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Development, Evaluation and Application of New Soil Moisture Products

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- Wang, Y., J. Mao*, et al. (2021b) Quantification of human contribution to soil moisture-based terrestrial aridity, Under review.

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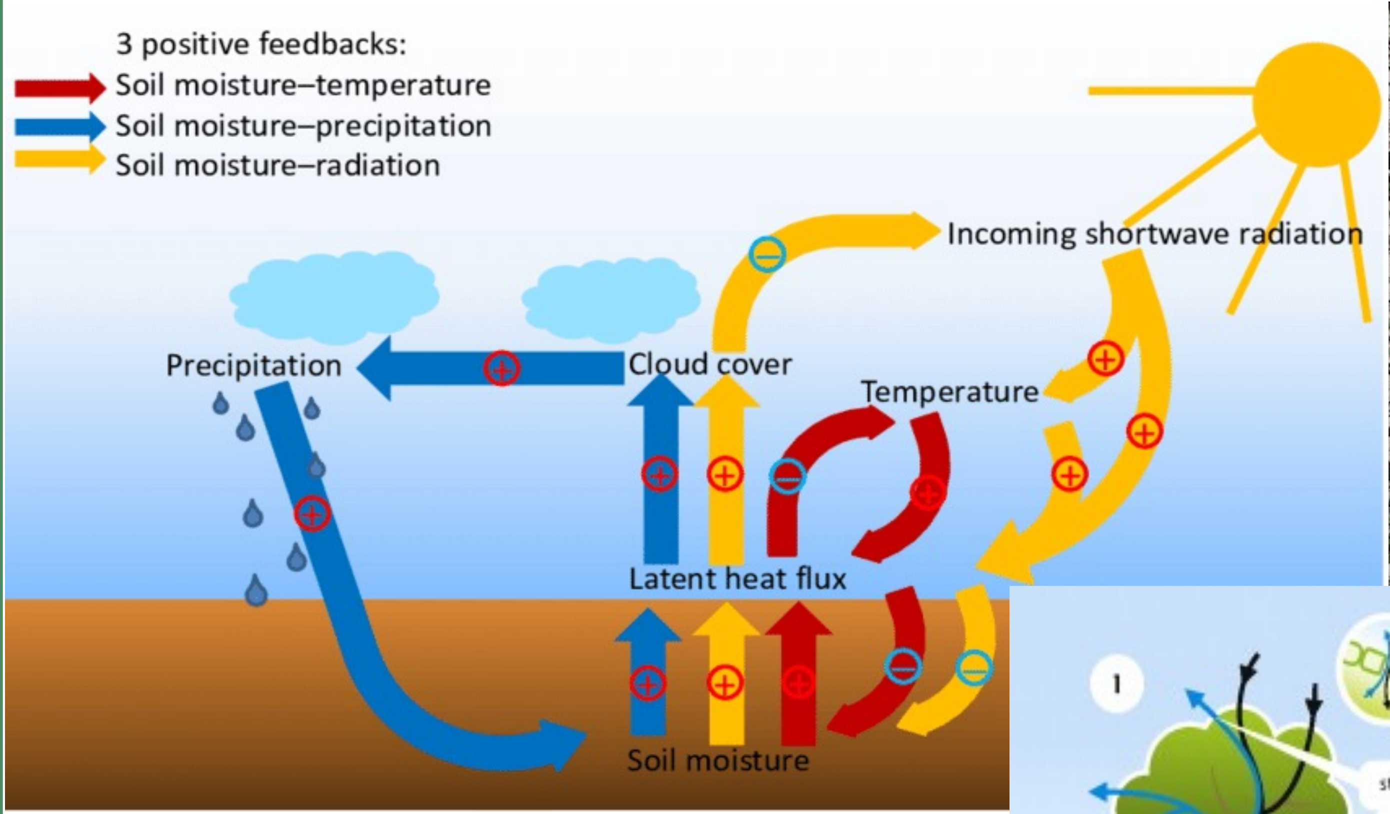
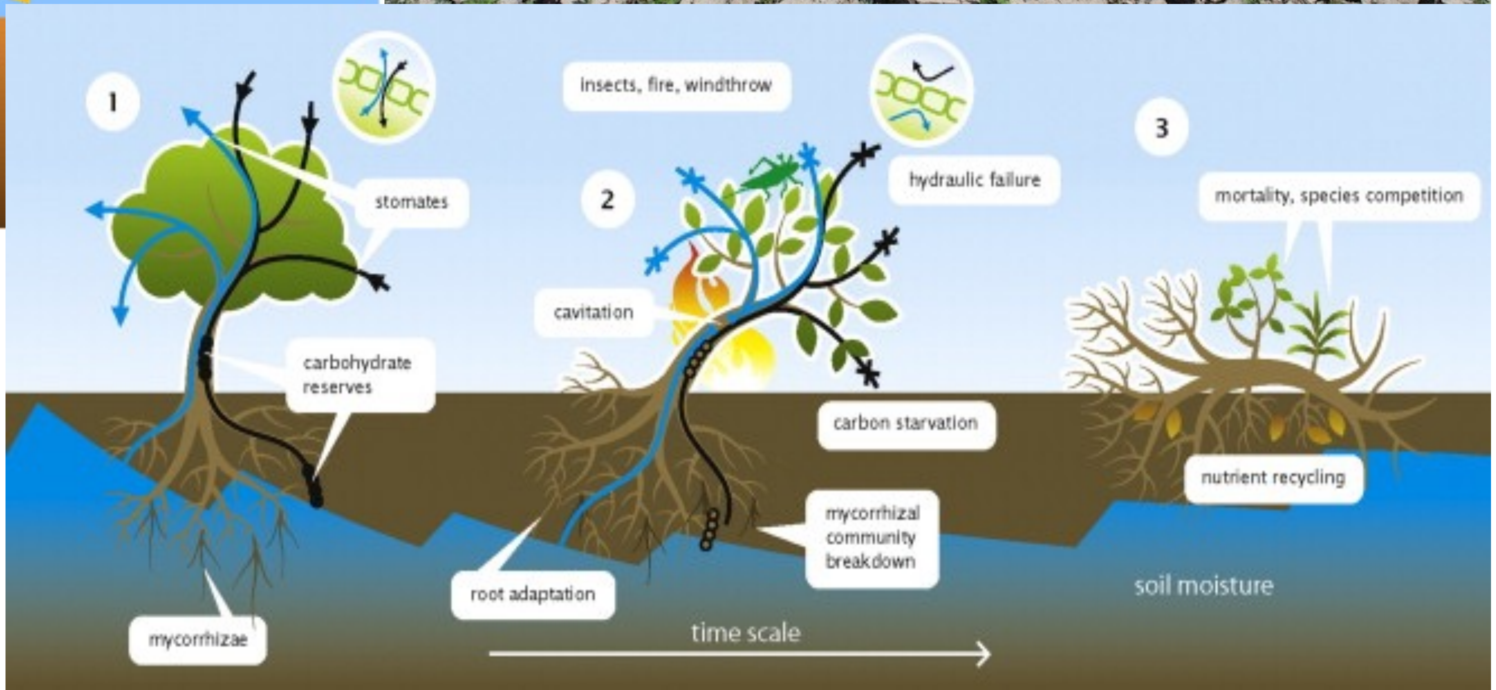
U.S. DEPARTMENT OF ENERGY

Importance of Soil Moisture (SM)





- ✓ *Droughts;*
- ✓ *Land-atmosphere feedbacks;*
- ✓ *Ecosystem dynamics;*

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Rationale for Creating Merged Soil Moisture Products

Data source	Pros	Cons
In situ observations	More accurate than remote sensing or model products	Represent only small spatial scale and too sparse
Remote sensing observations	Global, relatively high-resolution coverage	Have gaps, only represent the topsoil
Land surface models, reanalysis, and Earth system models	Gap-free, represent multiple soil layers	Subject to modeling biases

Merging multiple-source datasets would overcome the limitations of individual datasets, resulting in long-term, global, gap-free, multi-layer SM products for research purposes.

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Existing Data Merging Efforts for Soil Moisture

Data Descriptor | Open Access | Published: 27 May 2021

A long term global daily soil moisture dataset derived from AMSR-E and AMSR2 (2002–2019)

Panpan Yao, Hui Lu, Jiancheng Shi, Tianjie Zhao, Kun Yang, Michael H. Cosh, Daniel J. Short Gianotti & Dara Entekhabi

Scientific Data **8**, Article number: 143 (2021) | Cite this article

1123 Accesses | **2** Altmetric | Metrics

IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 12, NO. 9, SEPTEMBER 2019 3351

Validation of a New Root-Zone Soil Moisture Product: Soil MERGE

Kenneth J. Tobin, Wade T. Crow, *Member, IEEE*, Jianzhi Dong, and Marvin E. Bennett

ELSEVIER

Remote Sensing of Environment

Volume 203, 15 December 2017, Pages 185-215

ESA CCI Soil Moisture for improved Earth system understanding: State-of-the art and future directions

Wouter Dorigo [a], Wolfgang Wagner [a], Clement Albergel [b], Franziska Albrecht [c], Gianpaolo Balsamo [d], Luca Brocca [e], Daniel Chung [a], Martin Ertl [f], Matthias Forkel [a], Alexander Gruber [a], Eva Haas [c], Paul D. Hamer [g], Martin Hirschi [h], Jaakko Ikonen [i], Richard de Jeu [j], Richard Kidd [k], William Lahoz [g], Yi Y. Liu [l] … Pascal Lecomte [q]

Show more

Data Descriptor | Open Access | Published: 12 July 2021

Global soil moisture data derived through machine learning trained with *in-situ* measurements

Sungmin O. & Rene Orth

Scientific Data **8**, Article number: 170 (2021) | Cite this article

Merging Framework

Gridded data\Method	Unweighted averaging	Optimal Linear Combination (using in situ soil moisture observations)	Emergent Constraint (using gridded observed meteorological data)
Offline land surface model simulations, Reanalysis, and Satellite	Mean ORS	OLC ORS	EC ORS
Earth system models (CMIP5, CMIP6)	—	—	EC CMIP5, EC CMIP6, EC CMIP5+6
ORS and Earth system models	—	—	EC ALL

7 hybrid SM products based on 3 merging methods:

- ✓ *Coverage: global, 1970−2016;*
- ✓ *Spatial resolution: 0.5°;*
- ✓ *Temporal resolution: monthly;*
- ✓ *Vertical layers: 0-10cm, 10-30cm, 30-50cm, 50-100cm;*

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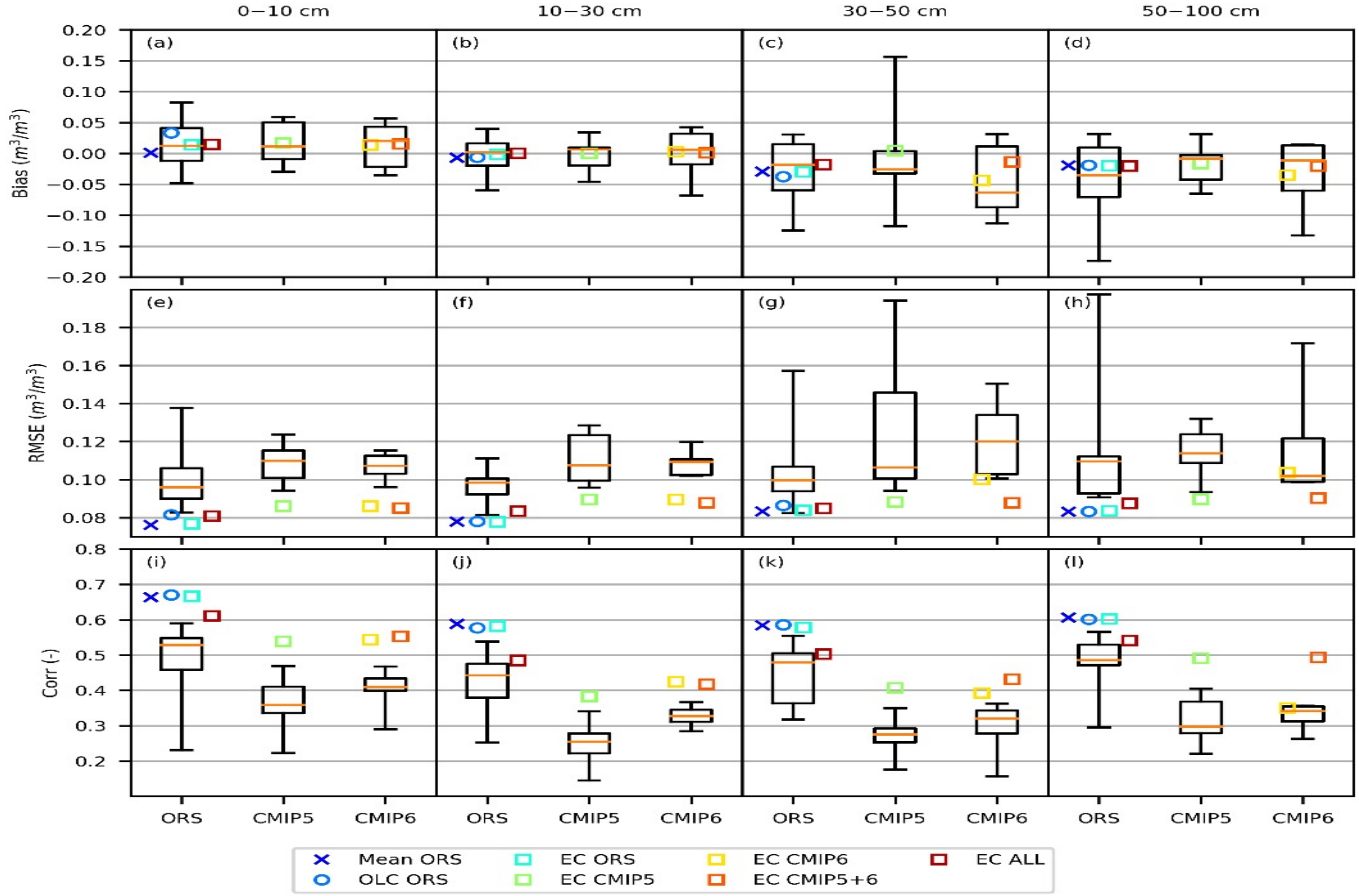
Evaluation Datasets

Dataset	Type	Period	Depth (cm)	Resolution	Coverage	Reference
SMOS L3 RE04 MIR_CLF3MA, MIR_CLF3MD	Satellite	2010–2020	Surface (0–5)	~25 km	Global with missing values	(Al Bitar et al., 2017)
SMOS L4 SCIE MIR_CLM4RD	Reanalysis	2010–2020	0–100	~25 km	Global with missing values	(Al Bitar et al., 2013)
GLEAM v3.3a	Reanalysis	1980–2018	0–100	0.25°	Global	(Martens et al., 2017)
SMERGE v2	Reanalysis	1979–2019	0–40	0.125°	Contiguous United States	(Tobin et al., 2017)
SoMo.ml	Machine learning upscaled from in situ observations	2000–2019	0–10, 10–30, 30–50	0.25°	Global	(O and Orth, 2020)

Performance of the Merged SM Products (Site Eval.)



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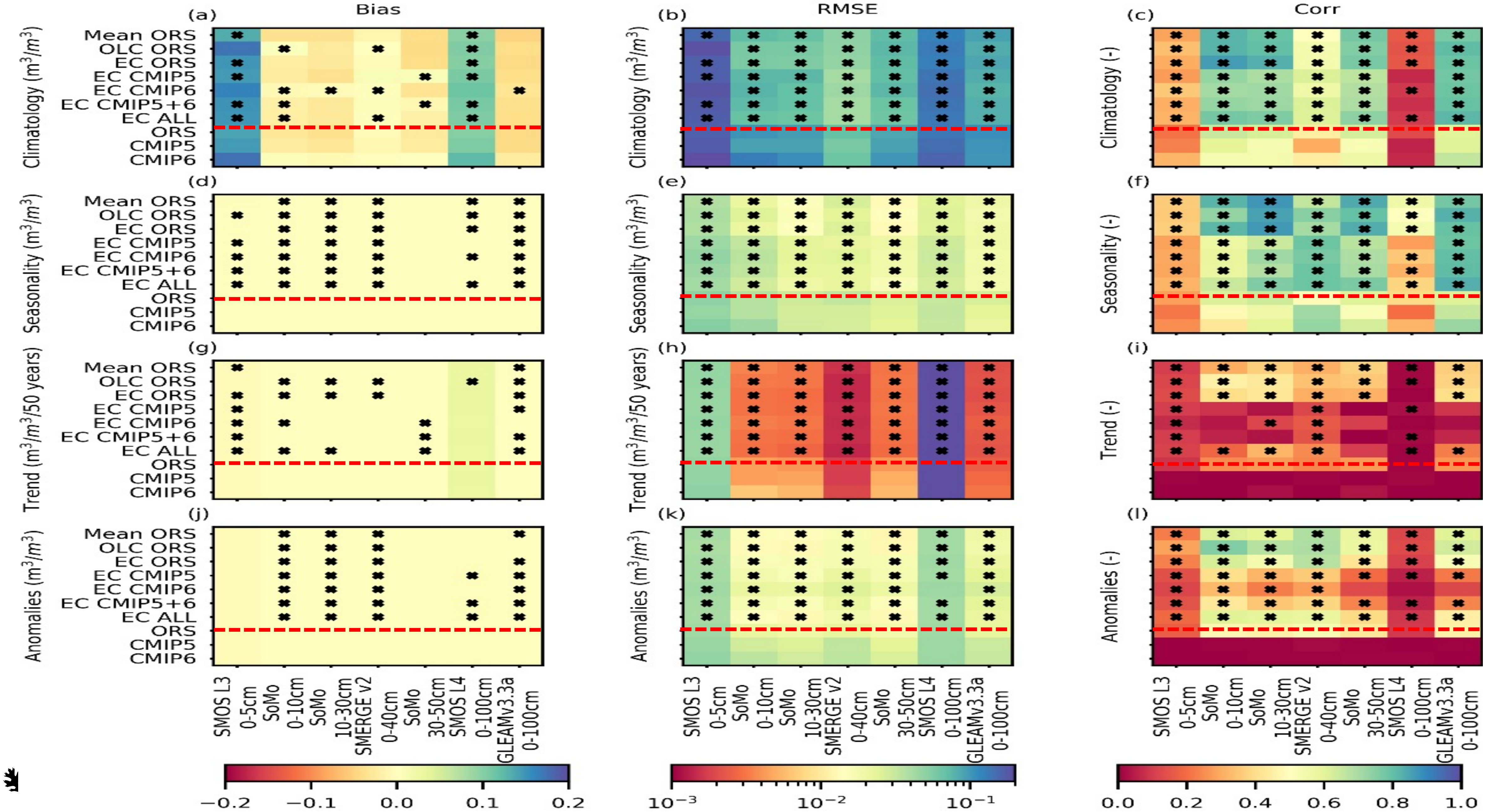
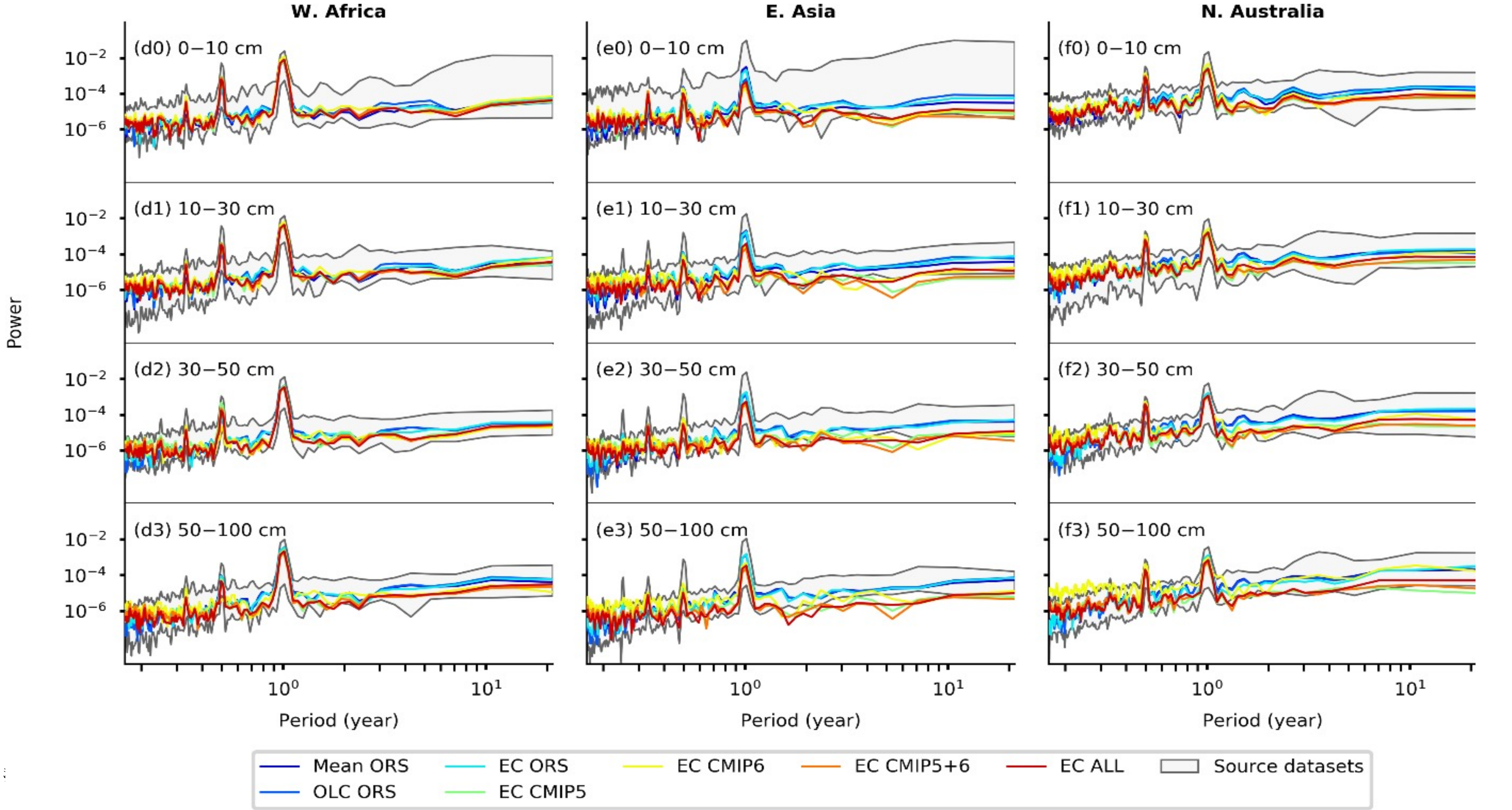
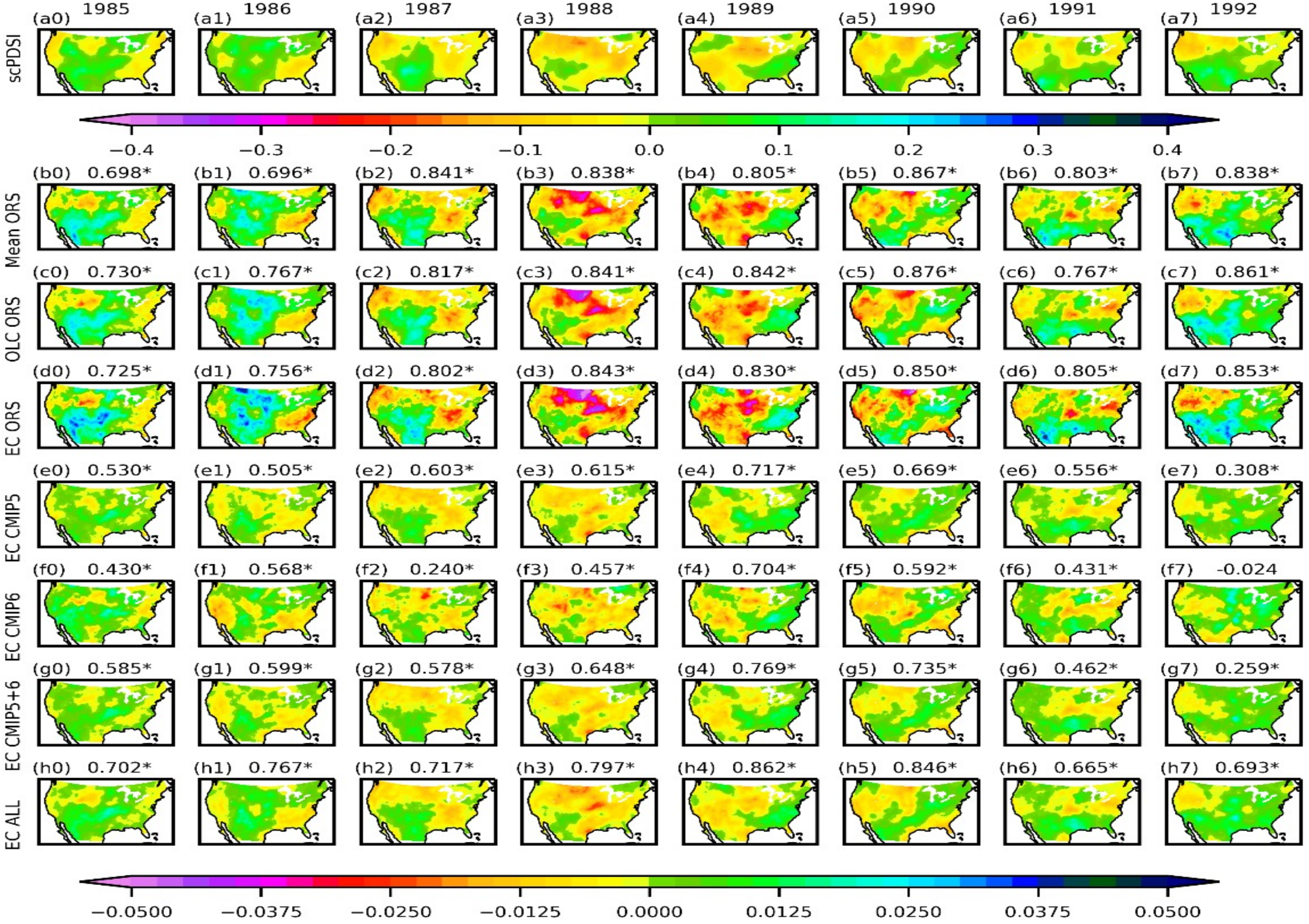
Performance of the Merged SM Products (Global Eval.)



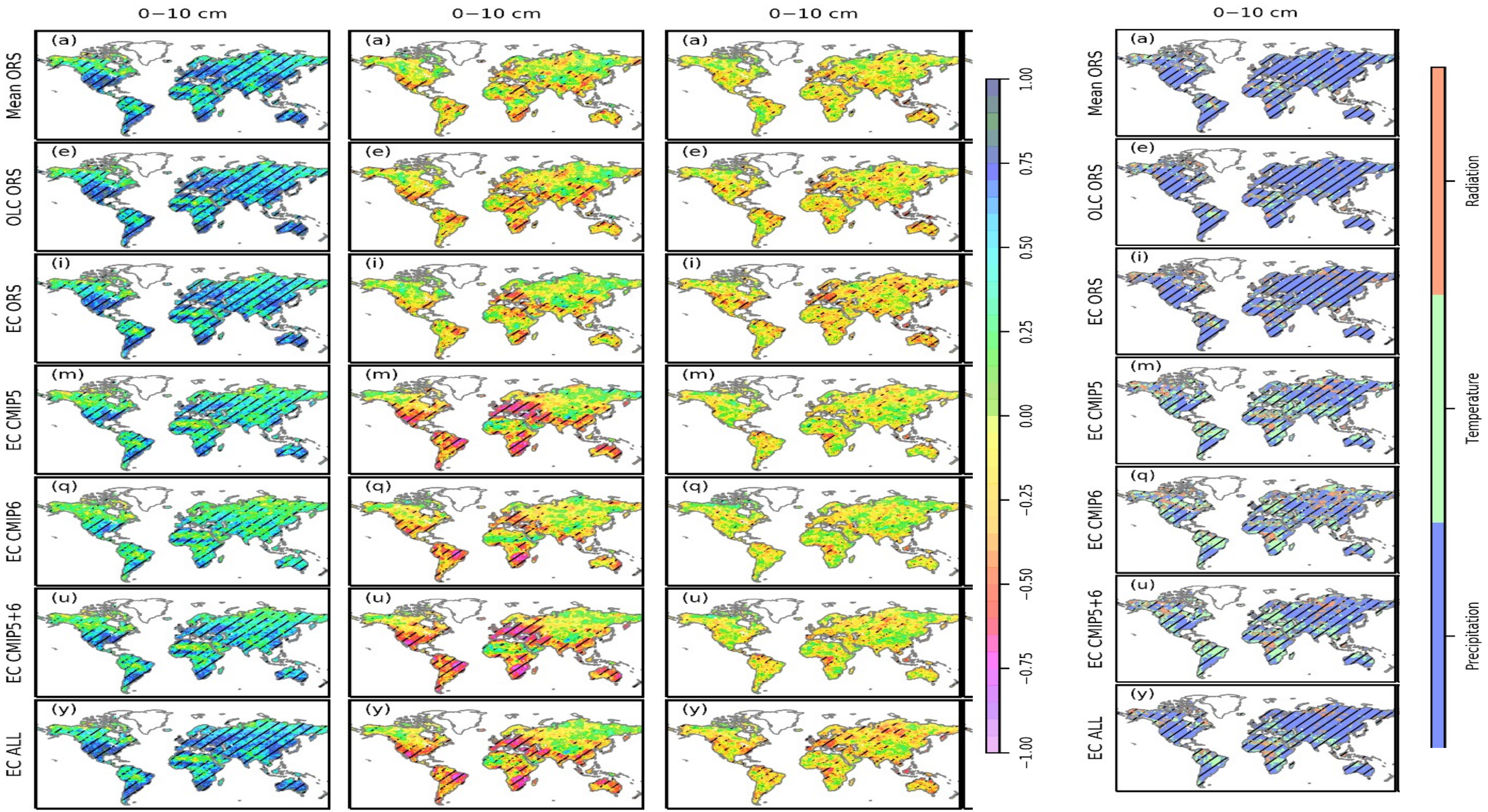
Performance of the Merged SM Products (Frequency Eval.)



Performance of the Merged SM Products (Drought Eval.)



Performance of the Merged SM Products (Sensitivity Eval.)



Partial correlations with Precipitation (left), Temperature (middle), and shortwave radiation (right)

Dominant driving factors

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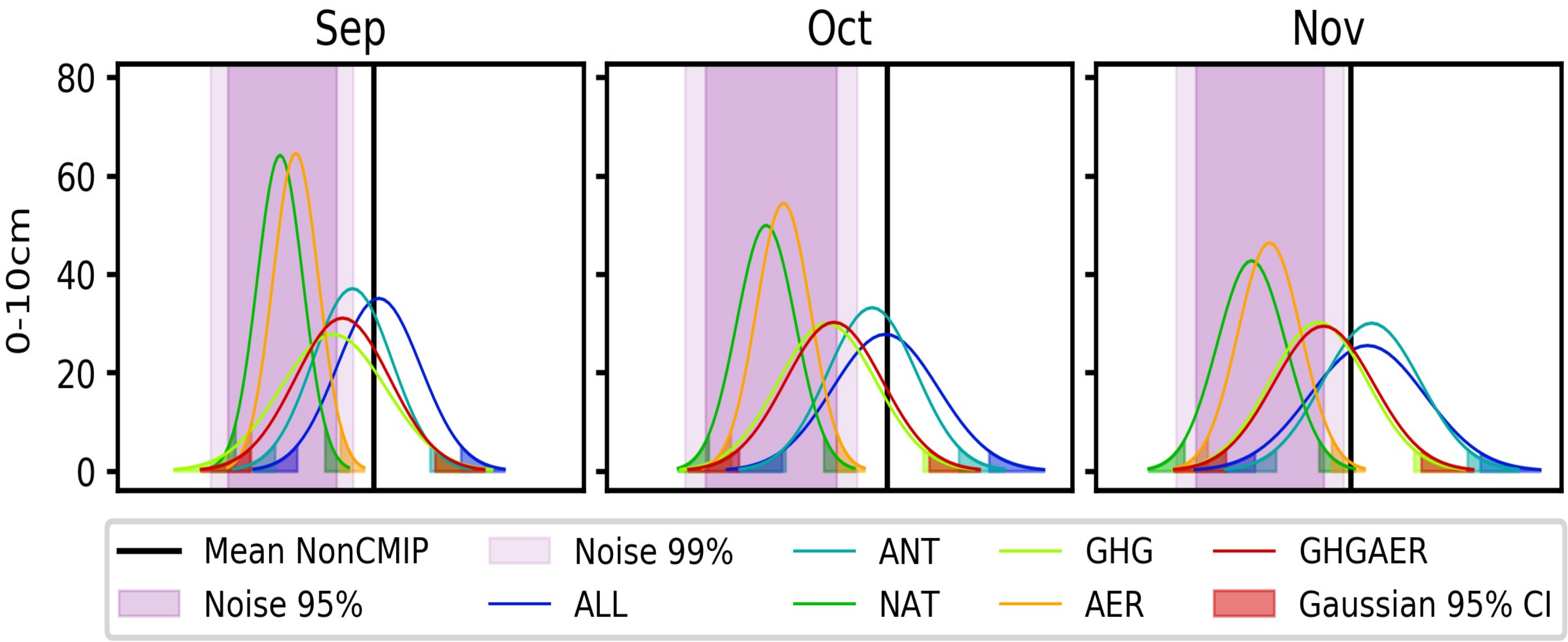
Application I: Quantification of Human Contribution to Soil Moisture-based terrestrial aridity



Yaoping Wang, Jiafu Mao*, Forrest M. Hoffman, Céline J. W. Bonfils, Hervé Douville, Mingzhou Jin, Peter E. Thornton, Daniel M. Ricciuto, Xiaoying Shi, Haishan Chen, Stan D. Wullschleger, Shilong Piao, and Yongjiu Dai, ***Quantification of Human Contribution to Soil Moisture-based terrestrial aridity***, Under review, 2021.

- ✓ Only some months of the year contain detectable signal, indicating the presence of seasonal variability;
- ✓ The signals are attributable to anthropogenic forcings (ALL/ANT), especially greenhouse gases (GHG);
- ✓ Provide a comprehensive basis for drought risk reduction strategies and activities;

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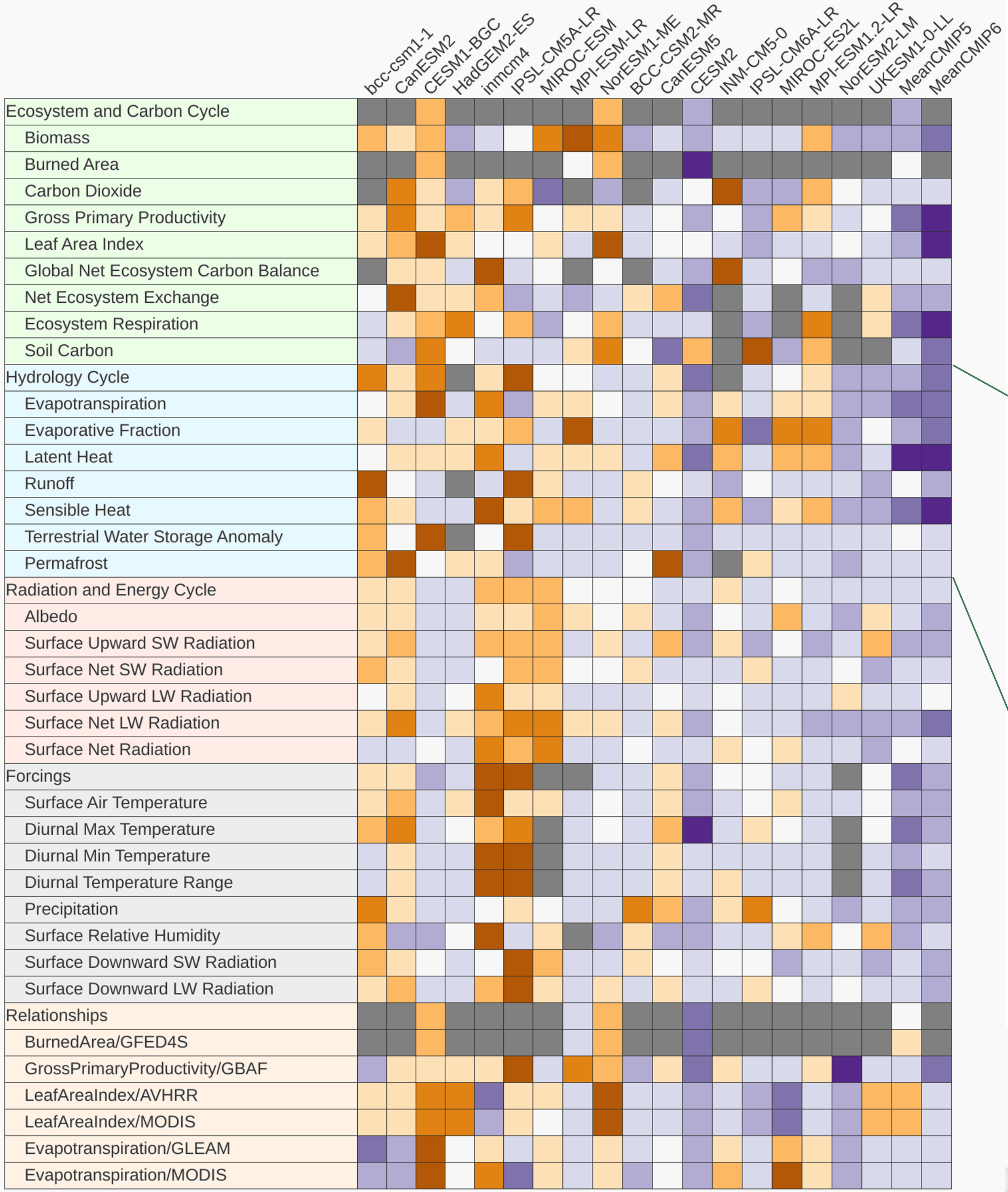
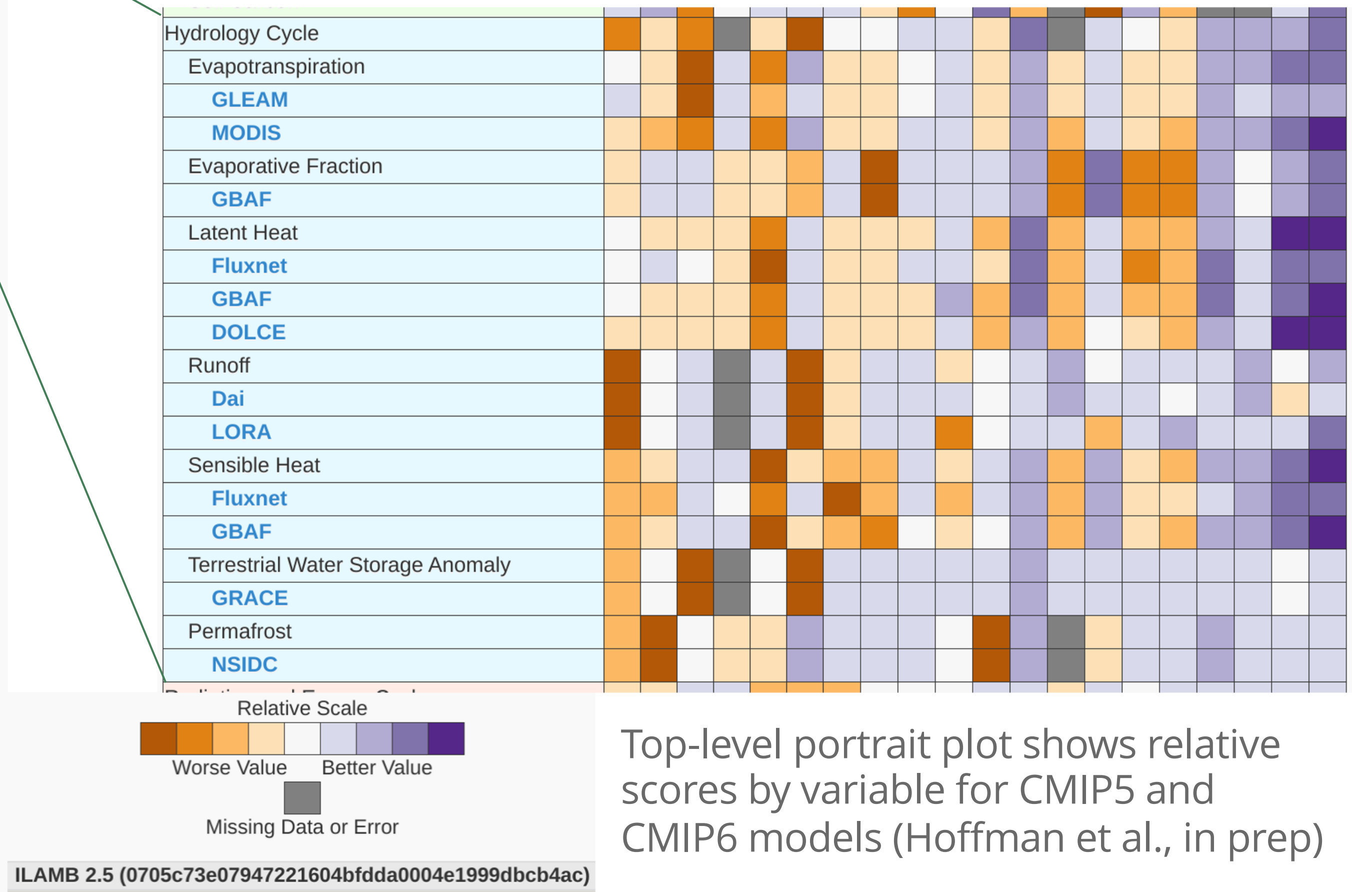
Application II: ILAMB Hydrology Benchmarking

- ILAMB evaluates model results by comparing with global-, regional-, and site-scale data
- The current set of variables and datasets (blue text) are shown below



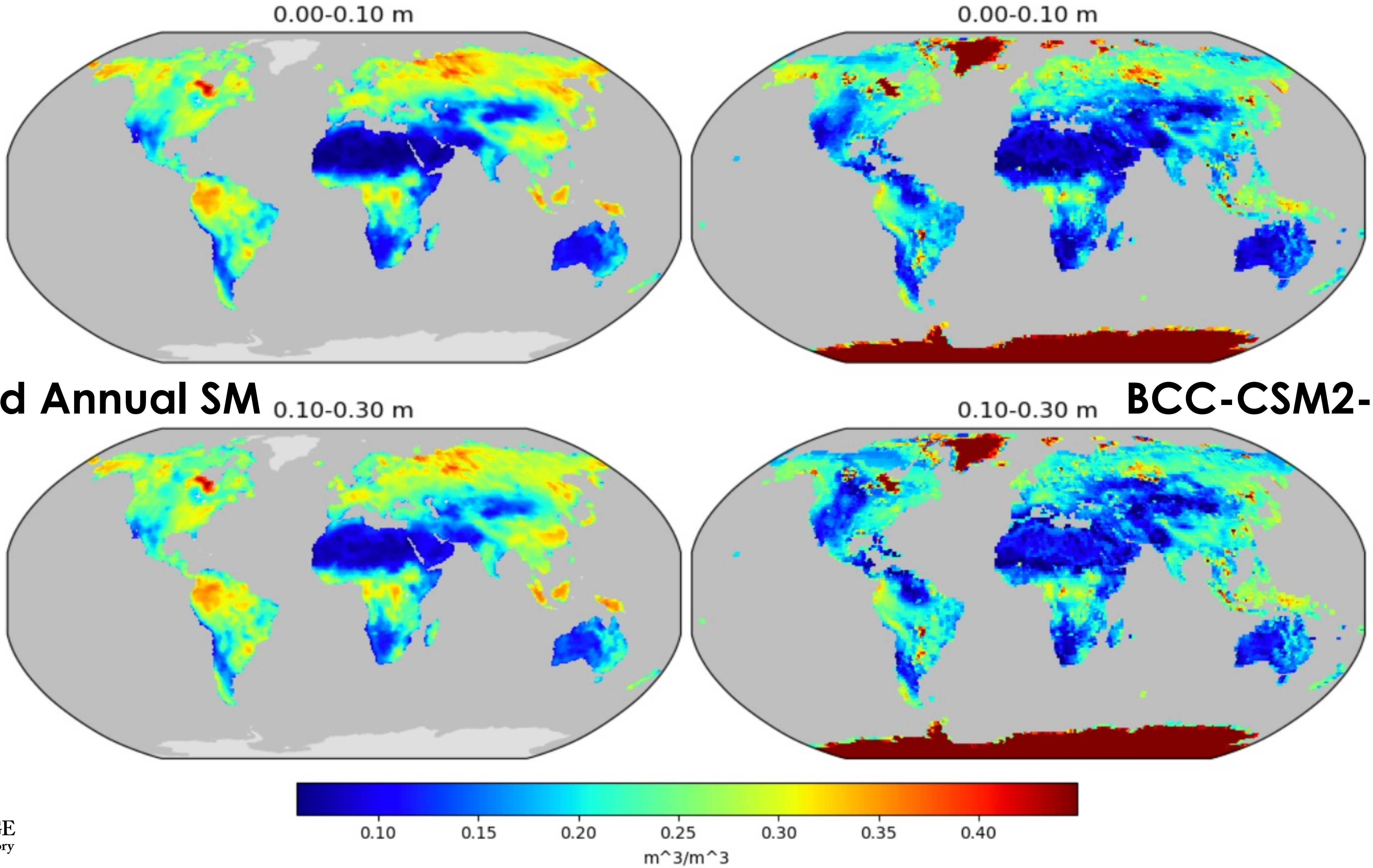


Top-level portrait plot shows relative scores by variable for CMIP5 and CMIP6 models (Hoffman et al., in prep)

Application II: ILAMB SM Benchmarking

Merged Annual SM

BCC-CSM2-MR SM



Summary of the Merged SM Products

- Achieved the goal of creating long-term, gap-free, multi-layer SM products (https://doi.org/10.6084/m9.figshare.13661312.v1);
- The merged SM products showed reasonable performances, and were broadly within the estimates reported by previous SM evaluations;
- Three "offline-based" SM products (mean ORS, OLC ORS, and EC ORS) were generally shown to perform better than those "online-based" ESM products;
- Opening doors to new applications;

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Next Steps

- **Further Application and Development**
  - ✓ *Analyze the impacts of long-term soil moisture changes on above- and belowground C dynamics;*
  - ✓ *Provide the initial and boundary conditions for atmospheric models;*
  - ✓ Assemble more in situ SM datasets and implement other advanced fusion algorithms;
- **New Ecohydrology Working Group**
  - ✓ *Leverage existing AmeriFlux/SOC-RUBISCO;*
  - ✓ *Understand and benchmark the global SM dynamics using multi-source and multi-scale datasets;*
  - ✓ *Improve existing SM databases and benchmarking methods;*
  - ✓ *Find innovative ways to use benchmarking results to improve model parameterization, predictions, and projections.*

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Thanks for Your Attention!
Questions and Comments?