Is the soil enthalpy an unheeded source of predictability ?

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Context

- LS4P experiment (Xue et al. 2021) : correct the LST bias over the Tibetan Plateau at initialization of subseasonal forecasts

- Adjusting LST regardless of soil moisture breaks the soil thermodynamical equilibrium
  - spurious land-atmosphere interactions ?
  - questionable atmospheric response ?

- Tug of war between soil temperature and soil moisture as a dominant driver of atmospheric predictability

- Can we adapt the LS4P setup to reconcile the point of views ?

Rationale

- We developped a strategy to conserve the soil enthalpy and soil water mass ‘as well as possible’ when adjusting the initial soil temperature

- The **enthalpy** quantifies the **soil energy** :
  It integrates temperature, ice and liquid water content as well as soil texture.

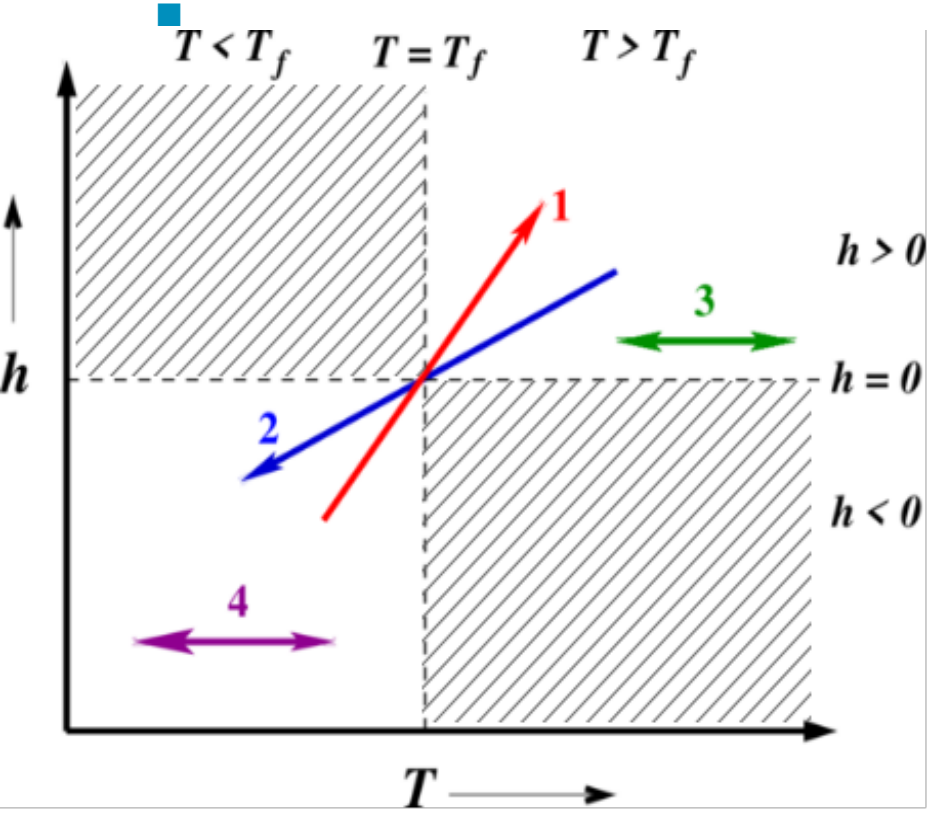
- Enthalpy (h) equation for a soil layer :

$$h = [\rho_s c_s (1 - w_{sat}) + \rho_l c_l w_l + \rho_i c_i w_i](T - T_f) - \rho_i L_f w_i$$

w_l *liquid water content* T *temperature*
w_i *frozen water content* T_f *freezing point temperature*
w_{sat} *soil porosity*

The 4 pathways of soil temperature adjustment

- Enthalpy (h) equation for a soil layer :
- $h=[A + B\,w_l + C\,w_i](T - T_f) - D\,w_i$ with A, B, C and D >0
  - w_l *liquid water content* T *temperature*
  - w_i *frozen water content* T_f *freezing point temperature*



	Mass conservation	Enthalpy conservation
1	✓	✗
2	✓	✗
3	✗	✓
4	✓	✓

- If $T_1 < T_f$, then $h < 0$
  If $T_2 > T_f$, then $w_i=0$ and thus h > 0

→ **h cannot be conserved** (pathways 1 and 2)

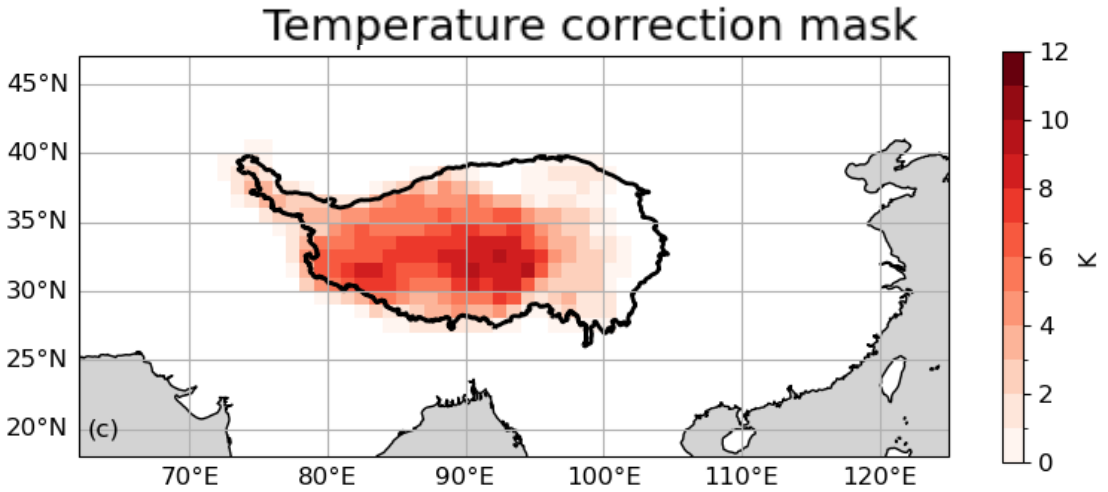
- If both T_1 and $T_2 > T_f$, then h remains > 0

But increasing T implies reducing W_l
in order to conserve h

→ **Mass cannot be conserved** (pathway 3)

Experimental setup

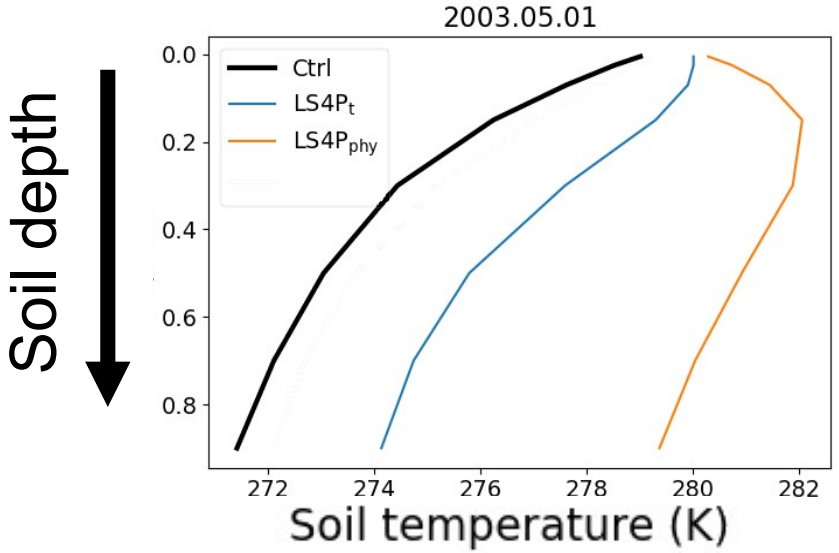
- Earth system model : CNRM-CM6.1 (Voldoire et al. 2019)
- 2-month ensemble reforecasts initialized on May 1st 2003

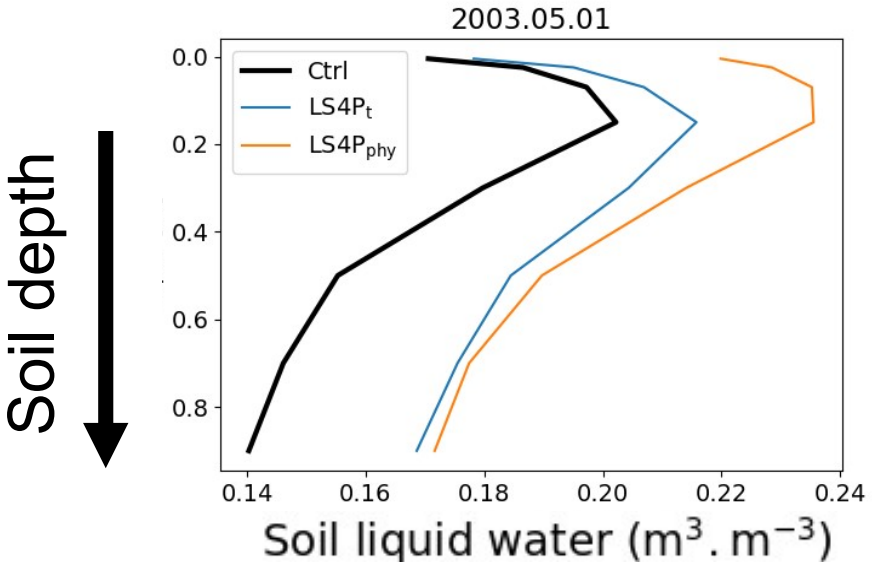


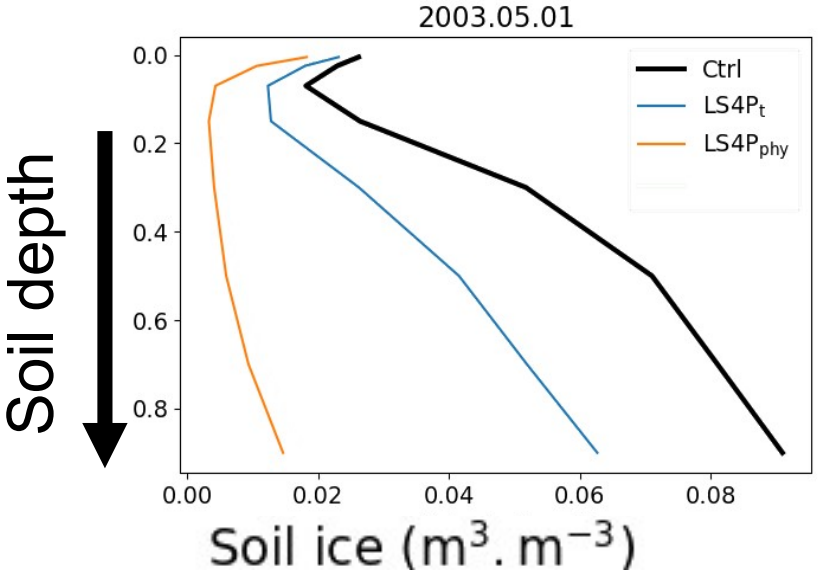
	Soil temperature	Soil liquid water	Soil ice
Ctrl	✗	✗	✗
$LS4P_t$	✓	✗	✗
$LS4P_{phy}$	✓	✓	✓

Impact on soil temperature profiles

- Initial soil profiles spatially averaged over the Tibetan Plateau





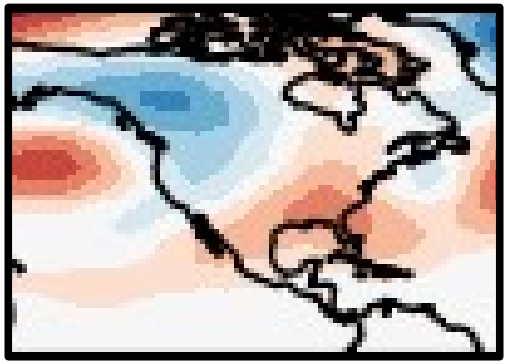


Impact on the forecast circulation : Z 500 hPa

May 2003

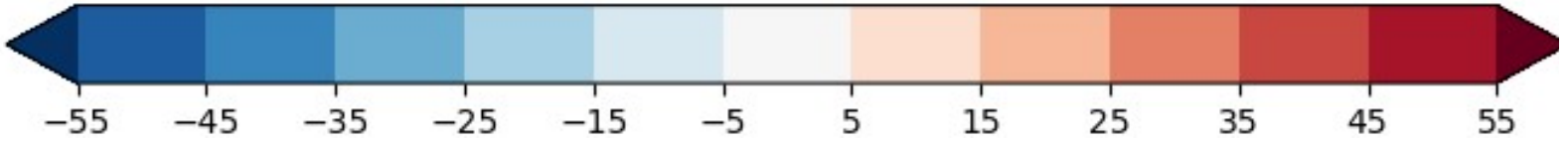
Obs. anomaly

LS4P$_t$ minus Ctrl



Ctrl anomaly

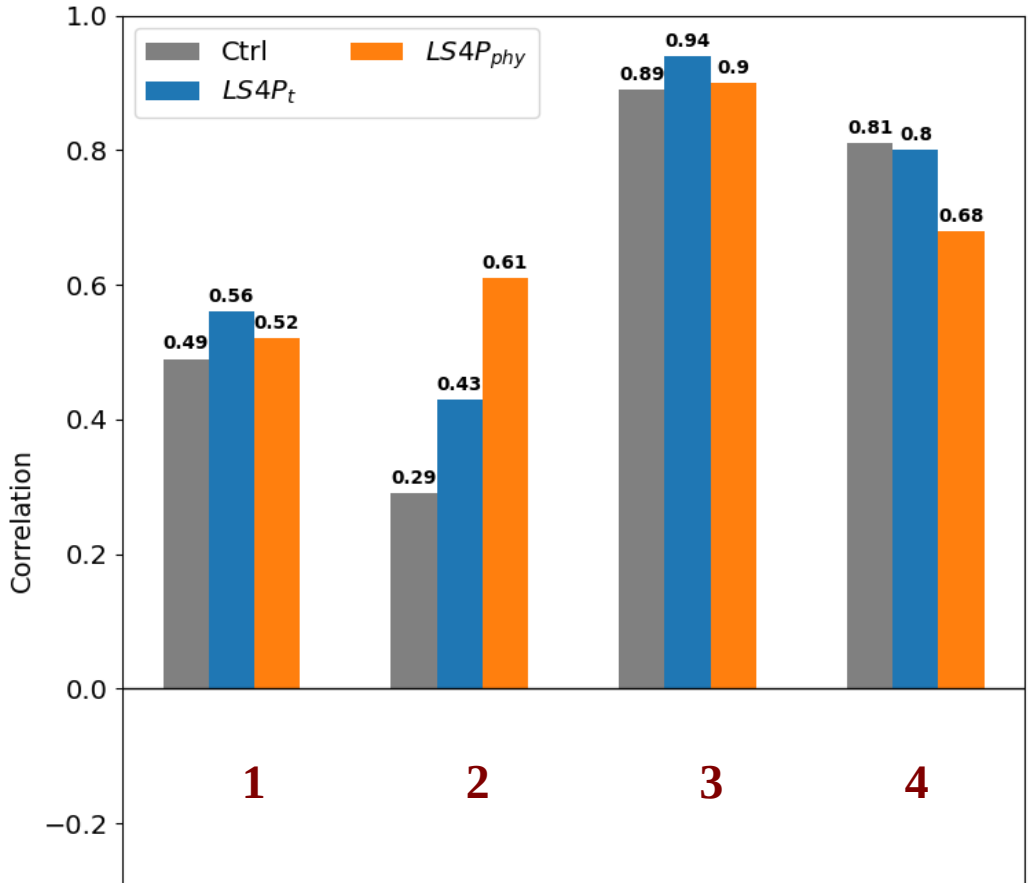
LS4P$_{phy}$ minus Ctrl



Impact on the forecast circulation : Z 500 hPa

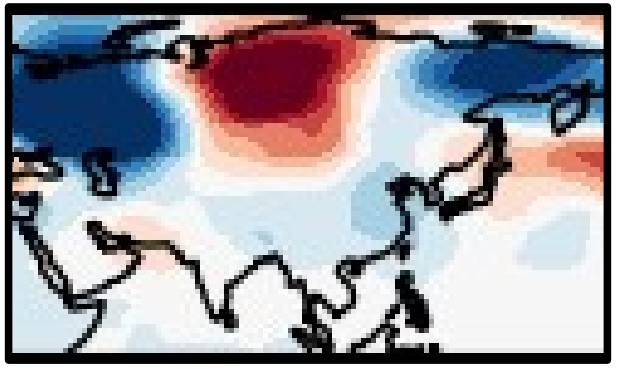
Z500 anomaly pattern correlation with ERA5 by domain.

May 2003



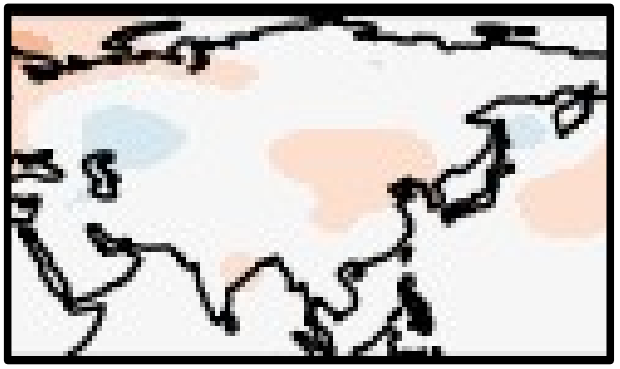
Impact on the forecast circulation : Z 500 hPa

June 2003



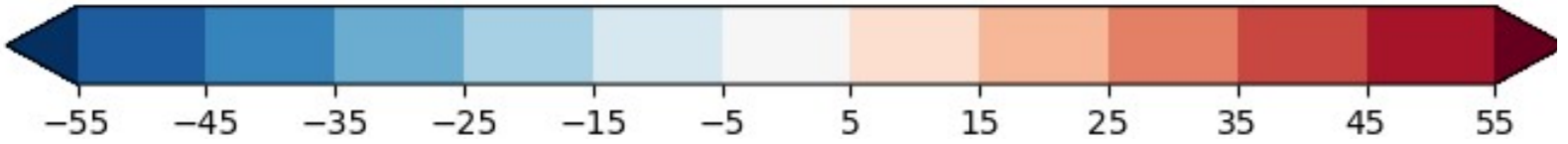
Obs. anomaly

LS4P$_t$ minus Ctrl



Ctrl anomaly

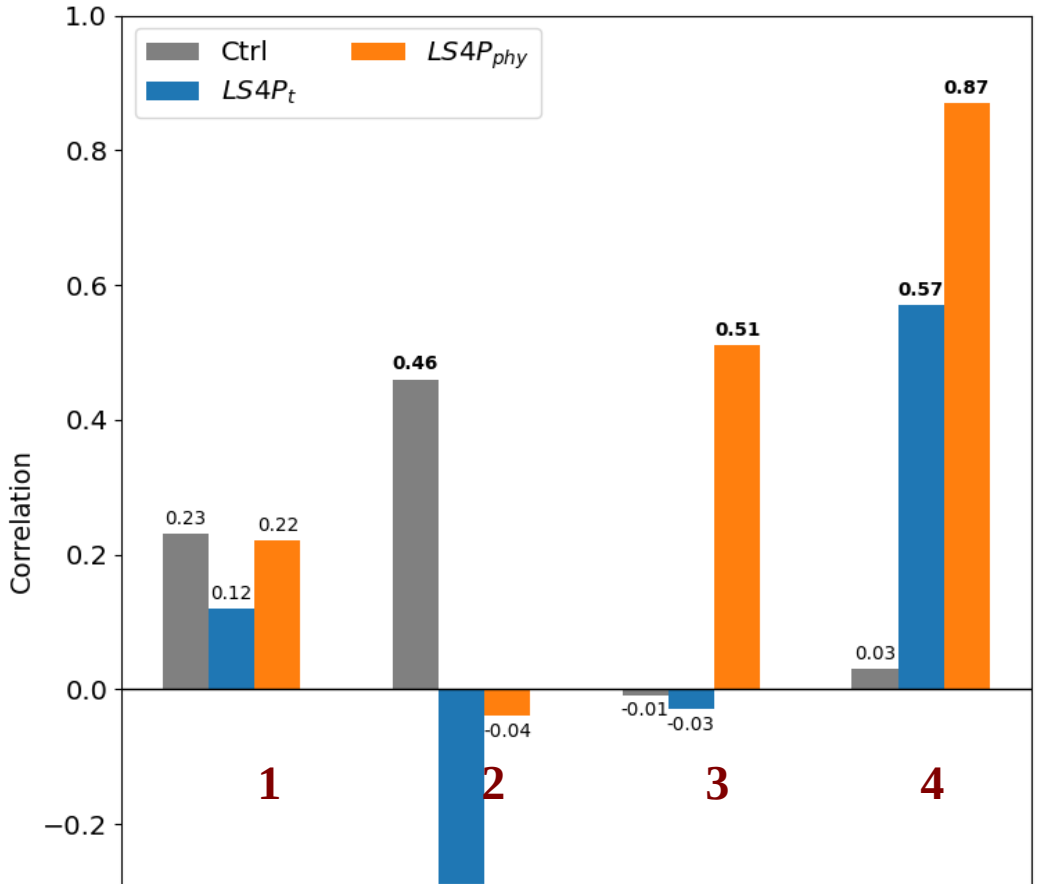
LS4P$_{phy}$ minus Ctrl



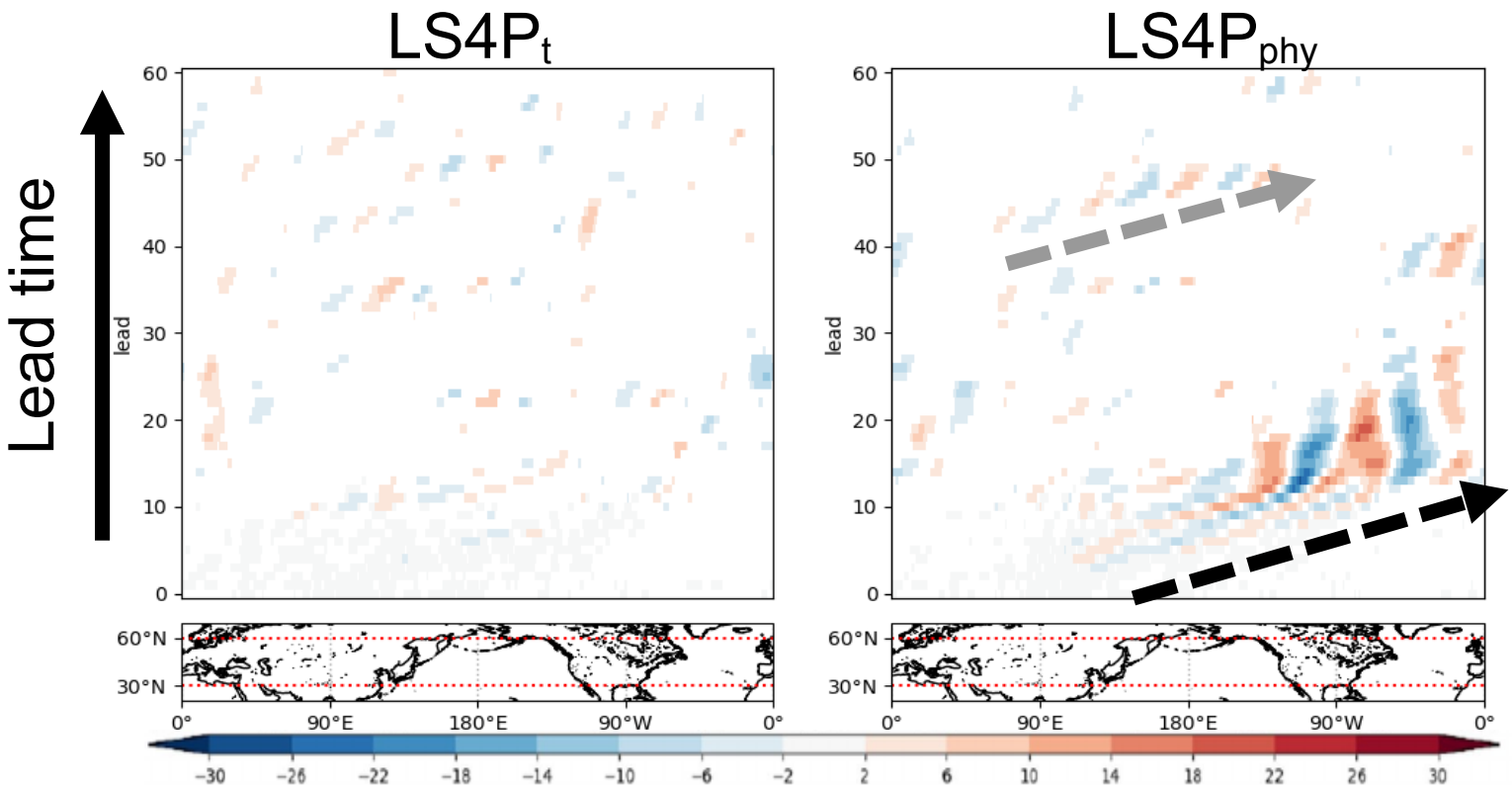
Impact on the forecast circulation at 500 hPa

Z500 anomaly pattern correlation with ERA5 by domain.

June 2003

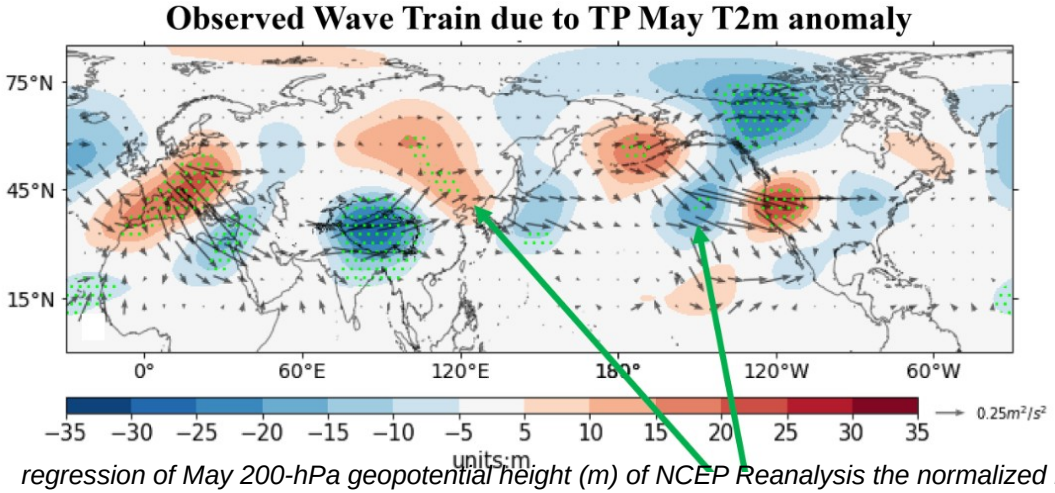


Evidence of a propagating wave train



250 hPa meridional wind anomaly averaged between 30◦N and 60◦N

Tibetan Plateau-Rocky Mountains Circumglobal (TRC) wave train
(Fig. from Xue et al, 2022)



regression of May 200-hPa geopotential height (m) of NCEP Reanalysis the normalized May TPI

Conclusion and prospects

- Initializing forecast systems with **thermodynamically balanced land conditions** is crucial
- A broader evaluation (on multiple start dates) is yet to be done

- Applying our initialization method concurrently to the TP and the Rockies could further improve the atmospheric response (LS4P stage II)

- Check out our new paper published last week in the special issue :

Ardilouze, C., Boone, A.A. Impact of initializing the soil with a thermally and hydrologically balanced state on subseasonal predictability. Clim Dyn (2023). https://doi.org/10.1007/s00382-023-07024-x

To download it :

- Scan the QR-code
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- https://tinyurl.com/yr6bm22e

Questions ?

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