The Modes of Interannual Variability of Southern Hemisphere Atmospheric Circulation in CMIP5 Models: Assessment and Projected Changes

www.cawcr.gov.au

Simon Grainger, **Carsten S. Frederiksen and Xiaogu Zheng**

6th CLIVAR C20C International Workshop

November 6, 2013

Australian Government
Bureau of Meteorology

The Centre for Australian Weather and Climate Research
A partnership between the Bureau of Meteorology and CSIRO

CSIRO

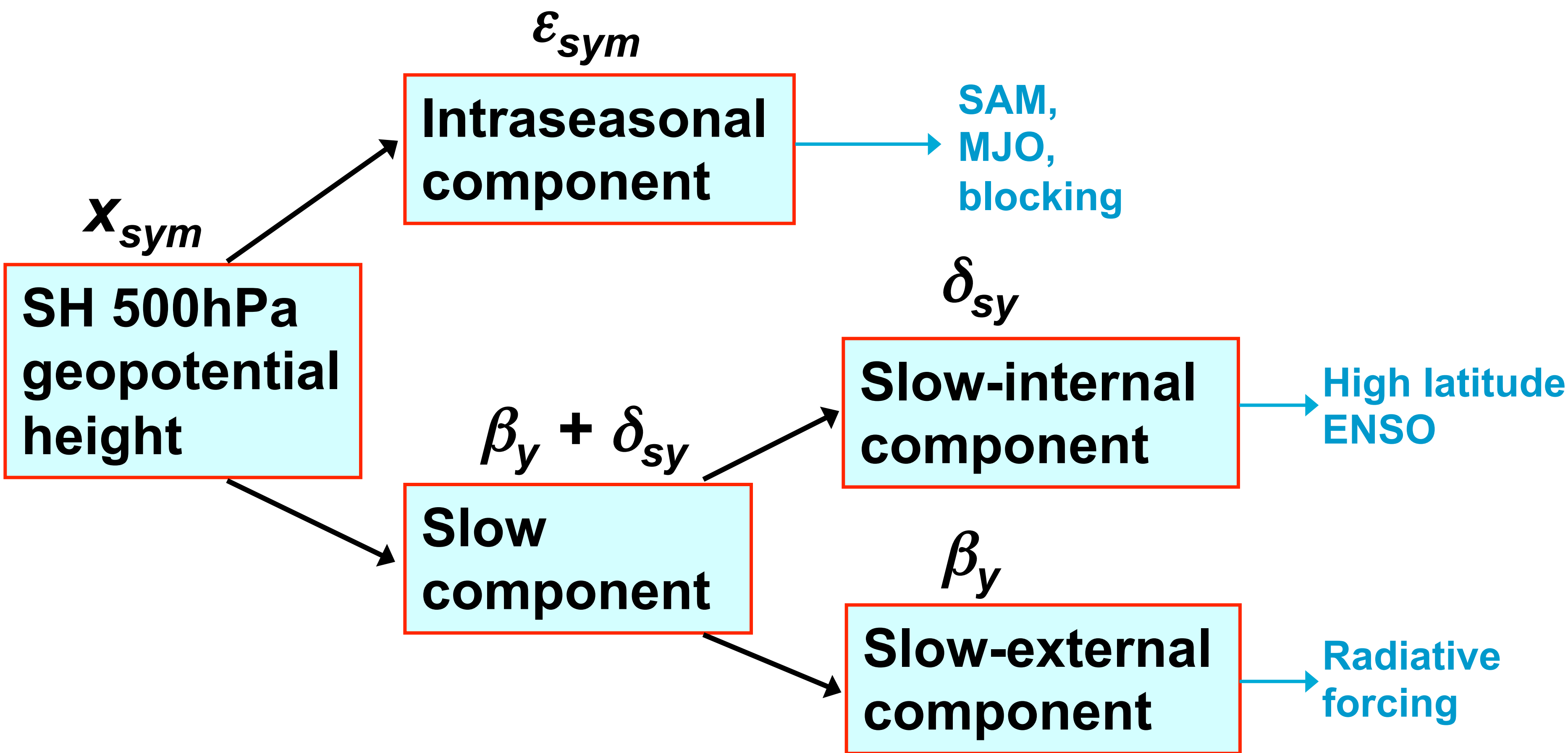
Motivation

- Analysis of climate change can be seen as a signal-to-noise problem
- Want to understand the covariability between large-scale climate forcings and surface climate (e.g. Australian rainfall)
  - And the impact of climate change
- Focus on atmospheric circulation variability as major teleconnection
  - Necessary condition for reproducing observed changes in climate

Motivation

$$x_{sym} = \beta_y + \delta_{sy} + \varepsilon_{sym}$$

S **realisations,** ***Y*** **years,** ***M*** **months**



Methodology

- Estimate interannual covariance matrices for seasonal mean of each component
- EOF decomposition to obtain modes of variability for each component
- Select 1-1 “best matches” in CMIP5 models to 20CR slow (and intraseasonal) modes

S. Grainger, C.S. Frederiksen, X. Zheng, D. Fereday, C.K. Folland, E.K. Jin, J.L. Kinter, J.R. Knight, S. Schubert, J. Syktus (2011), *Clim. Dyn.*, **36**, 473-490, doi:10.1007/s00382-009-0720-7

S. Grainger, C.S. Frederiksen, X. Zheng (2013), *Clim. Dyn.,* **41**, 479-500, doi:10.1007/s00382-012-1659-7

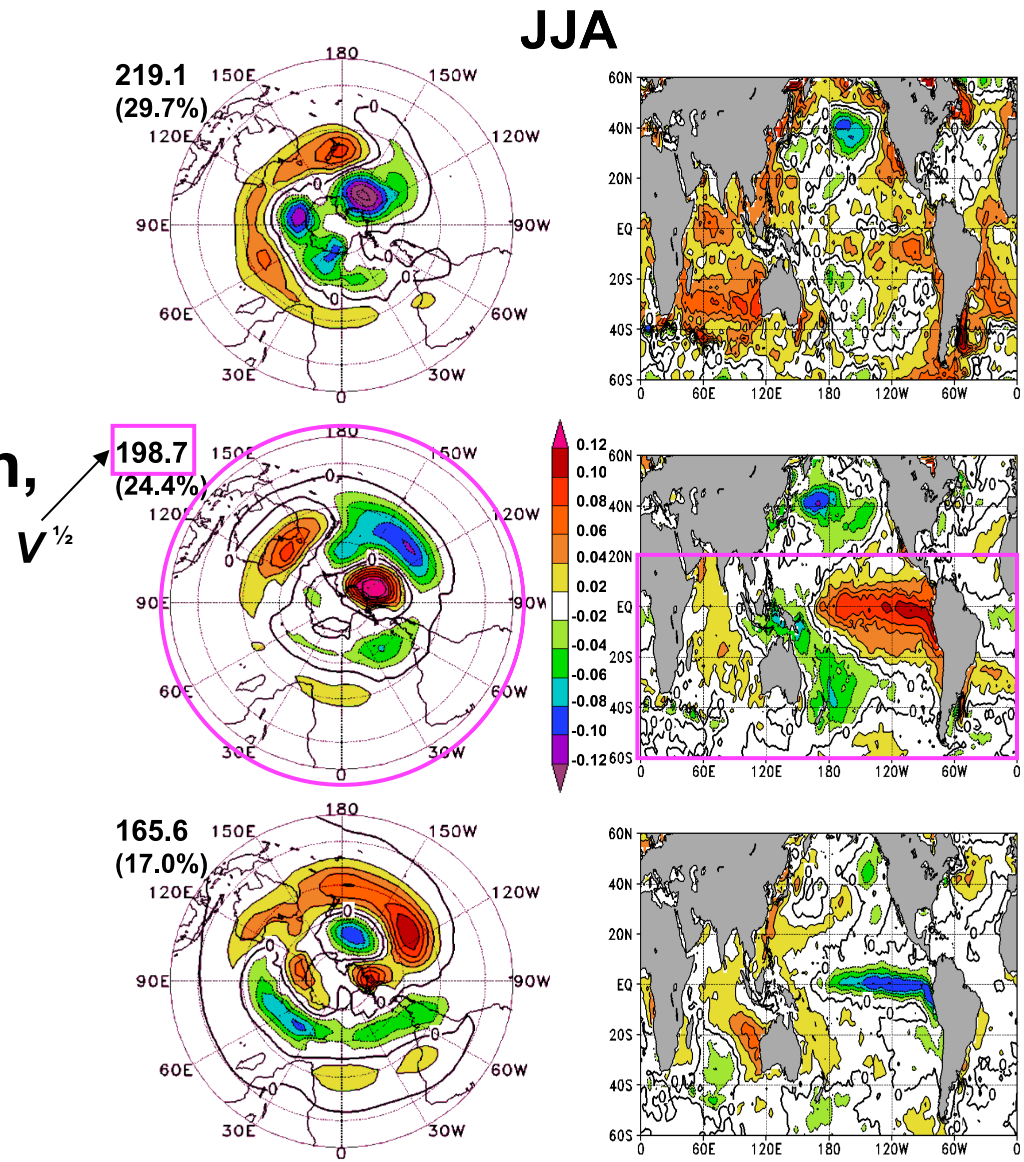
SH Z500 Slow Modes – 20CR 1951-2000

Mode diagnostics:

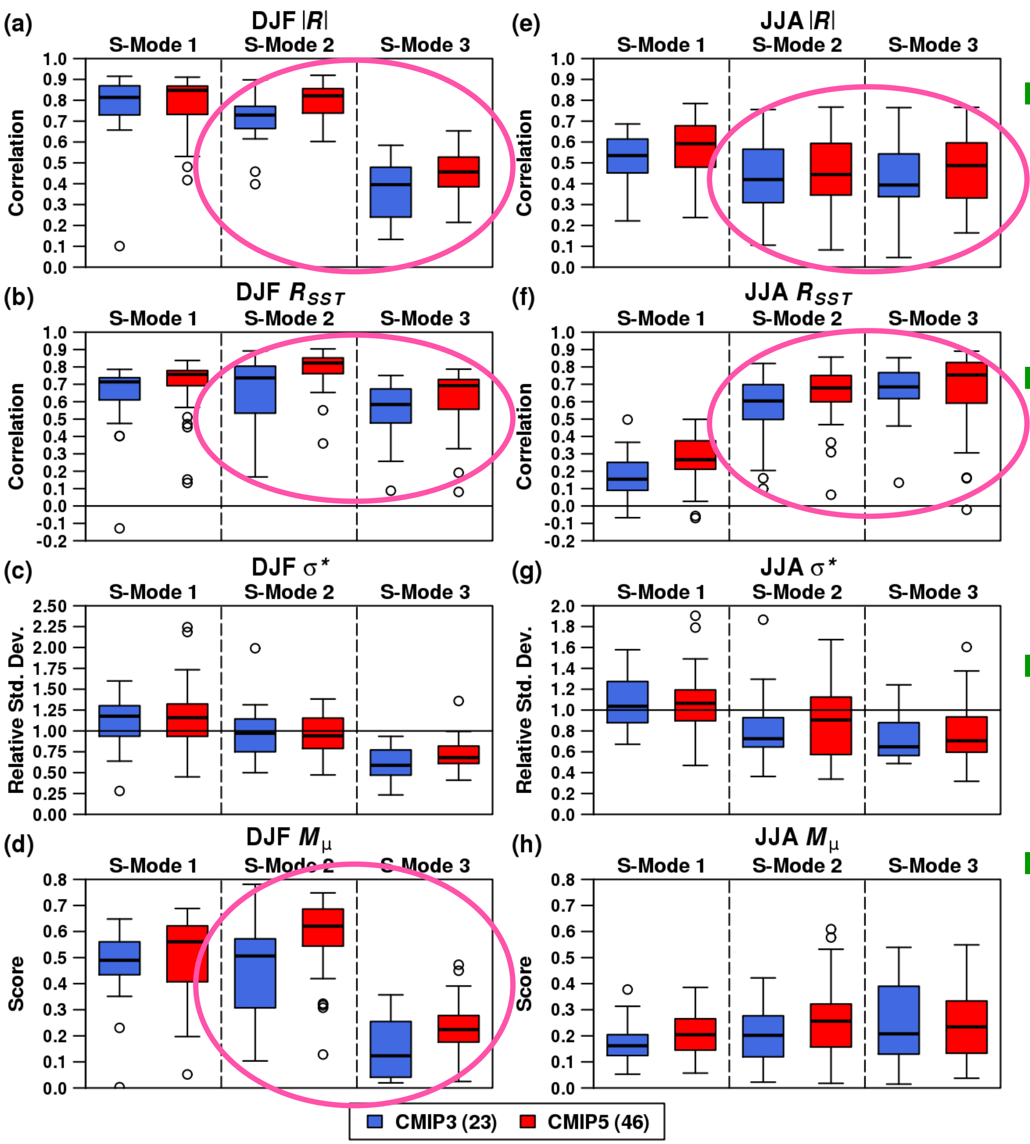
- **EOF pattern correlation, *R***
- **SST covariance pattern correlation, R_{SST}**
- **Relative standard deviation, $\sigma^* = V'^{1/2}/V^{1/2}$**

Score:

$$M_\mu = \frac{|R|\left(1+R_{SST}\right)^2}{2\left(\frac{V'}{V}+\frac{V}{V'}\right)}$$

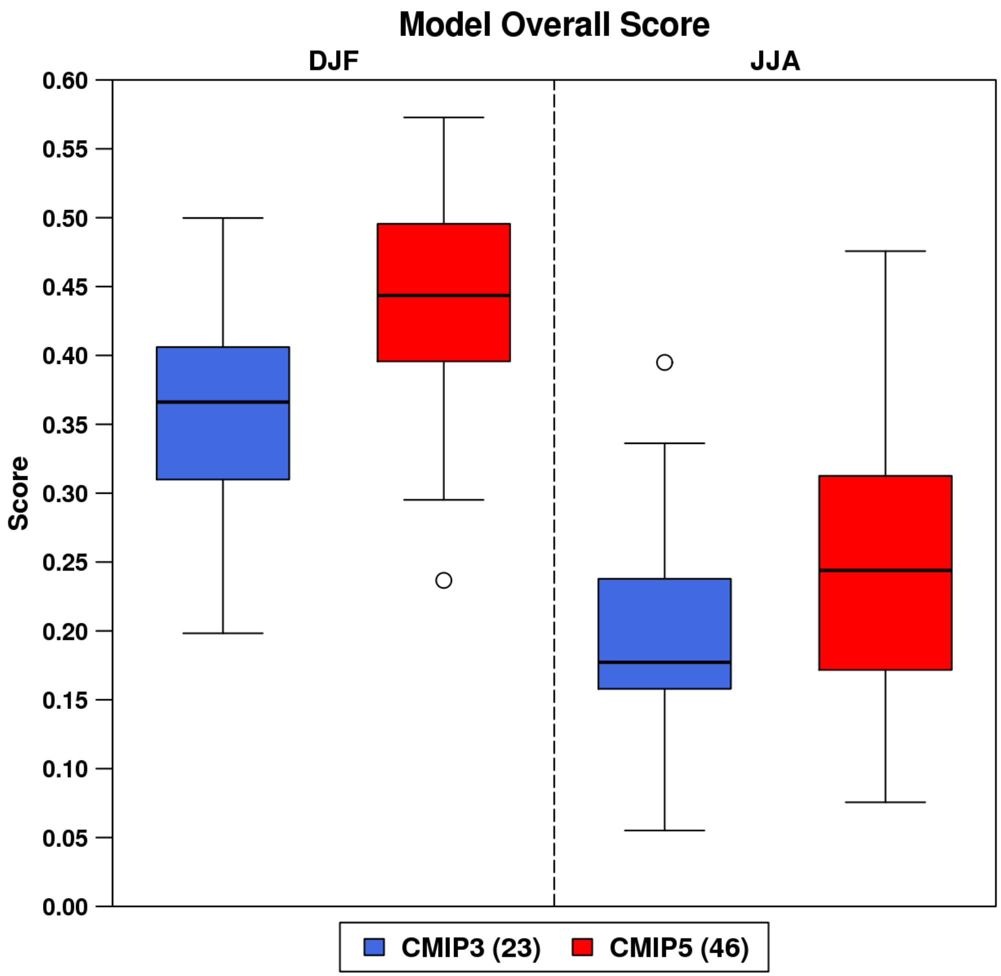


Comparison – CMIP5 vs CMIP3



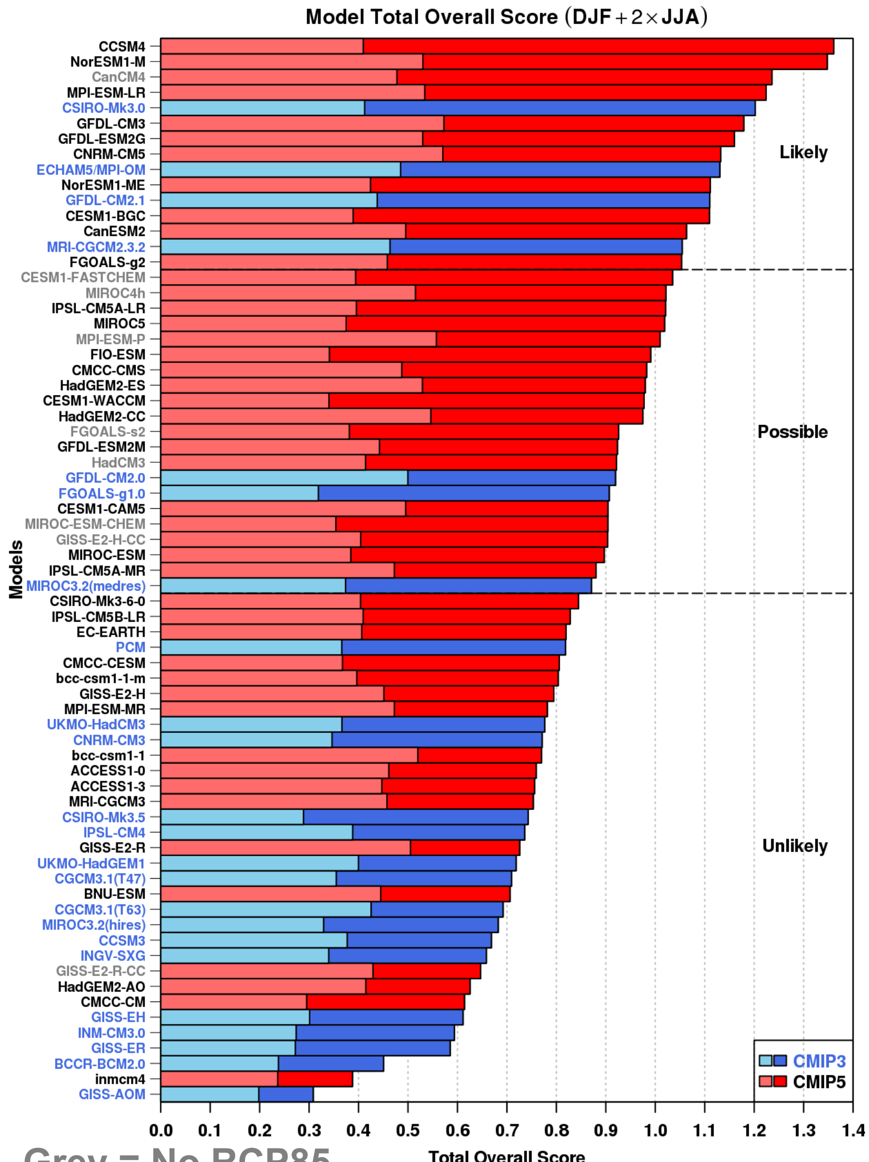
- Clear improvement in structure of ENSO modes in DJF
- Similar range in JJA, but higher median values
- Small improvements in associated variance
- Largest improvement in score is DJF ENSO-modes

CMIP5 vs CMIP3 – Overall Score



- Average score over leading three S-Modes in each season
- Clear improvements in both seasons
  - Largest in DJF
- Differences in medians likely to be significant in both seasons

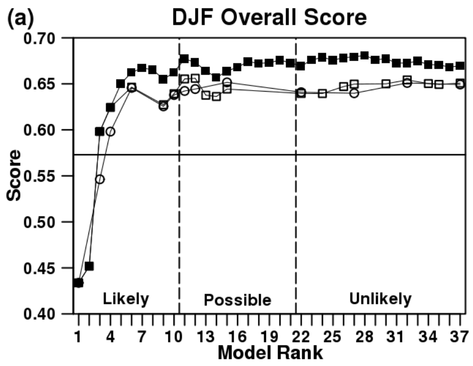
CMIP5 vs CMIP3 – Individual Models

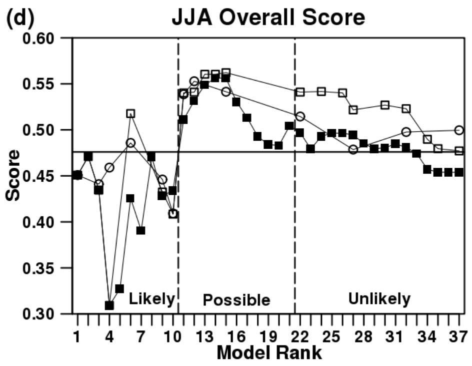


Grey = No RCP85

- Total Score ≡ DJF + 2×JJA
- Set thresholds for whether model is “likely”, “possible” or “unlikely” to be “suitable for further analysis”
  - “Necessary” condition (Grainger et al., 2013)
- CMIP5: 11/18/17 models
- CMIP3: 4/3/16 models

CMIP5 Multi-Model Ensemble size





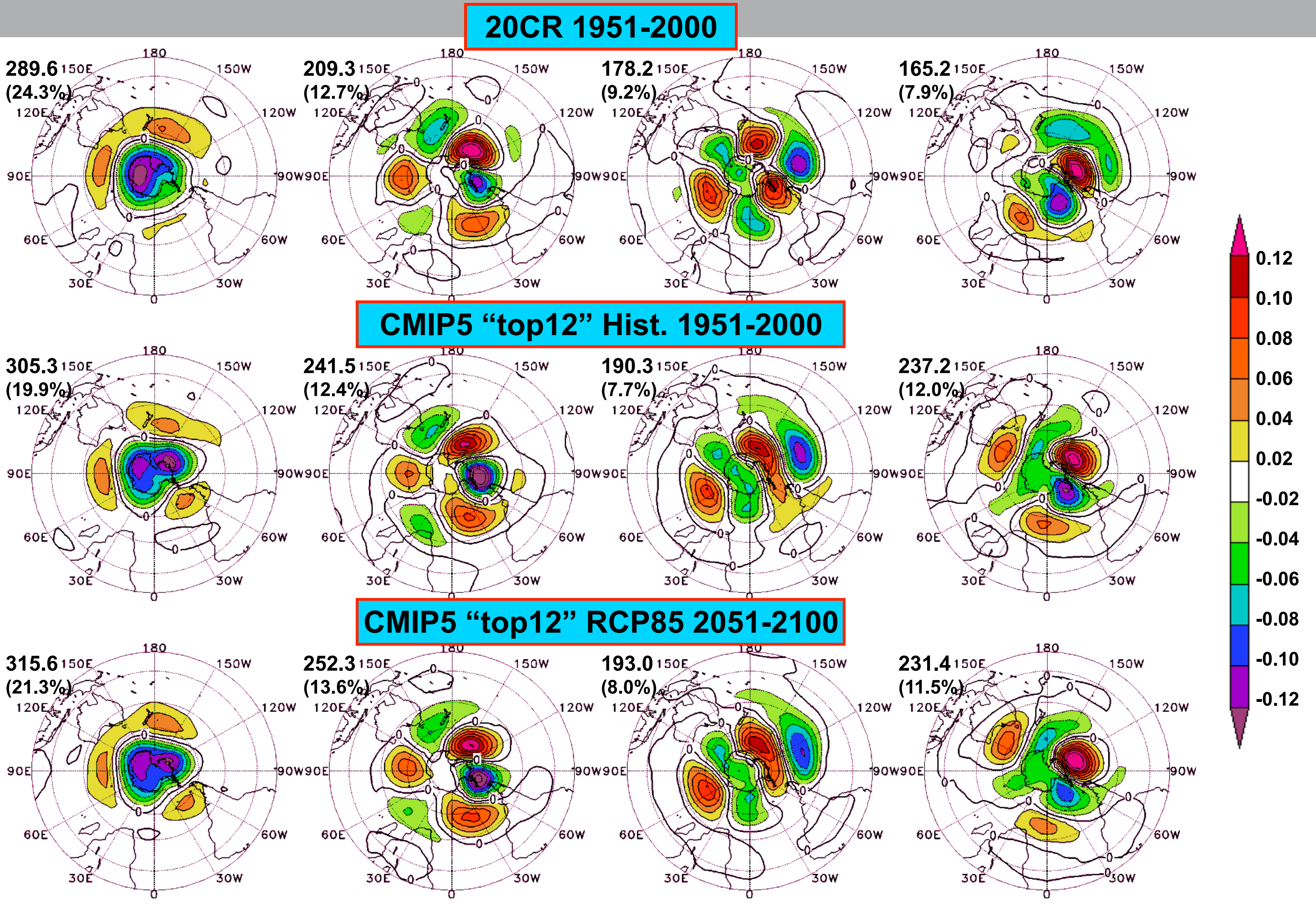
- Add CMIP5 models to MME by Total Score
  - 1-37, excluding no RCP85
- DJF MME reaches optimum Score at S = 6
- JJA “best” at S = 13-15
- Slow-external variance stabilises at S ≈ 12
- **S = 12** “optimum”?
- Smaller MME possible with diverse models

CMIP5 MME – Selected by Rank

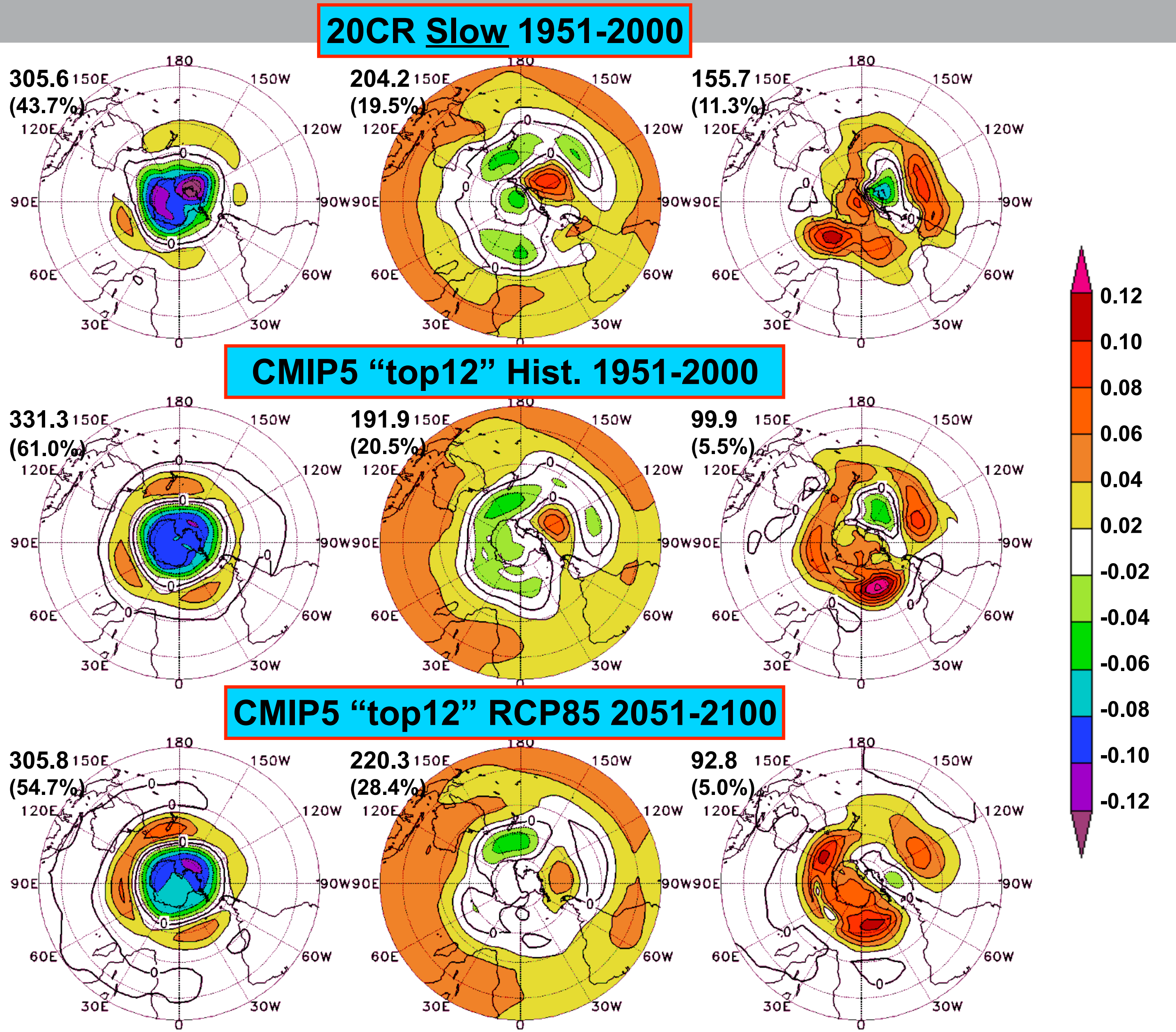
Ensemble	DJF	JJA
CMIP5 “top12”	0.673	0.532
CMIP5 “mid12”	0.653	0.395
CMIP5 “bot12”	0.606	0.205
CMIP5 single model	0.573	0.476
CMIP3 “best4”	0.500	0.420

- “Necessary” condition – models must reproduce SH Z500 S-modes “reasonably well”

SH Z500 JJA Intraseasonal Modes



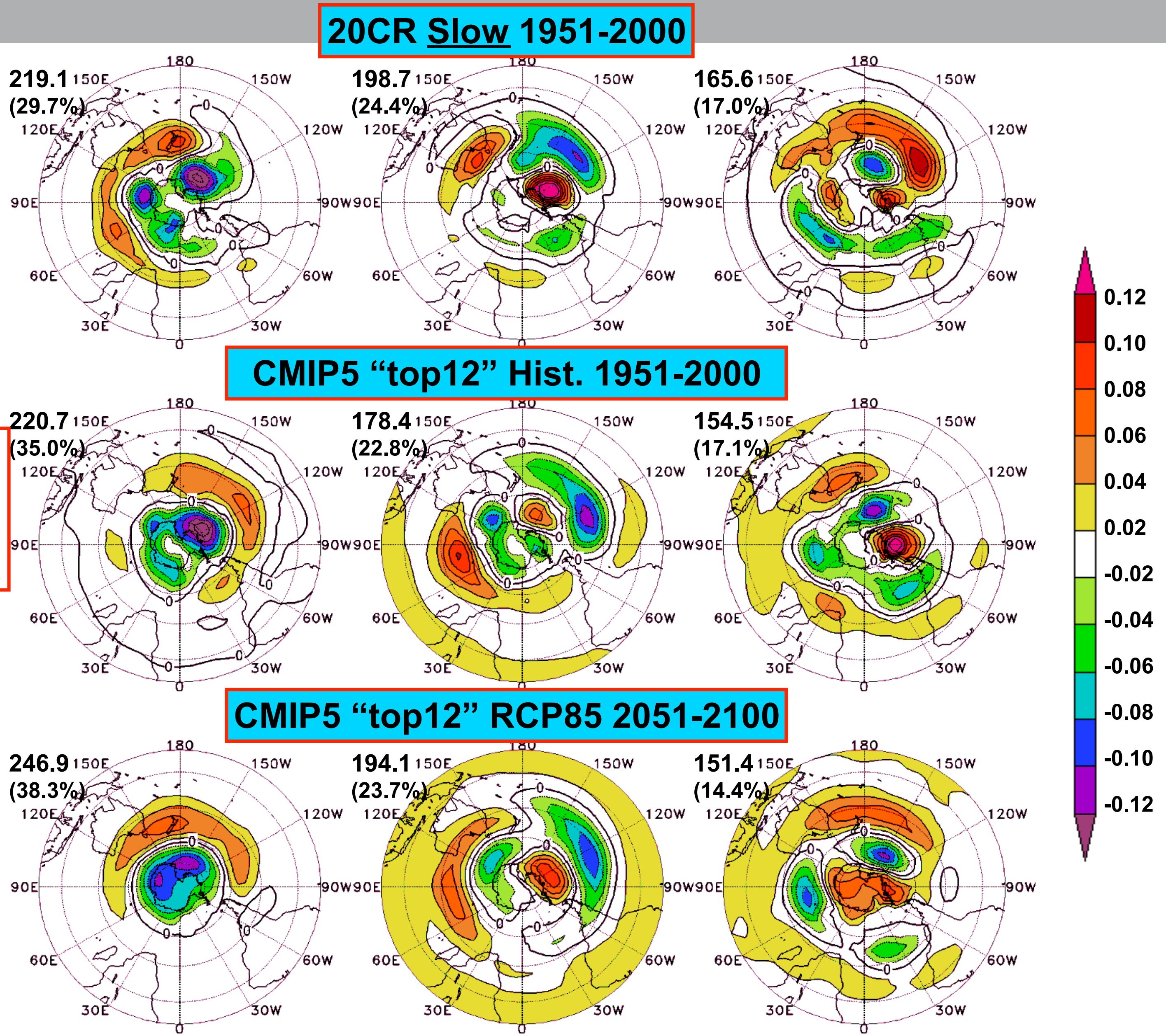
SH Z500 DJF Slow-Internal Modes



HLM too strong, ENSO-2 too weak

Little change in modes

SH Z500 JJA Slow-Internal Modes

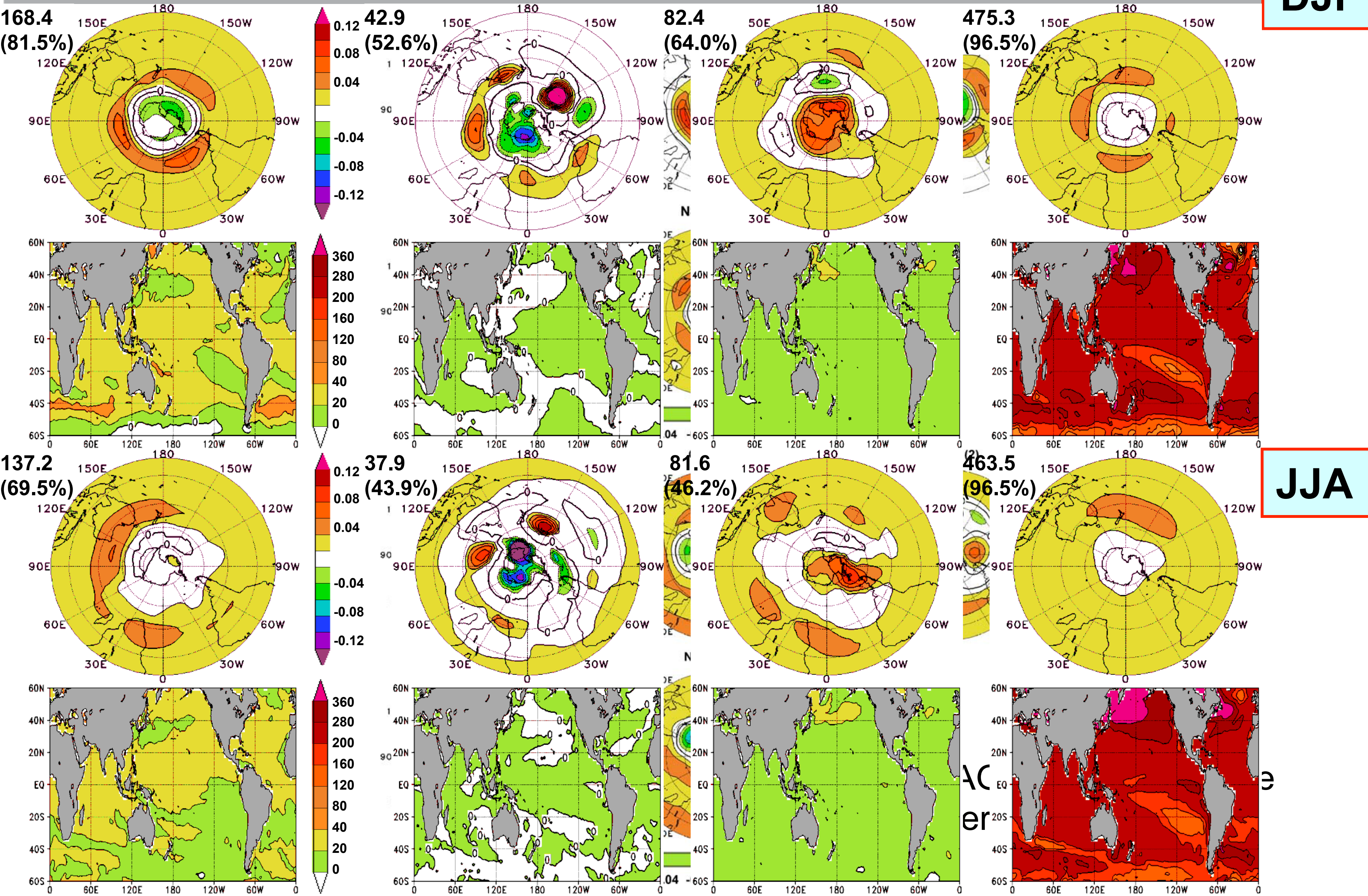


“HLM” +
2 “ENSO”
Modes

Modes
closer to
20CR

SH Z500 – CMIP5 "top12" Trend Mode

Historical RCP26 RCP45 RCP85



CMIP5 “top12” – Variance Change

Mode	RCP26	RCP45	RCP85
DJF SI-Mode 1	0.96	0.99	0.92
DJF SI-Mode 2	1.06	1.03	1.15
DJF SI-Mode 3	0.85	1.00	0.93
JJA SI-Mode 1	0.89	0.99	1.12
JJA SI-Mode 2	0.89	0.92	1.09
JJA SI-Mode 3	0.65	0.67	0.98
DJF SE-Mode 1	0.25	0.49	2.82
JJA SE-Mode 1	0.28	0.60	3.38

$$\Delta\sigma \equiv \frac{\sqrt{V_{RCP}}}{\sqrt{V_{Hist.}}}$$

- Consistent changes in associated variance of DJF SI-Modes
- Some scaling with RCP scenario in JJA
- Changes in associated variance of “Trend” mode up to an order of magnitude larger than in SI-modes

Conclusions

- General improvement in CMIP5 in reproducing SH Z500 slow modes
  - Largest improvement in DJF ENSO-modes
- CMIP5 MME of size 8-15 suitable models should be used for SH Z500 modes
  - S = 12 is “optimum”
- Very little change RCP85 intraseasonal modes
- Larger changes in RCP85 slow-internal modes
  - More ensembles required to understand regional-scale
- By far the largest change is in leading slow-external mode, related to changes in radiative forcing