Climate projections using MRI-AGCM3.2 with 20-km and 60-km grid

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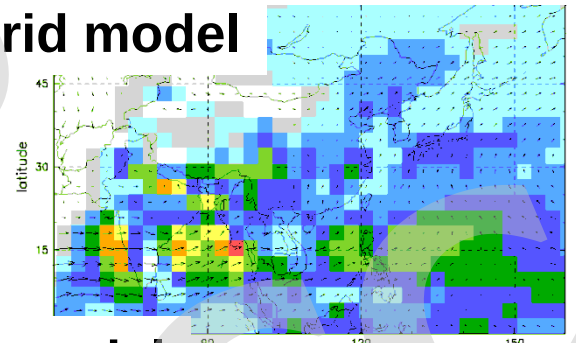
High-resolution Atmospheric Global Climate Model

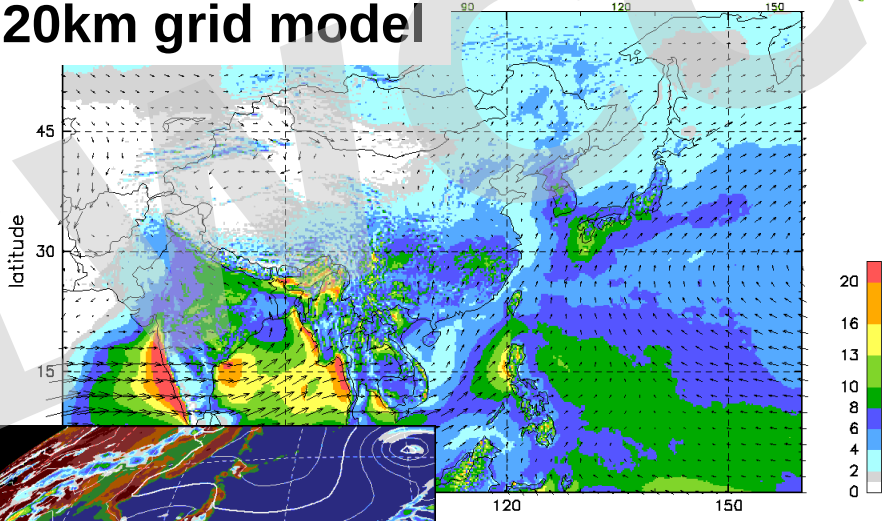
- High-resolution model
  - Small-scale structures such as tropical cyclones
  - Localized phenomena associated with small-scale topography

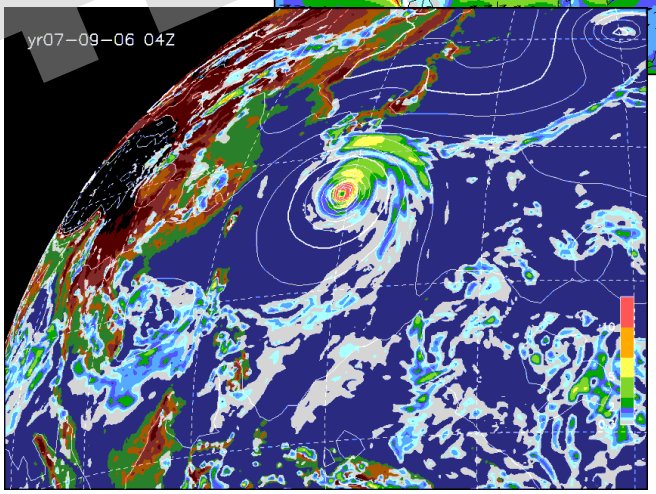
- Long-term simulations over several decades require good representations of:
  - Physical structures of the small-scale phenomena
  - Statistical climate of the small-scale phenomena
  - Global-scale climatology

270km grid model



20km grid model





JJA precip. over Asia

Mizuta et al. (2006)

MRI-AGCM3

MRI-AGCM3.0 **developed from JMA operational NWP model**
first 20km climate model which simulates for
multi-decades (Mizuta et al. 2006)

very minor change

MRI-AGCM3.1 **(Kitoh et al. 2009)**

introducing new parameterization schemes etc.

MRI-AGCM3.2 (current model) **(Mizuta et al. 2012)**

Reductions of the model biases of:
- insufficient precipitation amounts over the W. Pacific
- geographical distribution of tropical cyclones
- overestimated weak rain, underestimated heavy rain
- resolution dependence in terms of global-scale climate

Ensemble simulations with lower-resolution version

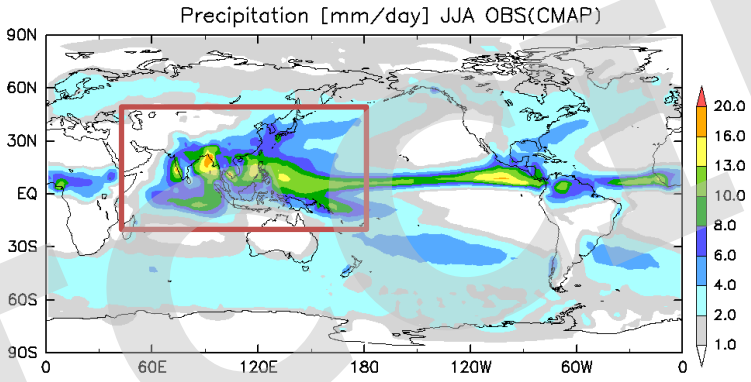
Large-scale model climate: JJA Precipitation

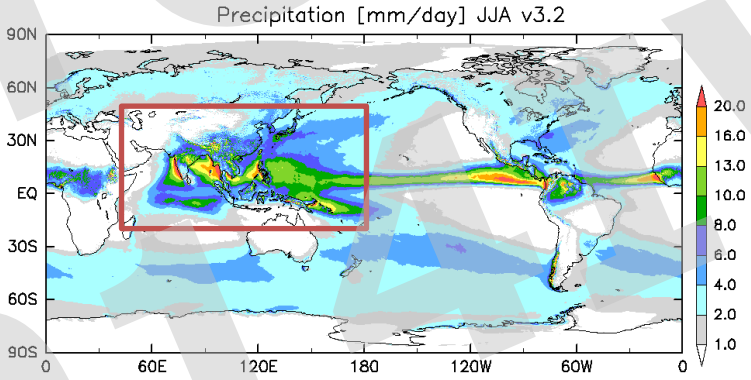
AMIP-type 25-year experiments using observed SST for the present-day climate

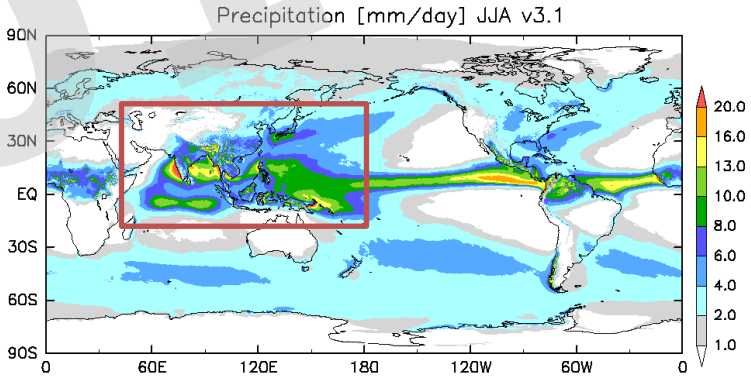
OBS（CMAP）

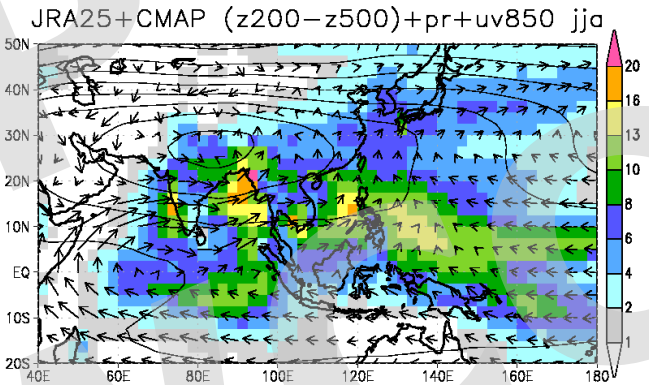
MRI-AGCM3.2
20km25years

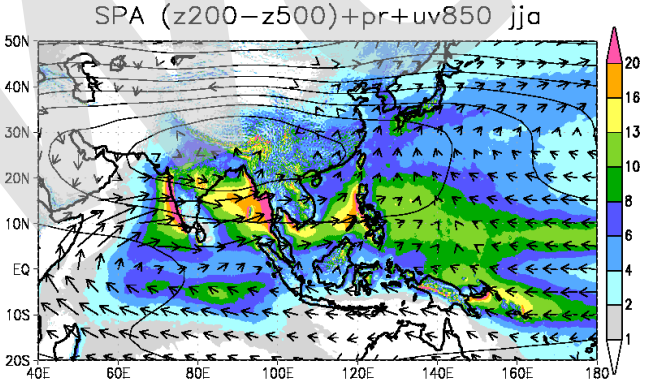
MRI-AGCM3.1
20km25years

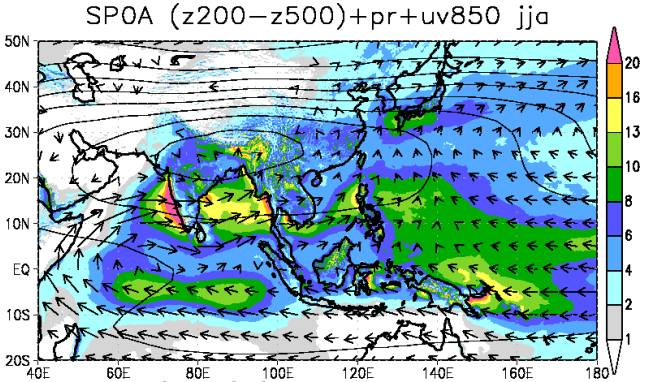








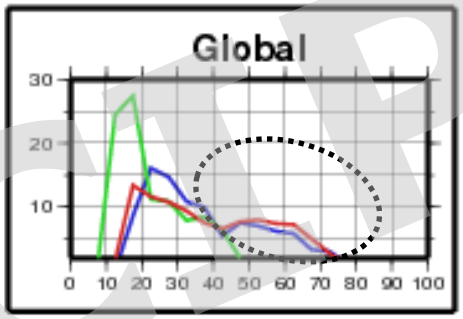




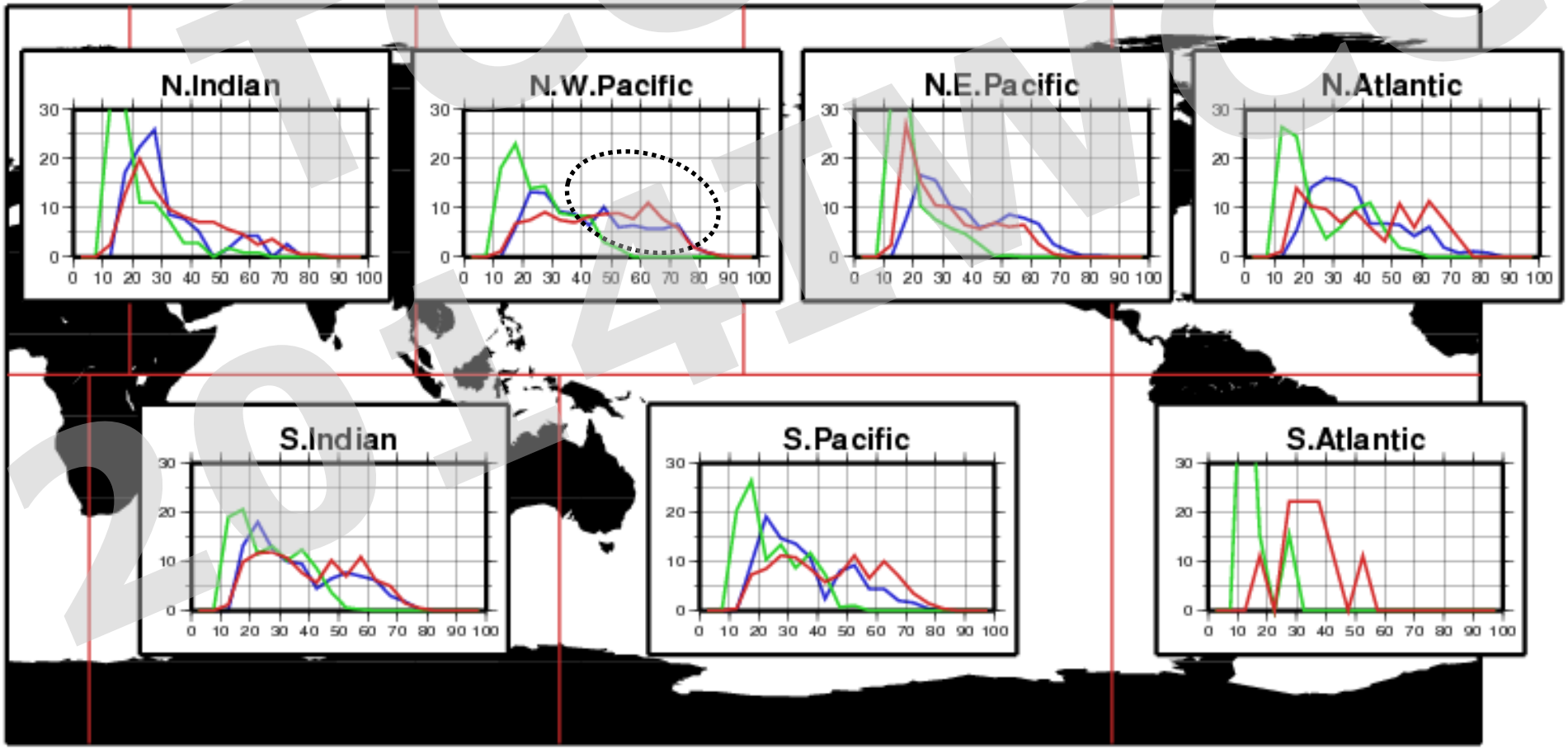
Arrows: 850hPa wind
Contours: Thickness(200-500hPa) 20 cint=50m

Small-scale model climate: intensity of tropical cyclones

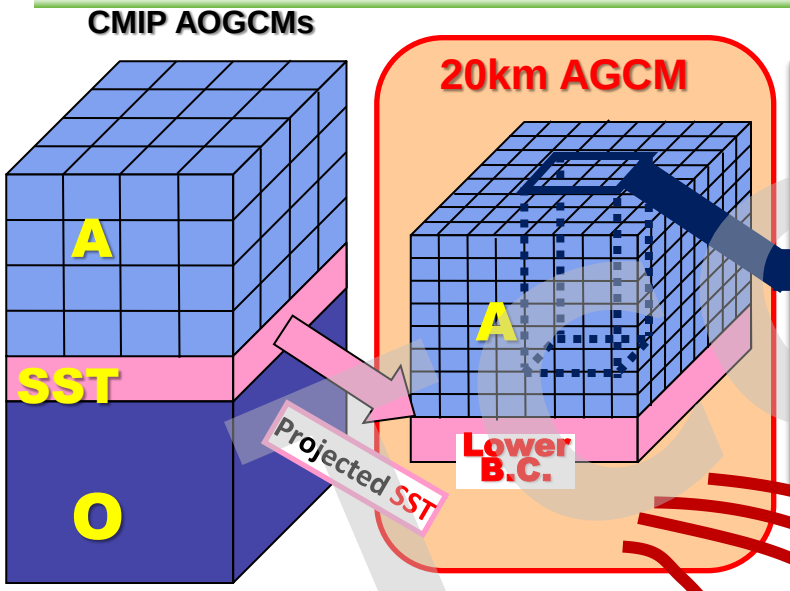
Horizontal:
maximum wind speed (m/s)
Vertical: probability (%)

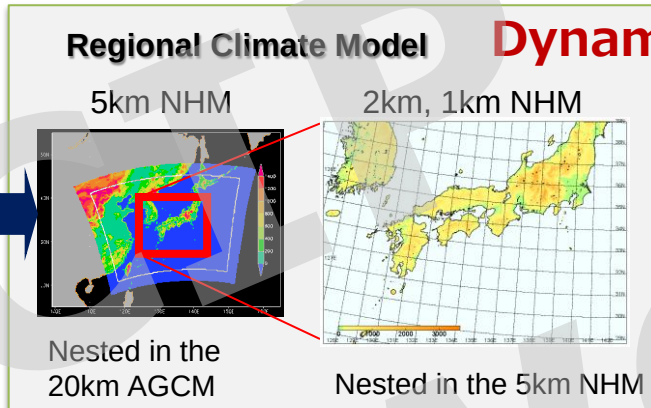


--- observation
--- MRI-AGCM3.2
--- MRI-AGCM3.1



Time-Slice Experiments using SST from CGCMs





Dynamical Downscaling by RCM

Impact Assessments

- Disasters
- Agriculture
- Water Resources

Study of Future Change in Extreme Events

- Tropical Cyclones (e.g.Oouchi et al. 2006)
  →less number, more intense
- East Asia Monsoon (e.g.Kusunoki et al.2006)
  →seasonal migration delayed
- Extreme Rainfall (e.g.Kamiguchi et al. 2006)
  →more frequent
- Blockings (e.g.Matsueda et al. 2009)
  →less frequent
- Extratropical Cyclones(e.g.Mizuta et al.2011)

Regional Climate Change

- Outputs provided to researchers of each region
  (Korea, China, Taiwan, Philippines, Thailand, Indonesia, Viet Nam, Bangladesh, India, Israel, Saudi Arabia, Senegal, Spain, Netherland, UK, Ireland, Denmark, Switzerland, Germany, USA, Mexico, Columbia, Barbados, Belize, Bolivia, Peru, Ecuador, Brazil, Argentina, Australia, Papua New Guinea)

Settings of time-slice experiments

- Present-day climate experiment (1979-2003): AMIP-type
  - observed SST and sea-ice concentration
  - observed global-mean concentrations of CO2 and other GHGs
- Future climate experiment (2075-2099)
  - SST warming in the CMIP coupled models is added to the obs. SST
  - changing concentrations of GHGs following the emission scenario
- Evaluating uncertainty of the change:
  Ensemble experiments with KAKUSHIN program (=prev. project)

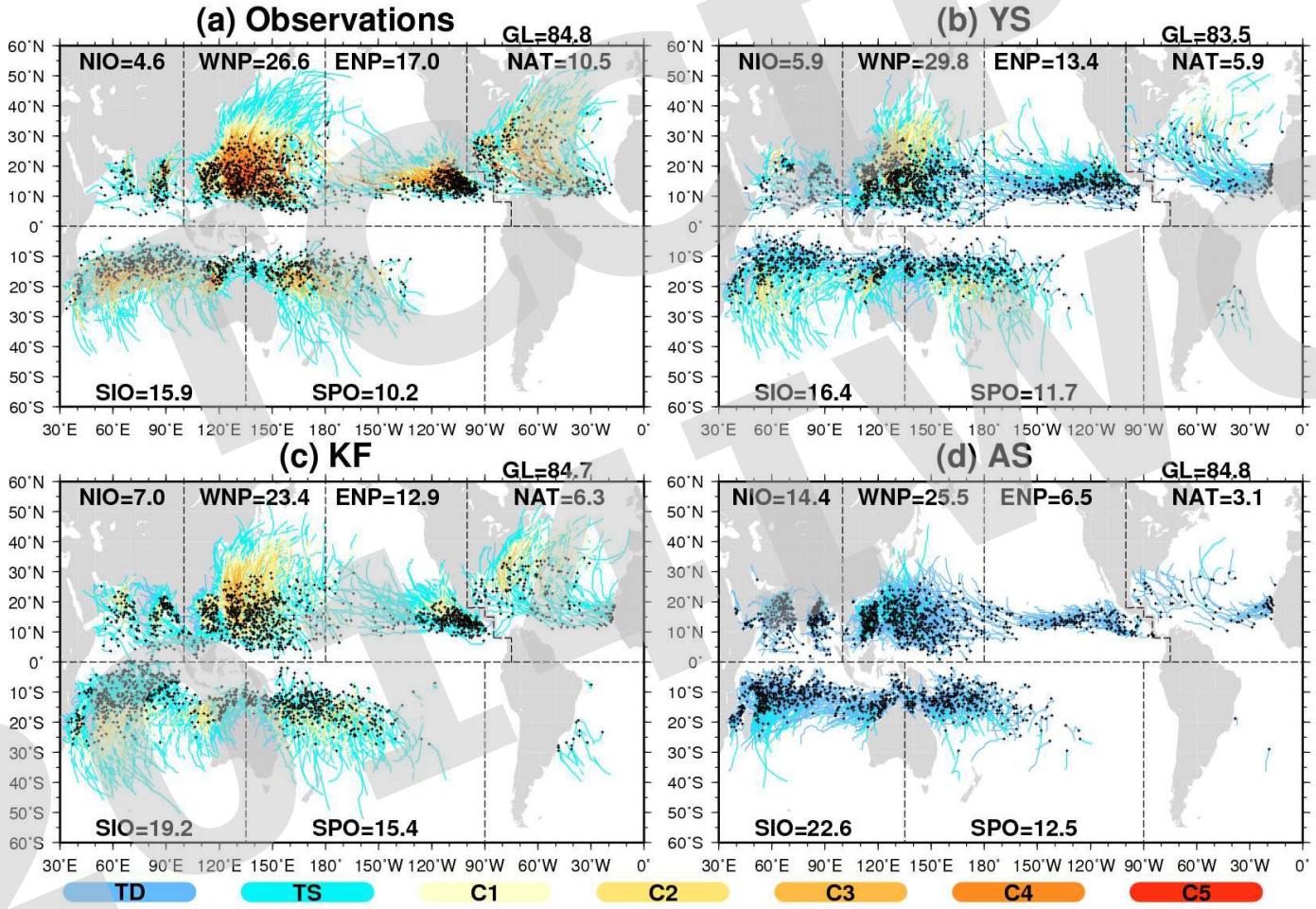
Duration	SST	Cumulus convection scheme		
		Yoshimura(YS)	Arakawa-Schubert(AS)	Kain-Fritsch(KF)
Present 1979-2003	Observation	HPA SPA	HPA_as	HPA_kf
Future 2075-2099 (CMIP3, SRES A1B)	Multi-model	HFA SFA	HFA_as	HFA_kf
	Cluster 1	HFA_cluster1	HFA_as_cluster1	HFA_kf_cluster1
	Cluster 2	HFA_cluster2	HFA_as_cluster2	HFA_kf_cluster2
	Cluster 3	HFA_cluster3	HFA_as_cluster3	HFA_kf_cluster3

20km

60km

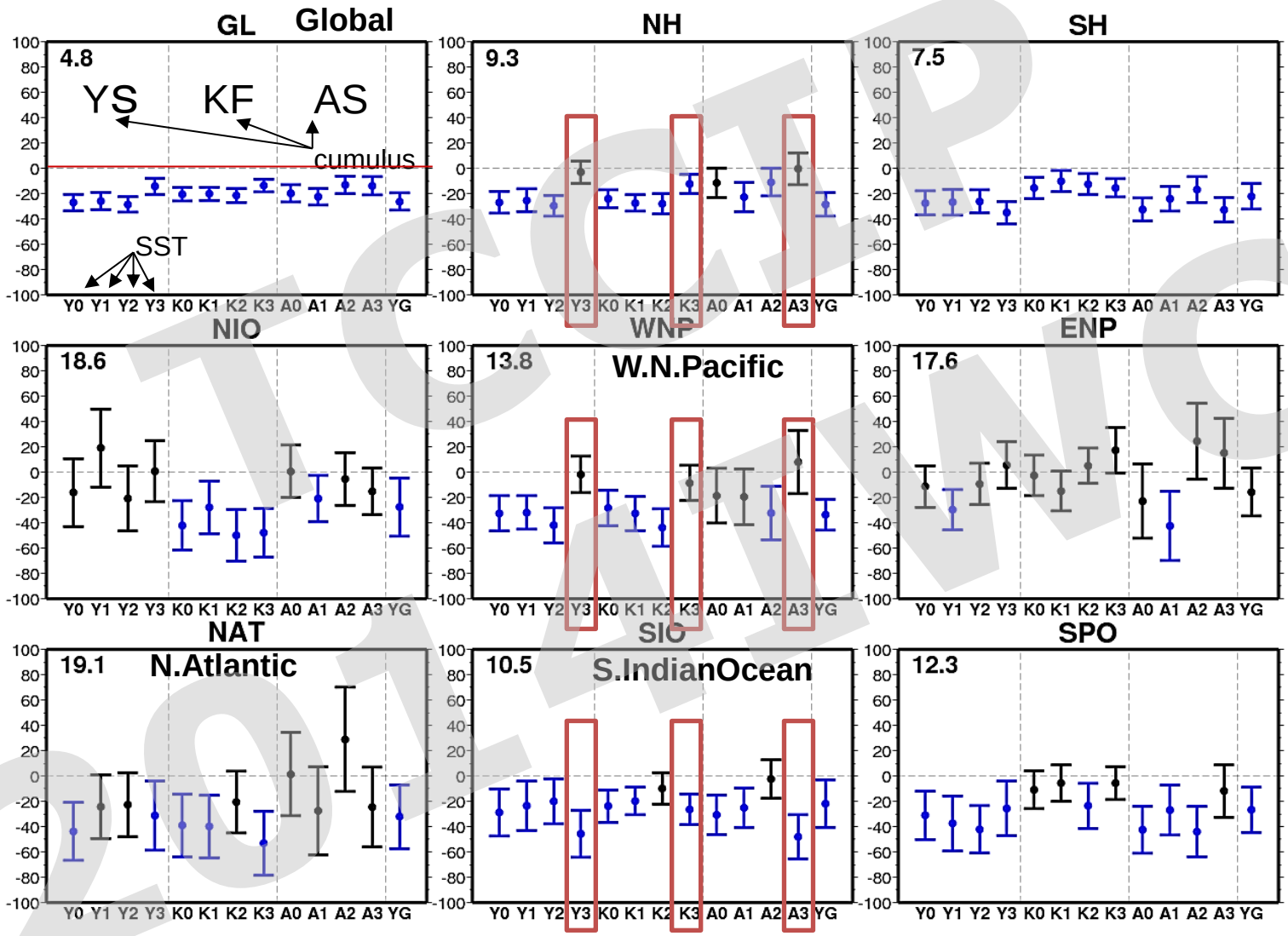
Tropical cyclone activity

- Cyclone tracks in observations and three 60km present experiments



Murakami H, R. Mizuta, and E. Shindo (2012) *Clim. Dyn.*, doi: 10.1007/s00382-011-1223-x.

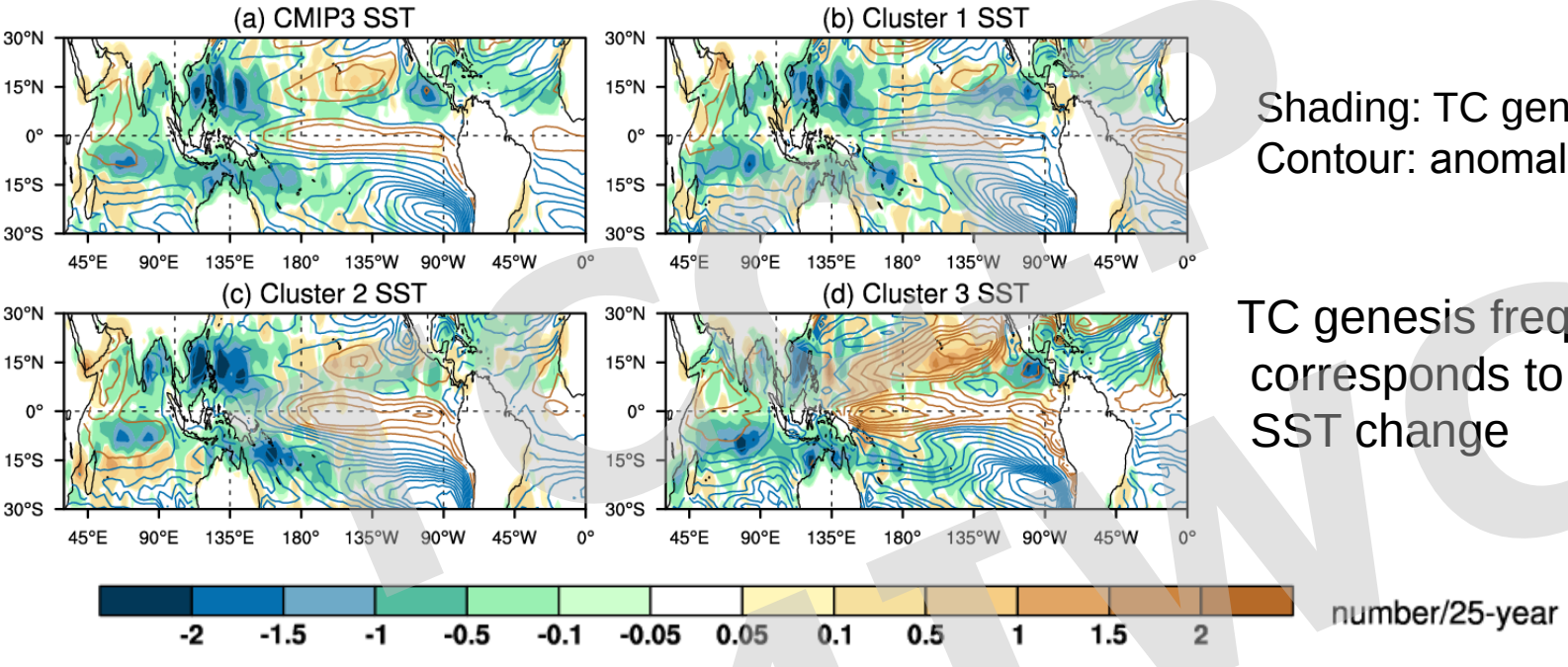
Future changes in TC number [%]



- Global total number decreases in all 12 experiments
- Regional change differs depending on SST changes

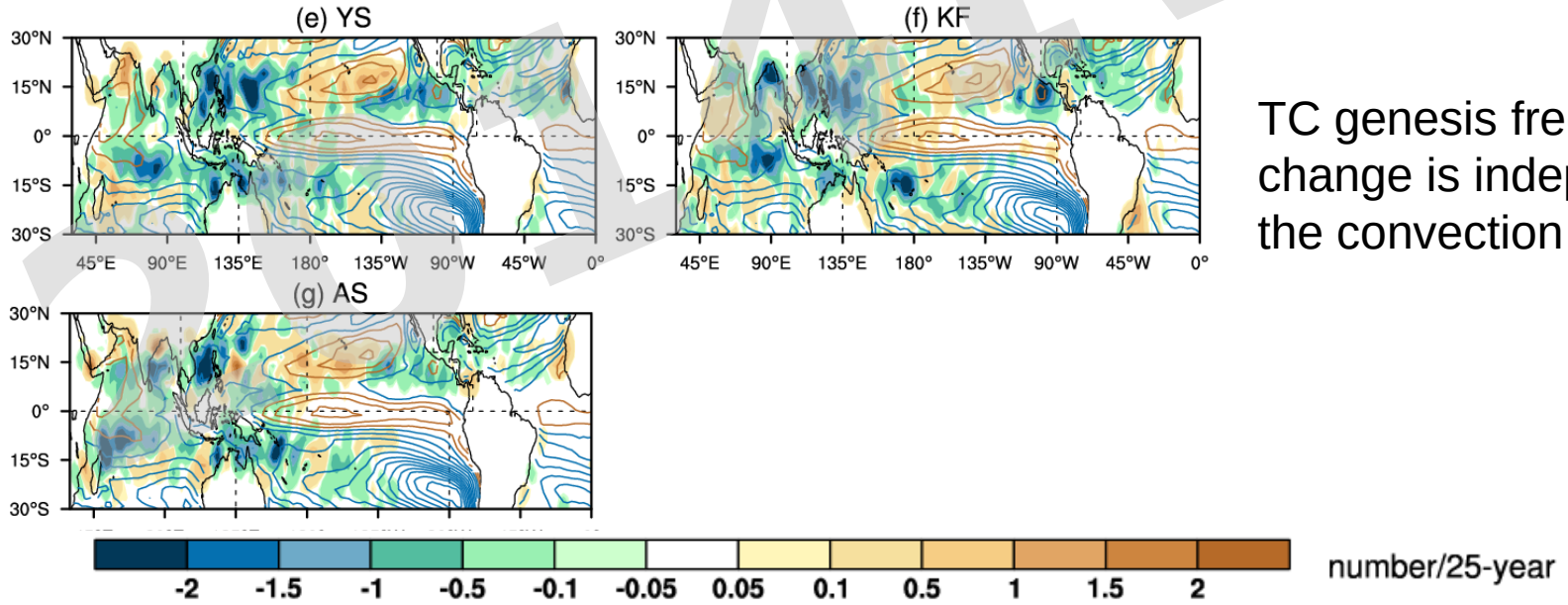
Blue indicates statistically significant decrease

Changes in TC genesis frequency and SST



Shading: TC genesis freq.
Contour: anomaly of ΔSST

TC genesis frequency change corresponds to anomaly of SST change



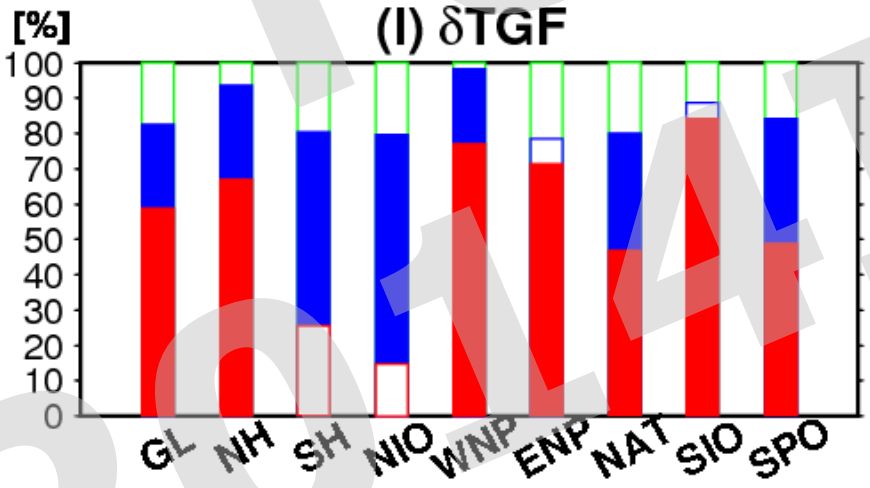
TC genesis frequency change is independent of the convection schemes

Responsible factor for inter-experimental variance

A two-way analysis of variance (ANOVA)

$$\sum_{i=1}^{a}\sum_{j=1}^{b}(X_{ij}-\overline{X}_{..})^2 = b\sum_{i=1}^{a}(\overline{X}_{i.}-\overline{X}_{..})^2 + a\sum_{j=1}^{b}(\overline{X}_{.j}-\overline{X}_{..})^2 + \sum_{i=1}^{a}\sum_{j=1}^{b}(X_{ij}-\overline{X}_{i.}-\overline{X}_{.j}+\overline{X}_{..})^2$$

All variance = Variance by different SST + Variance by different conv. schemes + Residual

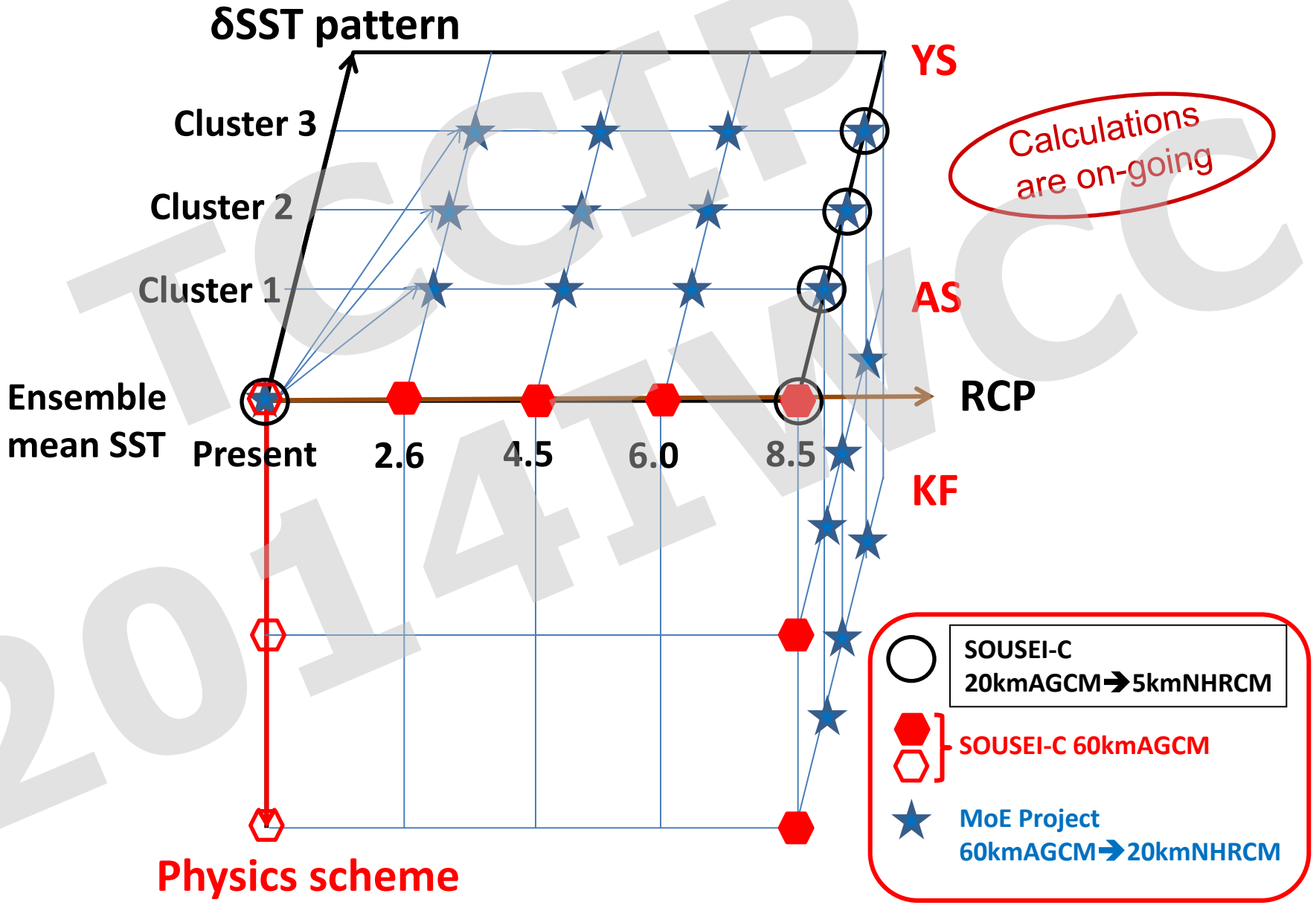


- Spatial distribution of SST change is a major source of uncertainty in terms of regional changes in TC genesis frequency

Re-design of the ensemble experiments

- Ensemble experiments in SOUSEI program (=current project)
- Update from using CMIP3 results to using CMIP5 results
- 20km model ensemble
  - 4 SST ensemble experiments by the 20km model
- Much more experiments by the 60km model
  - Generations of tropical cyclones need to be well simulated for the study of extreme events over East Asia
    → at least 60km resolution
- Considering more factors of uncertainties
  - uncertainty from scenario of greenhouse gas emission
    → 4 scenarios (RCP2.6, 4.5, 6.0, 8.5)
  - uncertainty from different climate models
    → SST ensemble
    + direct downscaling from 3 CGCMs to 3 RCMs
    (not shown today)

Matrix of ensemble experiments



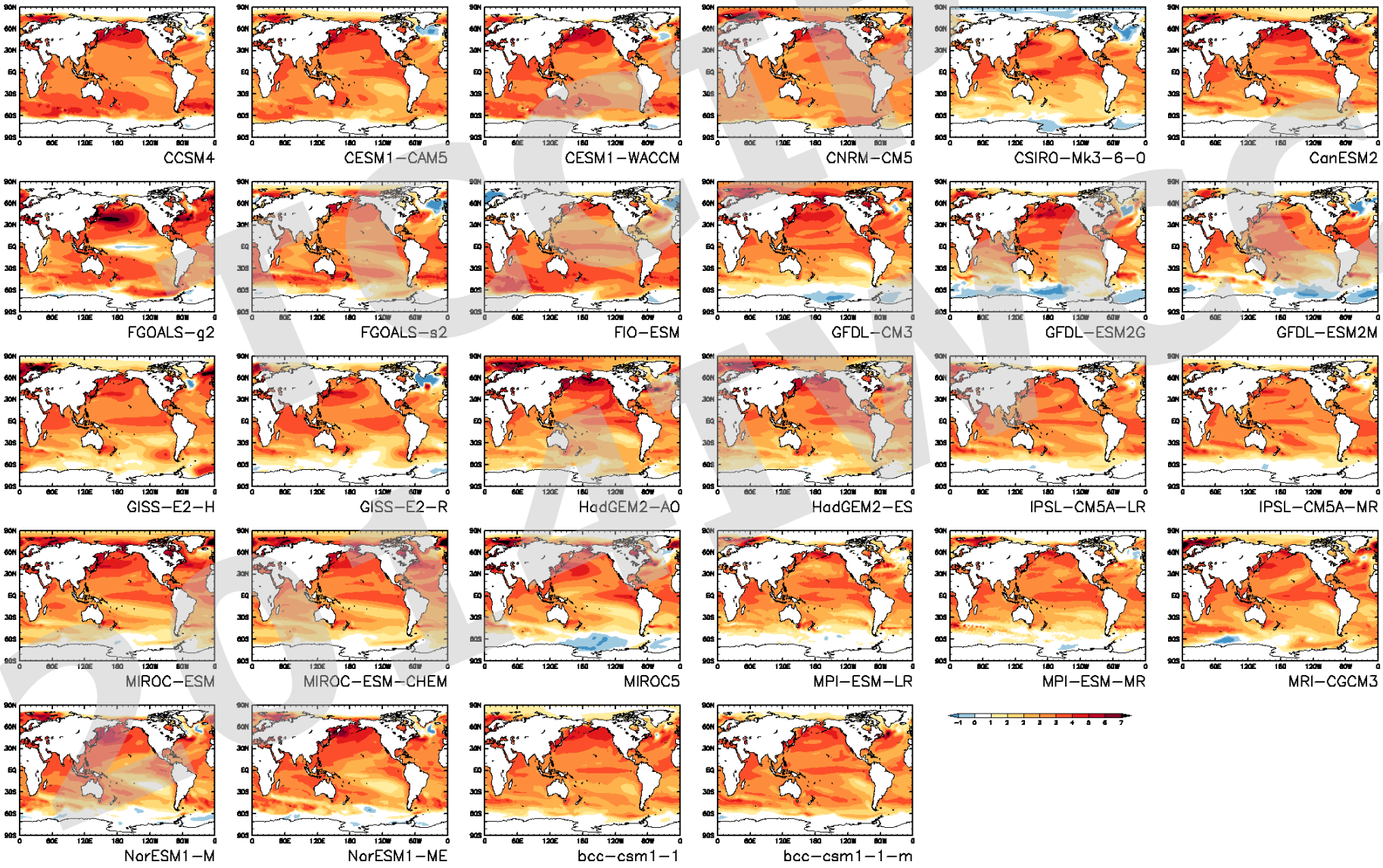
Cluster analysis of ΔSST pattern of CMIP5 models

- SST ensemble experiments uses 3 clusters of warming pattern, in addition to the average of all models.
- 28 CMIP5 models, of which historical+RCP2.6/4.5/8.5 results are available, are used.
- Basically the same method as before

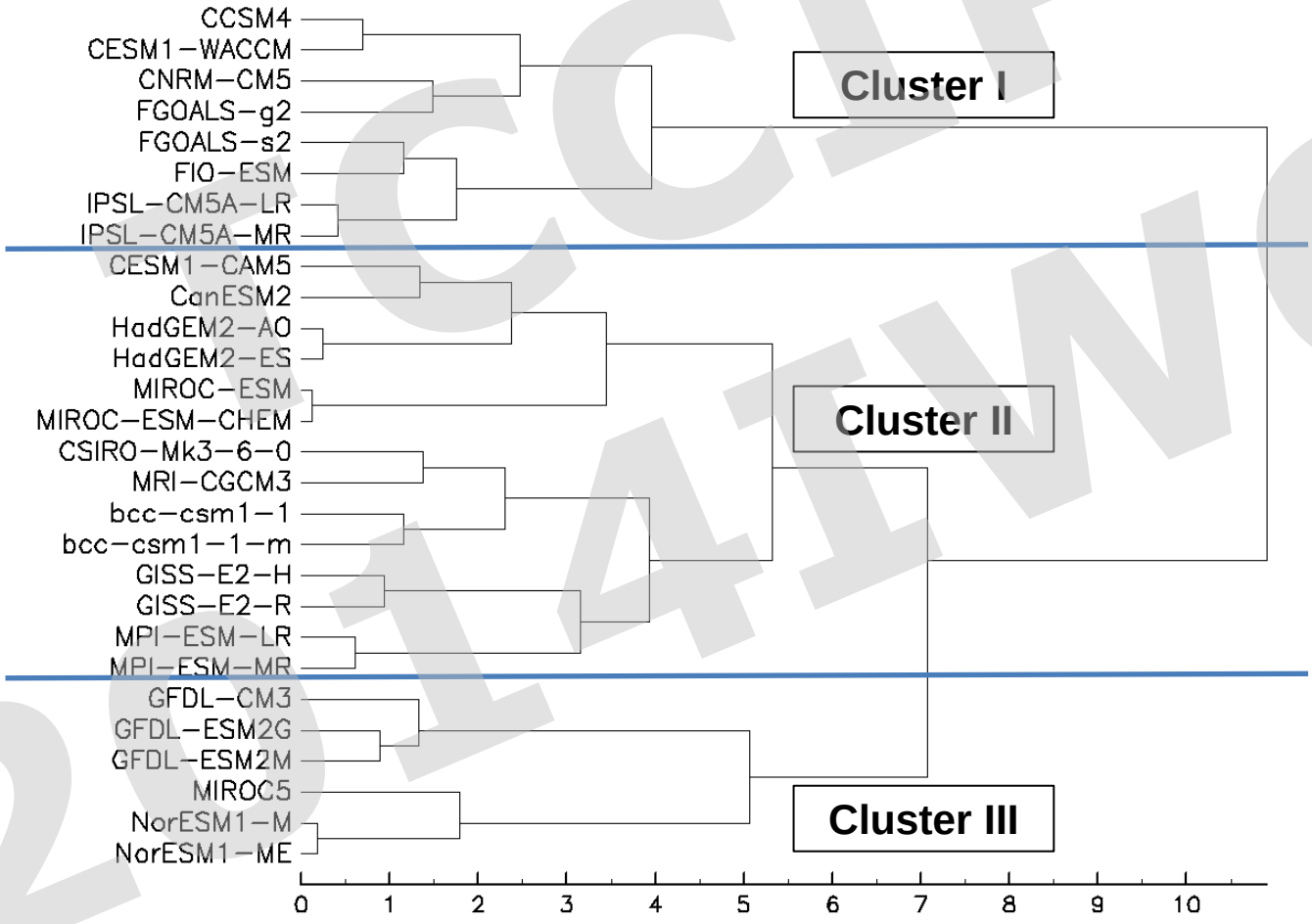
(Endo et al., 2013, JGR; Murakami et al., 2012, Clim. Dyn.)

1. For each model, a mean future SST change is computed by subtracting the 1979-2003 mean from the 2075-2099 mean.
2. The computed mean SST change is normalized by the tropical mean (30°S–30°N) SST change.
3. Multi-model ensemble mean of the normalized value is subtracted from that for each model.
4. The inter-model pattern correlation r of them are computed between all pairs of models.
5. Norms (or distances) are defined as $2 \times (1 - r)$ for each model, and the cluster analysis is performed using these norms.
6. When the final three groups are bounded, the clustering procedure is terminated.

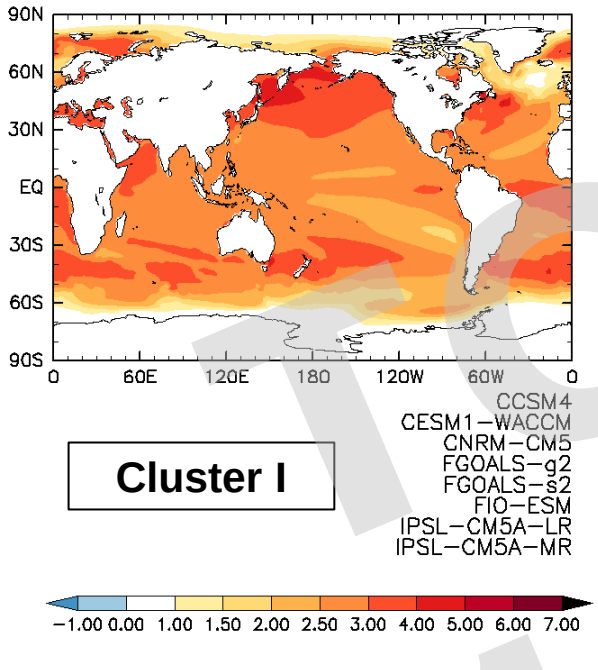
CMIP5 normalized SST change (RCP8.5-historical)



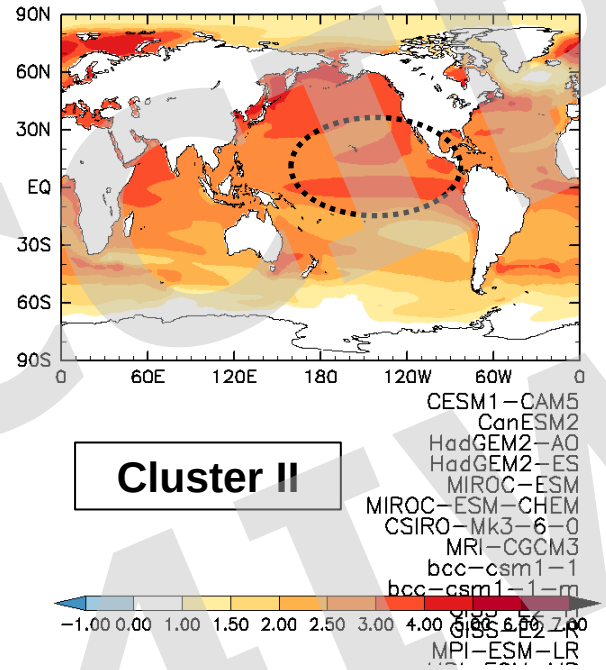
Cluster analysis results



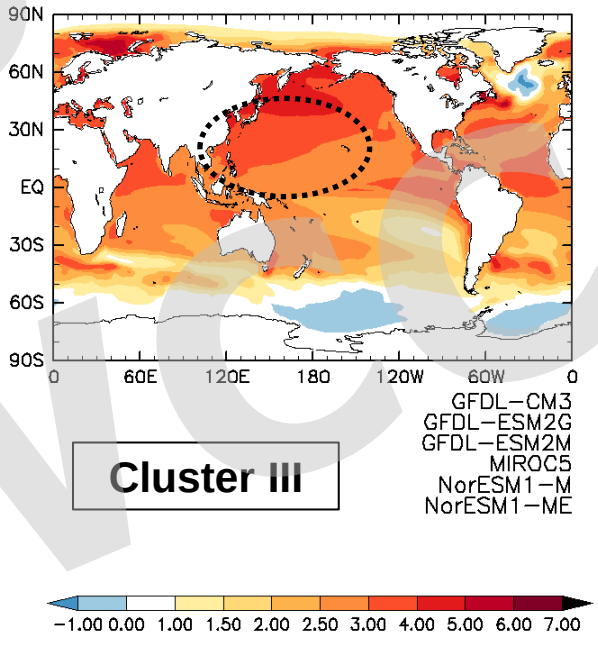
Averages of the patterns for each cluster



Uniform warming in the tropics

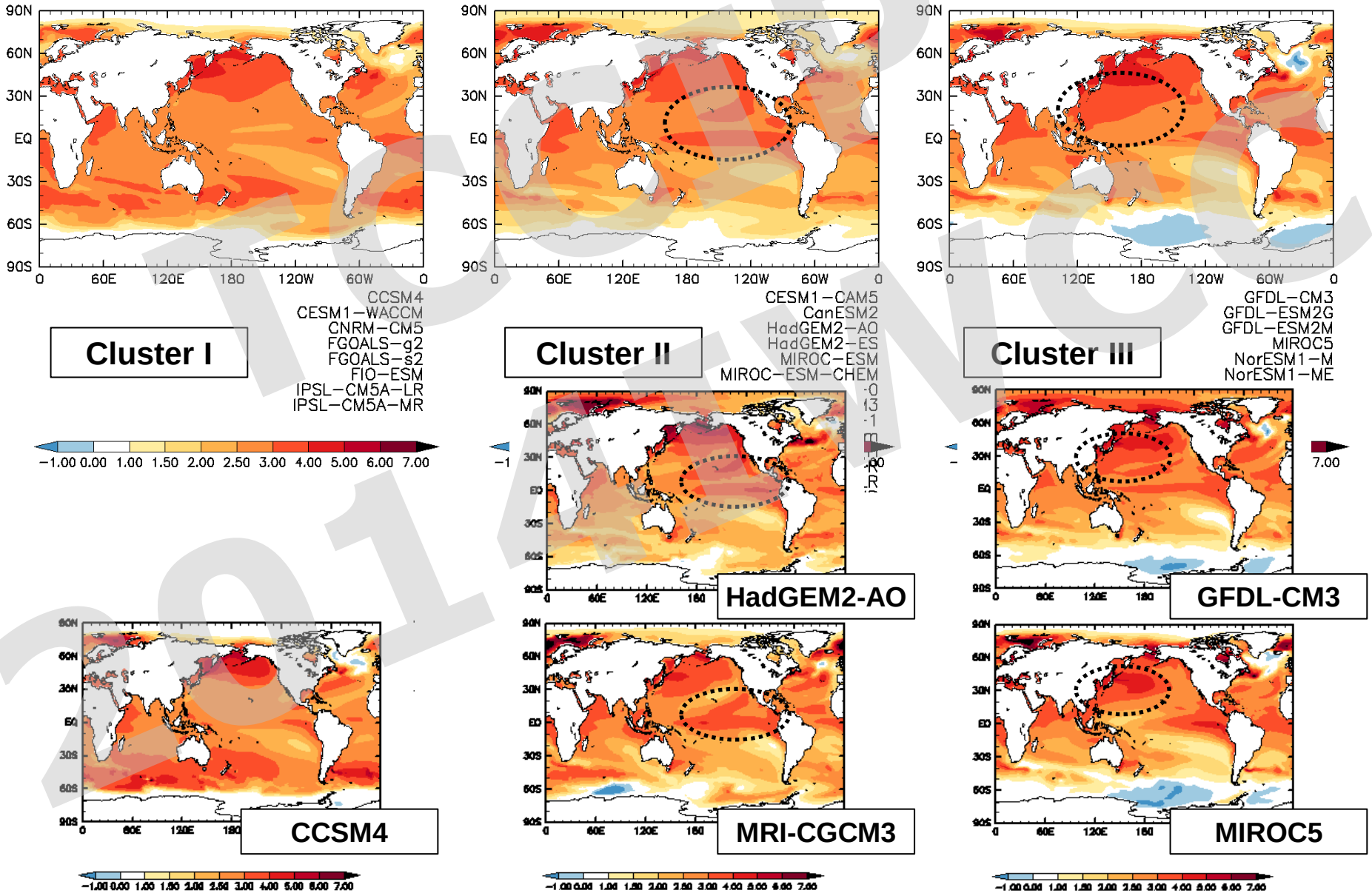


Larger warming in the subtropics of N.E. Pacific



Larger warming in the N. Indian Ocean and N.W. Pacific

Averages of the patterns for each cluster



Summary

- Evaluation of uncertainty of the change by global warming using 60km ensemble experiments
  - Global total number of TC decreases in all experiments.
  - Spatial distribution of SST change is a major source of uncertainty in terms of regional changes in TC genesis frequency.
  - Changes in intense precipitation over the lands are more dependent of cumulus convection scheme (not shown).

KAKUSHIN

- Re-designed ensemble experiments with 20km and 60km models are on-going
  - 4 SST ensemble simulations by the 20km model, and much more ensembles by 60km model.
  - SST ensemble uses 3 clusters of warming patterns from 28 CMIP5 models, in addition to the average of all models.

SOUSEI