The Danish Meteorological Institute

fiducial reference temperature measurements

IST products, validation and plans

- OSISAF, DMI, MET and EUMETSAT

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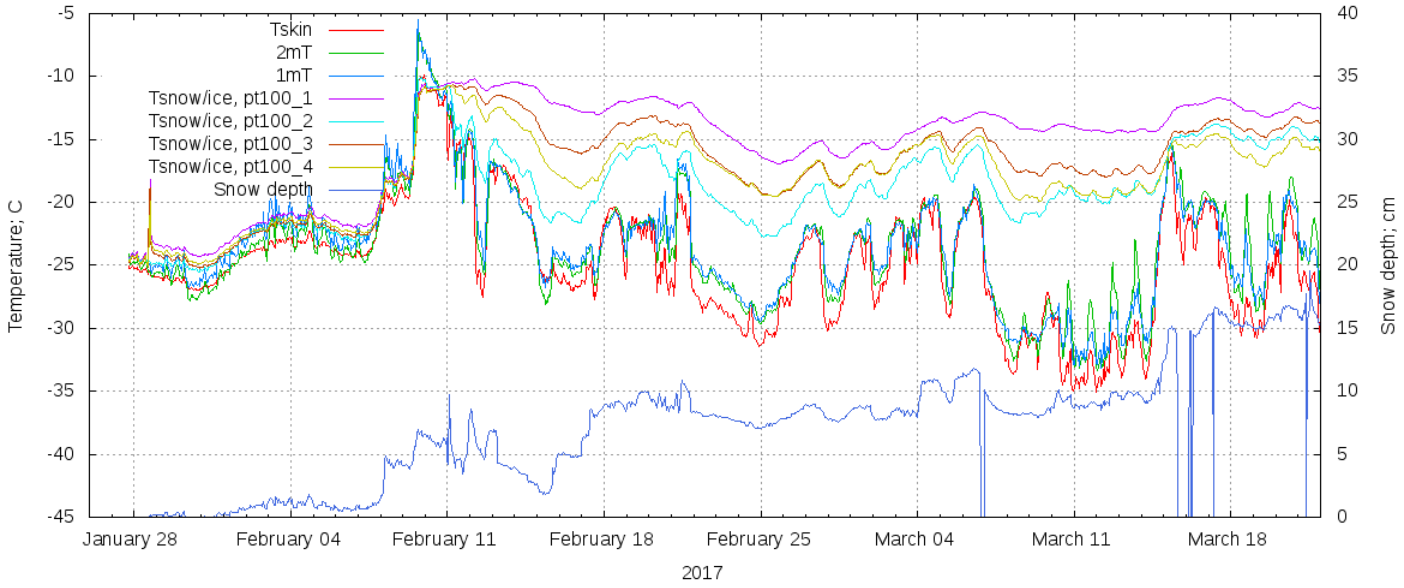
FRM4STS International Workshop, Fiducial Reference Measurements for satellite derived surface temperature product validation
October 16-18, 2017, NPL, Teddington, UK

Outline

- Satellite IST measurement challenge
  - IST – spatial and temporal variability
- Algorithm and general characteristics of OSISAF AVHRR level 2 IST.
  - uncertainties and quality assessment
- OSI-205 IST (OSISAF, Metop-AVHRR)
  - Level2
- CMEMS IST (DMI, Metop-AVHRR)
  - level 4
- AASTI IST (DMI+METNO, GAC-AVHRR, CDR)
  - level 2+3
- IASI IST (EUMETSAT, IASI+AMSU+MHS)
  - level 2+3
- Compiling a data base of ice buoy measurements with QC
- Plans

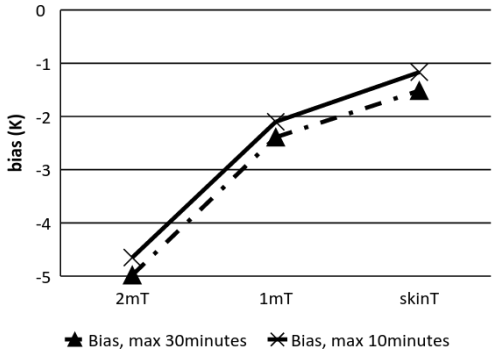
The IST challenge

- skin temperature vs snow and air temperatures

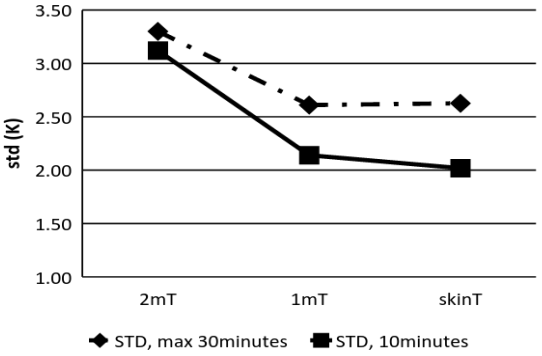


- Large vertical variability
- Large diurnal variability
- Skin T is coldest

DMI-AWS observations from Qaanaaq.



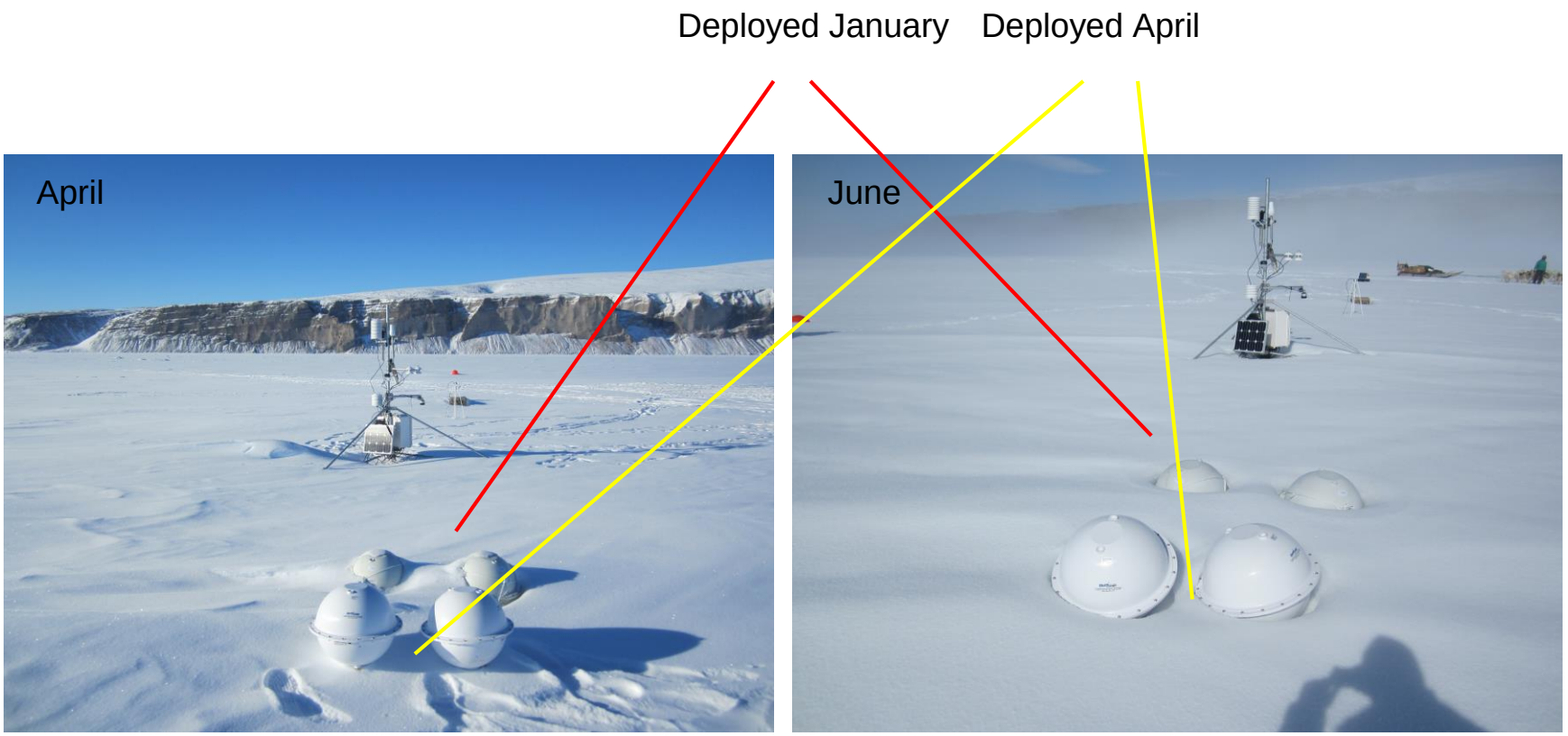
Bias



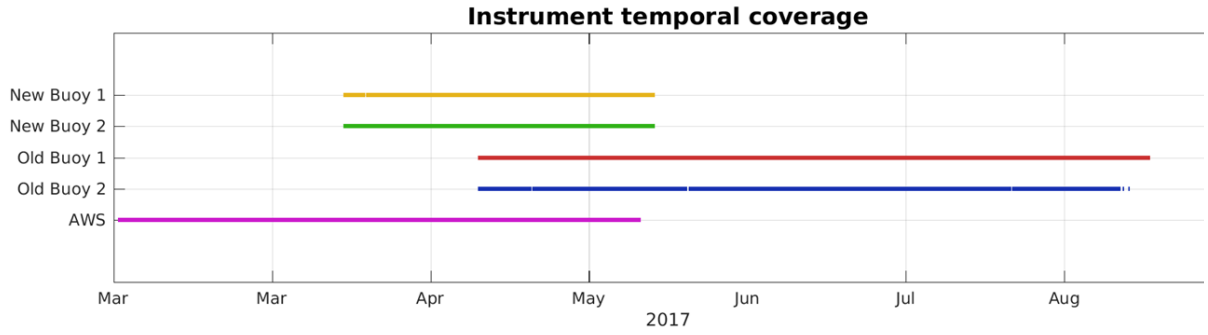
STD

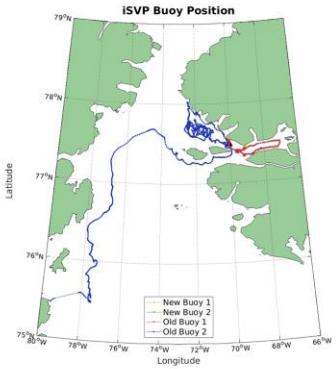
Metop AVHRR IST compared with in situ air and skin temperature measurements: STD and bias from comparing Metop AVHRR IST with 2m, 1m and skin temperature observations – within 10 min. (solid line) and 30 min. (dashed line).

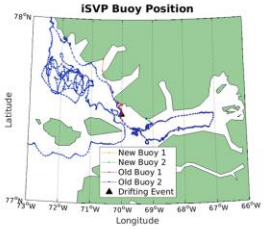
FRM - iSVP buoy intercomparison in Qaanaaq

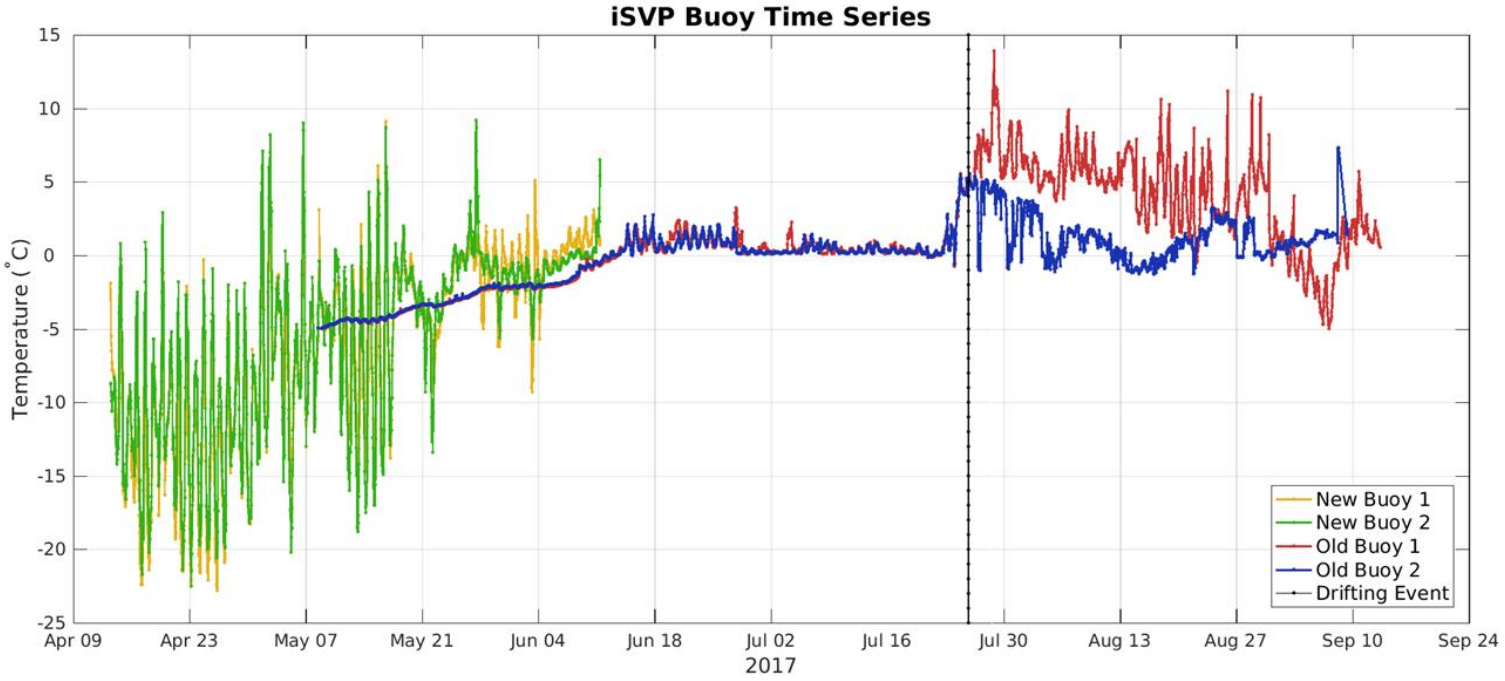


Measurements from iSVP

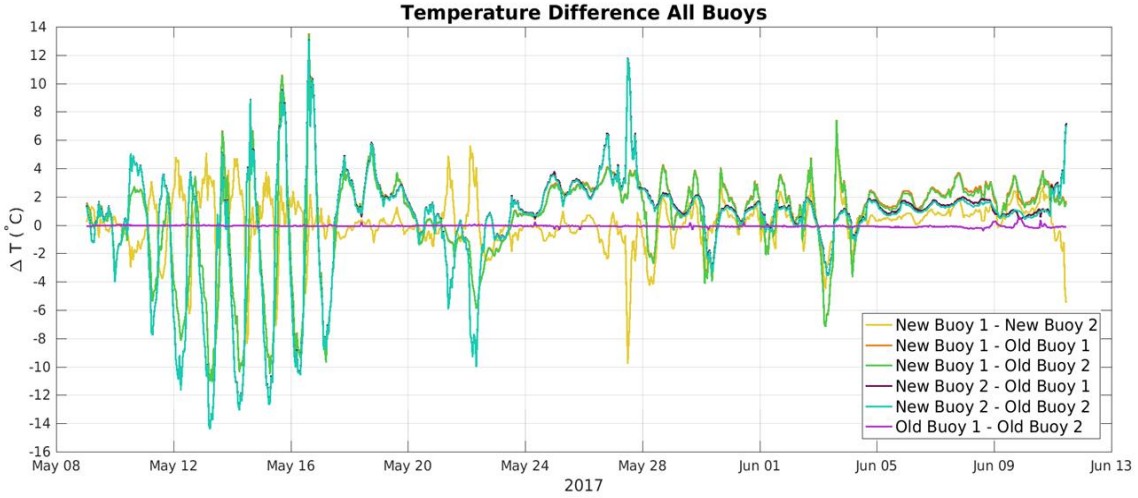


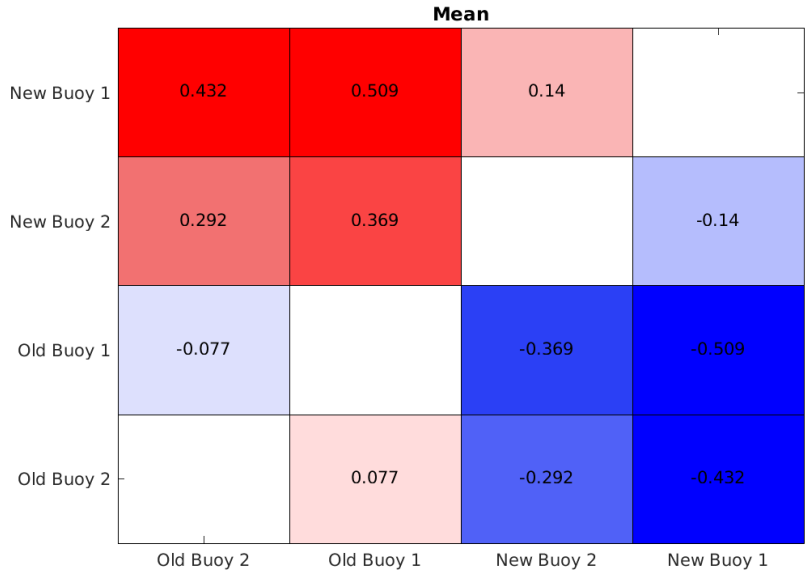


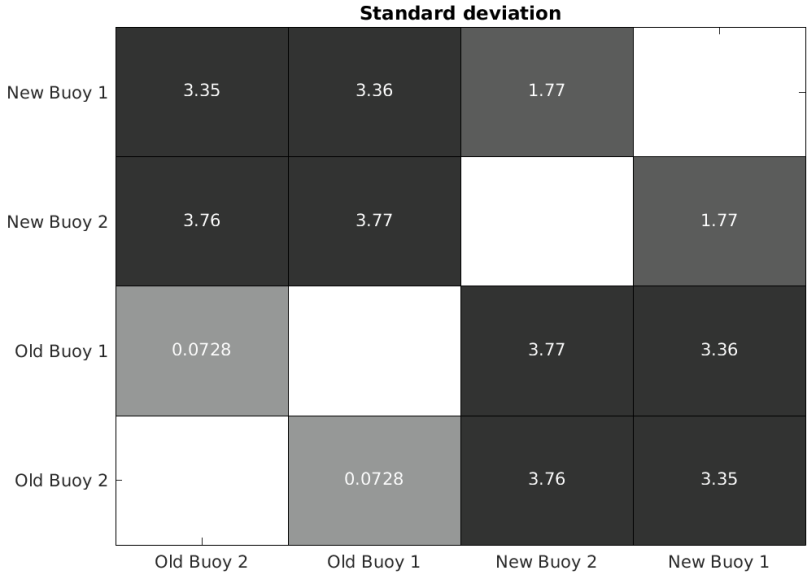




Stats from Qaanaaq iSVP







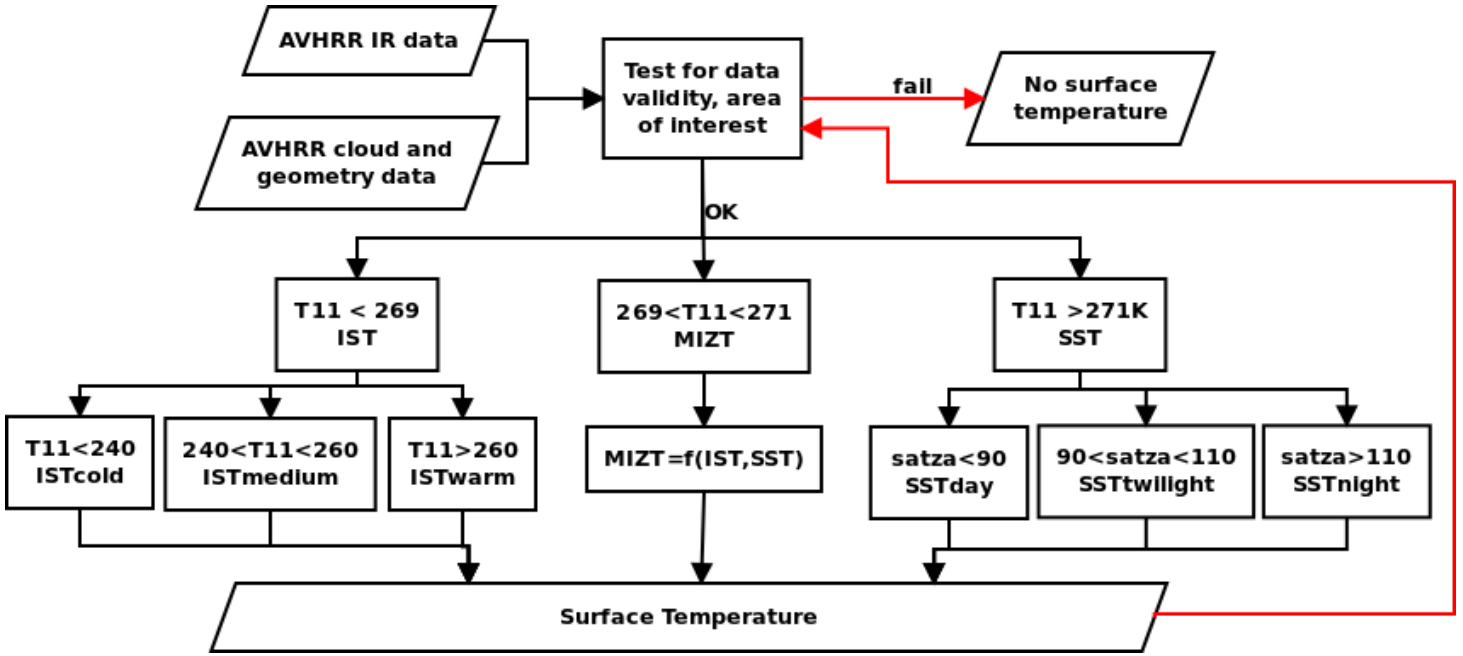
TIR Satellite IST

Baseline algorithm for AVHRR

$$IST = a + bT11 + c(\overline{T11 - T12}) + d(\overline{T11 - T12})steta\ (Key\ et\ al. 1997);$$

$Where\ steta = \frac{1}{\cos(satza)} - 1\ and\ (\overline{T11 - T12})$ is the mean value within 3x3 pixels.

The algorithm is sensor specific, tuned using NWP surface and atmosphere data from ERA-INTERIM and corresponding Top-of-Atmosphere radiances calculated by RTTOV.



Quality levels

- adapted from GHRSST

	Cloud mask (cm)	cm-quality	Cloud-box (3x3)	Scan-angle	Sunzen-angle
IST-test	Cloud free	High	All cloud free	<60	<80
Penalty	Major	Minor	Minor	Minor	Minor

IST is tested for clouds, scan and sun angles. A penalty given if a given pixel does NOT comply to the test:

- Not-cloudy: a pixel must be cloud free or ice contaminated.
- Cm-quality high: The cloud mask quality indicator must be of high-quality
- Cloud-box 3x3: all 8 adjacent pixels must be cloud free or “ice contaminated”
- Scan-angle <60: Scan angle (view angle) must be less than 60 degrees
- Sun-zenith angle must be less than 80 degrees

QL 5, best	Comply to all criteria
QL 4, acceptable	Fail 1 minor criterion
QL 3, low	Fail 2 minor criteria
QL 2, worst	Fail 3 or more minor criteria
QL 1, bad	Fail 1 major or more criteria, or flagged, i.e. T outside 150-350K
QL 0, no data	Everything else

Uncertainty algorithm

Pixel Uncertainty $= \sqrt{U_{synoptic}^2 + U_{Random}^2 + U_{Global}^2}$

- ***Random uncertainty*** $= \sqrt{U_{geo}^2 + U_{NEdT}^2}$

Ugeo, geolocation error (Temperature difference between ocean and ice, Ice Concentration, spatial resolution coeff.)
Unedt, sensor noise (sensor specific)

- **Synoptic scales Uncertainty** $= \sqrt{U_{emis}^2 + U_{fmt}^2}$

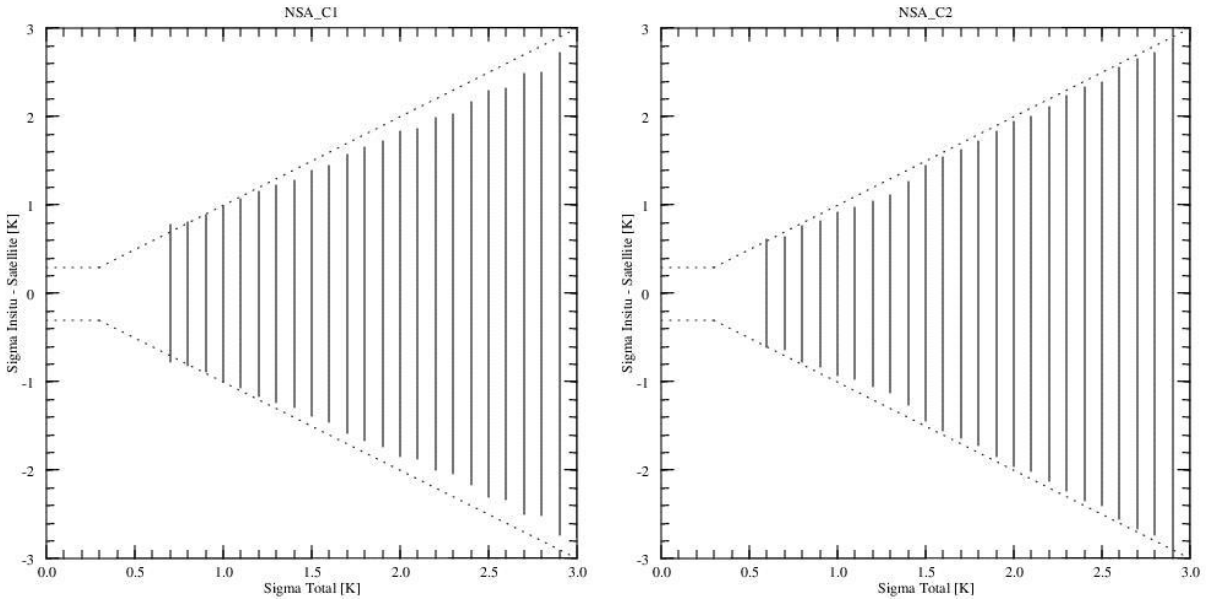
Uemis, snow emissivity variations (satellite zenith angle dependency, snow density and grain size)
Ufmt, algorithm uncertainty (residual of fit)

- **Large/global scale Uncertainty** $= Uglob$

Fixed uncertainties for each quality level (Expert judgement)

Quality level	Uglob
5	0
4	0.5
3	1
2	2
1	Fillvalue
0	Fillvalue

Uncertainty validation

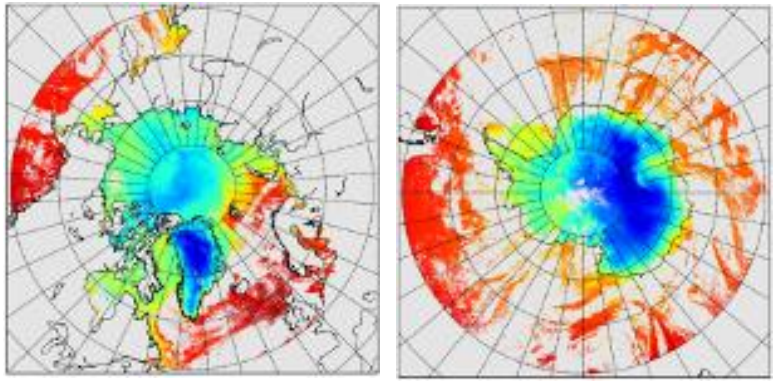


AASTI IST uncertainty validation with respect to ARM in-situ data for 2009. Dashed lines show ideal uncertainty model accounting for uncertainties in the in situ data and geophysical uncertainties arising from spatial and temporal collocation. Solid black lines show one standard deviation of the retrieved minus in situ IST differences for each 0.1 K bin (EUSTACE deliverable D3.1, D Ghent)

EUMETSAT OSISAF level 2 IST OSI-205

OSI-205 characteristics

- Metop-AVHRR / VIIRS
- Integrated IST, SST and MIZT surface temperature product
- Operational since May 2016
- Level 2 – multiple daily coverage
- 1.1/0.7 km at Nadir
- Cover sea ice and waters polewards from 50 North and 50 South. Greenland and Antarctic ice sheets are included.



One day coverage, March

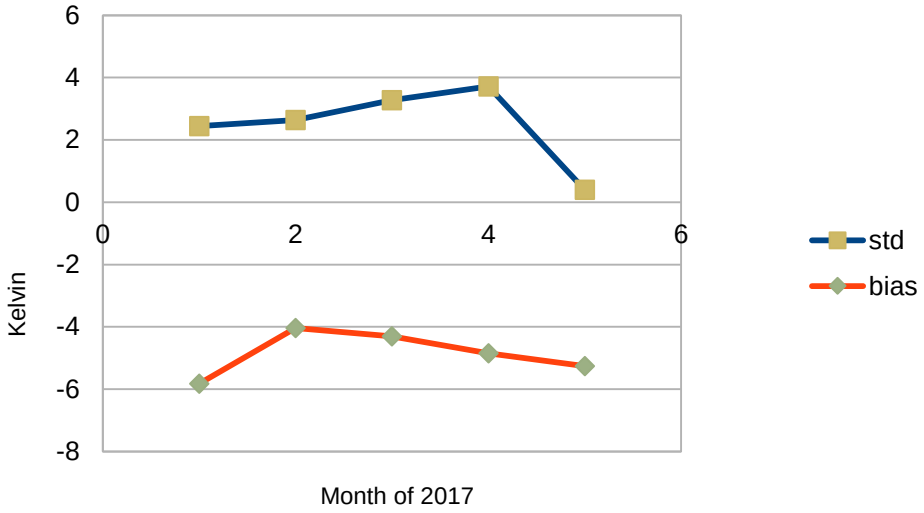
OSISAF validation

- against raw data from DMI-GTS

Metop AVHRR IST quality results over JUL. 2016 to JUN. 2017, night-time							
Month	Number of cases	Bias °C	Bias Req °C		Std Dev °C	Std Dev Req °C	
	Night-time						
JAN. 2017	474	-7.46	-3.0		5.21	4.0	
FEB. 2017	480	-4.78	-3.0		4.35	4.0	
MAR. 2017	25	-1.20	-3.0		1.11	4.0	
	Day-time						
JAN. 2017	93	-3.64	-3.0		2.99	4.0	
FEB. 2017	1002	-5.43	-3.0		4.30	4.0	
MAR. 2017	4818	-5.24	-3.0		3.76	4.0	
APR. 2017	9228	-4.70	-3.0		3.40	4.0	
MAY 2017	4335	-4.78	-3.0		3.83	4.0	
JUN. 2017	20	-4.22	-3.0		2.12	4.0	

Quality results for Metop AVHRR IST, for quality levels 4 and 5 (acceptable and best qualities), by night and by day.

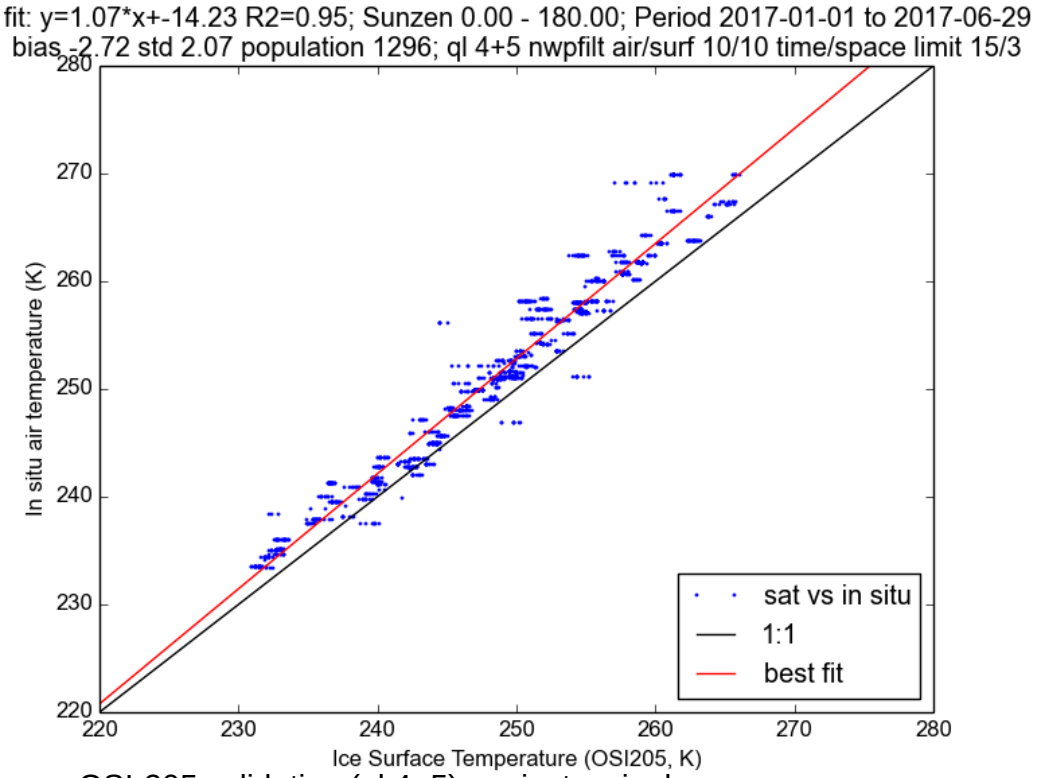
Mean IST error and bias with respect to conventional buoys measurements from the DMI GTS. Only data with for quality level 5 are shown.



Validation

- against one selected in situ platform

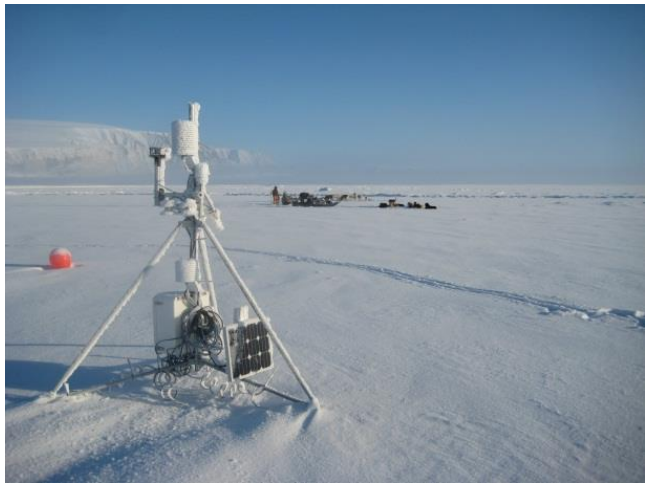
This one-buoy validation seen in context of the general validation suggest that the algorithm works, but there are serious issues with the cloud mask and/or the in situ temperature data sets need thorough QC.



OSI-205 validation (ql 4+5) against a single WMO buoy. Bias is -2.72 K and STD is 2.07 K.

Satellite IST intercomparison

- Agains DMI-AWS at Qaanaaq field site (FRM4STS case study)



DMI-AWS, Qaanaaq.

IST average over available satellite pixels that fall within the site ± 1.5 km

Spatial average	Metop_A AVHRR	NPP VIIRS	MODIS TERRA	MODIS AQUA
Mean difference	- 0.4 K	-2.0 K	-1.4 K	-1.9 K
Median abs difference	0.8 K	1.7 K	0.9 K	1.1 K
RMSE	2.0 K	4.3 K	3.4 K	4.3 K
stdv (differences)	2.0 K	3.8 K	3.1 K	3.9 K
N(matches)	352	349	147	207

IST from the *SINGLE* pixel that covers the actual site

Closest pixel	Metop_A AVHRR	VIIRS	MODIS TERRA	MODIS AQUA
Mean difference	- 0.4 K	-1.7 K	-1.4 K	-1.9 K
Median abs difference	0.8 K	1.5 K	0.8 K	1.1 K
RMSE	2.0 K	3.6 K	3.5 K	4.8 K
stdv (differences)	1.9 K	3.2 K	3.3 K	4.4 K
N(matches)	227	197	122	165

IST average only if *ALL* pixels within ± 1 km pass the cloud free quality control

Cloud-free average	Metop_A AVHRR	VIIRS	MODIS TERRA	MODIS AQUA
Mean difference	-0.2 K	-0.9	-0.6 K	-1.7 K
Median abs difference	0.8 K	1.0 K	0.7 K	1.1 K
RMSE	1.7 K	2.8 K	1.4 K	3.5 K
stdv (differences)	1.7 K	2.7 K	1.3 K	3.1 K
N(matches)	173	26	52	75

Pairwise statistics between DMI AWS Ice surface temperatures and the 4 different satellite IST products for normal averaging (top), closest pixel (middle) and cloud free average (bottom).

Copernicus, level 4 IST

based on OSI-205

- Metop-AVHRR
- Integrated IST, SST and MIZT surface temperature
- Operational since May 2016
- Level 4, daily
- 0.05 degree x 0.05 degree
- Cover ice and water areas North of 50 North

AASTI CDR, level 2 and 3

- NOAA and Metop AVHRR
- Integrated IST, SST and MIZT surface temperature
- Climate Data Record, based on the CLARA radiance CDR (cmsaf)
- Version 1 by 2015, 2000-2009
  - version 2 in progress, 1982-2015
- Level 2/3, multiple daily/daily
- ~4 km/0.25x0.25 degrees, based Global-Area-Coverage data.
- Cover ice and water areas polewards from 50 North and 50 South

ASTI CDR Validation
- for ice/snow on land

Greenland ice sheet + Alaska AWS

			ISTsat – ISTinsitu			ISTsat – IATinsitu			
Station	N	corr	Bias (°C)	std (°C)	RMS (°C)	corr	Bias (°C)	std (°C)	RMS (°C)
ARM_Atq	1235	93.8	-2.47	3.69	4.44	93.7	-3.17	3.69	4.87
ARM_Bar	1594	94.1	-0.73	4.30	4.36	94.6	-1.14	4.02	3.86
PROMICE KAN-M	422	93.9	-3.65	3.37	4.96	94.6	-4.56	3.14	5.53
PROMICE KAN-U	239	93.9	-1.75	3.32	3.75	94.4	-3.39	3.17	4.64
PROMICE KPC-U	488	97.6	-1.31	2.62	2.92	98.2	-3.20	2.27	3.92
PROMICE NUK-U	296	77.7	-4.09	5.00	6.45	84.7	-7.19	4.01	8.23
PROMICE QAS-U	407	83.9	-1.65	4.20	4.51	86.3	-3.70	3.75	5.27
PROMICE SCO-U	403	91.5	-4.60	4.25	6.26	93.7	-7.55	3.75	8.43
PROMICE TAS-U	386	67.5	-1.03	5.43	5.52	79.5	-3.61	4.39	5.68
PROMICE UPE-U	125	88.2	-3.13	3.88	4.97	90.0	-5.49	3.50	6.50
All data	5595	92.9	-2.03	4.24	4.70	93.2	-3.36	4.12	5.32

Validation of AASTI v.1 Level 3 IST against in situ IST and air Temperature (IAT).

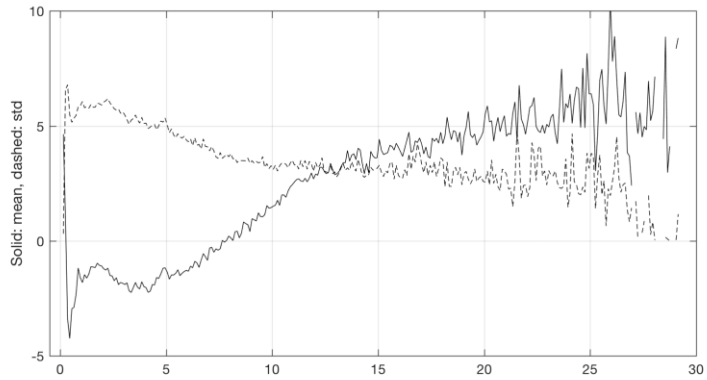
EUMETSAT IASI IST

- IASI All-Sky IST algorithm
  - A Piece-Wise Linear Regression algorithm combining IASI, AMSU and MHS radiances. A cloud screening procedure decides whether to use Thermal Intra Red (TIR) algorithm only – or the combined IR and MW algorithm.
- Since 2011(I think…)
- Level 2
- ~12 km

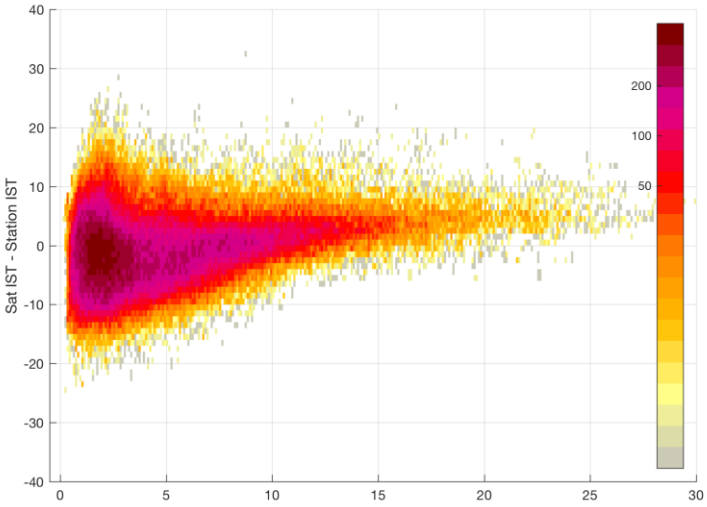
IASI IST performance on Greenland land ice

– against Water Vapour

Seems to perform best at intermediate humid atmospheres…



STD and bias



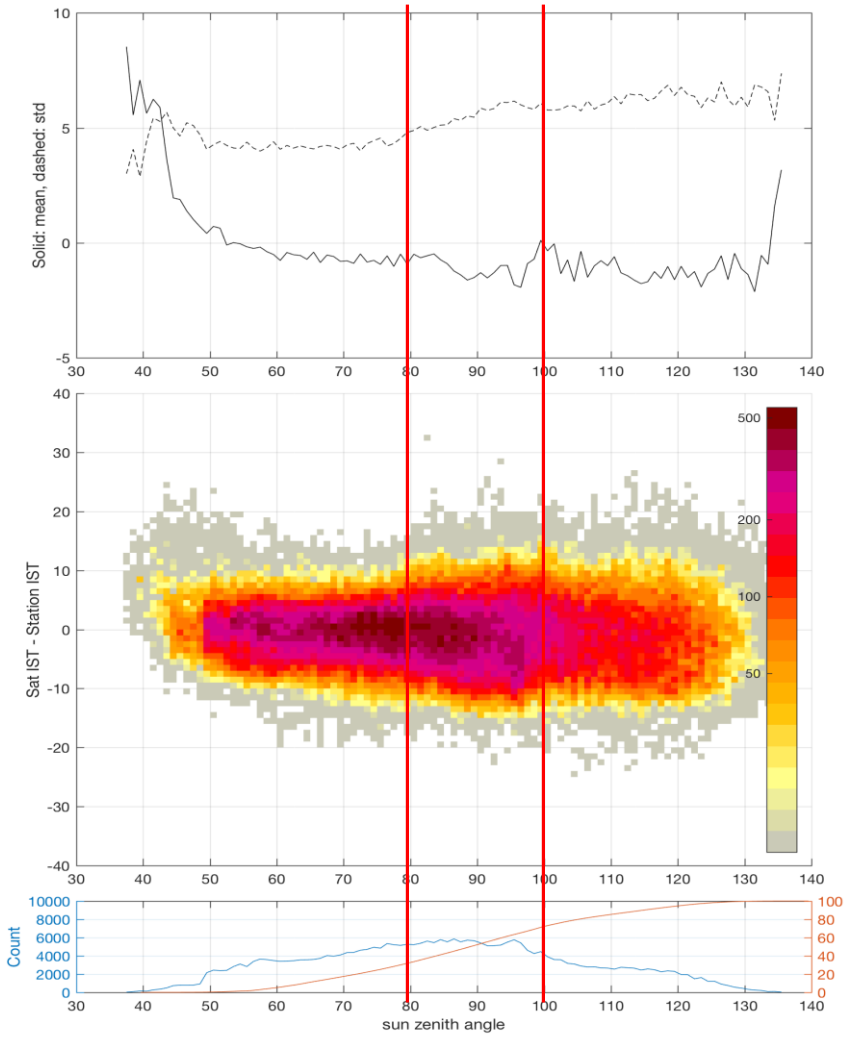
IASI IST – in situ IST

counts

IASI IST performance on Greenland land ice

– against Sun-Zenith angle; day/night

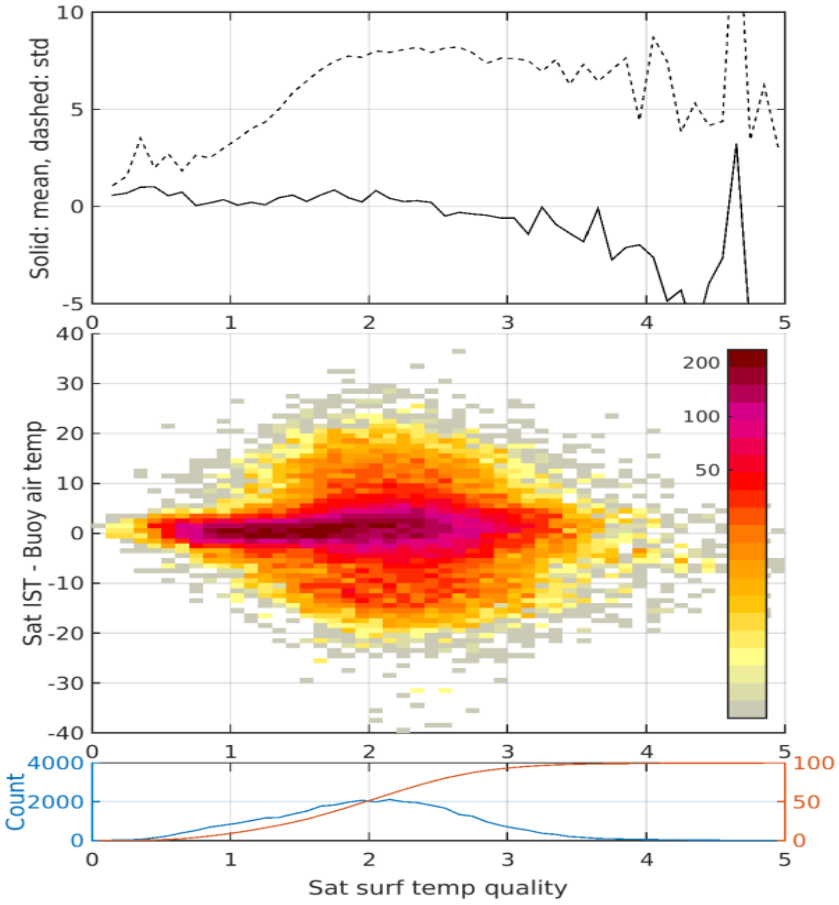
Performance is best during day light hours.



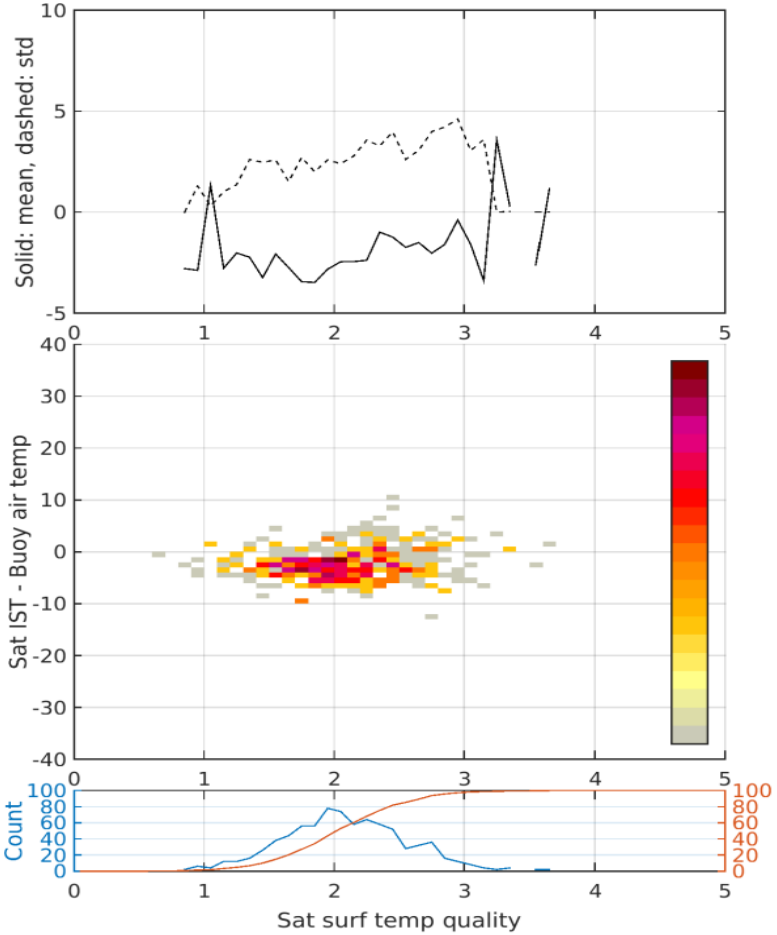
Performance on sea ice

- against IST quality indicator

Northern Hemisphere



Southern Hemisphere

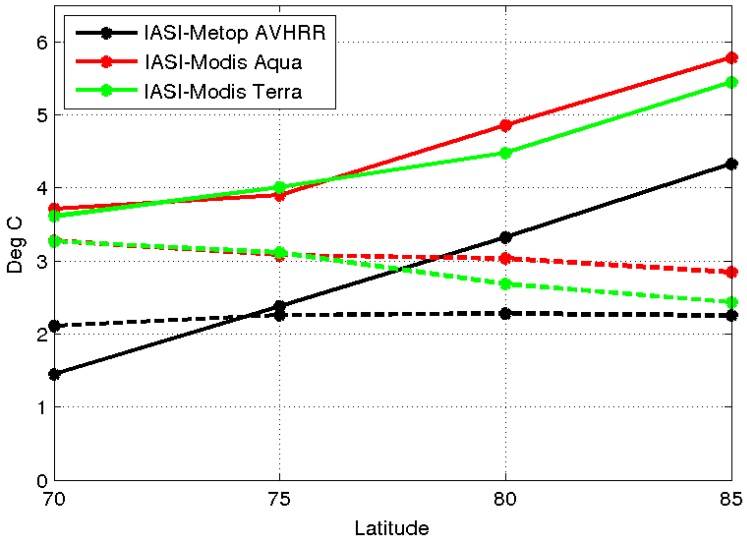


STD, Bias and distribution for IASI IST – Buoy air Temperature, as a function of IASI IST quality indicator.

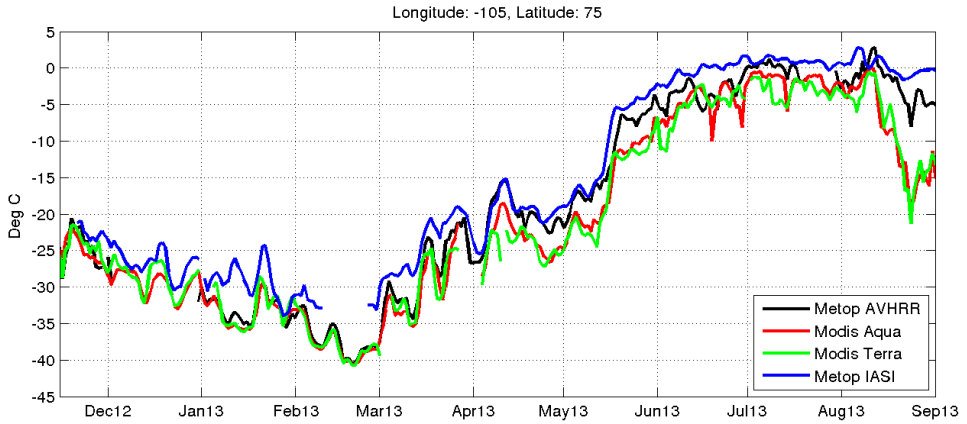
IASI IST vs other Satellite algorithms – level 3

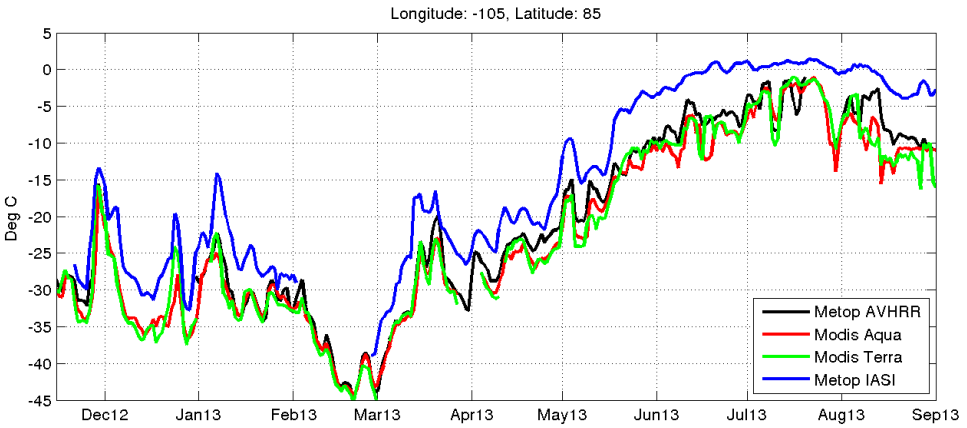
- Latitude dependency

IASI IST is warm biased against TIR IST
- increasing polewards



Latitudinal bias (solid) and standard deviation (dashed) of temperature differences, IASI minus other satellite L3 IR products





A new observation db

- OSISAF, EUSTACE, EUMETSAT

- A new uniform sea ice observation db for IST and ice drift validation.
- Data are gathered from all known one-off field campains and continous programs.
- All in situ data are converted to a uniform netCDF format, using CF conventions where possible
- Quality Control – 15 steps

FRM'ing traditional ice buoy measurements with Quality tests

1. Gross Error: The temperature is outside of the interval (−80, 20)
2. Spike Test Short: The absolute temperature difference from the median temperature of a 1 day rolling window is greater than 10 degrees
3. Spike Test Long: The absolute temperature difference from the median temperature of a 3 day rolling window is greater than 20 degrees
4. Buddy Check: The absolute difference from the median of a '500 km x 500 km x 1 day' bin, to which the temperature value belongs, is greater than 20 degrees
5. Neighbouring bins check: The rolling variance (using a 1 day time window) is greater than twice the mean variance of measurements from neighboring stations (i.e. those in the same '500 km x 500 km x 1 day' bin).
6. Age Check: The data-point is greater than 1 year from start date of file
7. Sea Ice Concentration test: The sea ice concentration is less than 30%
8. Temperature variability check: The series standard deviation in a 1 day window is less than 0.1 C
9. Speed test: The speed is greater than 0.5 m/s
10. Position Sanity: The absolute latitude is greater than 50 ◦ , or the longitude is 0 ◦ while the latitude is 90 ◦
11. Duplicates: There is another value with the same timestamp
12. Global tests applied: True for whole series if no global quality flags have been checked. Only if the check has been applied and ALL global tests were passed are ALL the 1s set to 0s
13. Has flag 5 been tested: The buddy check has not been applied. The flag is set for all points if not every point has been tested in test 5.
14. Gappiness: The interval between successive points is greater than 2.5 times the median interval
15. Close to land : The location of the measurement is less that 15 km from land
16. Very close to land: The location of the measurement is less that 5 km from land

PLANS for all IST products

- OSISAF OSI-205; Level-2
  - Adaption to METimager
  - Product bias correction using RTM
  - Further geographically stratified algorithm tuning
  - Testing and further development of probability data (of land, sea and ice)
  - Improve QC/QL
- Copernicus; Level-4
  - Improvements based on OSI-205 developments
  - (Southern Hemisphere…)
- AASTI CDR; Level-3
  - Version 2, based on CLARA version2 (climate saf)
  - Level 4 CDR
- Applying the new MUDB for sea ice surface temperatures