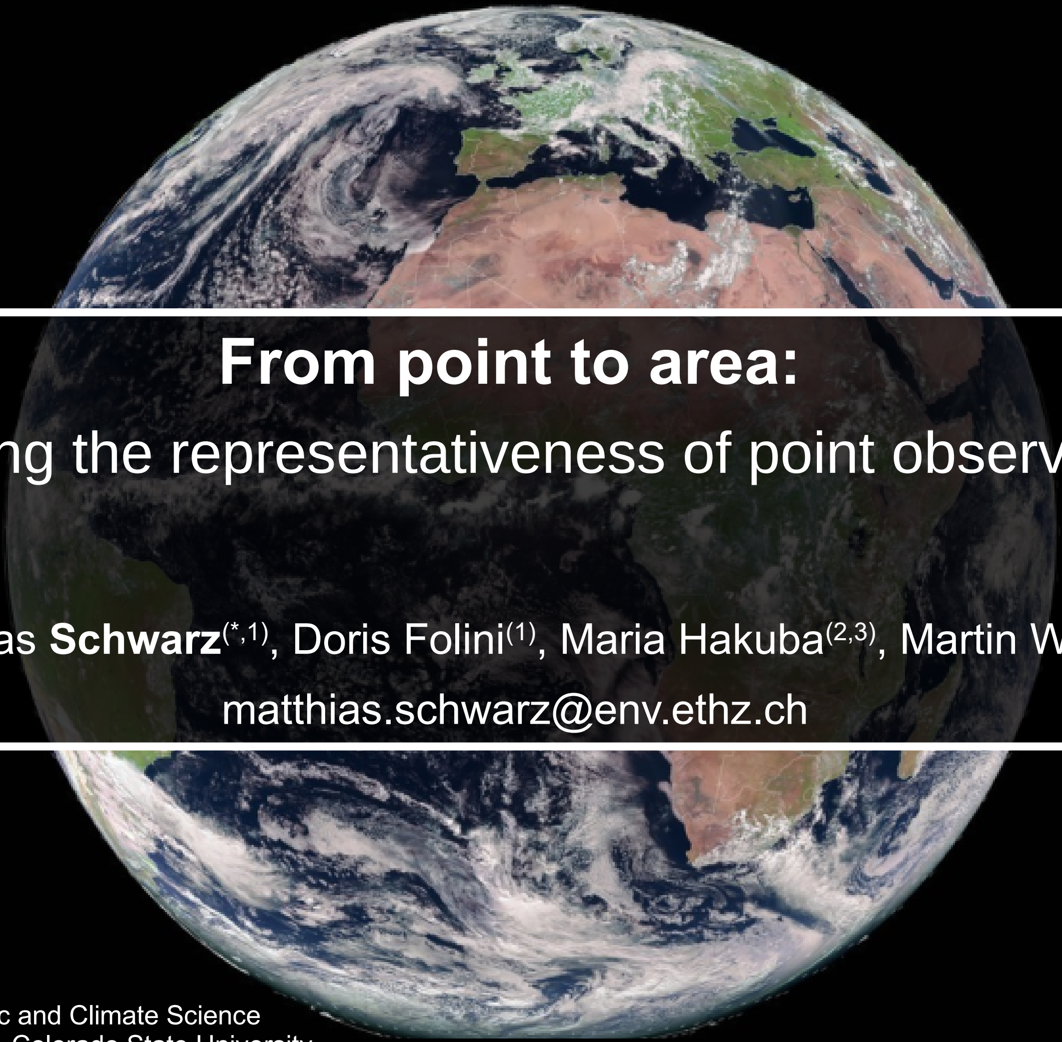

From point to area:
assessing the representativeness of point observations

Matthias **Schwarz**[*,1], Doris Folini[1], Maria Hakuba[2,3], Martin Wild[1]

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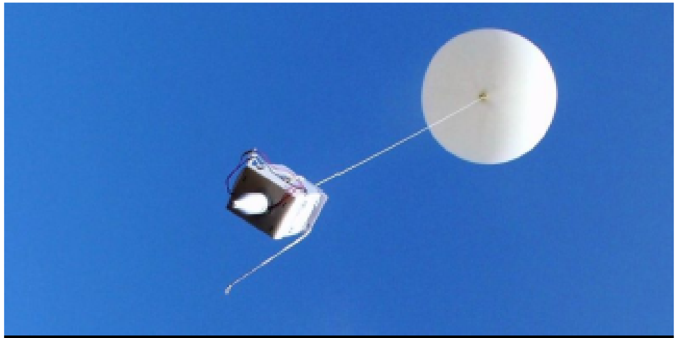
Affiliations:
(1) ETHZ Zürich, Institute for Atmospheric and Climate Science
(2) Department of Atmospheric Sciences, Colorado State University
(3) Jet Propulsion Laboratory, California Institute of Technology

Image: Meteosat 0° Natural Colour Enhncd. Full disc **(28.05.2019 12 UTC)**

Why representativeness?

Temperature

Radiation



Radiosonde

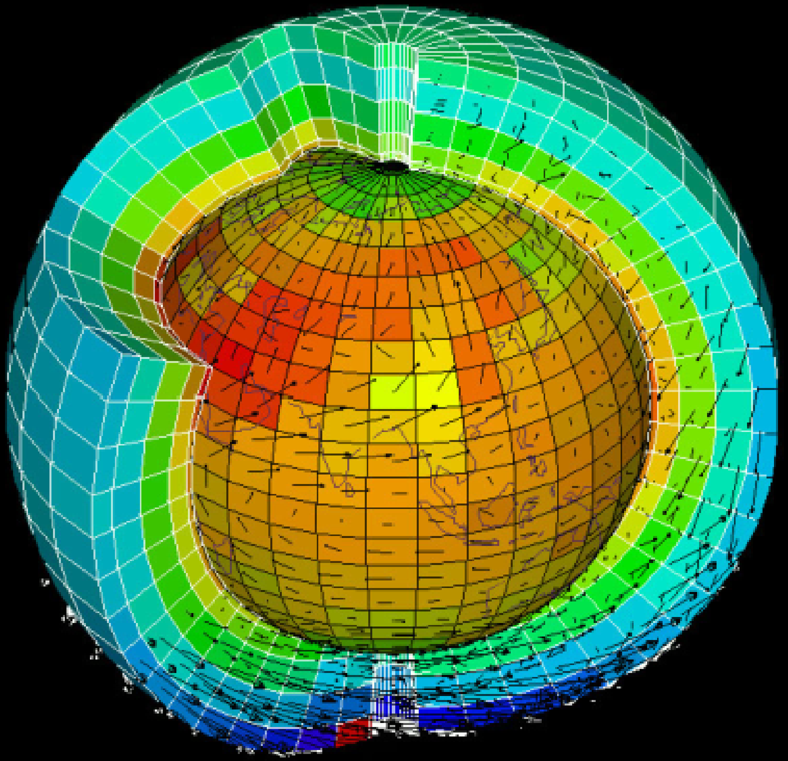
Wind

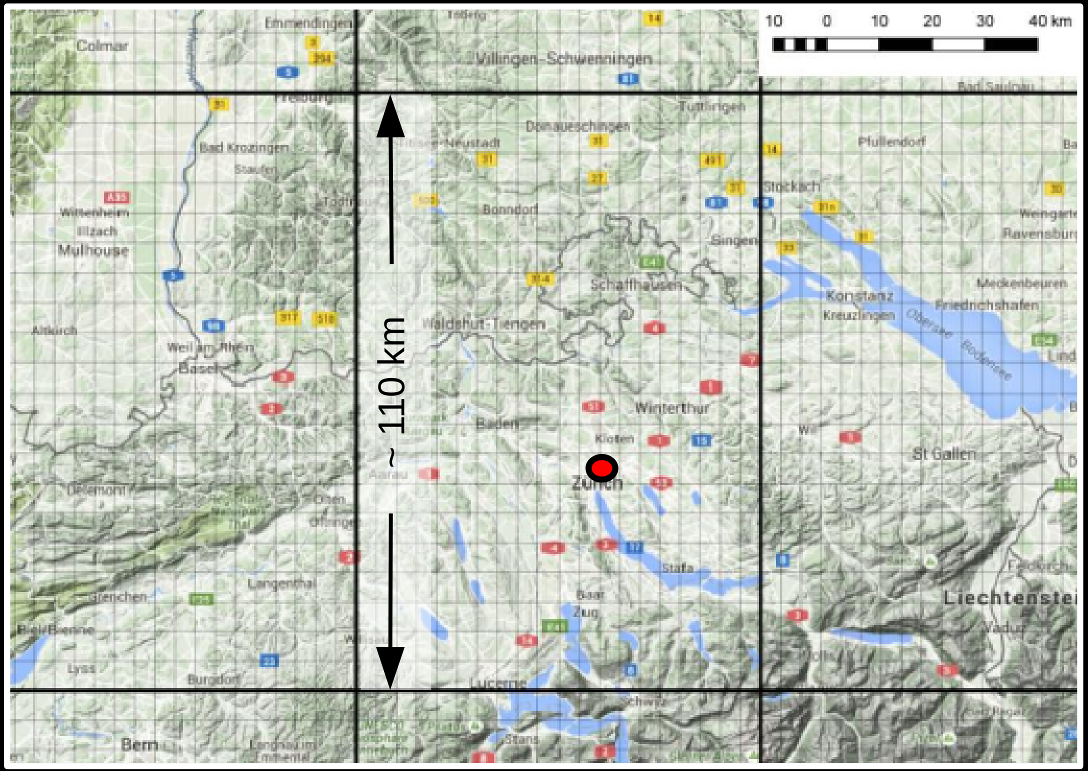
Airborn

AERONET

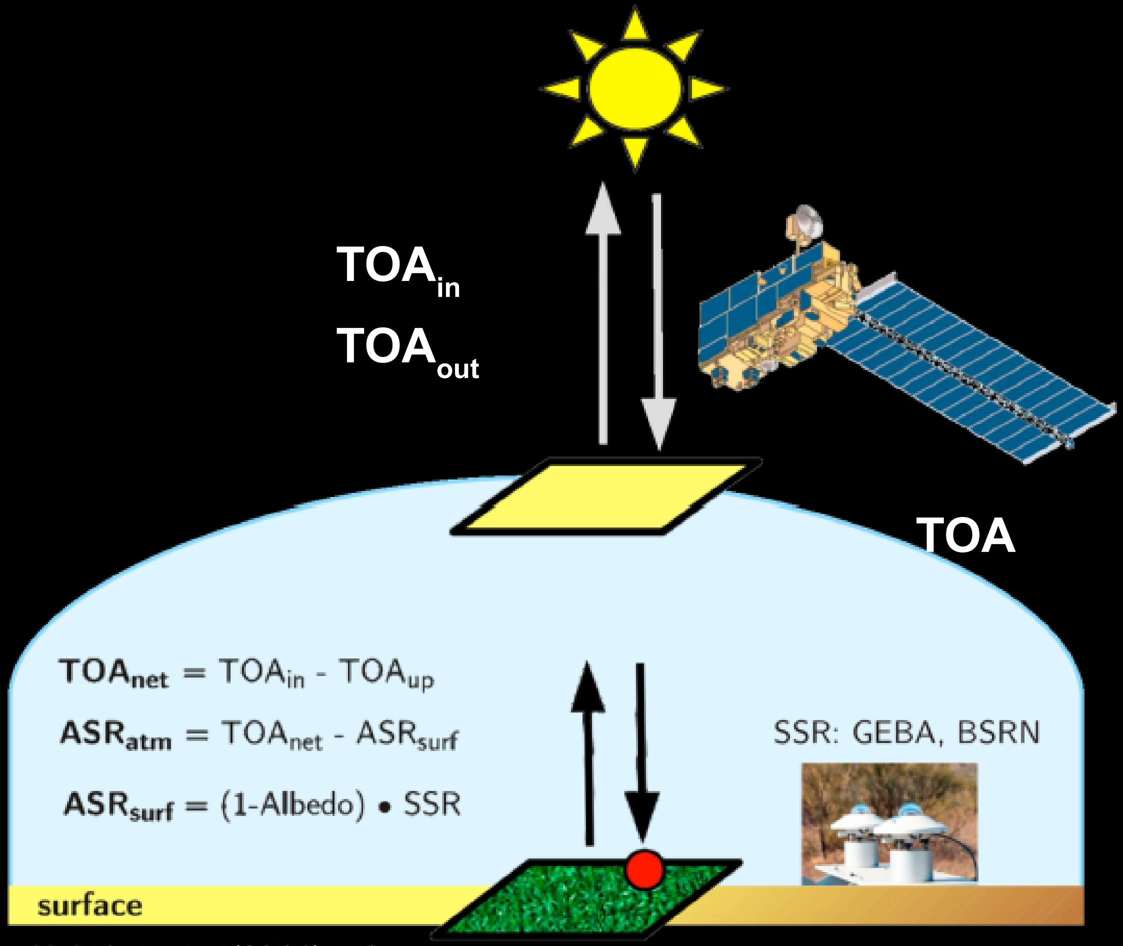
FLUXNET

Why representativeness?



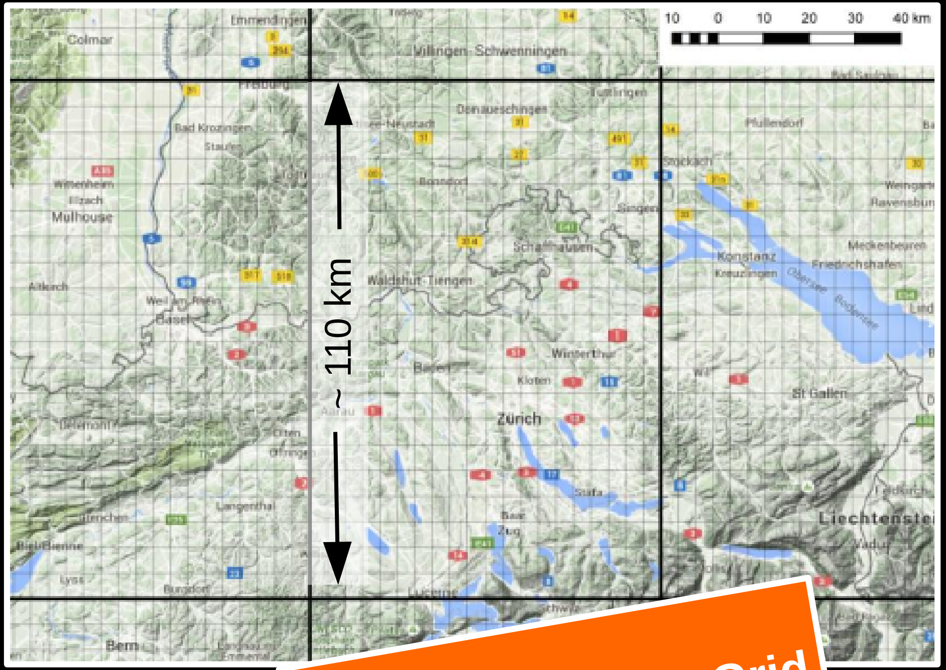


Combining TOA and surface observations



Hakuba et al. (2014)

Is a single monthly mean surface solar radiation (SSR) time series representative for a 1° gridbox?

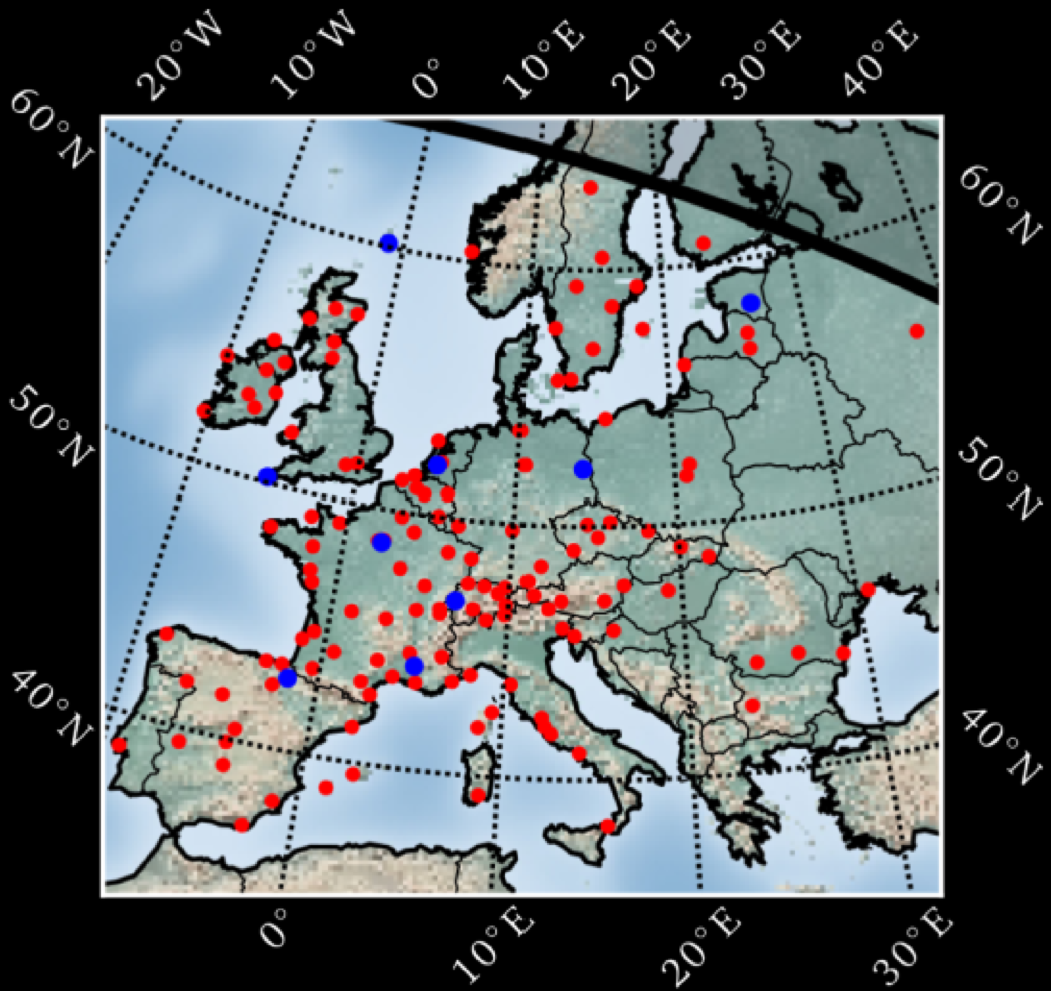


Target: 1° CERES Grid

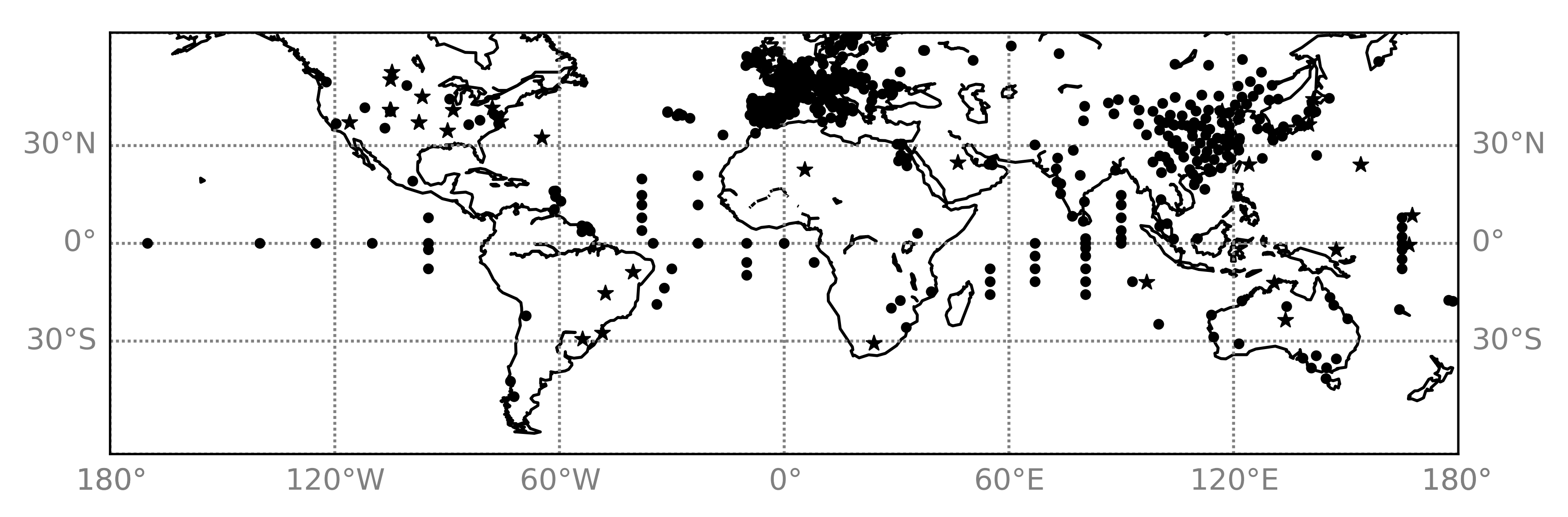
Sonnblick Observatory (AUT)

Observation with Pyranometer

Station coverage – Europe



Station coverage



Too few stations available for global analysis

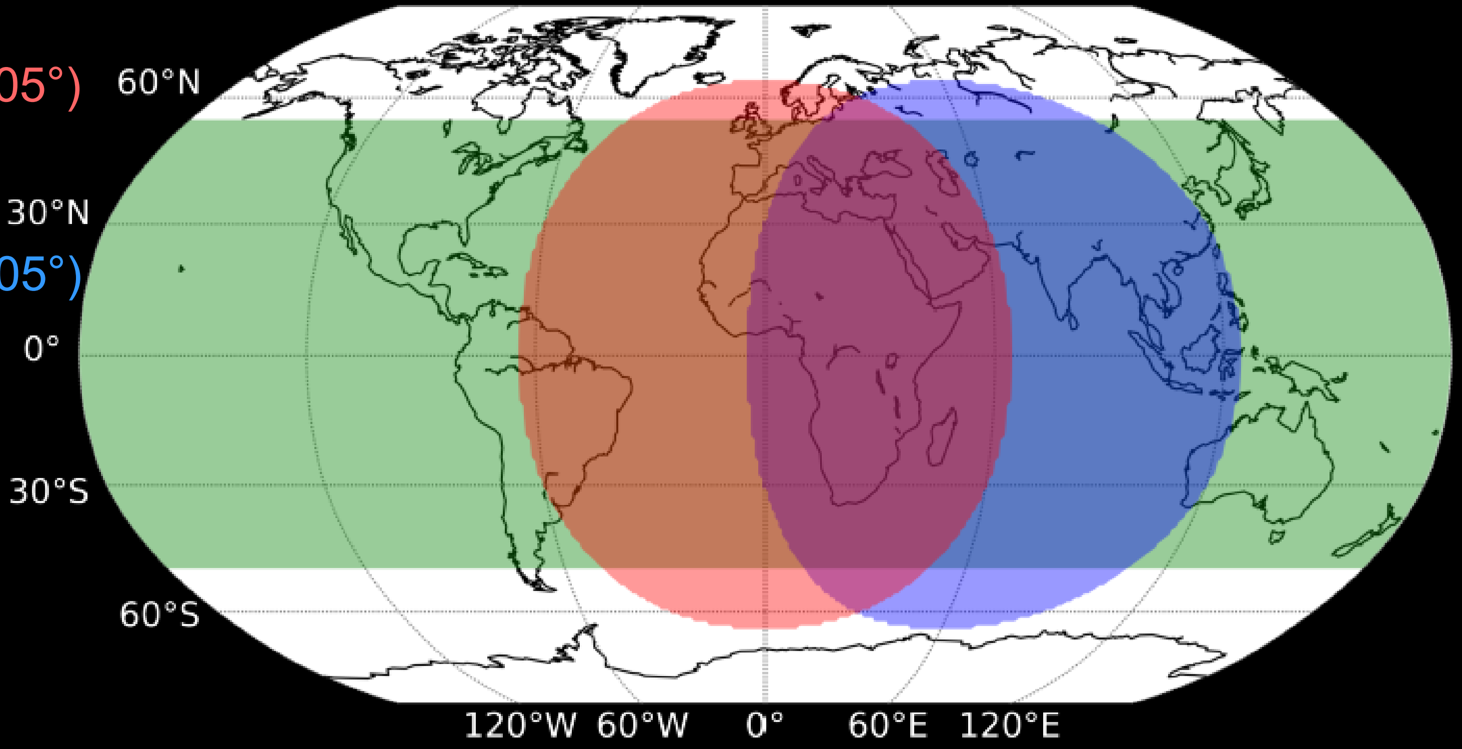
→ Using satellite derived surface radiation as surrogate for in-situ obs.

→ allows near global assessment of representativeness

CM-SAF's High Resolution Satellite-derived SSR Data

Global scale analysis with **monthly mean** satellite derived SSR from CM-SAF

- SARAH-P V002 (0.05 x 0.05°)
  Pfeifroth, et al. (2018)
- SARAH-E V001 (0.05 x 0.05°)
  Huld, et al. (2016)
- CLARA-A2 (0.25 x 0.25°)
  Karlsson, et al. (2017)



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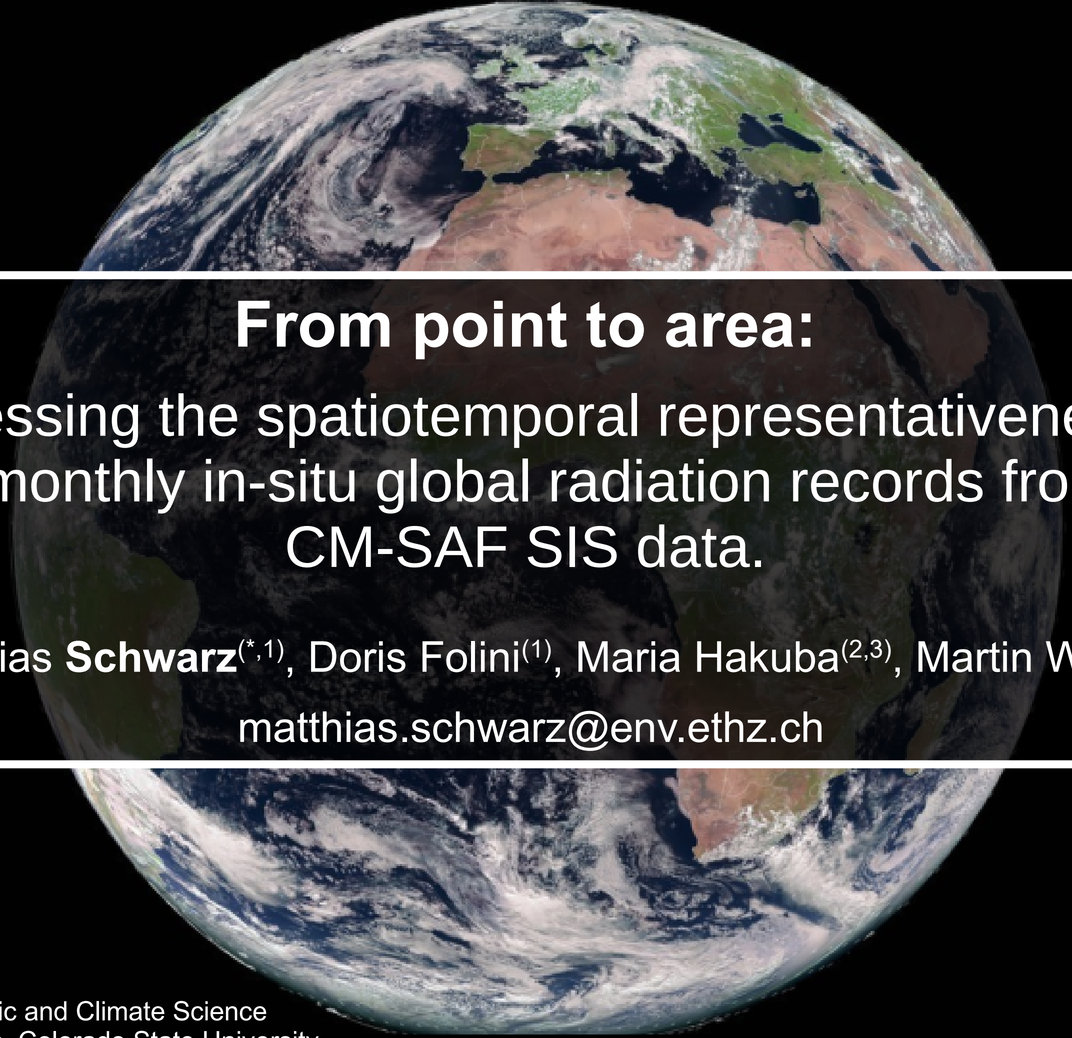

From point to area:

assessing the spatiotemporal representativeness of monthly in-situ global radiation records from CM-SAF SIS data.

Matthias **Schwarz**(*,1), Doris Folini(1), Maria Hakuba(2,3), Martin Wild(1)

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Affiliations:
(1) ETHZ Zürich, Institute for Atmospheric and Climate Science
(2) Department of Atmospheric Sciences, Colorado State University
(3) Jet Propulsion Laboratory, California Institute of Technology

Image: Meteosat 0° Natural Colour Enhncd. Full disc **(28.05.2019 12 UTC)**

Three aspects of representativeness:

I. Spatial correlations (R^2)

II. Spatial Sampling Biases (β)

III. Spatial Sampling Errors (ε)

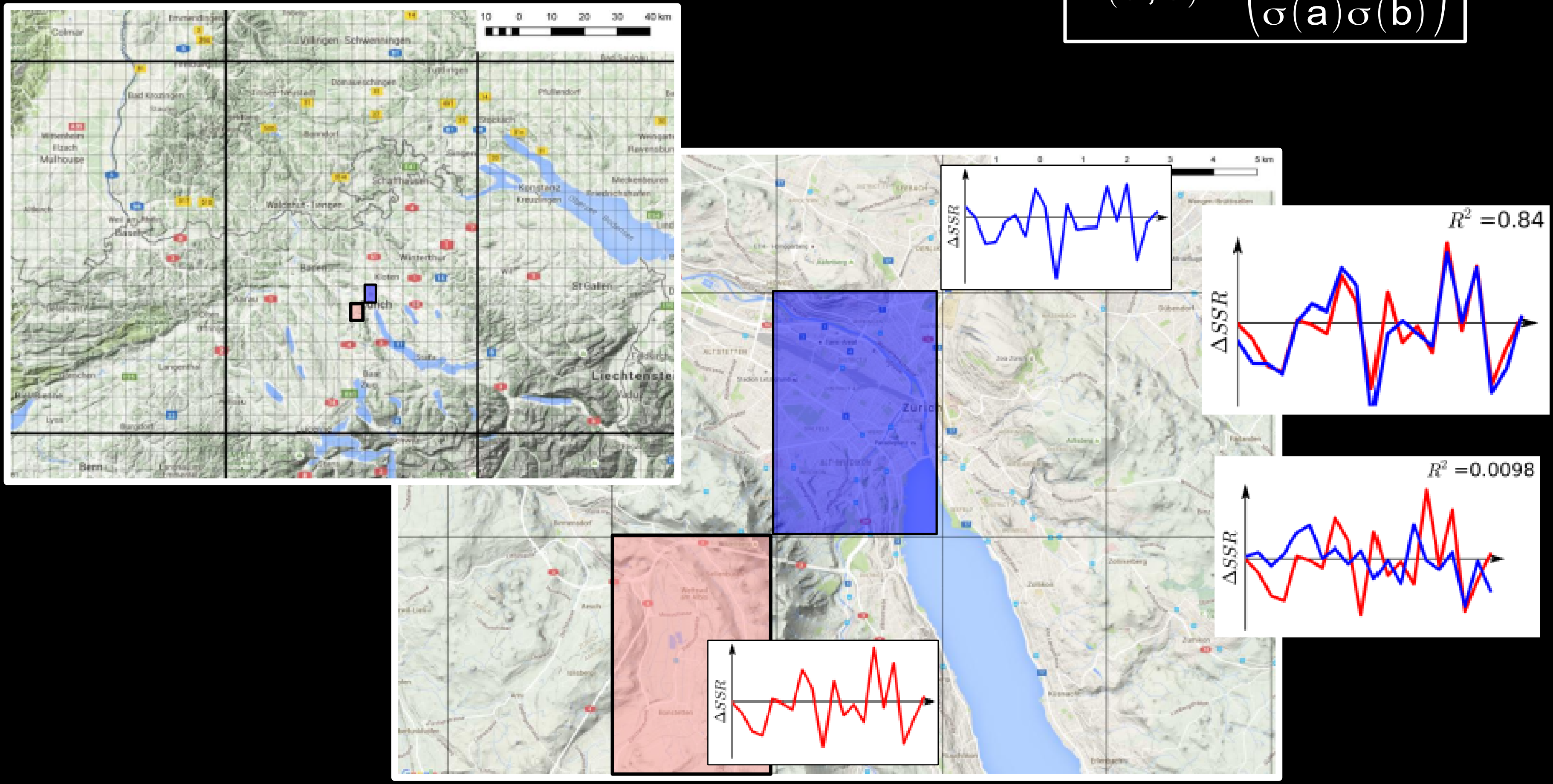
Target: 1° CERES Grid

Spatial Correlations

Schwarz et al. (2017)

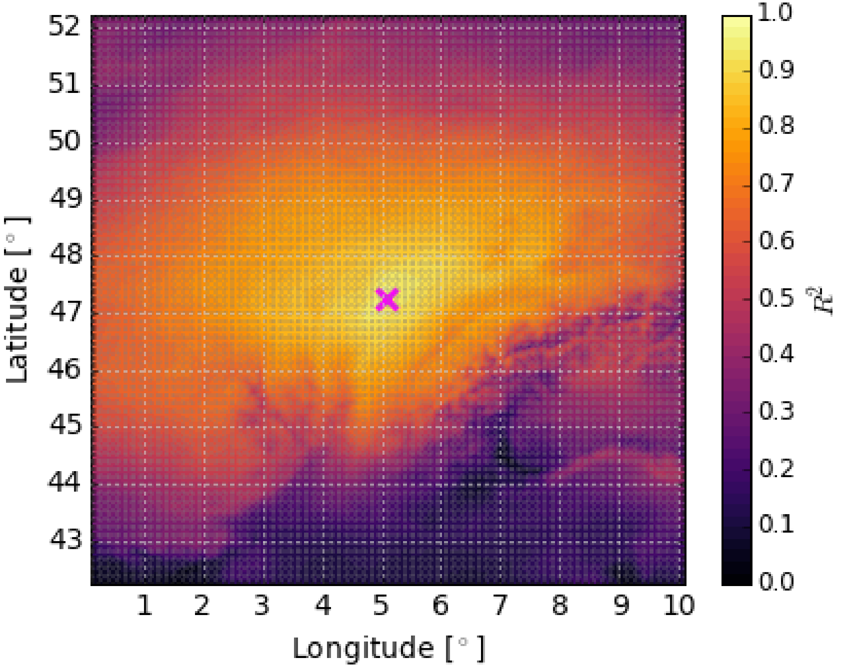
$$R(a,b)^2 = \left(\frac{cov(a,b)}{\sigma(a)\sigma(b)} \right)^2$$

CERES 1° GRID



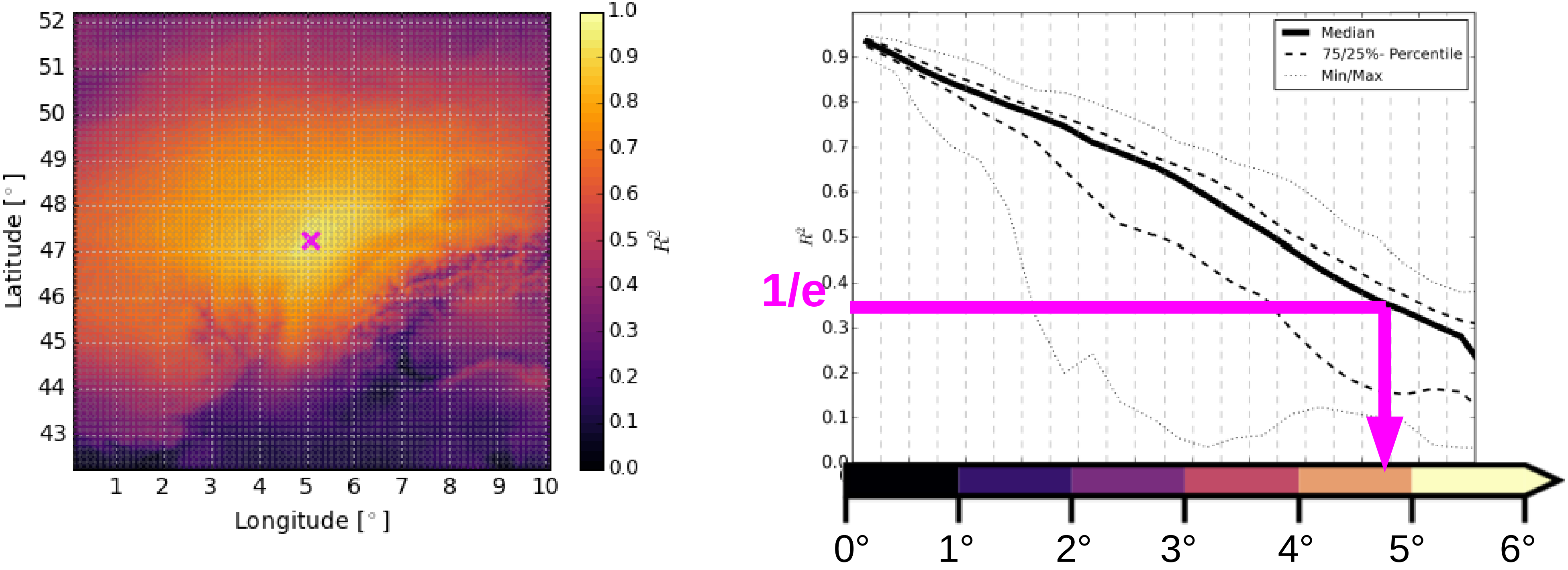
Spatial Correlations: Decorrelation Length (δ)

Example for Dijon (France)

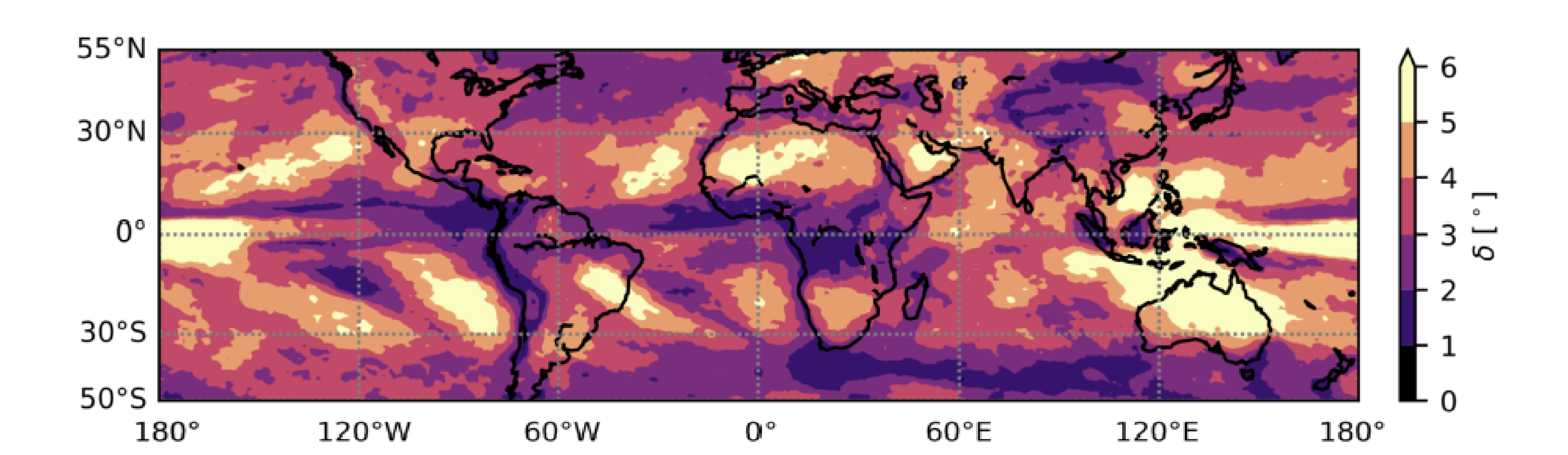


Spatial Correlations: Decorrelation Length (δ)

Example for Dijon (France)



Spatial Correlations: Decorrelation Length (δ)



- Near-global (50S-55N) mean δ ≈ 3.4°
- Roughly
  - ~2% of 1° boxes have average δ < 1°
  - ~5% of 1° boxes have average δ < 2°

Combination of SSR from point observations with 1° gridded data is feasible in most regions!

Three aspects of representativeness:

I. Spatial correlations (R^2) ✓ } Grid independent metric

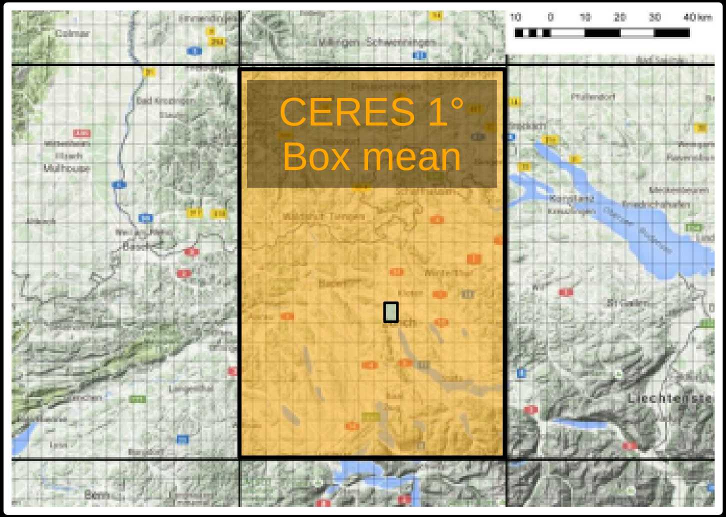
II. Spatial Sampling Biases (β)

III. Spatial Sampling Errors (ε)

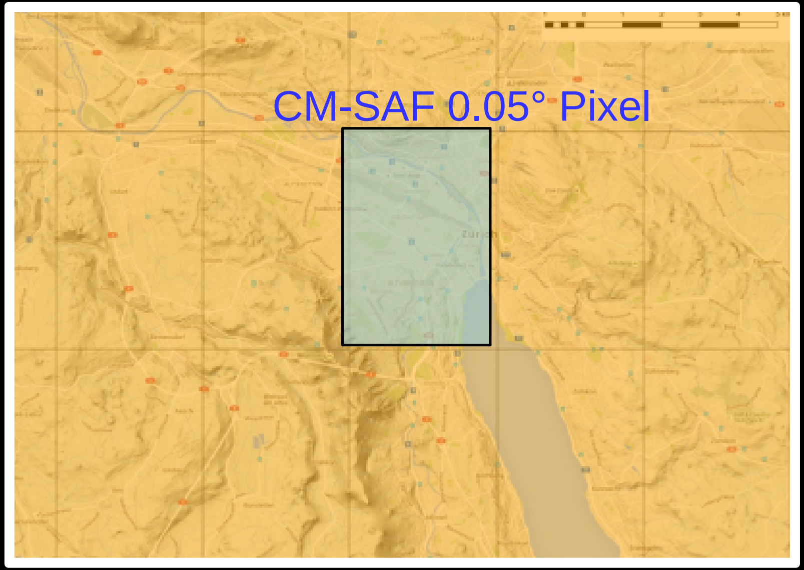
} Grid dependent metrics

Target: 1° CERES Grid

Grid dependent metrics

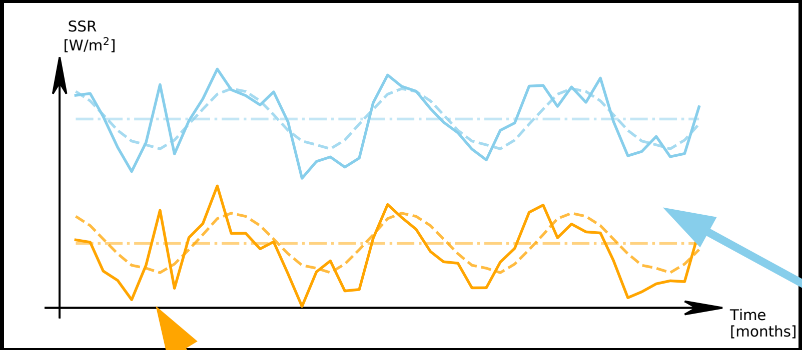


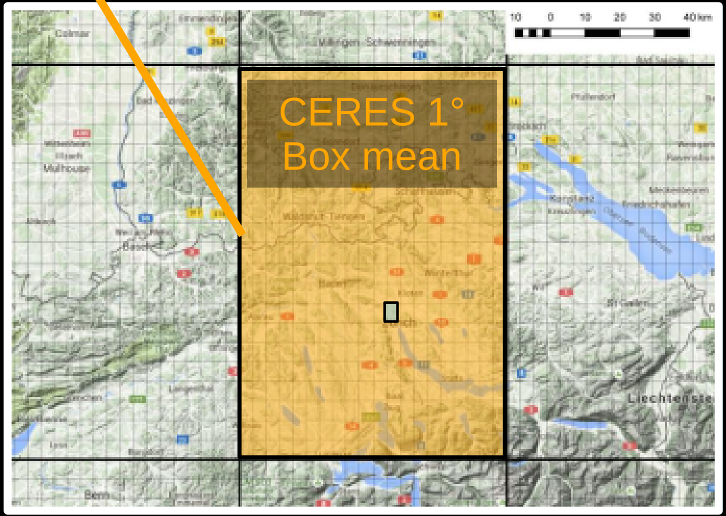
vs.



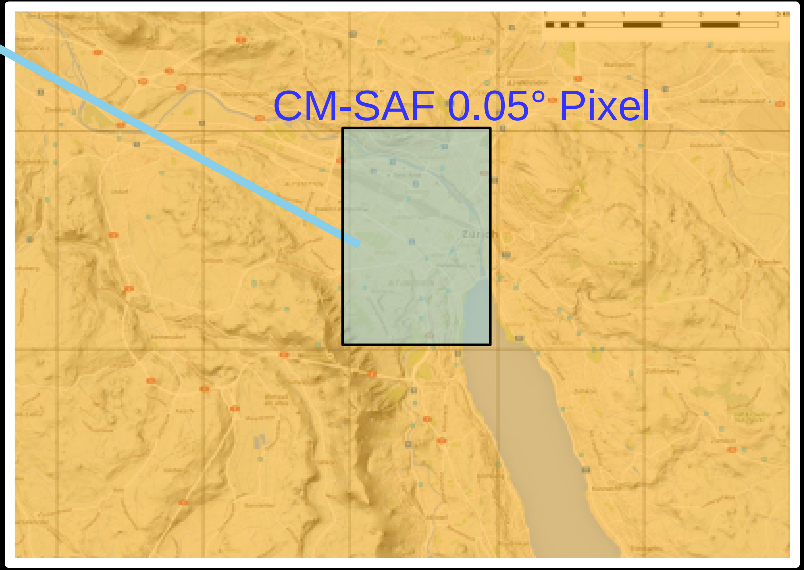
Spatial Sampling Bias (β)

Hakuba et al. (2013)



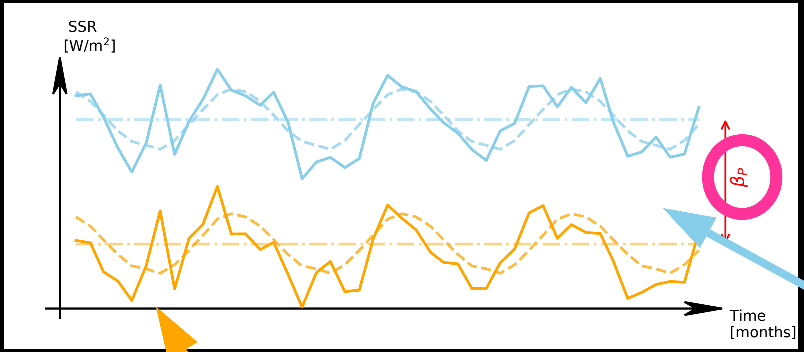


vs.

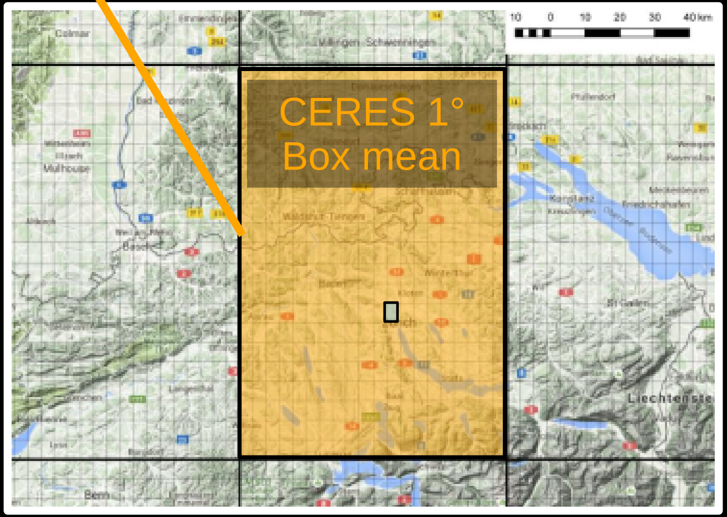


Spatial Sampling Bias (β)

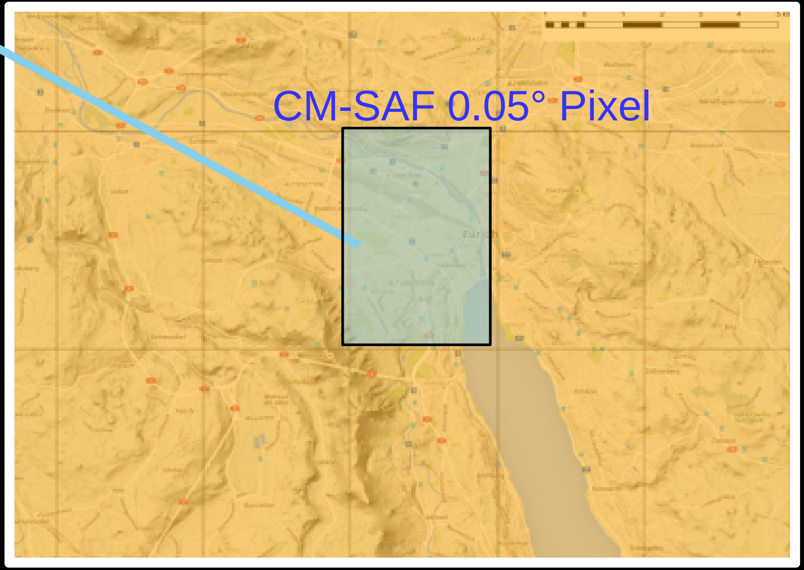
Hakuba et al. (2013)



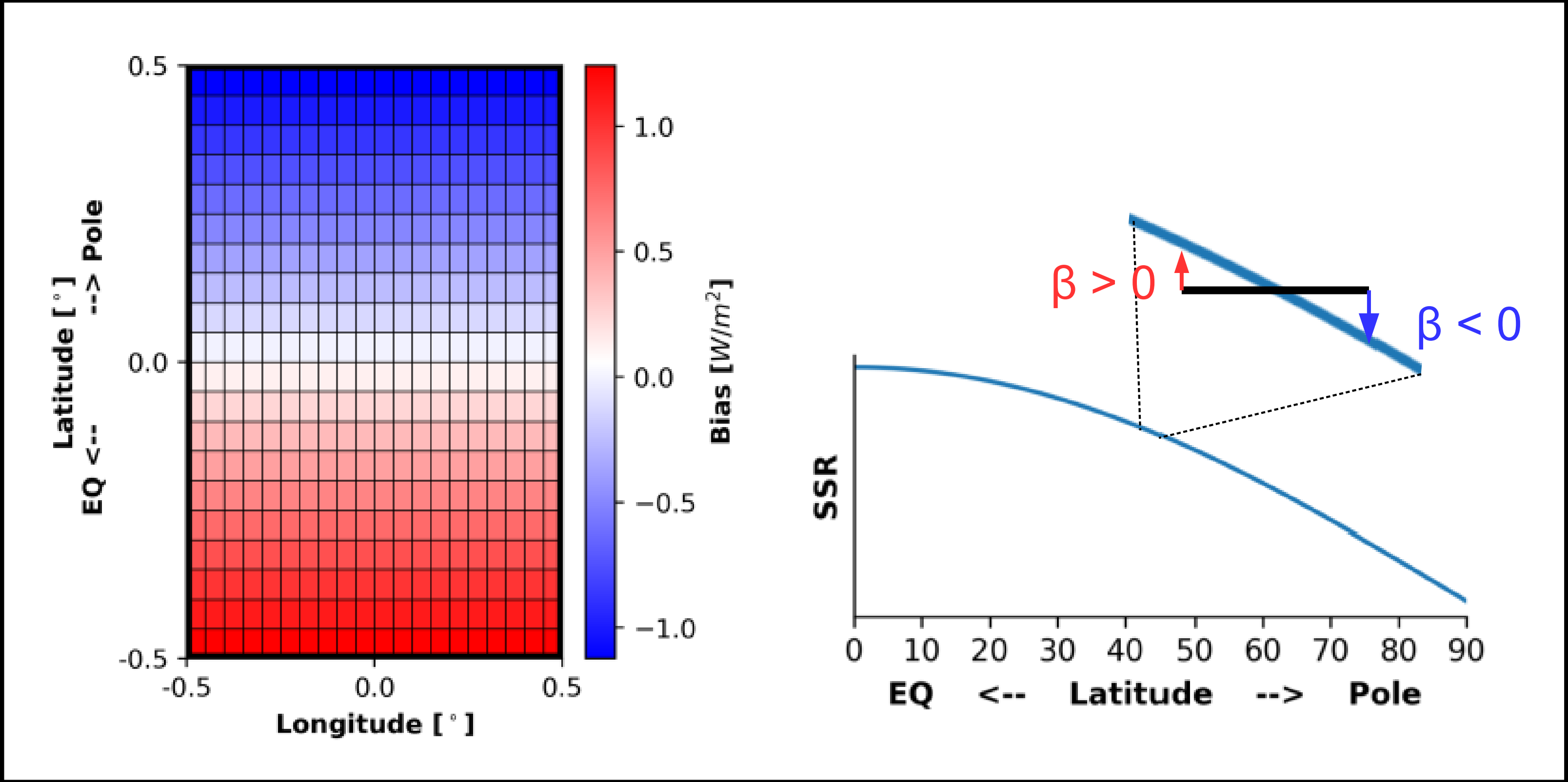
$$\beta_P = \overline{SSR_P} - \overline{SSR_B}$$



vs.



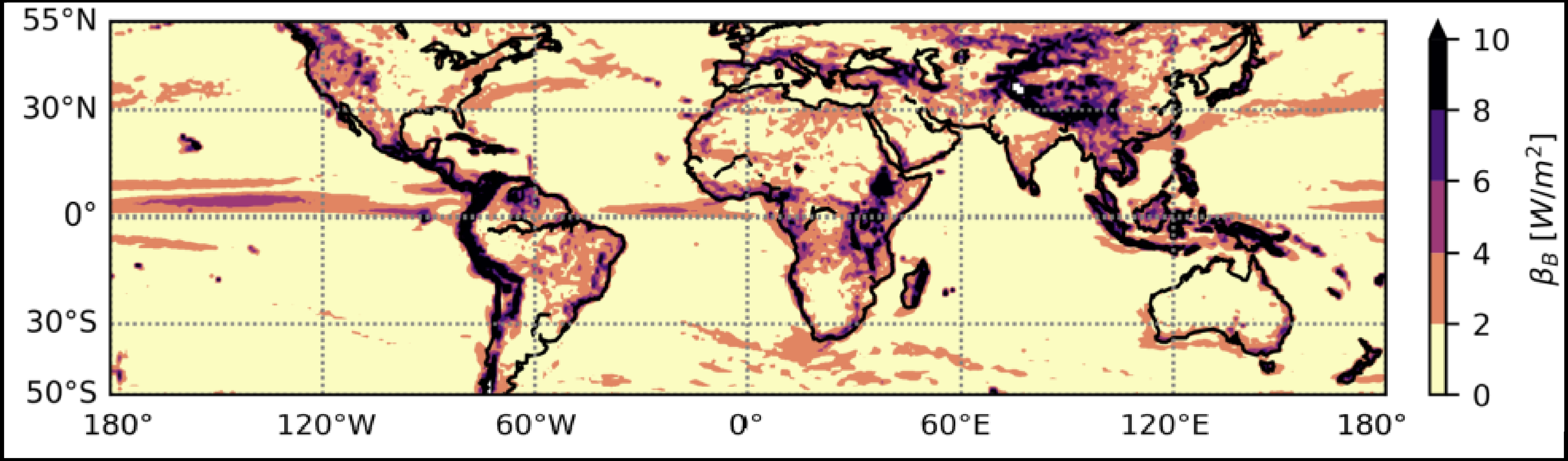
Spatial Sampling Biases – Pixel Based



"Typical" magnitude of biases within 1° box

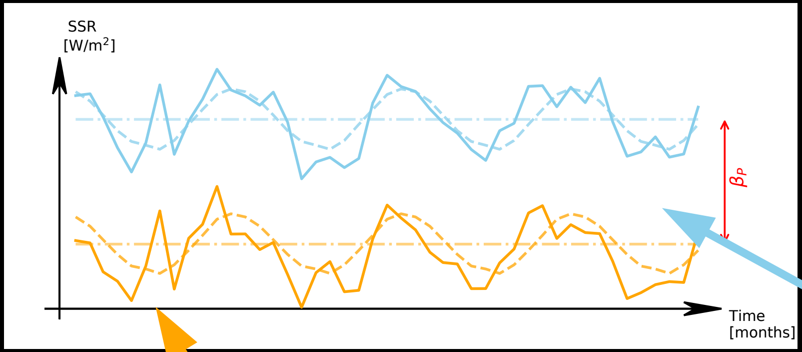
$$\beta_B = \sqrt{\frac{1}{N}\sum_N \left(\beta_P - \overline{\beta_P}\right)^2}$$

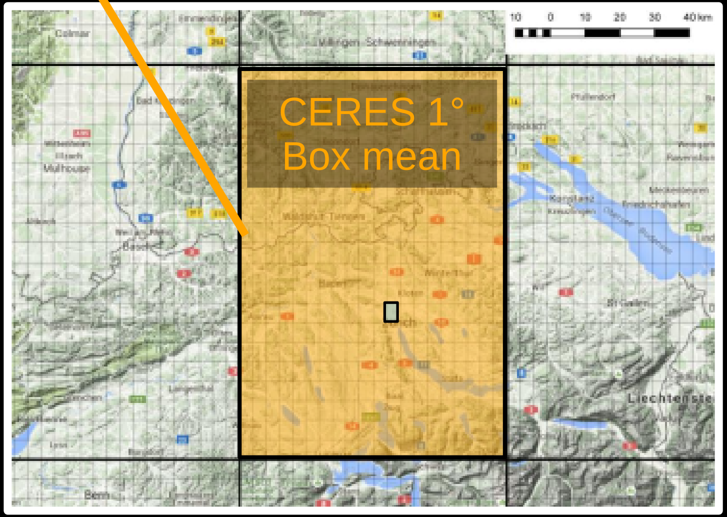
Spatial Sampling Biases – Box Aggregated



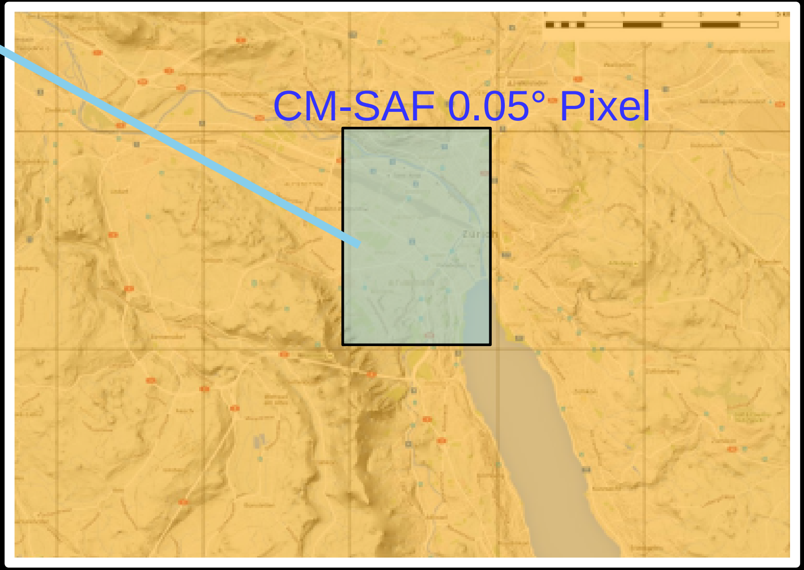
- Near-global (50S-55N) β_B ≈1.4 W/m²
- Magnitudes of biases vary across regions
- Bias of station depends on position within 1° box
- Biases can be corrected (if known)
- (biases have annual cycle)

Spatial Sampling Error (ε)

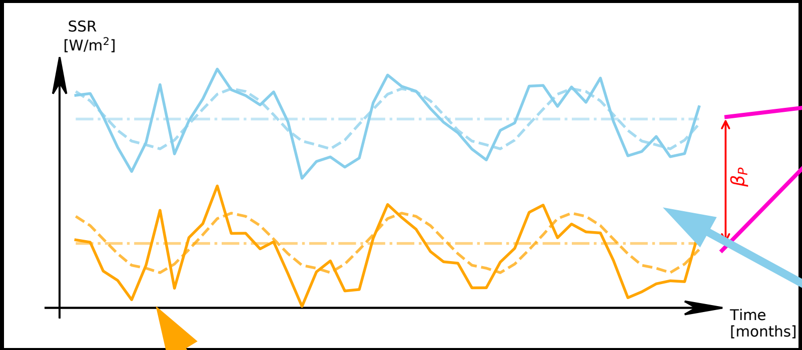




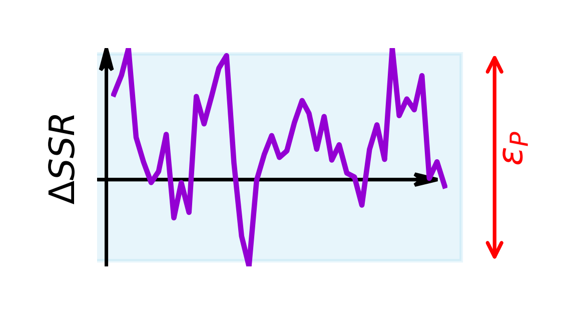
vs.



Spatial Sampling Error (ε)

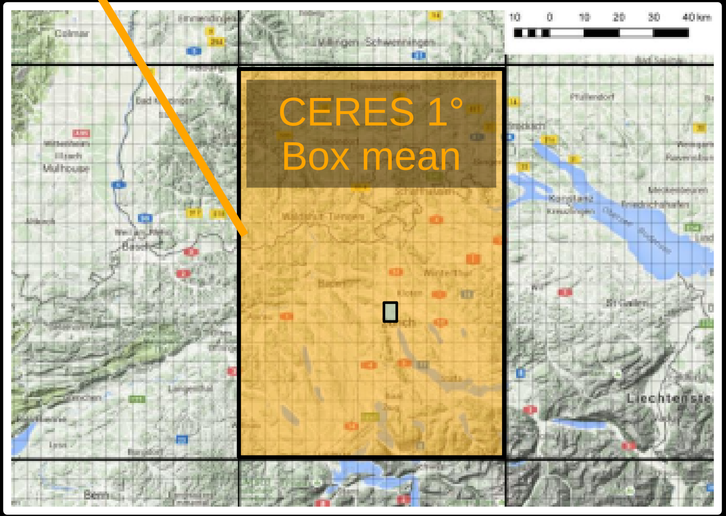


Difference time series

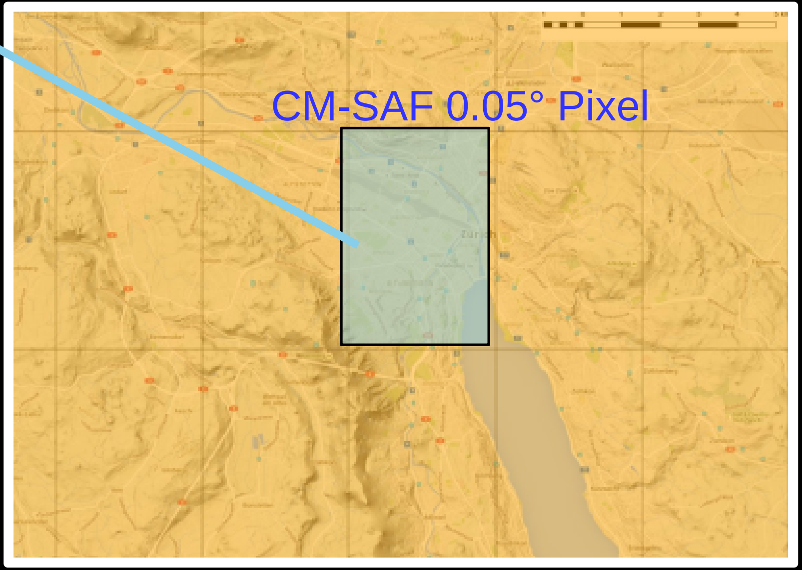


$$\epsilon_P = P^{95}(|SSR'_P(t) - SSR'_B(t)|)$$

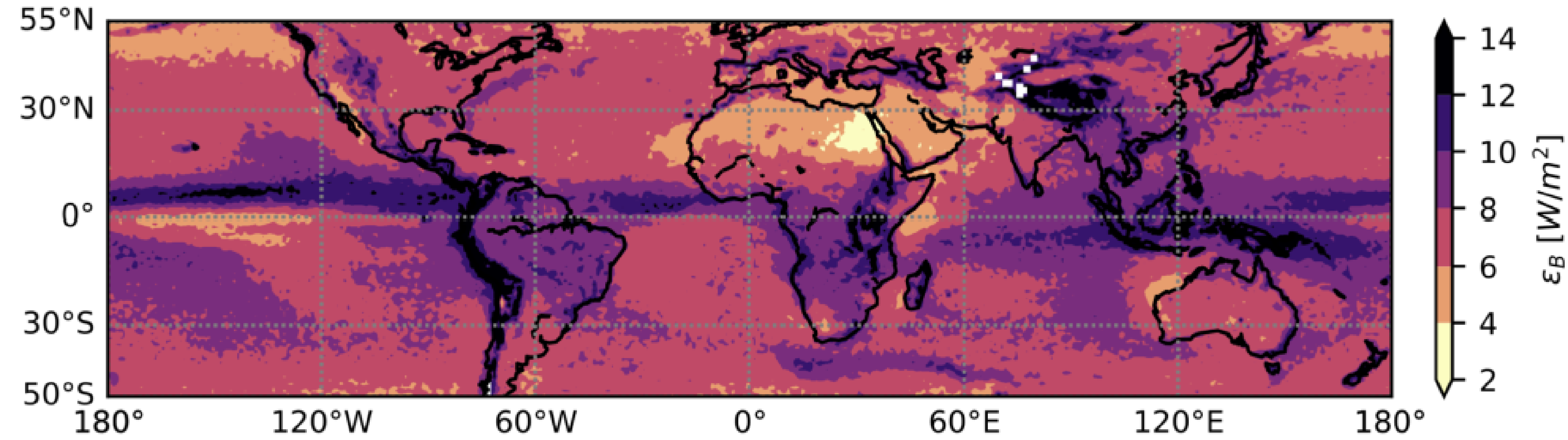
$$\epsilon_B = P^{68.2}(\epsilon_P)$$



vs.



Spatial Sampling Errors – Box Aggregated



- Global mean (50S-55N) $\varepsilon_B \approx 7.5$ W/m^2
- Errors are calculated form individually deseasonalized time series
  → implicit bias correction
- Without bias correction errors are 10-15% higher
- Errors for other grids:
  - 0.5°x 0.5° grid ~ 30% smaller
  - 2.5° x 2.5° grid ~ 60% larger

Three aspects of representativeness:

I. Spatial correlations (R^2) ✓ } Grid independent metrics

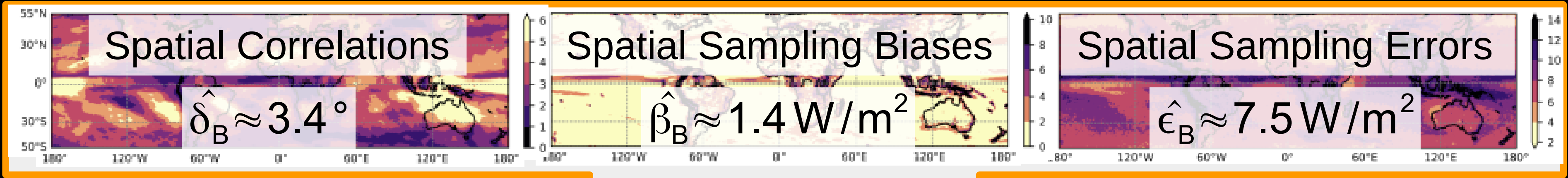
II. Spatial Sampling Biases (β) ✓ } Grid dependent metrics

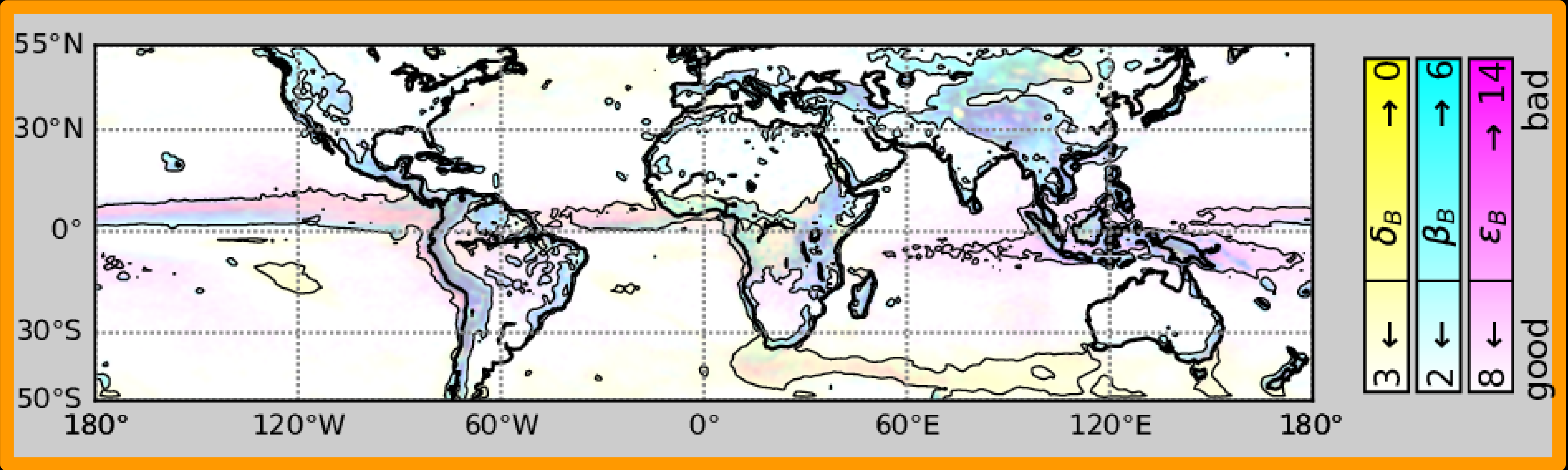
III. Spatial Sampling Errors (ε) ✓

Let's combine all metrics…..

Target: 1° CERES Grid

Combining the metrics

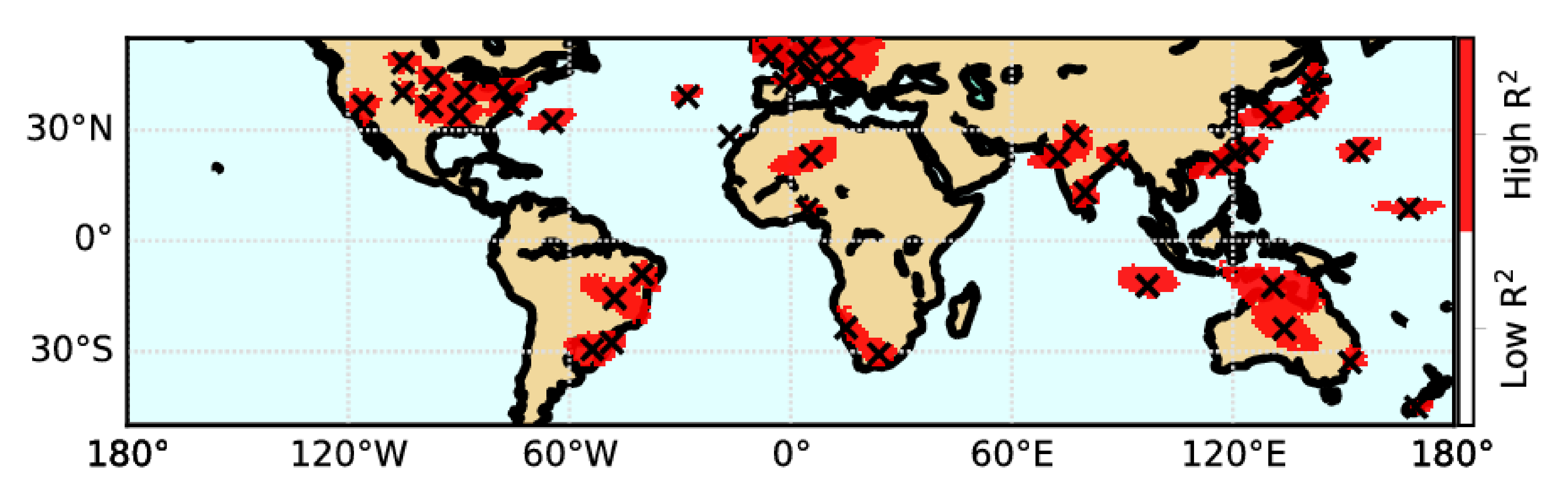




→ **Different metrics limit representativeness in different regions**

Case Study:
Direct sampling capacity of the Baseline Surface Radiation Network (monthly mean SSR)

Case Study BSRN



The 47 BSRN stations inside domain can together directly ($R^2 > 1/e$) sample

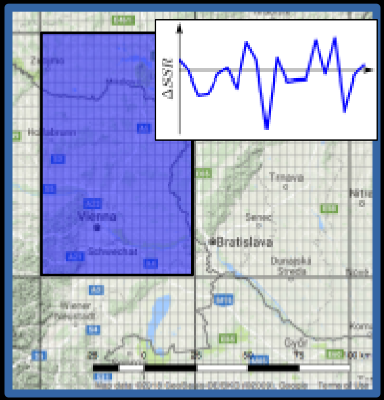
- 16% of the domains land pixels
- 7% of the domains total pixels

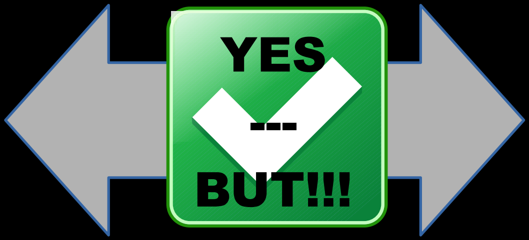
$\langle\delta\rangle_{BSRN} \approx 3.5°$

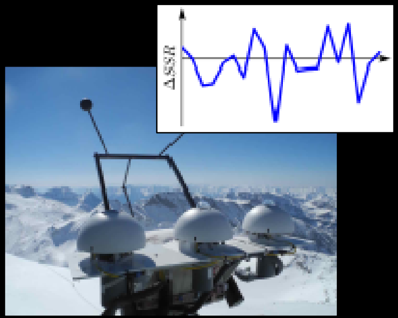
$\langle\beta_B\rangle_{BSRN} \approx 3.7\ W/m^2$ $\langle|\beta_P|\rangle_{BSRN} \approx 2.9\ W/m^2$

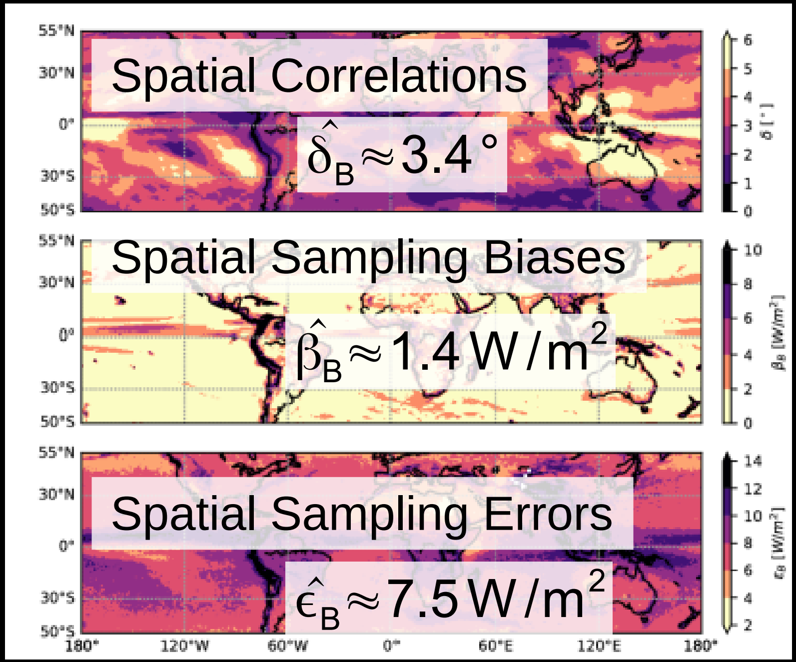
$\langle\varepsilon_B\rangle_{BSRN} \approx 8.6\ W/m^2$ $\langle\varepsilon_P\rangle_{BSRN} \approx 8.9\ W/m^2$

Synthesis







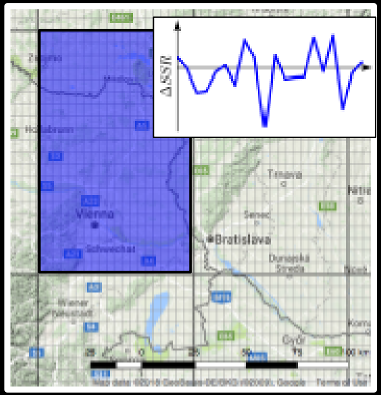


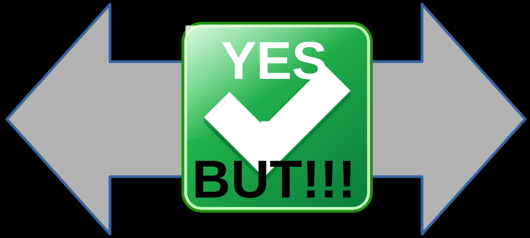
- Combining point and (1°) gridded data is possible in most regions
- Grid specific bias correction is advisable
- Combined uncertainty (1° grid):

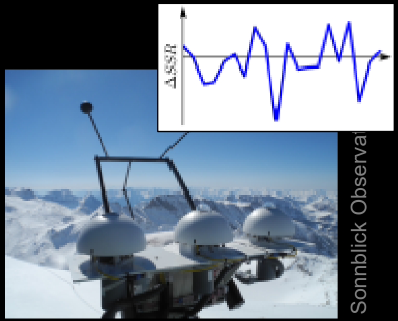
  Measurement uncertainty
  \+ spatial sampling error (ε)
  \---------------------------------------
  Total uncertainty ~40-50% higher than measurement uncertainty alone

- Large regional differences!
- Representativeness is limited in different regions due to different reasons!

Summary







- Correcting β is suggested!
- Uncertainty increases (pyranometer + ε)
- Large regional differences

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Schwarz, M., Folini, D., Hakuba, M.Z., Wild, M., 2018. **From Point to Area: Worldwide Assessment of the Representativeness of Monthly Surface Solar Radiation Records**. J. Geophys. Res. Atmos. 123, 13,857-13,874. https://doi.org/10.1029/2018JD029169

Schwarz, M., Folini, D., Hakuba, M.Z., Wild, M., 2017. **Spatial Representativeness of Surface-Measured Variations of Downward Solar Radiation**. J. Geophys. Res. Atmos. 122, 2017JD027261. https://doi.org/10.1002/2017JD02726

Image: Meteosat 0° Natural Colour Enhncd. Full disc **(28.05.2019 12 UTC)**

Appendix

Pixel as Surrogate for Point Observation

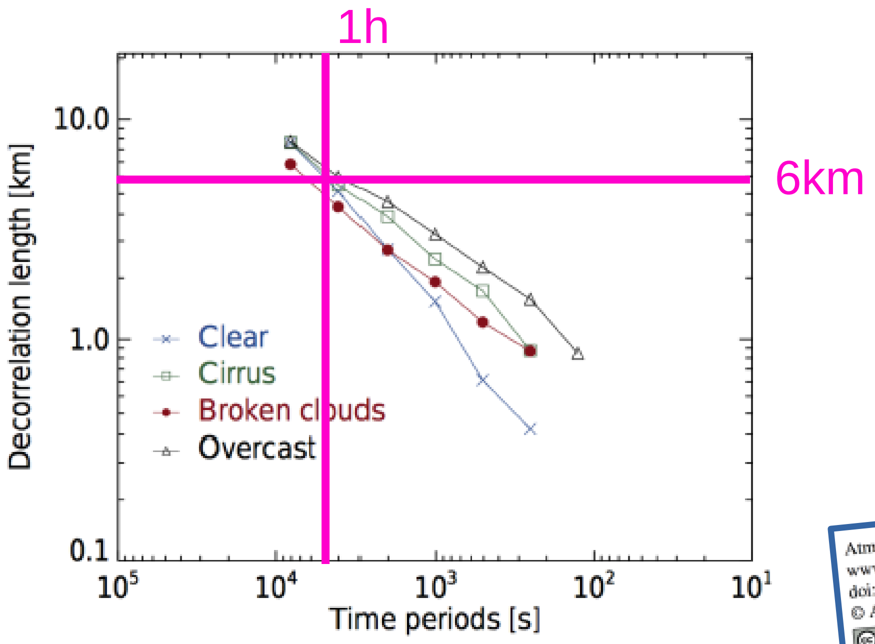
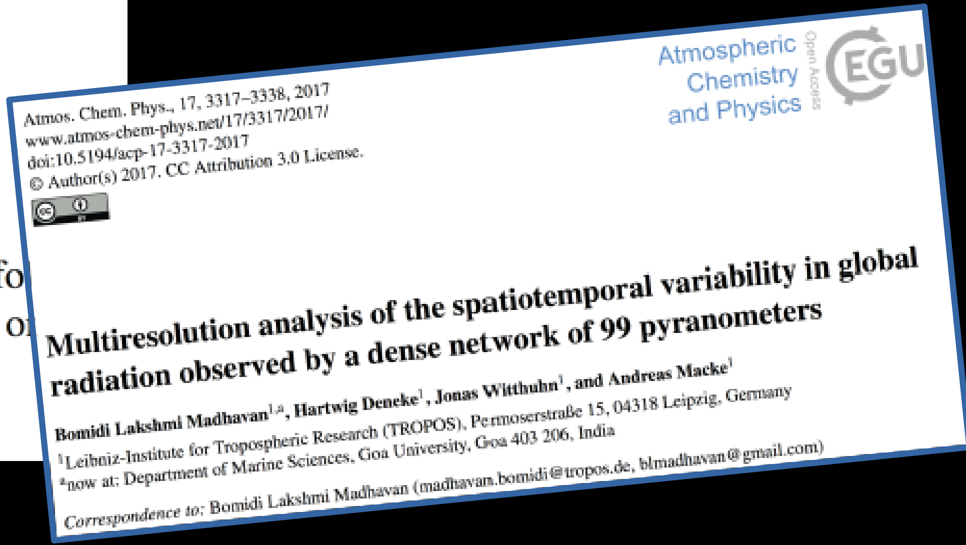


Figure 7. Decorrelation lengths a (in km), determined as e-fo
time of the spatial correlation function, and its dependence o
time period of variations.


Atmos. Chem. Phys., 17, 3317–3338, 2017
www.atmos-chem-phys.net/17/3317/2017/
doi:10.5194/acp-17-3317-2017

Multiresolution analysis of the spatiotemporal variability in global radiation observed by a dense network of 99 pyranometers

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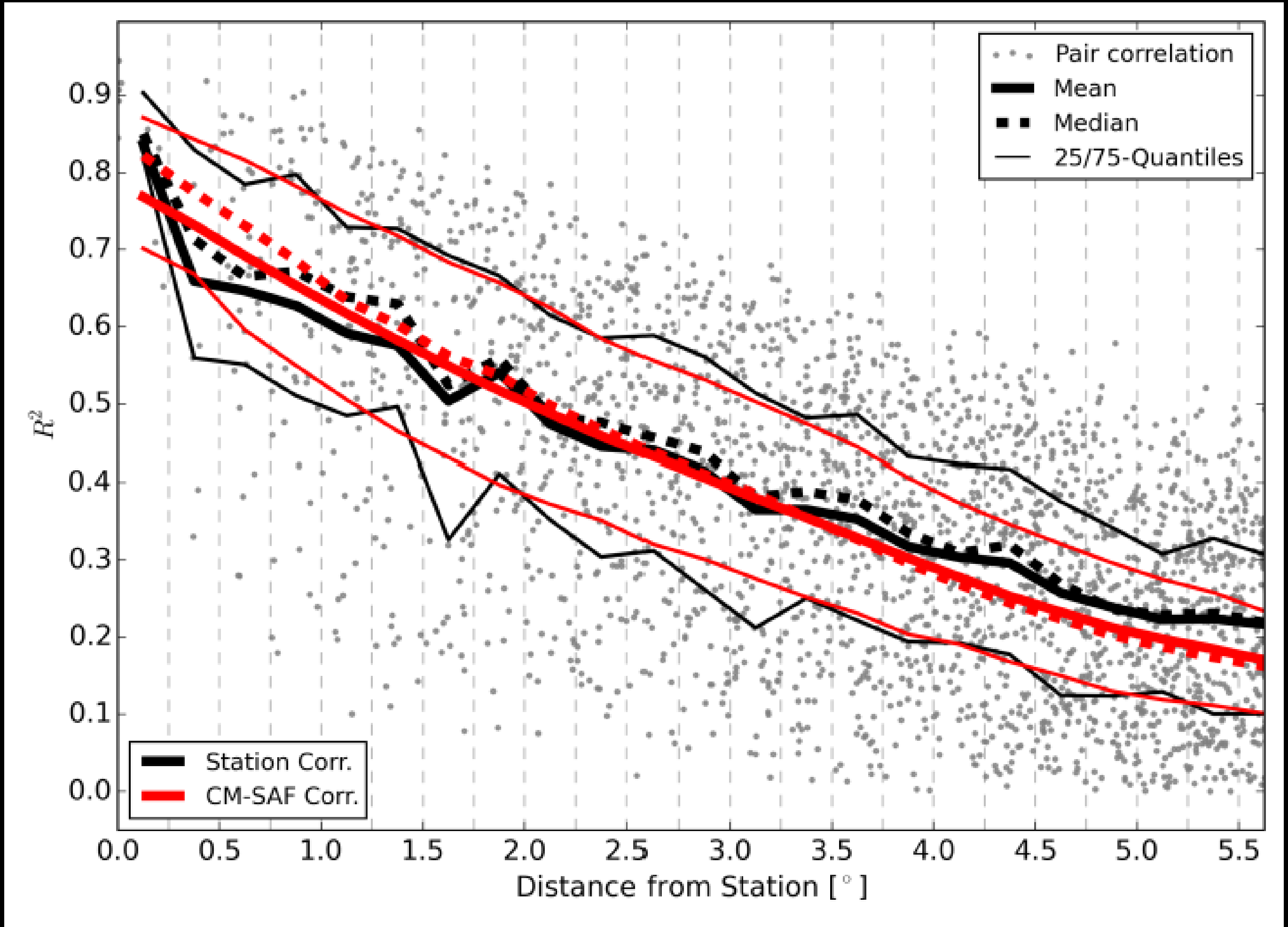
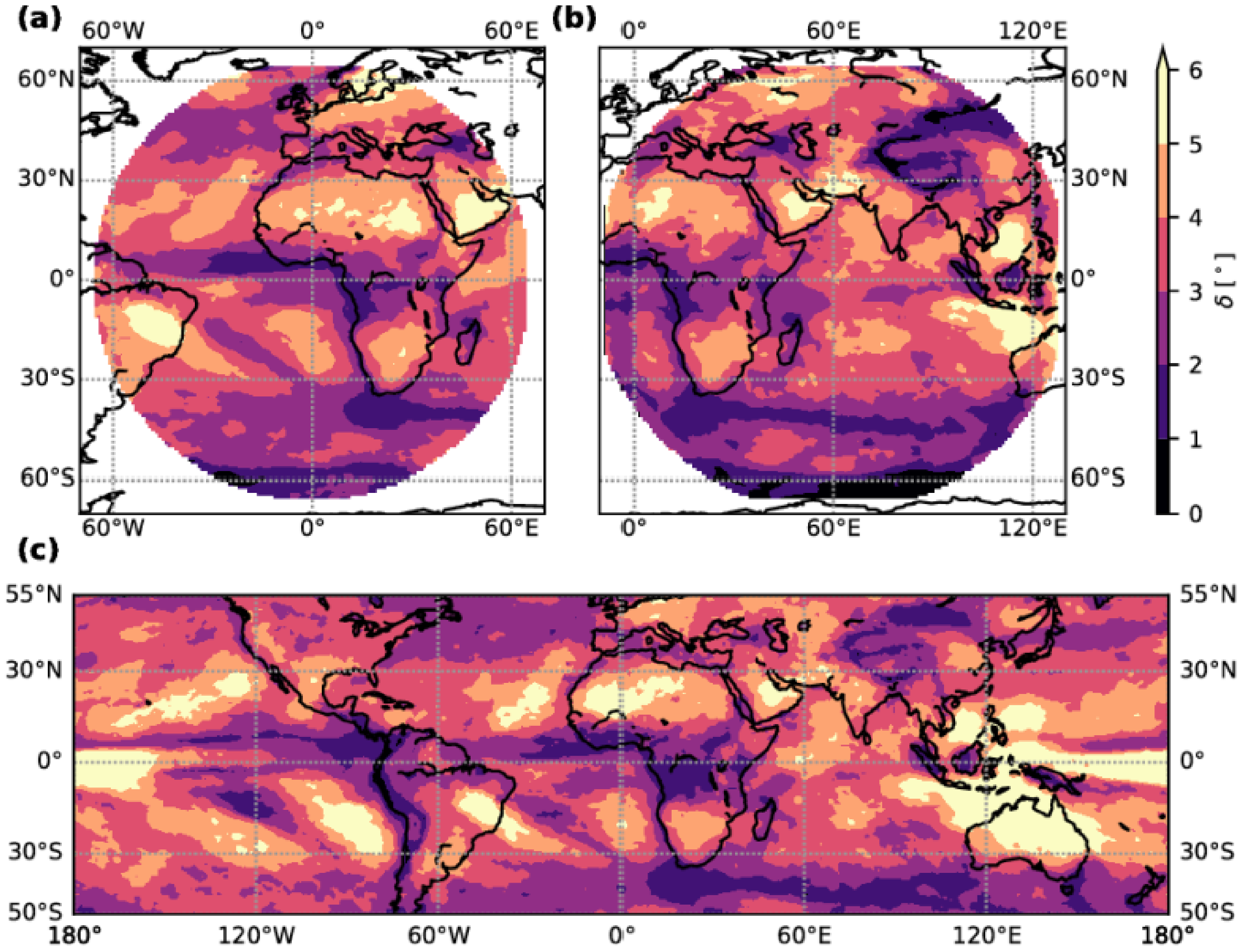
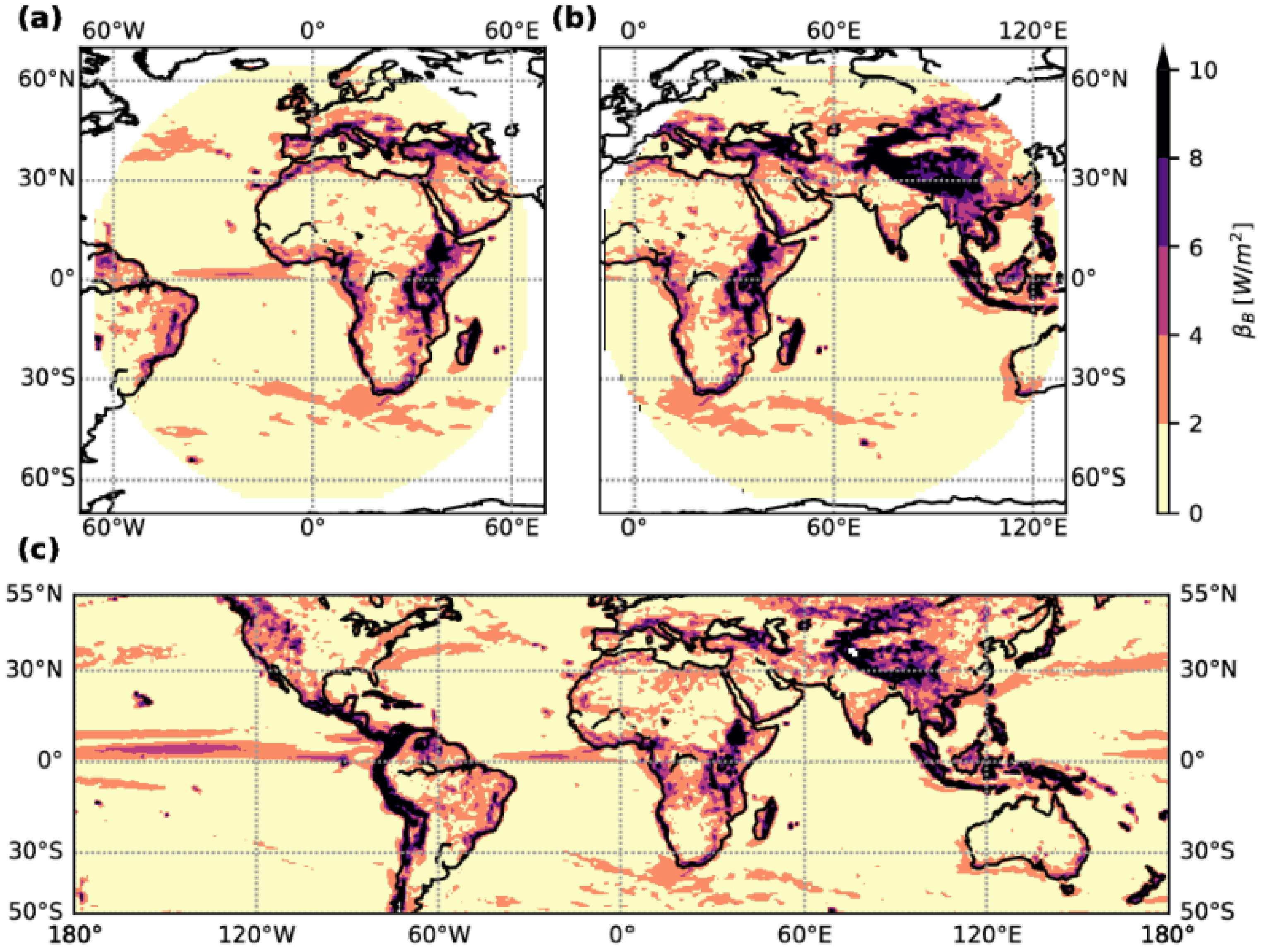
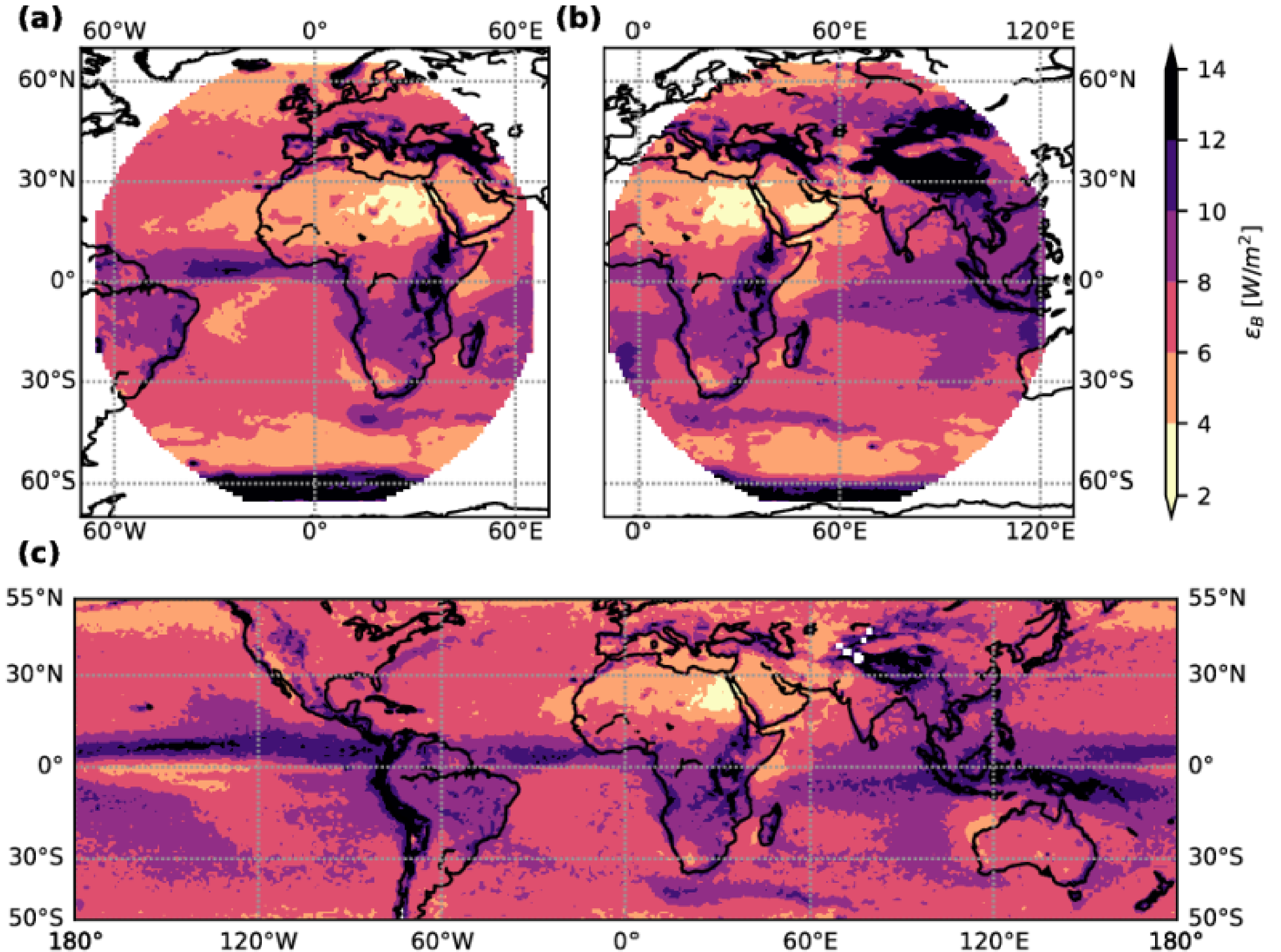
[a]now at: Department of Marine Sciences, Goa University, Goa 403 206, India
Correspondence to: Bomidi Lakshmi Madhavan (madhavan.bomidi@tropos.de, blmadhavan@gmail.com)

Site-to-Site vs Site-to-Pixel correlations

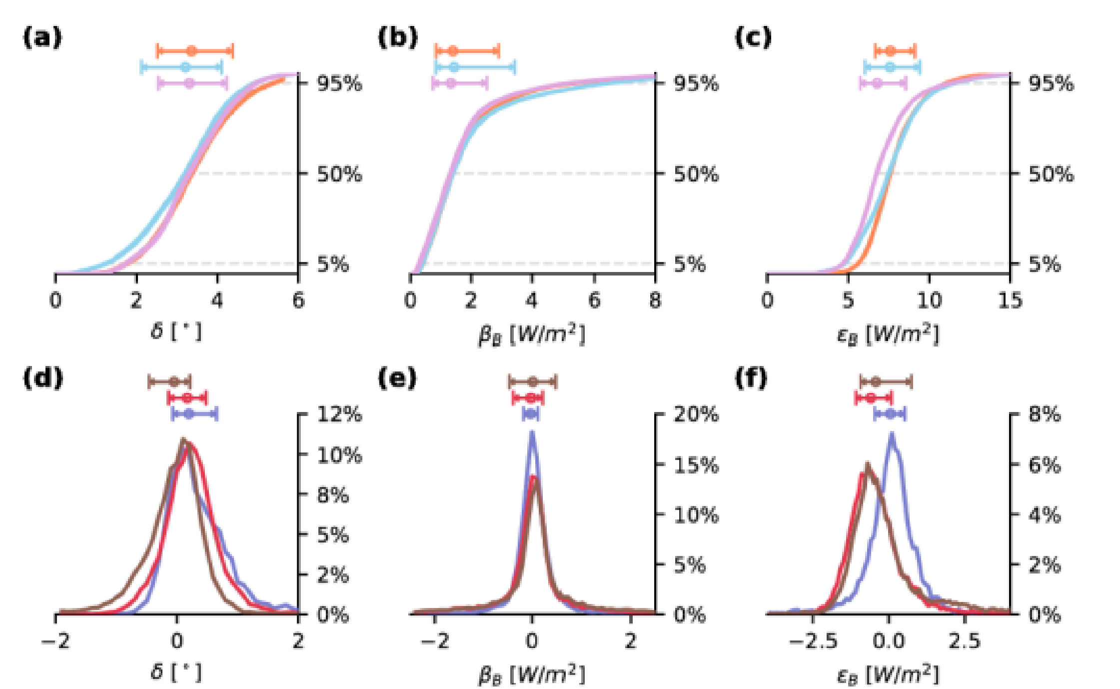



(a)
60°W
0°
60°E
60°N
30°N
0°
30°S
60°S
(b)
120°E
δ [°]
0
1
2
3
4
5
6
(c)
55°N
50°S
180°
120°W


(a)
(b)
(c)
60°W
0°
60°E
120°E
180°
120°W
60°N
30°N
0°
30°S
60°S
55°N
50°S
β_B [W/m^2]
0
2
4
6
8
10


(a)
(b)
(c)
60°W
0°
60°E
120°E
60°N
30°N
30°S
60°S
55°N
50°S
180°
120°W
14
12
10
8
6
4
2
ϵ_B $[W/m^2]$

Comparison (CDFs and PDFs) of δ, β, and ε from SARAH, SARAH-E, and CLARA



	$\delta_B [°]$	β_B [Wm^{-2}]	ϵ_B [Wm^{-2}]
SARAH-P	3.31 (2.41, 4.36)	1.33 (0.57, 2.69)	6.96 (5.56, 9.06)
SARAH-E	3.21 (2.00, 4.23)	1.43 (0.66, 3.61)	7.75 (5.82, 9.95)
CLARA	3.36 (2.39, 4.50)	1.39 (0.67, 3.08)	7.58 (6.32, 9.39)
SARAH-P - SARAH-E	0.20 (-0.16, 0.74)	-0.03 (-0.28, 0.23)	0.05 (-0.63, 0.70)
SARAH-P - CLARA	0.17 (-0.22, 0.56)	-0.02 (-0.49, 0.33)	-0.41 (-1.08, 0.45)
SARAH-E - CLARA	-0.05 (-0.55, 0.30)	0.02 (-0.57, 0.59)	-0.23 (-0.91, 1.08)