# Interactions between the atmosphere and snow covers from winter to spring season over the Tibetan Plateau


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Abstract

During the winter season, strong sub-tropical jet in the upper troposphere with calm areas at the sub-surface prevails over the central Tibetan Plateau. Besides, clear diurnal change of the surface winds, such as more than 10 m/s at 10 m height in the evening with very calm in the night, were observed.

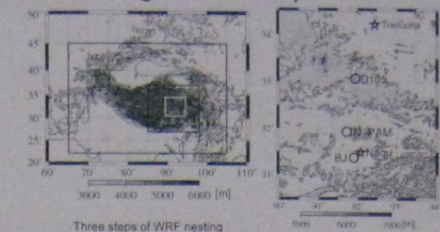
According to the in-situ albedo data and MODIS-Aqua satellite estimates of snow cover percentage, seasonal snow covers existed trough the analysis periods only in the mountains with high elevations, such as more than 5000 m a.s.l., and discontinuous shallow snow covers existed in the flat lower altitudes in January, and it was extinguished in the end of February.

WFR model simulated the diurnal change of surface winds due to development of shallow PBL under the strong STJ over the thin and discontinuous snow cover condition, and diabatic heating (Q1) in the troposphere was not apparent. The feature did not change even if the snow covers were removed, but excessive continuous snow covers more than 100 mm SWE (MuchSNOW experiment) apparently reduced the sub-surface diurnal changes. Namely, thin and discontinuous snow covers in the winter have small albedo effects, but PBL development is depressed under strong sub-tropical jet stream.

Intra-seasonal variability of the winter weather was characterized by weakening of both sub-polar jets and daytime surface winds, affected by the meandering of mid-latitude sub-polar jet streams followed with precipitation events. Weakening of surface winds associated with occurrence of snow covers were not due to suppression of surface heating. In 2004, the STJ became weak after the middle of March and provided convective seasons over the plateau. WRF model simulated the development of PBL up to more than 3 km above the surface in spring season.

The model also simulated evident diurnal increase of Q1 in the lower troposphere over the central TP. MuchSNOW experiments abruptly reduced the heating, and induced negative advections of Q1 associated with strengthen of northerly and westerly winds associated with sub-polar jets. Namely, snow covers in the spring season strongly recover the synoptic flows from the mid-latitudes, and may reduce the spring convections over the TP.


## Target areas and periods

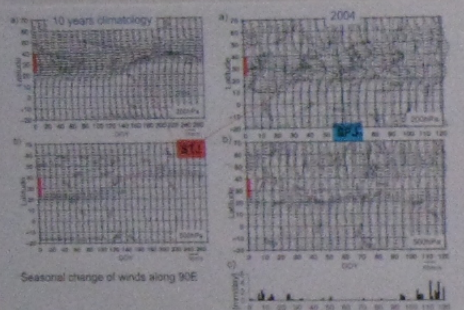



Three steps of WRF nesting

2004 Jan.- April
Period 1: Jan. 11-20 snow & weak jet
Period 2: Feb. 1-10 snow & strong jet
Period 3: March 7-15 no snow & tangent jet
Period 4: April 2-12 no snow & no jet

Snow covers in the Tibetan Plateau are shallow and patchy (Ueno et al., 2007)

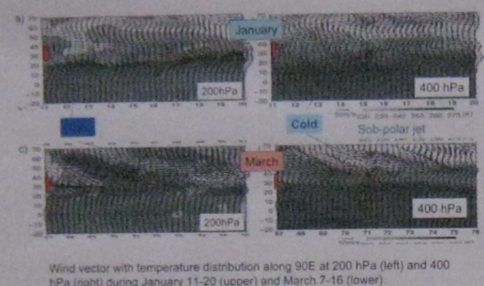
Sheet 1 Snow covers in 2004 February at Naqu basin, central TP




Seasonal change of winds along 90E

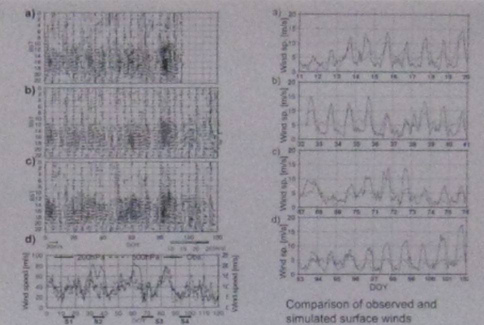
Daily precipitation in the central TP

Synoptic condition is managed by sub-tropical jet (STJ) and sub-polar jet (SPJ)




Wind vector with temperature distribution along 90E at 200 hPa (left) and 400 hPa (right) during January 11-20 (upper) and March 7-16 (lower)

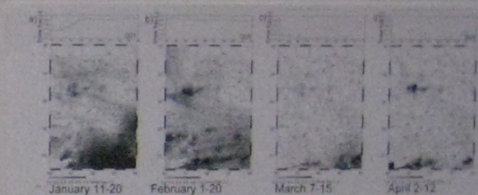
Sub-polar front jet prevails in the spring season.



Surface winds at 3 AWSs (up), and comparison with NCEP data (low)

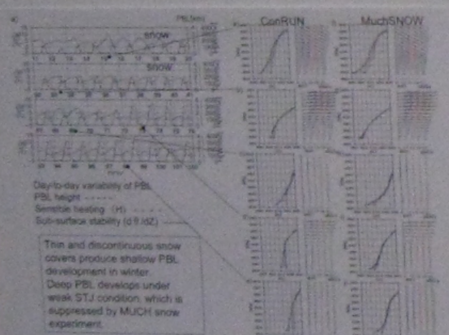
Comparison of observed and simulated surface winds

There existed evident diurnal variation in the surface winds linked with STJ activity



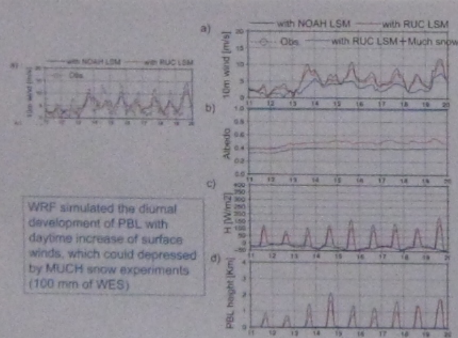

Seasonal change of snow covers in the WRF simulation (lower) with area average of snow cover portion (upper)

Shallow snow covers started to extinguish from the lower plains, which was well represented by the WRF model.

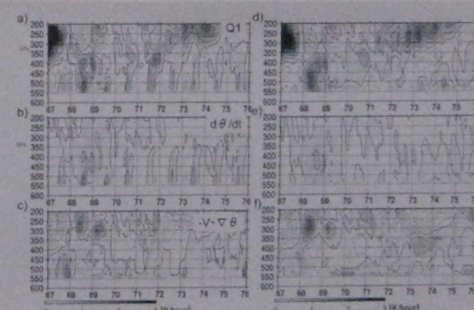



Day-to-day variability of PBL
PBL height
Sensible heating (H)
Sub-surface stability (dθ/dZ)

Thin and discontinuous snow covers produce shallow PBL development in winter.
Deep PBL develops under weak STJ condition, which is suppressed by MUCH snow experiment.

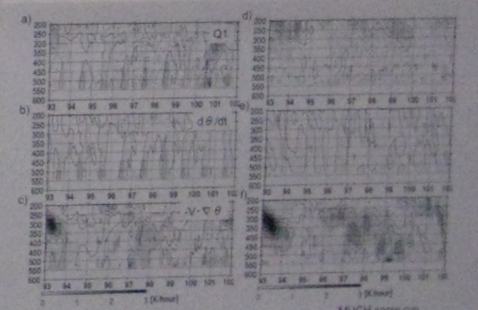



WRF simulated the diurnal development of PBL with daytime increase of surface winds, which could depressed by MUCH snow experiments (100 mm of WES)



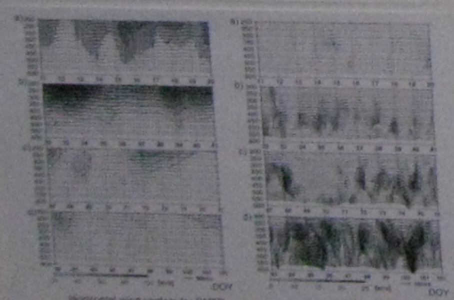

CONT. run
MUCH snow run

$$Q_1 = C_p\left(\frac{p}{p_0}\right)^{\kappa}\left(\frac{\partial\theta}{\partial t} + V\cdot\nabla\theta + \omega\frac{\partial\theta}{\partial p}\right)$$



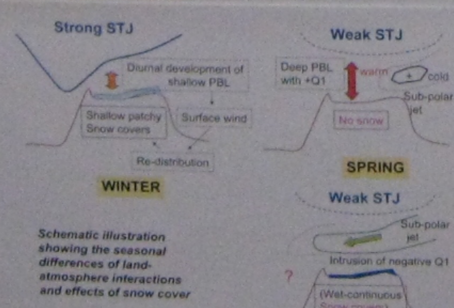

CNT. run
MUCH snow run

Snow covers reduce Q1 due to surface heating, and enhance advection



Horizontal wind vectors for CNTR
Anomaly (MUCHsnow-CNTR)

MUCHsnow enhances intrusions from north - northwest




*Schematic illustration showing the seasonal differences of land-atmosphere interactions and effects of snow cover*

## Summary

- Does snow cover in the core winter affect the atmosphere ? >> "No". Patchy snow cover under strong sub-tropical jet could cause evident diurnal changes in surface winds, but few effects to suppress heating of the atmosphere.
- Does snow cover in the spring affect the atmosphere ? >> "Yes". Weakening of subtropical jet potentially provides active convections. WRF model experiments showed that excess of snow cover abruptly depress the heating, and enhance intrusion of negative diabatic energy associated with sub-polar jets.