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Projection and Possible causes of Summer Precipitation in Eastern China using Self-organizing map

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Background

- Global climate models (GCMs) are main tools for climate simulation and projection at global scale, but they can be hardly applied to regional climate researches with complex terrains due to their low spatial resolution (Gao et al. 2006; Wang et al., 2008).

- Compared with dynamical downscaling, statistical downscaling is less intensive for computational resources and easier to be setup for multiple simulations with different GCMs (Fan et al., 2007).

- First tests of statistical downscaling were applied mainly at monthly (seasonal) scale (Hertig et al., 2008; Zhu et al., 2008). However, they can not be used to study intensity and frequency of extreme precipitation events which are closely related to the synoptic scale circulation patterns.

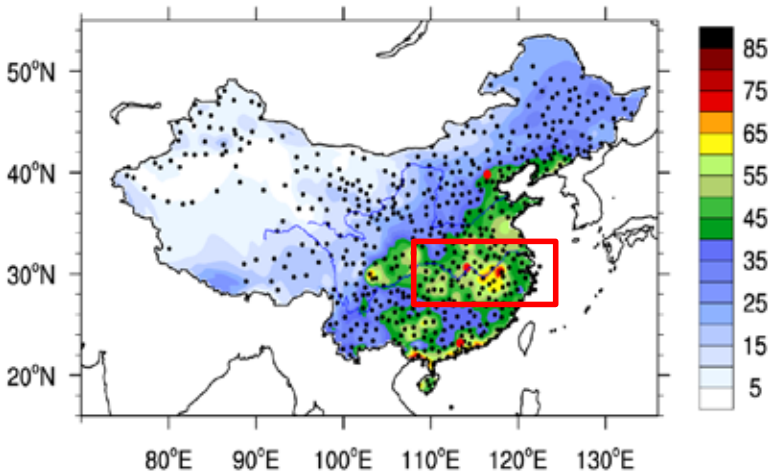
Background

- The Self-Organizing map (SOM), proposed by Kohonen (1982), is an unsupervised ANN model, which can search the relationship between daily synoptic patterns and local rainfall. Utilization of SOM has been reported for climate downscaling in the Arctic, Australia and North America. Nevertheless, there are few attempts on SOM statistical downscaling in Eastern Asia.

- Since SOM links the synoptic patterns and daily precipitation together, possible causes of rainfall variation could be explored from the perspective of these patterns. Previous researches aimed to diagnose through this relationship. Clearly, it is also possible to explore the causes of future rainfall changes from the view of these patterns' variation.

Objective

- To evaluate SOM downscaled model in terms of daily rainfall PDF and rainfall indices.
- To perform multi-model climate projection in the 21st century with focus on summer precipitation in East China.
- To explore the explanations of precipitation variation in view of changes of synoptic patterns.

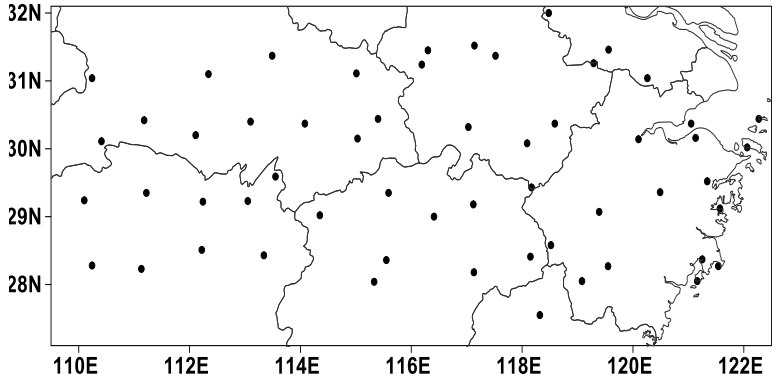


- The Yangtze-Huaihe river basin in Eastern China, located in the climatic transition zone of the subtropical zone and warm temperate belt, with its complex climatic conditions and frequent meteorological disasters, is highly sensitive to climate change (Chen et al., 2012; Wu et al., 2016).

Dataset

Observational dataset:

- China Meteorological Administration
- Daily precipitation from 56 stations
- Time Period： 1961–2005 (June-August)



56 precipitation stations

Reanalysis ERA-40 dataset: (Uppala et al., 2005)

- European Centre for Medium-Range Weather Forecasts
- Time Period : 1961-2002 (June-August)
- large-scale variables (Such as SLP, V850, U850, R850, …)

3 GCMs from CMIP5:

Institution ID	Model name	Resolution
BCC	BCC-CSM1.1(m)	1.125°×1.12°
MPI-M	MPI-ESM-MR	1.875°×1.875°
CNRM-CERFACS	CNRM-CM5	1.4°× 1.4°

1986-2005 is considered as a reference period

5 precipitation indices:

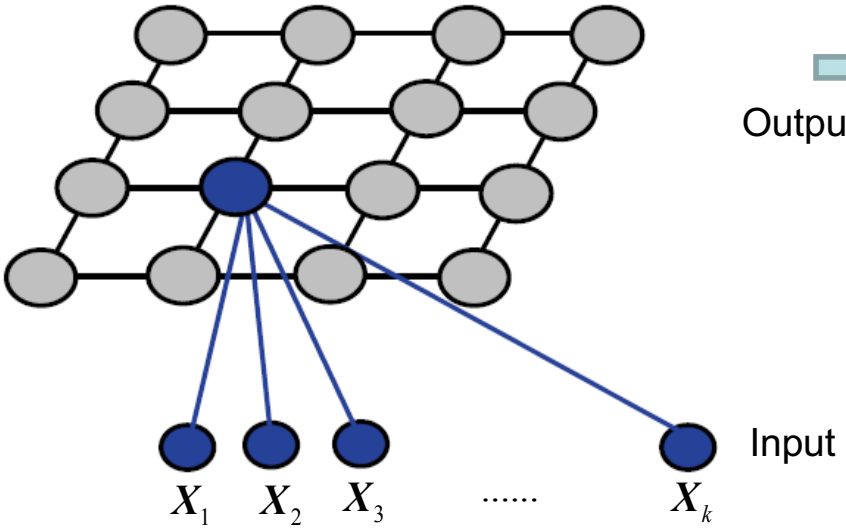
Indicator	Definition
PRCPTOT	Total precipitation in wet days
SDII	Average precipitation on wet days PRCP>=1.0mm
R1mm	The total count of days when PRCP ≥1mm
R10mm	Number of heavy precipitation days when PRCP ≥10mm
P95	The 95th percentile of precipitation

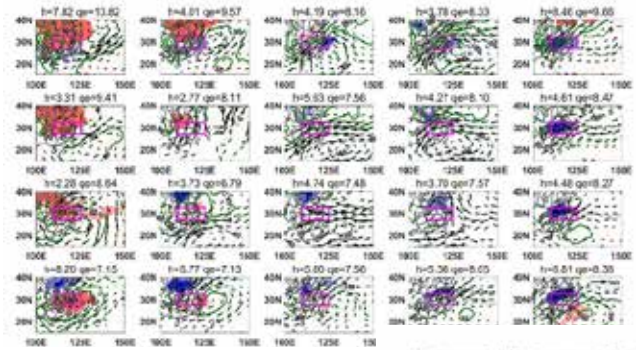
(Frich et al.,2002; Zhang et al.,2011; Chen Xiaochen et al. 2015)

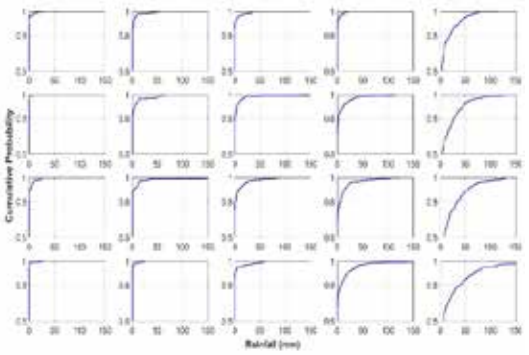
Methodology

➢ SOM:

- First, select the 'winning node' whose reference vector is the closest to the observation one following the principle of Euclidean distance minimization;
- Second, update the weight vectors of the winning node and its neighboring nodes;
- Third, obtain the SOM synoptic patterns and their corresponding summer precipitation PDF .







(Kohonen,1982,2001; Hewitson and Crane, 2006)

Evaluation of SOM

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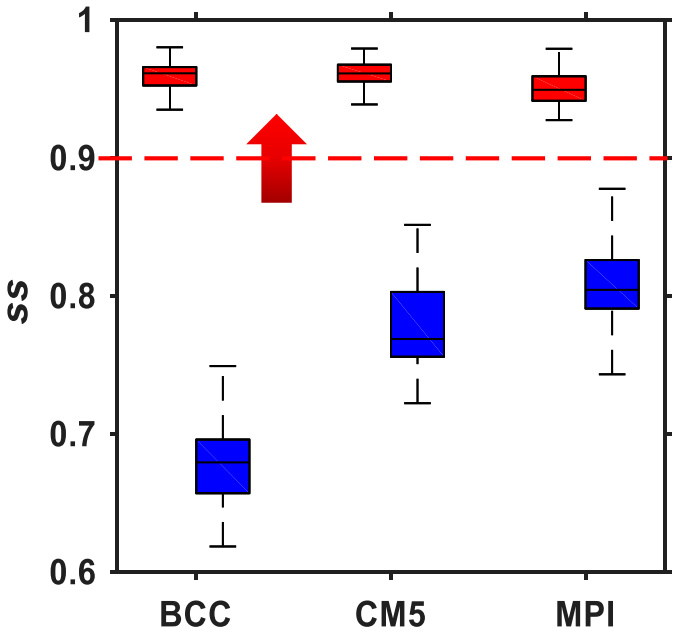
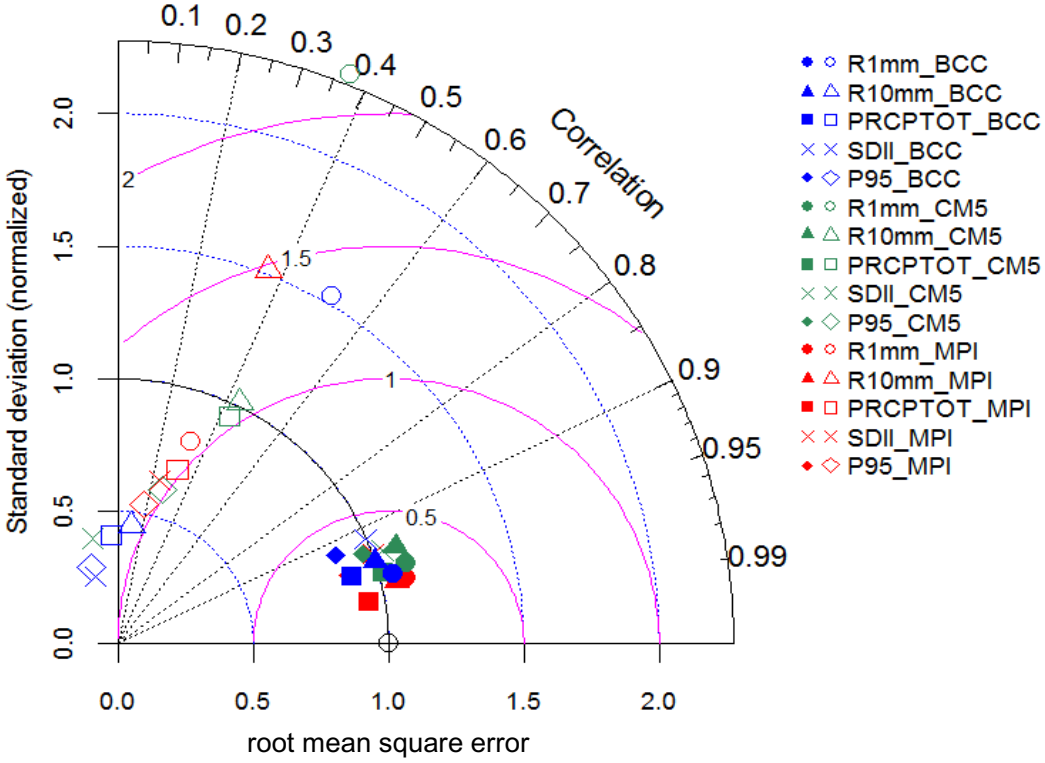
PDFs of daily precipitation



Boxplot of Sscore of daily precipitation PDF in East China before (blue) and after (blue) downscaling.

precipitation indices



Taylor diagrams of multi-year (1986-2005) mean summer precipitation indices before (hollow) and after (solid) downscaling.

Projection under RCP4.5

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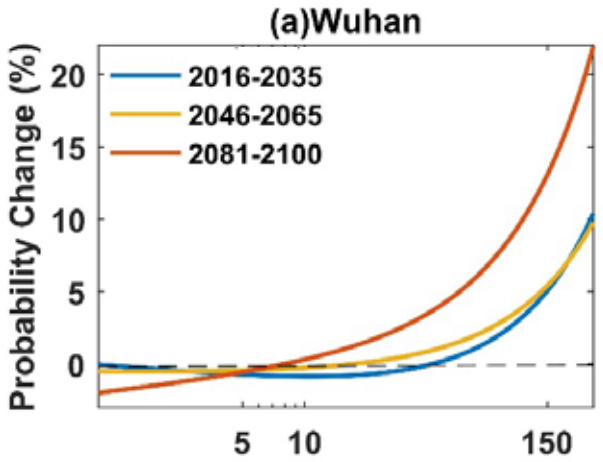
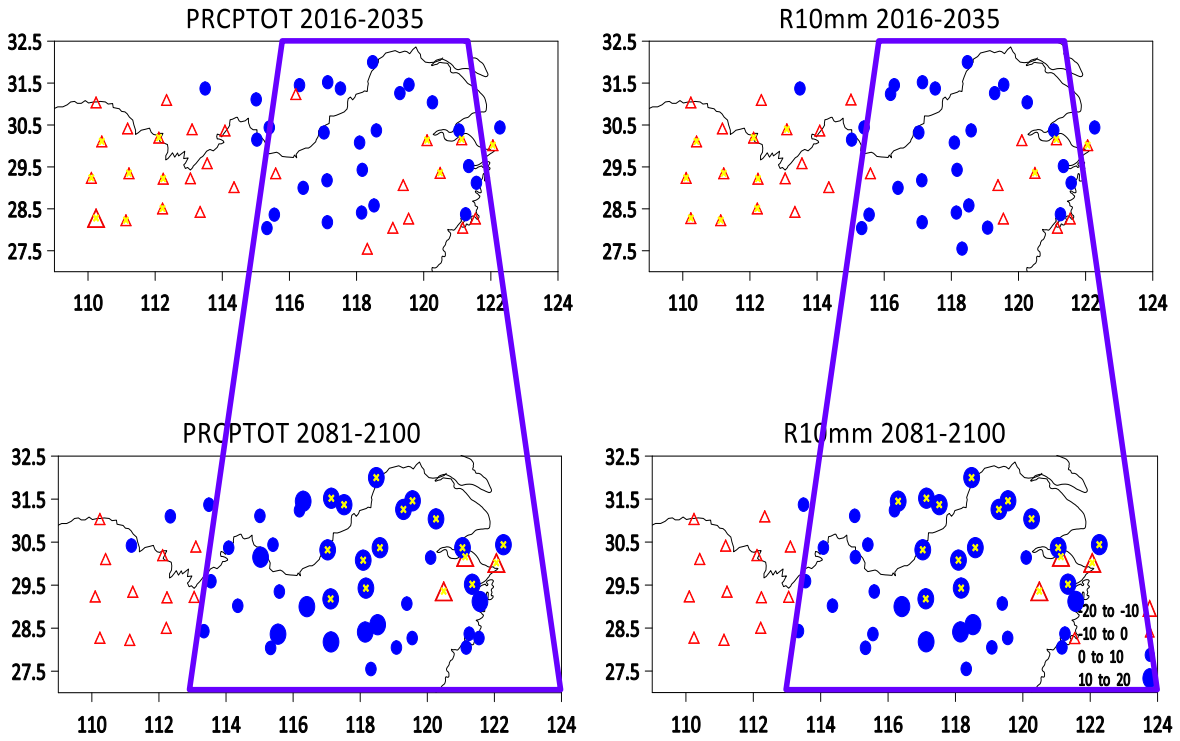
Projection of Daily rainfall PDF change and Rainfall indices change



70%



Spatial distributions of downscaled ensemble mean summer PRCPTOT and R10mm variations (relative to 1986-2005) in the 21st century.

Projection of under RCP4.5

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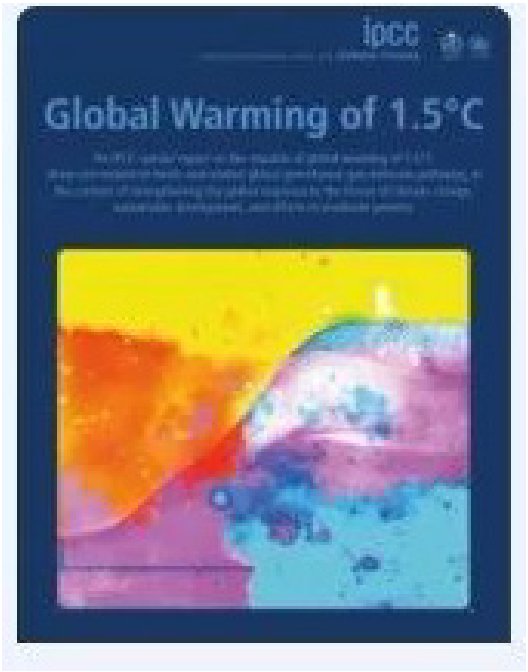
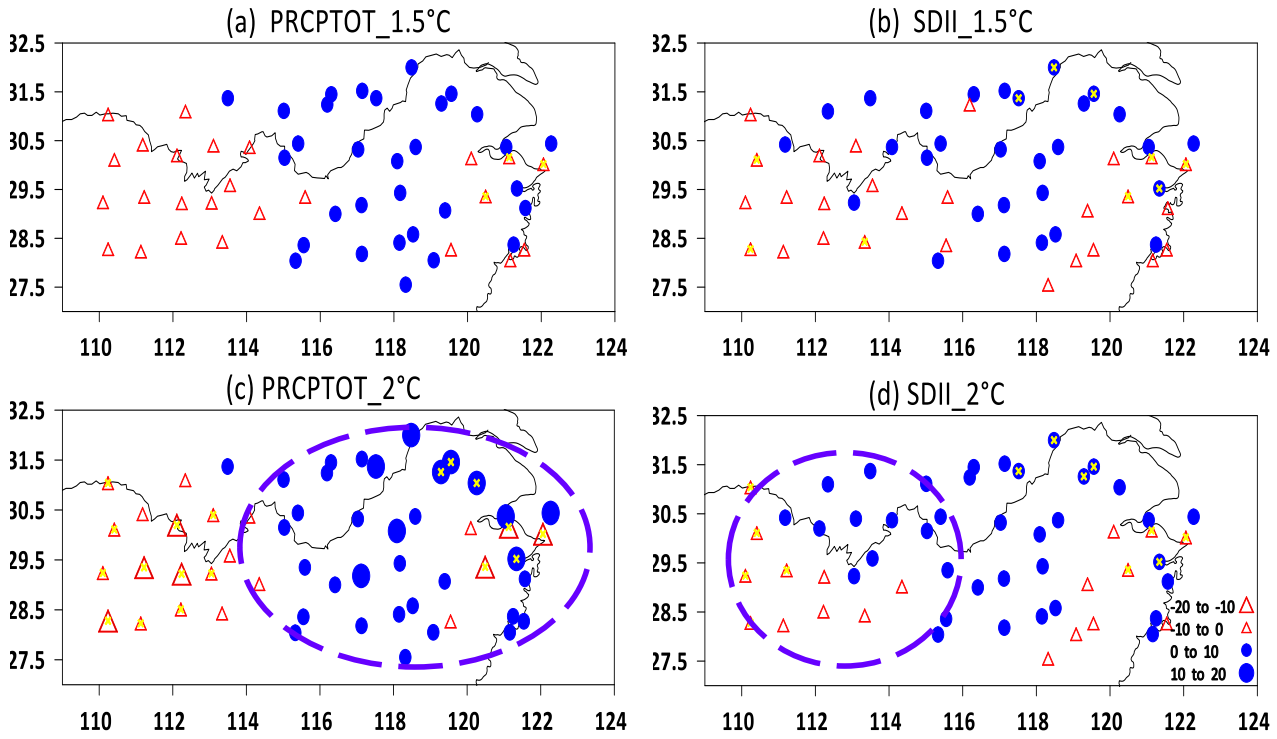
Projection of Rainfall indices change at global warming of 1.5 ° C and 2 ° C

Two main goals in Paris Agreement:
To hold the global average temperature rise within 2 °C .
To pursue effort to limit it below 1.5 °C above the pre-industrial level.





Spatial distributions of downscaled ensemble mean summer PRCPTOT and SDII in YHRB at global warming of 1.5 ° C and 2 ° C

Physical explanations of projected Precipitation variation

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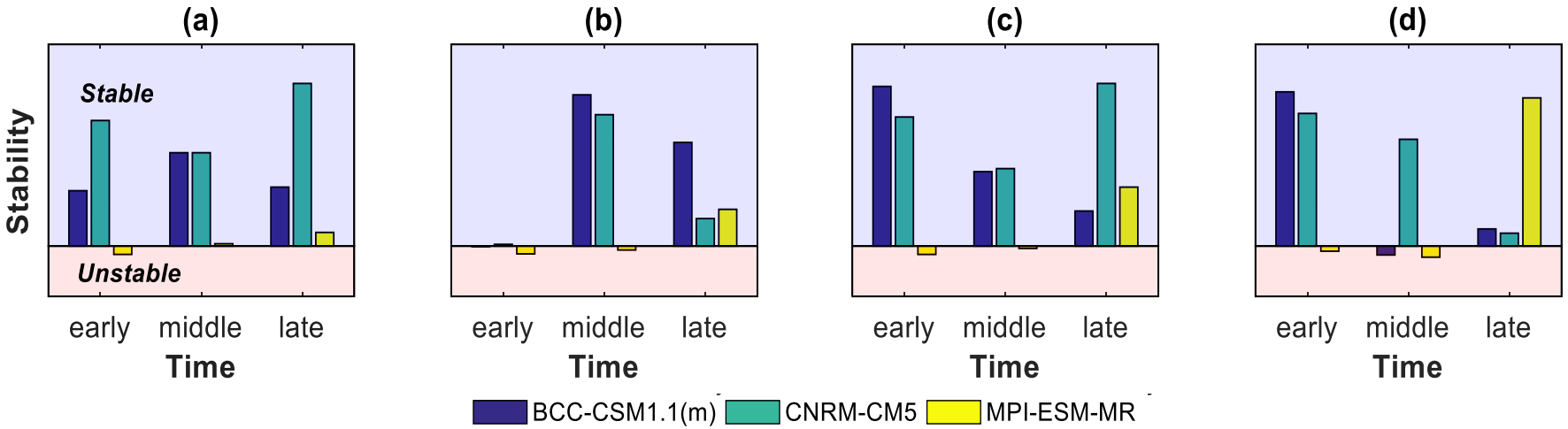
future change of precipitation

- **Stability of Future synoptic patterns**
- **Variations in frequency of Future synoptic patterns**

Stability of Future Regional synoptic patterns

Quantization Error (QE)



Stability of 4 R-SPs (a-d) in the early 21st century (2016-2035), middle (2046-2065) and late (2081-2100)
Purple shadow area: QE in this period has no significant change compared with the historical period;
Red shadow region: QE in this period occurs significant change compared with the historical period.

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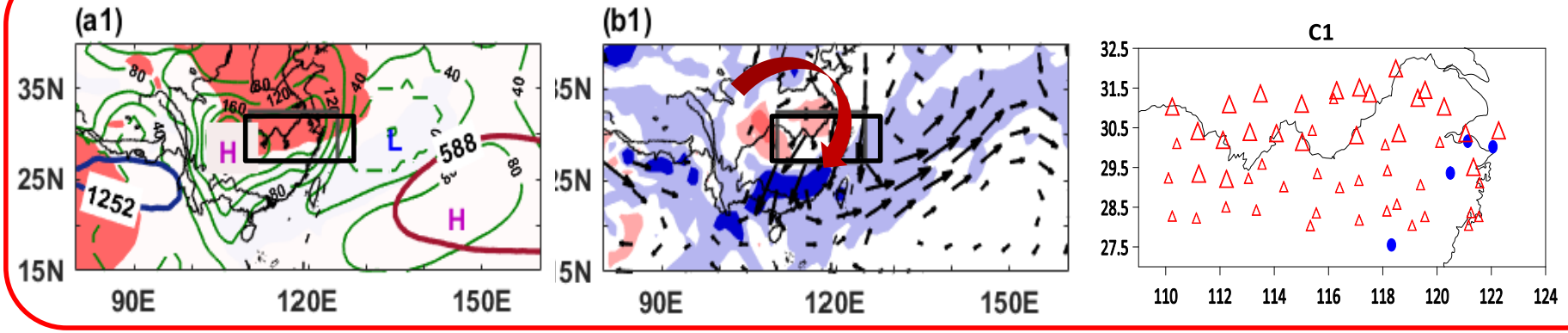
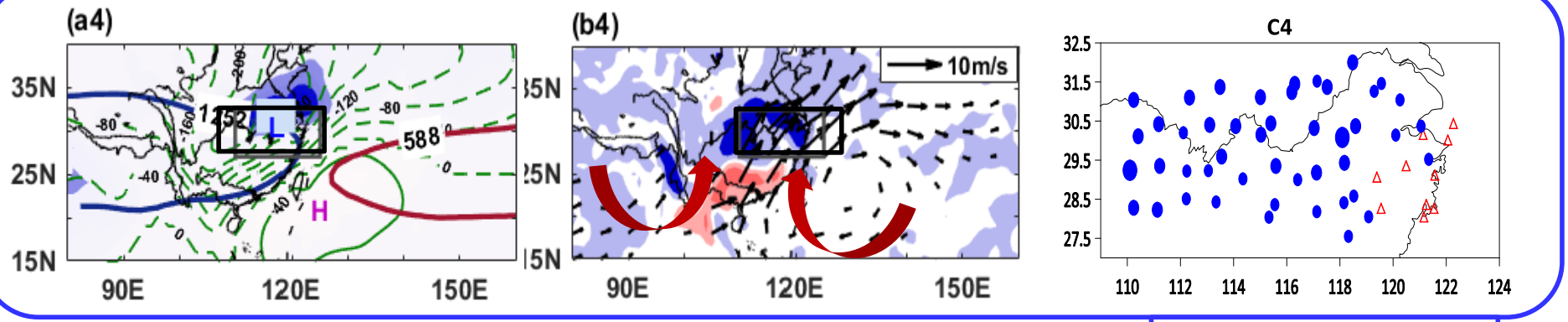
Variations in frequency of Future Regional synoptic patterns

Extreme Dry Pattern





Extreme Wet Pattern

850hPa Relative humidity (shaded); SLP (green lines); Characteristic isolines of 200hPa SAH (1250dagpm) and 500hPa Western Pacific SH (588dagpm)

850hPa UV(arrows); 850hPa Divergence (shaded)

Spatial distribution of average daily precipitation

Physical explanations of projected Precipitation variation

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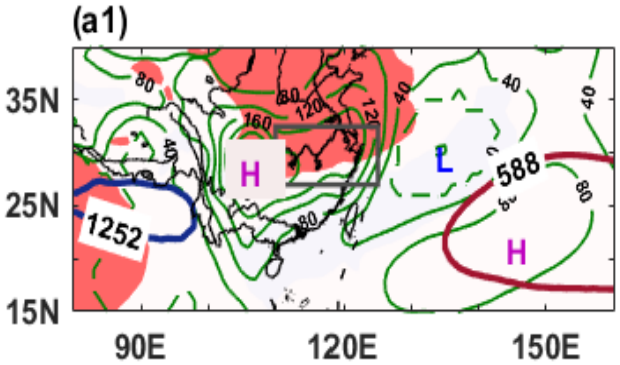
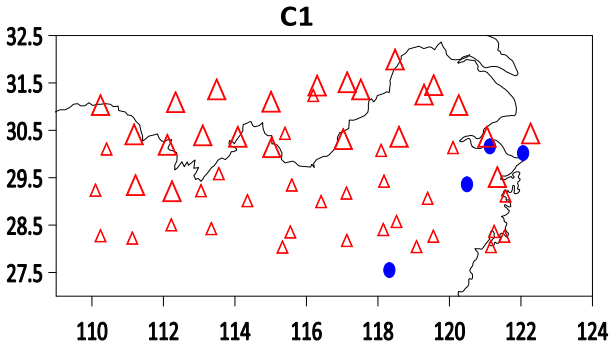
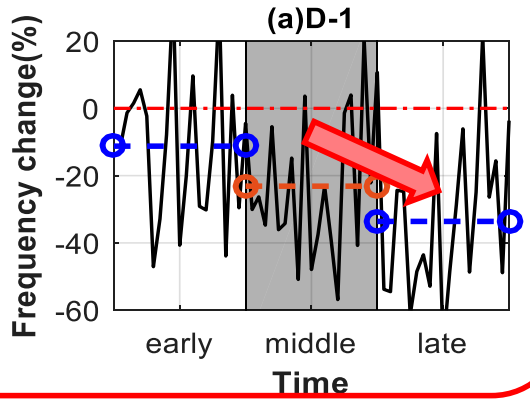
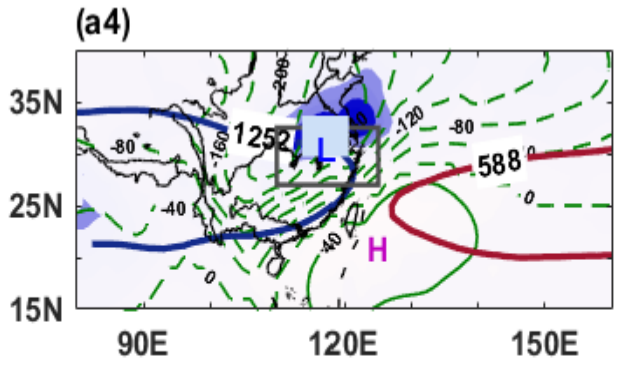
Variations in frequency of Future Regional synoptic patterns

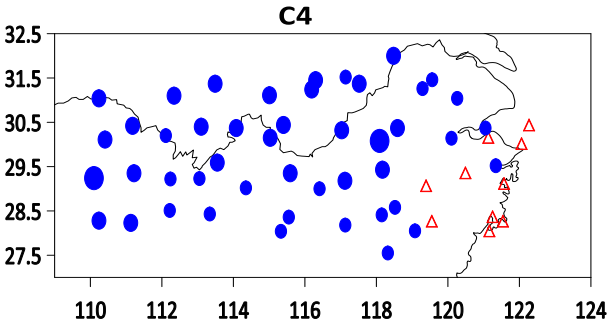
Extreme Dry Pattern

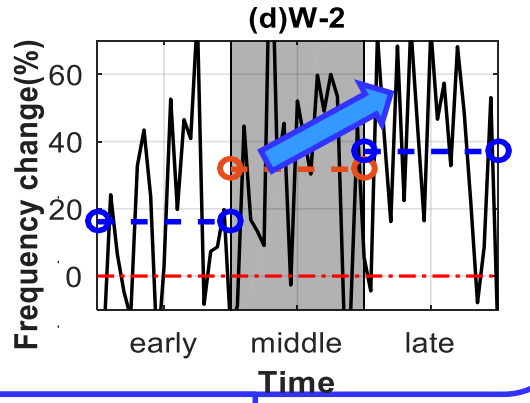


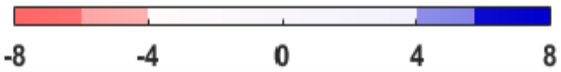












Extreme Wet Pattern

850hPa Relative humidity (shaded); SLP (isolines); Characteristic isolines of 200hPa SAH (1250dagpm) and 500hPa Western Pacific SH (588dagpm)

Spatial distribution of average daily precipitation

Occurrence frequency

Conclusions

- The evaluation shows that SOM can bring "added value" to GCMs' outputs.

- In the 21st century under RCP4.5 Scenario, daily rainfall at roughly 70% sites in Yangtze-Huaihe river basin is projected to shift towards large value. Mean and extreme precipitation may experience a general enhancement from early to late stage, reaching nearly 30%. The 0.5° C additional warming leads to more precipitation over lower reaches and higher intensity over middle Yangtze River.

- The regional synoptic patterns in the future are found with high stability, suggesting precipitation change in this basin is mainly related to the frequency variation of patterns. Future expansion and overall intensification of large-value precipitation are linked to the raise of extreme wet pattern whose westward Subtropical High staying closely to the eastward South Asia High by almost 40% ultimately and the reduction of extreme dry pattern with far-away SH and SAH.

Thanks for your attention!

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