Models for the Dielectric Constant of Sea Water for Remote Sensing of Salinity: A Perspective

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Passive Microwave Remote Sensing

Brightness Temperature: T_B

$$T_B = e\,T$$

e = Emissivity

T = Physical Temperature

$$e = 1 - R^2$$

$$= 1 - \left| \frac{1-\sqrt{\varepsilon}}{1+\sqrt{\varepsilon}} \right|^2 \quad \text{(normal incidence)}$$

$$\varepsilon = \varepsilon(f, S, T)$$

Relative Dielectric Constant: ε(**f, S, T**)

$$\varepsilon = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_1}{1 + j\omega\tau_1} + \frac{\varepsilon_1 - \varepsilon_\infty}{1 + j\omega\tau_2} - j\frac{\sigma}{\omega\varepsilon_o}$$

Response of molecular dipole; One term at low frequency with additional terms at higher frequency

Effect of current (moving ions)

Models for the Dielectric Constant

- $\varepsilon = \varepsilon_\infty + \frac{\varepsilon_S - \varepsilon_\infty}{1 + j\omega\tau_1} - j\frac{\sigma}{\omega\varepsilon_o}$

- KS: Klein and Swift [1977]
- EL: Ellison et al [1998]
- BA: Blanch-Aguasca [2004]
- GW: Zhou et al [2021]
- BV: Boutin et al [2021]

- $\varepsilon = \varepsilon_\infty + \frac{\varepsilon_S - \varepsilon_1}{1 + j\omega\tau_1} + \frac{\varepsilon_1 - \varepsilon_\infty}{1 + j\omega\tau_2} - j\frac{\sigma}{\omega\varepsilon_o}$

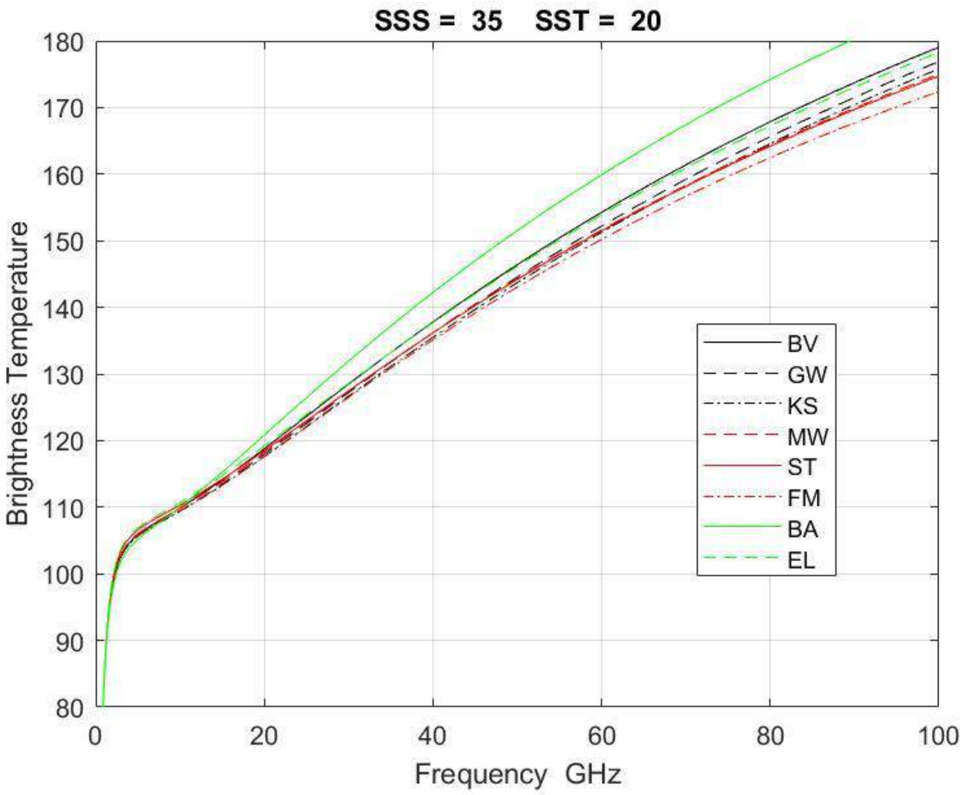
- ST: Stogryn [1995]
- MW: Meissner-Wentz [2004, 2012]
- FM: FASTEM-4: Liu et al [2011]

Brightness Temperature vs Frequency

- Similar Dependence on Frequency: TB(f)
  - Common functional form

$$\varepsilon = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_1}{1 + j\omega\tau_1} + \frac{\varepsilon_1 - \varepsilon_\infty}{1 + j\omega\tau_2} - j\frac{\sigma}{\omega\varepsilon_o}$$

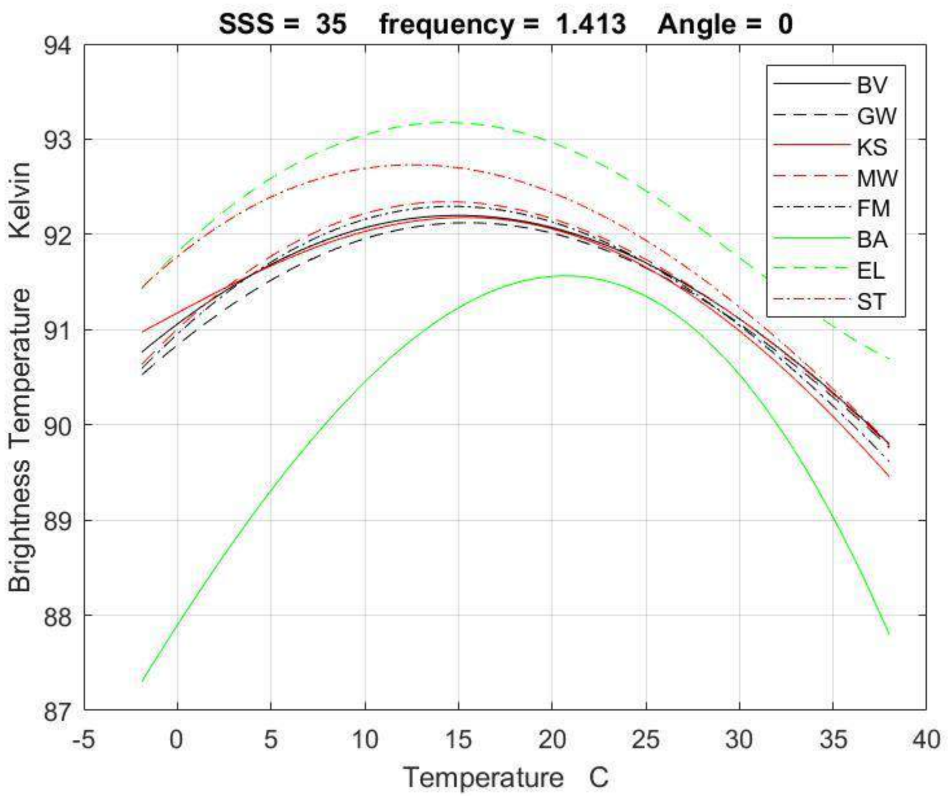
  - All based on some level of data
    - laboratory measurements of dielectric constant
    - Observations from satellite sensors

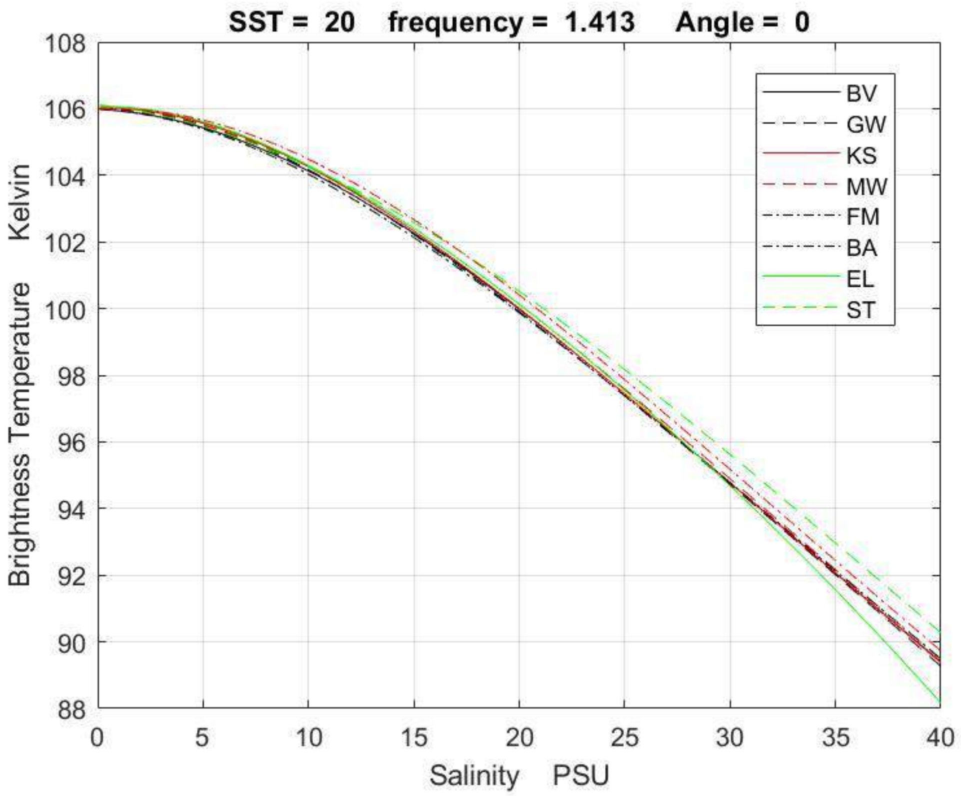


$T_B = e\,T$ and $e = 1 - [(1-\sqrt{\varepsilon})/(1+\sqrt{\varepsilon})]^2$

Brightness Temperature at 1.4 GHz

Significant Differences Exist at Level of Accuracy Needed to Retrieve Salinity

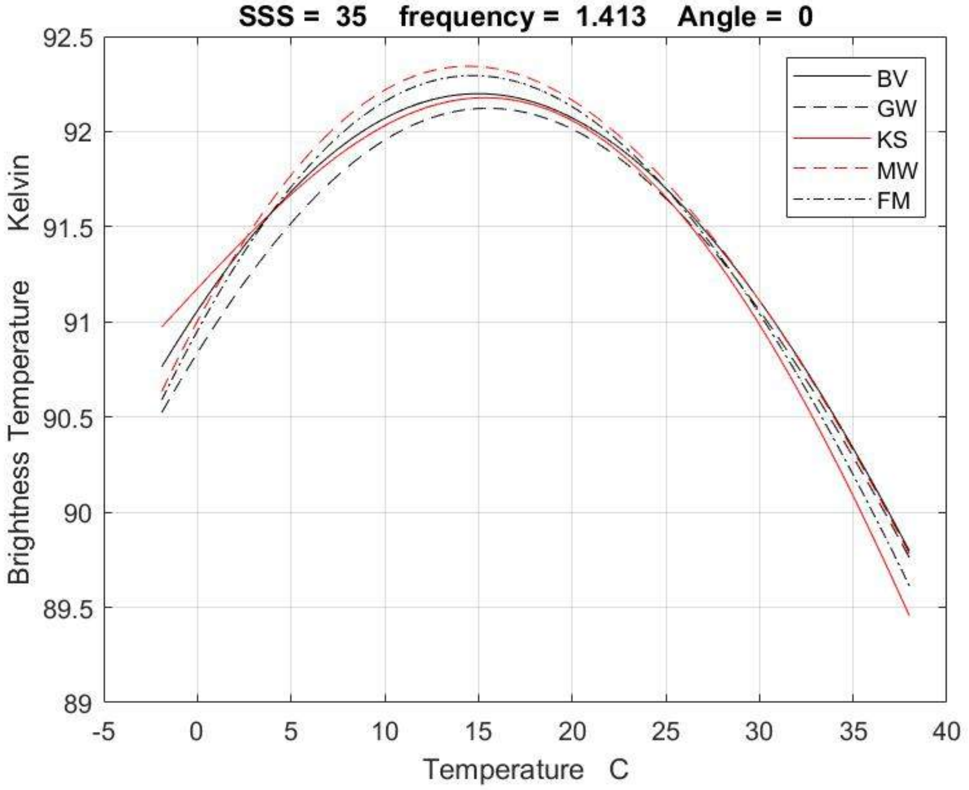


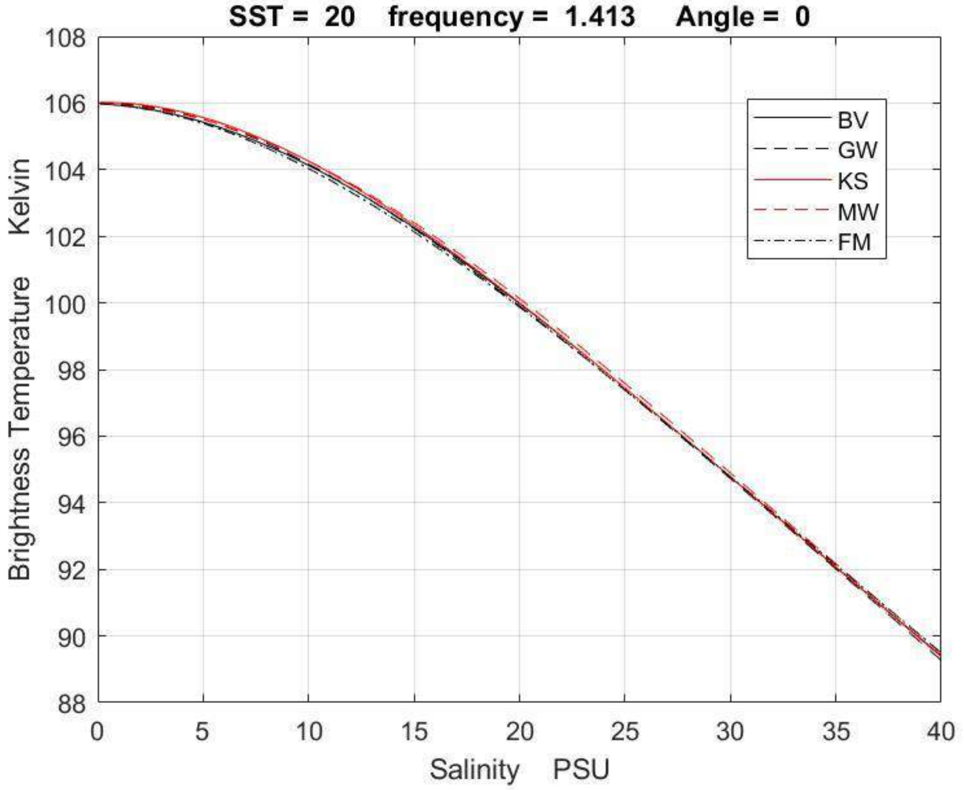


$$\varepsilon = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + j\omega\tau_1} - j\frac{\sigma}{\omega\varepsilon_o}$$

Brightness Temperature at 1.4 GHz

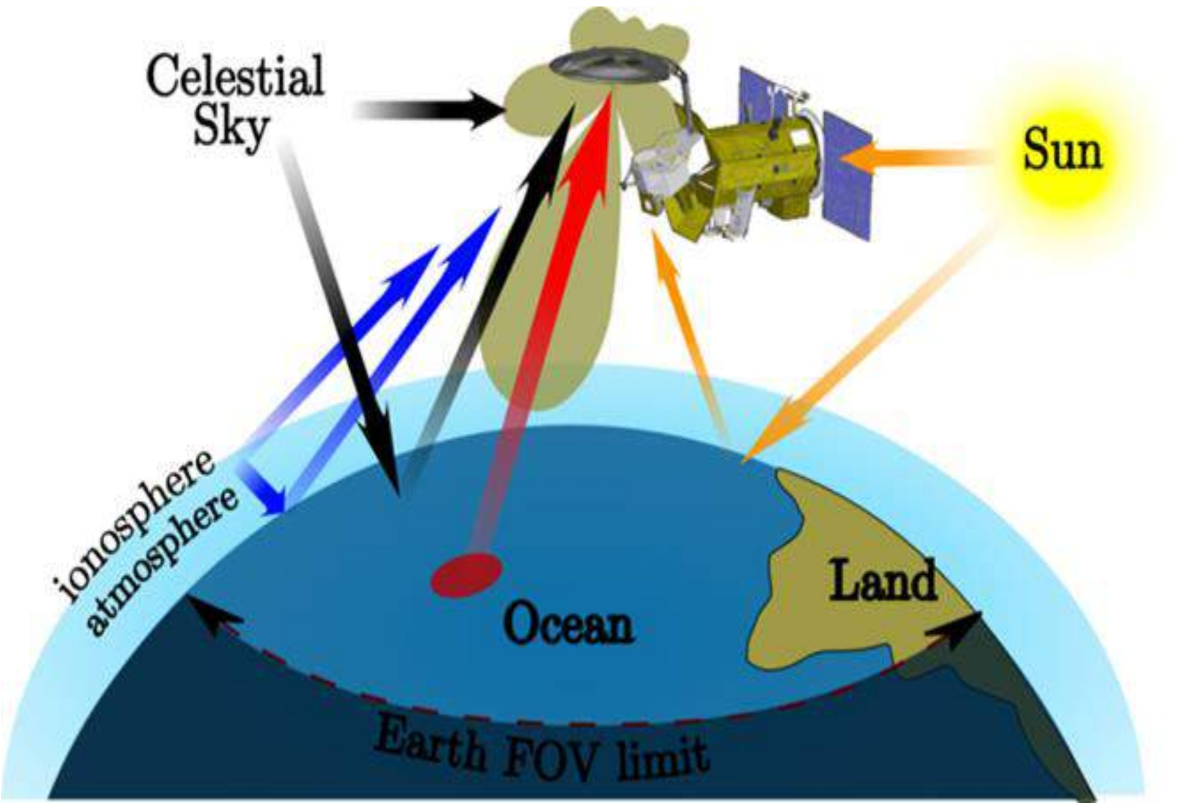
Without models not intended for 1.4 GHz (ST and EL) and without outlier (BA)





How to Distinguish Among Models?

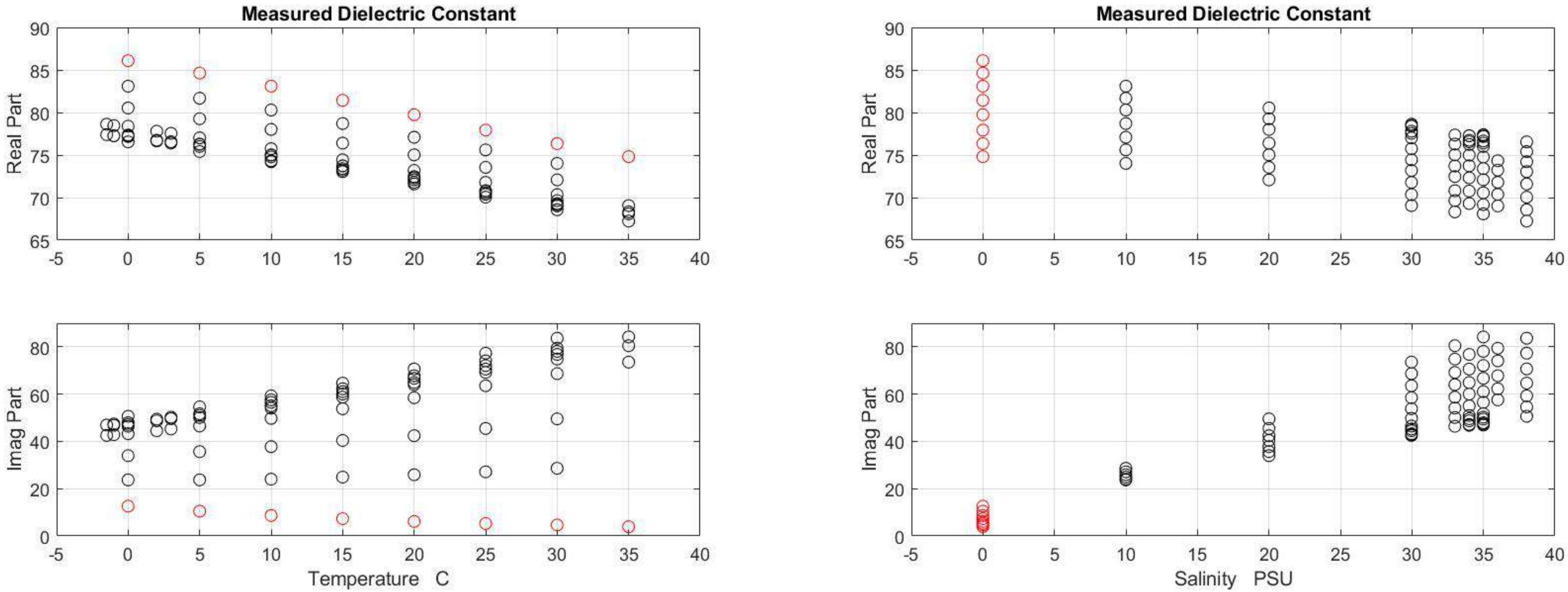
- Success retrieving SSS not sufficient:
  - Retrieval introduces issues not associated with ocean
  - Retrieval mixes errors associated with retrieval and model for dielectric constant
- Need
  - Accurate representation of sea water
  - Will lead to improved understanding of errors in retrieval



Proposal: Compare with Measurements

Measurements

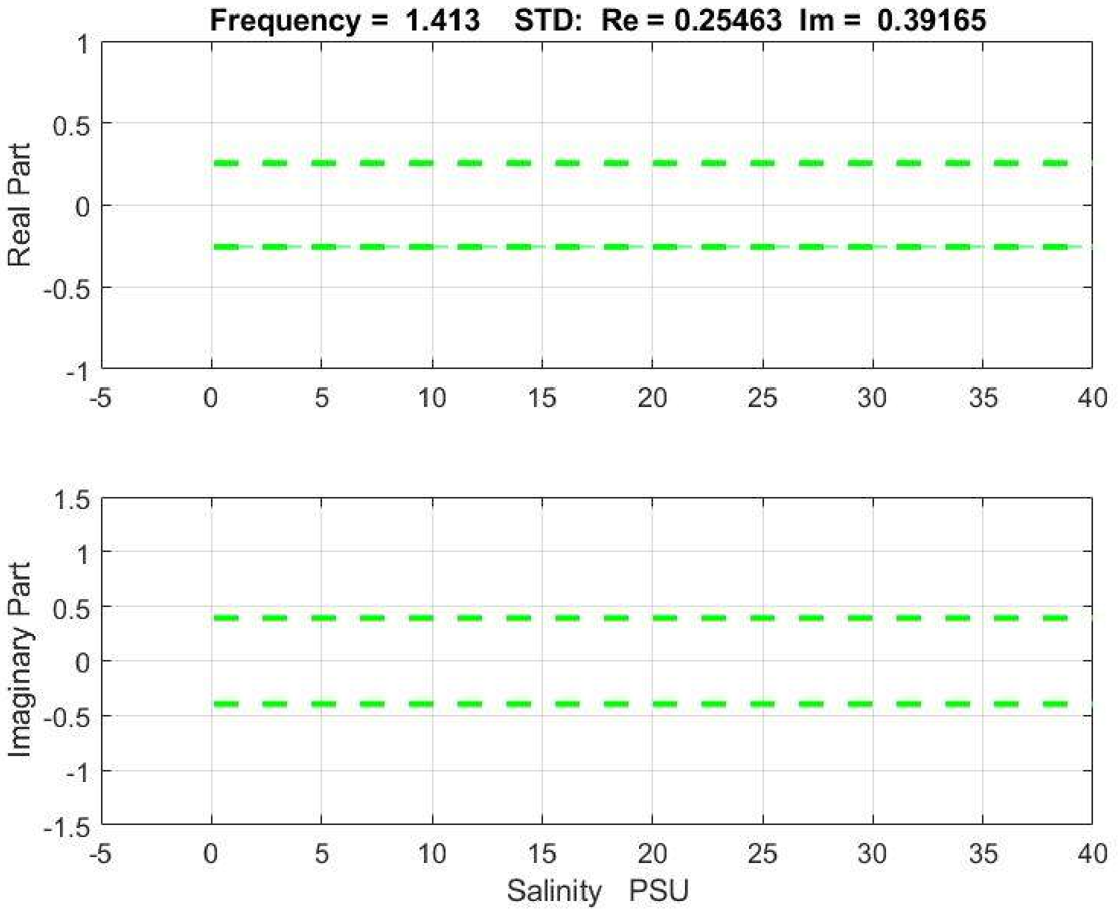
R. H Lang et al., Radio Sci., 51, 2–24, 2016 (Table V)
Y. Zhou et al., IEEE Trans. Geosci. Remote Sensing, Vol 59 (#10) 2021 (Table I-III)
https://podaac.jpl.nasa.gov/Aquarius?sections=data



O = Freshwater: S = 0

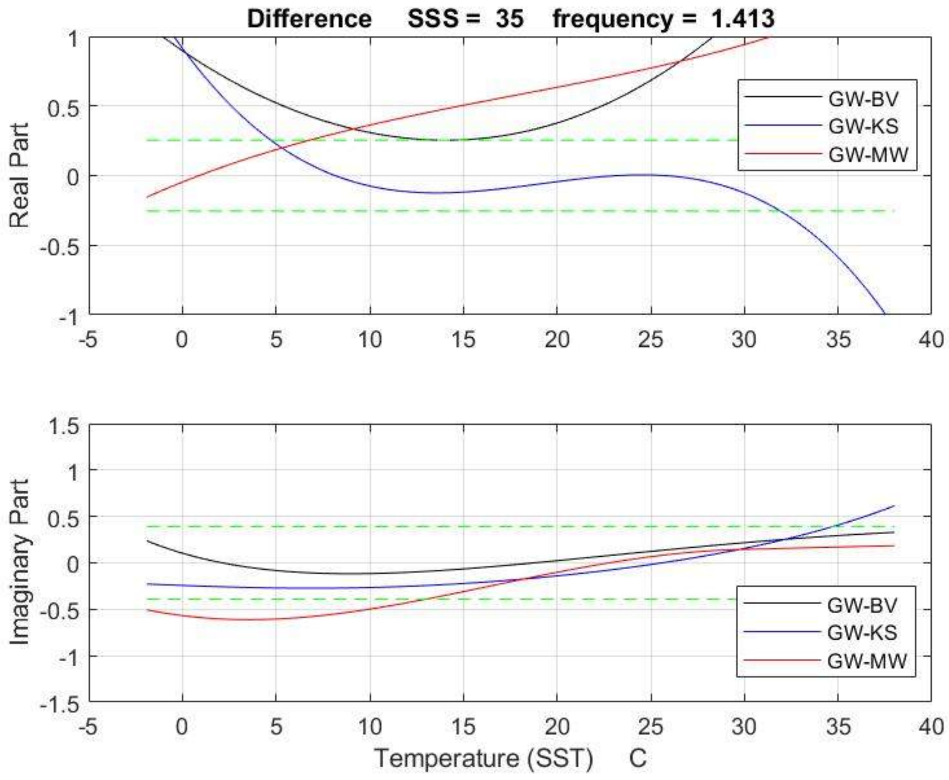
Compare with Measurements

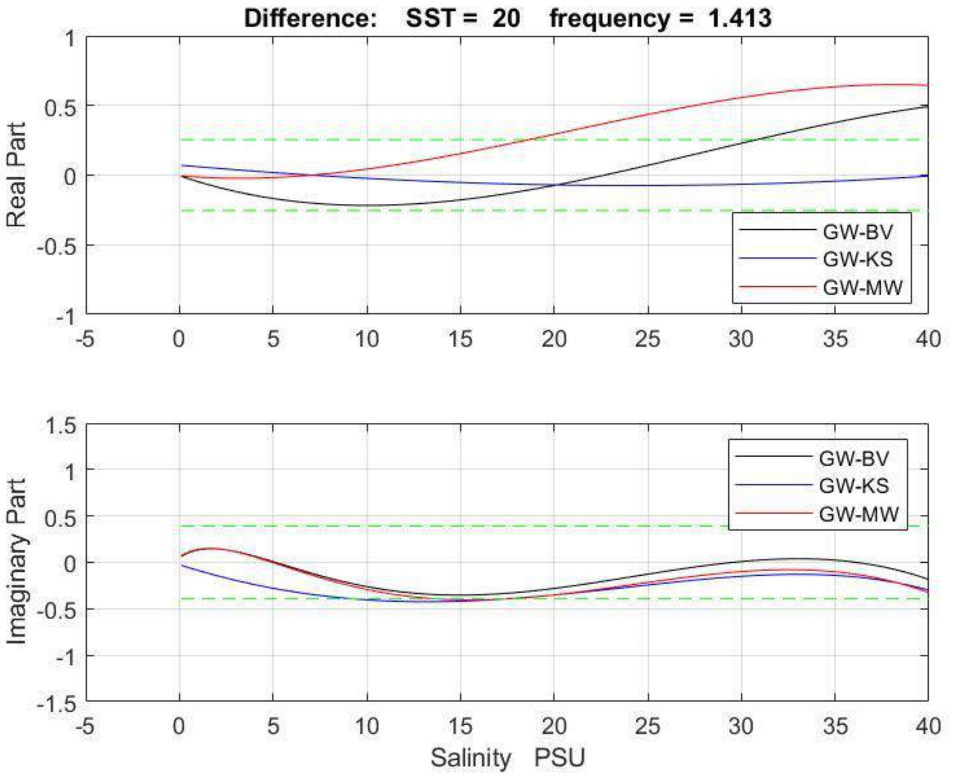
- Use “interpolation function” to obtain better visualization
  - Zhou et al model function
  - Y. Zhou et al., IEEE Trans. Geosci. Remote Sensing, Vol 59 (#10) 2021
- Accuracy of the representation
  - Measurement accuracy (STD)
    - Re: 0.23
    - Im: 0.26
  - Add representation error (model fit)
    - Re: 0.11
    - Im: 0.29
  - Total Error: Assume RMS combination
    - Total STD Real part: 0.25
    - Total STD Imaginary part: 0.39
- Total Error ($\pm$ 1 STD) represented by green dashed line



Comparison

KS = Klein-Swift; MW = Meissner-Wentz; BV = Boutin et al



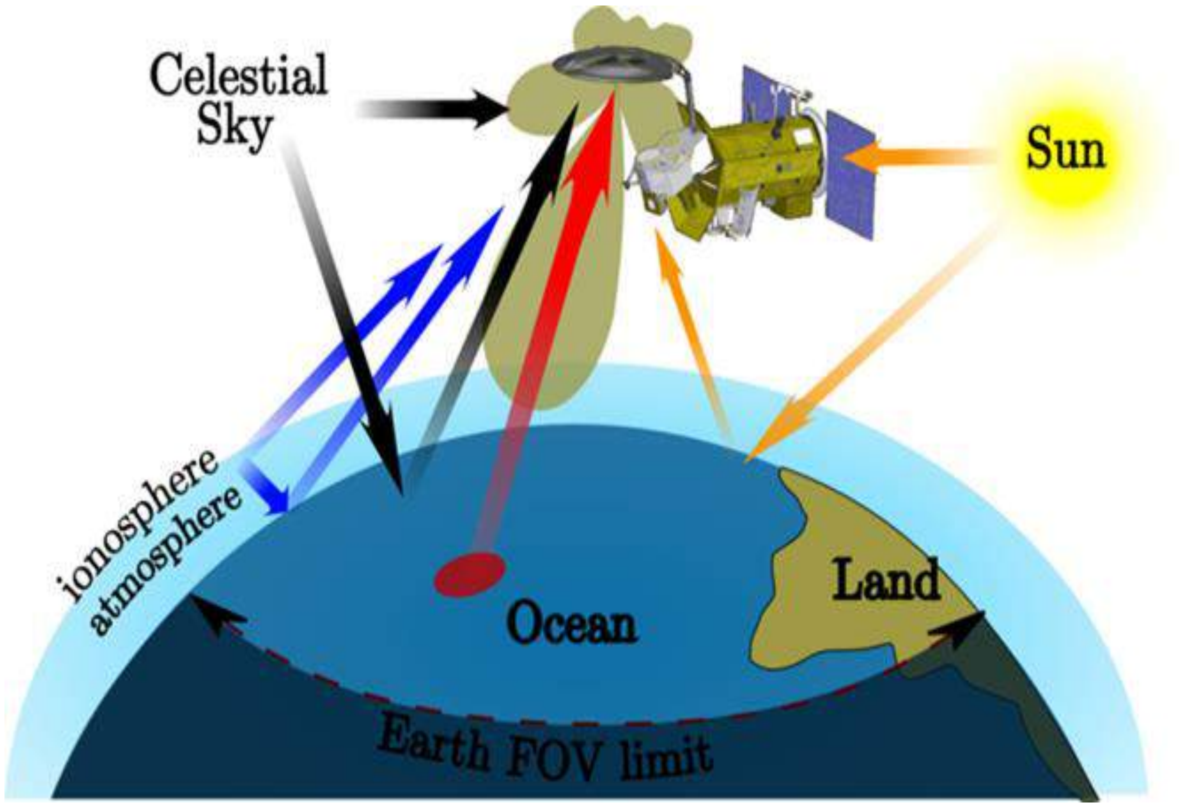


Note 1: KS diverges for T<5 and T>30 which is outside limits of data used in building the model; SSS retrieval also fails outside this range.

Note 2: The major differences among models occur in the temperature dependence of the real part

Conclusion

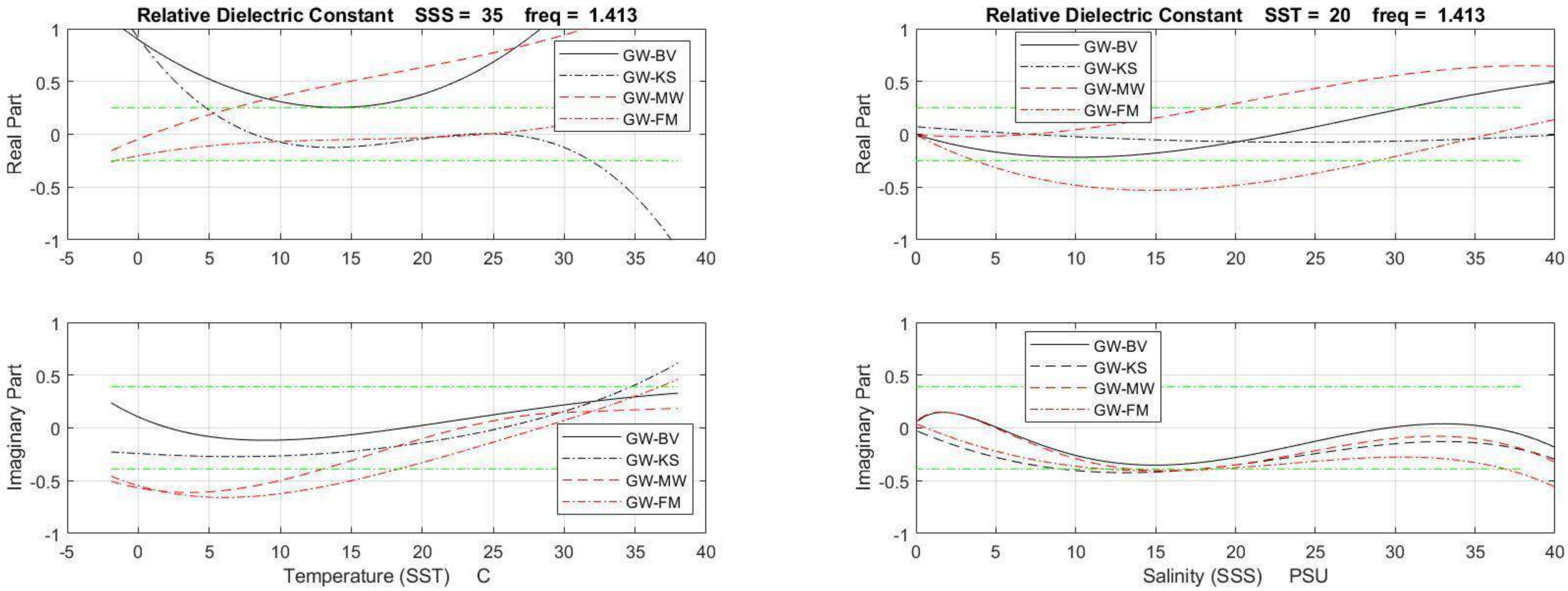
- Models based entirely on lab measurements (KS, GW) are in good agreement
- Models currently used to retrieval SSS are in good agreement with measurements
  - KS, MW, BV best among models
  - Good fit to measurements
- But …
  - Need to pay attention to range of (S,T) in data used to build model
    - KS at T< 5 C X
    - EL at f = 1.4 GHz X
  - Models that optimize retrieval of SSS are not necessarily best representation of $\varepsilon(S,T)$.
    - Include imperfections in retrieval algorithm
    - Hide algorithm errors
    - Complicate further improvement of retrieval
- Long Term Goal: Accurate model for $\varepsilon(S,T)$ independent of retrieval
  - Will allow identification of errors in the retrieval
  - Will lead ultimately to better retrieval of SSS



The End

Comparison

KS = Klein-Swift; MW = Meissner-Wentz; BV = Boutin-et al; FM = FASTEM4



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