Towards traceability when validating satellite IST observations

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Outline

- Motivation
- Protocols
- FRM IST intercomparison experiment
    - Satellite validation
- Uncertainty budget
- Conclusions and way forward

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Motivation

- IST ranked 4 out of 22 parameters in SI CCI survey
- Several satellite products are available:
  - Metop
  - Modis
  - Viirs
  - AVHRR-GAC reanalysis
- In situ observations very difficult to use
  - Sparse
  - Representativeness effects often larger than product uncertainty
  - No SI traceability

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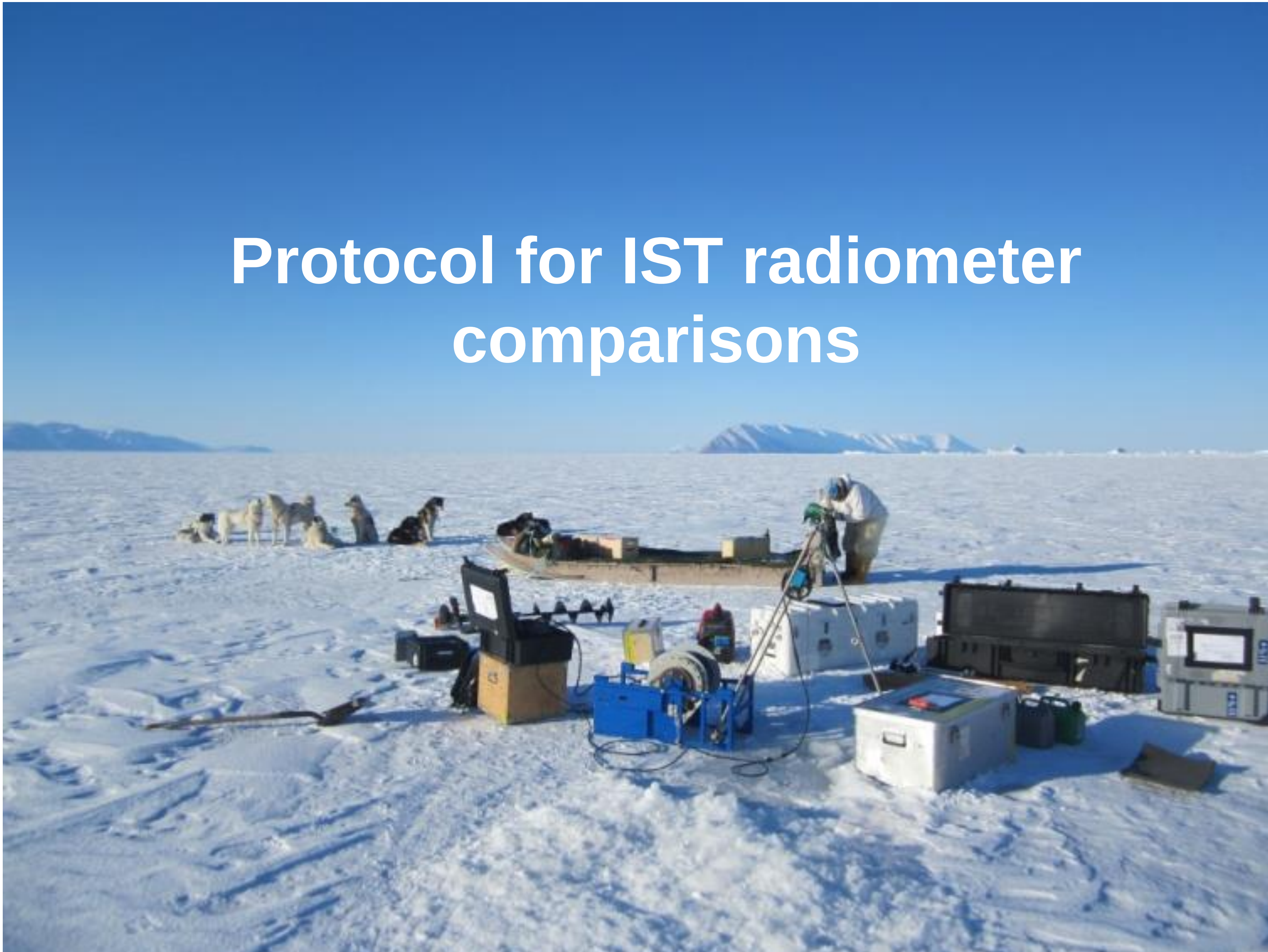
Protocol for IST radiometer comparisons



Protocol for IST radiometer comparisons

- Developed for the IST FICE
  - Guidelines for IST radiometer experiment
- General purpose experiment:
  - Can be used for other camaigns


Fiducial Reference Measurements for validation of Surface Temperature from Satellites (FRM4STS) – Ice Surface Temperature Comparison of Participants Radiometers

Technical Report 1
Protocol for the FRM4STS LCE (LCE-IP)

ESA Contract No. 4000113848_15I-LG

Jacob Hoyer

OCTOBER 2015

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Date of Issue	30 October 2015
Status	DRAFT

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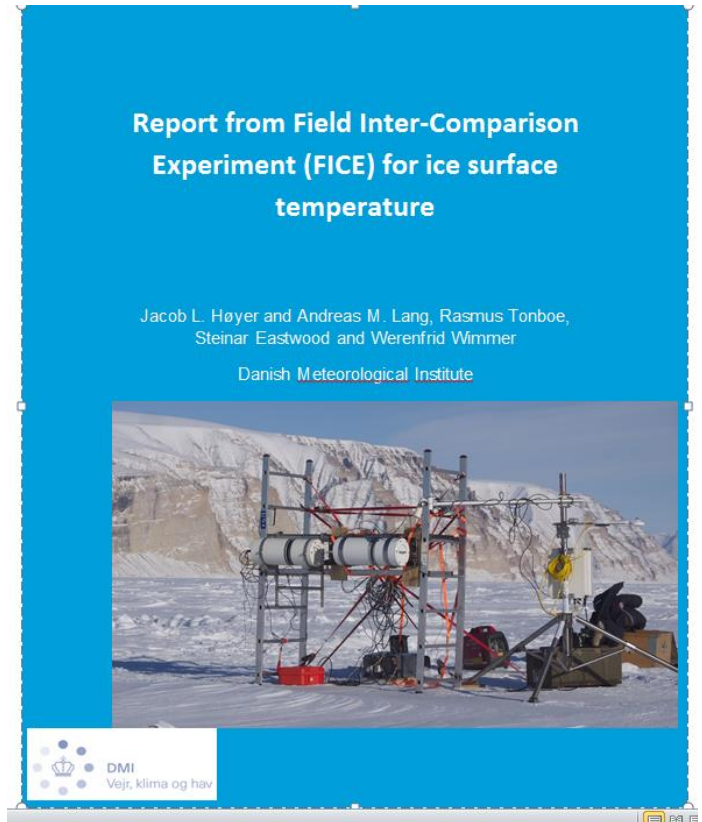
Field Inter-Comparison Experiment (FICE) for Ice surface- temperature


Report from Field Inter-Comparison Experiment (FICE) for ice surface temperature

Jacob L. Høyer and Andreas M. Lang, Rasmus Tonboe, Steinar Eastwood and Werenfrid Wimmer

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IST FICE introduction

- March 30 – April 7, 2016
- 3 research teams and 6 TIR radiometers
  - 2 x ISARs (DMI + NOCS)
  - 1 x KT 15.85II (DMI)
  - 3 x Cambell IR 120 (DMI + 2 Metno)
- All instruments mounted on sea ice for intercomparison
- Additional experiments:
  - Spatial variability
  - Freeze up experiment
  - Angular emissivity experiment

Site

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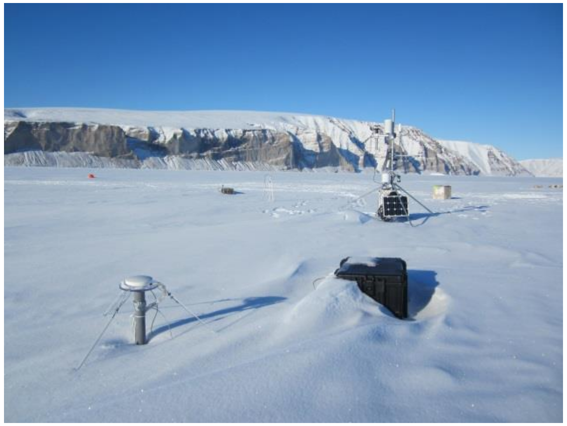
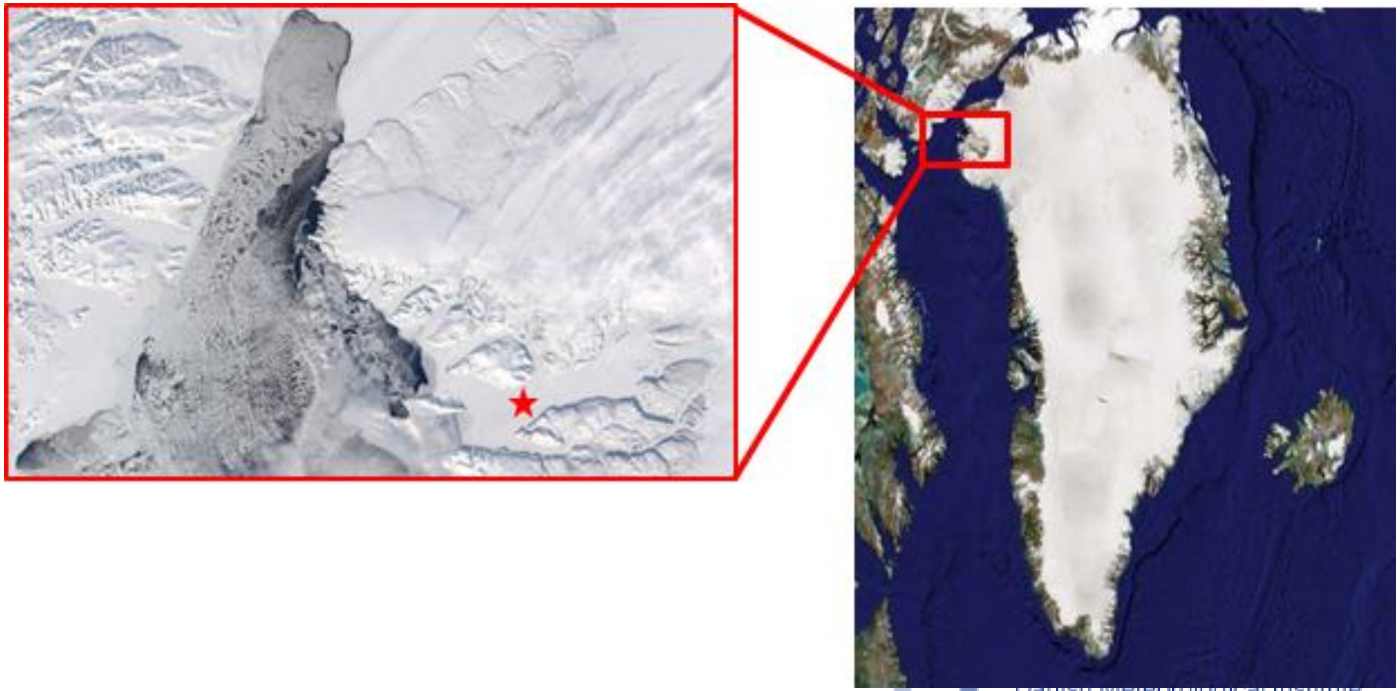
- *Inglefield Bredning, off Qaanaaq*
- *High Arctic environment*
- *1 meter of sea ice*
- *9 cm of snow*
- *4 km from the coast*
- *DMI field campaigns since 2011*





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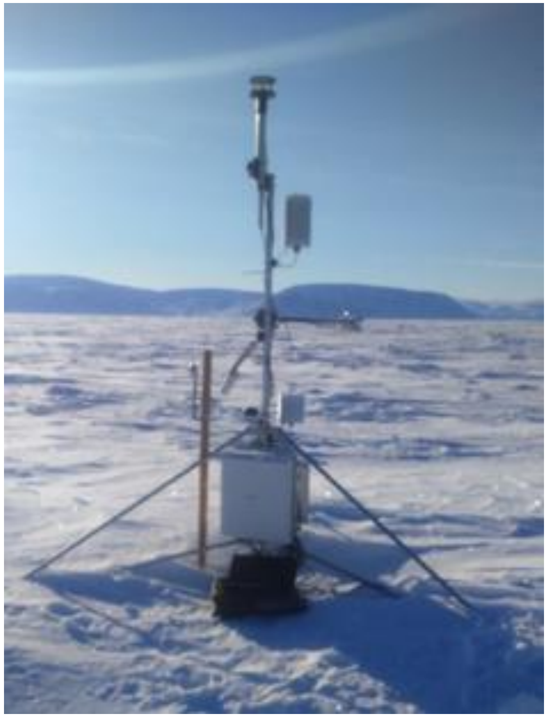
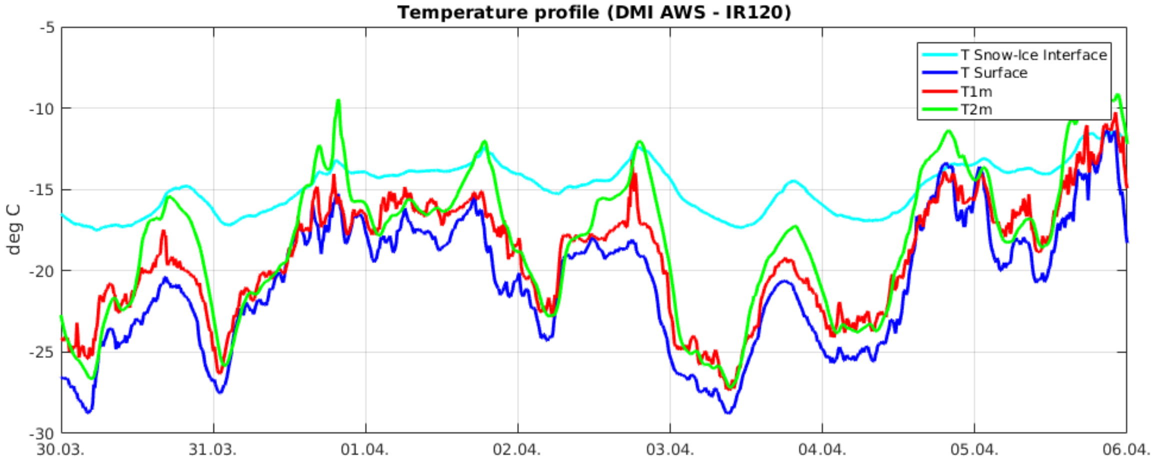
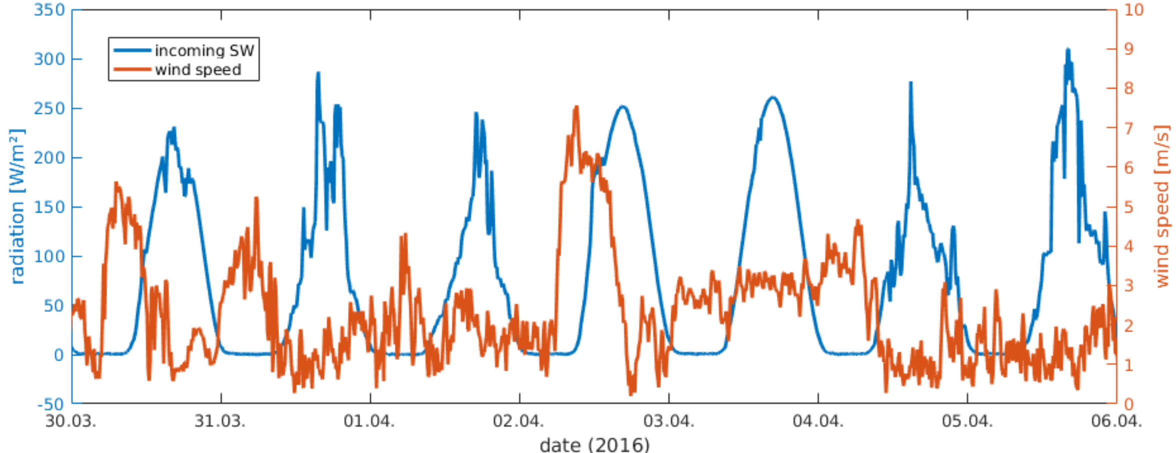
Weather conditions

- *Typical conditions for transition season:*
  - *Cold and calm*
- *Pronounced daily variation*
- *Uneven snow distribution*
- *Favourable conditions for field work*







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Instrumentation

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Radiometers	Institution	Ice sampling rate	Spectral range (μm)	Measured parameters
ISAR08	DMI	2-3 minutes	9.8-11.5	Radiometric IST/Sky temp
ISAR03	NOCS	2-3 minutes	9.8-11.5	Radiometric IST/Sky temp
KT15.85 II	DMI	1 sec	9.6-11.5	Radiometric IST
IR120 WS	METNO	1 min	8-14	Radiometric IST
IR120 CS	METNO	1 min	8-14	Radiometric IST
IR120 AWS	DMI	10 min	8-14	Radiometric IST
Other instruments				
DMI AWS	DMI	10 minute		-Wind -Radiation (short/long, in/out) -Humidity -T_{2m}, T_{1m}, $T_{snow/ice}$ - Radiometric IST (IR120, see top of table)
WS	METNO	1 min		-Radiation (long,in) - Radiometric IST (IR120, see top of table)
IMB	SAMS/DMI	2 hourly		Vertical Snow and Sea Ice temperature (every 2 cm)

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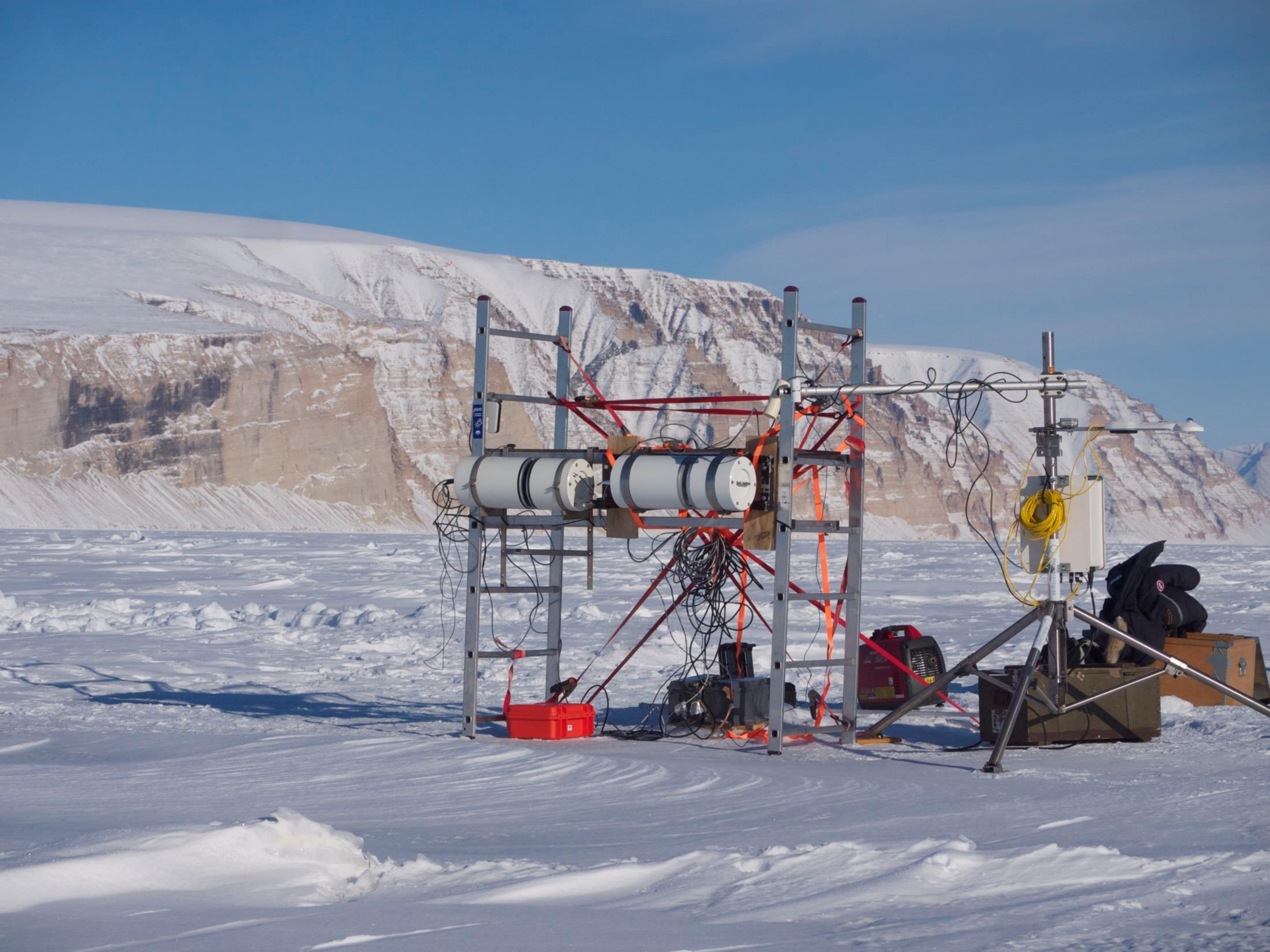

Intercomparison experiment

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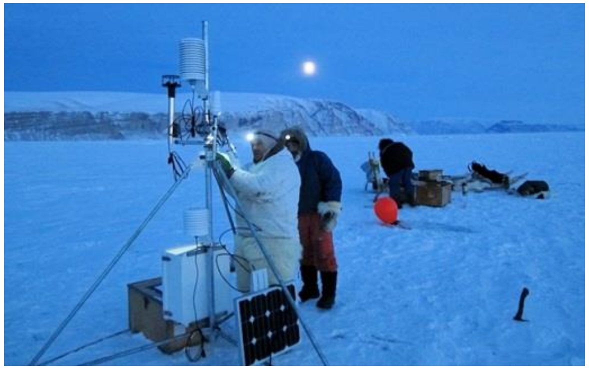
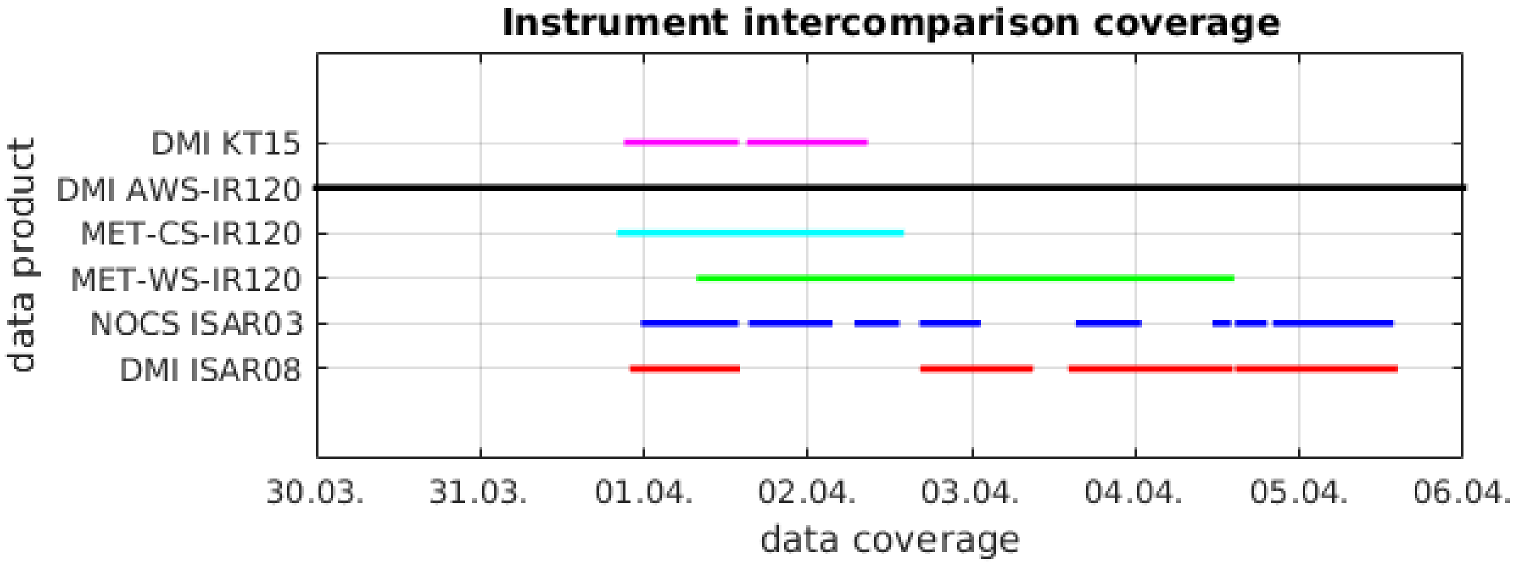
- All instruments worked during intercomparison experiment
- Cold conditions challenging for setup and instruments





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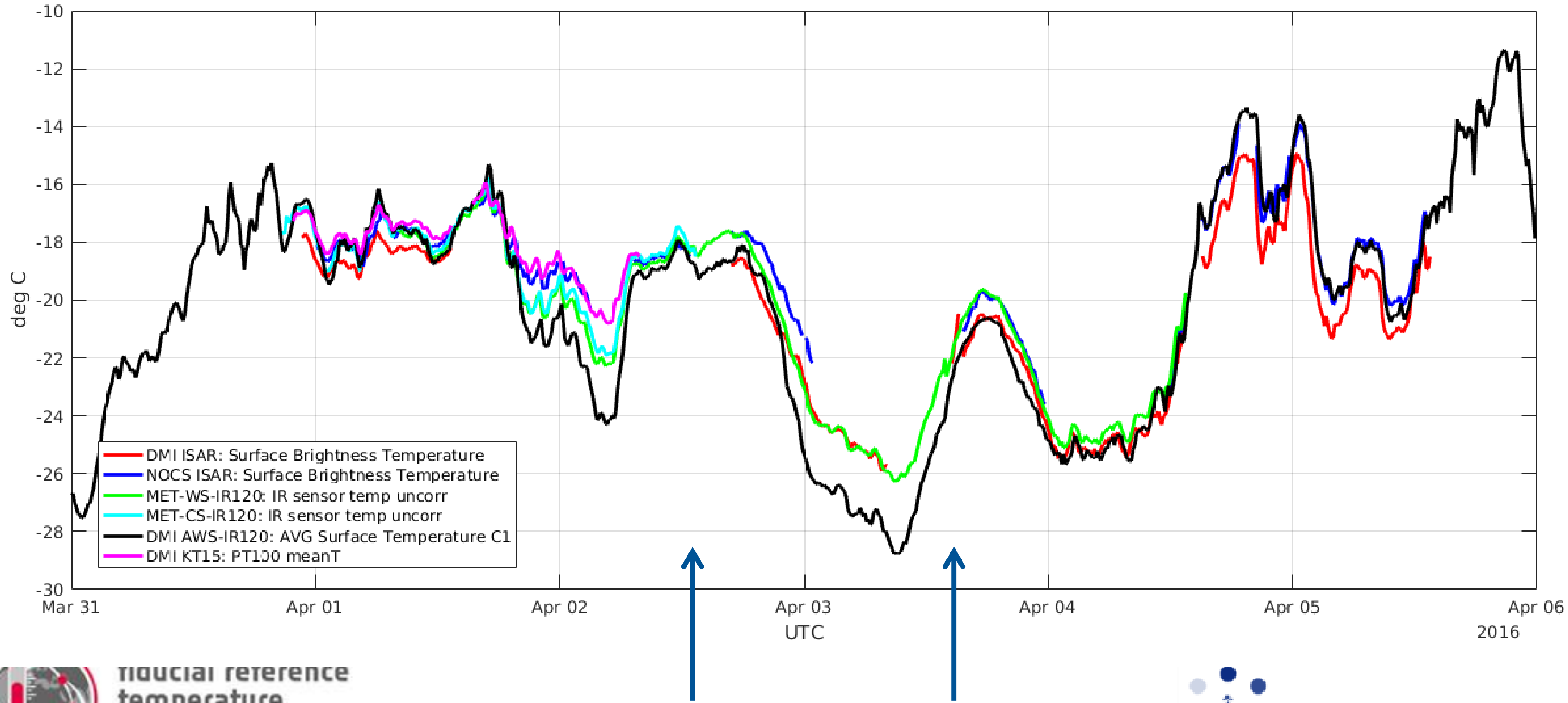
Radiometer results, Brightness temperatures

- Sampling intervals for different radiometers: 1Sec – 10 min
- DMI AWS placed about 40 meters away



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Pairwise intercomparison, Mean

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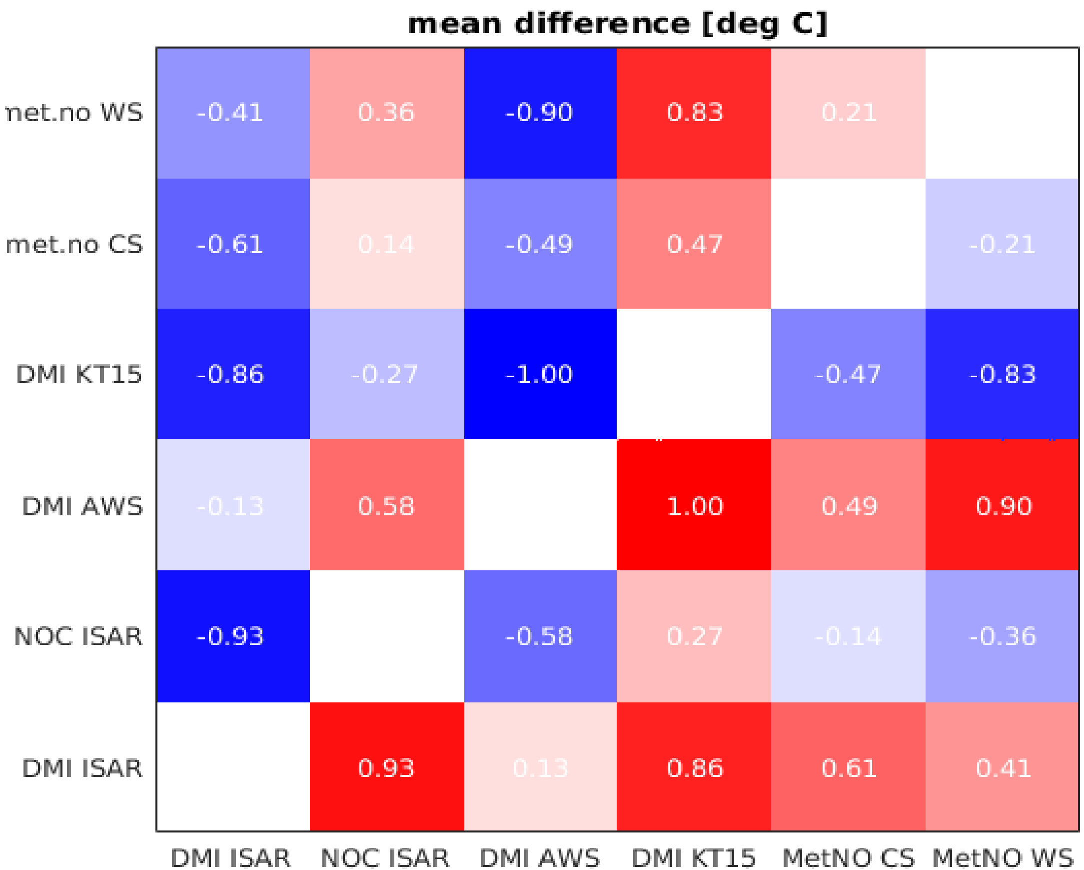
- Very different sampling intervals for different radiometers (1Sec – 10 min)
- For intercomparison, interpolated to minute observations and averaged every 10 minute



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Pairwise intercomparisons, stddev

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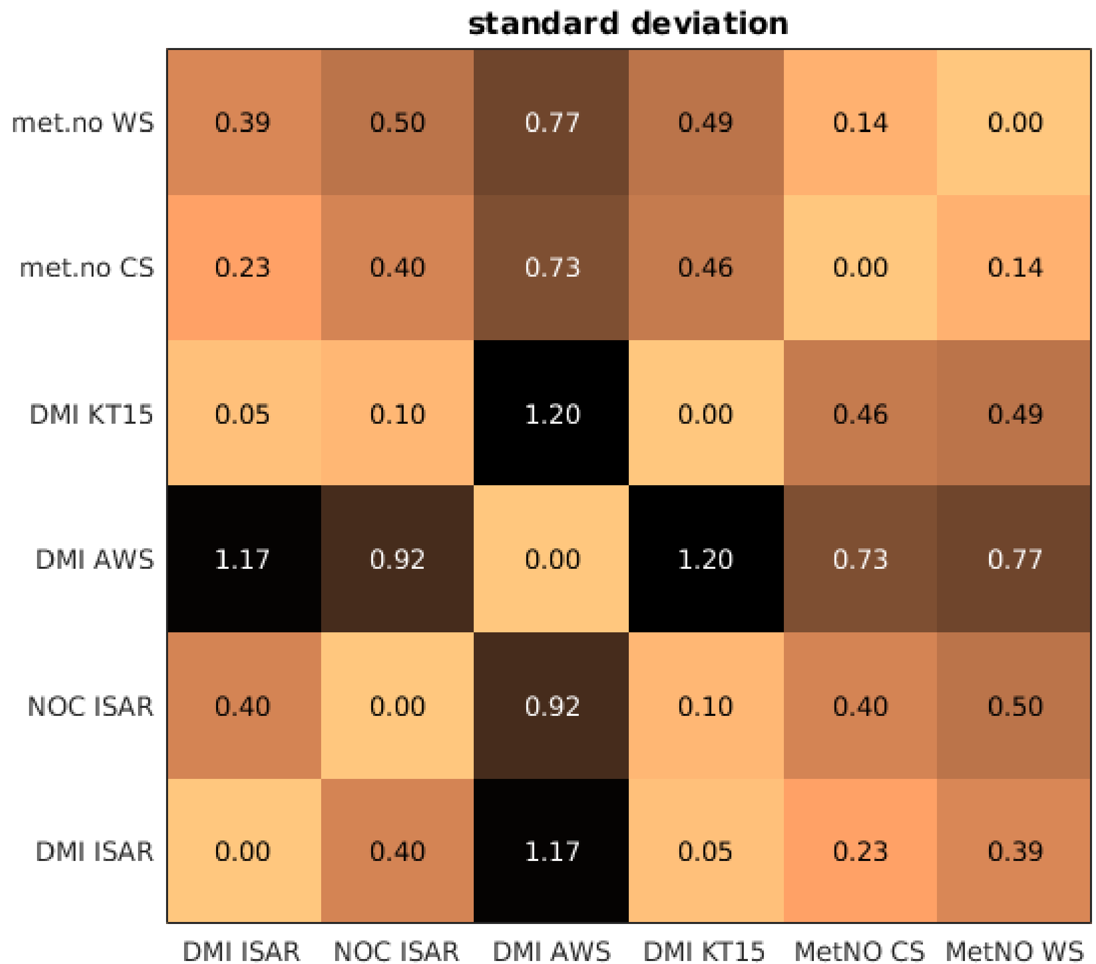
- AWS stands out due to 10 minute subsampling versus 10 minut averaging
- Stddev within 0.5 degrees C



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ISAR comparison

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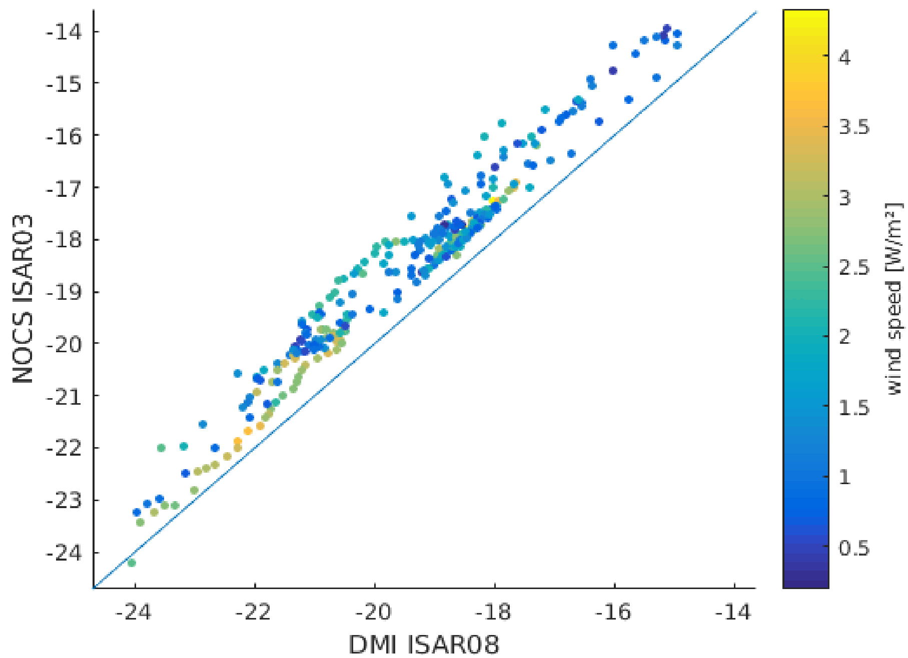
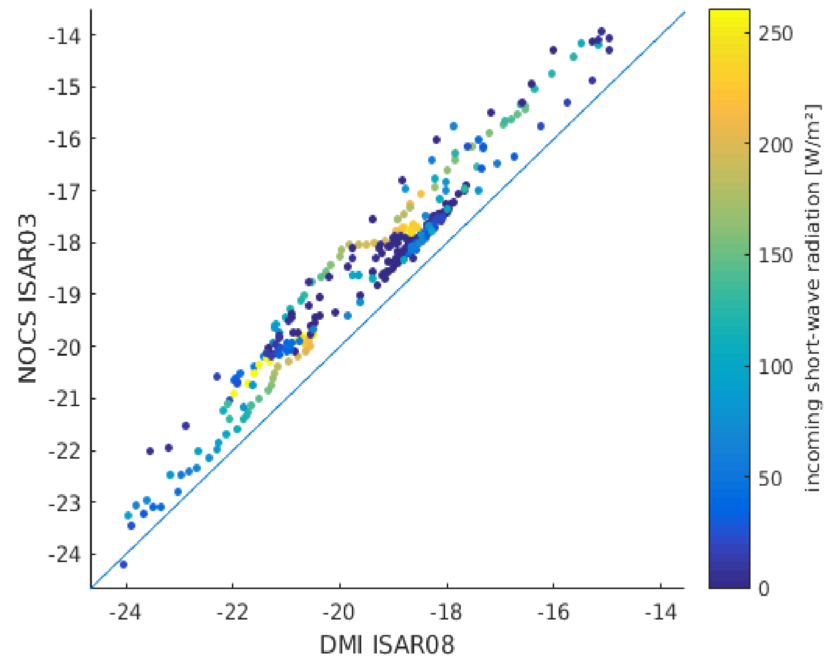
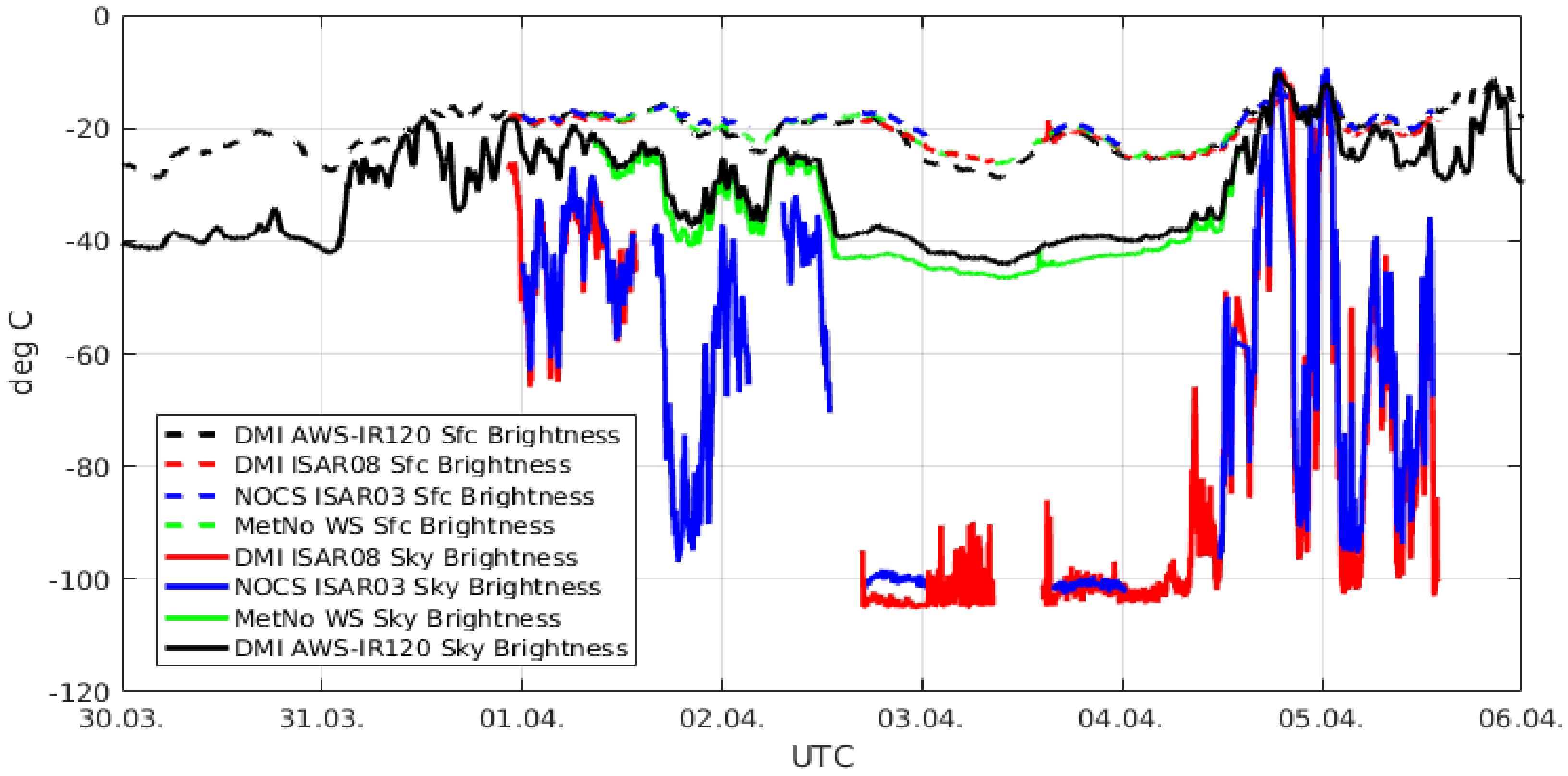
- No apparent dependencies on temperature, wind speed or insolation
- Differences might be due to: reference thermistor noise, window contamination effects and scan drum misalignment.





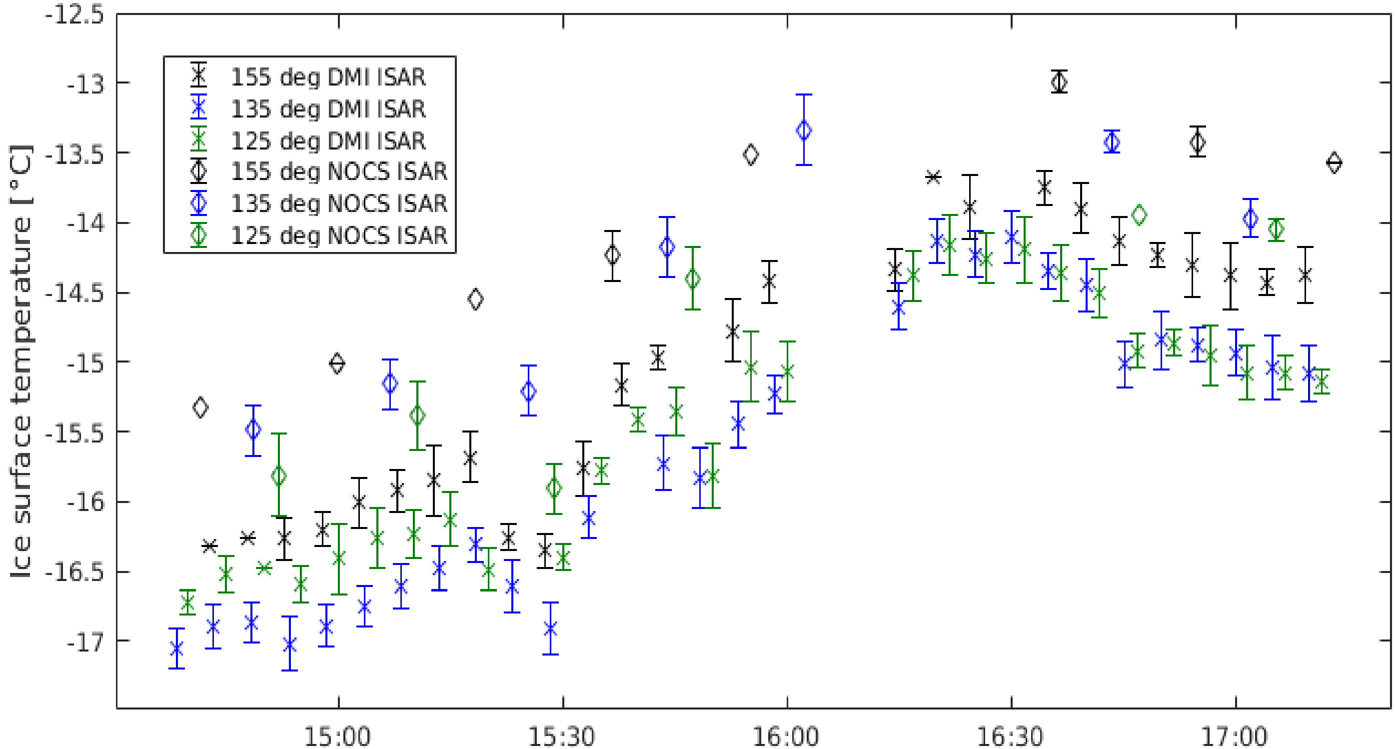
SKY TEMPERATURES

- Large variability
- Agreement between DMI and NOCS ISARs
- -100 ºC temperatures appears is the lower limit for KT15



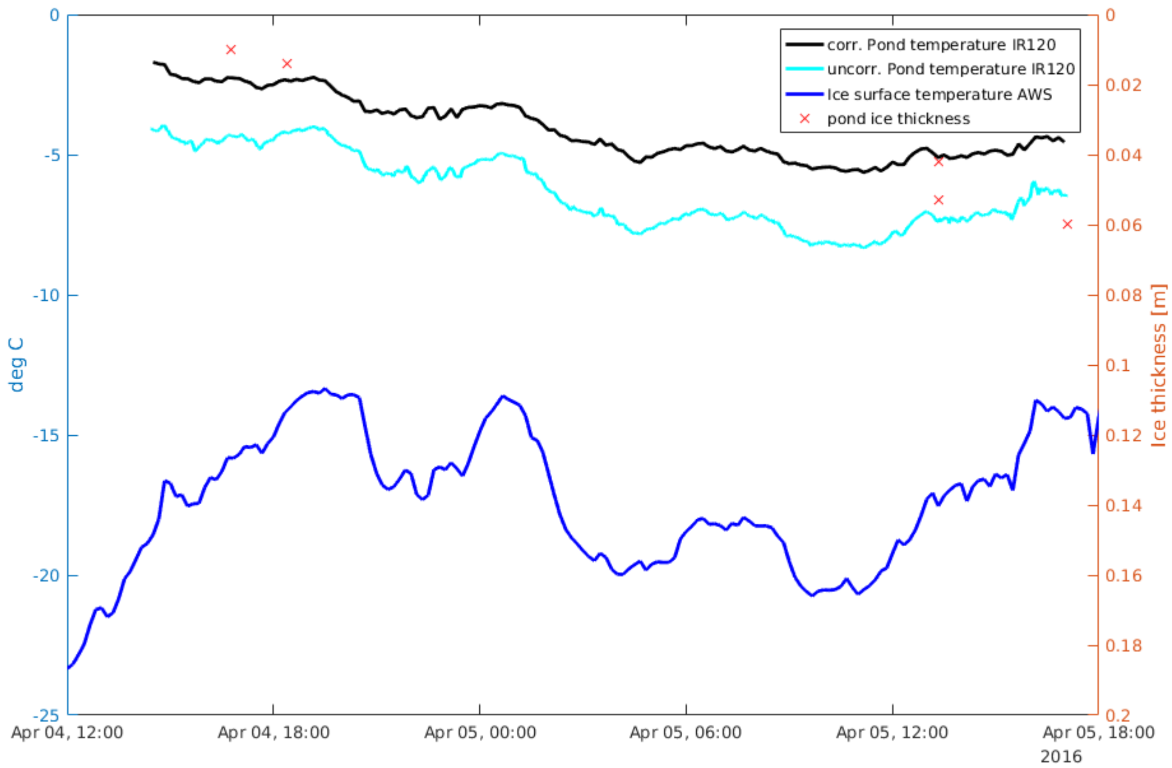
ANGULAR DEPENDENCY

- Brightness temperatures
- Angles from Zenith (25,45, 55 incident)
- TBs at 125° about 0.25-0.5°C colder than at 155°,
- Differences can be more than 1°C.



FREEZE UP EXPERIMENT

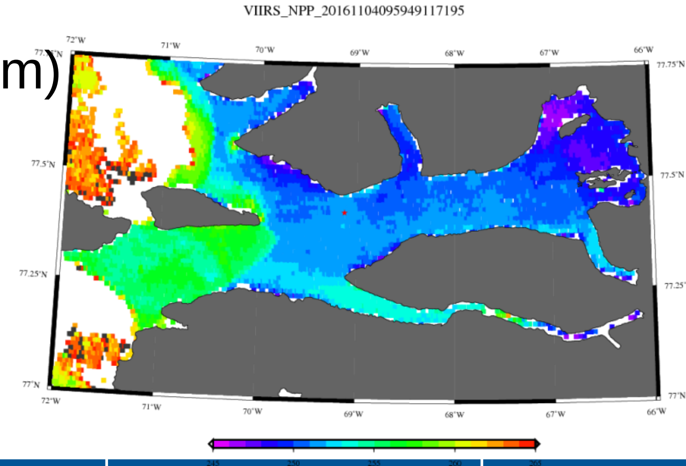
- First large hole filled over night
- New experiment last day
- One radiometer (MetNo)
- Smaller hole with ice contamination from sides



Example of validation of satellite IST with radiometer comparisons

SATELLITE VALIDATION

- Validated againt DMI TIR on AWS
  - 4.5 months (Jan-June, 2016)
  - Cambell Scientific IR120 (8-14 μm)
  - 10 minute observations



Satellite product	Spatial resolution	File granule	Data Provider
Metop_A AVHRR OSI 205	1.1 km	3 min	EUMETSAT OSI-SAF
NPP SUOMI VIIRS	750 m	5 min	NOAA
MODIS TERRA (MOD29.006)	1 km	5 min	NASA-GSFC
MODIS AQUA (MYD29.006)	1 km	5 min	NASA-GSFC

SATELLITE VALIDATION

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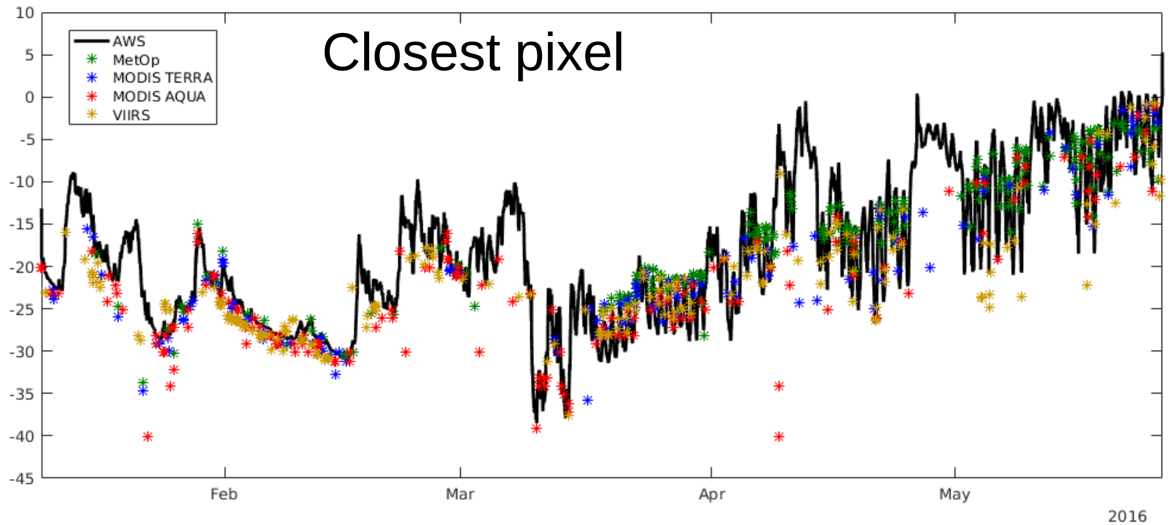
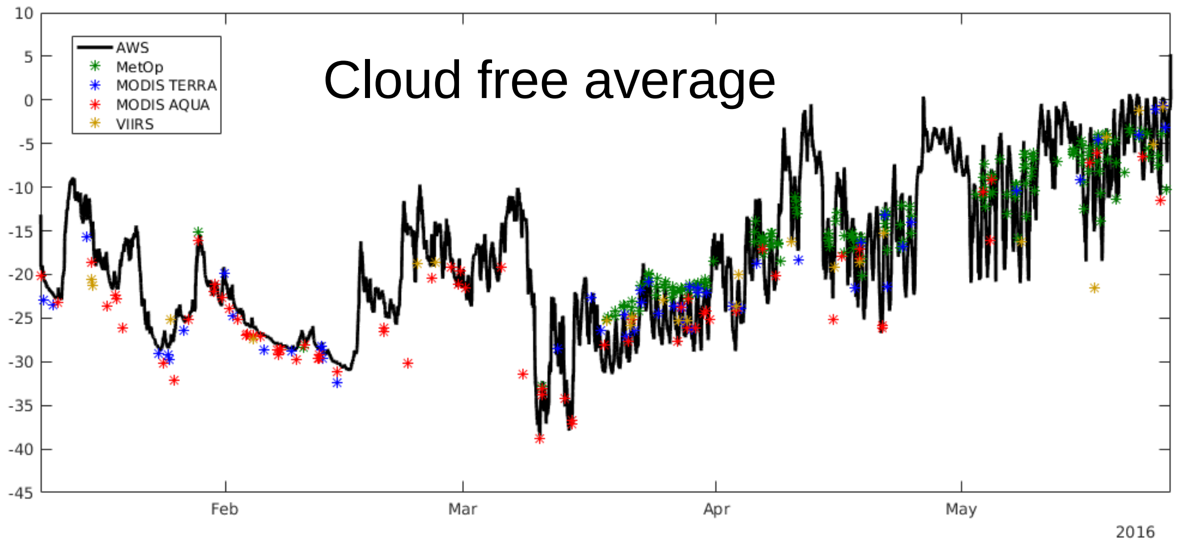
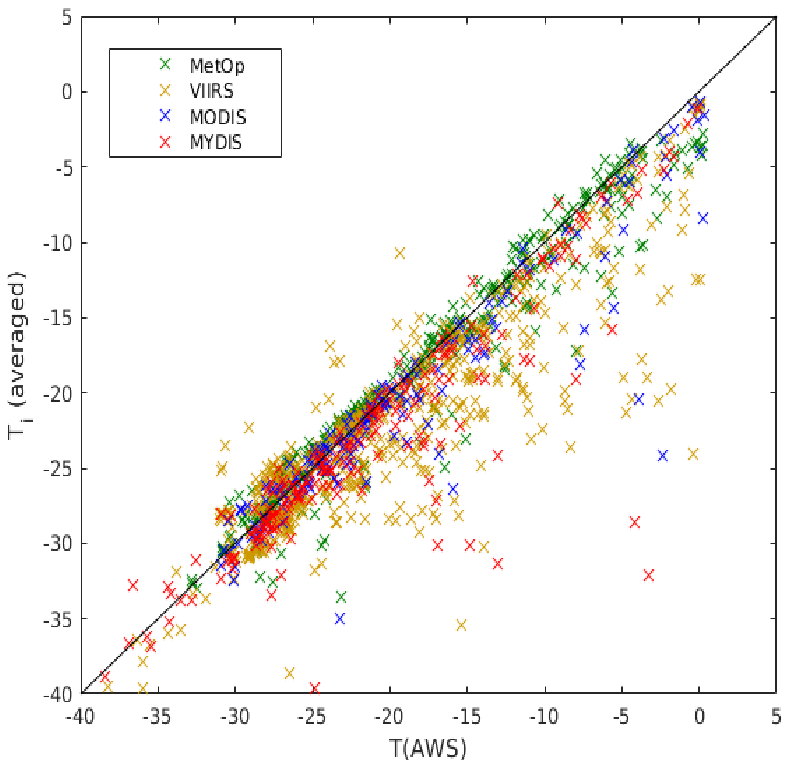
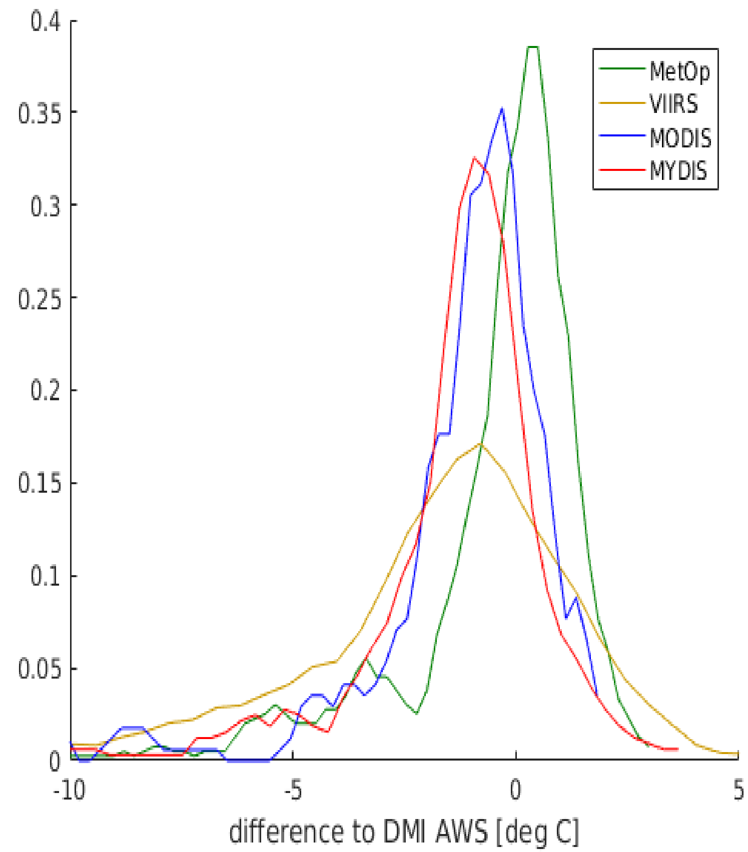
- Only best quality included
- Cold outliers in all products





SATELLITE VALIDATION





- Cold tail evident in all products
- OSI-SAF Metop AVHRR looks OK.
- VIIRS_NPP shows a broad peak.

EXAMPLES, WITHIN 3H14MIN

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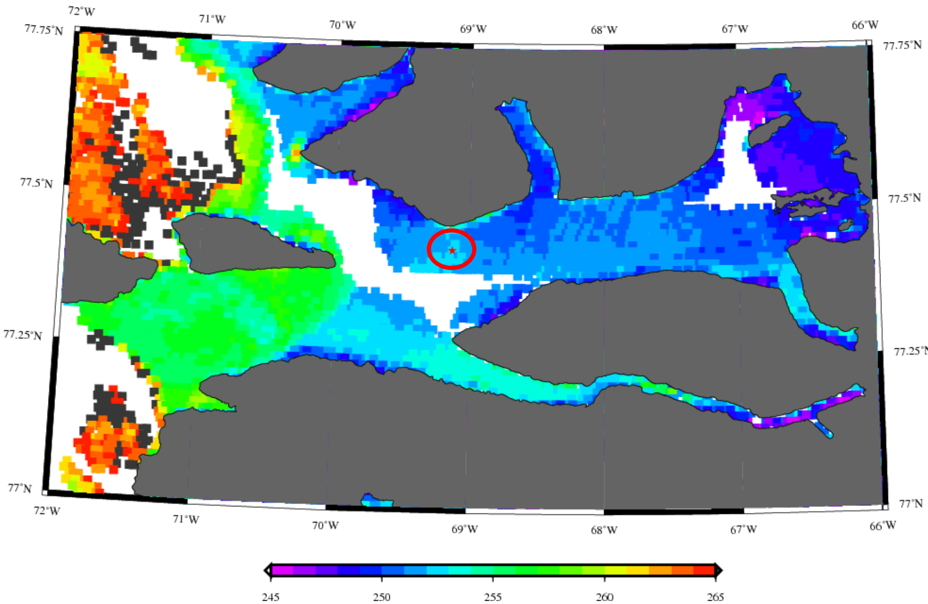
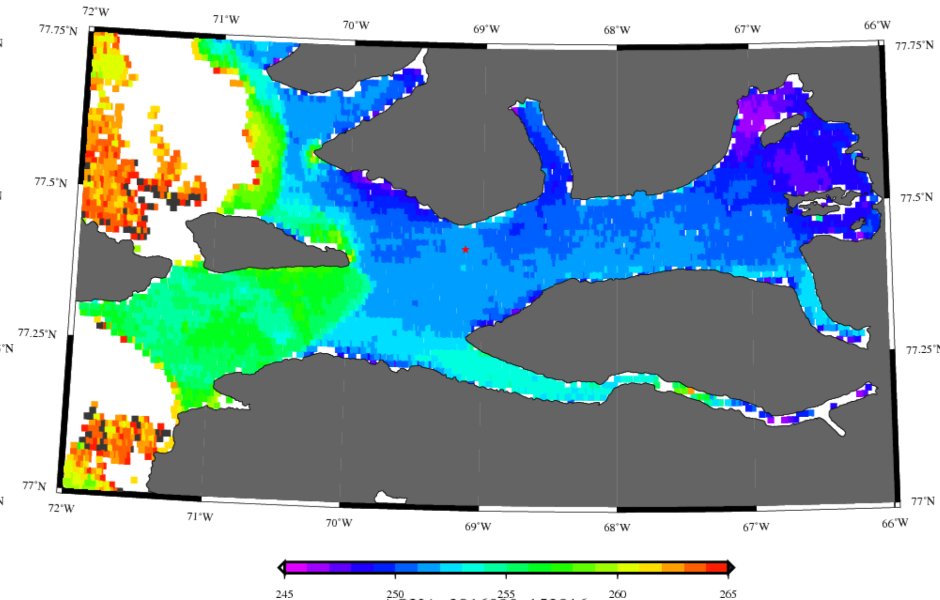
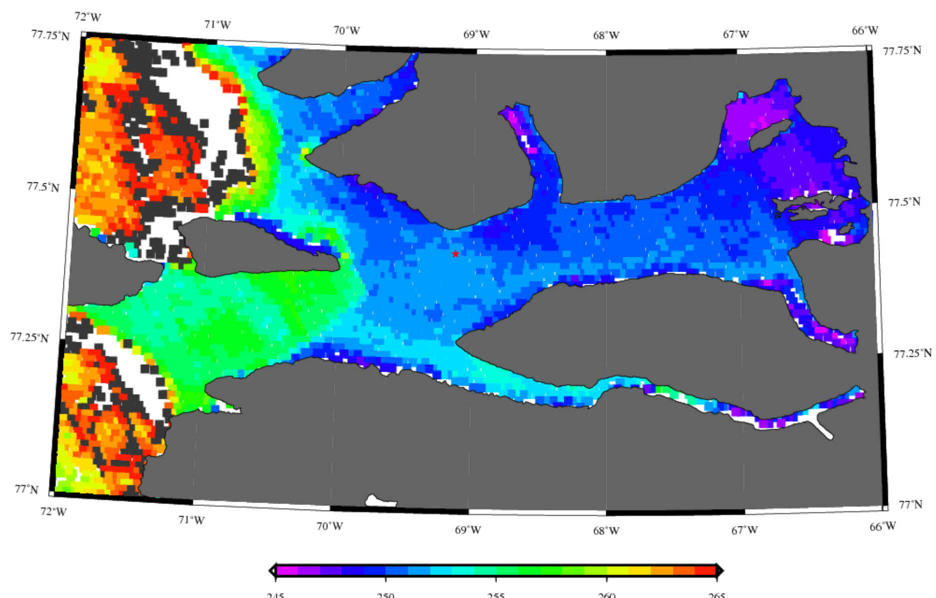
Metopa_20160329T154600–DMI–metopa



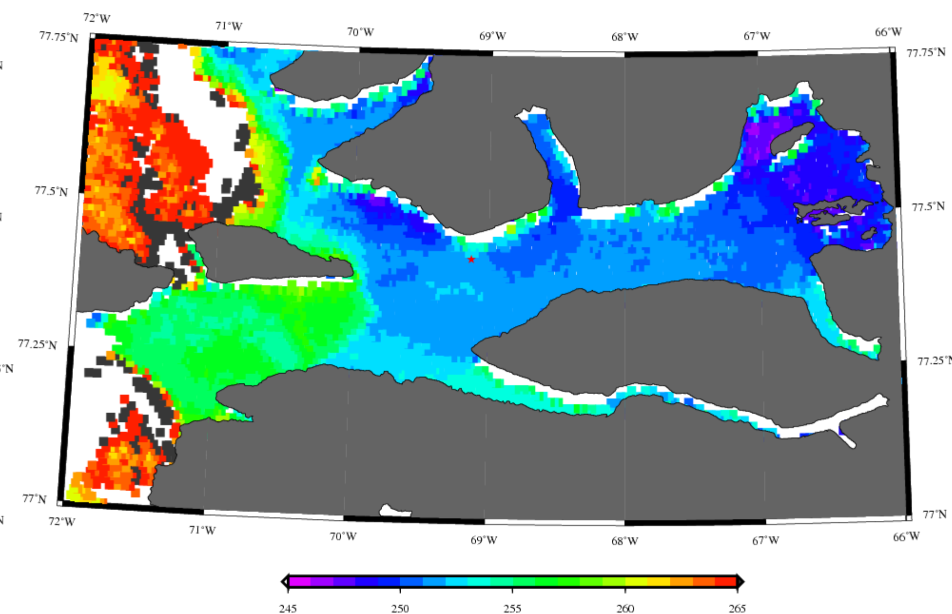
VIIRS_NPP_20161104095949117195



TERRA_2016102_153635



AQUA_2016090_152816



SATELLITE VALIDATION

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

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

Uncertainty budget for traditional in situ IST observations

Motivation

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- Operational satellite products require operational in situ observations for monitoring and validation.
- iSVP Buoy observations available from IABP through GTS

- **Task: How can we best use the GTS observations for satellite validation ?**
  - Deploy iSVP buoys
    - Perform inter-comparison of iSVP observations
  - Assess the different uncertainty components when validating satellite IST
    - Automatic QC procedures to identify representative observations

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Satellite vs. In situ

- Differences include:
  - Uncertainty on iSVP sensor
  - Uncertainty on satellite IST product
  - Spatial difference (footprint vs. point)
  - Temporal difference
  - Vertical difference (skin vs. snow, 1m or 2m air temp)

Spatial Variability

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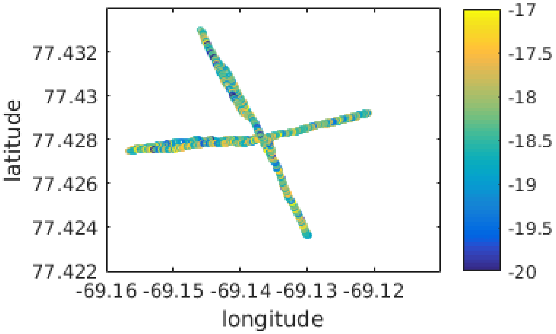
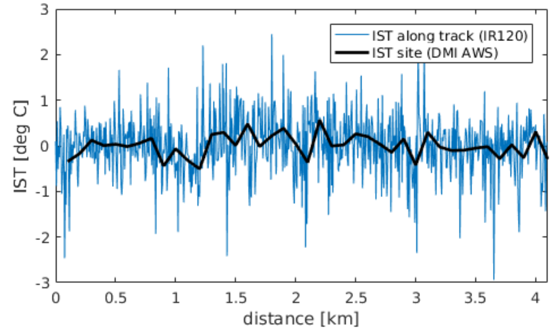
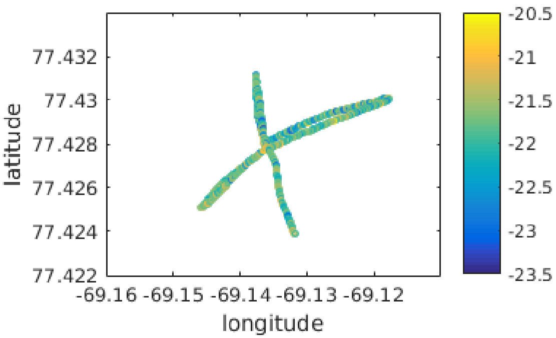
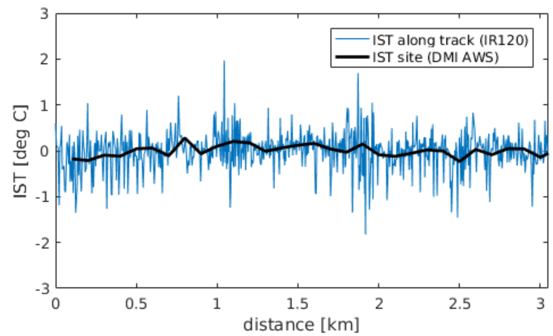




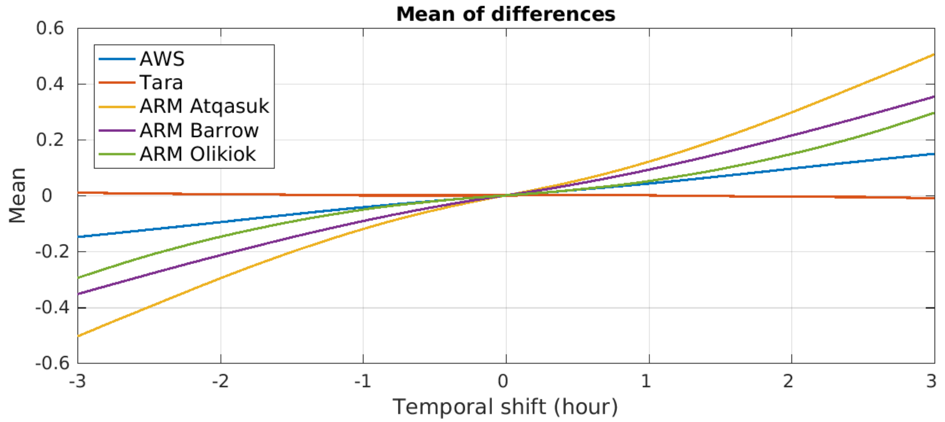


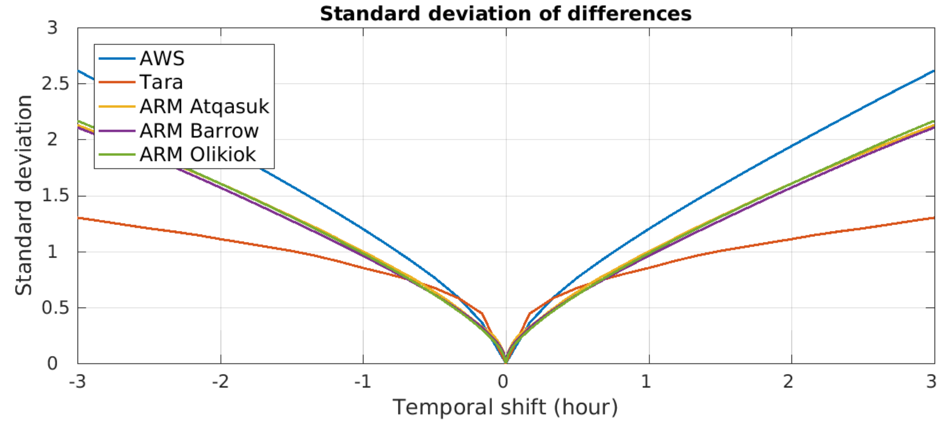


	N(obs)	Distance	Duration	Stdv (σ)	Bias to AWS	Spatial stdv
Part 1 (Apr-02)	718	4.08 km	00:59:45	0.69 °C	-0.01 °C	0.25 °C
Part 2 (Apr-03)	709	3.04 km	00:59:00	0.42 °C	0.50 °C	0.12 °C

Temporal difference

- Large hourly variability, compared to SST
- Three years of AWS data, + Tara + ARMS data





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Vertical difference

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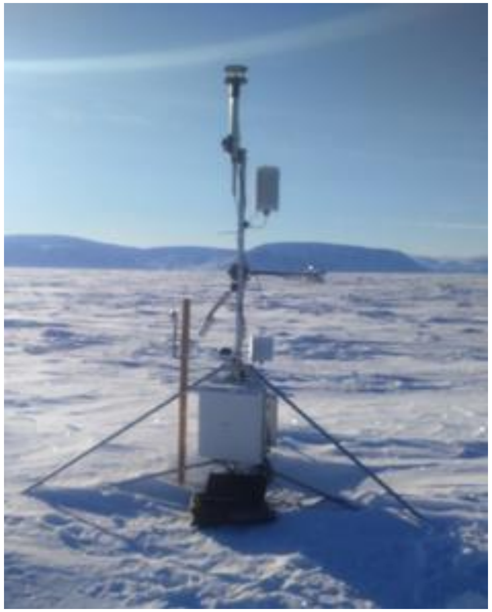
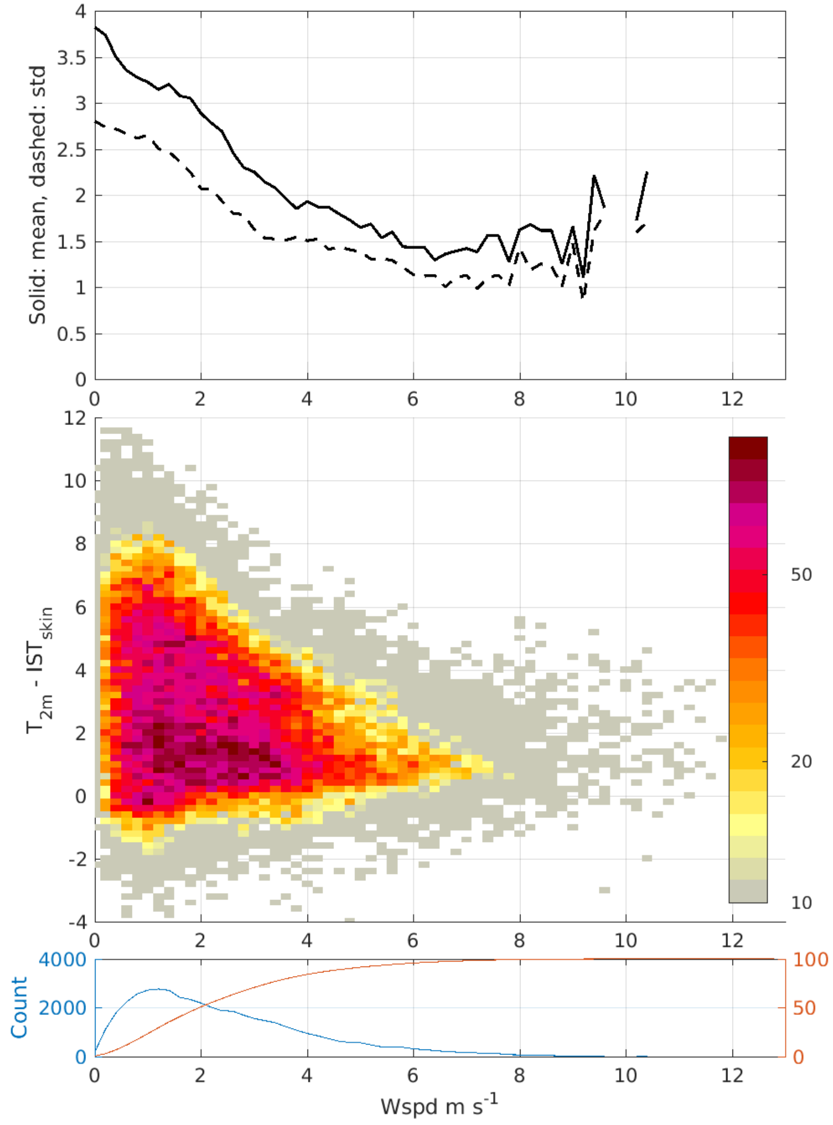
- AWS Qaanaaq, 2015-2017
  - T2m - Tskin
  - Large wind speed dependency





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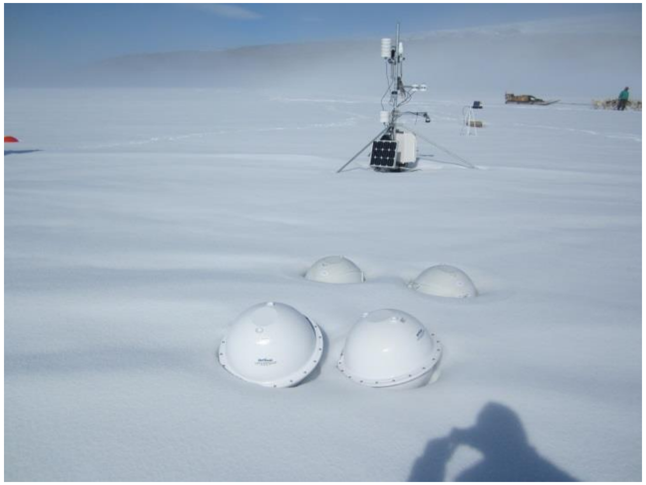
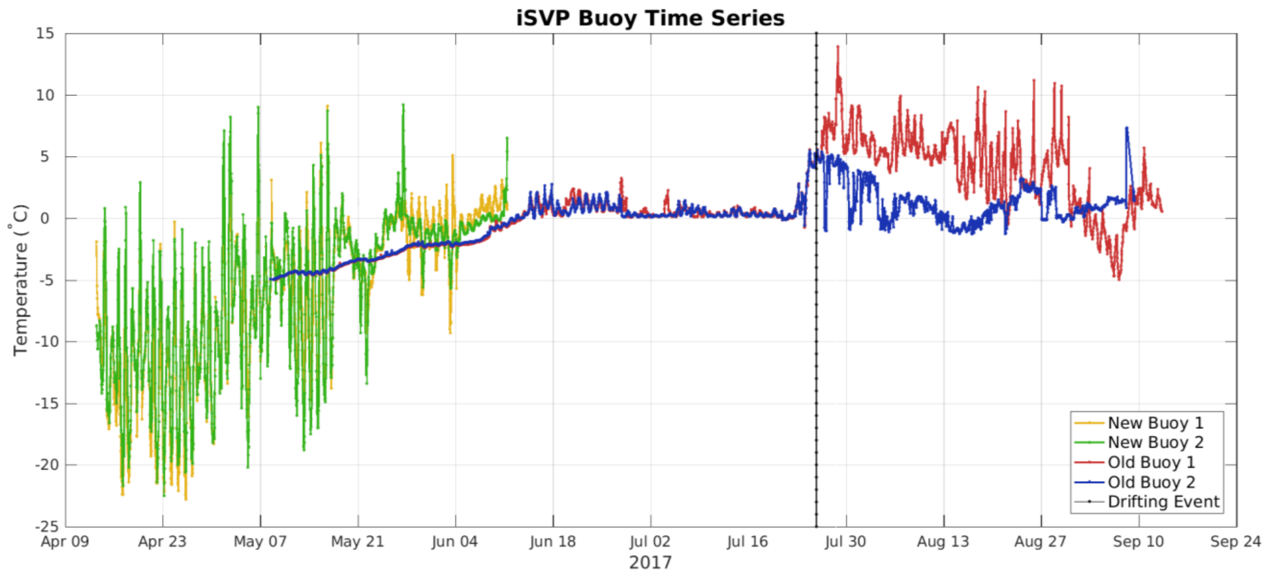
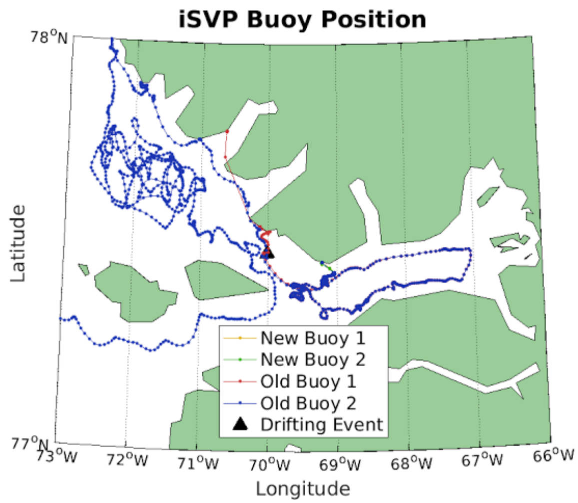
iSVP buoys

- Two iSVP buoys deployed in January 2017, at AWS site
- Wrong software, reporting -5ºC !
- Two new deployed in April, 2017
- New buoys recovered in June
- Old buoys left on ice -> ocean







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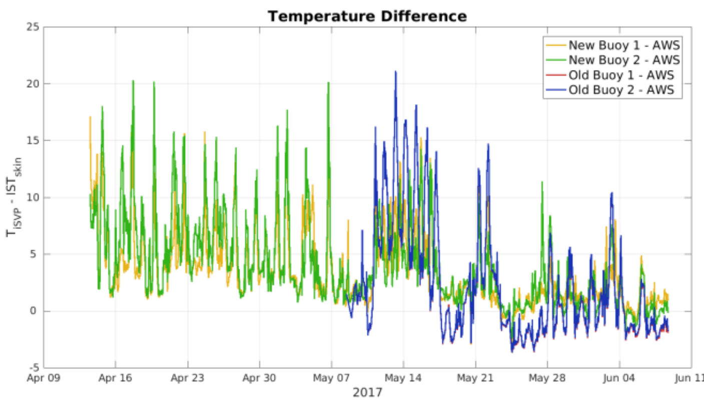
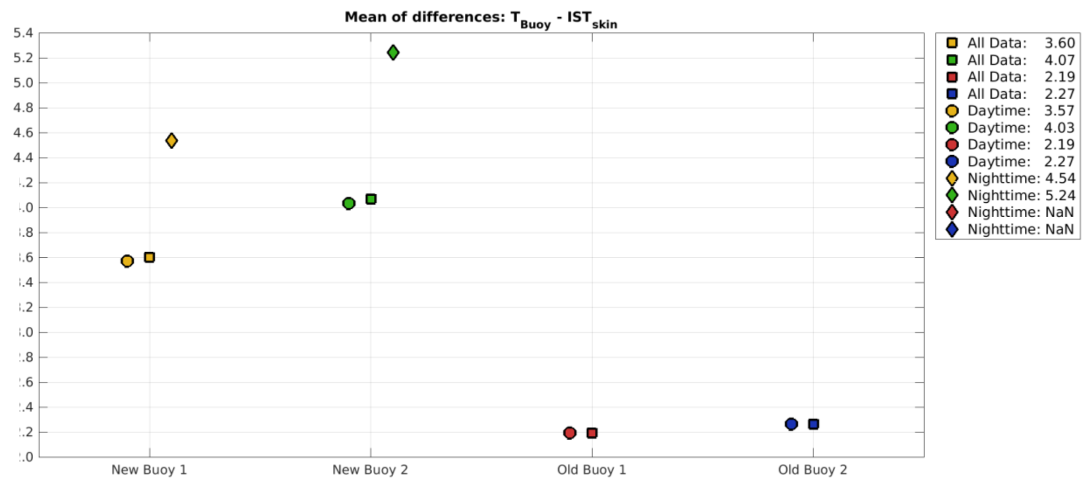
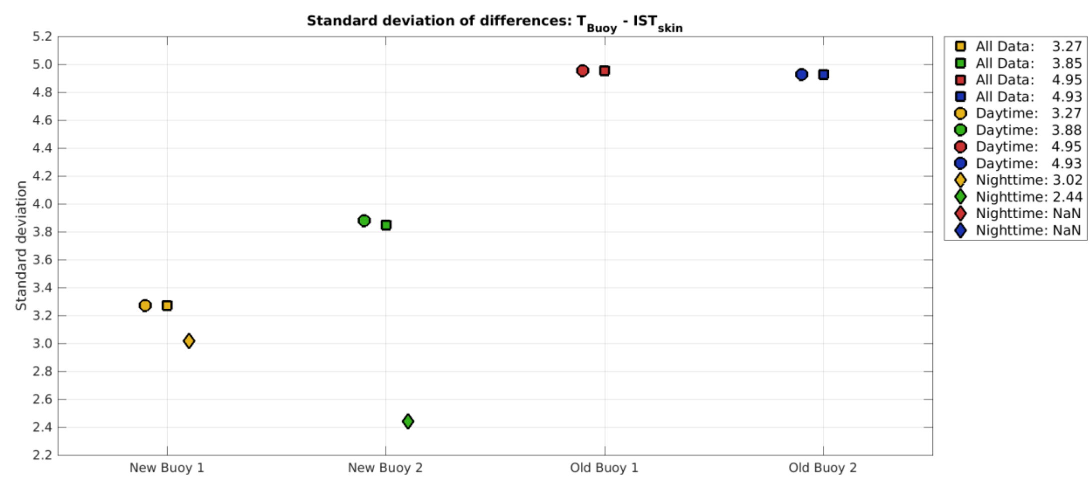
Buoy inter-comparison with AWS

- Buoys 2-4 degrees warmer than IST
- Stddev 3-5 degrees, lowest for new buoys







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CONCLUSIONS

- A successfull pilot IST FICE conducted
- Challenging environmental conditions
- Mean radiometer differences between 0.21 and 1 ^{o}C
- Satellite validation against TIR:
    - All products have diffuculties detecting the clouds
    - Metop_A had highest data return and showed best performance

- iSVP buoys within 1 meters showed up to 20 degrees C difference
- Sampling effects much larger than algorithm effects

- Effect of angular dependency: 0.25-0.5^{o}C

- FICE report available, paper in preparation

Way forward

- Repeat campaign:
  - Additional FRM TIR calibration experiments in cold conditions
  - Spatial variability experiment with drones
  - Freeze-up experiment with larger basin
  - Measurement of surface emissivity

- Uncertainties on FRM TIRs should be evaluated
- Need for an all-year maintained TIR FRM radiometer at, e.g. Summit
- Systematic intercomparison of all satellite IST products (SNOs)

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