IRISS: Ocean Surface Skin Temperature Measurements using a Simplified Calibration Technique

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Simplified Design for T_{skin} Measurement

Conventional Approach (ISAR, SISTeR, ROSR)

- **Single radiometer with mirror**
- **Two-point calibration using hot and ambient blackbodies (Gain and Offset)**

New Approach

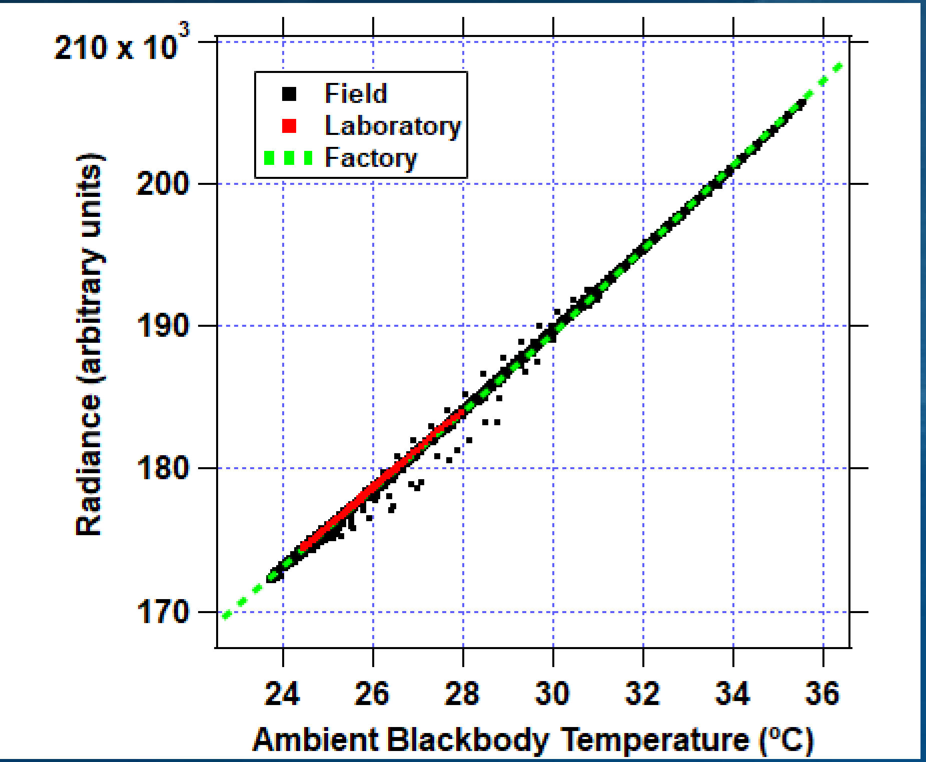
- **Separate radiometers to measure sea and sky**
- **One-point calibration with ambient blackbody (Offset) + Lab cal/characterization**

Outline

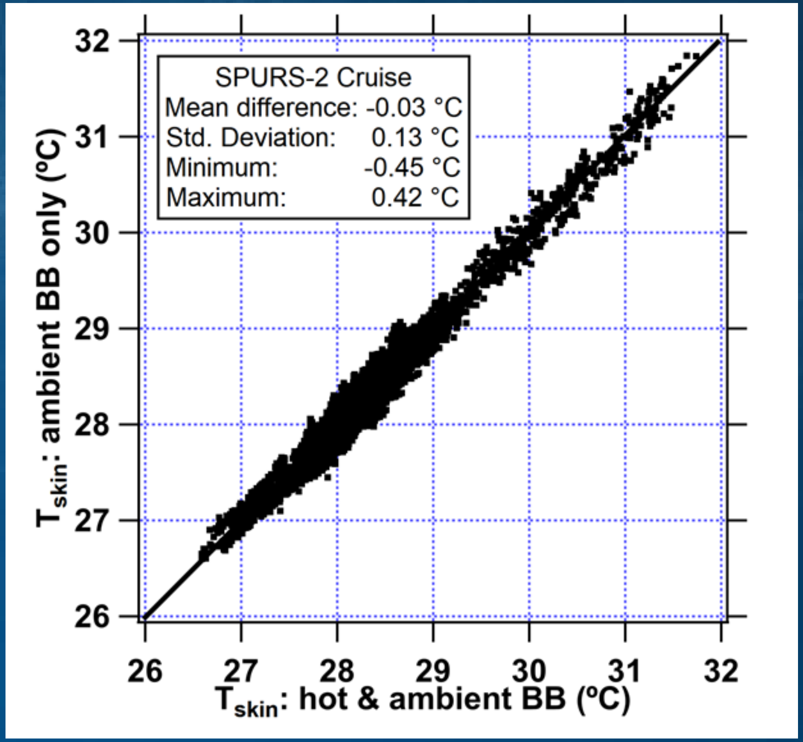
- **IRISS: Simplified Calibration with Separate Sky Measurement**
  - **Radiometer Uncertainty: Self-Emission Effect**
  - **Design and Results compared to ROSR**
  - **Relevance to 2022 CEOS Comparison [Yamada et al., 2024]**
- **Proposal for 2025 Ship-based Field Comparison**

Gain Stability: ROSR3 on 2016 SPUR-2 Cruise

Radiance vs Ambient BB Temperature



T_{skin}: 1-pt vs 2-pt Calibration



- Gain appears stable except for outliers due to rapid solar heating
- Threshold of $dT_{int}/dt < 4.5$ °C/hr

IRISS Design Strategy

- Laboratory calibration to determine gain
- Radiometer gain is stable for $dT_{int}/dt < 4.5$ °C/hr (sun shield)
- Offset provided by *in situ* ambient blackbody
- Self-emission effect corrected using laboratory characterization

Laboratory calibration
+
1-point ambient temperature *in situ* calibration
+
Self-emission correction

Radiometer Uncertainty

Primarily due to two sources of non-ideal effects [*Nutter*, 1988]

- Radiation Detector: responsivity changes, internal ref. uncertainty
- Optical System: Self-emission from internal element and housing

Heitronics KT15/CT15 Pyranometer Manufacturer Specification

"±0.5 °C + 0.7% of the difference between the target & housing temp.

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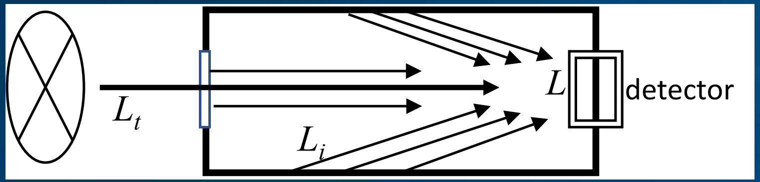
Sensor Self-Emission



target radiometer

(after Chang and Cao [2013])

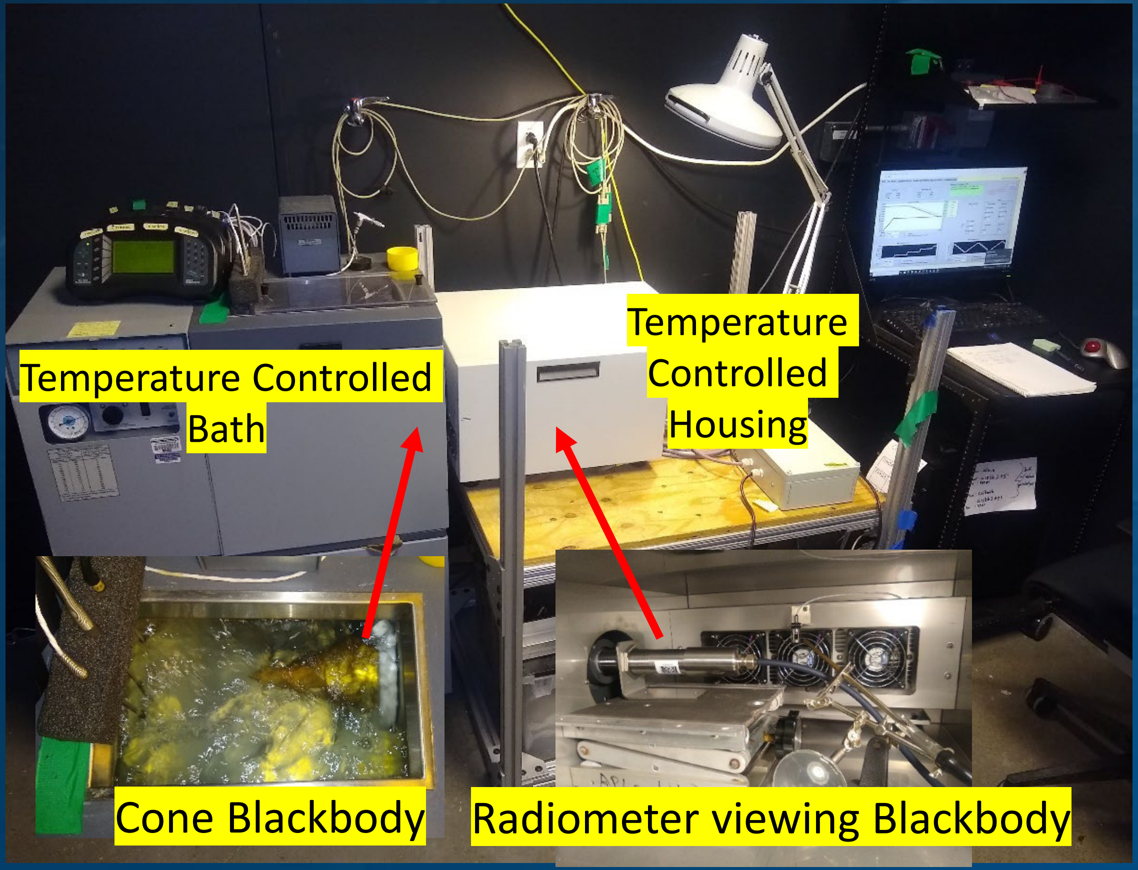
$$L = L_t + \sum L_i$$

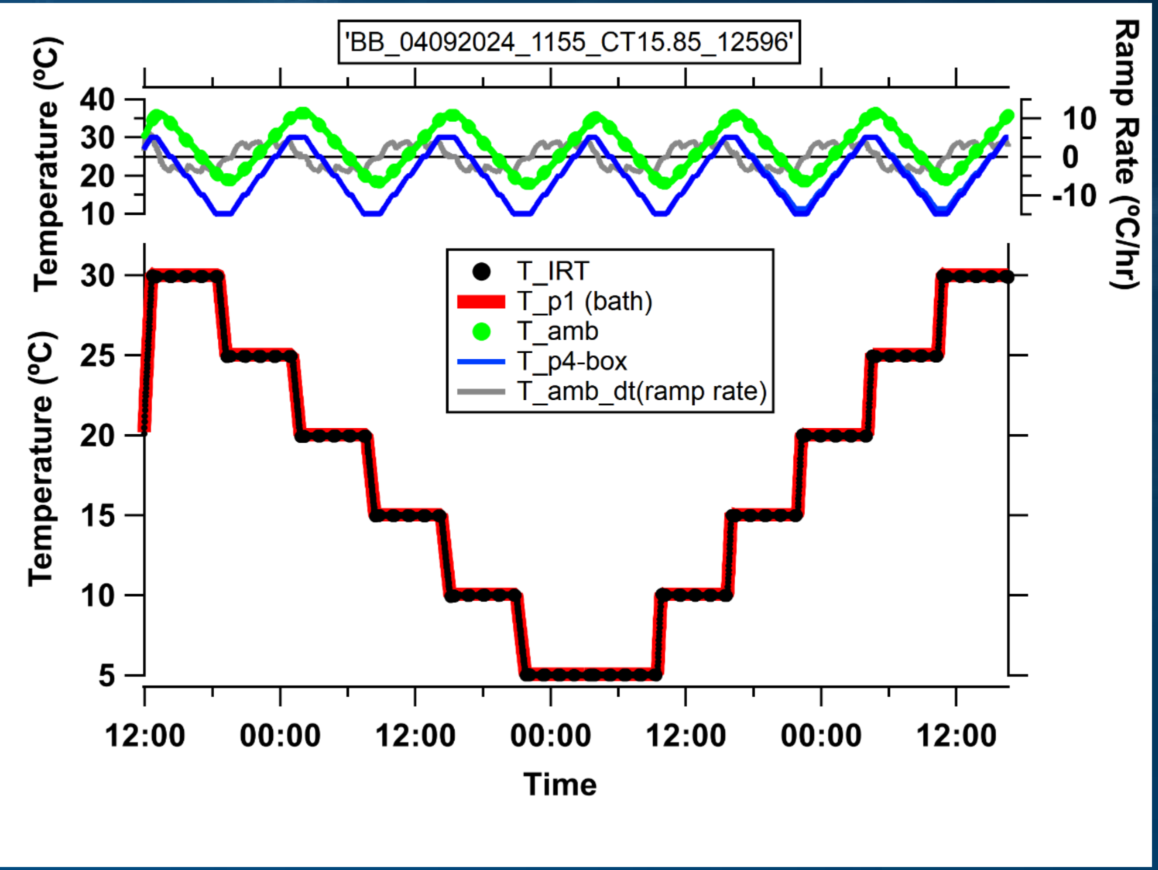
Error $\propto (T_i - T_t) \approx 15$°C

$\approx 0.7\% \times (T_i - T_t)$

$\approx \mathcal{O}(0.1)$ °C

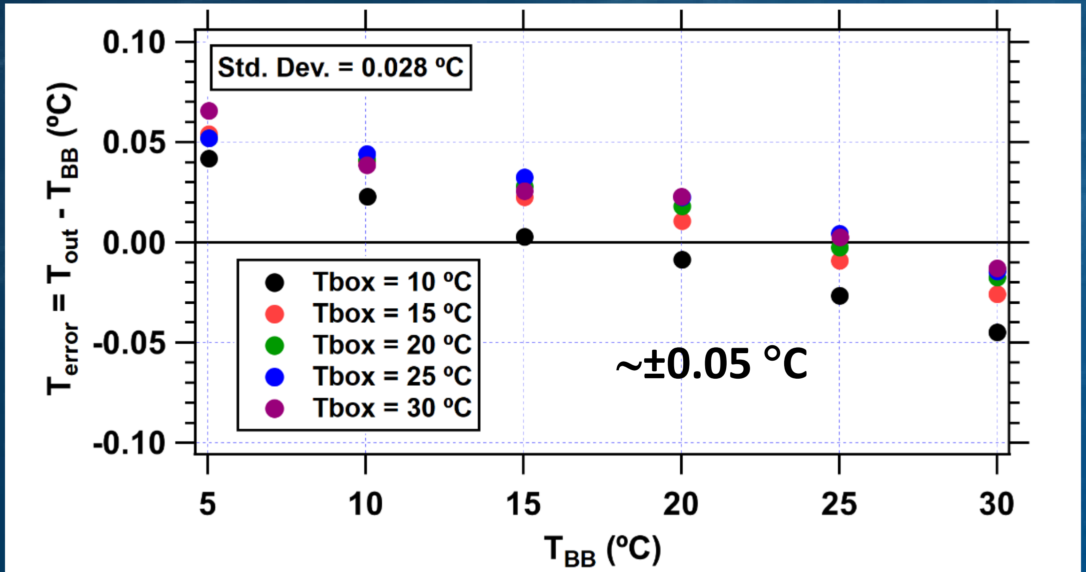
Laboratory Characterization





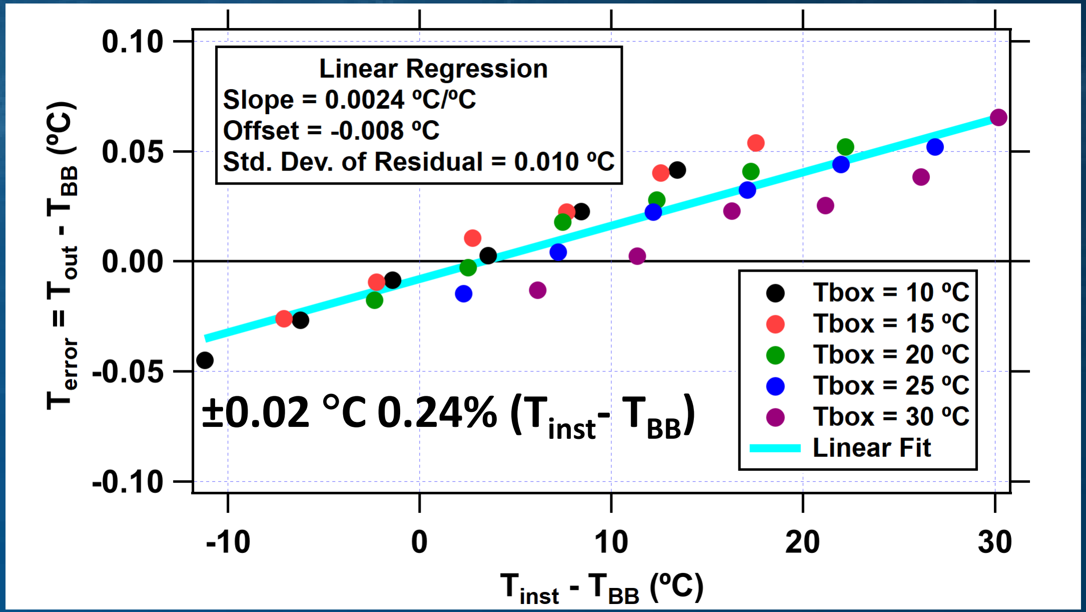
Example Self-Emission Characterization

T_{error} vs T_{BB} as a function of T_{box}



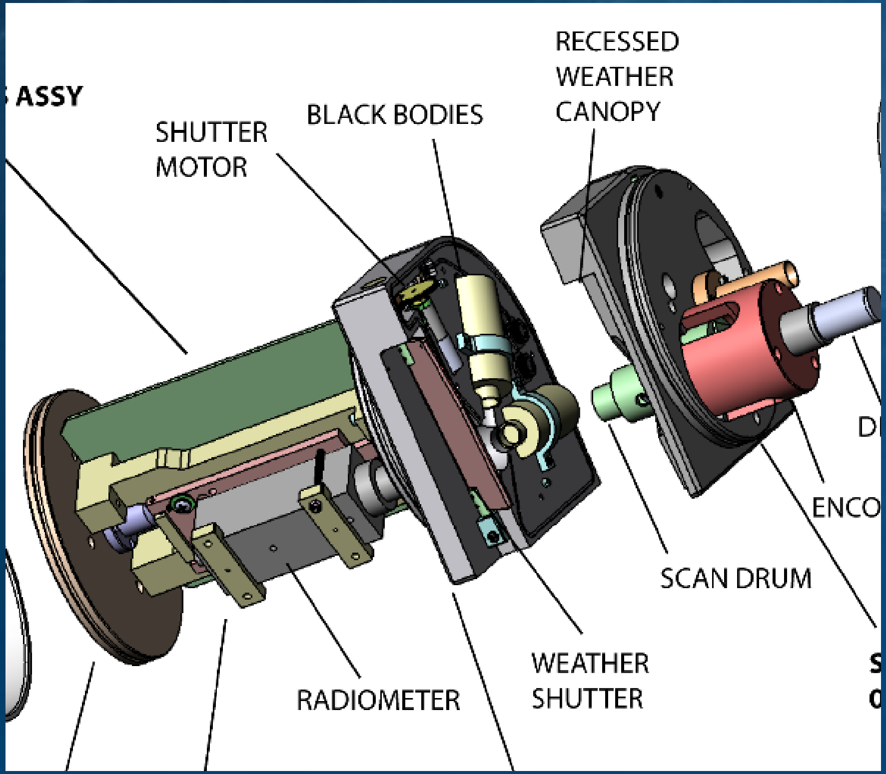
CT15.10 (8-14 μm) Manufacturer Calibration

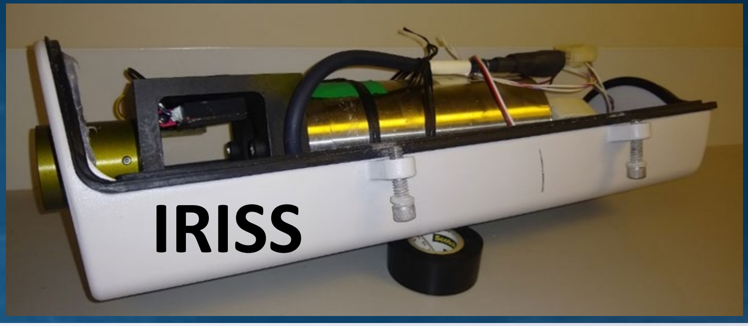
T_{error} vs (T_{inst} - T_{BB}) as a function of T_{box}



Conventional vs New Approach

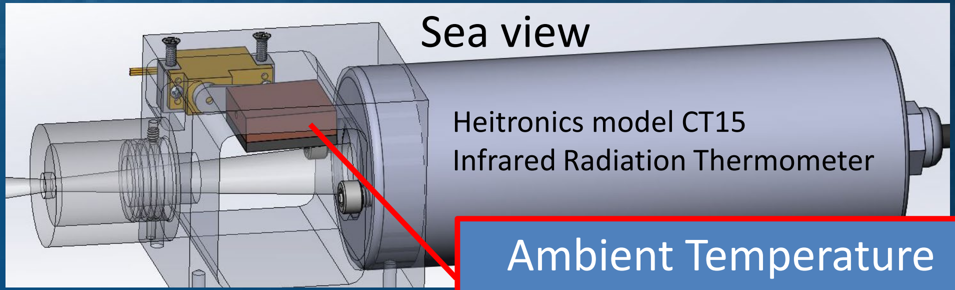
Use a reference standard



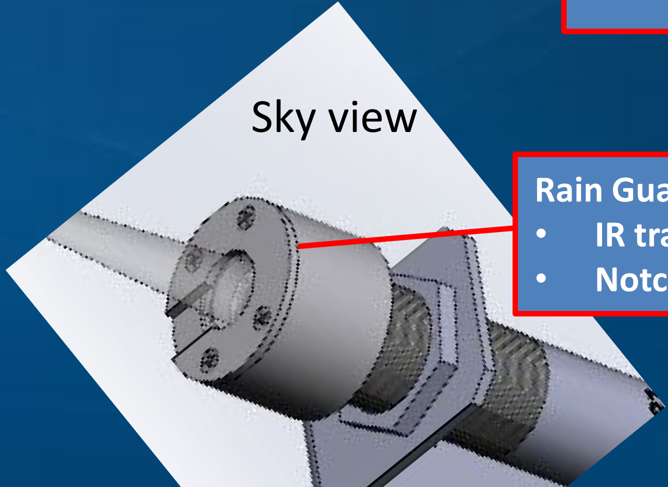


Self-Emission

- **Radiometer**
- **External elements**



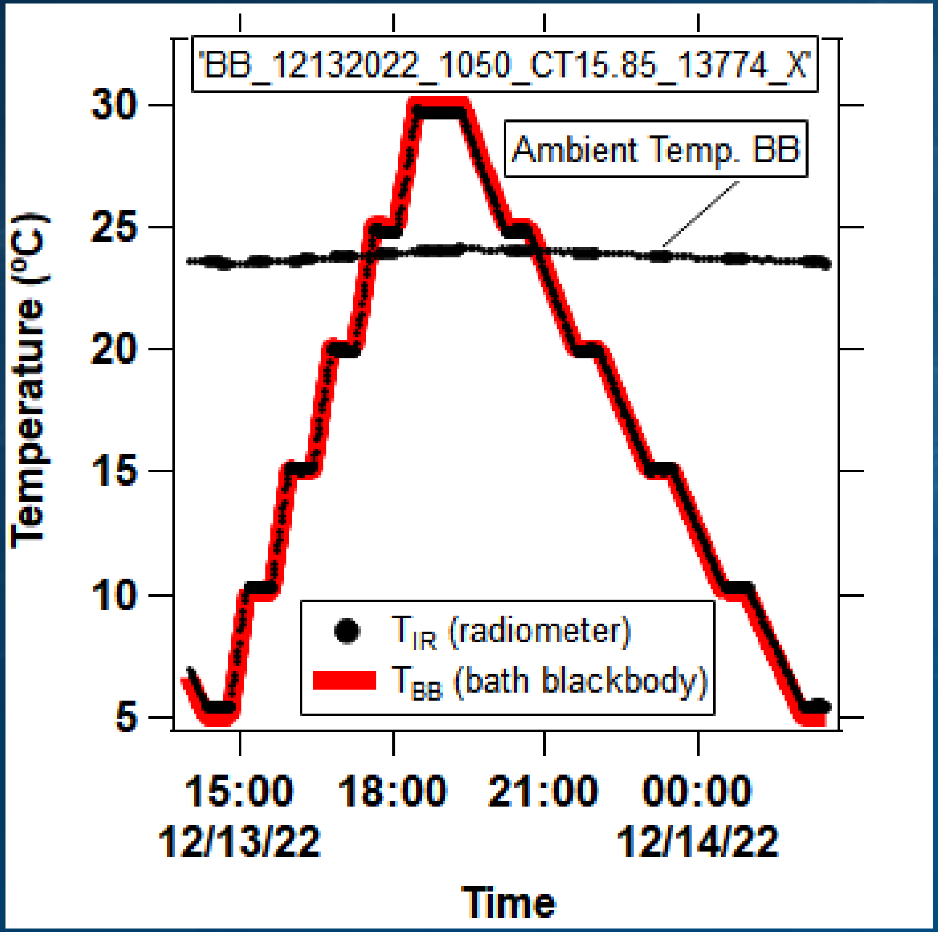
Ambient Temperature Blackbody



Rain Guard
- **IR transparent window**
- **Notched plate for rain to drain**

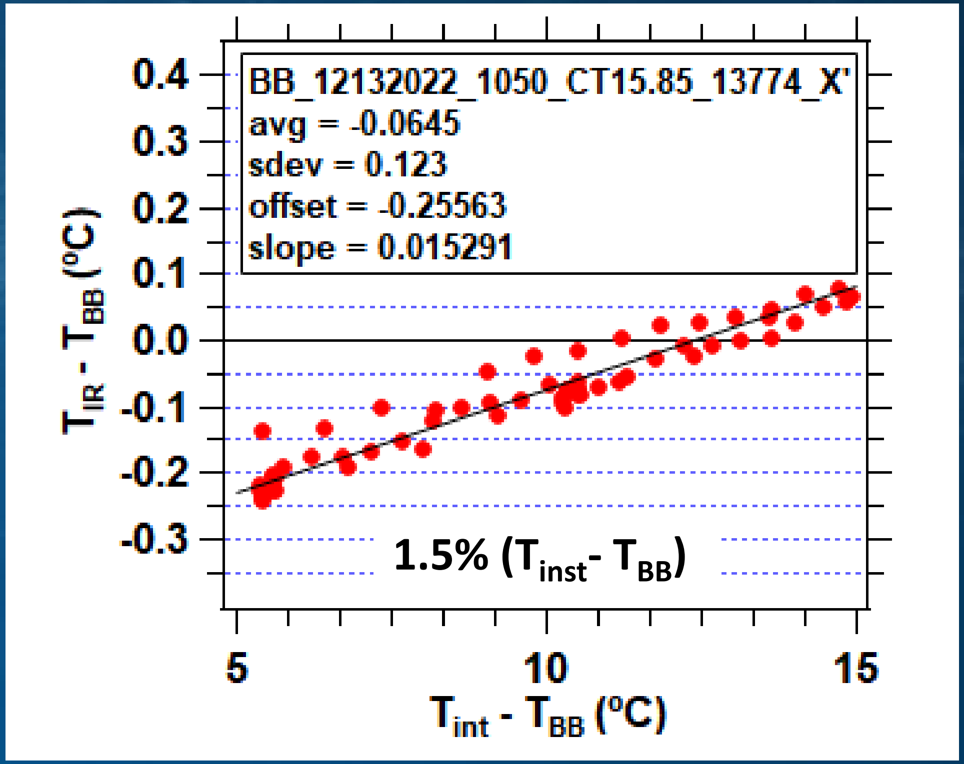
IRISS Self-Emission

Calibration Time Series



CT15.85 (9.6-11.5 μm): T_{box} = constant

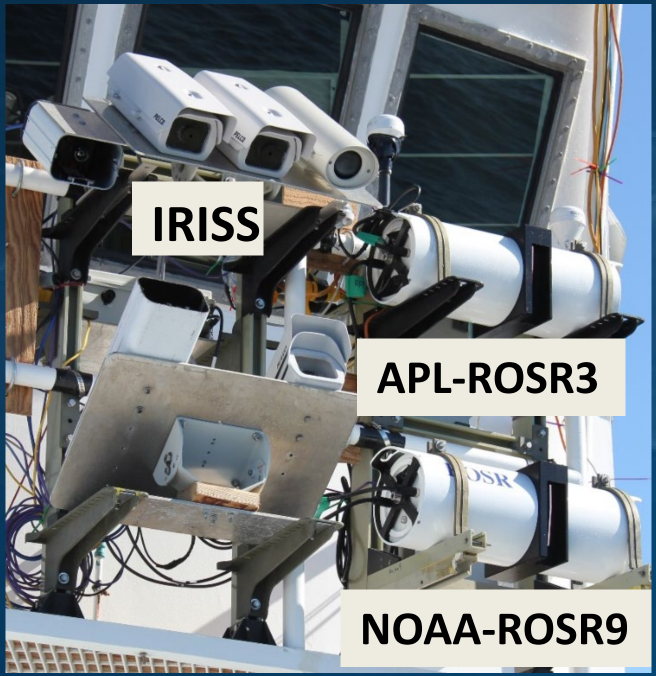
T_{error} vs (T_{inst}- T_{BB})



Radiometer alone: 0.24% (T_{inst}- T_{BB})
Manufacturer spec: 0.70% (T_{inst}- T_{BB})

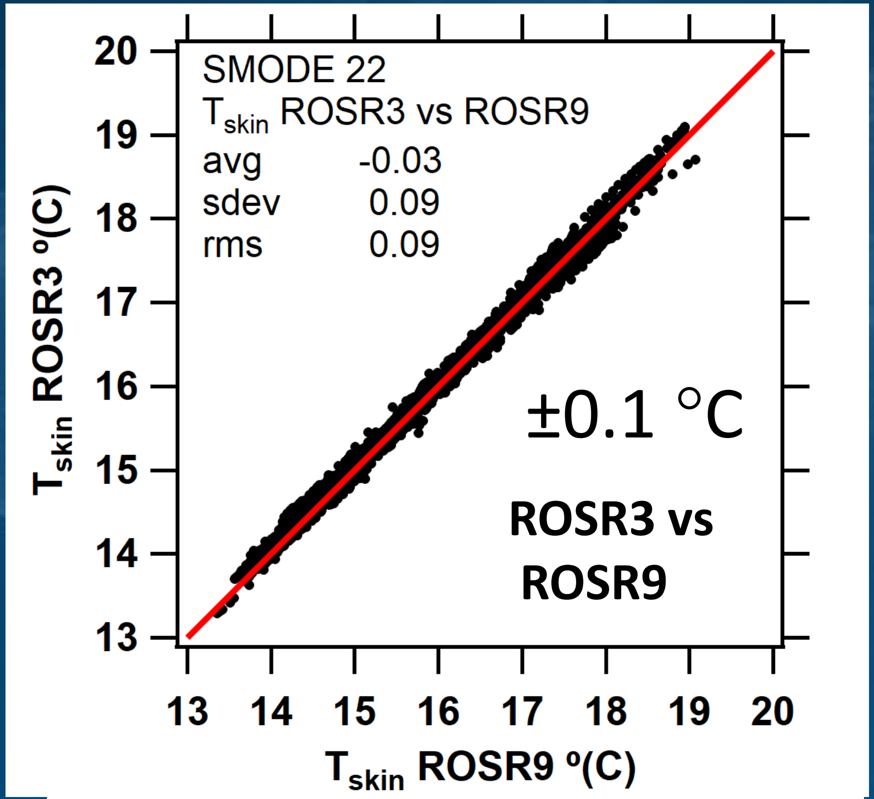
ROSR and IRISS Accuracy

S-MODE IOP1
10-30 October 2022
100 km off San Francisco



R/V Oceanus

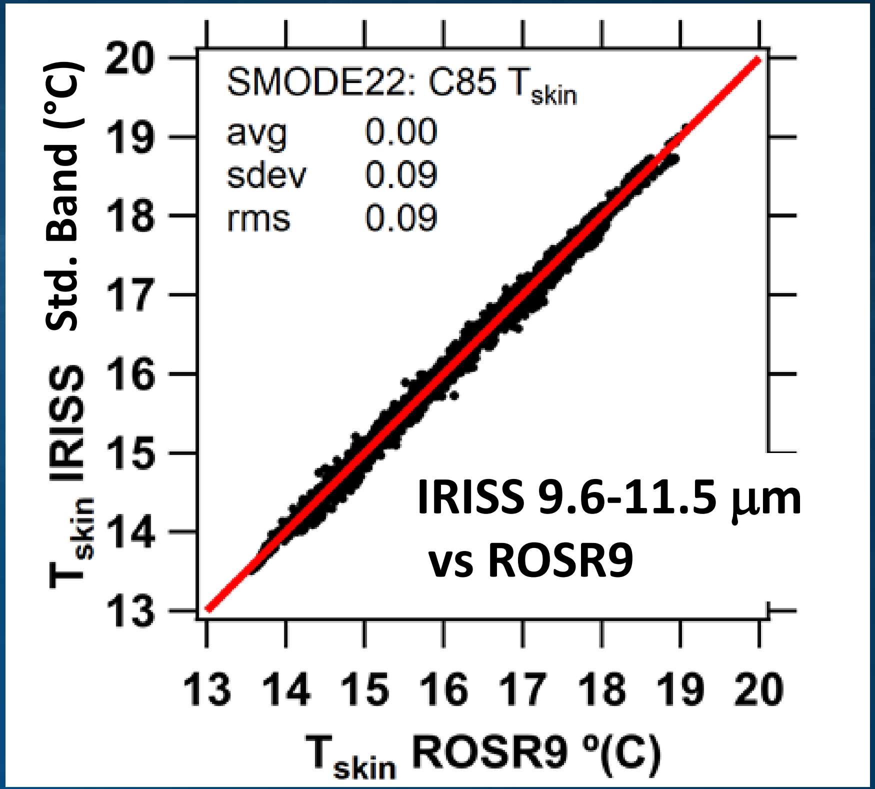
ROSR3 vs ROSR9



Quantity	Mean	Std dev
$T_{ISAR} - T_{CIRIMS}$	0.00	0.13
$T_{ISAR} - T_{MAERI}$	−0.08	0.15
$T_{MAERI} - T_{CIRIMS}$	0.08	0.15

[Jessup and Branch, 2008]

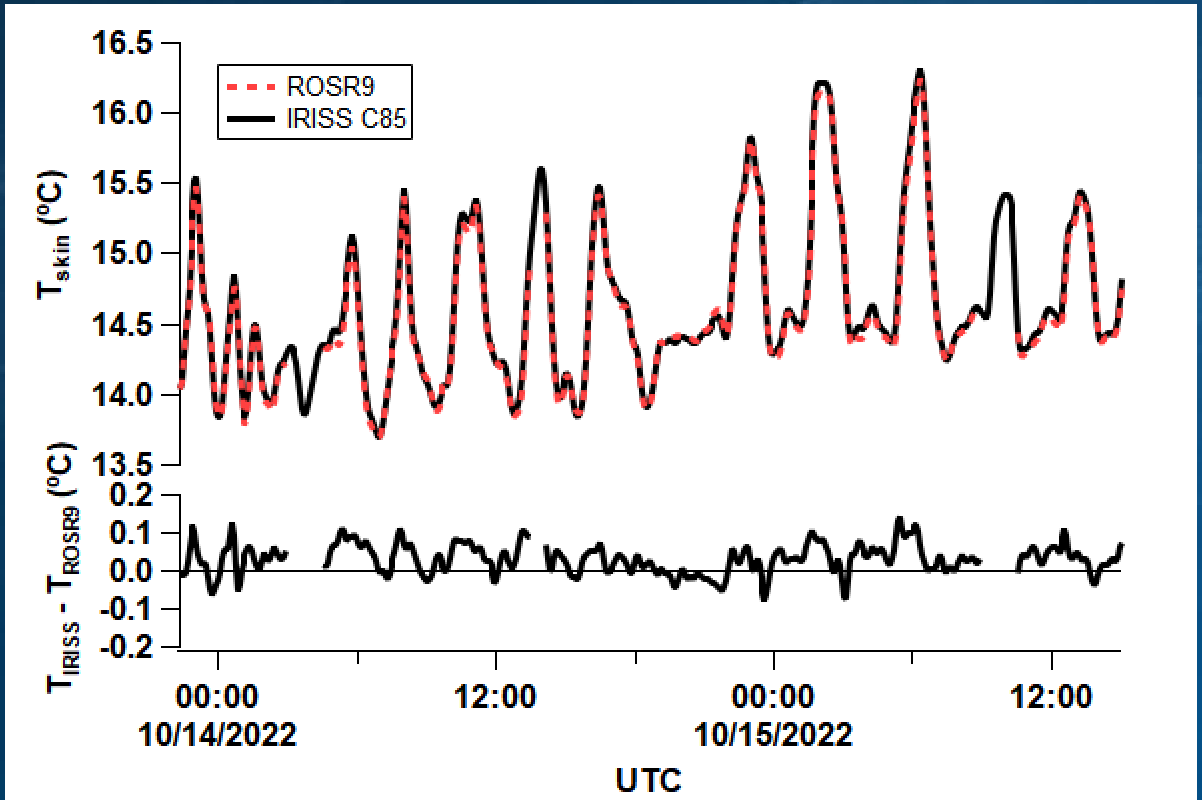
IRISS vs ROSR9



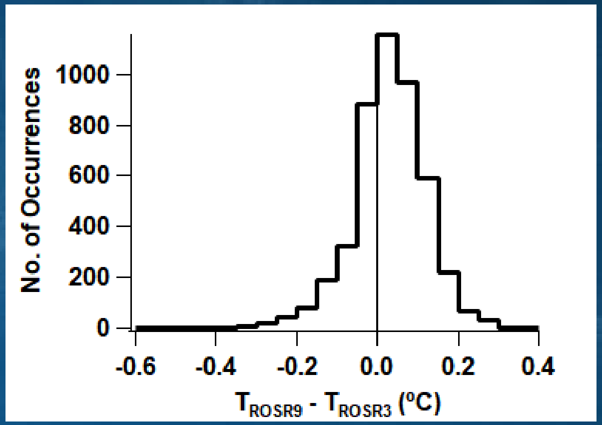
CONCLUDE
IRISS w/ 1-pt in situ cal. has accuracy comparable to ROSR

IRISS/ROSR Time Series and Histograms

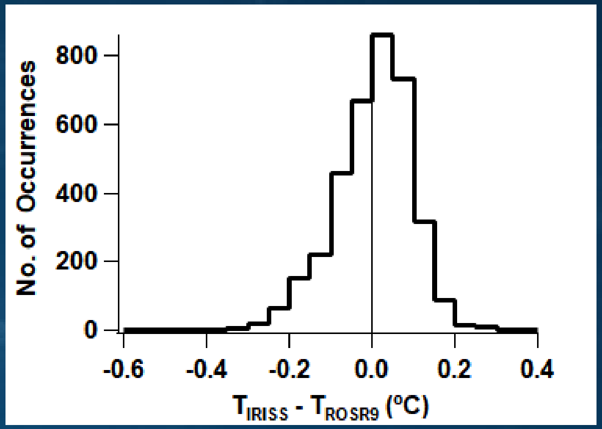
ROSR & IRISS Time Series: T_{skin} and Difference



ROSR3 vs ROSR9



IRISS vs ROSR9

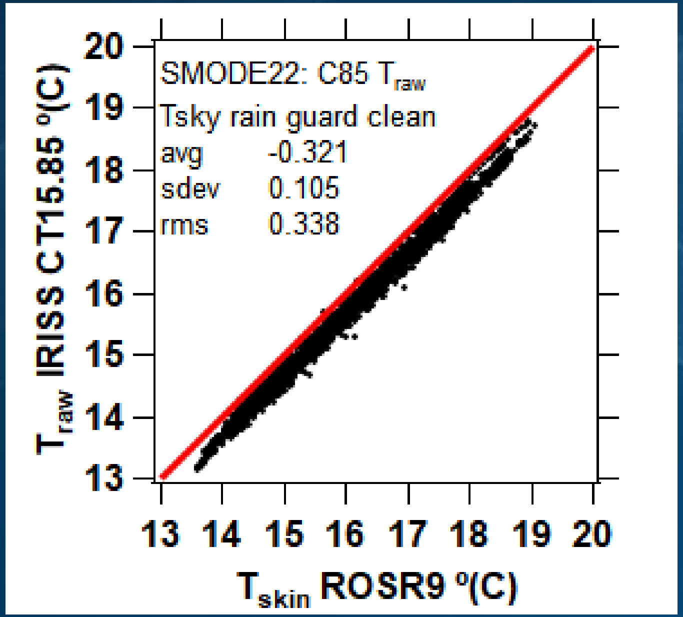


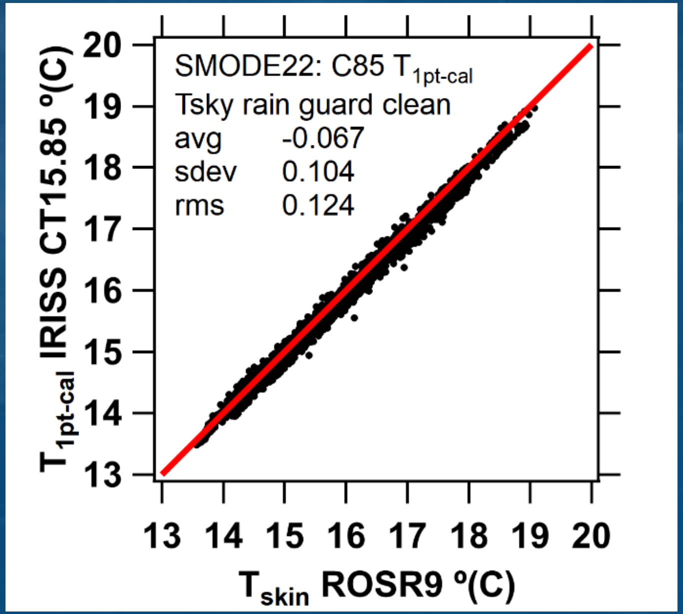
Quantity	Mean	Std. Dev	Minimum	Maximum
$T_{ROSR3-ROSR9}$	-0.030	0.088	-0.295	0.359
$T_{IRISS-ROSR9}$	0.001	0.096	-0.525	0.336

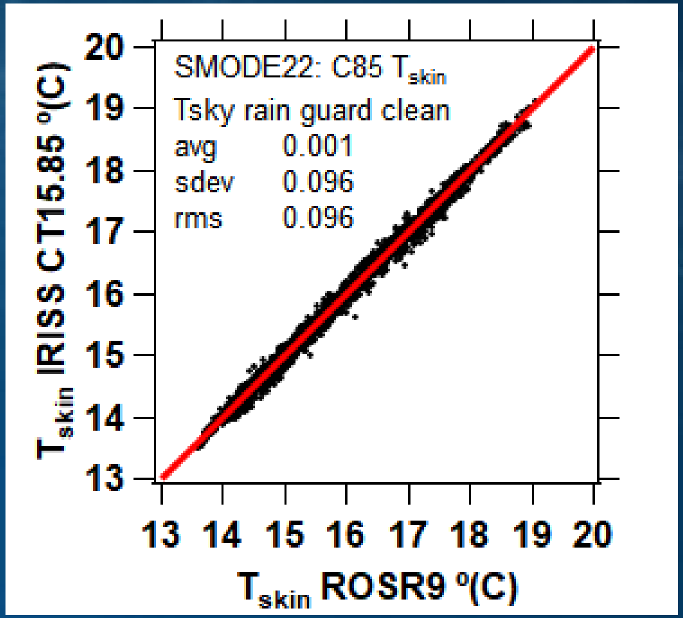
Quantity	Mean	Std dev	Min	Max
$T_{ISAR} - T_{CIRIMS}$	0.00	0.13	−0.64	0.52
$T_{ISAR} - T_{MAERI}$	−0.08	0.15	−0.84	1.01
$T_{MAERI} - T_{CIRIMS}$	0.08	0.15	−1.15	1.10

Steps in Field Calibration Process

1. ***T_{raw}*: Lab calibration applied**
2. ***$T_{1pt\text{-}cal}$*: Apply 1-point *in situ* cal**
3. ***T_{skin}*: Apply self-emission correction**

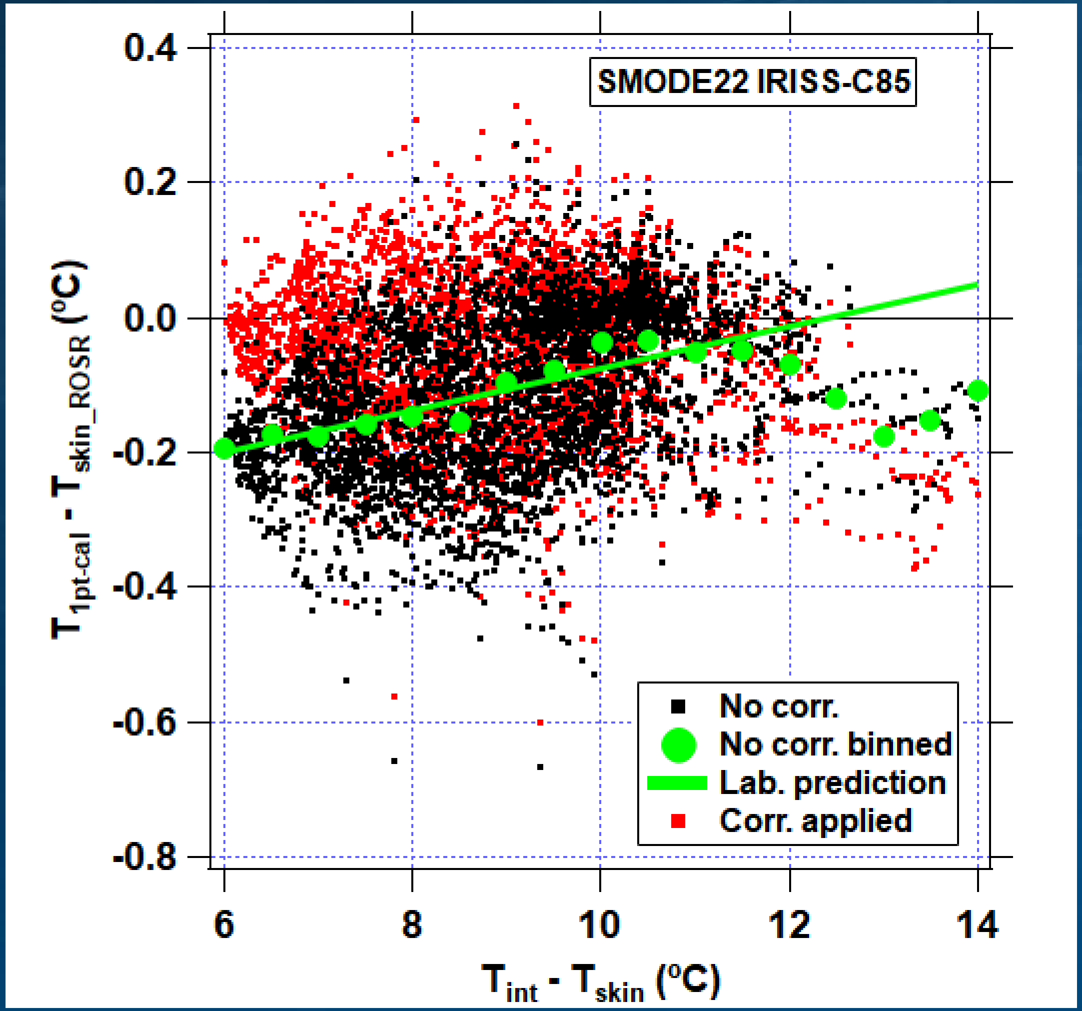






IRISS Field and Laboratory Self-Emission

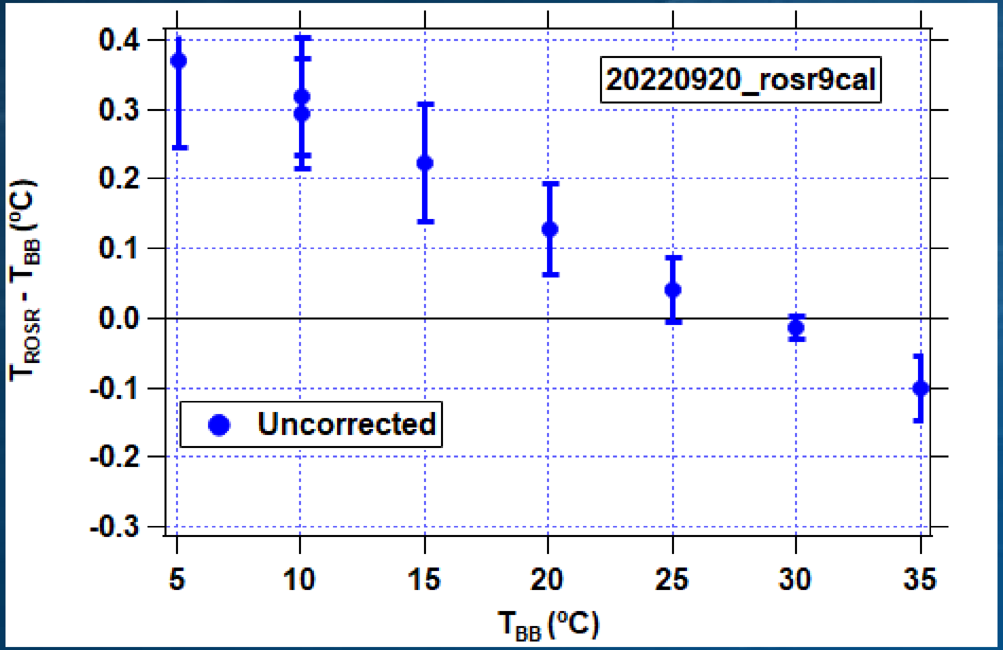
$(T_{1pt\text{-}cal} - T_{skin\text{-}ROSR})$ vs $(T_{inst} - T_{skin\text{-}ROSR})$



Binned field data follow laboratory characterization

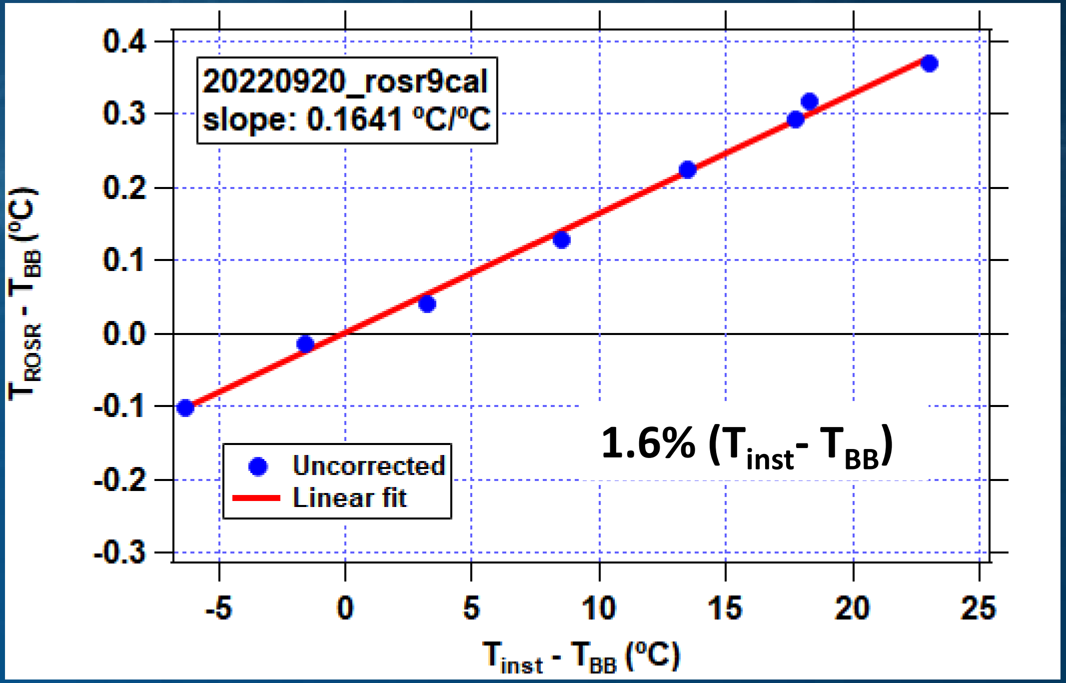
ROSR Self-Emission: Lab Data

T_{ROSR}-T_{BB} vs T_{BB}

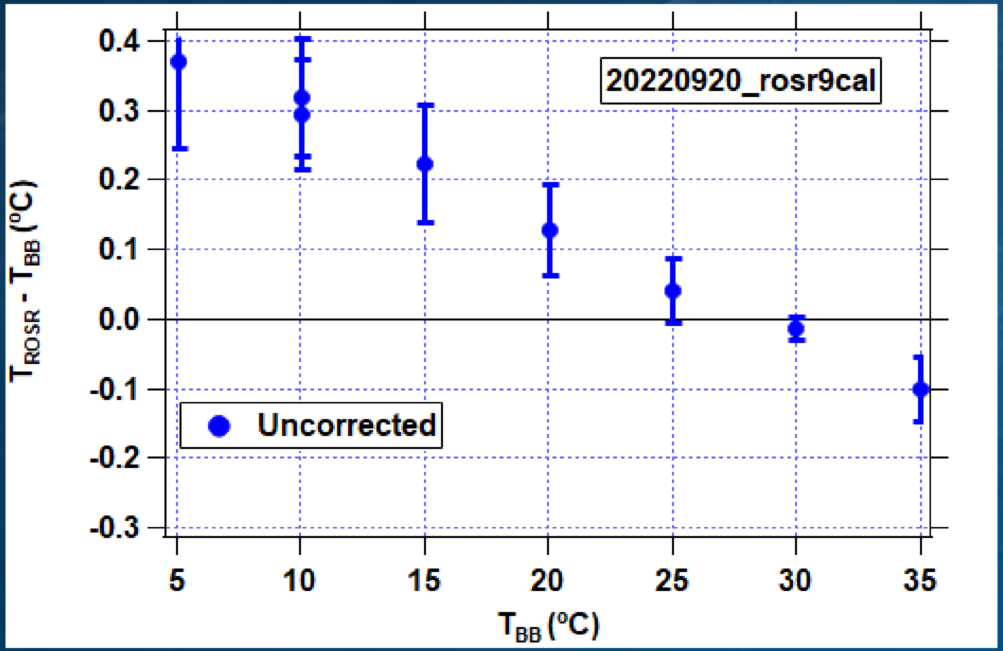


Constant Room Temperature: $T_{int} \approx 29$ °C

T_{ROSR}-T_{BB} vs T_{inst}- T_{BB}

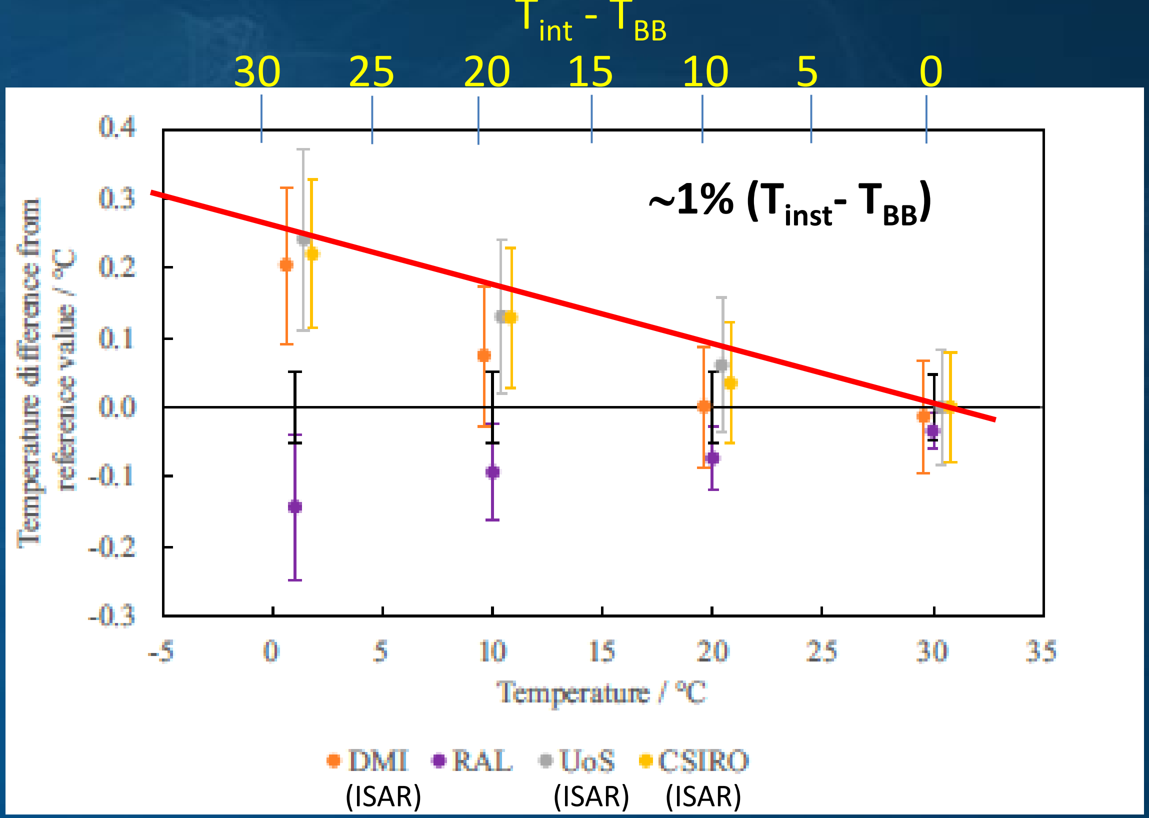


ROSR – ISAR Comparison



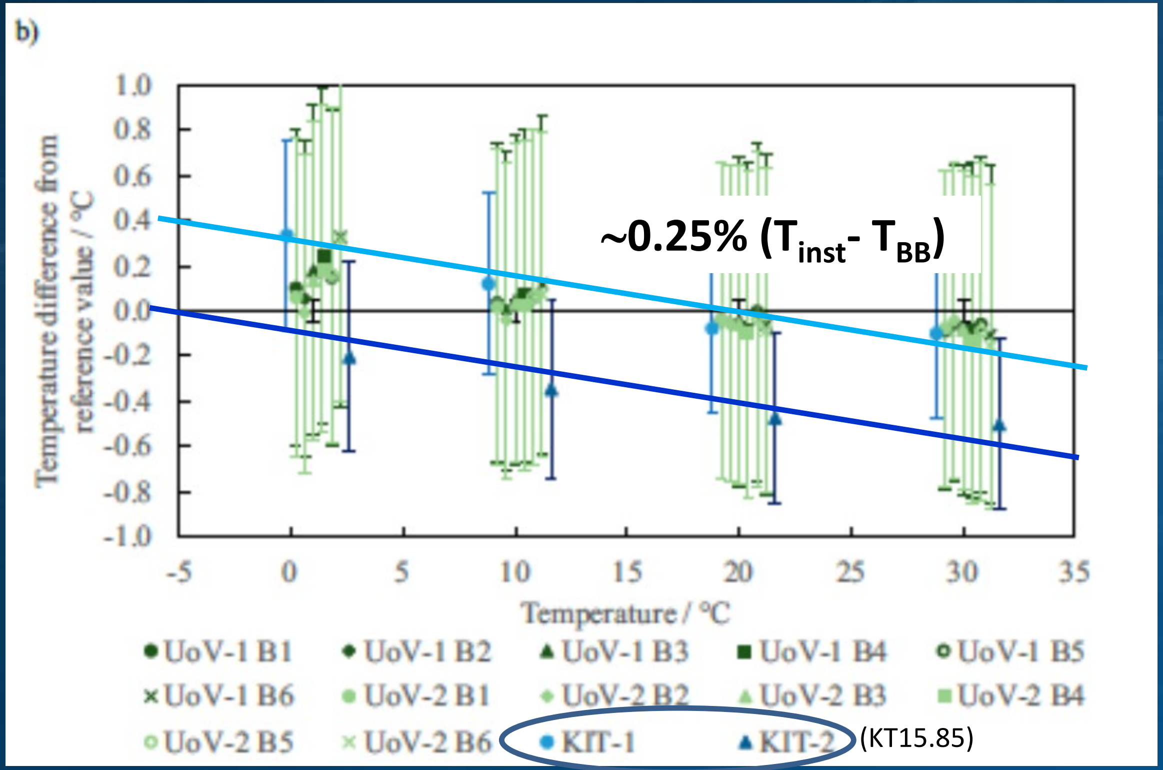
Constant Room Temperature: $T_{int} \approx 29$ °C

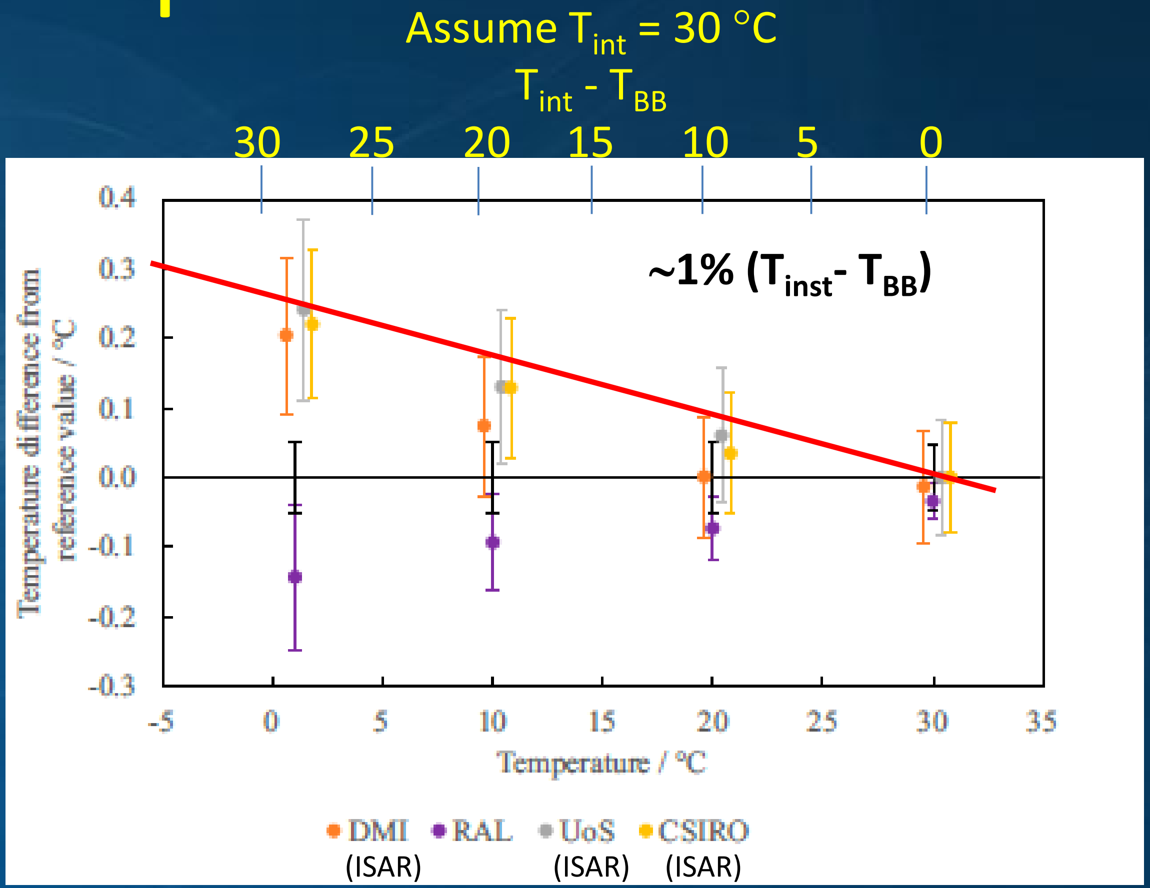
Assume T_{int} = 30 °C



2022 CEOS Comparison: Figure 5a, Yamada et al. [2024]

KT15 – ISAR Comparison





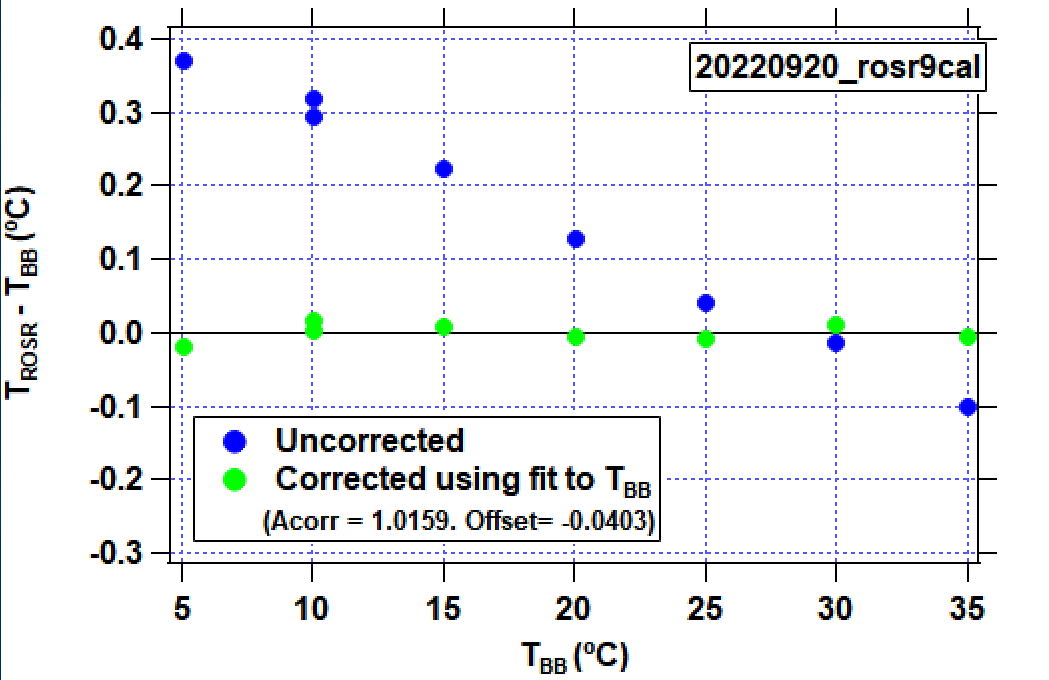
2022 CEOS Comparison: Figure 5a, Yamada et al. [2024]

Rule out

Systematic error in ISAR – occurs in ROSR (derivative design)

Extrapolation error due to being away from ambient – occurs in CT15, which uses factory curves with wide range

ROSR Correction Approach



Reynolds' Method

- Linear Regression to characterized effect
- Compute coefficient Acorr applied to each *in situ* cal
- Compute Offset applied after *in situ* cal
- Works best when T_{inst} = constant = lab cal value
- Not optimal…

Proposed New Method

- Monitor T_{inst}
  - KT15/CT15 standard output
  - Other: add case thermistor
- Apply correction based on $T_{inst} – T_{skin\text{-}uncorrected}$

OR…

- Make T_{inst} = constant
- Use Reynolds' Method

Conclusions

- IRISS approach provides accuracy comparable to ROSR
  - Laboratory calibration
  - 1-point ambient temperature *in situ* calibration
  - Self-emission correction
- Self-Emission Effect
  - Inherent in all radiometers – even M-AERI?!
  - May explain historical comparison differences
  - Next: Reanalysis of ROSR data with new method

Sensor	Effect (%)
Heitronics spec.	0.7
CT15.10	0.24
KT15.85	~0.25
IRISS	1.5
ROSR	1.6
ISAR	~1.0

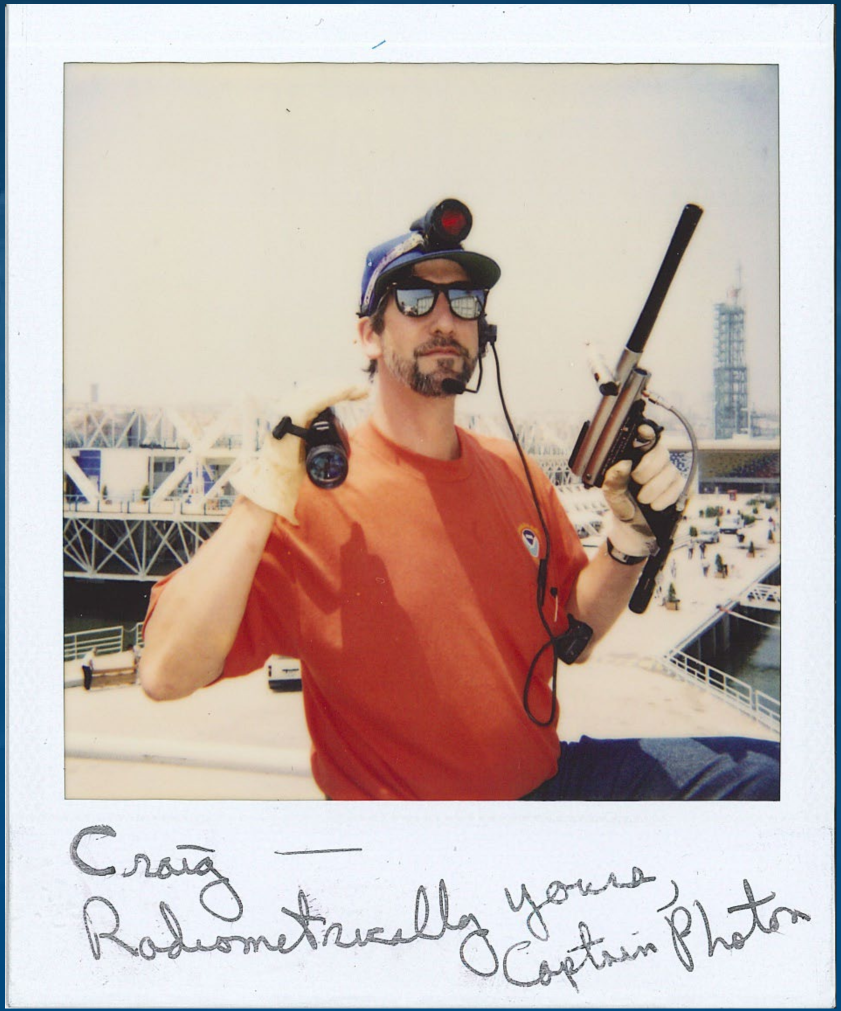
Radiometer Field Comparison 2025

- Coastal Pacific
- Instruments
  - ROSR
  - IRISS
  - M-AERI
- 7-10 days
- Ship time support likely
  - Request time on current grant
  - U.S.-UK Research Collaboration under the NSF-UKRI/Engineering and Physical Sciences Research Council Lead Agency Opportunity
- Travel support – explore options

<u>R/V Rachel Carson</u>

76 ft length
26 ft beam
4 crew
9 scientist
4 heads with showers
Galley, wet and dry labs
Full meteorological package

1998 Postcard to Craig from Lisbon (GasEx98)



On the R/V Ronald H. Brown