The Limits of Detecting Forced Responses on Seasonal and Continental Scales

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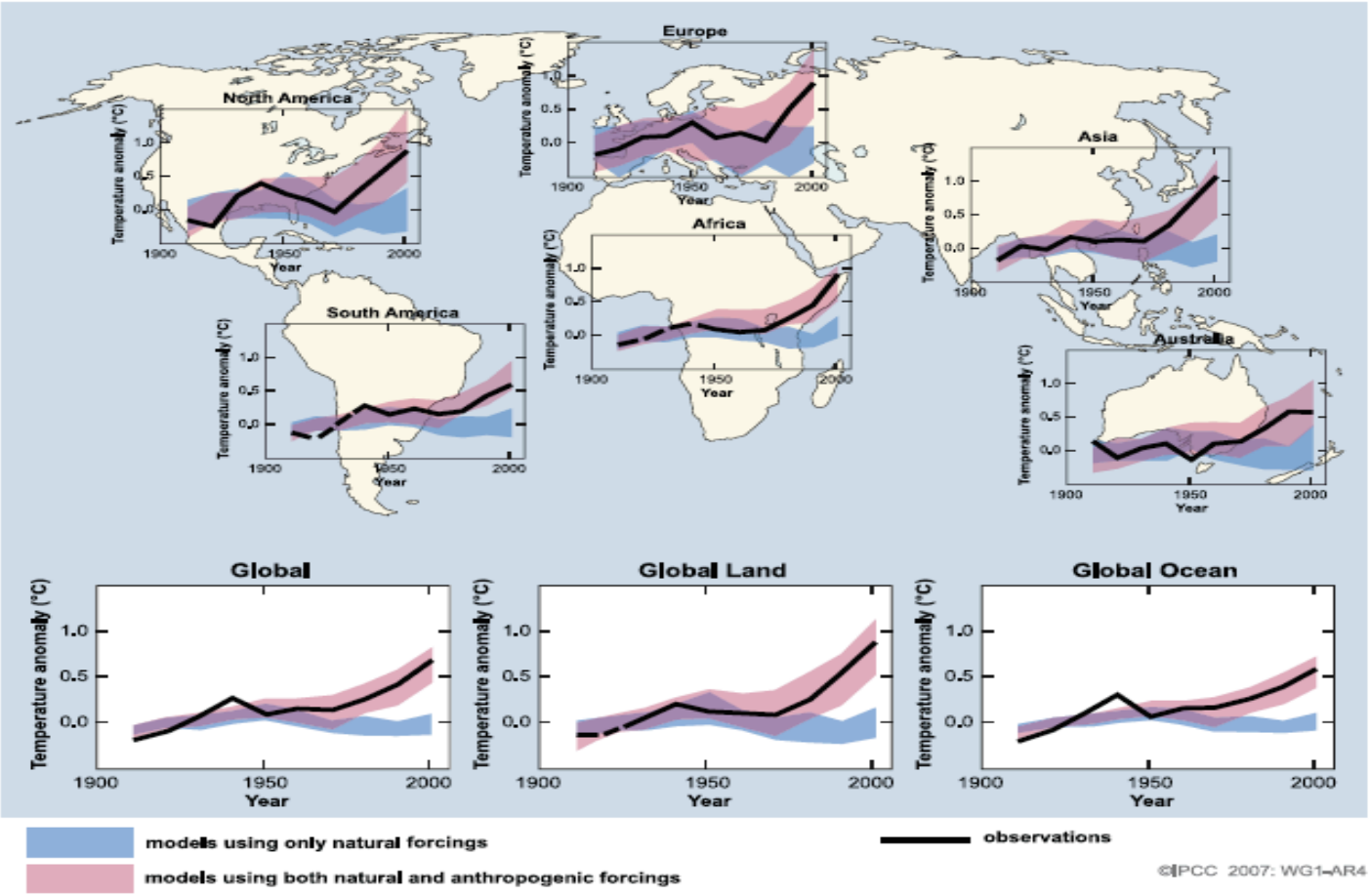
Temperature Response to External Forcing



Simulated and observed global and continental temperature changes (IPCC).

Red: middle 90% simulations that include natural and human factors.

Blue: middle 90% simulations that include only natural factors.

Questions

- What are the shortest space and time scales for which detection, attribution, and prediction of the forced response are possible (i.e., the limits of detecting forced response)?

- Can we identify forced response objectively with limited spatial and temporal averaging?

Identification of Forced Response (1/2)

Assume forced & unforced variability are independent and additive,

$$\sigma_T^2 = \sigma_U^2 + \sigma_F^2$$

- Variance of simulations with forcing (20C runs):

$$\sigma_{20c}^2 = \sigma_U^2 + \sigma_F^2$$

- Variance of simulations without forcing (PICNTRL runs): $\sigma_{control}^2 = \sigma_U^2$

$$\phi = \frac{\sigma_{20C}^2}{\sigma_{control}^2} = \frac{\sigma_U^2 + \sigma_F^2}{\sigma_U^2} = 1 + \frac{\sigma_F^2}{\sigma_U^2}$$

The larger the ratio, the more forced response.

Identification of Forced Response (2/2)

- Find spatial weights q, such that the linear combination of variables maximizes ϕ .

$$\Sigma_{20C} q = \lambda \Sigma_{control} q$$

- Eigenvalues are the variance ratios
- Time series are $q^T x_{20C}$ and $q^T x_{control}$
- Spatial pattern is $\Sigma_{control} q$

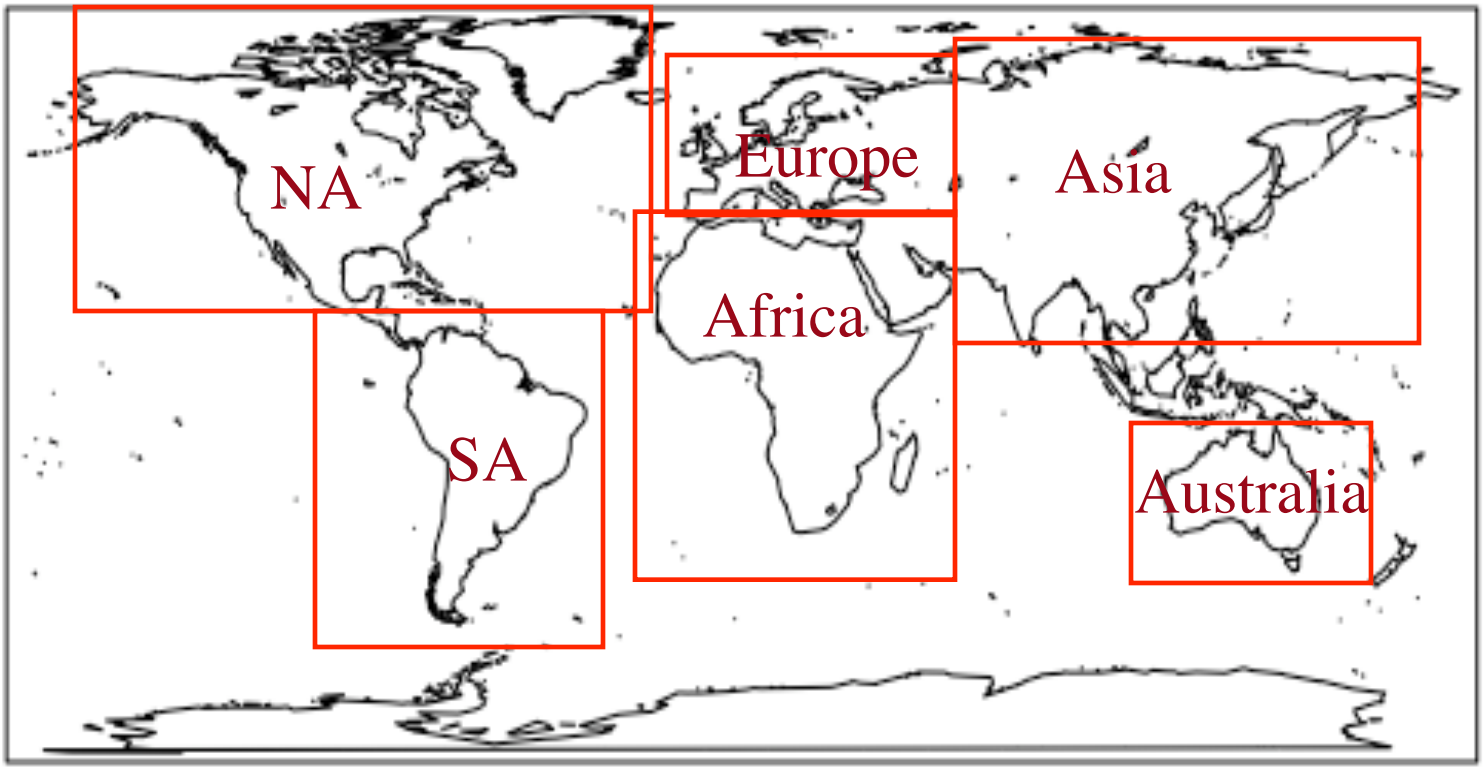
Model Data

- Output of CMIP3 **20th-century runs and control runs**.
- Reject outliers on trends and variance in control runs.
- Model grids are interpolated into common grid ($5^\circ X 5^\circ$).
- 3-month mean (JFM and JAS) 2m temperature and precip..
- Control runs: last 300 years. First half is training data. The rest is verification data.
- 20C runs: maximum 5 members. One member of each model is training data. The rest is verification data.
- Selected 20C and control runs are pooled respectively.
- Each run's climatology is subtracted out.
- 30 EOF truncation.
- **Show results in verification data.**

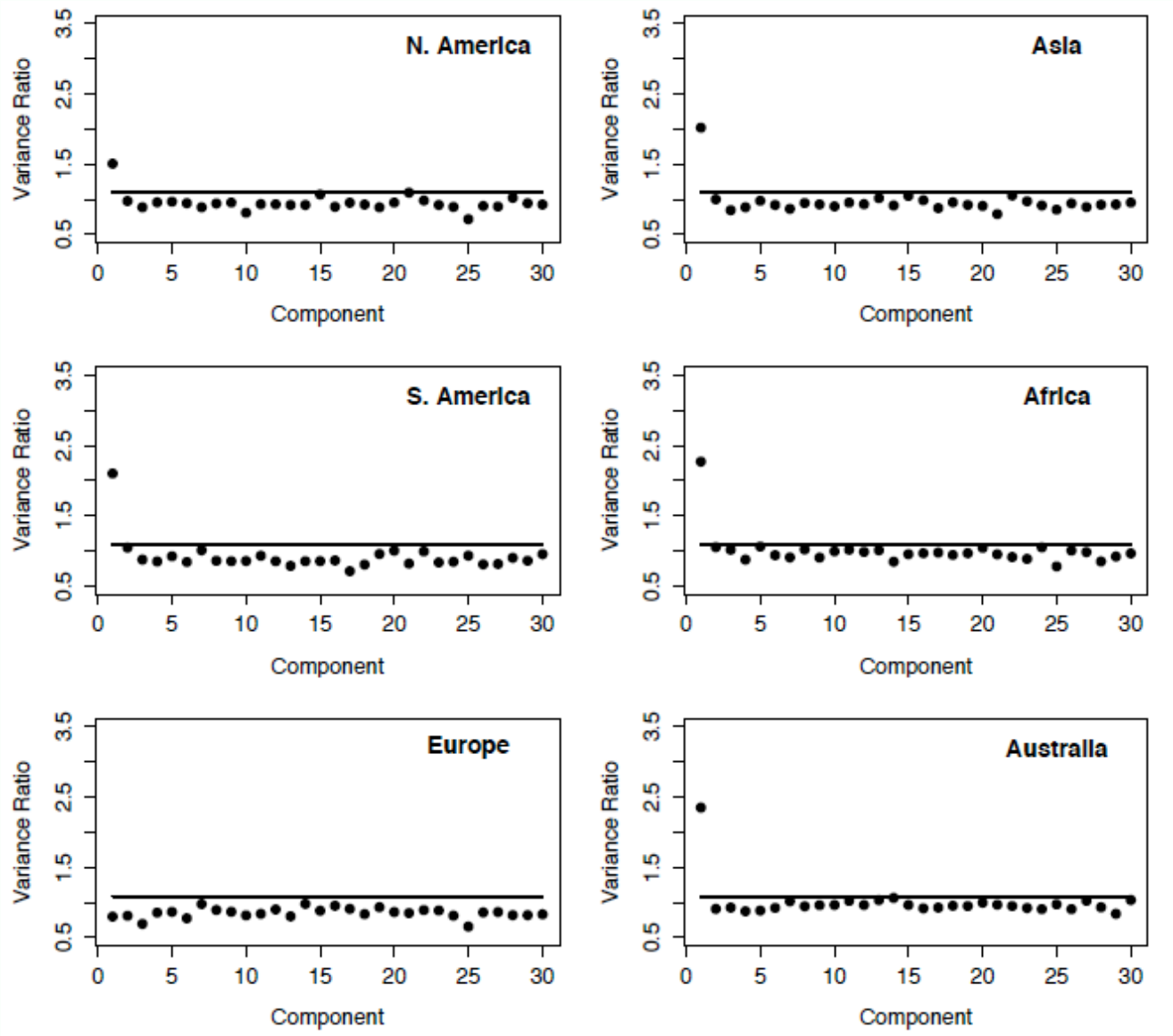
Selected Models

Model Name	Institute/Country
1. GFDL-CM2.0	(GFDL,USA)
2. GFDL-CM2.1	(GFDL,USA)
3. IPSL-CM4	(France)
4. MIROC3.2(medres)	(Japan)
5. ECHO-G	(Germany/Korea)
6. MRI-CGCM2.3.2	(Japan)
7. CCSM3	(NCAR,USA)
8. UKMO-HadCM3	(UK)

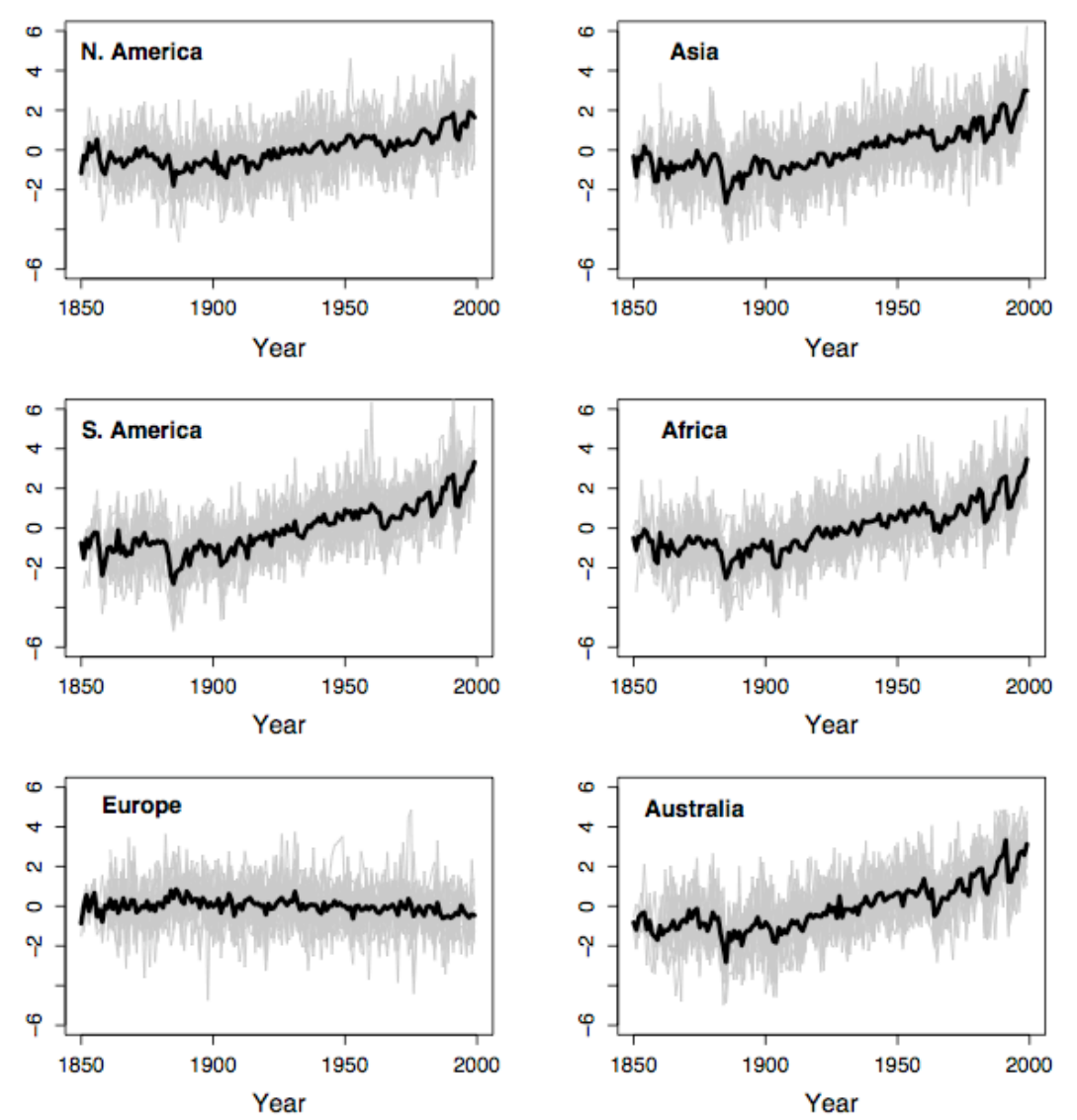
Domains of Six Continents



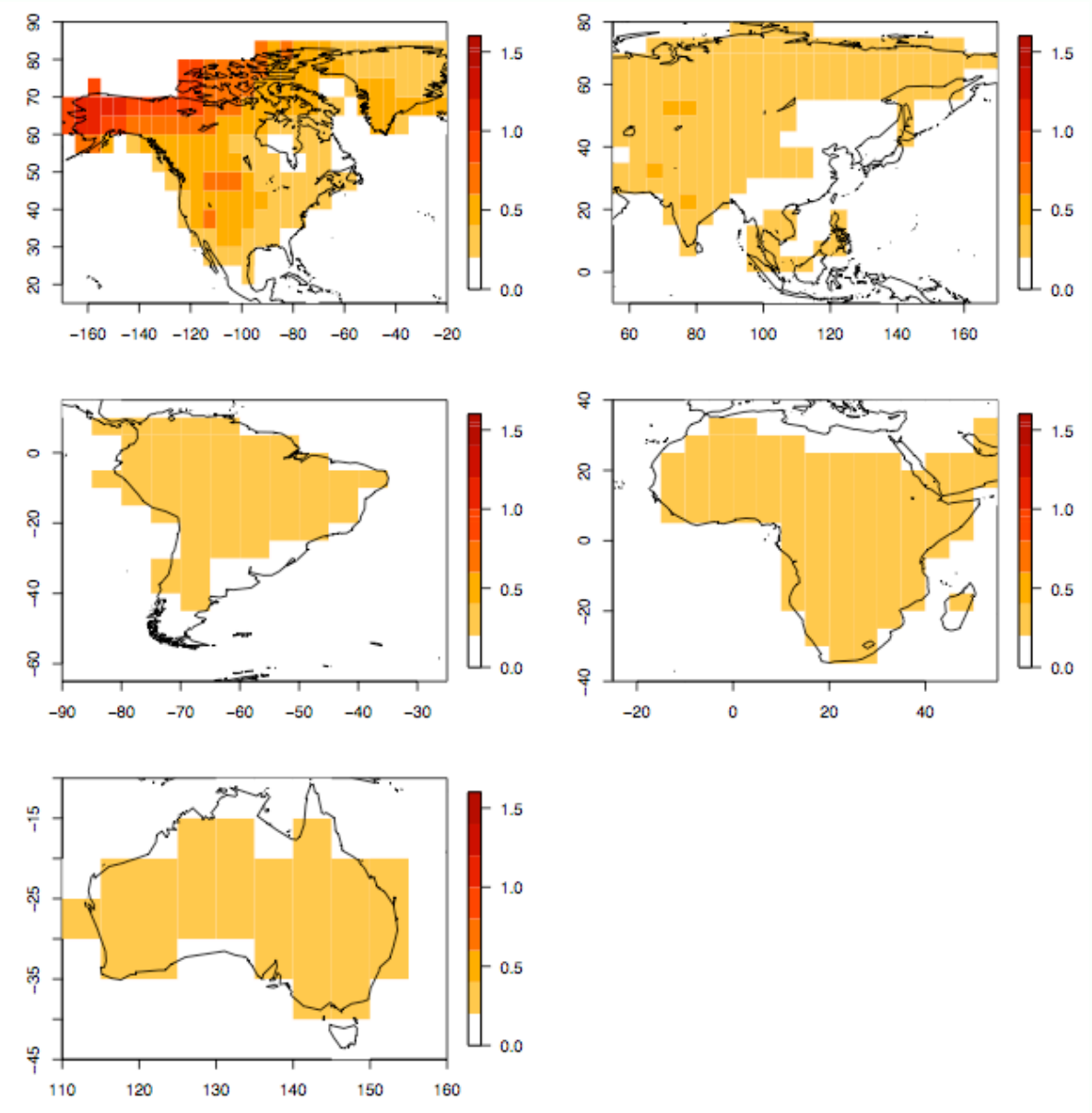
Variance Ratio of Discriminant Components (T2m, JFM)



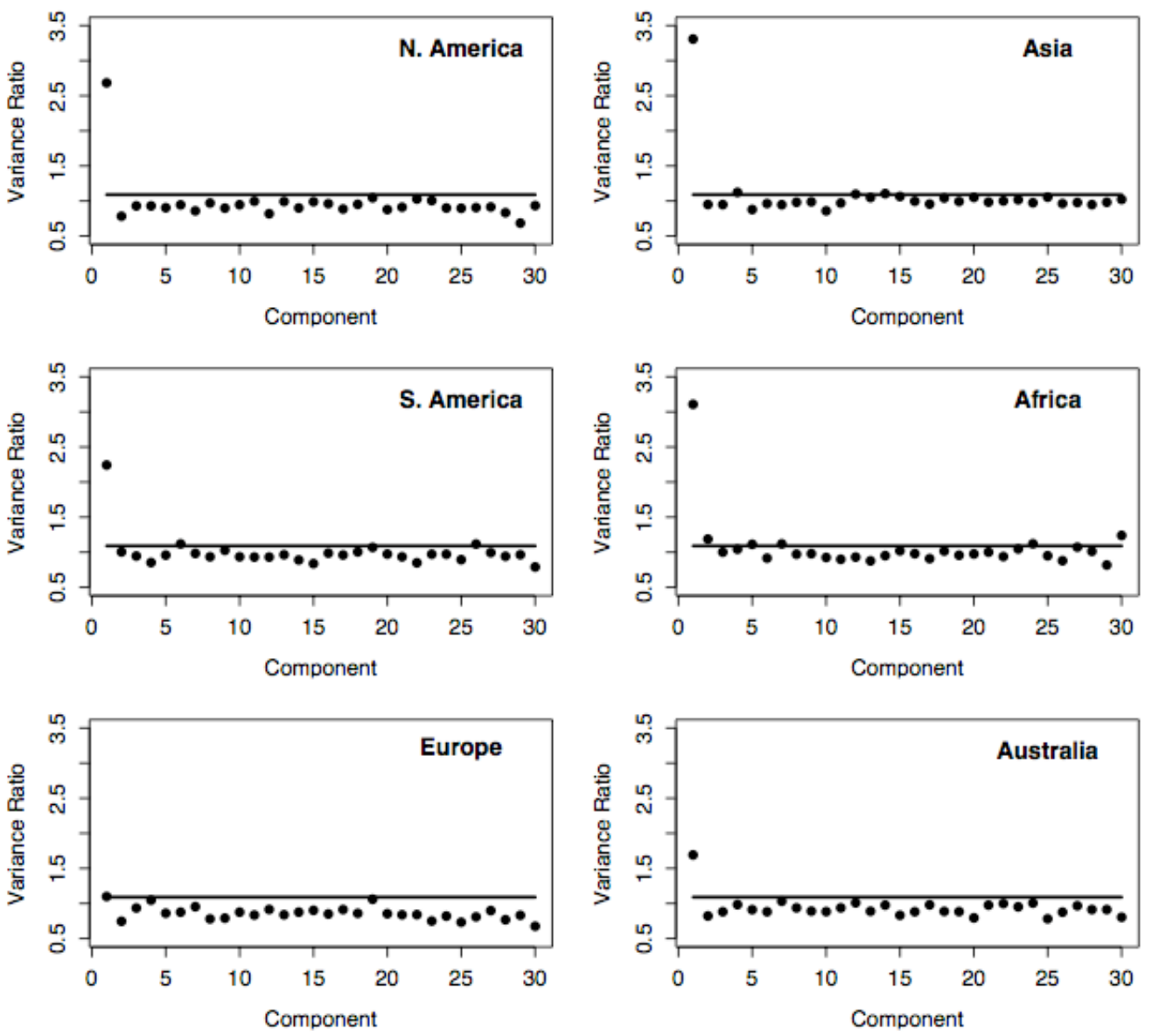
Time Series of the Leading Component (T2m, JFM)



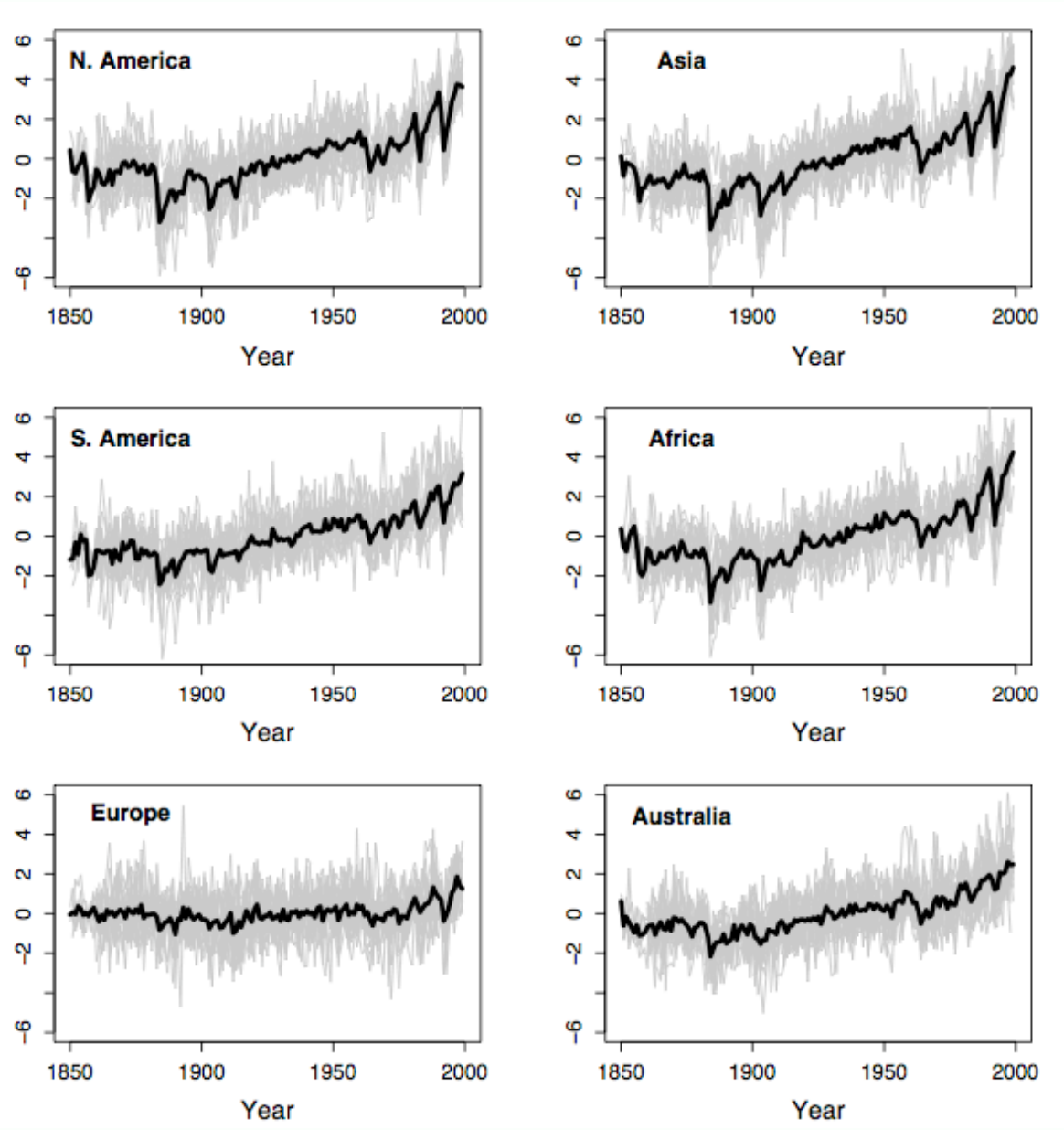
Spatial Pattern of the Leading Component (T2m, JFM)



Variance Ratio of Discriminant Components (T2m, JAS)



Time Series of the Leading Component (T2m, JAS)



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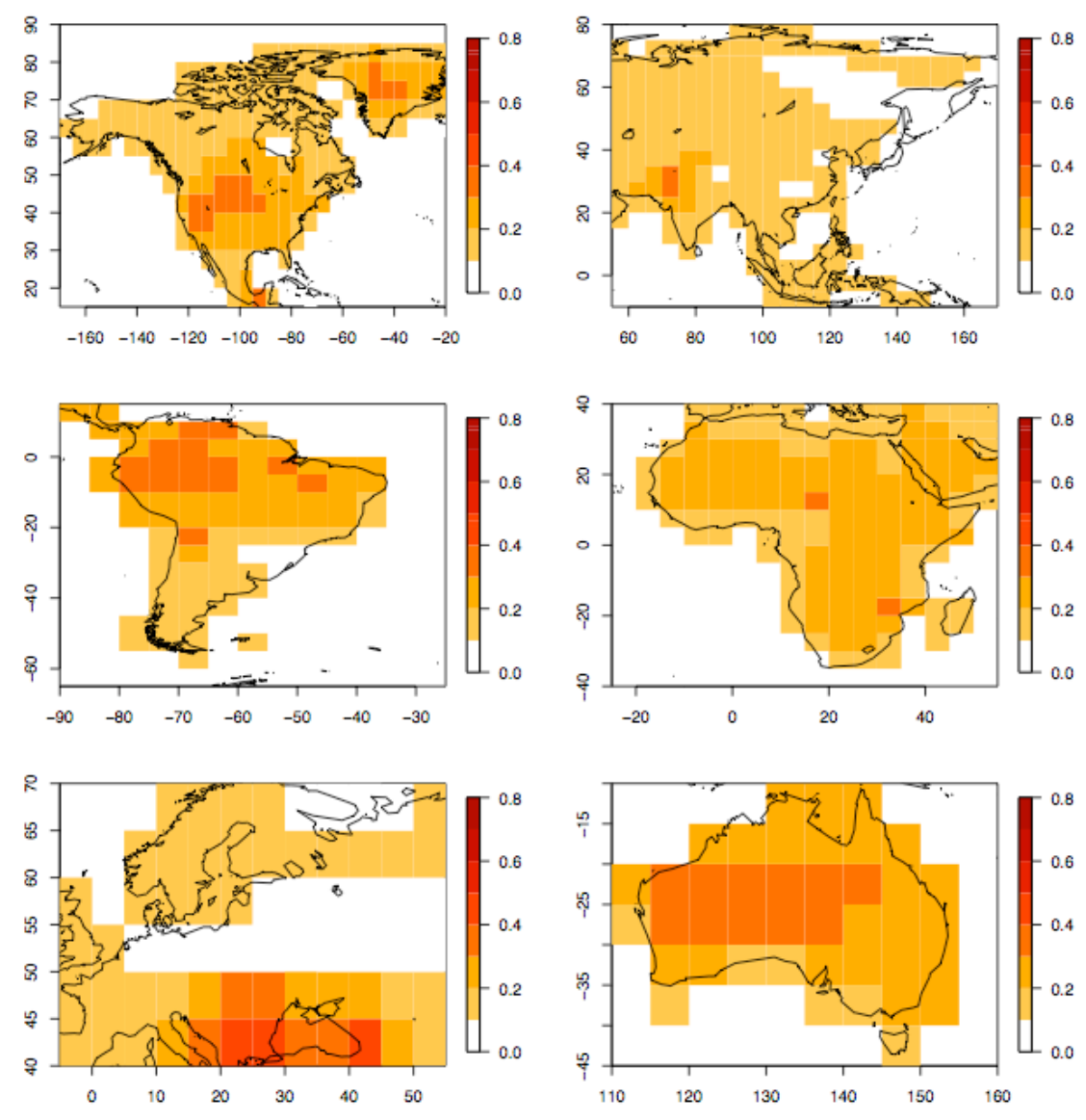
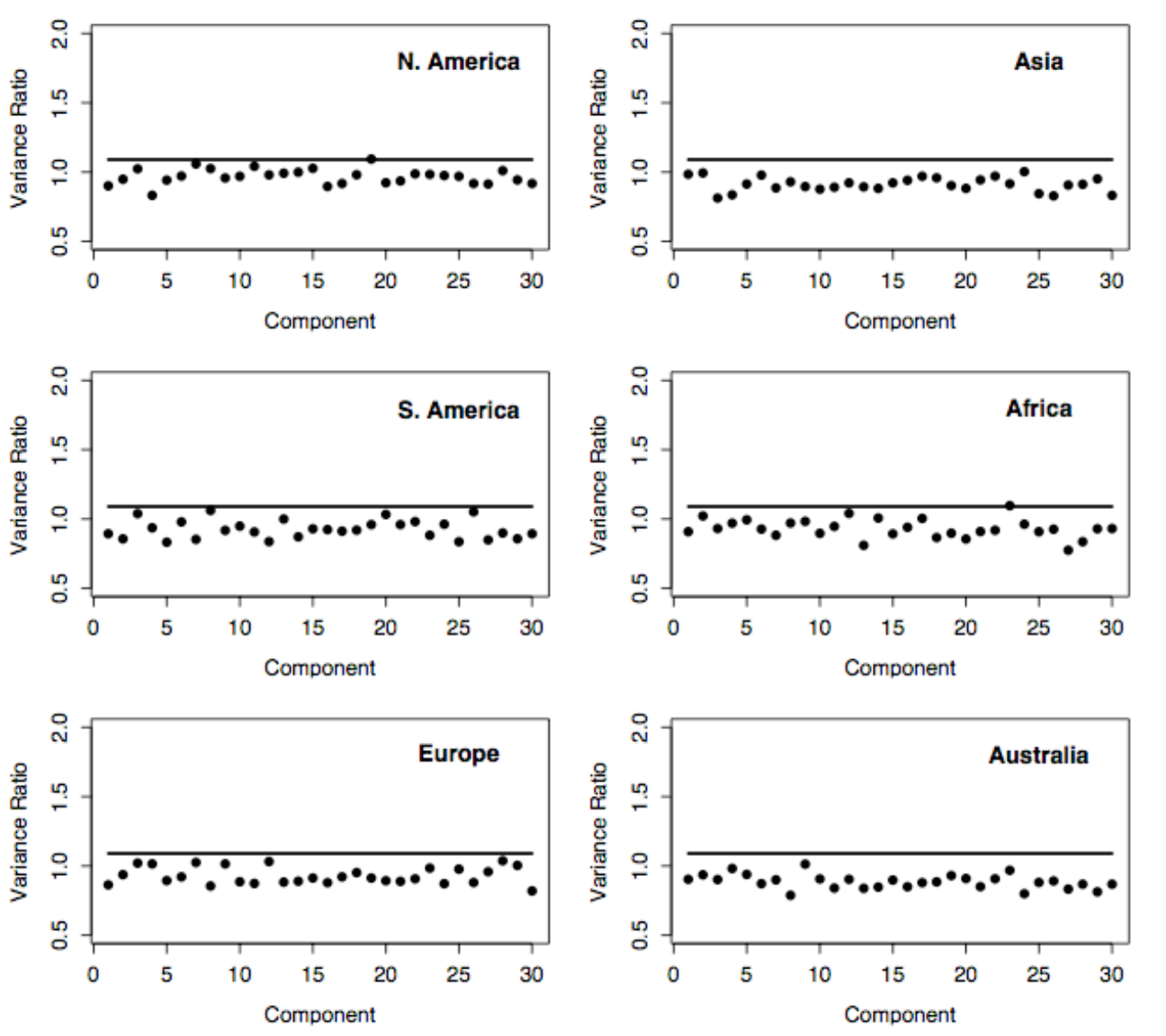


Ratio for Spatial Average vs. Leading Component (T2m)

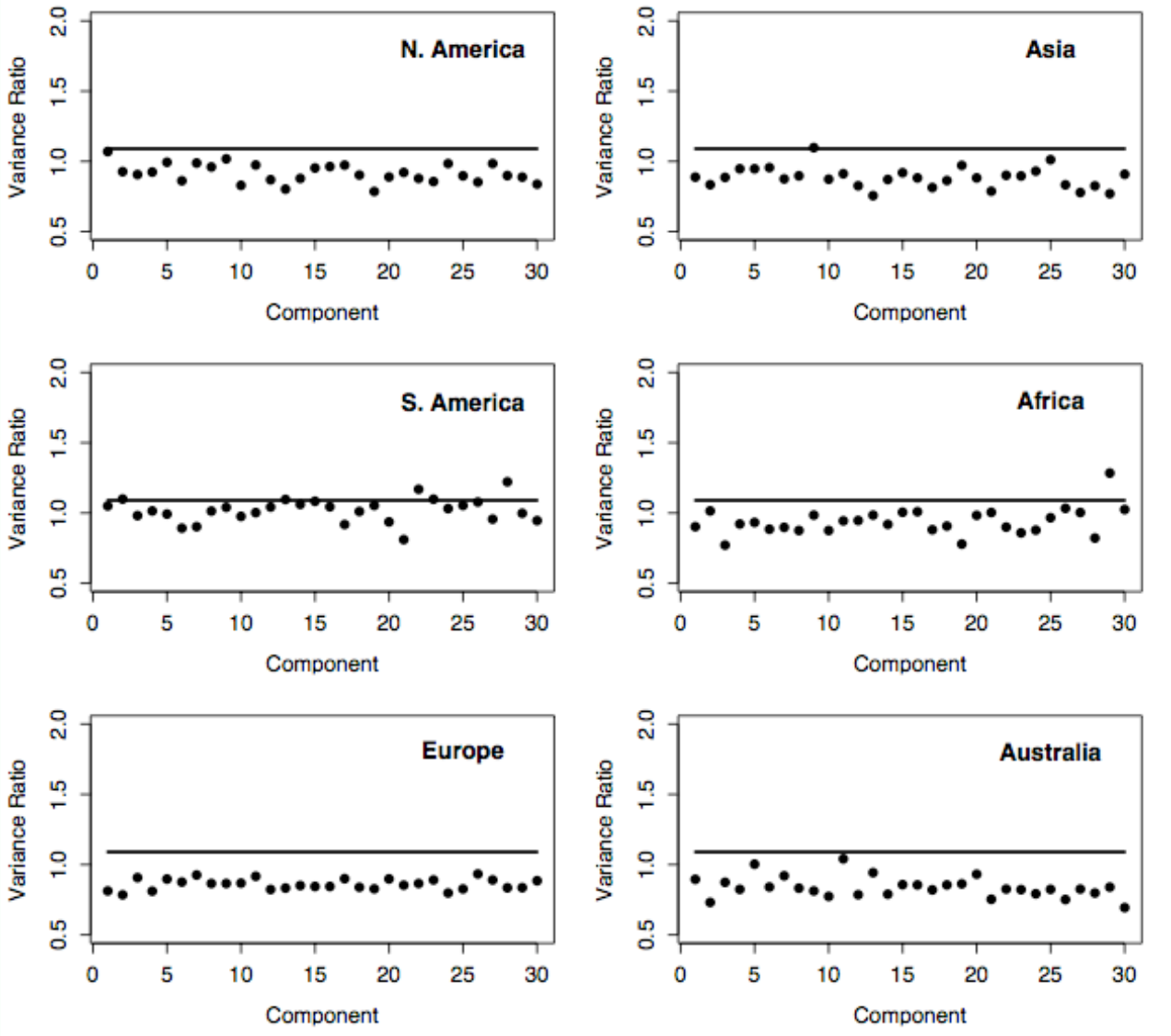
Season	Strategy	North America	Asia	South America	Africa	Europe	Australia
JFM	Average	1.22	1.36	1.42	1.55	1.02	1.15
	Max	1.51	2.02	2.10	2.27	0.80	2.35
AMJ	Average	1.38	1.46	1.71	2.05	1.15	1.23
	Max	2.08	2.64	1.92	2.64	1.03	1.98
JAS	Average	2.06	2.19	1.58	2.39	1.15	1.26
	Max	2.68	3.31	2.24	3.11	1.10	1.69
OND	Average	1.59	1.57	1.58	1.89	1.01	1.23
	Max	2.11	2.91	2.70	2.93	0.92	2.36
Annual	Average	1.97	2.23	2.02	3.19	1.16	1.72
	Max	3.50	4.37	3.15	4.04	1.49	3.53

Discriminant analysis gives better results than spatial averaging.

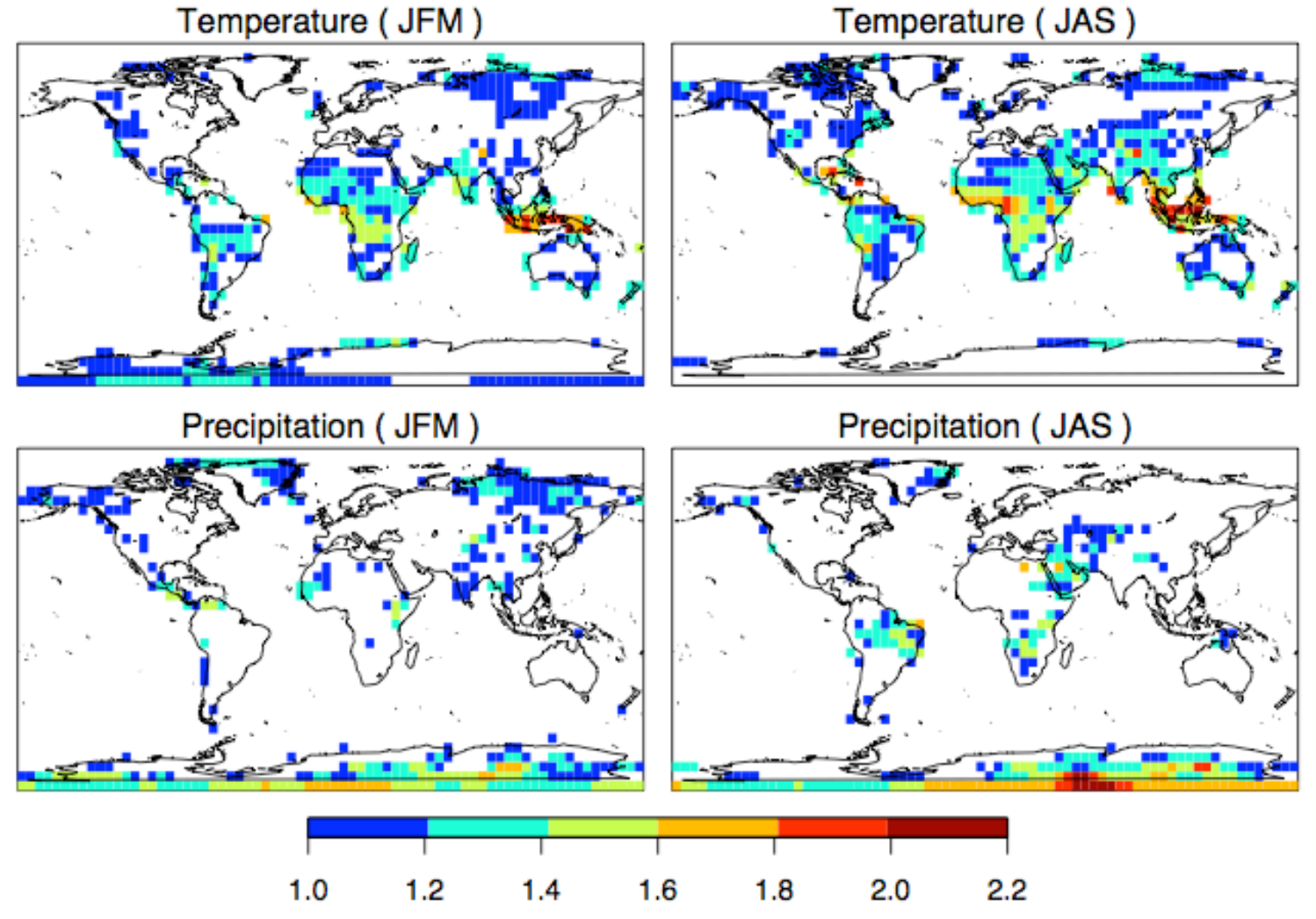
Variance Ratio of Discriminant Components (Pr, JFM)



Variance Ratio of Discriminant Components (Pr, JAS)



Ratio of 20C to Control Variance at Each Grid Point



Summary

- Identified only one significant forced pattern of seasonal mean T2m in each continent (except Europe).
  - ※ Detecting forced response of T2m on seasonal and continental scales is possible.
  - ※ Separating different forcings may be difficult.
- Spatial pattern of T2m is of single sign and consistent with long-term warming .
- No significant forced pattern of precipitation.
  - ※ Detecting of forced response of precipitation is not generally possible on continental and seasonal scales.