Extending the Calibration Traceability of Longwave Radiation Time-Series (ExTrac)

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ExTrac project duration: 1 Aug. 2020 – 31 Jul. 2022

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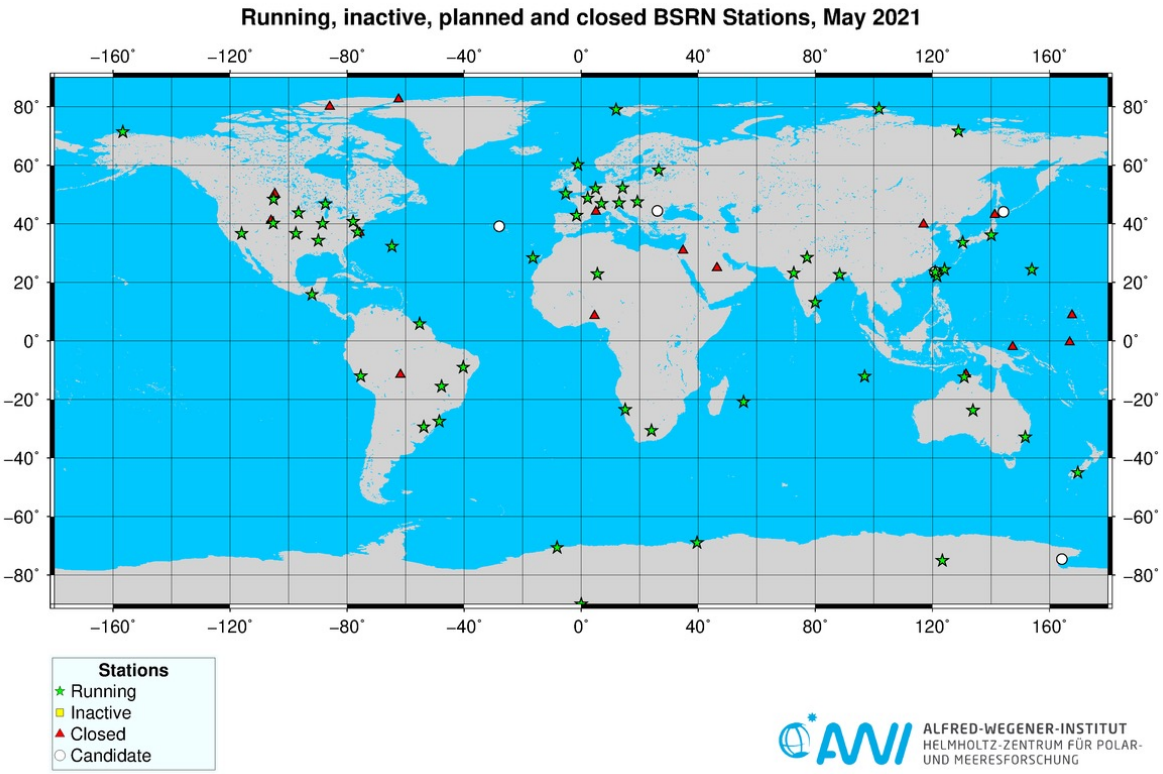
Baseline Surface Radiation Network (BSRN)



- BSRN (bsrn.awi.de) is hosted by the World Radiation Monitoring Centre (WRMC).
- BSRN designated as the global baseline network for surface radiation of GCOS in 2004.
- Time-series of DLR/ULR in the BSRN archive are primarily traceable to the WISG.

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ExTrac: Rationale

- Several issues regarding longwave meas. being addressed by *CIMO* (2018), e.g. WISG reference scale, IWV dependence
- Scale revision: Could / should BSRN DLR be revised in the future? Study at several BSRN stations (*Nyeki et al*., 2017):

  ~5.1 $W.m^{-2}$ (clear-sky sites), 0.7 – 1.3 $W.m^{-2}$ (cloudy sites)

- With raw pyrgeo. data and a calibration traceable to the WISG → DLR timeseries re-calculation
- However, raw pyrgeo. data not submitted to BSRN archive in the past (… soon though). WISG traceability of BSRN pyrgeos not fully known.
- Raw pyrgeo. data might not be fully available due to IT issues, loss of a knowledge-base, etc.

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ExTrac: Aims

- Investigate whether a methodology can be applied to retrieve the original raw pyrgeometer data from DLR_{BSRN} and other parameters in the BSRN archive.
- Prevent the loss of legacy data and ensure future availability when traceability and instrumental issues have been resolved by the research community.
- Extend the traceability of BSRN longwave time-series to the WISG.
    - Up to 10 pyrgeometers from BSRN Payerne and other BSRN stations will be calibrated as part of our in-kind contribution.
    - Five calibrated so far and 2+ to follow in March 2022.

Determination of DLR with Ground-Based Pyrgeometers

Extended Albrecht and Cox equation (amongst others for DLR)

$$DLR = \frac{U}{C}\left(1 + k_1\sigma T_b^3\right) + k_2\sigma T_b^4 - k_3\sigma\left(T_d^4 - T_b^4\right)$$ Eg Eppleys

$$DLR = \frac{U}{C}\left(1 + k_1\sigma T_b^3\right) + k_2\sigma T_b^4$$ Eg K&Zs

- **DLR equation is non-linear so scale revision not trivial.**
- **BSRN archives: DLR is archived but not U, T_b, T_d**
- **Can these parameters be "retrieved" or "reconstructed"?**

DLR in [$W.m^{-2}$] U = pyrgeometer voltage [V] C = calibration factor [$V.W^{-1}.m^2$]

σ = 5.670e-8 [$W.m^{-2}.K^{-4}$] Stefan-Boltzmann constant T_b = pyrgeometer body temp. [K] T_d = dome temp. [K]

k_1 = correction for sensor non-linearity k_2 = correction for body T k_3 = dome correction

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Retrieving “Raw” Pyrgeometer Data

- Train a station-specific algorithm using 1-min / 1-hr data and not empirical corrections (eg annual cycle etc):

  i) DLR, DSR, T_{2m}, other parameters (BSRN archives)

  ii) $U_{original}$ and cloud fraction* (station archives)

- Step 1: T_b, T_d and T_{2m} → $T_{b\ proxy}$ and $T_{d\ proxy}$
- Step 2: Using DLR_{BSRN} , $T_{b\ proxy}$, $T_{d\ proxy}$, in A&C eq → $U_{retrieved}$

* PCA method, Dürr and Philipona (2004)

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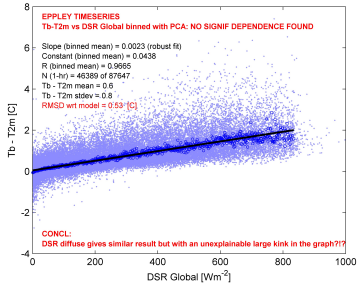
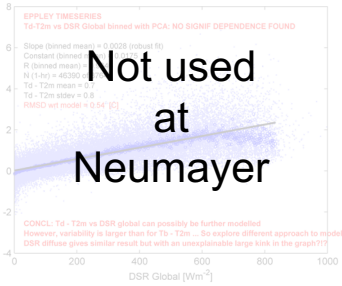
Station-Specific Algorithm: Neumayer Station, 2006 – 2015, Eppley PIR, 1-hr data

"Current Best Model" for Neumayer Data

T_b-T_{2m} vs DSR_{global}

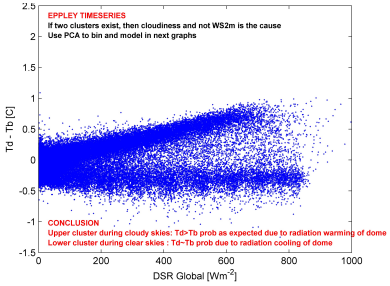


T_d-T_{2m} vs DSR_{global}

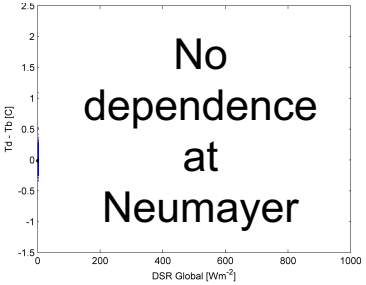


Not used at Neumayer

T_d-T_b vs DSR_{global}



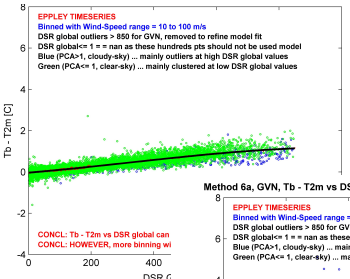
T_b-T_{2m} vs T_{2m}



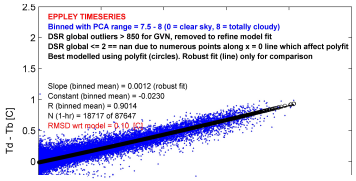
No dependence at Neumayer

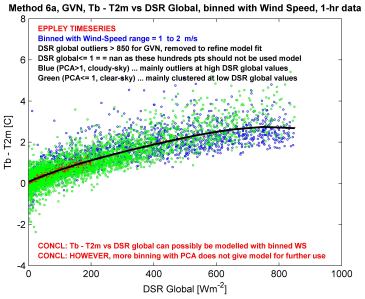
… similarly, T_d-T_{2m} vs T_{2m} etc

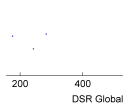
… with 10 Wind Speed bins

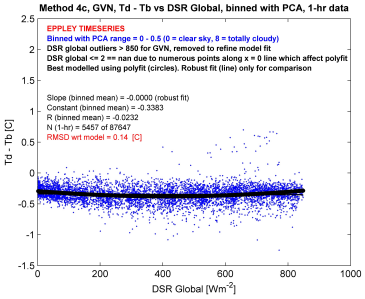


… with 8 Cloud Fraction bins









$T_{b\ proxy}$, $T_{d\ proxy}$

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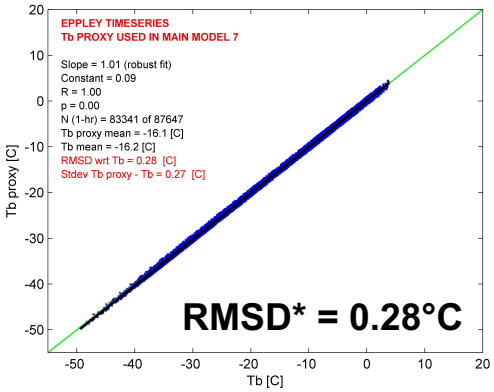
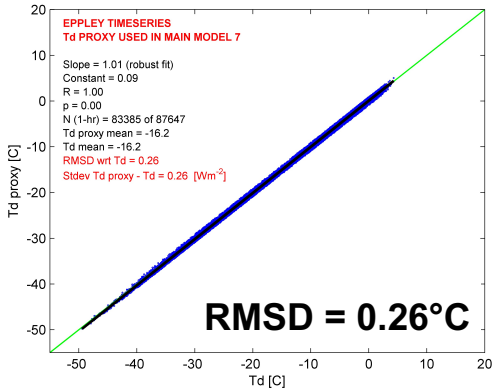
Station-Specific Algorithm: Neumayer Station, 2006 – 2015, Eppley PIR, 1-hr data

$T_{b\ proxy}$ vs T_b



$T_{d\ proxy}$ vs T_d



$U_{retrieved}$ via A&C eq

- Constructing accurate values of $T_{b\ proxy}$ and $T_{d\ proxy}$ are the key to determining accurate $U_{retrieved}$
- How accurate is the retrieved DLR? Use U, $T_{b\ proxy}$ and $T_{d\ proxy}$ in A&C eq to give $DLR_{proxy\ calc}$

*Use the root-mean-square deviation (RMSD) as a statistic to compare two data distributions.

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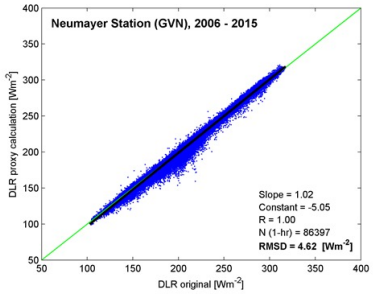
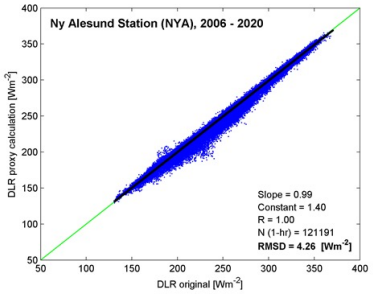
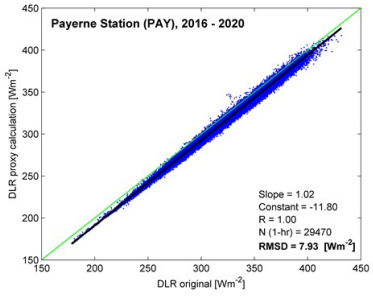
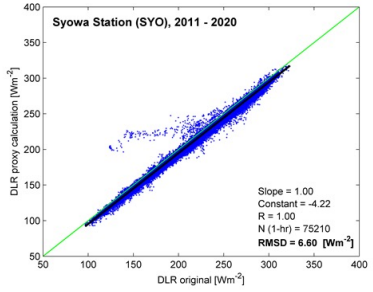
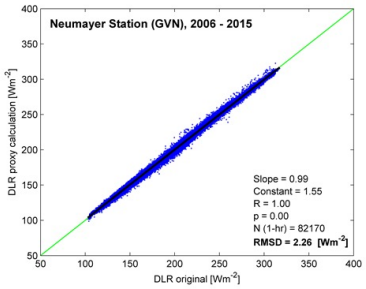
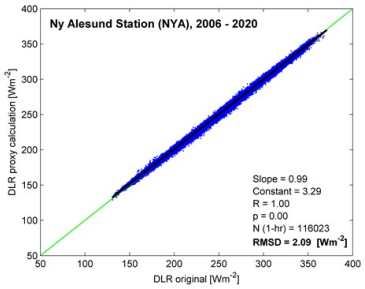
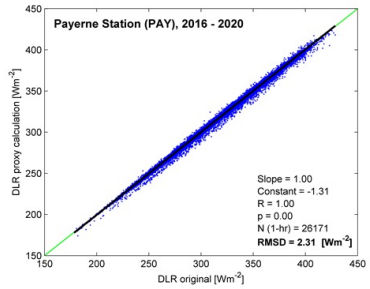
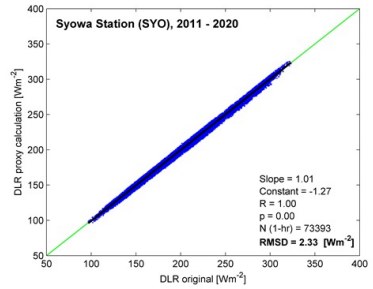
How good is "Current Best Model" vs a Basic Model?

- Basic Model: replace T_b and T_d with T_{2m} in A&C eq

  → RMSD ~ 4 – 8 Wm^{-2}

- Current Best Model: RMSD agreement at all 4 stations < 2.3 Wm^{-2}

	Neumayer Station Eppley PIR	Ny Alesund Station Eppley PIR	Payerne Station Eppley PIR	Syowa Station K&Z CG4
Basic Model				
Current Best Model				

*Use the root-mean-square deviation (RMSD) as a statistic to compare two data distributions.

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Conclusions

- RMSD agreement of DLR_{BSRN} vs $DLR_{proxy\ calculation}$ <2.3 Wm^{-2} standard uncertainty of DLR measurements is 4 – 5 Wm^{-2}
- So far, only data with a 1-hr resolution can be retrieved to within the DLR measurement uncertainty. BSRN archive data is 1-min data.
- Pyrgeometer ventilation units must have operated stably in the past.
- A station-specific model rather than a basic (or universal) model is currently seen as best option to determine $U_{retrieved}$, $T_{b\ proxy}$ and $T_{d\ proxy}$ with an acceptably low RMSD.
- The project was designed as an exploratory analysis …

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Outlook

Outlook

- ExTrac algorithm to be used on a “real” test case:

  Payerne raw pyrgeo time-series <2007 very difficult to extract from station archives.

  Can retrieved data be considered valid?

- Technical report / literature paper.

Acknowledgement

We gratefully thank GCOS Switzerland for supporting the ExTrac project.

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