ships4sst

shipborne radiometers for sea surface temperature

Radiometer Uncertainty Models

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Space ConneXions

Overview

- Uncertainty
- The ISAR model
  - Principle design
  - Estimating values
  - Some results
- Validation of uncertainty models
  - QM2 with SISTeR
  - AMT two ISAR's
- A updated model – ISAR UC v2
- Conclusions

Uncertainty

When reporting the result of a measurement of a physical quantity, it is obligatory that some **quantitative indication of the quality** of the result be given so that those who use it can assess its reliability. Without such an indication, measurement results cannot be compared, either among themselves or with reference values given in a specification or standard. It is therefore necessary that there be a readily implemented, easily understood, and generally accepted procedure for characterizing the quality of a result of a measurement, that is, for evaluating and expressing its uncertainty.

Evaluation of measurement data — Guide to the expression of uncertainty in measurement

Uncertainty

Classic

- Adding all uncertainties in quadrature

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 + .. + \sigma_n^2}$$

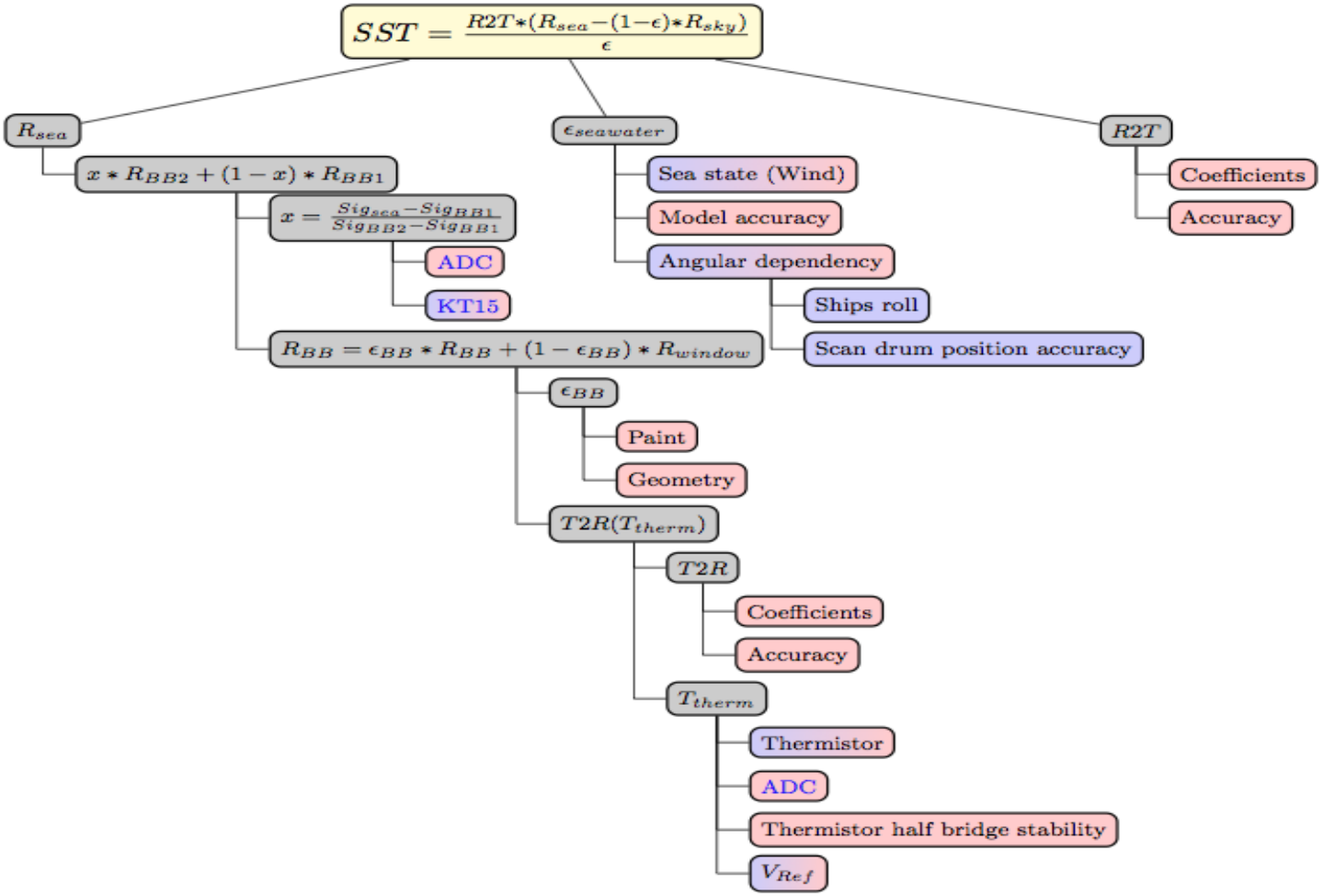
  Self calibrating radiometer

- Measurement equation

$$SST = \frac{R2T * \left(R_{sea} - (1-\epsilon)R_{sky}\right)}{\epsilon}$$

BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML. Guide to the Expression of Uncertainty in Measurement. International Organization for Standardization, Geneva. ISBN 92-67-10188-9, First Edition 1993, corrected and reprinted 1995. (BSI Equivalent: BSI PD 6461: 1995, Vocabulary of Metrology, Part 3. Guide to the Expression of Uncertainty in Measurement. British Standards Institution, London.)

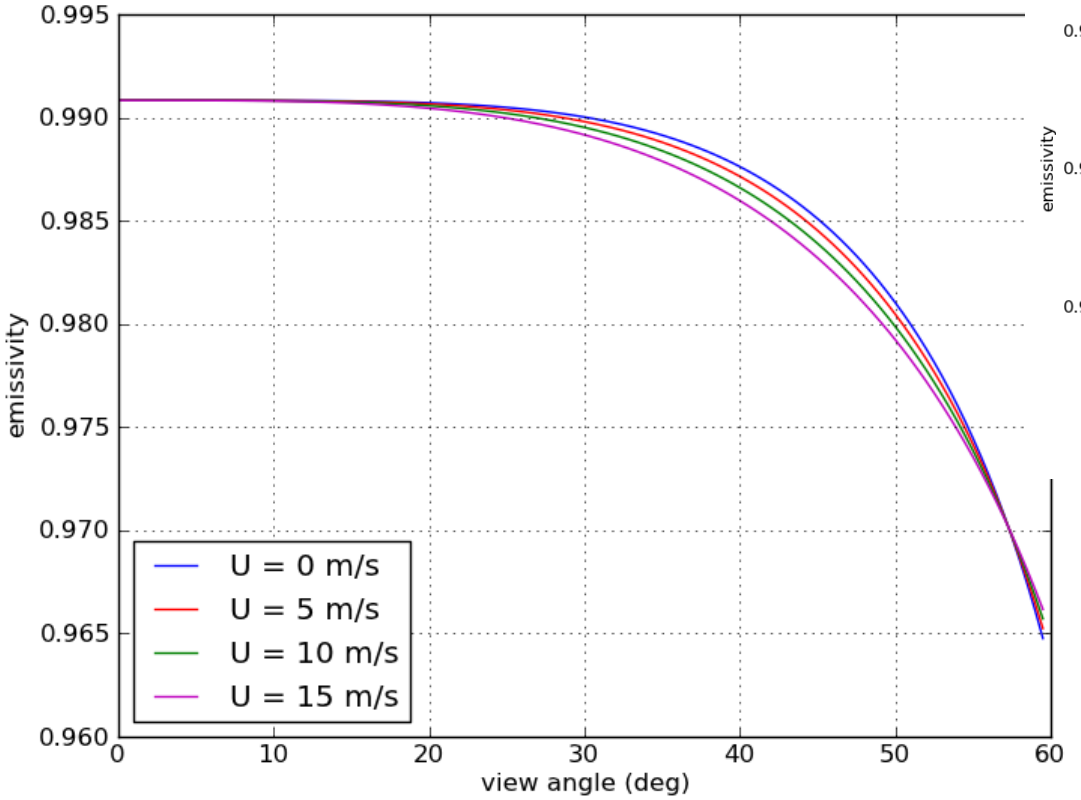
Uncertainty – radiometers

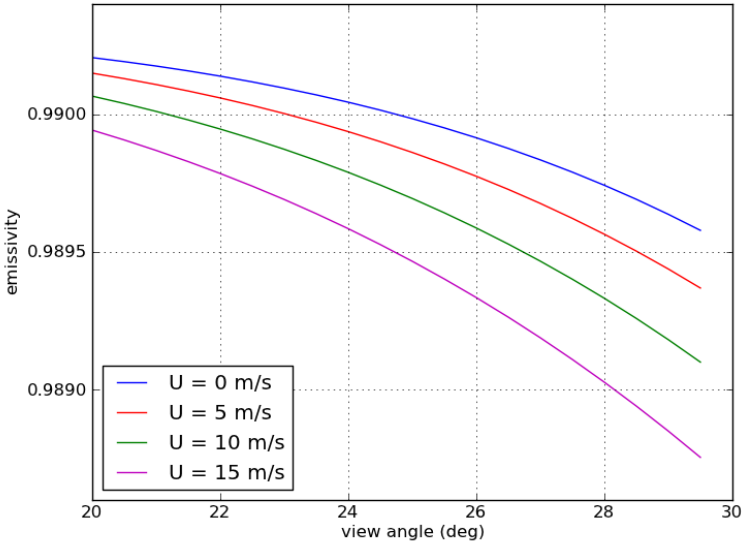


Uncertainty – values

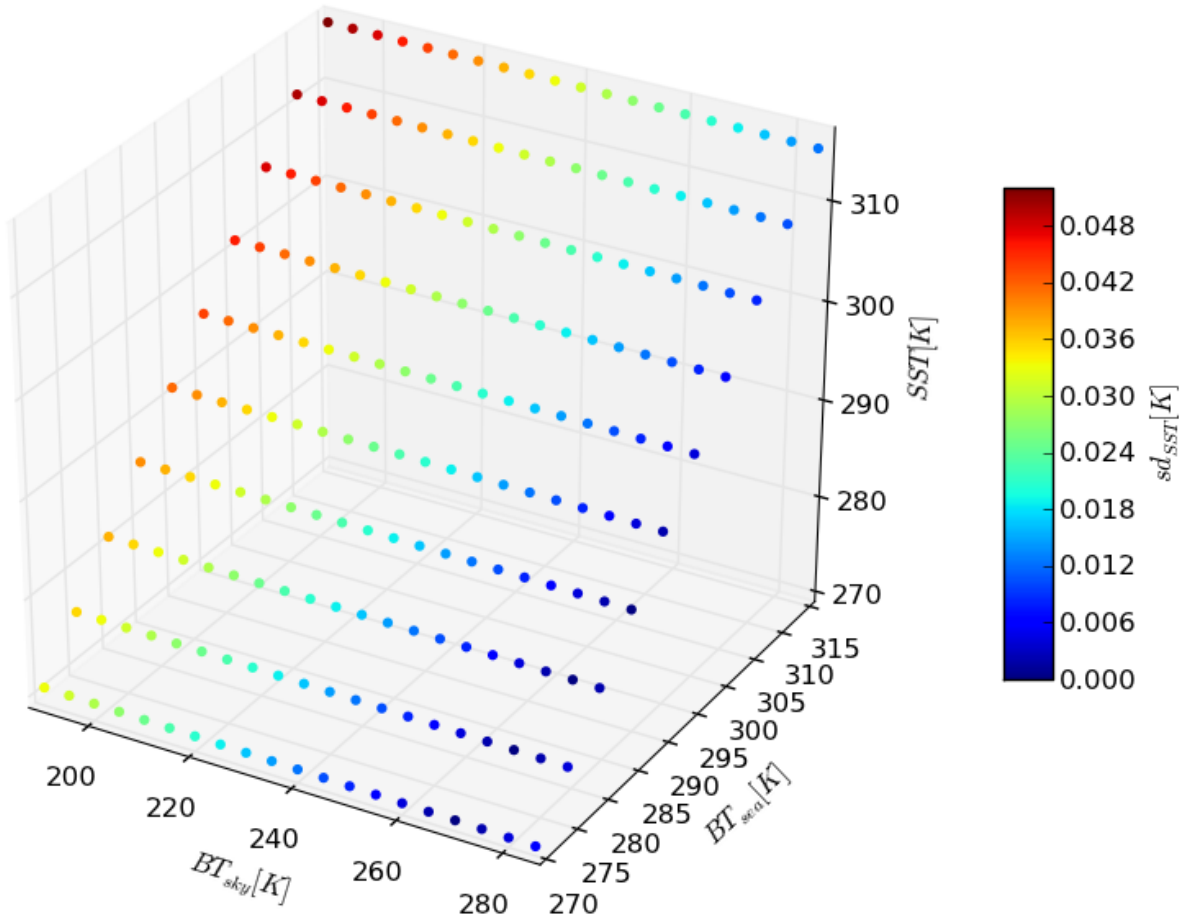
Item (X_i)	Uncertainty ($u(x_i)$)	Unit	Uncertainty type
Detector linearity	< 0.01%	K/month	B
Detector noise	~0.002	Volts	A
Detector accuracy	± 0.5	K	B
Analogue to Digital converter (ADC)	± 1	LSB	B
ADC accuracy	± 0.1%	Range	B
ADC zero drift	± 6	µV /C	B
Reference voltage 16 bit ADC	± 15	mV	B
Reference voltage 12 bit ADC	± 20	mV	B
Reference resistor	1	%	B
Reference resistor temperature coefficient	± 100	Ppm/C	B
Black Body emissivity	± 0.000178	emissivity	B
Sea surface emissivity	± 0.07	emissivity	B
Steinhart-Hart approximation	± 0.01	K	B
Radiative transfer approximation	± 0.001	K	B
Thermistor	± 0.05	K	B
Thermistor noise	~0.002	Volts	A

Uncertainty – emissivity



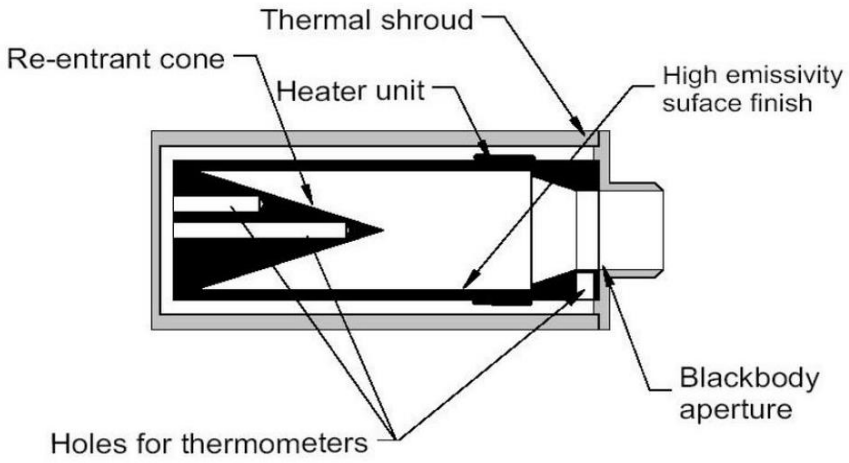


Uncertainty – emissivity effect on SST



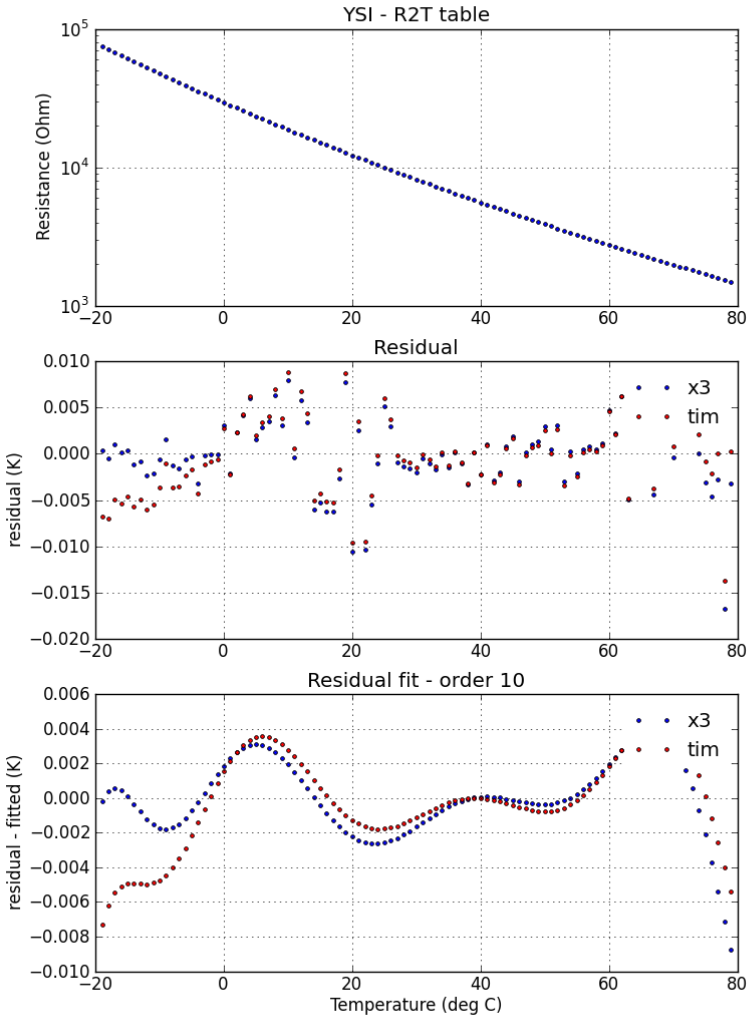
Uncertainty – black bodies

- Emissivity 0.9993 +/- 0.000178
  - Estimated through modelling

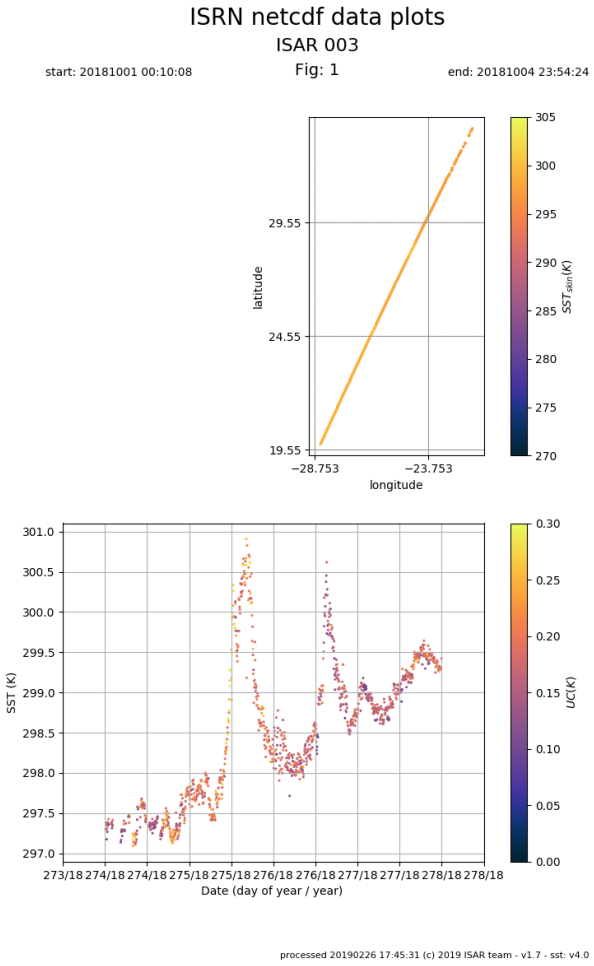


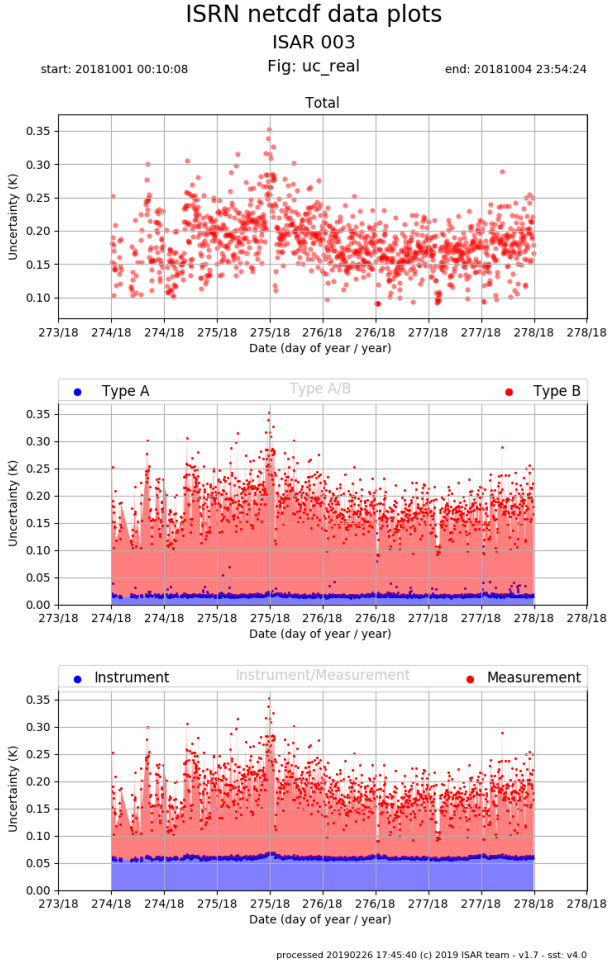
Uncertainty – thermistors

- 0.05K

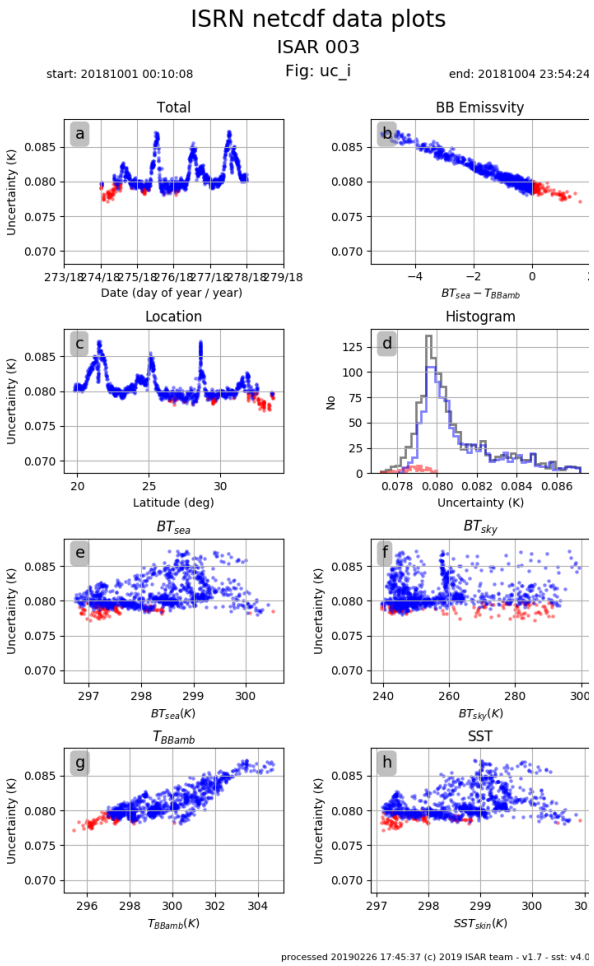


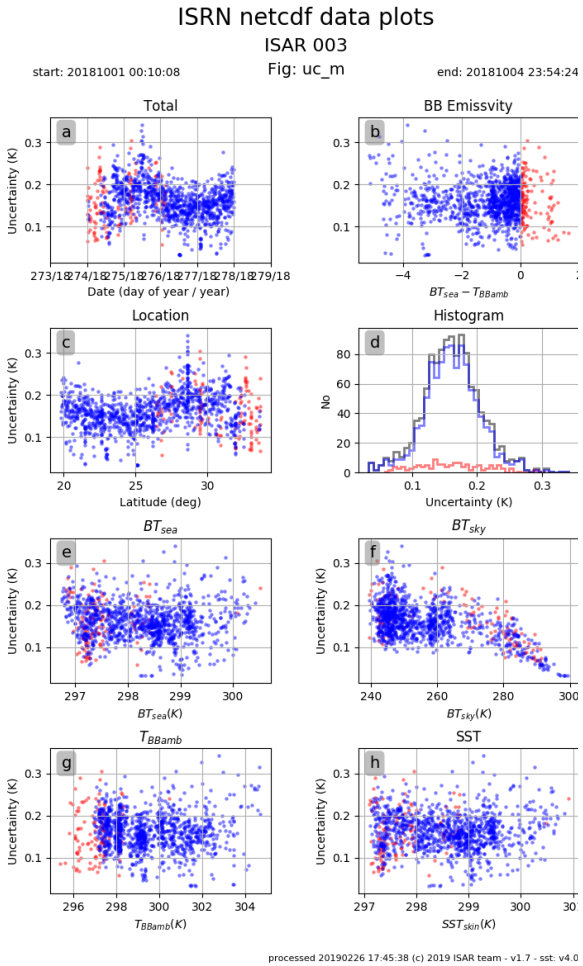
Uncertainty – results

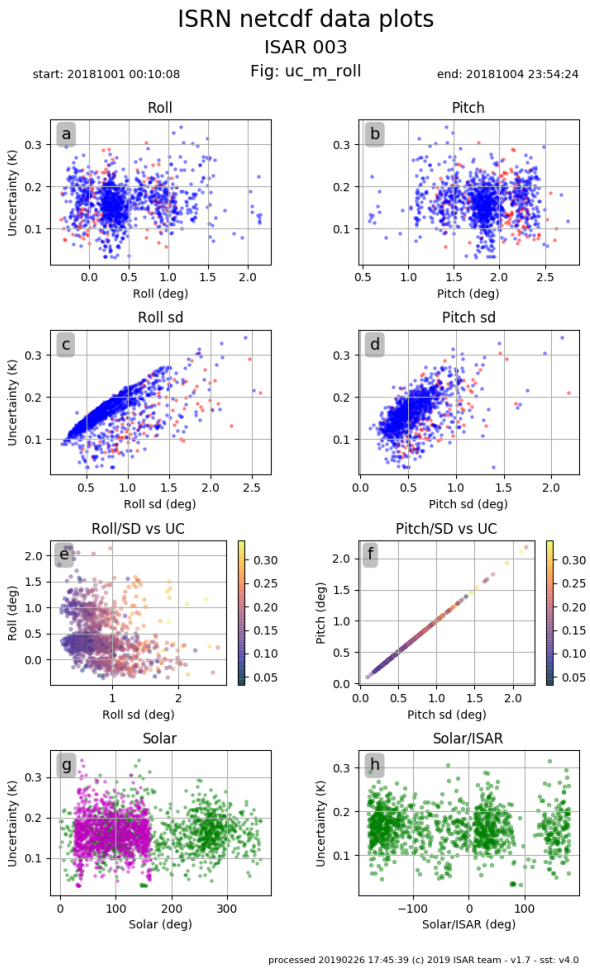




Uncertainty – results





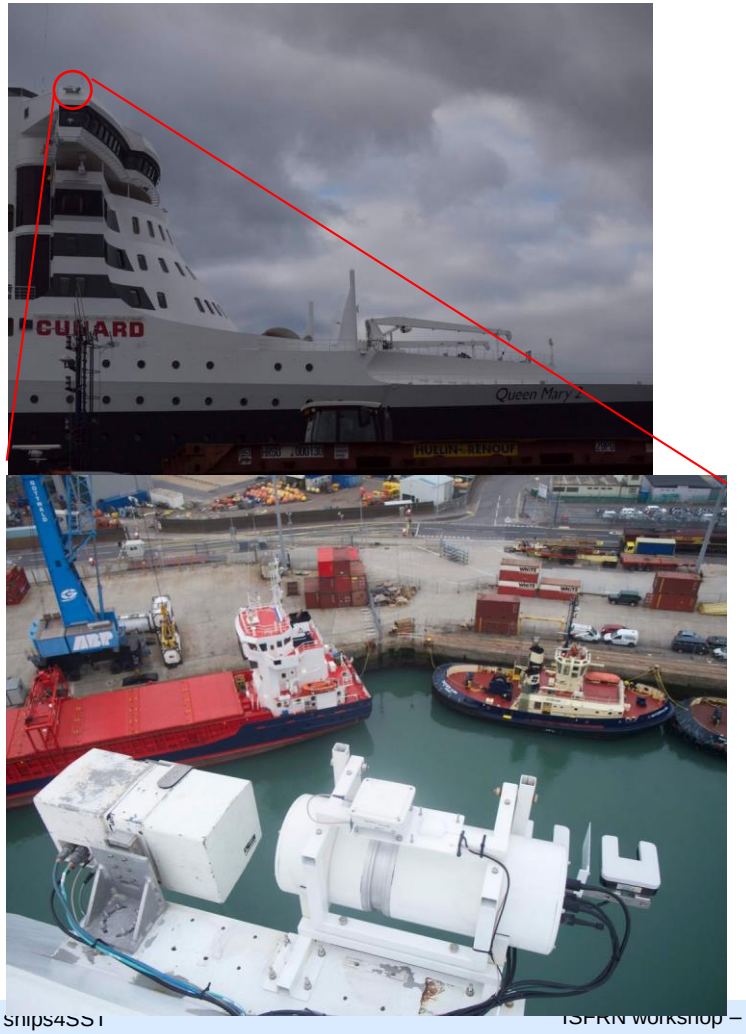


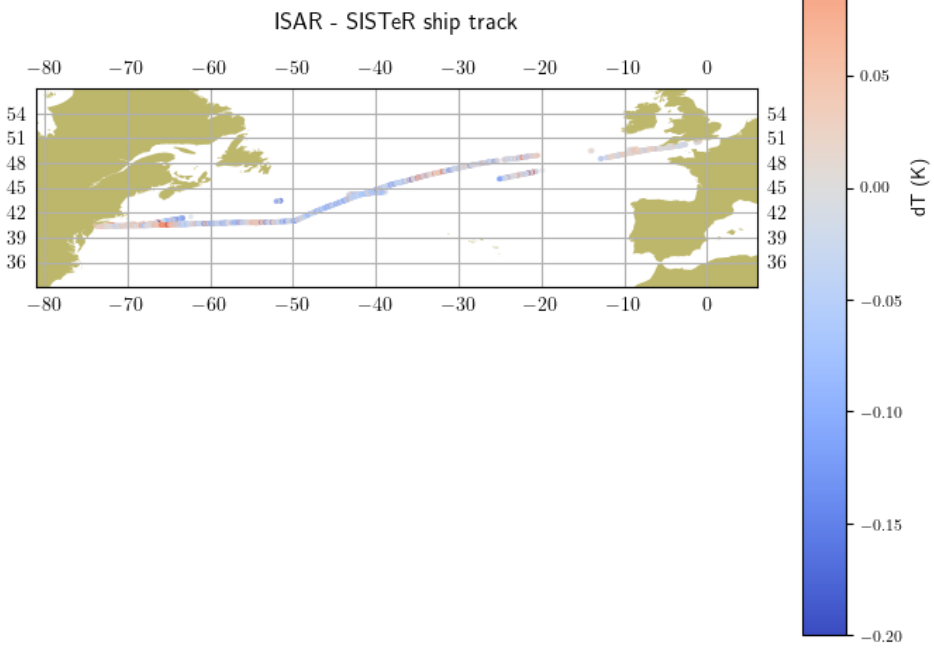
Uncertainty Validation

- Laboratory inter-comparisons
  - FRM4SST … (not covered here)
- Four side by side comparison
  - SISTeR – ISAR 03, M/V Queen Mary 2, 18.10. – 05.11. 2015
  - ISAR 03 – ISAR 12, RRS James Clark Ross, 24.09. – 29.10. 2018
  - ISAR 03 – ISAR 07, RRS Discovery, 12.10. - 22.11. 2019
  - ISAR 03 – KIT, M/V Friedrichshafen, 01.09. – 23.09. 2020
- Data below 2kts excluded

Data - QM2

SISTeR – ISAR 03, M/V Queen Mary 2, 18.10. – 05.11. 2015

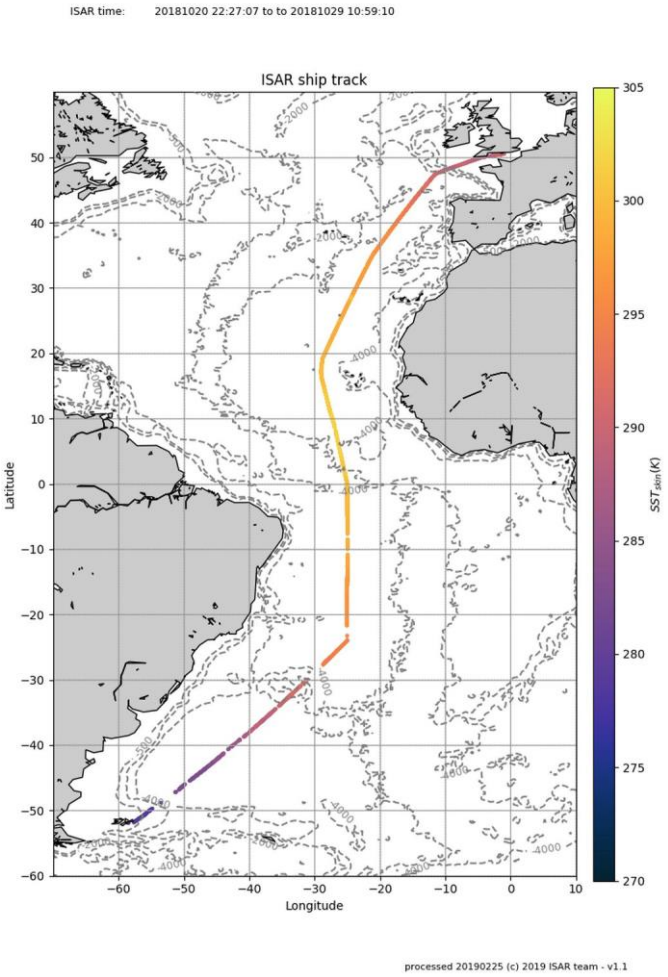


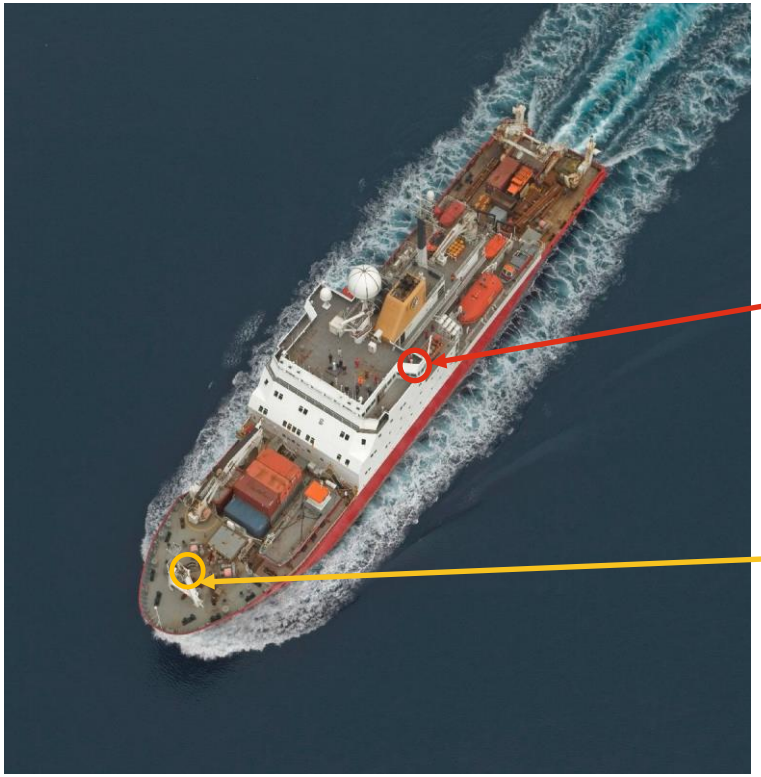


single sea view, single sky view setup

Data - JCR

ISAR 03 – ISAR 12, RRS James Clark Ross, 24.09. – 29.10. 2018





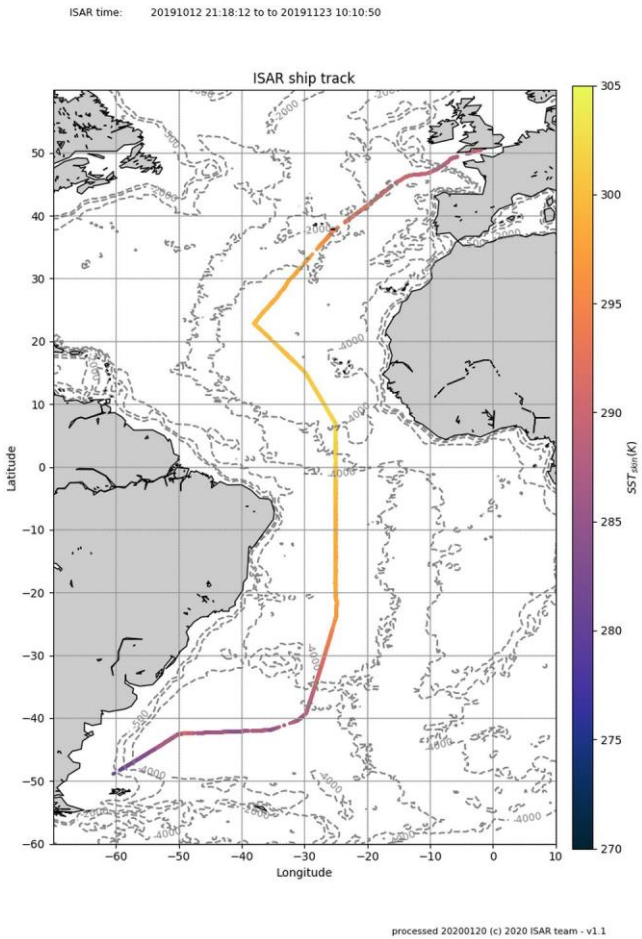
ISAR 012

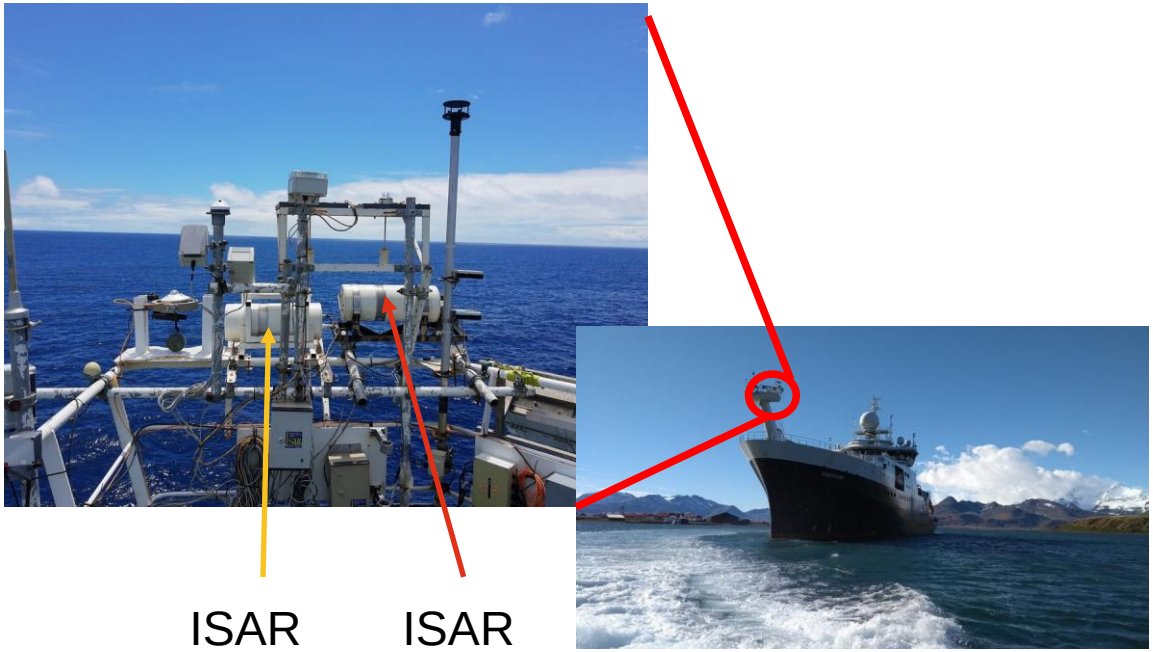
ISAR 003

ISAR 03: 1 sea view and 3 sky view setup
ISAR 12: 3 sea view and 5 sky view setup

Data - DCY

ISAR 03 – ISAR 07, RRS Discovery, 12.10. - 22.11. 2019





ISAR 003

ISAR 007

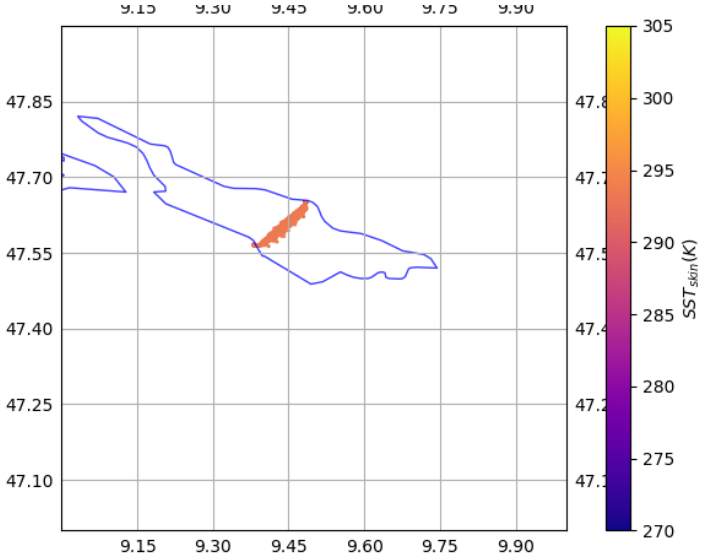
ISAR 03: 1 sea view and 3 sky view setup
ISAR 07: 3 sea view and 5 sky view setup

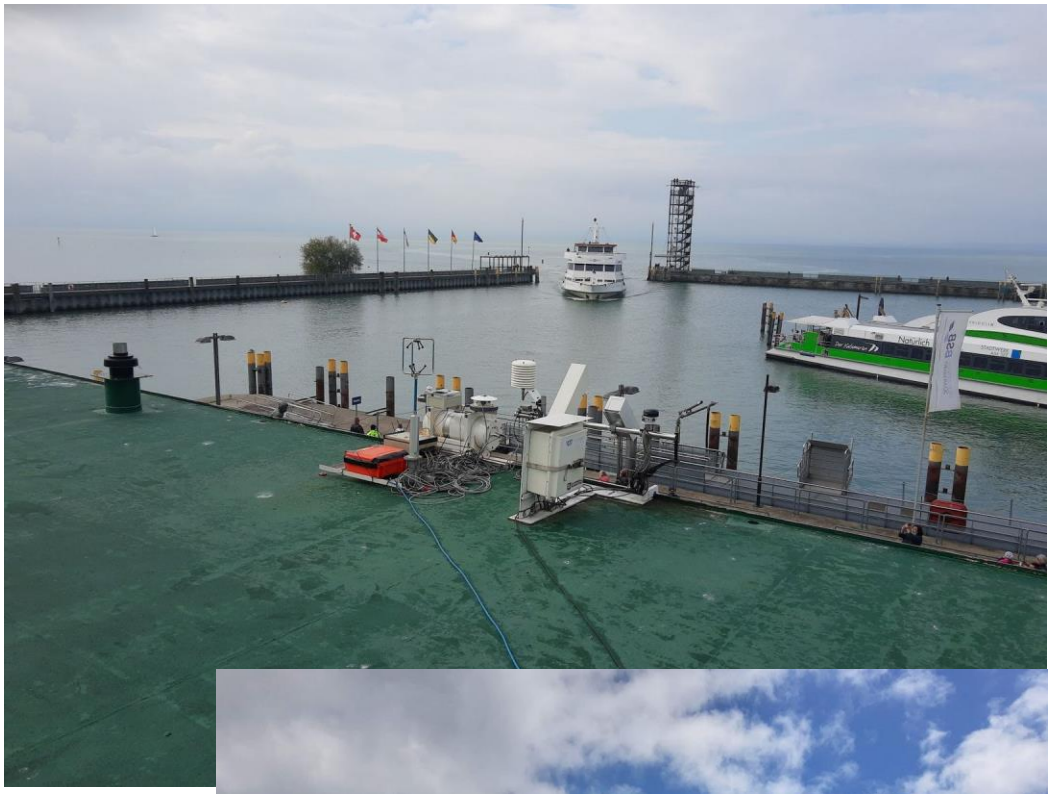
Data - LC

ISAR 03 – KIT, M/V Friedrichshafen, 01.09. – 23.09. 2020

Lake Constance

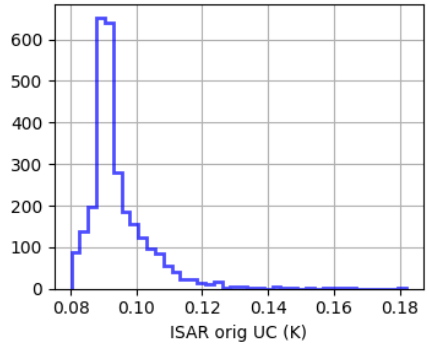
single sea view,
single sky view setup

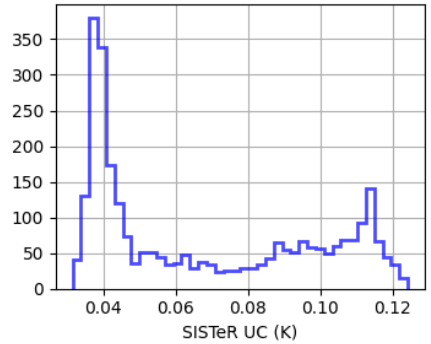


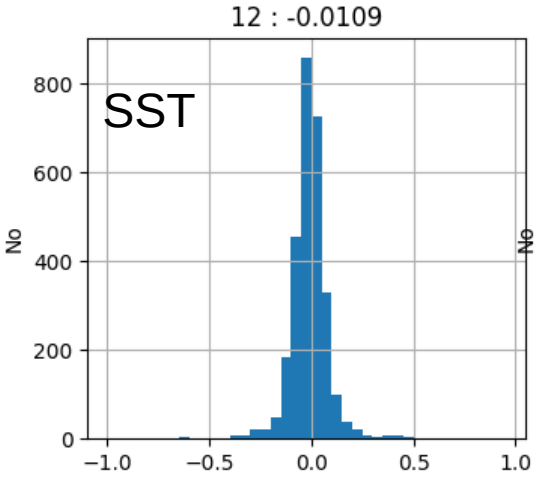


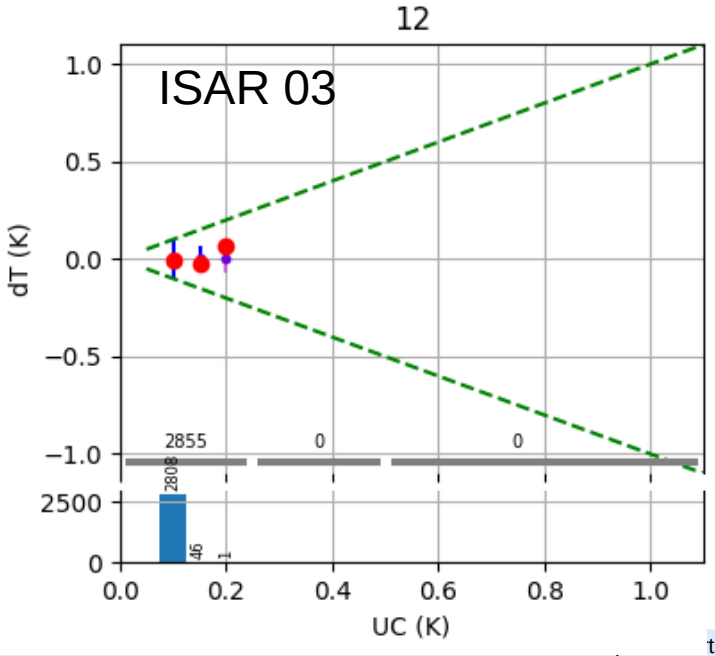
Uncertainty validation

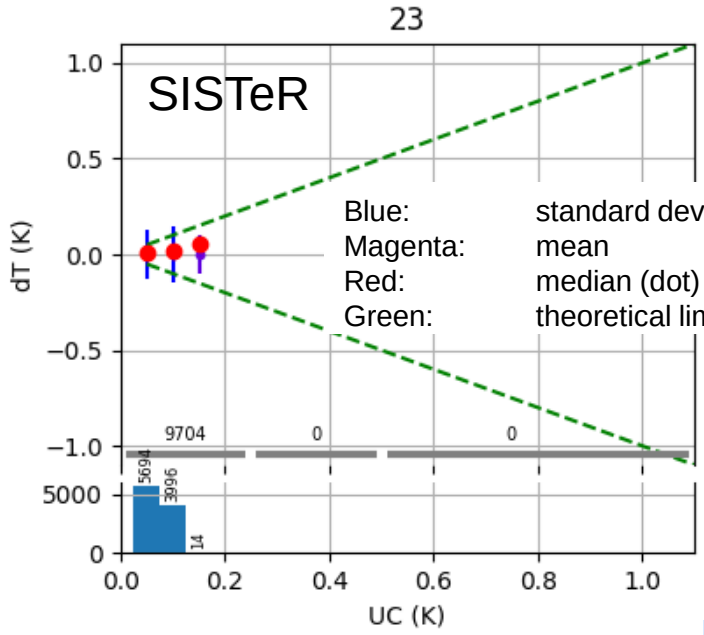
- QM2: ISAR (1,3) – SISTeR (2)





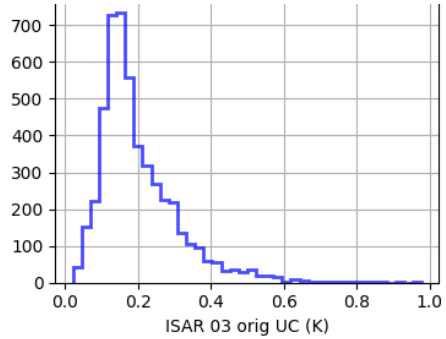


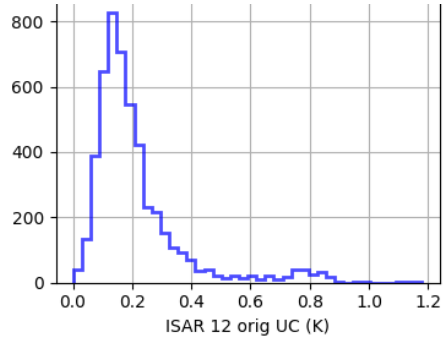


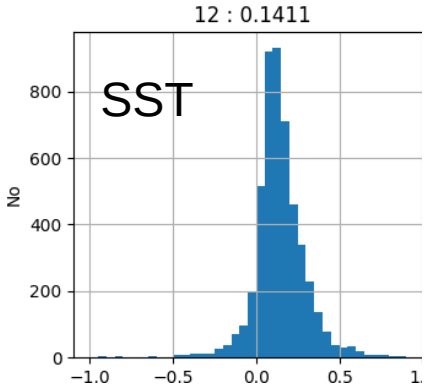


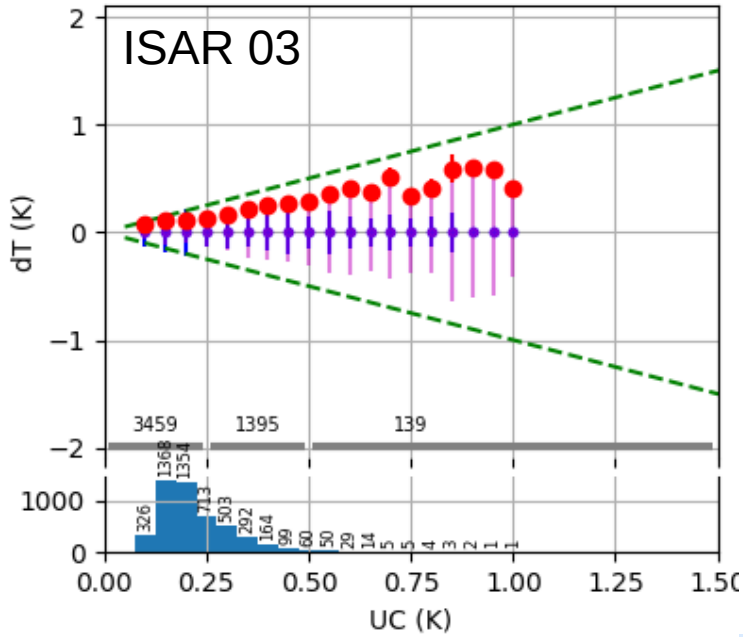
Uncertainty validation

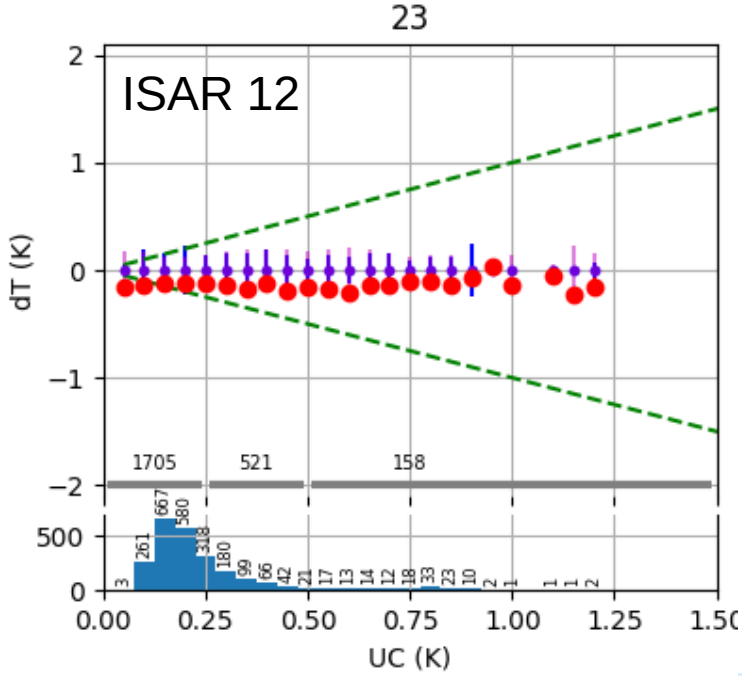
- AMT28: ISAR 03 (1,3) – ISAR 12 (2)





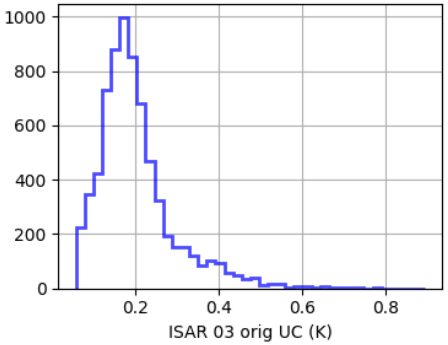


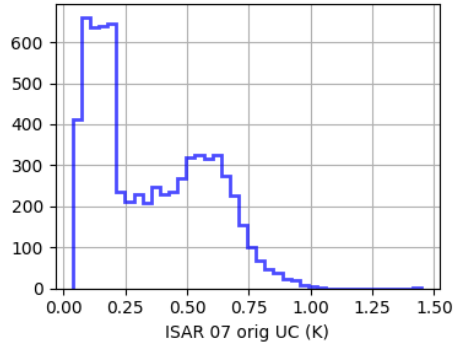


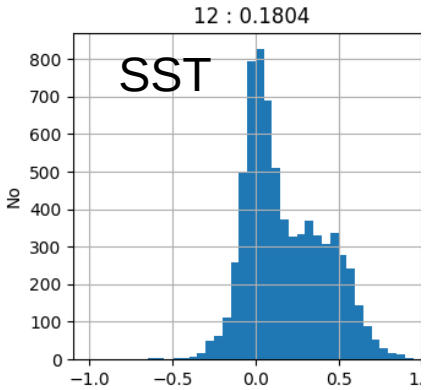


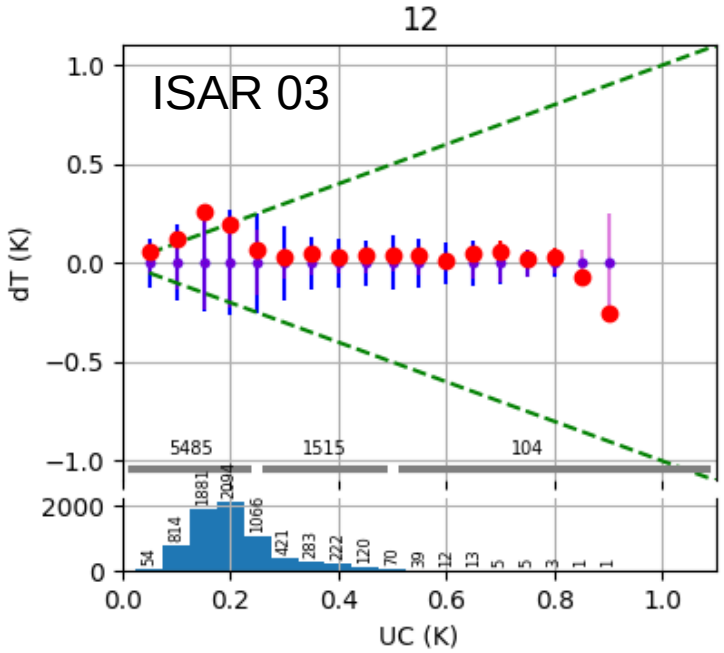
Uncertainty validation

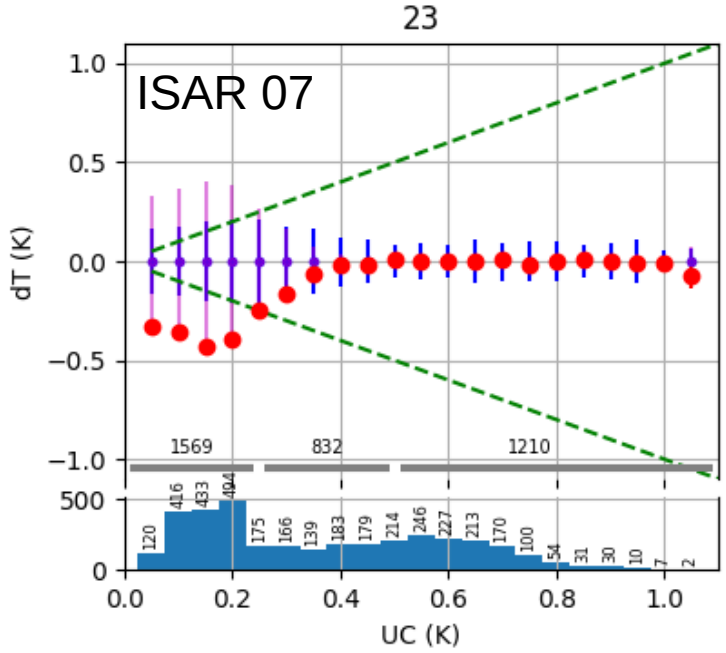
- AMT 29: ISAR 03 (1,3) – ISAR 07 (2)





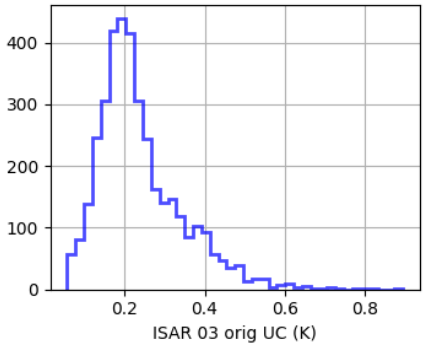


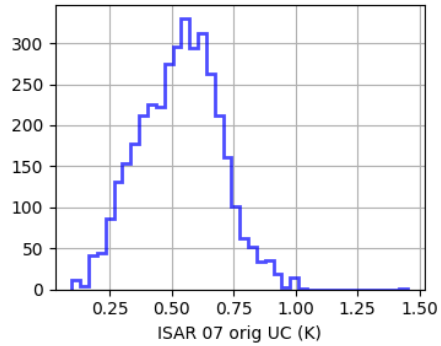


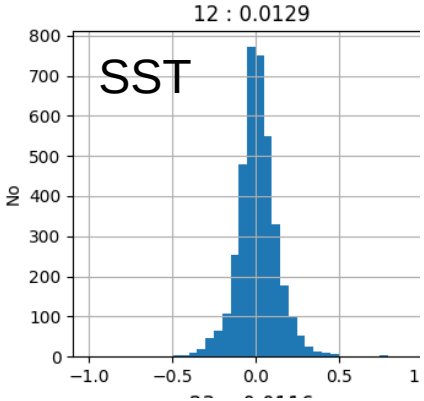


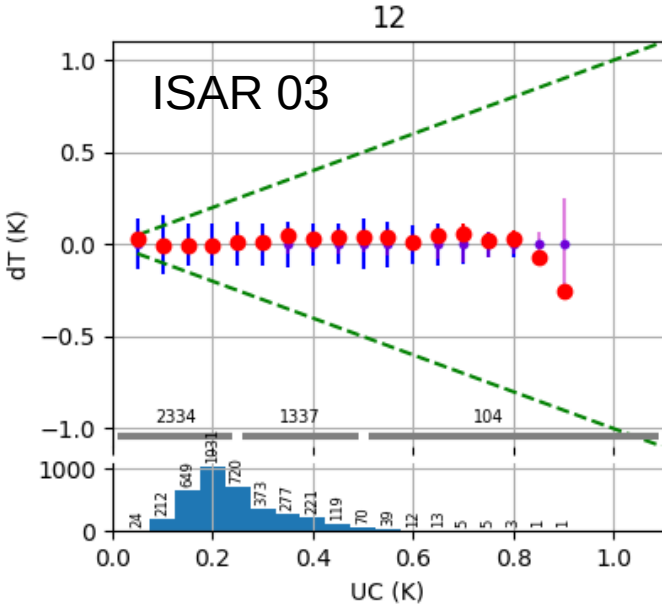
Uncertainty validation

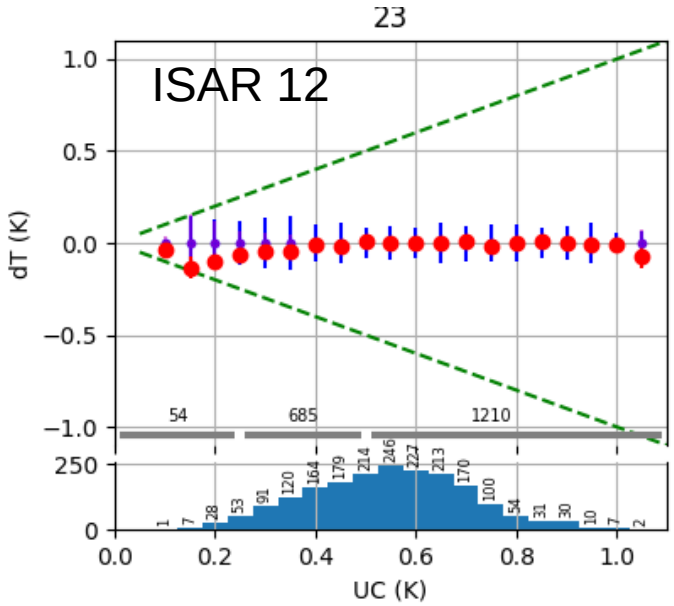
- AMT 29: ISAR 03 (1,3) – ISAR 07 (2)





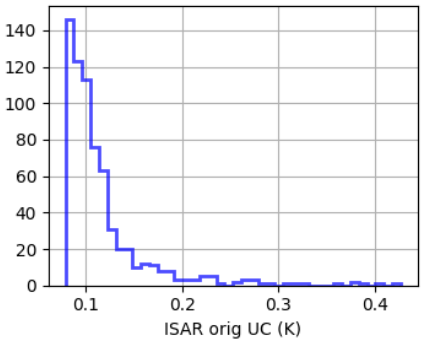


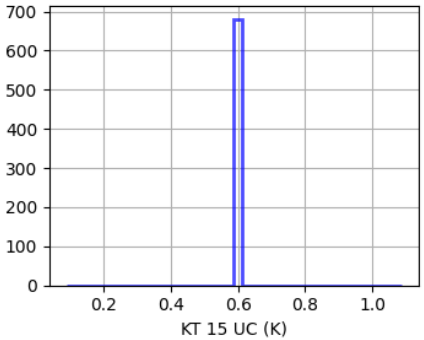


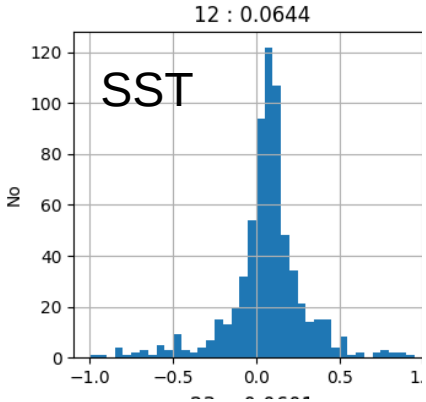


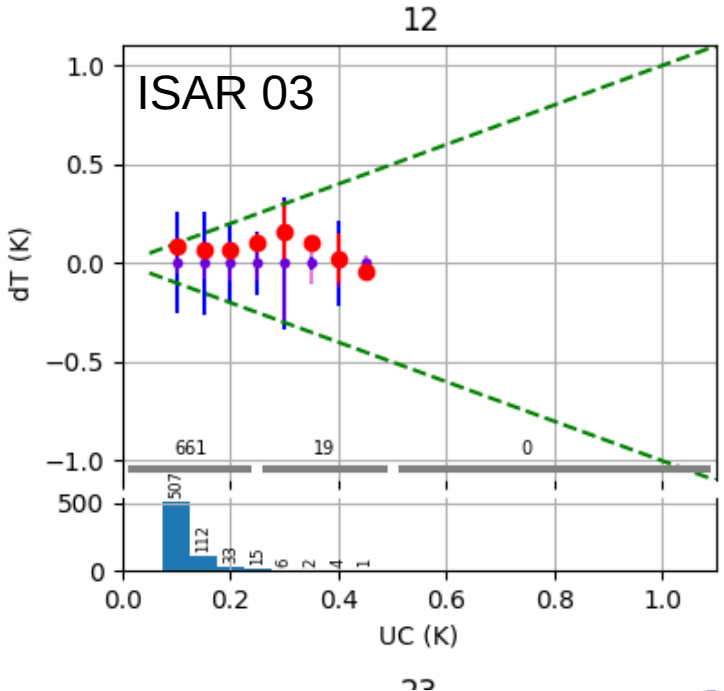
Uncertainty validation

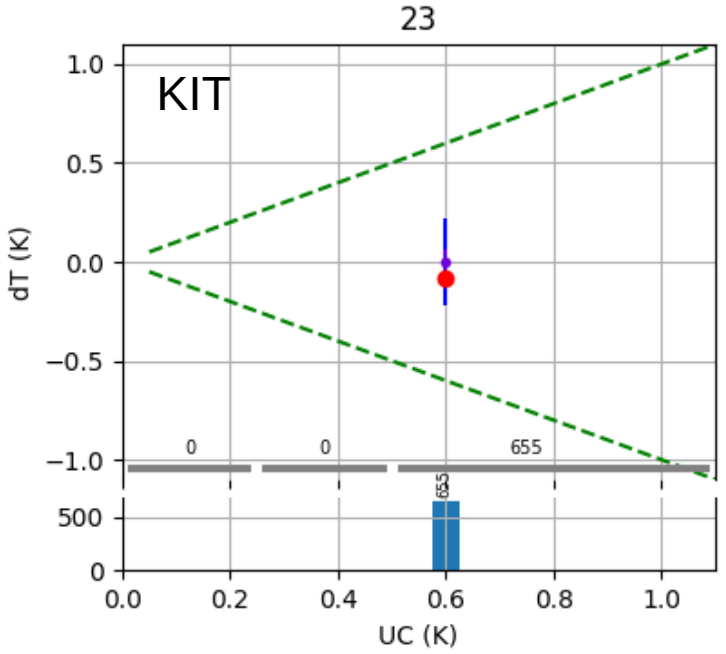
- LWST: ISAR 03 (1,3) – KIT (2)





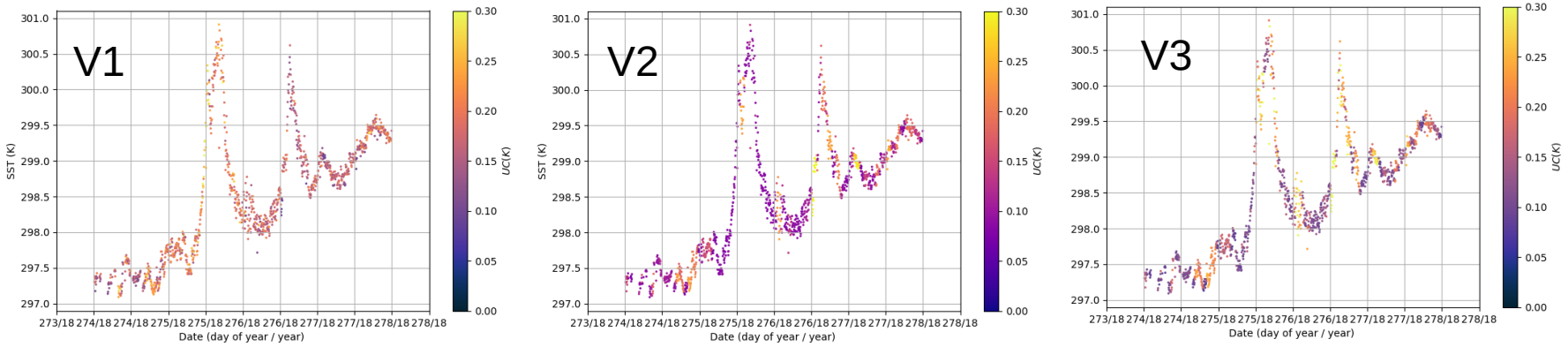






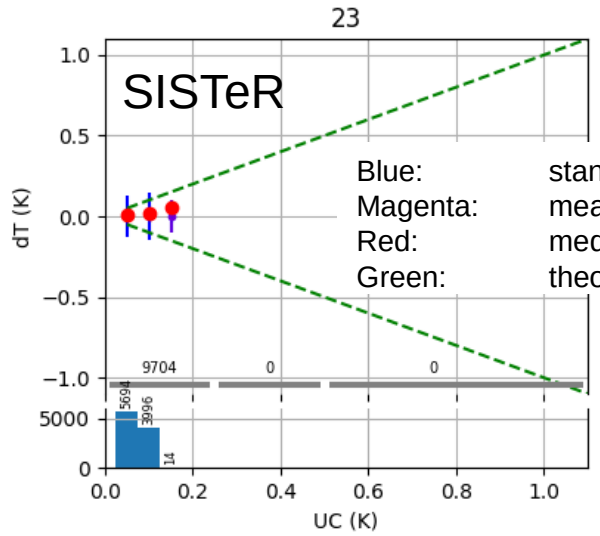
Updating the existing model

- Changes to v1
  - Version New v2:
    - Roll is Hanning filtered, length is 11 values
    - Sky, sea signal over 5 SST samples
      - Centre Weighted average - 1, 4, 4,1
      - Variance of the signal gets added to the sea and sky signal uncertainty before internal calibration
  - Version New v3
    - SST weighted std gets estimated as geophysical indicator → extra uncertainty variable

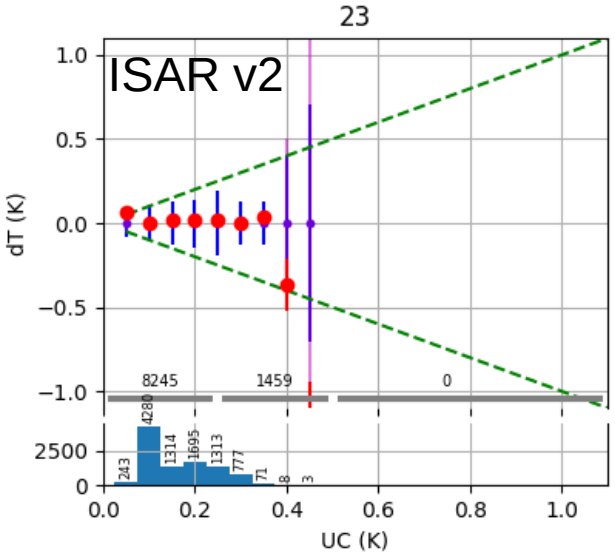


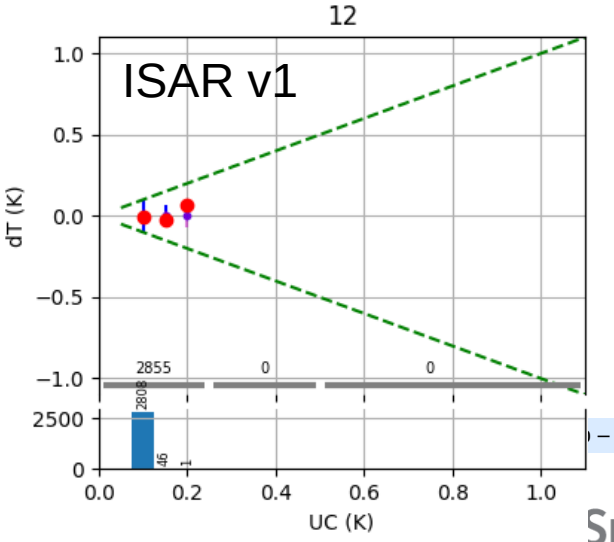
Uncertainty validation- new model

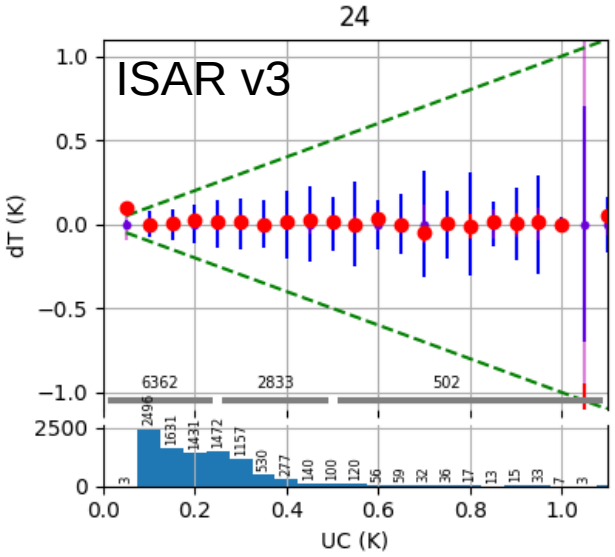
- QM2: ISAR (1,3, 4) – SISTeR (2)



Blue: standard deviation
Magenta: mean
Red: median (dot) + std error
Green: theoretical limit

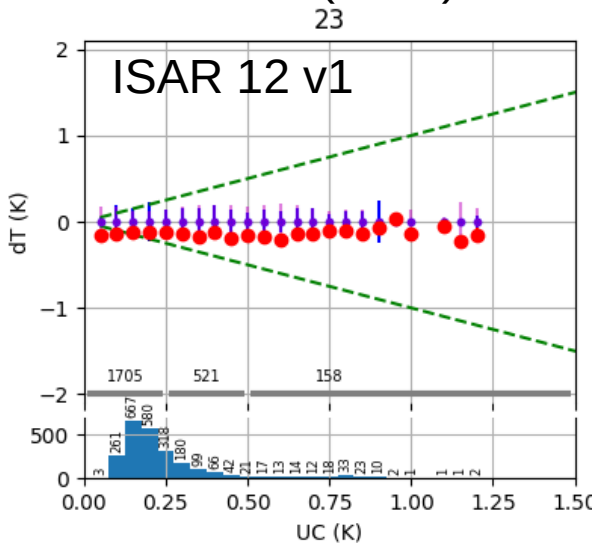


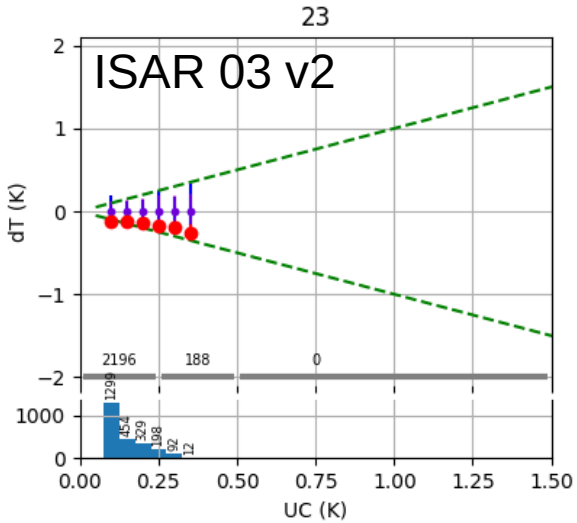


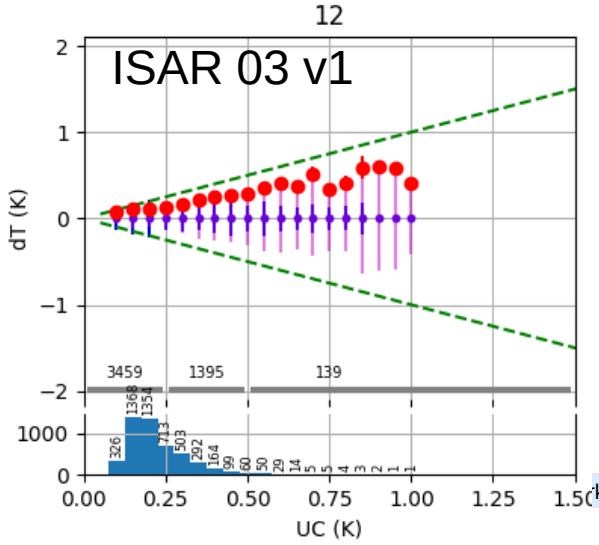


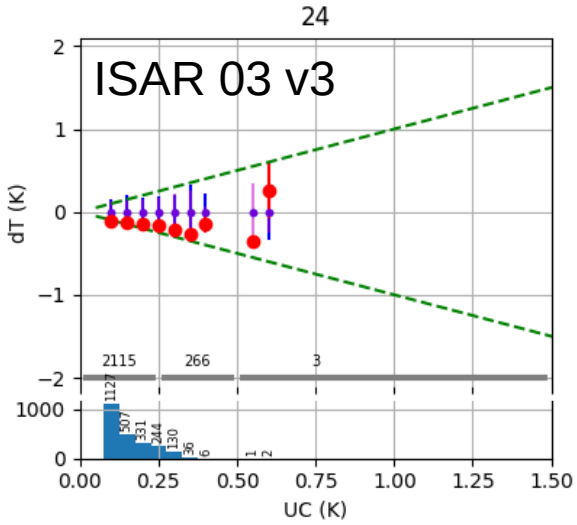
Uncertainty validation- new model

- AMT28: ISAR 03 (1,3,4) – ISAR 12 (2)



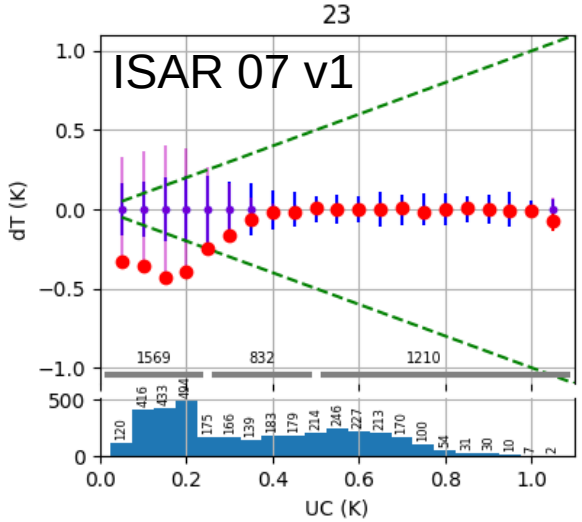


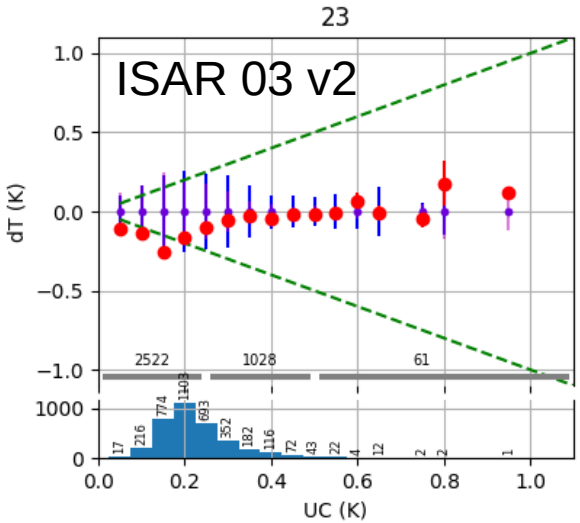


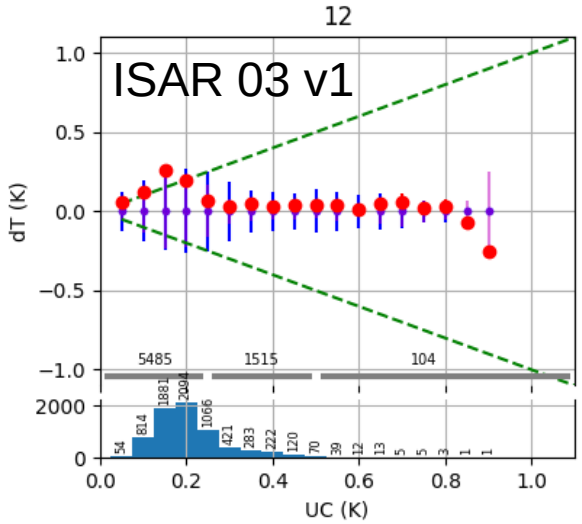


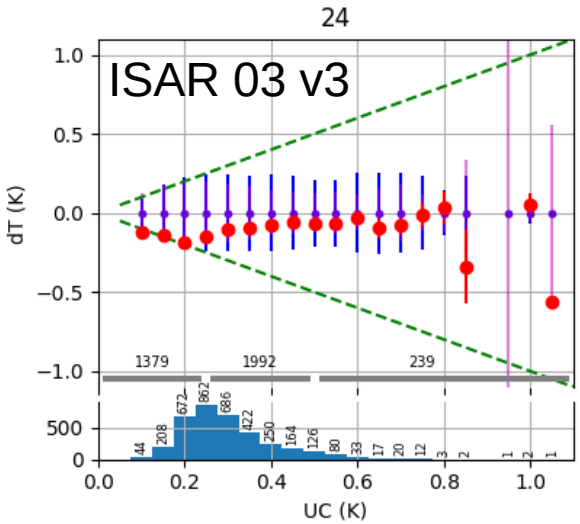
Uncertainty validation – new model

- AMT 29: ISAR 03 (1,3,4) – ISAR 07 (2)



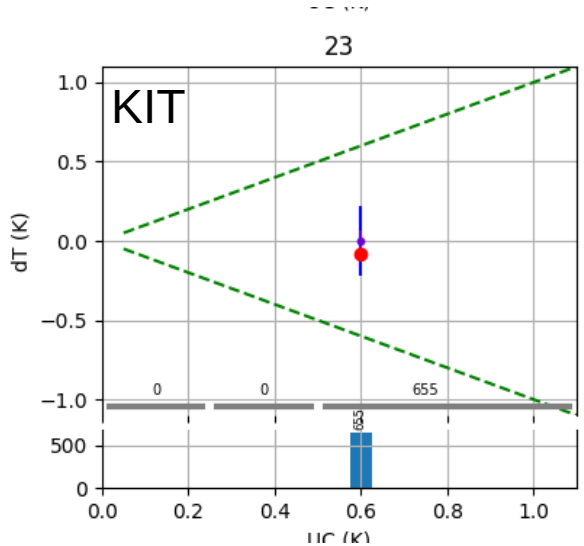


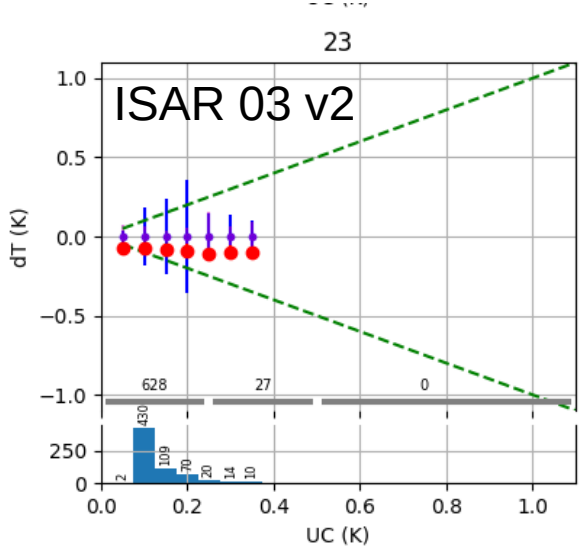


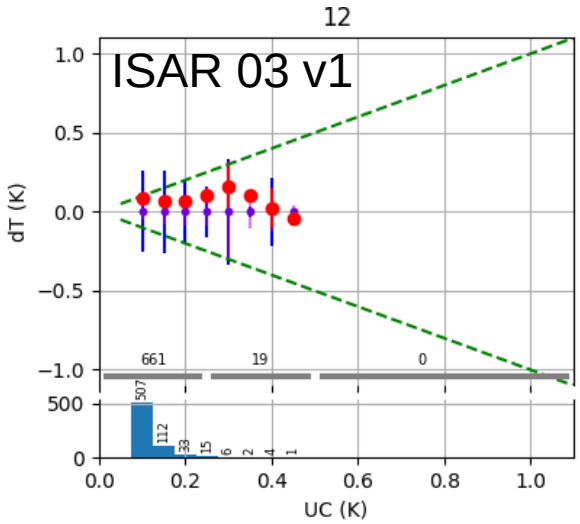


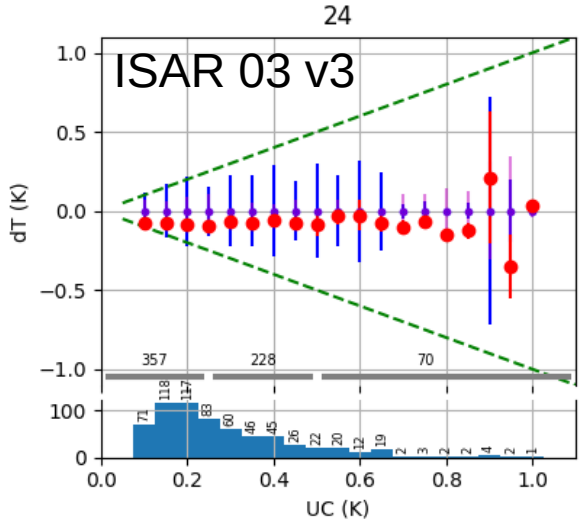
Uncertainty validation – new model

- LWST: ISAR 03 (1,3,4) – KIT (2)



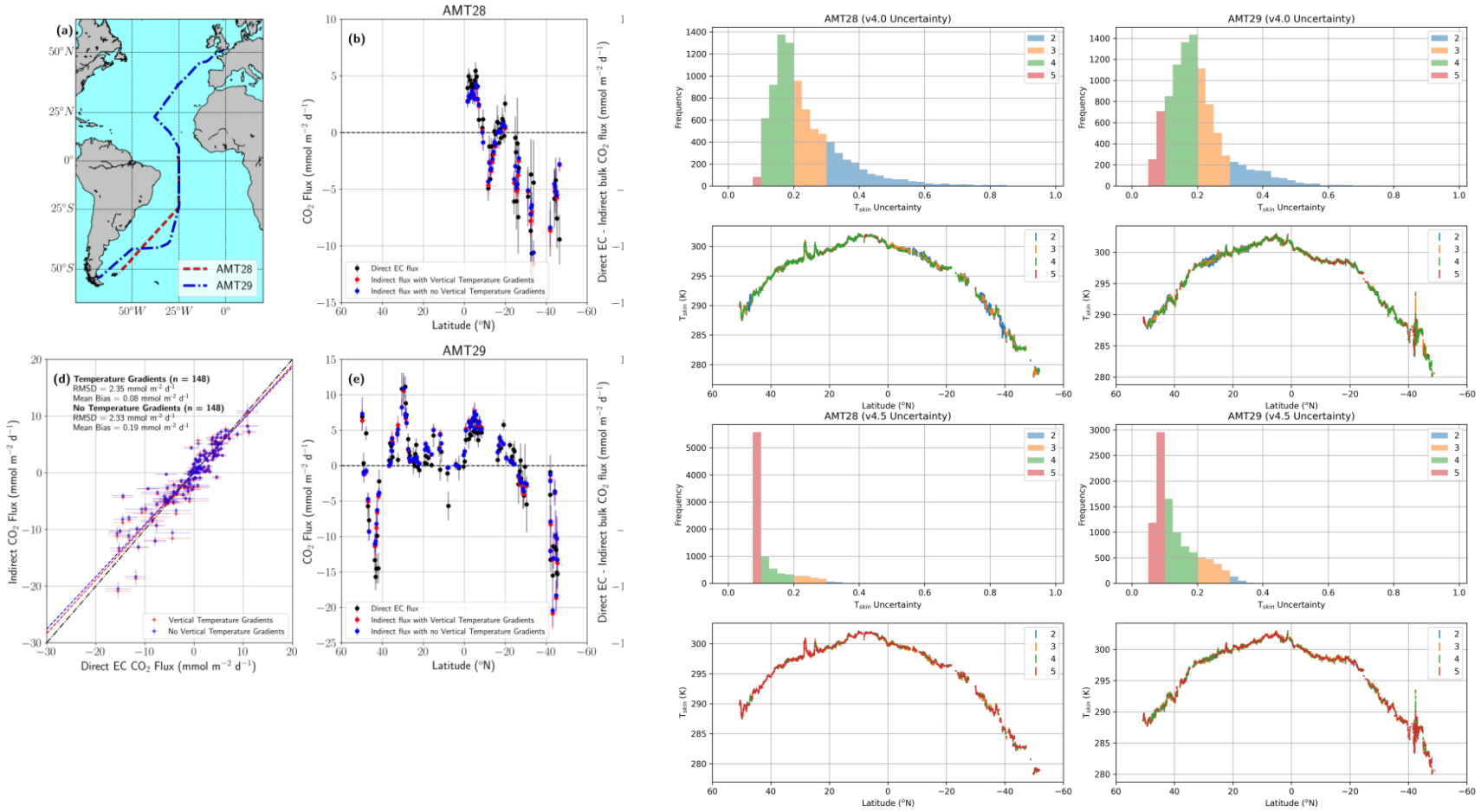






Uncertainty validation – new model

- AMT 28/29 CO2flux evaluation of uncertainties



Conclusion

- Field inter-comparisons are essential for uncertainty validation
  - Data sparse – especially for higher uncertainties
  - Over 70% below 0.25K and over 95% below 0.5K
- Original total ISAR uncertainties too large
  - But instrument uncertainty looks correct.
  - Mainly because of the roll dependence of the emissivity uncertainty
  - New version addresses the roll dependence
- Some information missing in the uncertainties:
  - Real physical differences not measured → this is a more a match-up uncertainty than part of the instrument uncertainty
  - Non perfect type B uncertainties
    - Emissivity
    - Cloud variability

Outlook

- More inter-comparisons
  - Currently unfunded so not easy to undertake.
- Analyse the ancillary data for AMT28 and AMT29
  - Other SST sources
  - Wind, surface roughness, short and long wave radiation
  - Sky data
    - KT15 domes
    - IR camera