Outcome of Workshop on SI-Traceable Space-based Climate Observing System (SITSCOS)

Tim Hewison, *EUMETSAT, Germany*
Nigel Fox, *National Physics Laboratory, UK*
Bruce Wielicki, *retired NASA Langley*
Greg Kopp, *CU-LASP*

A CEOS and GSICS International Workshop

held at the

National Physical Laboratory

London, UK

2019-09-09/11

GSICS Global Space-based Inter-Calibration System

CEOS Committee on Earth Observation Satellites

SITSCOS Workshop Overview

- **~ 100 international participants**
- **Space-based climate observations**
- **Relevant SI-traceable climate change accuracy requirements**
- **Current/future accuracy + stability capabilities**
  - for satellite sensors
  - Ground-based metrology laboratories
  - pre- and post-launch calibration
- **~200 page Workshop Report**
  - using input from the presentations, discussions, and participants' written contributions.
  - set of recommendations was developed as part of the report

Group Photo of SITSCOS Workshop, NPL 2019

Workshop Report, Agenda and Presentations can be found at the CEOS Cal/Val Portal:
http://calvalportal.ceos.org/sitscos-ws

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SITSCOS Workshop Report Structure

1. Executive Summary

Bruce Wielicki , Tim Hewison, Nigel Fox, Greg Kopp

- 26 page summary
- Distributable as a stand-alone document

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SITSCOS Workshop Report Structure

1. **Executive Summary**
2. **Societal Need for an Advanced Climate-Observing System**

B. Wielicki, R. Cooke

- Current space-based observations are typically factors of 5 to 10 less accurate than climate-change science requirements
- An advanced climate observing system (*including SITSats*) could reduce trend-detection uncertainties by 15 to 30 years from current approaches
- Cost of delay in establishing an adequate climate observing system is 50x that of the investment

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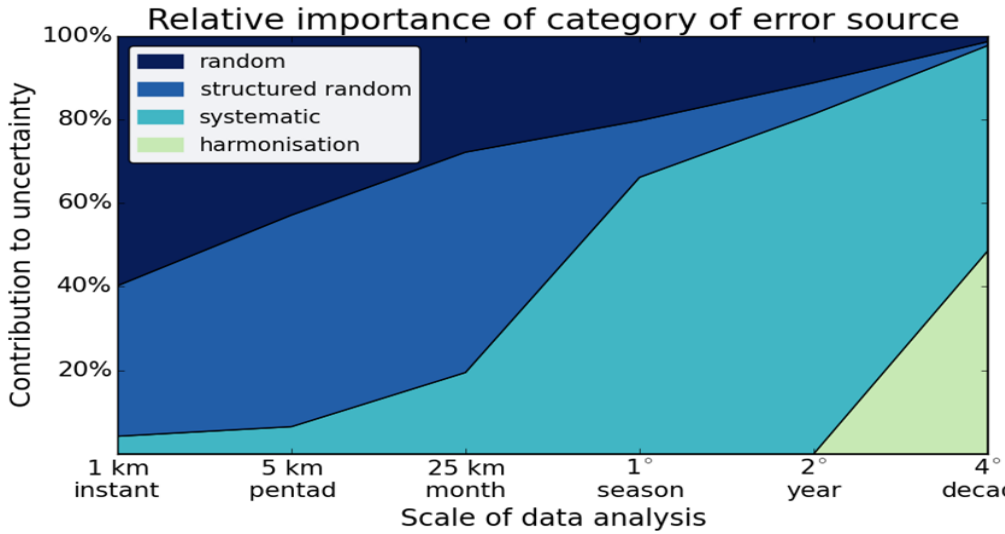
SITSCOS Workshop Report Structure

1. **Executive Summary**
2. **Societal Need for an Advanced Climate-Observing System**
3. **Metrology and CDRs**

S. Hunt, E. Woolliams, J. Mittaz, C. Merchant

- Rigorous metrology in the development of climate data records is crucial to ensure datasets produced are of irrefutable credibility and are stable at a level that justifiably permits the evaluation of climatic trends



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1. **Executive Summary**
2. **Societal Need for an Advanced Climate-Observing System**
3. **Metrology and CDRs**
4. **SI-Traceable Calibrations**

N. Fox, P. Green, S. Devlin

- International metrology laboratories and space agencies have developed and demonstrated new technologies to provide space-based SI-traceable reference instruments to achieve climate-change accuracy requirements

The seven defining constants of the SI and the seven corresponding units they define:

Defining constant	Symbol	Numerical value	Unit
hyperfine transition frequency of Cs	$\Delta\nu_{Cs}$	9 192 631 770	Hz
speed of light in vacuum	c	299 792 458	m s^{-1}
Planck constant	h	6.626 070 15 x 10^{-34}	J s
elementary charge	e	1.602 176 634 x 10^{-19}	C
Boltzmann constant	k	1.380 649 x 10^{-23}	J K^{-1}
Avogadro constant	N_A	6.022 140 76 x 10^{23}	mol^{-1}
luminous efficacy	K_{cd}	683	lm W^{-1}

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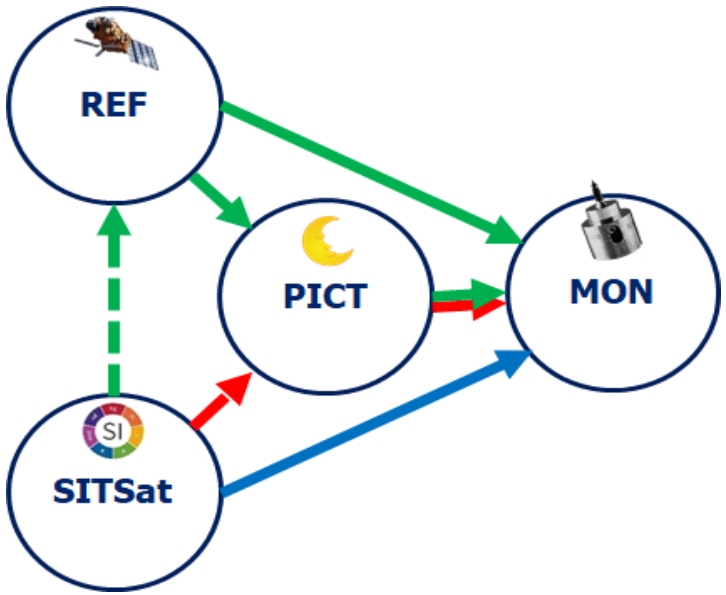
3. **Metrology and CDRs**
4. **SI-Traceable Calibrations**
5. **Extending GSICS to an Absolute Scale**

T. Hewison, D. Doelling, C. Lukashin, D. Tobin, V. John, X. Hu, L. Wang, D. Coppens

- Global Space-based Inter-Calibration System
- See poster



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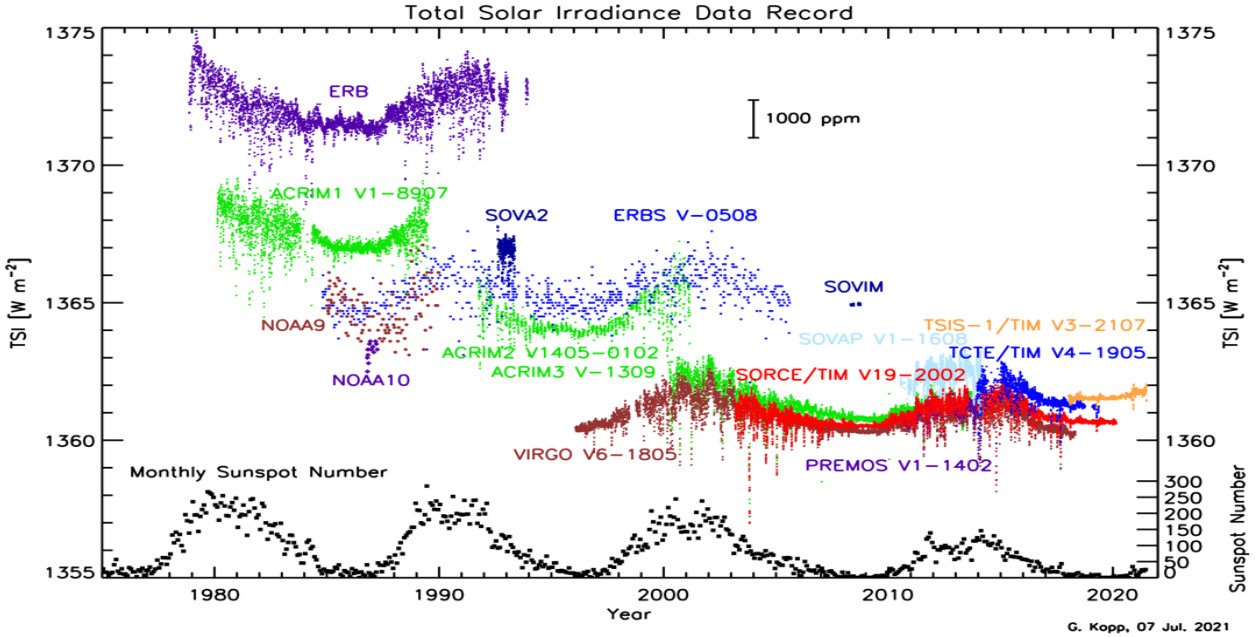
6. **Earth Radiation Budget**

G. Kopp, X. Ye, X. Zhang, X. Yi, C. Lin, and L. Wang, E. Richard, O. Coddington, P. Pilewskie, M. Mlynczak,

- Outgoing Earth radiation budget measurements complete the energy-balance assessment
- Continuity provides record of net incoming energy



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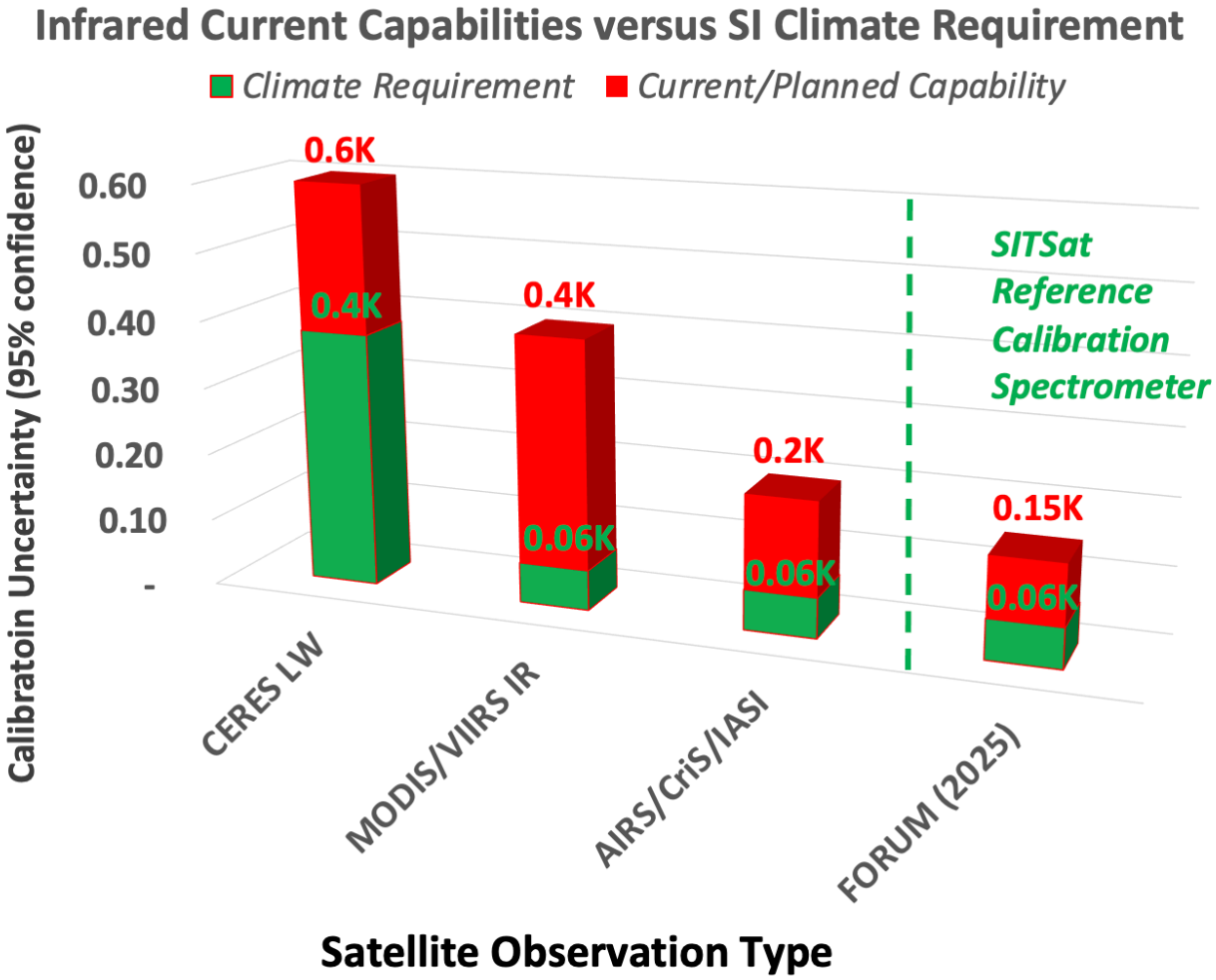
7. **Thermal Infrared**

D. Smith, D. Peters, T. Nightingale, J. Pearce, R. Veltcheva, X. Xiong, J. Butler, T. S. Pagano, E. M. Manning, S. E. Broberg, H. Aumann, S. Ray, E. Fetzer, J. Teixeira, L. Strow, H. Revercomb, F. Best, D. Tobin, J. Taylor, J. Gero, R. Knuteson, D. Adler, C. Pettersen, M. Mulligan, R. Holz, F. Nagle

- Designs to realise a SITSat in IR exist and are virtually ready to fly



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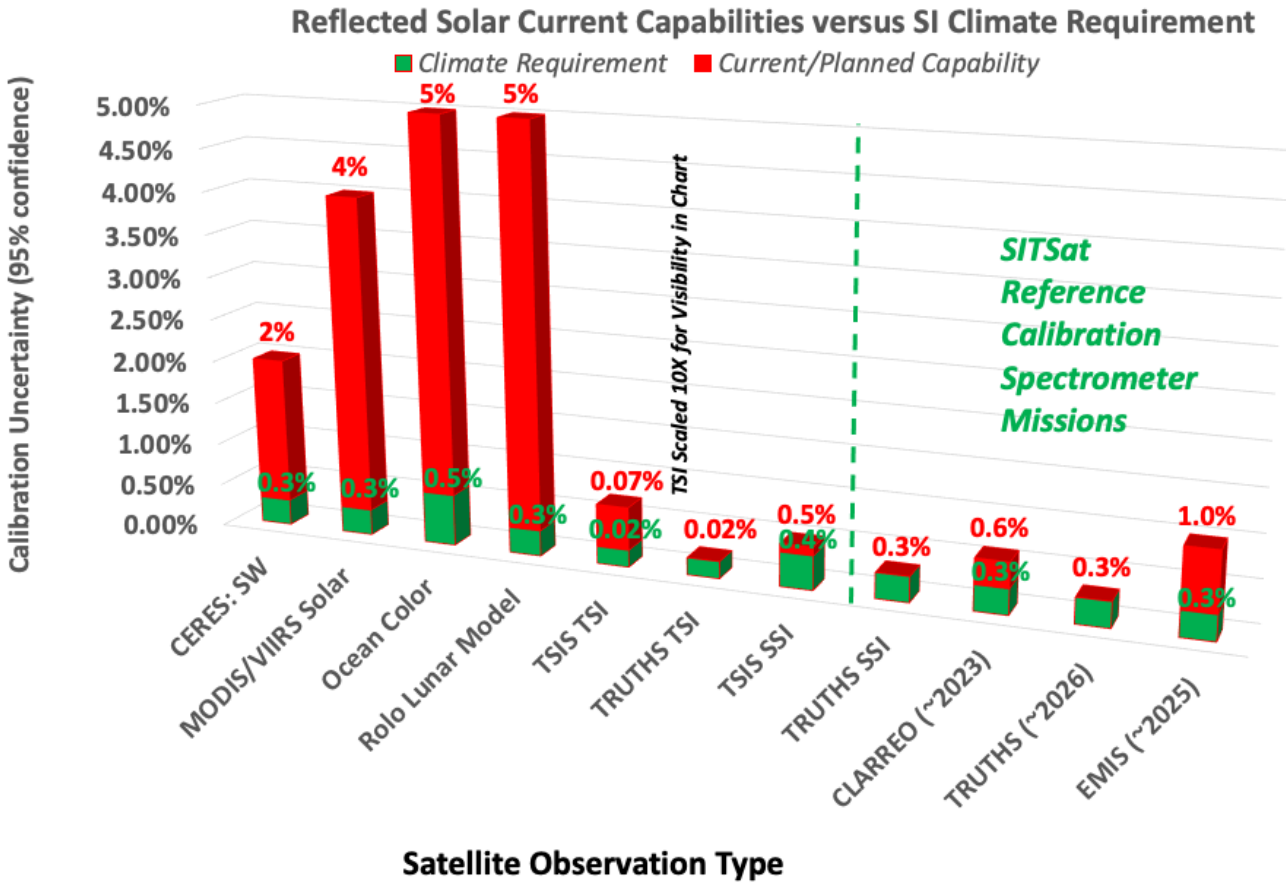
7. **Thermal Infrared**
8. **Reflected Solar Measurements**

X. Xiong, J. Butler, T. C. Stone, C. Lukashin, K. Turpie, D. Helder, W. Sun, Y. Shea, B. A. Wielicki, R. R. Baize, G. A. Fleming

- Reviewed calibration of current operational VIS/NIR sensors compared to climate reqs.



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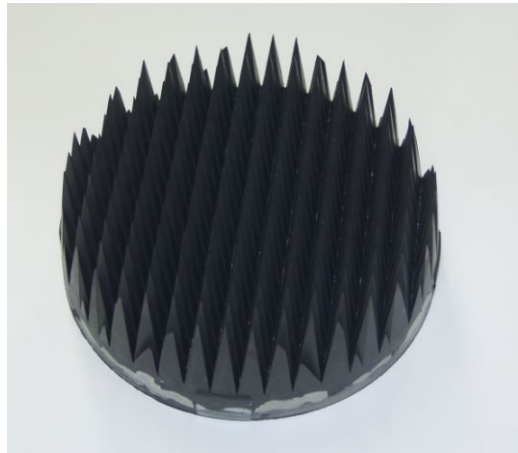
8. **Reflected Solar Measurements**
9. **Microwave**

D. Houtz, P. Rosenkranz, H. Yang, M. Burgdorf, R. V. Leslie, W. Blackwell, E. Kim,

- Microwave sounders provide high impact observations for NWP
- Current satellite sensors are optimized for weather, not climate
- Further calibration improvements would bring large benefits

A microwave black body calibration target



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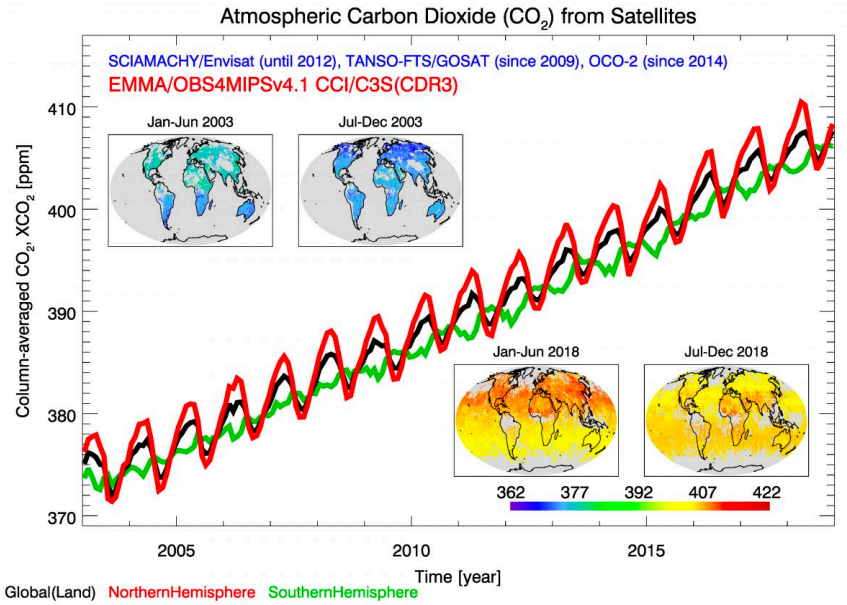
8. **Reflected Solar Measurements**
9. **Microwave**
10. **Additional Applications**

F. Carminati, C. Harlow, Y. Shea, D. Helder, S. Simis, T. Jackson, G. Zibordi, H. Boesch, T. Trent

- Reviewed benefits of applying SITSats to:
- Numerical Weather Prediction
- Cloud Radiative Forcing
- Land Imaging
- Ocean Colour
- Trace Gases



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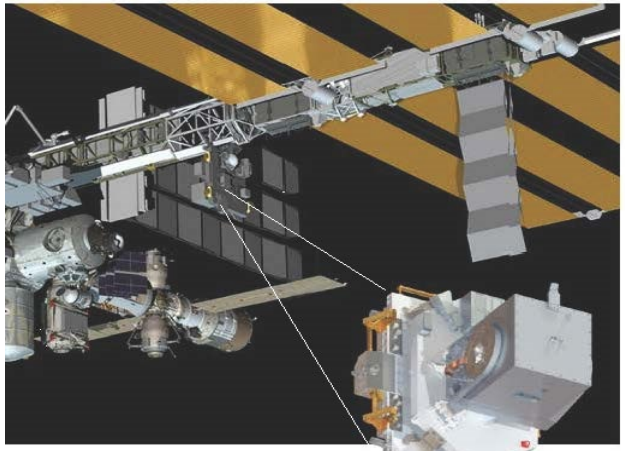

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10. **Additional Applications**
11. **SITSats in Development**

G. Kopp, P. Pilewskie, P. Smith, B. Wielicki, C. Lukashin, G. Fleming, C. Currey, D. Goldin, C.M. Roithmayr, Y. Shea, W. Sun, K. Thome, A. Wu, X. Xiong, N. Fox, P. Green, X. Ye, X. Zhang, X. Yi, C. Lin, L. Wang, H. Brindley, R. Bantges, L. Palchetti, S. Buehler, B. M. Dinelli, L. Labonnote, Q. Libois, M. Mlynczak, H. Oetjen, M. Ridolfi, M. Riese, R. Saunders,

- NASA CLARREO Pathfinder on ISS
- ESA TRUTHS
- Chinese Space Agency CSRB
- ESA FORUM
- Chinese Space Agency LIBRA
- Multiple independent sensors for verification (as for international metrology standards)

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10. **Additional Applications**
11. **SITSats in Development**
12. **Conclusions**

Bruce Wielicki , Tim Hewison, Nigel Fox, Greg Kopp

- 3 page conclusions
- Including Recommendations of Workshop…

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SITSCOS Workshop Report: Recommendations 1

- **Space agencies should plan a long-term operational SI-traceable climate observing system, building on the currently planned SITSats**
  - Overlapping continuity improves sensitivity monitoring climate change due to natural events
  - With SI traceability, gaps in observations may not compromise long-term data record
- **NASA should plan for CLARREO Pathfinder to intercalibrate additional sensors and surface sites**
  - Should also extend the mission operations plan to five years to enable overlap with the TRUTHS and CSRB SITSats
- **Encourage U.S. to add IR SITSat spectrometer**
  - to reach required goals from independent sensors through entire thermal-infrared spectrum
  - The complimentary FORUM mission covers the far-infrared
  - Chinese LIBRA mission aims to achieve those goals through improvement of multiple missions

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SITSCOS Workshop Report: Recommendations 2

- **Use the Moon to improve reflected-solar sensors' calibration accuracies and stabilities**
  - Lunar observations enable stabilities of < 0.1 %/decade
  - Further improvements in the accuracy of lunar irradiance models are required
- **Passive microwave instruments require further work on SI-traceability**
  - for climate-change accuracies of calibration references
  - to demonstrate reference calibration sensors in orbit
- **FRM surface measurements complement SITSats**
  - Integrate to further improve models and understanding of climate processes
- **Plan follow-on SITSCOS workshop for 2026 to consider status and early results of SITSat missions**
  - Include progress and plans for SI traceability of microwave, polarimeter, and active satellite sensors

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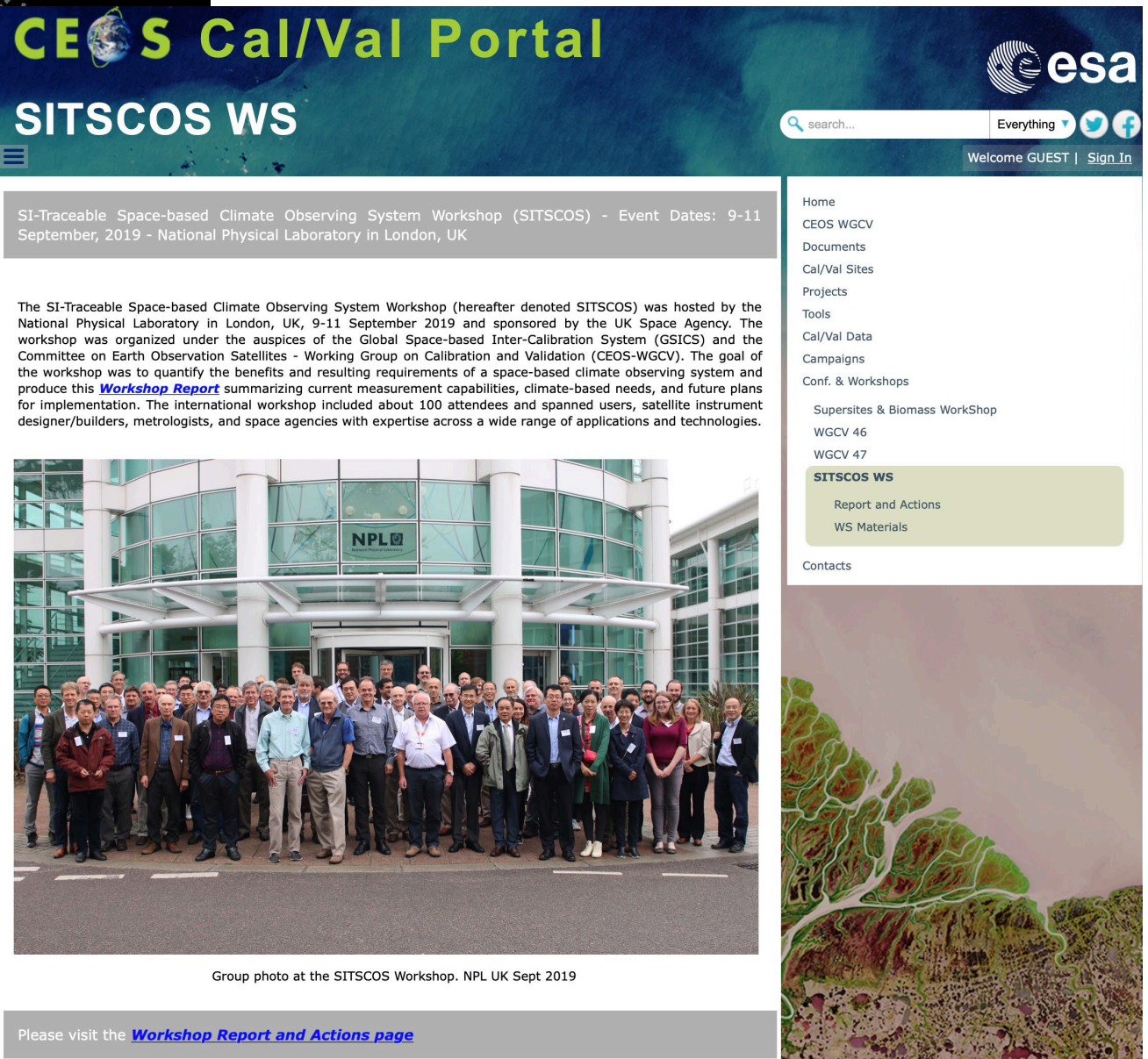
Where to Find the Report: CEOS Cal/Val Portal



https://calvalportal.ceos.org/sitscos-ws

doi.org/10.47120/npl.9319

Thank you!

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