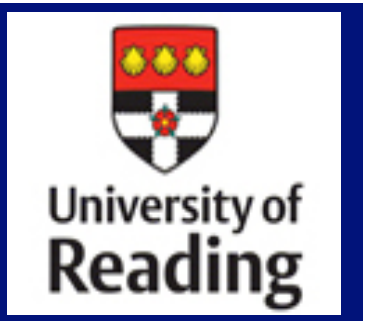


Sensitivity of zonal-mean circulation to air-sea roughness

Inna Polichtchouk, Ted Shepherd

Drag Processes Workshop, ECMWF
15.09.2016

MOTIVATION & METHOD

- Question: How sensitive is the large-scale circulation to changes in the surface drag parameters?
- Use CAM3 mostly in aquaplanet setup (no topography or seasonal cycle, QOBS SST) and vary air-sea momentum roughness length Z_{0m}.

$$\{\tau, E, H\} = \{C_d \Delta \mathbf{v}, C_e \Delta q, C_h \Delta \theta\}$$

$C_d = C_d(Z_{0m})$

$C_e = C_e(Z_{0m}, Z_{0e})$

$C_h = C_e(Z_{0m}, Z_{0h})$

τ = surface stress
E = evaporation
H = sensible heat
$C_{\{d,e,h\}}$ = transfer coefficients
$\psi_{\{m,e,h\}}$ = integrated flux profiles
$Z_{\{0m,0h,0e\}}$ = roughness lengths

MOTIVATION & METHOD

- Question: How sensitive is the large-scale circulation to changes in the surface drag parameters?
- Use CAM3 mostly in aquaplanet setup (no topography or seasonal cycle, QOBS SST) and vary air-sea momentum roughness length Z_{0m}.

$$\{\tau, E, H\} = \{C_d \Delta \mathbf{v}, C_e \Delta q, C_h \Delta \theta\}$$

$C_d = C_d(Z_{0m})$

$C_e = C_e(Z_{0m}, Z_{0e})$

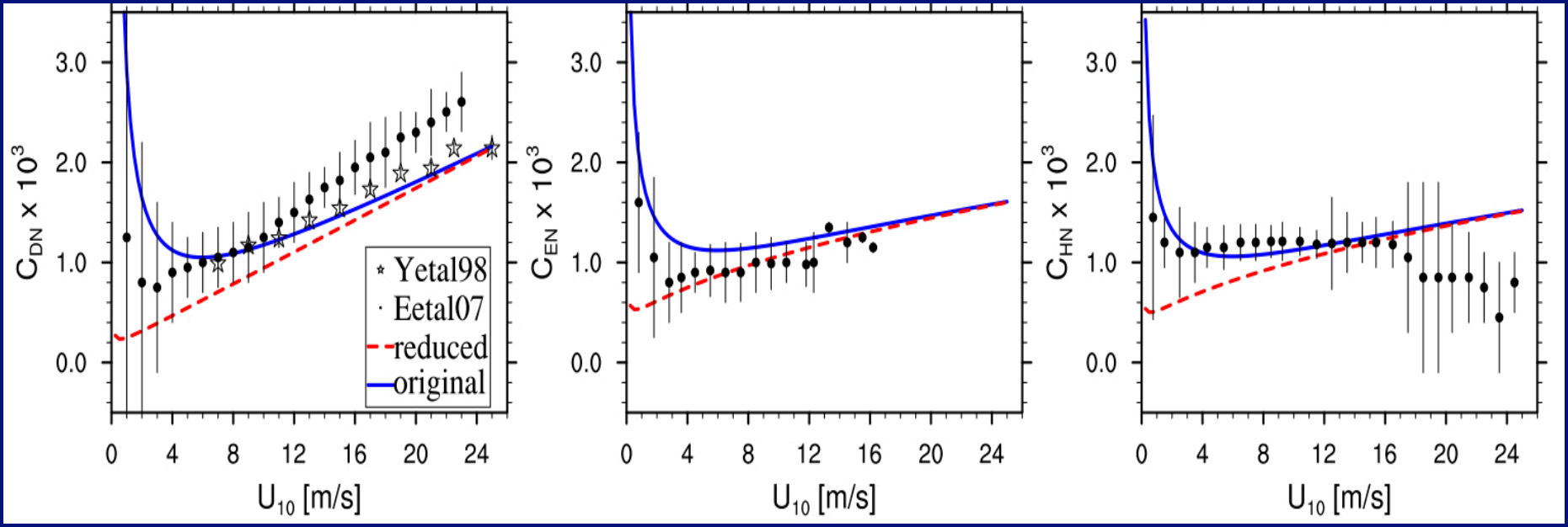
$C_h = C_e(Z_{0m}, Z_{0h})$

Change Z_{0m}

$\tau =$ surface stress
$E =$ evaporation
$H =$ sensible heat
$C_{\{d,e,h\}} =$ transfer coefficients
$\psi_{\{m,e,h\}} =$ integrated flux profiles
$Z_{\{0m,0h,0e\}} =$ roughness lengths

MOTIVATION & METHOD

- Two experiments: 1) Original Z_{0m}; 2) Reduced Z_{0m}
- Other model details:
  - Eulerian pseudospectral core
  - T85L26 resolution (top at 3 hPa)

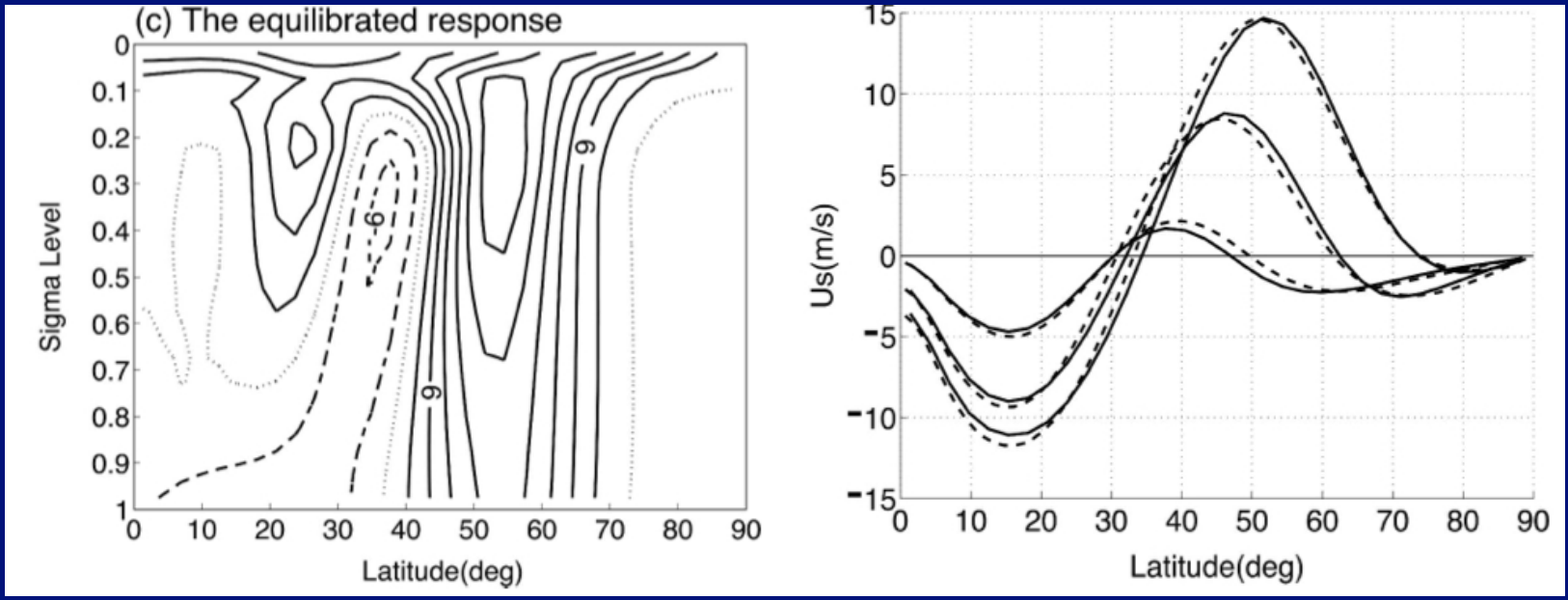


Neutral drag profiles in CAM3

MOTIVATION

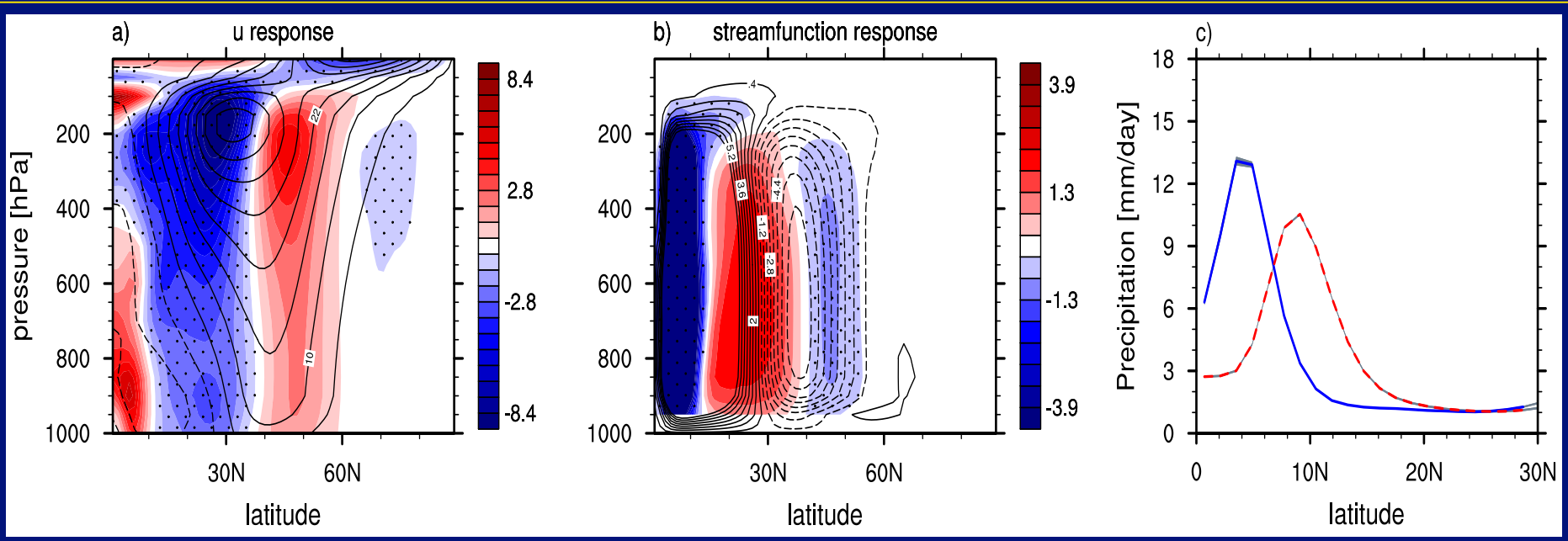
- Chen et al (2007) showed sensitivity of eddy-driven jet latitude to surface friction in idealized dry GCM:
  Decrease in Rayleigh drag → jets move poleward

- Question: Does this sensitivity to surface friction carry over to more complex GCMs with more realistic boundary layer?



Chen et al (2007, *JAS*)

RESULTS: Zonal-mean circulation response



Polichtchouk & Shepherd (2016,QJRMS)

Response to reduced surface roughness ENSO-like:

i) A poleward shift of the mid-latitude westerlies extending to the surface.

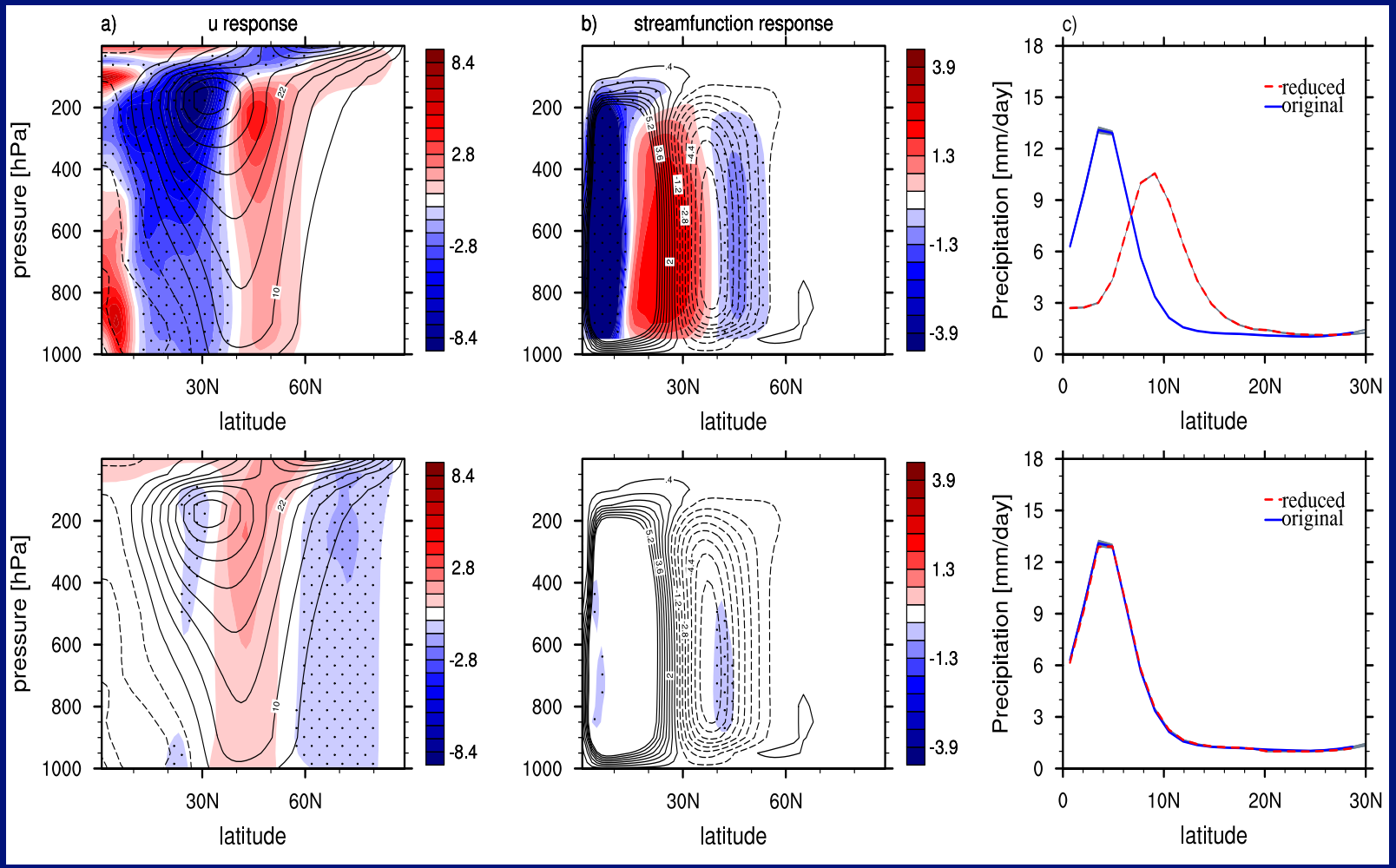
ii) A weak poleward shift of the subtropical descent region.

iii) A weakening of the HC and a poleward shift of the ITCZ.

iv) A poleward shift of the tropical surface easterlies.

RESULTS: Tropics vs. extratropics

- Question: Is the response mediated from the tropics or the extratropics?



MOTIVATION & METHOD

- Question: How sensitive is the large-scale circulation to changes in the surface drag parameters?
- Use CAM 3.0 mostly in aquaplanet setup (no topography or seasonal cycle, QOBS SST) and vary momentum roughness length Z_{0m}.

$$\{\tau, E, H\} = \{C_d \Delta \mathbf{v}, C_e \Delta q, C_h \Delta \theta\}$$

$C_d = C_d(Z_{0m})$

$C_e = C_e(Z_{0m}, Z_{0e})$

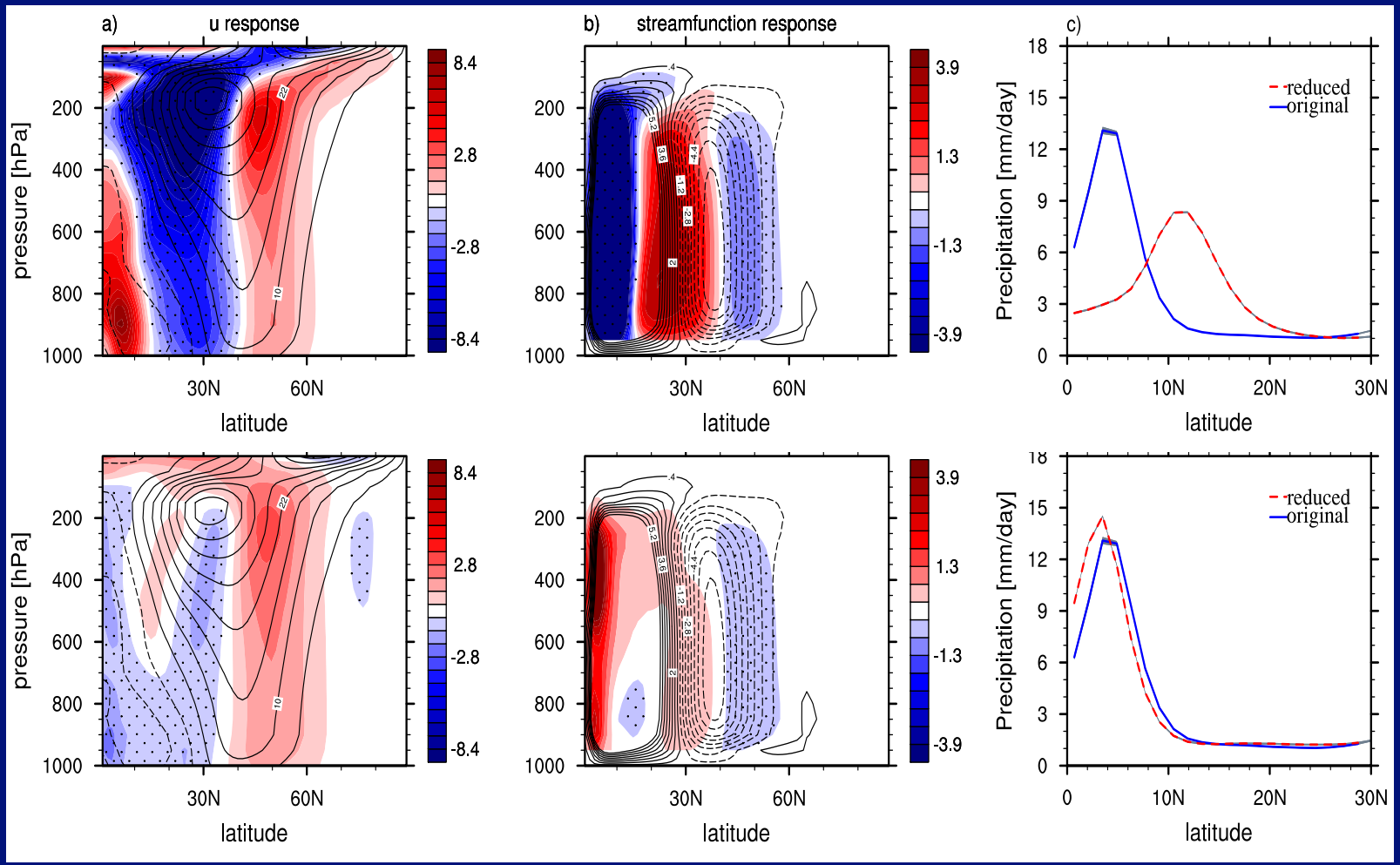
$C_h = C_e(Z_{0m}, Z_{0h})$

Change Z_{0m}

$\tau =$ surface stress
$E =$ evaporation
$H =$ sensible heat
$C_{\{d,e,h\}} =$ transfer coefficients
$\psi_{\{m,e,h\}} =$ integrated flux profiles
$Z_{\{0m,0h,0e\}} =$ roughness lengths

RESULTS: Heat vs. momentum fluxes

- Question: Is the response mediated thermodynamically or dynamically?



Understanding the circulation response

- Question: Why does the circulation change in response to reduced Z_{0m}? Contradicts the null hypothesis: BL winds accelerate to maintain constant surface stress leaving H and E unchanged.

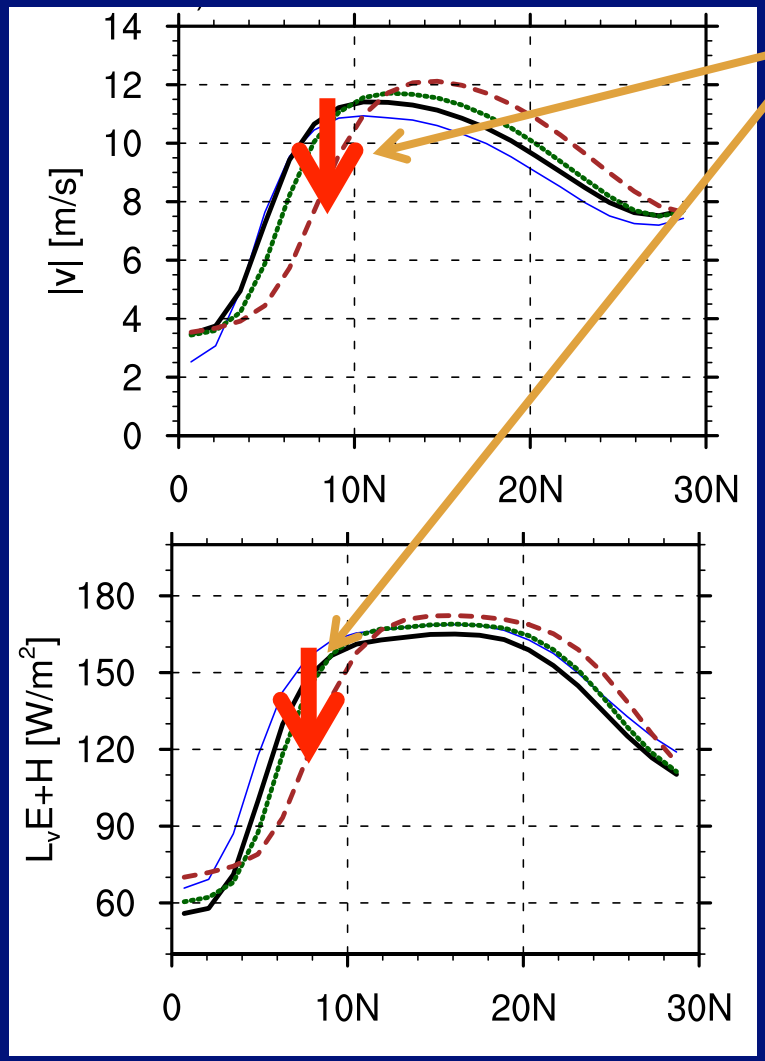
- Ensemble of switch-on simulations reveal:

1. Initial reduction in equatorial zonal surface stress leads to decrease in BL meridional winds → BL wind magnitude decreases → E & H decrease → cooling of the tropics.

2. Cooler tropics ←→ reduced meridional temperature gradient → reduced subtropical jet speed and baroclinic eddy generation.

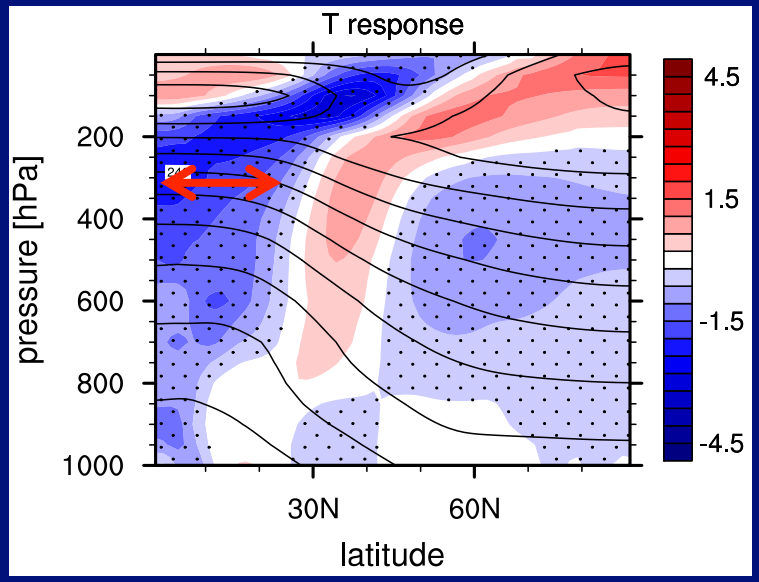
3. Reduced eddy generation and poleward shift in the critical latitude lead to poleward mid-latitude jet shift.

1. Tropical Cooling and Hadley Cell weakening



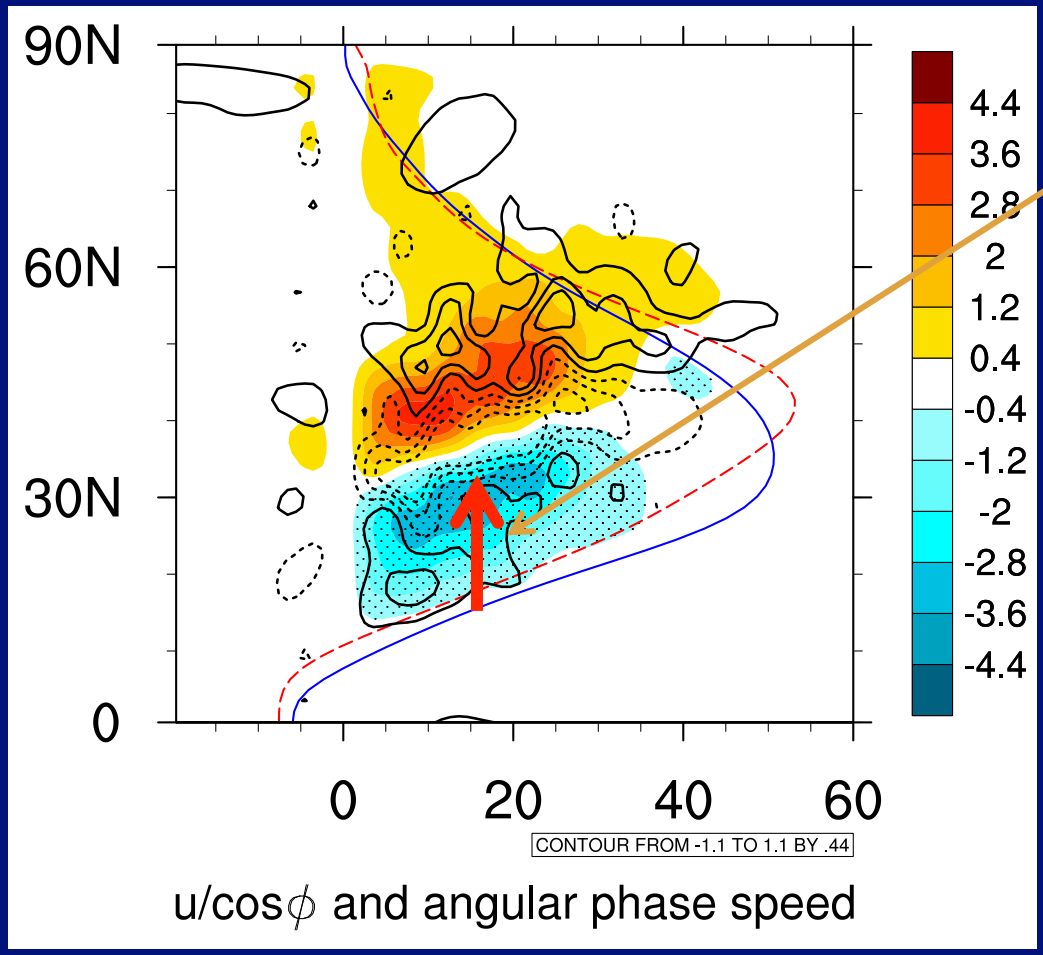
Decrease in BL wind magnitude and energy fluxes.

Cooling of the tropics and weakening of Hadley Cell.



2. Critical latitude shift

Eddy momentum flux convergence spectra

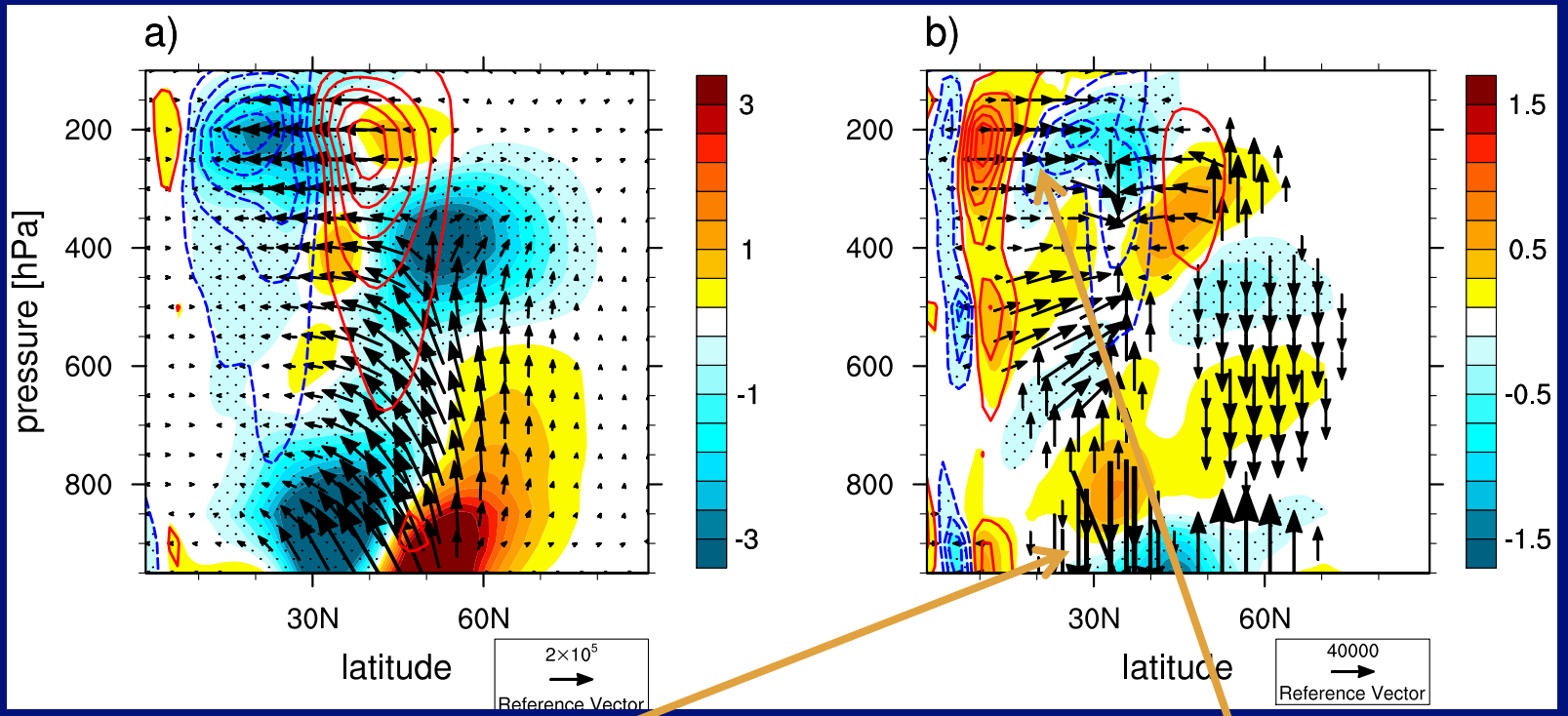


Poleward critical latitude shift.

2. Reduced Eddy Generation

EP flux climatology

EP flux response

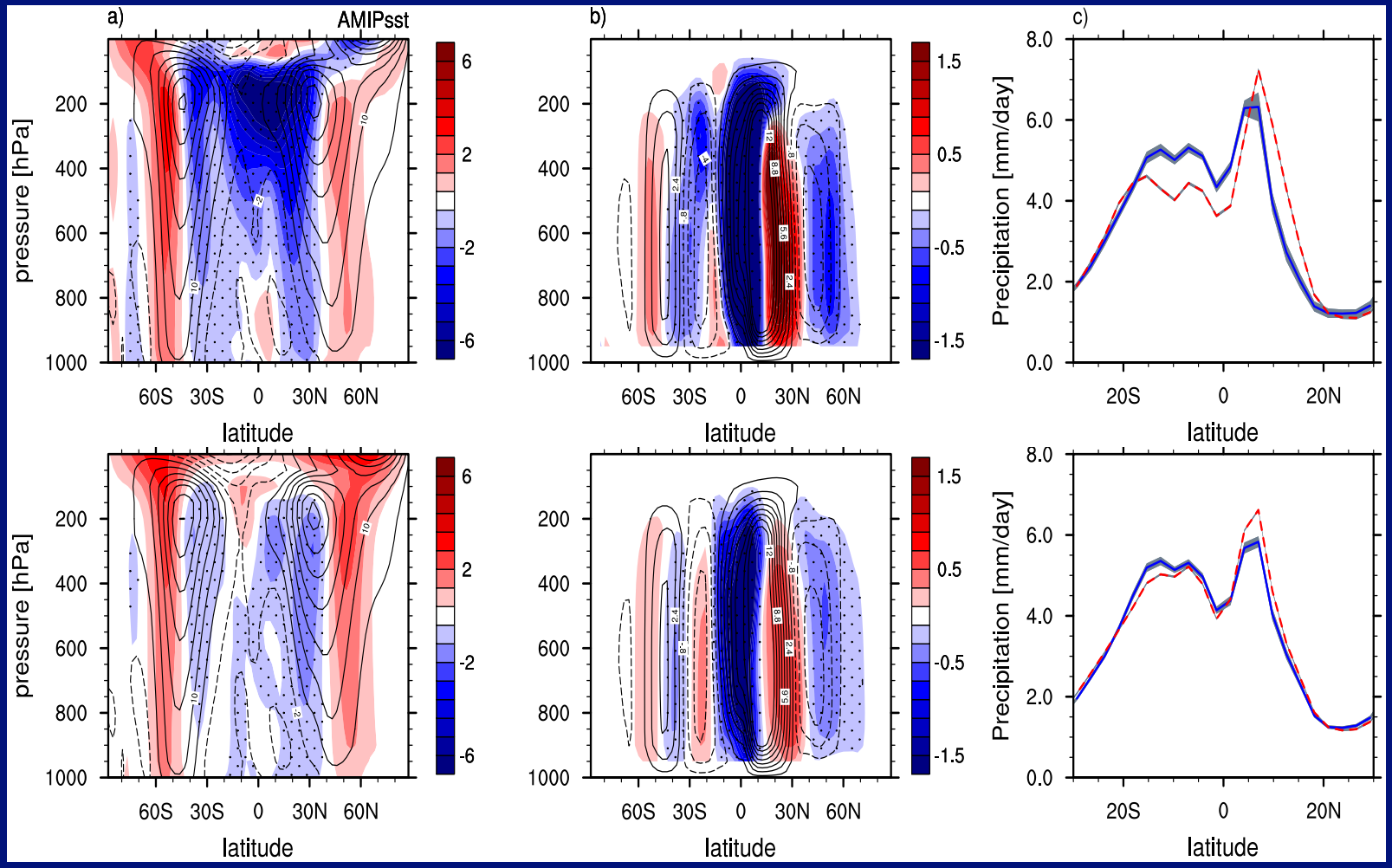


Reduced eddy generation in the subtropics.

Poleward critical latitude shift

RESULTS: AMIP-type and slab ocean setup

- Question: Does the sensitivity to reduced Z_{0m} carry over to setups with seasonal cycle and full complexity of surface-atmosphere interaction?



SUMMARY

- Circulation response to the reduced air-sea roughness ENSO-like:

  i. A poleward shift of the subtropical jet extending to the surface.
  ii. A weak poleward shift of the subtropical descent regions.
  iii. A weakening of the Hadley circulation generally accompanied by the poleward shift in the ITCZ.

- Response mediated thermodynamically and from the tropics.

  – Tropical circulation response due to reduced energy fluxes.
  – Extra-tropical response through critical latitude shift and reduced eddy forcing.