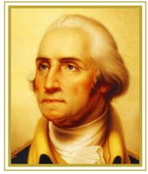
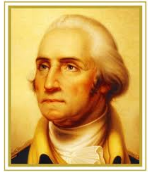


Improved Seawater Model Function and its Comparison with Argo Data

Roger H. Lang[1], Yiwen Zhou[1], Calvin Drego[1], Cuneyt Utku[2], David Le Vine[2]

1] George Washington University(GW), Washington D.C. 20052

2] Cryospheric Sciences Branch NASA /Goddard Space Flight Center, Greenbelt, MD,20771



OUTLINE

I. Purpose

II. Basic Algorithm and Method

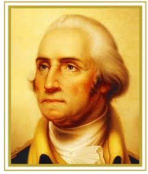
III. Measurements

IV. Results

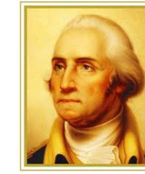
V. Comparison with in-situ data

PURPOSE

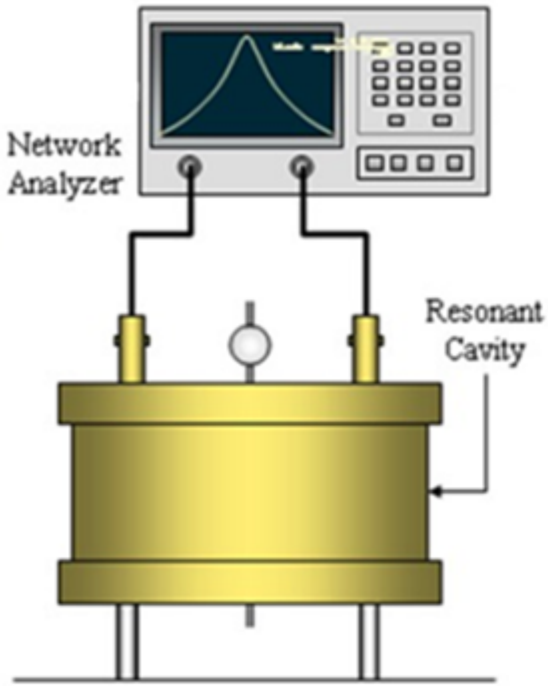
- Develop an accurate relationship for the dependence of the dielectric constant of seawater on temperature and salinity.
- Compare salinity obtained by various algorithms with Argo buoy data.

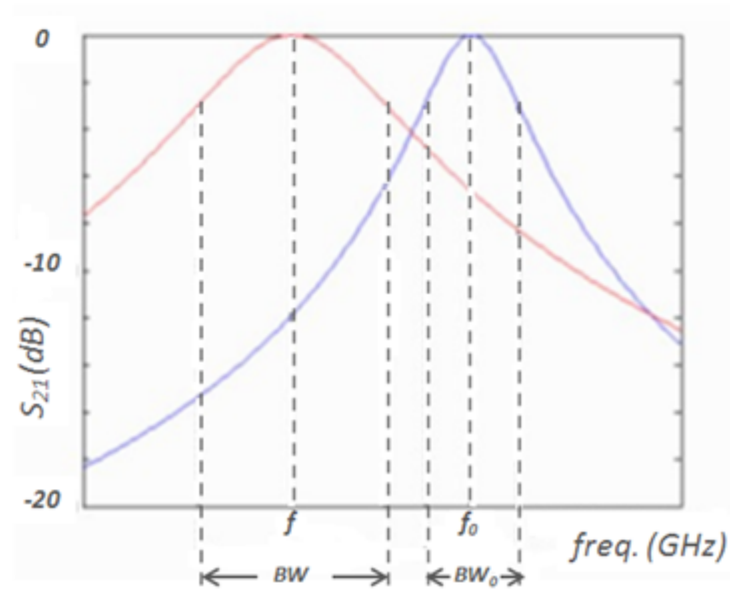


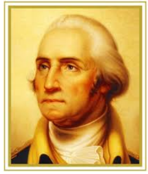
Algorithm and Method



Cavity Technique







The Algorithm

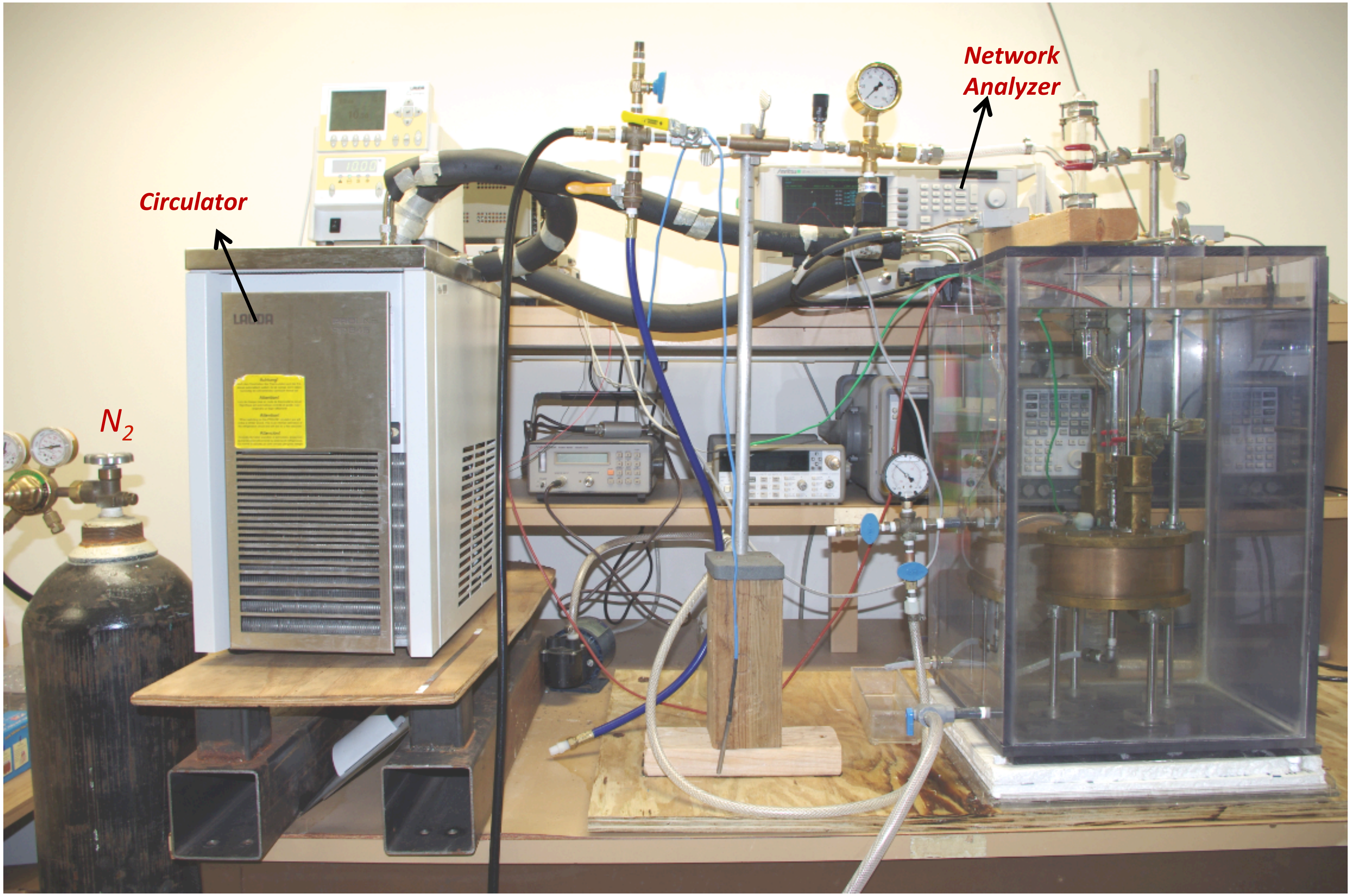
- Use perturbation theory.
- Valid when sample volume is small.
- The dielectric constant, $\varepsilon = \varepsilon' + i\varepsilon''$ of the sample is:

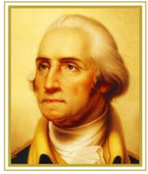
$$\varepsilon' - 1 = 2C\frac{\Delta f}{f}, \qquad \varepsilon'' = C\Delta\left(\frac{1}{Q}\right)$$

$$\Delta f = f - f_0, \qquad \Delta\left(\frac{1}{Q}\right) = \frac{1}{Q} - \frac{1}{Q_0} = \frac{BW}{f} - \frac{BW_0}{f_0}$$

C - Calibration Coefficient

Experimental Setup





Measurements

Old Measurements vs. New Measurements

2007-2008 2011-2012

Calculation of *C* Constant

- Based on the algorithm, use sample with known dielectric constant value as a reference.

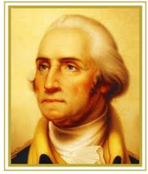
- Obtain C value by:

$$\varepsilon' - 1 = 2C_1 \frac{\Delta f}{f}, \qquad \text{or} \qquad \varepsilon'' = C_2 \Delta\left(\frac{1}{Q}\right)$$

- Use methanol as the reference solution.

  - A.P. Gregory and R.N. Clark ---*Tables of the Complex Permittivity of Dielectric Reference Liquids at Frequency up to 5 GHz* , NPL(National Physical Laboratory), March 2009

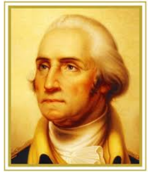
  - Measurement errors are within 0.1% for both real and imaginary parts of the permittivity



New Calibration Method

- For new calibration measurements, the distilled water is not used to clean the tube in the measurements. Instead, nitrogen gas flowing through the tube was used to evaporate any methanol that was remaining in the socket.
- Use new methanol stored in a glass bottle with permanent rubber cap to prevent water absorption from the air.
- New calibration constant increased about 2%. As a result, new measurements closer to Klein Swift for mid temperature range.

Measurements

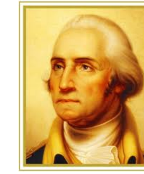


➢New measurements based on the seawater purchased from OSIL(Ocean Scientific International ltd), 2011

1. 30 psu: $0 \sim 35^{o}$ C
2. 35 psu: $0 \sim 40^{o}$ C
3. 38 psu: $0 \sim 35^{o}$ C

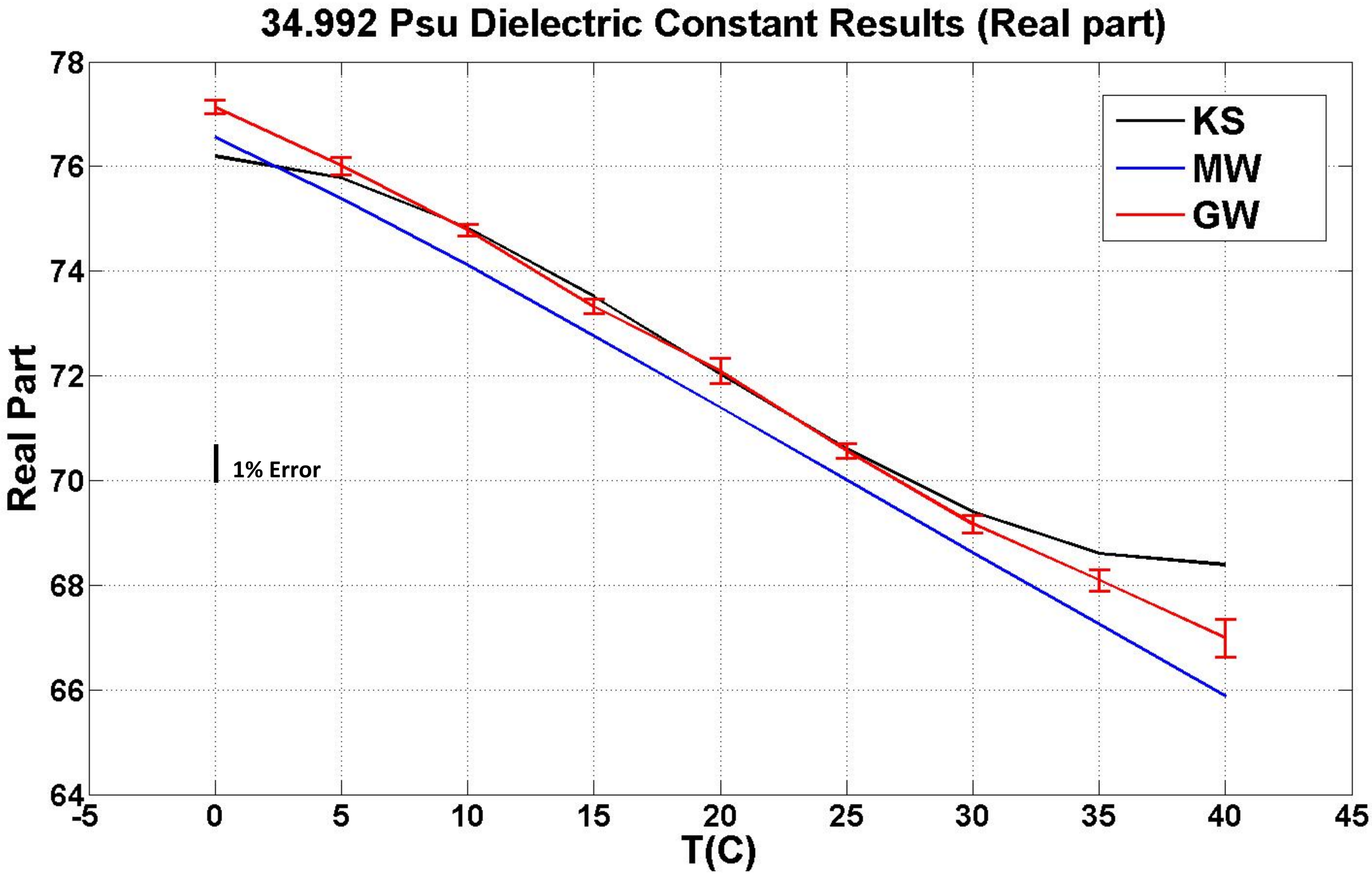
➢ For one temperature and salinity, at least three measurements were made.

➢ The results of our measurements will be compared with Klein-Swift Model and Meissner-Wentz Model.

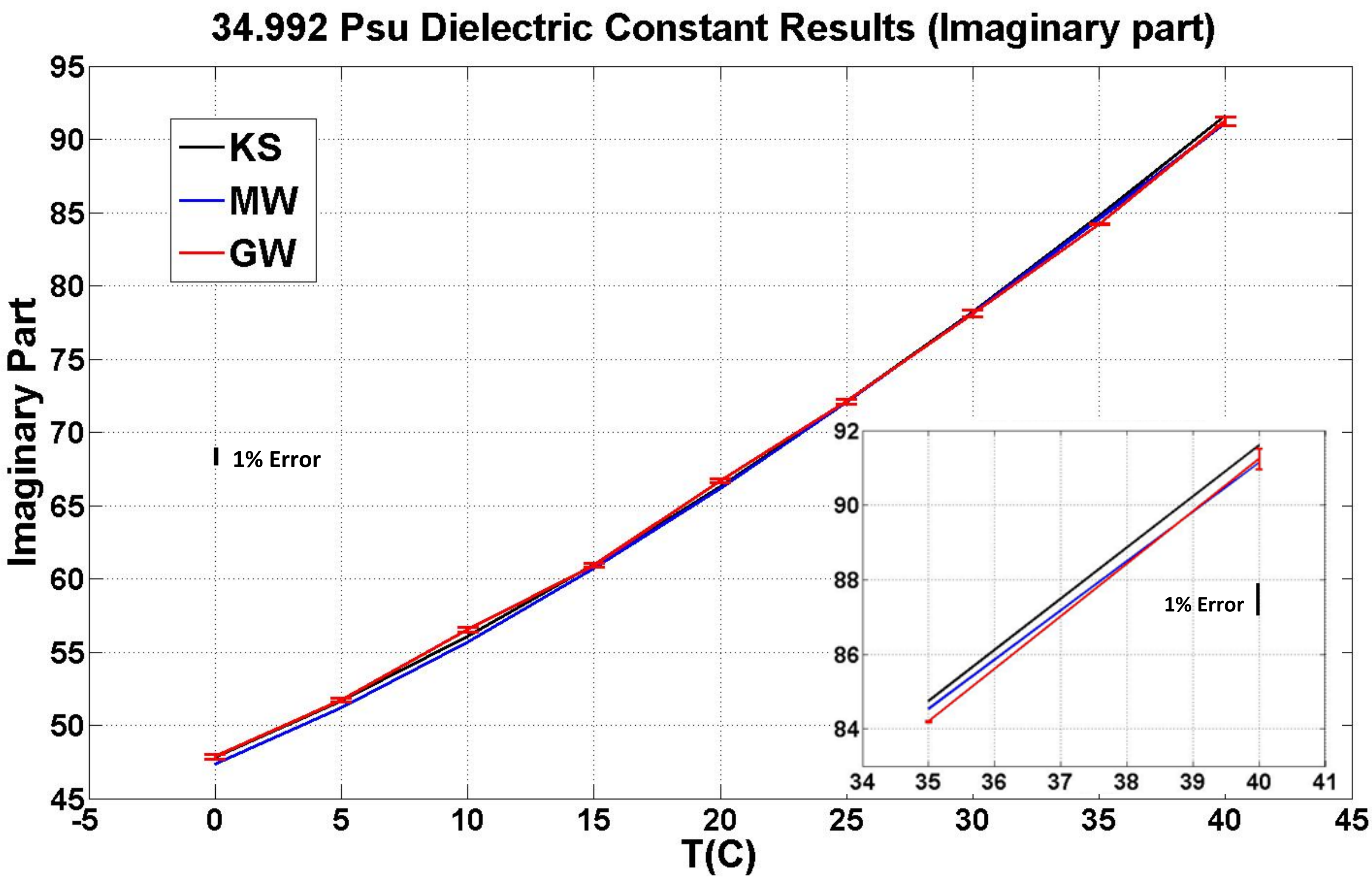


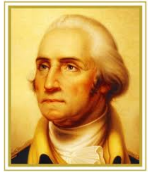
Results

Real Part of Seawater Dielectric Constant (35 psu)



Imaginary Part of Seawater Dielectric Constant (35 psu)





Uncertainty Analysis

- For and Imaginary part, the uncertainty can be represented as

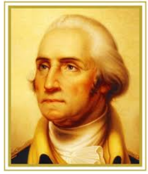
$$\sigma_\varepsilon^2 = \sigma_\varepsilon^2(SW) + \sigma_\varepsilon^2(C_M) + \sigma_\varepsilon^2(C_{ref})$$

$\sigma_\varepsilon^2(SW)$ is the uncertainty from seawater measurements

$\sigma_\varepsilon^2(C_M)$ is the uncertainty from methanol measurements

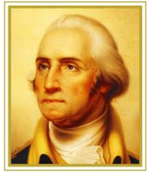
$\sigma_\varepsilon^2(C_{ref})$ is the uncertainty from Gregory & Clark's report we used to determine the permittivity of methanol

Error reduction in the results



Real Dielectric Constant Uncertainty					
Temp	σ_ε(SW)	σ_ε(C)	σ_ε(ref)	σ_ε(total)	σ_ε(2008)
0	0.12	0.17	0.14	0.25	-
5	0.14	0.17	0.14	0.26	-
10	0.10	0.17	0.14	0.24	0.62
15	0.20	0.16	0.13	0.29	0.67
20	0.12	0.16	0.13	0.24	0.63
25	0.14	0.16	0.13	0.24	0.70
30	0.22	0.15	0.12	0.29	0.86
35	0.14	0.15	0.12	0.24	1.02
Average				0.26	0.75

Error reduction in the results



Imaginary Dielectric Constant Uncertainty					
Temp	**σ_ε(SW)**	**σ_ε(C)**	**σ_ε(ref)**	**σ_ε(total)**	**σ_ε(2008)**
0	0.09	0.19	0.08	0.22	-
5	0.22	0.20	0.09	0.31	-
10	0.19	0.22	0.1	0.31	0.44
15	0.29	0.24	0.11	0.38	0.62
20	0.29	0.26	0.12	0.40	0.53
25	0.16	0.28	0.13	0.34	0.68
30	0.29	0.31	0.14	0.45	1.03
35	0.27	0.34	0.15	0.46	1.06
Average				0.36	0.73

GW Model Functions

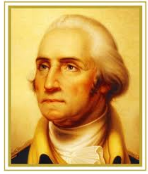
- GW Model Function was determined from the measurement results for seawater at 30 psu,35 psu, and 38 psu in the temperature range $0 < T < 35^{o}$C

$$\varepsilon(S,T) = \sum_{i=0}^{2}\sum_{j=0}^{2} c_{i,j} S^i T^j$$

where

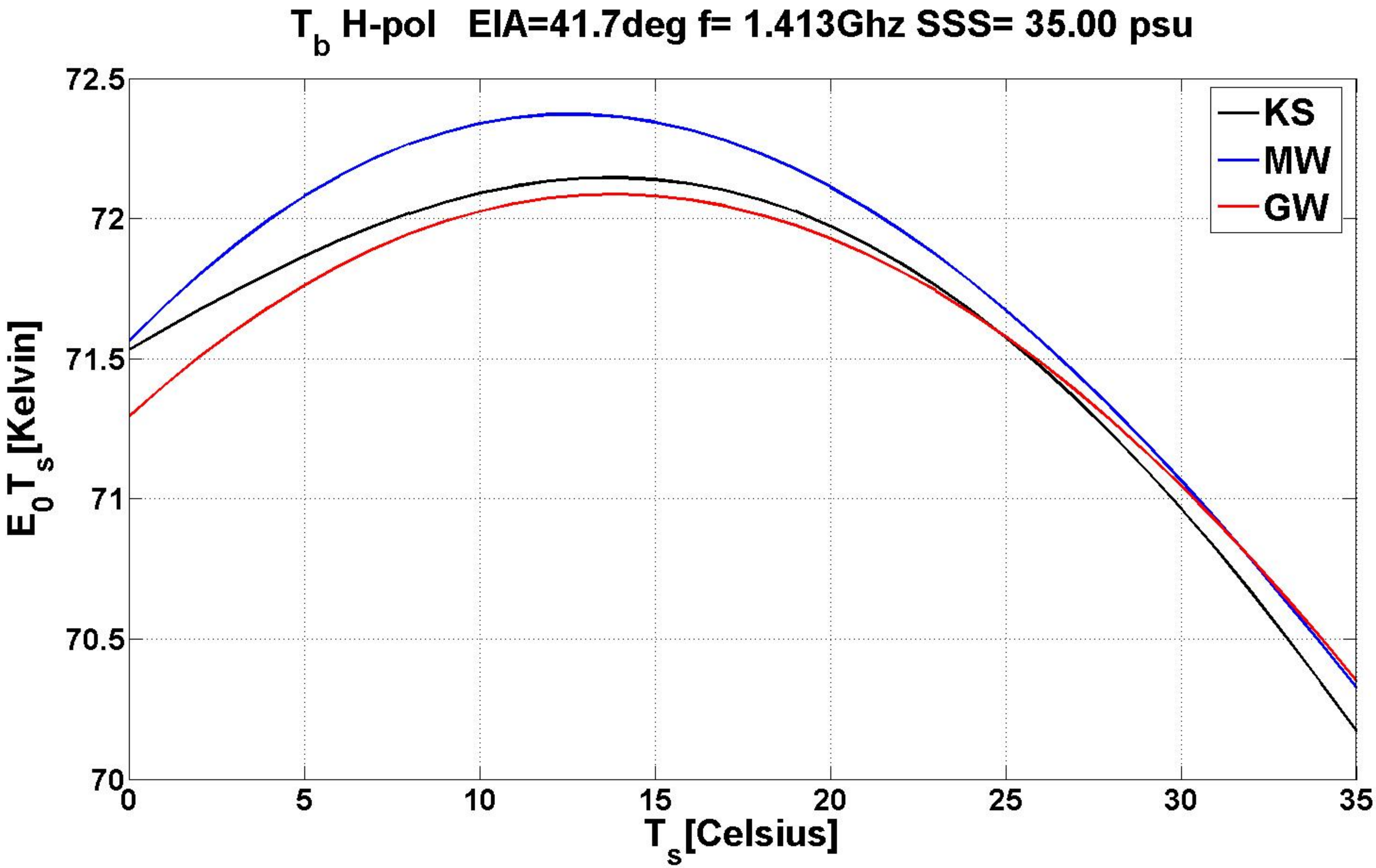
$$c_{i,j} = a_{i,j} + j b_{i,j}$$

In the model function, ε is the complex dielectric constant, S is seawater salinity, T is the measured temperature (Celsius), and $c_{i,j}$ are complex coefficients. The average difference between GW model function and measurement data is 0.09 for real part and 0.21 for imaginary part.

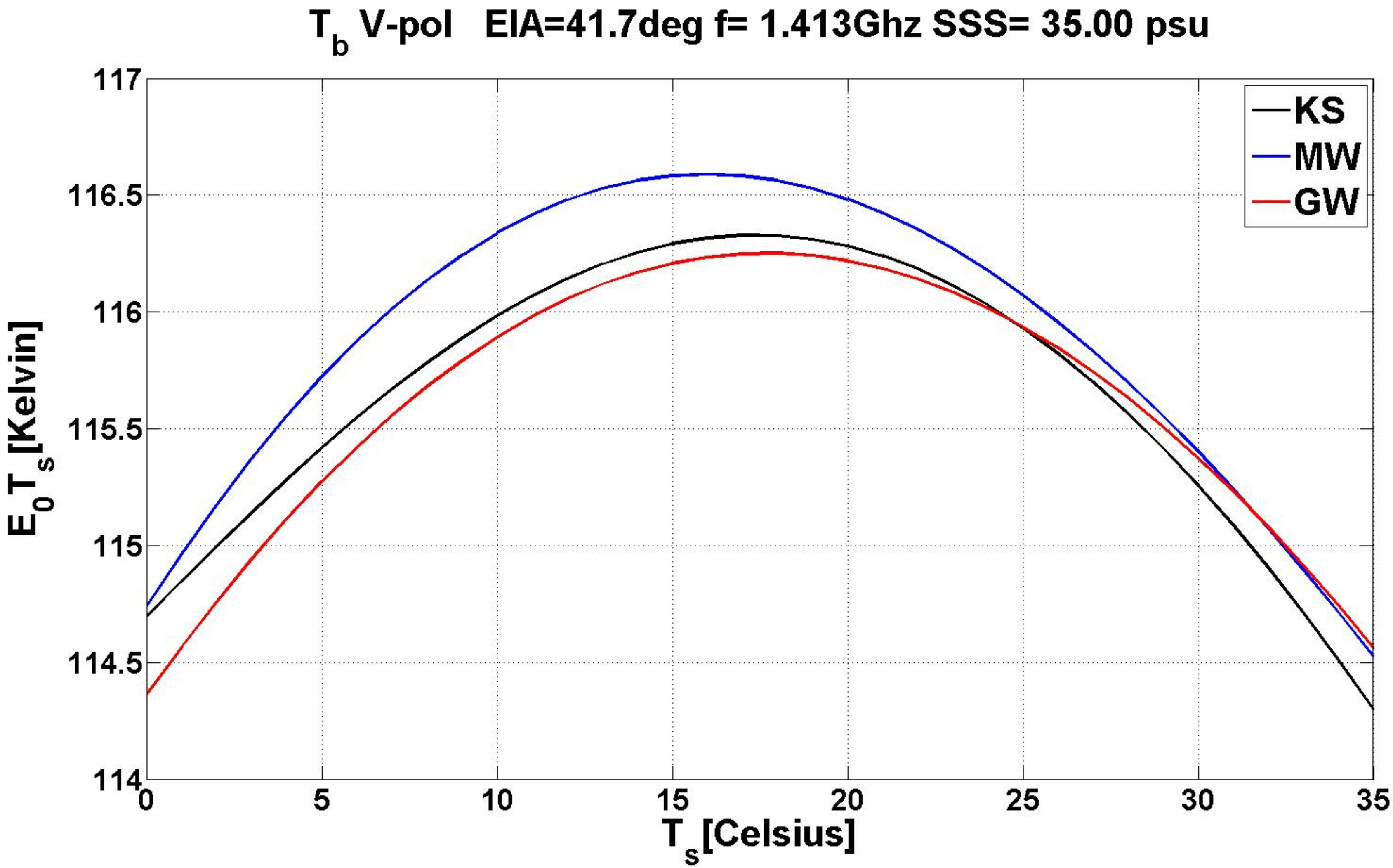


Brightness Temperature

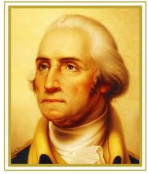
Brightness Temperature for 35 psu seawater in H polarization



Brightness Temperature for 35 psu seawater in V polarization

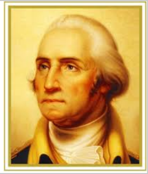


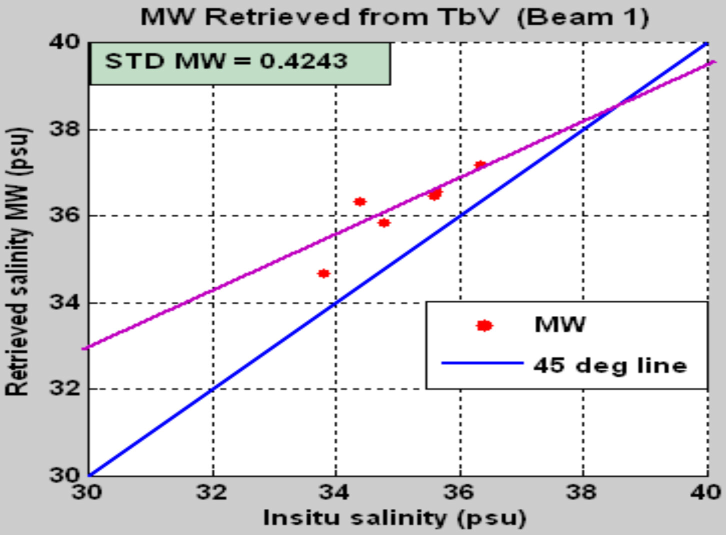
Verification of Model Function Using Aquarius Validation Data System (AVDS)

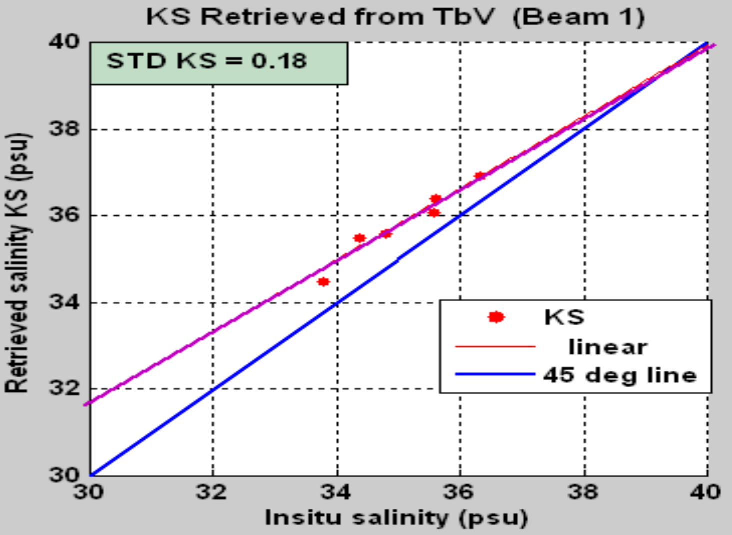


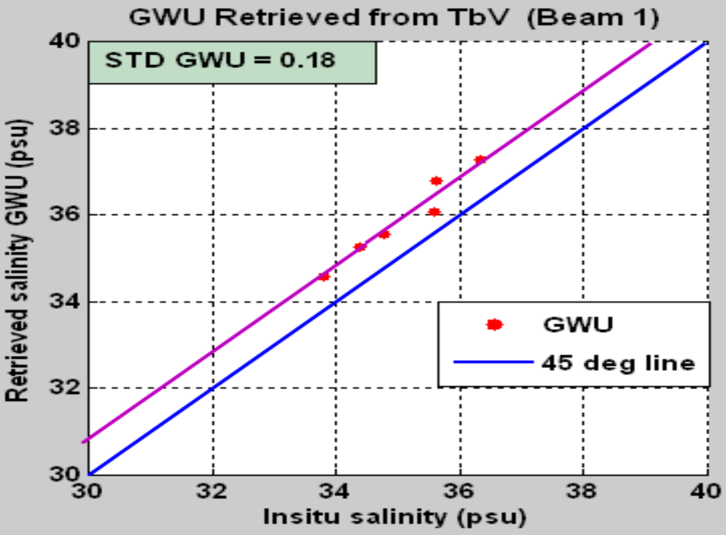
- AVDS Version 1.1 (Beam 1)
- Time Period : Oct 1st 2011 - Jan 31st 2012
- Inversion Algorithms : MW, KS, GWU
- Inversion is carried out only for calm waters
- Brightness temperature : TbV (V-Pol)
- Physical temperature : Sea surface temperature (SST) at the closest point of approach (cpa_T)

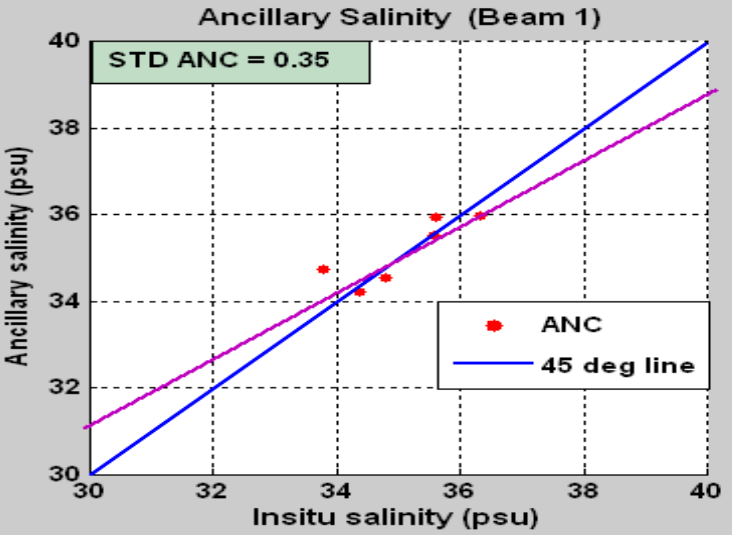
V 1.1 Oct 2011 – Jan 2012
CPA < 5 KM Data Points = 8
Wind speed < 1m/s Wave Height < 0.1m Land/Ice < 0.001



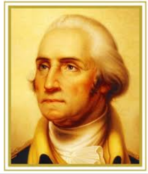


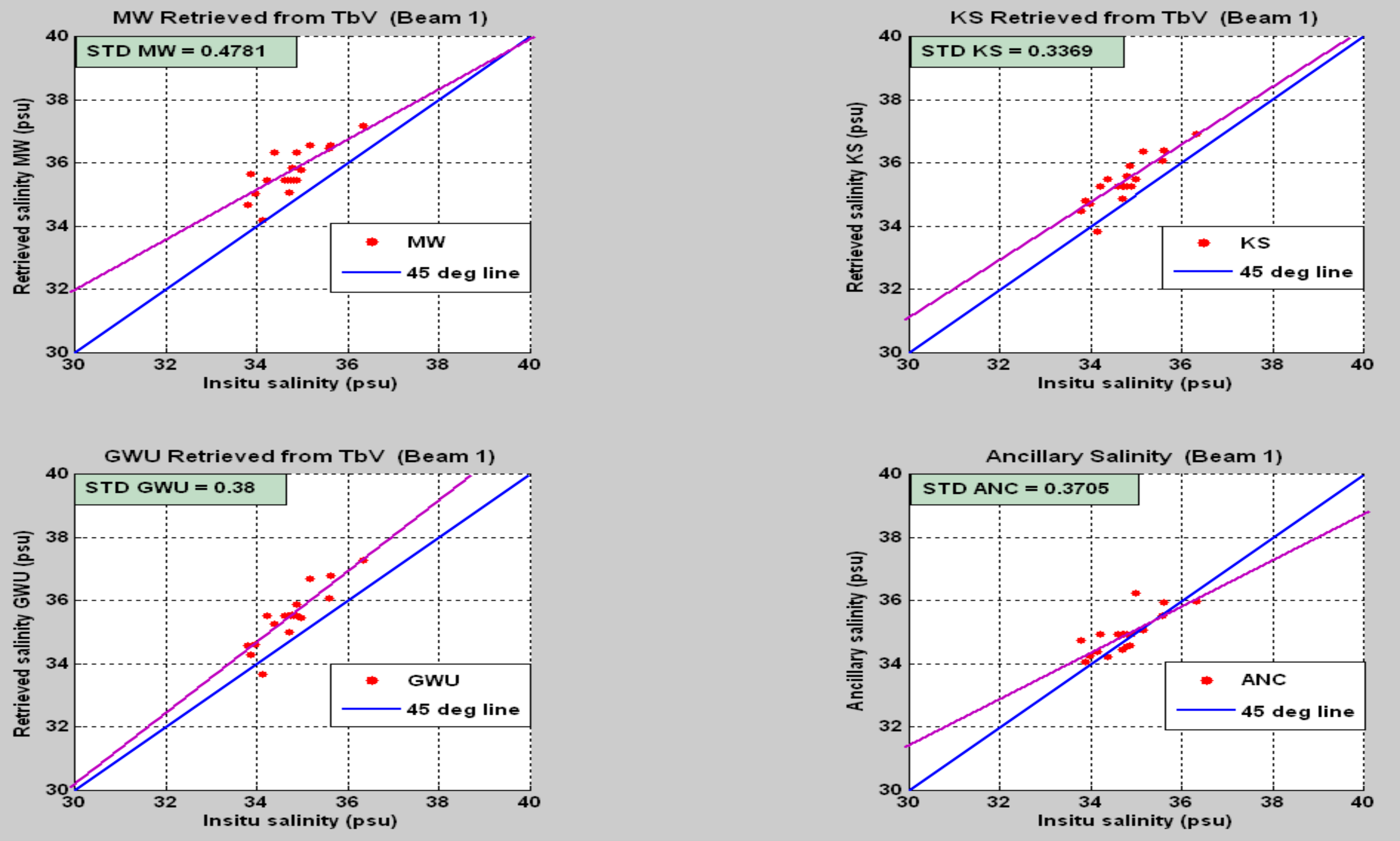




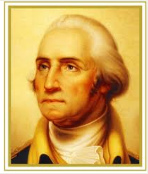


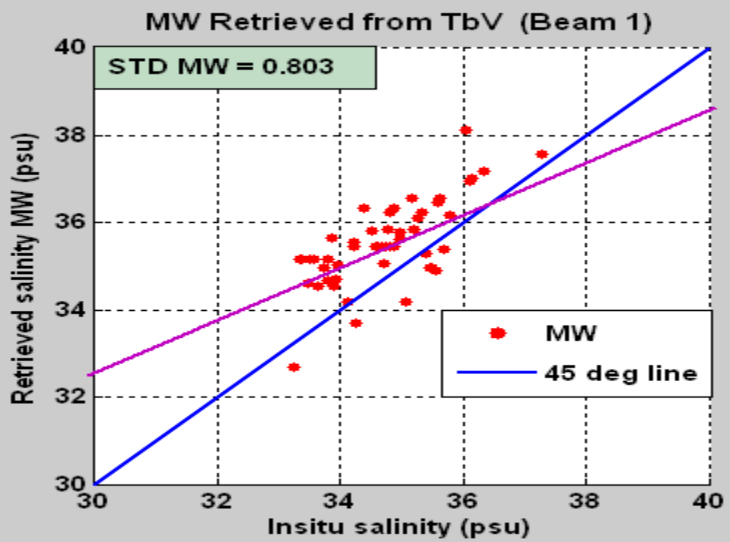
V 1.1 Oct 2011 – Jan 2012
CPA < 10 KM Data Points = 24
Wind speed < 1m/s Wave Height < 0.1m Land/Ice < 0.001

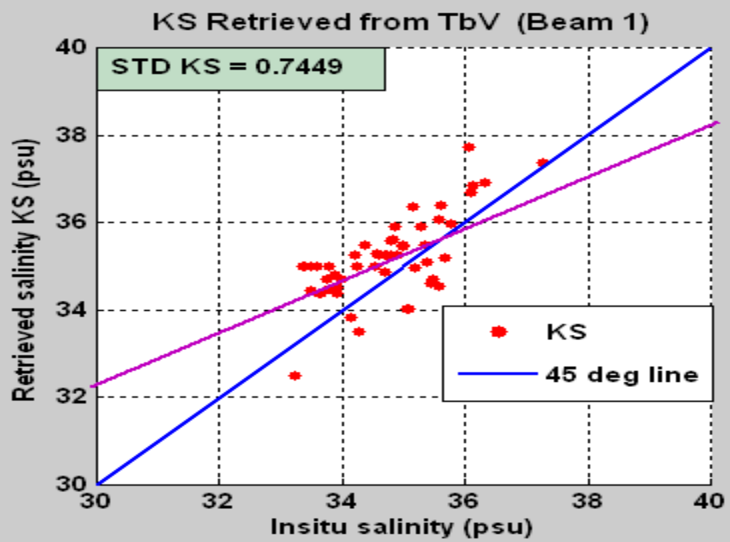


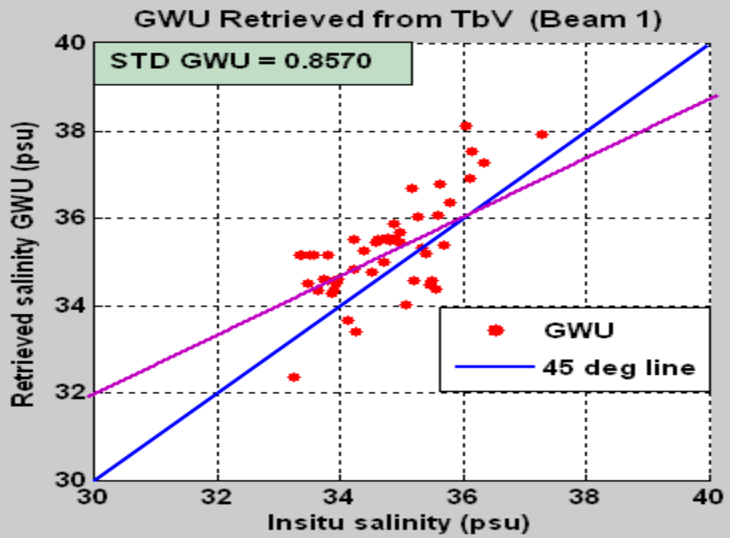


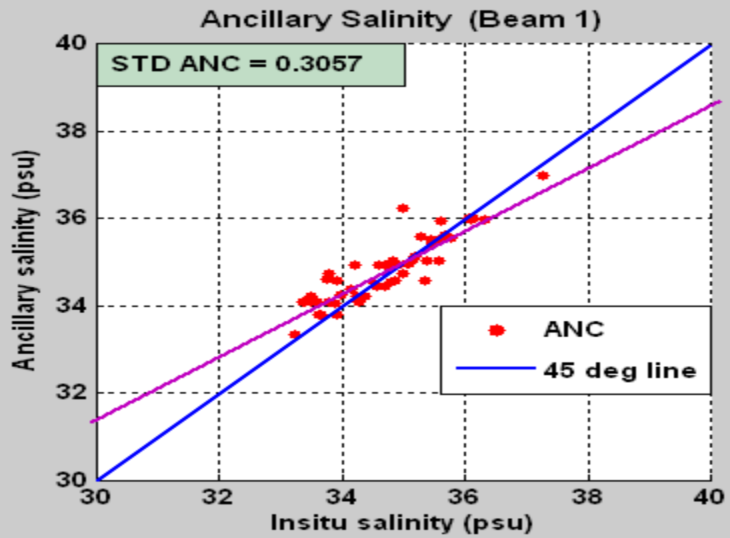
V 1.1 Oct 2011 – Jan 2012
CPA < 25 KM Data Points = 66
Wind speed < 1m/s Wave Height < 0.1m Land/Ice < 0.001



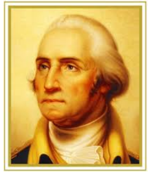






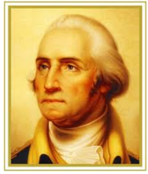


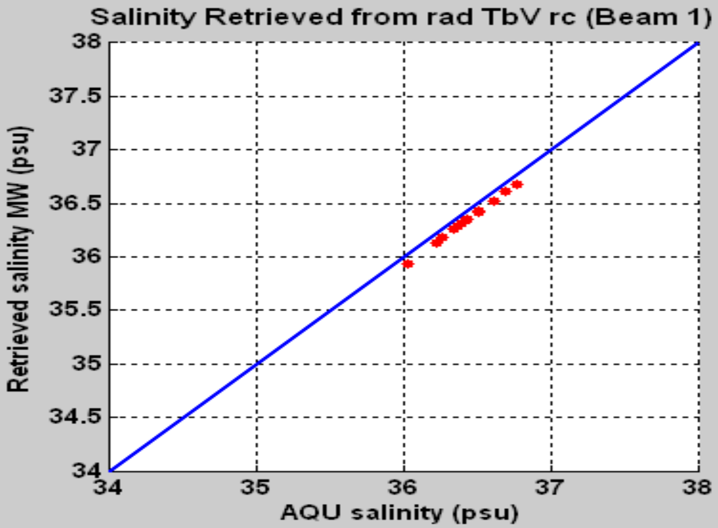
Inversion Using Data from Aquarius Website

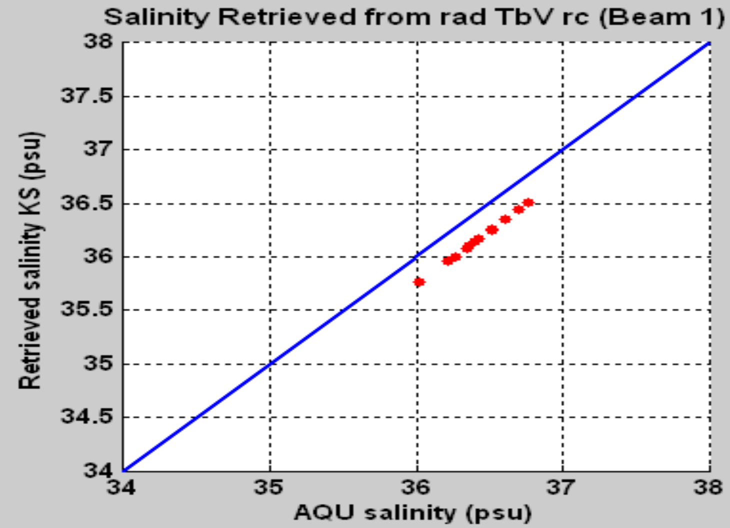


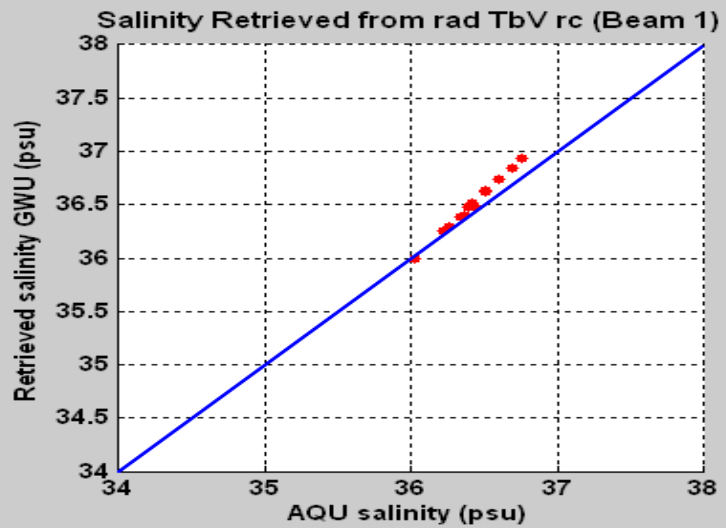
- Aquarius Version V 1.2.4 (Beam 1)
- Date: March 31st 2012 (5 orbits worth of data)
- Brightness Temperature : V-Pol *TbV_rc* (roughness corrected)
- Wind Speed < 1m/s
- Land/Ice < 0.001

V 1.2.4 Data Points = 13
Wind speed < 1m/s Land/Ice < 0.001
Backscatter < -25 dB



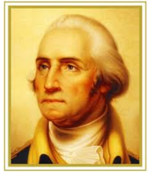






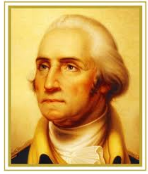
Conclusion

- More accurate new measurements have been made. The average variance for all measurements is reduced to 0.31 compared with 0.74 in 2008.
- Temperature range has been expanded to include 0 and 5 degrees.
- Initial comparison with in-situ data shows that the slope and variance of retrieved salinity vary with the closest point of approach (CPA distance) from the Argo buoys.

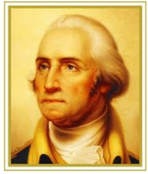


Future Work

- Investigate frequency pulling effect due to the interaction of capillary tube with exit holes in cavity covers.
- Finish the measurements at 40 degree for 30, 35, and 38 psu seawater.
- Compare data from Aquarius site with in situ Argo buoy data using roughness corrected brightness temperatures. Use radar backscatter to determine calm surface conditions.

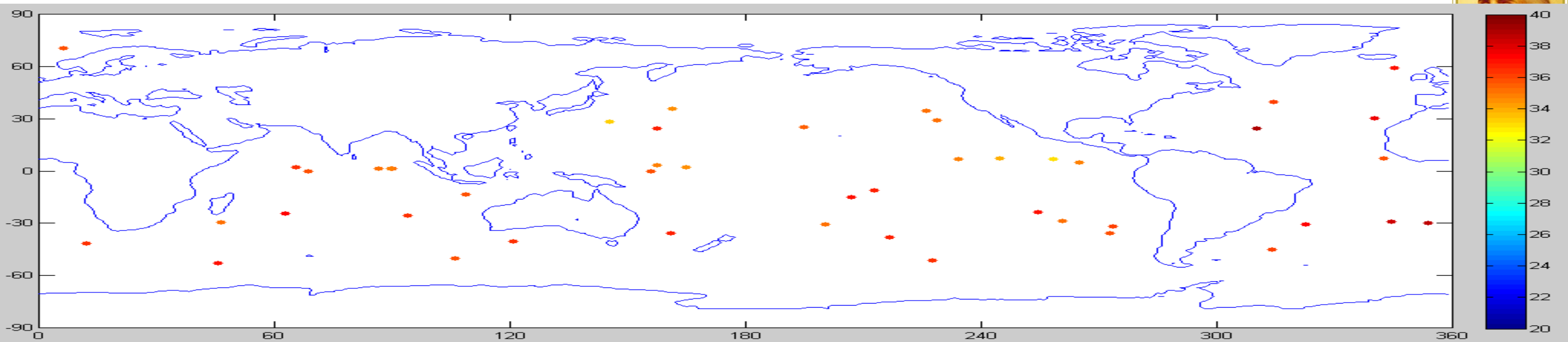


Thank you!

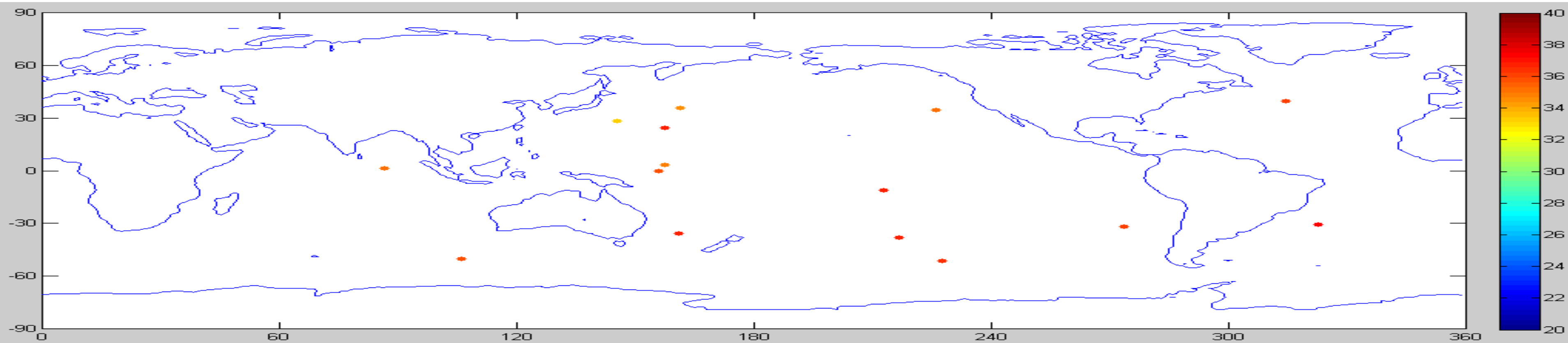


Back up Slides

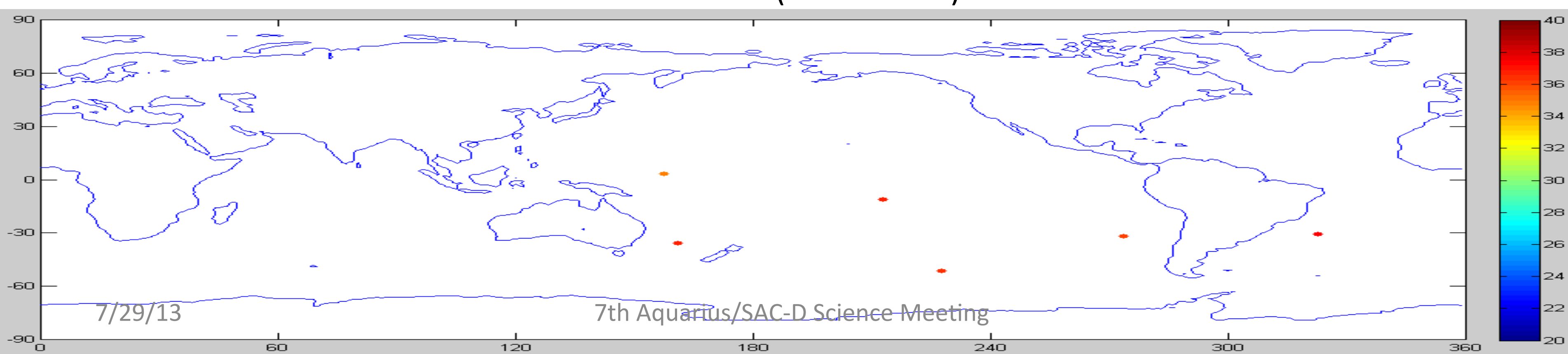
AVDS Data Points (CPA < 25 KM)

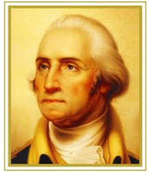


AVDS Data Points (CPA < 10 KM)

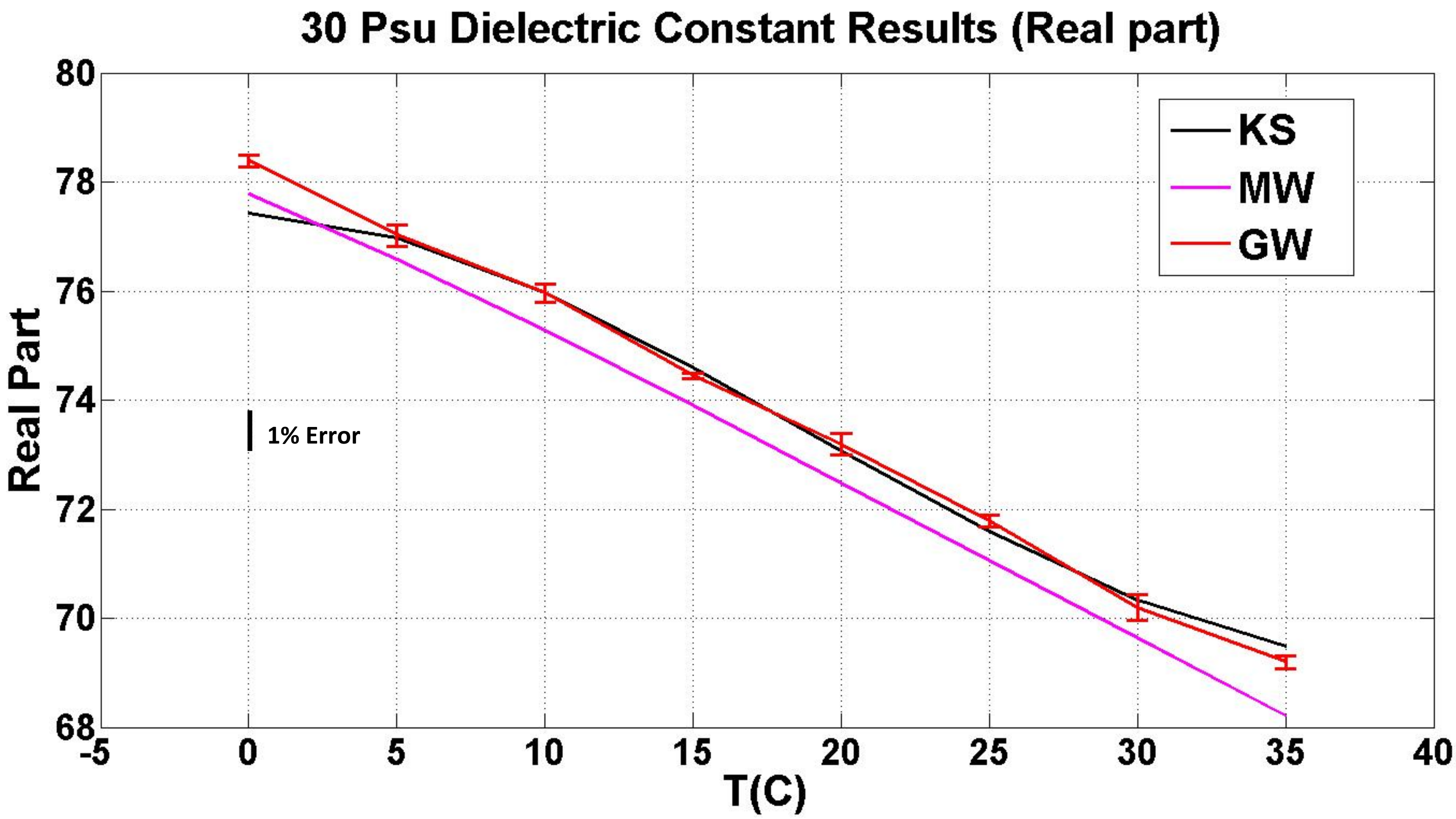


AVDS Data Points (CPA < 5 KM)

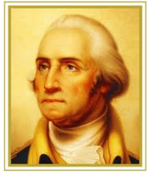


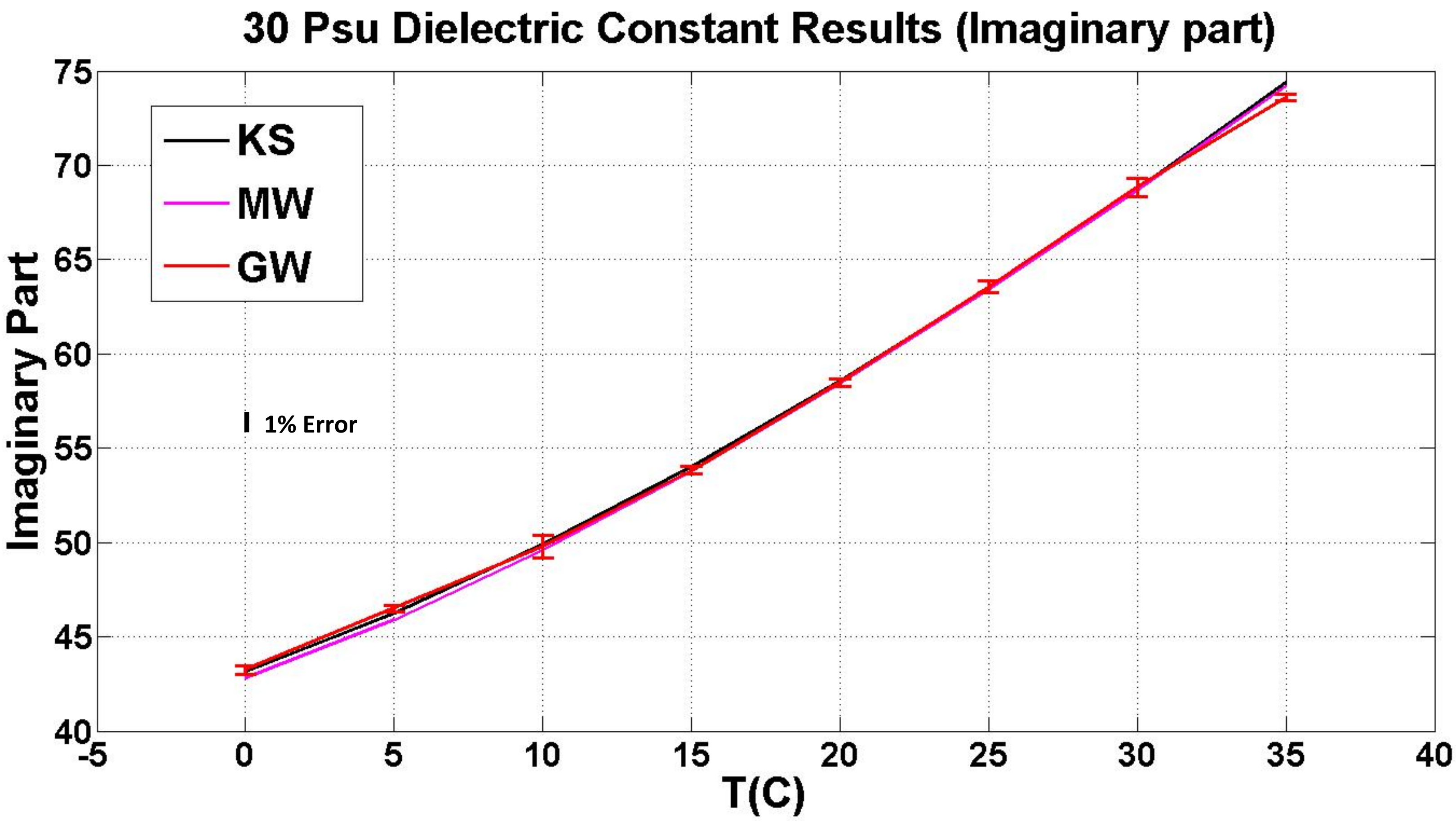


Real Part of Seawater Dielectric Constant (30 psu)

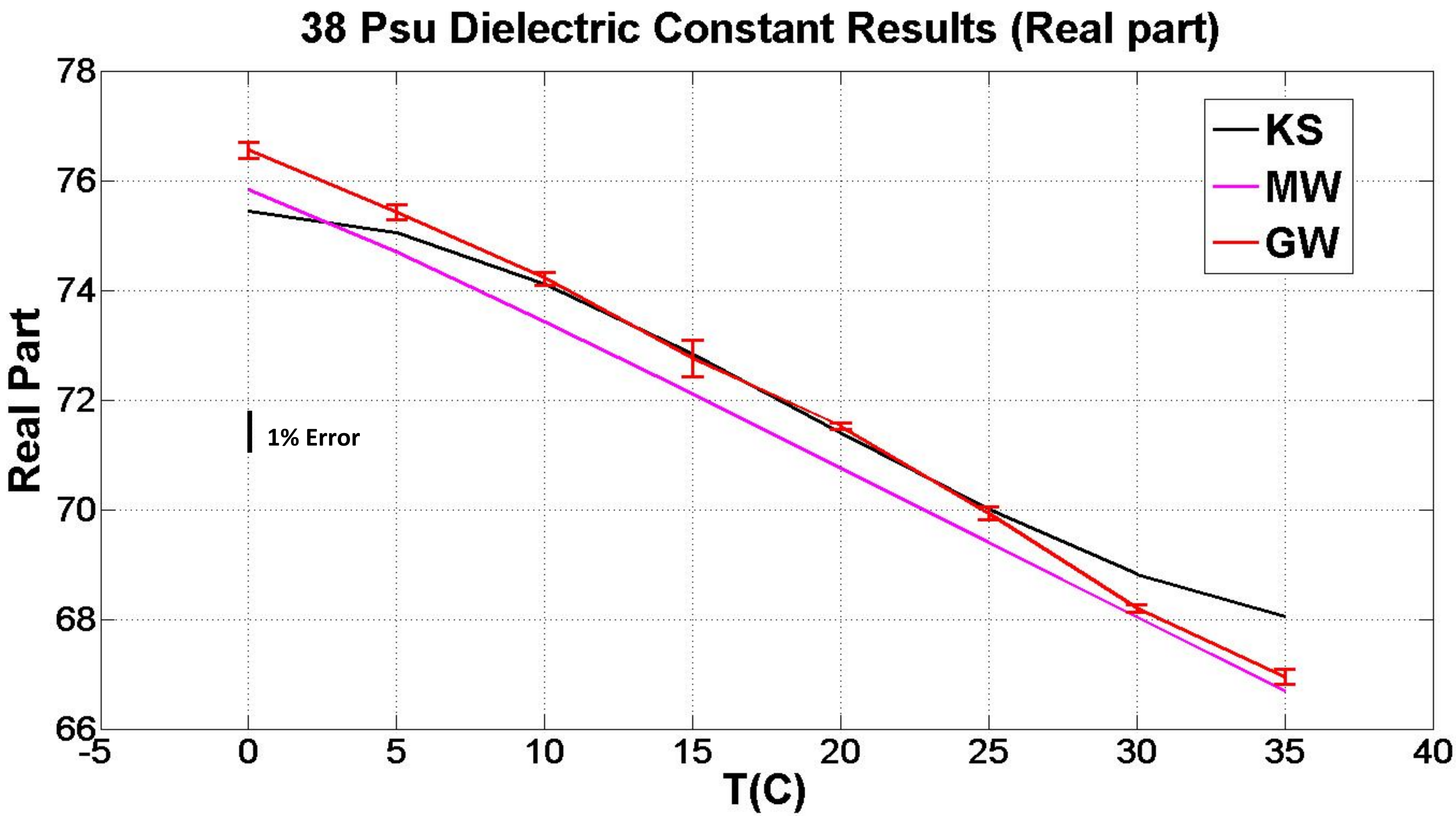


Imaginary Part of Seawater Dielectric Constant (30 psu)

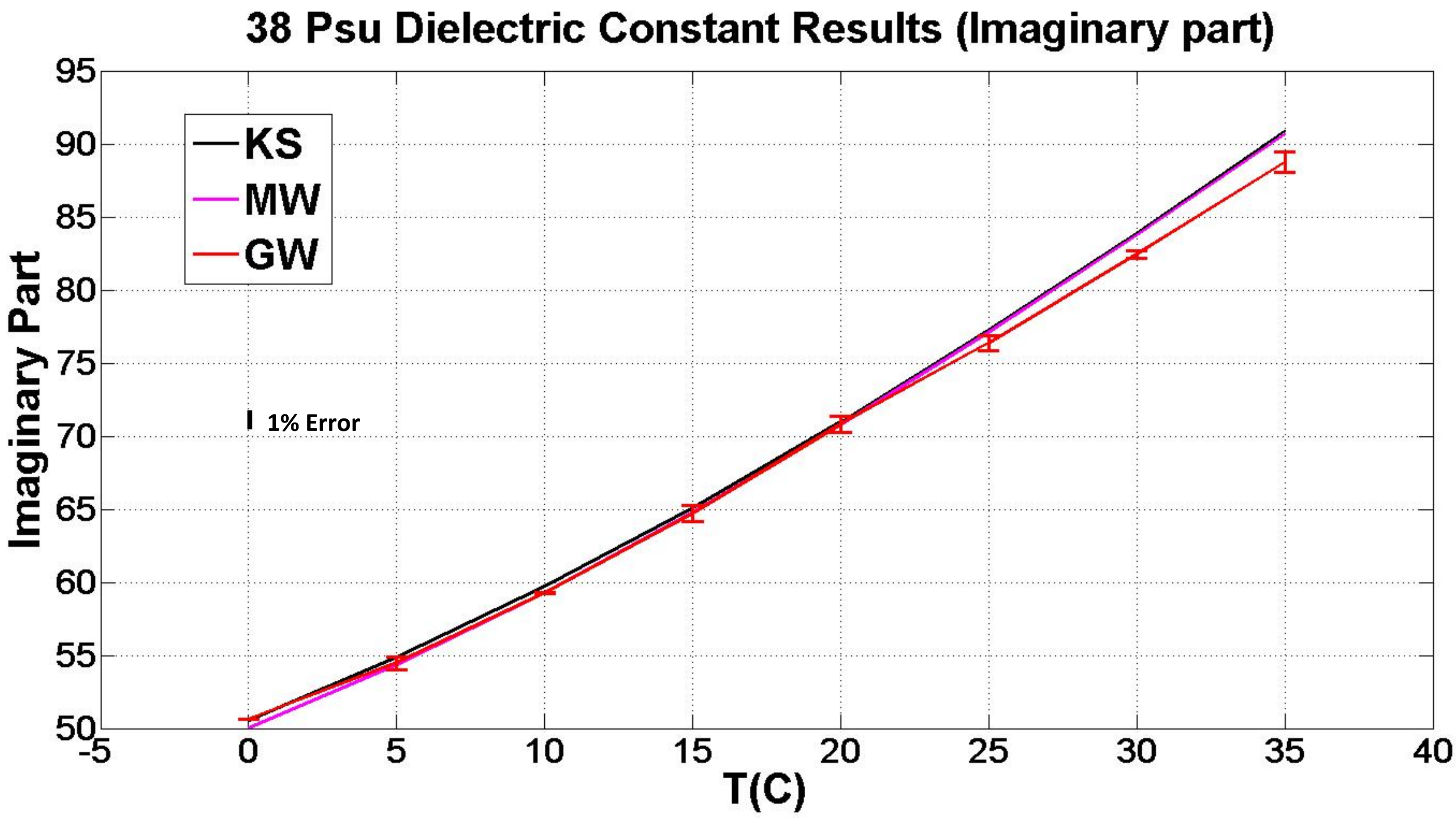




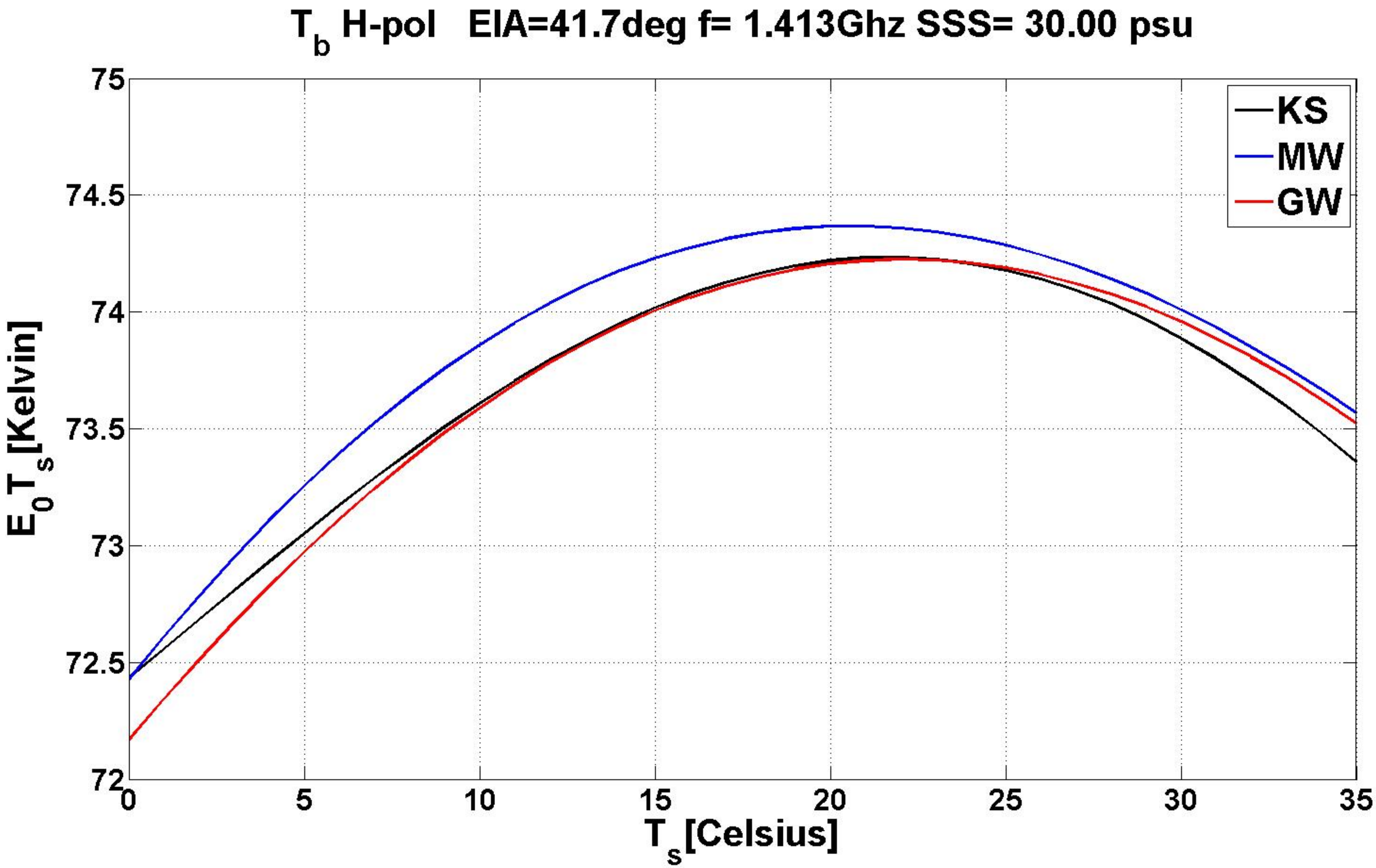
Real Part of Seawater Dielectric Constant (38 psu)



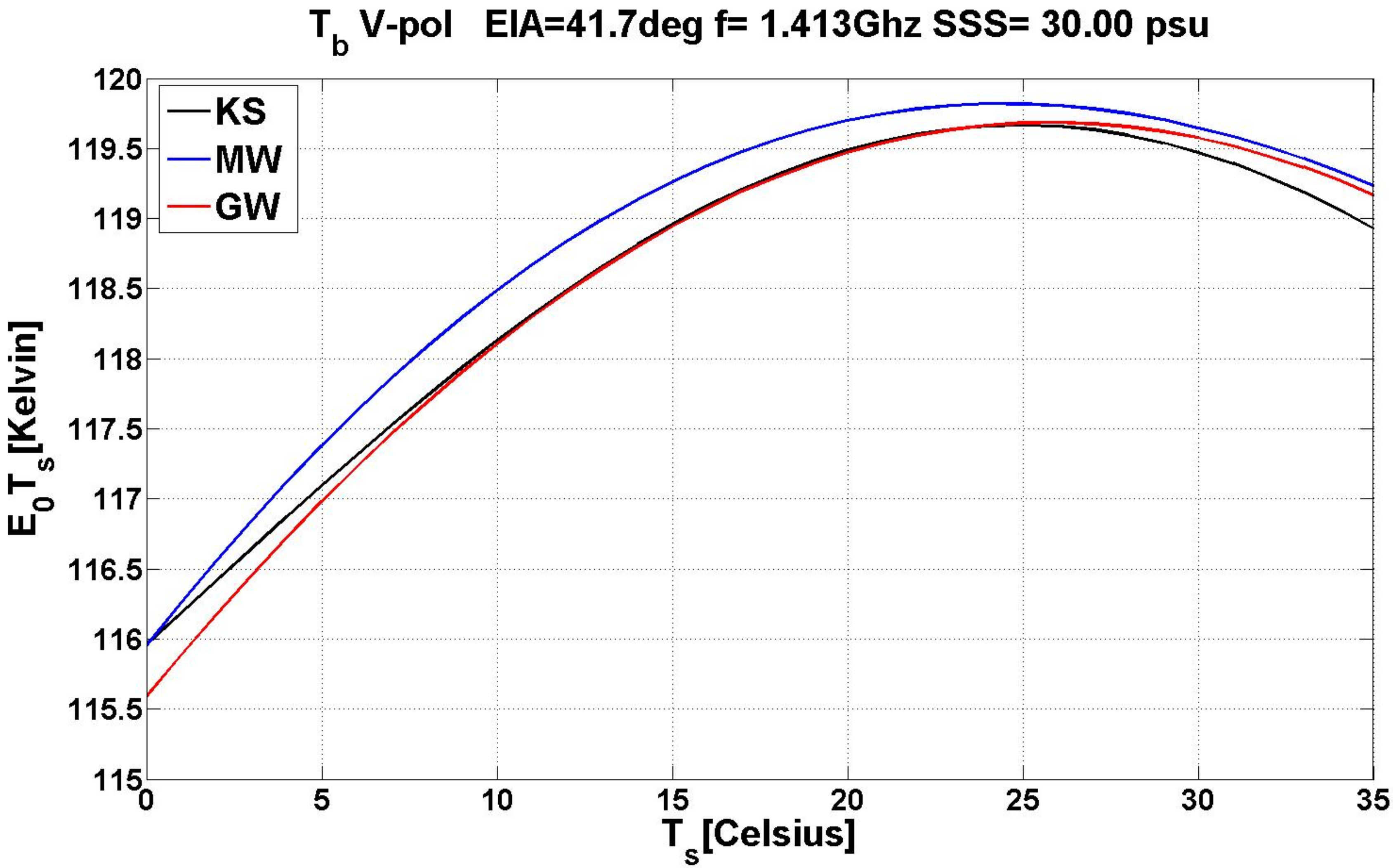
Imaginary Part of Seawater Dielectric Constant (38 psu)



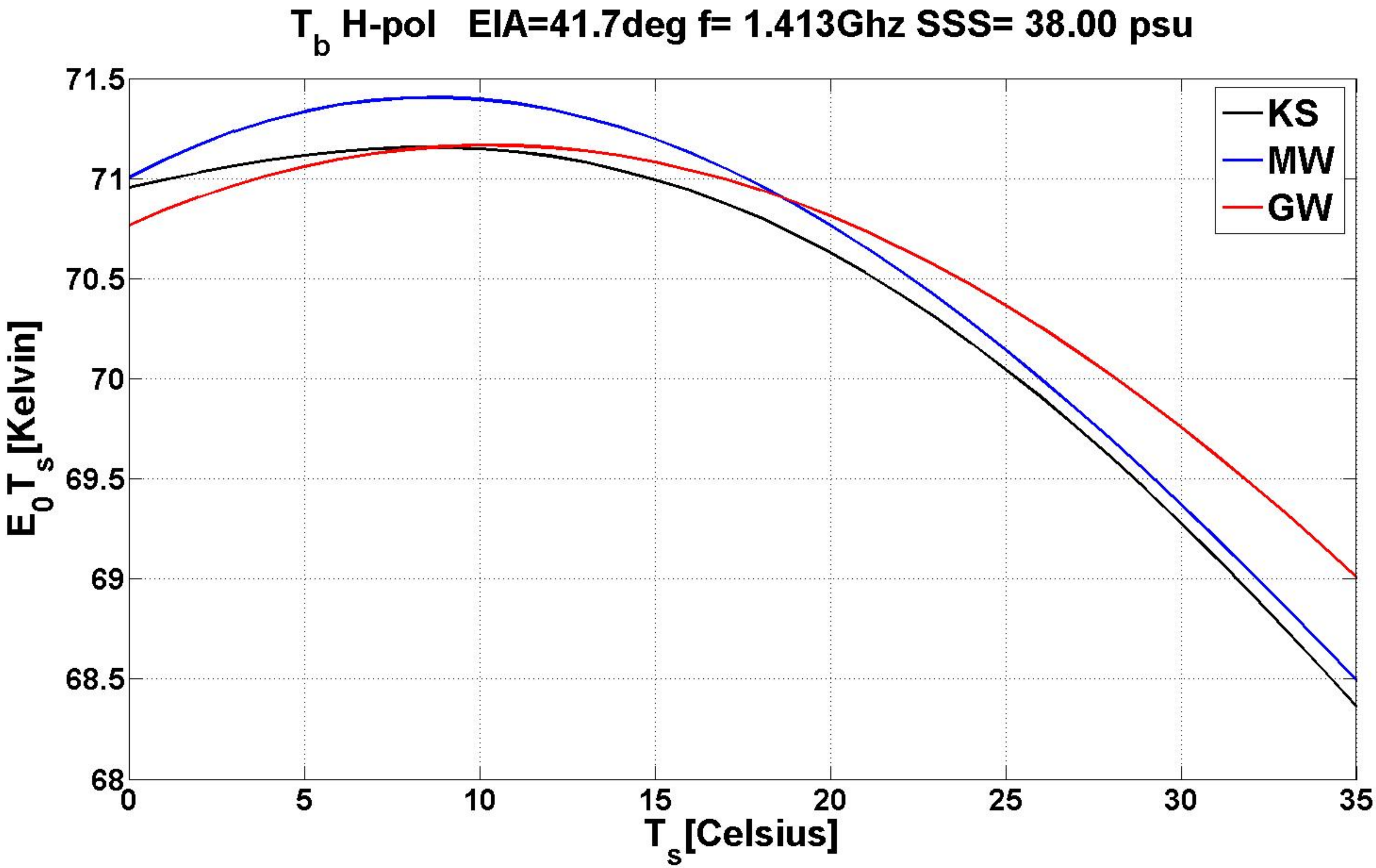
Brightness Temperature for 30 psu seawater in H polarization



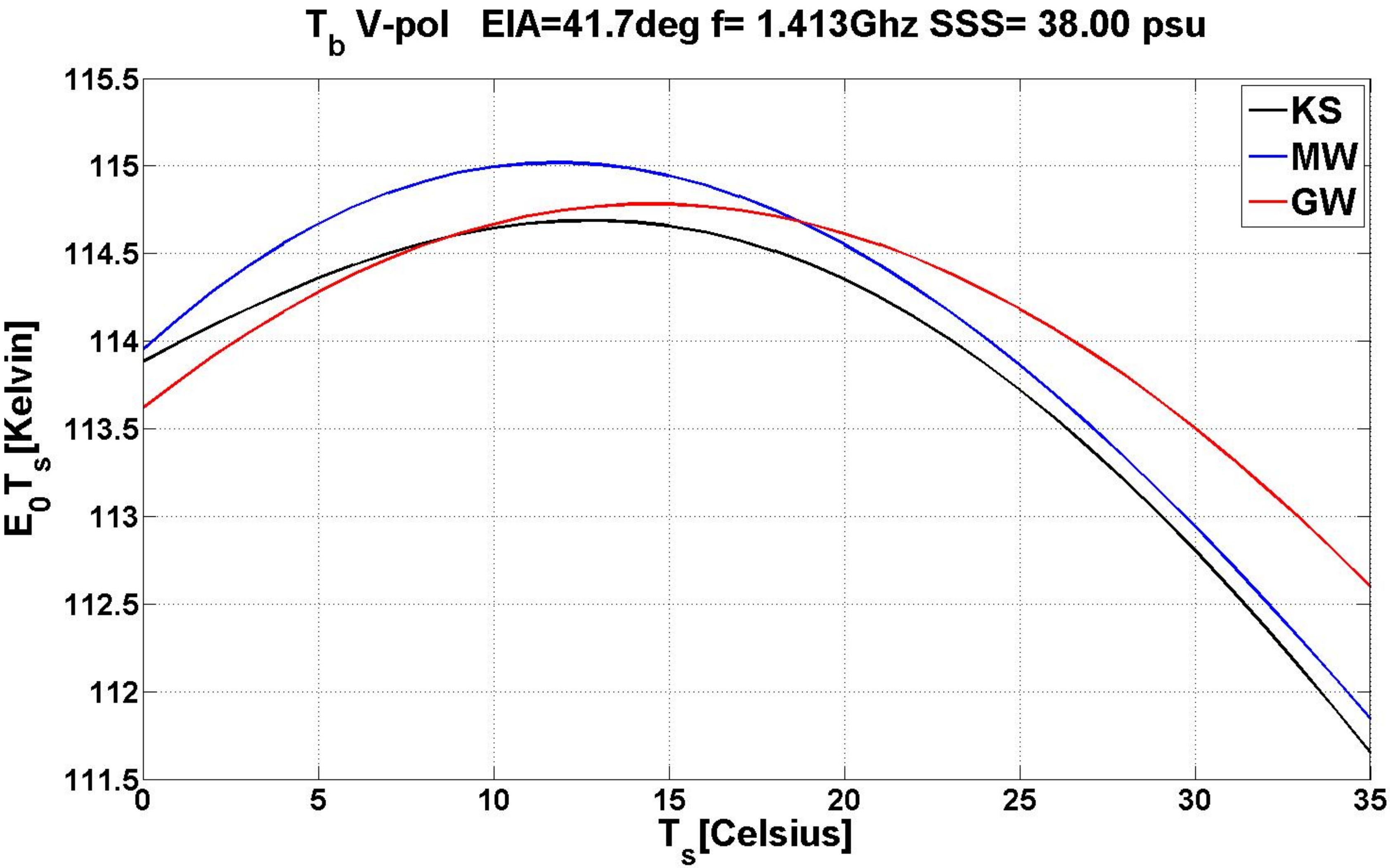
Brightness Temperature for 30 psu seawater in V polarization

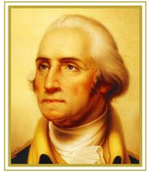


Brightness Temperature for 38 psu seawater in H polarization



Brightness Temperature for 38 psu seawater in V polarization





The Improvements of Accuracy

- The error of the calibration measurements has been reduced to 0.23% compared with an error of 0.76% found in 2008.
- For new seawater measurements, the average variance for all seawater measurements is reduced to 0.22 compared with 0.45 in 2008.

V 1.2.4
Data Points = 87
Wind speed < 1m/s   Land/Ice < 0.001