



ships4sst

shipborne radiometers for sea surface temperature

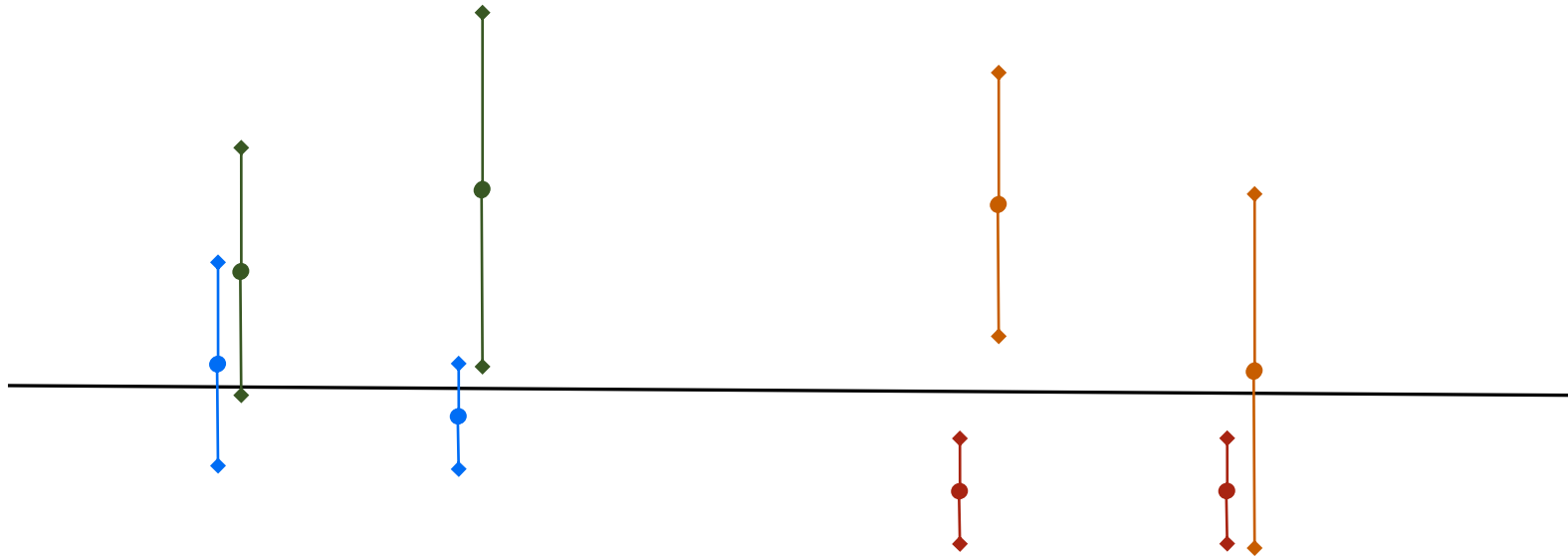
Radiometer Uncertainty Models

Werenfrid Wimmer

Overview

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

Uncertainty



Uncertainty – radiometers

- Classic

- Adding all uncertainties in quadrature

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

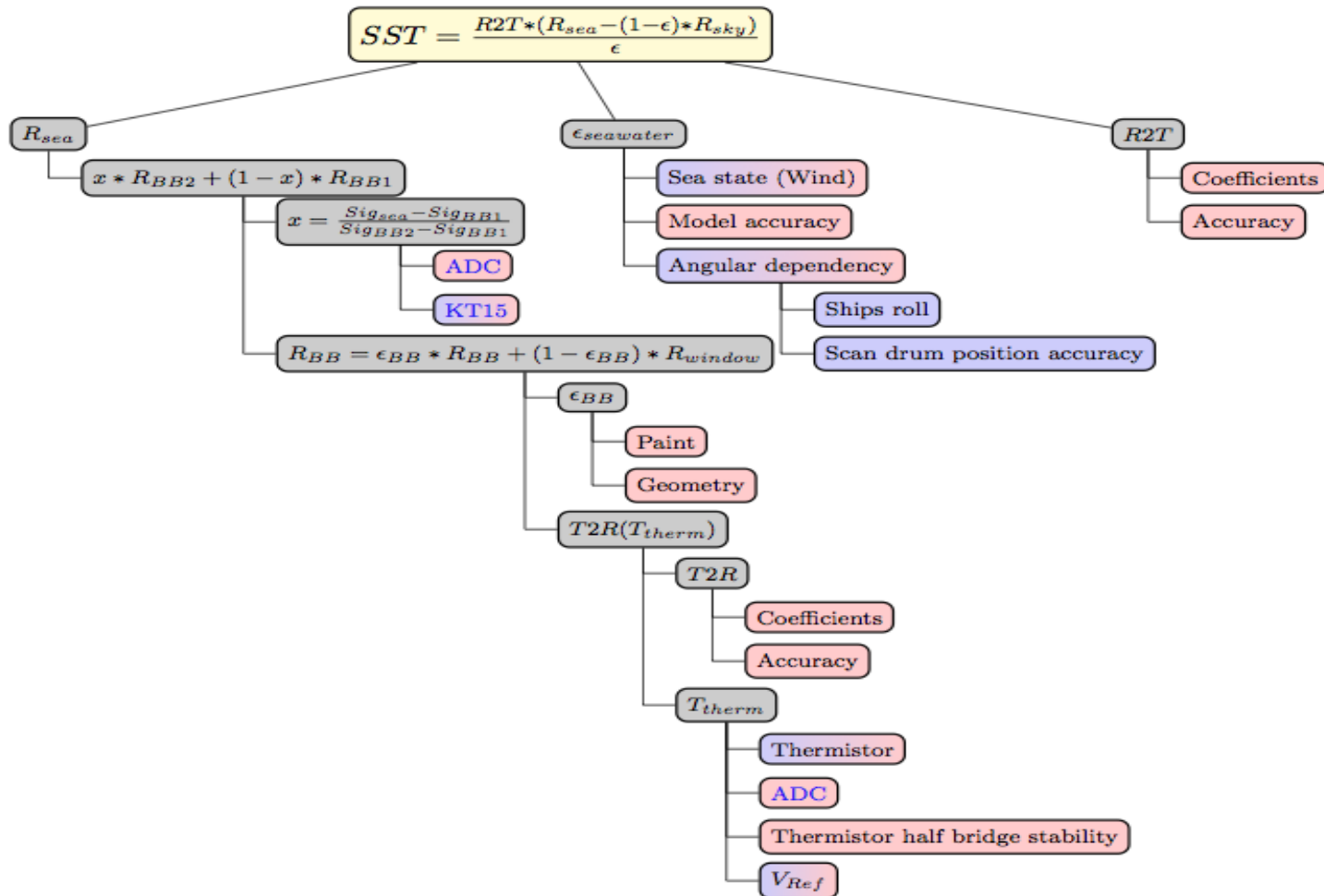
- Self calibrating radiometer

- Measurement equation

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

- 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.)

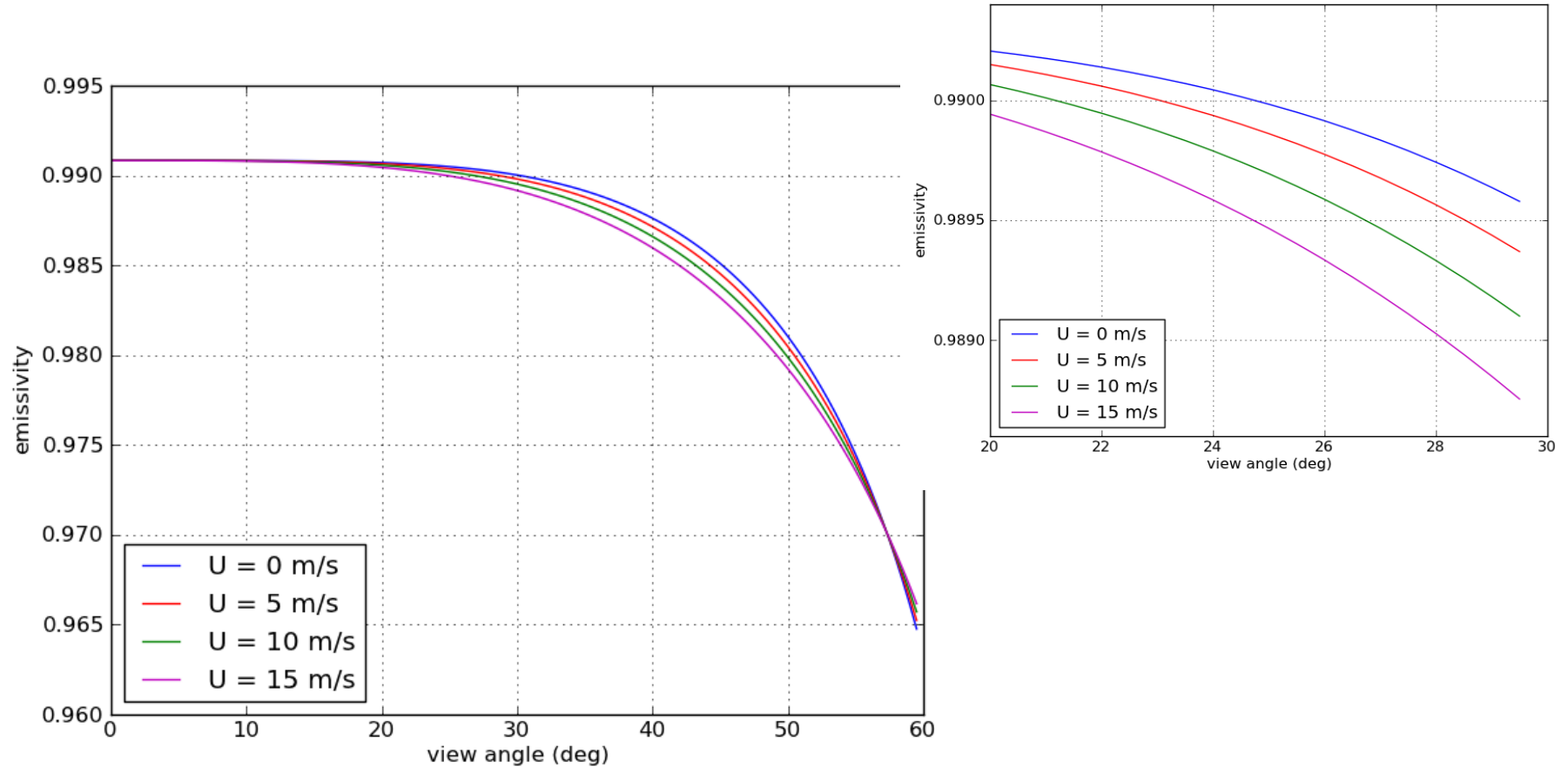
Uncertainty – radiometers



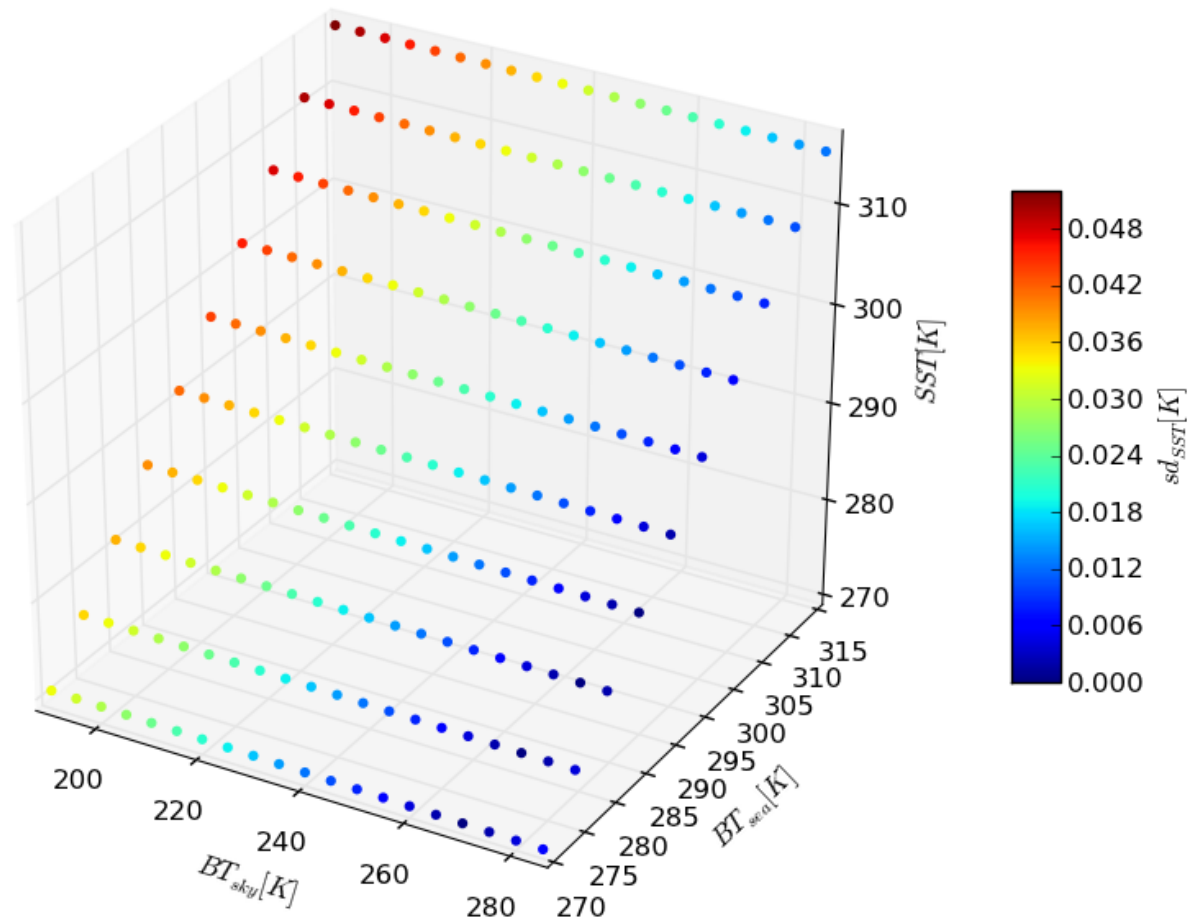
Uncertainty – values

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

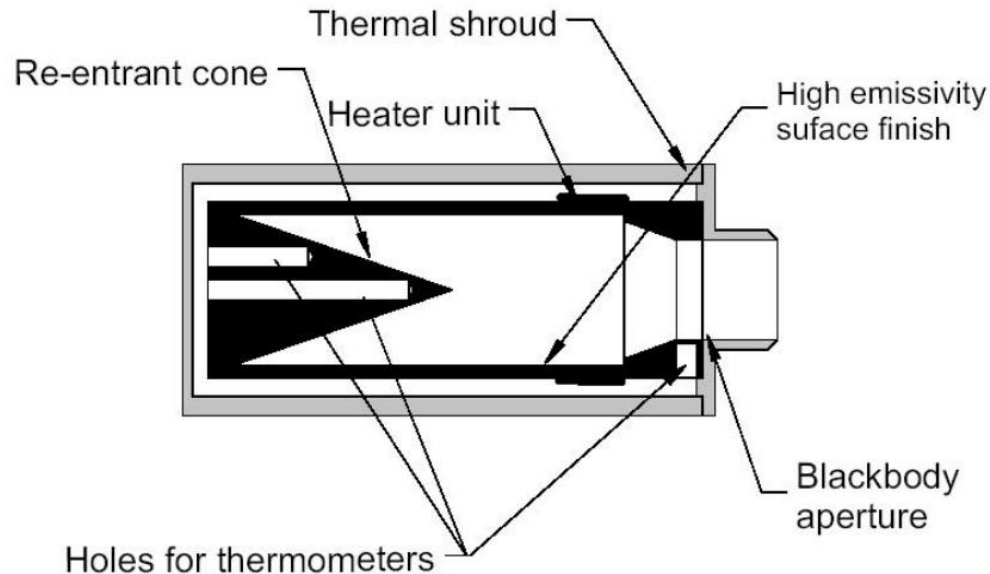


Uncertainty – emissivity effect on SST



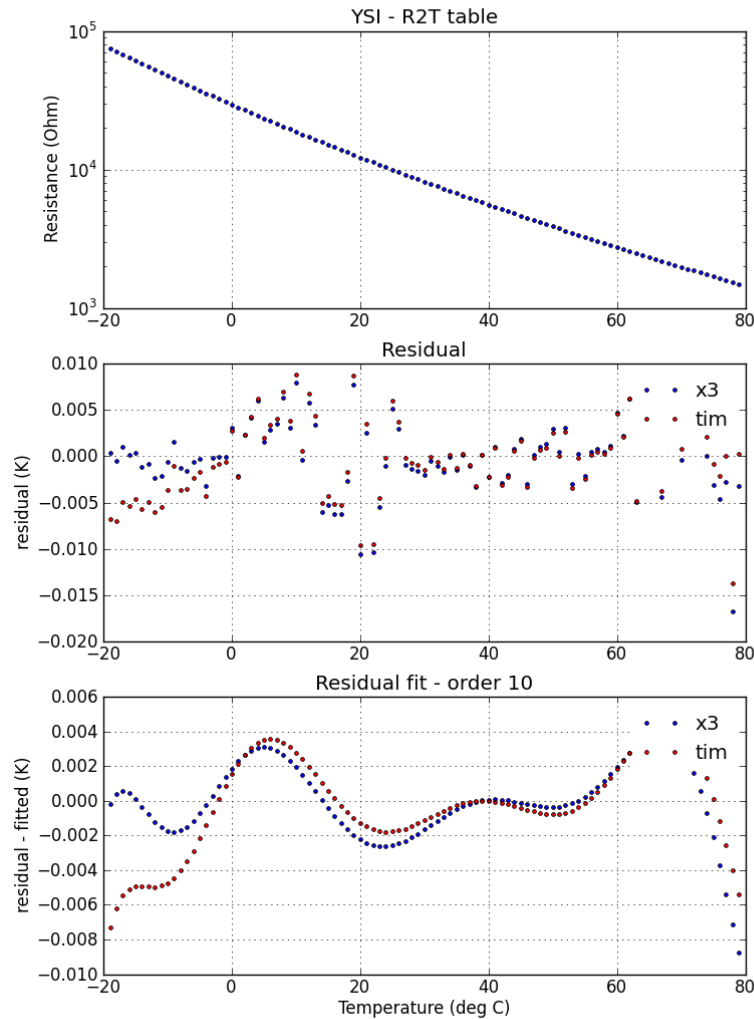
Uncertainty – black bodies

- Emissivity 0.9993 +/- 0.000178
 - Estimated through modelling



Uncertainty – thermistors

- 0.05K



Uncertainty – results

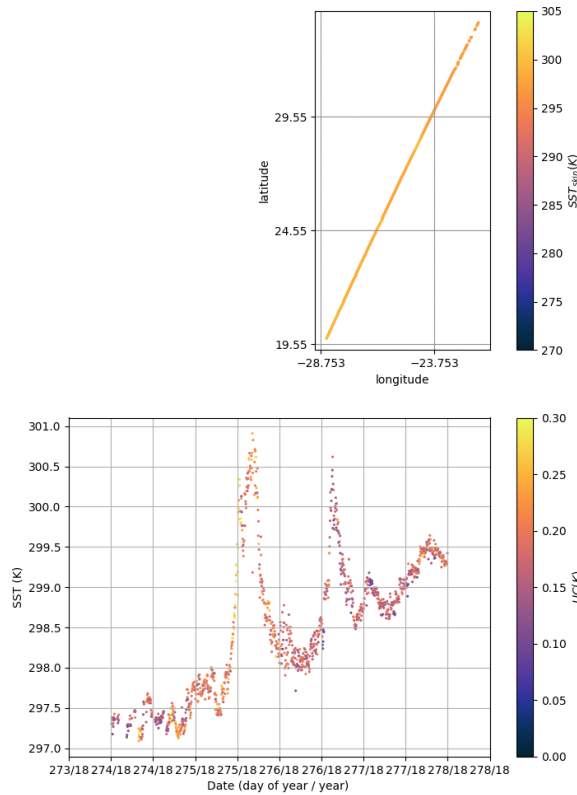
ISRN netcdf data plots

ISAR 003

start: 20181001 00:10:08

Fig: 1

end: 20181004 23:54:24



processed 20190226 17:45:31 (c) 2019 ISAR team - v1.7 - sst: v4.0

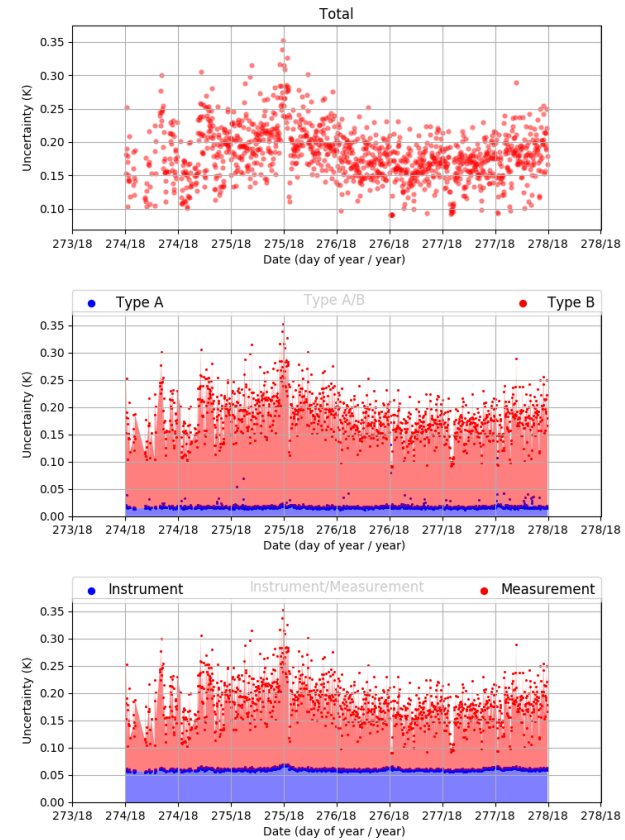
ISRN netcdf data plots

ISAR 003

start: 20181001 00:10:08

Fig: uc_real

end: 20181004 23:54:24



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Uncertainty – results

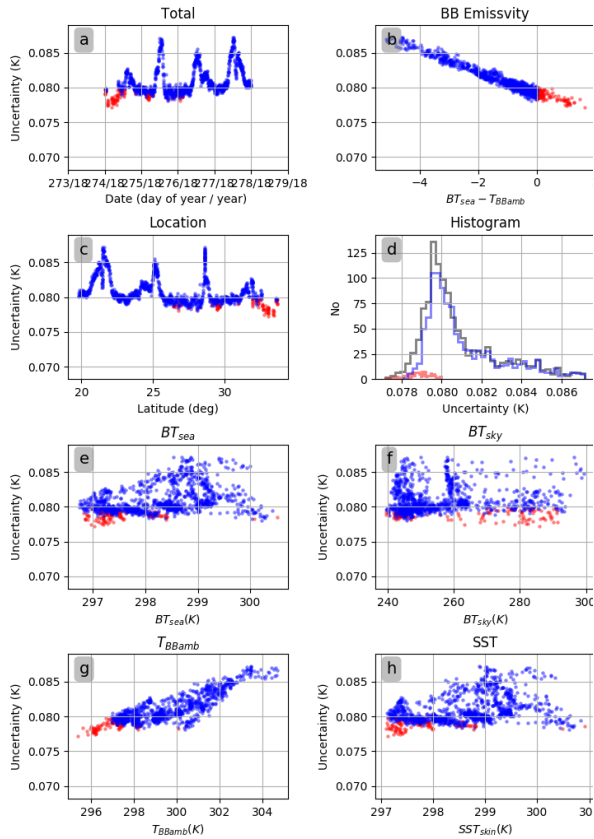
ISRN netcdf data plots

ISAR 003

Fig: uc_i

start: 20181001 00:10:08

end: 20181004 23:54:24



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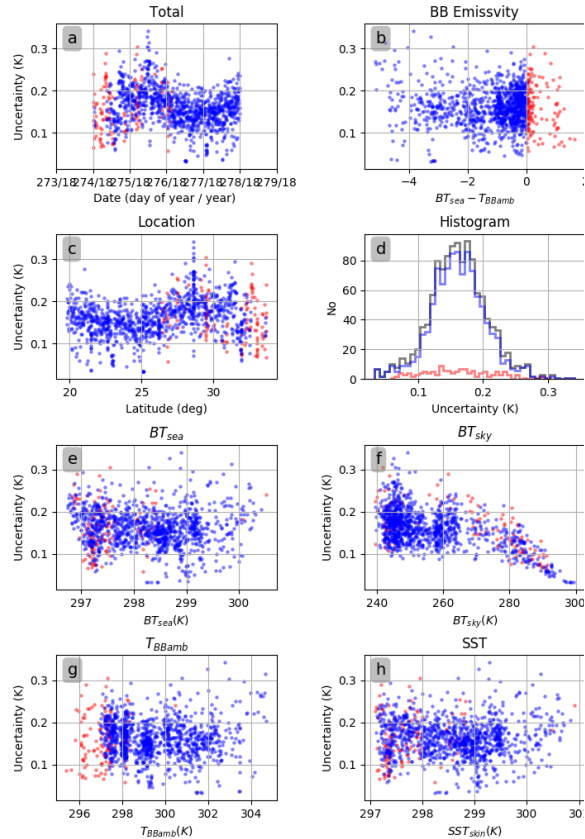
ISRN netcdf data plots

ISAR 003

Fig: uc_m

start: 20181001 00:10:08

end: 20181004 23:54:24



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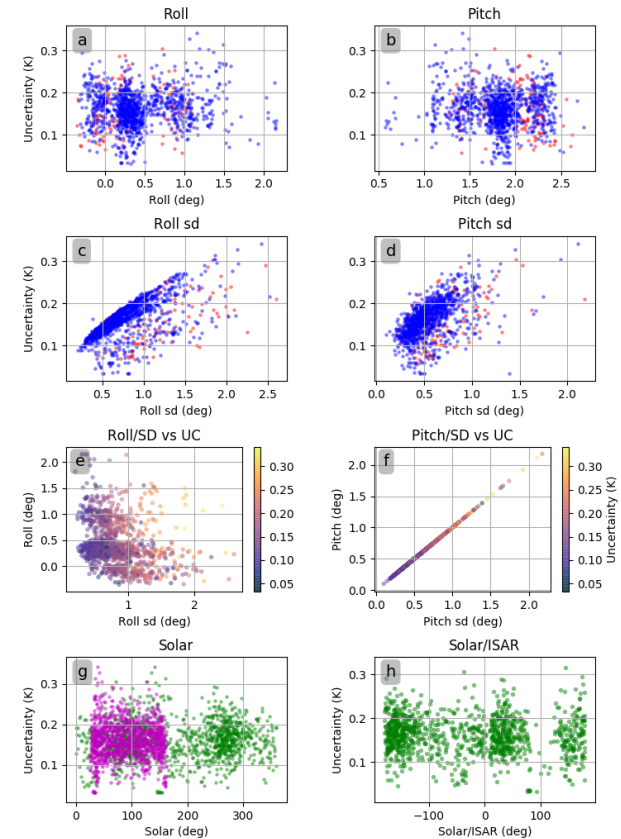
ISRN netcdf data plots

ISAR 003

Fig: uc_m_roll

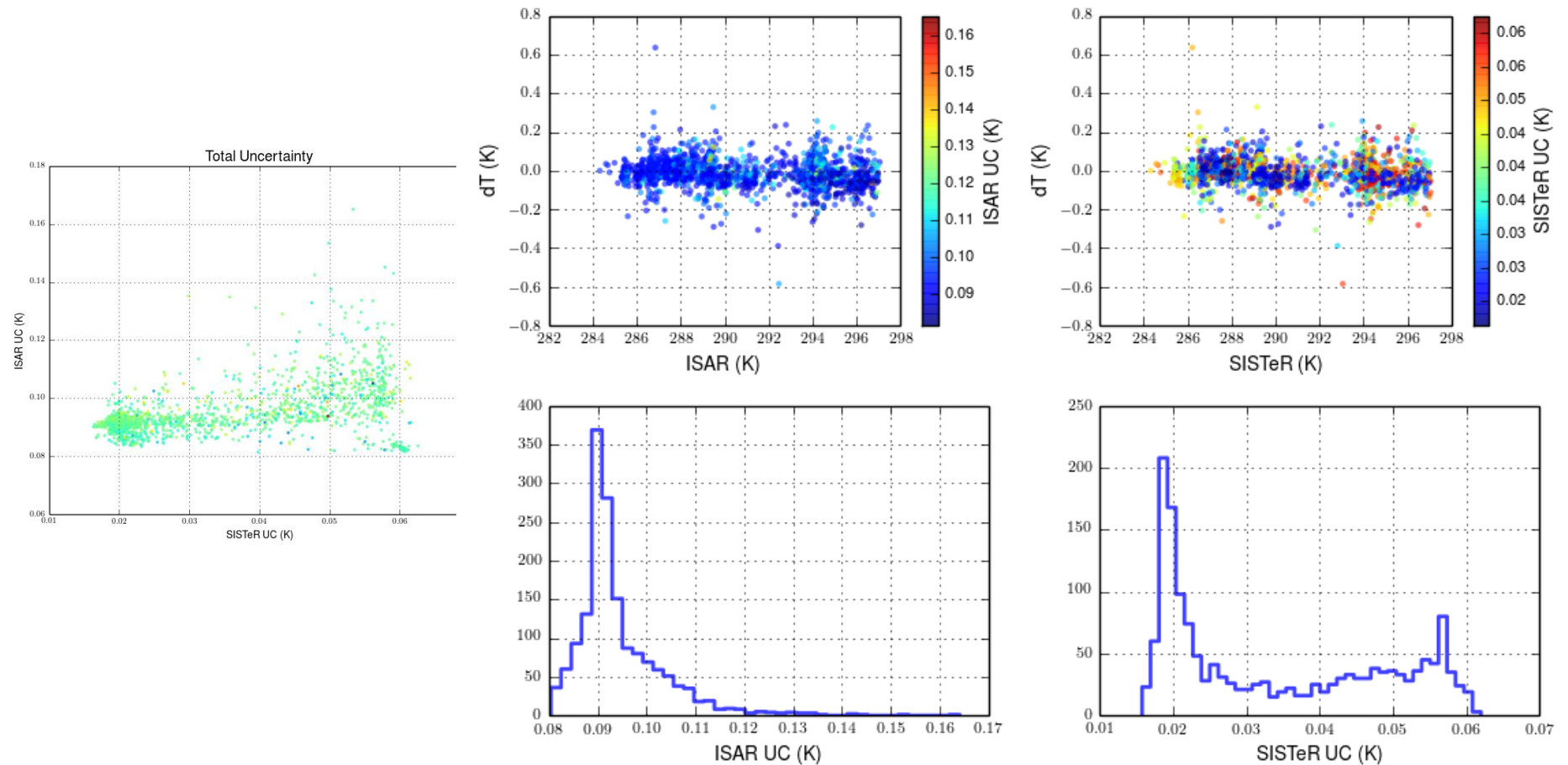
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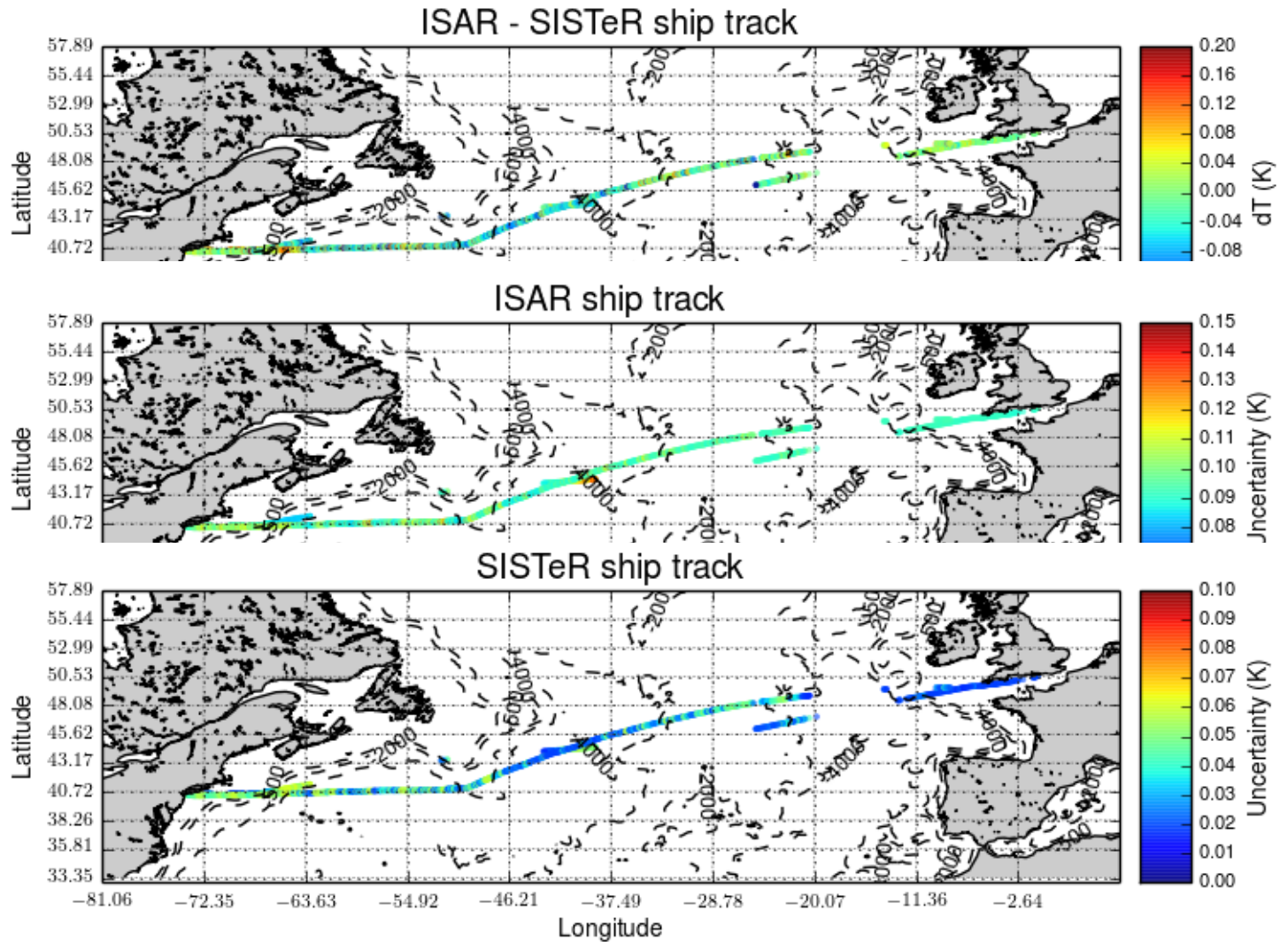


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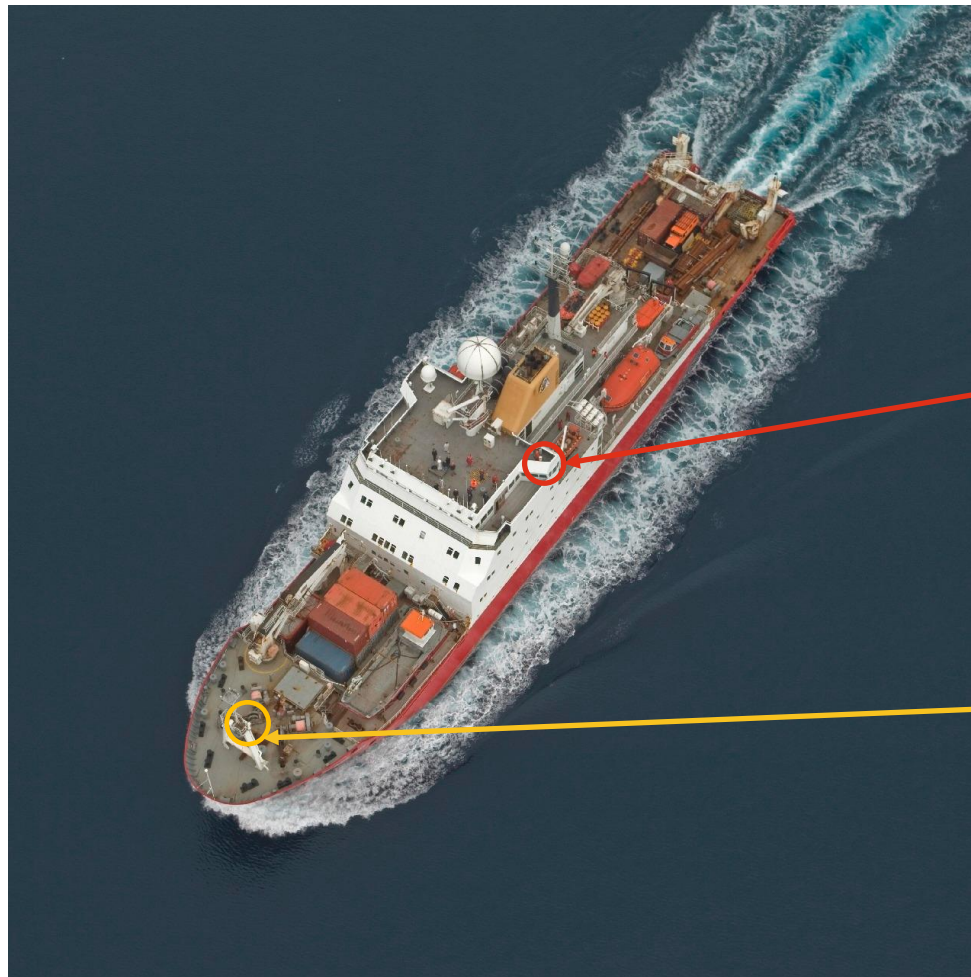
Uncertainty – validation – QM2



Uncertainty – validation QM2



Uncertainty – validation - AMT

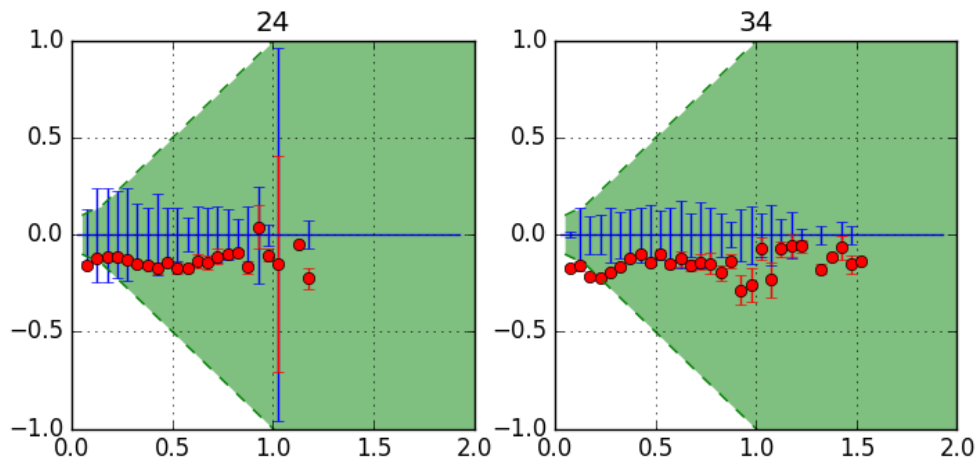


ISAR 012

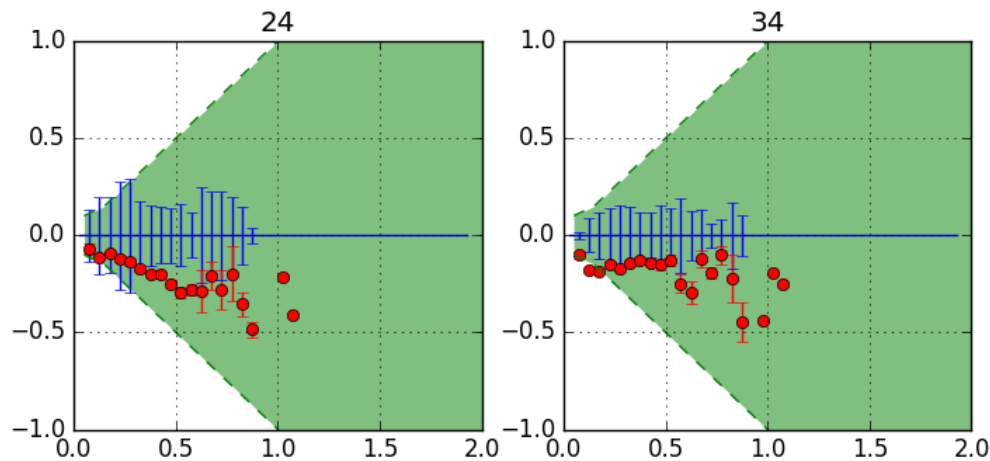
ISAR 003

Uncertainty – validation - AMT

- 1: 25 - 12
- 2: 35 - 12
- 3: 45 - 12
- 4: 35 - 3



UC 12

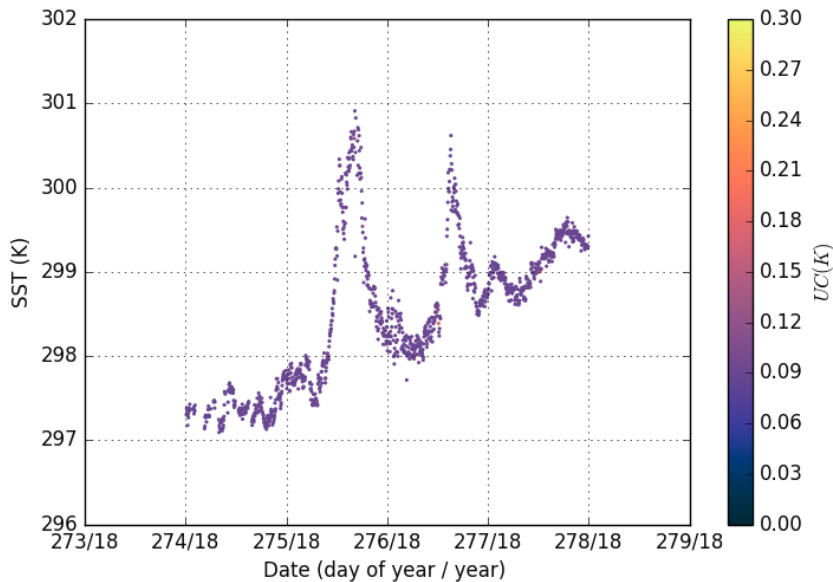


UC 03

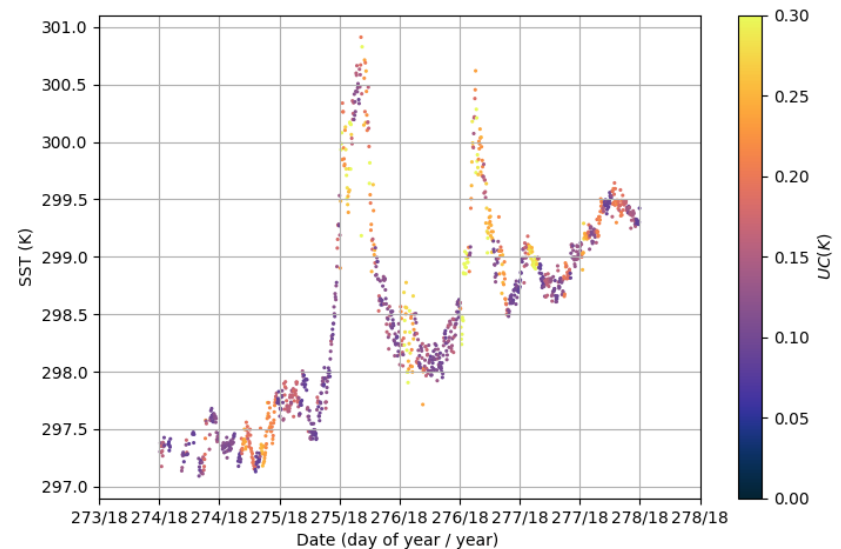
Uncertainty – validation – AMT – v2

■ Changes to v1

- 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 gets added to the sea and sky signal uncertainty before calibration
 - SST weighted std gets added to final SST uc in quadrature



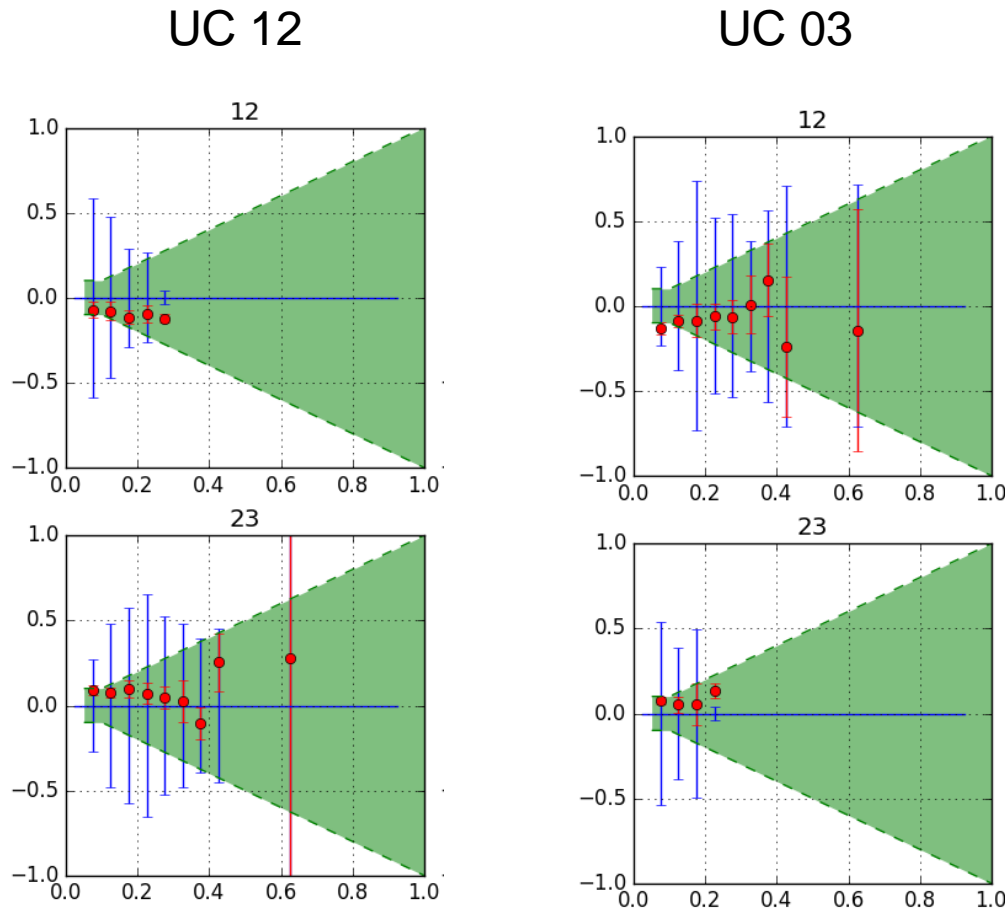
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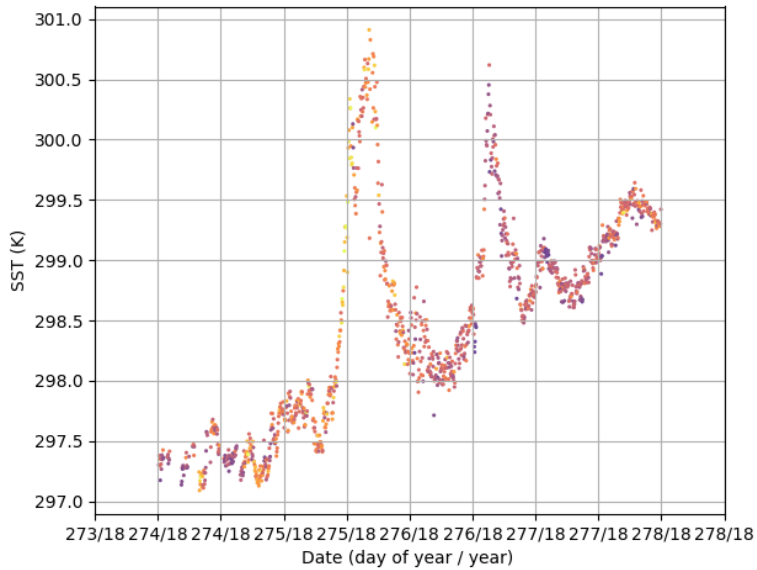
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Uncertainty – validation – AMT – v2

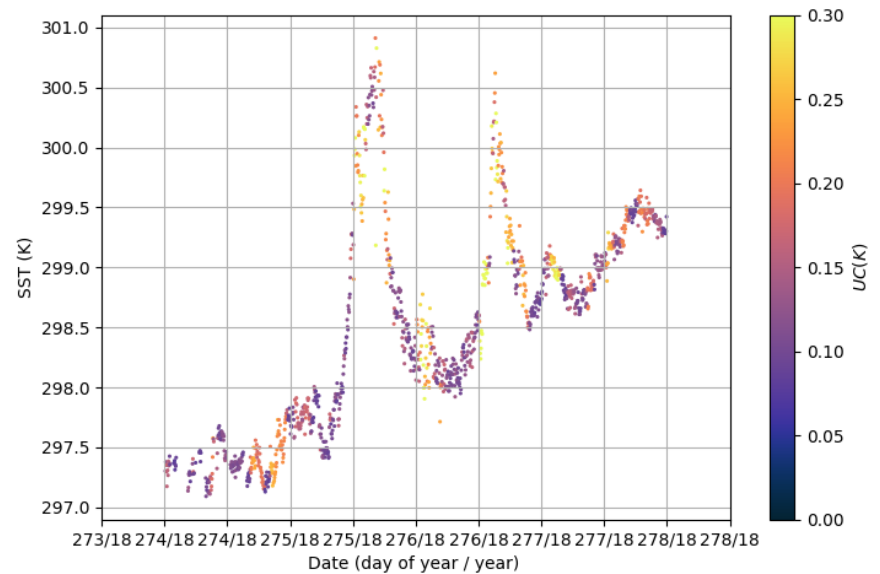
- 1: 35 – 12 - idx
- 2: 35 – 03 - final
- 3: 45 – 12 - sroll
- 4: 35 – 3 - idx



Uncertainty – validation – AMT – v2



processed 20190226 17:45:31 (c) 2019 ISAR team



processed 20190226 18:09:15 (c) 2019 ISAR team - v1.0 - sst: v 4.1

Threeway error

- Classic
 - ISAR 03 : 0.099268655975 K
 - ISAR 012: 0.207749984467 K
 - Seabird: 0.237381473668 K
- Challenor et.al.
 - ISAR 03 : 0.08351921 K
 - ISAR 012: 0.16033502 K
 - Seabird: 0.18997807 K
- View angle is 145/35 degrees
 - Issues with ships wake for ISAR 012

Conclusion

- Uncertainty model
 - Principle is relatively straight forward
 - Potentially lots of components and covariance matrix might be tricky to resolve
 - Numbers are sometimes difficult to estimate
- ISAR uncertainty model
 - Was first of its kind
 - Instrument uncertainty seems right
 - Measurement uncertainty overestimates
 - Roll dependence of emissivity
- Uncertainty model validation
 - Not easy to achieve
 - Showed instrument uncertainty is ok – QM2
 - Also showed measurement uncertainties generally over estimate but do not capture SST gradients well
 - V2 in progress