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

TURNER Andrew George and Slingo Julia
University of Reading
Walker Institute for Climate System Research
Department of Meteorology Earley Gate, Whiteknights
P.O. Box 243, RG6 6BB Reading
UNITED KINGDOM
Snow-monsoon teleconnections: testing competing mechanisms using idealized snow forcing in a GCM

Andrew Turner¹,² & Julia Slingo³,²,¹

¹Walker Institute for Climate System Research
²NCAS-Climate (University of Reading, UK)
³UK Met Office
More than a century ago, heavy winter snowfall was thought to precede weak Indian monsoons (Blanford 1884).

Several studies have examined this in observations:
- *e.g.*, Fasullo (2004): regions neighbouring India have robust negative correlations in weak ENSO years (snow cover).

These rely on the Blanford hypothesis:
- persistent 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.
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
HadCM3 1050yr control run under pre-industrial greenhouse conditions, fully-coupled model:

– atmosphere $3.75^\circ \times 2.5^\circ \times L19$

– ocean $1.25^\circ \times 1.25^\circ \times L20$
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?

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
Snow-monsoon correlations in CMIP3 models

Correlations of JJAS AIR with FMA snow amount

Correlations of JJAS DMI with FMA snow amount
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.
Can strong snow forcing in either region lead to a deficient summer monsoon over India?
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.
Composite evolutions generated from heavy minus light snow years followed by weak minus strong monsoon rainfall under neutral ENSO conditions.

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

- Hadley Centre atmosphere model HadAM3: atmosphere $3.75^\circ \times 2.5^\circ \times L30$ vertical levels$^{1,2}$
- Snow forcing derived from HadCM3 1050yr run: using $\pm 2\sigma$ anomalies in FMA snow indices over:
  - Eurasia ($30-110E, 50-65N$)
  - Himalaya ($67.5-100E, 27.5-40N$)
- Climatological snow elsewhere.
- Climatological SST forcing.


Snow forcing anomalies

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

TP/Himalaya +ve

TP/Himalaya -ve

WEurasia +ve

WEurasia -ve
Experiments initialized 1 Nov.

Snow depth updated hourly to chosen forcing over Eurasia.

32 member ensemble begun 1 Apr for 8 months [members initialized from daily start dumps over the 15 Mar–16 Apr period].

Snow no longer constrained [free to melt].
Himalaya ensemble results
(strong minus weak composites)
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 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
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. 3: 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 al. 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.