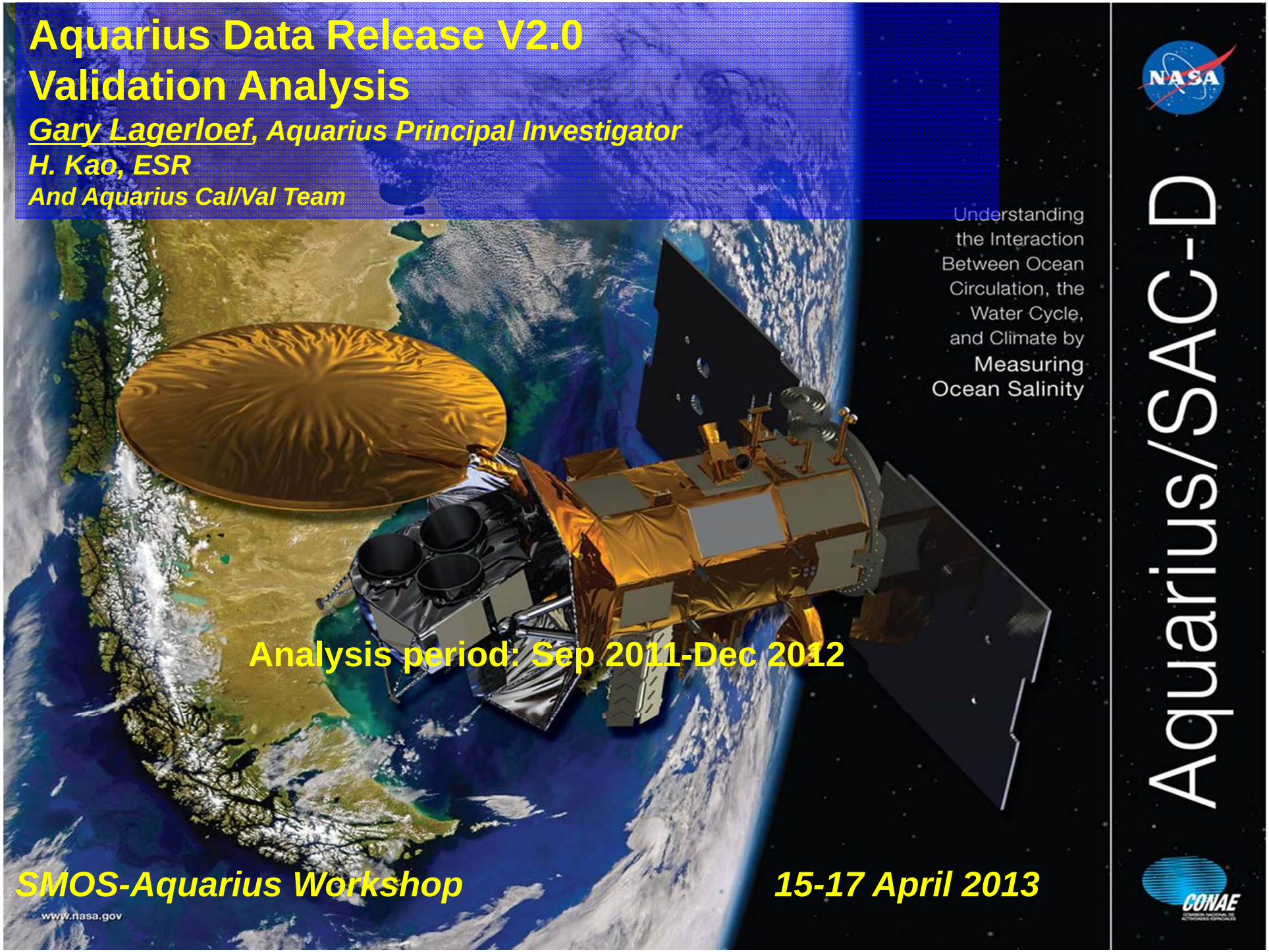
Aquarius Data Release V2.0 Validation Analysis

Gary Lagerloef, Aquarius Principal Investigator
H. Kao, ESR
And Aquarius Cal/Val Team



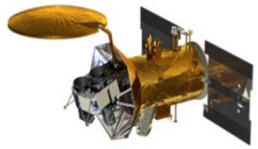
Analysis period: Sep 2011-Dec 2012

SMOS-Aquarius Workshop

15-17 April 2013

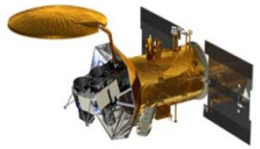
AQUARIUS/SAC-D

Outline



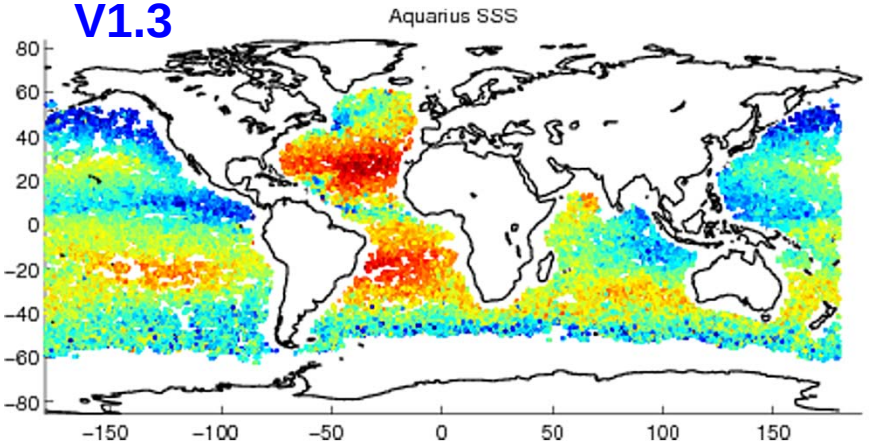
- V1.3.9 data is precursor test run for V2.0; Results shown for V1.3.9
- Contrast changes from V1.3
- Analyses cover the period Sep 2011 – Dec 2012 (16 months)
- HYCOM model – buoy comparisons
- Monthly maps – buoy differences and seasonal biases
- Seasonal error analysis & minimum mission requirement.
- Time series of global buoy differences
- Ascending – descending sides of the orbit, more seasonal bias
- Global buoy difference maps and statistics
- Triple Point analysis for global error

Comparison to Argo Buoys

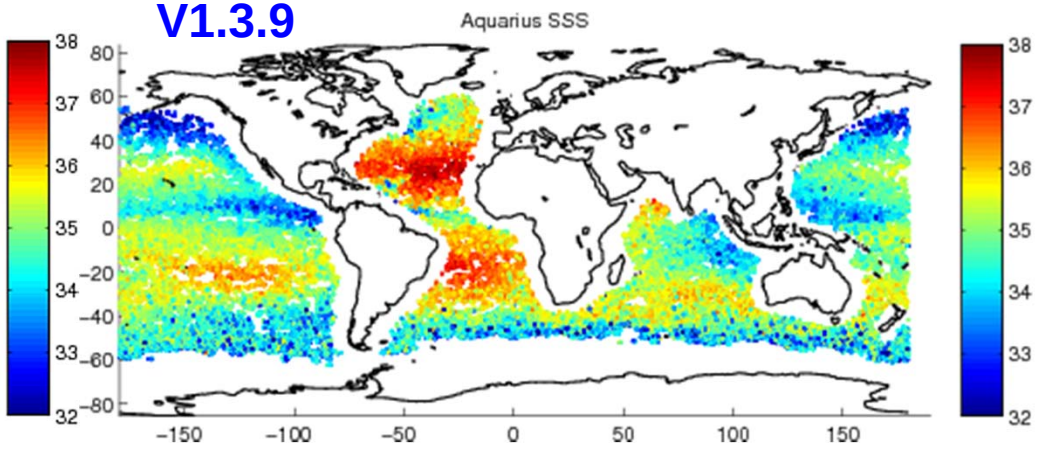


Aquarius salinity at buoy location & time

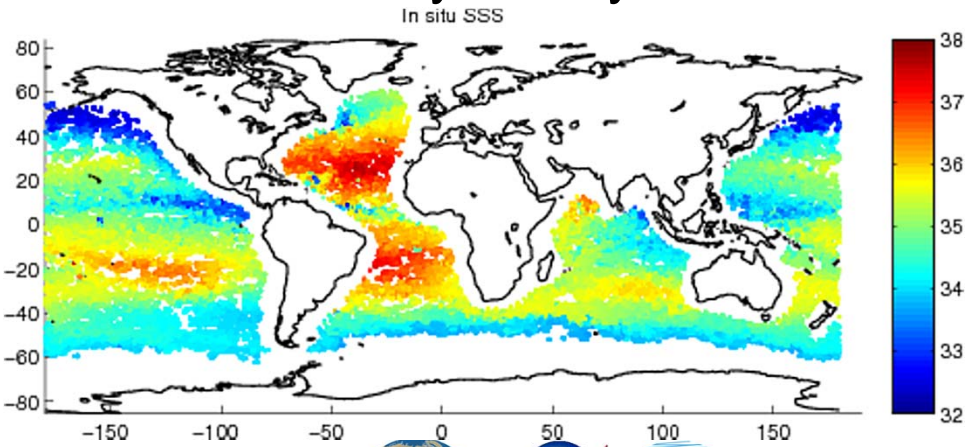
V1.3



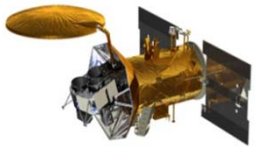
V1.3.9



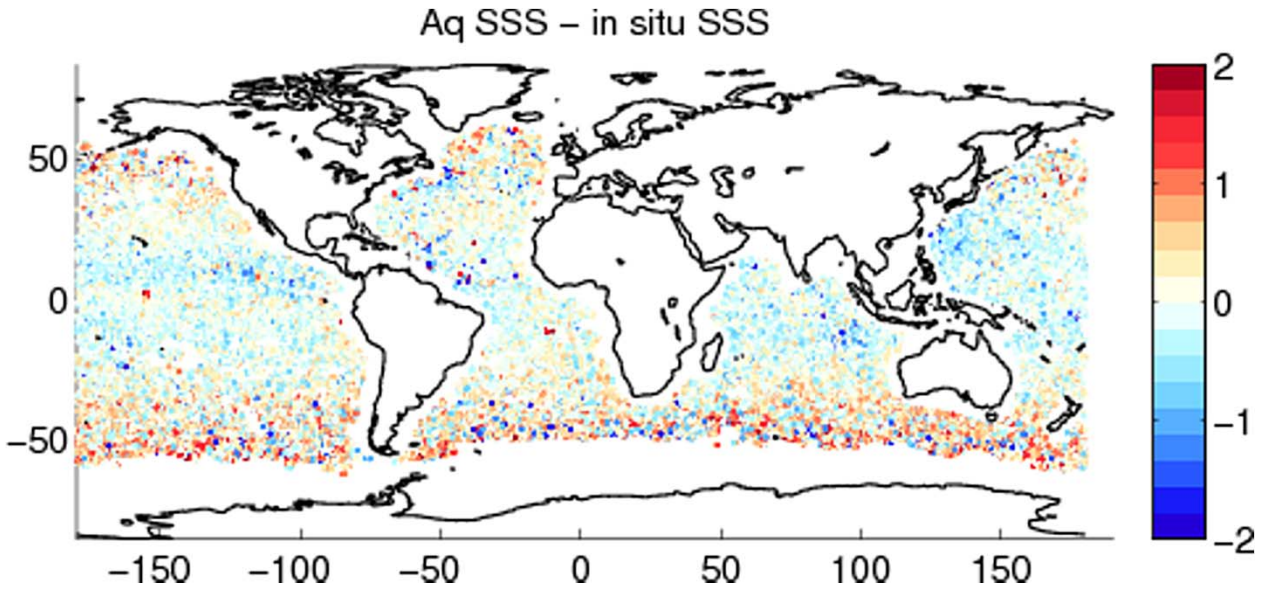
Buoy salinity



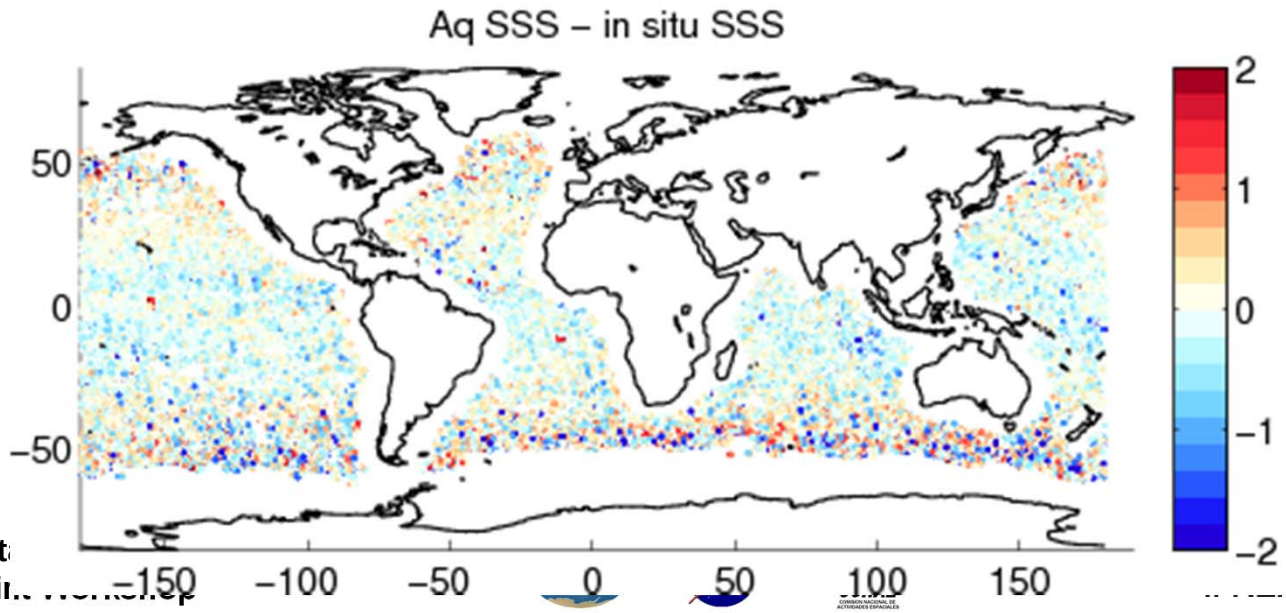
Aquarius – Argo Difference



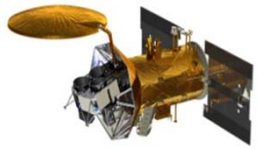
V1.3



V1.3.9

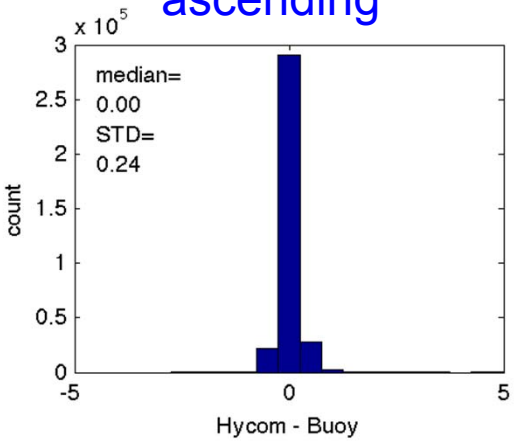


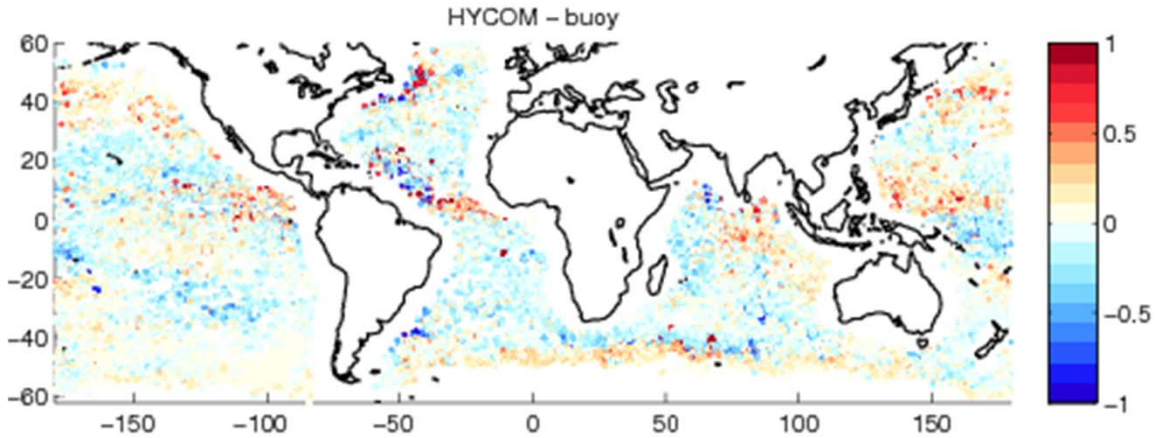
HYCOM – in situ SSS



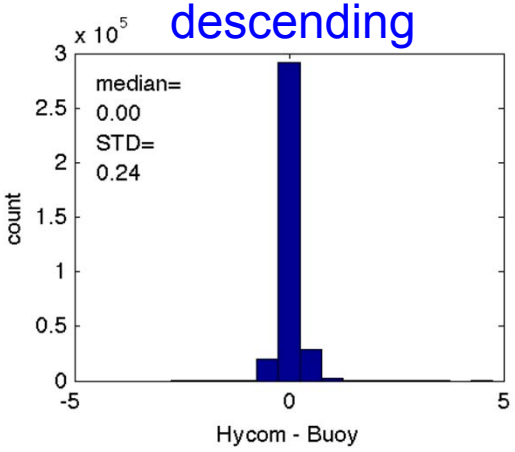
Note the considerable large scale systematic differences between HYCOM and the buoys (V1.3.9 data with HYCOM position offset corrected)

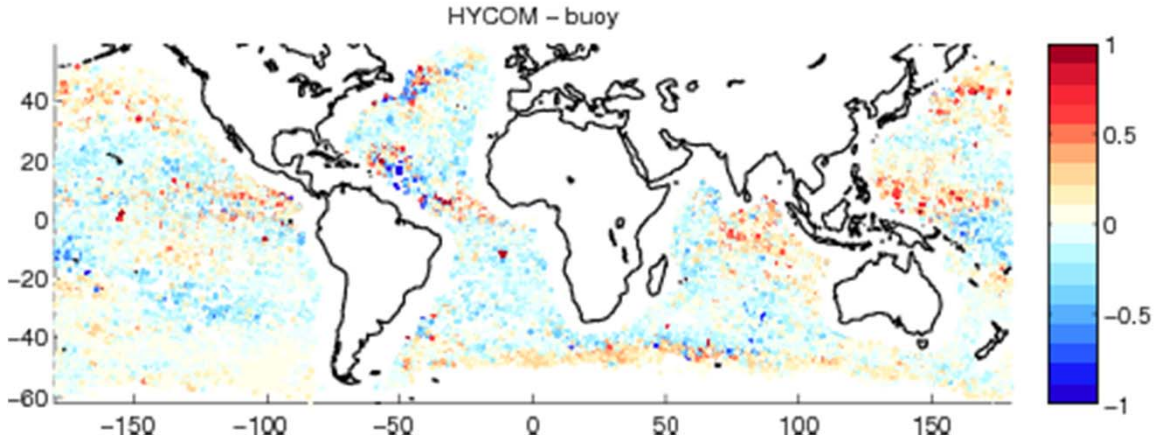
ascending



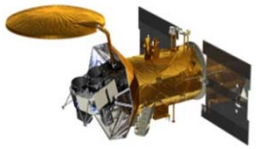


descending



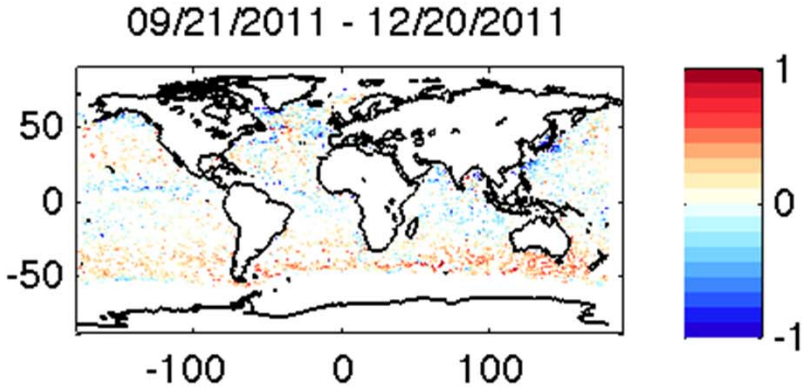


Three-month (seasonal) average buoy differences, V1.3.9

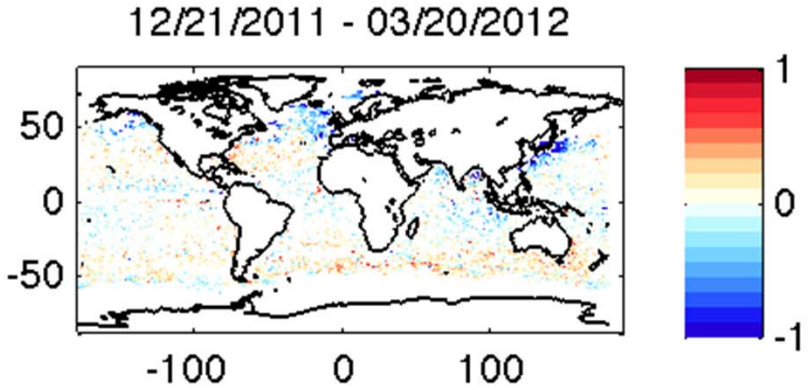


Clearly evident seasonal error variation

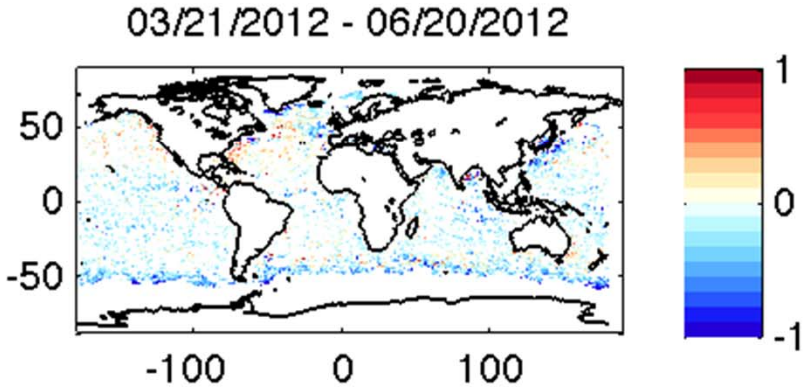
SON



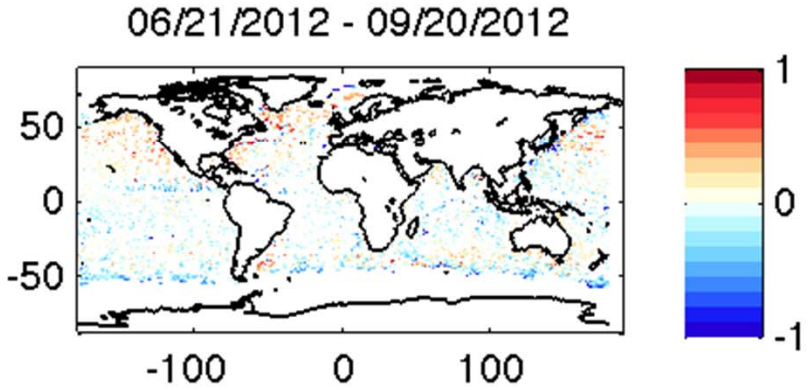
DJF



MAM

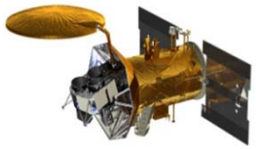


JJA



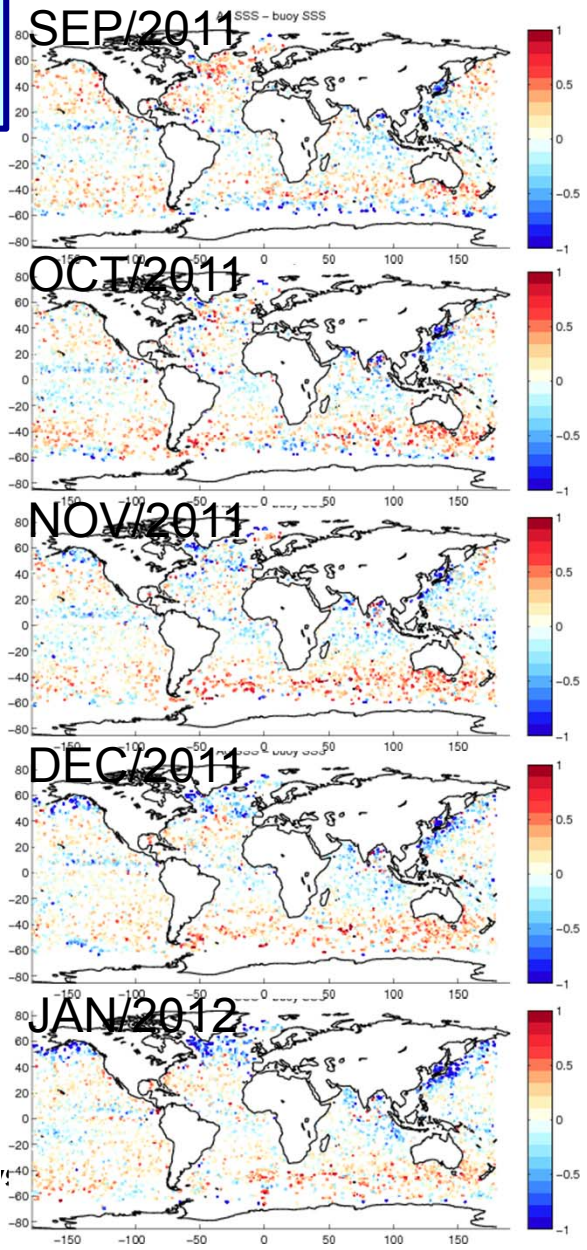
AQUARIUS/SAC-D

Aq V2.0 – buoy, Monthly L3 data from ADPS



ADPS gridding
land_frac <0.02; ice_frac <0.005
Higher AQ-buoy STD

	median	STD
SEP/11	0.07	0.37
OCT/11	0.07	0.37
NOV/11	0.06	0.37
DEC/11	0.05	0.38
JAN/12	0.05	0.40
FEB/12	0.02	0.41
MAR/12	-0.10	0.37
APR/12	-0.14	0.37
MAY/12	-0.11	0.36
JUN/12	-0.07	0.37
JUL/12	-0.03	0.37
AUG/12	-0.01	0.36
SEP/12	0.01	0.35



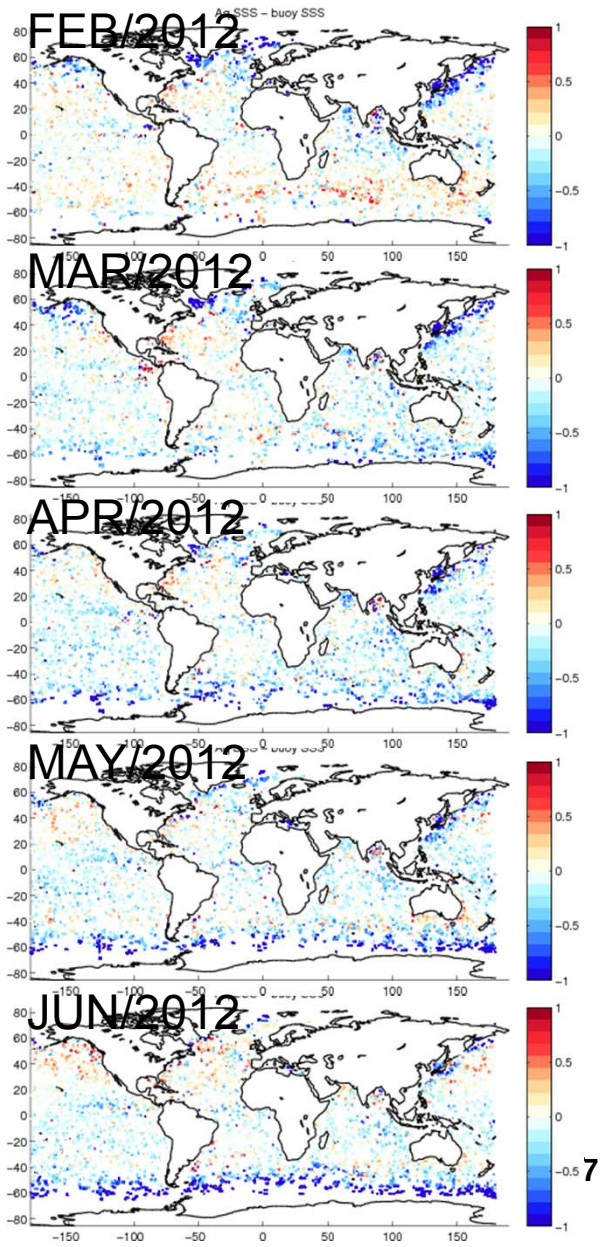
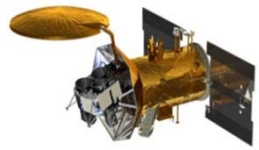


Table 5: Triple point analyses by month and season

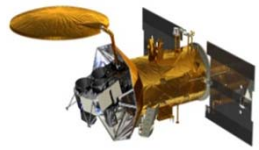


Yr-Month	Aquarius RMSE	HYCOM RMSE	Buoy RMSE
11-Dec	0.34	0.17	0.16
12-Jan	0.34	0.18	0.13
12-Feb	0.34	0.15	0.16
12-Mar	0.30	0.17	0.15
12-Apr	0.30	0.18	0.16
12-May	0.28	0.19	0.15
12-Jun	0.31	0.17	0.16
12-Jul	0.27	0.19	0.15
12-Aug	0.28	0.18	0.20
12-Sep	0.25	0.19	0.18
12-Oct	0.28	0.19	0.16
12-Nov	0.28	0.19	0.18
12-Dec	0.30	0.19	0.14

2011-12 Season	Aquarius RMSE	HYCOM RMSE	Buoy RMSE
SON	0.26	0.19	0.17
DJF	0.27	0.16	0.14
MAM	0.32	0.17	0.16
JJA	0.26	0.19	0.17

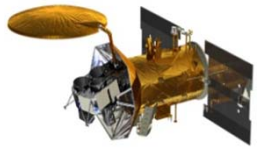
AQUARIUS/SAC-D

Table 6: Baseline and Minimum Mission - Status



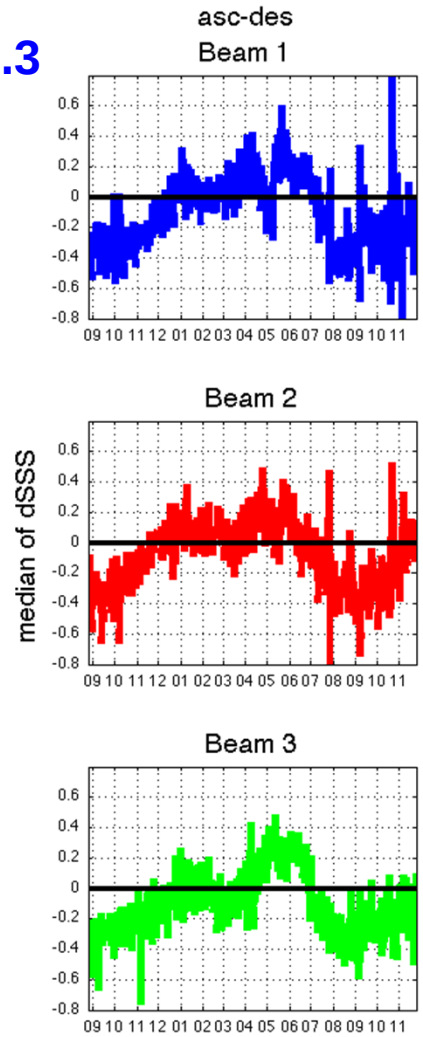
	Level 1 Science Mission Requirement	Baseline Mission	Minimum Mission
1	The Aquarius Mission shall collect the space-based measurements to retrieve Sea Surface Salinity (SSS) with global root-mean-square (rms) random errors and systematic biases no larger than **0.2 psu** on 150 km by 150 km scales over the open ocean.	V1.3: 0.44	V1.3: 0.38
		V2.0 0.30	V2.0 0.27
2	SSS Averaging Interval	1 Month	3 Months
3	Mission Duration	At least 3 Years	At least 1 Year
4	Deliver data products to a NASA Distributed Active Archive Center (DAAC). Level 1a Reconstructed Unprocessed Instrument Data Level 1b Calibrated Sensor Units Level 2 Derived Geolocated SSS Level 3 Time-space averaged SSS on a standard Earth Projection		Yes

Ascending and Descending trends

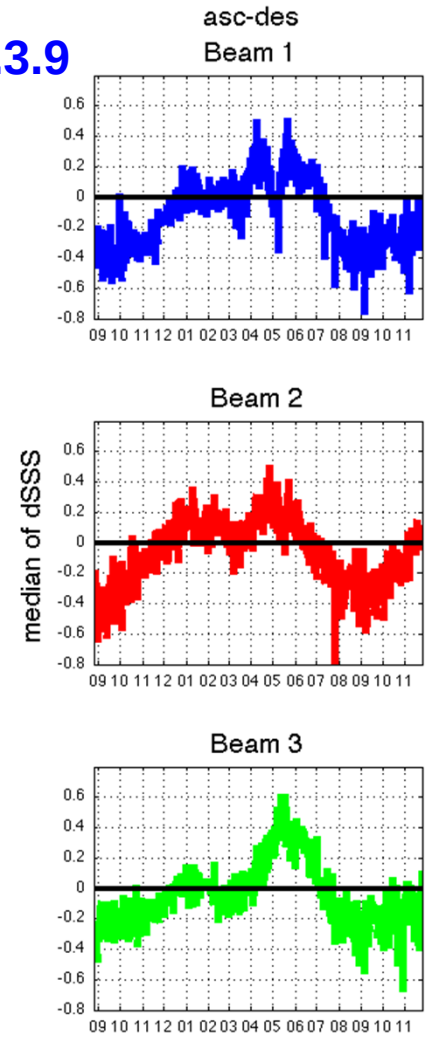


V1.3 trends are different for ascending and descending. Likely sources are antenna coupling, galaxy reflection and others

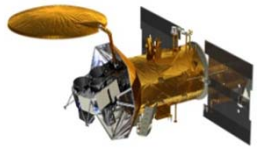
V1.3

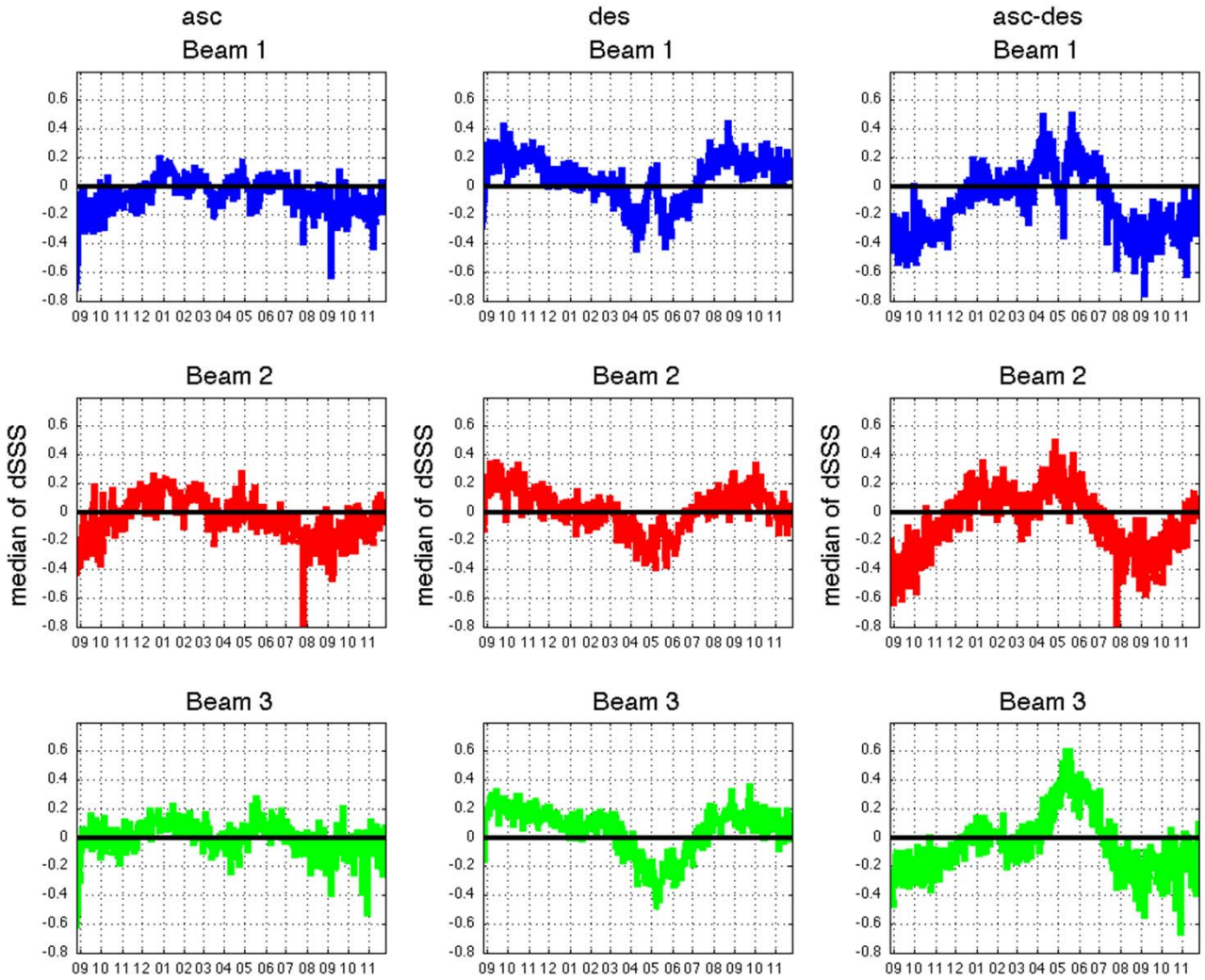


V1.3.9



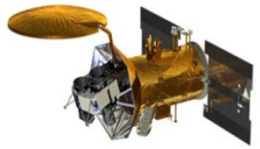
V1.3.9 Buoy Match-up Timeseries

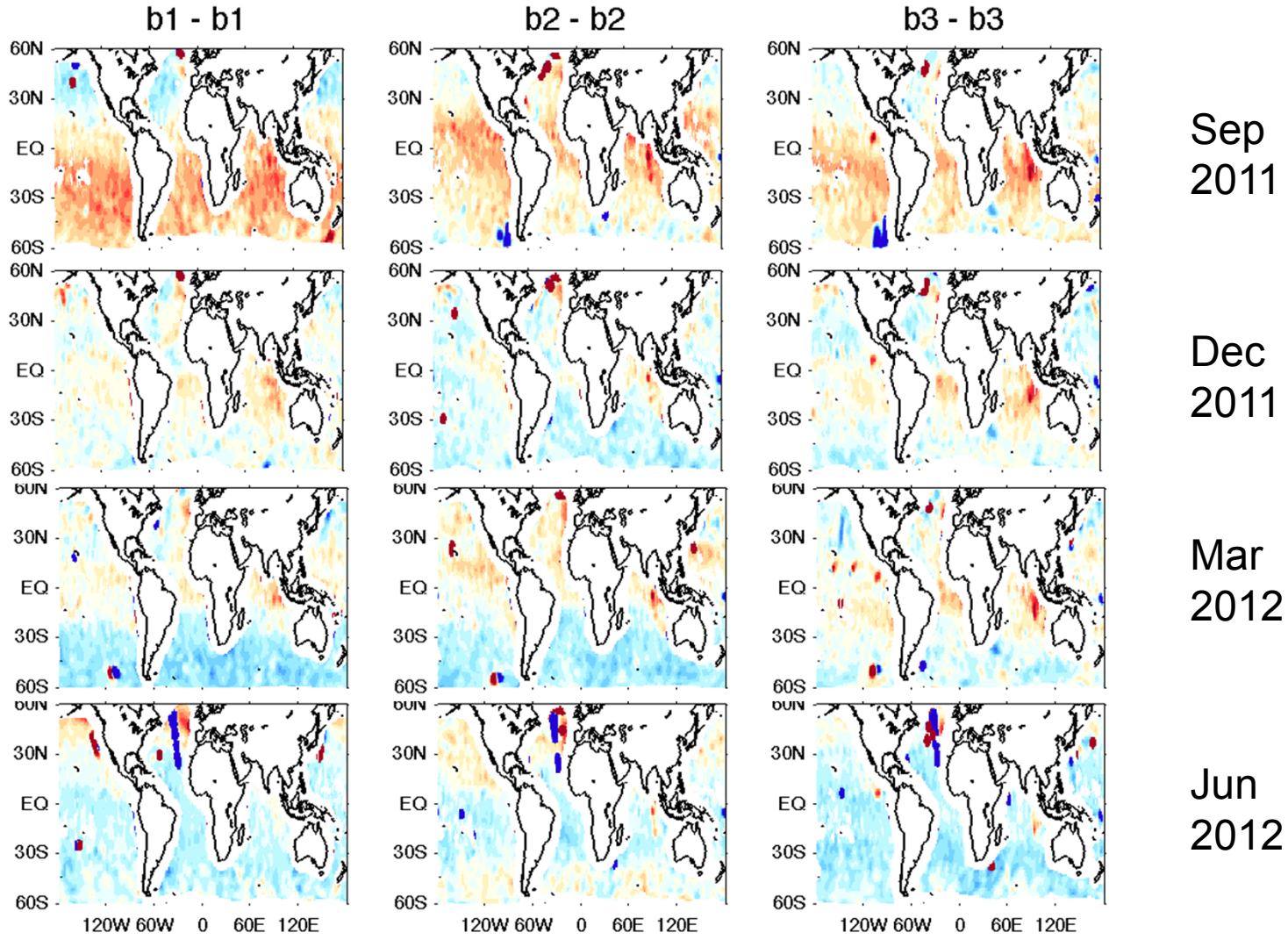




AQUARIUS/SAC-D

Asc-Des Beams Annual





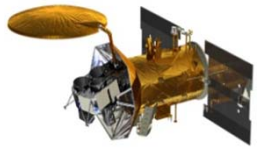
Sep 2011

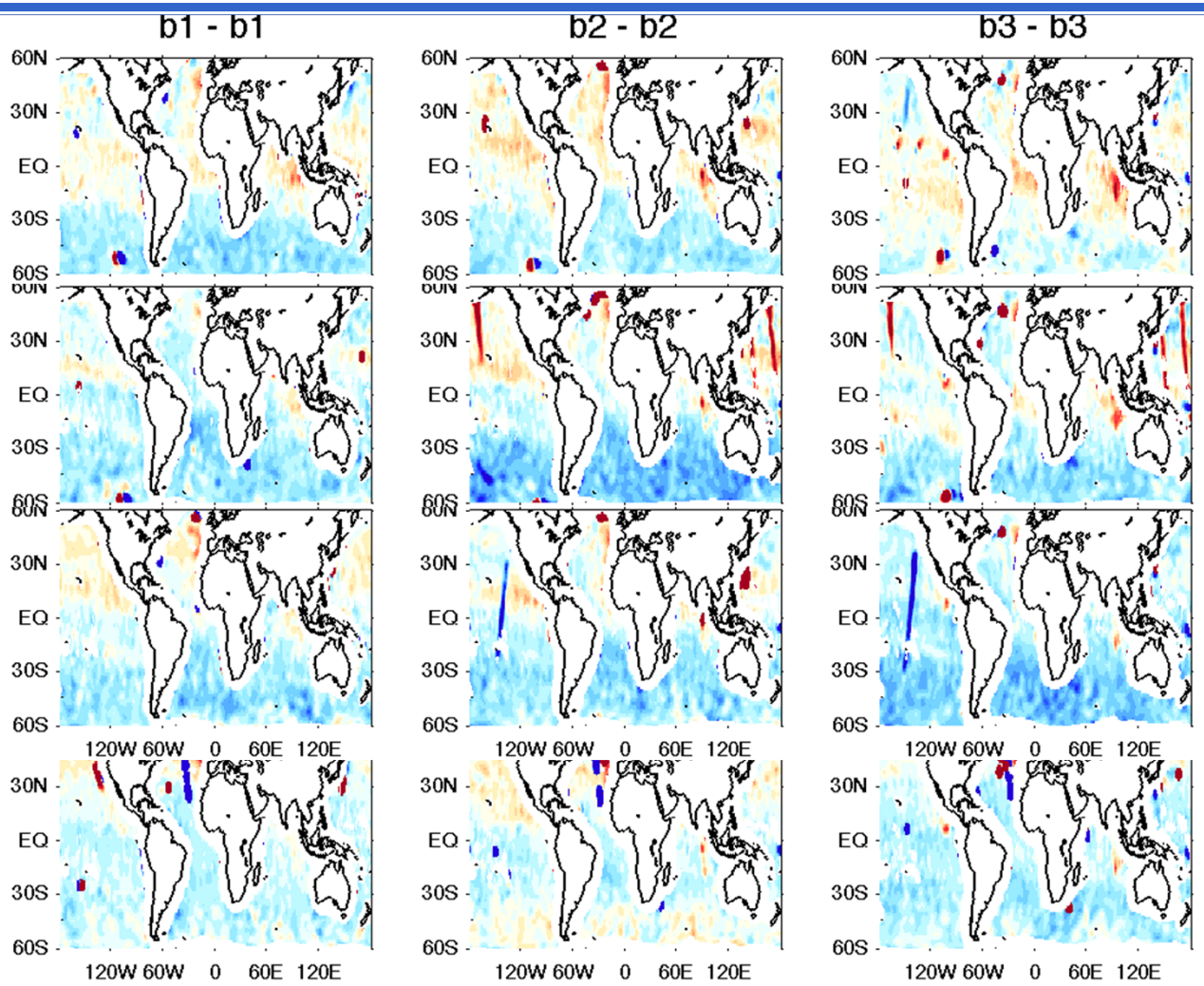
Dec 2011

Mar 2012

Jun 2012

Asc-Des Beams Mar-Jun 2012





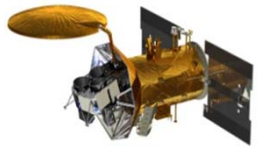
Mar 2012

Apr 2012

May 2012

Jun 2012

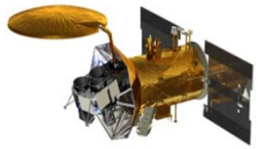
Summary



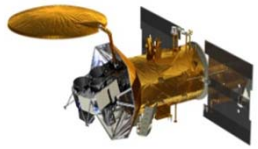
- Global RMSE, for the entire 16-months together, ~0.46 psu (triple point analysis, point measurements, no averaging)
- Monthly mean RMSE approximately 0.33 psu
- Significant annual error cycle and geographic error patterns, >0.5 psu amplitude, especially in southern hemisphere.
- Ascending-descending annual cycle bias, mostly in the descending side of the orbit (6am)
- **Beware of making any conclusions about the annual cycle in the data**
- Three-month average gridded fields global RMSE ~ 0.27 psu; Minimum Mission Requirement = 0.20 psu
- SPURS RMSD (1-month) ~0.23 psu, RMSE(Aquarius) ~0.17 psu

AQUARIUS/SAC-D

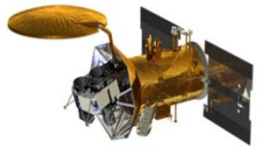
Summary



- Monthly mean RMSE approximately 0.33 psu
- Three-month average gridded fields global RMSE ~ 0.27 psu; Minimum Mission Requirement = 0.20 psu
- Significant annual error cycle and geographic error patterns, >0.5 psu amplitude, especially in southern hemisphere.
- Ascending-descending annual cycle bias, mostly in the descending side of the orbit (6am)
- Ascending-descending Ta difference maps show much broader hemispheric pattern than SSS because SSS error patterns are concentrated in cold water
- **Beware of making any conclusions about the annual cycle in the data**

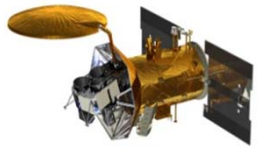


Summary



Backup Material

Triple point uncertainty estimate of Aquarius and validation data



The satellite salinity measurement S_S and the *in situ* validation measurement S_V are defined by:

$$S_S = S \pm \varepsilon_S$$

$$S_V = S \pm \varepsilon_V$$

where S is the true surface salinity averaged over the Aquarius footprint area and microwave optical depth in sea water (~ 1 cm). ε_S and ε_V are the respective satellite and *in situ* measurement errors relative to S. The mean square of the difference ΔS between S_S and S_V is given by:

$$\langle \Delta S_{SV}^2 \rangle = \langle \varepsilon_S^2 \rangle + \langle \varepsilon_V^2 \rangle \quad (1)$$

where $\langle\ \rangle$ denotes the average over a given set of paired satellite and *in situ* measurements, and $\langle \varepsilon_S \varepsilon_V \rangle = 0$.

Likewise, define HyCOM salinity interpolated to the satellite footprint as $S_H = S \pm \varepsilon_H$, and mean square differences

$$\langle \Delta S_{HV}^2 \rangle = \langle \varepsilon_H^2 \rangle + \langle \varepsilon_V^2 \rangle \quad (2)$$ HyCOM vs in situ validation data

$$\langle \Delta S_{SH}^2 \rangle = \langle \varepsilon_S^2 \rangle + \langle \varepsilon_H^2 \rangle \quad (3)$$ Satellite vs HyCOM

Equations (1)-(3) comprise three equations with three variables given by:

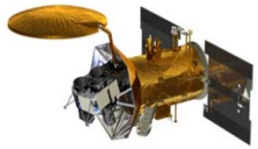
$$\langle \varepsilon_S^2 \rangle = \{\langle \Delta S_{SV}^2 \rangle + \langle \Delta S_{SH}^2 \rangle - \langle \Delta S_{HV}^2 \rangle\} /2 \quad (4)$$ satellite measurement error

$$\langle \varepsilon_H^2 \rangle = \{\langle \Delta S_{SH}^2 \rangle + \langle \Delta S_{HV}^2 \rangle - \langle \Delta S_{SV}^2 \rangle\} /2 \quad (5)$$ HyCOM measurement error

$$\langle \varepsilon_V^2 \rangle = \{\langle \Delta S_{SV}^2 \rangle + \langle \Delta S_{HV}^2 \rangle - \langle \Delta S_{SH}^2 \rangle\} /2 \quad (6)$$ In situ validation measurement error

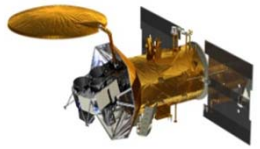
AQUARIUS/SAC-D

Seasonal Error Estimates Compared with Minimum Mission Requirements

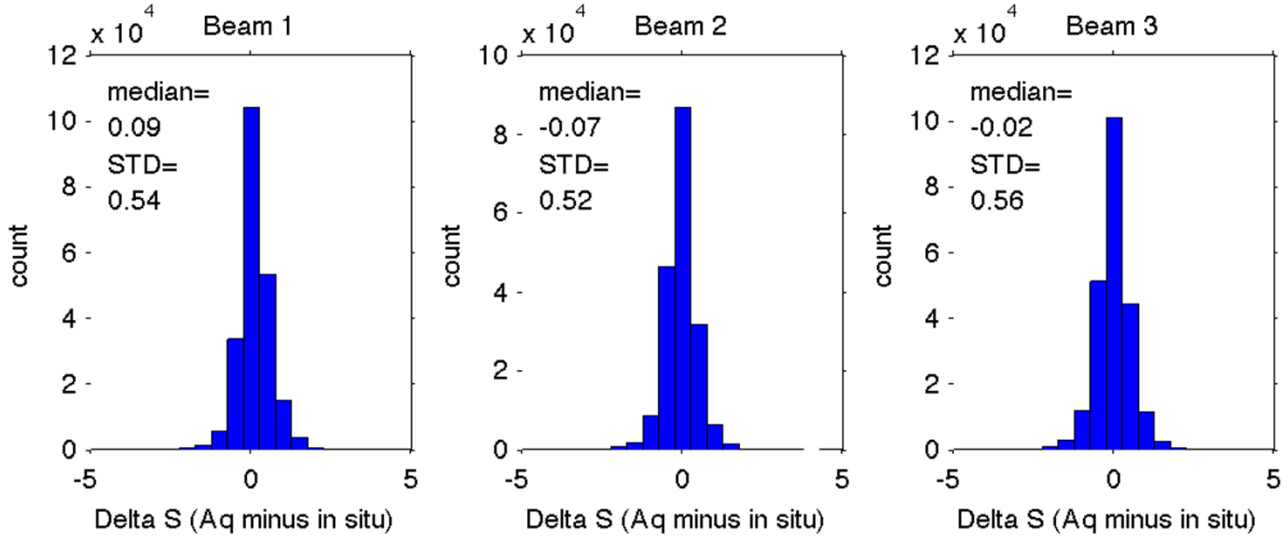


Minimum Mission Seasonal Salinity Error (psu)		SON	DJF	MAM	JJA
Latitude Range	Allocation (psu)	STDa	STDa	STDa	STDa
0-10	0.15	0.24	0.27	0.24	0.24
11-20	0.16	0.26	0.24	0.26	0.26
21-30	0.16	0.25	0.23	0.25	0.25
31-40	0.18	0.29	0.39	0.29	0.29
41-50	0.21	0.29	0.26	0.29	0.29
51-60	0.24	0.26	0.24	0.26	0.26
61-70	0.26				
Global RMS	0.20	0.26	0.28	0.27	0.27

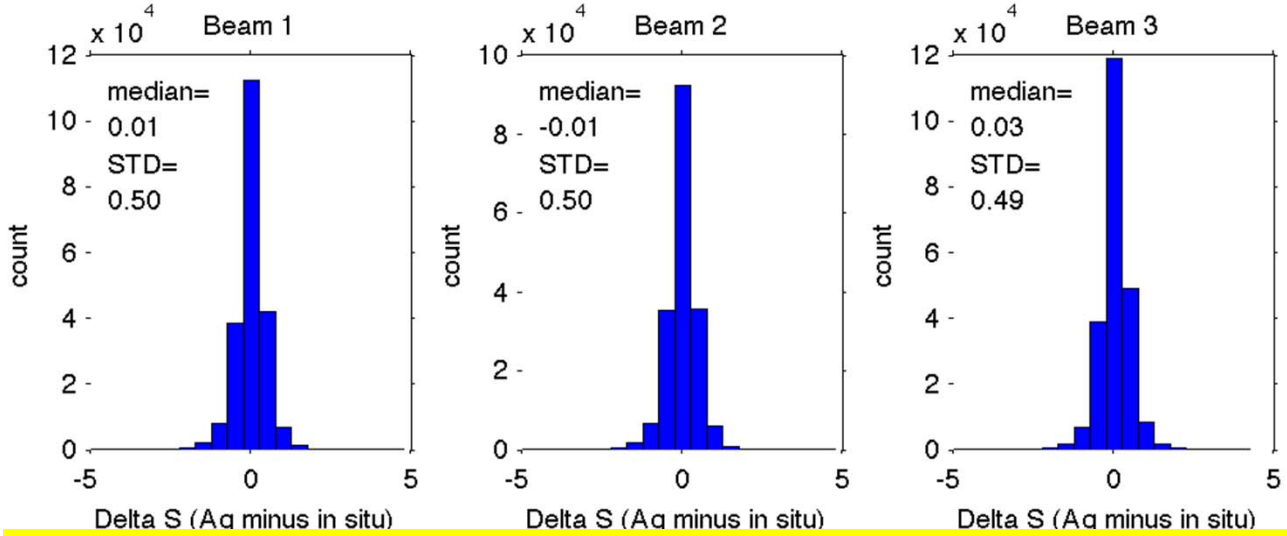
Aquarius – Argo Histograms



V1.3

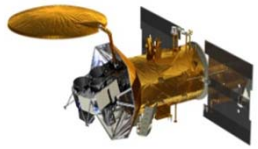


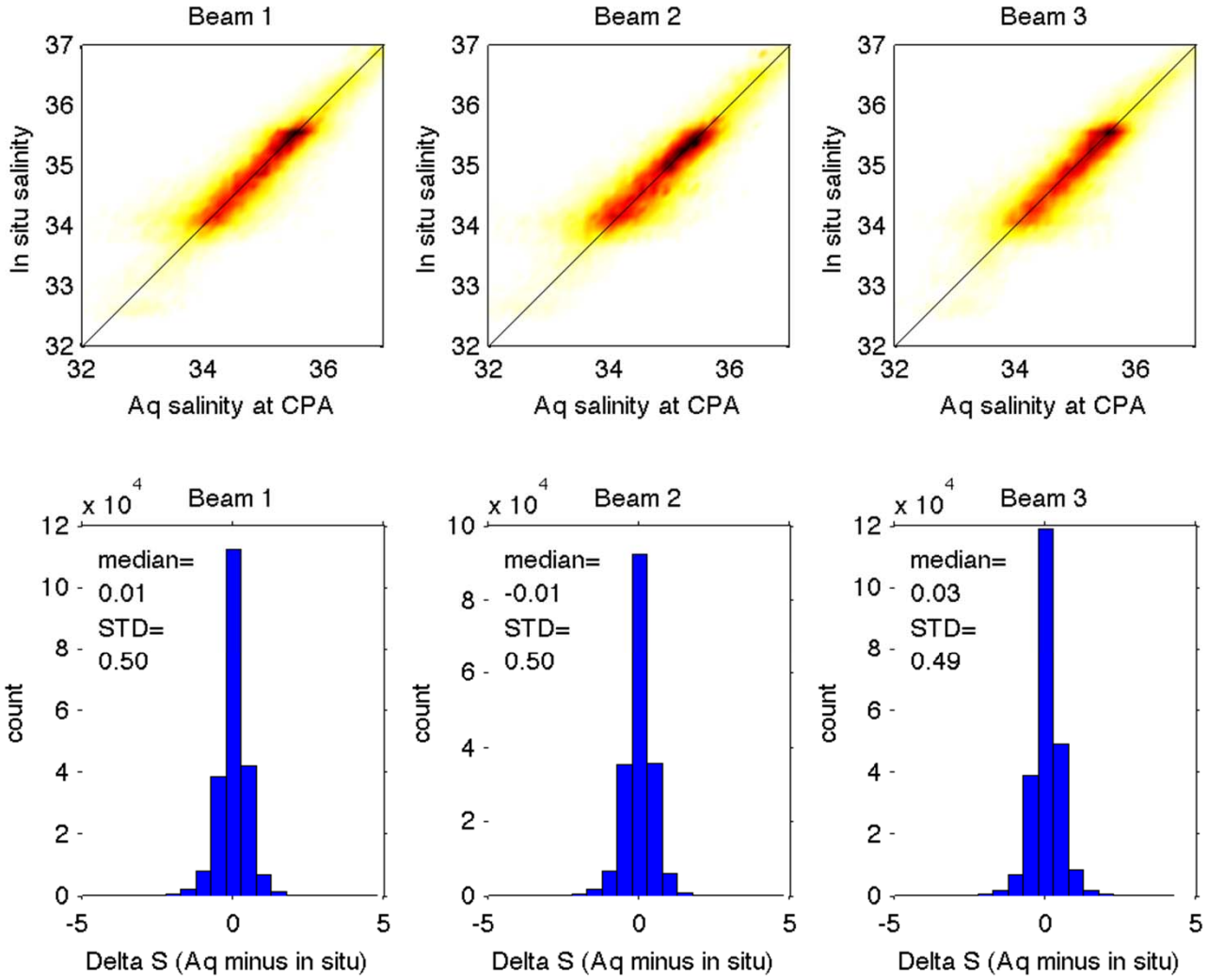
V1.3.9



SST > 5C, windspeed <15m/s, Land and ice fraction < 0.0005

V1.3.9 Scatter Plots





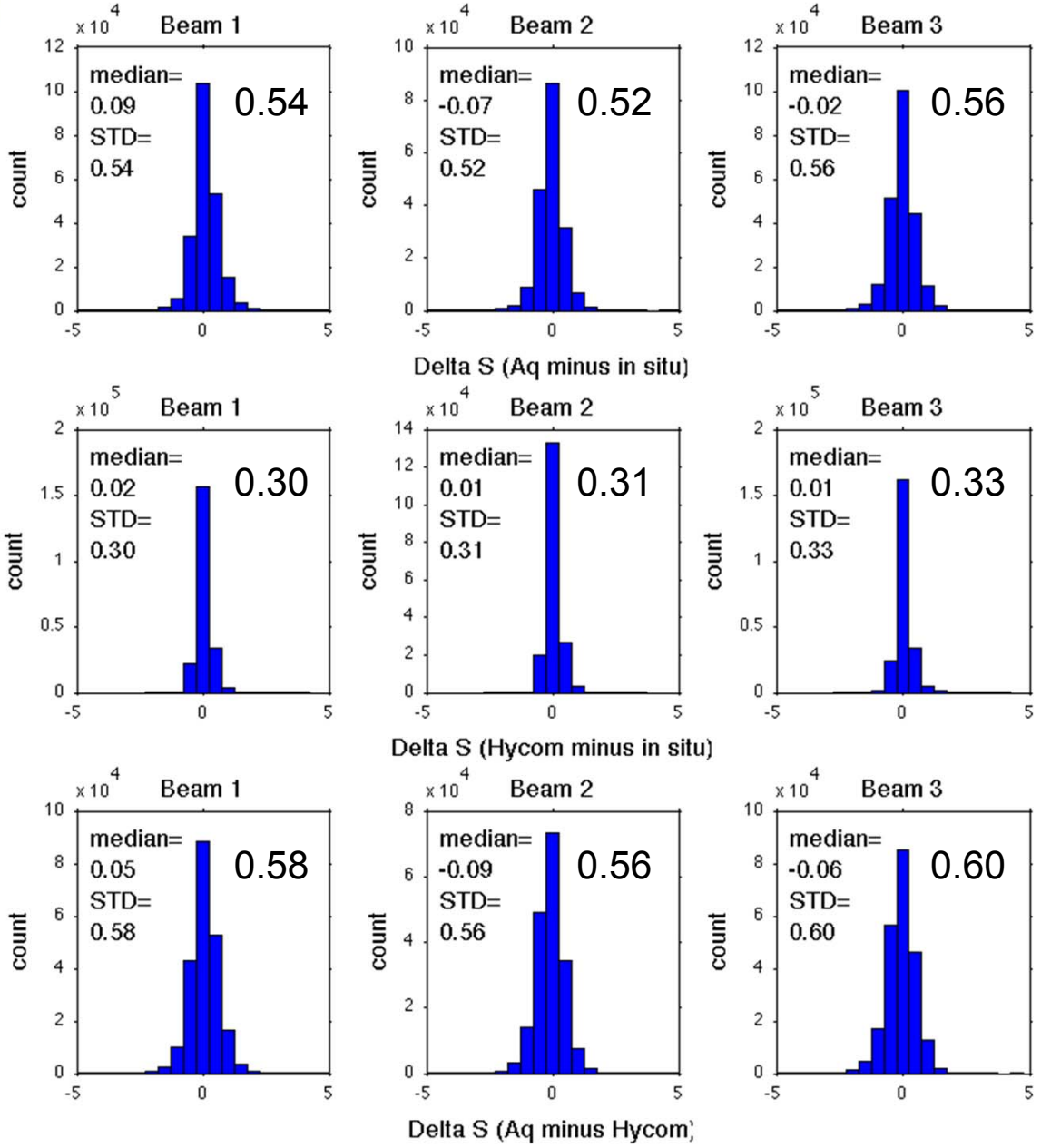
Summary of 3 co-located differences

Aq – in situ

dSSS V1.3
8/25/2011-11/25/2012
Matchup Specifications
land and ice frac < 0.0005
SST > 5C,
windspeed <15m/s

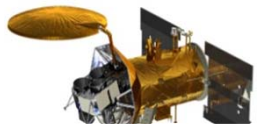
HYCOM – in situ

Aq – HYCOM



AQUARIUS/SAC-D

Summary of 3 co-located differences



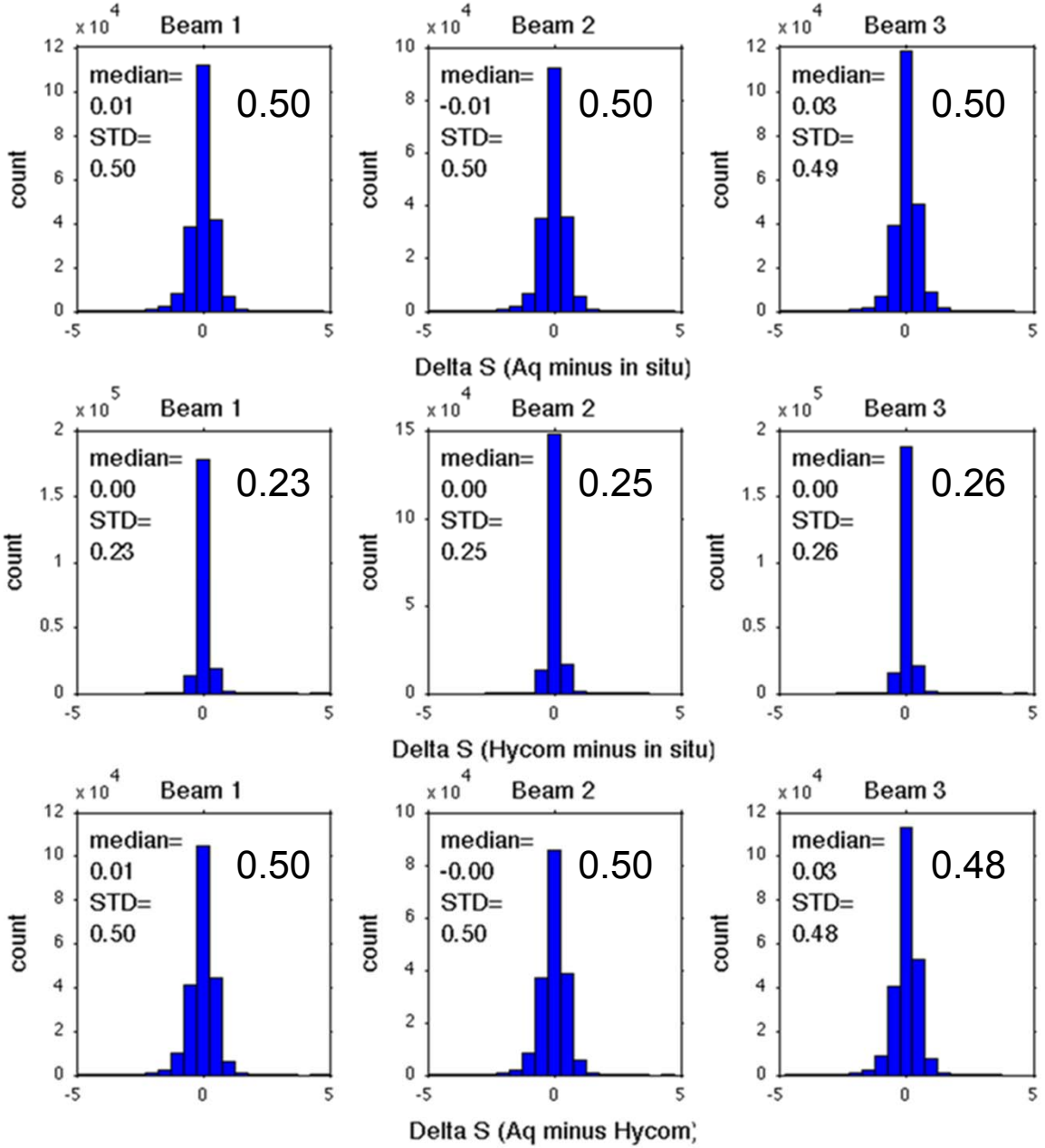
Aq – in situ

dSSS V1.3.9
8/25/2011-11/25/2012
Matchup Specifications
land and ice frac < 0.0005
SST > 5C,
windspeed <15m/s

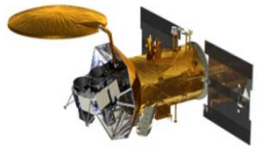
HYCOM – in situ

RMSE = sqrt(Bias^2 + STD^2)

Aq – HYCOM



Triple Point Analyses: V1.3 & V1.3.9



- Aquarius RMSE is reduced (~0.52 -> 0.46 psu)
- HYCOM RMSE is significantly reduced in V1.3.9 matchup because of the correction in V1.3.9 for the HYCOM latitude offset that was in earlier versions
- Now HYCOM RMSE is consistent with buoy RMSE
- The Aquarius rms error remains ~ 0.46 psu because of the spurious seasonal cycle

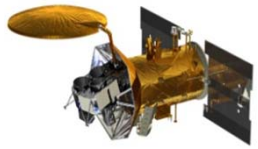
V1.3

	Beam 1	Beam 2	Beam 3
Aquarius RMSE	0.52	0.50	0.53
Hycom RMSE	0.25	0.27	0.28
Insitu RMSE	0.16	0.16	0.17
Theoretical monthly RMSE if all errors are uncorellated			
Monthly RMSE (8 samples worst case) psu	0.19	0.18	0.19

V1.3.9

	Beam 1	Beam 2	Beam 3
Aquarius RMSE	0.47	0.47	0.45
Hycom RMSE	0.16	0.18	0.17
Insitu RMSE	0.16	0.18	0.20
Theoretical monthly RMSE if all errors are uncorellated			
Monthly RMSE (8 samples worst case) psu	0.17	0.17	0.16

AQUARIUS/SAC-D Quasi-monthly calibration variations

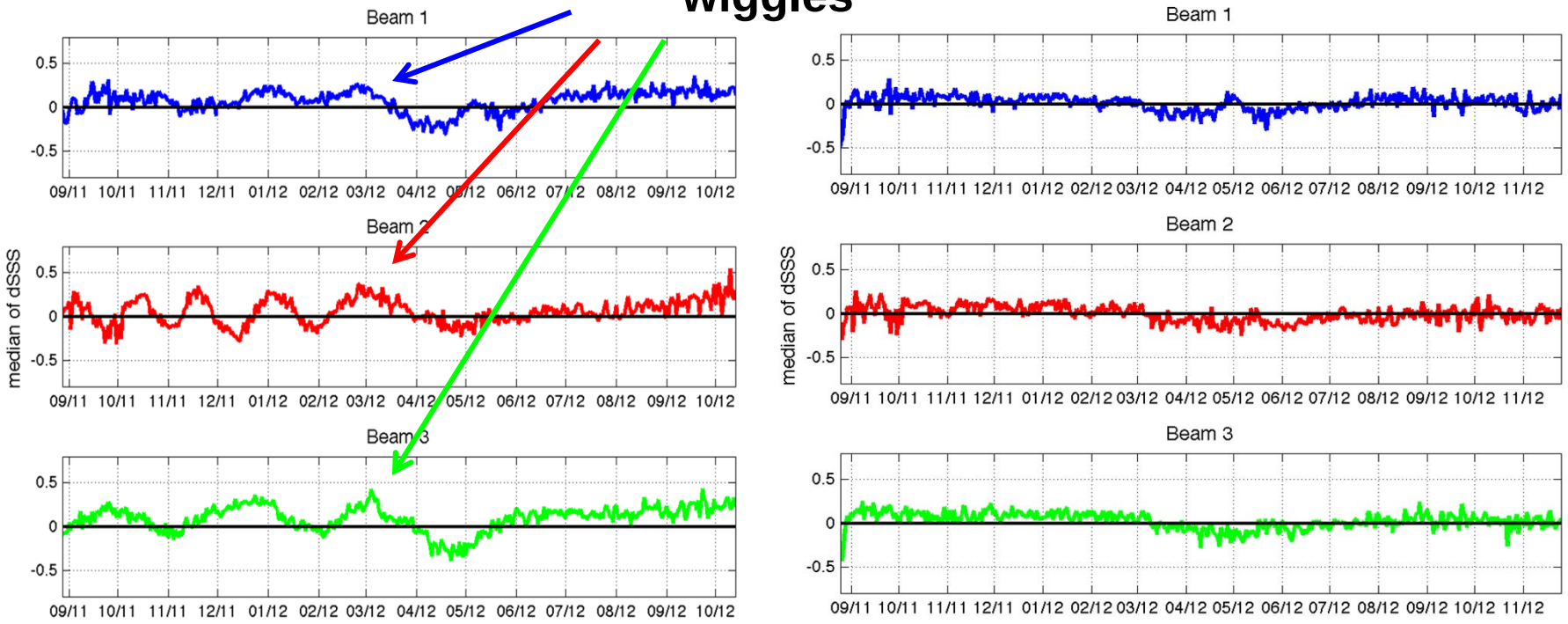


Prior to V2.0, the data have transient quasi-monthly calibration errors. These are removed in V2.0 as we now partition of the sources between instrument the model error.

V1.3.5 & earlier

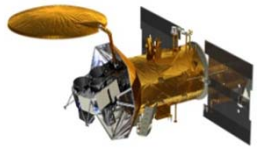
Calibration "wiggles"

V2.0



Quick-Look files and images still contain calibration wiggles

Ascending and Descending trends



V1.3 trends are different for ascending and descending. Likely sources are antenna coupling, galaxy reflection and others