The Application of Satellite Sea-Surface Salinity (SSS) Observations to Operational Passive Microwave Radiometry

Eric Bayler

NOAA / NESDIS / Center for Satellite Applications and Research (STAR)

AMS 2012 Annual Meeting

- *2nd Conference on Transition of Research to Operations*
- *18th Conference on Satellite Meteorology, Oceanography and Climatology*
- *1st Joint AMS-Asia Satellite Meteorology Conference*

Traceability of Sea-Surface Salinity (SSS) to Brightness Temperature (T_b)

Generic T_b:

$$Tb_p(\theta) = Tb^{\uparrow}(\theta) + \tau_{atm}\left[E_p(\theta)T_{sfc} + Tb_p^s(\theta)\right]$$

Tb_0 = surface brightness temperature;

$E_p(\theta)$ = polarized surface emissivity

Generic Ocean Surface Emissivity (ϵ):

$$\epsilon_{sfc}(v,\theta,p,SST,SSS,U,\phi) = \epsilon_{flat}(v,\theta,p,SST,SSS) + \epsilon_{rough}(\epsilon_{flat},U,\phi) + \varepsilon_{foam}(U,\theta)$$

Fresnel Reflectivity (polarization):

$$E_v = \left(\frac{P_r\cos\theta - \sqrt{P_r - 1 + \cos^2\theta}}{P_r\cos\theta + \sqrt{P_r - 1 + \cos^2\theta}}\right)^2 + \left(\frac{P_i\cos\theta - \sqrt{P_i - 1 + \cos^2\theta}}{P_i\cos\theta + \sqrt{P_i - 1 + \cos^2\theta}}\right)^2 \qquad E_h = \left(\frac{\cos\theta - \sqrt{P_r - 1 + \cos^2\theta}}{\cos\theta + \sqrt{P_r - 1 + \cos^2\theta}}\right)^2 + \left(\frac{\cos\theta - \sqrt{P_i - 1 + \cos^2\theta}}{\cos\theta + \sqrt{P_i - 1 + \cos^2\theta}}\right)^2$$

P_r , P_i = ocean permittivity (real, imaginary)

Permittivity (dielectric constant):

$$P = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_1}{1 + j2\pi v\tau_1} + \frac{\varepsilon_1 - \varepsilon_\infty}{1 + j2\pi v\tau_2} - j\frac{\sigma}{2\pi v\varepsilon_0}$$

complex double Debye model

Empirical models: ε_s, ε_1, σ, τ = f(SSS)

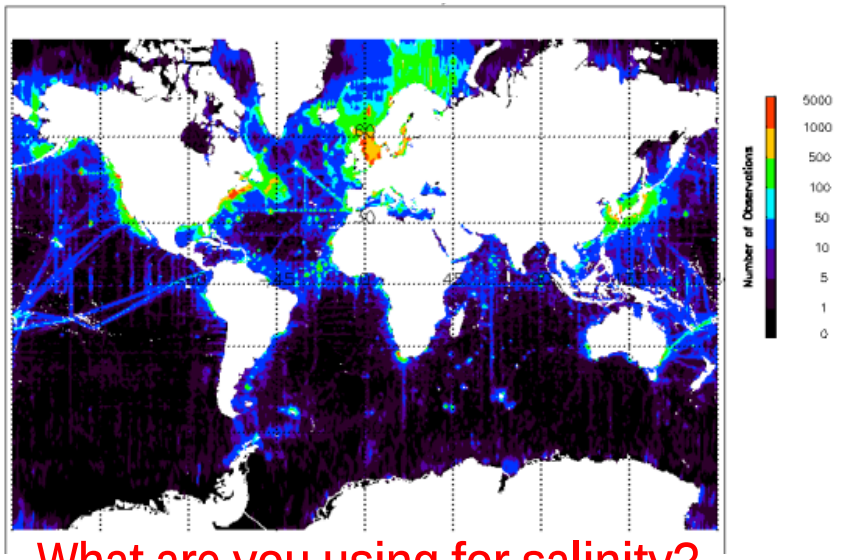
Passive Microwave Radiometry Potentially Influences by SSS

INSTRUMENT	FREQUENCY (GHZ)	SATELLITE
Aquarius	1.413	AQUARIUS
SMOS	1.413	SMOS
WindSat	6.800	CORIOLIS
AMSR-E	6.925	AQUA
AMSR-E	10.650	AQUA
TMI	10.650	TRMM
WindSat	10.700	CORIOLIS
SeaWinds	13.400	QuikScat
TOPEX MWR	18.000	TOPEX
AMSR-E	18.700	AQUA
Jason MWR	18.700	Jason-1; Jason-2
WindSat	18.700	CORIOLIS
SSMI	19.350	DMSP-08, 10, 11, 13, 14, 15
SSMIS	19.350	DMSP-16, 17, 18, 19, 20
TMI	19.350	TRMM
TOPEX MWR	21.000	TOPEX
SSMIS	22.235	DMSP-16, 17, 18, 19, 20
TMI	22.235	TRMM
SSMI	22.240	DMSP-08, 10, 11, 13, 14, 15
AMSR-E	23.800	AQUA
AMSU-A2	23.800	NOAA-15, 16, 17, 18, 19; AQUA; METOP-A, B, C
ATMS	23.800	NPP
Jason MWR	23.800	Jason-1; Jason-2
WindSat	23.800	CORIOLIS
AMSU-A2	31.400	NOAA-15, 16, 17, 18, 19; AQUA; METOP-A, B, C
ATMS	31.400	NPP
Jason MWR	34.000	Jason-1; Jason-2
AMSR-E	36.500	AQUA
SSMI	37.000	DMSP-08, 10, 11, 13, 14, 15
SSMIS	37.000	DMSP-16, 17, 18, 19, 20
TMI	37.000	TRMM
TOPEX MWR	37.000	TOPEX
WINDSAT	37.000	CORIOLIS

SSS Observations and Climatology

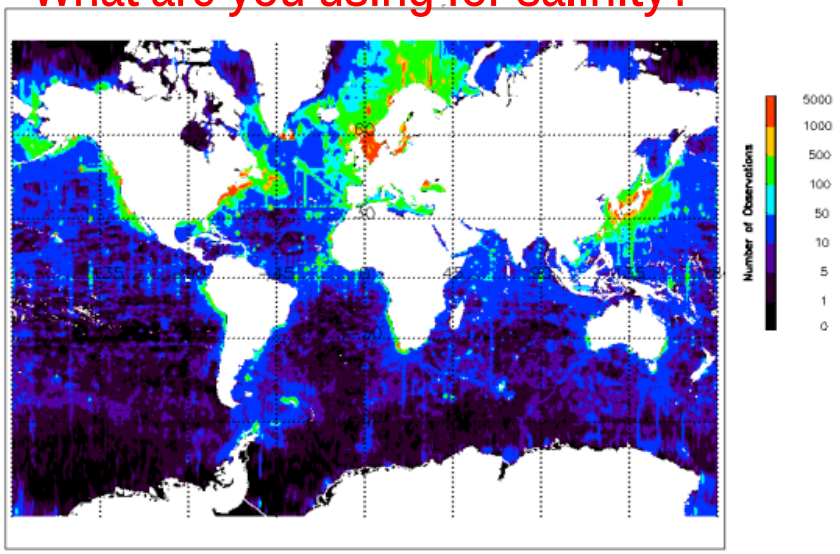
WOA Number of Observations

1998

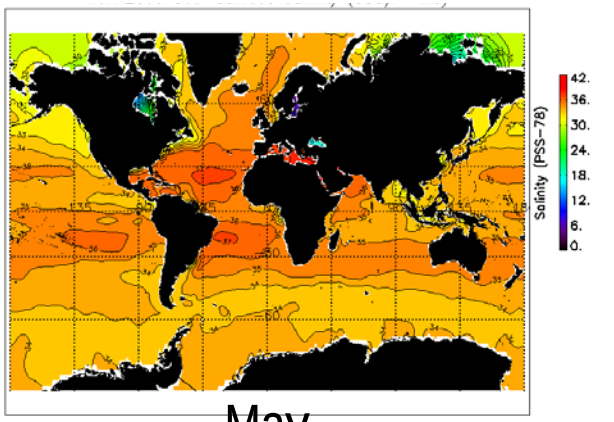


What are you using for salinity?

2009

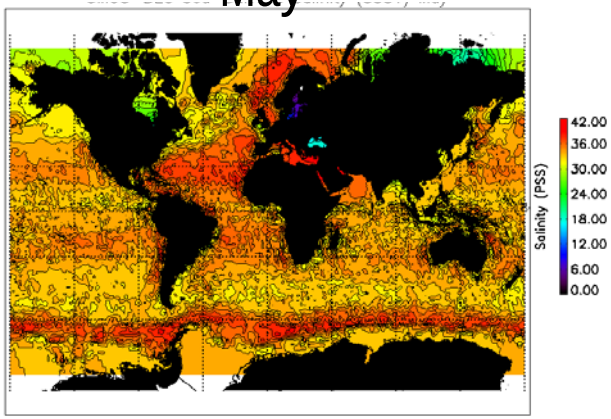


WOA Monthly Mean

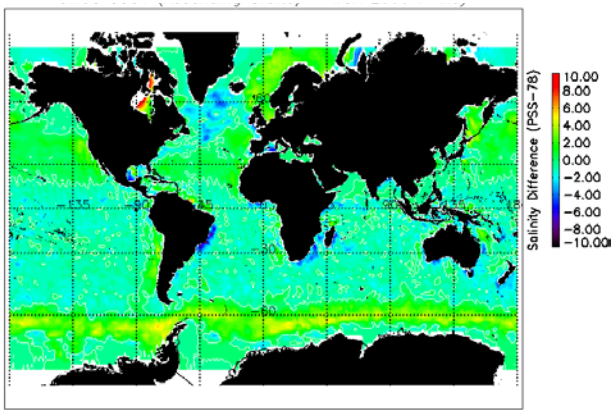


May

SMOS Monthly Mean



Salinity Difference

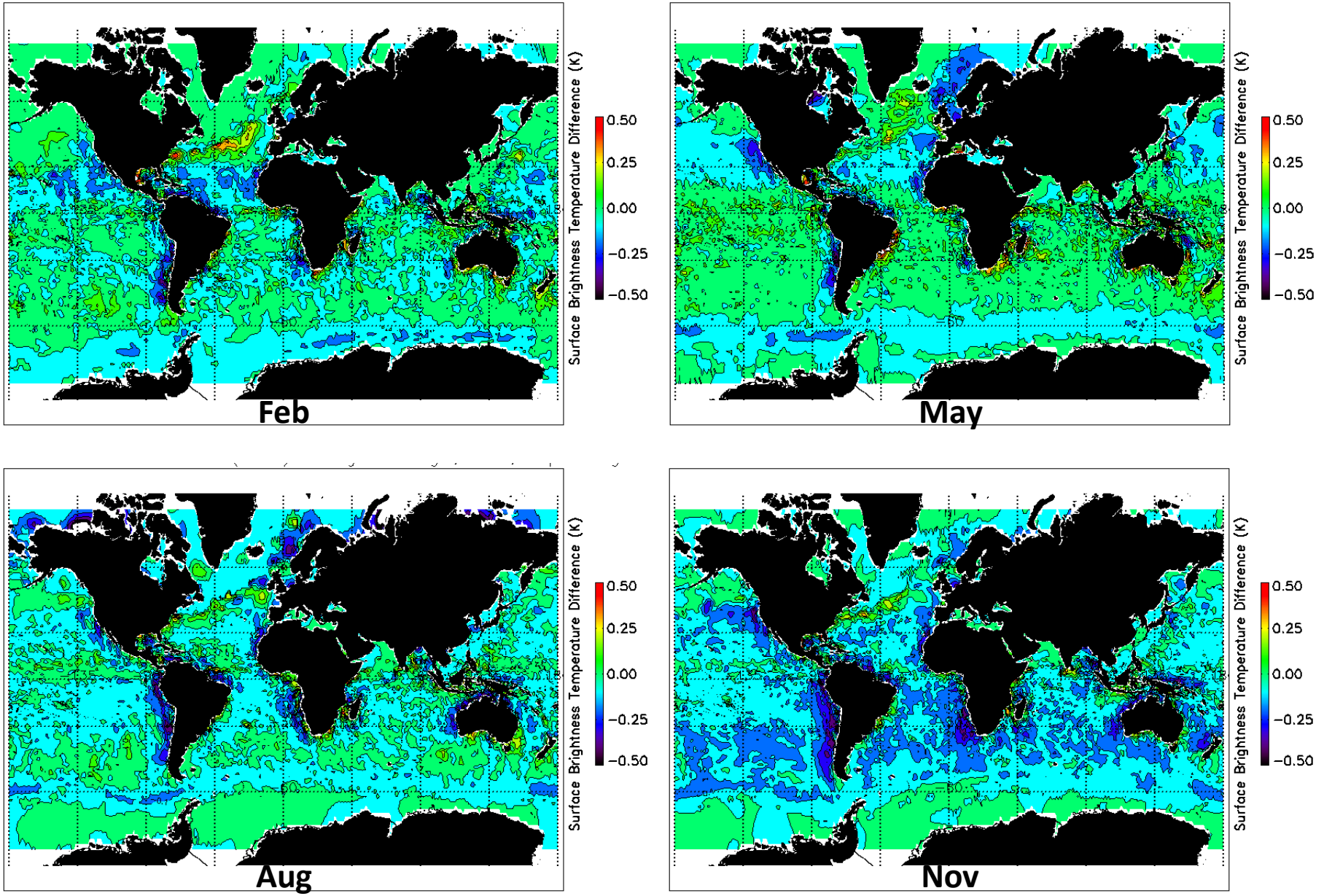


Approach

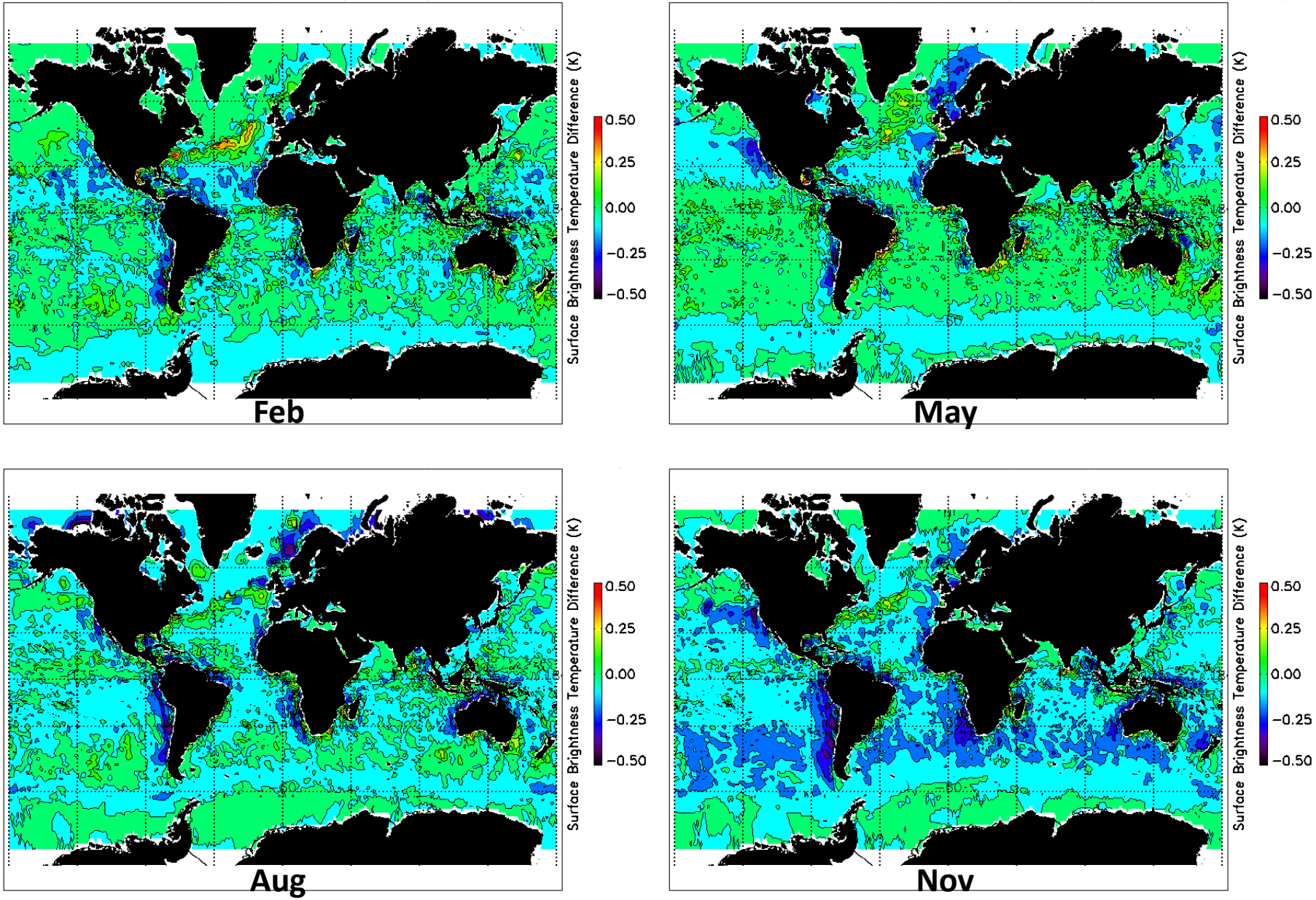
- **Data**
  - **NOAA World Ocean Atlas (WOA) 2009 monthly climatology**
    - Sea-surface salinity
    - Sea-surface temperature
  - **European Space Agency (ESA) Soil Moisture – Ocean Salinity (SMOS) mission SSS data**
    - **SMOS Barcelona Expert Centre (BEC) Level-3 SSS (OCCAF3 product)**
      - Optimally interpolated, full-polarization, ascending node (surface roughness model #1) data
      - 100-km resolution, with averaging period of 30 days.

- **Method**
  - ***Operationally-representative frequencies and viewing angle***
    - 6, 11, 19, 23, 37 GHz
    - 55° viewing angle
  - ***Assumptions***
    - No wind, flat sea, no foam
  - ***Permittivity model***
    - **Community Radiative Transfer Model (CRTM)**
      - (Joint Center for Satellite Data Assimilation (JCSDA)
      - 6, 11, 19 GHz
    - **FASTEM4** (implemented in next operational version of CRTM)
      - 23, 37 GHz
      - Current CRTM is not sensitive to salinity variations at frequencies $\geq$ 20 GHz
  - ***Fresnel reflectivity equations relate permittivity to surface emissivity***
  - ***Tb_0 = surface emissivity $\times$ SST***
    - Tb_0 computed using WOA sea-surface temperature (SST)

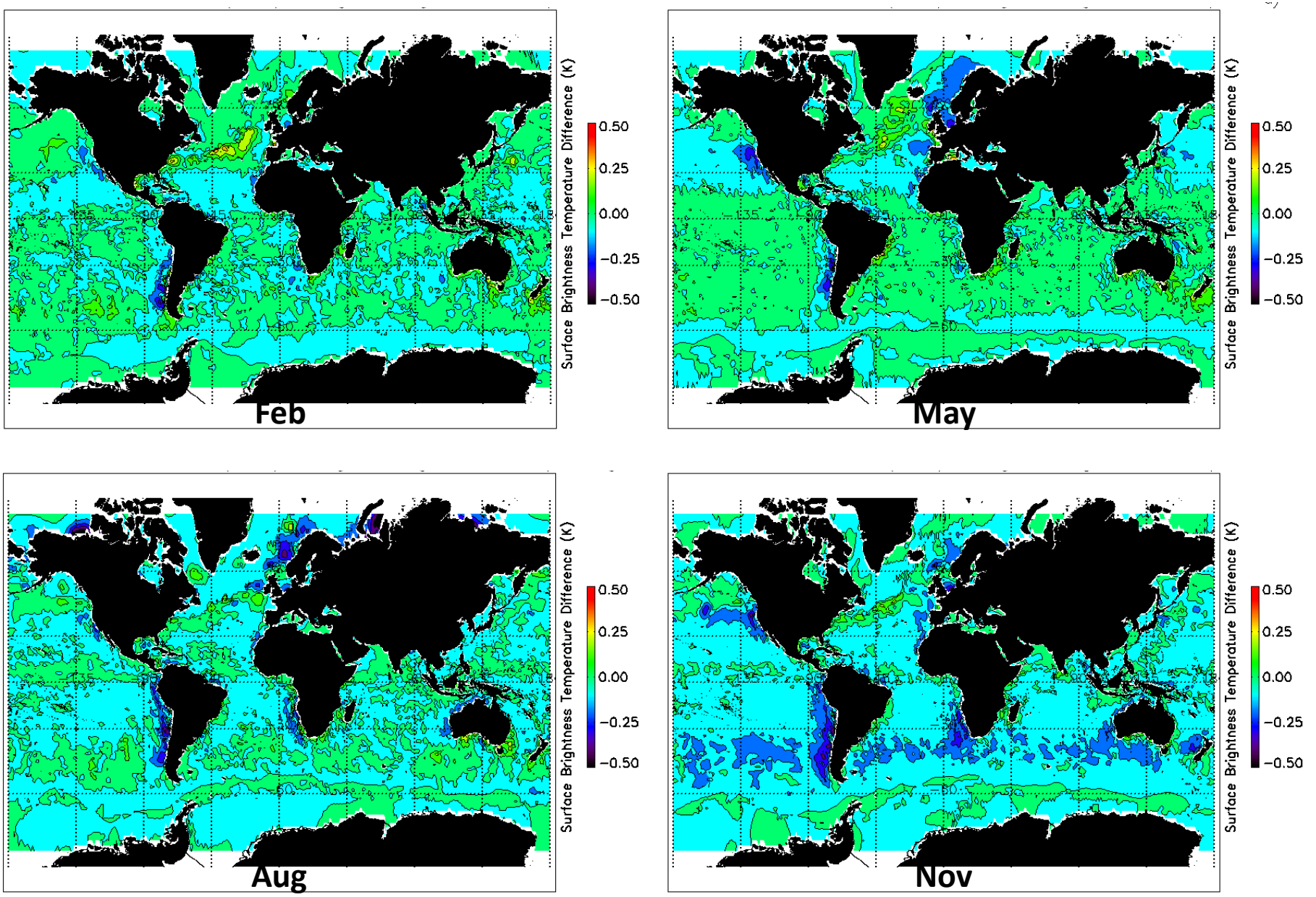
Surface Brightness Temperature (Tb_0) Difference (SMOS – WOA): 6 GHz, 55°, v-pol (CRTM)



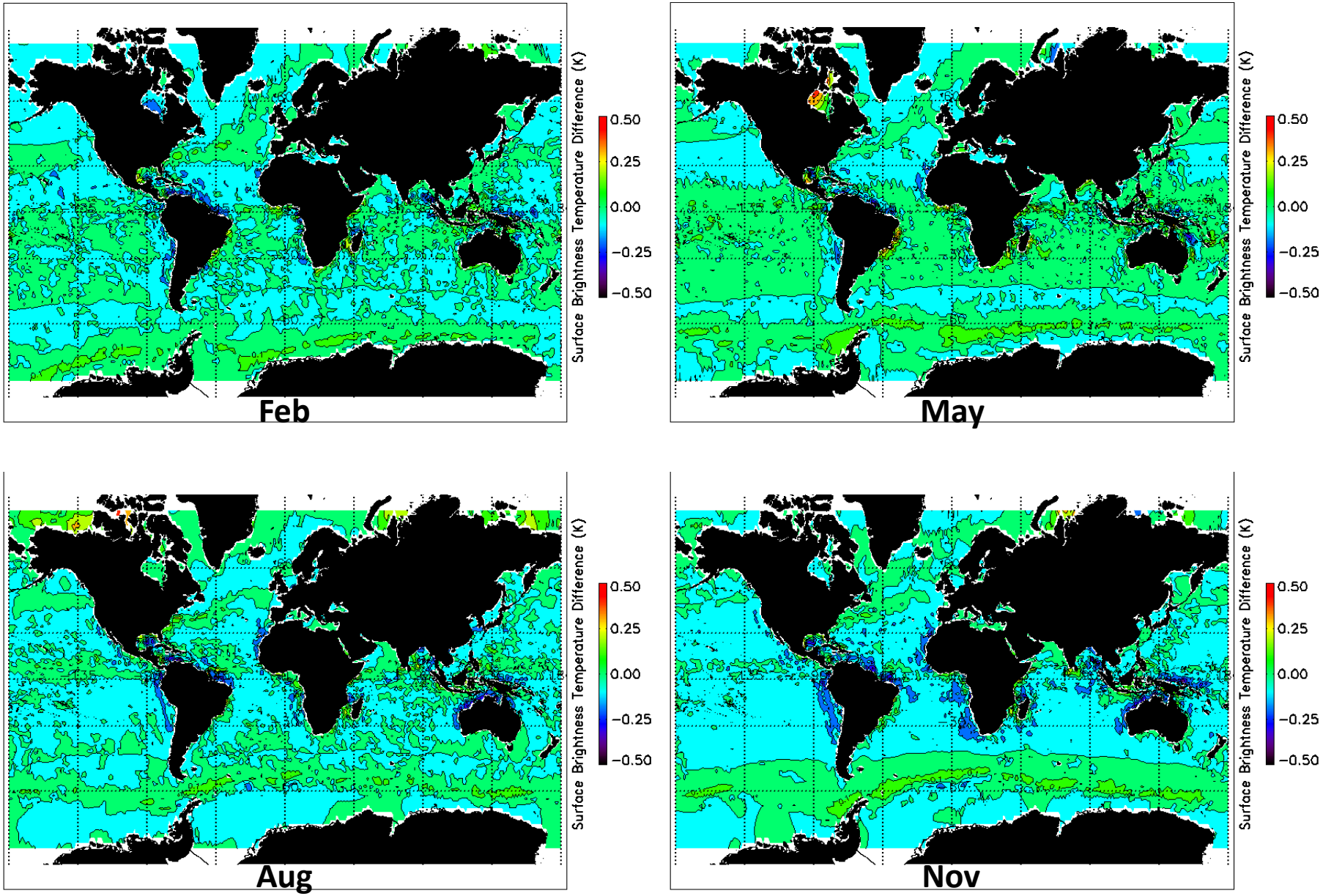
Surface Brightness Temperature (Tb_0) Difference (SMOS – WOA): 11 GHz, 55°, v-pol (CRTM)



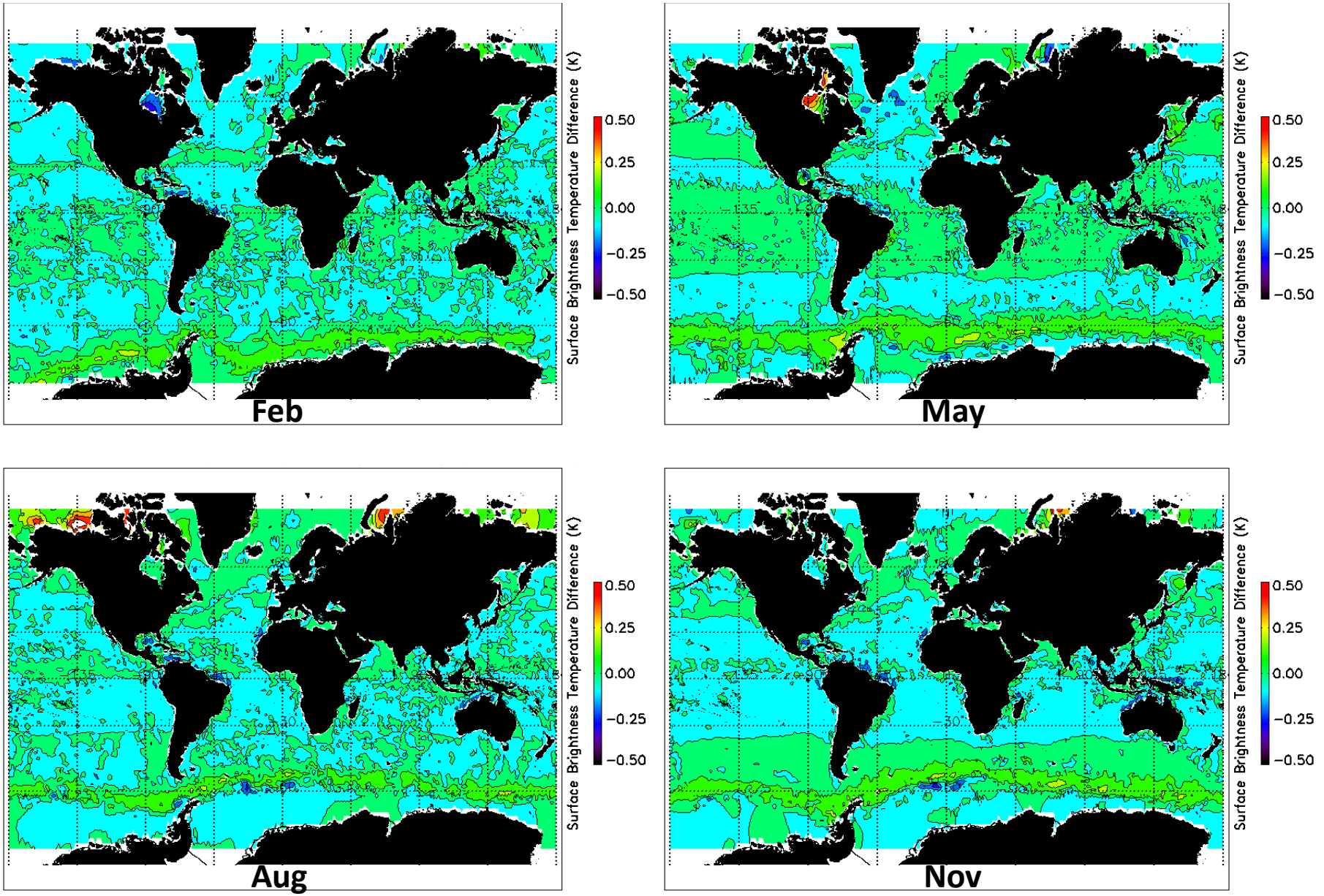
Surface Brightness Temperature (Tb_0) Difference (SMOS – WOA): 19 GHz, 55°, v-pol (CRTM)



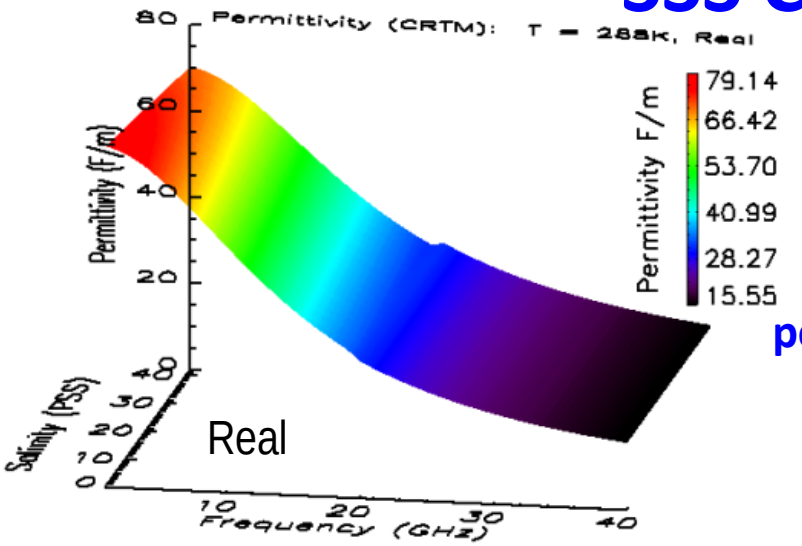
Surface Brightness Temperature (Tb_0) Difference (SMOS – WOA): 23 GHz, 55°, v-pol (FASTEM4)



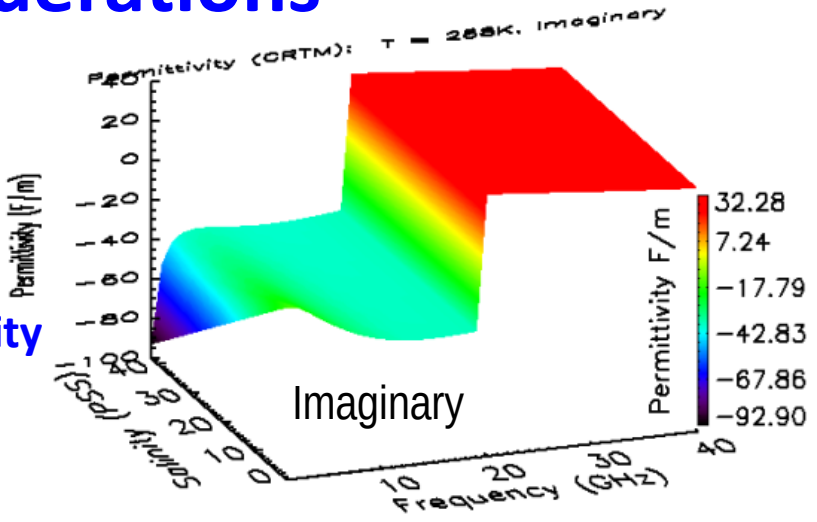
Surface Brightness Temperature (Tb_0) Difference (SMOS – WOA): 37 GHz, 55°, v-pol (FASTEM4)

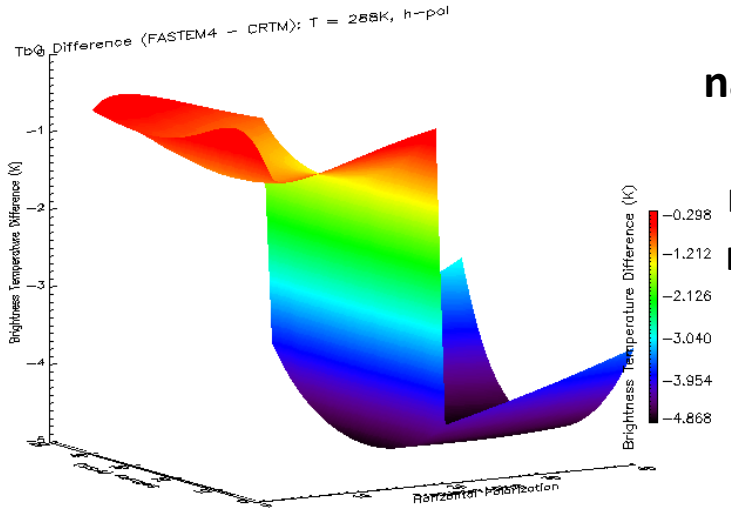


CRTM Transition: Implementing FASTEM4 SSS Considerations

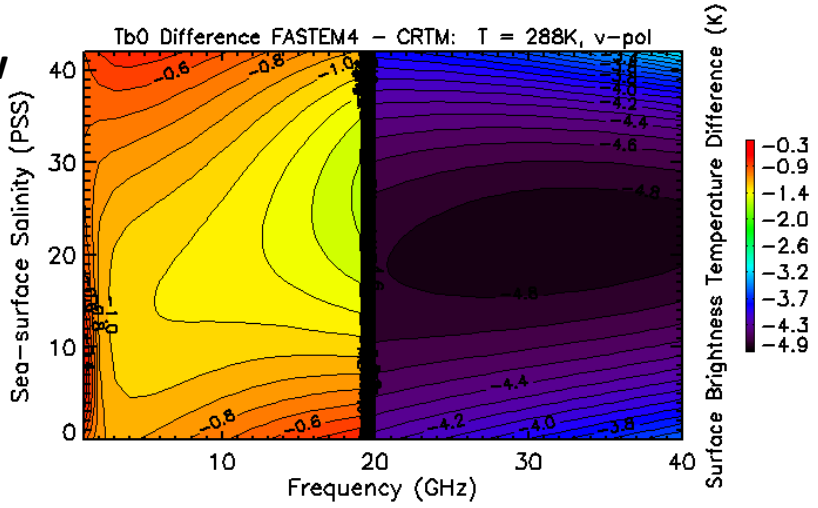


CRTM permittivity now





V-pol
nadir view
flat sea
no wind
no foam



Tb0 Difference @ 288K: (CRTM with FASTEM4) – (current CRTM)

Summary

- Salinity is a factor in passive microwave retrievals that have a significant ocean surface term.
- Current sea-surface salinity (SSS) climatologies are very sparse in space and time, resulting in biases and uncertainty due to non-representativeness .
- The new ability to observe sea-surface salinity (SSS) globally in quasi-near-real time provides the opportunity for improving passive microwave retrievals and dependent applications.