ESA Climate Change Initiative Phase-II

Sea Surface Temperature (SST)

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Preparing for retrieval of SST from Copernicus Imaging Microwave Radiometer (CIMR)

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Outline

- Motivation
- CIMR
- Test setup
  - Multi-sensor matchup data base (MMD)
  - Retrieval algorithms (OE and Statistical)
- Assessment strategy
- Performance of CIMR and other channel combinations
- Conclusions and way forward

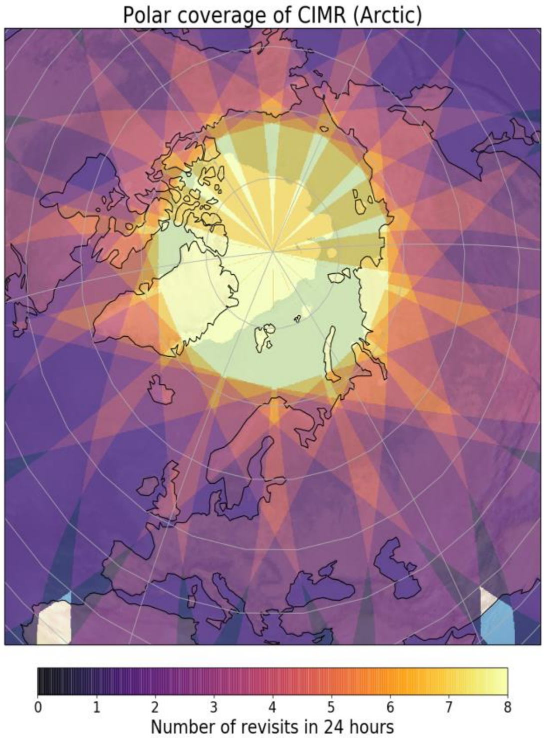
Motivation

- PMW SST retrievals are valuable supplement to IR SSTs due to the capability to see through clouds and no response to aerosols
- Several different PMW missions exists with different channel combinations
- A new PMW satellite (CIMR) is candidate for the Copernicus expansion mission
- CIMR channel configuration different from existing missions
- Important to assess for the different channel selections
  - Impact on retrieved SST compared to existing missions.
  - Feasibility of different type of retrievals

CIMR observation characteristics

- ***Two primary parameters***
- *Sea Ice Concentration (≤5 km, 5%)*
- *SST (15 km, <0.3 K)*

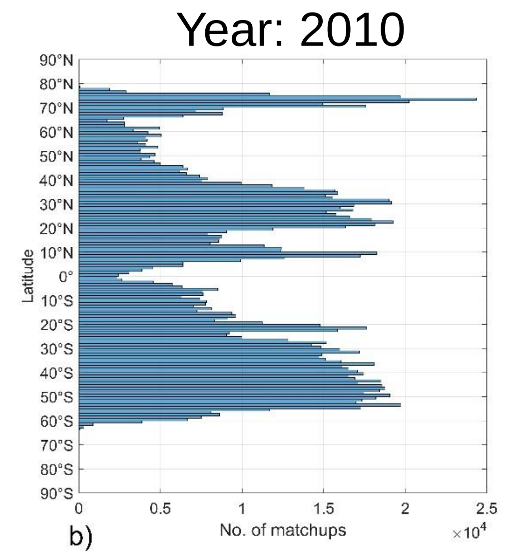
- ***Many secondary:***
- *Sea Surface Salinity*
- *Extreme Wind*
- *Soil Moisture*
- *Thin Sea Ice Thickness*
- *Terrestrial Snow extent*



Channels (GHz, Full Stokes):	**1.4**	**6.9**	**10.65**	**18.7**	**36.5**
Resolution (km):	**≤60**	**≤15**	**≤15**	**≤5.5**	**≤5**
NEΔT (K @150K):	**≤0.3**	**≤0.2**	**≤0.3**	**≤0.4**	**≤0.7**
Swath	**>1900 km**				

Multisensor Matchup Dataset (MMD6C)

- **AMSR-E L2A TBs from RSS (NSIDC), version 7**
  - Resampled to resolution; 10 km, all channels
  - Orbit files, ascending and descending
- **Every matchup includes:**
  - 21x21 extract of AMSR-E TBs + aux info
  - 5x5 extract of NWP variables
  - 60 vertical layers for NWP
  - In situ SST history
  - 5x5 sea ice
- Netcdf format



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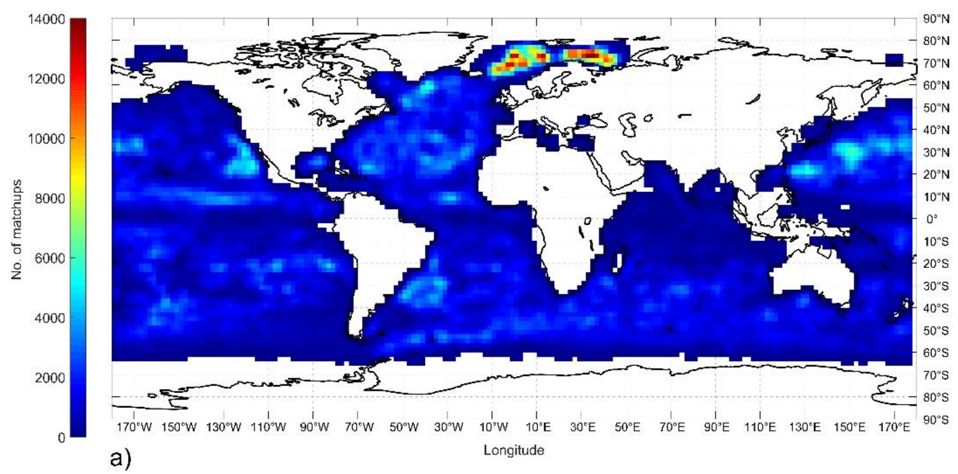
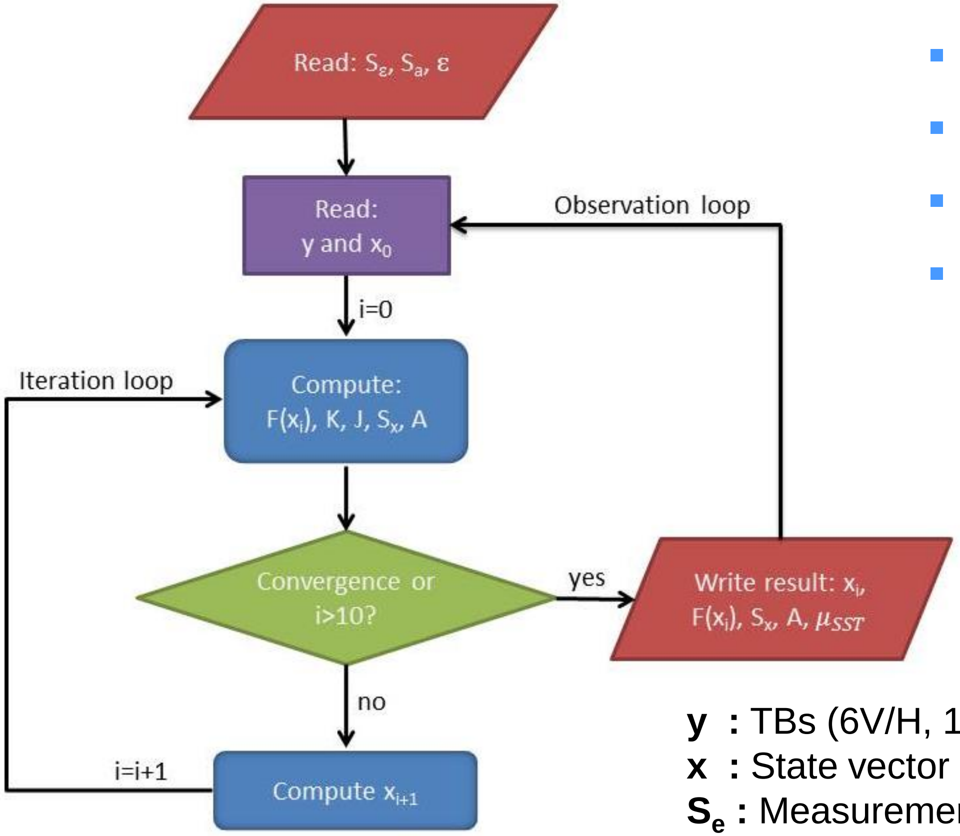


a)

Optimal Estimation (OE) algorithm



- Nielsen-Englyst et al. 2018
- Wentz-DMI FW model
- Increased $\mathbf{S_a}$ element for SST
- Sensitivity of to SST=0.99

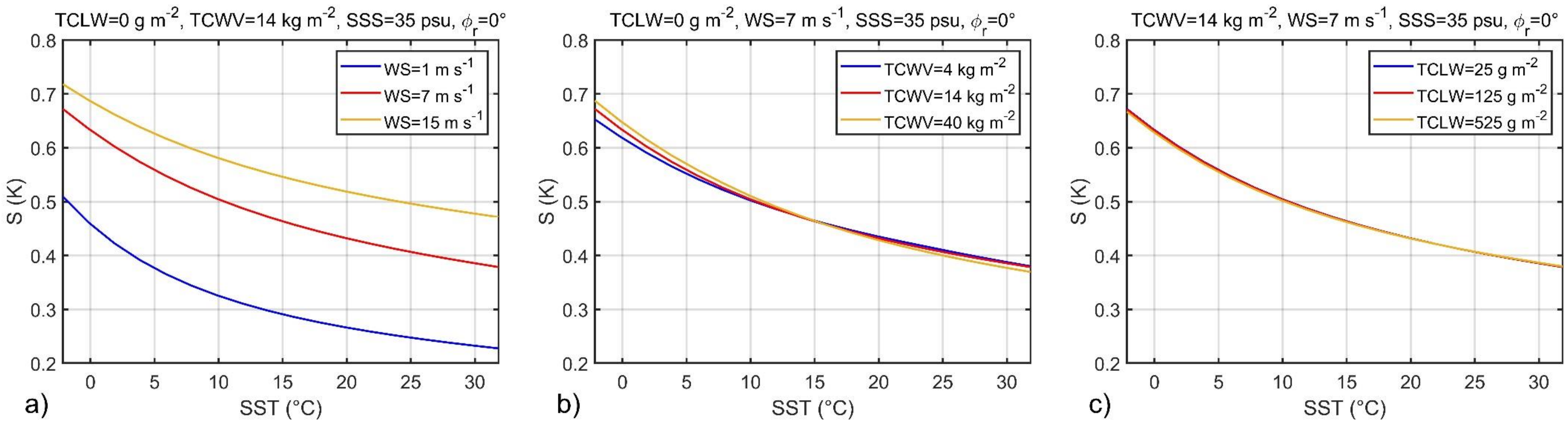
y : TBs (6V/H, 10V/H, 18V/H, 23V/H, 36V/H)
x : State vector (SST, TCWV, TCLW, WS)
$\mathbf{S_e}$: Measurement and FW model error covariance
$\mathbf{S_a}$: á priori error of state variables
$\mathbf{x_0}$: First Guess values

OE Theoretical retrieval error

- The simulated retrieval error, S, as a function of SST for different a) WSs, b) TCWVs and c) TCLWs.

$$\mathbf{S} = (\mathbf{S}_\mathbf{a}^{-1} + \mathbf{K}_\mathbf{i}^\mathbf{T}\mathbf{S}_\epsilon^{-1}\mathbf{K}_\mathbf{i})^{-1}$$

- Several information content studies (Pearson et al., 2018, Kilic et al., 2018)



Regression (RE) algorithm

- Alerskans et al. (2020)
- Usual way of retrieving SST from PMW (Wentz and Meissner, 2007, Han et al., 2012)
- RSS uses a two step algorithm, coefficients derived for SST and wind intervals.
- We use brightness temperature (T_B) for all channels, incidence angle (θ_{EIA}), wind speed (WS) and the relative angle between satellite azimuth angle and wind direction (φ_{REL})

$$SST_r = a_0 + \sum_{i=1}^{12} a_i t_i + b_i t_i^2 + c\theta + dWS + \sum_{j=1}^{2} e_j \cos j\varphi_{REL} + f_j \sin j\varphi_{REL}$$

- Where

$t_i = T_{Bi} - 150,$ for all channels except the 23.6 GHz channels

$t_i = -\ln(290 - T_{Bi}),$ for the two 23.6 GHz channels

$\theta = \theta_{EIA} - 55$

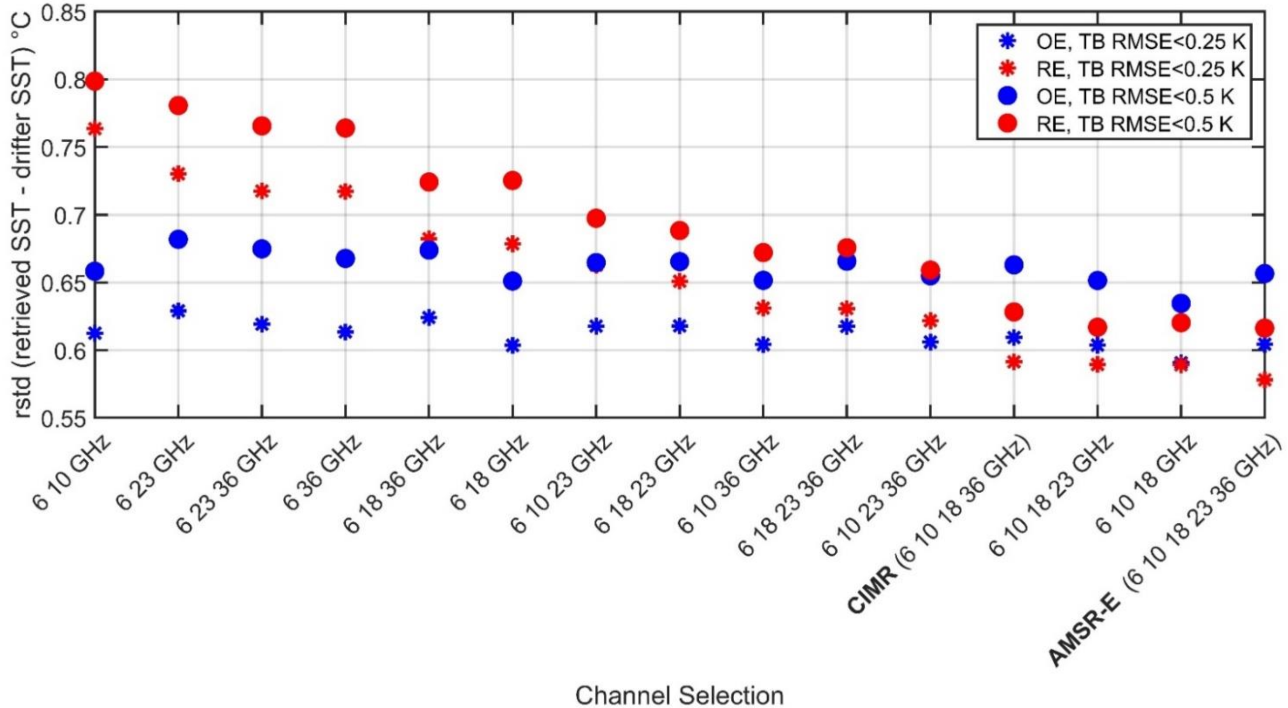
- Algorithm regressed towards drifting buoy observations
- Different from paper: Global coefficients

Assessment strategy

- Test performance of the OE and RE algorithms on all channel combinations (>2 channels)
- Always include 6 GHz
- Test all combination types
  - Independent drifting buoys
    - Global results
    - Range of environmental conditions
  - Use sensitivity to assess relative importance of channels for retrievals
- Focus on four channel scenarios:
  - 6 10 18; 6 10 23; CIMR-like; AMSR-like
- Assess 4 scenario performance:
    - Spatial differences
    - Seasonal variations
    - Regional aspects

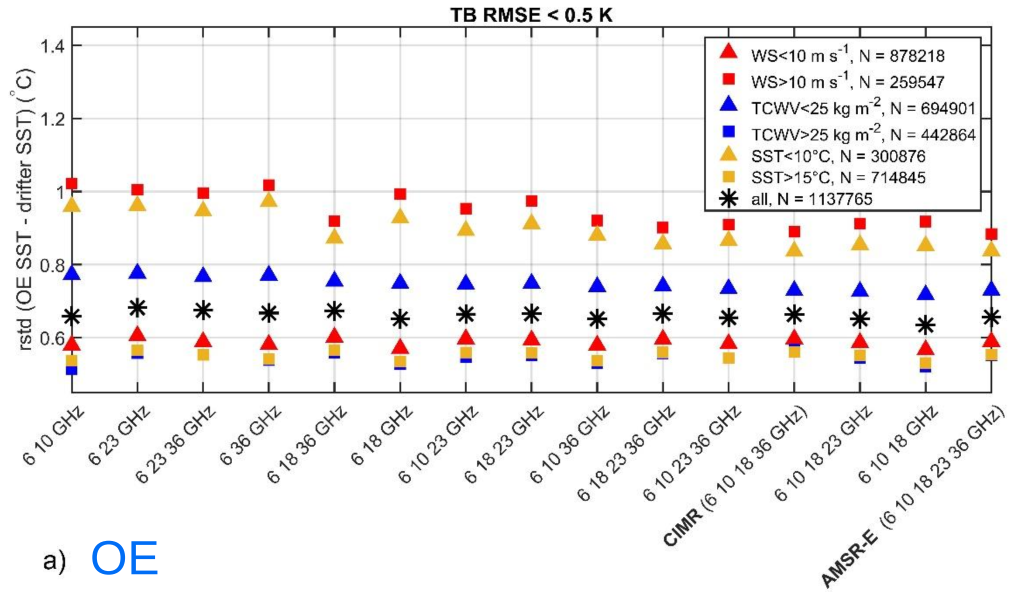
Performance of different channel selections

- Robust standard deviations (rstd) of retrieved SST vs drifter SST for different channel selections
- Filters are based on TB RMSE from the AMSR-E channel configuration
- Ranking order is based on the RE, TB RMSE < 0.25 K

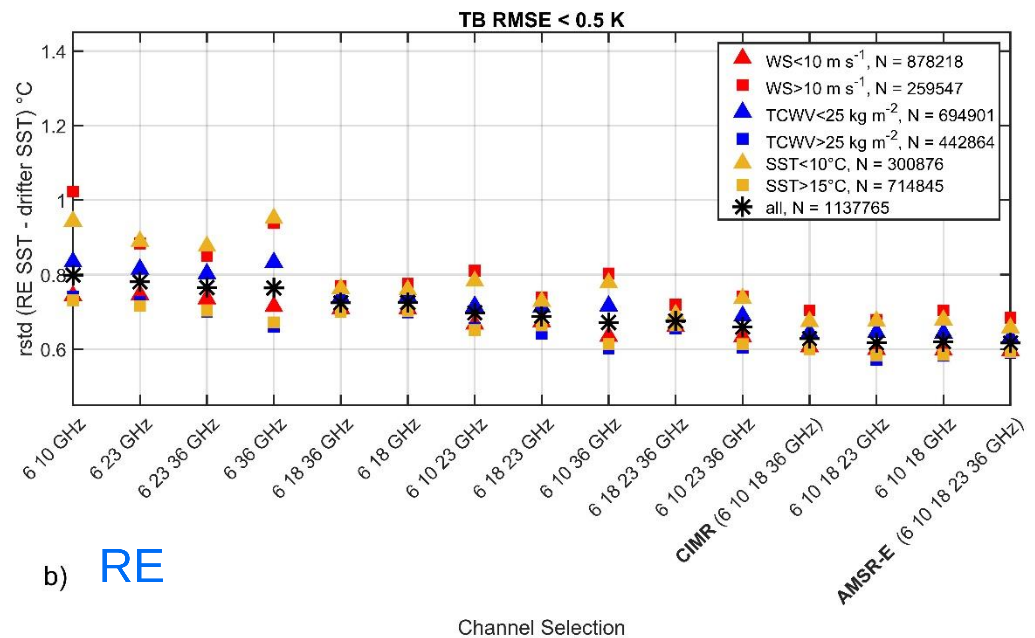


Performance in different observing conditions

- OE is more sensitive to the different observing conditions
- RE is able to correct for the decreased SST sensitivity in cold waters
- OE and RE agree that more channels improve SST retrievals for the full range of observing conditions



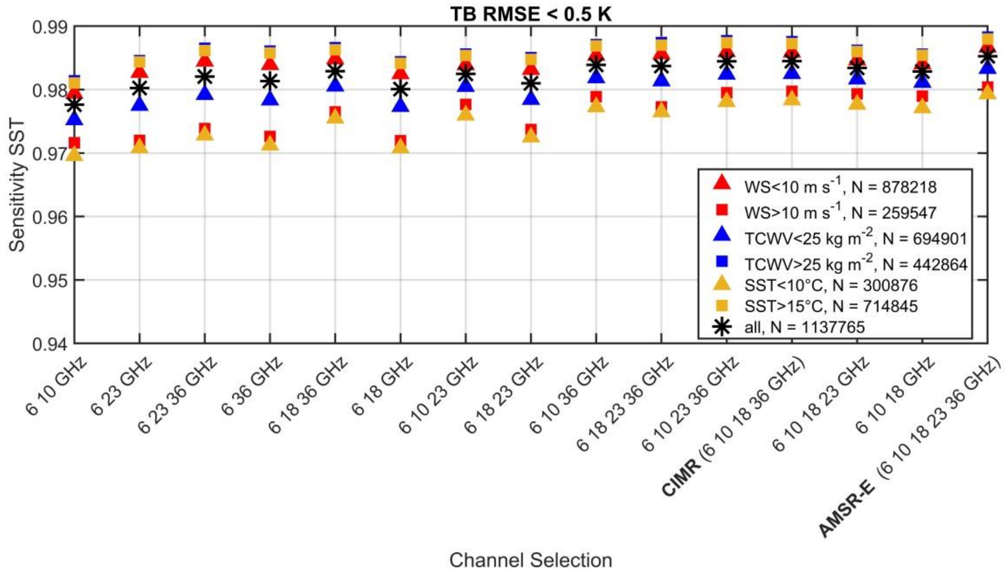
a) OE



b) RE

Impact from adding different frequencies

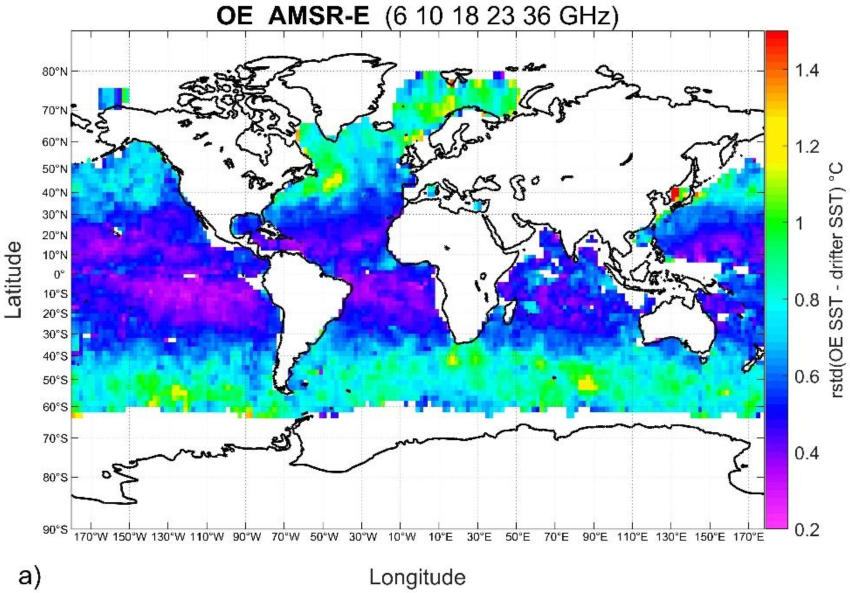
- Table shows:
  - Improvement in retrieved SST performance for OE and RE
- 6 GHz most important
- 10 and 18 equally important.
- Withholding the 23 and 36 GHz observations has the least impact on SST performance

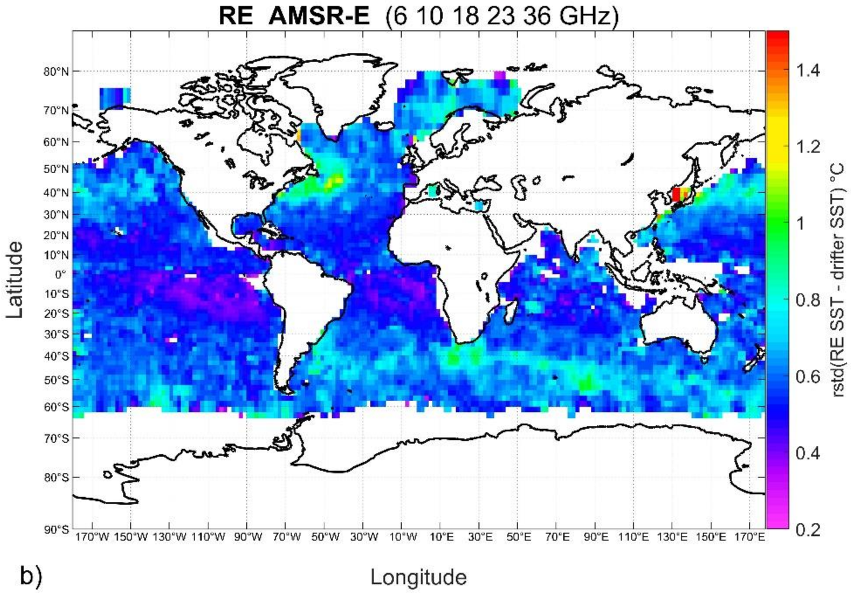


	OE SST	RE SST
6 GHz	**0.2402**	**0.0907**
10 GHz	0.0876	0.0148
18 GHz	0.0811	0.0117
23 GHz	0.0309	0.0089
36 GHz	0.0289	0.0114

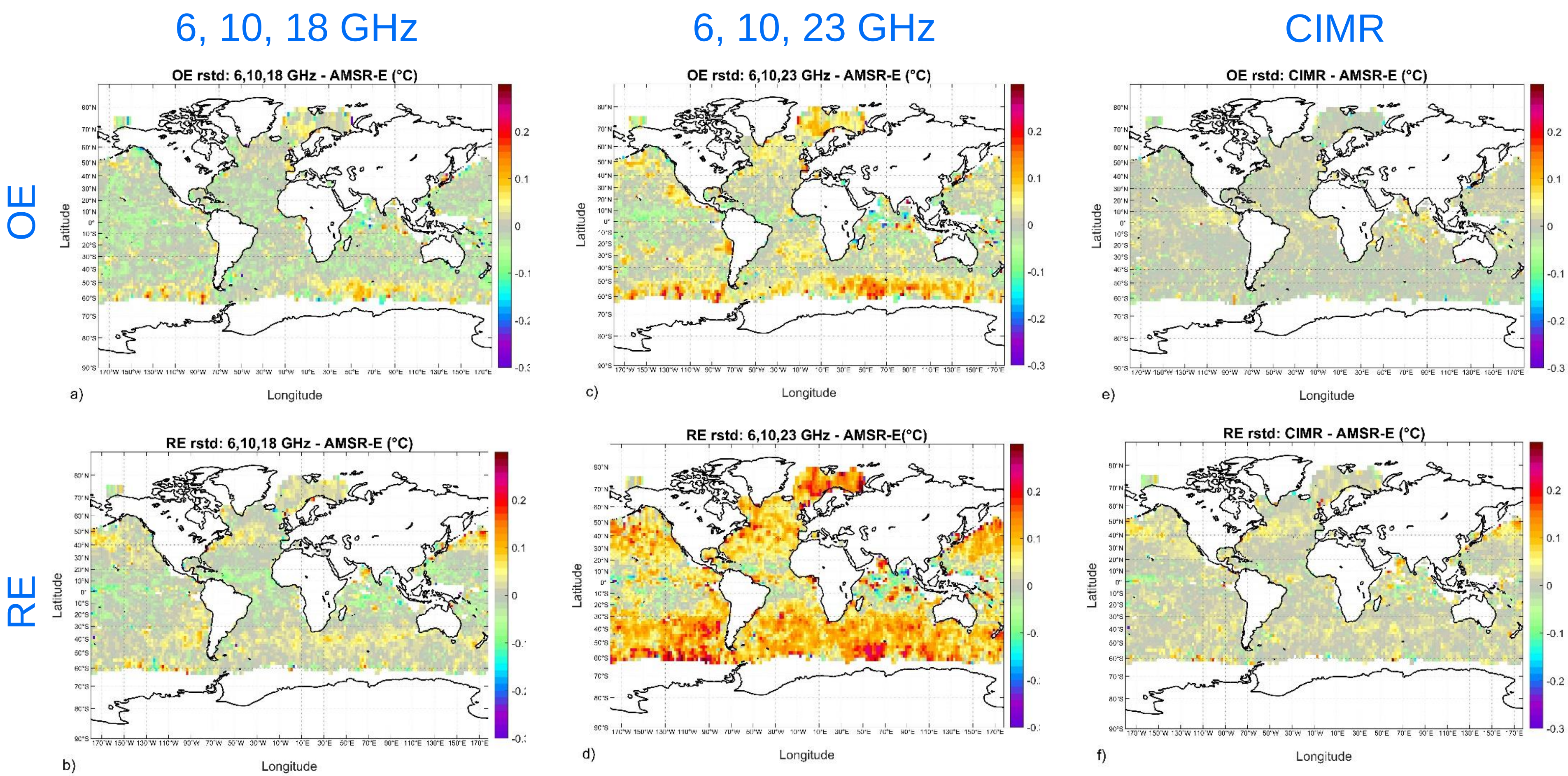
Performance of the AMSR-E configuration

- Evaluate 6,10,18; 6,10,23; CIMR-Like
- All channel configuration
- OE shows larger latitudinal variation
- RE more stable

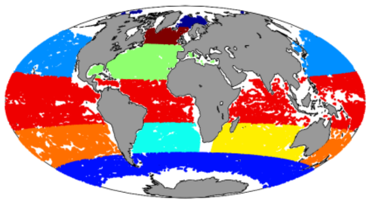


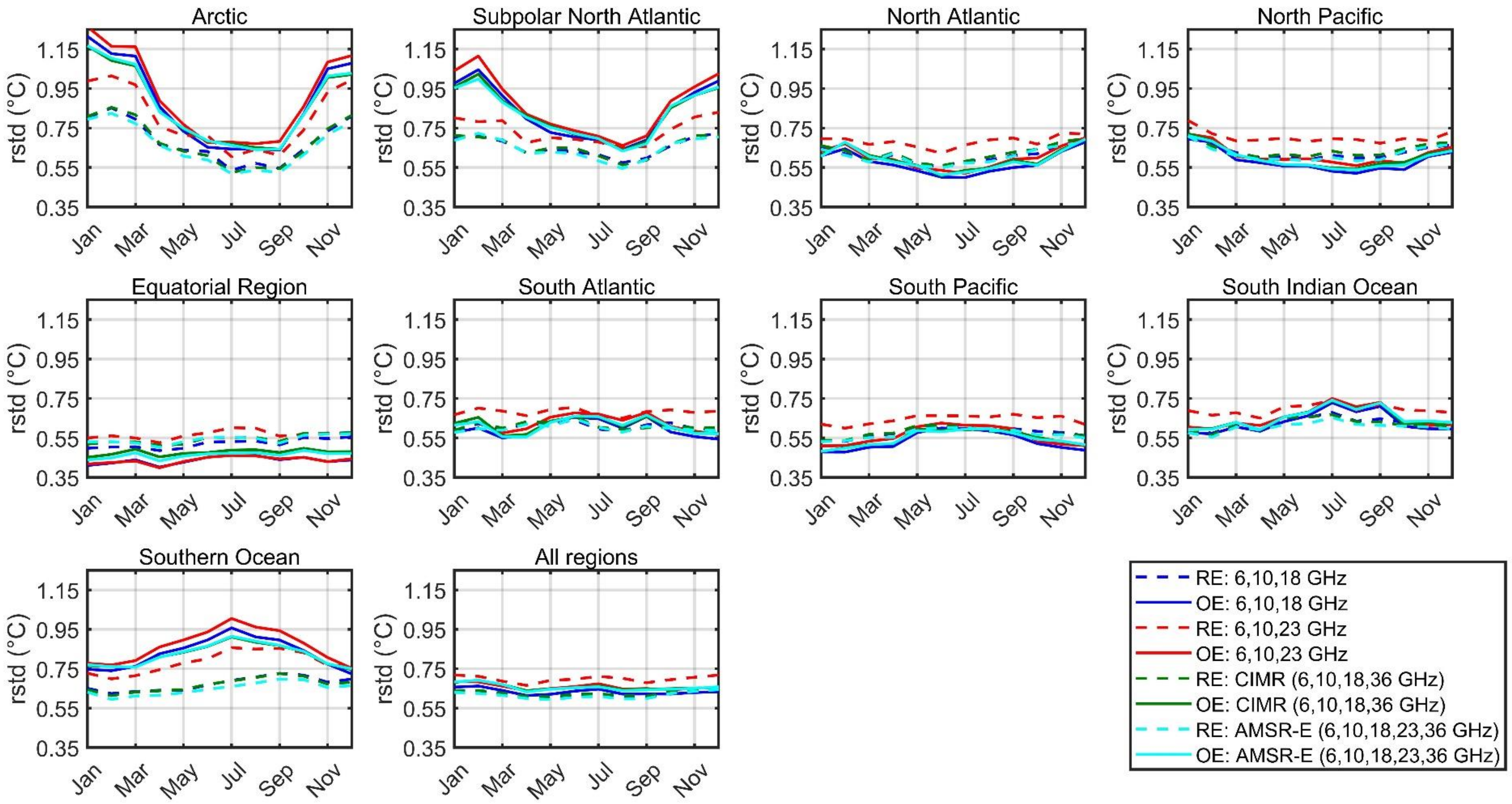


Comparisons with the AMSR-E config.



Seasonal cycle in different regions





Overall performance in different regions

- Using 6, 10, 18 GHz is better than the 6, 10, 23 GHz configuration for SST retrievals
- CIMR and AMSR-E show very similar performance

	RE algorithm				OE algorithm				
Region	**6, 10, 18**	**6, 10, 23**	**CIMR**	**AMSR-E**	**6, 10, 18**	**6, 10, 23**	**CIMR**	**AMSR-E**	**N**
Arctic	0.70	0.82	0.69	**0.67**	0.92	0.96	0.90	**0.89**	109,493
Subpolar North Atlantic	0.67	0.75	0.68	**0.66**	**0.82**	0.85	**0.82**	**0.82**	43,160
North Atlantic	**0.62**	0.68	0.63	**0.62**	**0.57**	0.60	0.59	0.59	110,870
North Pacific	0.64	0.71	0.65	**0.63**	**0.58**	0.62	0.60	0.60	163,072
Equatorial Region	**0.53**	0.57	0.55	0.55	**0.44**	**0.44**	0.48	0.47	188,331
South Atlantic	**0.61**	0.69	0.62	**0.61**	**0.60**	0.63	0.61	0.61	76,185
South Pacific	0.58	0.65	0.58	**0.57**	**0.53**	0.56	0.55	0.54	116,675
South Indian Ocean	0.63	0.70	0.63	**0.61**	**0.63**	0.65	0.65	0.65	83,632
Southern Ocean	0.68	0.79	0.67	**0.65**	0.83	0.87	**0.82**	0.83	174,069
All regions	**0.62**	0.70	0.63	**0.62**	**0.63**	0.66	0.66	0.66	1,065,487

Conclusion

- Retrieval assessment against in situ observations give new insights
- Demonstrated similarities with theoretical studies, but important differences due to forward model
- Important to use different types of retrievals for these studies
- More channels give better performance
- 6, 10, 18 GHz better than 6, 10, 23 GHz combination
- Optimal choice with CIMR channels
- CIMR performance very close to all-channel AMSR-E
  - In both types of retrievals
  - For range of environmental conditions
  - Seasonal and regional performance