VALIDATION OF WIDEBAND OCEAN EMISSIVITY RADIATIVE TRANSFER MODEL

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Outline

- Thesis Statement
- Data and Model Background
- Methodology
- Results
- Conclusion and Recommendations
- References

Thesis Objective

Validate the performance of CFRSL wideband ocean emissivity radiative transfer model.

- Compare CFRSL simulated emissivity against XCAL simulated emissivity and emissivity retrieved from measured WindSat Tb using collocated GDAS environmental parameters, including Wind Speed.
- Repeat comparison using EDR Wind Speed.
- *Objective does not include making corrections to model.*

Data and Model Background

Inter-Satellite Calibration Working Group (XCAL) RTM

- RTM result of work to improve consistency in Tb measurements across satellite radiometers
- Used near simultaneous measurements for comparisons
- Developed the XCAL RTM using the Elsaesser Emissivity Model
- Used as a comparison model to the CFRSL RTM in this thesis

Central Florida Remote Sensing Laboratory RTM

- Developed by Salem El-Nimri to calculate ocean emissivity over a wide range of frequencies (1 – 90 GHz), incidence angles (nadir – 75°) and the full dynamic range of observed ocean sea surface temperatures and salinity, and wind vector (speed and direction).

WindSat L1C Data

- WindSat is a Satellite-based polarimetric microwave radiometer on the Coriolis mission, designed to measure the ocean surface wind vector from space
- WindSat Level 1C (L1C) Tb data (provided by Colorado State University) is a subset of the Sensor Data Record (SDR) product from WindSat
- Operating Frequencies: 6.8, 10.7, 18.7, 23.8, 37.0 GHz
- V and H polarizations across 50° - 54 ° incidence angles
- Used measurements from July 2005 through June 2006

WindSat Environmental Data Record (EDR)

- Wind retrievals from WindSat with the same temporal and spatial resolution as the WindSat SDR

Global Data Assimilation System (GDAS) Atmospheric Profiles

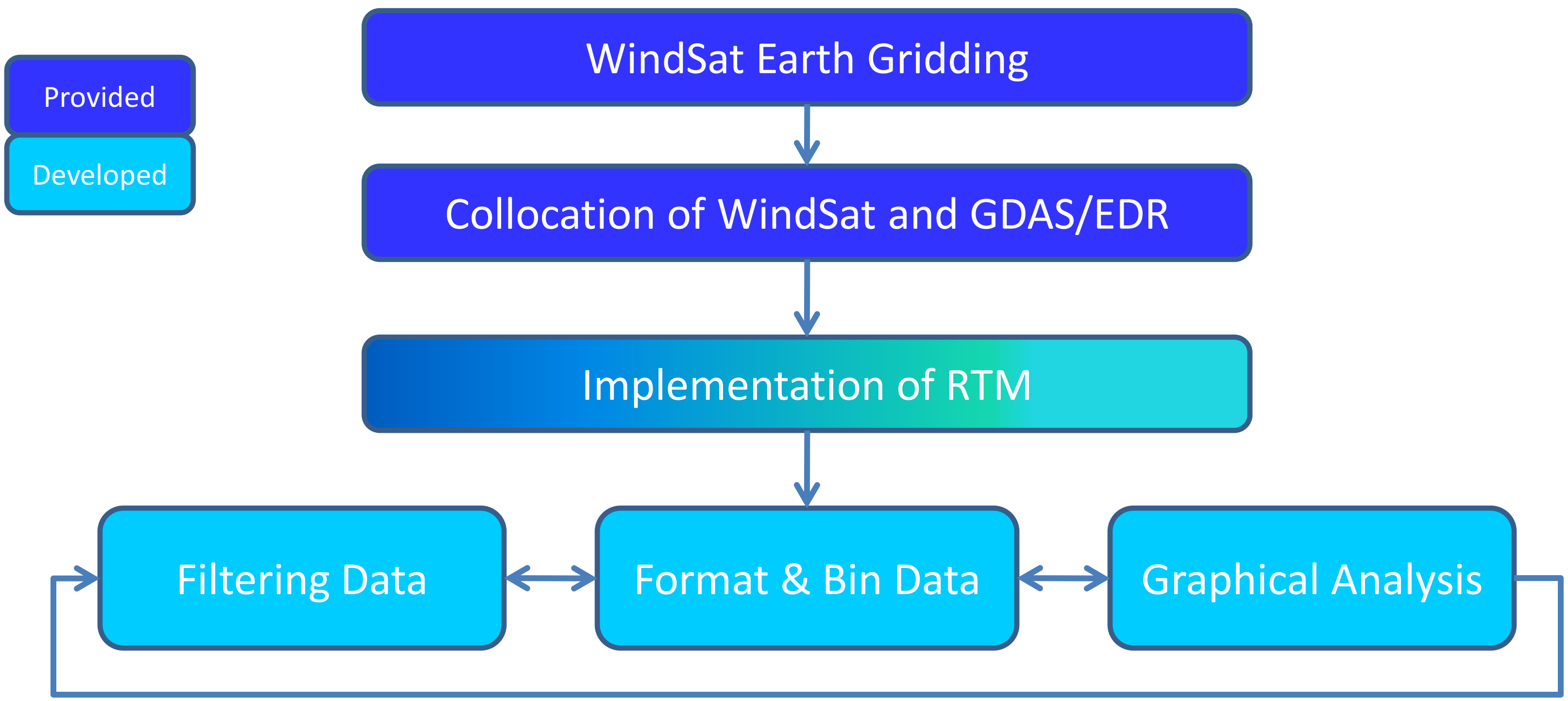
- Environmental data collected from a variety of platforms such as buoys, ships, planes, radiosondes, weather radars, and earth orbiting satellites
- Provided by the National Centers for Environmental Prediction (NCEP)
- Gridded for every 6 hours for 00Z, 06Z, 12Z, and 18Z at the edges of 1° boxes on earth's surface
- Includes key environmental parameters for RTM:
  - Sea Surface Temperature (SST)
  - Water Vapor (WV)
  - Cloud Liquid Water (CLW)
  - Wind Speed (WS)

Methodology

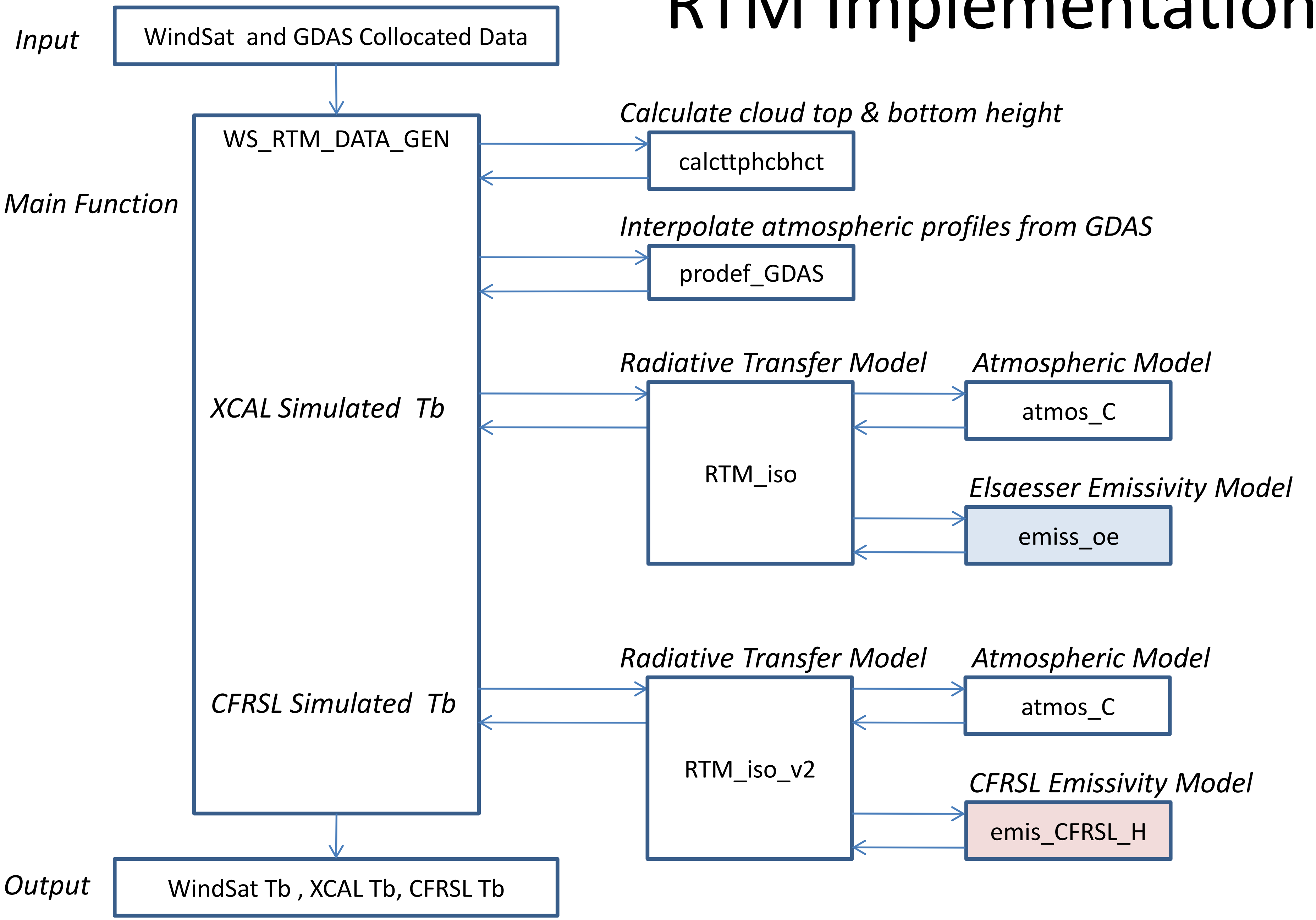
Overall Process Overview

Three Main Iterations

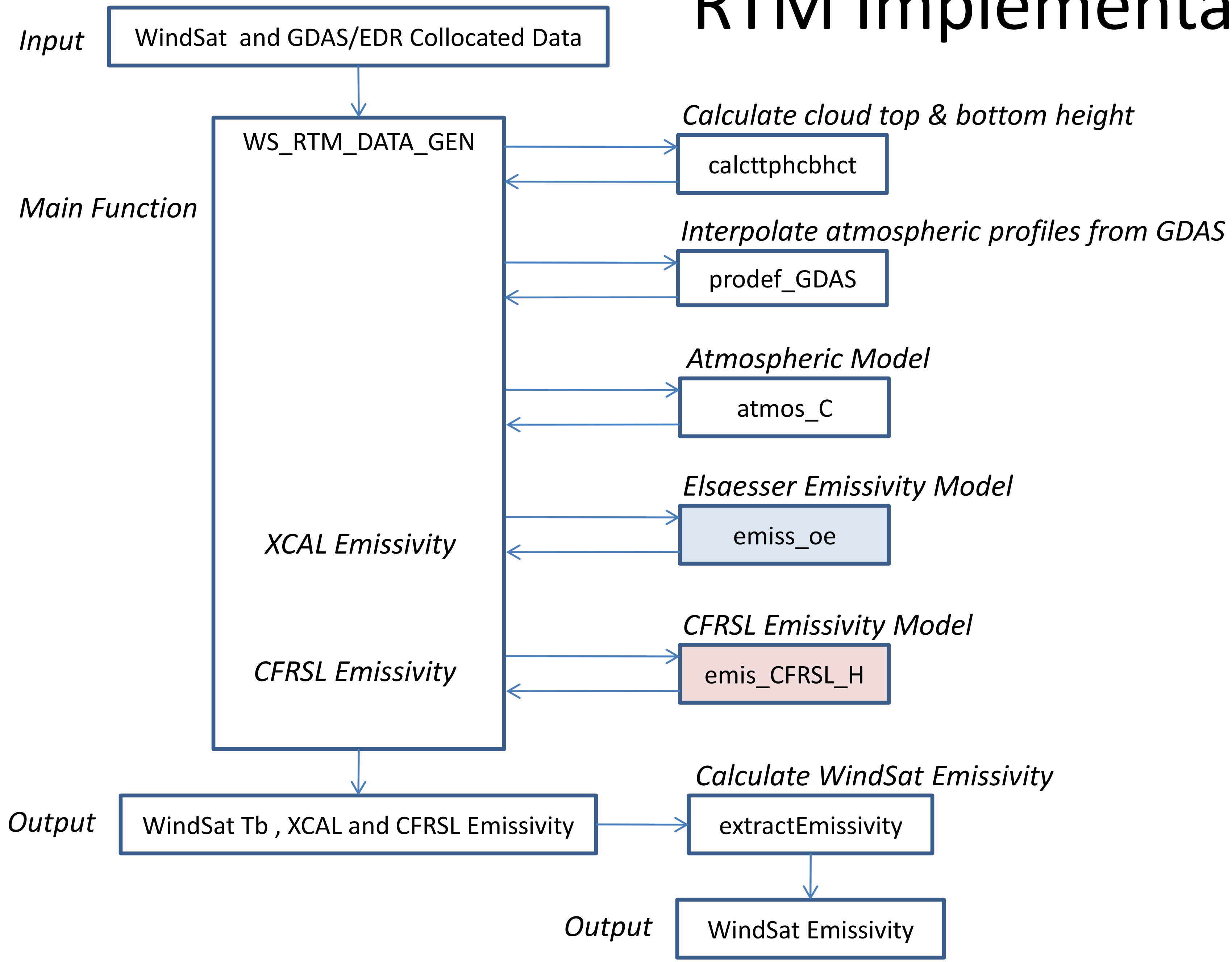
- Brightness Temperature Analysis using GDAS Wind Speed
- Emissivity Analysis using GDAS Wind Speed
- Emissivity Analysis using EDR Wind Speed

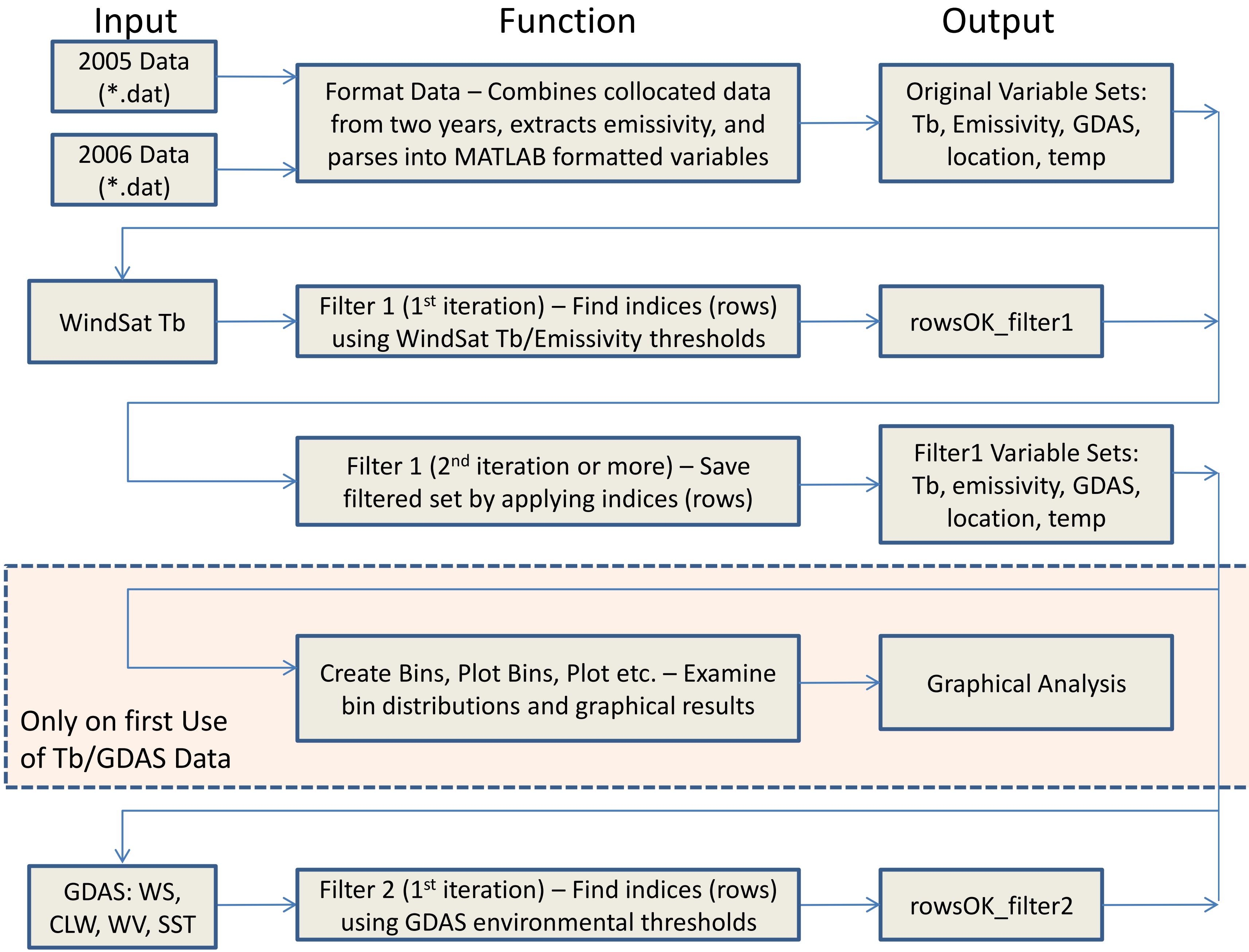


RTM Implementation

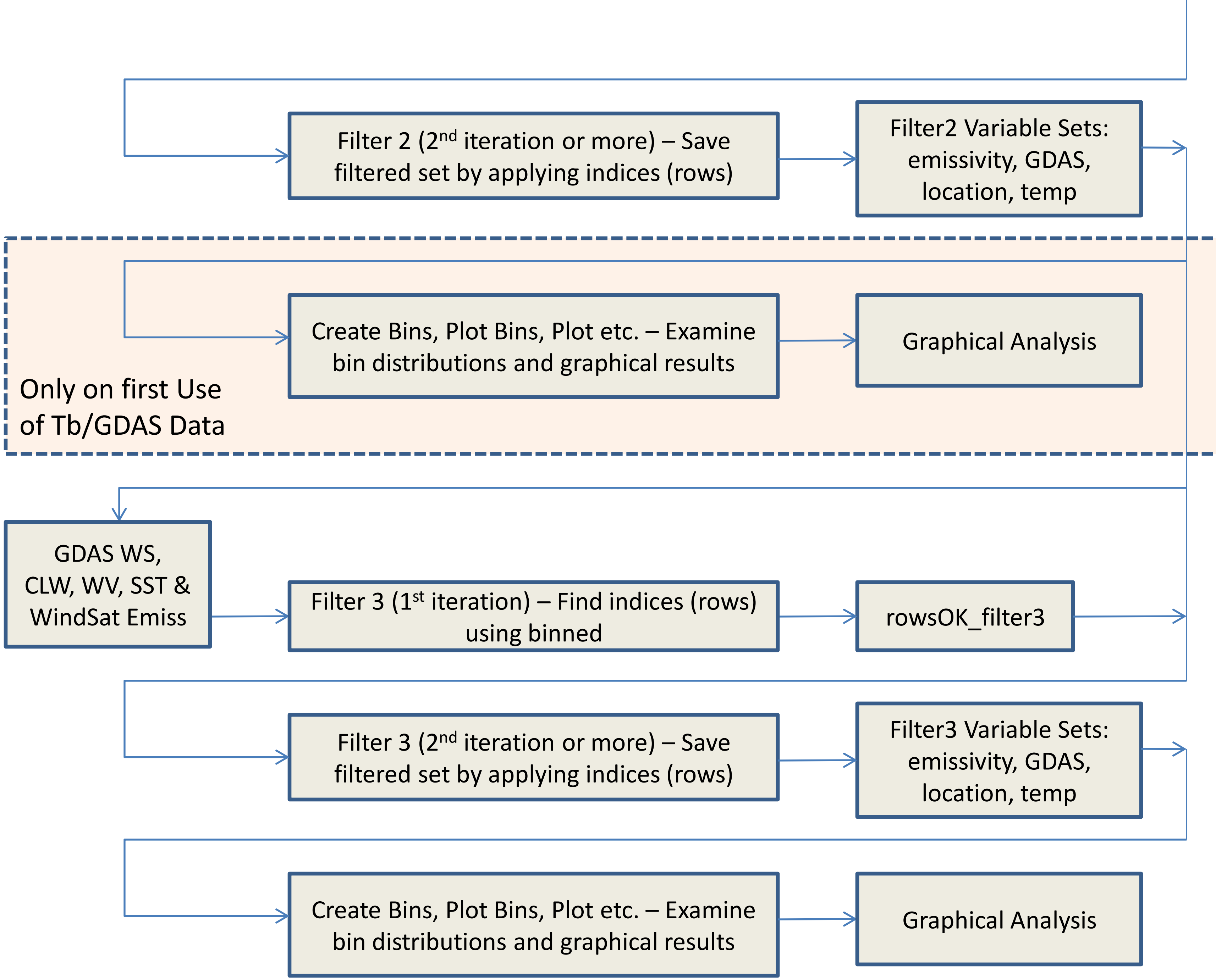


RTM Implementation





Input
Function
Output
2005 Data (*.dat)
2006 Data (*.dat)
Format Data – Combines collocated data from two years, extracts emissivity, and parses into MATLAB formatted variables
Original Variable Sets: Tb, Emissivity, GDAS, location, temp
WindSat Tb
Filter 1 (1st iteration) – Find indices (rows) using WindSat Tb/Emissivity thresholds
rowsOK_filter1
Filter 1 (2nd iteration or more) – Save filtered set by applying indices (rows)
Filter1 Variable Sets: Tb, emissivity, GDAS, location, temp
Create Bins, Plot Bins, Plot etc. – Examine bin distributions and graphical results
Graphical Analysis
Only on first Use of Tb/GDAS Data
GDAS: WS, CLW, WV, SST
Filter 2 (1st iteration) – Find indices (rows) using GDAS environmental thresholds
rowsOK_filter2



Filter 2 (2nd iteration or more) – Save filtered set by applying indices (rows)
Filter2 Variable Sets: emissivity, GDAS, location, temp
Create Bins, Plot Bins, Plot etc. – Examine bin distributions and graphical results
Graphical Analysis
Only on first Use of Tb/GDAS Data
GDAS WS, CLW, WV, SST & WindSat Emiss
Filter 3 (1st iteration) – Find indices (rows) using binned
rowsOK_filter3
Filter 3 (2nd iteration or more) – Save filtered set by applying indices (rows)
Filter3 Variable Sets: emissivity, GDAS, location, temp
Create Bins, Plot Bins, Plot etc. – Examine bin distributions and graphical results
Graphical Analysis

Bin Definitions

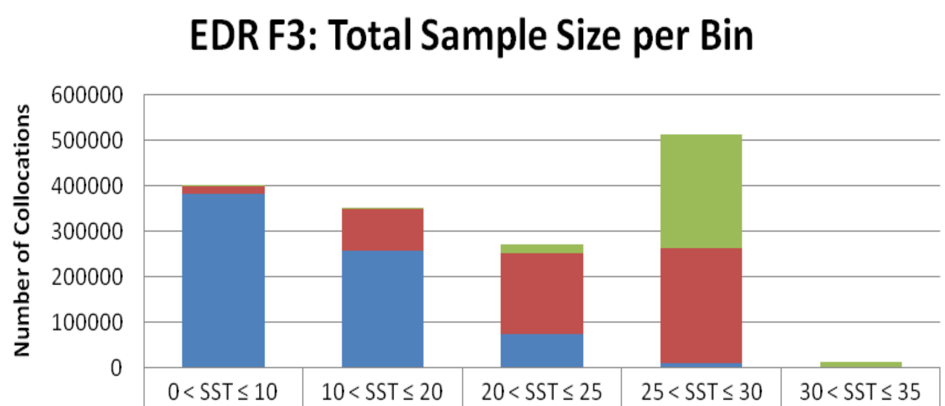
	0 < CLW ≤ 0.1	0.1 < CLW ≤ 0.2	0.2 < CLW ≤ 0.5
	0 < SST ≤ 10		
0 < WV ≤ 20	bin_111	no data	no data
20 < WV ≤ 40	bin_121	no data	no data
40 < WV ≤ 70	bin_131	no data	no data
	10 <SST≤ 20		
0 < WV ≤ 20	bin_211	no data	no data
20 < WV ≤ 40	bin_221	no data	no data
40 < WV ≤ 70	bin_231	no data	no data
	20 <SST≤ 25		
0 < WV ≤ 20	bin_311	no data	no data
20 < WV ≤ 40	bin_321	no data	no data
40 < WV ≤ 70	bin_331	no data	no data
	25 <SST≤ 30		
0 < WV ≤ 20	bin_411	no data	no data
20 < WV ≤ 40	bin_421	no data	no data
40 < WV ≤ 70	bin_431	no data	no data
	30 < SST ≤ 35		
0 < WV ≤ 20	bin_511	no data	no data
20 < WV ≤ 40	bin_521	no data	no data
40 < WV ≤ 70	bin_531	no data	no data

Geophysical Parameter Classifications	Water Vapor (mm)	Cloud Liquid Water (mm)
Low (1)	0 < WV ≤ 20	0 < CLW ≤ 0.1
Medium (2)	20 < WV ≤ 40	0.1 < CLW ≤ 0.2
High (3)	40 < WV ≤ 70	0.2 < CLW ≤ 0.5

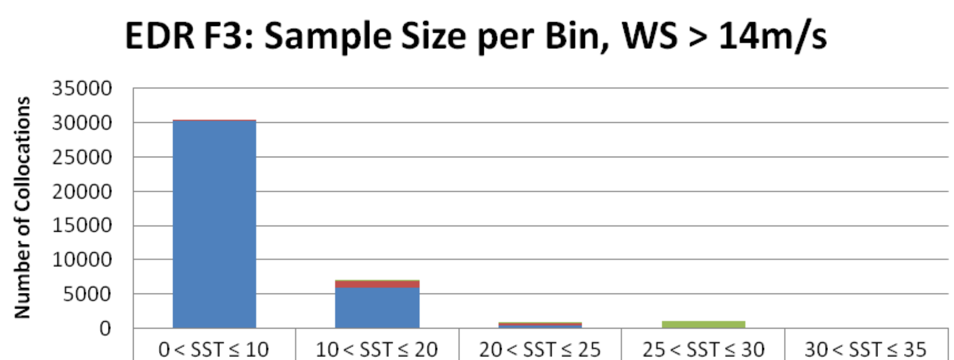
	Sea Surface Temperature (C)
1	0< SST ≤ 10
2	10< SST ≤ 20
3	20< SST ≤ 25
4	25 <SST≤ 30
5	30 <SST≤ 35

Naming Convention: Bin XYZ, X = SST range, Y = WV, and Z = CLW

Bin Distributions



	0 < SST ≤ 10	10 < SST ≤ 20	20 < SST ≤ 25	25 < SST ≤ 30	30 < SST ≤ 35
WV high	102	2860	20357	250284	11205
WV med	15108	91440	177111	253130	1500
WV low	383387	256683	73987	9710	34



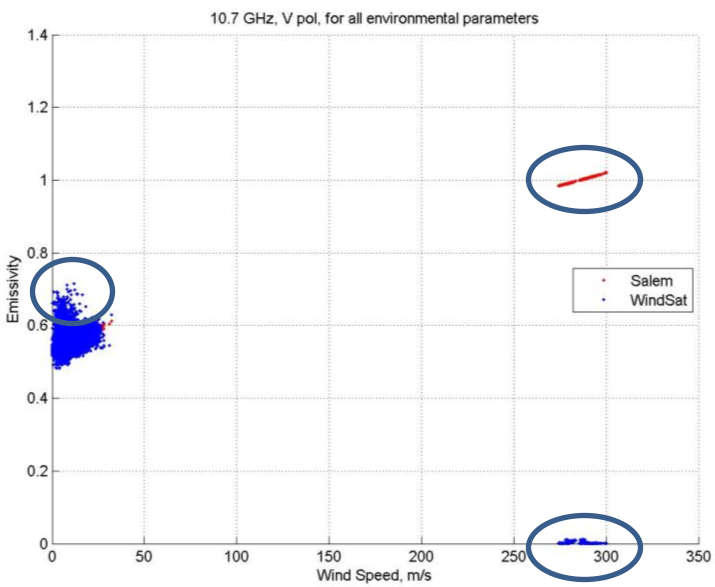
	0 < SST ≤ 10	10 < SST ≤ 20	20 < SST ≤ 25	25 < SST ≤ 30	30 < SST ≤ 35
WV high	0	14	63	920	43
WV med	212	951	410	125	0
WV low	30288	6010	362	13	0

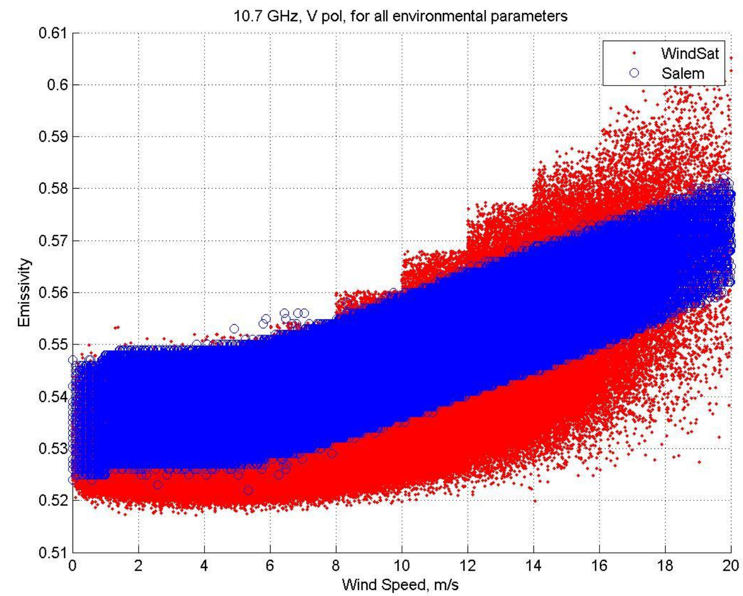
The two graphs show the rationale for focusing the analysis on the bin with 0 < SST ≤ 10 and 0 < WV ≤ 20. This bin is both the most populated and contains the most samples with wind speeds > 14 m/s.

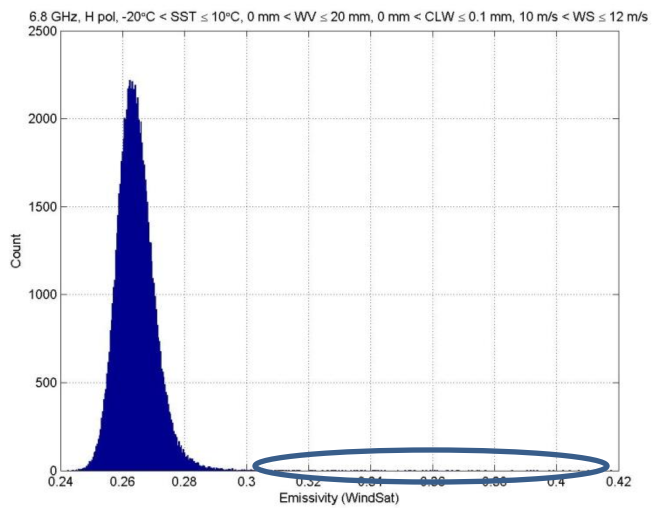
Filter Method

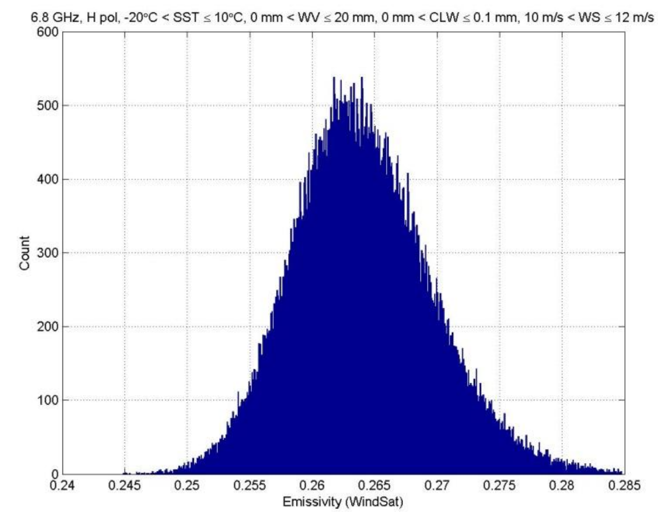
- Iterative method
- Brightness Temperature thresholds
- Environmental parameter thresholds
- Three standard deviations within each bin

Filter Method (before & after)

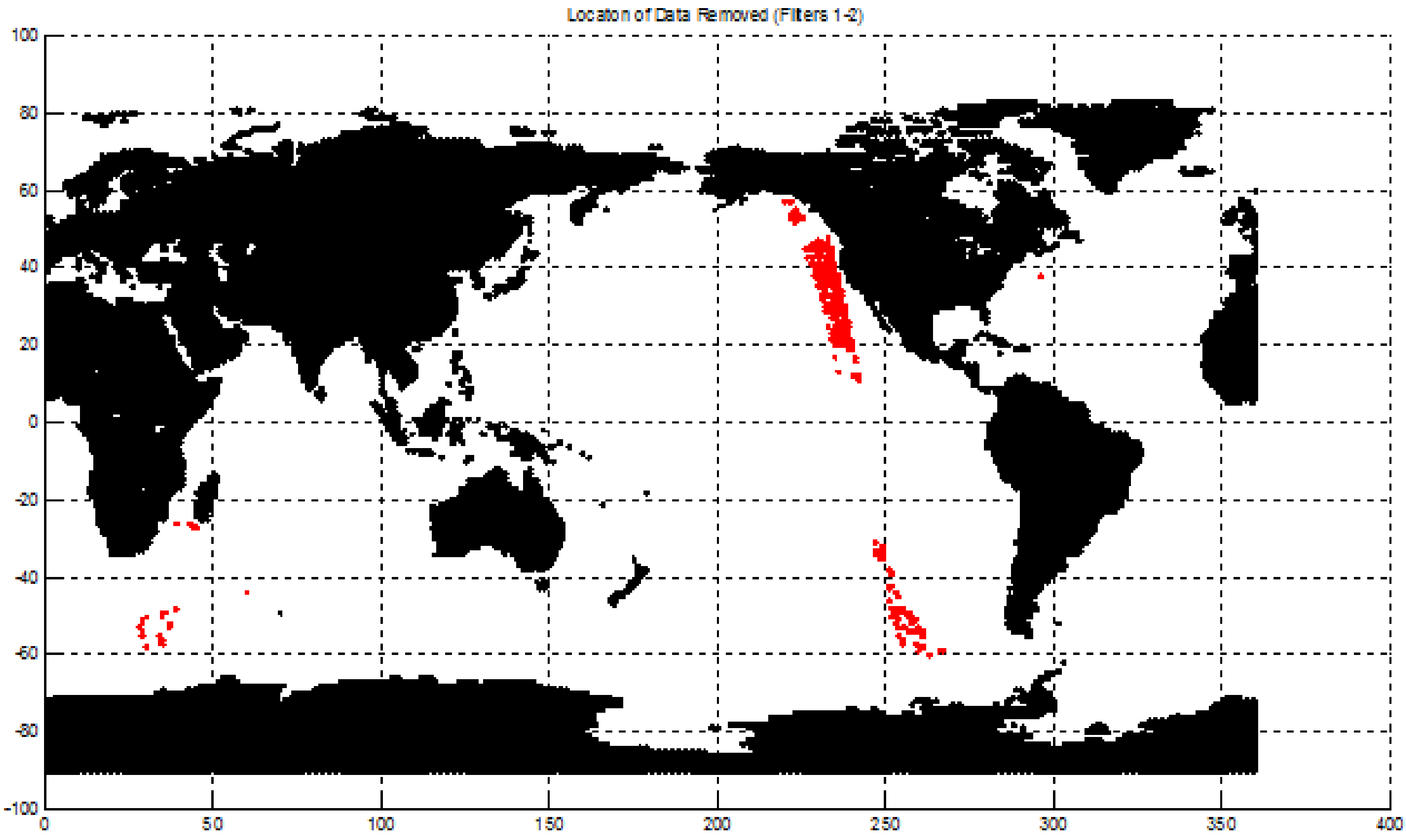






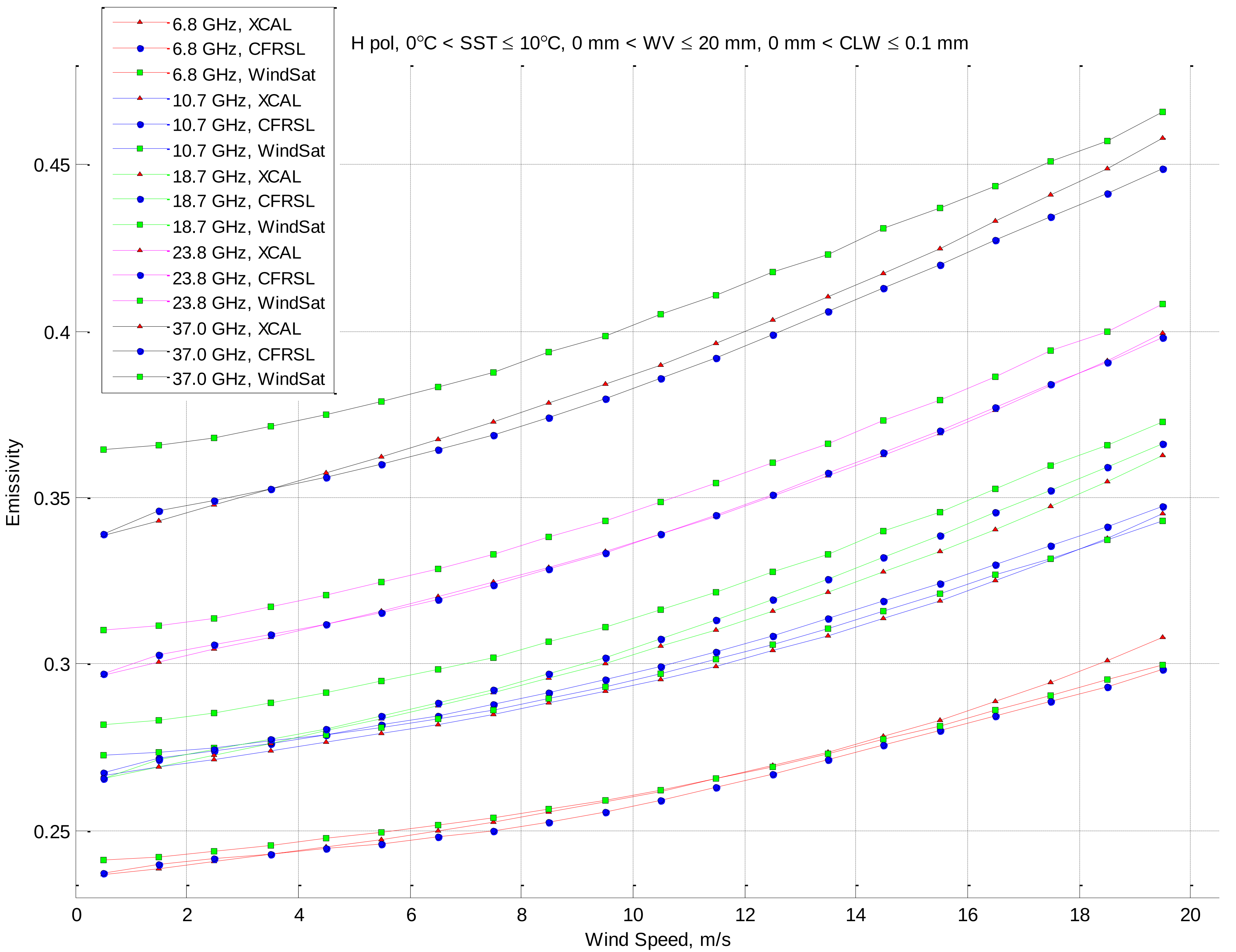


Location of Bad GDAS

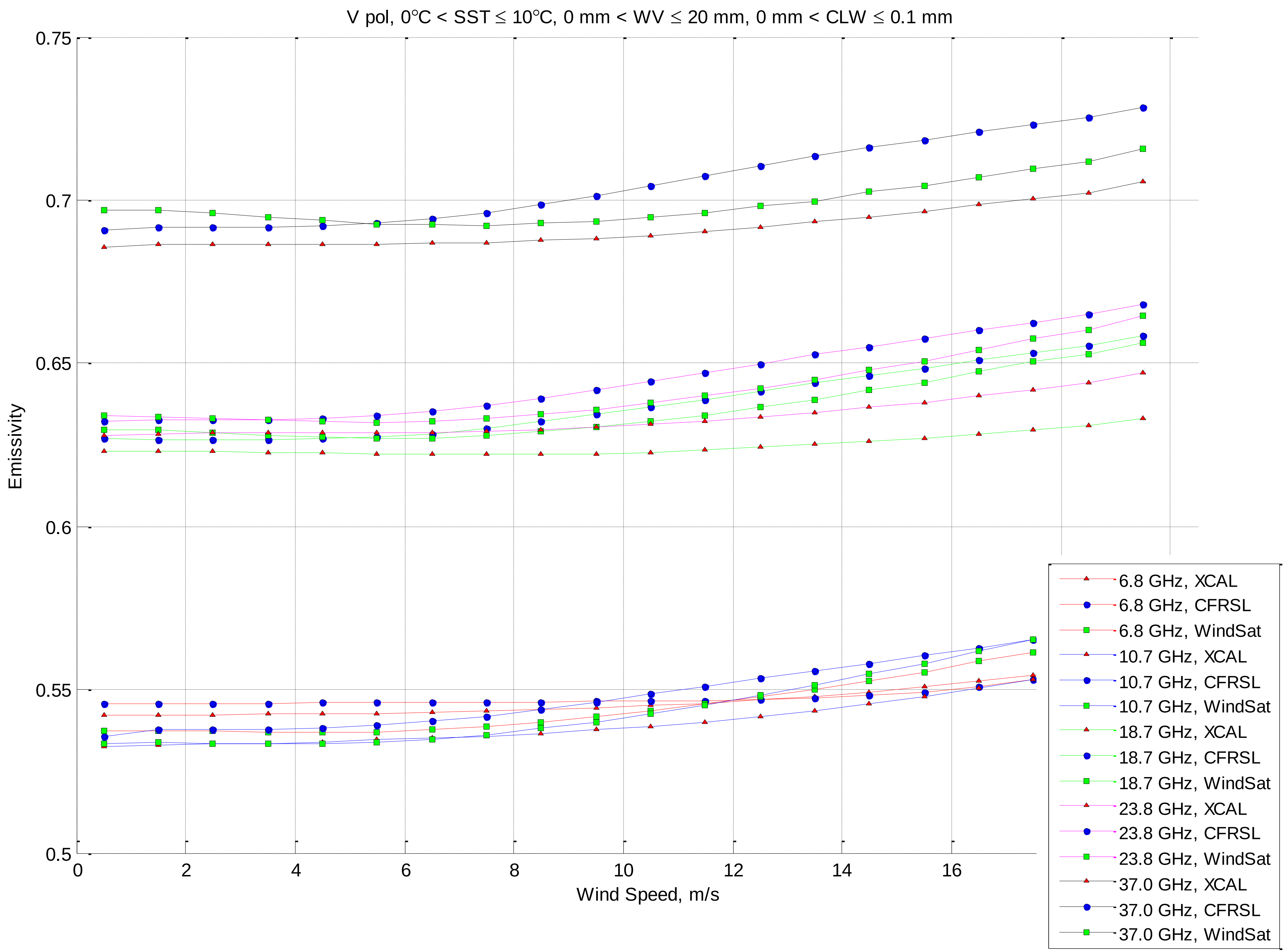


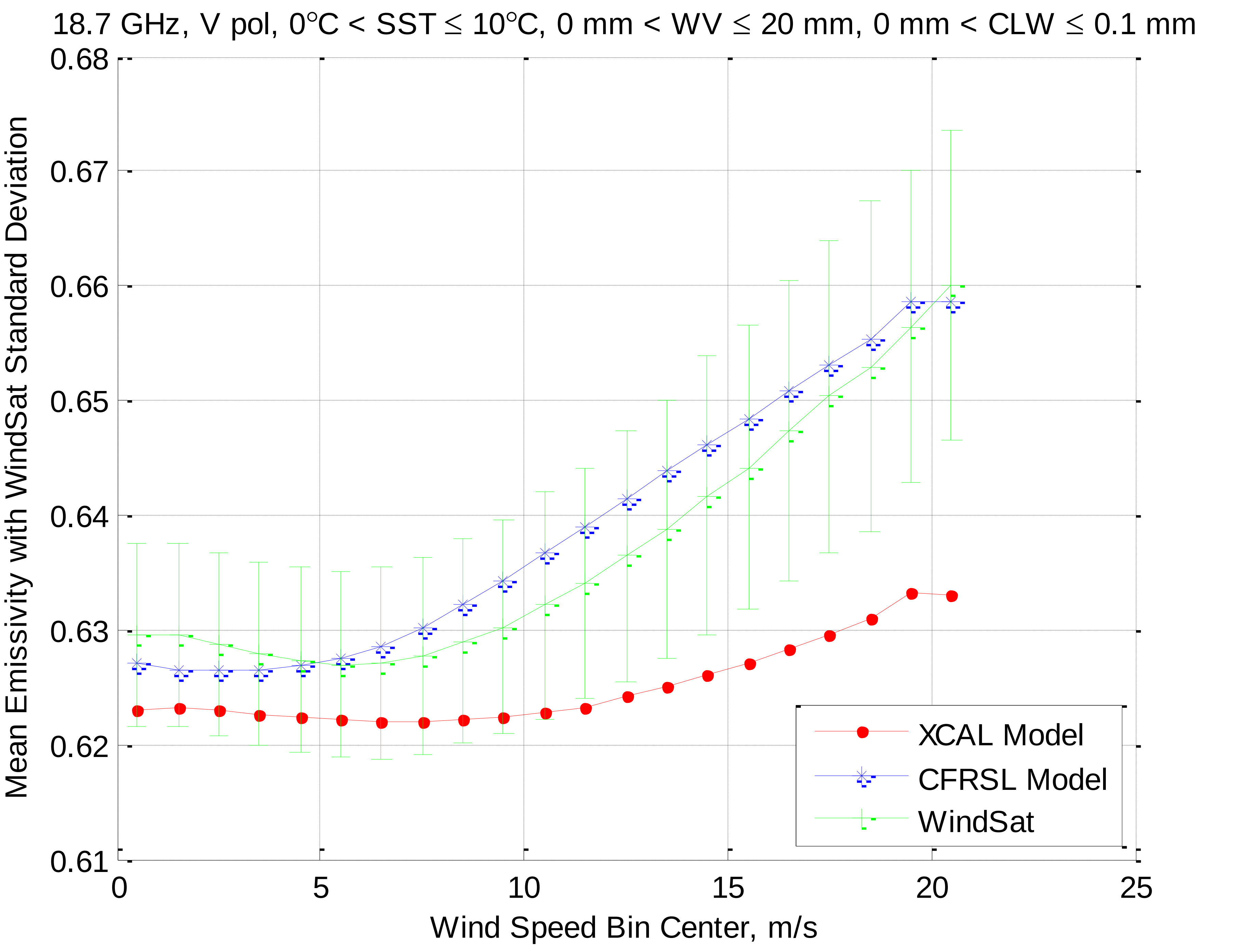
Results

EMISSIVITY COMPARISON USING GDAS WIND SPEEDS

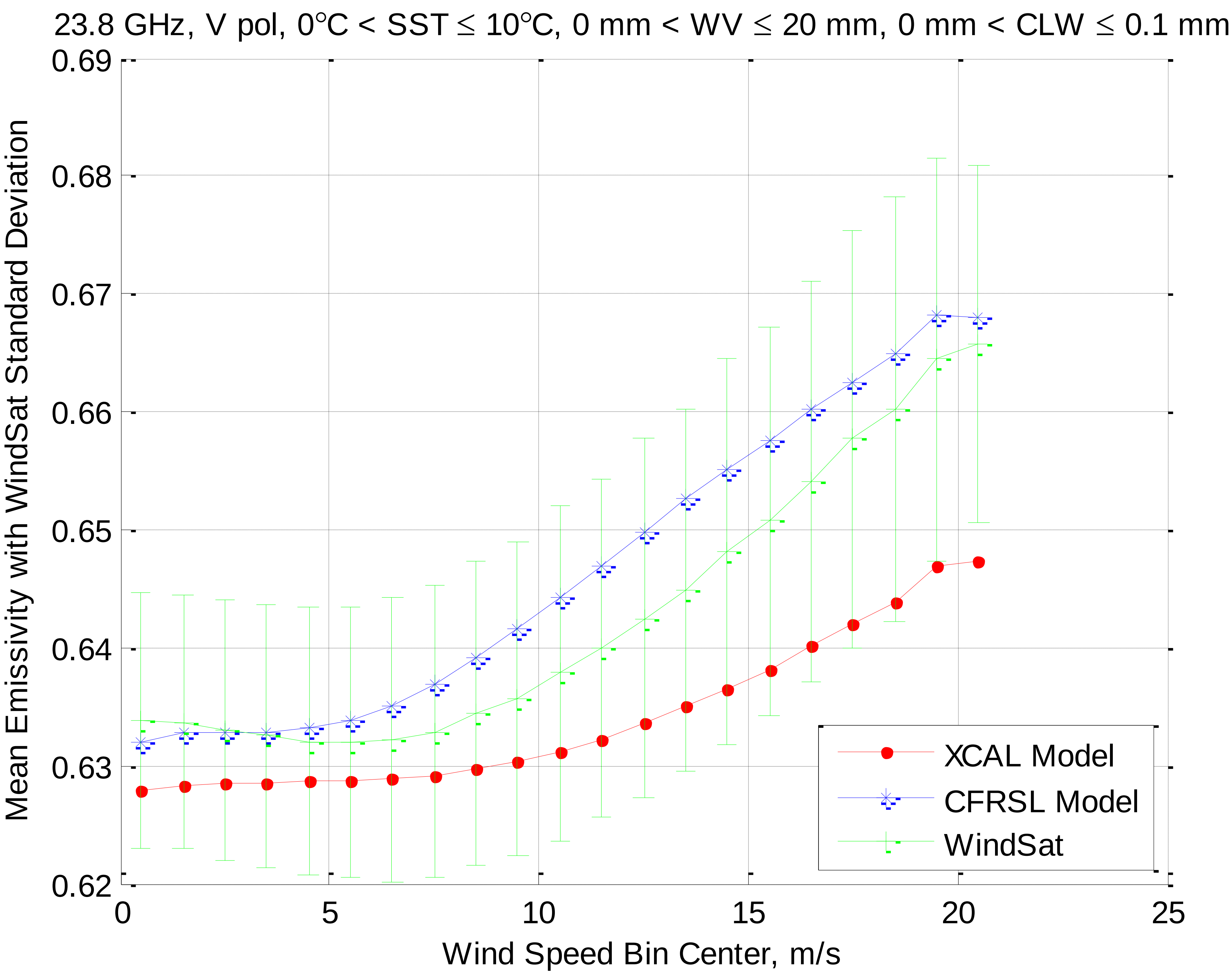


6.8 GHz, XCAL
6.8 GHz, CFRSL
6.8 GHz, WindSat
10.7 GHz, XCAL
10.7 GHz, CFRSL
10.7 GHz, WindSat
18.7 GHz, XCAL
18.7 GHz, CFRSL
18.7 GHz, WindSat
23.8 GHz, XCAL
23.8 GHz, CFRSL
23.8 GHz, WindSat
37.0 GHz, XCAL
37.0 GHz, CFRSL
37.0 GHz, WindSat
H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Emissivity
0.45
0.4
0.35
0.3
0.25
0
2
4
6
8
10
12
14
16
18
20
Wind Speed, m/s


V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Emissivity
Wind Speed, m/s
0.75
0.7
0.65
0.6
0.55
0.5
0
2
4
6
8
10
12
14
16
6.8 GHz, XCAL
6.8 GHz, CFRSL
6.8 GHz, WindSat
10.7 GHz, XCAL
10.7 GHz, CFRSL
10.7 GHz, WindSat
18.7 GHz, XCAL
18.7 GHz, CFRSL
18.7 GHz, WindSat
23.8 GHz, XCAL
23.8 GHz, CFRSL
23.8 GHz, WindSat
37.0 GHz, XCAL
37.0 GHz, CFRSL
37.0 GHz, WindSat

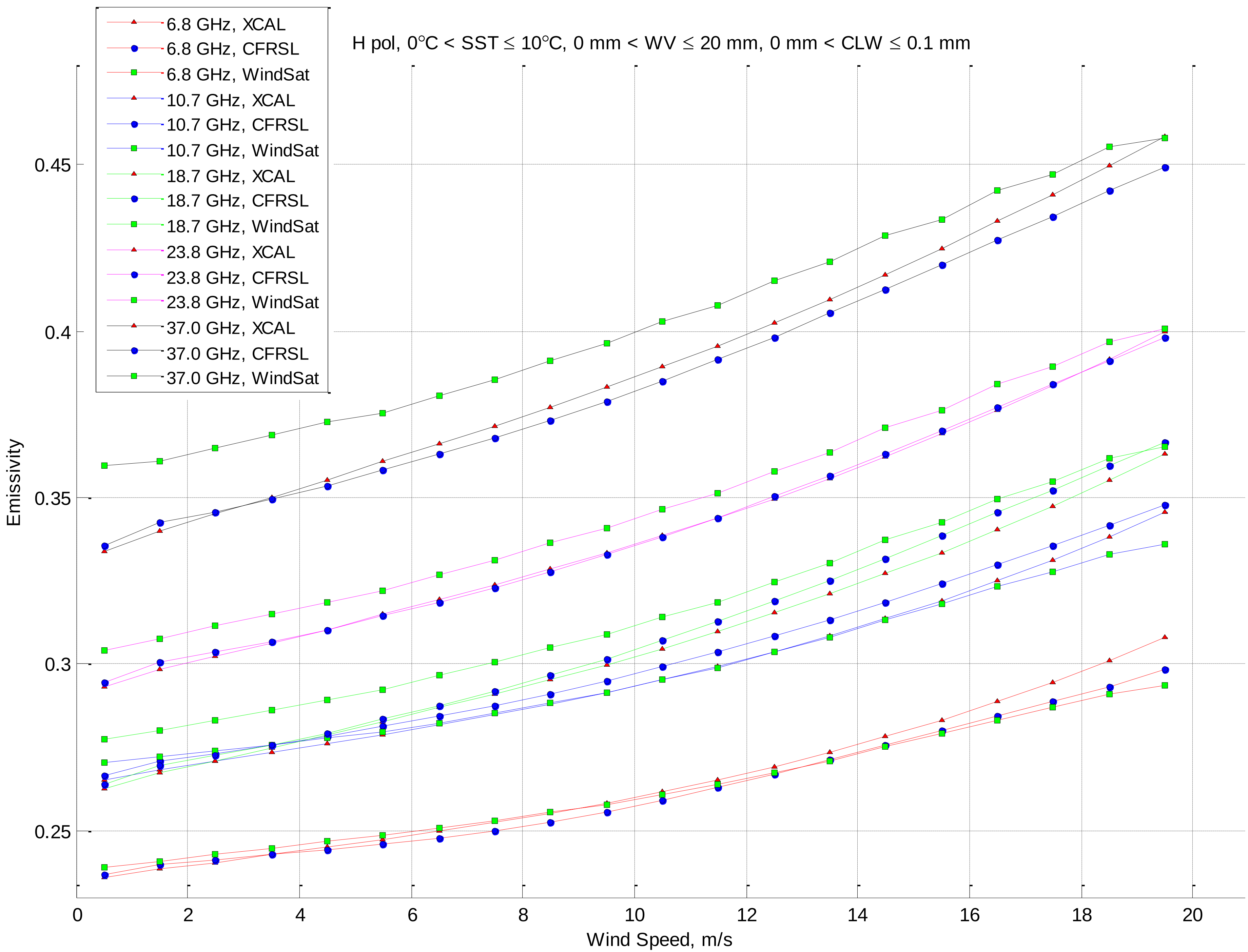


18.7 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

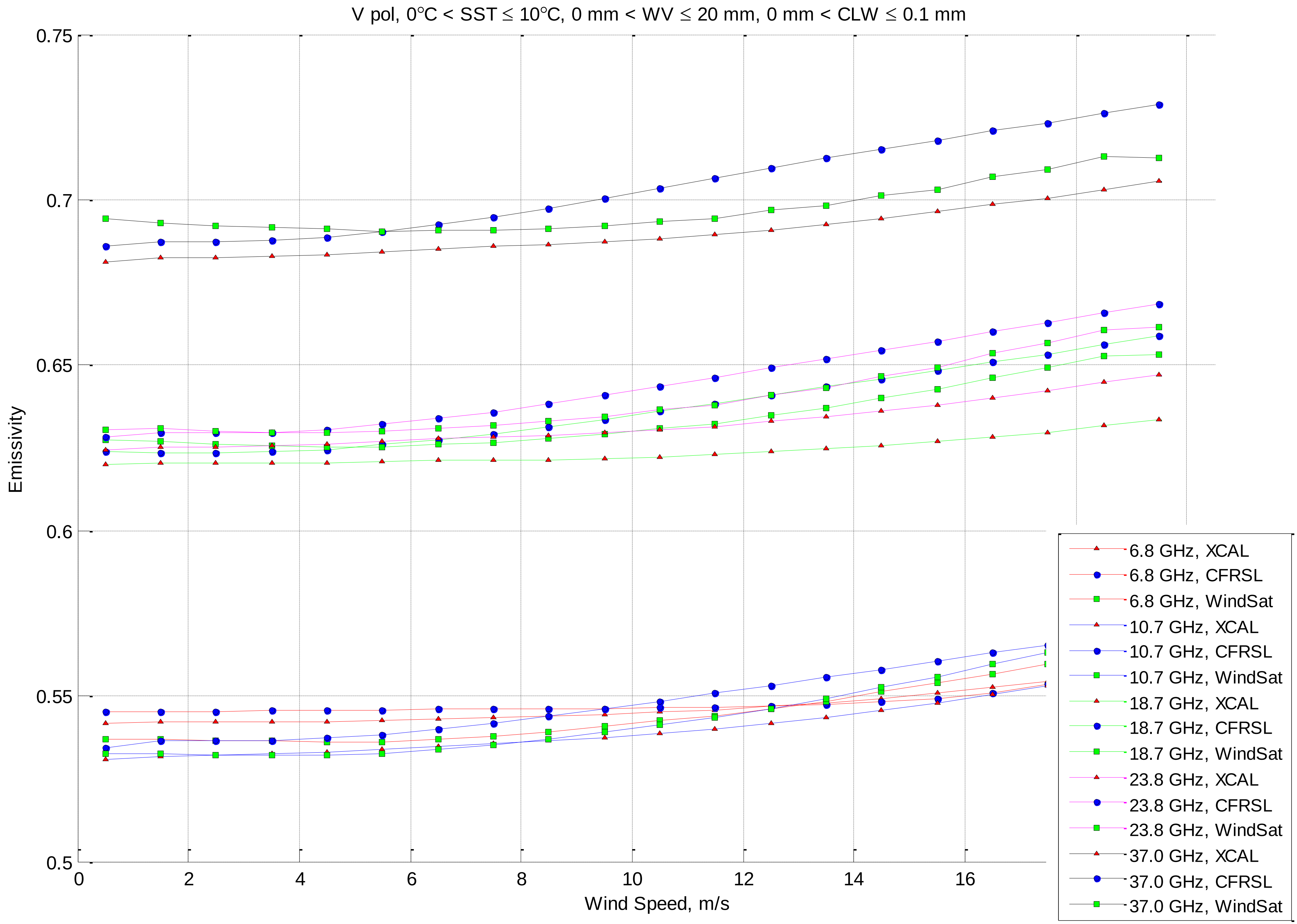


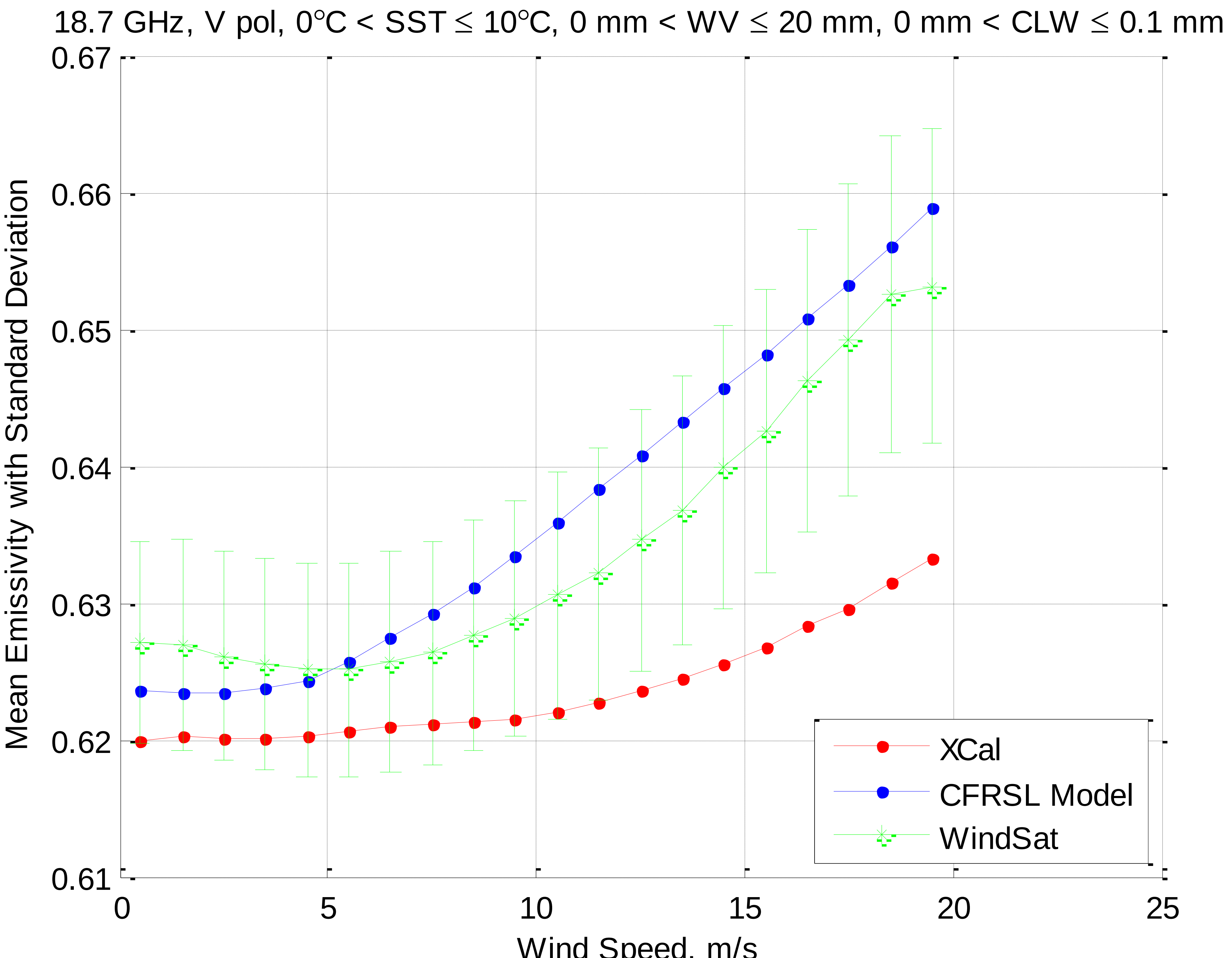
23.8 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
0.69
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0
5
10
15
20
25
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
XCAL Model
CFRSL Model
WindSat

EMISSIVITY COMPARISON USING EDR WIND SPEEDS

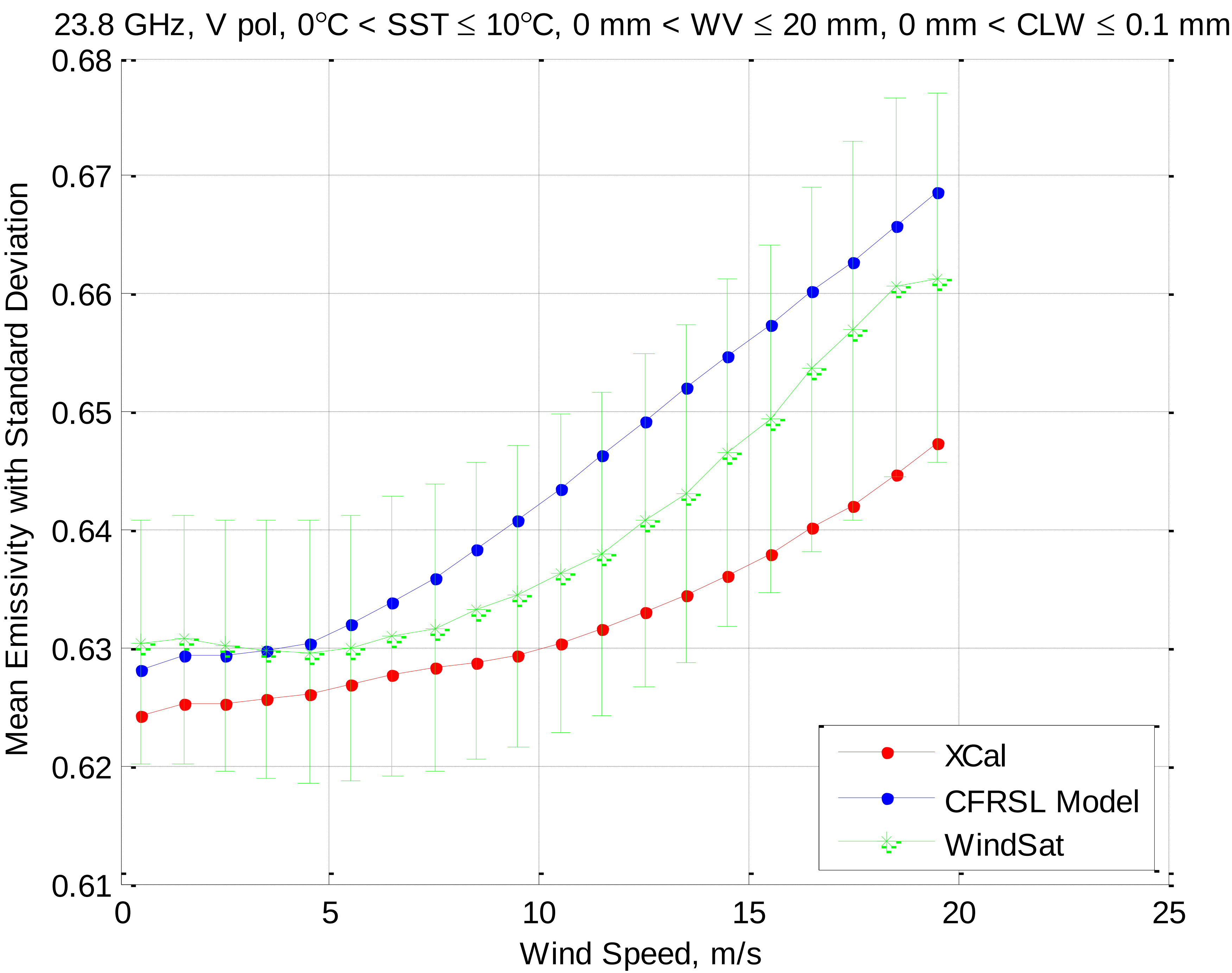


6.8 GHz, XCAL
6.8 GHz, CFRSL
6.8 GHz, WindSat
10.7 GHz, XCAL
10.7 GHz, CFRSL
10.7 GHz, WindSat
18.7 GHz, XCAL
18.7 GHz, CFRSL
18.7 GHz, WindSat
23.8 GHz, XCAL
23.8 GHz, CFRSL
23.8 GHz, WindSat
37.0 GHz, XCAL
37.0 GHz, CFRSL
37.0 GHz, WindSat
H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Emissivity
0.45
0.4
0.35
0.3
0.25
0
2
4
6
8
10
12
14
16
18
20
Wind Speed, m/s


V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Emissivity
Wind Speed, m/s
0.75
0.7
0.65
0.6
0.55
0.5
0
2
4
6
8
10
12
14
16
6.8 GHz, XCAL
6.8 GHz, CFRSL
6.8 GHz, WindSat
10.7 GHz, XCAL
10.7 GHz, CFRSL
10.7 GHz, WindSat
18.7 GHz, XCAL
18.7 GHz, CFRSL
18.7 GHz, WindSat
23.8 GHz, XCAL
23.8 GHz, CFRSL
23.8 GHz, WindSat
37.0 GHz, XCAL
37.0 GHz, CFRSL
37.0 GHz, WindSat

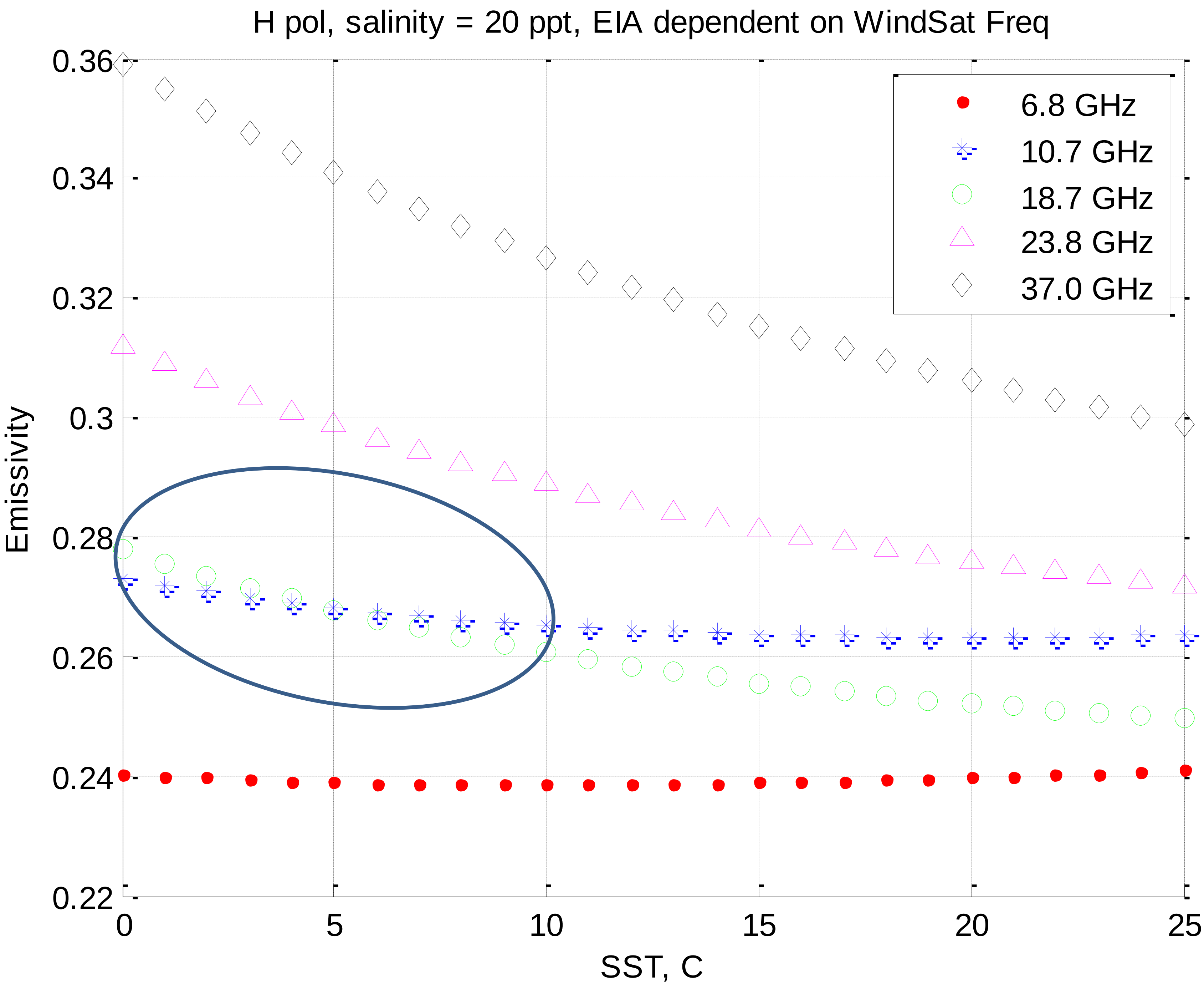


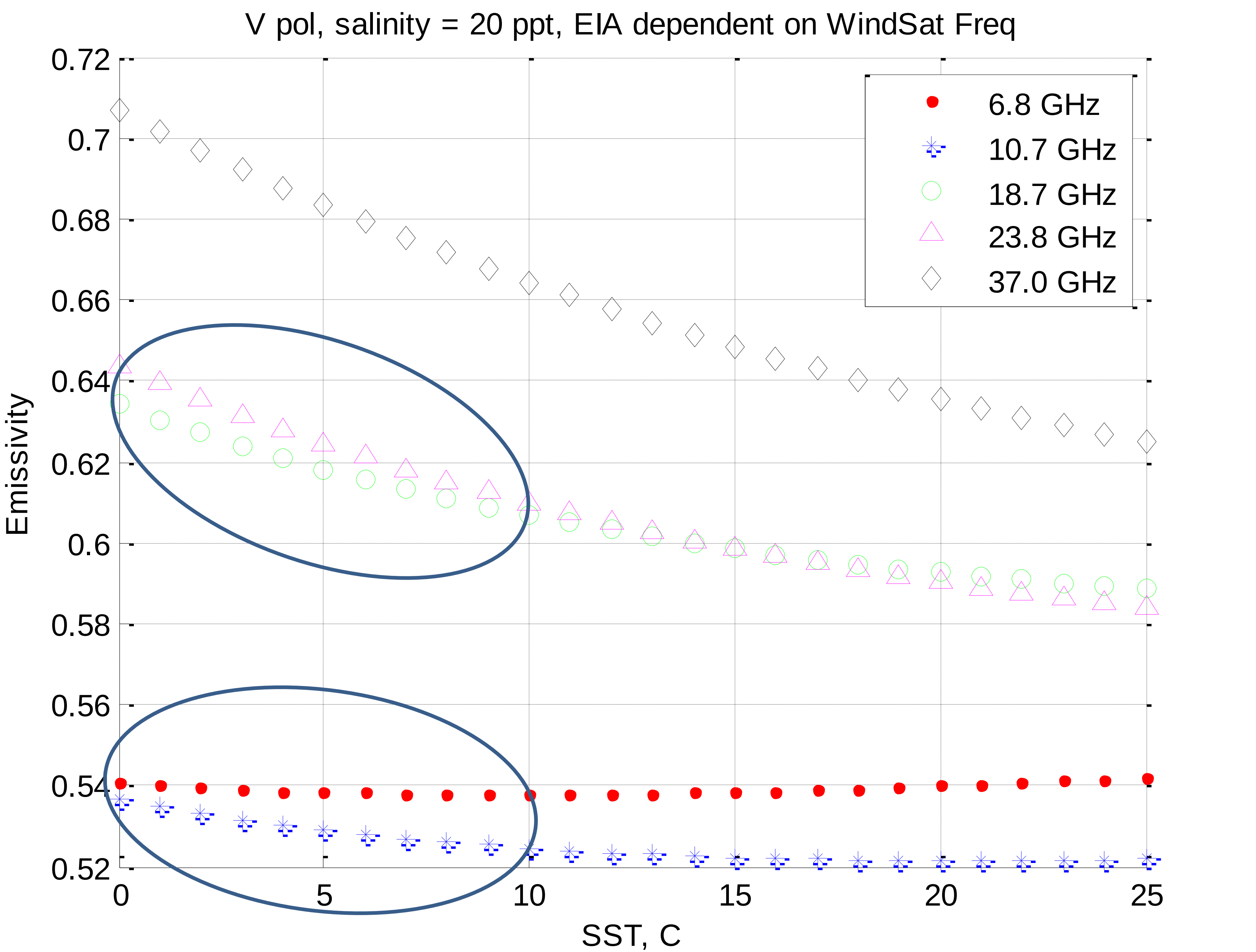
18.7 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat



23.8 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat

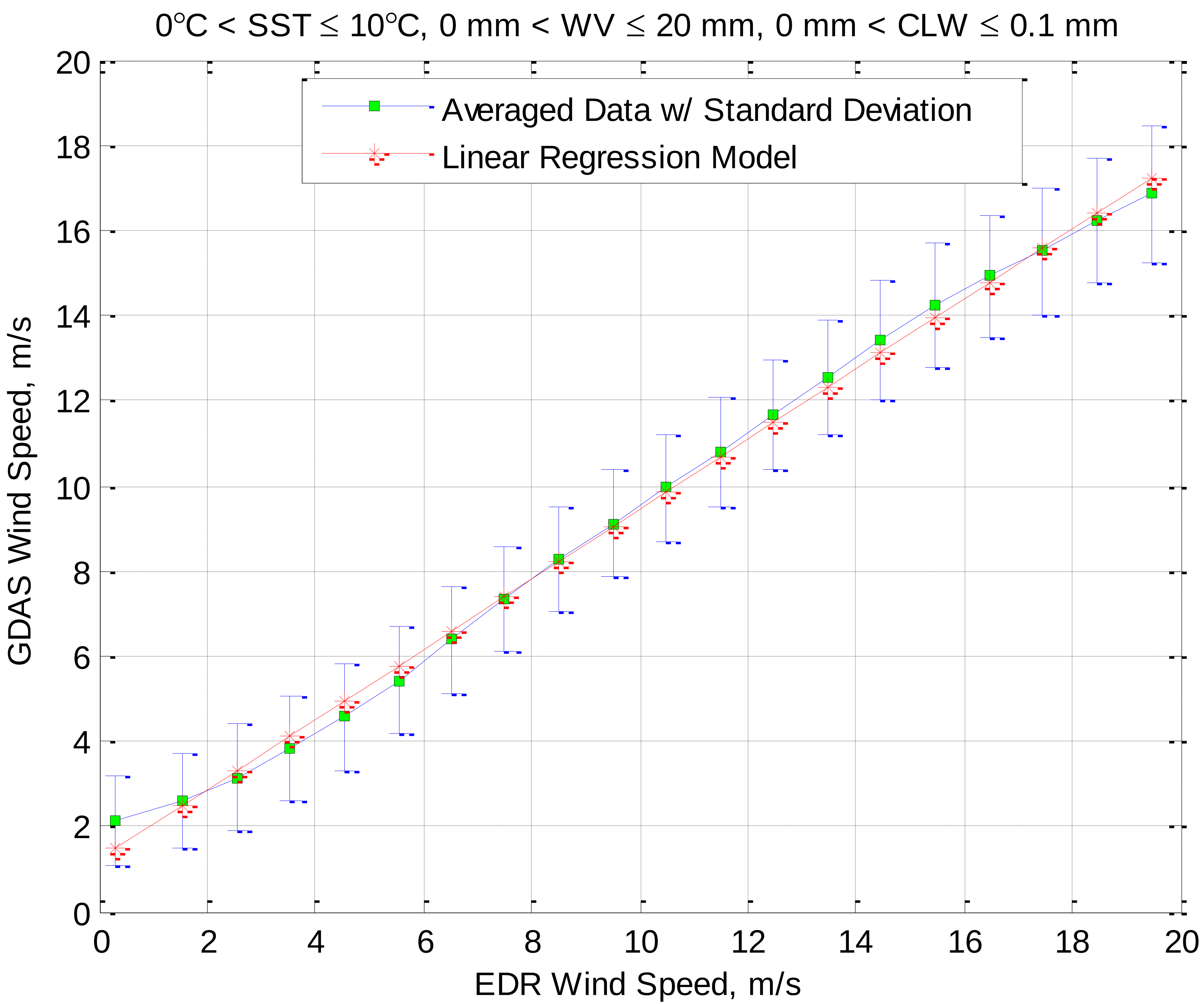
FREQUENCY CROSS-OVER EXPLANATION


H pol, salinity = 20 ppt, EIA dependent on WindSat Freq
Emissivity
SST, C
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0
5
10
15
20
25
6.8 GHz
10.7 GHz
18.7 GHz
23.8 GHz
37.0 GHz

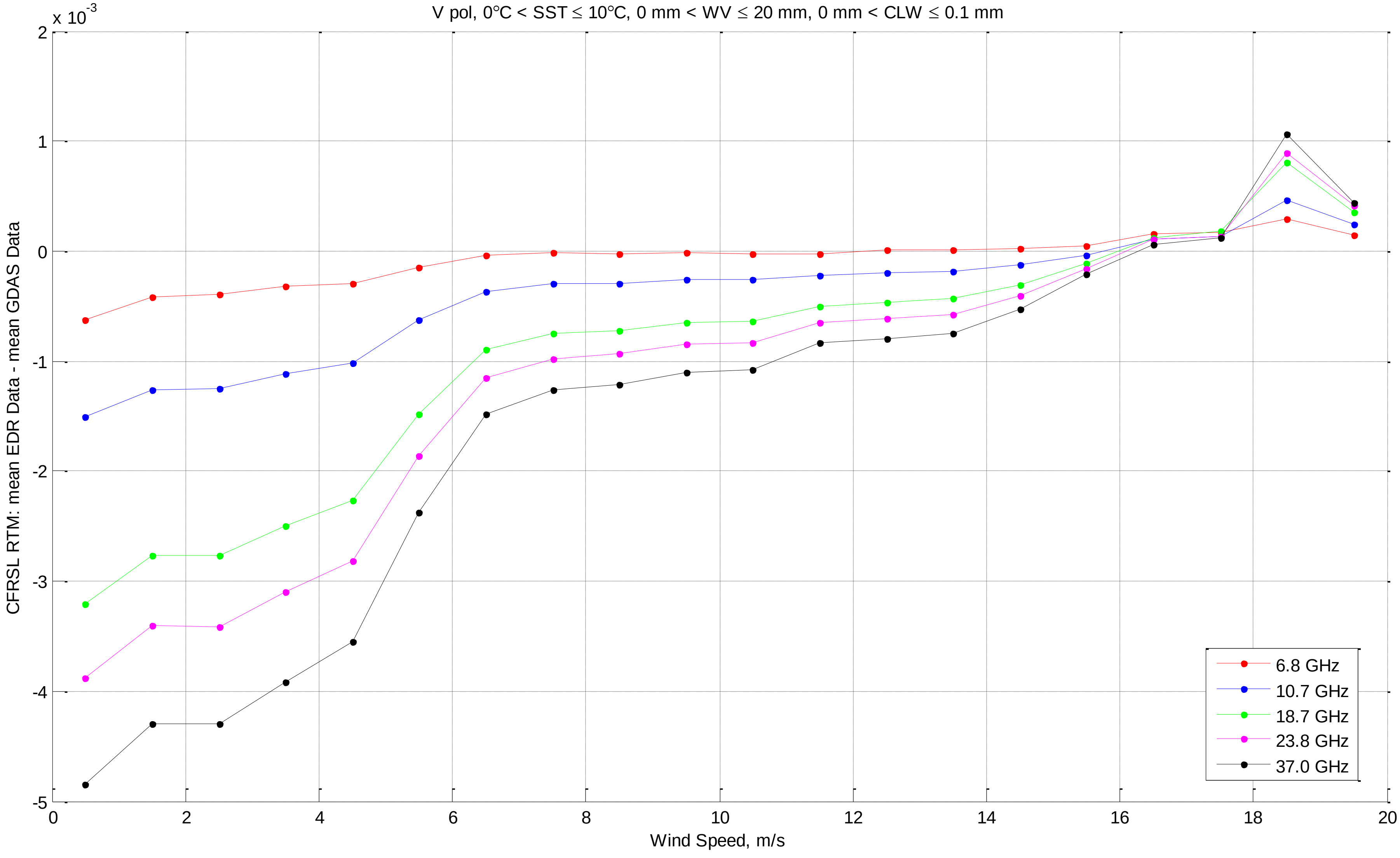


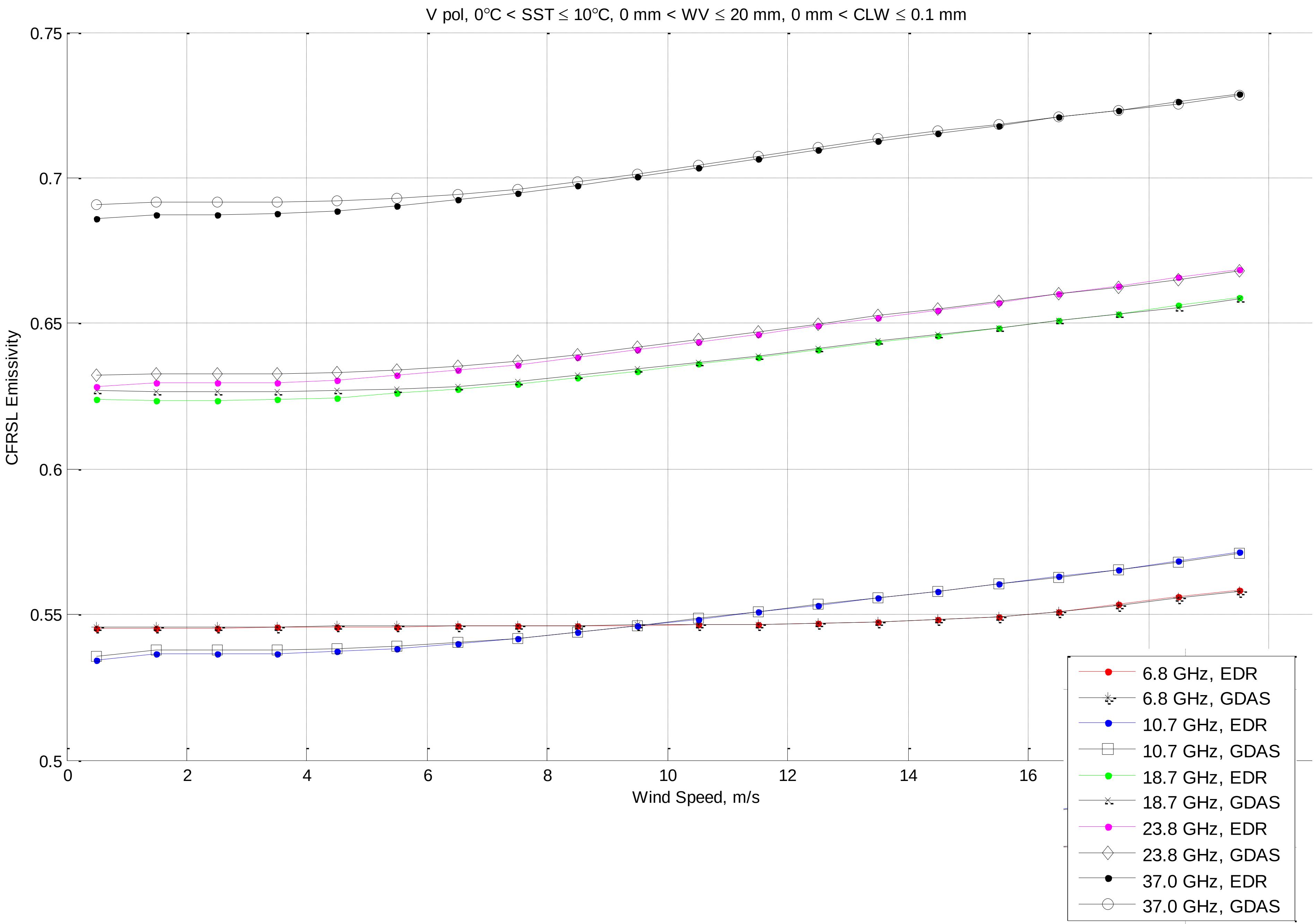
V pol, salinity = 20 ppt, EIA dependent on WindSat Freq
Emissivity
SST, C
0.72
0.7
0.68
0.66
0.64
0.62
0.6
0.58
0.56
0.54
0.52
0
5
10
15
20
25
6.8 GHz
10.7 GHz
18.7 GHz
23.8 GHz
37.0 GHz

GDAS WIND SPEED VS EDR WIND SPEED


0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Averaged Data w/ Standard Deviation
Linear Regression Model
GDAS Wind Speed, m/s
EDR Wind Speed, m/s
0
2
4
6
8
10
12
14
16
18
20

Delta Emissivity: EDR - GDAS Data





V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
CFRSL Emissivity
Wind Speed, m/s
0.75
0.7
0.65
0.6
0.55
0.5
0
2
4
6
8
10
12
14
16
6.8 GHz, EDR
6.8 GHz, GDAS
10.7 GHz, EDR
10.7 GHz, GDAS
18.7 GHz, EDR
18.7 GHz, GDAS
23.8 GHz, EDR
23.8 GHz, GDAS
37.0 GHz, EDR
37.0 GHz, GDAS

Conclusions

- Significant improvement not identified across all frequencies and polarizations
- Most improvement seen in 18.7 and 23.8 GHz V polarization results for low SST and WV
- Lack of data at higher wind speeds distorts comparison for additional bins

Recommendations

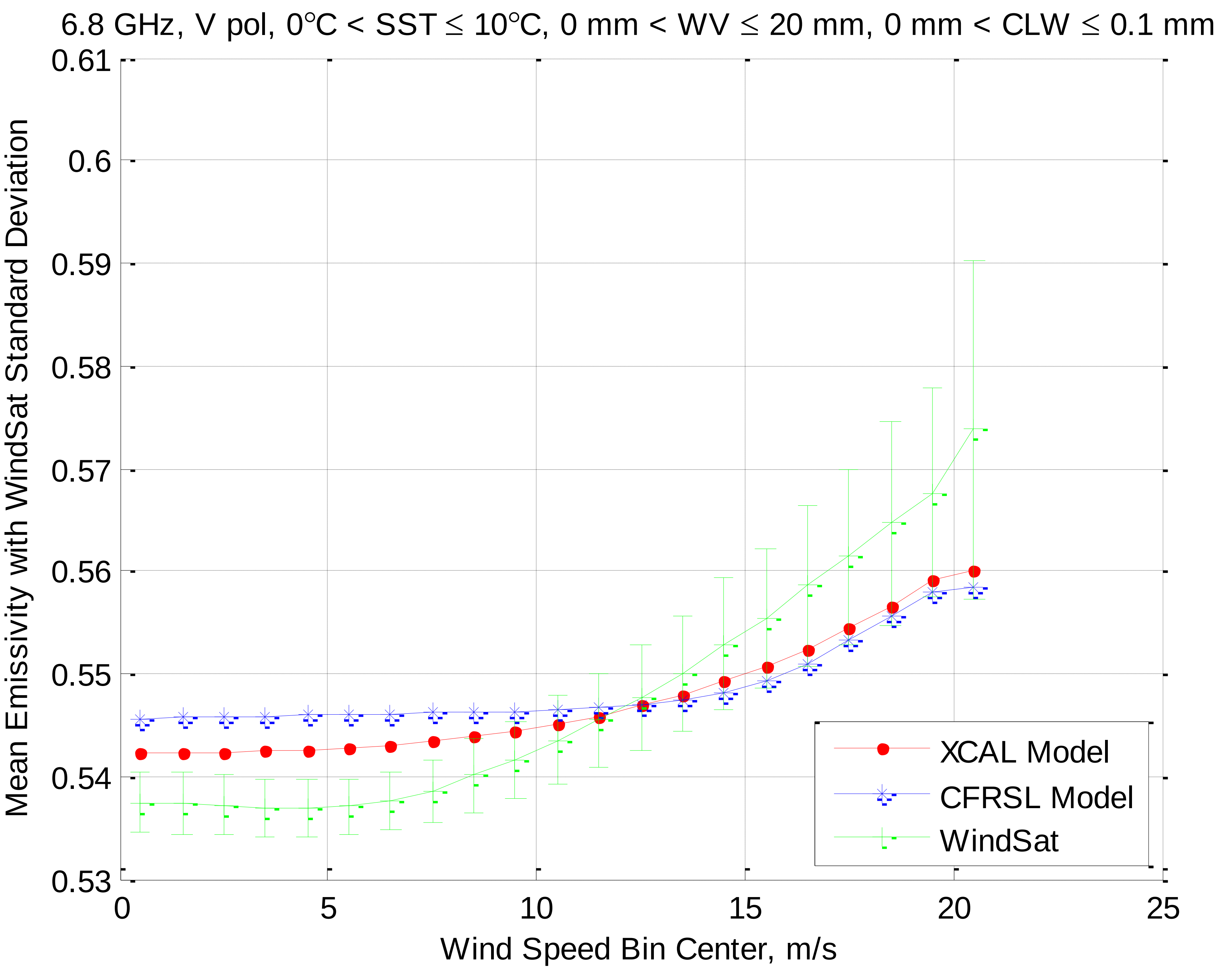
- Examine the effect of wind direction
- Obtain EDR and Satellite measurements for higher wind speeds
- Conduct analysis for more frequencies, incidence angles, and wind speeds

References

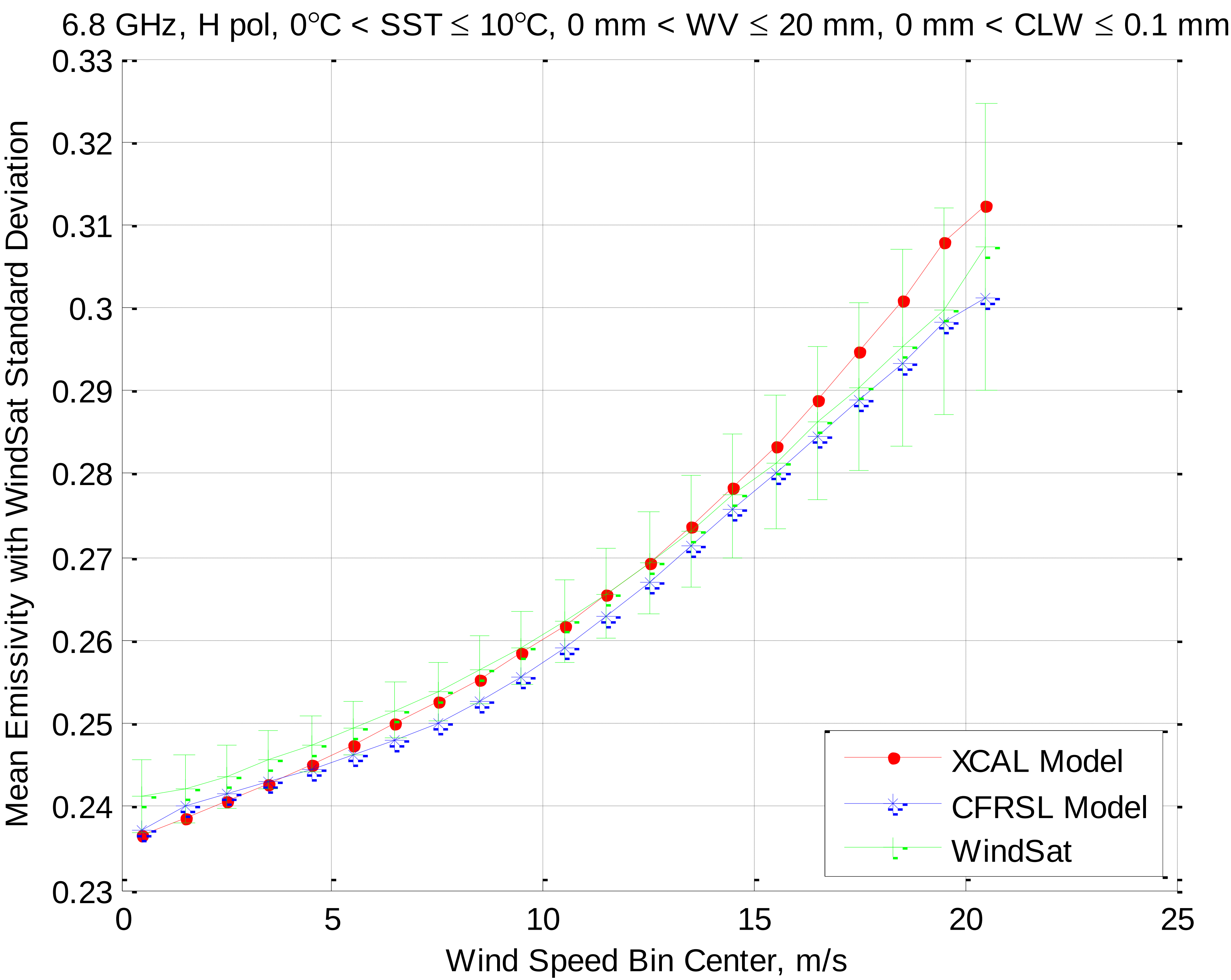
- Simonetta D Thompson, "Evaluation of a microwave radiative transfer model for calculating satellite brightness temperature", Master's Thesis, University of Central Florida, 2002
- Liang Hong, " Inter-Satellite Microwave Radiometer Calibration", Doctor's Dissertation, University of Central Florida, 2004
- WindSat Description. http://www.nrl.navy.mil/WindSat/Description.php
- Salem Fawwaz El-Nimri, "Development of an Improved Microwave Ocean Surface Emissivity Radiative Transfer Model", Doctor's Dissertation, University of Central Florida, 2010

Backup Charts

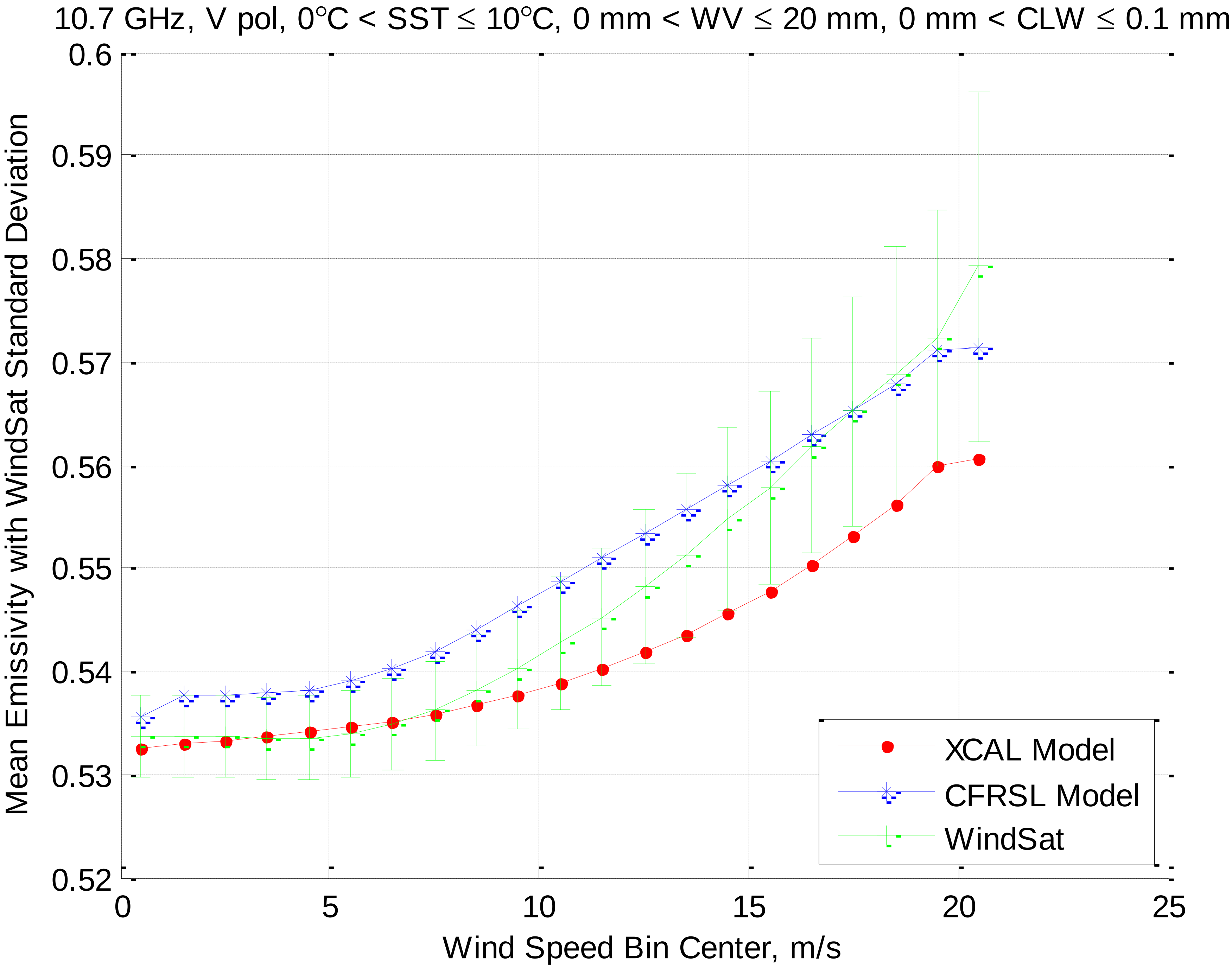
EMISSIVITY VERSUS GDAS WIND SPEED

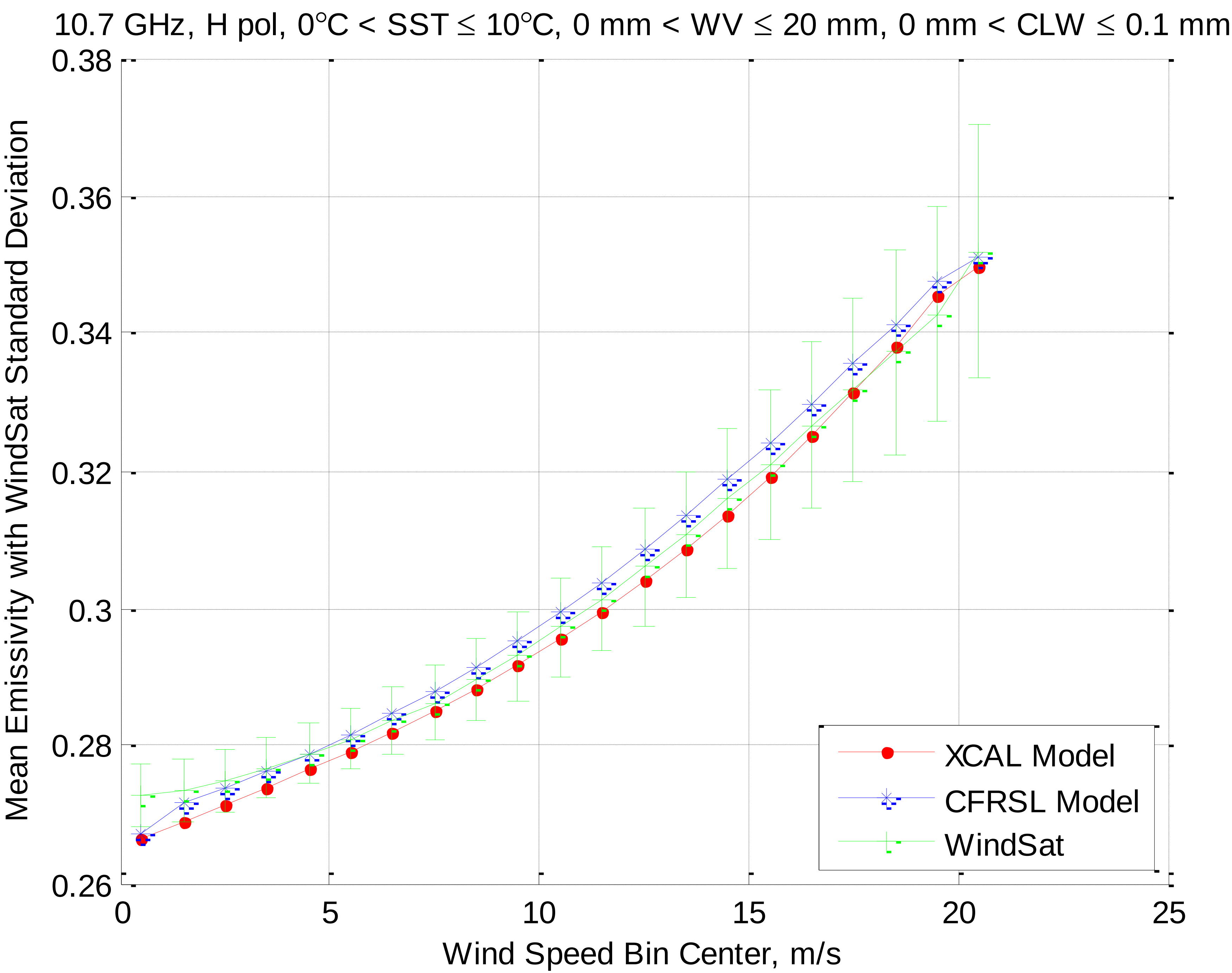


6.8 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.61
0.6
0.59
0.58
0.57
0.56
0.55
0.54
0.53
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

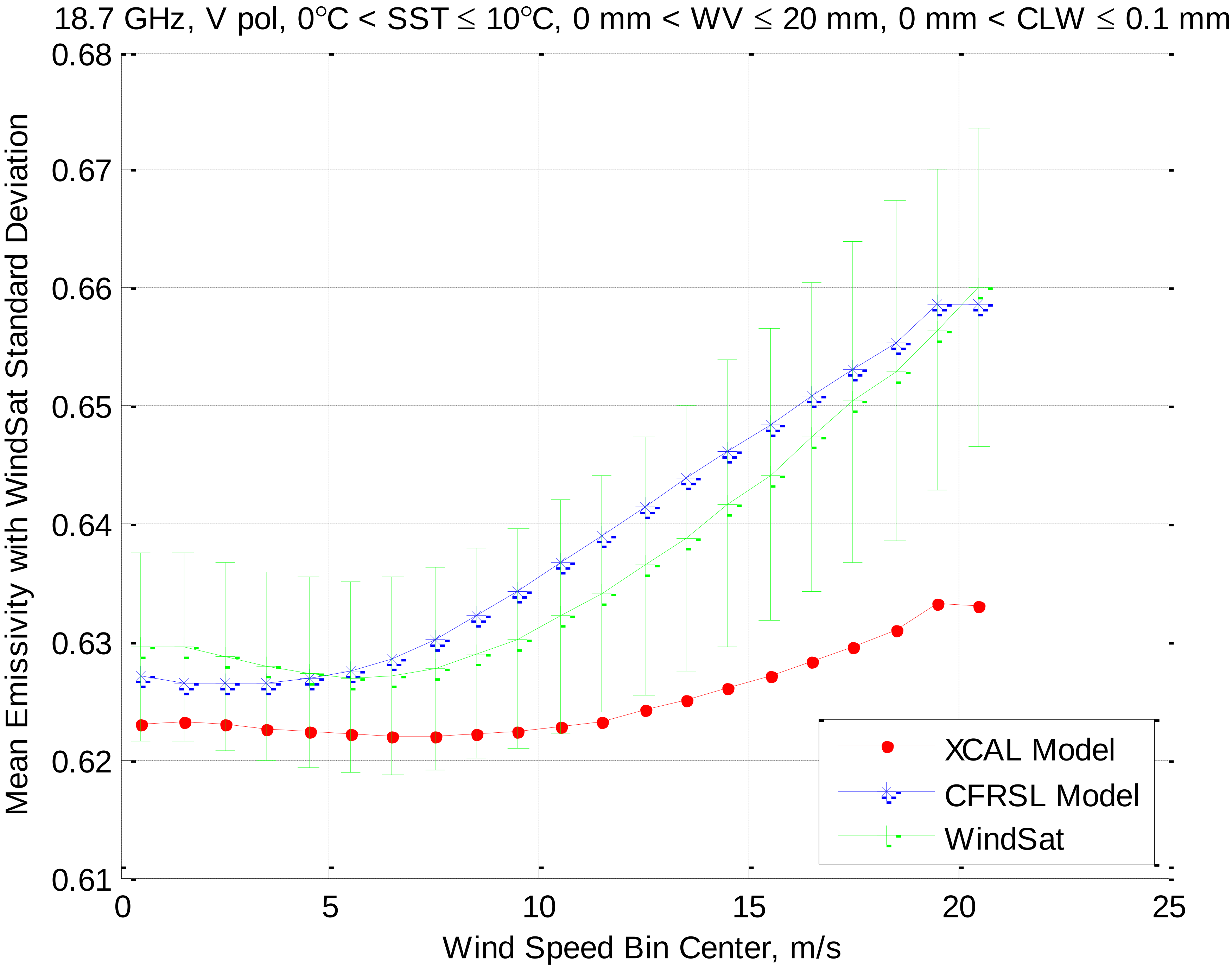


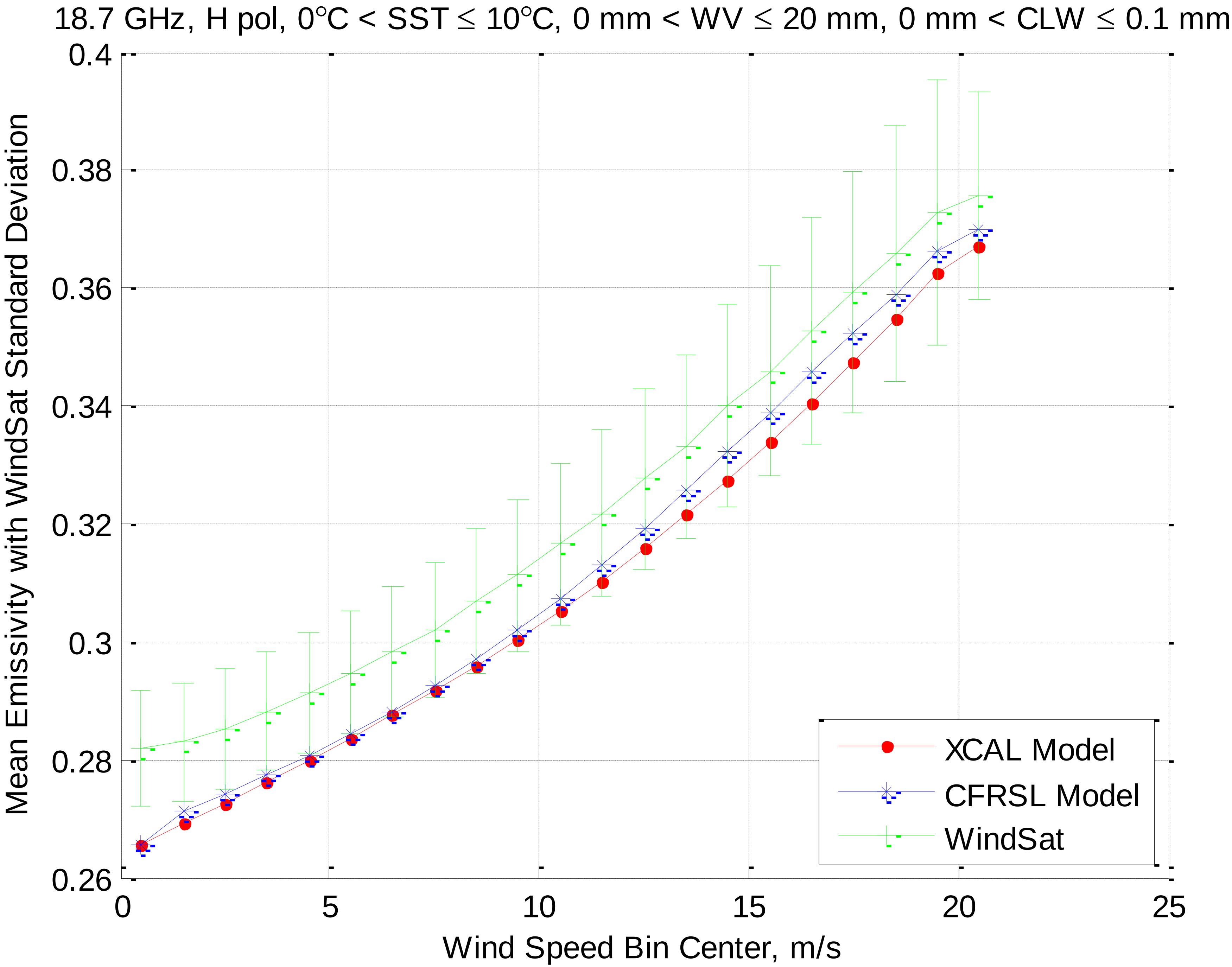
6.8 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.33
0.32
0.31
0.3
0.29
0.28
0.27
0.26
0.25
0.24
0.23
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

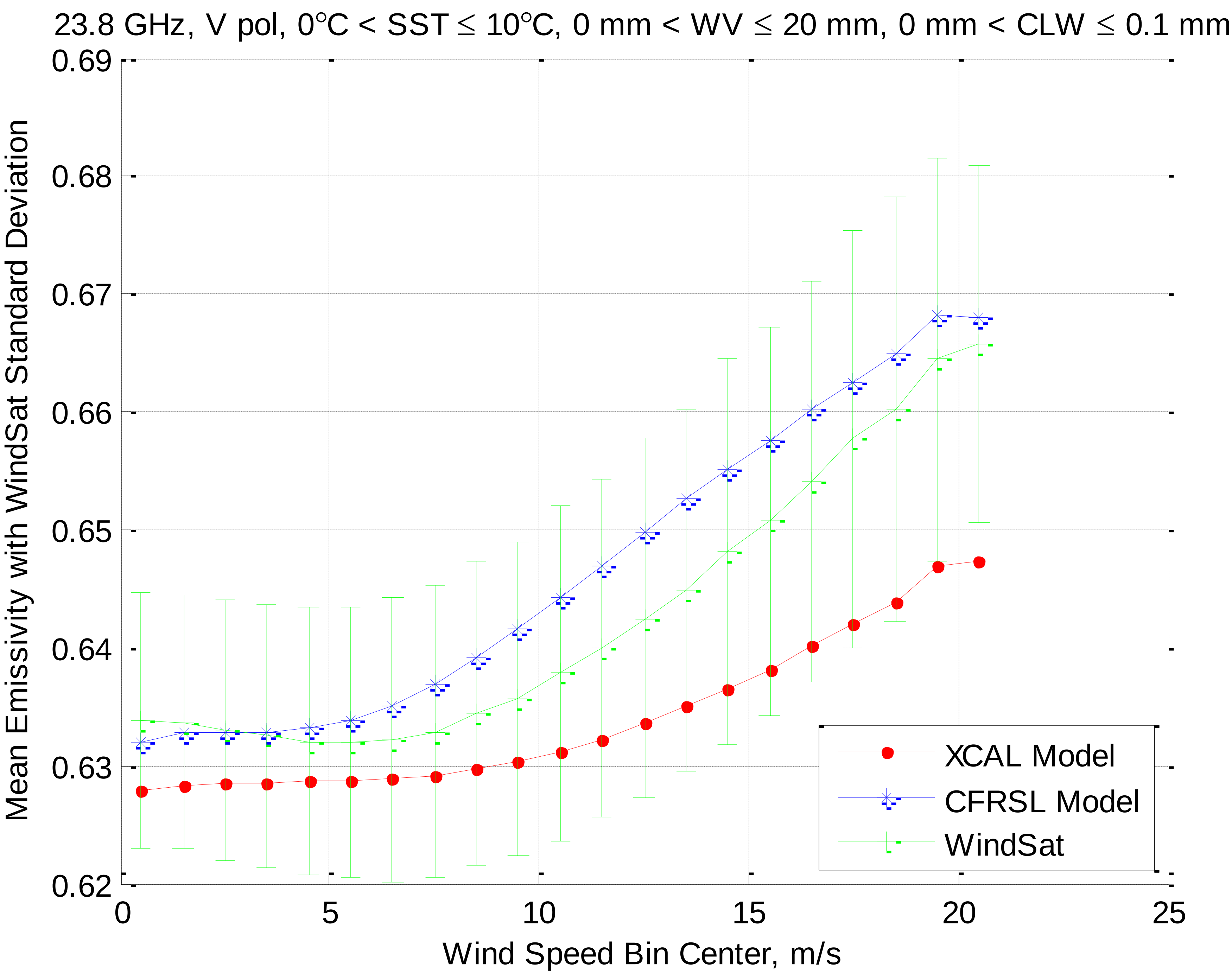

10.7 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.6
0.59
0.58
0.57
0.56
0.55
0.54
0.53
0.52
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat



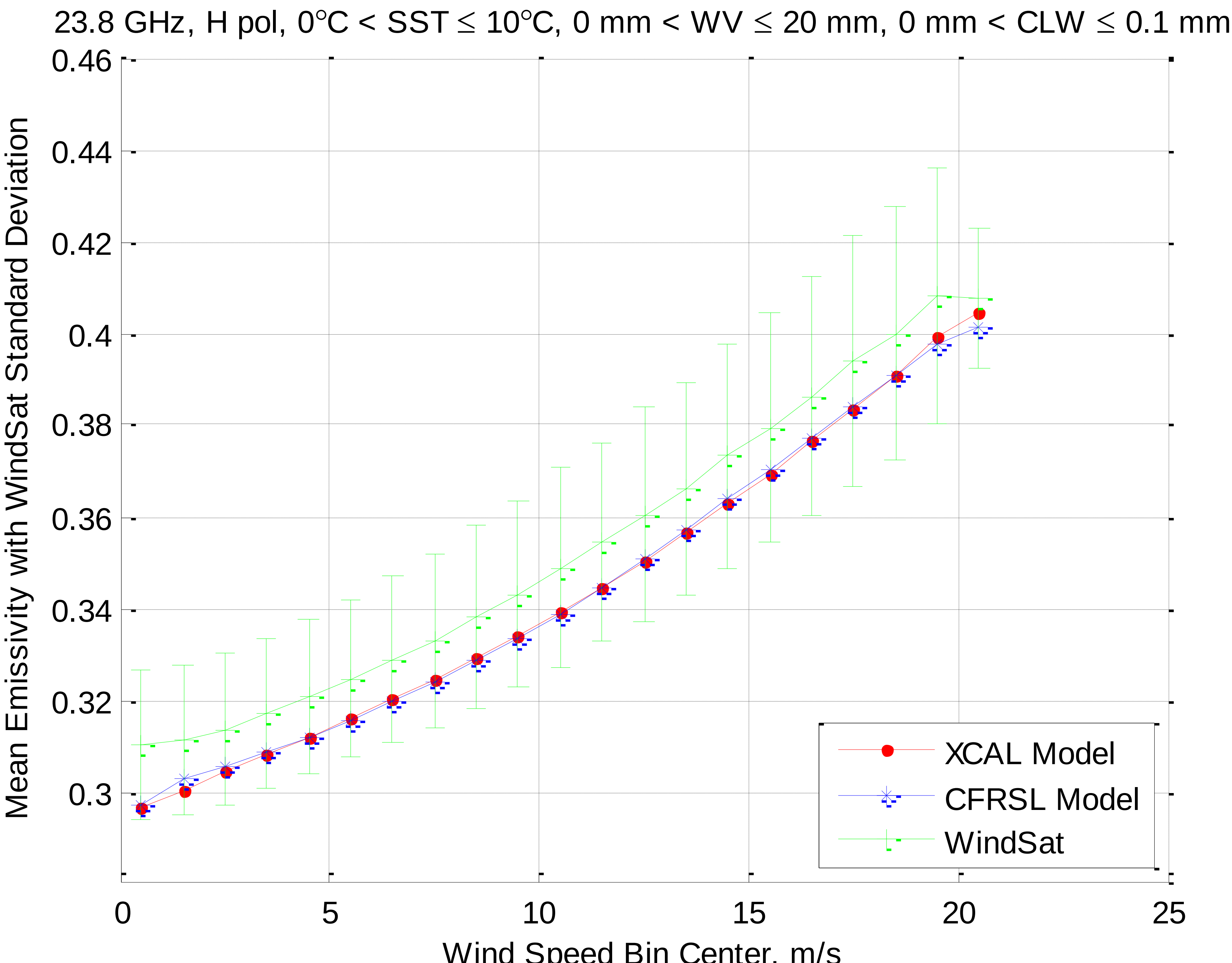
10.7 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0
5
10
15
20
25
Wind Speed Bin Center, m/s
XCAL Model
CFRSL Model
WindSat


18.7 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

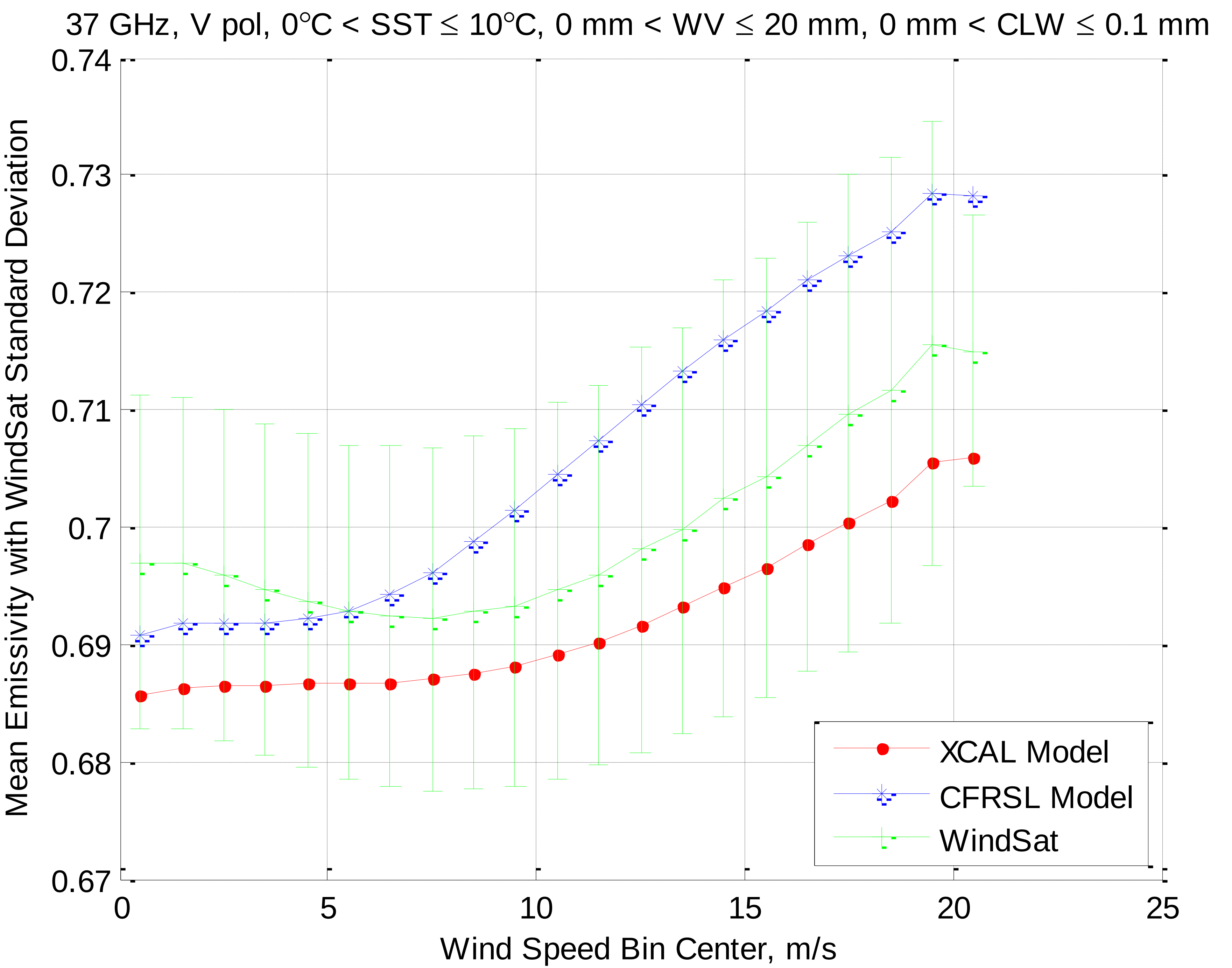

18.7 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

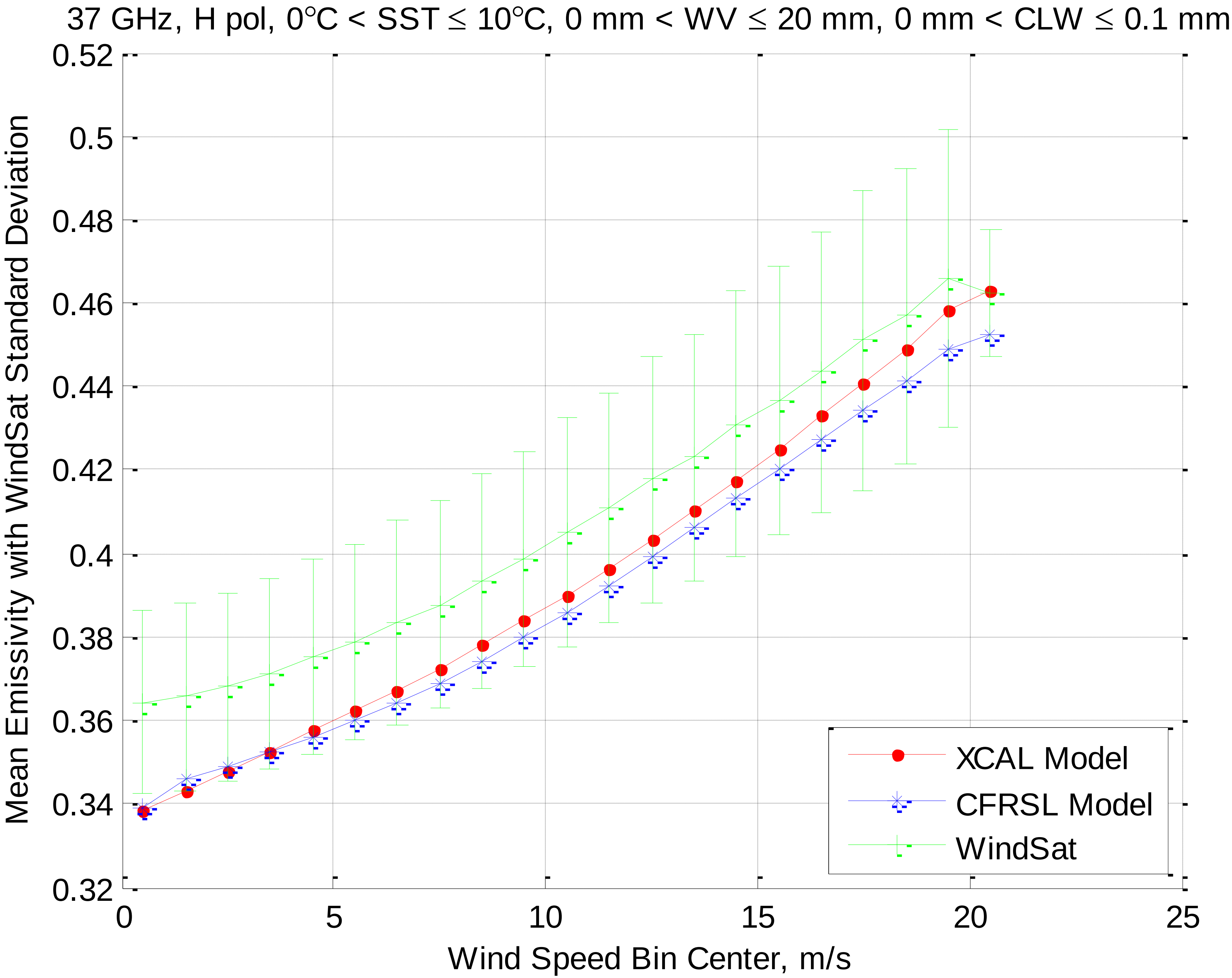


23.8 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.69
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

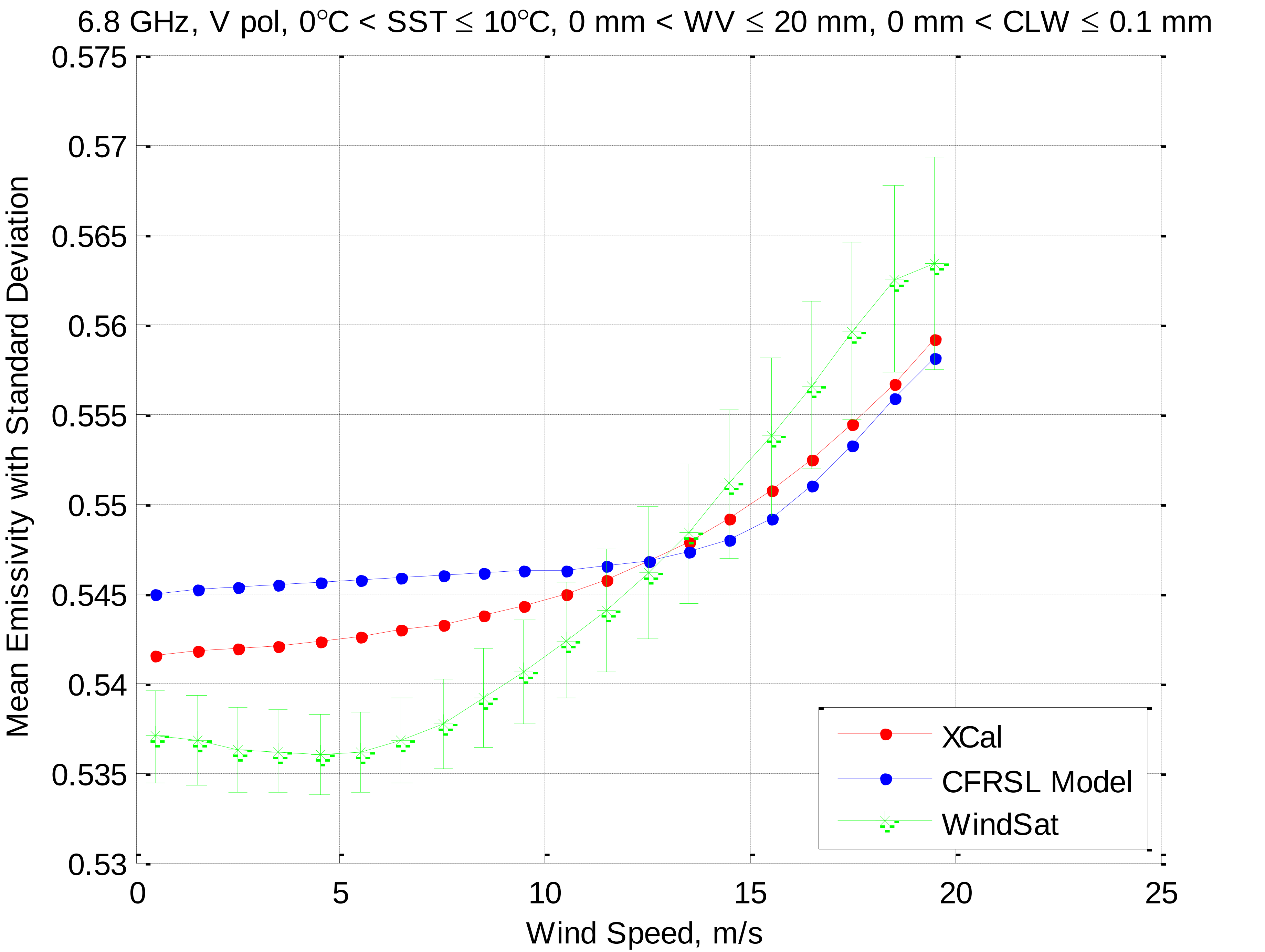


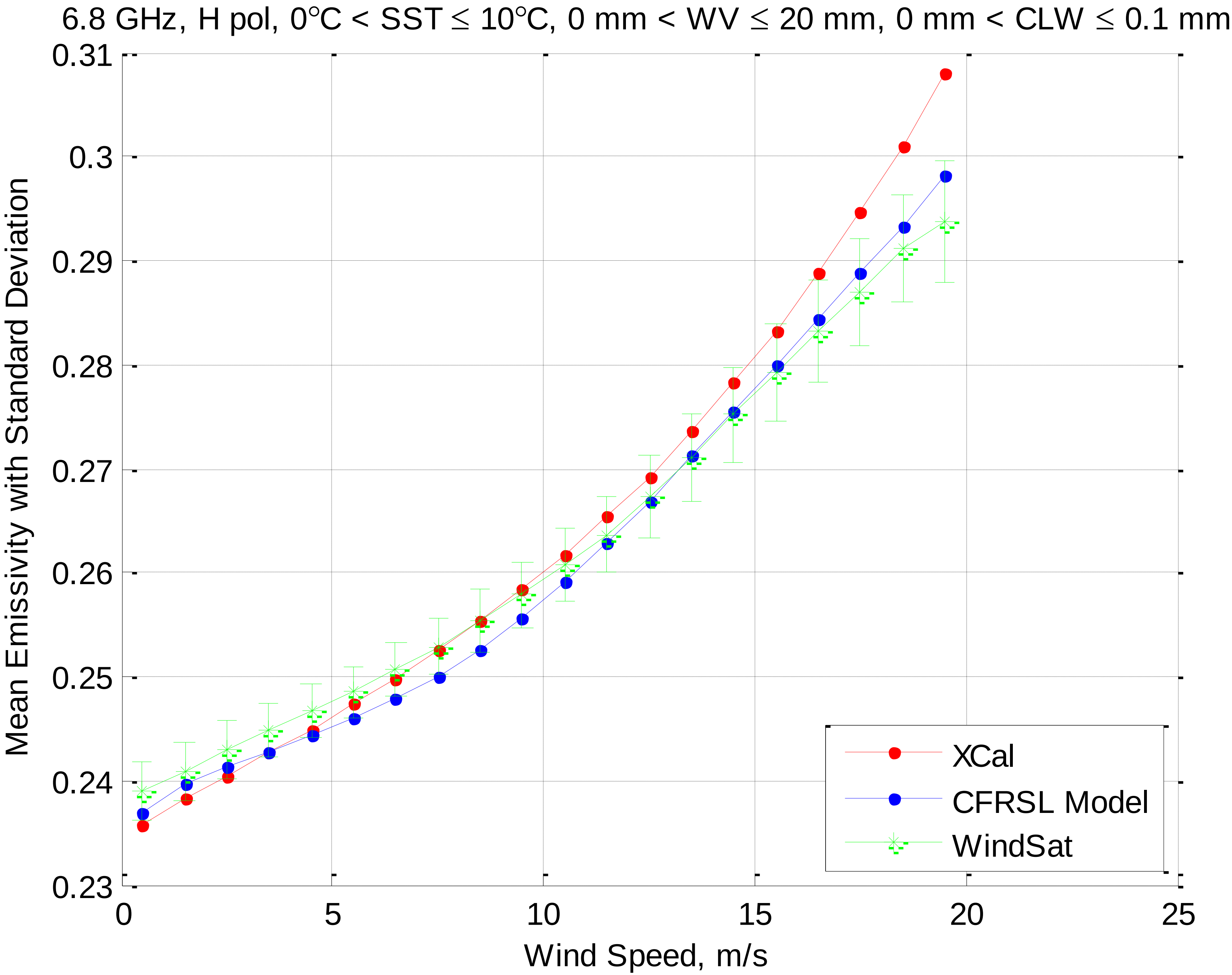
23.8 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat


37 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.74
0.73
0.72
0.71
0.7
0.69
0.68
0.67
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

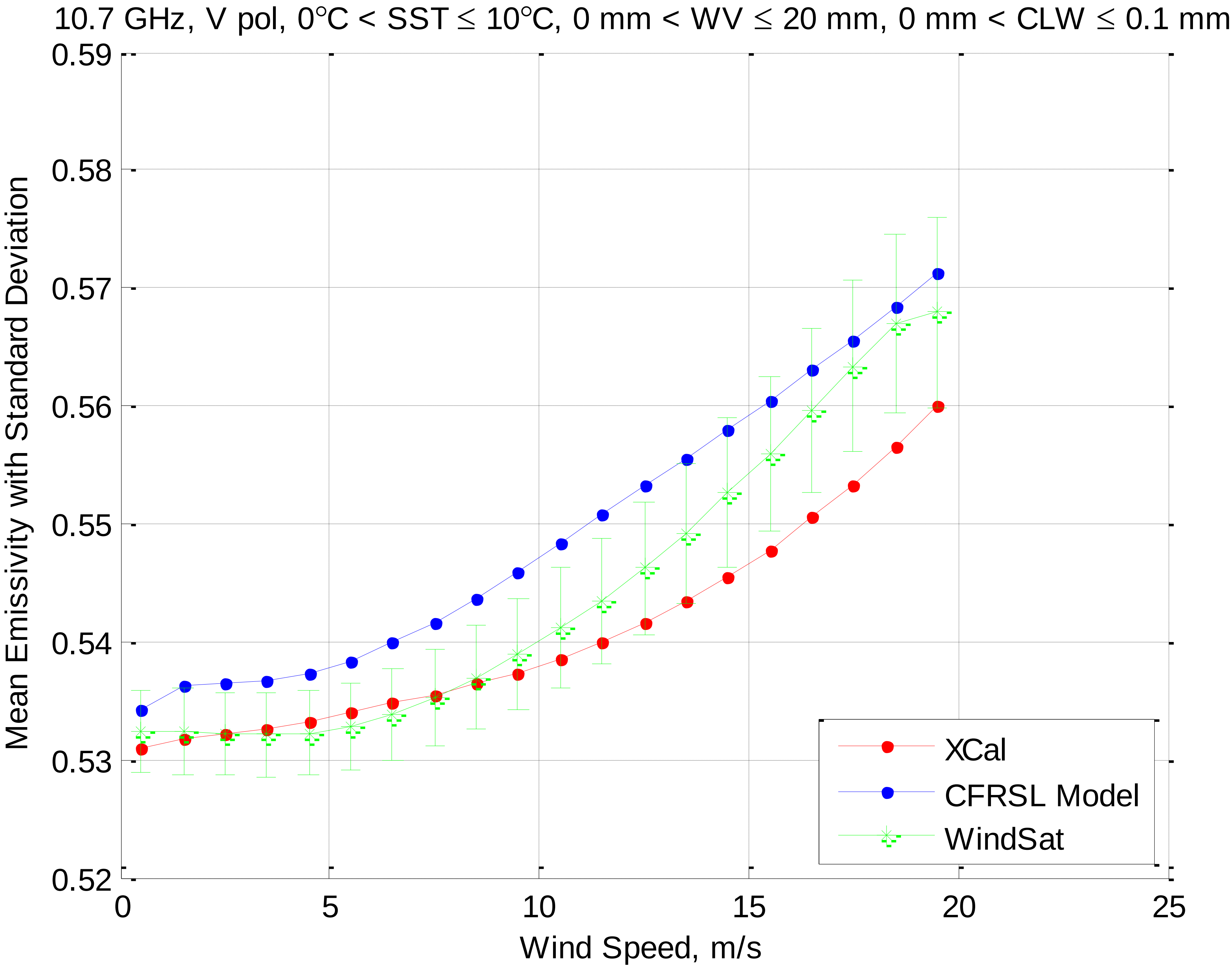

37 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
0.52
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0
5
10
15
20
25
XCAL Model
CFRSL Model
WindSat

EMISSIVITY VERSUS EDR WIND SPEED

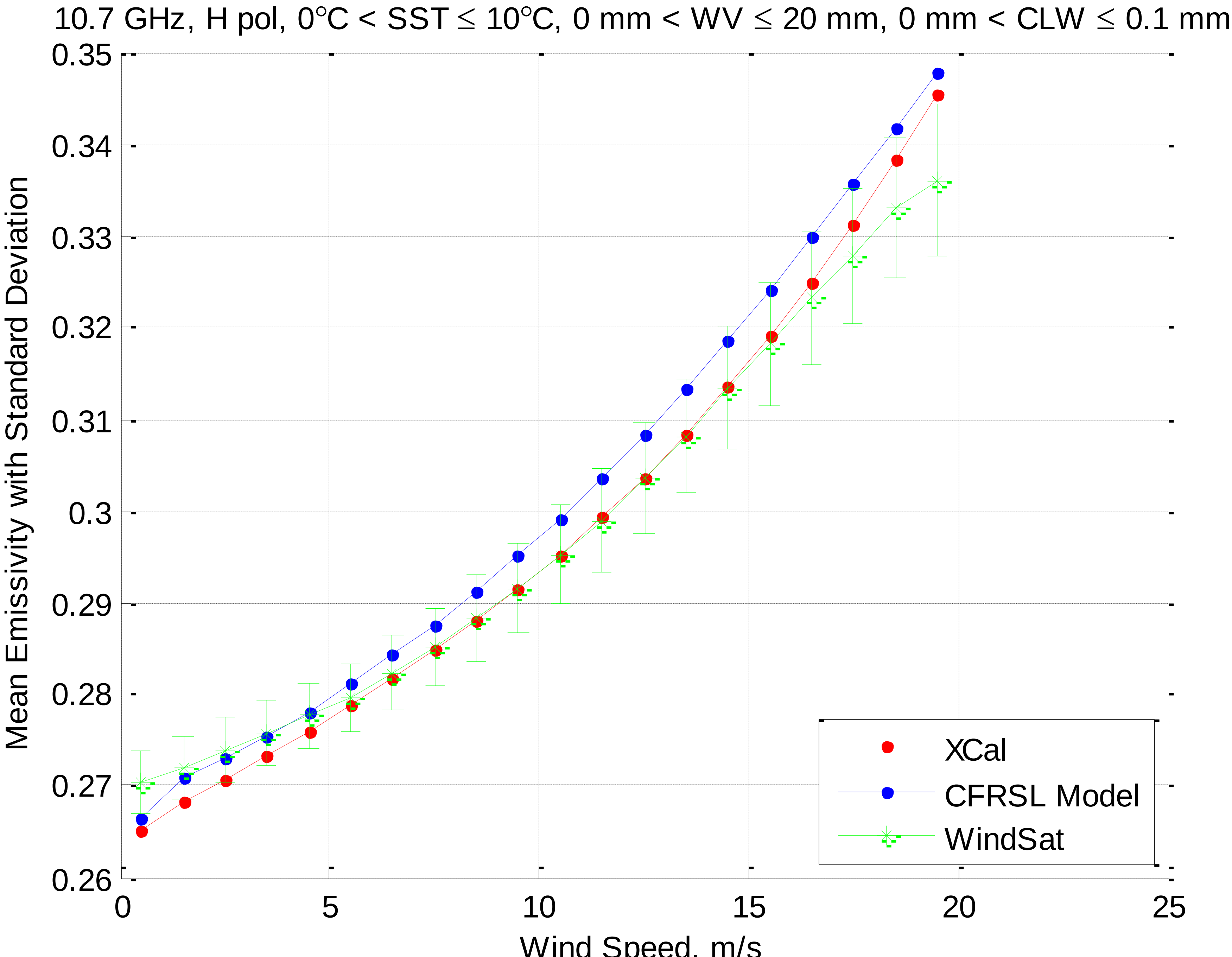

6.8 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
Wind Speed, m/s
0.575
0.57
0.565
0.56
0.555
0.55
0.545
0.54
0.535
0.53
0
5
10
15
20
25
XCal
CFRSL Model
WindSat

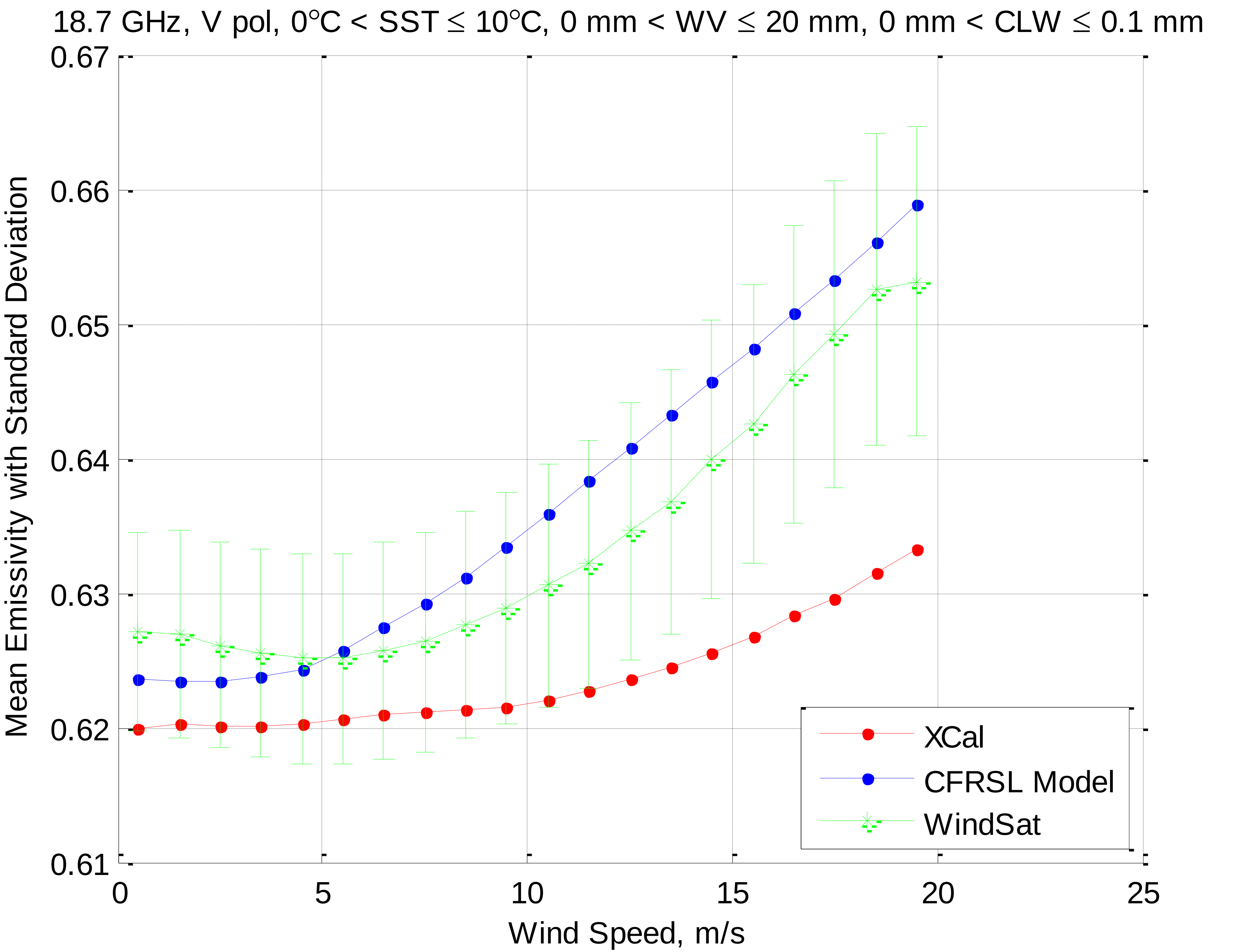


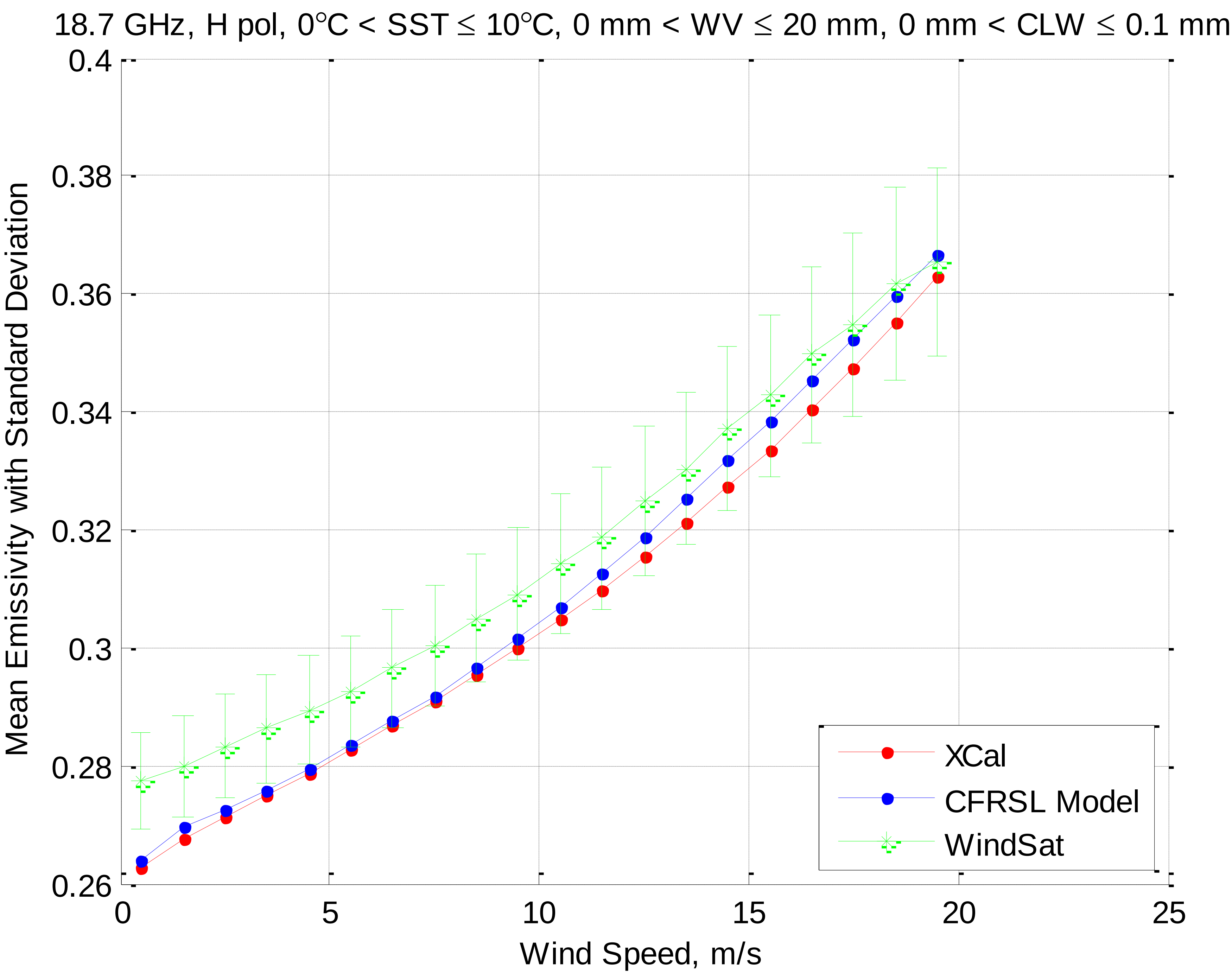
6.8 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.31
0.3
0.29
0.28
0.27
0.26
0.25
0.24
0.23
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat

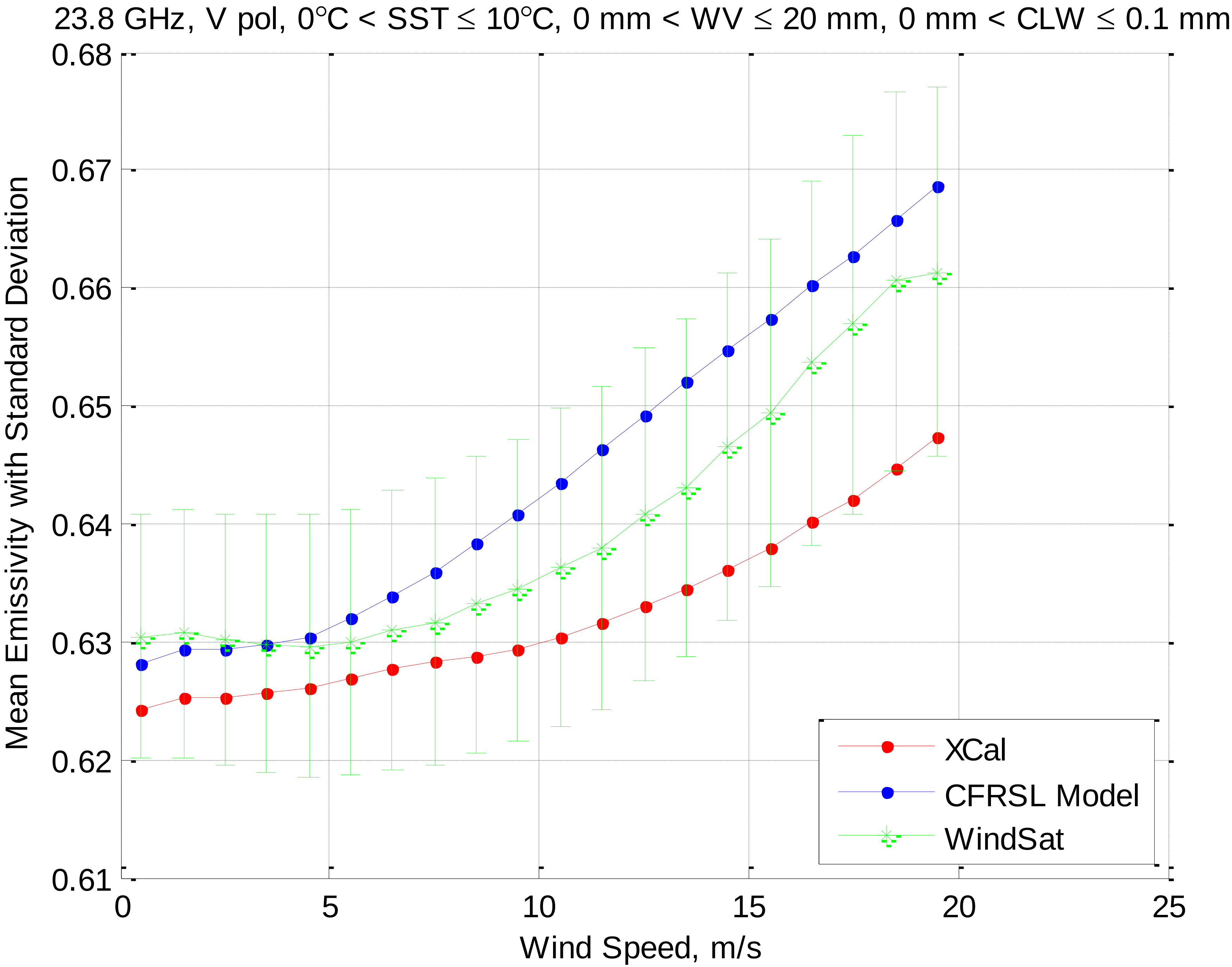


10.7 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.59
0.58
0.57
0.56
0.55
0.54
0.53
0.52
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat

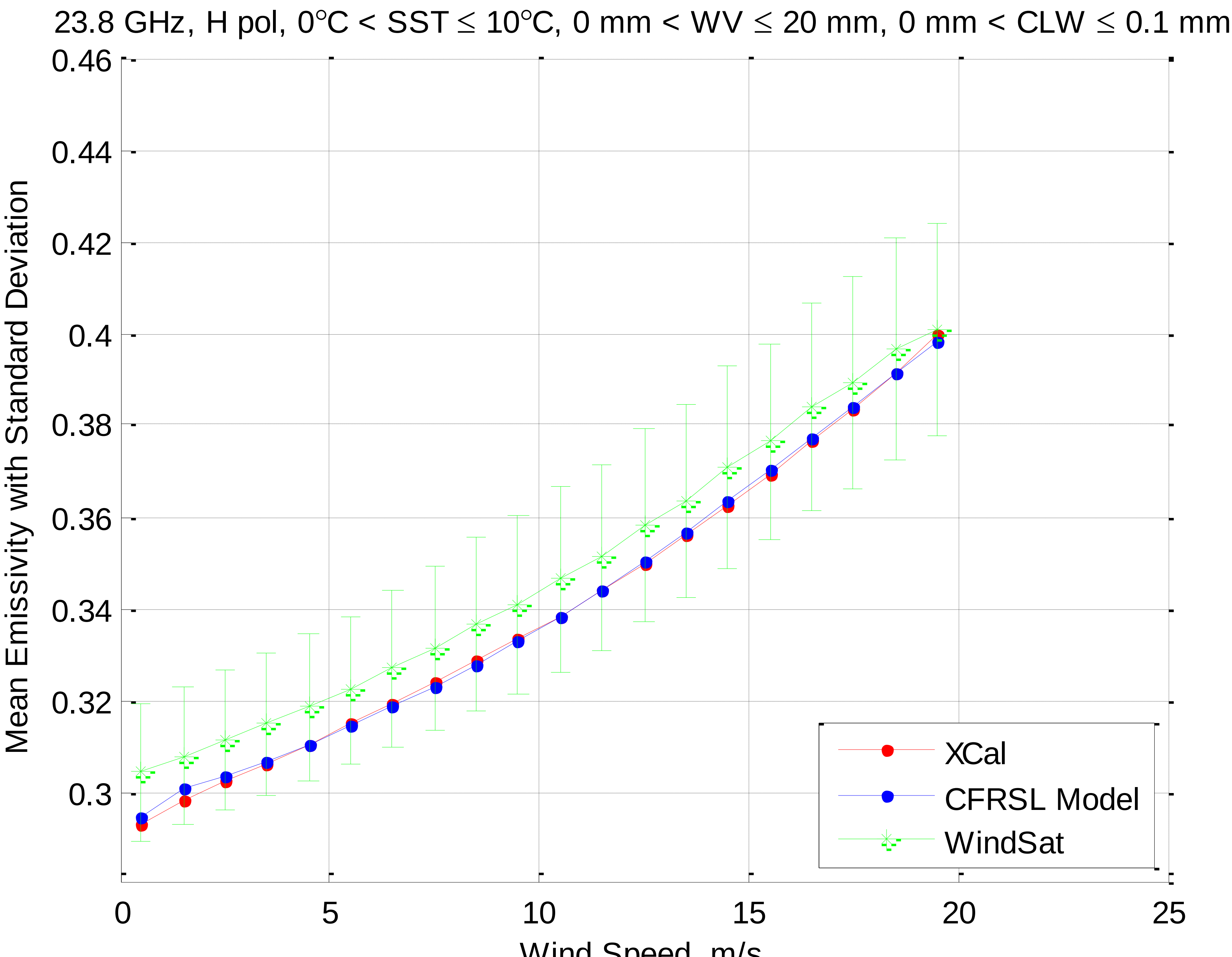

10.7 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.35
0.34
0.33
0.32
0.31
0.3
0.29
0.28
0.27
0.26
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat


18.7 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat

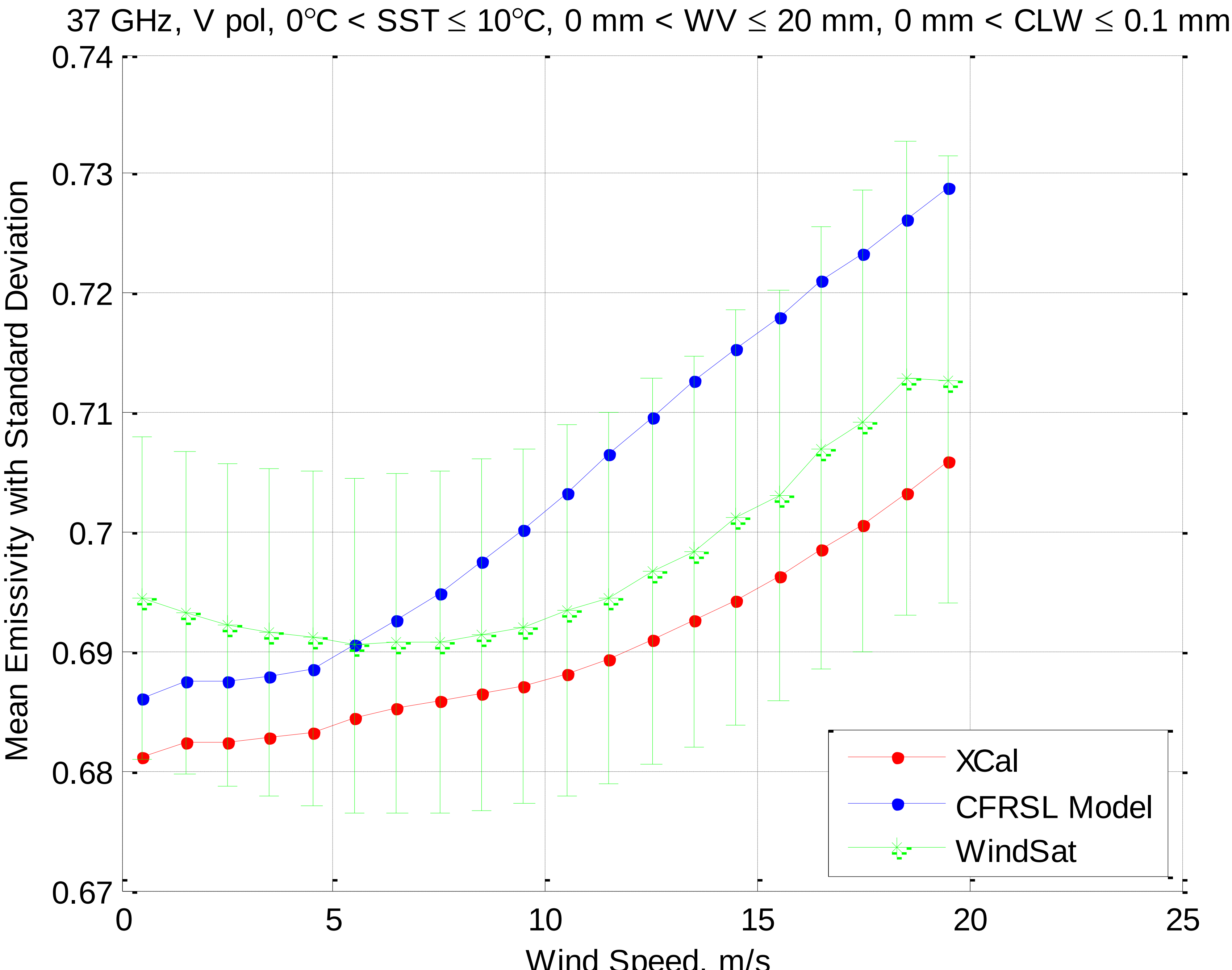

18.7 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
Wind Speed, m/s
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0
5
10
15
20
25
XCal
CFRSL Model
WindSat



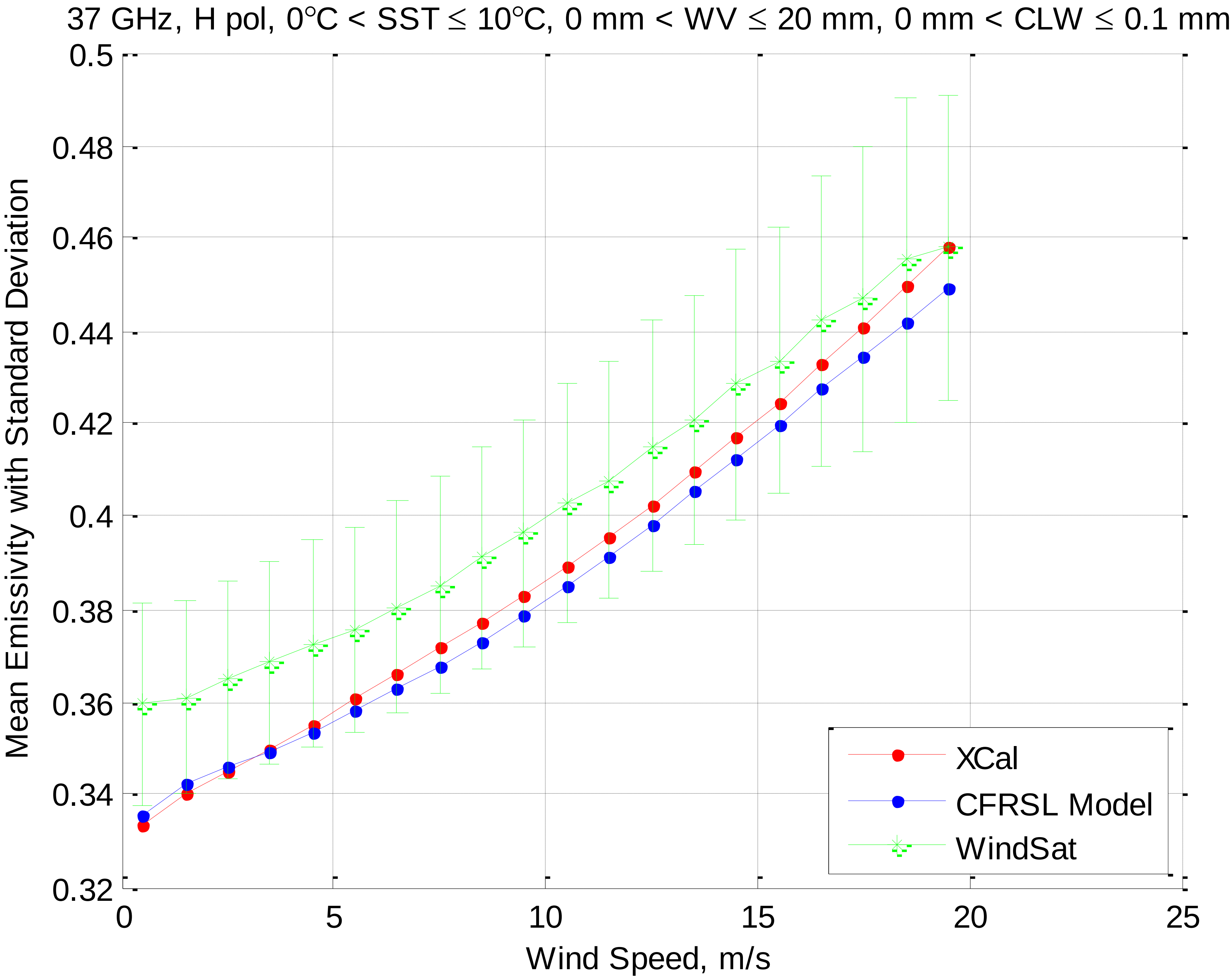
23.8 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat



23.8 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
Wind Speed, m/s
0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0.3
0
5
10
15
20
25
XCal
CFRSL Model
WindSat

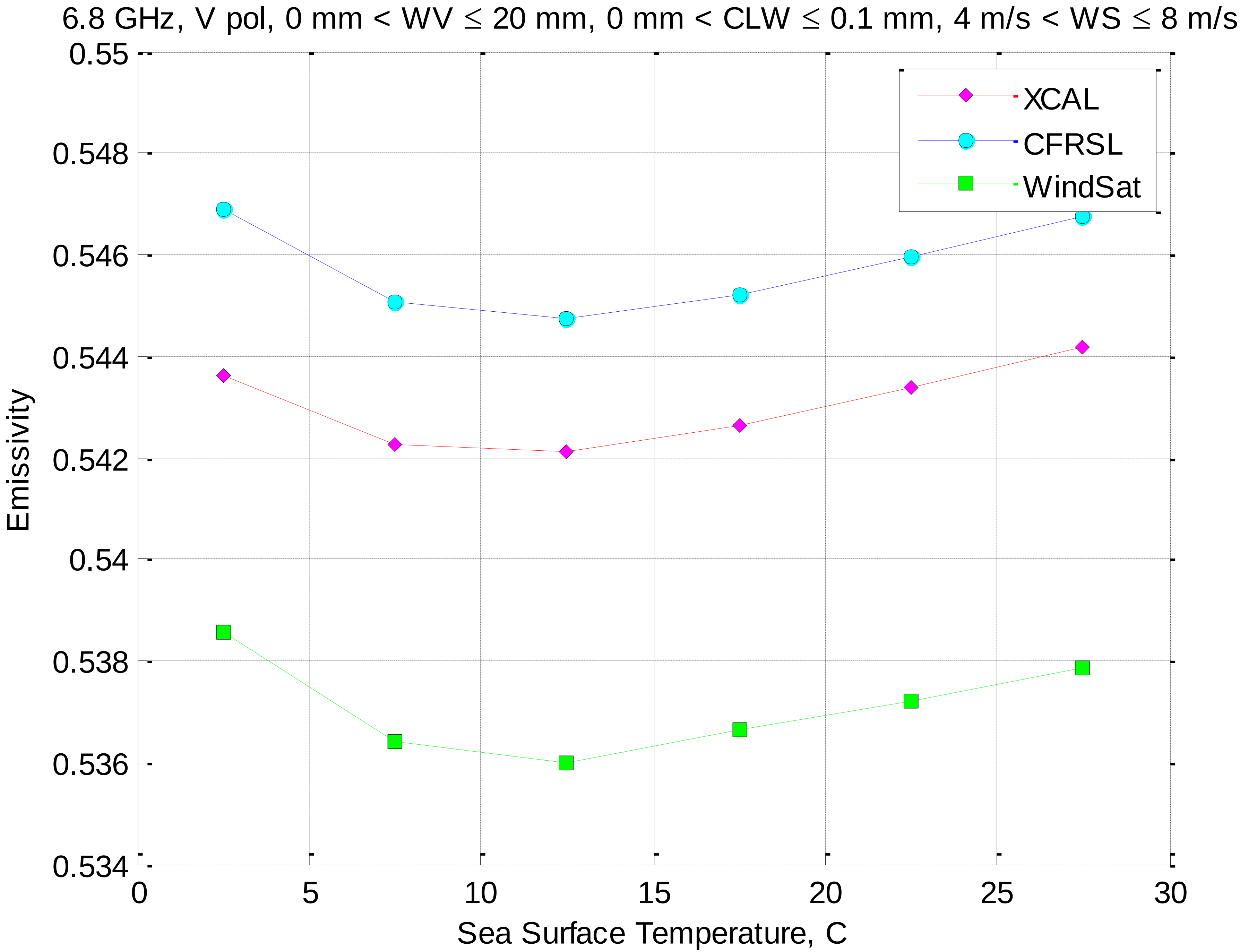


37 GHz, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.74
0.73
0.72
0.71
0.7
0.69
0.68
0.67
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat

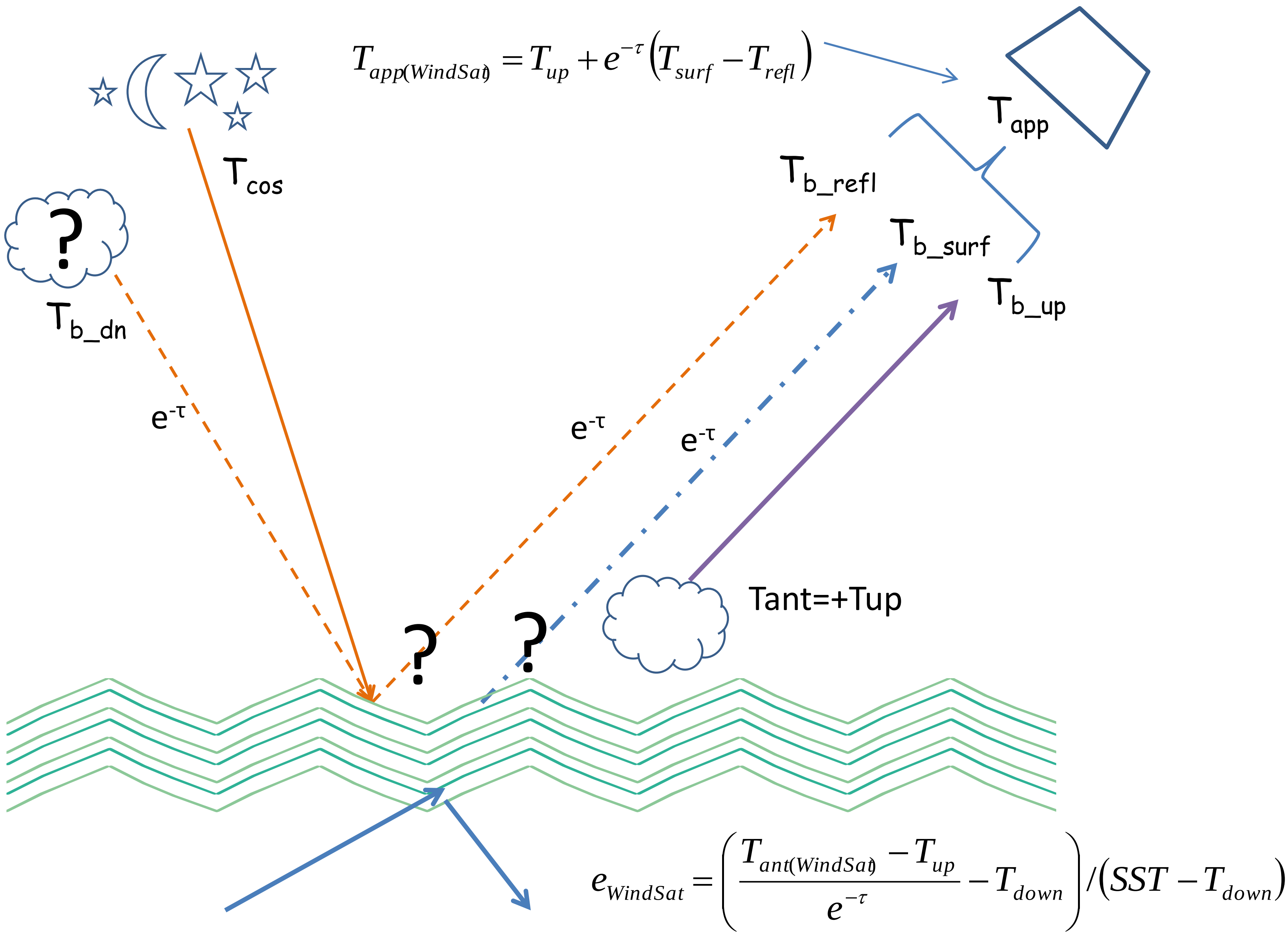


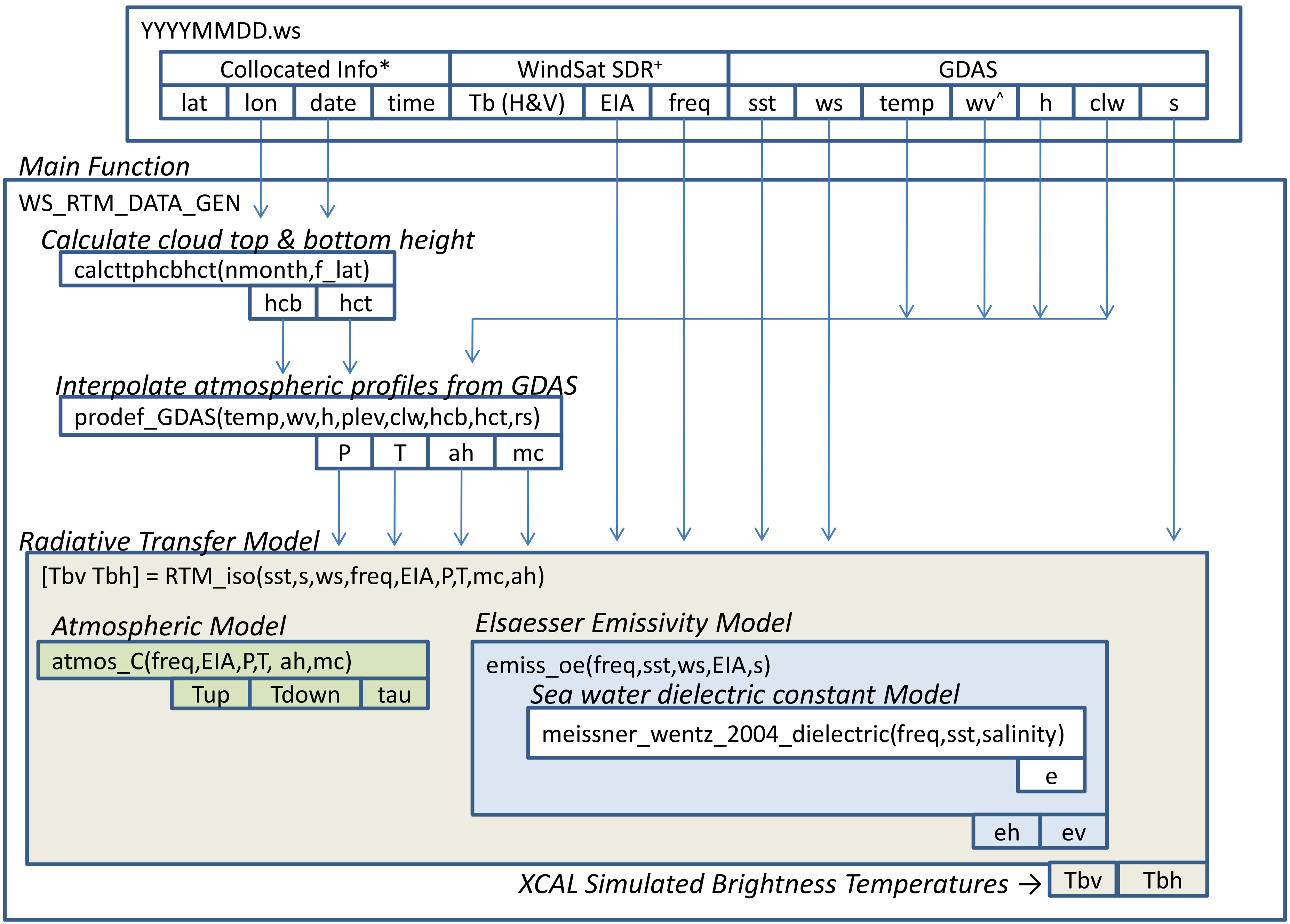
37 GHz, H pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with Standard Deviation
0.5
0.48
0.46
0.44
0.42
0.4
0.38
0.36
0.34
0.32
0
5
10
15
20
25
Wind Speed, m/s
XCal
CFRSL Model
WindSat

EMISSIVITY VS SST

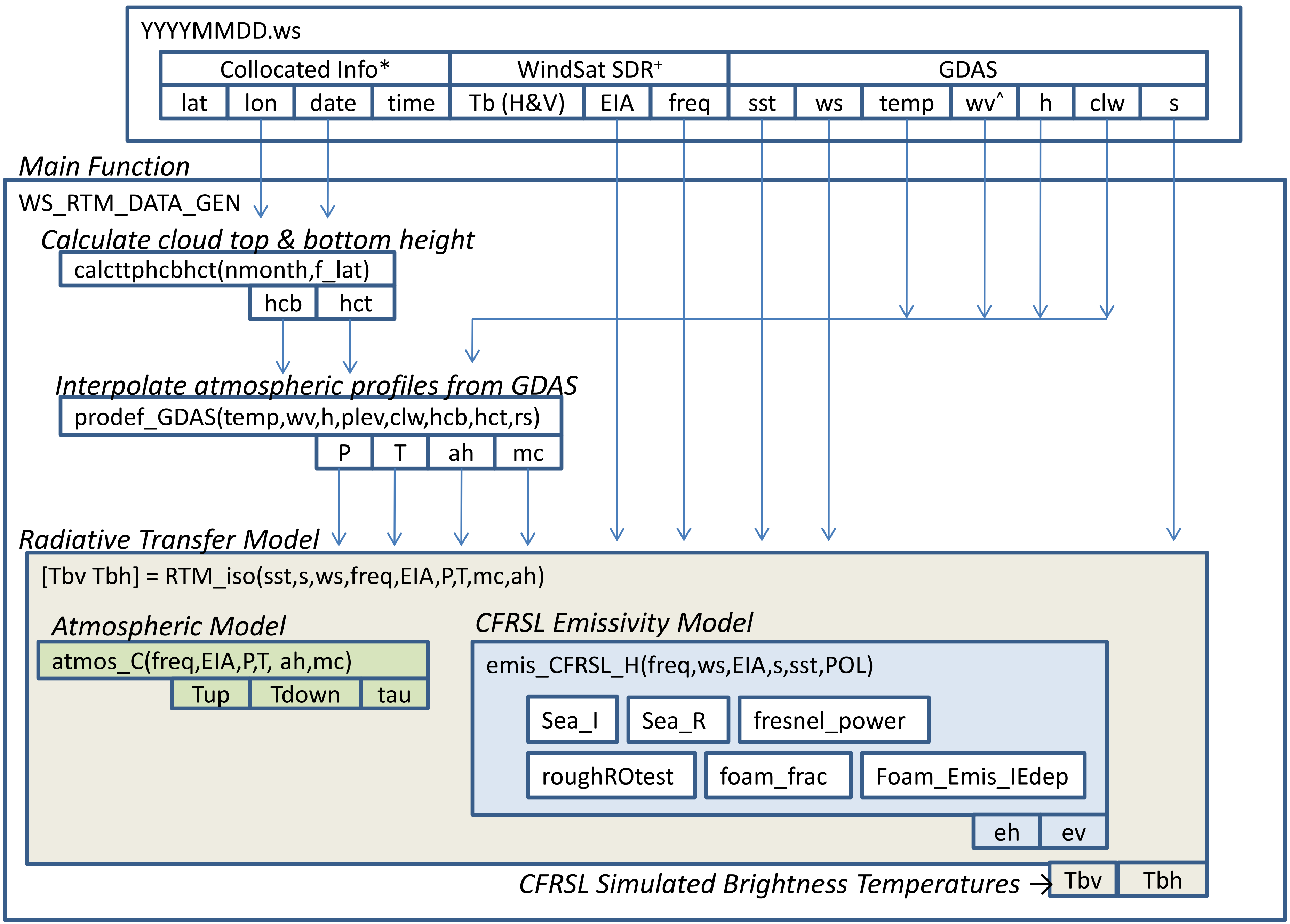

6.8 GHz, V pol, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm, 4 m/s < WS ≤ 8 m/s
XCAL
CFRSL
WindSat
Emissivity
Sea Surface Temperature, C
0.55
0.548
0.546
0.544
0.542
0.54
0.538
0.536
0.534
0
5
10
15
20
25
30

Discuss obstacles of emissivity model for rough ocean due to high wind speeds





YYYYMMDD.ws
Collocated Info*
WindSat SDR+
GDAS
lat
lon
date
time
Tb (H&V)
EIA
freq
sst
ws
temp
wv^
h
clw
s
Main Function
WS_RTM_DATA_GEN
Calculate cloud top & bottom height
calcttphcbhct(nmonth,f_lat)
hcb
hct
Interpolate atmospheric profiles from GDAS
prodef_GDAS(temp,wv,h,plev,clw,hcb,hct,rs)
P
T
ah
mc
Radiative Transfer Model
[Tbv Tbh] = RTM_iso(sst,s,ws,freq,EIA,P,T,mc,ah)
Atmospheric Model
atmos_C(freq,EIA,P,T, ah,mc)
Tup
Tdown
tau
Elsaesser Emissivity Model
emiss_oe(freq,sst,ws,EIA,s)
Sea water dielectric constant Model
meissner_wentz_2004_dielectric(freq,sst,salinity)
e
eh
ev
XCAL Simulated Brightness Temperatures →
Tbv
Tbh



YYYYMMDD.ws
Collocated Info*
WindSat SDR+
GDAS
lat
lon
date
time
Tb (H&V)
EIA
freq
sst
ws
temp
wv^
h
clw
s
Main Function
WS_RTM_DATA_GEN
Calculate cloud top & bottom height
calcttphcbhct(nmonth,f_lat)
hcb
hct
Interpolate atmospheric profiles from GDAS
prodef_GDAS(temp,wv,h,plev,clw,hcb,hct,rs)
P
T
ah
mc
Radiative Transfer Model
[Tbv Tbh] = RTM_iso(sst,s,ws,freq,EIA,P,T,mc,ah)
Atmospheric Model
atmos_C(freq,EIA,P,T, ah,mc)
Tup
Tdown
tau
CFRSL Emissivity Model
emis_CFRSL_H(freq,ws,EIA,s,sst,POL)
Sea_I
Sea_R
fresnel_power
roughROtest
foam_frac
Foam_Emis_IEdep
eh
ev
CFRSL Simulated Brightness Temperatures
Tbv
Tbh

Collocation Process

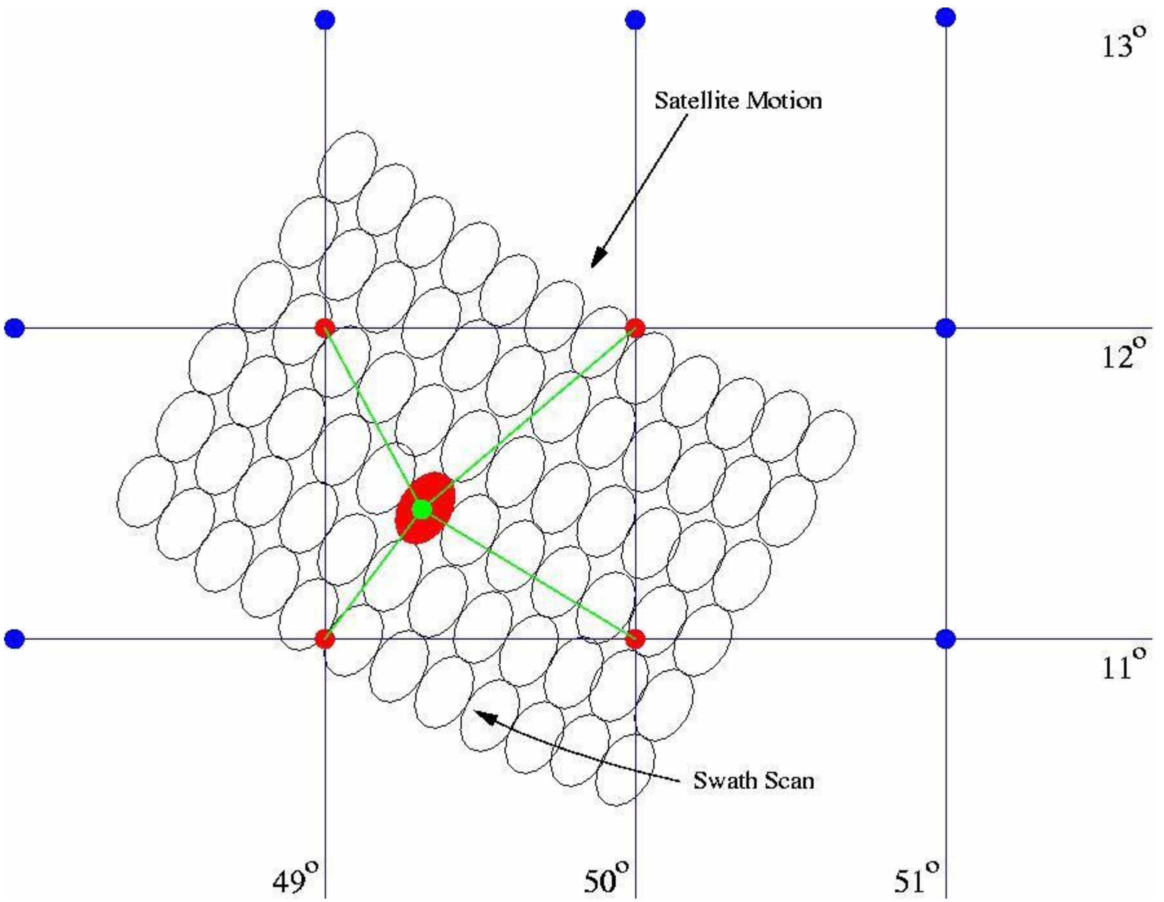
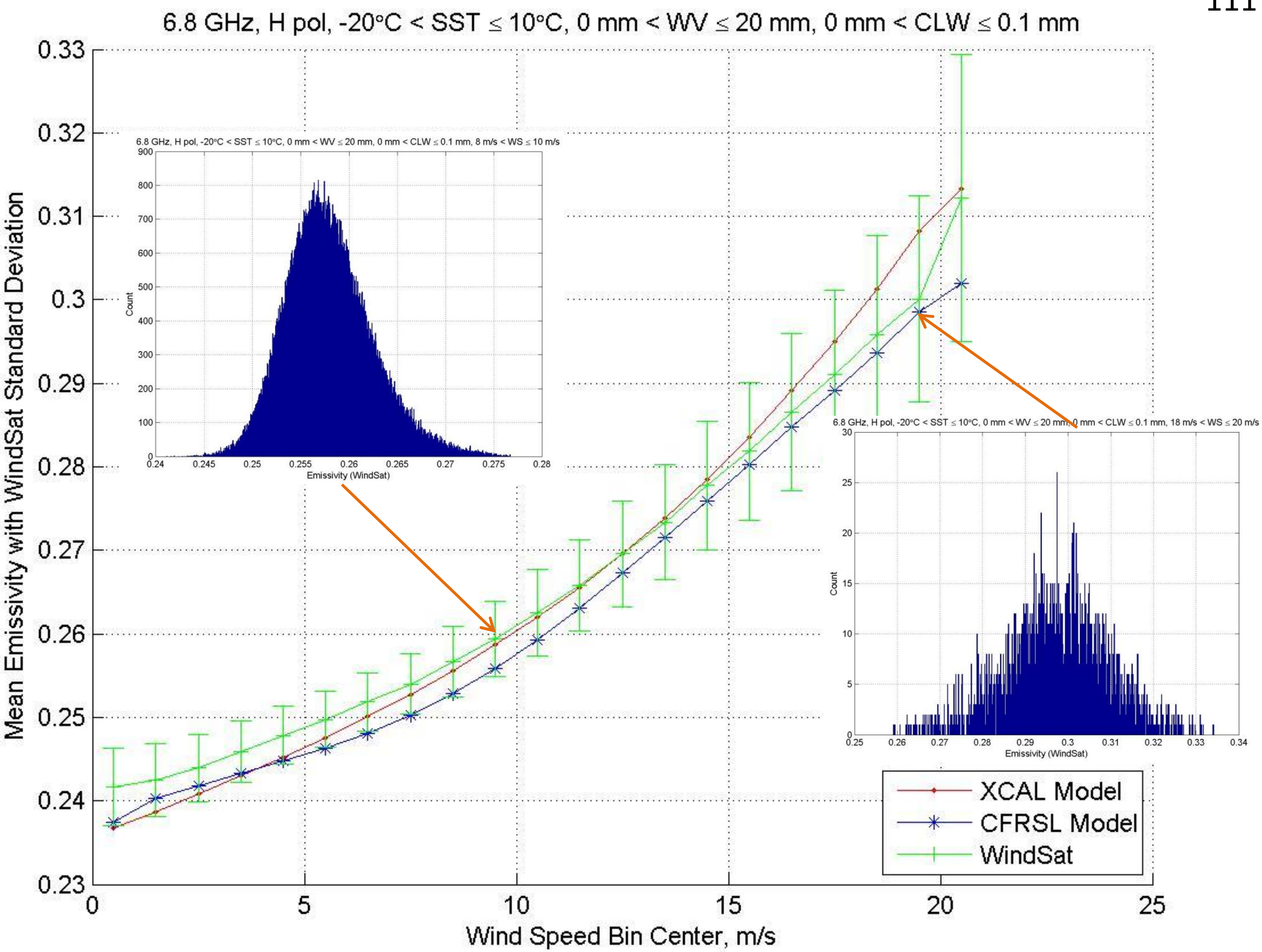
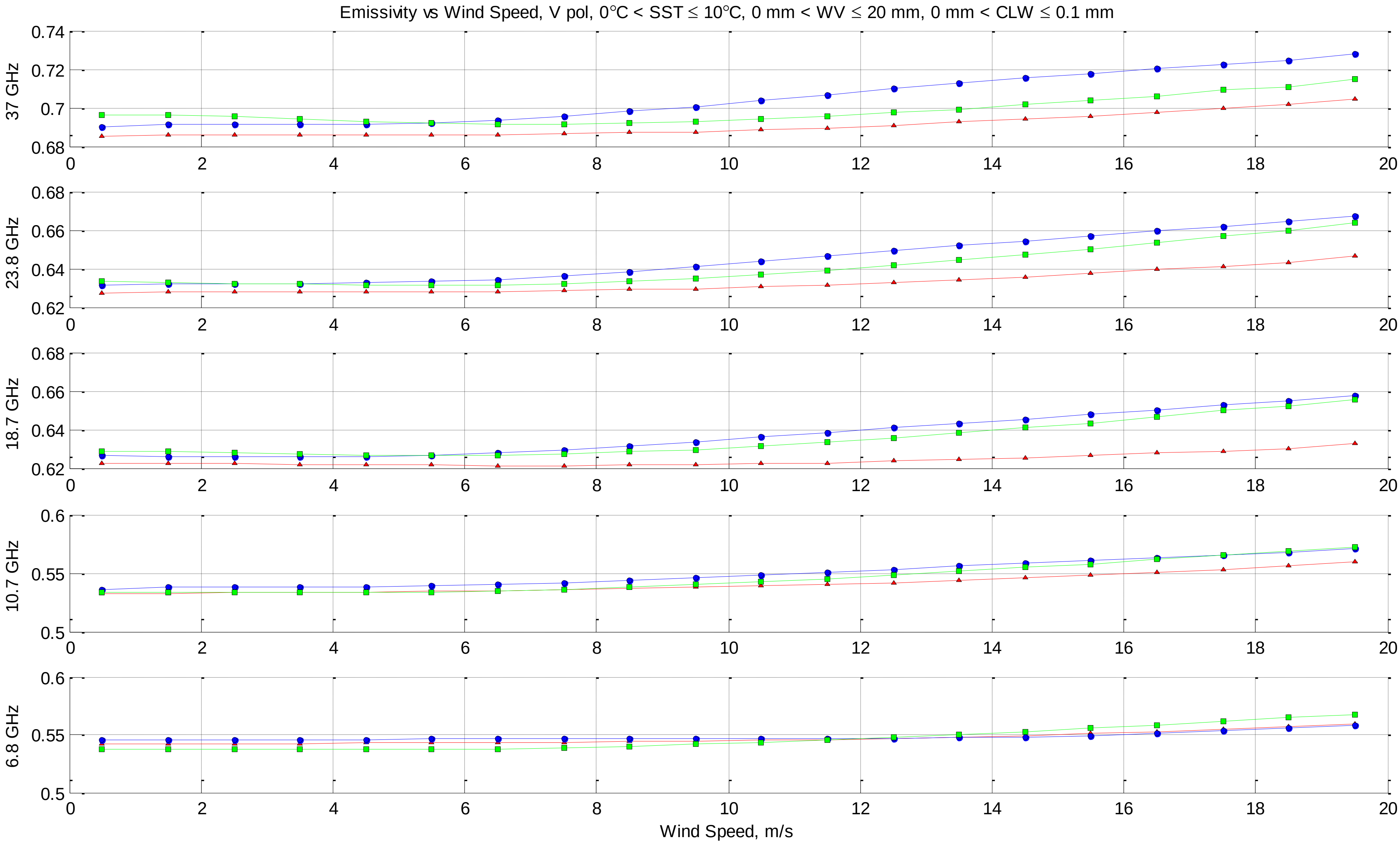


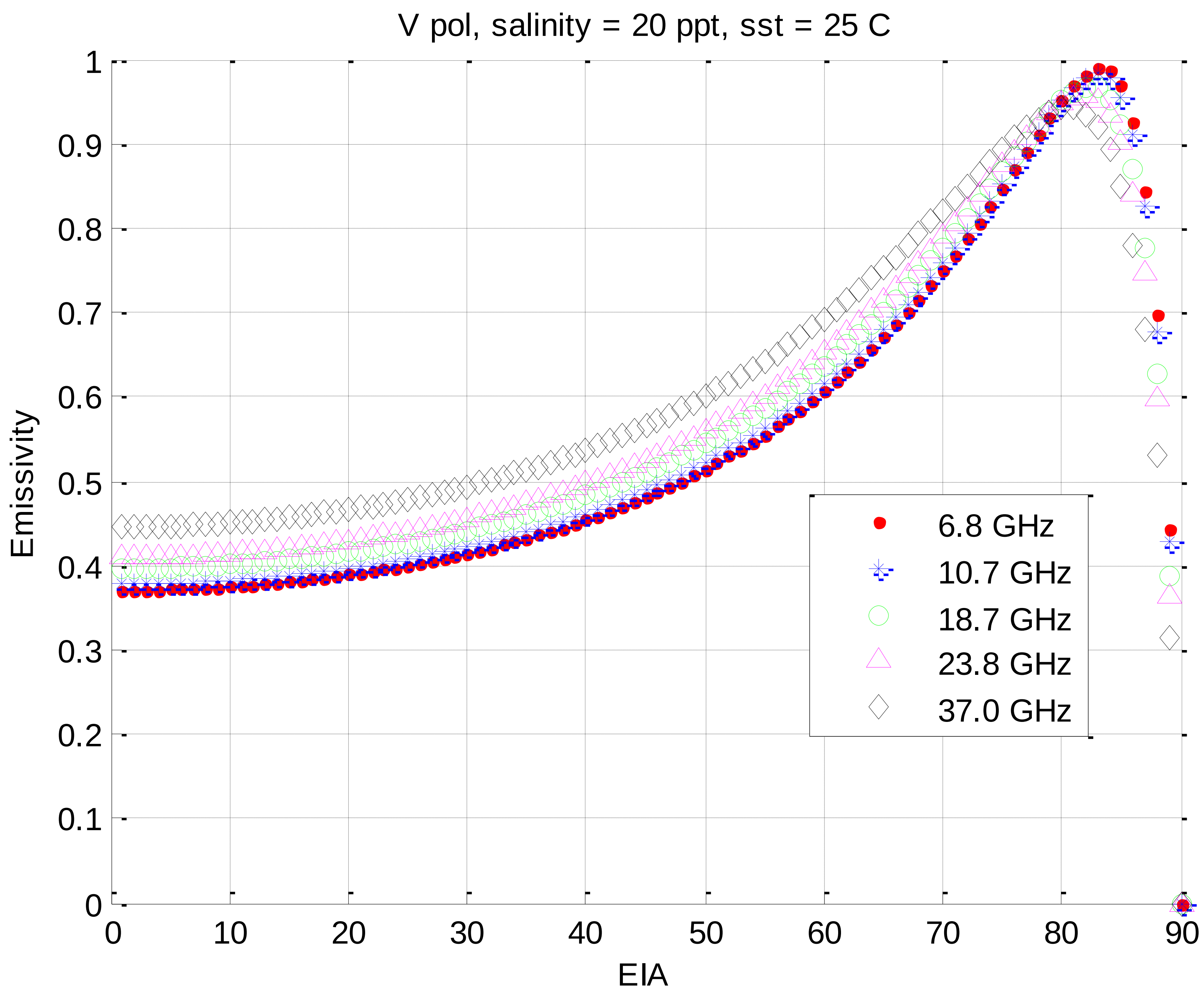
Table 1. WindSat Configuration

Band (GHz)	Polarization	Bandwidth (MHz)	Earth Incidence Angle (deg)	Horizontal Spatial Resolution (km)
6.8	V, H	125	53.5	40 × 60
10.7	V, H, ±45, L, R	300	49.9	25 × 38
18.7	V, H, ±45, L, R	750	55.3	16 × 27
23.8	V, H	500	53.0	12 × 20
37.0	V, H, ±45, L, R	2000	53.0	8 × 13

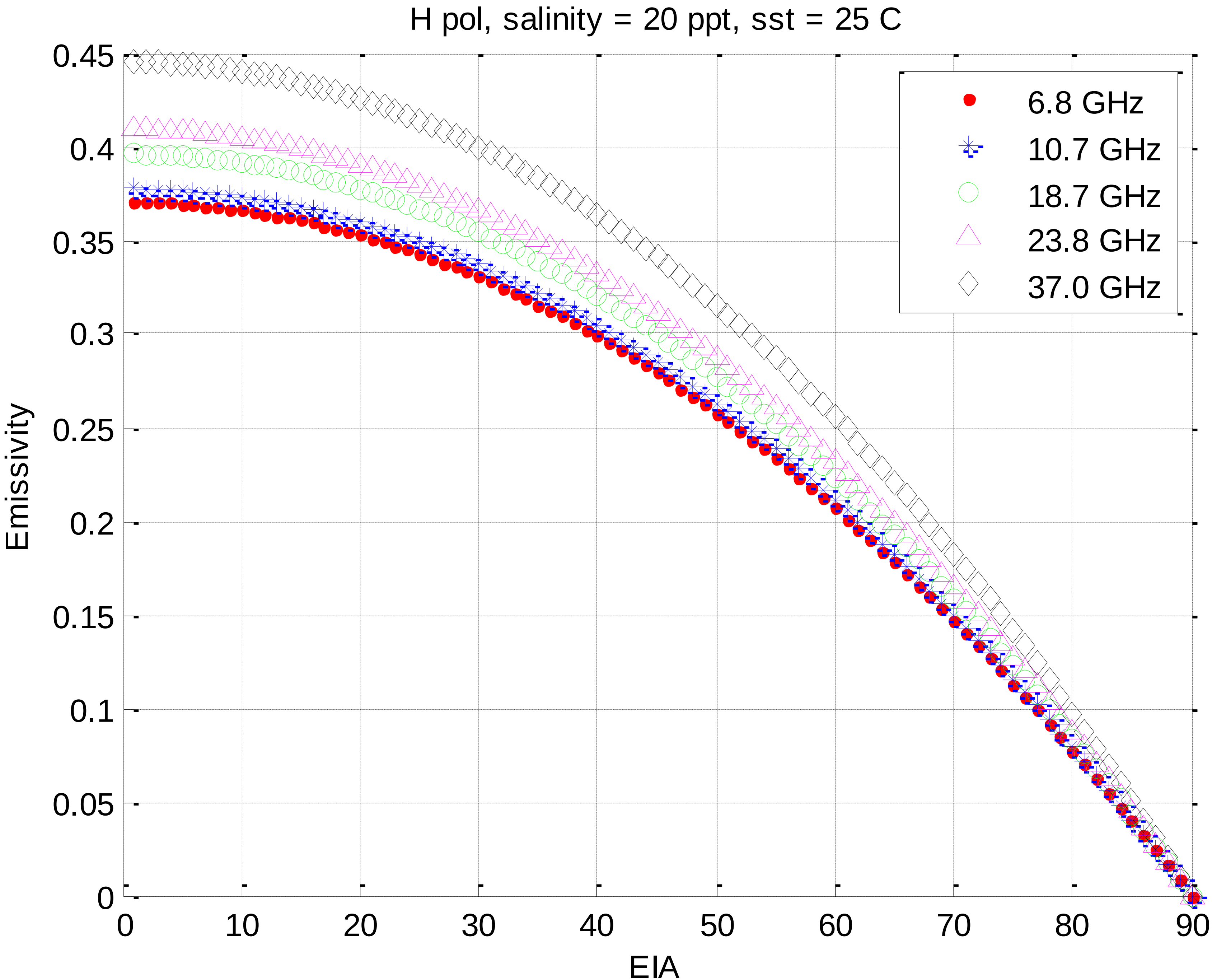
http://www.nrl.navy.mil/WindSat/Description.php


6.8 GHz, H pol, -20°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
Mean Emissivity with WindSat Standard Deviation
Wind Speed Bin Center, m/s
6.8 GHz, H pol, -20°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm, 8 m/s < WS ≤ 10 m/s
Count
Emissivity (WindSat)
6.8 GHz, H pol, -20°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm, 18 m/s < WS ≤ 20 m/s
Count
Emissivity (WindSat)
XCAL Model
CFRSL Model
WindSat


Emissivity vs Wind Speed, V pol, 0°C < SST ≤ 10°C, 0 mm < WV ≤ 20 mm, 0 mm < CLW ≤ 0.1 mm
37 GHz
23.8 GHz
18.7 GHz
10.7 GHz
6.8 GHz
Wind Speed, m/s



V pol, salinity = 20 ppt, sst = 25 C
Emissivity
EIA
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
10
20
30
40
50
60
70
80
90
6.8 GHz
10.7 GHz
18.7 GHz
23.8 GHz
37.0 GHz


H pol, salinity = 20 ppt, sst = 25 C
6.8 GHz
10.7 GHz
18.7 GHz
23.8 GHz
37.0 GHz
Emissivity
EIA
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90