ESA Climate Change Initiative Phase-II

Sea Surface Temperature (SST)

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Generating a Climate data record for SST from Passive Microwave observations

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Outline

- Motivation
- Development of PMW retrieval algorithms
  - MMD generation
  - Regression retrievals
  - Optimal estimation retrievals
- Impact of clouds
- Summary

Motivation

- PMW SST retrievals are valuable supplement to IR SSTs due to the capability to see through clouds and small response to aerosols
- Little European activity within the PMW retrieval work
- DMI has been working with PMW for sea ice concentration for many years
- Optimal Estimation is currently being developed for Sea ice within ESA CCI Sea Ice (SICCI) context

Aims

- Develop retrieval algorithms for AMSR-E + AMSR2 MW SST
- Produce and validate L2 MW SST products for 2002 to 2016
- Produce blended IR + MW L4 SST analysis
- Assess impact of MW in analysis relative to analysis including AVHRR GAC
- Assess the impact of clouds on PMW SST retrievals
- Publish results

Development of PMW retrievals

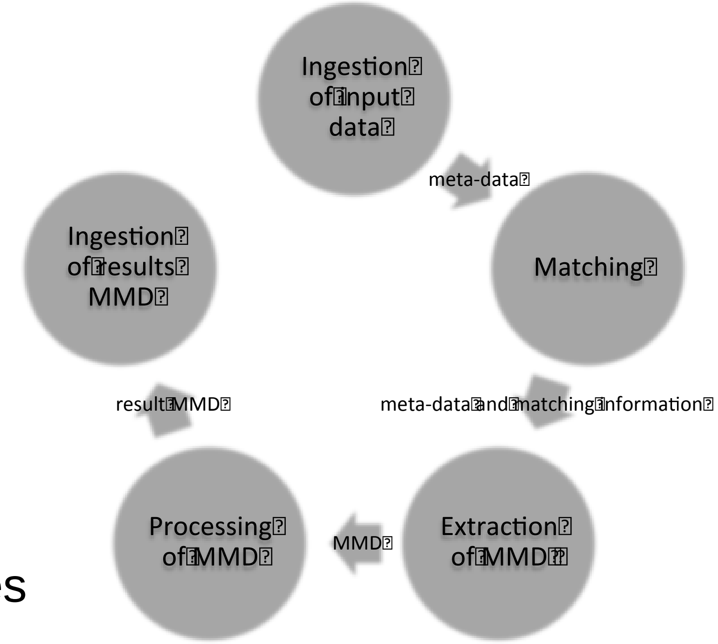
Multisensor Matchup Dataset (MMD)

Matchups with In situ and satellite

- MMD06b
  - AMSR-2 vs in situ (2012-2014)
- MMD06C
  - AMSR-E vs In situ (2002-2011)
- MMD14
  - AMSR-E vs AATSR (2002-2011)

- All MMDs include level 1 brightness temperatures and auxiliary data, such as NWP, needed for algorithm developments

- In situ data: Drifting buoys, Argo floats,GTMBA, Radiometer, Ships, XBT, CTD, Bottle, Animal

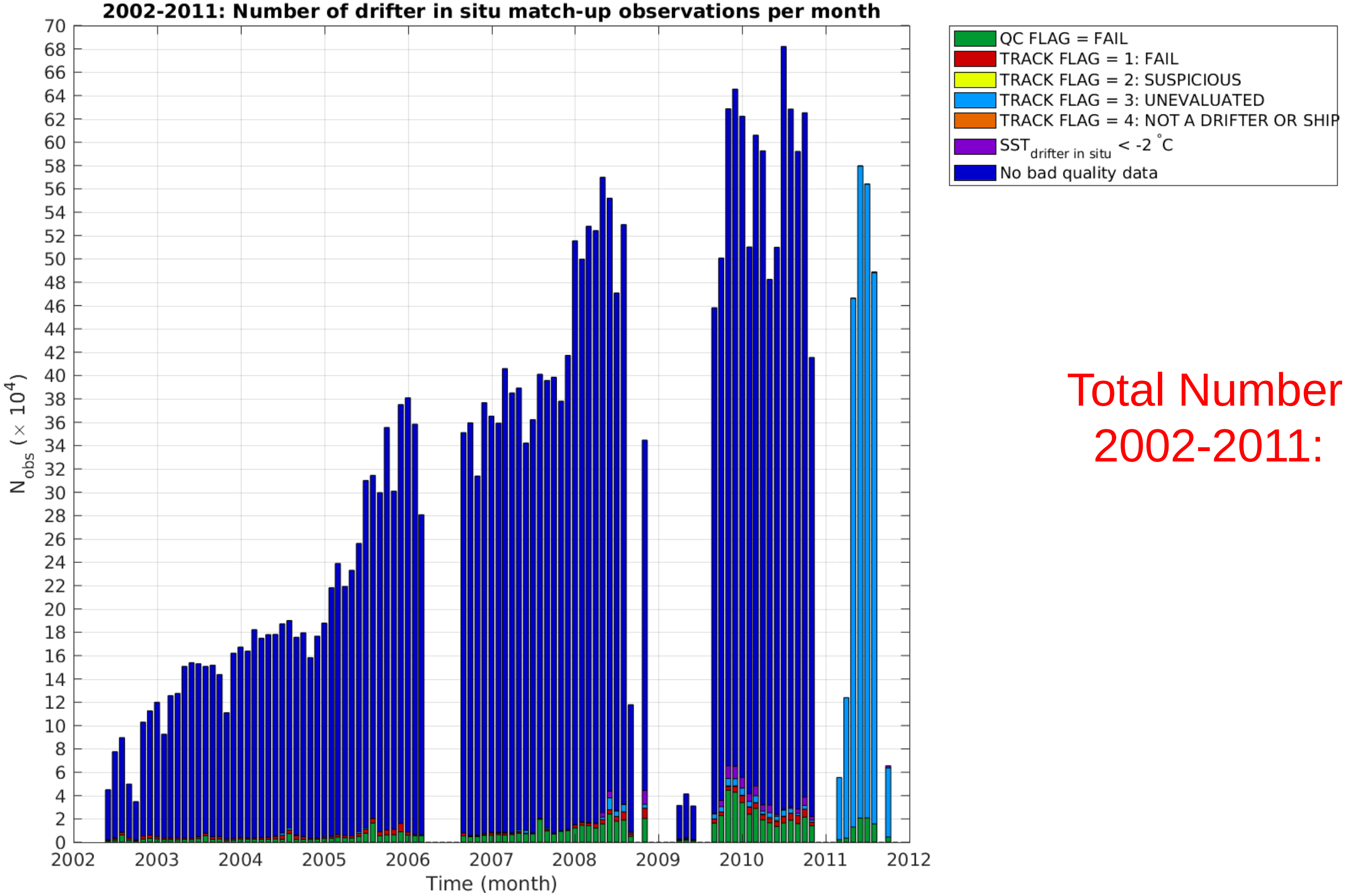


MMD6c: AMSR-E vs insitu

- **L2A TBs from RSS (NSIDC), version 7**
  - Resampled to a data resolution; 10 km, all channels
  - Orbit files, ascending and descending
- **2002-2011**
- **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
- 114 variables for each matchup.
- Netcdf format

MMD06c coverage, drifters

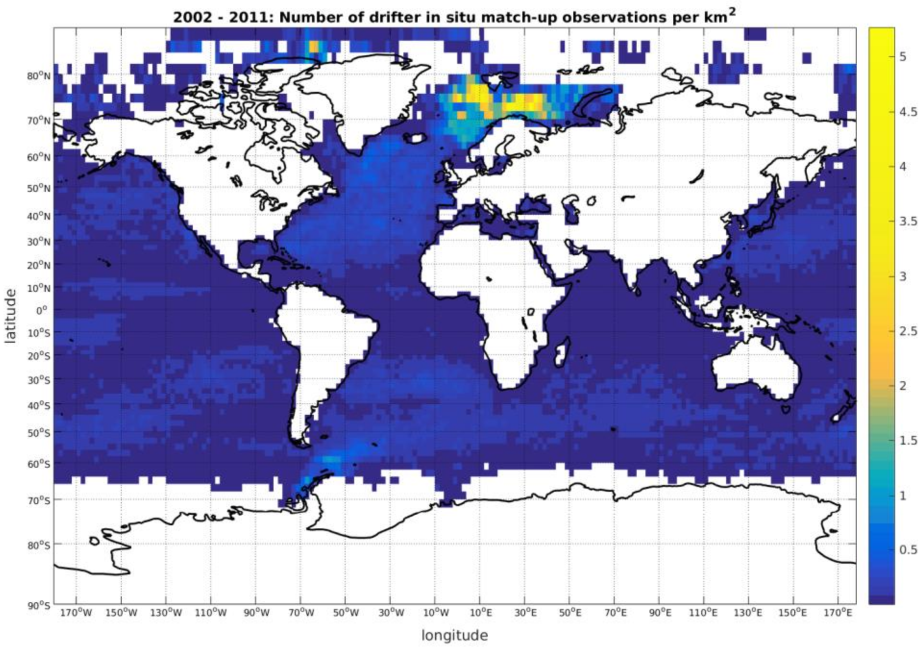
- Increasing data coverage from 2002
- Gaps will be filled in update

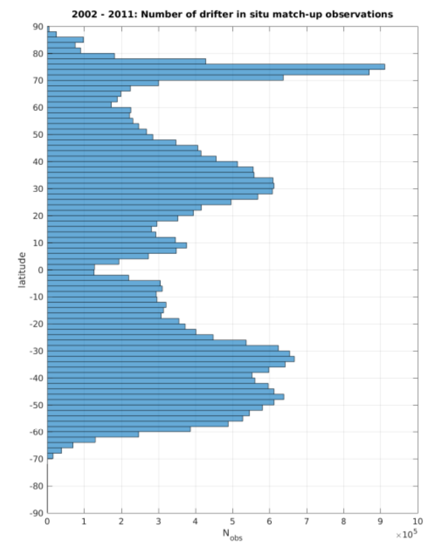


Total Number of matchups
2002-2011: **41 855 176**

Geographical distribution

- High density in Barents Sea, and North Atlantic
- Low coverage in equatorial regions and Indonesian waters





Regression algorithms

Regression algorithms

- 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
- In this work we have used: 6V, 6H, 10V,10H, 18V, 18H, 23V, 23H, 36V, 36H:
  - 1 simple overall (including windspeed)
  - 2 step (1:overall, 2:SST and wind, RSS like)
  - Latitudinal (coefficients every 10 degree latitude)
  - Latitudinal with cross track correction, separate Asc/Des

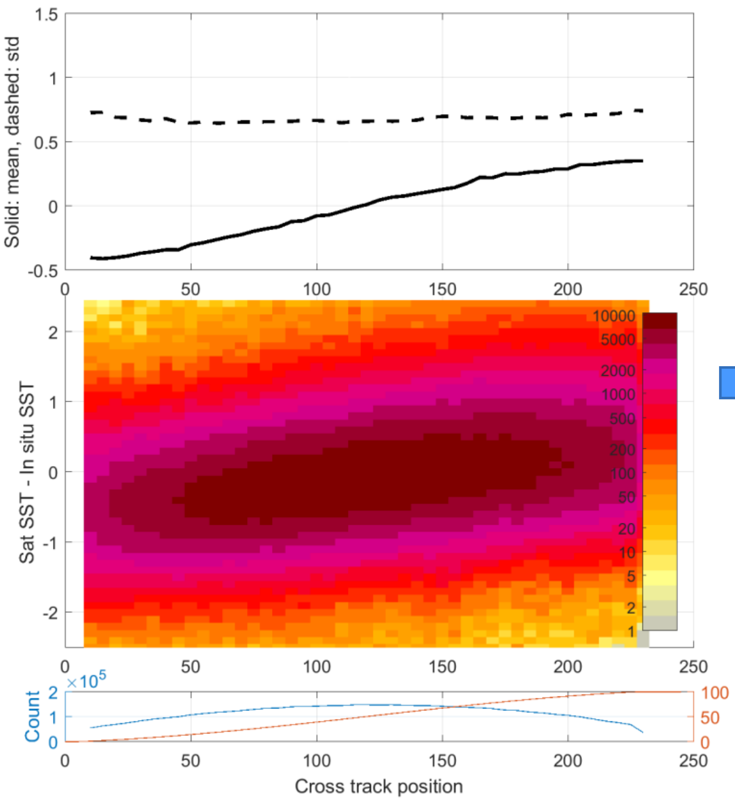
$$SST = A(lat) + \sum_{i}^{n} \left(B_i(lat) * Tb_i + C_i(lat) * Tb_i^2 \right) + D(Xpos, lat) \qquad , n = 10$$

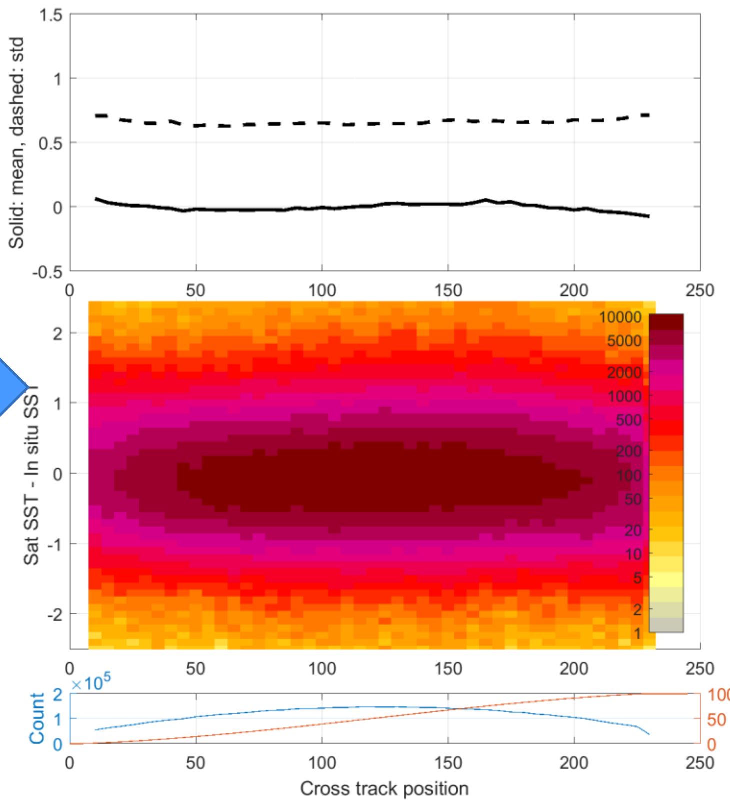
- Algorithm regressed towards drifting buoy observations

- Preliminary results shown here are from latitudinal retrieval method with crosstrack correction and for year 2010 only.

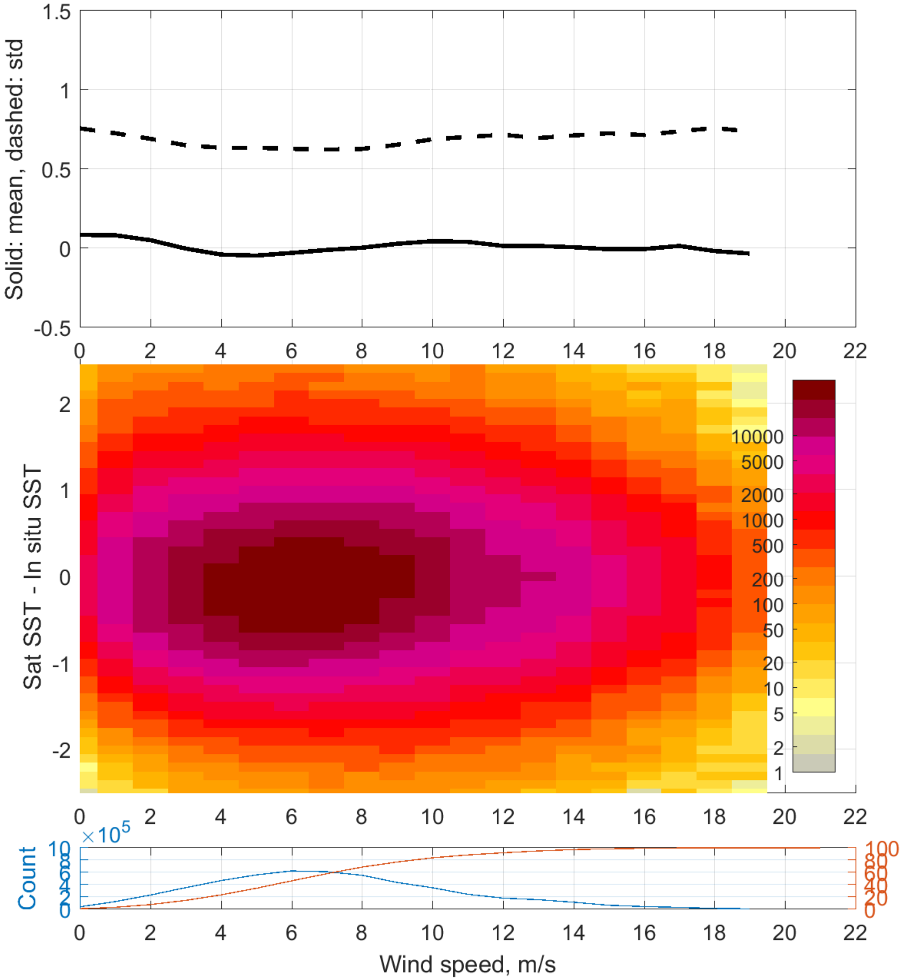
Effect of cross track biases

- Bias can be from -0.4 to 0.4 Deg C.
- Cross track position included in regression model





Wind dependence



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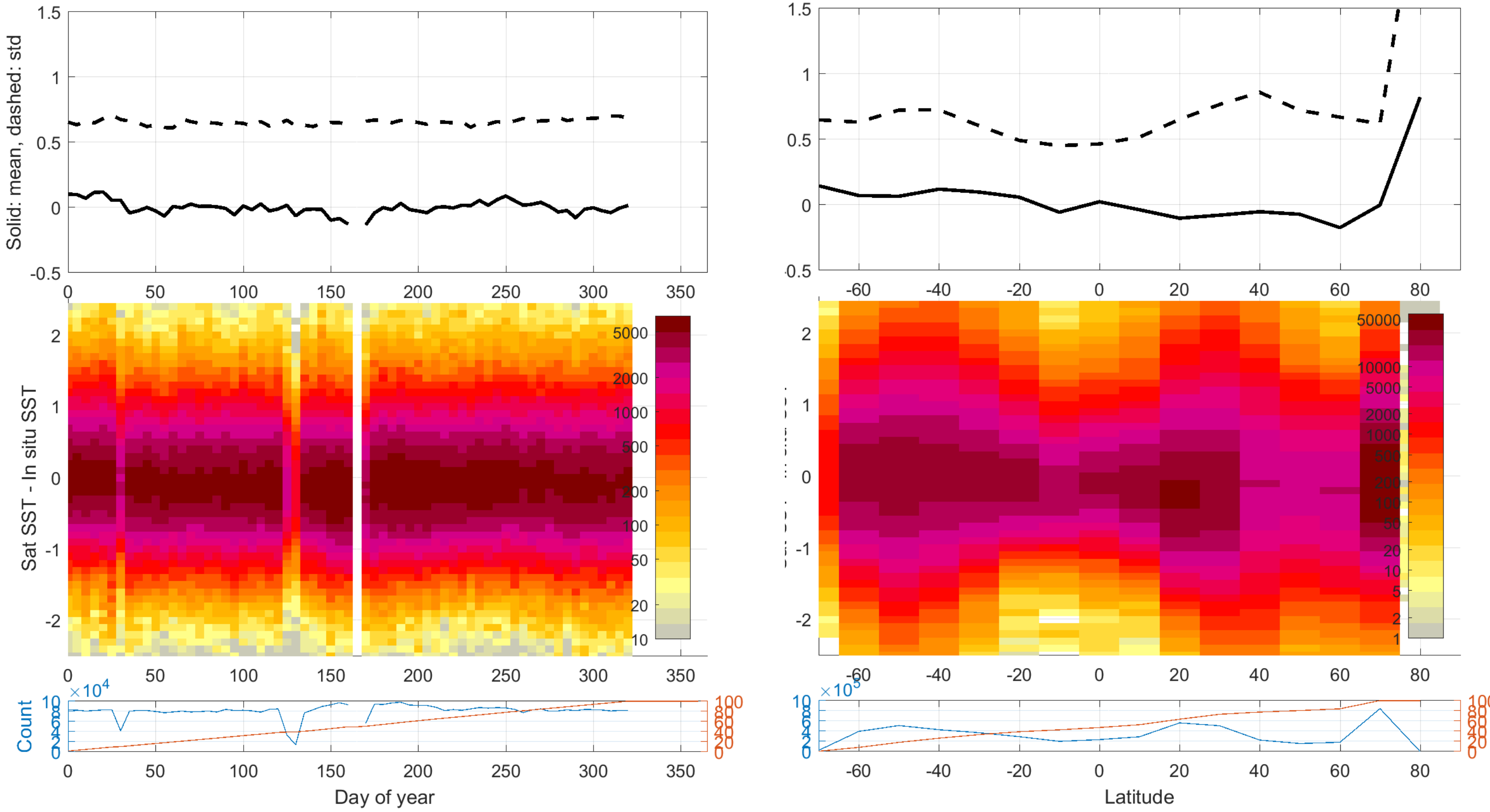
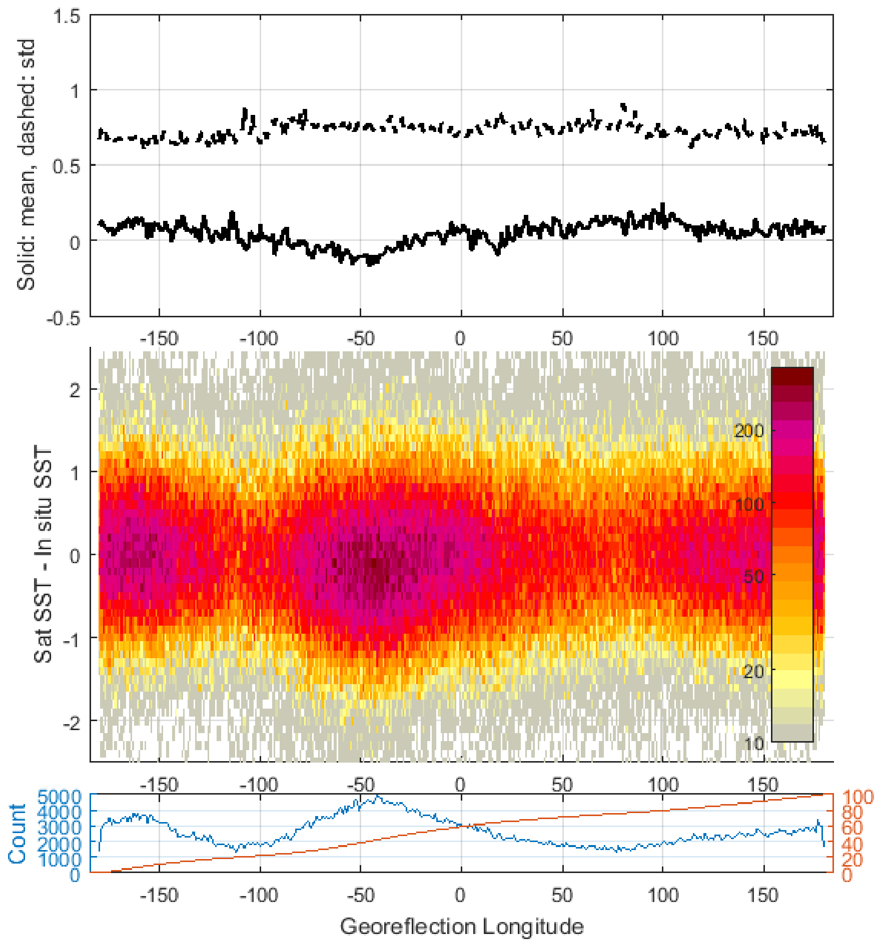
Error vs. Day of year and latitude



RFI influence

- RFI is included in regression model product
- One source is geostationary TV satellites
- In data set: Geostationary reflection longitude
- Work with Chelle on filtering criteria



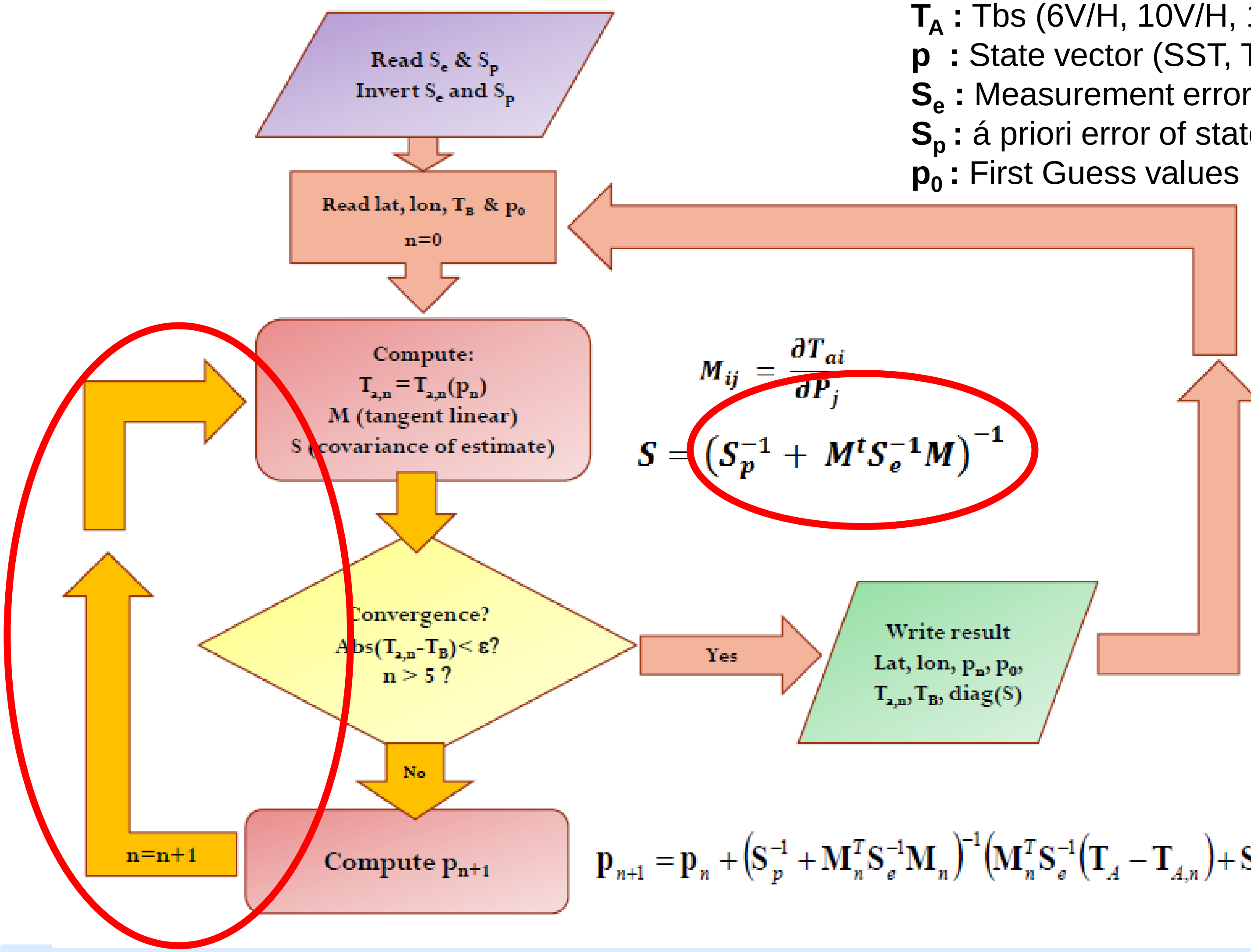
Optimal Estimation Algorithms

Why Optimal Estimation ?

- PMW contain valuable information about most of the geophysical ’noise’ parameters.
- OE is Inversion of forward model using statistical estimation theory
- Development of OE at Reading demonstrated challenges using RTTOV (wind speed bias)
- DMI implemented the Wentz et al., 2002, 2012 forward model and developed the inversion model.
- Important with iterative solutions for PMW retrievals

DMI OE setup

T_A : Tbs (6V/H, 10V/H, 18V/H, 23V/H, 36V/H)
p : State vector (SST, TCWV, TCLW, WS)
S_e : Measurement error covariance
S_p : á priori error of state variables
p_0 : First Guess values



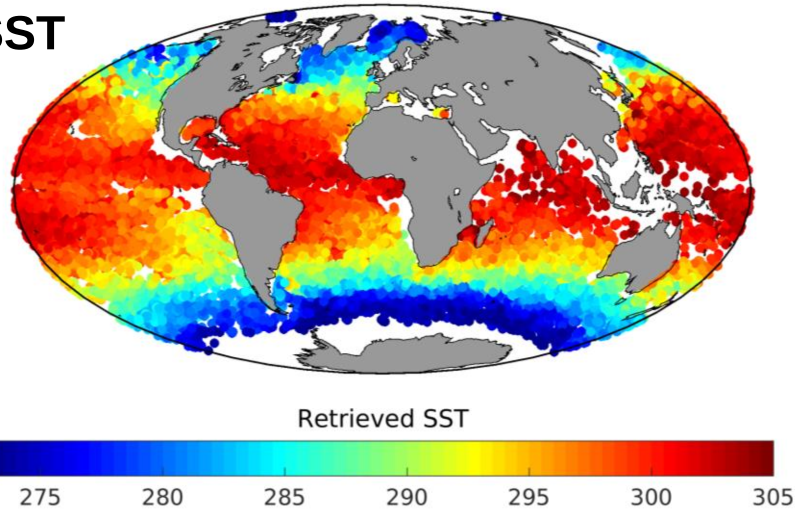
$$M_{ij} = \frac{\partial T_{ai}}{\partial P_j}$$

$$S = \left(S_p^{-1} + M^t S_e^{-1} M\right)^{-1}$$

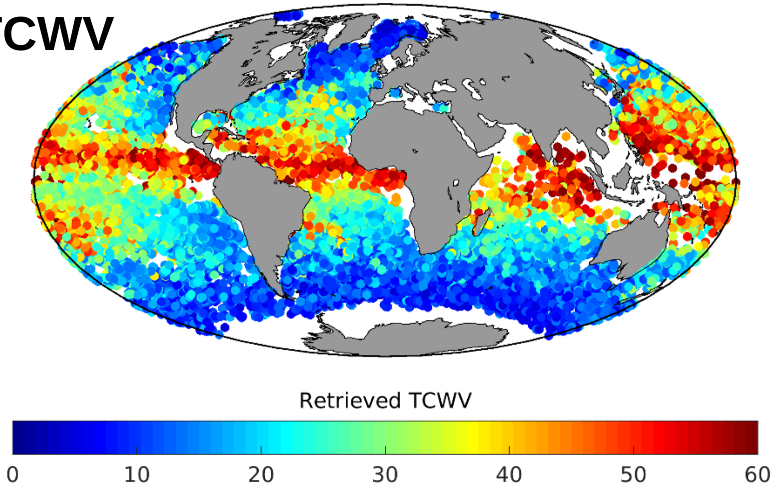
$$p_{n+1} = p_n + \left(S_p^{-1} + M_n^T S_e^{-1} M_n\right)^{-1} \left(M_n^T S_e^{-1}\left(T_A - T_{A,n}\right) + S_p^{-1}\left(p_0 - p_n\right)\right)$$

Retrieved parameters, 2010

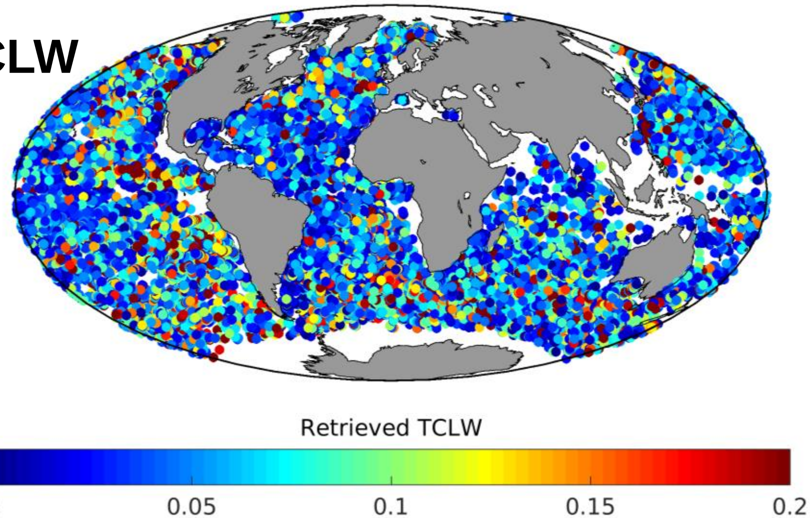
SST



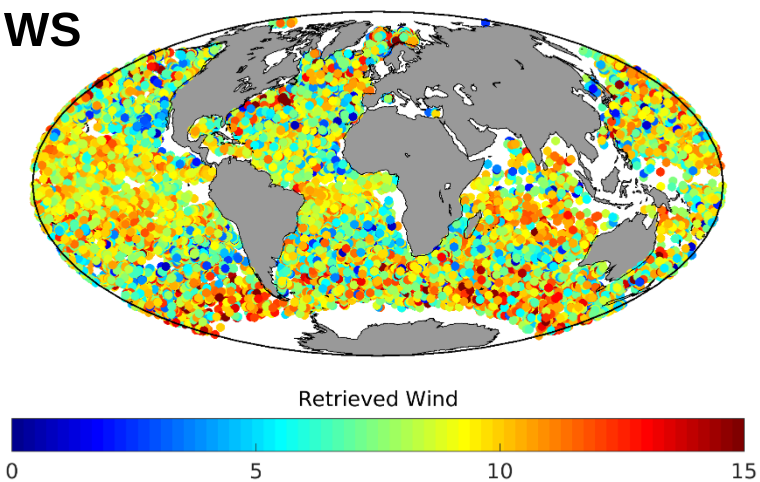
TCWV



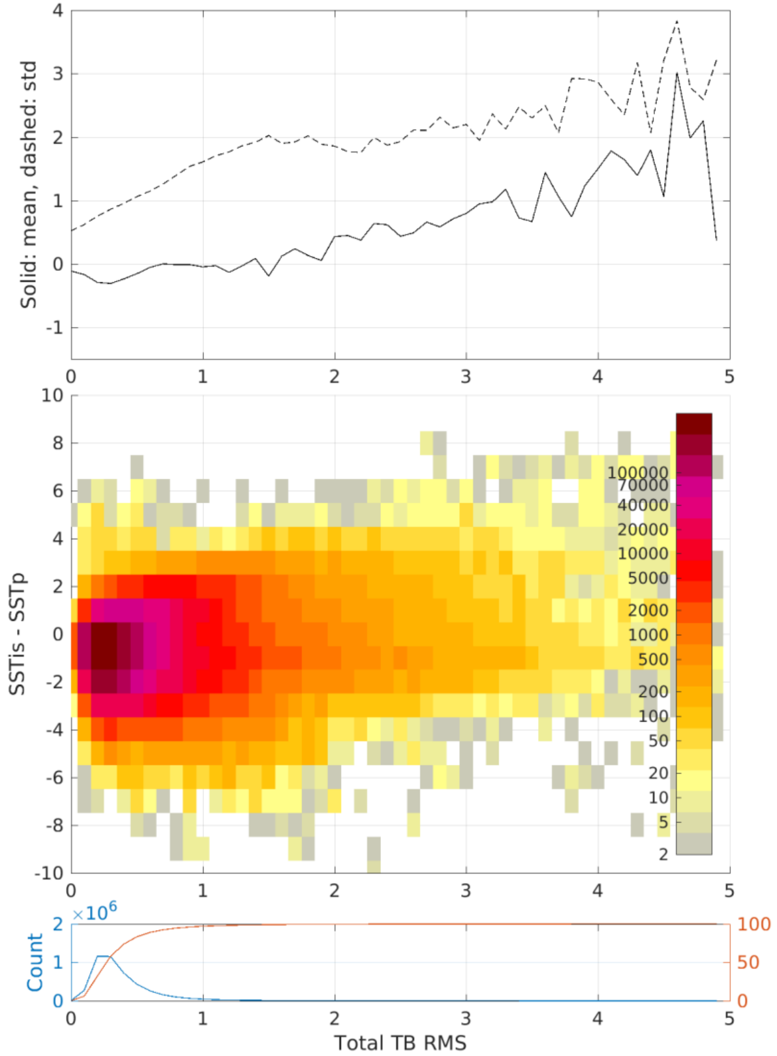
TCLW



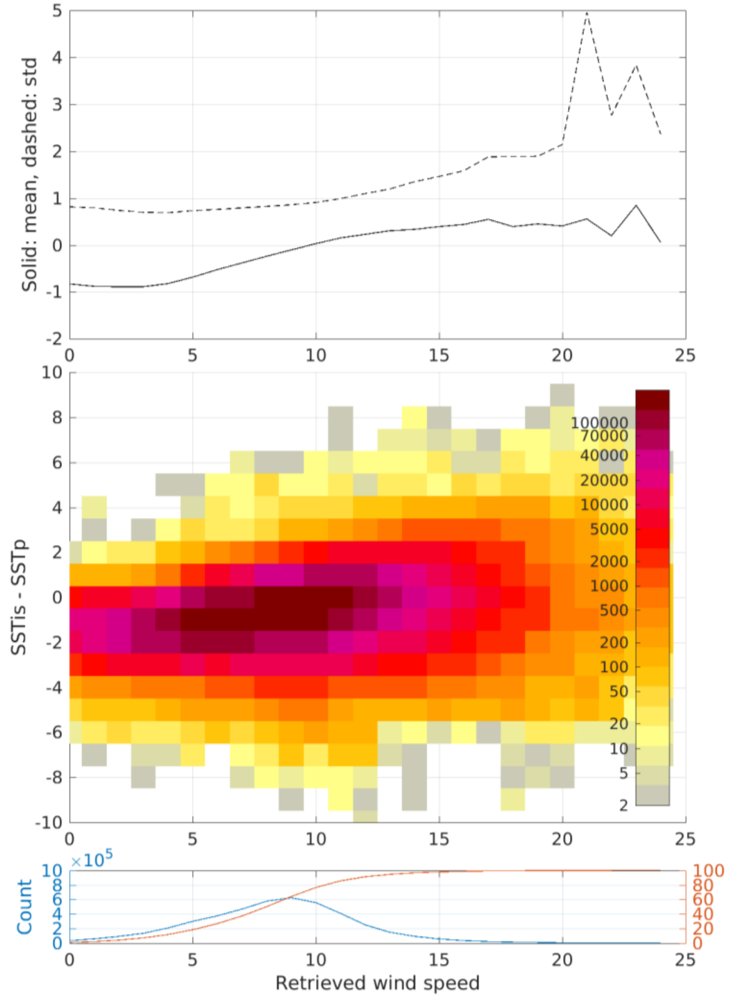
WS



SST error vs Sim - obs Tbs

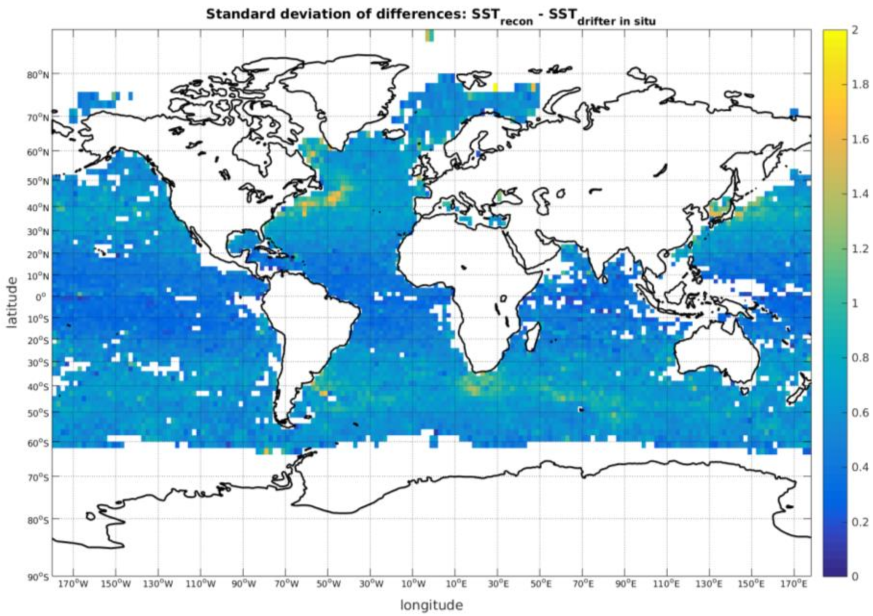


SST error vs retr. wind speed

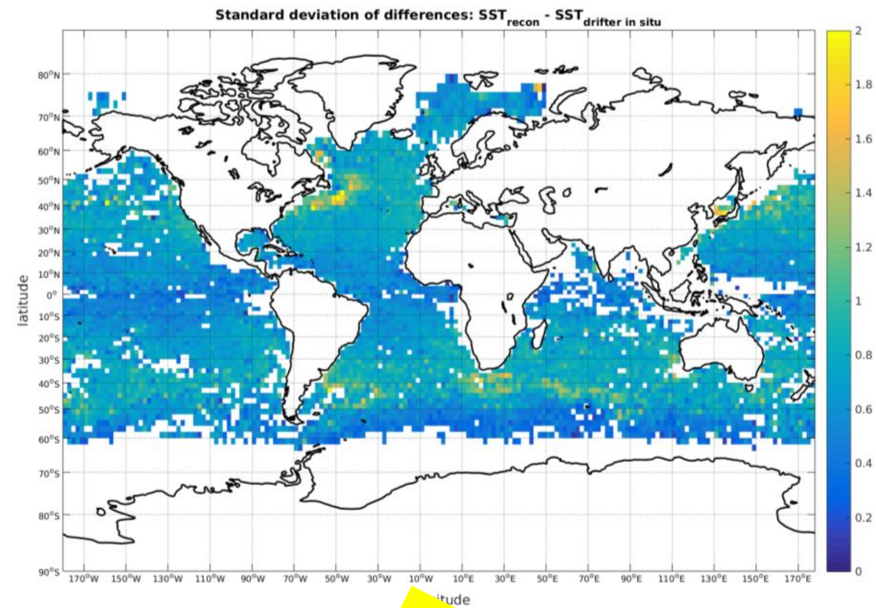


Global performance

Stddev Regression



Stddev OE



Preliminary

Retrieval	Mean	Stddev	Mean (filtered)	Stddev (filtered)
Regression	0.08	0.66	0.08	0.57
OE	-0.25	0.95	-0.28	0.78

Harmonizing AMSR-E and AMSR2

- A brightness temperature adjustment is anticipated to make AMSR-E and AMSR-2 consistent.
  - True SSTs from MMDs will be propagated through the forward model to generate simulated TBs
  - Simulated and observed TBs will be analysed to reveal absolute biases and temporal variations in TBs biases.
- Quadratic L1 adjustments to AMSR-2 to reference with AMSR-E will be tested.

Prototype PMW Products

Category of product and description	Satellite sensors & data to be used	Time period	Level of data to be produced for each sensor (resolution/grid spacing)
Prototype SST depth retrieved from data obtained from the AMSR-E instrument.	AMSR-E L2A (from RSS)	June 2002-October 2011	L2P (10km)
Prototype SSTs depth retrieved from data obtained from the AMSR2 instrument.	AMSR2 L1R (from JAXA)	July 2012 to December 2016	L2P (35km x 61km)
Analysis Prototype gap-free daily analyses of the ATSR, AVHRR, AMSR-E and AMSR2 products for 2002-2016.	ATSR, AVHRRs, AMSR-E and AMSR2 products	June 2002 to December 2016	L4 (0.05^{o})

Impact of clouds on PMW SSTs

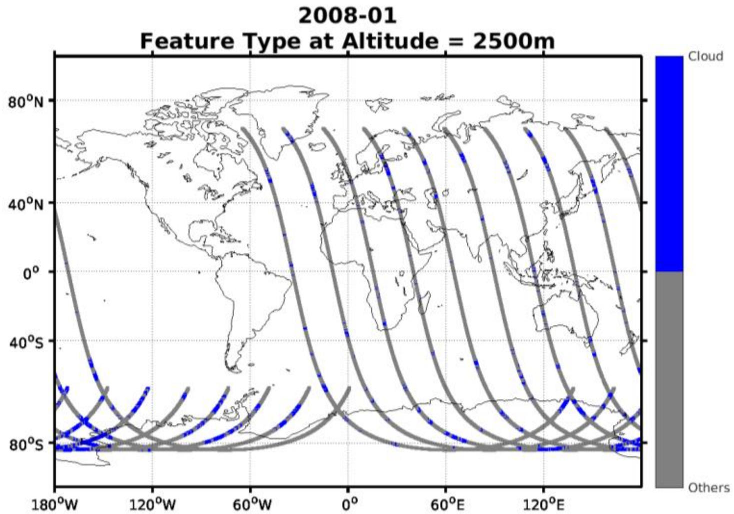
Tasks within SST CCI

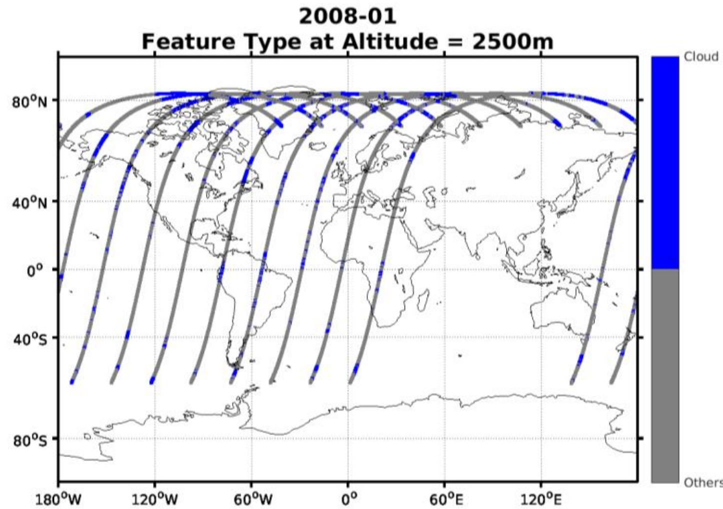
- Produce a multi-sensor matchup data set including cloud observations
- Assess the impact of clouds on the PMW SST algorithm performance
- Assess the potential for using auxiliary information to improve the PMW SST retrievals
- Publish the results

CALIPSO and Modis cloud products

- Modis cloud mask (46 parameters)
  - Cloud_Mask_1km
  - Cloud_Mask_5km
- Calipso Since April 28, 2006 with the cloud profiling radar system on the CloudSat satellite.
  - Level 2 cloud data products incl. 5 km cloud layer, 1 km cloud layer, 333m cloud layer, 5 km cloud profile, vertical feature mask and polar stratospheric cloud mask.

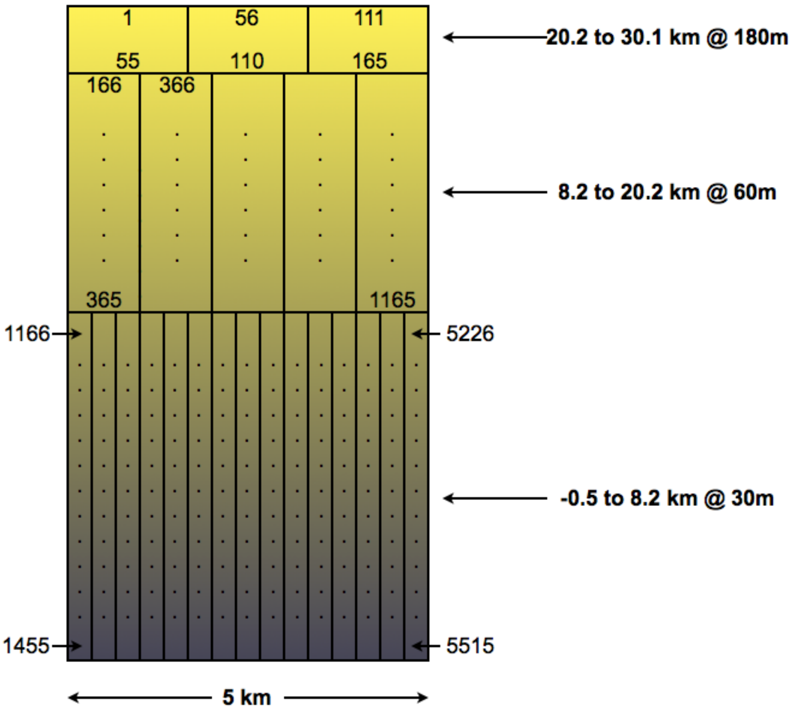
Examples of 10 daytime (left) and nighttime (right) view





CALIOP Vertical Feature Mask product

Vertical resolutions: 30m, 60m,180m

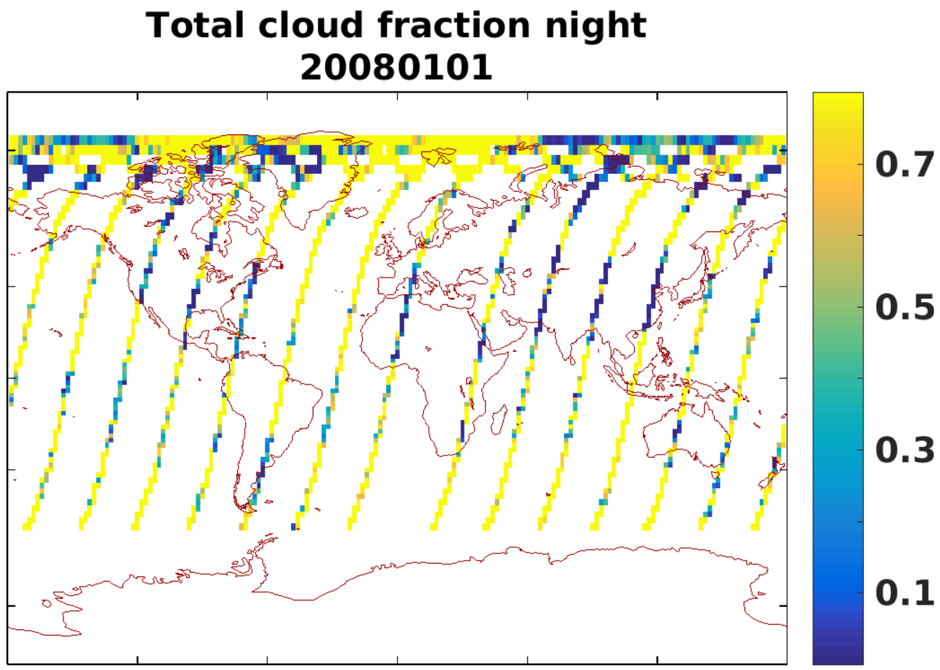


Key parameters

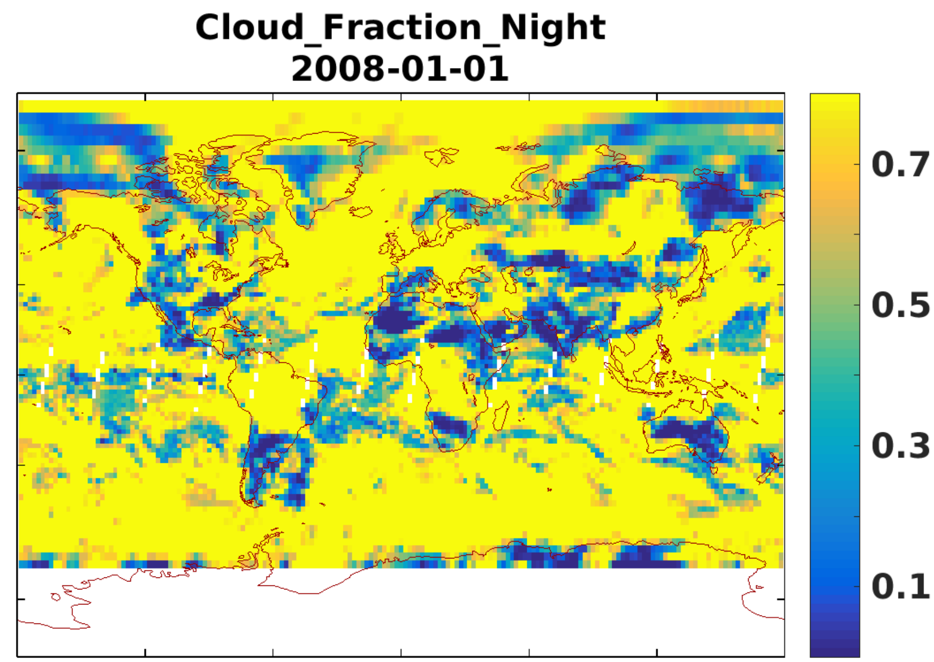
	Feature type	Cloud subtype	Phase
0	Invalid	Low, overcast, thin (transparent St, Sc and fog)	Unknown
1	Clear	Low, overcast, thick (opaque St, Sc and fog)	Ice
2	**Cloud**	Transition Stratocumulus	Water
3	Aerosol	Low, broken (trade Cu and shallow Cu)	HO
4	Strato	Altocumulus (transparent)	
5	Surface	Altocumulus (opaque, As, Ns, Ac)	
6	Subsurfa ce	Cirrus (transparent)	
7	No signal	Deep convective (opaque As, Cb, Ns)	

Examples of cloud fraction

Calipso



Modis Aqua



Summary

- Several activities within development of PMW retrieval algorithms within ESA CCI project
- MMDs have been created both for AMSR-E and AMSR2
- Tested retrieval models include regression and Optimal Estimation
- Atmospheric influence (clouds) will be examined using Calipso data
- CCI prototype products will include SSTdepth from AMSR-E and AMSR 2 (2002-2016) in L2P format (+ L4)

- Development still ongoing, and shows promising results