On the spatiotemporal variability of solar radiation and its consequences for the accuracy of satellite-based solar surface irradiance *and cloud properties*

Hartwig Deneke[1], Sebastian Bley[2], Anja Hünerbein[1], Andreas Macke[1], Fabian Senf[1], Frank Werner[1], Jonas Witthuhn[1]

[1] Leibniz Institute for Tropospheric Research

[2] Now at ESA-ESRIN

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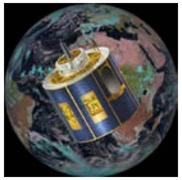

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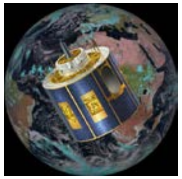
Motivation

- Clouds introduce significant spatiotemporal variability in the solar radiation field
  - Uncertainties and biases in imager-based cloud retrievals
  - Dependencies on sensor resolution
  - Limited representativeness of single point observations
- Comparison of observed and satellite-retrieved surface irradiance can provide:
  - Evaluation of cloud property retrievals (optical depth) through assessment of radiative closure
  - Accuracy assessment of satellite products for grid-integration of photovoltaic power generation



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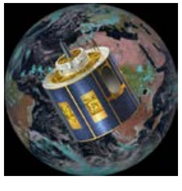
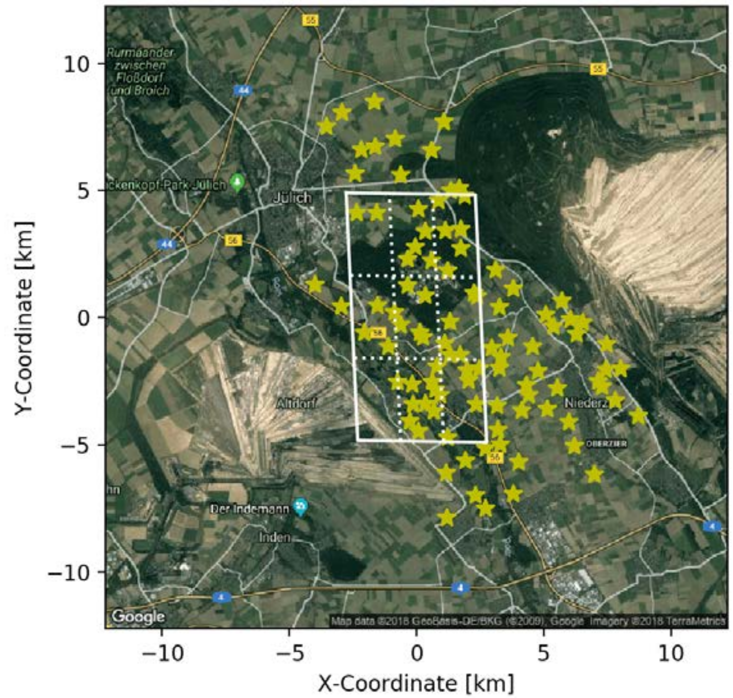
Goals

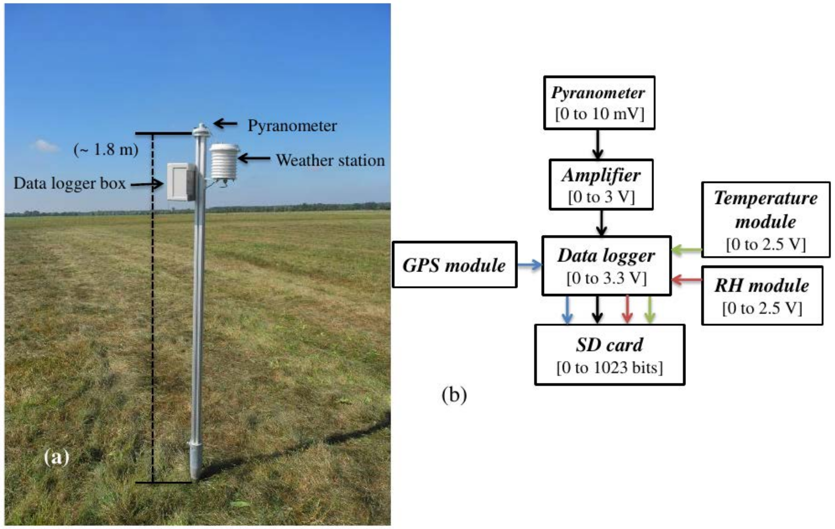
- Use unique network of 99 autonomous pyranometer stations to investigate effects of spatial variability
- Compare these ground-based observations with surface irradiance retrievals from METEOSAT SEVIRI
- Evaluate potential improvements by using SEVIRI's HRV channel (*1x1* vs. *3x3km²*) and *5min* Rapid Scan Service (within German project MetPVNet)



TROPOS Pyranometer Network

- 99 autonomous measurement stations
- Operated during HOPE campaign in Juelich, DE, from Apr-Jul during summer 2013
- 32 / 9 pyranometers within standard / HRV resolution SEVIRI pixel
- See *Madhavan et al (2016, 2017)*, and *Macke et al (2017)* for details





TROPOS Pyranometer Network

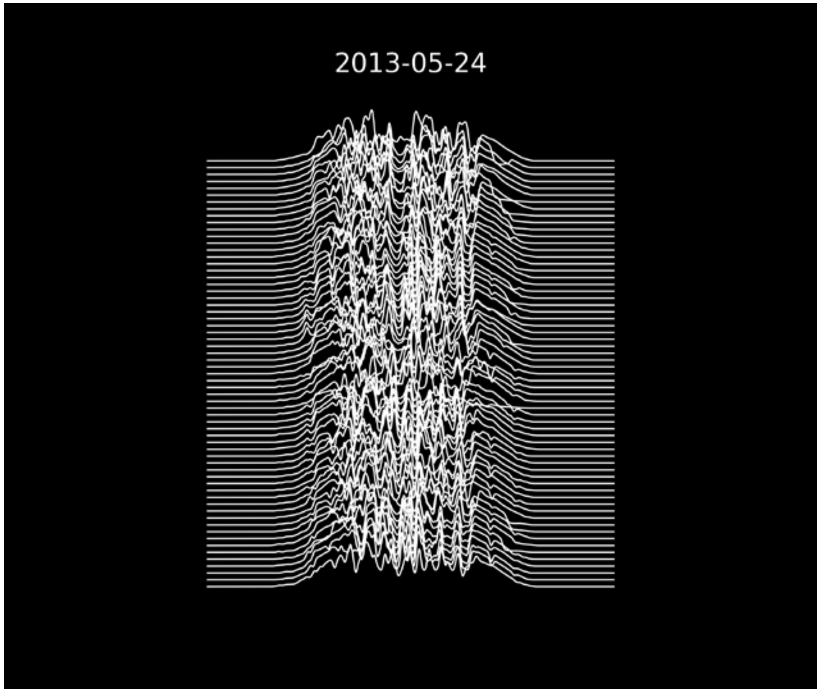


Fig.: (right) Cover of album Unknown Pleasures by Joy Division. (left) Ridge- or joyplot of the timeseries of global irradiance recorded by the pyranometer network on 24th of May 2013 comprising 64 quality-checked stations.

TROPOS Pyranometer Network

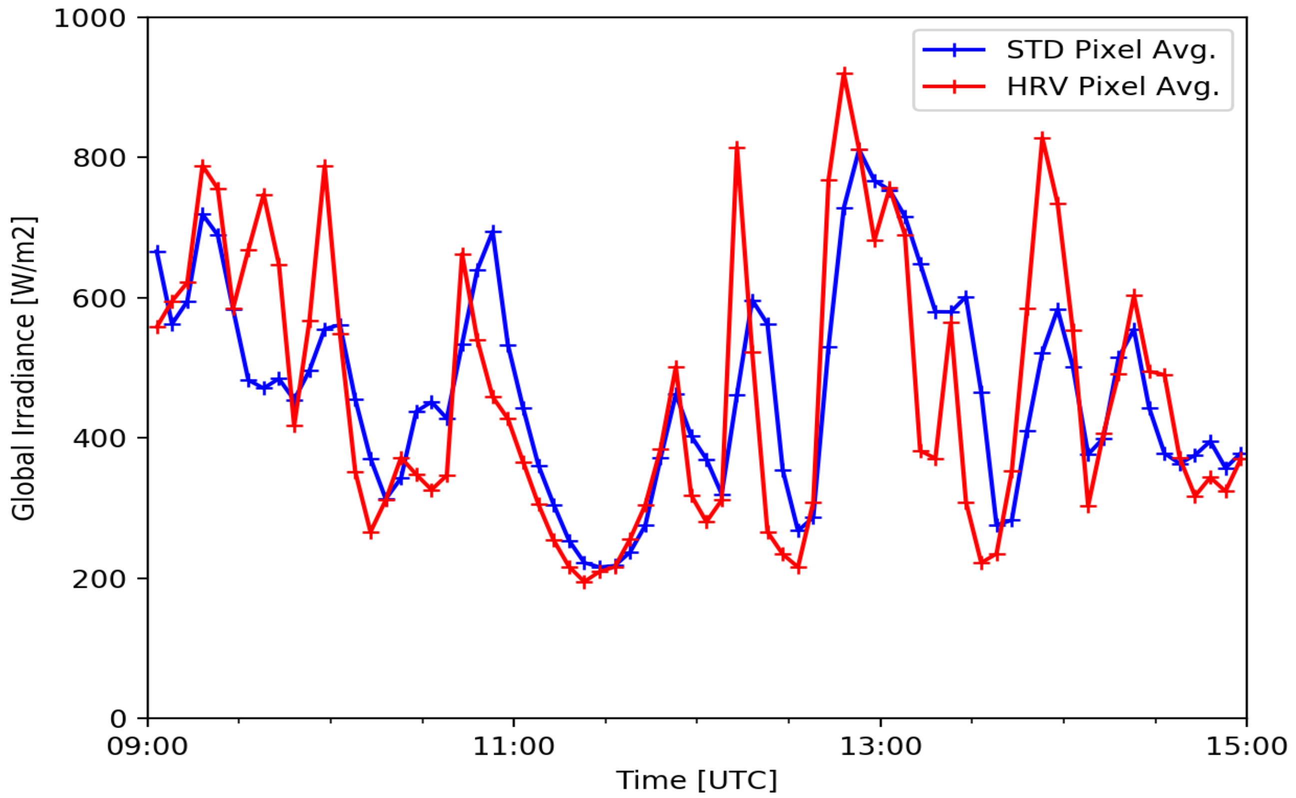
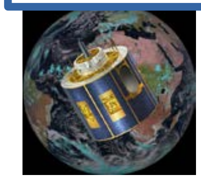


Fig.: Time series of global irradiance obtained by optimal averaging of pyranometer observations for the domain of a MSG standard and a HRV-resolution pixel on day 2013-05-24.



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Representativeness of Point Observation

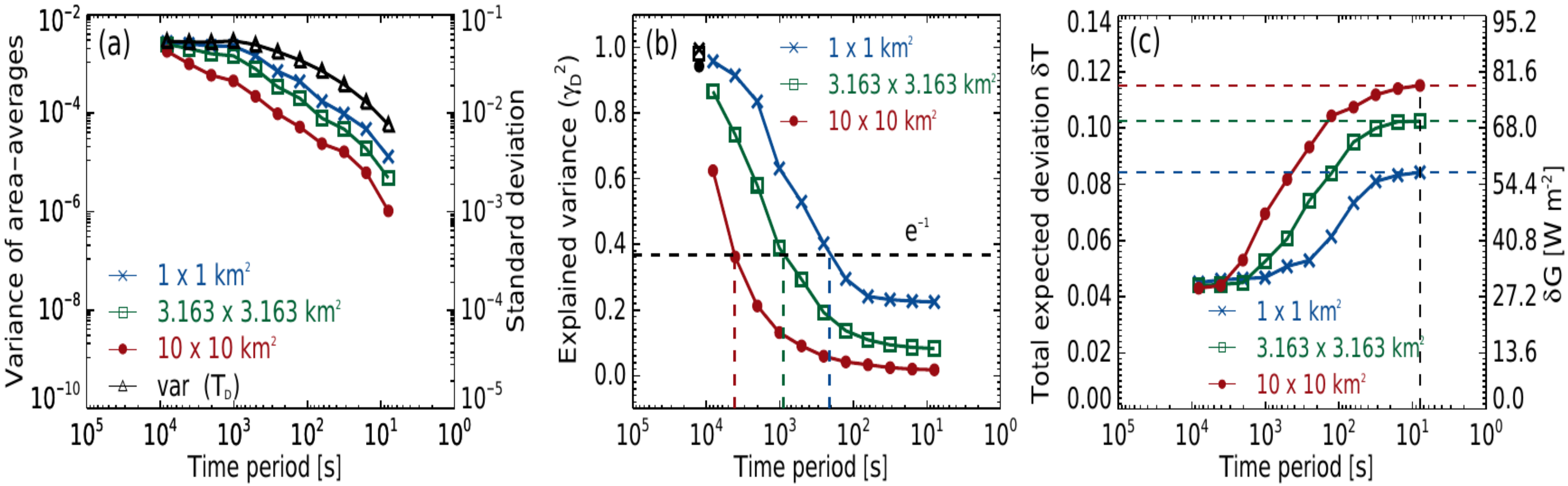
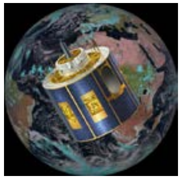


Fig.: Representativeness of point obs. under broken cloud conditions, as function of temporal period and domain size. (a) Variance of transmittance details. (b) Explained variance of point obs. and domain avg. (c) Expected deviation between point obs. and domain avg. (adapted from *Madhavan et al., ACP, 2017)*.



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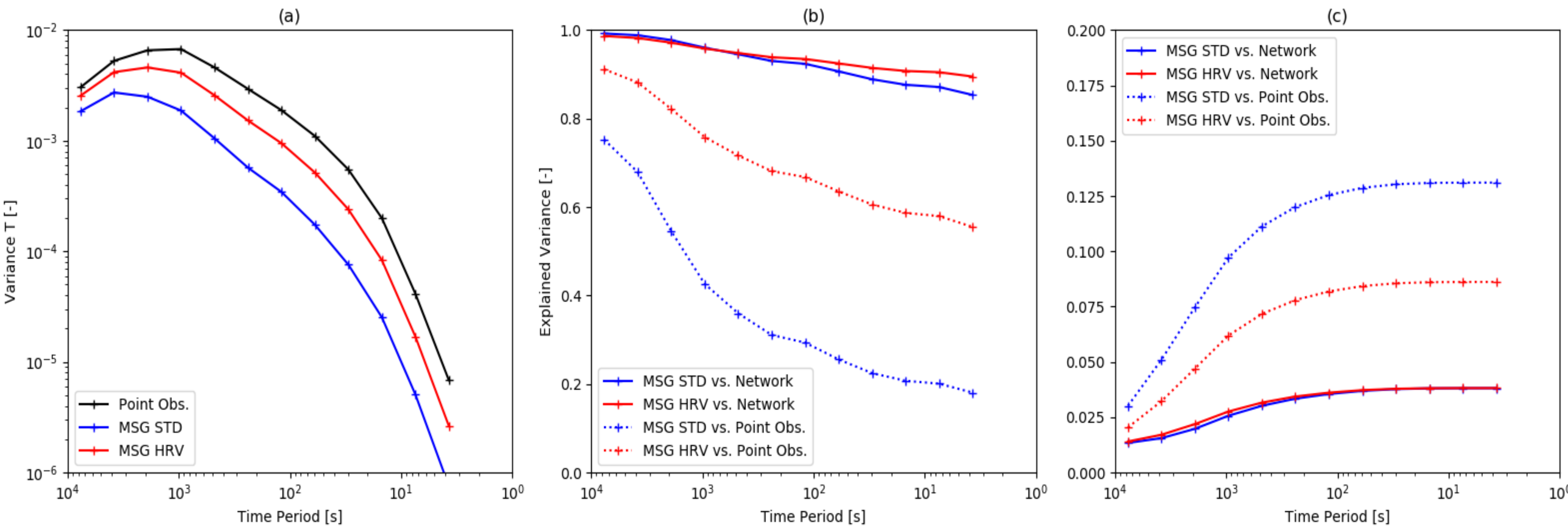
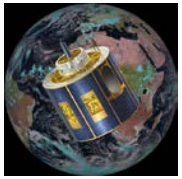


Fig.: Pixel-area estimates for broken cloud conditions (2013-05-24), as function of averaging period and pixel resolution. (a) Variance spectrum of transmittance. (b) Explained variance between pixel estimate and domain average. (c) Expected deviation between pixel estimate and domain average.



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MSG-CPP Retrievals @ HRV Resolution

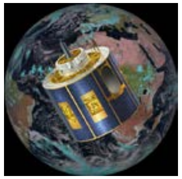
- Based on standard MSG-CPP retrieval *(Roebeling et al., 2006)* developed at KNMI within CM SAF context

- HRV channel for resolution enhancement of VIS006 / VIS008 / cloud optical depth *(Deneke&Roebeling,2010)*

- *Threshold-based HRV cloud mask* (see Bley&Deneke, 2013) *used for pixel sharpening*

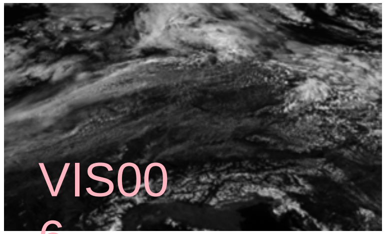
- *For downscaling of Reff/1.6um channel, estimate local covariance of COT & Reff*

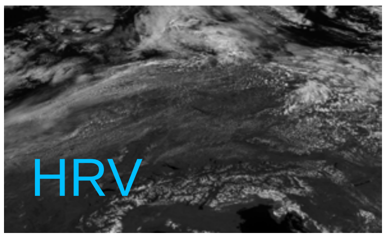
- Use cloud properties as basis for solar surface irradiance *(Deneke et al., 2008; Greuell et al., 2013)*

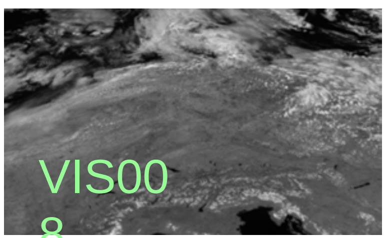


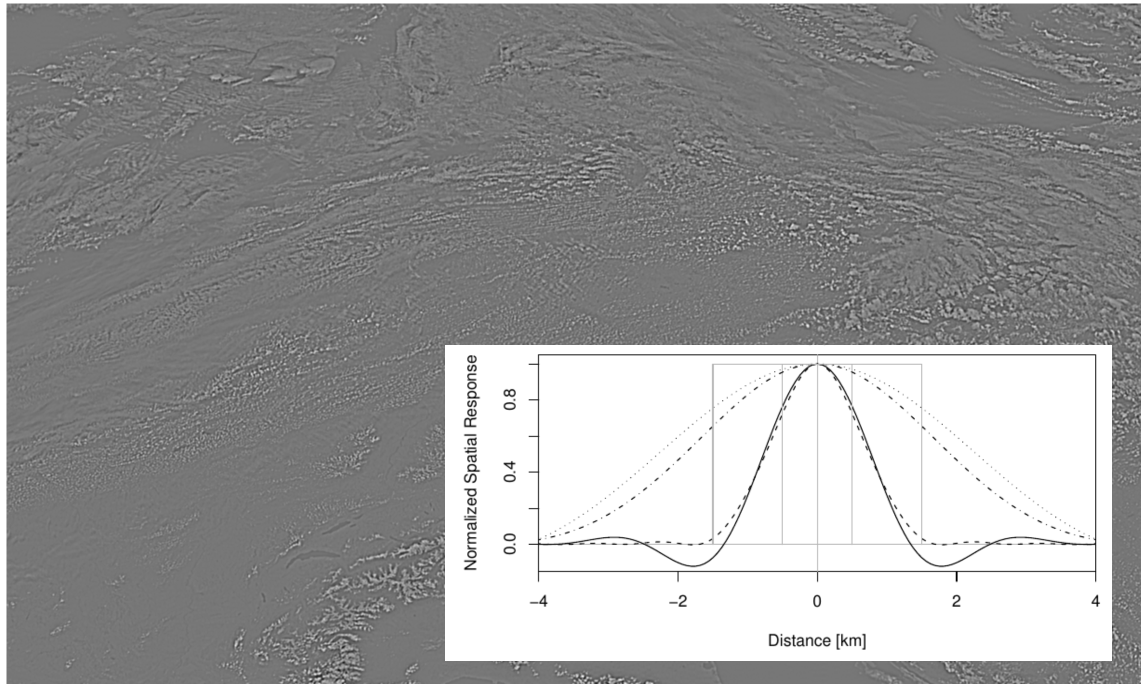
MSG-CPP Retrievals @ HRV Resolution

$$\delta r_h = a\,\delta r_{06} + b\,\delta r_{08}$$









1. Fit linear model between visible channels
2. Extract high-freq. variation of HRV channel *(see Deneke&Roebeling, ACP, 2010)*
3. Include above Eq. in CPP retrieval iteration, updating dR06/dR08 based on LUT

MSG-CPP based Surface Solar Irradiance Retrieval

SICCS: SURFACE INSOLATION IN CLOUDY CONDITIONS FROM METEOSAT SEVIRI IMAGERY - ALGORITHM

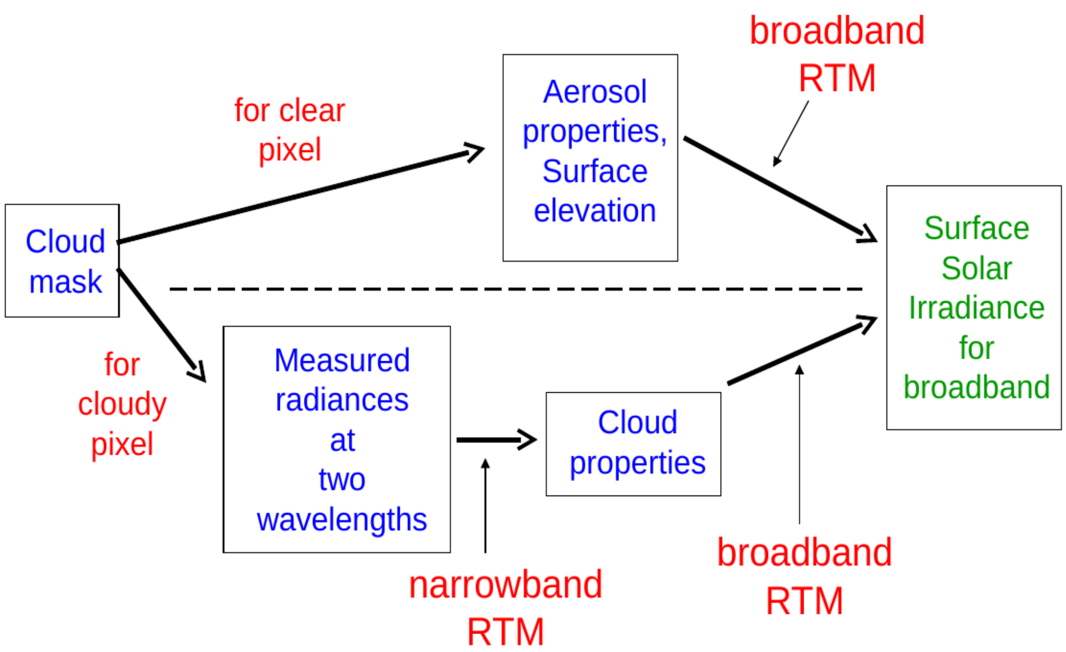
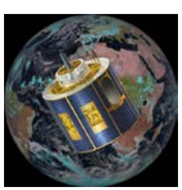


Fig: Flowchart of SICCS algorithm.

- Clear-sky model estimates aerosol radiative effects, water vapor absorption
- Cloudy-sky model estimates cloud transmissivity from CPP cloud properties

See Deneke et al., (2005, 2008); Greuell et al., 2013, for details



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MSG-CPP based Surface Solar Irradiance Retrieval

Fig.: Time sequence of TOA broadband albedo retrieved with SICCS algorithm for std.(left) and HRV (right) resolution for a ~ *50x50km*^{2} domain centered on the pyranometer network for 2013-05-24.

Comparison Satellite vs. Ground Observations

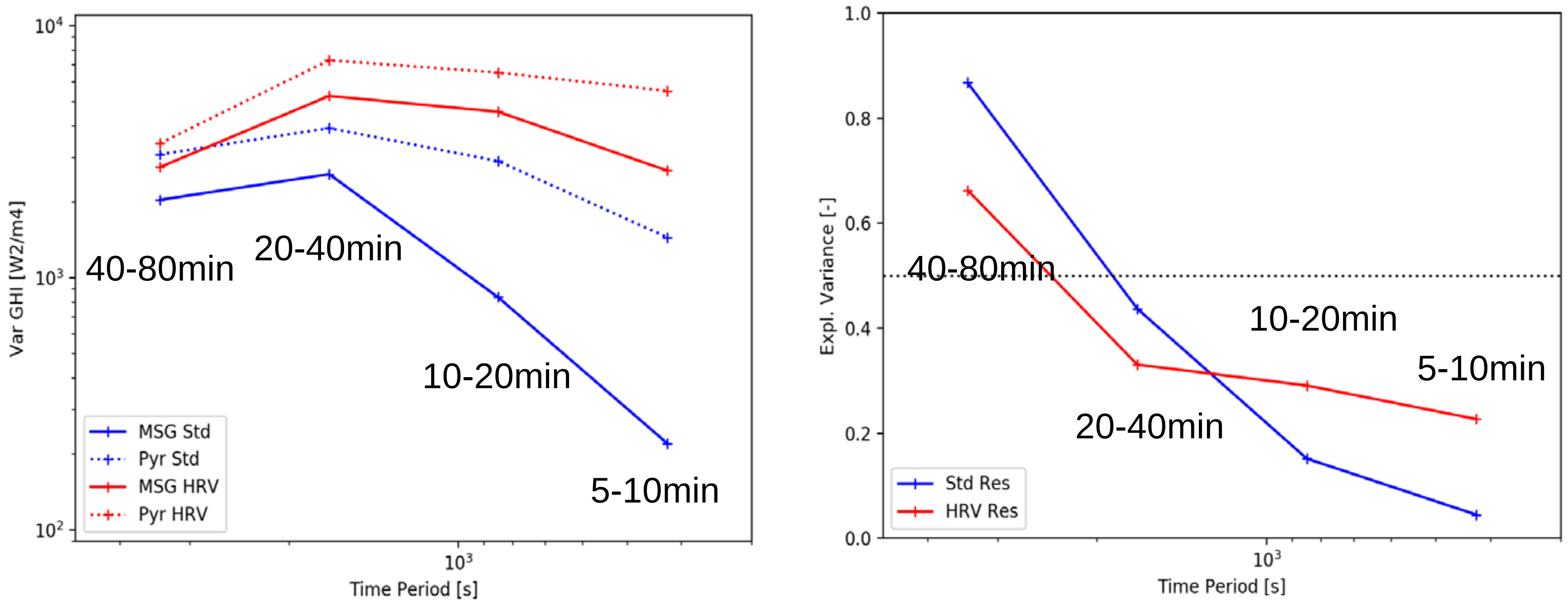
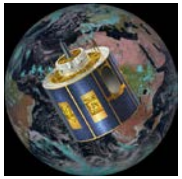


Fig.: (left) Wavelet-based variance spectrum for standard and HRV resolution global irradiance retrievals (solid) and for corresponding pyranometer averages (dashed). (right) Explained variance of wavelet details of satellite retrievals and pyranometer averages. Results for day 2013-05-24.



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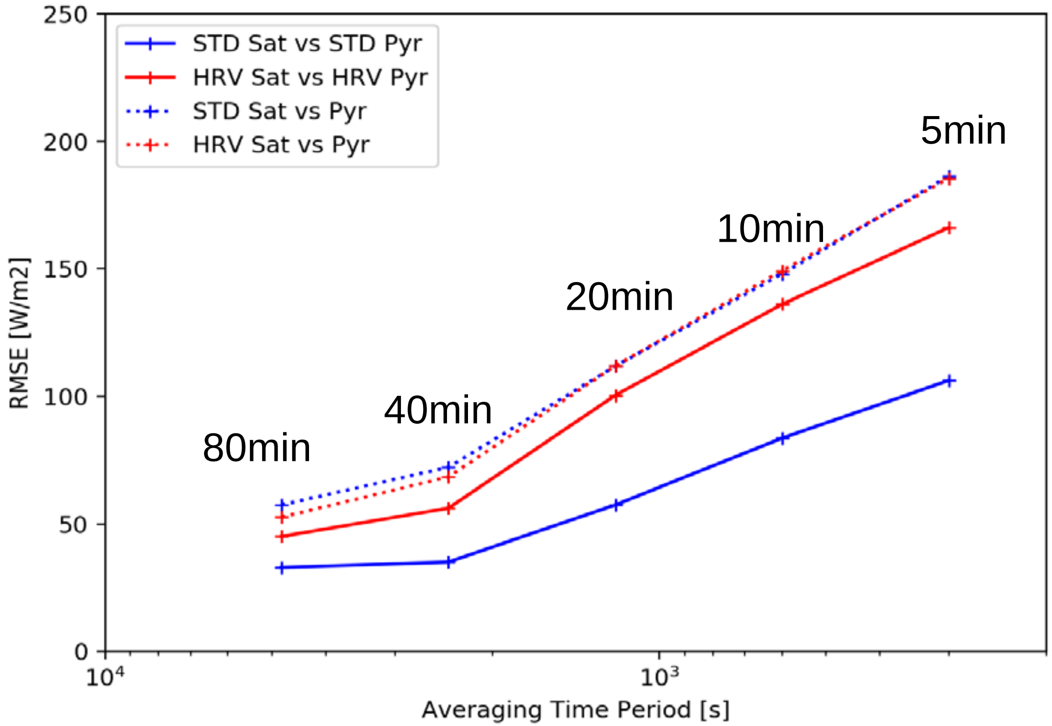
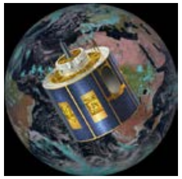


Fig.: Root mean square error (RMSE) for standard-res. and HRV retrieval versus pyranometer averages (solid) for and individual pyranometer records (dashed), and smoothing with different-length running means, for day 2013-05-24.



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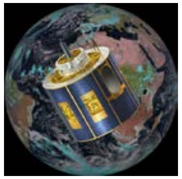
Conclusions and Outlook

- Unique pyranometer network enables investigation of the effects of irradiance variability and spatial sampling of point observations
- Introduced a novell HRV-resolution cloud and radiation dataset based on MSG-CPP *(no need to wait for MTG for 1km resolution! ;-)*
- Reduction of spatial sampling uncertainty enables investigations of other causes for devations (3d effects, ...) => towards column radiative closure/EarthCARE
- Situation/cloud-type dependent assessment of uncertainty of satellite-based irradiance planned



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