ships4sst

shipborne radiometers for sea surface temperature

Experiences : ISAR - UoS

Werenfrid Wimmer

Raymond Holmes, Ian Robinson, Craig Donlon, Gary Fisher, Kelvin Aylett, Ray Collins, ..

Overview

- IR measurements in Southampton
- ISAR
  - The early days
  - Design evolution
  - Calibration system
- Deployments
  - The early days
  - Bay of Biscay and English Channel
  - Other deployments and projects
- Inter-comparisons
- Summary

A bit of history

- AMT 3 (1996)

4.6.1 Radiometric Observations of the Sea Surface and Atmosphere (ROSSA) 1996

C J Donlon, University of Colorado/Southampton Oceanography Centre/BAS
T J Nightingale, Rutherford Appleton Laboratory, UK

Experiment Summary

The ROSSA experiment has operated within the framework of AMT-3 and the measurements made complement the biochemical measurements made by the AMT team. ROSSA is concerned with both the accurate validation of precision satellite sea surface temperature observations (such as those made by the ERS-2 Along Track Scanning Radiometer, the NOAA Advanced Very High Resolution Radiometer and the ADEOS Ocean Colour Temperature Scanner), and also the investigation of the small scale processes which in combination, are thought to govern the magnitude and variability of the SSST when referenced to a sub-surface bulk sea surface temperature (BSST). Such processes include the momentum flux (wind stress), the longwave, sensible, solar and latent heat fluxes which in combination define the thermal state of the air sea interface.

Instrument	Parameter	Location	Accuracy
TASCO THI-500L	Skin SST	Forward mast	0.15 +/-0.1K
TASCO THI-500L	Sky temperature	Forward mast	0.21 +/-0.1K
SISTeR	Skin SST	Forward mast	0.1 +/-0.05K
TH ?	Skin SST	Monkey Island	0.1 +/- 0.05 K
Thermal Camera	Skin SST (2D)	Monkey Island	0.1 +/- 0.1K
OPHIR MISTRC radiometer	Skin SST	Bow	Faulty for whole trip
Trailing thermistor	Bulk SST @ 0.1m	Port flank	0.05 +/- 0.005
Eppley Pyranometer	Solar Flux	Bird table (forward mast using gimbals)	0.5%
Eppley Pygeometer	Longwave flux	Bird table (forward mast using gimbals)	0.5%
IOS Psychrometer	Humidity & air temperature	Forward mast	Better than 0.05K
X band radar	Roughness	Forward mast	

Table 1. Summary of instruments installed on the RRS James Clark Ross for ROSSA 1996.

A bit of history

- AMT 5 (1997)
  - SOSSTR
    - The ship of opportunity sea surface temperature radiometer

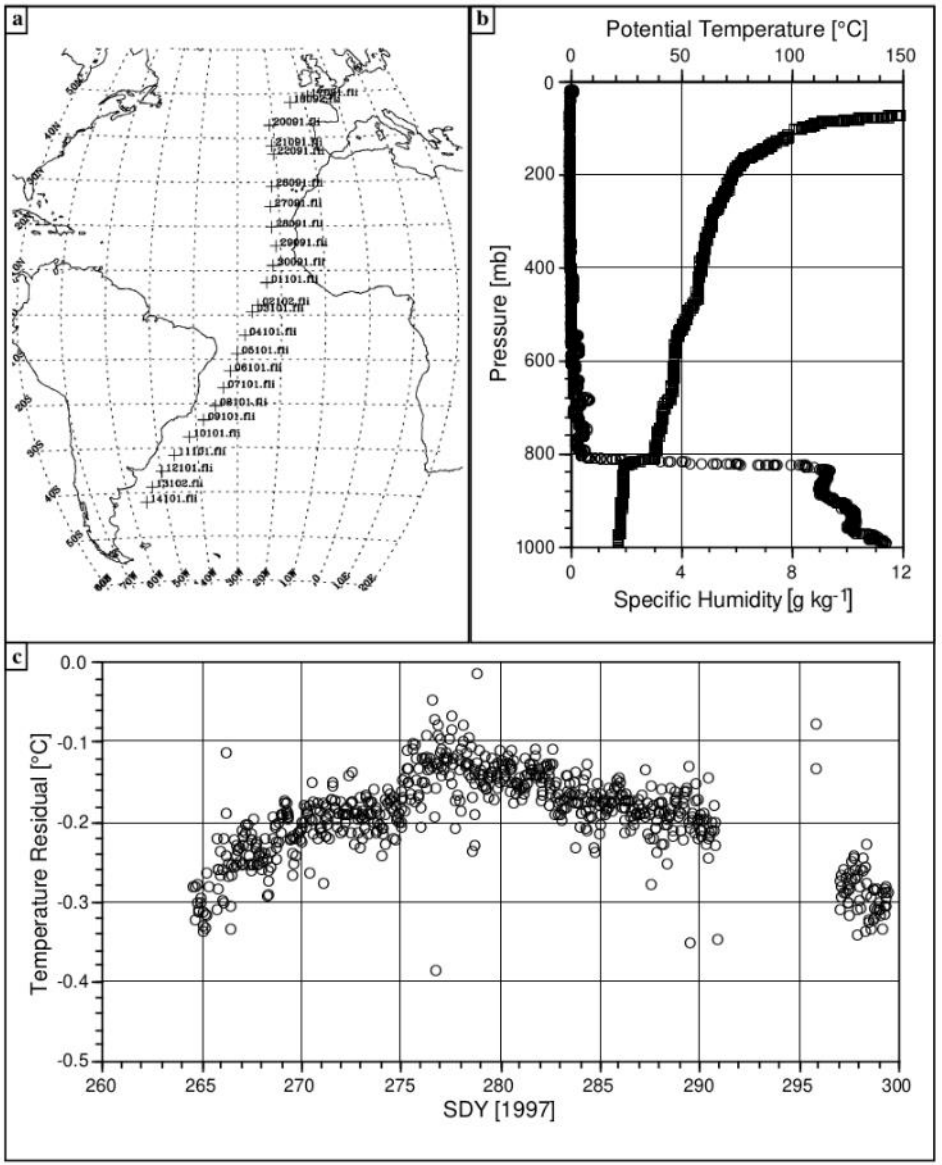
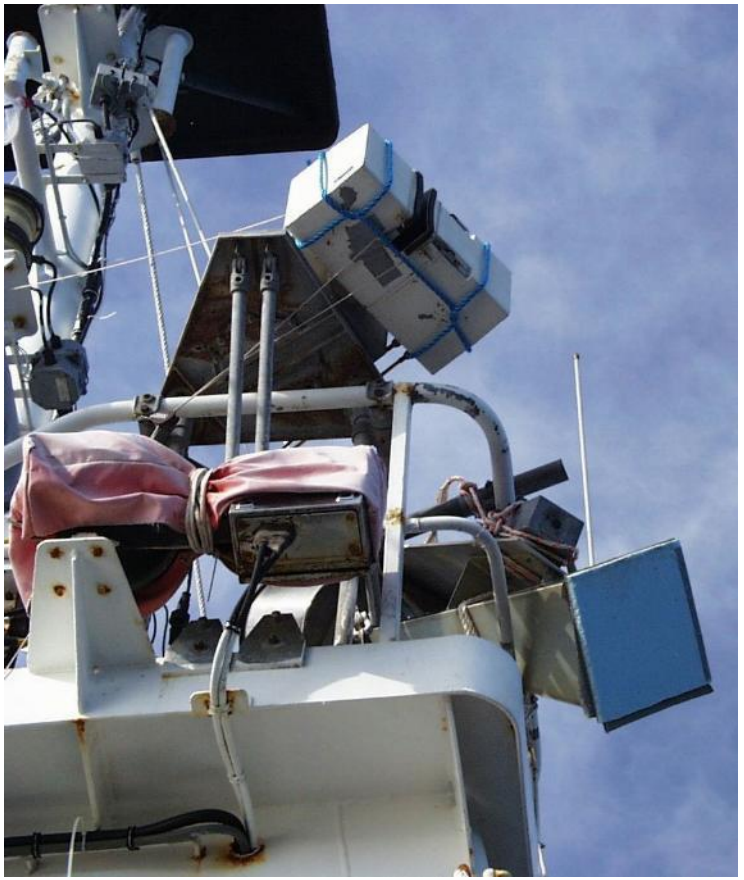


Fig. 13. SOSSTR summaries for AMT-5: **a)** the positions of all the radiosonde releases, **b)** potential temperature (squares) and specific humidity (circles) as a function of pressure, and **c)** the temperature difference (residual) between the SST and the hull mounted temperature probe.

A bit of history

- AMT 7 (1998)
  - SOSSTR
    - The ship of opportunity sea surface temperature radiometer
  - SISTeR
    - Scanning Infrared Sea Surface Temperature Radiometer



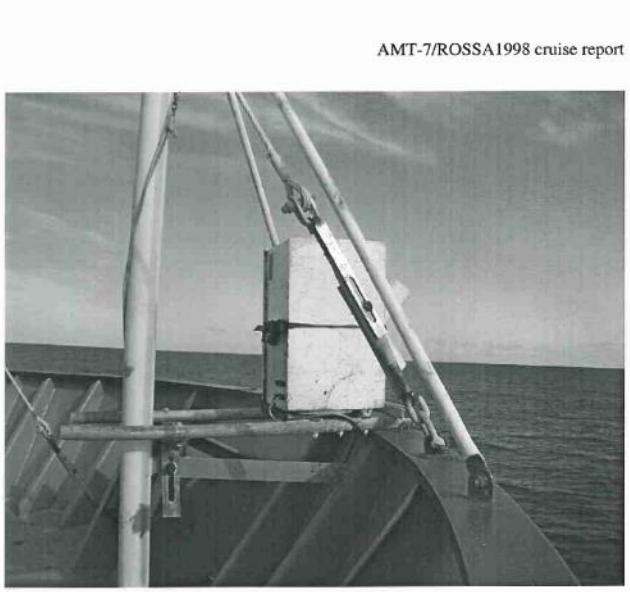


Figure 6 SOSSTR radiometer as deployed on James Clark Ross Bow during AMT-7/ROSSA 1998

A bit of history

- SUDOFEX (1997)
  - SOOSR
    - The ship of opportunity sea surface radiometer

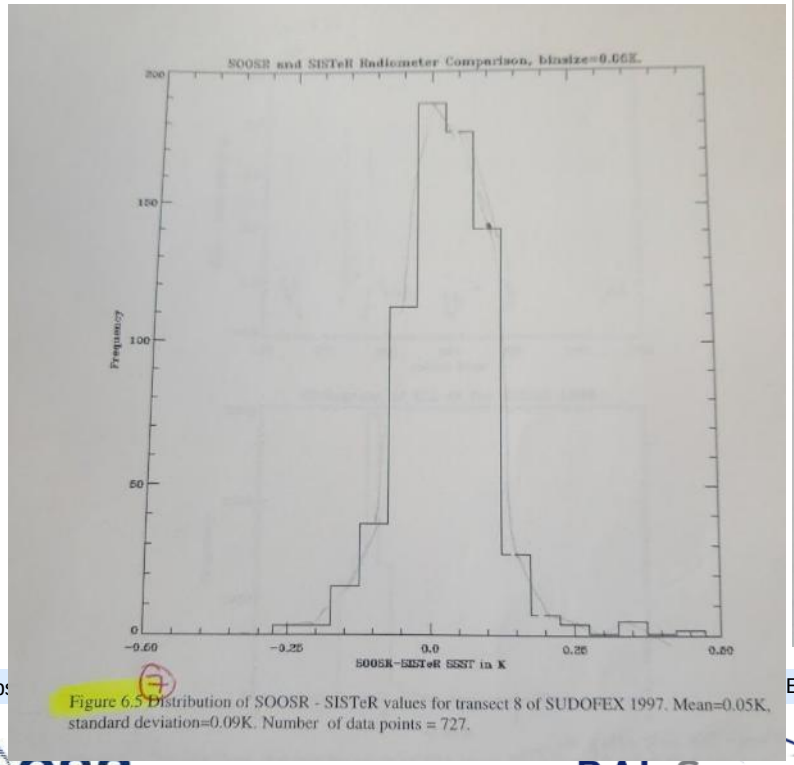


Figure 6.5 Distribution of SOOSR - SISTeR values for transect 8 of SUDOFEX 1997. Mean=0.05K, standard deviation=0.09K. Number of data points = 727.

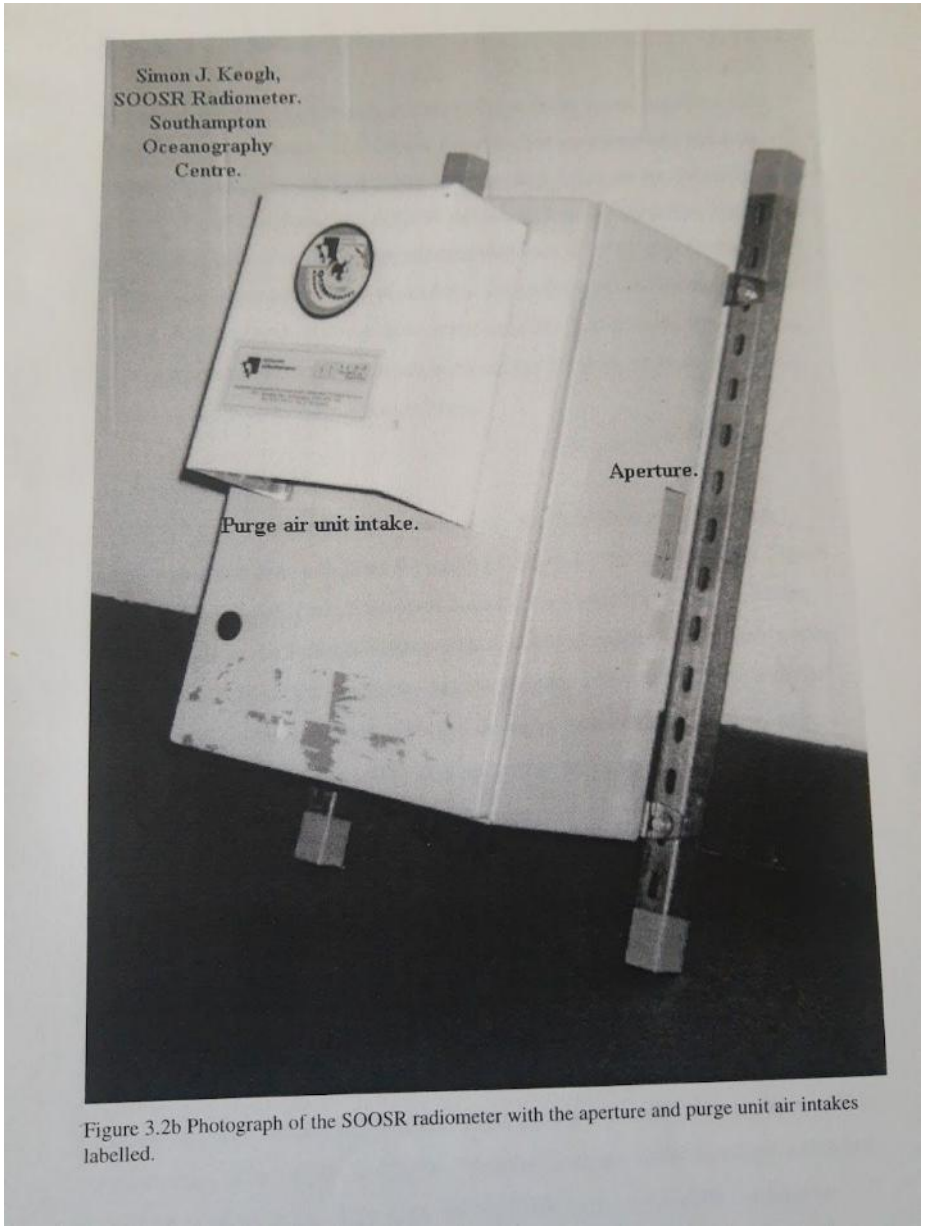


Figure 3.2b Photograph of the SOOSR radiometer with the aperture and purge unit air intakes labelled.

ISAR

- Infrared Sea surface temperature Autonomous Radiometer (1999)
- CASOTS – The combined action for the study of the ocean thermal skin (1999)

Project title:
Development of two (2) prototype Infrared Sea s
Autonomous Radiometer (ISAR) systems.

Project reference:	Date:	Auth
N00173-98-Q-6002	Thursday, April 1st, 1999	C.

Project PI:	Tel:	Fax:
Craig Donlon	+39 0332 786353	+39 0332 785656

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Supporting institutions(s):

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   Contact: Dr. M. R. Reynolds (reynolds@bnl.gov)

2. Space Science Department, Rutherford Appleton Lab
   Contact: Dr. T. J. Nightingale (t.j.nightingale@rl.a

SOC Developments and Initiatives Fund.

Proposal to construct and deploy an autonomous Infra Red radiometer (ISAR) for the purpose of satellite SST validation and the study of the oceanic thermal skin.

Prof. I.S. Robinson[1], Dr. C.J. Donlon[2], Dr. S.J. Keogh[1], G.J. Fisher[1], R.C. Collins[1], Dr. T.J. Nightingale[3].

1 SOES, Southampton Oceanography Centre, European Way, Southampton, SO14 3ZH.
2 CEC-JRC ISPRA, Space Applications Institute, Marine Environment Unit, I-21020, ISPRA, (VA)-Italy, TP690.
3 Space Science Department, Rutherford Appleton Laboratories, Chilton, Didcot, Oxfordshire, OX11 0QX.

Project outline.

The accuracy of sea surface temperature (SST) measurements from satellite borne infra red radiometers such as AVHRR and ATSR is of major concern to the climate community. By using infra red radiometers at sea, to measure sea surface skin temperature, errors in SST retrieval associated with atmospheric attenuation, the oceanic skin effect and diurnal thermocline can be eradicated from the satellite SST data by tuning the atmospheric algorithms to the in situ skin SST data. Unfortunately there is no on going programme at this time to gather skin SST data for this purpose. In fact there are no autonomous infra red radiometers available for this task at all. It is herein proposed that a novel design for an autonomous radiometer be funded to allow the construction of a prototype and its deployment on a ship of opportunity. Once the concept has been proven in this manner it should be possible to bid for funding from other s
on-goir

Overall
Amoun

Southampton Oceanography Centre

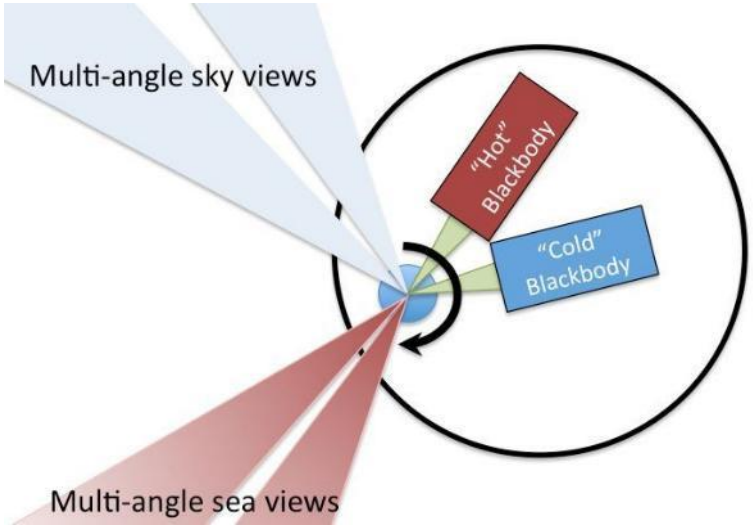
Memorandum
Centre Services Division
Finance Office
Room 346/25

To: Professor I.S. Robinson
From: Kevin Cripps
CC: Gwyn Griffiths, Keith Birch
Date: 26/07/99
Re: Technology Innovation Fund - SOES Radiometer

Further to Gwyn Griffith's memo of 20 July 1999 I can confirm that a new project has been set up within OTD to fund the in situ radiometer.

ISAR

- Infrared Sea surface temperature Autonomous Radiometer

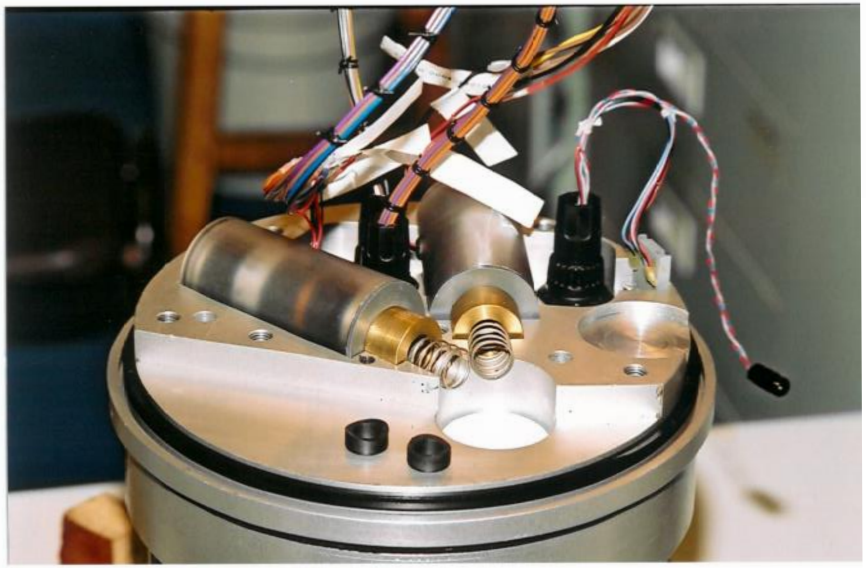


Donlon, C., Robinson, I., Reynolds, M., Wimmer, W., Fisher, G., Edwards, R. and Nightingale, T. (2008), '***An infrared sea surface temperature autonomous radiometer (ISAR) for deployment aboard volunteer observing ships (VOS)'***, *J. Atmos. Oceanic Technol.* 25, 93–113.

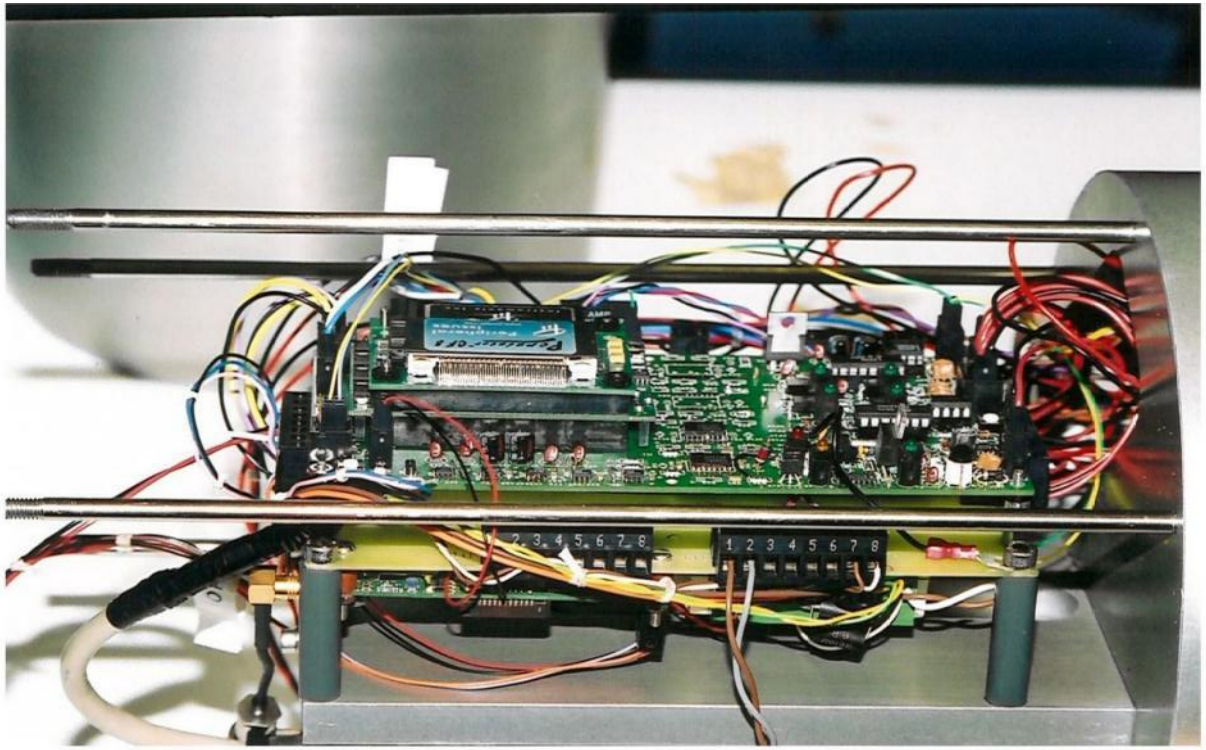
The early days

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1					TITLE:	ISAR–001 instrument working master (ISAR–5 Components database)												
2					LAST EDIT DATE:	11.01.00												
3					Author:	C J Donlon: Tel: +39 0332 786353;												
4					Document status:	CONFIDENTIAL												
5					Document name:	isar–001–budget–v2.3.xls												
6																		
7					All costs US$ (red) or GPB (blue)													
8					date:	1.6172												
9					date:	0.5294												
10					Component Id's shown in BLACK should not be purchased.													
11					Component Id's shown in PURPLE should be purchased by BNL and invoiced to SOC													
12					Component Id's shown in RED should be processed by Gary Fisher.													
13					Component id's in YELLOW are optional and should not be purchased													
14					GREEN highlights engineering work													
15					MAGENTA highlights problems													
16																		
17	ID	ISAR–01	Quot ref.	Quot date	Components to be bought for BNL by SOC	Model ref	Company	Quanti	Unit cost	U/C+O/h	Total estim	Total est	Actual cost	Adjustment	Purchas	Received	Inventor	Notes
18	IS–01–1	Y	isar-soc.xls	14.09.99	Tinitrale Model 8	TT–8 (1MB)	ONSETT	1	495	693	693	428.52	428.52		BNL			BNL to in
19	IS–01–3	Y	isar-soc.xls	23.09.99	Misc. parts for ISAR–EC99	As required	BNL	1	125	175	175	108.21	108.20		BNL			BNL to in
20	IS–01–2	Y	isar-soc.xls	14.09.99	Control board, TTS	PC–Board, TTS	BNL	1	100.5	140.7	140.7	87	87.00		BNL			BNL to in
21	IS–02	Y	Telephone	13.08.99	12–24V DC–DC converter	VI–J03–BZ	VICOR	1	85	119	119	73.58	73.00		BNL			BNL to in
22	IS–03	Y	isar-soc.xls	14.09.99	8 channel 18 bit A–D converter	GND–60 ?7	Solec	1	280	392	392	242.39	242.40		BNL			BNL to in
23	IS–MC–1	N	isar-soc.xls	14.09.99	[illegible]	[illegible]	ONSETT	0	45	63	0	0	0.00	0.00	BNL			BNL to in
24	IS–MC–2	N	isar-soc.xls	14.09.99	[illegible]	[illegible]	Peripheral Issues	0	295	413	0	0	0.00	0.00	BNL			BNL to in
25	IS–MC–3	N	isar-soc.xls	14.09.99	4MB Mem Card	[illegible]	Peripheral Issues	0	199	278.6	0	0	0.00	0.00	BNL			BNL to in
26	IS–04	Y	QB990722–01	22.07.99	Optical Rain Gauge with analogue output (Mini–ORG)	ORG–115–DA	SCTI	1	2190	3066	3066	1895.87	1172.52		SOC	YES		SOC to pa
27					TOTAL Cost of BNL parts procured by SOC						4385.7	2835.58	2111.66					
28																		
29	ID	ISAR–01	Quot ref.	Quot date	ISAR–5 components to be bought by SOC	Model ref	Company	Quanti	Unit cost	U/C+O/h	Total estim	Total es	Actual cost	Adjustment	Purchas	Received	Inventor	Notes
30	IS–05	Y	0102450 rev1	01.04.99	KT15.85D	96004318	HEITRONIC	1	4604.82	6446.75	6446.75	3986.37	2830.78		SOC	YES		6 week lea
31	IS–6	Y	E-mail	23.07.99	YSI Thermistors	014–46041–NA–IT–6–ST (YSI4604 10K@25C super stable +/–3.05C)	YSI	9	125	175	1575	973.91	1309.82		SOC	YES		
32	IS–7	Y	Fax	08.12.99	Optics for Research MR–25 700nm–far IR gold front surface mirror 25mm diameter 3mm thick	MR–25–3	LAMBDA–P	1	200.53	280.75	280.75	173.6	182.13		SOC	YES		
33	IS–8	Y	Telephone	23.07.99	Hall effect switch for 2 wire applications	A 3161 ELT	ALLEGRO	2	1.88	2.63	5.25	3.25		0.00	BNL			
34	IS–9	Y	Quote	01.04.99	Mankiewicz Nextel Velvet black paint	811–21	MPE	1	100	140	140	86.57	113.37		SOC	YES		
35	IS–10	Y	Quote	01.04.99	Nextel Thinners	8061	MPE	1	31	43.4	43.4	26.84	see IS–9		SOC	YES		
36	IS–11	Y	Quote	01.04.99	Nextel Primer	5523	MPE	1	13	18.2	18.2	11.25	see IS–9		SOC	YES		
37	IS–12	Y	Q–99–4147	23.07.99	Self adhesive Minco Kapton heater	HK5329R 80.1L12B (80.1 Ohm 25.4 x 97.6 mm)	CAREL	2	48.92	68.49	136.98	84.7	70.63		SOC	YES		
38	IS–14	Y	4448	01.04.99	Maxon A–Max, diameter 26mm, Graphite Brush, 6 Watt, ball bearing, 1 shaft output, 12V, with flying leads	110926	MAXON–UK	2	86.5	121.24	242.48	149.94	443.91		SOC	YES		
39	IS–15	Y	4448	01.04.99	Maxon Planetary gearhead, diameter 32mm, 0.75–4.5 Nm, 531:1 reduction	114493	MAXON–UK	2	216.7	303.39	606.77	375.2	see IS–15		SOC	YES		
40	IS–16	Y	E-mail	01.04.99	Absolute shaft encoder with special 6mm output shaft	A2–S–B–3–3 (Special 6mm output shaft)	USDIGITAL	1	336	470.4	470.4	290.87		0.00	SOC			
41	IS–17	Y	isar-soc.xls	14.09.99	Serial interface to US Digital shft encoder	AD2–A	USDIGITAL	1	48	67.2	67.2	41.55		0.00	SOC			
42	IS–18	Y	isar-soc.xls	14.09.99	9 pin plug connectors	Conxall 3–282–9PG–330	CONXALL	8	5.57	7.8	62.38	38.58		0.00	BNL			
43	IS–19	Y	isar-soc.xls	14.09.99	9 pin socket connectors	Conxall 4–282–9SG–300	CONXALL	8	7.41	10.37	82.99	51.32		0.00	BNL			
44	IS–20	Y	Telephone	22.07.99	Miniature Magnets at 250 Gauss (strength guaranteed for 12 months in shock environment)	Part Number: DSC0187C (10 x diameter x 5 mm SmCo5)	MAGNETS	2	19.21	26.9	53.79	33.26	21.50		SOC	YES		
45	IS–21	Y	E-mail	01.04.99	ZnSe window	Diameter 25 mm 2mm thick	CRYSTRAN	1	64.69	90.56	90.56	56	49.94		SOC	YES		
46	IS–22	Y	Telephone	22.07.99	Metric non metallic flanged bush bearing ID=25mm length=20 mm	PIC Part No. MBF–2532–20	PIC	1	4.37	5.11	6.11	3.78		0.00	SOC	YES		

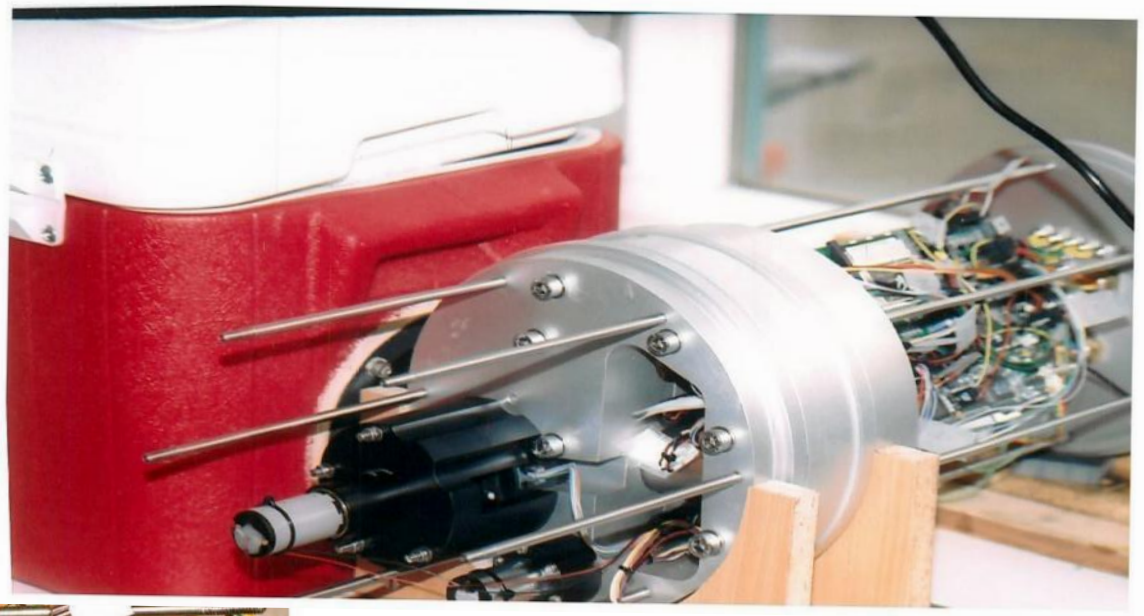
Seite 1

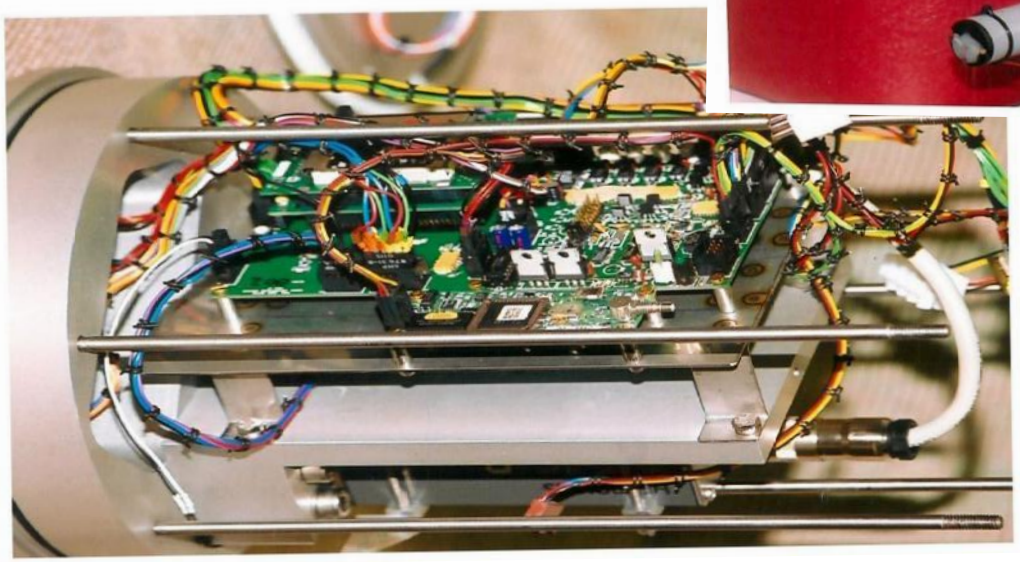


The early days



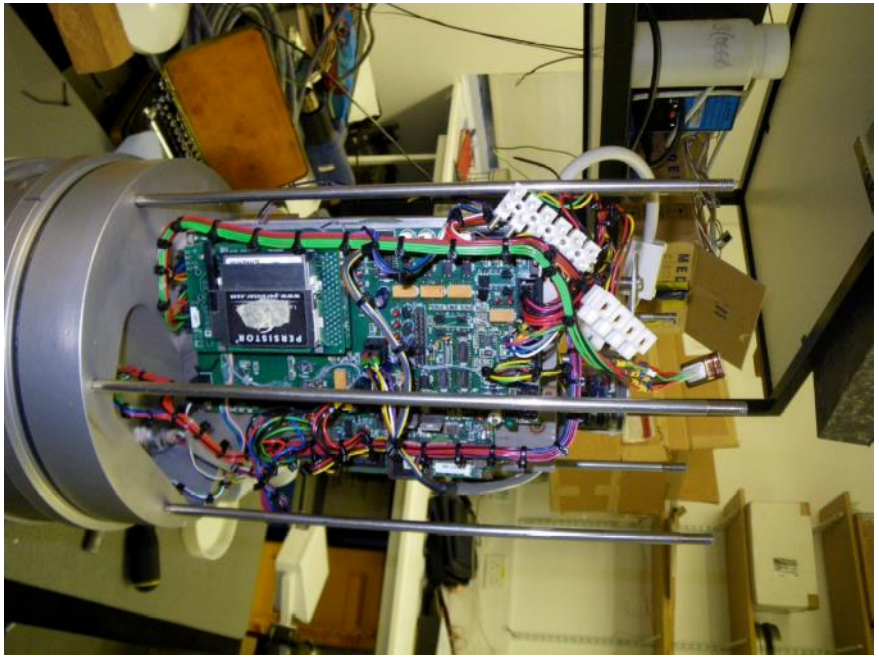
The early days

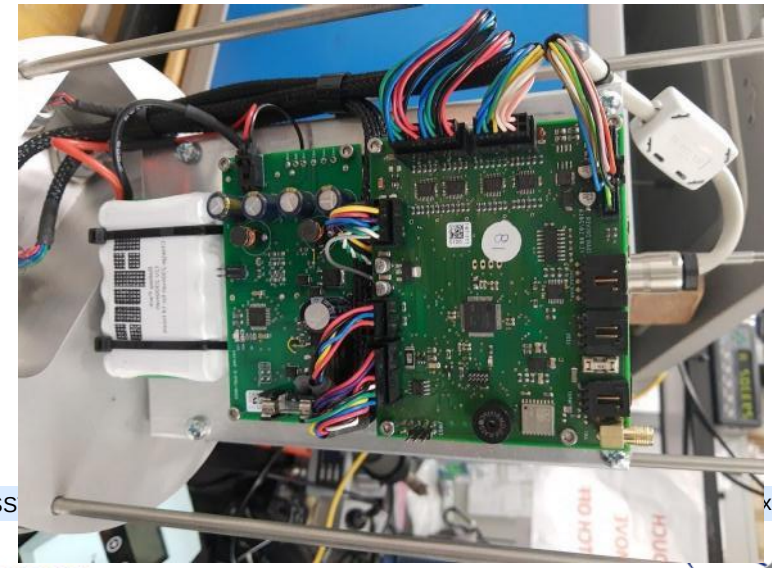


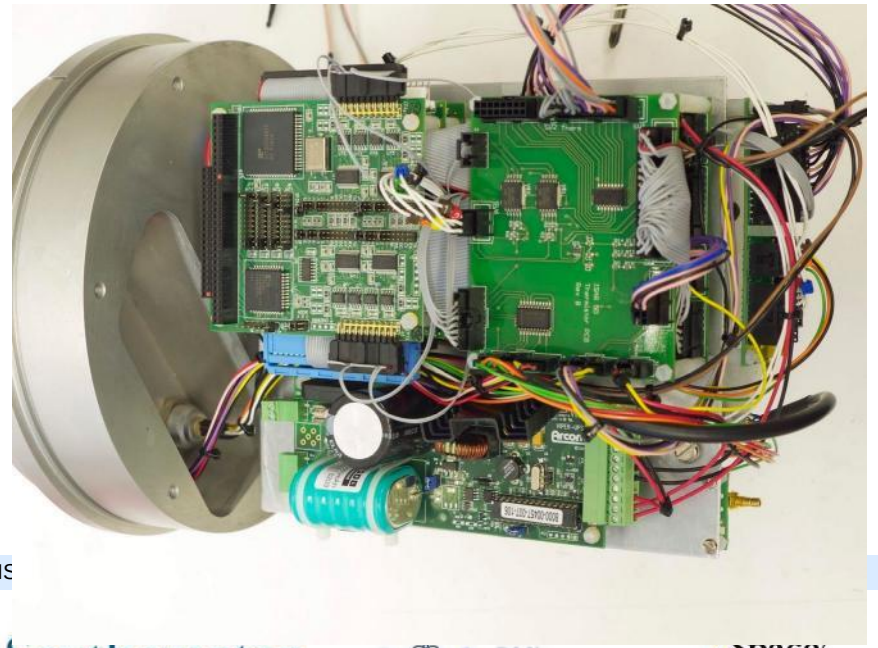


Design evolutions

- Electronics
  - Rev A-C (2000 – 2006, SN 1-5)
    - Motorola 68000
  - Rev D (2007 – 2014, SN 6-12, 2 retrofitted)
    - Intel Xscale on PC104
  - Rev E (2015 – now, SN13 -22, 7 & 12 retrofitted)
    - Raspberry Pi CM3/4 module

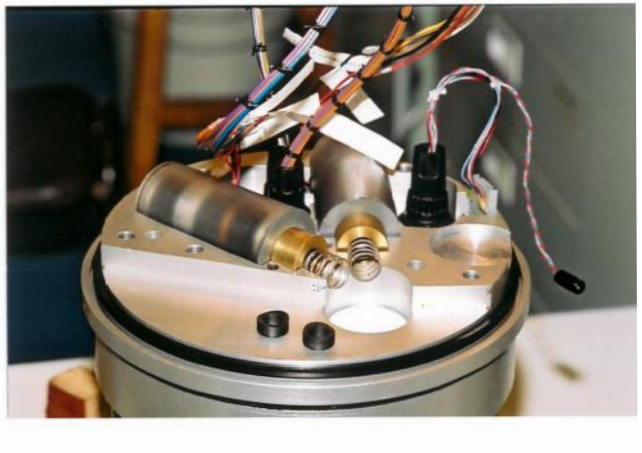


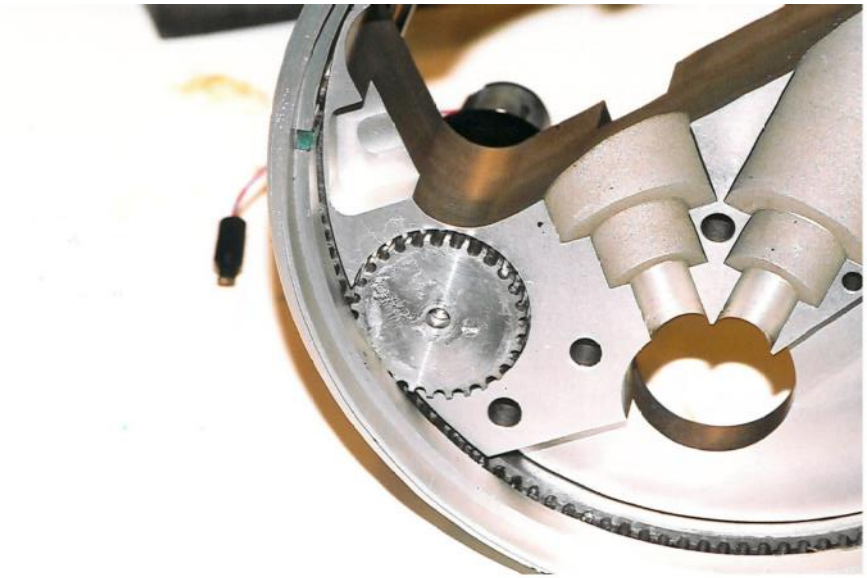


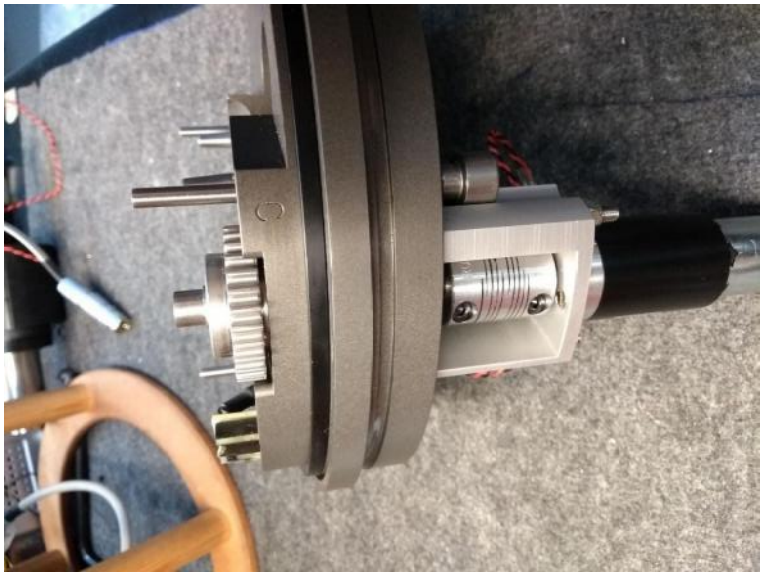


Design evolutions

- Hardware
  - Changes in BB design – removal of bushes
  - Shutter drive
  -

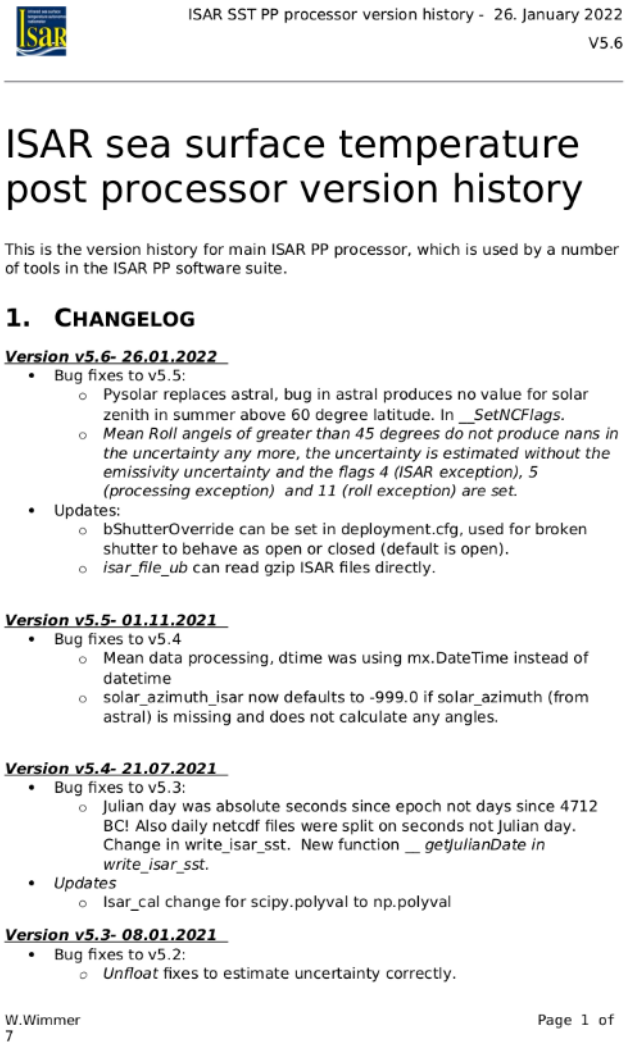






Design evolutions

- Software
  - ISAR 5C
    - Onboard C – 18 versions
    - Post-processing IDL, later python
  - ISAR 5D
    - Onboard C – 14 versions
    - Post-processing python
  - ISAR 5E
    - Onbaord
      - C for SAME54 – 6 versions
      - Python for Raspberry Pi – 11 versions
    - Post-processing python
  - Python post processor
    - Unified processor for all ISAR – 30 versions



ISAR sea surface temperature post processor version history

This is the version history for main ISAR PP processor, which is used by a number of tools in the ISAR PP software suite.

1. CHANGELOG

Version v5.6- 26.01.2022

- Bug fixes to v5.5:
  - Pysolar replaces astral, bug in astral produces no value for solar zenith in summer above 60 degree latitude. In *__SetNCFlags.*
  - *Mean Roll angels of greater than 45 degrees do not produce nans in the uncertainty any more, the uncertainty is estimated without the emissivity uncertainty and the flags 4 (ISAR exception), 5 (processing exception) and 11 (roll exception) are set.*
- Updates:
  - bShutterOverride can be set in deployment.cfg, used for broken shutter to behave as open or closed (default is open).
  - *isar_file_ub* can read gzip ISAR files directly.

Version v5.5- 01.11.2021

- Bug fixes to v5.4
  - Mean data processing, dtime was using mx.DateTime instead of datetime
  - solar_azimuth_isar now defaults to -999.0 if solar_azimuth (from astral) is missing and does not calculate any angles.

Version v5.4- 21.07.2021

- Bug fixes to v5.3:
  - Julian day was absolute seconds since epoch not days since 4712 BC! Also daily netcdf files were split on seconds not Julian day. Change in write_isar_sst. New function *__ getJulianDate in write_isar_sst.*
- *Updates*
  - Isar_cal change for scipy.polyval to np.polyval

Version v5.3- 08.01.2021

- Bug fixes to v5.2:
  - *Unfloat* fixes to estimate uncertainty correctly.

CASOTS

- Mk 1(1999)

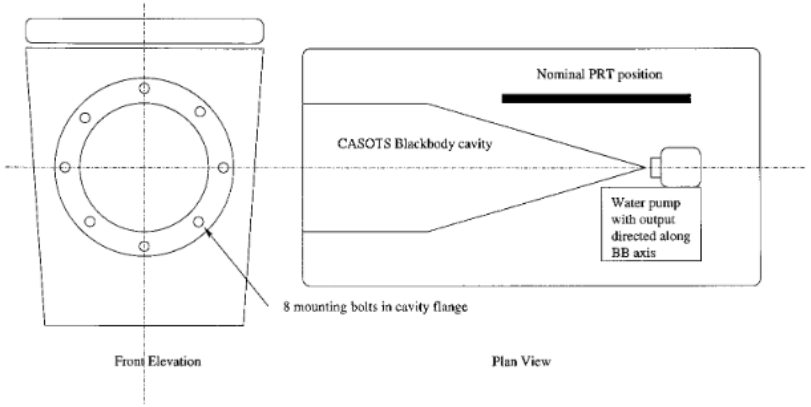


FIG. 1. A schematic diagram showing the general layout of the CASOTS blackbody unit. The relative positions of the blackbody cavity, a nominal PRT, and the water pump are shown. The water bath is approximately 70 × 30 × 30 cm.

Donlon, Craig; Nightingale, Timothy; Fiedler, Lars; Fisher, Gina; Baldwin, D.; Robinson, I.S.. (1999). **The Calibration and Intercalibration of Sea-Going Infrared Radiometer Systems Using a Low Cost Blackbody Cavity**. Journal of Atmospheric and Oceanic Technology - J ATMOS OCEAN TECHNOL. 16.

CASOTS

- Mk 2 (2005)

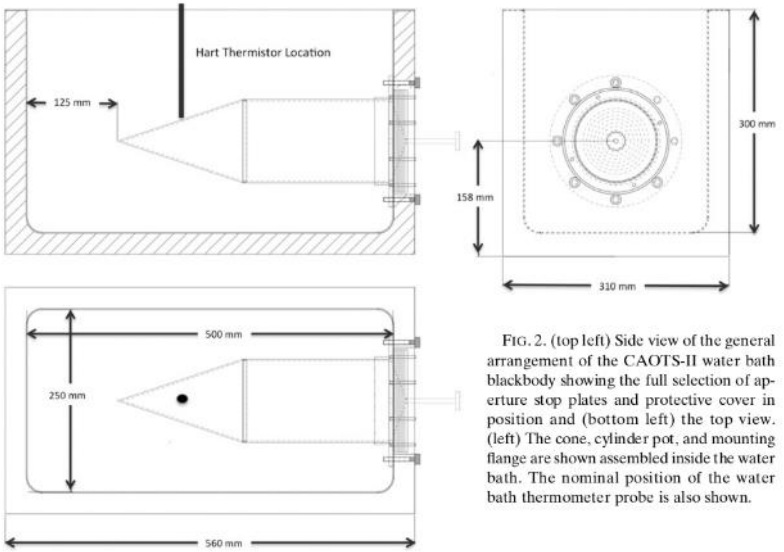


FIG. 2. (top left) Side view of the general arrangement of the CAOTS-II water bath blackbody showing the full selection of aperture stop plates and protective cover in position and (bottom left) the top view. (left) The cone, cylinder pot, and mounting flange are shown assembled inside the water bath. The nominal position of the water bath thermometer probe is also shown.

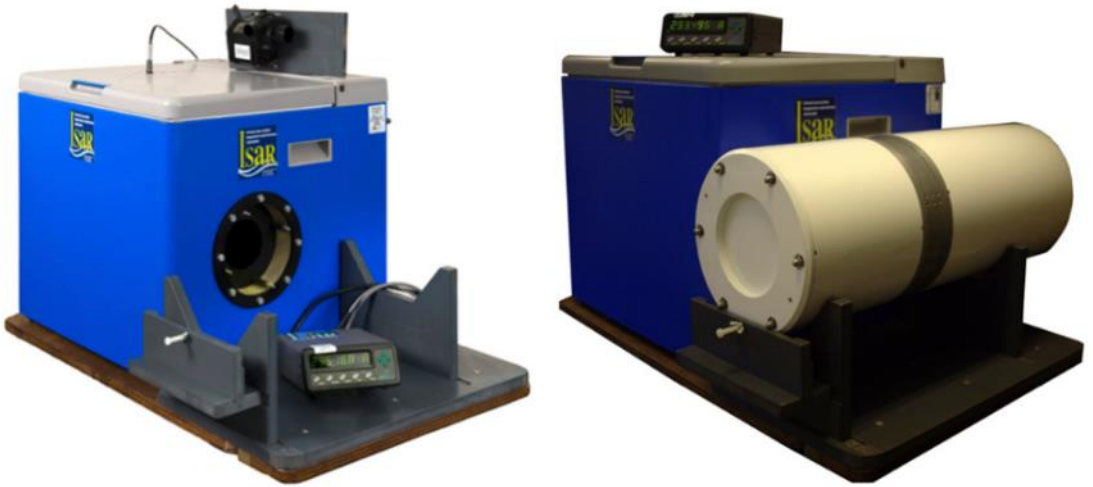


FIG. 1. CASOTS-II blackbody system with aperture protection plate removed from the protruding studs. (left) The ISAR radiometer mounting jig is shown in front of the circular aperture with the Hart Scientific 1504 bridge. A Thermometrics temperature probe 225 is shown at the top protruding from the water bath lid and the water bath pump (fitted internally when the unit is in operation) is also shown on top of the lid. (right) The CASOTS-II blackbody system showing an ISAR radiometer mounted for calibration verification.

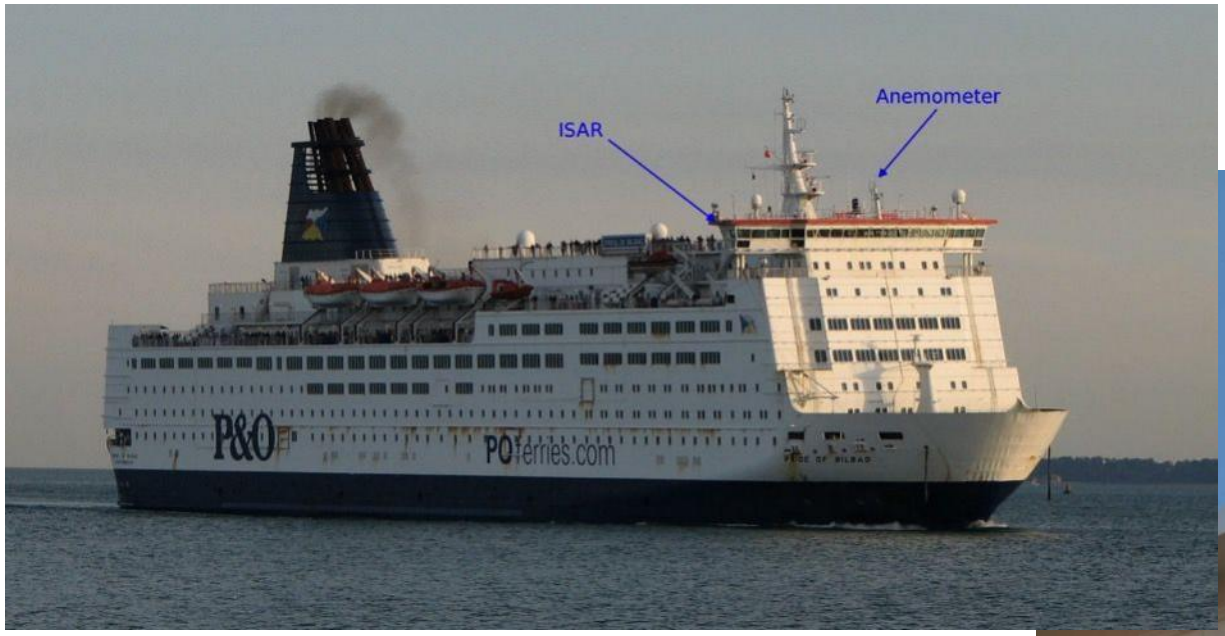
Donlon, Craig J., Wimmer, W., Robinson, I., Fisher, G., Ferlet, M., Nightingale, T. and Bras, B. (2014) **A Second-Generation Blackbody System for the Calibration and Verification of Seagoing Infrared Radiometers**. Journal of Atmospheric and Oceanic Technology, 31 (5), 1104-1127.

Deployments

- Val-de-Loire (2002)
- SOC (NOC,S) roof

ISAR installed on *Pride of Bilbao*

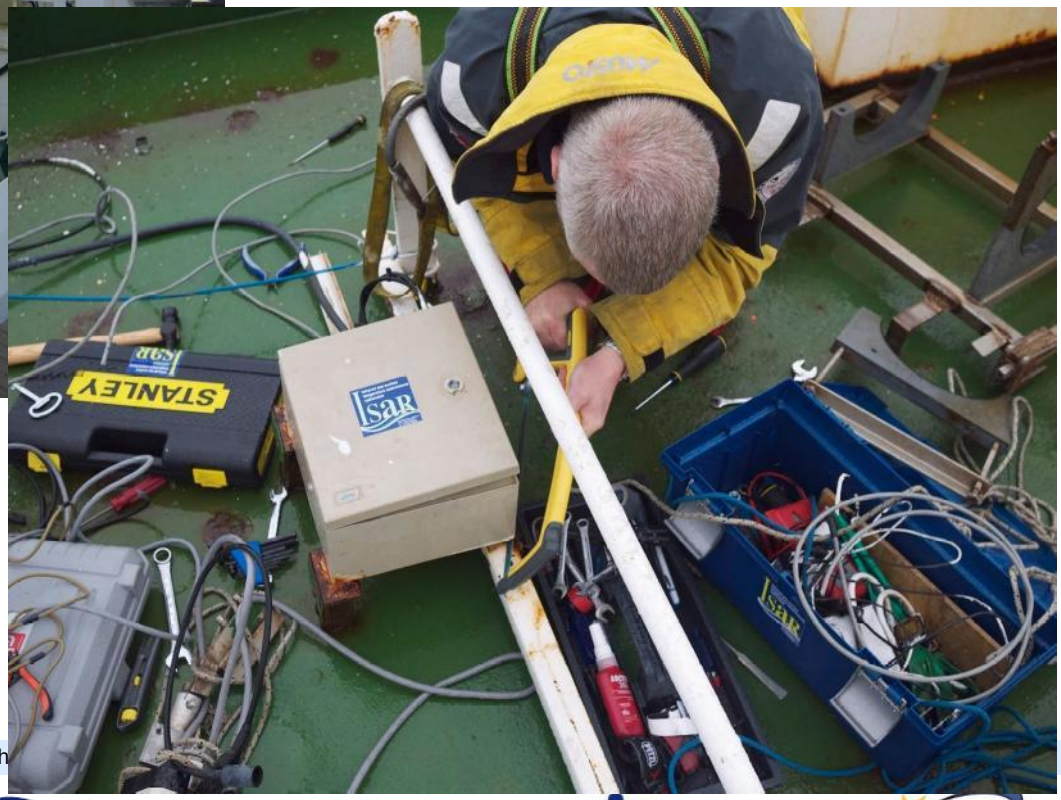
- 2004 - 2010



- Ancillary instrumentation;
  - Anemometer
  - Short- /Long wave Radiation
  - Hull temperature (5m)
  - Air temperature, Humidity
  - FerryBox, CPR

ISAR installed on *Pride of Bilbao*

- 2004 - 2010



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ISAR installed on *Cap Finistere*

- 2010 - 2012

ISAR installed on Pont Aven

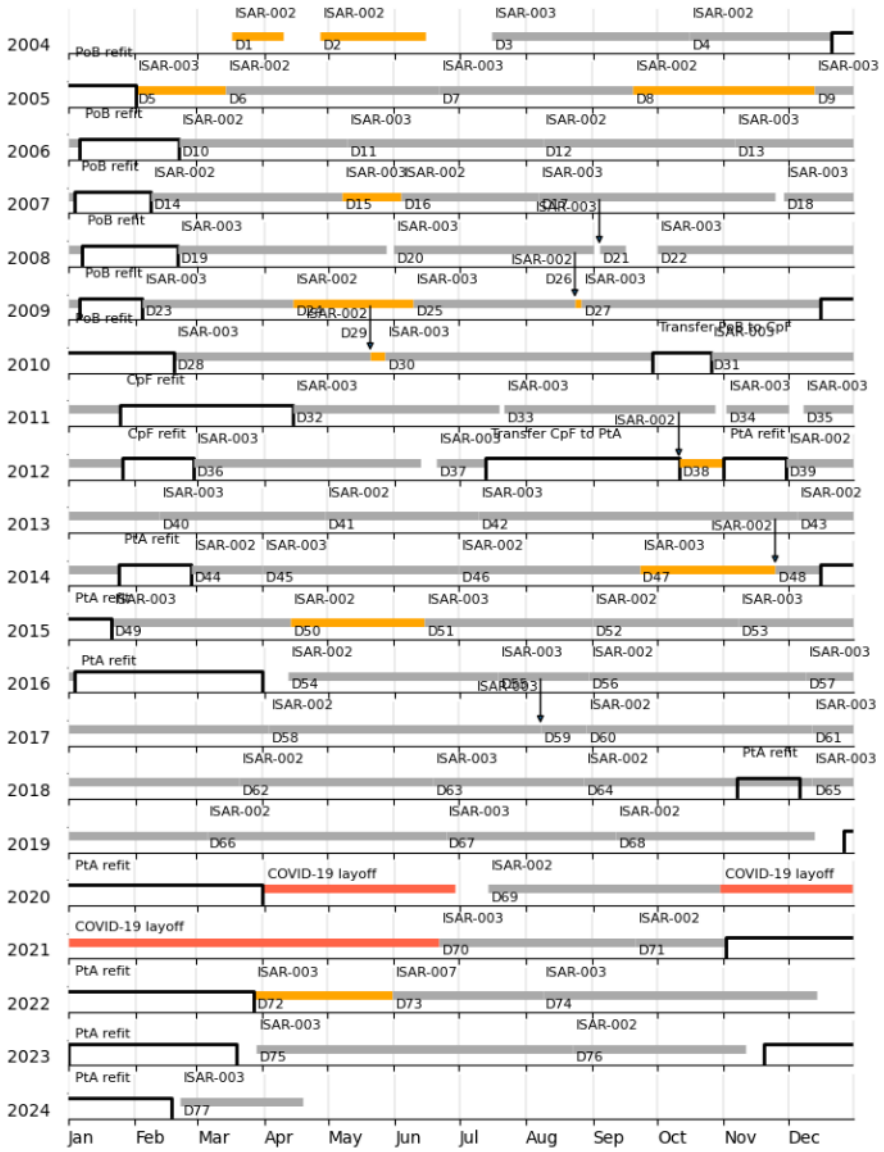
- 2012 - ongoing

ISAR installed on *Pont Aven*

- 2012 - ongoing

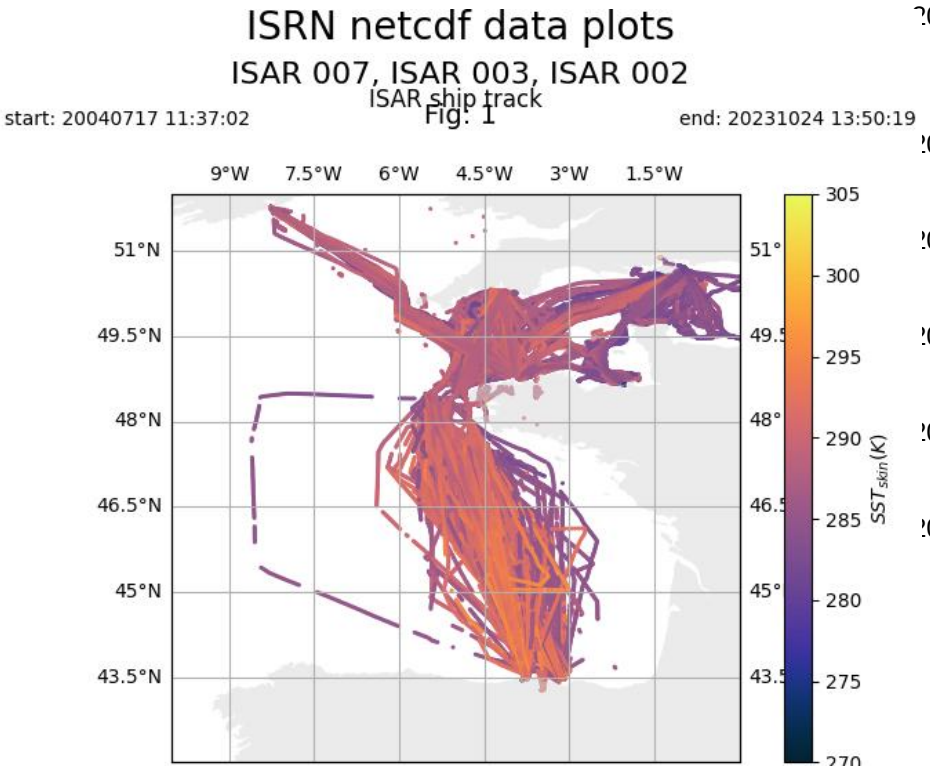
ISAR deployments

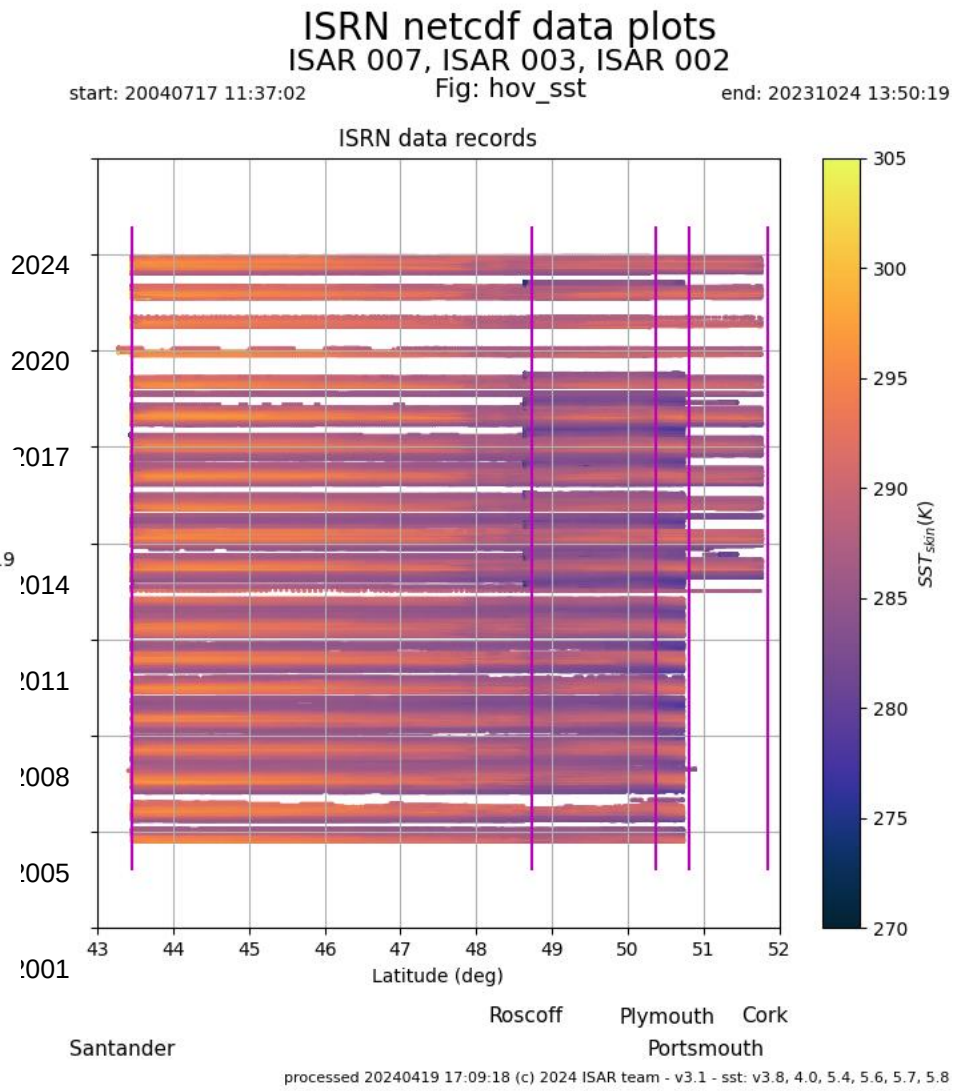
- Bay of Biscay and English Channel
  - 77 deployments
  - ~ 5700 days at sea
  - ~ 1 million SST measurements
  - ~ 200 SST /day
  - 12 failures:
    - 6 electronics issues,
      - 3 related to new electronics trails, 1 thermistors
    - 4 shutter failures
    - 2 configuration issues
      -



ISAR deployments

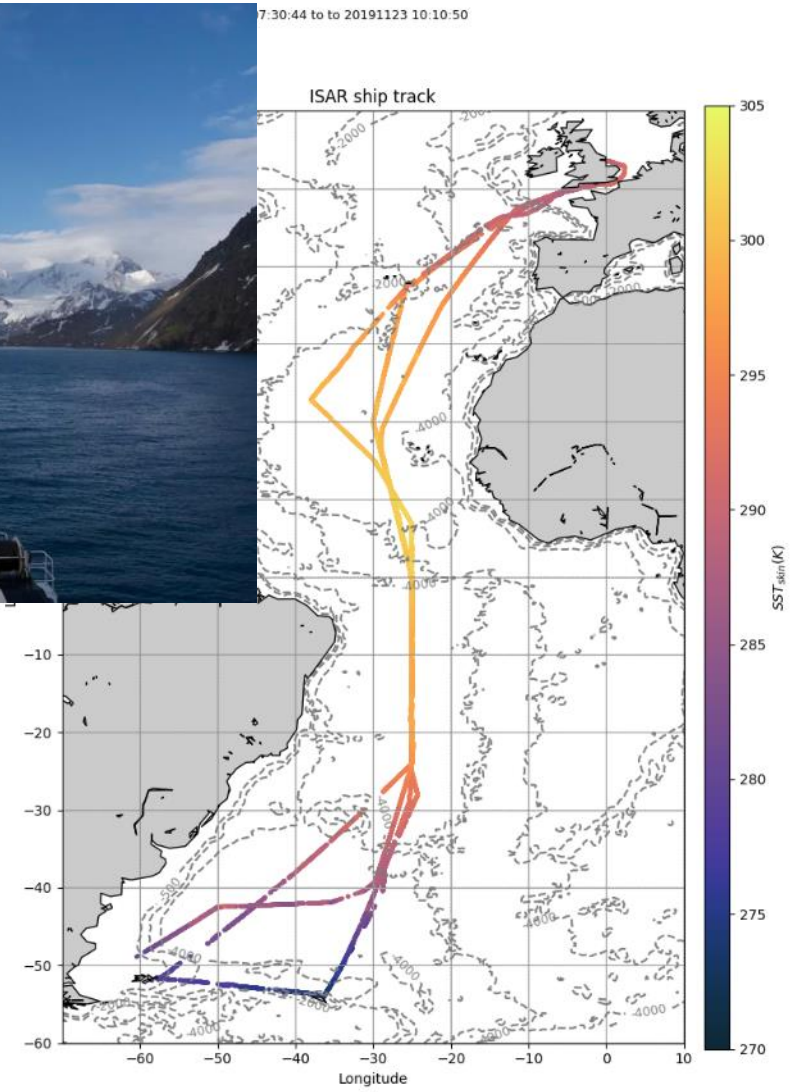
- Bay of Biscay and English Channel data





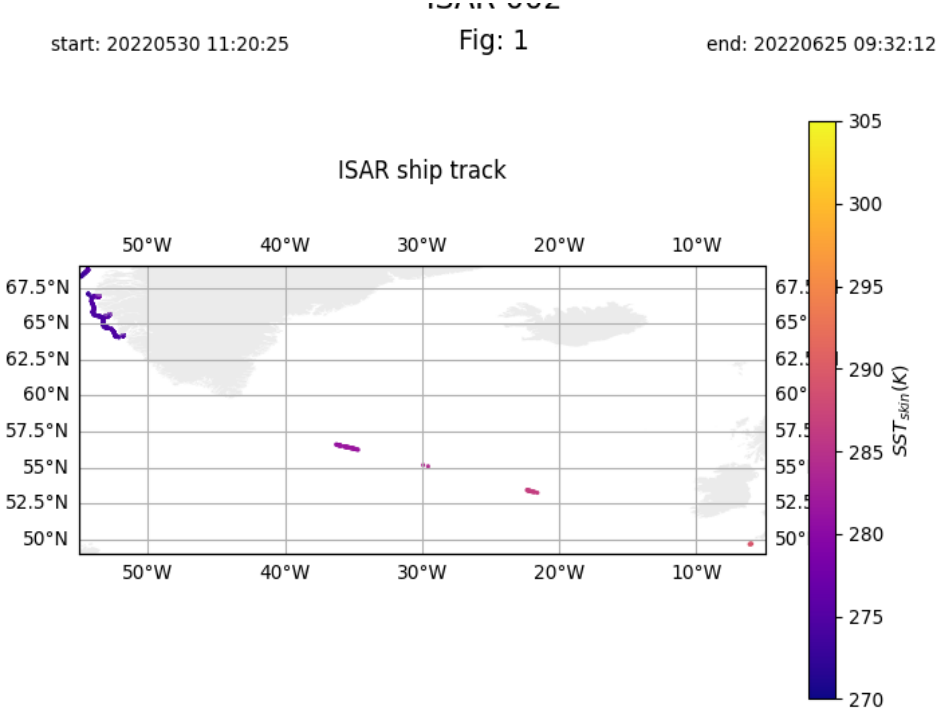
ISAR deployments

- AMT
  - 4 cruises
    - 2016, 2017, 2018, 2019
  - 166 days
  - ~ 40 000 SST
  - ~ 250 SST /day
  - ISAR side by side comparison



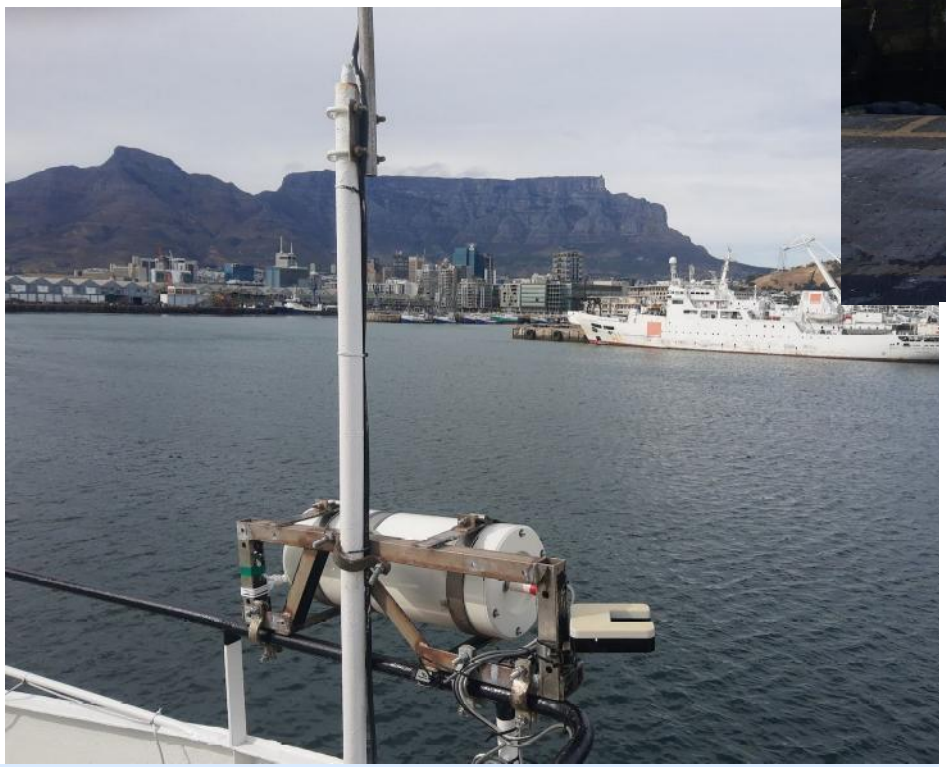
ISAR deployments

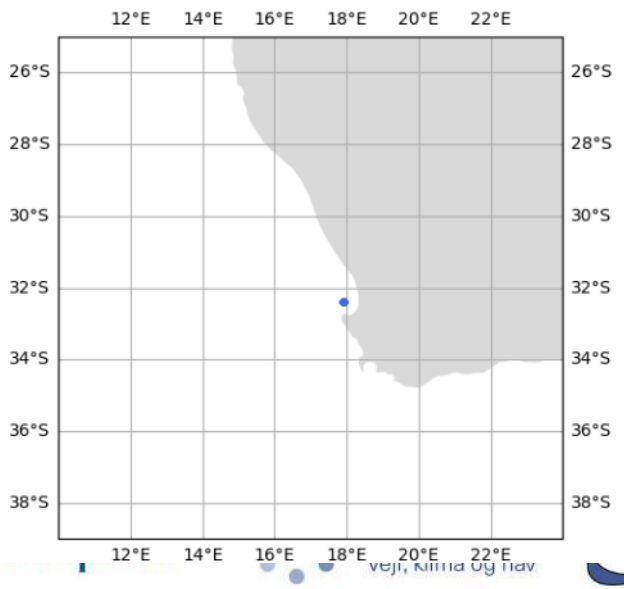
- AMT like
  - DY151, June 2022
  - Instruments only, some issues due to COVID protocols and instrument access
  -



ISAR deployments

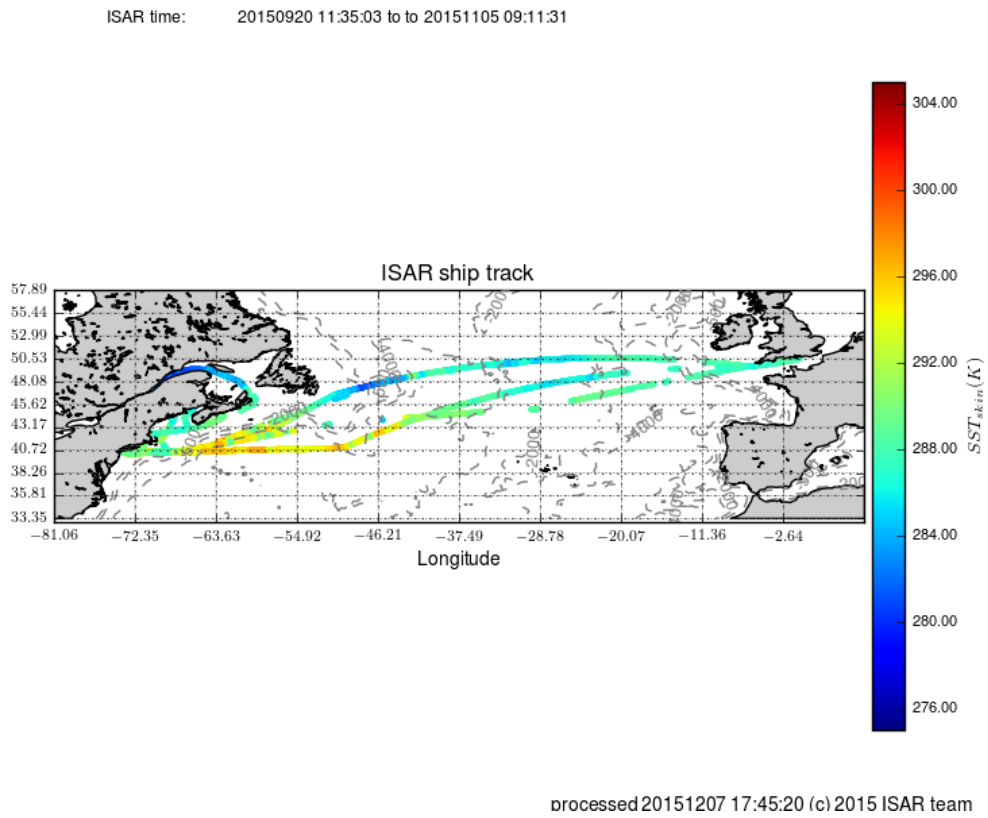
- S/A Algoa / BENFLUX
  - December 2021 protocols and instrument access

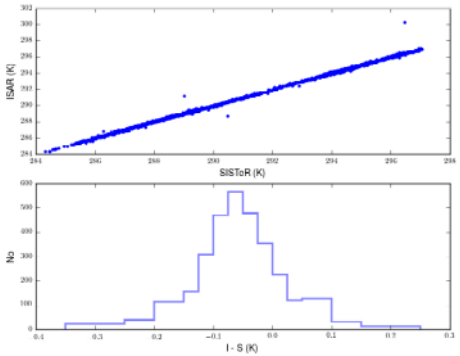




ISAR deployments

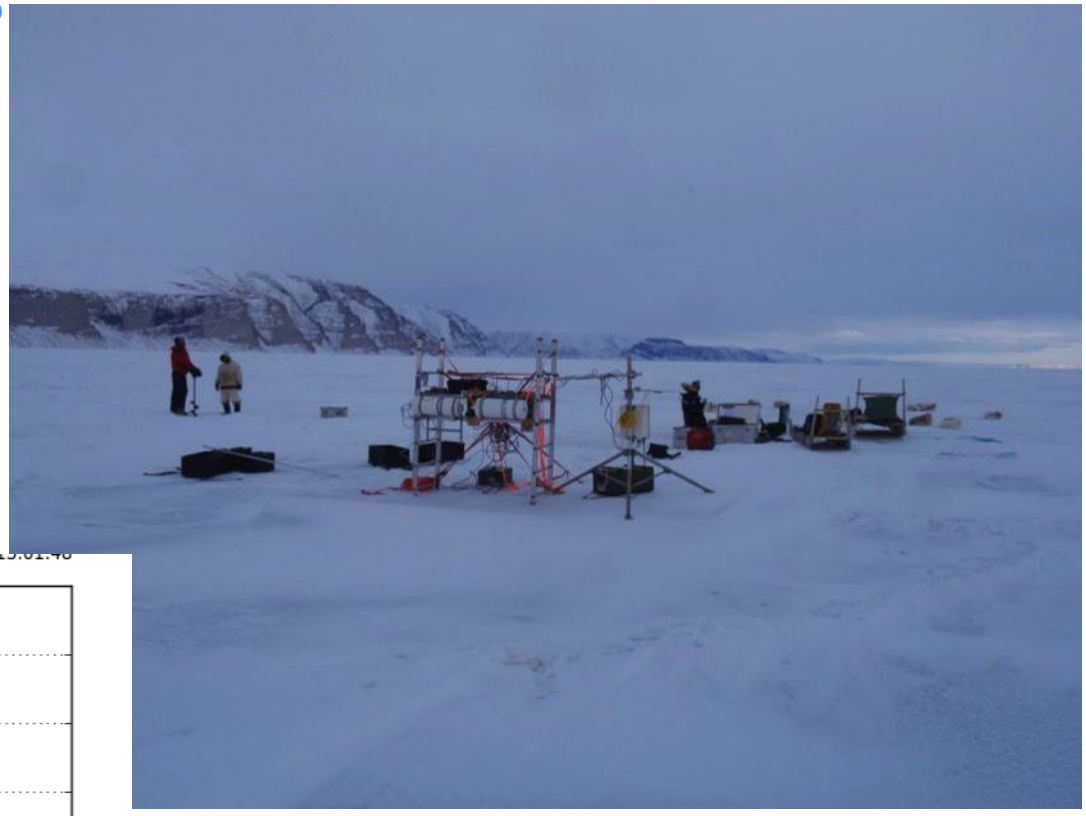
- QM2
  - ISAR – SISTeR side by side inter-comparison
    - 2015

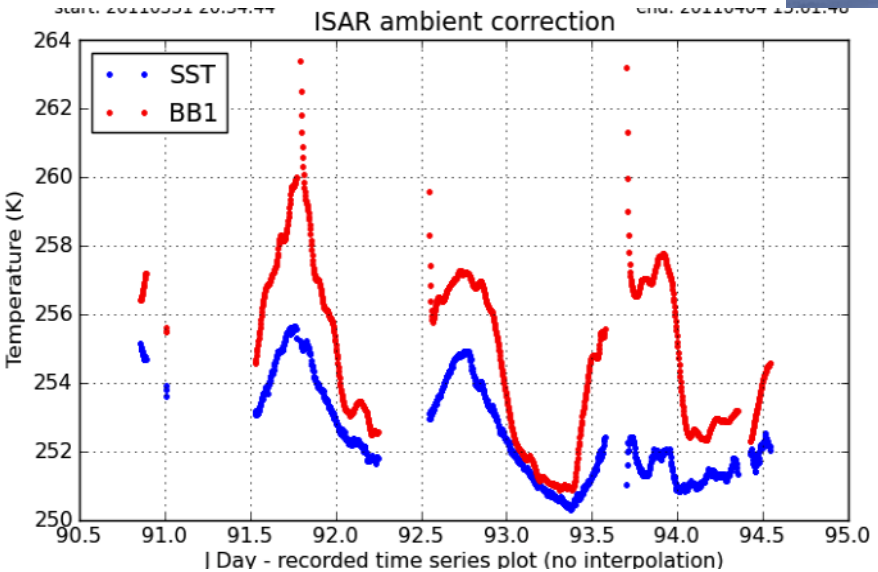




ISAR deployments

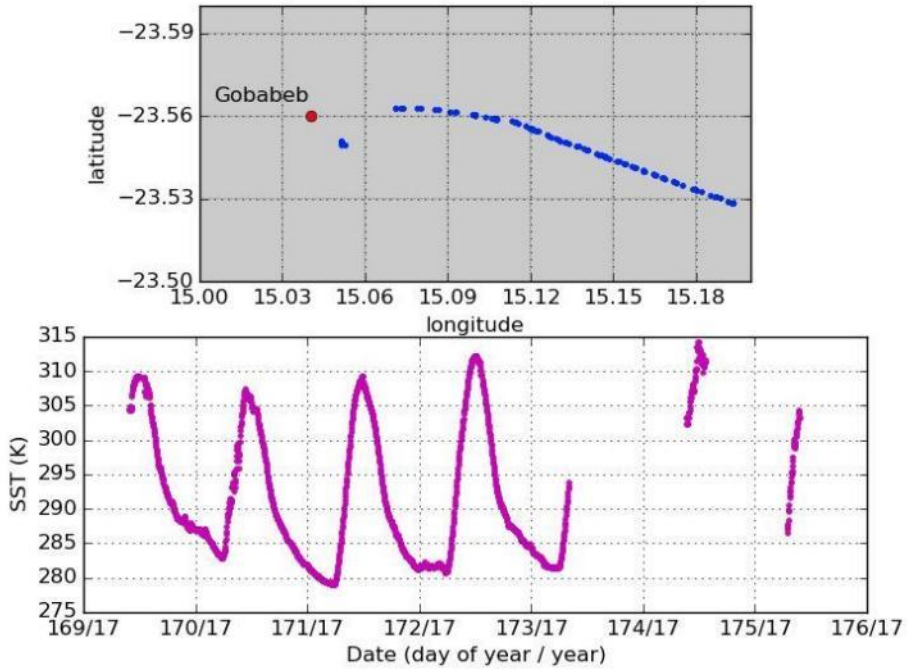
- FRM4STS – ICE
  - ISAR inter-comparison
  - 2016, (2011)





ISAR deployments

- FRM4STS – Land
  - 2017



Inter-comparisons

- 2nd Miami
  - 2001

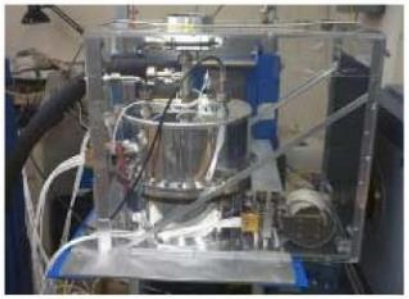


Figure 1. The NIST EOS TXR

Figure 4. Left – the infrared radiometers mounted on the upper deck. From the left these are SISTeR, ISAR, CIRIMS, M-AERI, DAR011, and the hand-held TASCO. Right – the view from above. The JPL radiometer was mounted on the fore-deck, viewed the sea between the two hulls of the *Walton Smith*, and is not visible in these photographs.

e RSMAS water-bath blackbody calibrator, following the design of Fowler.

Figure 3. The CASOST-style blackbody calibrator.

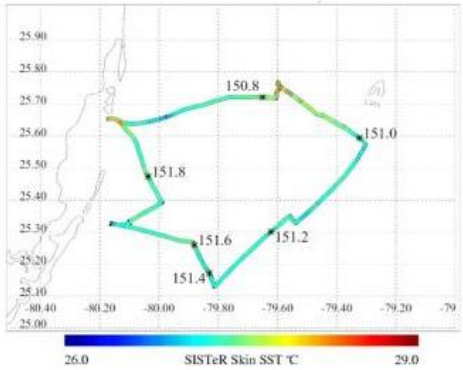
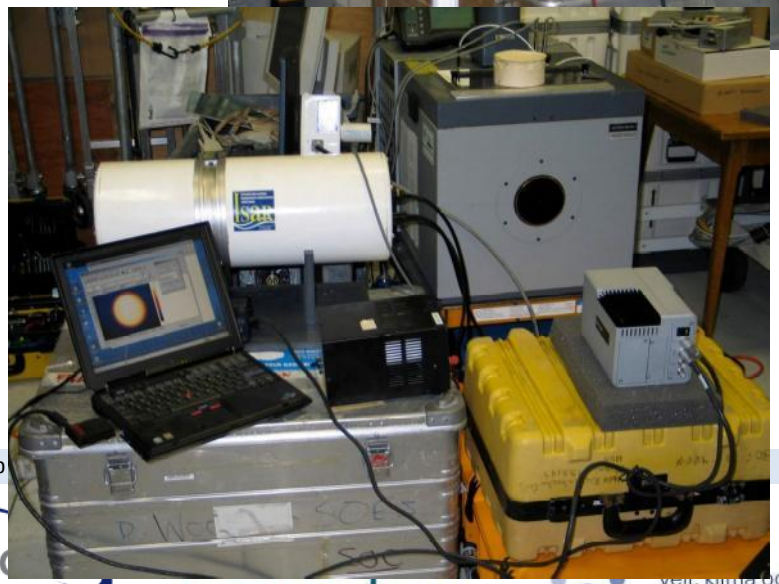


Figure 5. The track of the RV *Walton Smith* during the 2-day cruise. The times are day-of-year plus decimal days (UTC). Day 151.0 is 8:00 pm local time on May 30. The track is colored by the measurements of the SISTeR.

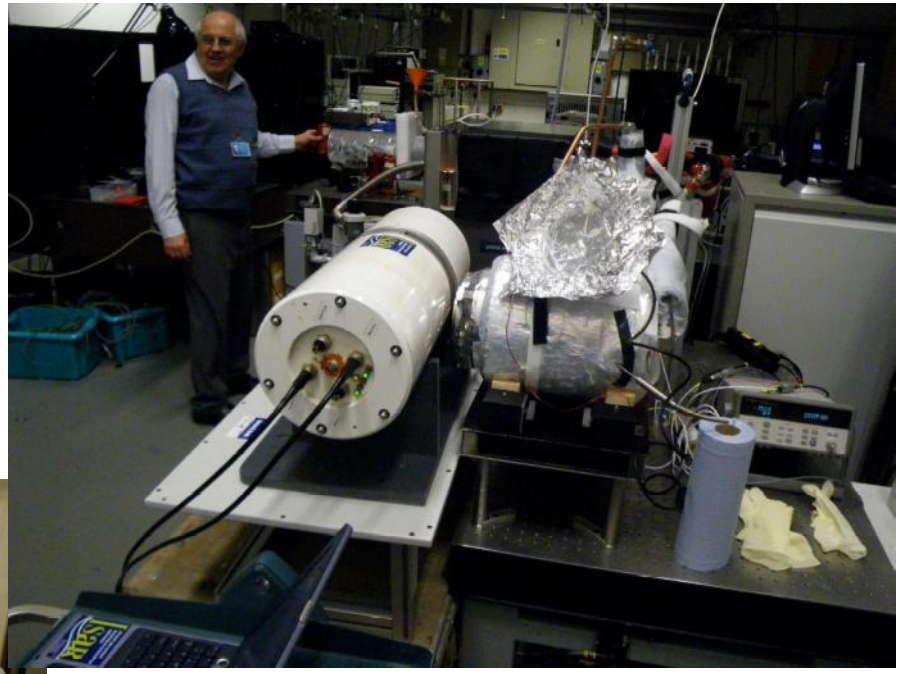
Inter-comparisons

- 2.5 Miami
  - 2006



Inter-comparisons

- 3nd Miami/NPL
  - 2009



Inter-comparisons

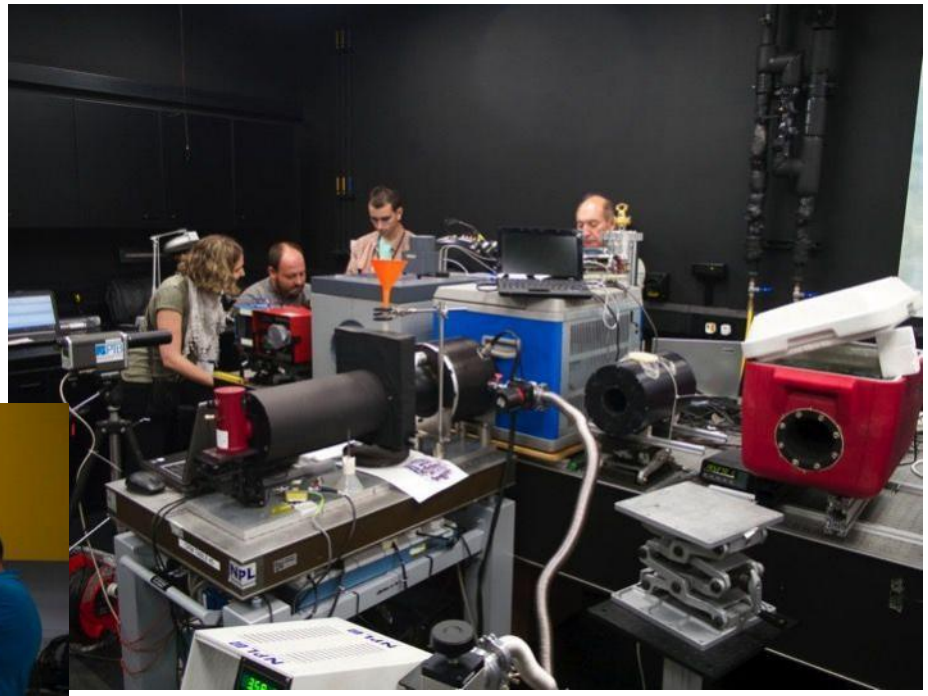
- 3nd Miami/NPL
  - 2009

Inter-comparisons

- 3nd Miami/NPL
  - 2009

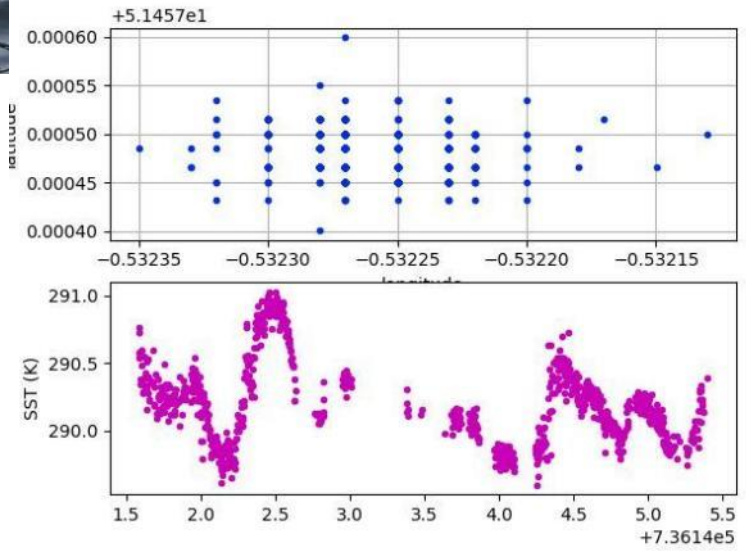
Inter-comparisons

- 4th FRM4STS – NPL
  - 2016



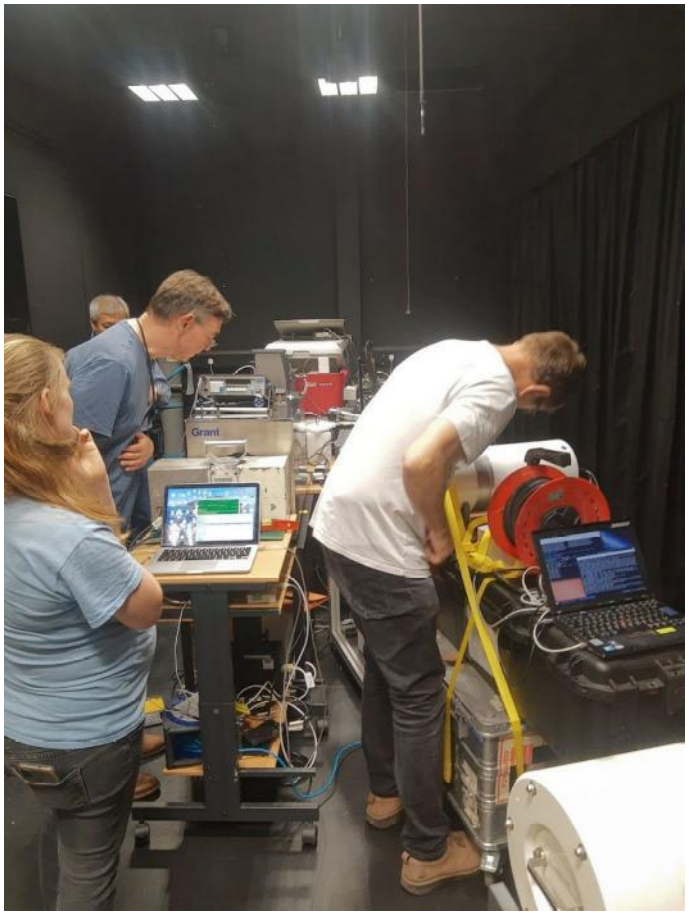
Inter-comparisons

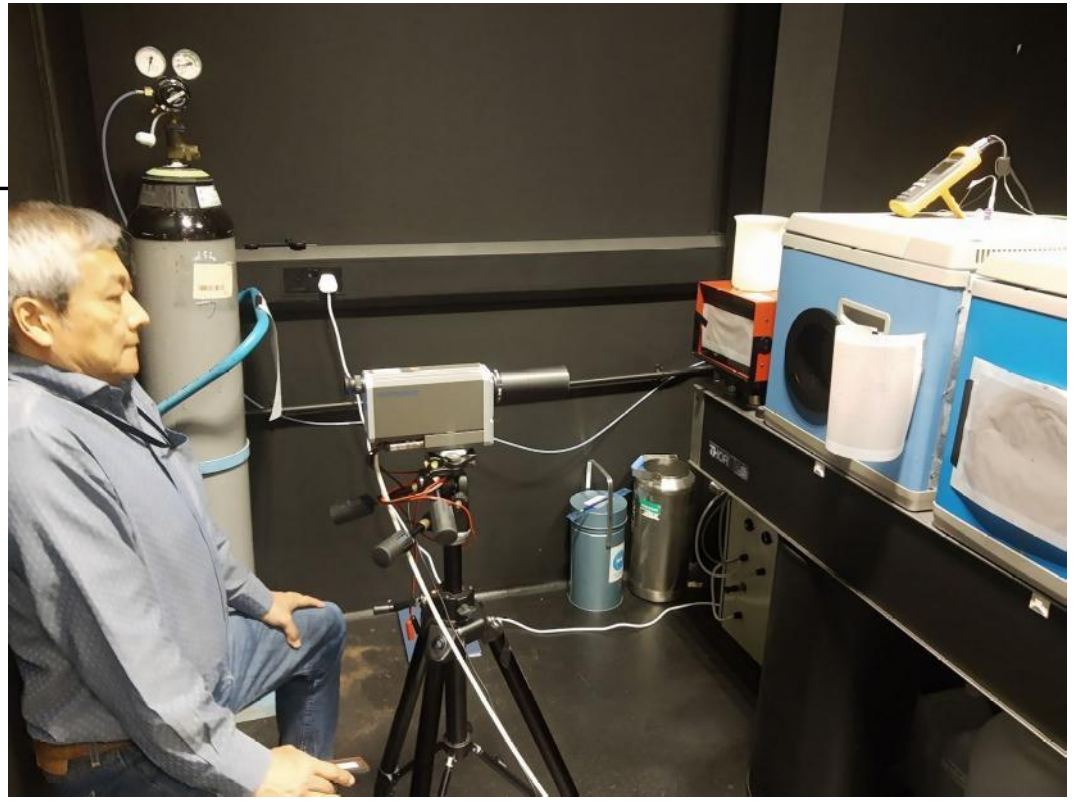
- 4th FRM4STS – SST
  - 2016

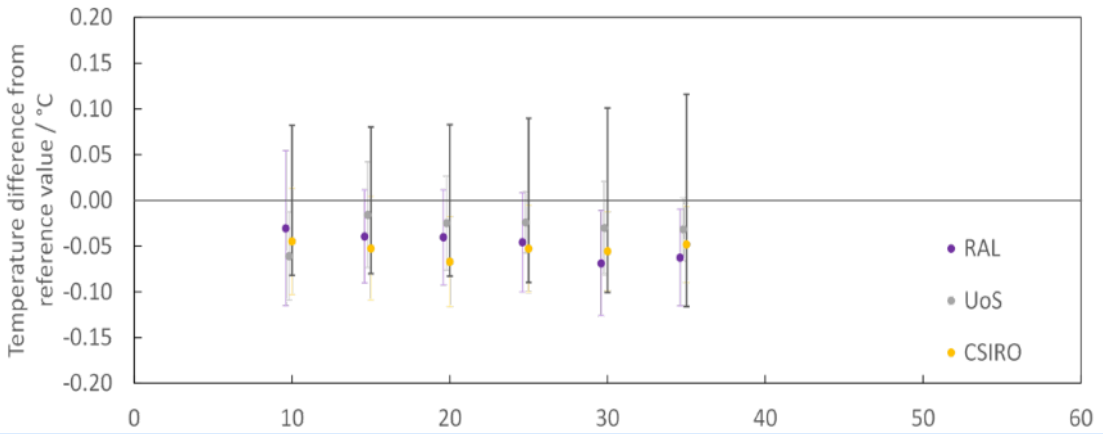


Inter-comparisons

- 5th Inter-comparison - FRM5SST–
  - 2022

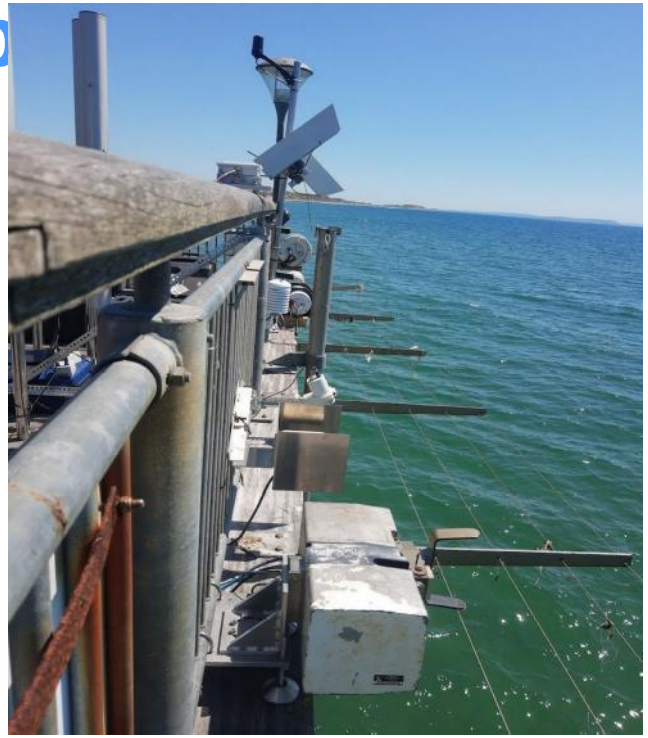


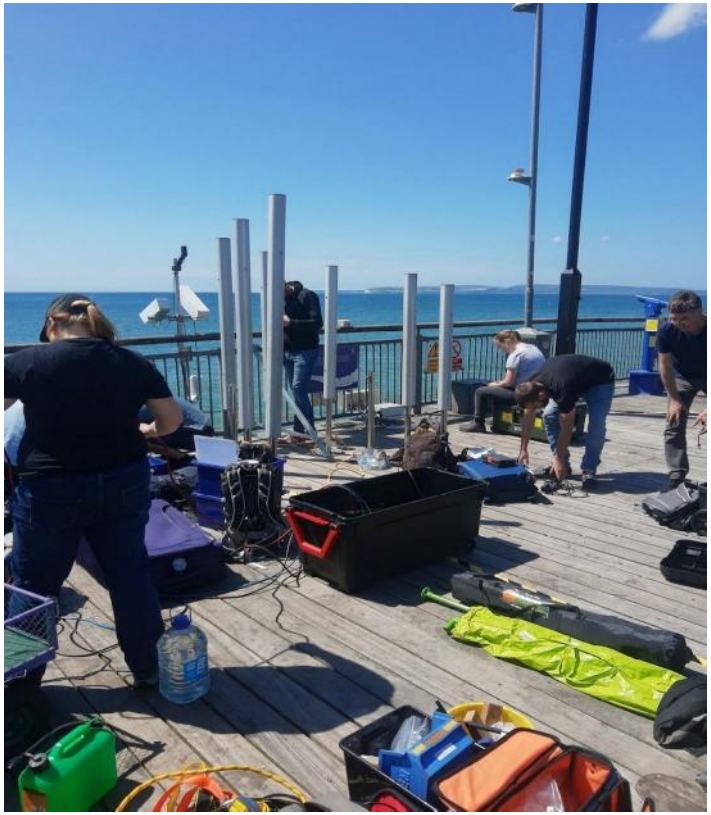


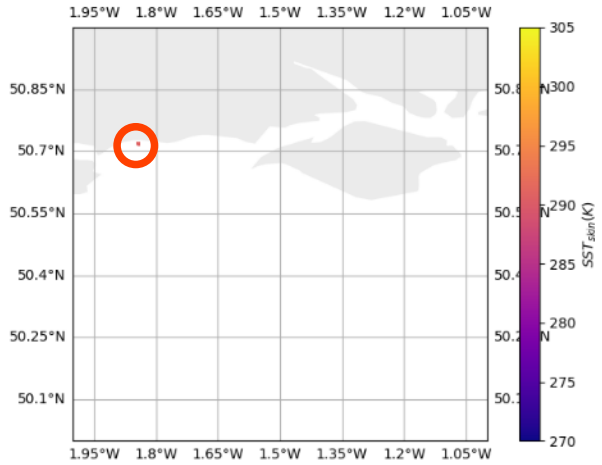


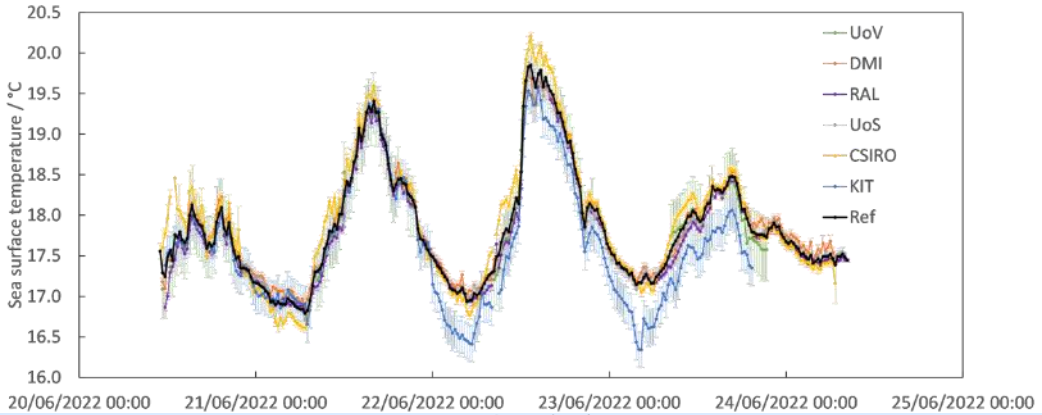
Inter-comp

- Inter-comparison
  - SST
  - 2022
  - Boscombe



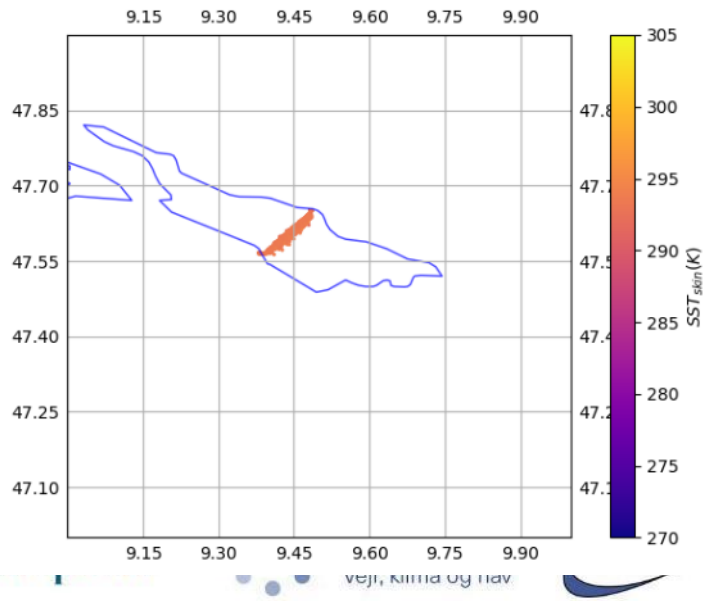




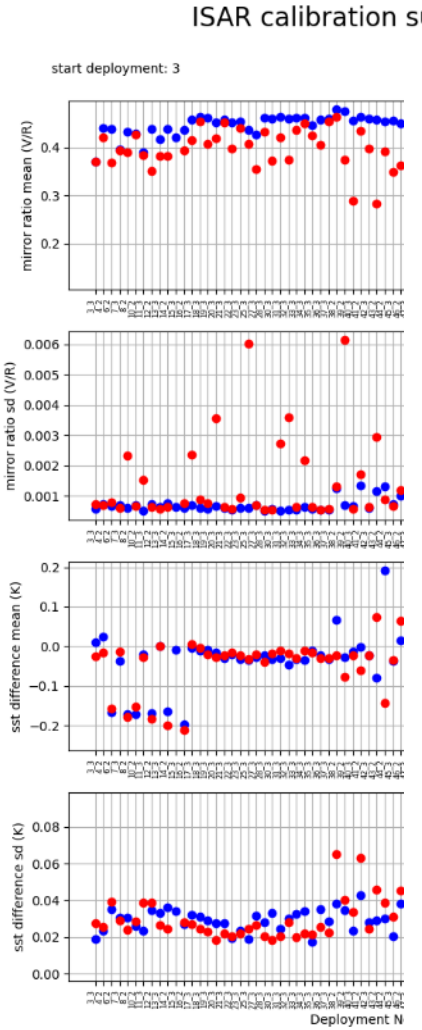


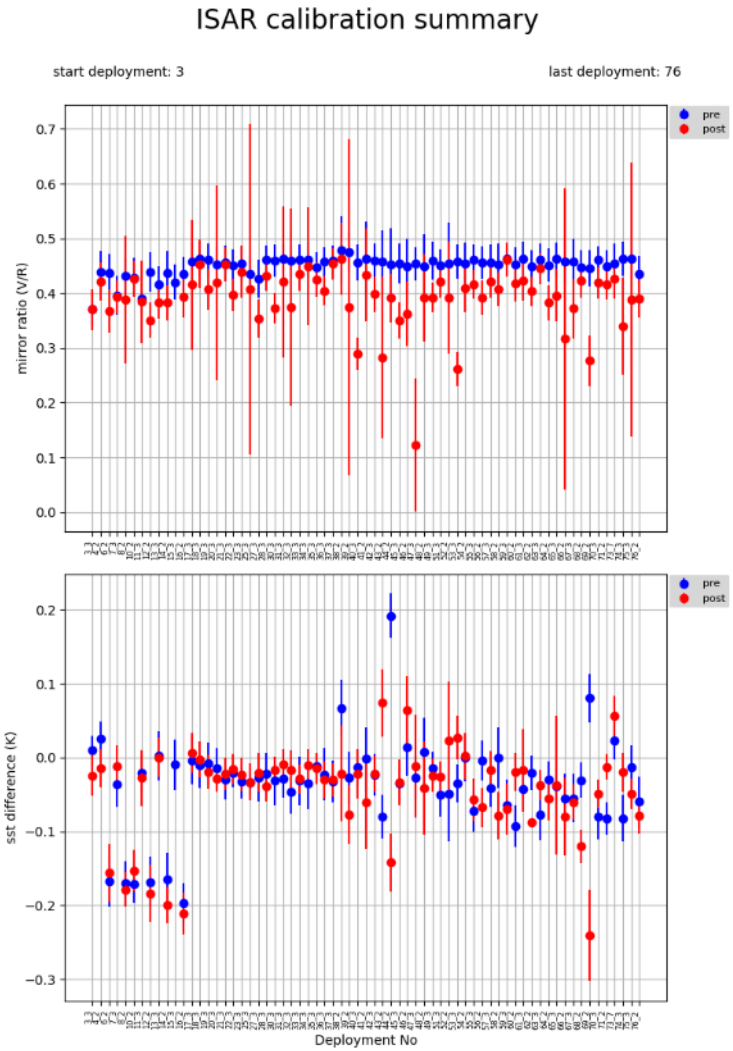
ISAR deployments

- EUMETSAT LWST
  - Lake Constance
  - ISAR – KT15 inter-comparison
  - 01.09.2020-23.09.2020



ISAR experienc





ISAR

ISAR-5D Procedures Manual – Issue: 1.02

University of Southampton

Infrared Sea Surface Temperature Autonomous Radiometer

ISAR

ISAR Procedures Manual v1.02

W. Wimmer
Ocean and Earth Science
National Oceanography Centre Southampton
University of Southampton Waterfront Campus
European Way, Southampton, SO14 3ZH, U.K.

Reference:	Procedures_manual_v1.02
Issue:	01
Date of issue:	November 2013
Document type:	Procedure Manual

ISAR User Manual v2.05

W. Wimmer
Ocean and Earth Science
National Oceanography Centre Southampton
University of Southampton Waterfront Campus
European Way, Southampton, SO14 3ZH, U.K.

Reference:	ISAR-User-Manual-v2.05
Issue:	2.05
Date of issue:	March 2018
Document type:	User Manual

ISAR status report

Author: W.Wimmer Date: 05.08.2004 No.: IS-IP-001

Report on the ISAR 002 shutter failure

Introduction

The shutter on ISAR 002 failed on the 15.06.2004, which left the shutter jammed in the open position. Figure 1 shows the instrument on board of the Pride of Bilbao on 15.06.2004. The shutter could not be moved by any means available and it was decided to switch the instrument off and take it off the Pride of Bilbao. Because the process of taking the ISAR off the Pride of Bilbao requires 3 people the instrument was recovered on 18.06.2004. To avoid any water ingress the shutter was taped over and the scan mirror positioned to look into the cold internal radiation source. After the recovery a were carried brations in the acilities at the aphic Centre f the instrument behaviour under deployment temperature ach was done for the ambient temperatures of 10, 15 and

Figure 1: Image of the jammed shutter on the Pride of Bilbao as found on 15.06.2004.

2 was jammed in an half open position (see figure 1). atory showed that under certain conditions the shutter ys got jammed in the position shown in figure 1. This be overcome with helping to push the shutter along from thorough investigation of the problem the instrument had to as the next step.

d that the sprocket which drives the drive belt and ad some of broken off teeth (see figure 2). Furthermore it had worn down quite substantially because of the wear ket. As a result of the wear and the broken off teeth the luminium dust and some bigger parts form the teeth (see h was used on the sprocket drive belt interlink collected all drive belt and consequently increased the wear on the

a certain extent able to drive through these particles, ight tolerances on the shutter door the amount of torque et by the motor indefinitely. This eventually led to the rrent limiting electronics on the shutter motor limited the way that the shutter motor could not provide the torque riction (Note that the shutter motor suffered no harm).

1 of 2

Infrared sea surface temperature autonomous radiometer ISAR

ISAR post processing manual

Author	W.Wimmer
DocRef	ISAR post processing manual
Date	07.02.2019
Version	4.0

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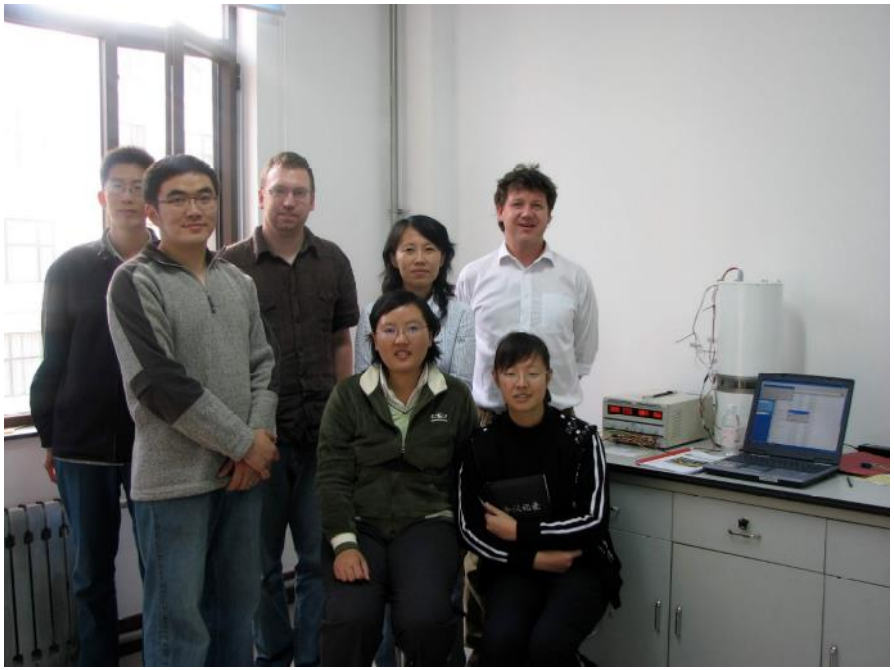
ISAR customers



- University of Miami
- Ocean University China
- JAXA
- Royal Navy
- Danish Metrological Institute
- WHOI
- CSIRO
- Seoul National University
- Vaisala (Australian Antarctic Division)
- National Ocean Technology Center of China
- MetNo

Conclusion

- 20 years of near continuous operations
  - English Channel and Bay of Biscay
- Hugh amount of high quality FRM data
- One of the longest SST skin data records
  - More than 1100000 SST measurements
- Autonomous instrument, works in most environments
  - However needs careful maintenance
- Expansion to other areas – AMT, LWST, LST
- Protocols for installation
  - Instrumentation
  - Ship owners
- Failures
  - Design changes (shutter, mirror, electronics)
  - Improved maintenance and pre-deployment checks