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Snow-monsoon teleconnections: testing competing mechanisms using idealized snow forcing in a GCM

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Snow-monsoon teleconnections: testing competing mechanisms using idealized snow forcing in a GCM

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ENSEMBLES

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Introduction

- More than a century ago, heavy winter snowfall was thought to precede weak Indian monsoons (Blanford 1884).
- Several studies have examined this in observations:
  – *eg*, Fasullo (2004): regions neighbouring India have robust negative correlations in weak ENSO years (snow cover).
- These rely on the Blanford hypothesis:
  – persistant heavy snow in spring reduces surface sensible heating over the Tibetan plateau, reducing the land-sea meridional temperature contrast and weakening the Asian summer monsoon.

Introduction

- Other studies have shown different results;
  - Bamzai & Skukla (1999): western Eurasia is the only region with significant negative correlations between snow cover and ISM rainfall (but only 22yr data). No consideration of ENSO.
  - Becker et al 2001: weakened monsoon circulation following heavy Western Eurasian snow cover (modelling study), positive correlation with AIR.
- Generally these rely on some circulation mechanism.

Outline

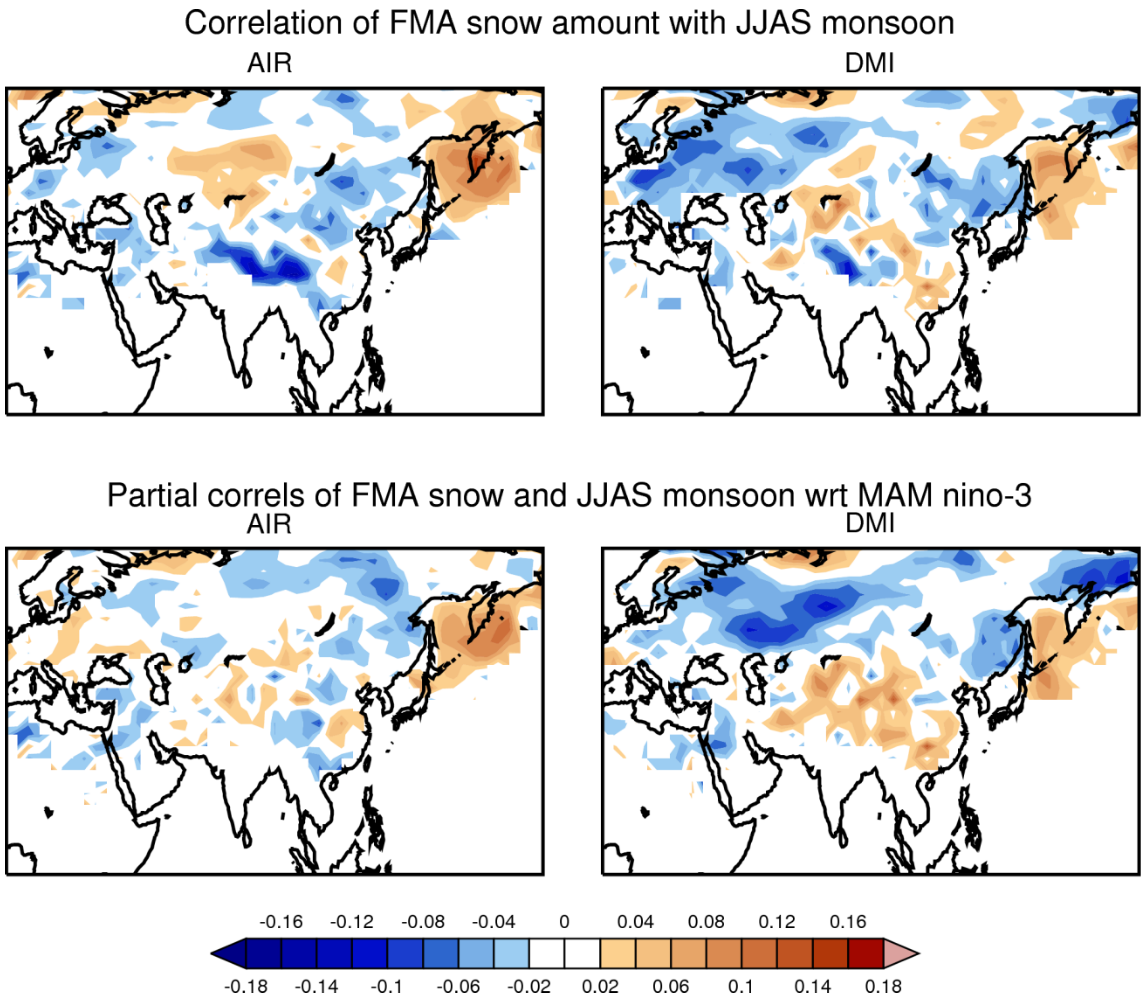
- Introduction
- Analysis of long coupled integration
- Ensemble AGCM experiment design
- Preliminary results
- Potential uncertainties and future plan

Analysis of a long coupled integration

HadCM3 1050yr control run under pre-industrial greenhouse conditions, fully-coupled model:

- atmosphere 3.75°x2.5°xL19
- ocean 1.25°x1.25°xL20

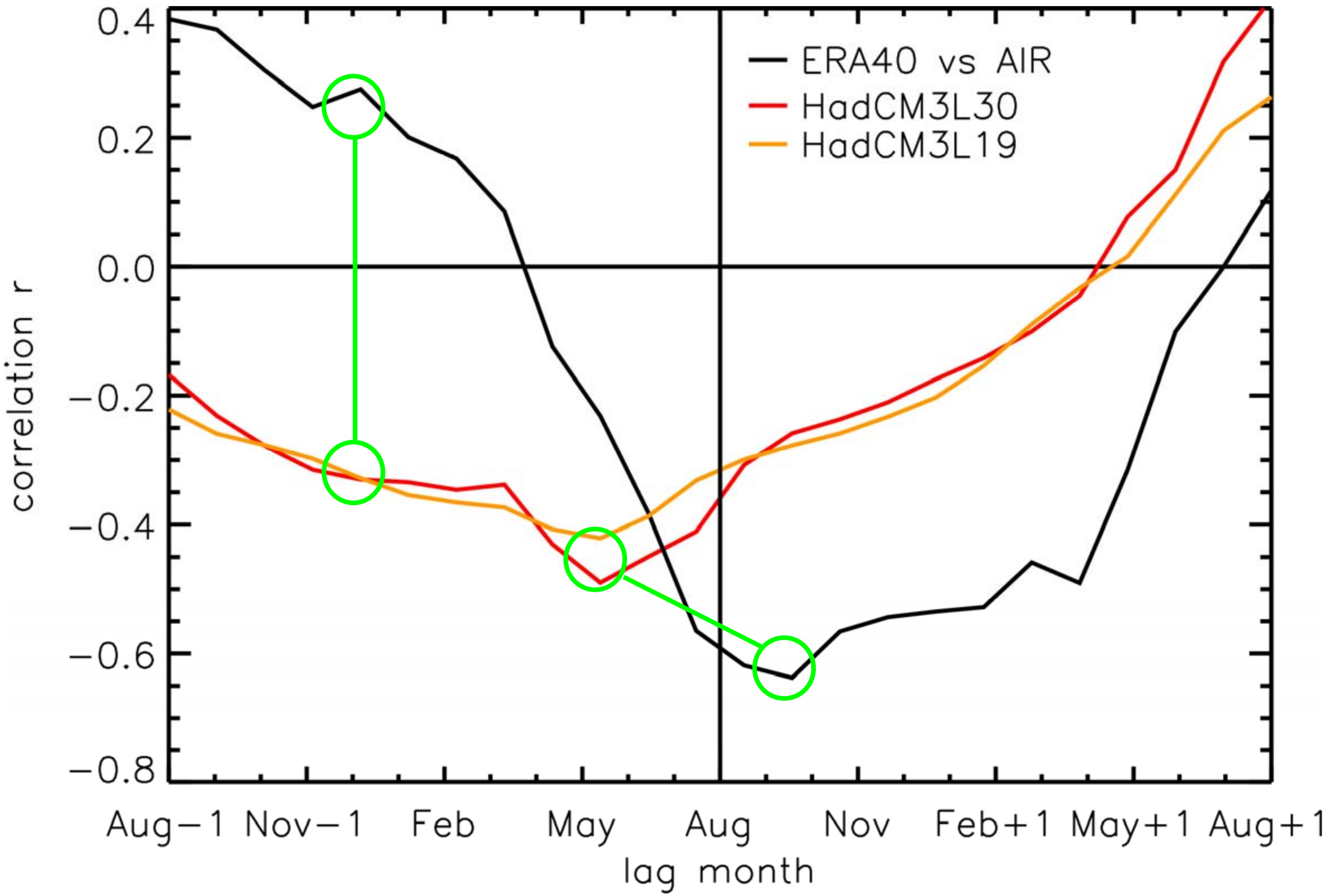
Snow-monsoon correlations in HadCM3



Weak but significant negative correlations:

- FMA Himalaya snow vs. JJAS AIR
- FMA Eurasia snow vs. JJAS DMI

Problems in the monsoon-ENSO teleconnection



Snow-monsoon correlations in CMIP3 models

- Do other state-of-the-art coupled models behave better than HadCM3?

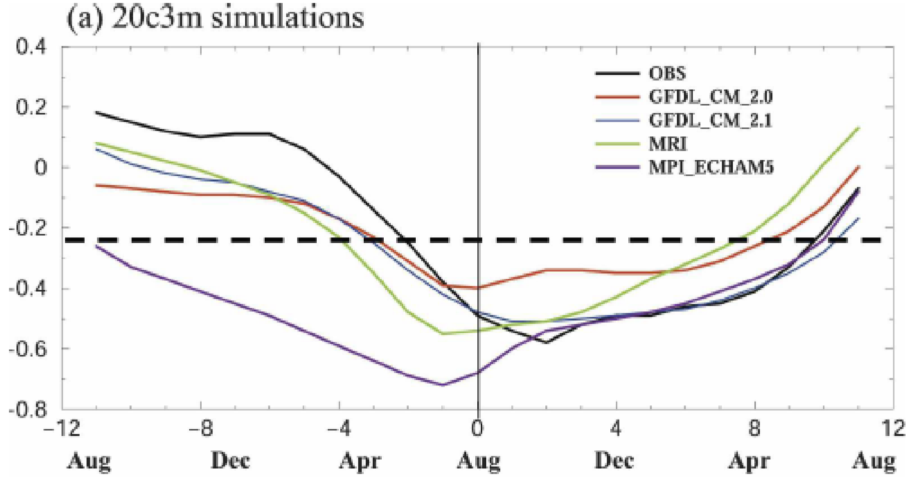


FIG. 12. Lag–lead correlation between AIR anomalies and Niño-3.4 SST anomalies: (a) 20c3m and (b) 1pctto2x simulations. In (a) and (b), the results from observations are also shown. Horizontal dotted lines represent the 5% significance level. Lag–12 corresponds to Niño-3.4 SST anomalies one year before the monsoon season.

- Correlations in the CMIP3 models which satisfy the Annamalai et al. (2007) test of well-simulating the present day monsoon-ENSO teleconnection.

Snow-monsoon correlations in CMIP3 models

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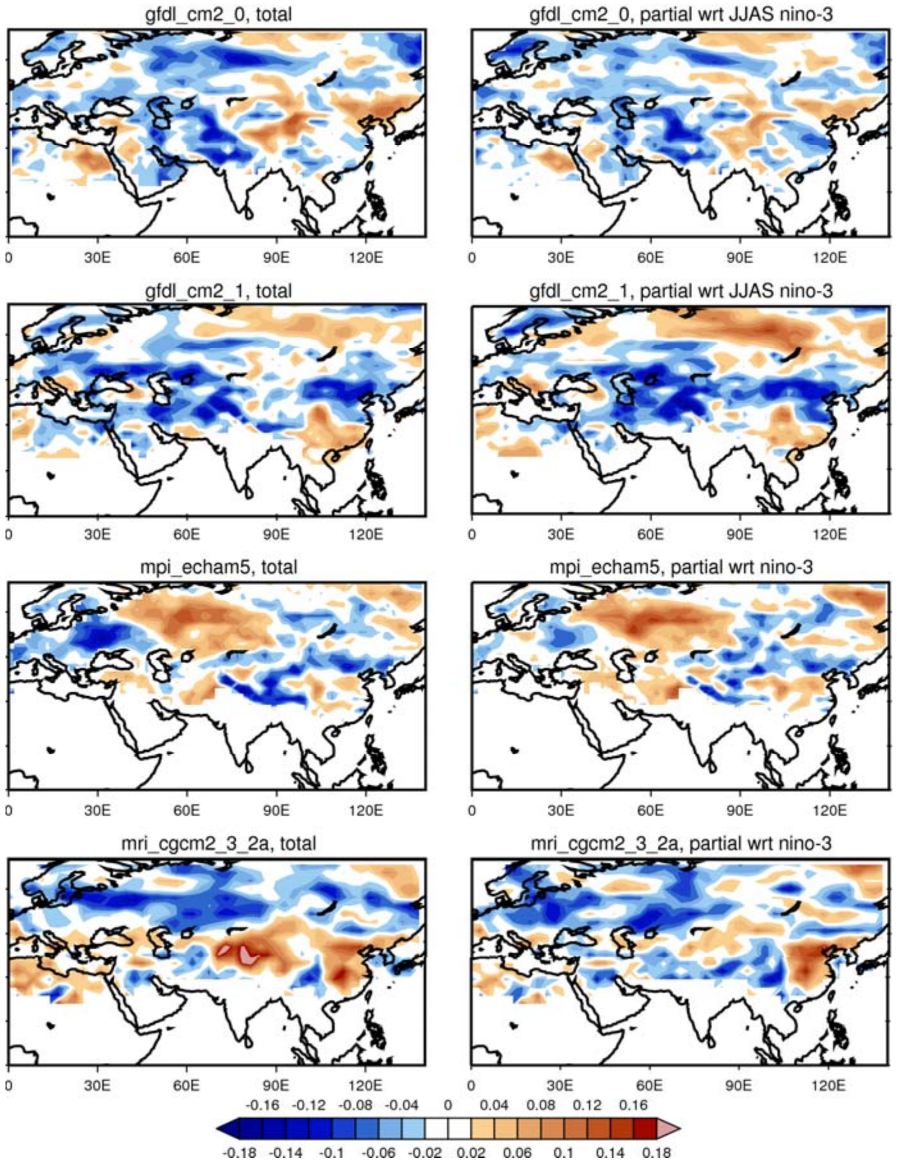
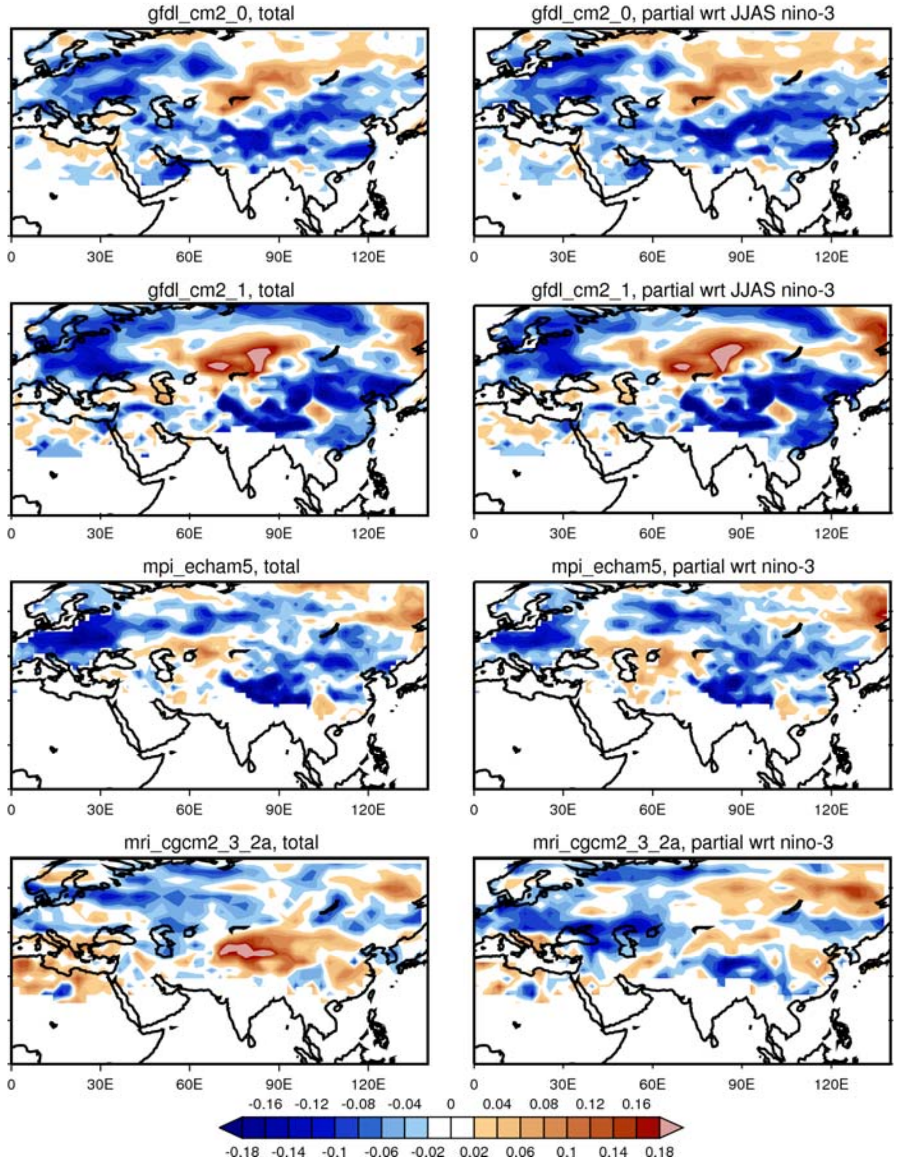
Correlations of JJAS AIR with FMA snow amount



Correlations of JJAS DMI with FMA snow amount



Snow-monsoon correlations in CMIP3 models

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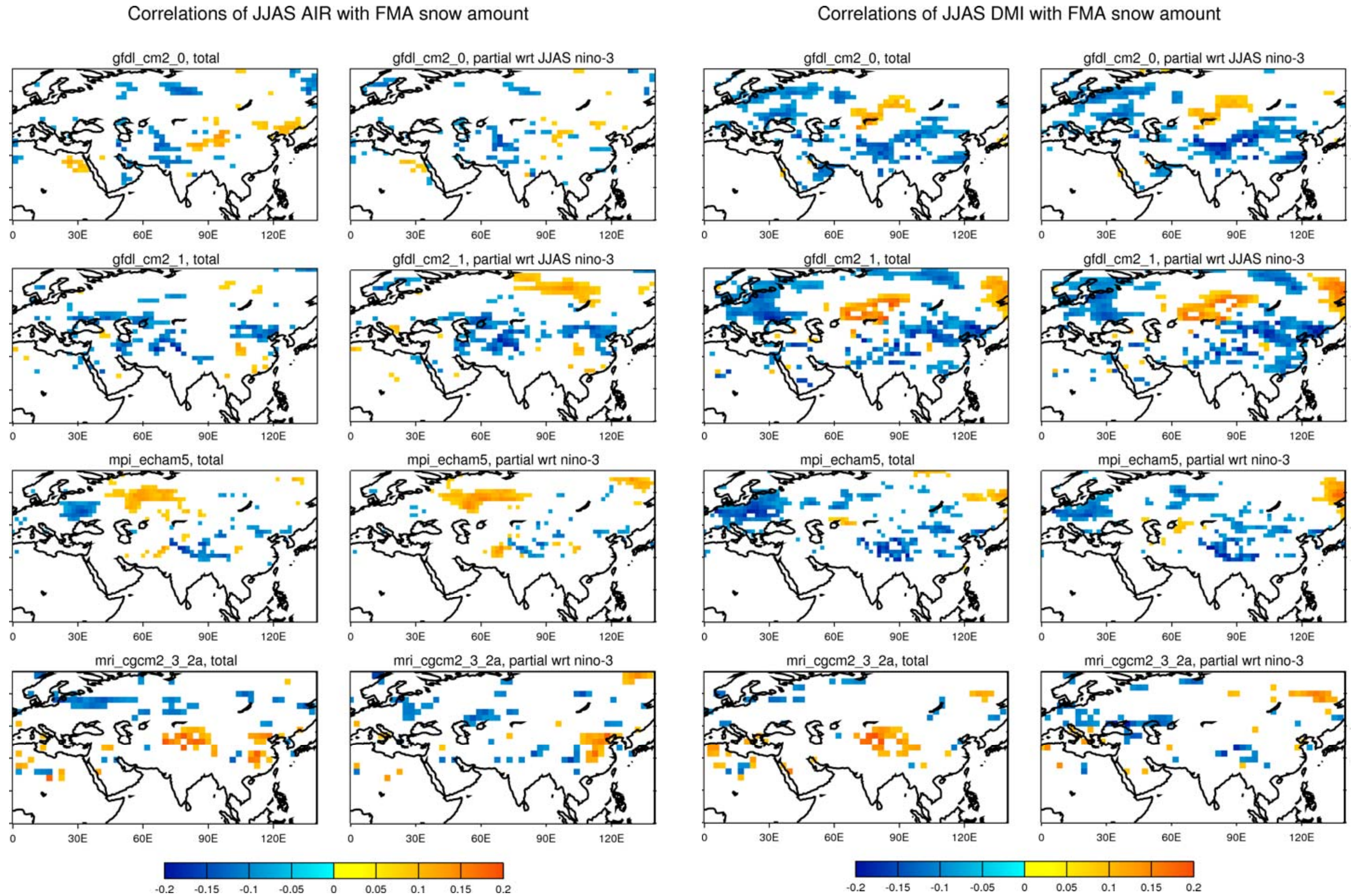
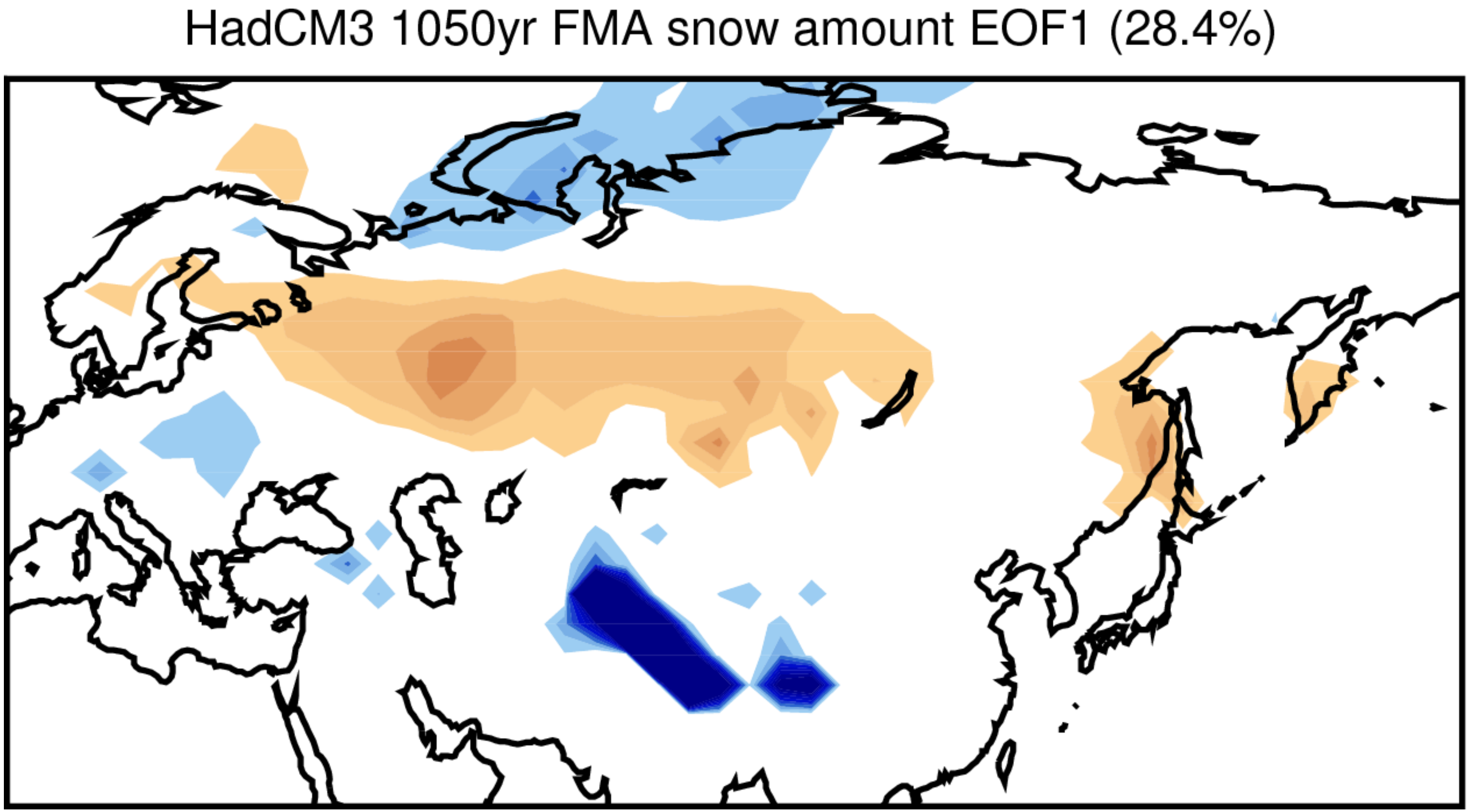


Snow-monsoon correlations in CMIP3 models

- ¾ give significant negative correlations for NW Eurasia snow amount and the dynamical monsoon index, in the absence of ENSO.
- Signal is much more mixed when considering the All-India Rainfall index.

EOF-1 of spring snow amount



Can strong snow forcing in either region lead to a deficient summer monsoon over India?

HadCM3 snow composite difference evolutions

Composites generated from the following conditions:

- Strong spring (FMA) snow amount followed by weak Indian summer monsoon.
- Weak spring (FMA) snow amount followed by strong Indian summer monsoon.

HadCM3 snow composite difference evolutions

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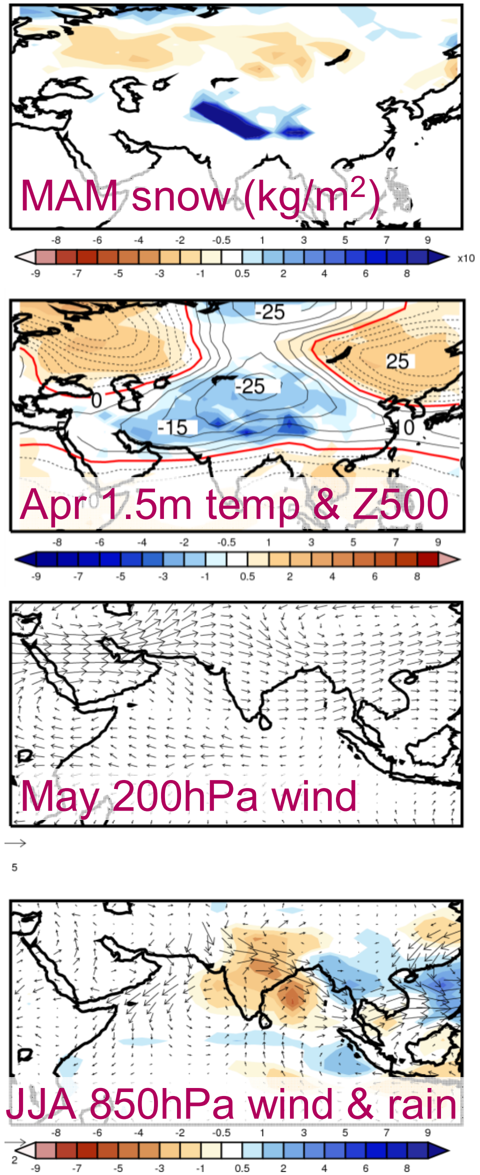
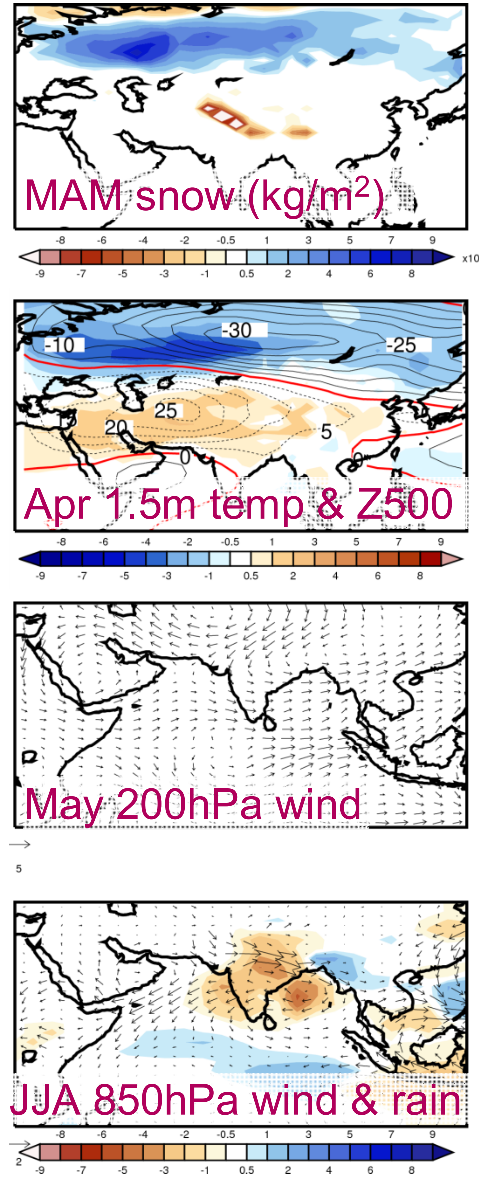


Composite evolutions generated from heavy minus light snow years followed by weak minus strong monsoon rainfall under neutral ENSO conditions

left: using Himalaya snow index

right: using west Eurasia snow index

In HadCM3, weak monsoon summers can be preceded by heavy Eurasian or Himalayan snow.



AGCM experiment design

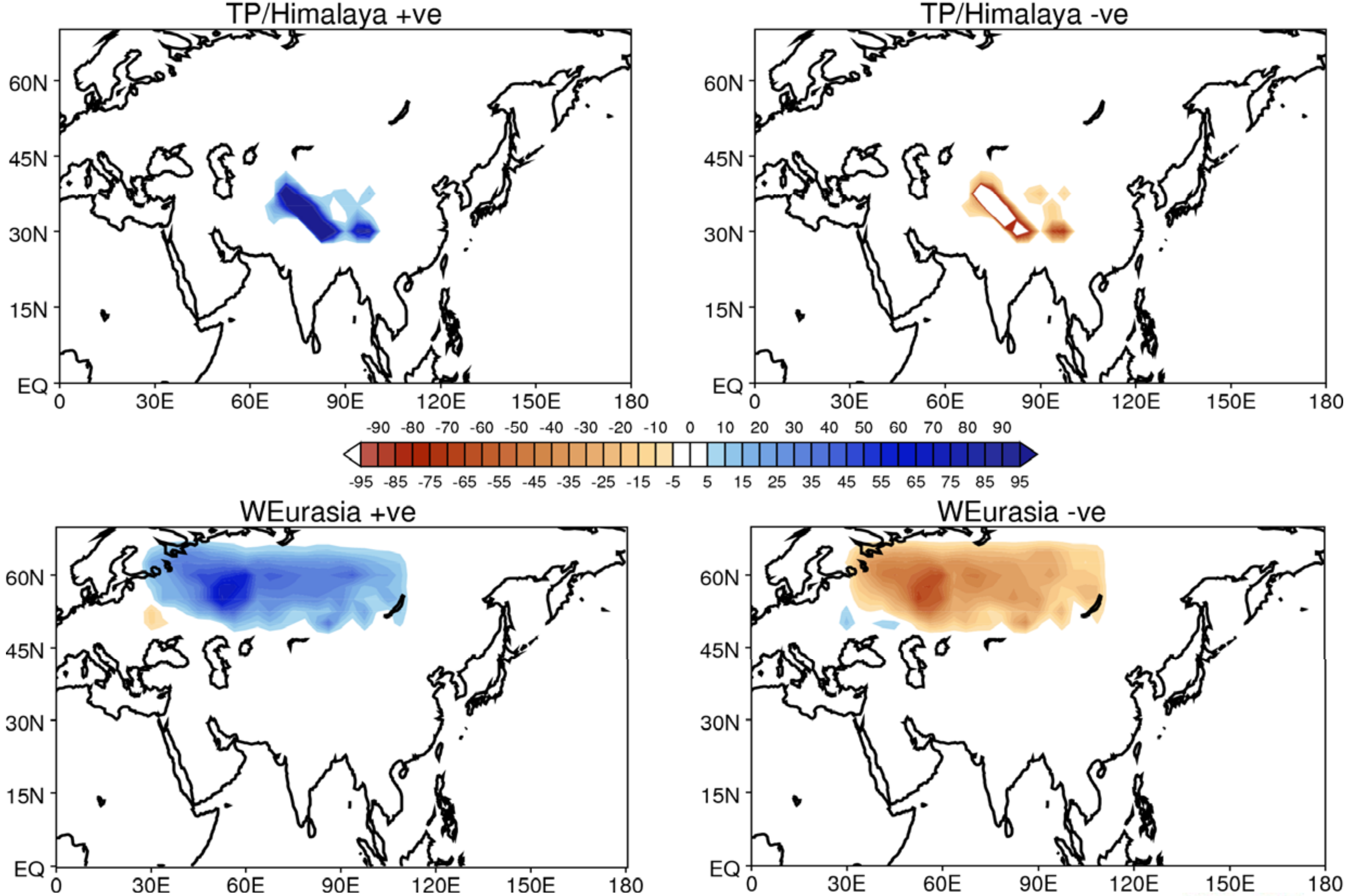
- Hadley Centre atmosphere model HadAM3: atmosphere 3.75° x 2.5° x L30 vertical levels[1,2]
- Snow forcing derived from HadCM3 1050yr run: using +/-2σ anomalies in FMA snow indices over:
  - Eurasia (30-110E, 50-65N)
  - Himalaya (67.5-100E, 27.5-40N)
- Climatological snow elsewhere.
- Climatological SST forcing.

[1]P.M. Inness, J.M. Slingo, S. Woolnough, R. Neale, V. Pope (2001). *Clim. Dyn*. **17**: 777—793.

[2]H. Spencer, J.M. Slingo (2003). *J. Climate* **16**: 1757—1774.

Snow forcing anomalies

FMA snow anomalies based on indices at +/-2sd together with climatology



Experiment procedure

- Experiments initialized 1 Nov.
- Snow depth updated hourly to chosen forcing over Eurasia.
- 32 member ensemble begun 1Apr for 8 months [members initialized from daily start dumps over the 15Mar–16Apr period].
- Snow no longer constrained [free to melt].

Himalaya ensemble results (strong minus weak composites)

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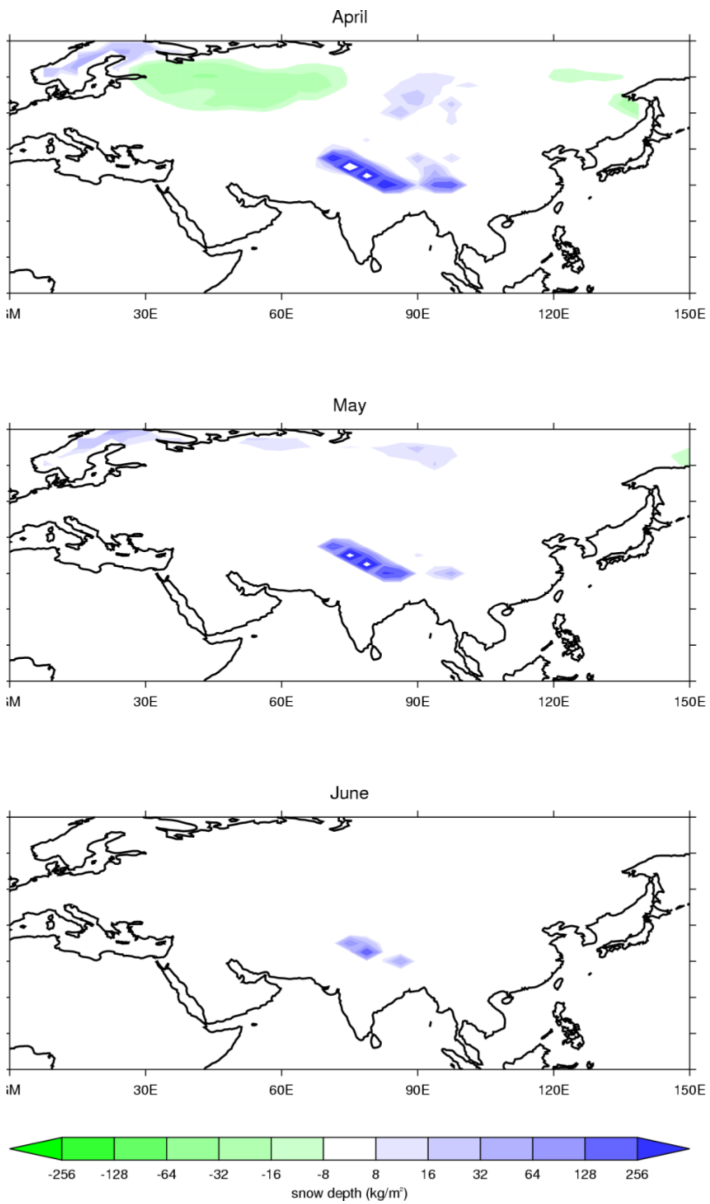
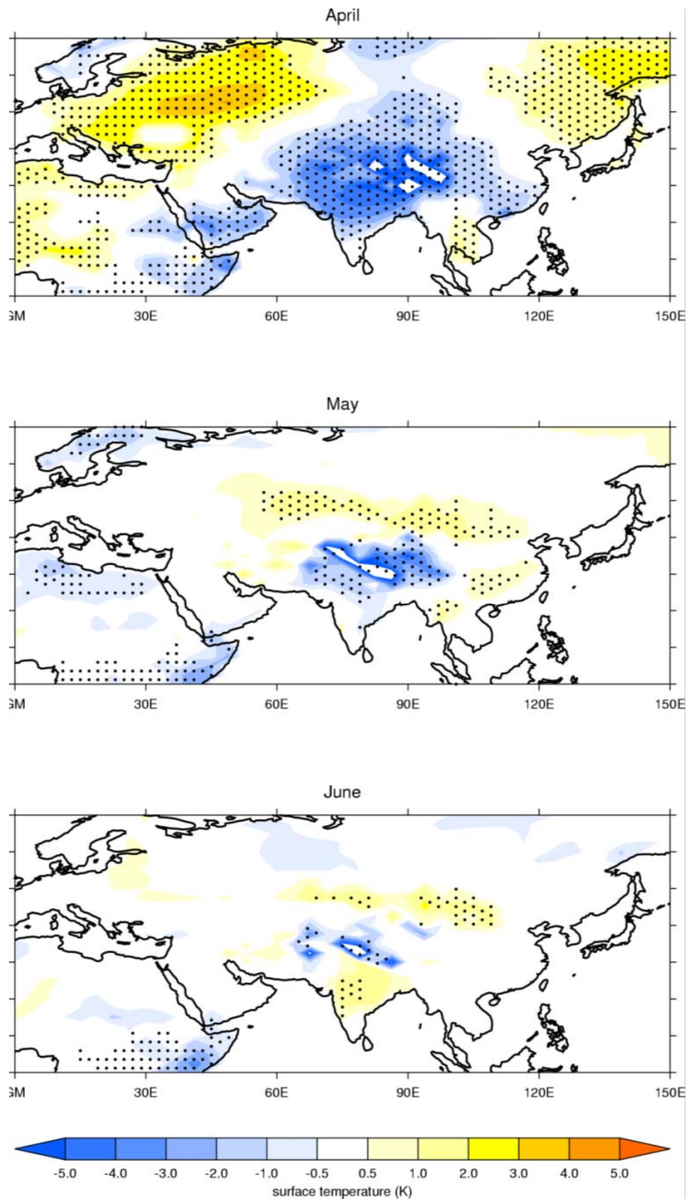
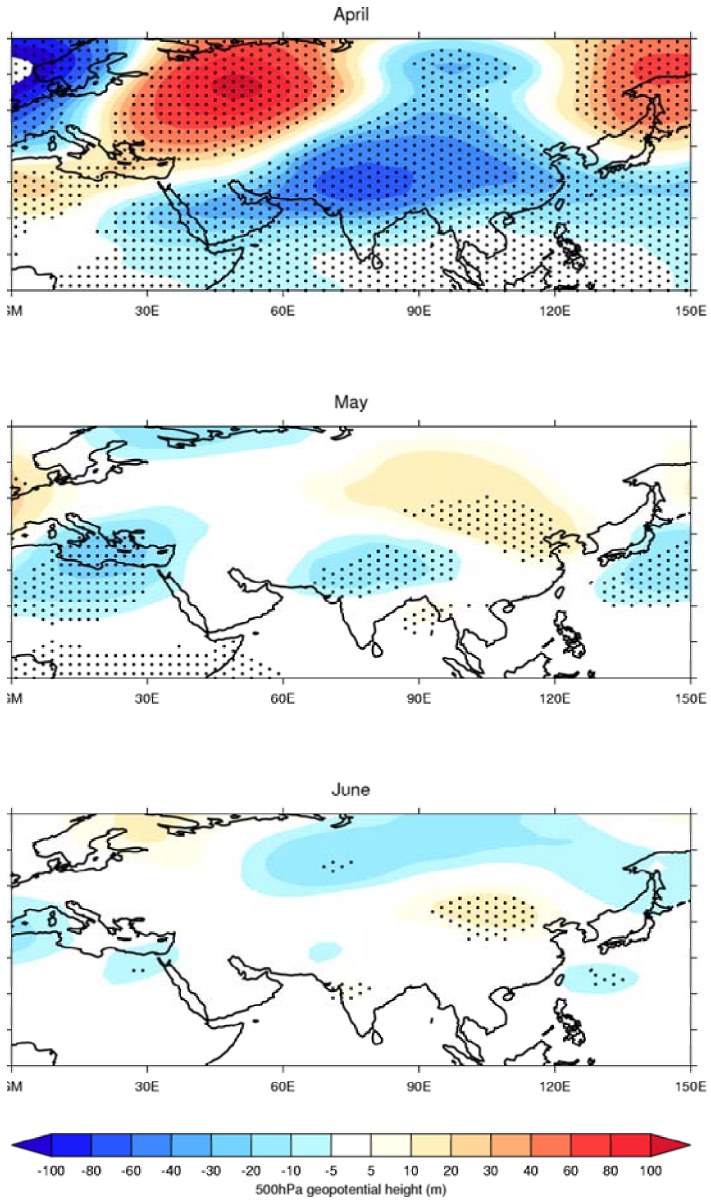
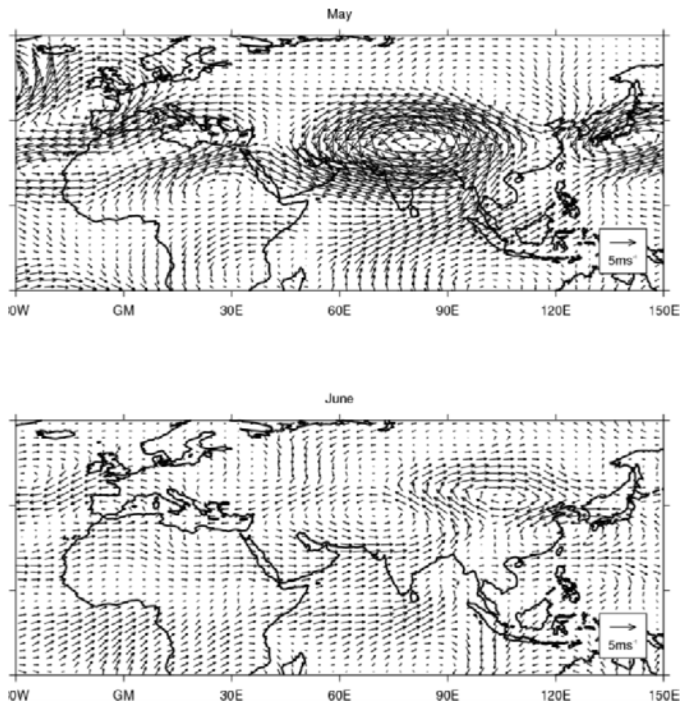


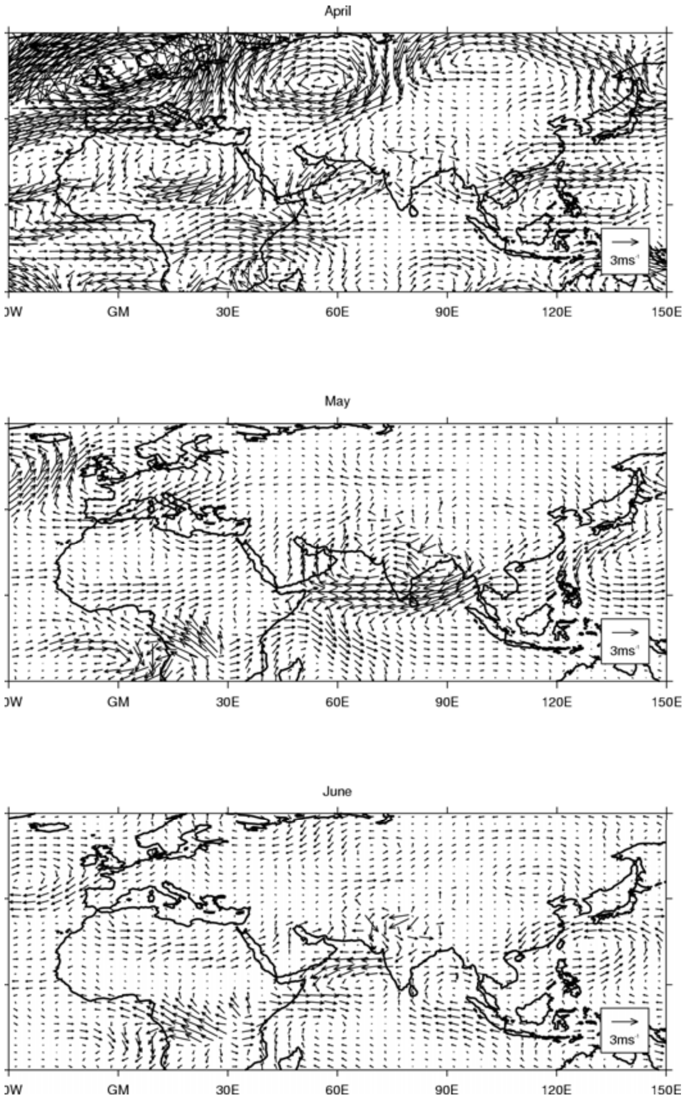


Himalaya ensemble results (strong minus weak composites)

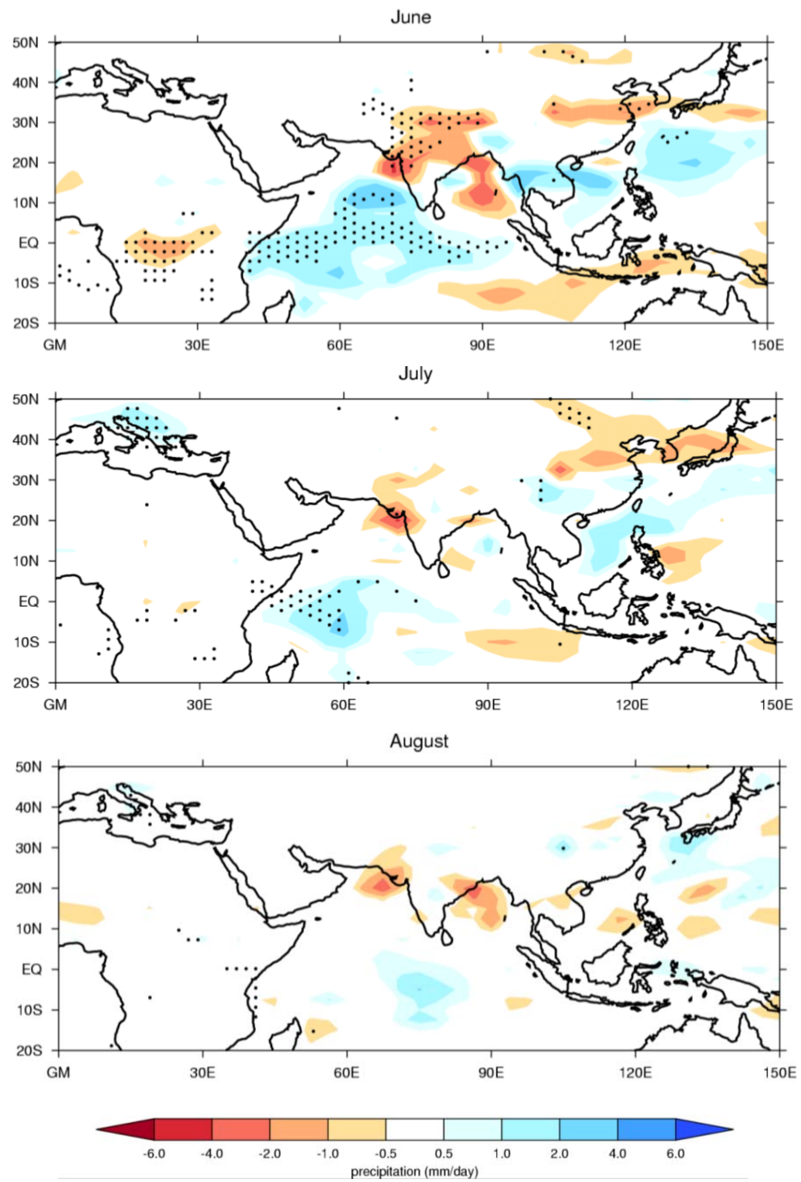




Himalaya ensemble results (strong minus weak composites)



Himalaya ensemble results (strong minus weak composites)



- Himalaya AGCM ensemble results consistent with coupled run composites.
- Strong Himalaya snow forcing → weakened Indian monsoon (June).

Eurasia ensemble results (strong minus weak composites)

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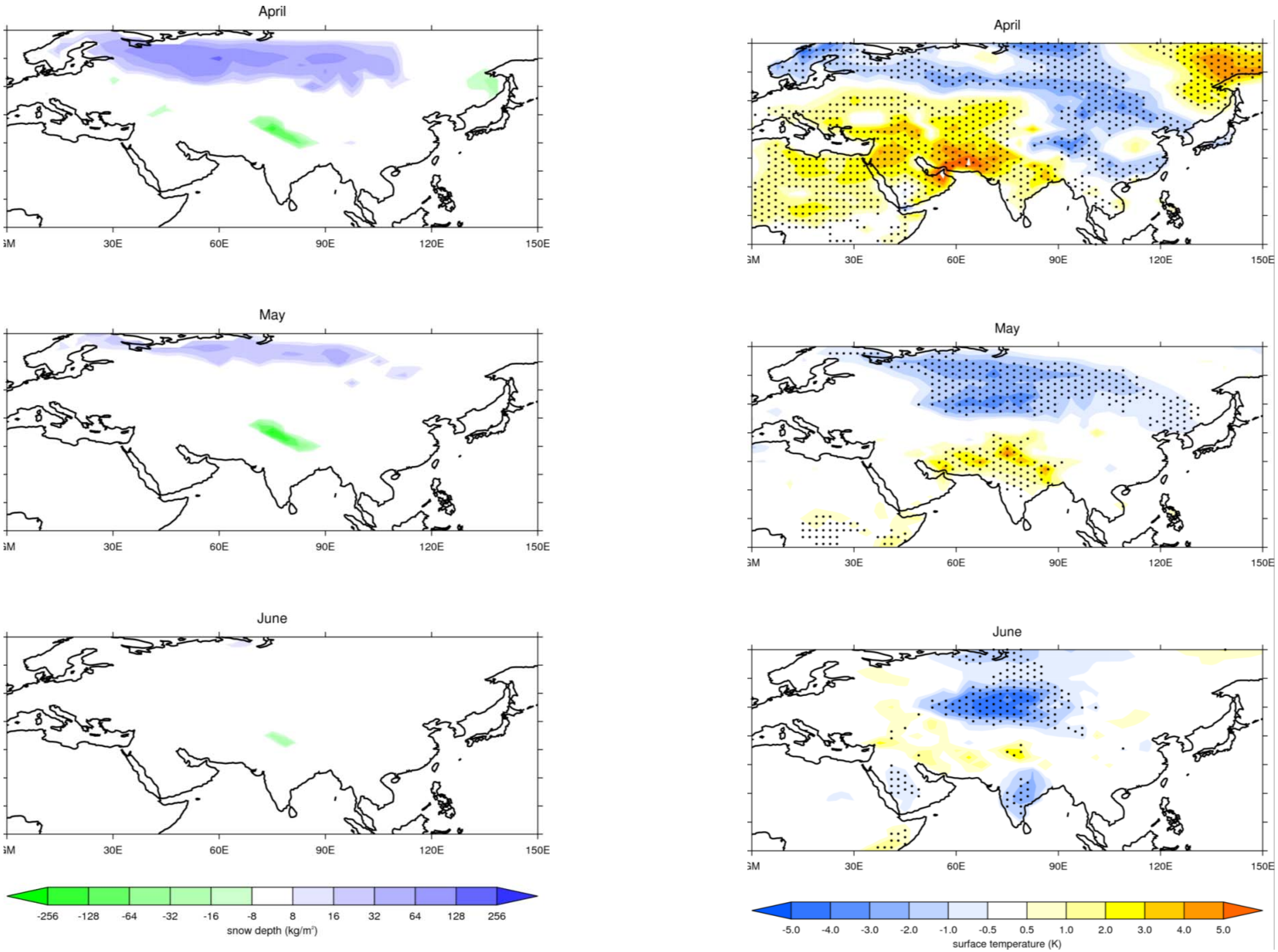

Eurasia ensemble results (strong minus weak composites)

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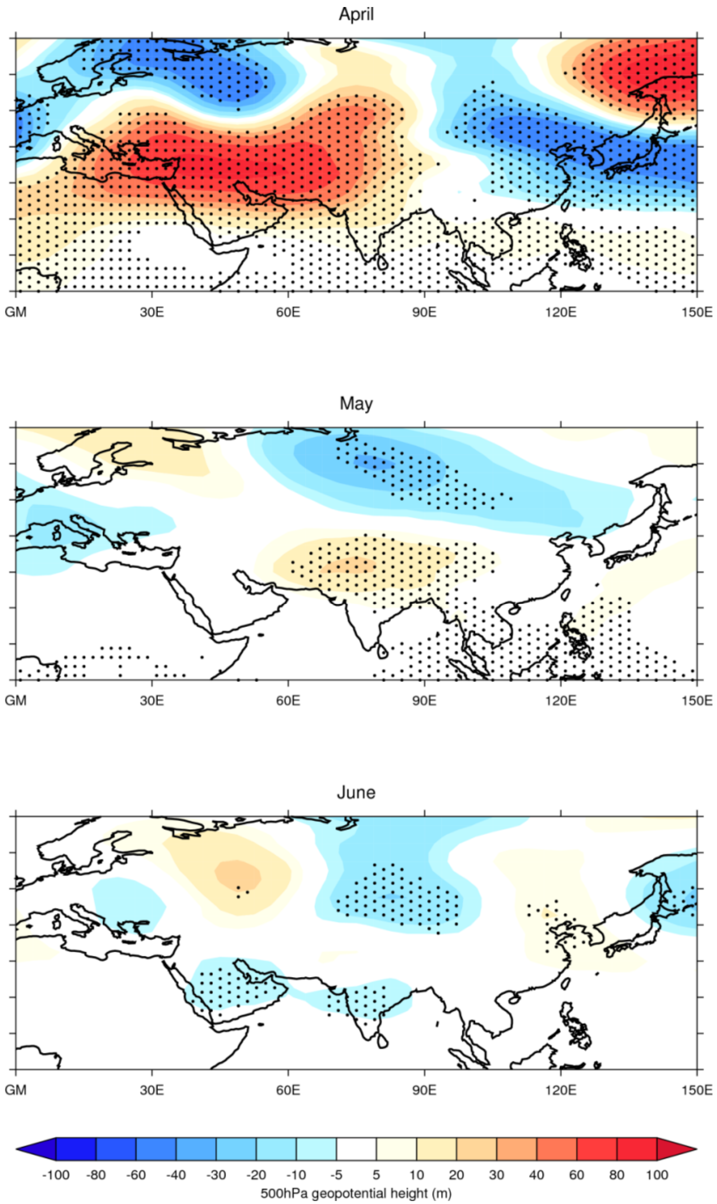

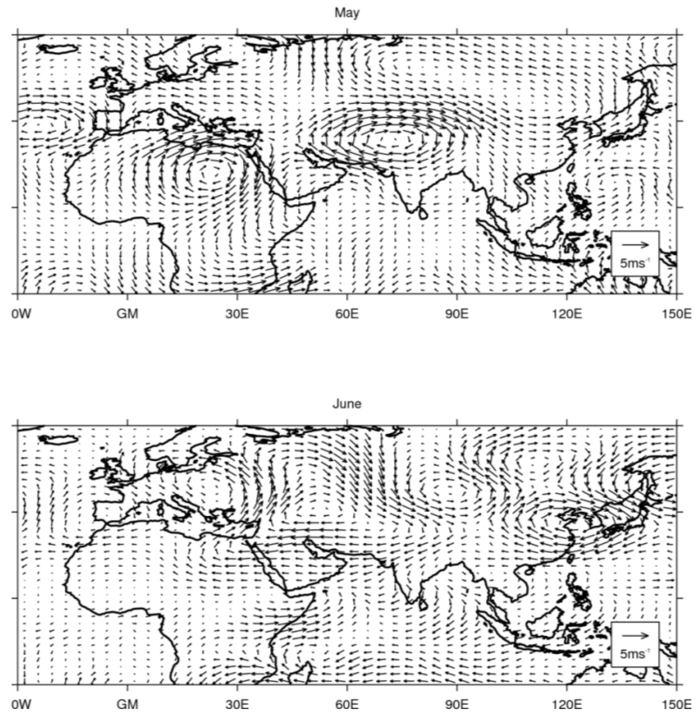

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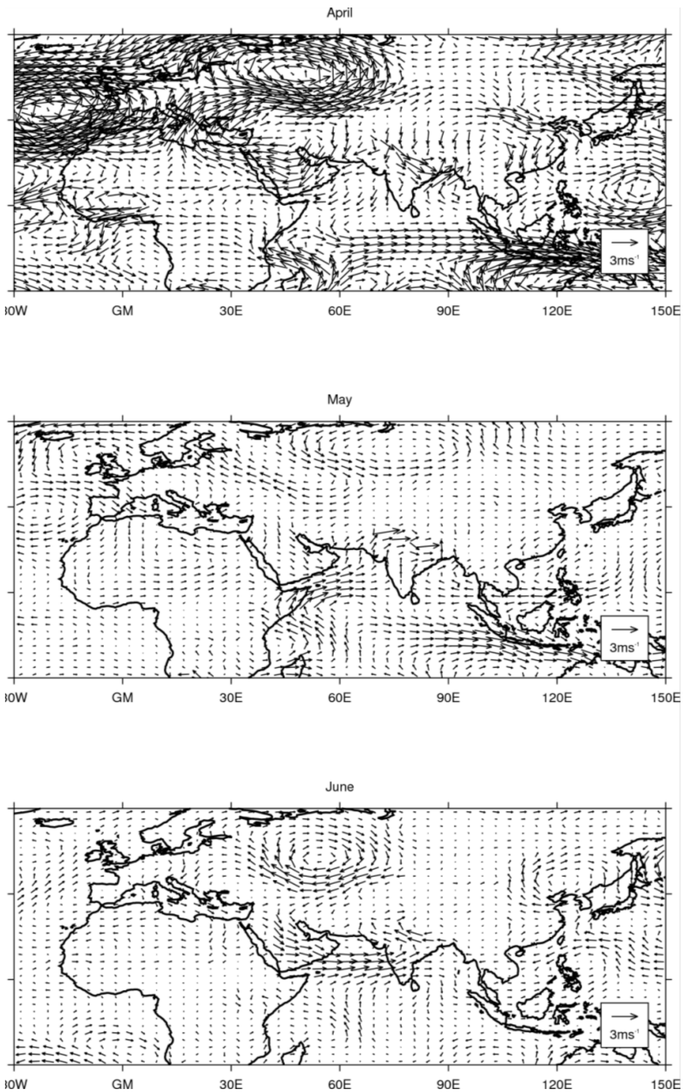
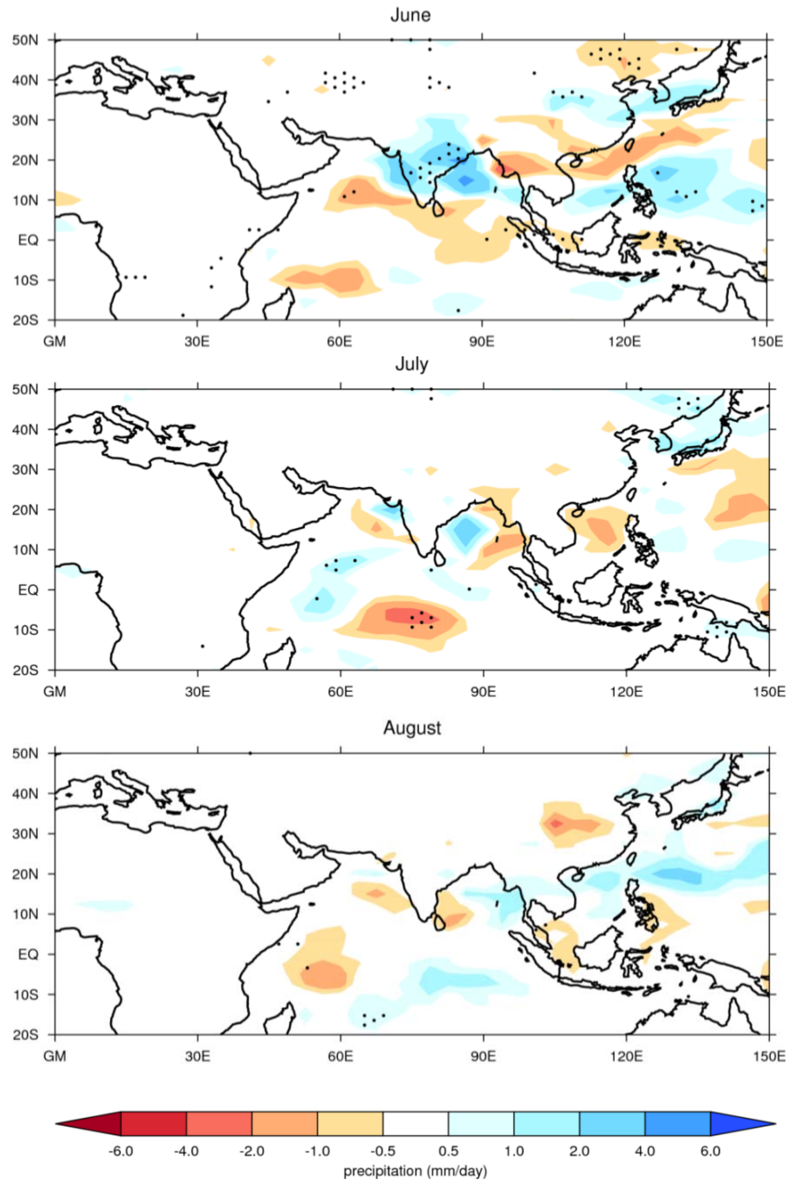
Eurasia ensemble results (strong minus weak composites)



Eurasia ensemble results (strong minus weak composites)



- Eurasia AGCM ensemble results seem contrary to coupled run composites.
- Strong Eurasia snow forcing → strong Indian monsoon (June).
- Possible contamination from induced Himalaya anomaly?

Preliminary conclusions

- Snow forcing of the ASM is complex, even when broken down into separate regions.
- Results here suggest that Himalayan forcing is dominant, in support of the Blanford hypothesis.
- Better land surface initialization required in order to examine mechanisms involved.

Future ensemble set-up

- Clim experiment
- +/- anomaly experiments over Him/TP
- +/- anomaly experiments over WEur
- +/- same anomalies over both
- +/- opposite anomalies over both

To find *the dominant* mechanism

To test region-specific mechanisms

Potential uncertainties

- Land surface initialization:
  - More simple: just impose a snow forcing in April and release it (no time for balancing)
  - The present method: impose the previous winter and allow a certain amount of agreement with soil moisture / atmosphere
  - More rigorous: match snow forcing conditions with contemporaneous soil moisture conditions.

Thank you!

- Fasullo 2004: 1966-2001 snow cover data (weekly presence or absence of snow)

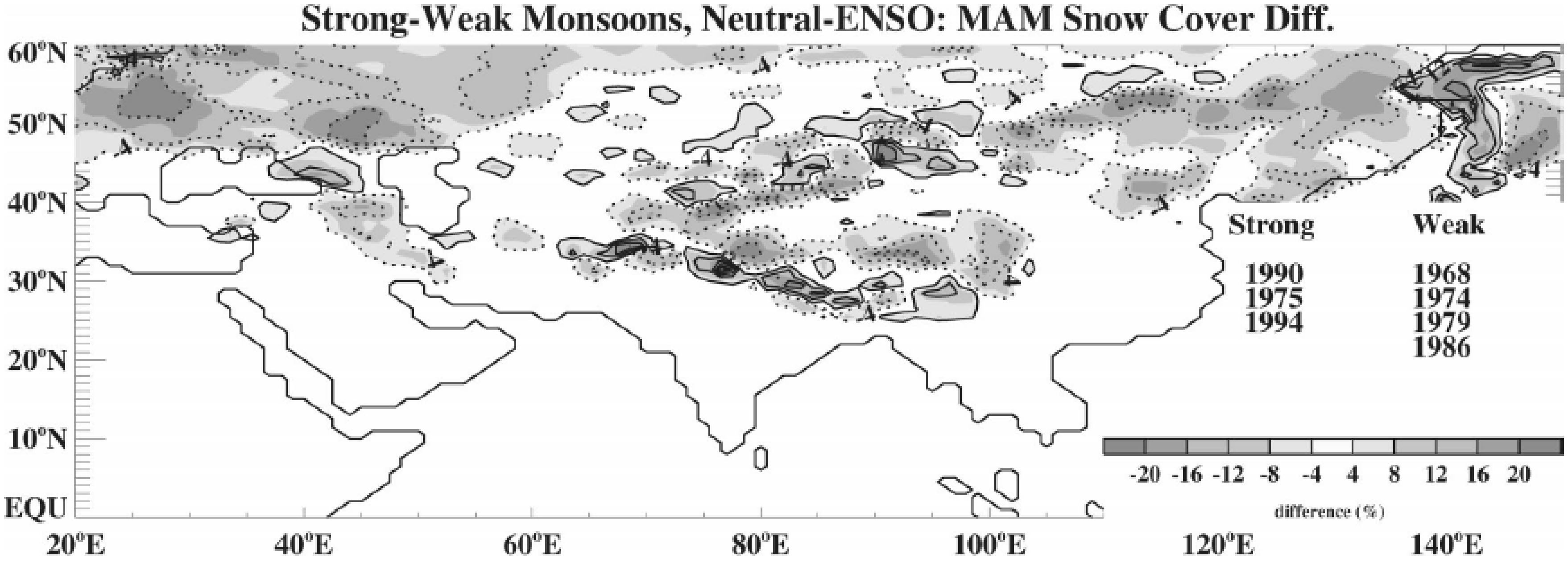


FIG. 5. Difference in MAM snow cover between strong and weak monsoon seasons in which ENSO conditions are neutral.

- Corti *et al*. 2001:
  - Neutral ENSO: inverse relationship between Tibetan snow and monsoon rain
  - Strong El Nino: strong circulation anomalies, inverse relation between Eurasian snow and DMI. Regional effects are overcome & stronger DMI/AIR relationship → inverse relationship between Eurasian snow and monsoon rain.
- Becker *et a*l. 2001: “the results [of climatological SST experiment] have shown that the monsoon circulation is substantially weakened in association with above normal snow amounts over western Eurasia, whilst AIR is slightly increased”
  - AIR responding to Himalayan snow.
  - DMI responding to Eurasian snow.

- Becker *et al*. 2001: “results…with observed SSTs show an opposite response in AIR, suggesting that SSTa forcing is potentially dominating the monsoon interannual variability”

→ Introduce ENSO and the circulation forcing from W Eurasia becomes dominant, together with stronger coupling between AIR and DMI.