Sub-monthly Timescale Causality between Snow Cover and Surface Air Temperature in the Northern Hemisphere Inferred by Liang–Kleeman Information Flow Analysis

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Takaya, Y, K. K. Komatsu, N. Ganeshi, T. Toyoda, H. Hasumi: A sub-monthly timescale causality between snow cover and surface air temperature in the Northern Hemisphere inferred by Liang–Kleeman information flow analysis, *Clim. Dyn.* (in revision)

Komatsu, K. K., Y. Takaya, T. Toyoda, and H. Hasumi, (2023): A submonthly scale causal relation between snow cover and surface air temperature over the autumnal Eurasian continent. *J. Climate*, 36, 4863–4877.

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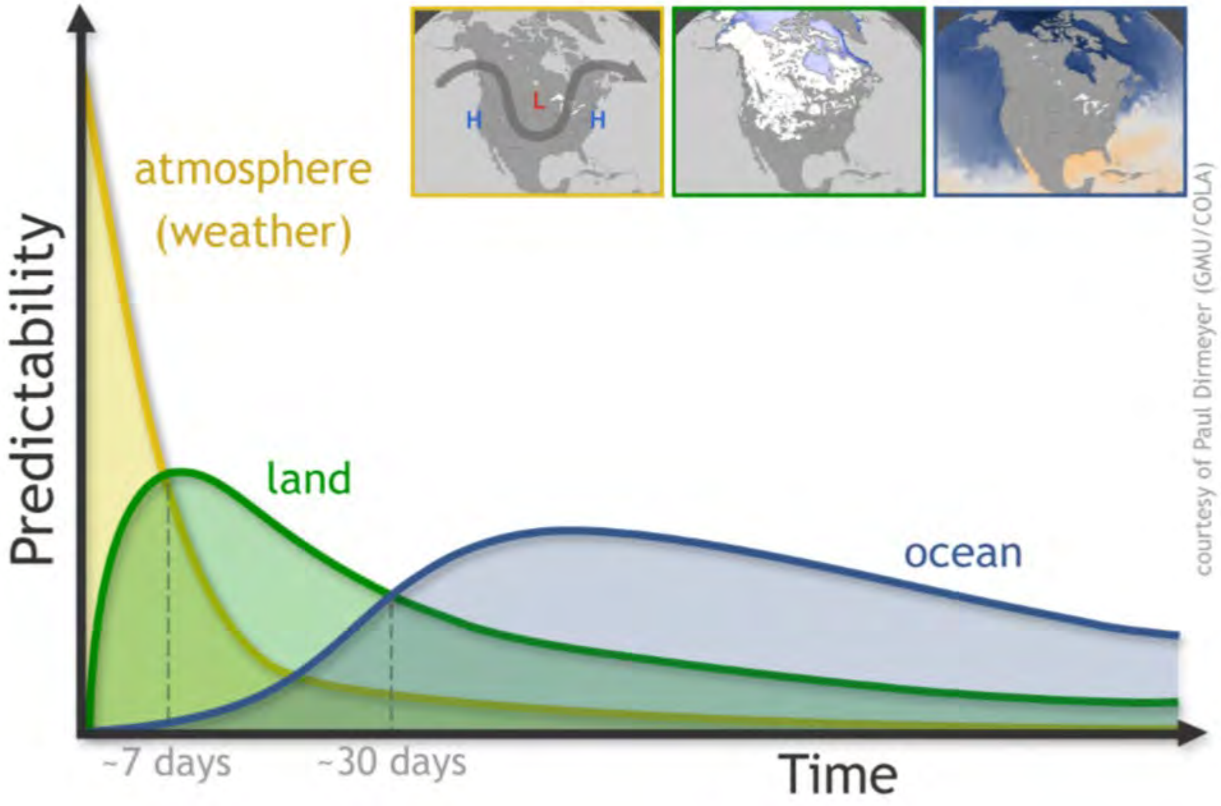
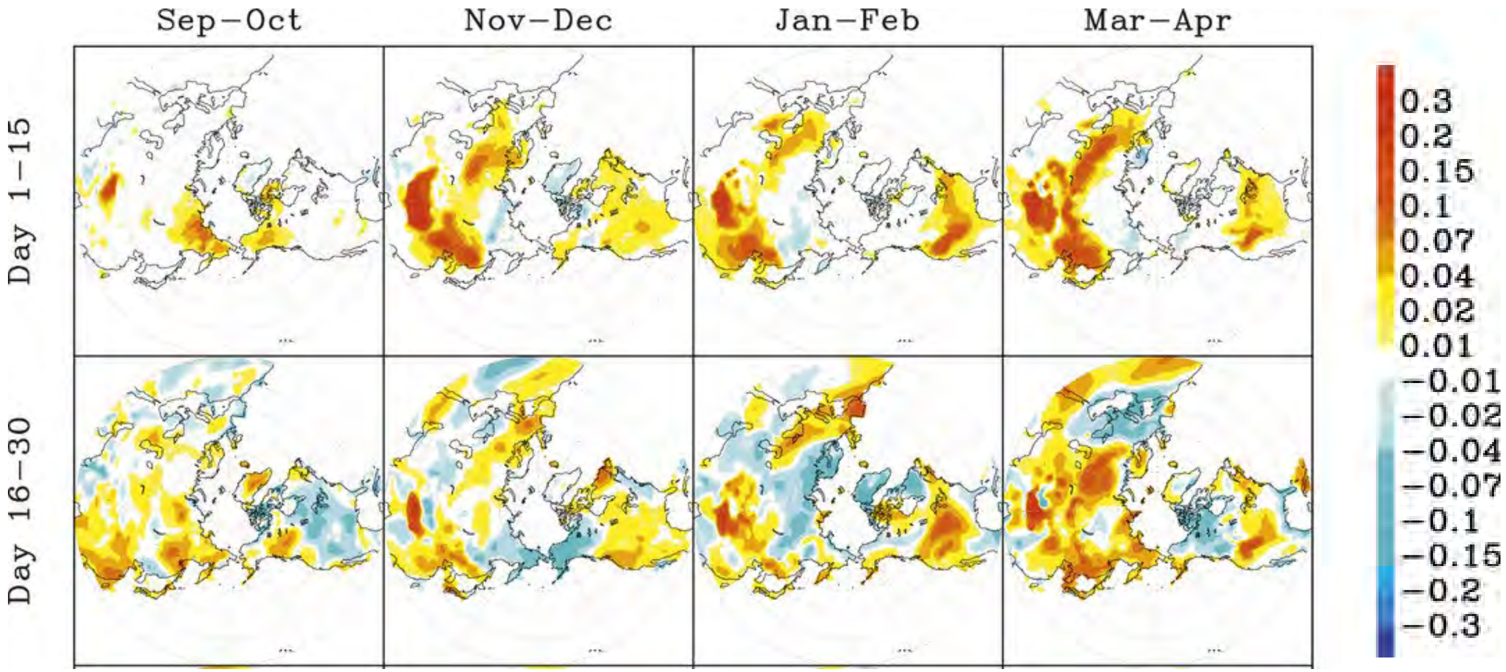


The ocean and land conditions are important sources of the predictability for the S2S prediction.

In particular, roles of the land are considered important over mid-latitude continents, where the S2S forecast skill remains low.

Source: Prof. Paul Dirmeyer (GMU/COLA)

Introduction : Land impacts in the S2S prediction



Snow impacts

Change in potential predictability (r^2) of SAT hindcast using the snow depth initialization

(Experiment using the CAM3 model with the CMC land analysis)

During snowmelt season, snow–atmosphere coupling is strongest over many parts of midlatitude Eurasia and America.

Source: Jeong et al. (2013)

Purpose of this study

Previous studies

Assessed snow impacts using statistical analysis (correlation/regression) or model sensitivity experiments

This study (Komatsu et al. 2023, Takaya et al. in revision)

- Evaluating the snow impacts using a simplified transfer entropy analysis (Liang-Kleeman information flow)
- Diagnosing models' representation of snow-SAT interaction
- Underpinning the predictability originated from the snow condition in S2S models

Method: Liang-Kleeman information flow

Simplified transfer entropy analysis

Liang (2014) deduced rigorous formula to compute maximum likelihood estimate of information flow ($T_{2\rightarrow1}$) using variance and covariance of X_1 and X_2.

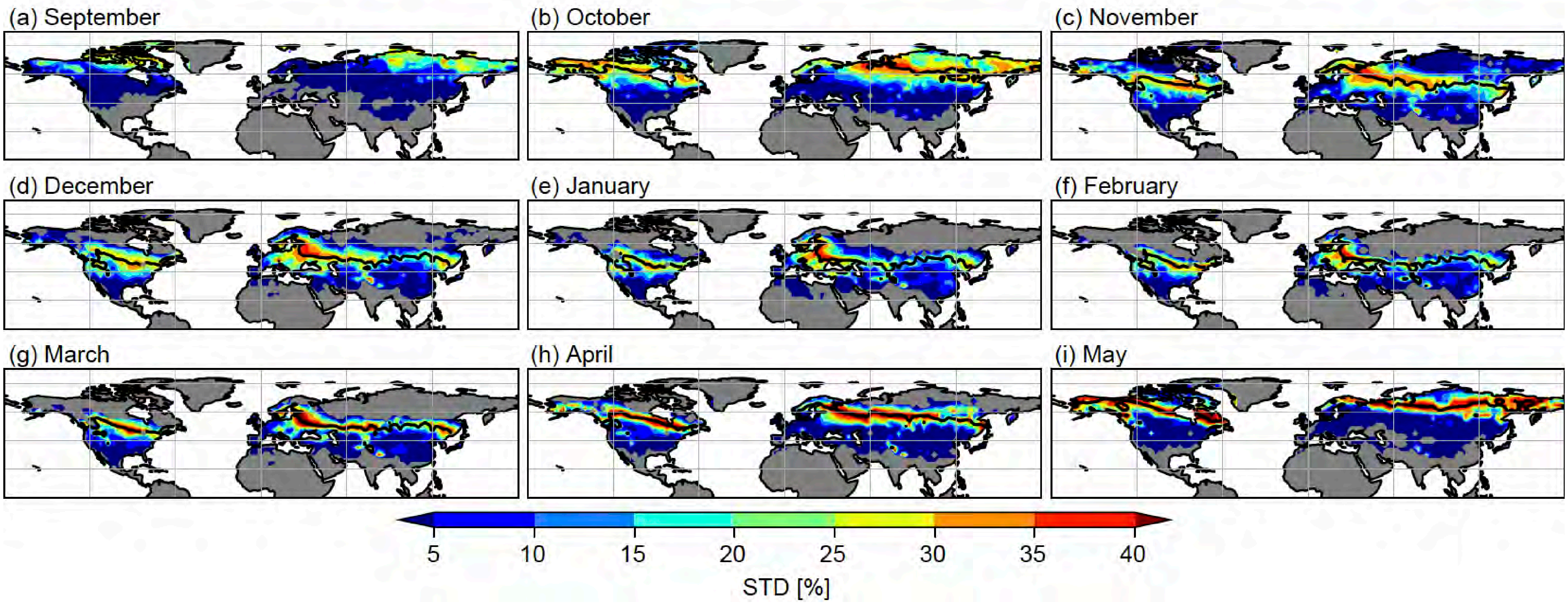
$$T_{2\rightarrow1} = \frac{C_{11}C_{12}C_{2,d1} - C_{12}^2 C_{1,d1}}{C_{11}^2 C_{22} - C_{11}C_{12}^2},$$

C：(co)variance, d1：forward differential of X_1

This study uses the normalized information flow (Liang 2016)

$$\tau_{2\rightarrow1} = T_{2\rightarrow1}/Z_{2\rightarrow1}. \qquad Z_{2\rightarrow1} \equiv |T_{2\rightarrow1}| + \left|\frac{dH_1^*}{dt}\right| + \left|\frac{dH_1^{\text{noise}}}{dt}\right|.$$

Standard deviation of weekly average SC (MERRA-2)



Black contours: mean SC of 50%

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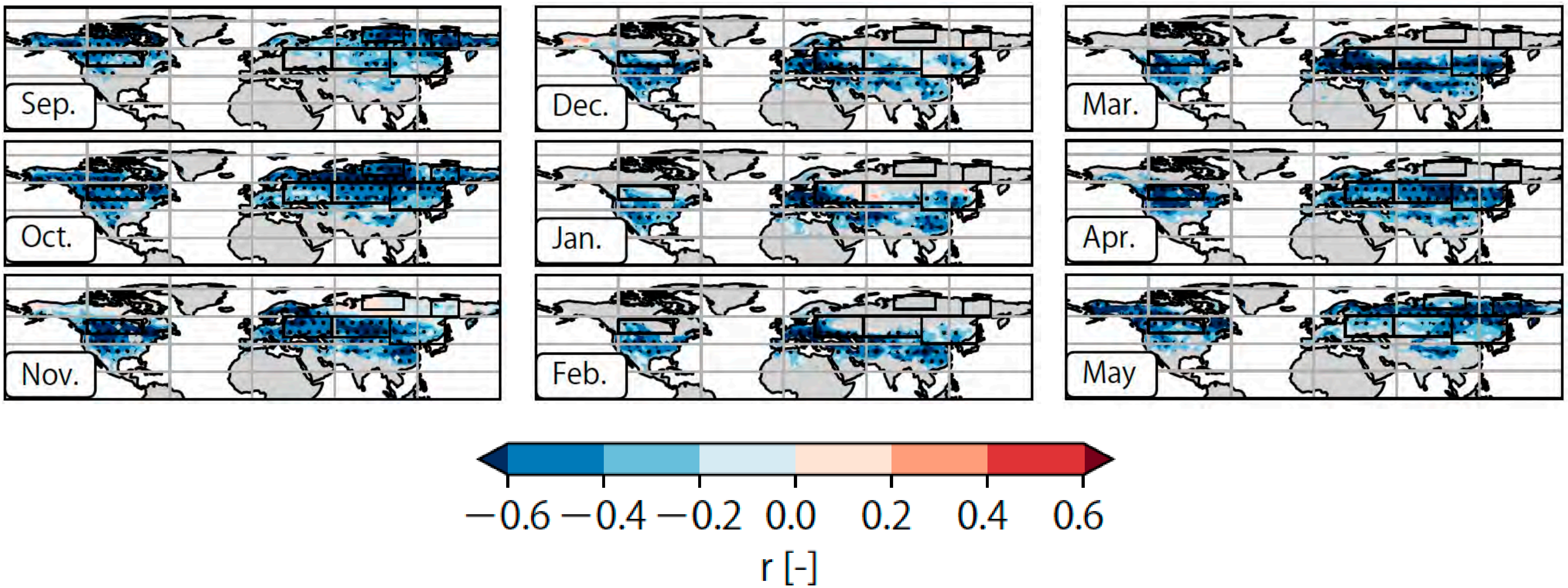
T2m-SC Correlation (MERRA-2)



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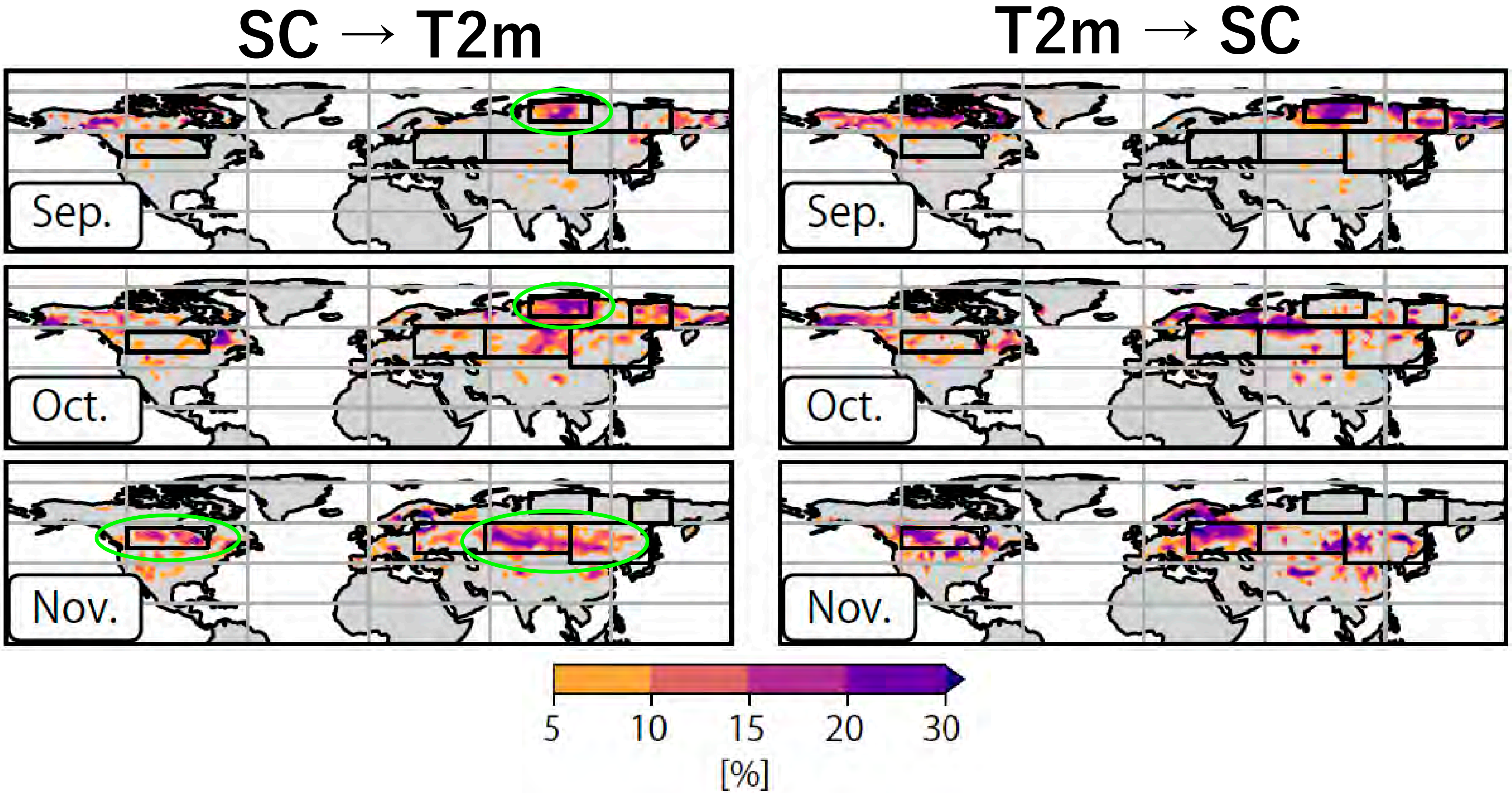
T2m-SC Liang-Kleeman information flow (MERRA-2)



Information flow was computed using four consecutive weeks.

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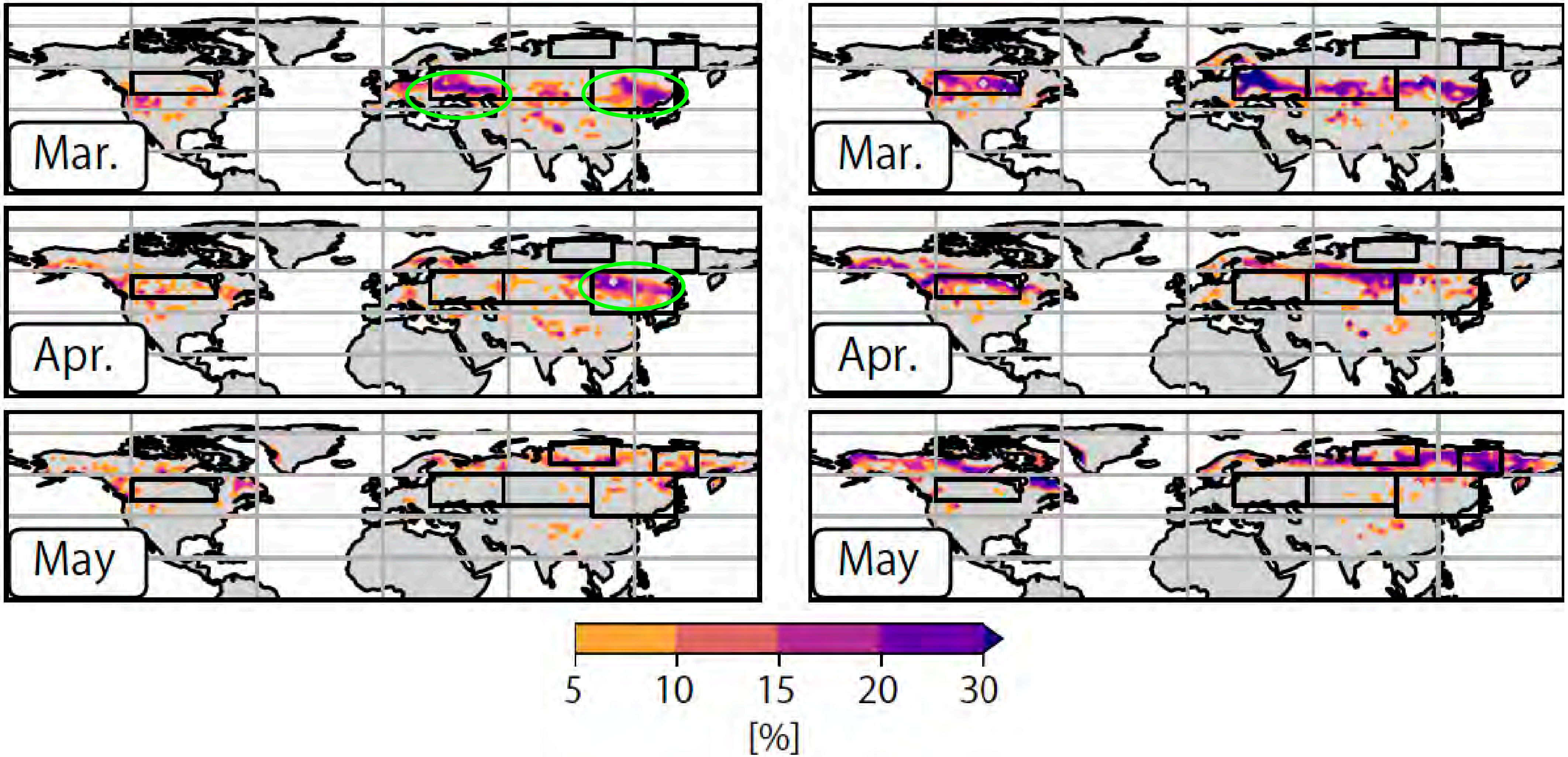
T2m-SC Liang-Kleeman information flow (MERRA-2)

SC → T2m

T2m → SC



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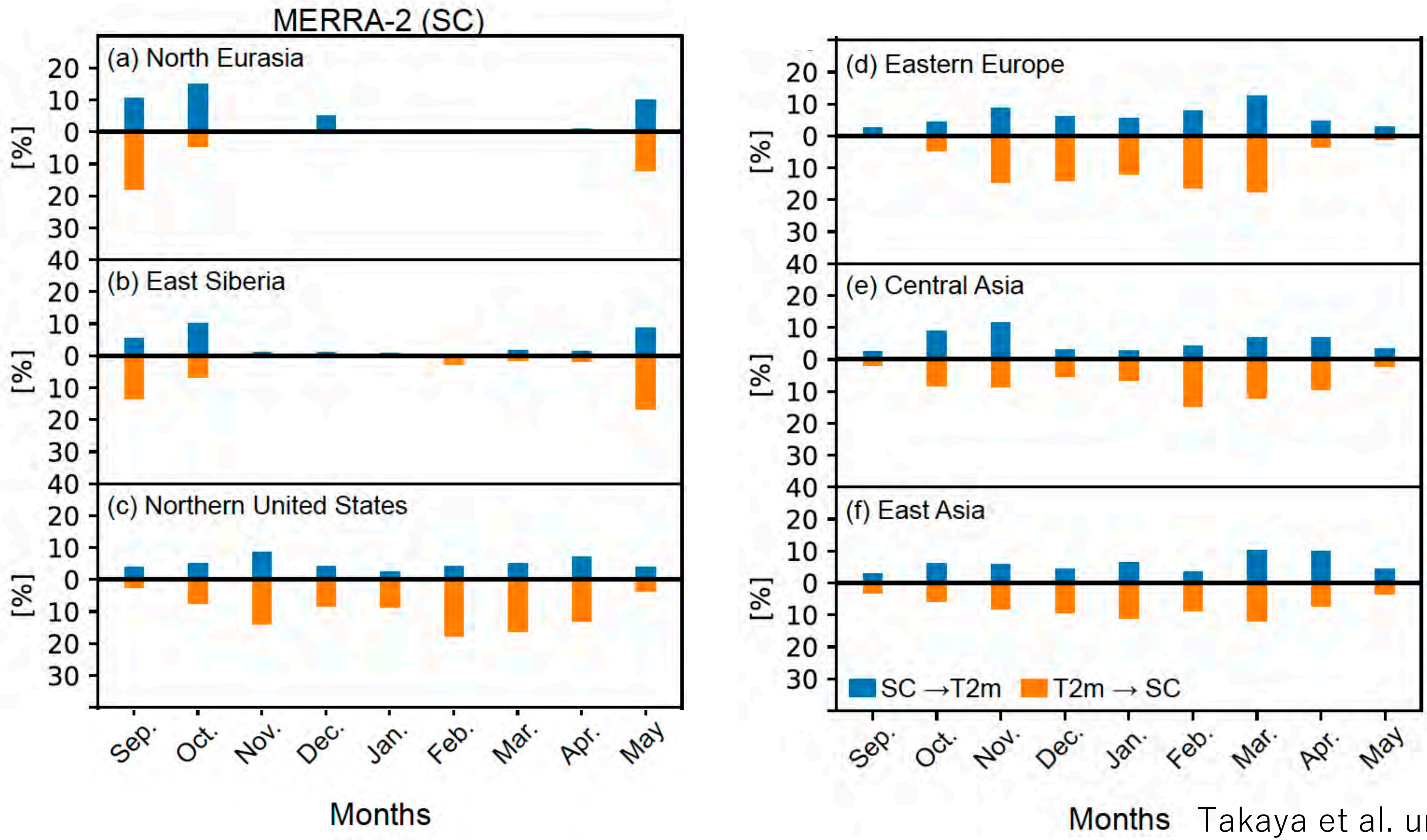

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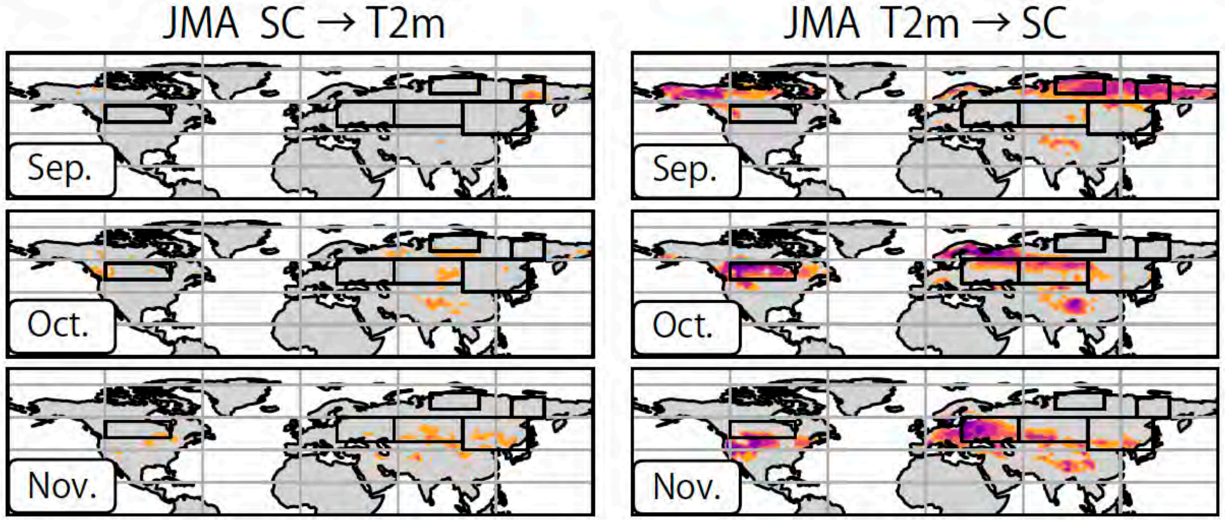
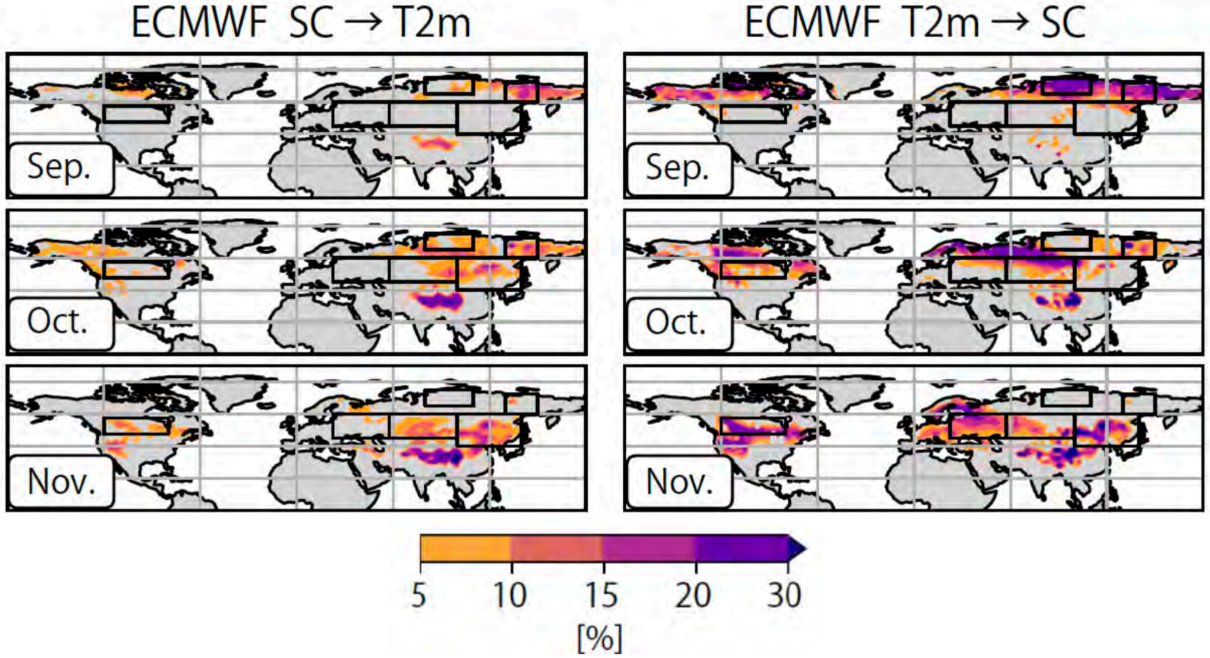
T2m-SC Liang-Kleeman information flow (S2S model)

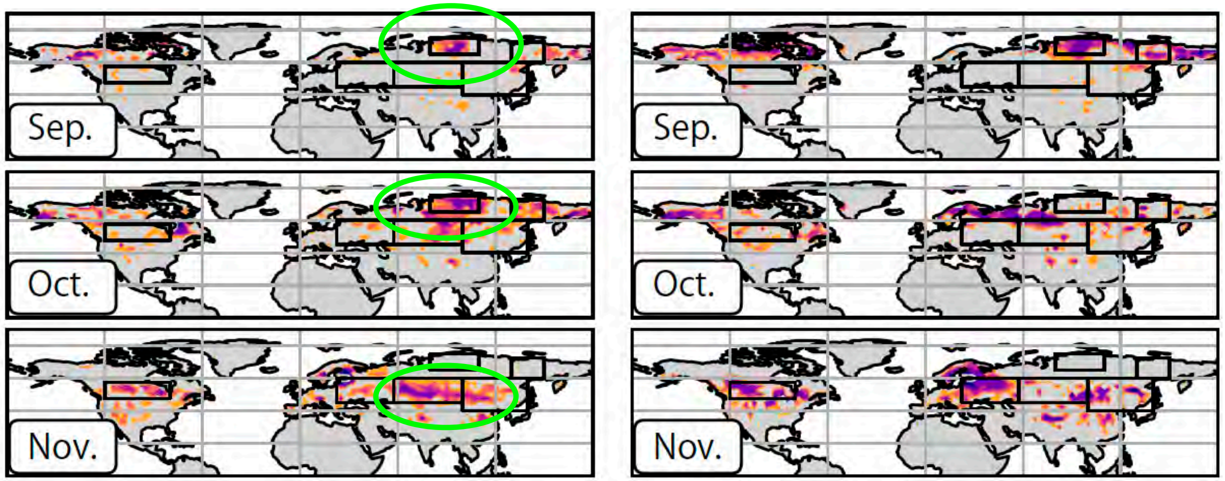
JMA



ECMWF



MERRA-2



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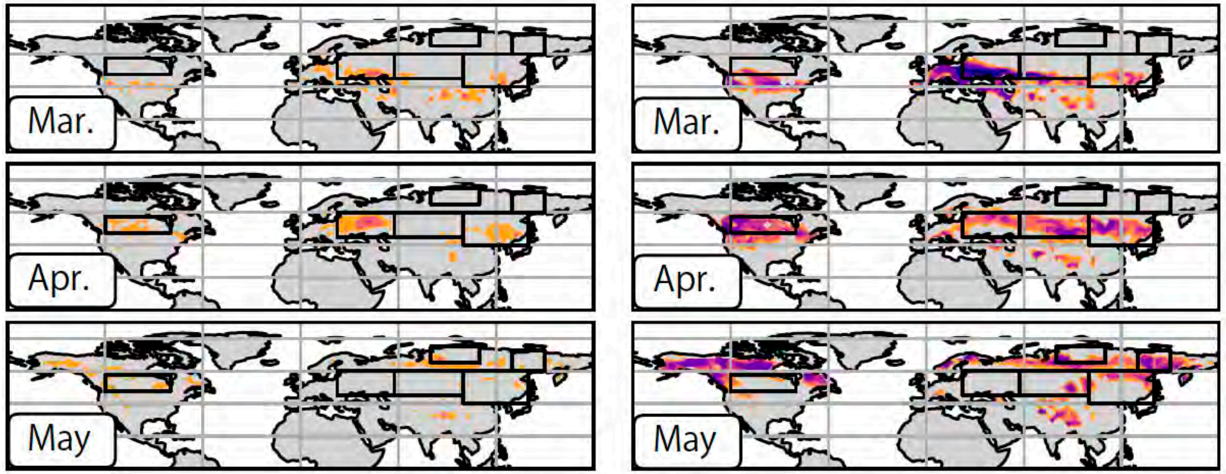
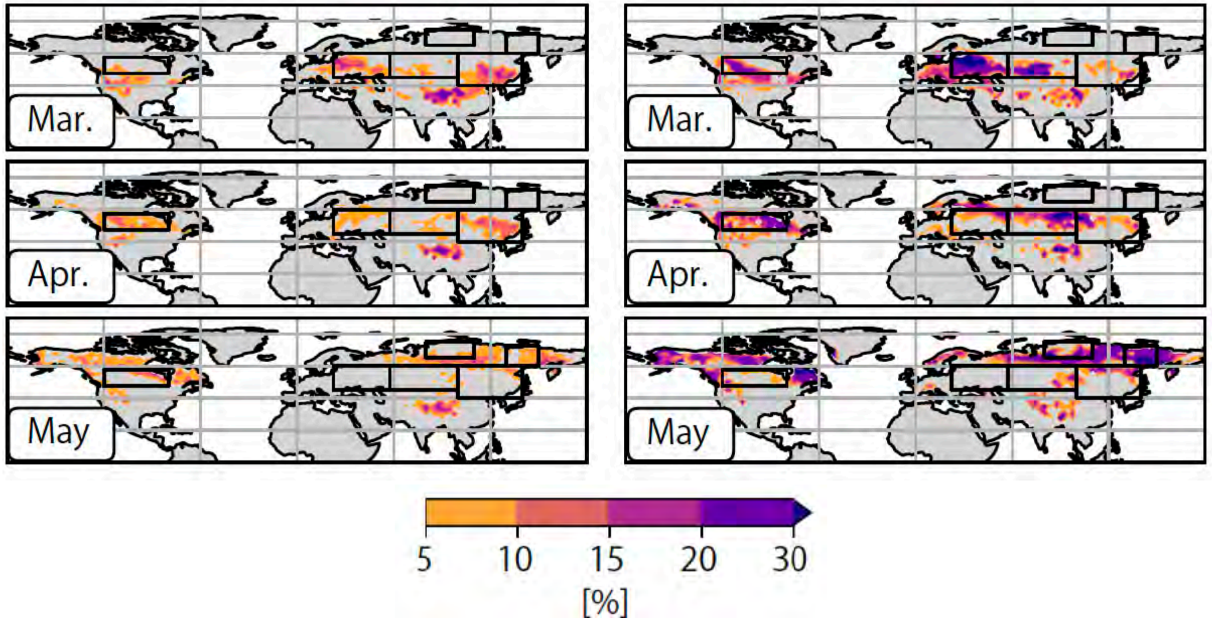
T2m-SC Liang-Kleeman information flow (S2S model)

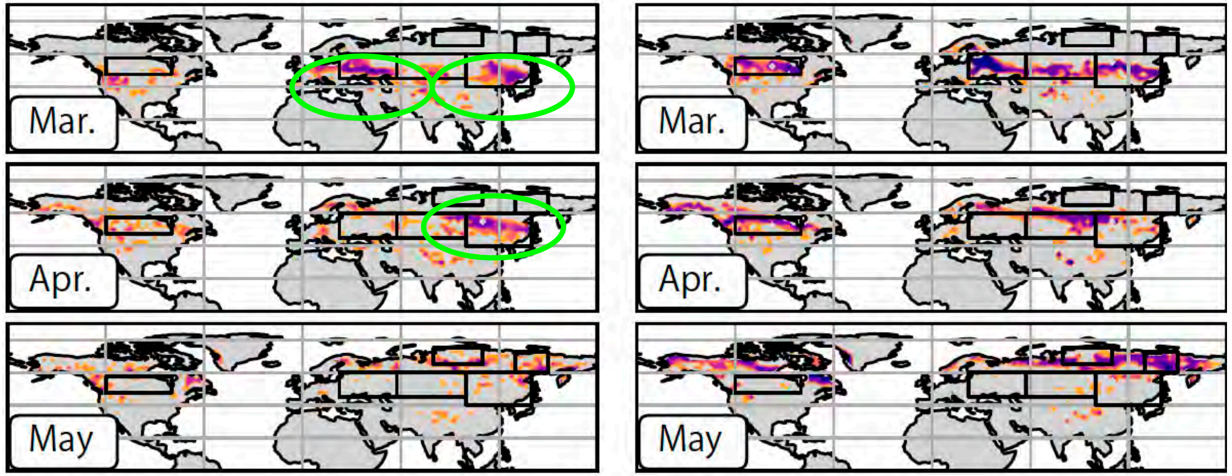
JMA



ECMWF



MERRA-2



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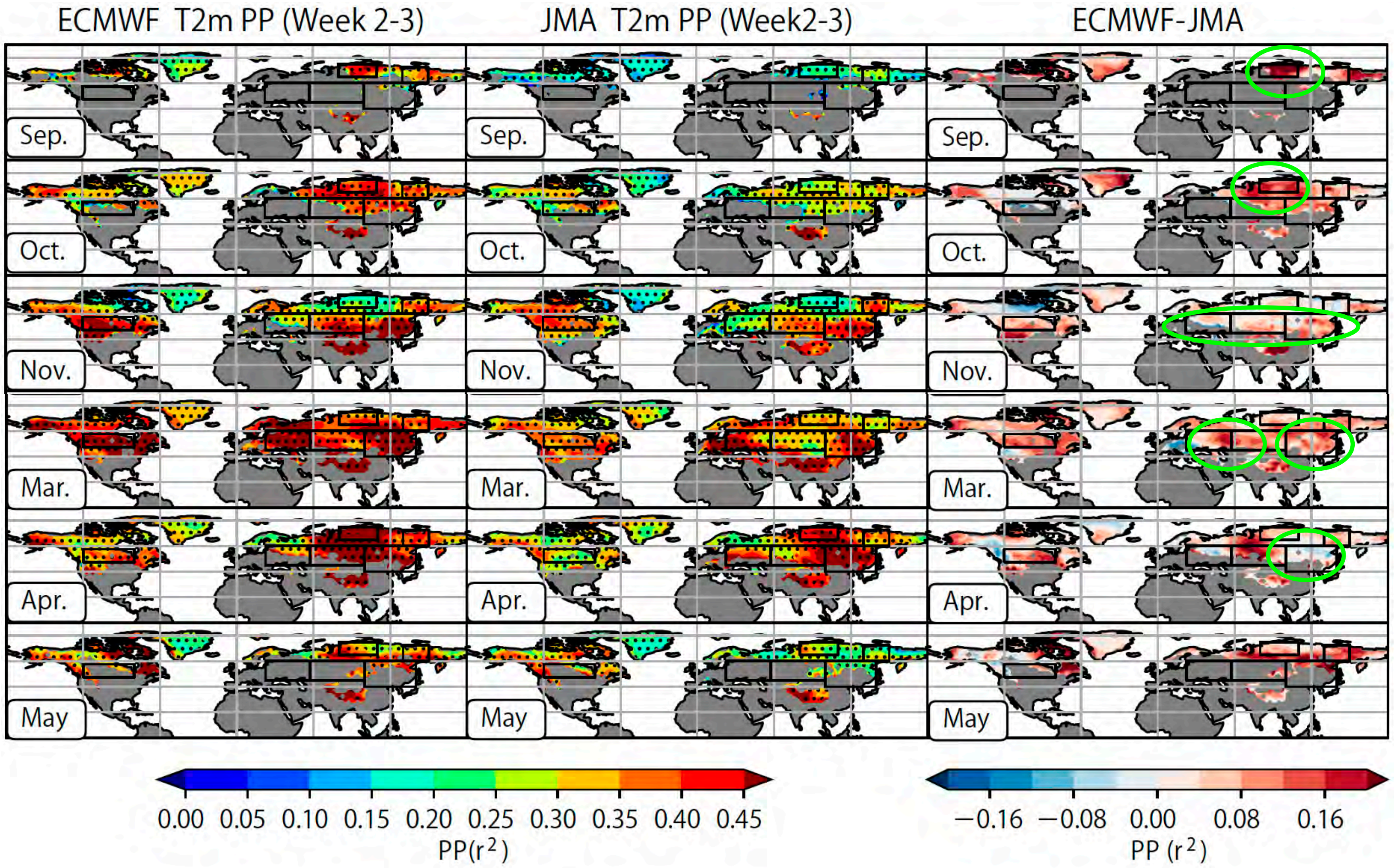
Impacts on the potential predictability of SAT



The potential predictability over the cold spots tends to be lower in the JMA model than in the ECMWF model (Except for East Asia in April)

Strong SC effect on SAT
→ High SAT potential predictability

Weak SC effect on SAT
→ Low SAT potential predictability

It may a natural conclusions as the entropy is mathematically related to the potential predictability measured by the correlation (r^2).

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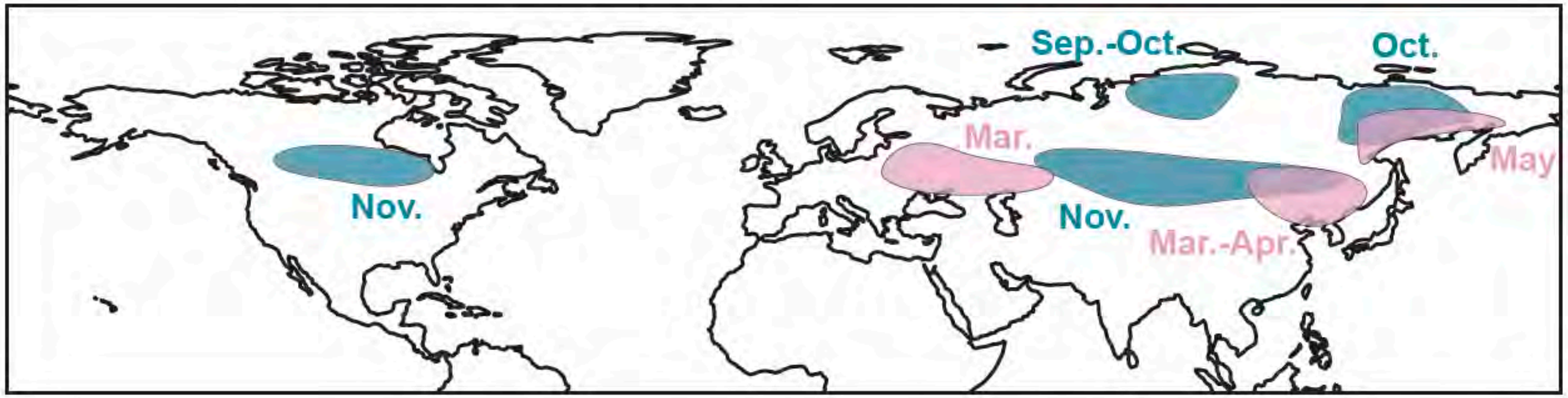
Summary

- This study investigated the sub-monthly causal relationship between observed snow cover (SC) and surface air temperature (SAT) in the Northern Hemisphere.
- Evaluation of S2S models revealed the shortcomings of the model in representing snow influence on SAT.
- The diagnostics of this study are useful for advancing our understanding of S2S predictability and contributing to the future improvement of S2S prediction.

'Cold spots' identified by Liang-Kleeman information flow analysis



Takaya et al. : A sub-monthly timescale causality between snow cover and surface air temperature in the Northern Hemisphere inferred by Liang–Kleeman information flow analysis, *Clim. Dyn*. (under review)