Update of Radiation References: Results from the WMO Expert Team on Radiation References

Expert Team on Radiation References[1)] from WMO SC-MINT

(Standing Committee on Measurements, Instrumentation and Traceability)

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Update of Radiation References: Results from the WMO Expert Team on Radiation References

1) Problem statement
2) Solar and terrestrial radiation reference update
3) Impacts, potential problems and tasks
4) Recommendations

Primary metrological references for solar (shortwave) & terrestrial (longwave) radiation are instrument-based, managed by PMOD/WRC.

New references (new instruments) have been proposed with improved traceability to SI. However, comparisons show bias between the old and new references.

ET-RR should advise WMO whether and how to proceed with the change in radiation references without disrupting climate (and meteorological) science.

Balance to be found between a) updating the references ASAP to benefit from improved accuracy / traceability and b) waiting that conditions are met to insure change without excessive disruptions to meteorology and climatology:

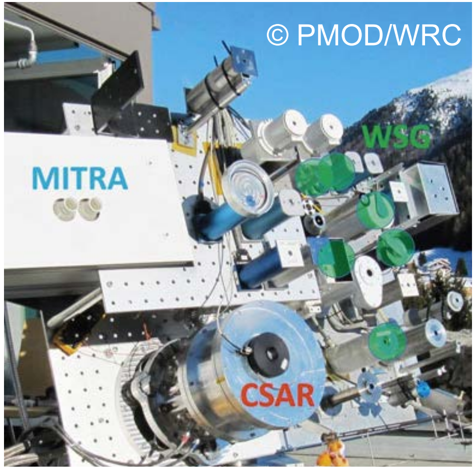
a) New instruments / methods are proposed since ~10 years with improved accuracy / traceability now demonstrated; their implementation is required for some uses.

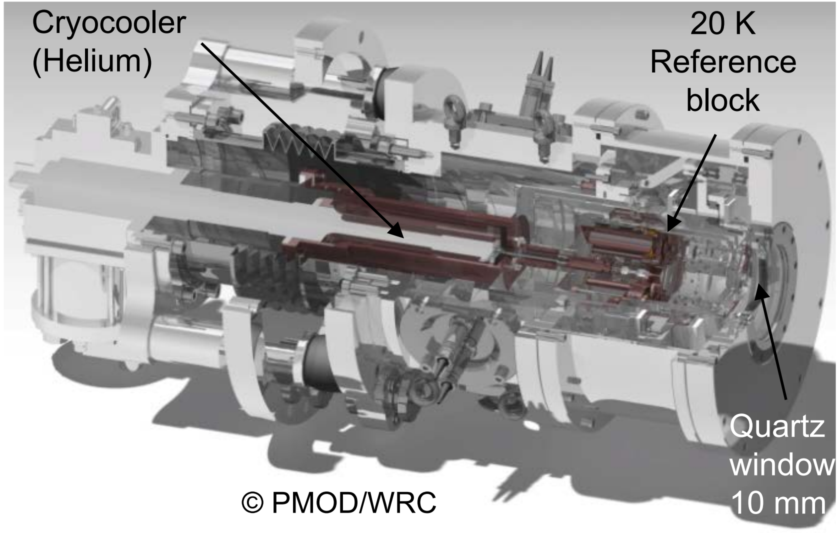
b) Anticipated changes of scale may lead to disruptions in meteorology / climatology and mitigation methods are required; other conditions should also be met for the primary references (e.g., redundancy).

Solar radiation ref update

- World Radiation Reference (WRR) defined with total direct solar radiation measurements by an ensemble of absolute radiometers (WSG)
- Fröhlich (1977, WMO No. 490) states accuracy of 0.3%, (no indication of confidence level)
- Traceability to SI through first principles understanding of instruments

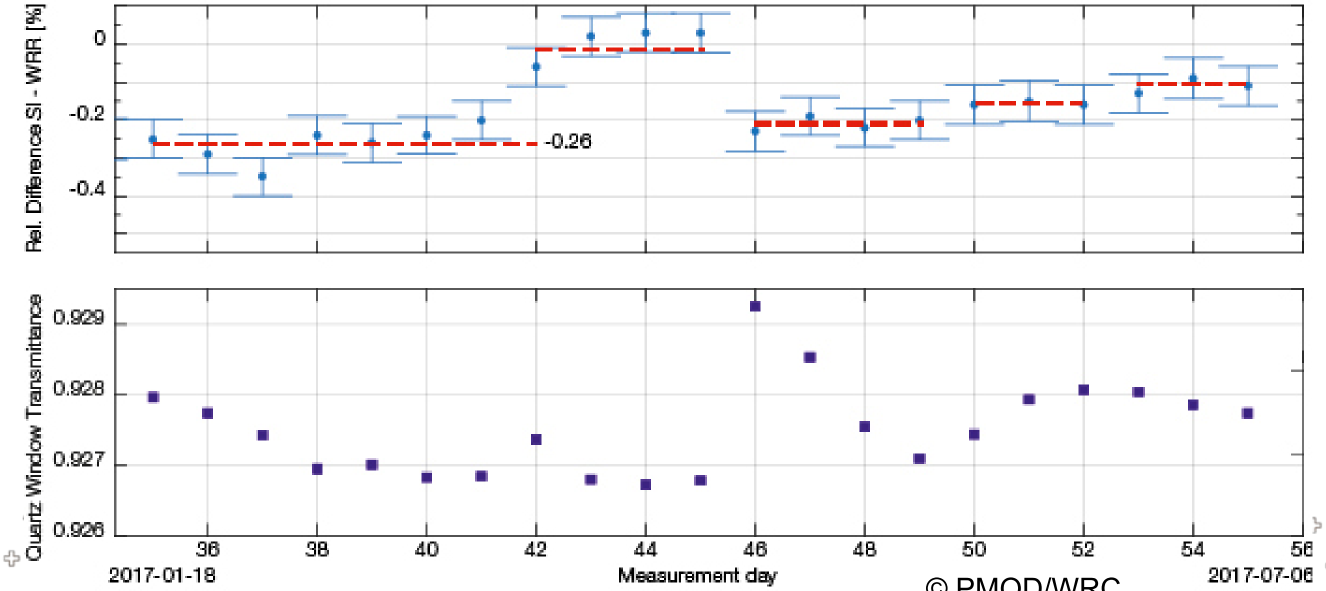
- Cryogenic Solar Absolute Radiometer (CSAR) newly developed for better traceability to SI
- Winkler (2013, PhD thesis, University College London) states standard uncertainty of ~0.03% for ground operation during 1 day, mostly due to window transmittance; window transmittance uncertainty reduced since (MITRA) → **Goal ~0.01%**





Solar radiation ref update

- Comparisons between CSAR/MITRA and current reference showed WRR to be ~0.3% above SI scale (defined by CSAR), consistent with previous comparisons (Fehlmann et al, 2012)



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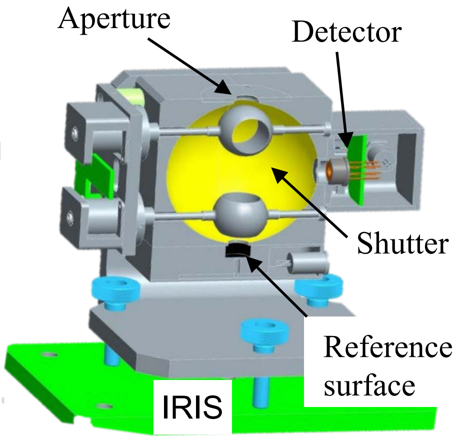
Terrestrial radiation ref update

- Primary terrestrial radiation reference defined by an ensemble of pyrgeometers (WISG)
- WISG uncertainty about ±4 Wm^{-2} (Gröbner et al. 2014), stability about ±1 Wm^{-2}
- Traceability to SI through PMOD/WRC blackbody (originally calibrated with Absolute Sky-Scanning Radiometer)

- Infrared integrating sphere (IRIS) and Absolute Cavity Pyrgeometer (ACP) developed for solving transmittance issues & better traceability to SI
- Uncertainty estimates are ±2.4 Wm^{-2} for IRIS and ±4 Wm^{-2} for ACP



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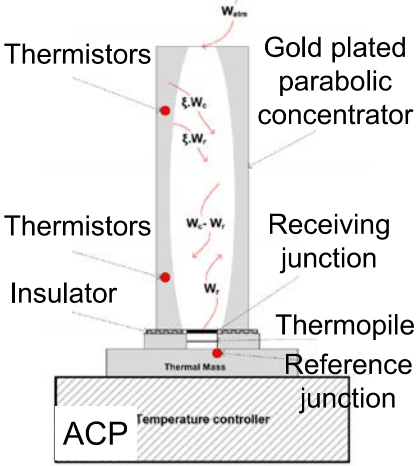
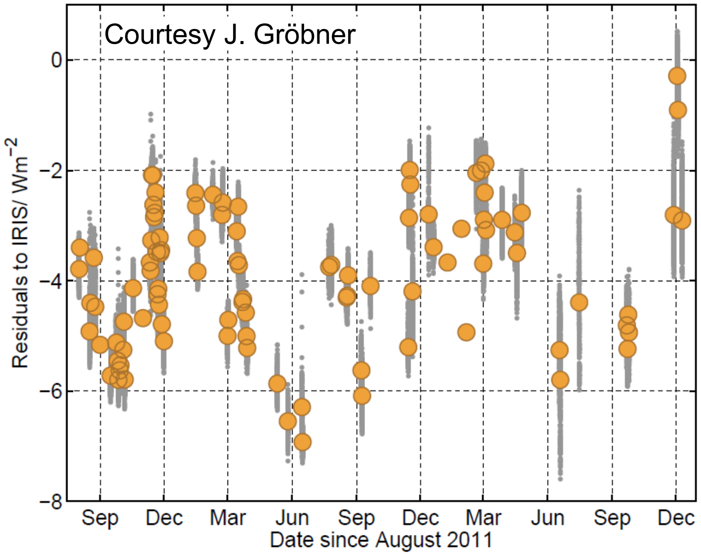
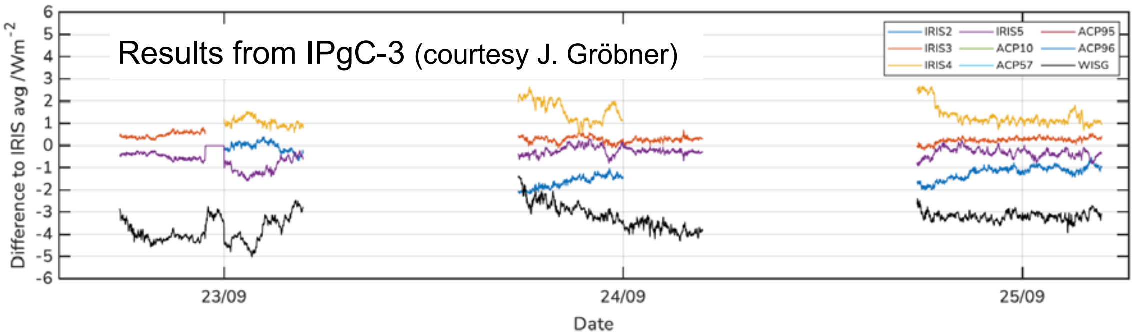


(Reda et al. 2012, doi: 10.1016/j.jastp.2011.12.011)

Terrestrial radiation ref update

- Comparisons showed WISG to be 2-7 Wm^{-2} lower than IRIS (clear-sky nights)
- Agreement within uncertainty between IRIS and ACP





Impacts, potential problems and tasks

Users affected mainly by scale changes or changes in instrument traceability

- Climate modelling community:
  - expected scale change for terrestrial radiation impactful for weather and climate model validation: CMIP6 multimodel mean now 2 Wm^{-2} higher than best estimate from BSRN data for all-sky and 4 Wm^{-2} for clear-sky → comparable to scale change; may have significant impact on trend analysis
  - For solar radiation, scale change small compared to uncertainties in most recent model estimates; may impact trend analysis because worldwide change
- Satellite community:
  - impact of scale change for terrestrial radiation can be significant for product validations (surface observations used): expected scale change (~5 Wm^{-2} for clear-sky situations) significantly larger than mean bias of satellite monthly mean downward longwave irradiance

Impacts, potential problems and tasks

Users affected mainly by scale changes or changes in instrument traceability

- Climate monitoring databases
  - potential scale change-linked inhomogeneity in long-term data series
  - primary responsibility in harmonization (homogenization) of database
- Monitoring / measurement community:
  - instruments traceable to new references progressively to be used in monitoring:
    - potential inhomogeneity → community to contribute to harmonization effort
    - metadata documenting measurement traceability must be recorded/used
    - potential inhomogeneity □community to contribute to harmonization effort
- Instrument manufacturers:
  - Produced radiometers progressively to become traceable to new radiation references → manufacturers must inform their customers (information note to be added to the calibration certificates)

Impacts, potential problems and tasks

The **World Radiation Center** at PMOD (PMOD/WRC) will hold primary responsibility for the operational implementation of the new references:

- Ensure understanding of new references (accuracy, traceability to SI, etc.) is fully documented, preferably in metrology peer-reviewed journals
- Ensure new references are operational in a stable way
  - Only a single instrument is proposed as primary reference for solar radiation, representing a potential vulnerability in case of malfunction
- Ensure dissemination of reference (upper echelon of traceability chain toward monitoring instruments)
  - Currently, it is guaranteed via International Pyrheliometer Comparisons and International Pyrgeometer Comparisons

Recommendations

References

- Proposed solar radiation reference to be compared with cryoradiometer from NMI with CMC for spectral sensitivity
- Documentation available on traceability and accuracy for solar and terrestrial proposed references reflecting status as operational reference
- Current solar and terrestrial reference instrument groups (WSG and WISG) to be continued/renewed as transfer standard
- Production of second instrument of CSAR/MITRA design + other independent realization of cryogenic solarradiation reference
  - Planning for backup system ready before radiation references update

Recommendations

Data and observations

- Data homogenization necessary for major climate time series: harmonizing historical data to new references
  - Centers responsible for databases should perform this task by central processing feasibility still to be fully assessed: available (human) resources
  - Procedures for harmonization of data traceable to current solar(WSG) and terrestrial radiation reference (WISG) must be fully understood/prepared
  - Recording of pyrgeometer raw data (terrestrial radiation) mandatory for major climate time series (BSRN)
- Information notice explaining nature of radiation reference change, corresponding scale shift / consequences, guidelines on method for correcting historical data

Potential timeline

Following discussion with Secretary of SC-MINT, WMO responsibility for radiation reference following MRA with BIPM implies decision of updating reference is at level of WMO Congress

2025: IPC XIV & IPgC-4

- New references “operational” state established / documented (peer-reviewed publication)
- Procedure for continuation of current reference as transfer standard established

2026: reference update documentation established

- Analysis and publication of IPC XIV and IPgC-4 final testing/comparison of proposed (new) and current (old) references
- Drafting of resolutions pertaining to reference update for WMO congress
- Resolution & process review by relevant WMO commission (INFCOM)

2027: WMO Congress

Thank you!

comments/questions to

ET-RR members

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