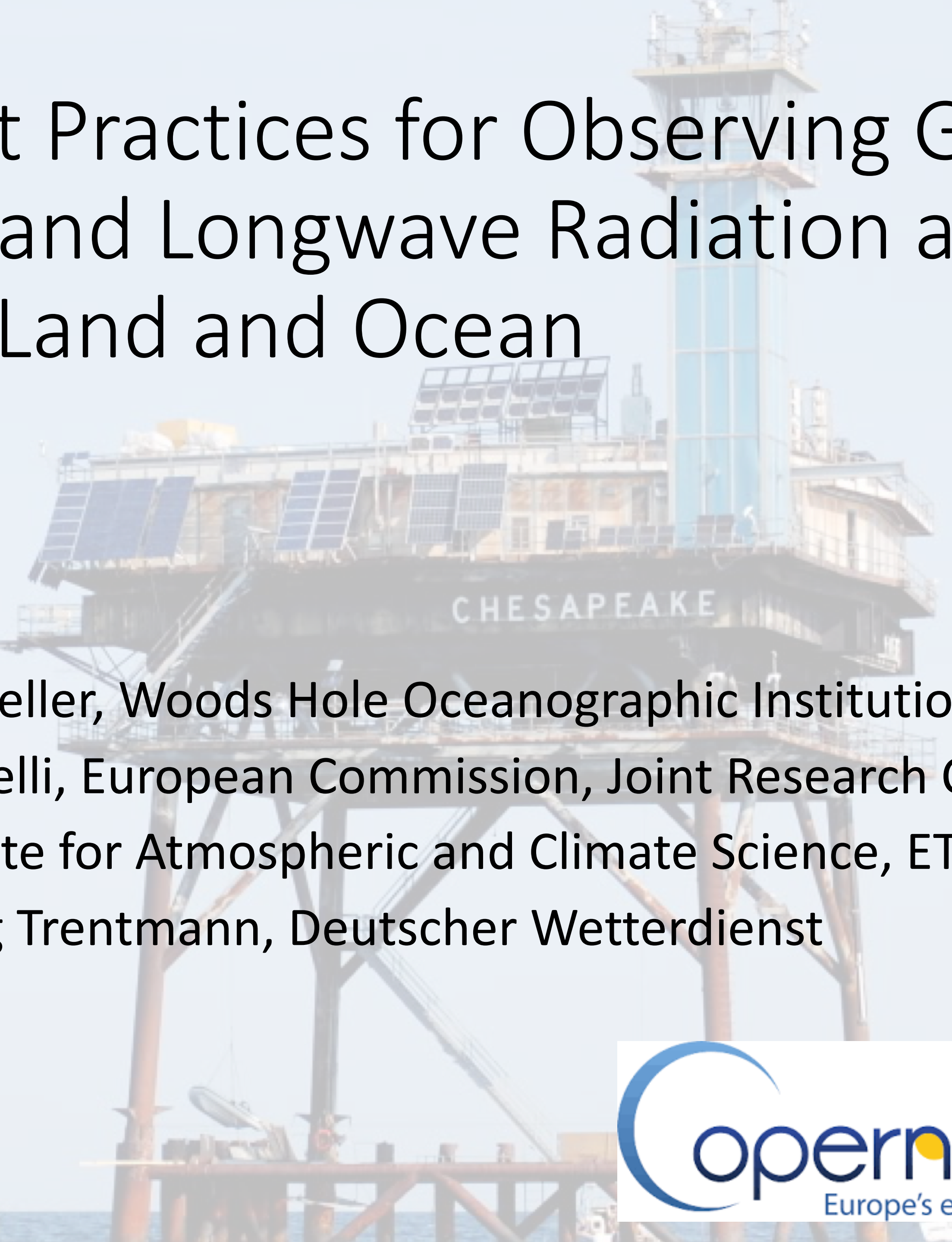
Developing Best Practices for Observing Global Surface Shortwave and Longwave Radiation across the Land and Ocean



Robert A. Weller, Woods Hole Oceanographic Institution
Christian Lanconelli, European Commission, Joint Research Centre
Martin Wild, Institute for Atmospheric and Climate Science, ETH Zurich
Joerg Trentmann, Deutscher Wetterdienst

GCOS
GLOBAL CLIMATE OBSERVING SYSTEM

Copernicus
Europe's eyes on Earth

European Commission

Long-term goal: Establish the foundation for integrating diverse surface shortwave and longwave radiation measurements into global fields.

Immediate goal: Establish a dialog across the different methods of in-situ and remote sensing of surface radiation.

Objectives:

- Share knowledge and experience across different methods
- Document calibration methods
- Assess uncertainties of different methods
- Improve in-situ sampling
- Validate and assess climate models
- Contribute to understanding of earth’s energy balance

Surface radiation observing targets

GCOS observing requirements, GCOS Implementation Plan, GCOS-200

ECV	Frequency	Spatial resolution	Required measurement uncertainty	Stability
Surface longwave	Monthly (resolving diurnal cycle)	100 km	Global mean: 1 W m^{-2}	0.2 W m^{-2}/decade
Surface shortwave	Monthly (resolving diurnal cycle)	100 km	Global mean: 1 W m^{-2}	0.2 W m^{-2}/decade

GOOS observing requirements, GCOS Implementation Plan, GCOS-200

ECV/EOV	Frequency	Resolution	Uncertainty	Stability
Radiative heat flux (ocean surface)	Hourly to monthly	1 – 25 km	10-15 W m^{-2}	1-2 W m^{-2}

Surface radiation observing targets, refinements and updates

ECV Product: downward short-wave irradiance at Earth's surface

	Unit	Threshold	Breakthrough	Goal	Ref. and standards
Horiz resolution	km	1000	250	50	
Vert resolution	n/a	n/a	n/a	n/a	
Temporal res		Monthly	Daily	Hourly	
Timeliness		1 month after	complete year		
Uncertainty	$W\ m^{-2}$	10	5	1	Traceability to world references/standards
Stability	$W\ m^{-2}\ decade^{-1}$	1	0.5	0.2	Traceability to world references/standards

ECV Product: downward long-wave irradiance at Earth's surface

	Unit	Threshold	Breakthrough	Goal	Ref. and standards
Horiz resolution	km	1000	250	50	
Vert resolution	n/a	n/a	n/a	n/a	
Temporal res		Monthly	Daily	Hourly	
Timeliness		1 month after the	observation period		
Uncertainty	$W\ m^{-2}$	10	5	1	Traceability to world references/standards
Stability	$W\ m^{-2}\ decade^{-1}$	1	0.5	0.2	Traceability to world references/standards

GCOS observing requirements, GCOS Implementation Plan review, draft (expected release 2021)

Fiducial Reference Measurements (FRM) concept (Thorne et al., 2018), hierarchy of networks with different observing capabilities

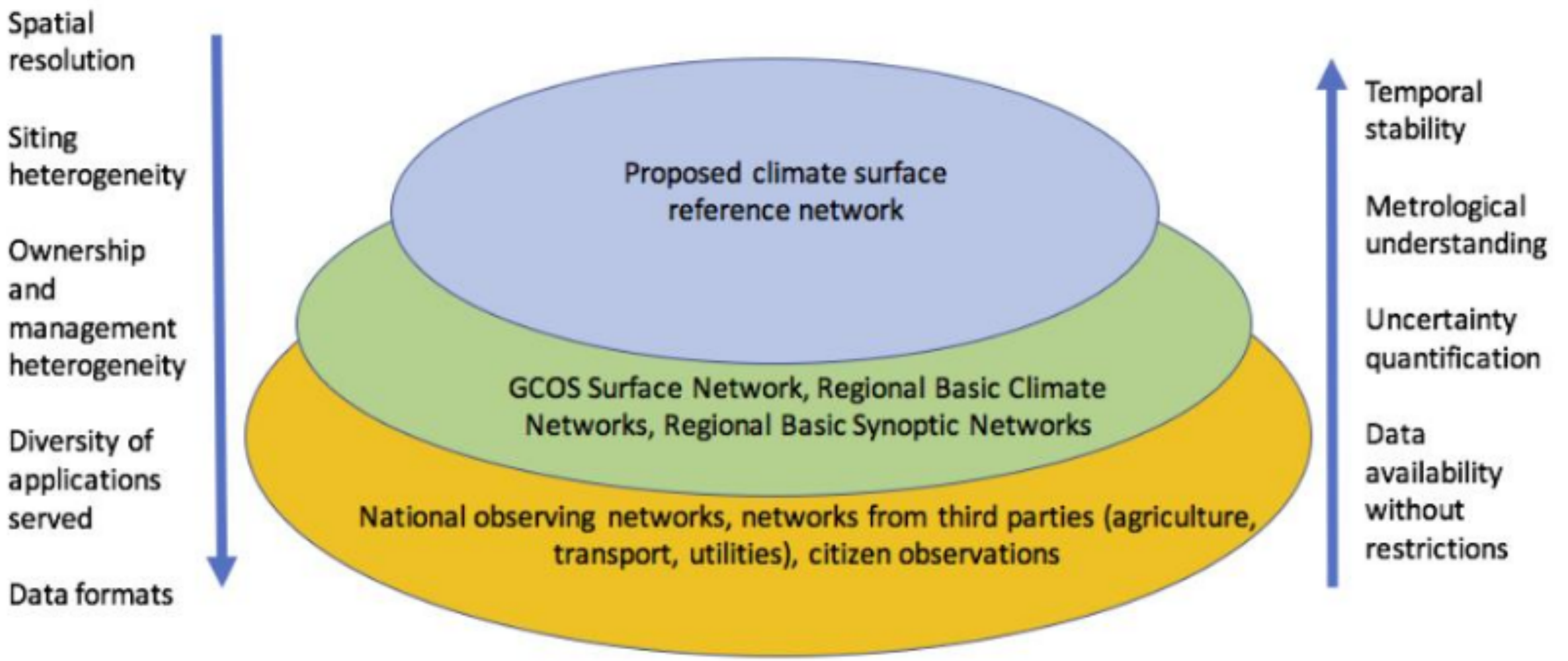


Figure 1 Conceptual outline of how climate observational capabilities map onto the Thorne et al. (submitted). The tiers from top to bottom are: Reference, Baseline and associated text denote important facets of the measurements that increase as you m tiers (right hand side).

https://frm4soc.org/

http://www.frm4sts.org/

https://frm4veg.org/

Remote Sensing of Environment 241 (2020) 111690

Contents lists available at ScienceDirect

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

ELSEVIER

Fiducial Reference Measurements for validation of Sentinel-2 and Proba-V surface reflectance products

Niall Origo[a,b,*], Javier Gorroño[a], James Ryder[a], Joanne Nightingale[a], Agnieszka Bialek[a]

[a] Earth Observation, Climate and Optical group, National Physical Laboratory, Hampton Road, Teddington, Middlesex TW11 0LW, UK
[b] Department of Geography, University College London, Gower Street, WC1E 6BT, UK

How best to move forward under GCOS in coordination with the hierarchy of networks and existing guidelines, e.g. CIMO Guide WMO no. 8?

Quality assurance and maintenance are of special interest for instrument measurements. Throughout this Guide many recommendations are made in order to meet the stated performance requirements. Particularly, Part IV of this Guide is dedicated to quality assurance and management of observing systems. It is recognized that quality management and training of instrument specialists is of utmost importance. Therefore, on the recommendation of CIMO,[1] several regional associations of WMO have set up Regional Instrument Centres (RICs) to maintain standards and provide advice regarding meteorological measurements. Their terms of reference and locations are given in Annex 1.A. In addition, on the recommendation of the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology[2] (WMO, 2010*a*) a network of Regional Marine Instrument Centres has been set up to provide for similar functions regarding marine meteorology and other related oceanographic measurements. Their terms of reference and locations are given in Part II, Chapter 4, Annex 4.A.

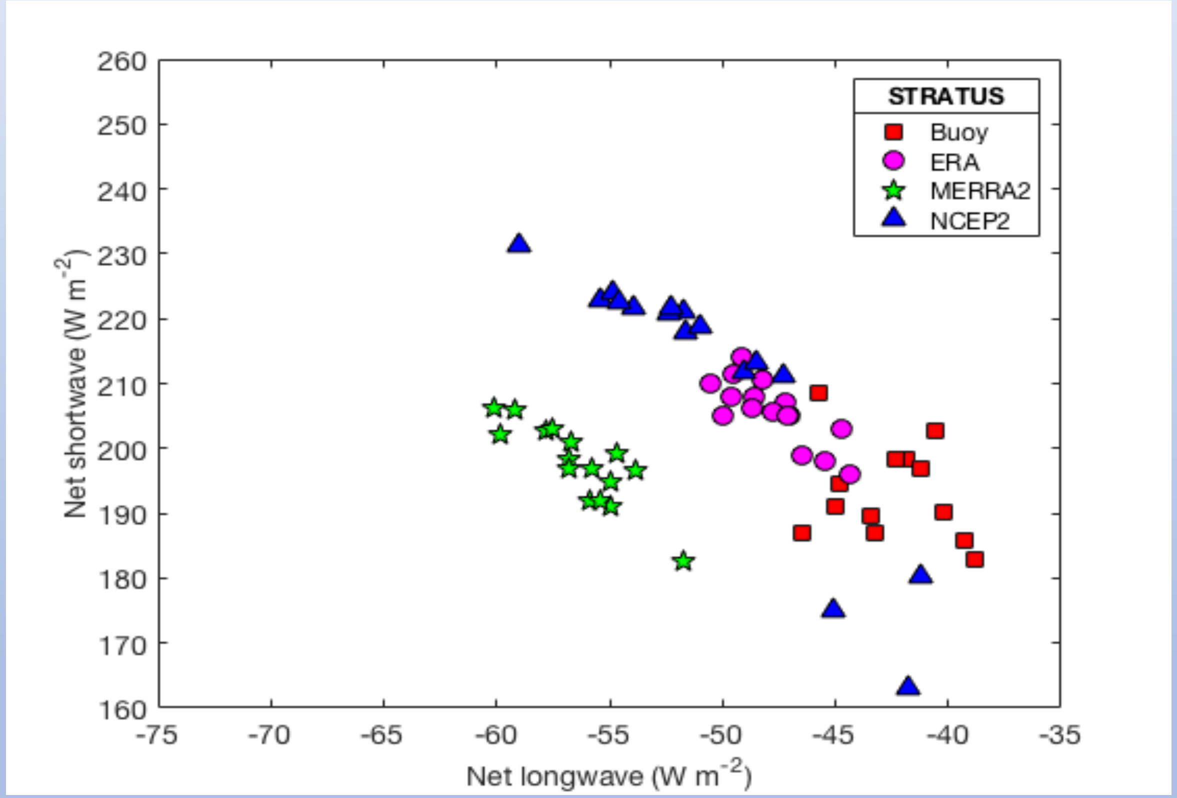
https://library.wmo.int/doc_num.php?explnum_id=3148

Goals and capabilities: Surface radiation targets – the climate change perspective, what drives the “goal” specification?

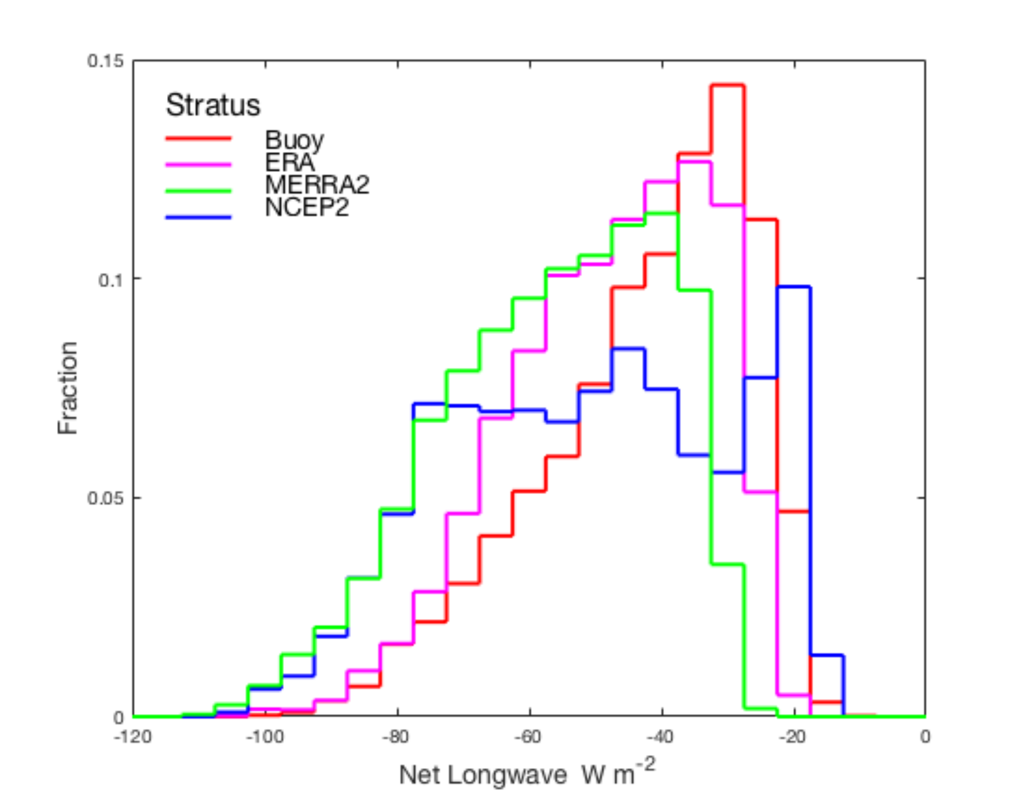
- IPCC Fifth Assessment – what are the magnitudes of signals?
    - Surface solar radiation
        - Norris and Wild (2007) “..dimming between 1971 and 1986 of 2.0 to 3.1 W m^{-2} per decade and subsequent brightening of 1.1 to 1.4 W m^{-2} per decade from 1987 to 2002 in a pan-European time series comprising 75 sites….”
        - “Available satellite-derived products qualitatively agree on a brightening from the mod-1980s to 2000 averaged globally as well as over the ocean, on order of 2 to 3 W m^{-2} per decade (Hatzianastassiou et al 2005, Pinker et al 2005, Hinkelman et al 2009)”
    - Surface thermal radiation
        - “Wild et al (2008) determined an overall increase of 2.6 W m^{-2} per decade in the 1990s…”

Goals and capabilities: Well documented capability to observe surface radiation has merit for model assessment:

- Assess models – differences between models and in-situ are large



Comparing annual means of both net shortwave and longwave at Stratus buoy with annual means from the site from reanalyses.



Histograms of daily mean net longwave at Stratus buoy off northern Chile versus reanalyses values at same site.

Goals and capabilities: Well documented capability to observe surface radiation has merit for ground-truthing, anchoring remote sensing and hybrid fields:

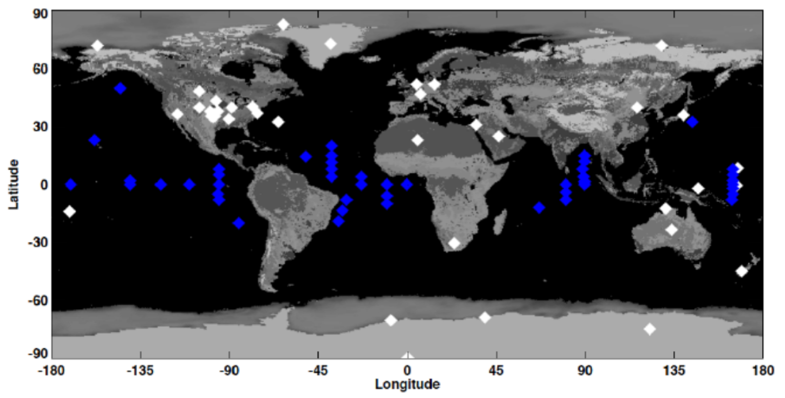


Figure 4: Location of 46 buoys (blue diamond) and 36 land surface sites (white diamond) where downward irradiances used in this study were taken (After Rutan et al. 2015).

Kato et al., Surface Irradiances of Edition 4.0 Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) Data Product . Submitted to J. Climate

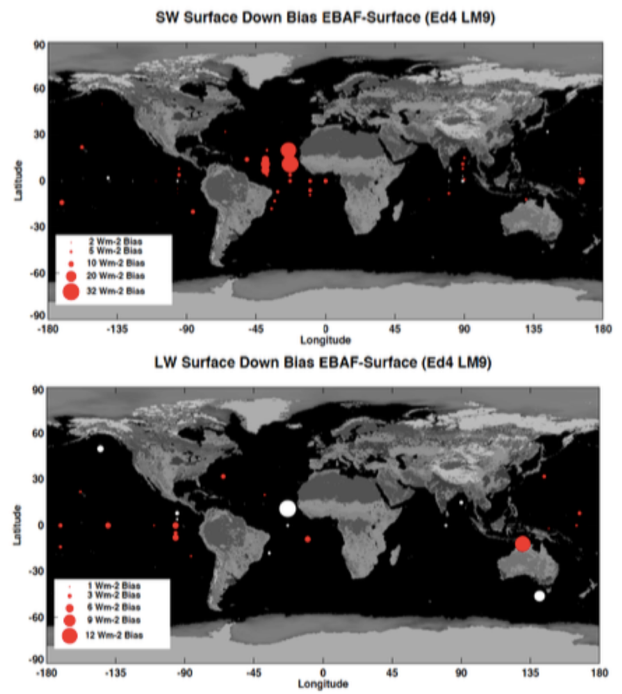
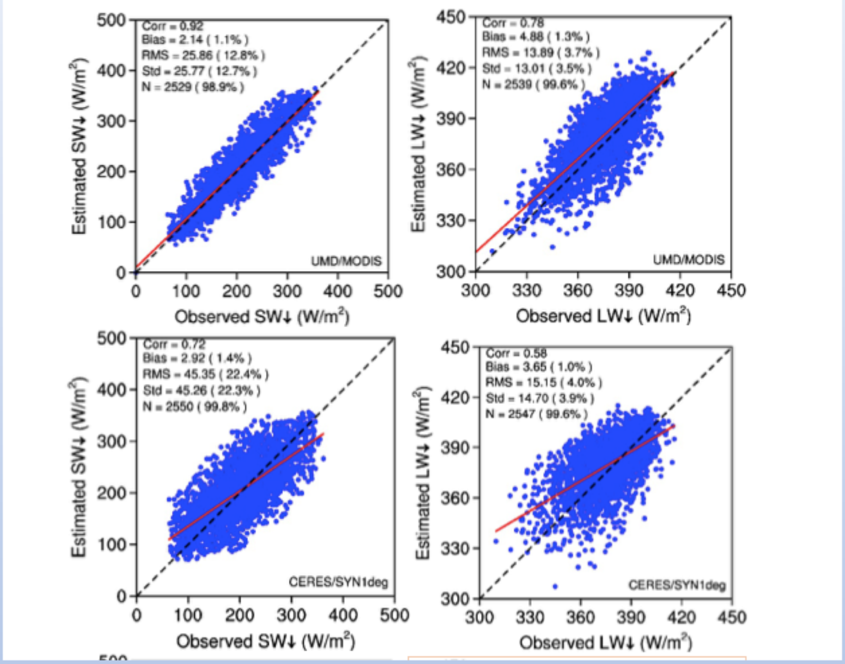


Figure 6: Difference of EBAF monthly 1°×1° mean surface (top) shortwave and (bottom) longwave downward irradiances from observed irradiances at buoys (computed minus observed). The size of the circle is proportional to the difference. The red and white circles indicate, respectively, a positive and a negative difference. The number of months used for comparisons varies depending on buoys.



CERES Ed4 1°x1°, hourly

Uncertainties:

SW↓~ 4 W m^{-2}
SW↑ ~ 3 W m^{-2}
LW↓ ~6 W m^{-2}
LW↑ ~3 W m^{-2}
LW+SW ↓↑ ~8 W m^{-2}

Pinker et al., 2017, submitted.

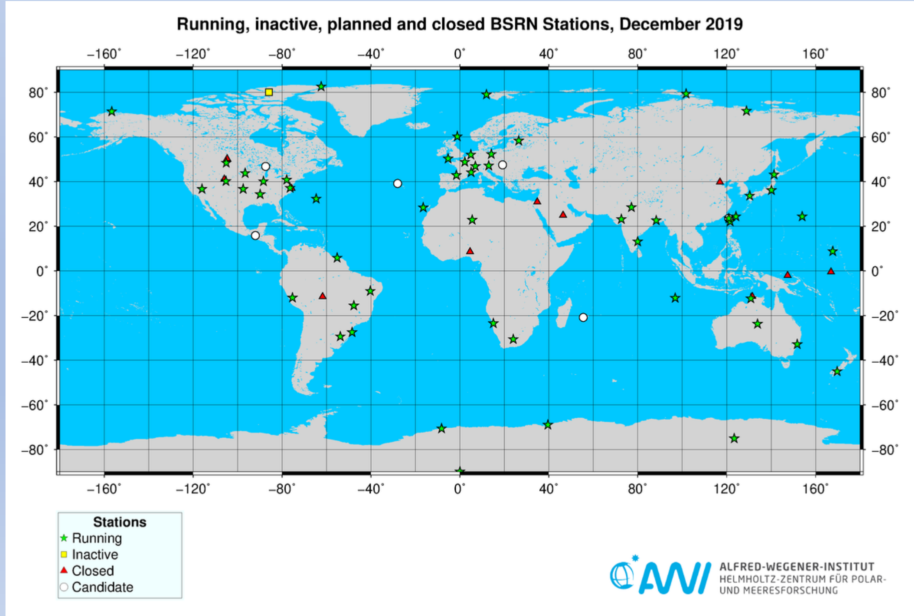
UMD/MODIS surface radiation
SW↓ at Stratus 2.1 W m^{-2} bias
LW↓ at Stratus 4.9 W m^{-2} bias

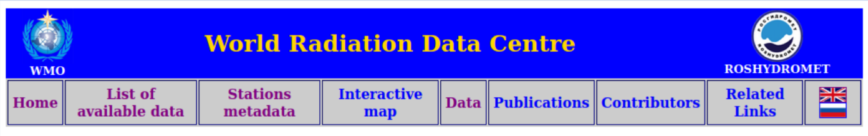
Present tools for observing surface radiation

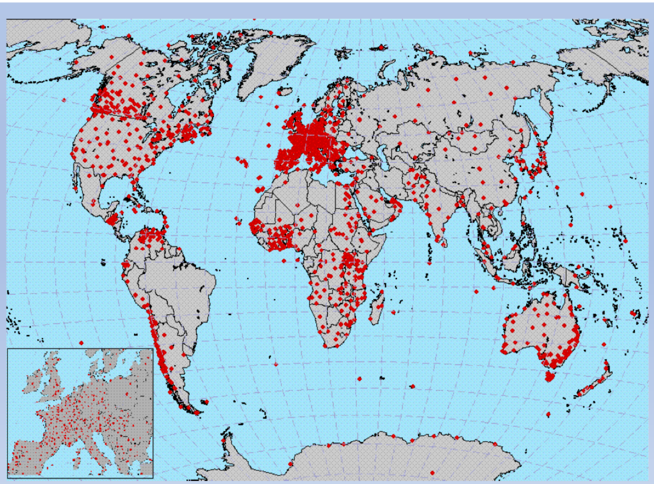
Baseline Surface Radiation Network
http://bsrn.awi.de
- Broadband SW and LW, DOWN (UP)
- Pyranometers/pyrheliometer/pyranometers
- Secondary standard (global and diffuse)/first class (Direct)
- Traceability of calibration
- Routinely cleaning
- Well tested QC/QA procedures (while not always fully/broadly/uniformly implemented)
- Offline

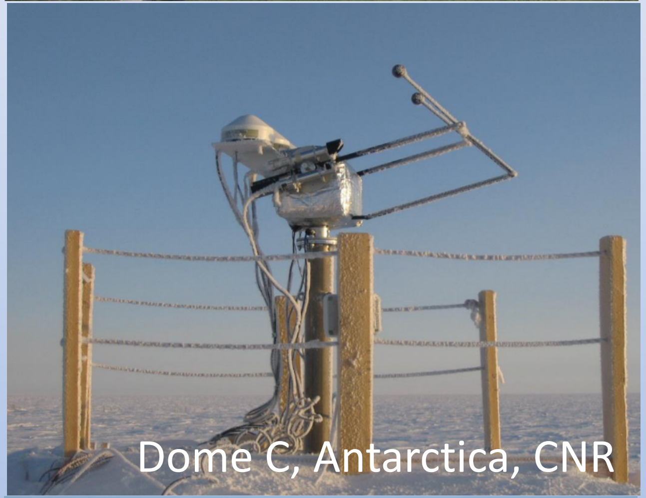
World Radiation Data Centre
http://wrdc.mgo.rssi.ru/
- Global and diffuse SW radiation
- Daily SW sums
- Monthly SW sums and averages
- Monthly total sunshine duration
- Monthly totals radiation balance

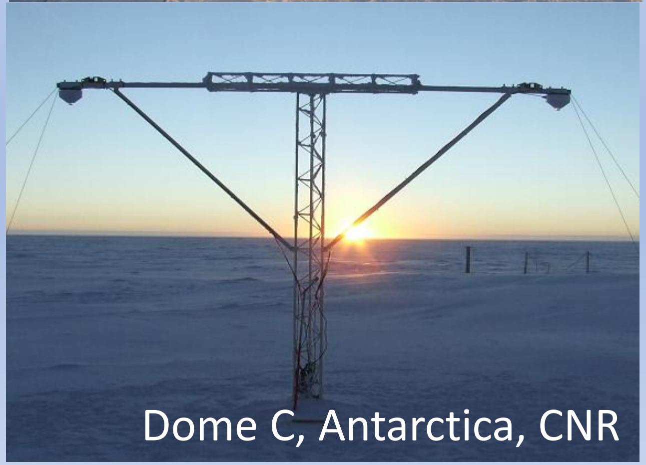
http://wrdc.mgo.rssi.ru/wwwrootnew/publ/WRDC_issue_2019_1.pdf





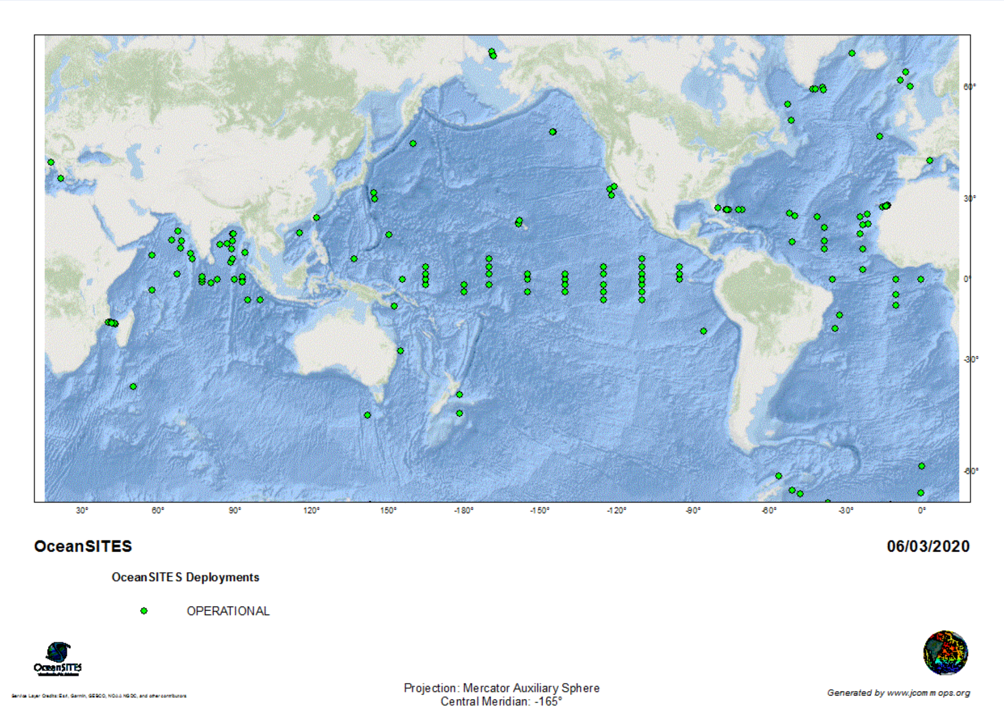


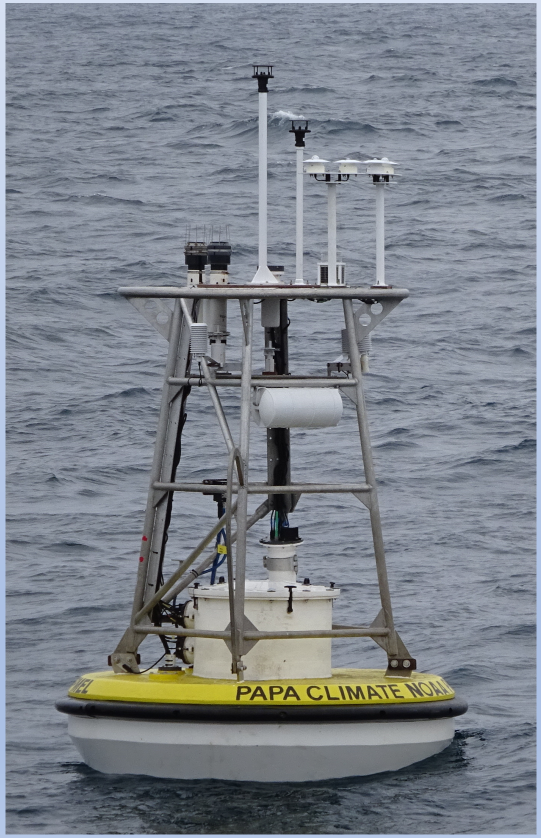




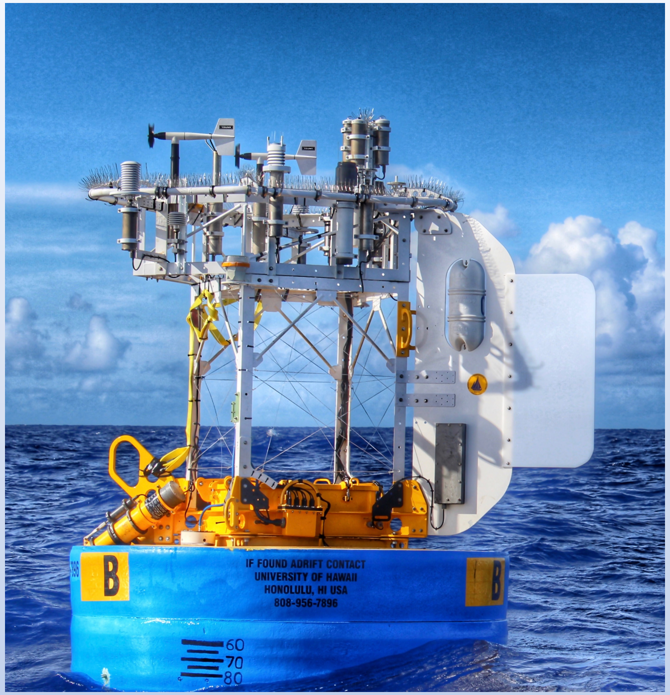
Present tools for observing surface radiation

Ocean based: OceanSITES





Gulf of Alaska PMEL buoy (M. Cronin)



WHOI WHOTS surface mooring

Present tools for observing surface radiation

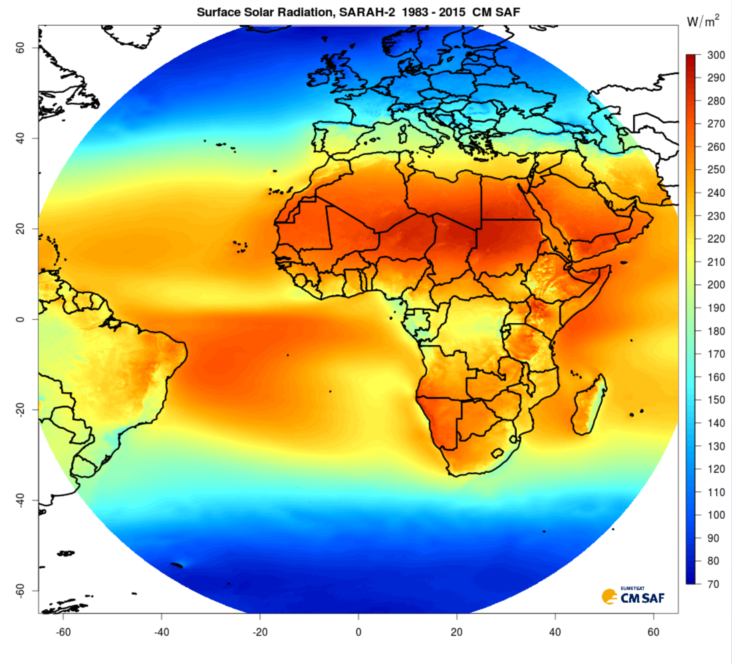
See "Satellite and model studies" session here: https://www.esrl.noaa.gov/gmd/grad/meetings/bsrn2018.html

Space based

NASA Earth Radiation Budget Satellite

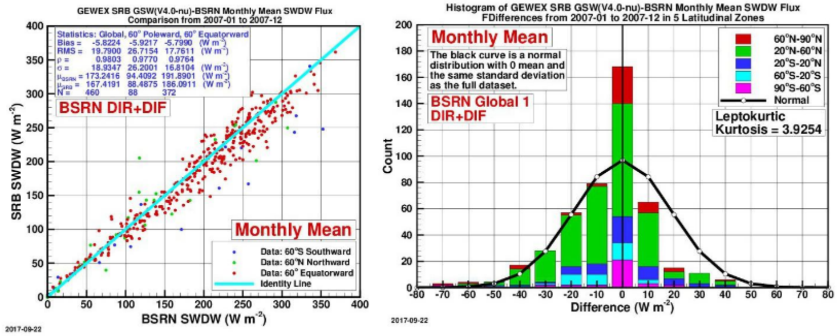
https://ceres.larc.nasa.gov/

https://gewex-srb.larc.nasa.gov/



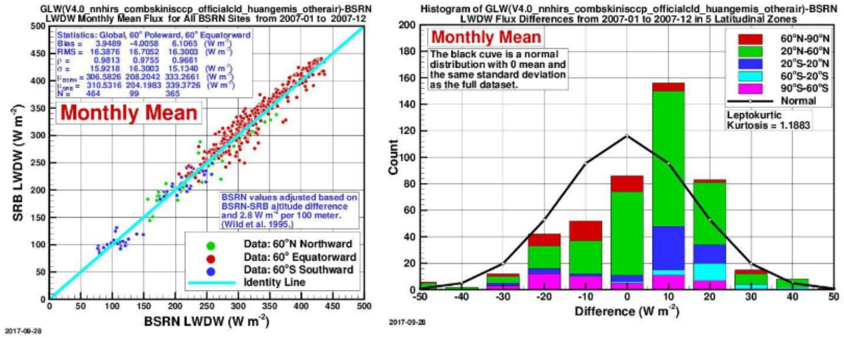
Eumetsat
Surface Solar Radiation Data Set - Heliosat (SARAH) - Edition 2.1
10.5676/EUM_SAF_SARAH/V002_01

Validating Downwelling SW Against BSRN



BSRN monthly mean shortwave downward flux comparison statistics for the period from 2007-01 to 2007-12.

Downwelling LW



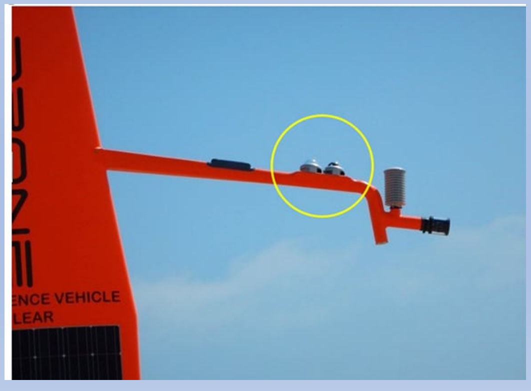
BSRN monthly mean longwave downward flux comparison statistics for the period from 2007-01 to 2007-12.

The different observing domains have different technical challenges. How best to guide implementation and coordination?

For example, consider the challenges and growth in ocean observing of surface radiation:

Ocean observing has challenges

- Platform orientation and motion: pitch, roll, men tilt
- Sensor contamination: spray, dust, birds sitting on sensors, bird guano
- Shadowing of sensors
- Unattended for ~1 year
- Access to only limited power
- Routine surface radiation observation a more recent development
- Reliance on factory calibration



Direction of growth

- Ocean observing system expanding to include Lagrangian platforms
  - Example, Saildrone, shown to right
  - How to assess observing quality and merge with moored buoys?

Jennifer Keane, PMEL

The need for common best practices

- Guide the development of surface shortwave and longwave observing
- Establish shared calibration procedures and reference standards
- Quantify performance of different sensors
- Provide a foundation for integration of different observing methods
- Provide uncertainty estimates for data used for ground-truthing, validation, assessment

Paths forward

- Under GCOS/GOOS bring together communities
  - Planned splinter meeting. - now a web based forum
  - Share experience
  - Stimulate interaction between technical and scientific staff
- Ocean community under TPOS advocating a land-based intercomparison of buoy sensors to be deployed in equatorial Pacific – Can we work to include BSRN/land-based sensors?
- Document/share/agree on calibration and standards protocols
- Establish one or more intercomparison sites – new Chesapeake Bay Light Towers or other sites at sea and one or more land-based sites