The roles of static stability and tropical-extratropical interactions in North Atlantic and European sector summertime storminess

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Overview

Introduction

Methods

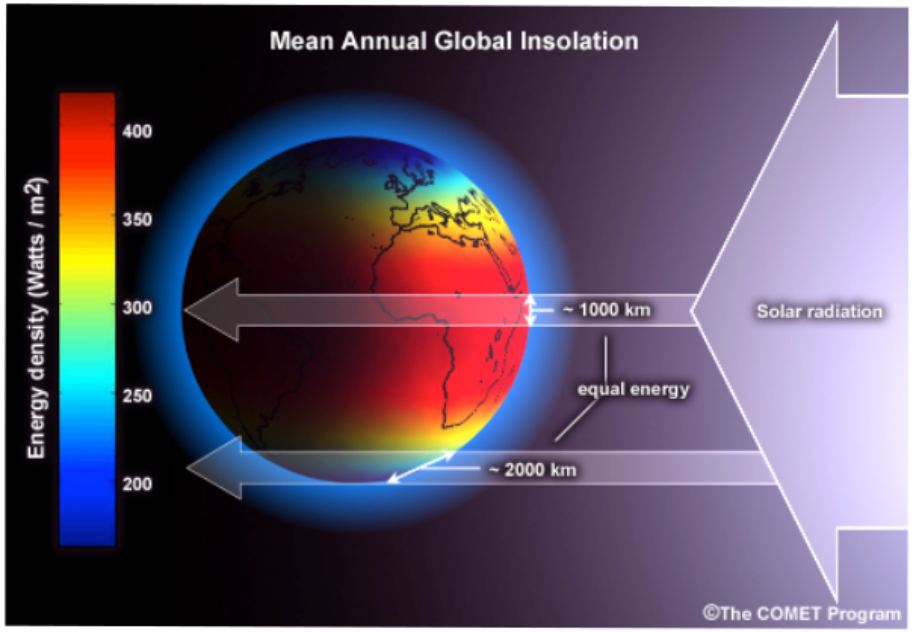
Contrasts in seasonal-mean static stability and the implications for differences in seasonal predictability.

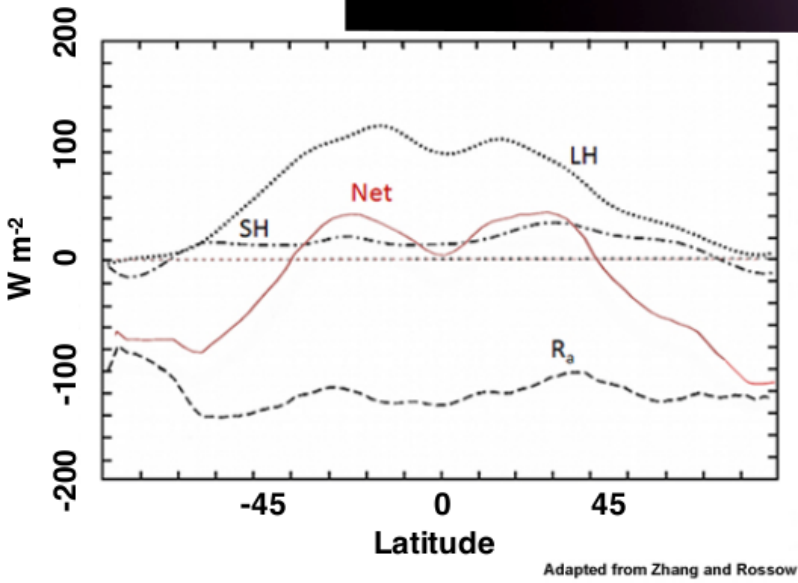
The spatial and temporal distribution of mean static stability imply different seasonal spatial and temporal distributions of baroclinic sensitivity.

Static stability, storm tracks, and North Atlantic sector variability.

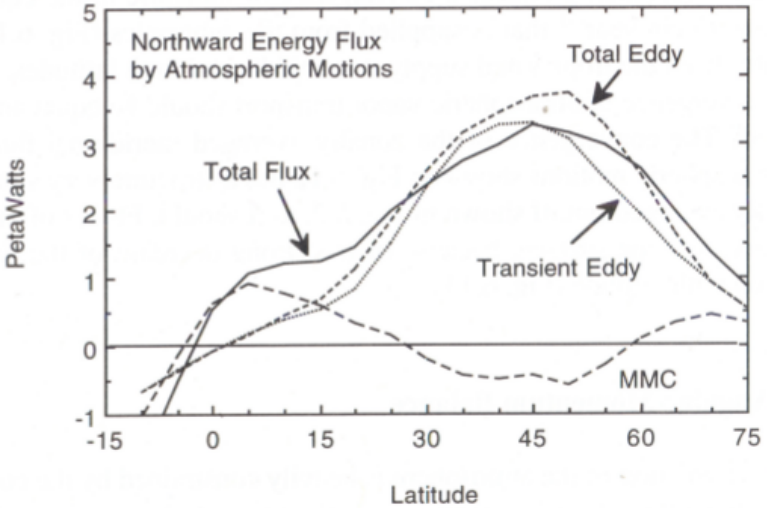
Interannual variations in upper-level static stability suggests a Tropical Atlantic driver of NAEU variability.

The atmosphere's drivers





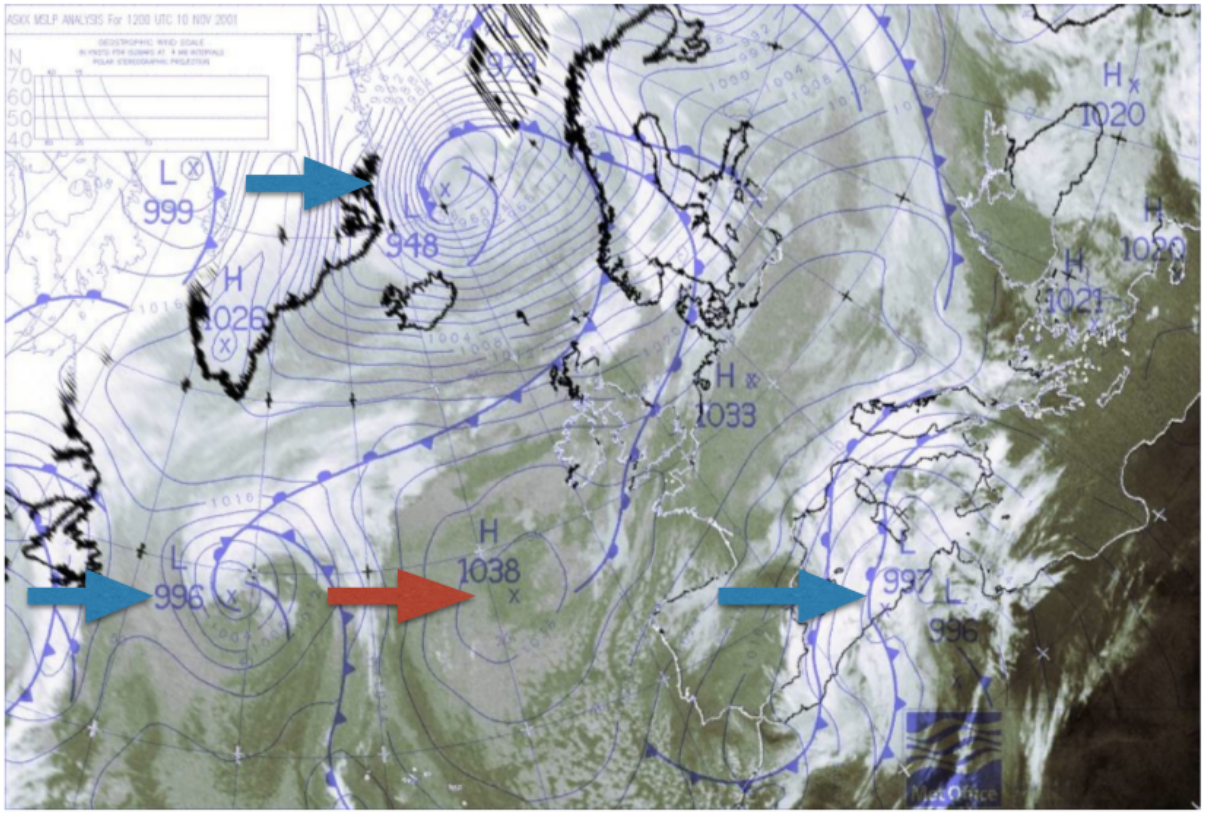
Adapted from Zhang and Rossow (1997)



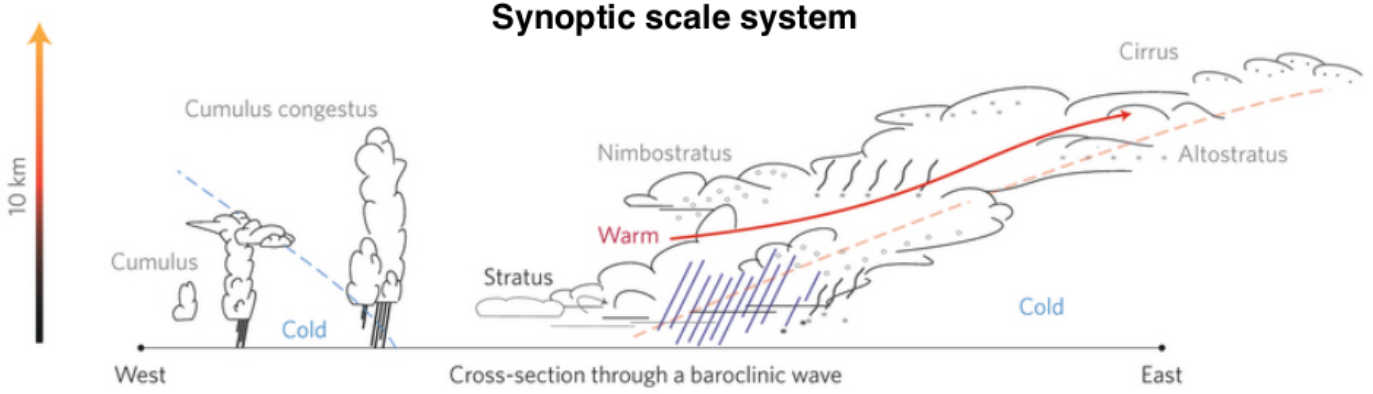
Hartmann, AP, 1994

$$\overline{[v\ \zeta]} = \overline{[v]}\ \overline{[\zeta]} + \overline{[v]'\ [\zeta]'} + [\bar{v}^*\ \bar{\zeta}^*] + \overline{[v'^*\ \zeta'^*]}$$

Storm tracks: the phenomenon

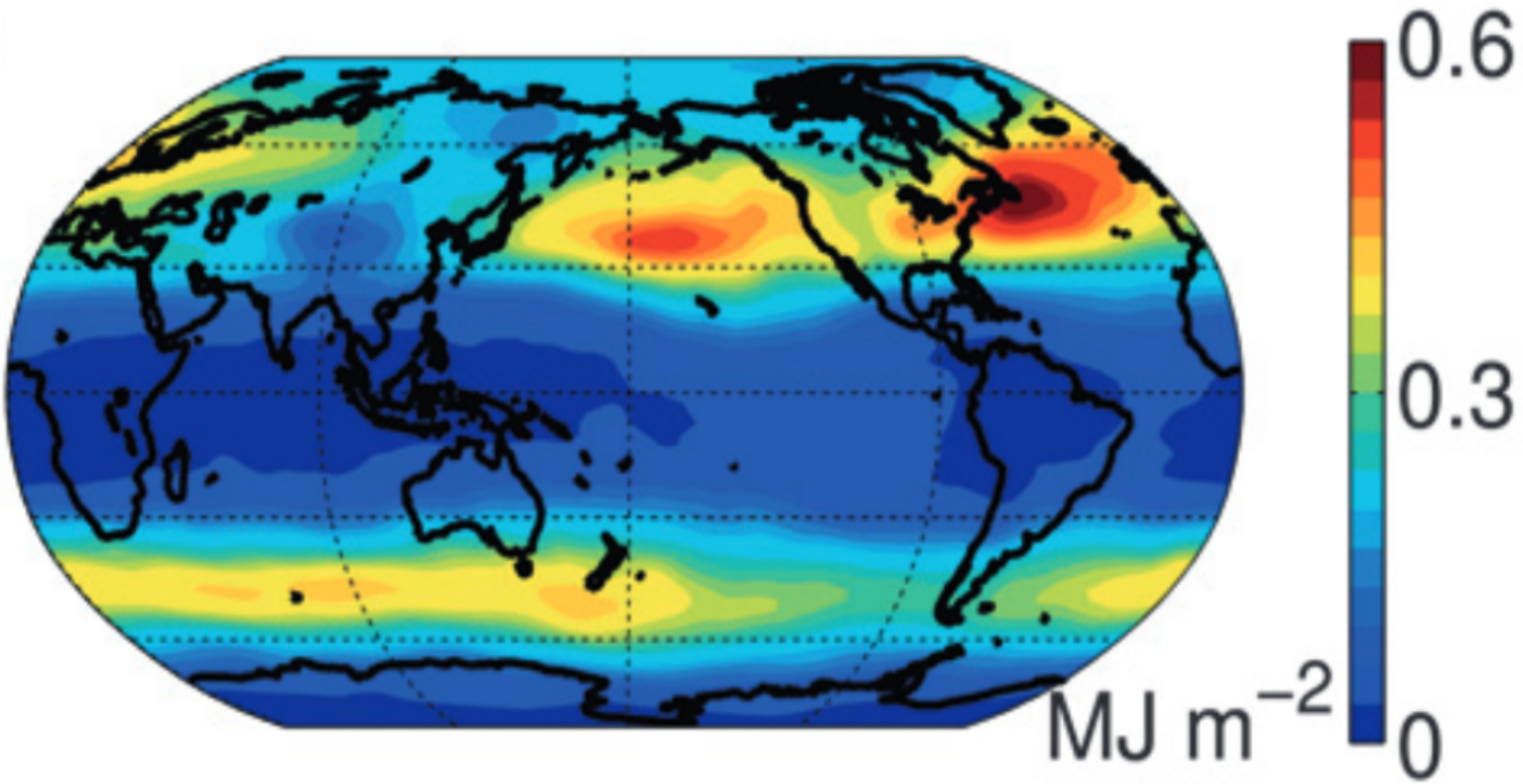


Synoptic scale system



Bony et al., Nat. Geo. Sci., 2015

Storm tracks: the phenomenon



Kaspi and Schneider, J. Atmos. Sci, 2013

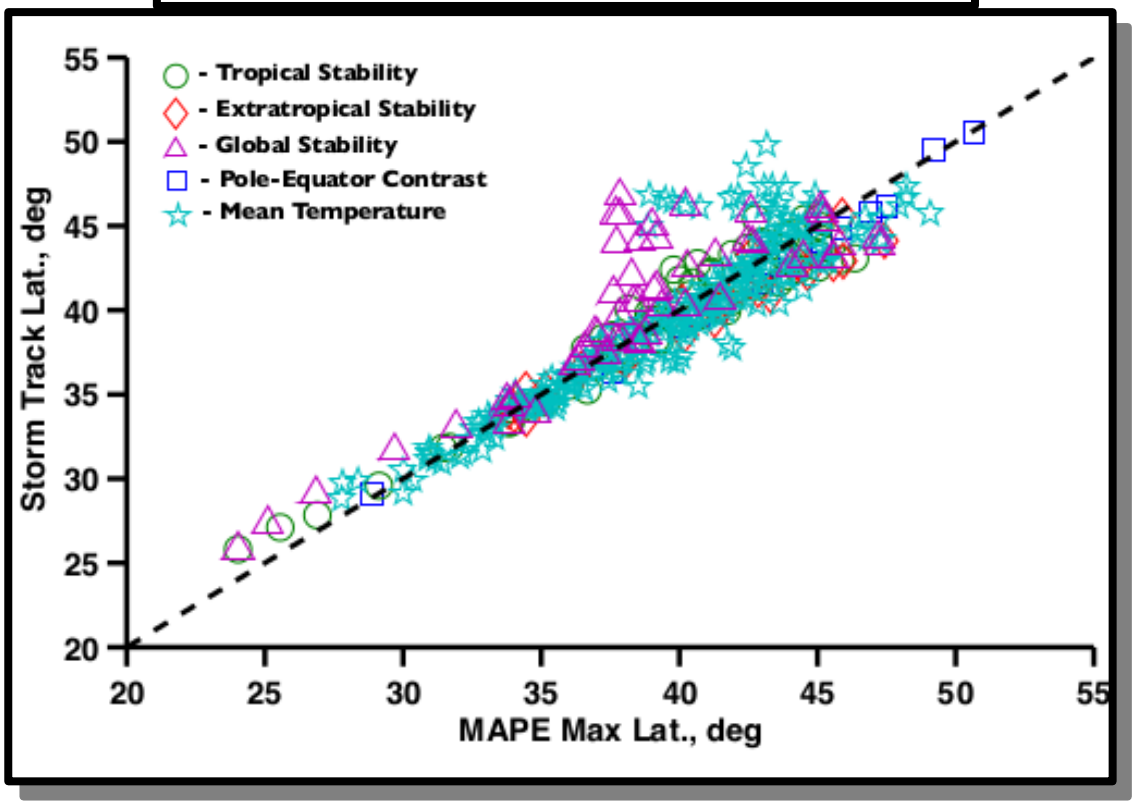
$$(2g)^{-1} \int \overline{[u]'^2} + \overline{[v]'^2}\ dp$$

Introduction

- NA/EU sector summertime seasonal-forecast skill is inferior to wintertime.
- Is the summer time inherently less predictable?
- Are important drivers missing in climate and forecast models?
- We combine statistical and theoretical approaches to show how seasonal variations in static stability influence predictability.
- Through a decomposition of baroclinicity, we show how variations in the overturning circulation in the tropical Atlantic can influence storm-track variability.

Using MAPE to understand storm track shifts

$$\mathrm{MAPE} = \frac{\kappa\, c_p \left\langle \overline{p}_t - \overline{p}_s \right\rangle}{24\, p_0\, g \left\langle \overline{\partial_p \theta}_s \right\rangle} \left\langle \partial_y \overline{\theta}_s \right\rangle^2 L_z^2$$



(Mbengue and Schneider, J. Atmos. Sci. 2017)

Maxima of local MAPE and EKE collocate as the climate changes.

MAPE decomposition

Using positive definite nature of climatological fields in the midlatitudes, we can decompose MAPE as follows:

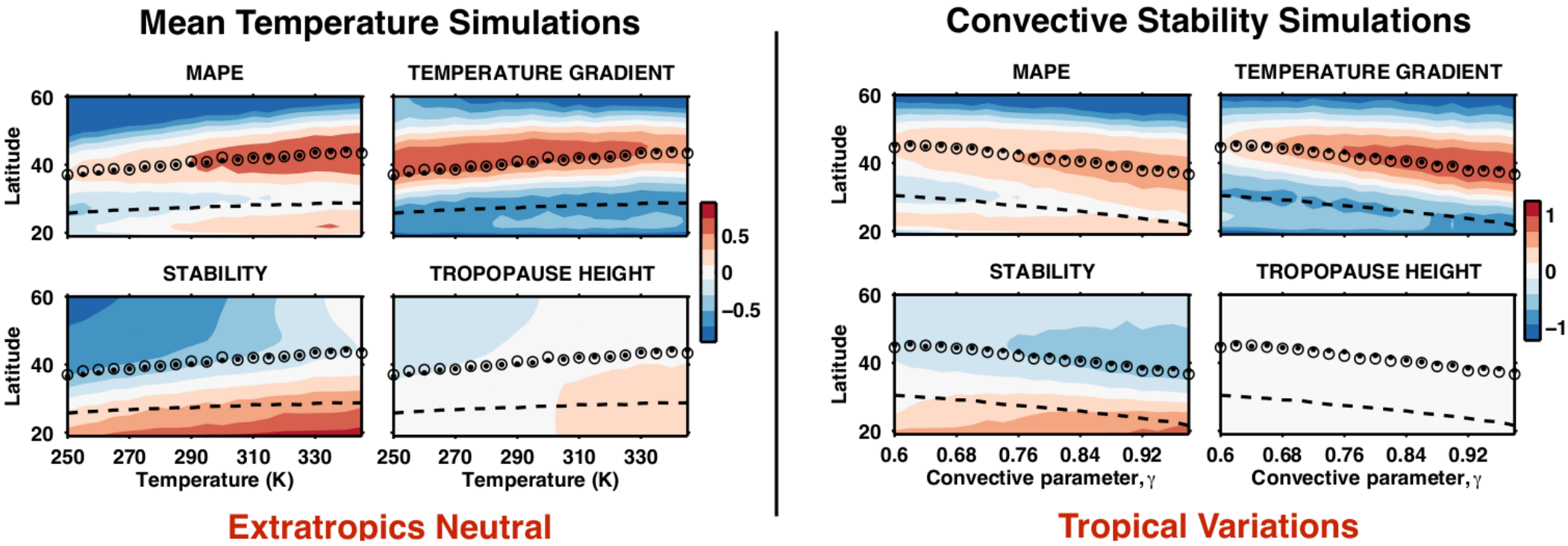
$$
\begin{aligned}
ln\ \overline{A} &= ln\ \frac{\xi\ \overline{\Delta p}\ \left(\partial_y \overline{\theta_s}\right)^2}{\overline{\partial_p \theta_s}} \\
&= ln\ \xi + ln\ \overline{\Delta p} + ln\ \left(\partial_y \overline{\theta_s}\right)^2 - ln\ \overline{\partial_p \theta_s}
\end{aligned}
$$

thus

$$
ln\ \frac{\overline{A}}{\overline{A}^*} = ln\ \frac{\overline{\Delta p}}{\overline{\Delta p}^*} + ln\ \frac{\left(\partial_y \overline{\theta_s}\right)^2}{\left(\partial_y \overline{\theta_s}\right)^{2*}} + ln\ \frac{\overline{\partial_p \theta_s}^*}{\overline{\partial_p \theta_s}}
$$

where $(\cdot)^*$ = geometric mean

Fields of decomposed MAPE



(Mbengue and Schneider, J. Atmos. Sci. 2017)

- Near-surface temperature gradients dominate the shifts in MAPE---even when changing deep tropical stability.
- Static stability influences the magnitude of MAPE.

Methods

- Datasets
  - General
    - ECMWF ERA-INTERIM reanalysis, 1979-2017 (Dee et al., 2011)
  - UK precipitation
    - UK MetOffice Hadley Center, 1937-2015 (Alexander and Jones, 2001)
  - Land temperature and precipitation
    - University of East Anglia Climatic Research Unit, 1901-2014 (Harris et al. 2014)
  - Outgoing longwave radiation
    - NOAA/OAR/ESRL Physical Sciences Division, 1974-2013 (Liebmann and Smith, 1996)

Methods

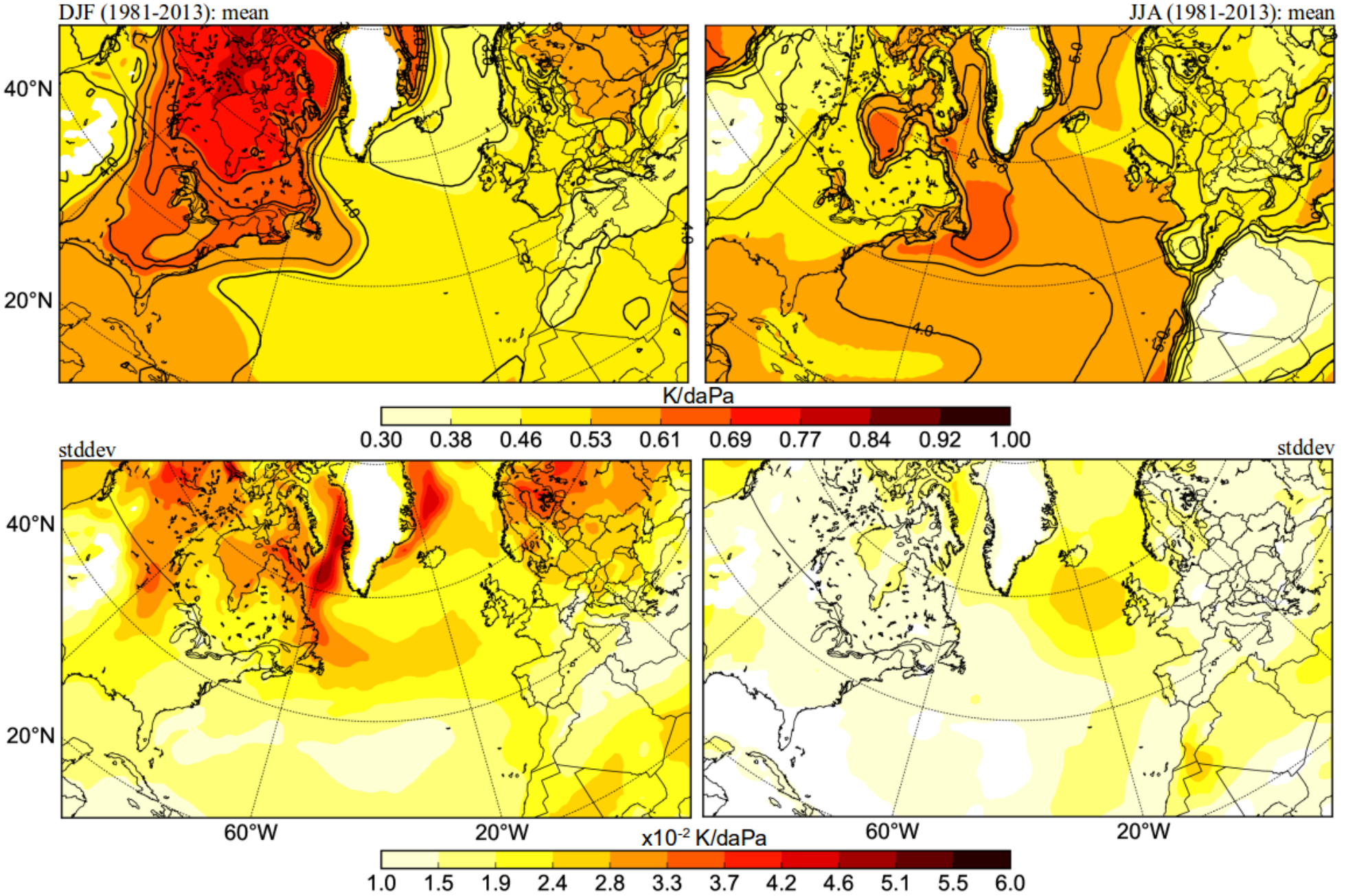
- Analysis
  - EOFs
    - Seasonal means
    - Region: (20N – 60N, 70W – 10W)
    - Detrended, weighted, and normalized.
    - Positive phase: composite of upper 75% of scores
    - Negative phase: composite of lower 25% of scores
  - Track statistics (Hodges, 1995)
    - ERA-INTERIM, T42-truncated, 6-hourly 850hPa relative vorticity.
    - Travel 1000km, live at least 2 days, with relative vorticity exceeding $10^{-5}\ s^{-1}$
  - Storm Tracks
    - 2 – 6 day bandpass filtered EKE, using a spectral truncation
    - $\mathrm{EKE}(\phi, \lambda) \simeq \int \left(\overline{u'^2} + \overline{v'^2} \right) \frac{dp}{2g}$
  - Baroclinicity
    - (O'Gorman and Scneider, 2008; Mbengue and Schneider, 2017)
    - $\mathrm{MAPE}(\phi, \lambda) \simeq \frac{p_0}{24\,\Gamma_d} (1 - p_t / p_s) [L_z\, \partial_y T]^2 \left\{ -\kappa\, \partial_p \theta / p \right\}^{-1}$

PART I

Contrasts in seasonal-mean static stability and the implications for differences in seasonal predictability.

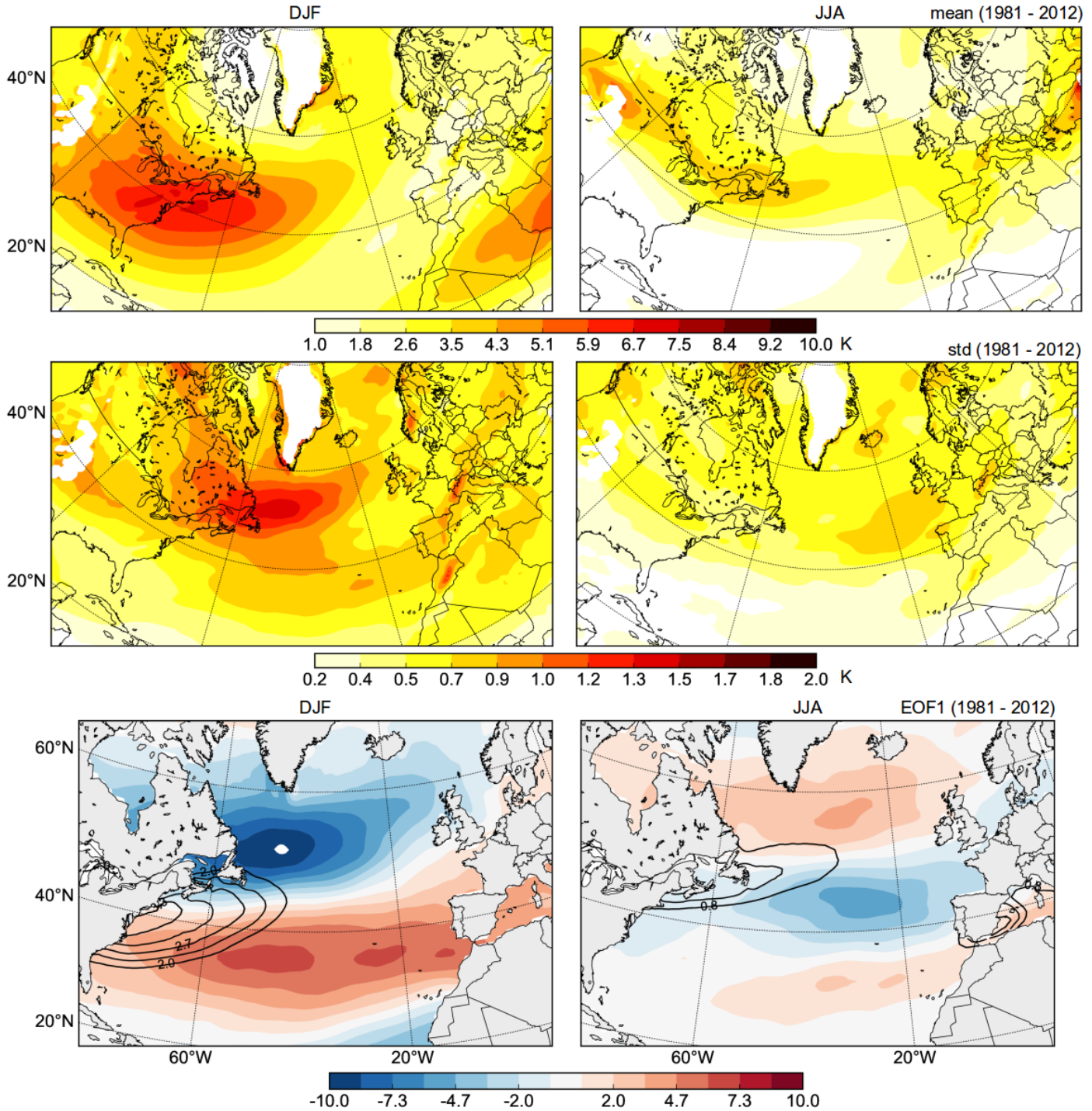
The spatial and temporal distribution of mean static stability imply different seasonal spatial and temporal distributions of baroclinicity sensitivity.

Seasonal-Mean Static Stability



$$\mathrm{MAPE}(\phi, \lambda) \simeq \frac{p_0}{24\,\Gamma_d}\,(1 - p_t / p_s)\,[L_z\,\partial_y T]^2\,\{-\kappa\,\partial_p\,\theta / p\}^{-1}$$

Seasonal-Mean Temp. Gradient



Interim Conclusions

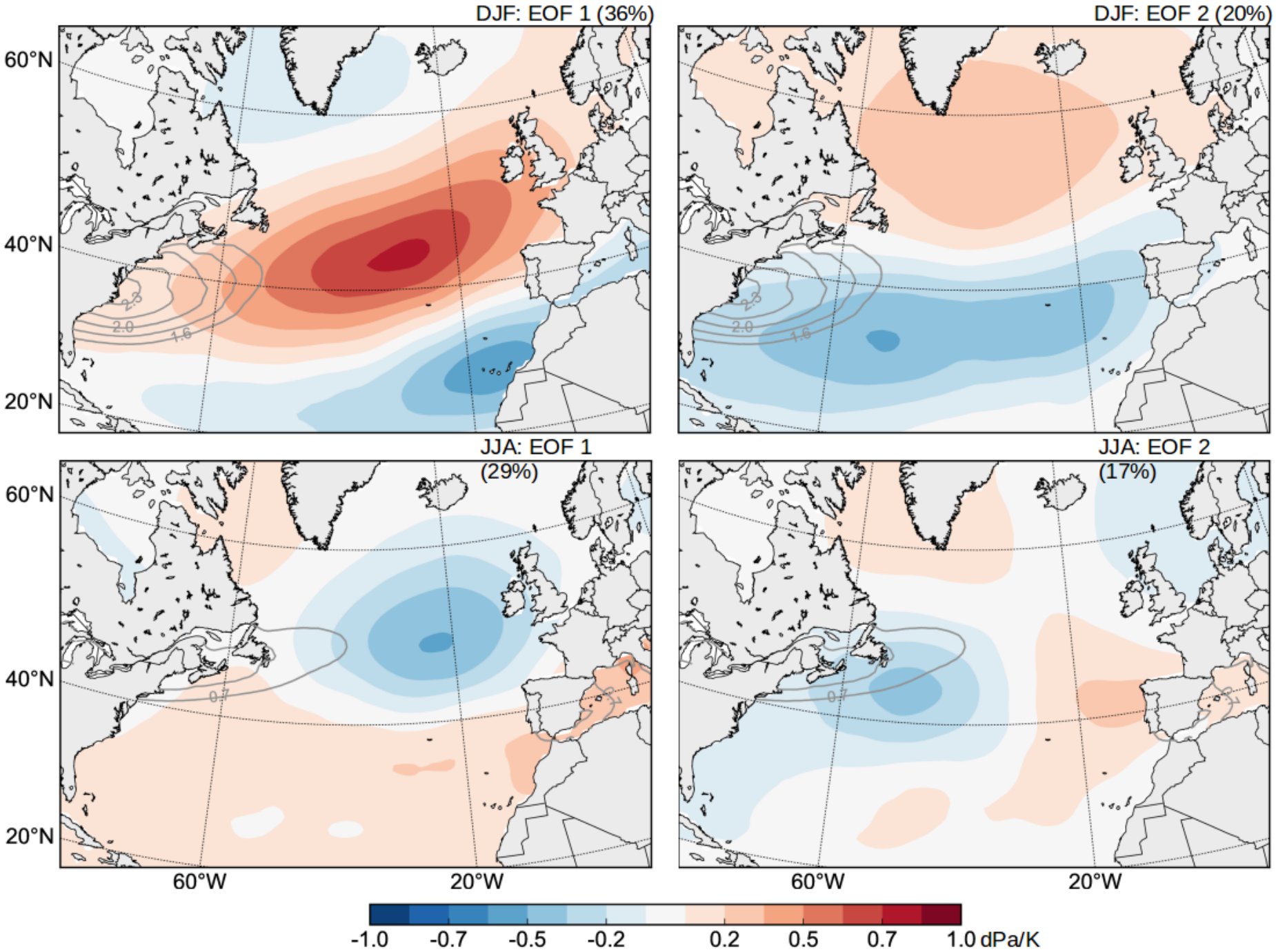
- $MAPE = \alpha G^2 P / S$
- $\delta MAPE \sim (\alpha 2 H G / S) \delta G$
- Summer and winter time in the North Atlantic sector exhibit different sensitivities to baroclinicity because of different spatial and temporal distributions of static stability.
- Predictable drivers that act through local baroclinicity will be amplifed over ocean during winter and over land in summer.
- Improve land-related predictors to improve summer seasonal forecasts.

PART II

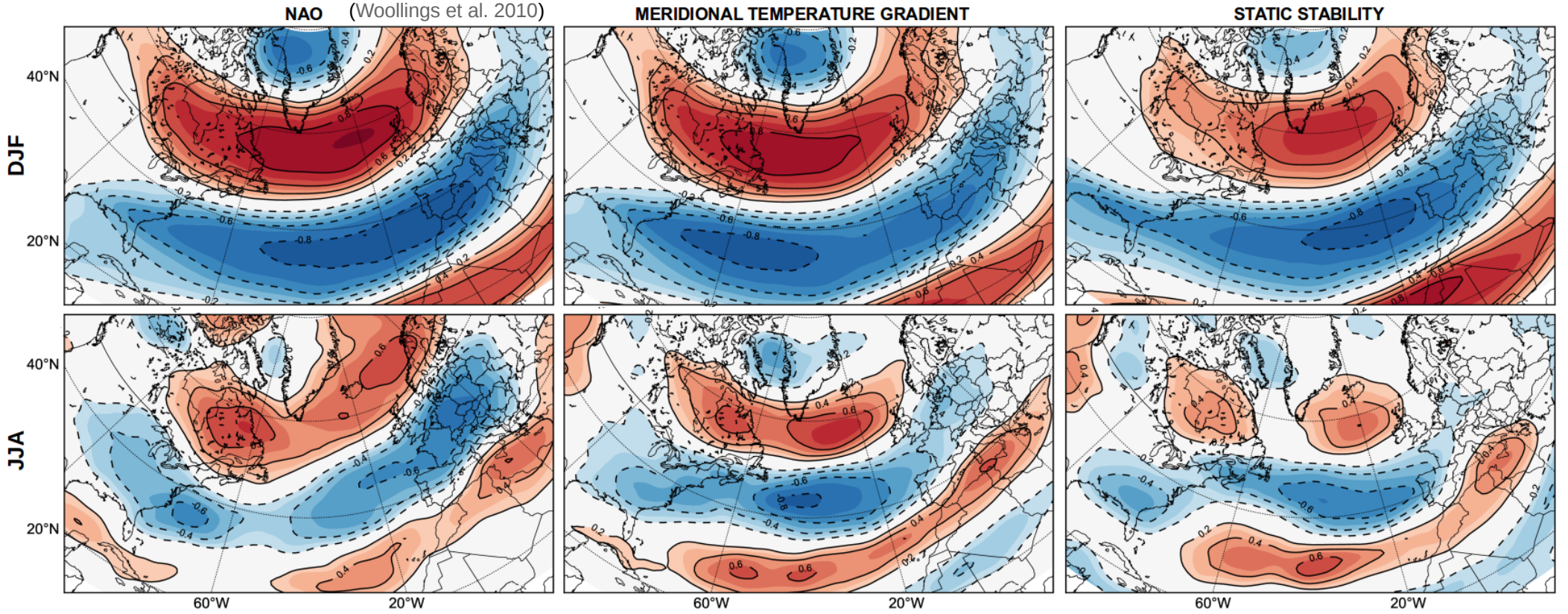
Static stability, storm tracks, and North Atlantic sector variability.

Interannual variations in upper-level stability suggests a tropical Atlantic driver.

Seasonal-Mean Static Stability EOF

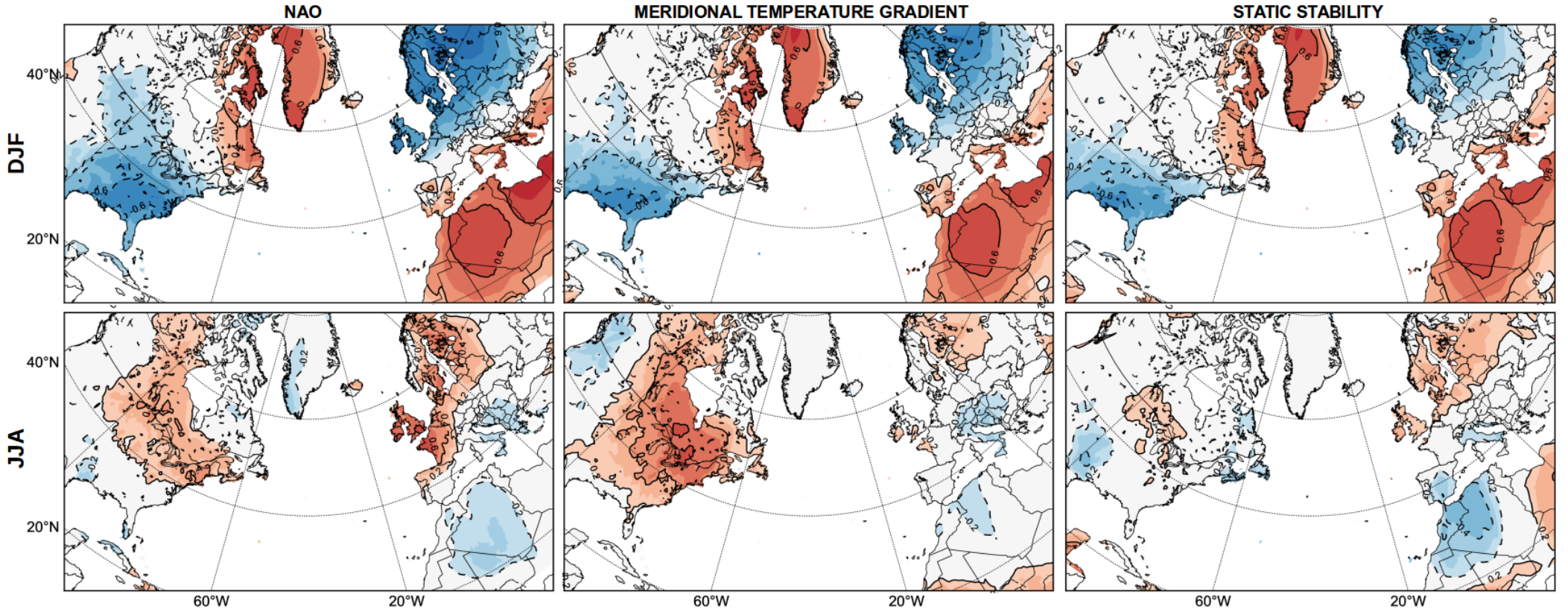


EOF Comparison: Upper-level Winds

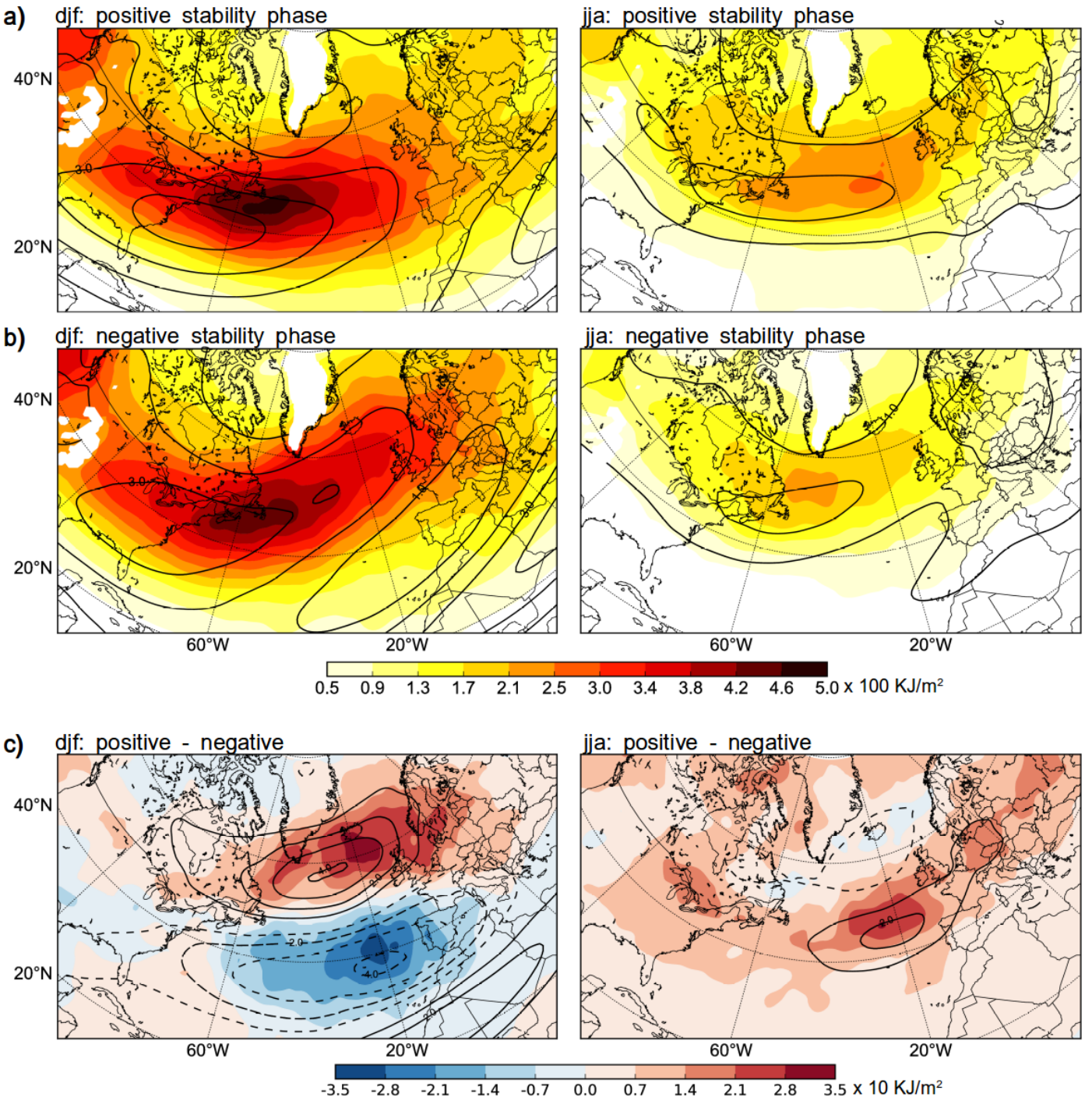


(Woollings et al. 2010)

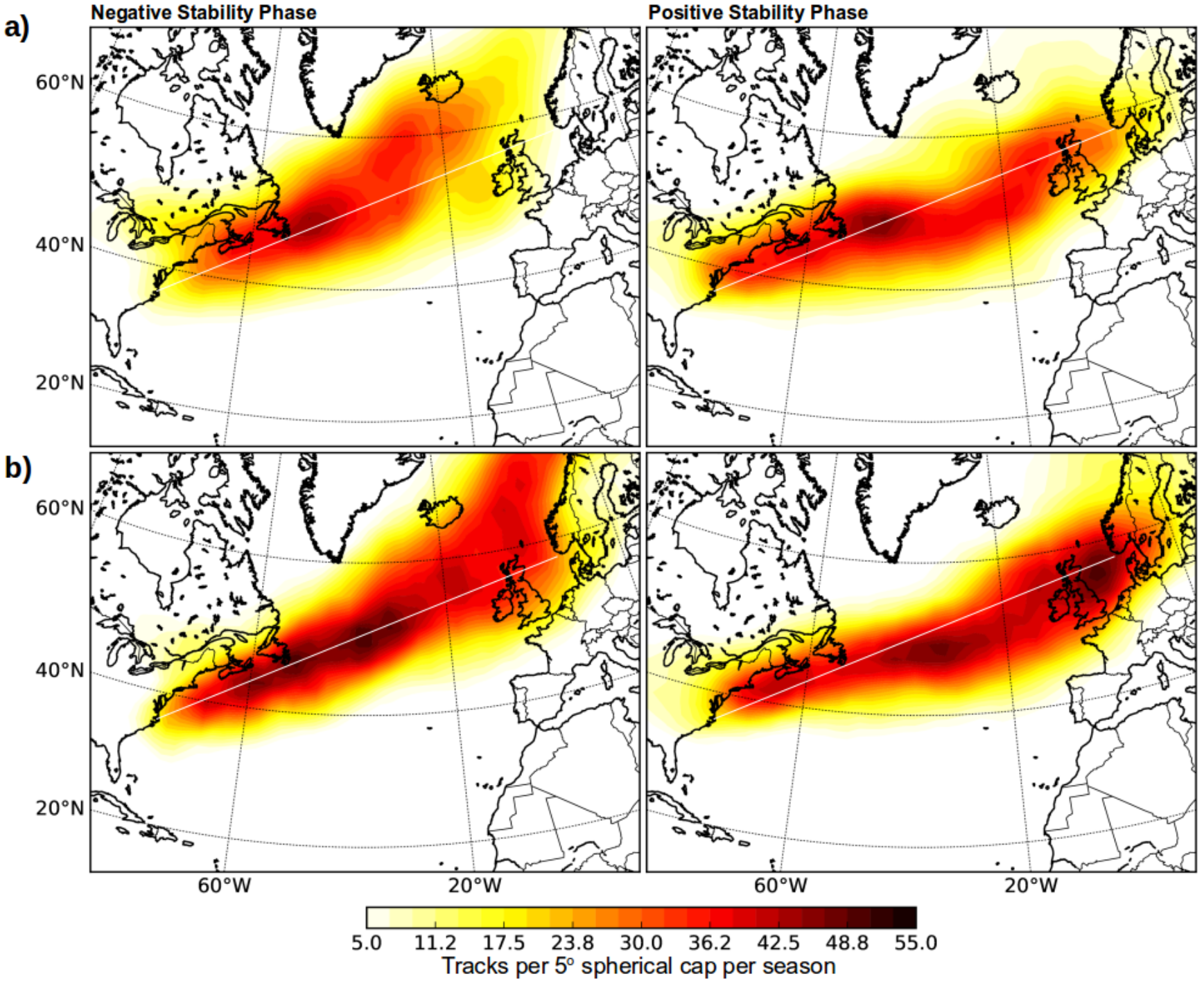
EOF Comparison: Land-Surface Temperature



Seasonal Composites: EKE



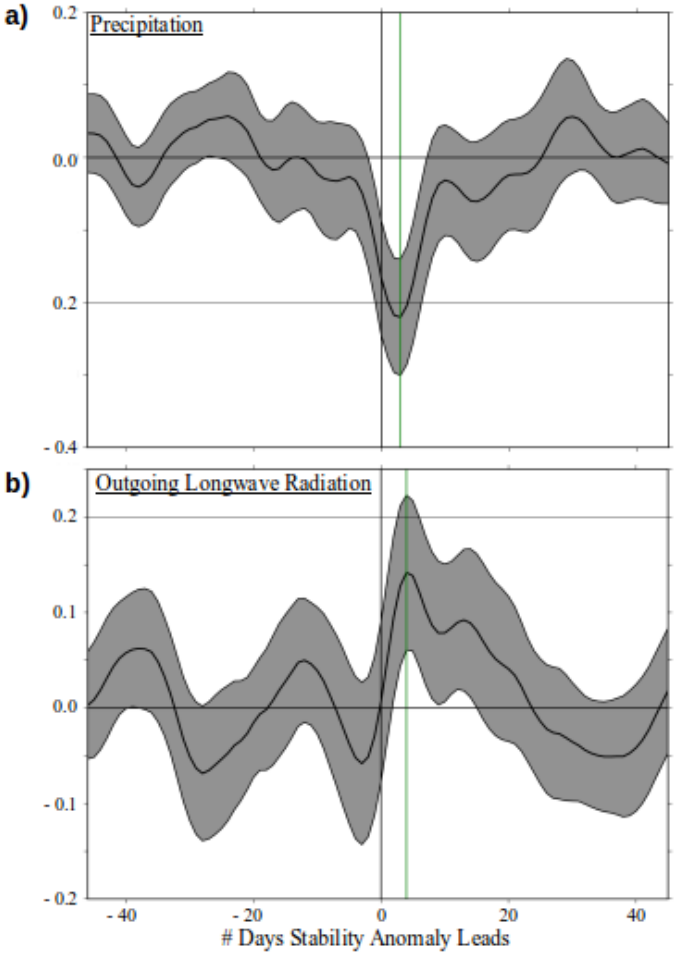
Summer Composites: cyclone tracks



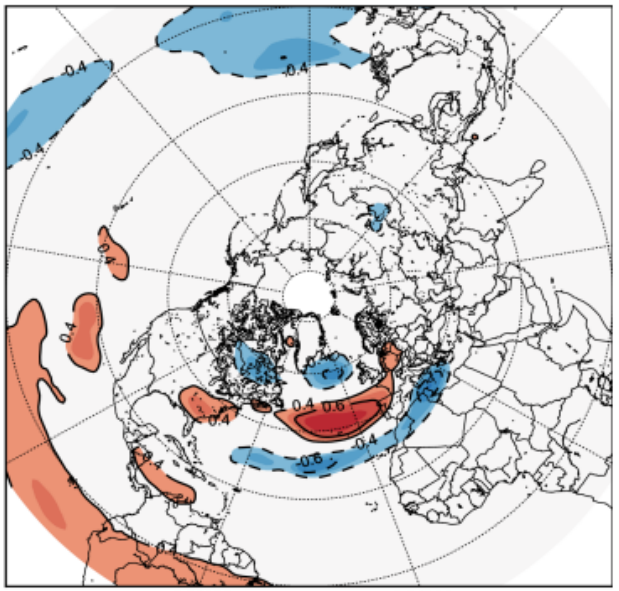
Mechanisms of Upper-Level Midlatitude Static-Stability Variability

- Midlatitude eddy dynamics
  - Schneider, 2004; Haqq-Misra et al., 2011
- Stratospheric dynamics
  - Haqq-Misra et al., 2011
- Rossby waves excited from the tropics
  - Hoskins and Karoly, 1981; Rodwell and Hoskins
- Overturning circulation
  - Gaetani et al., 2013; Mbengue et al., 2017

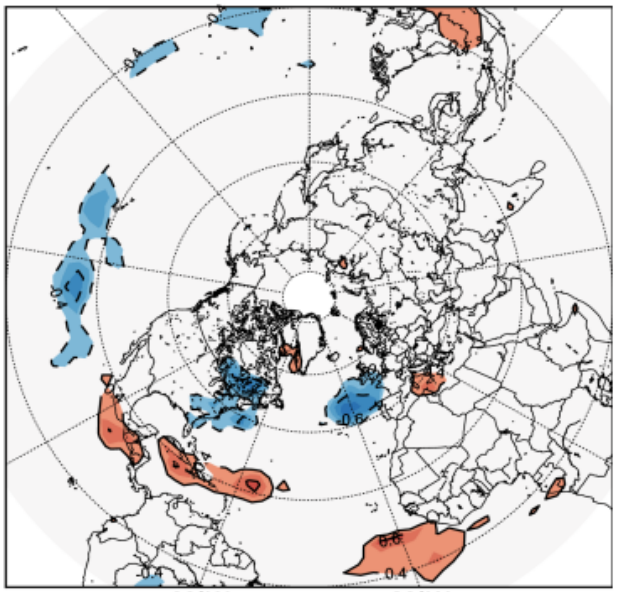
Summer Stability-Anomaly regressions



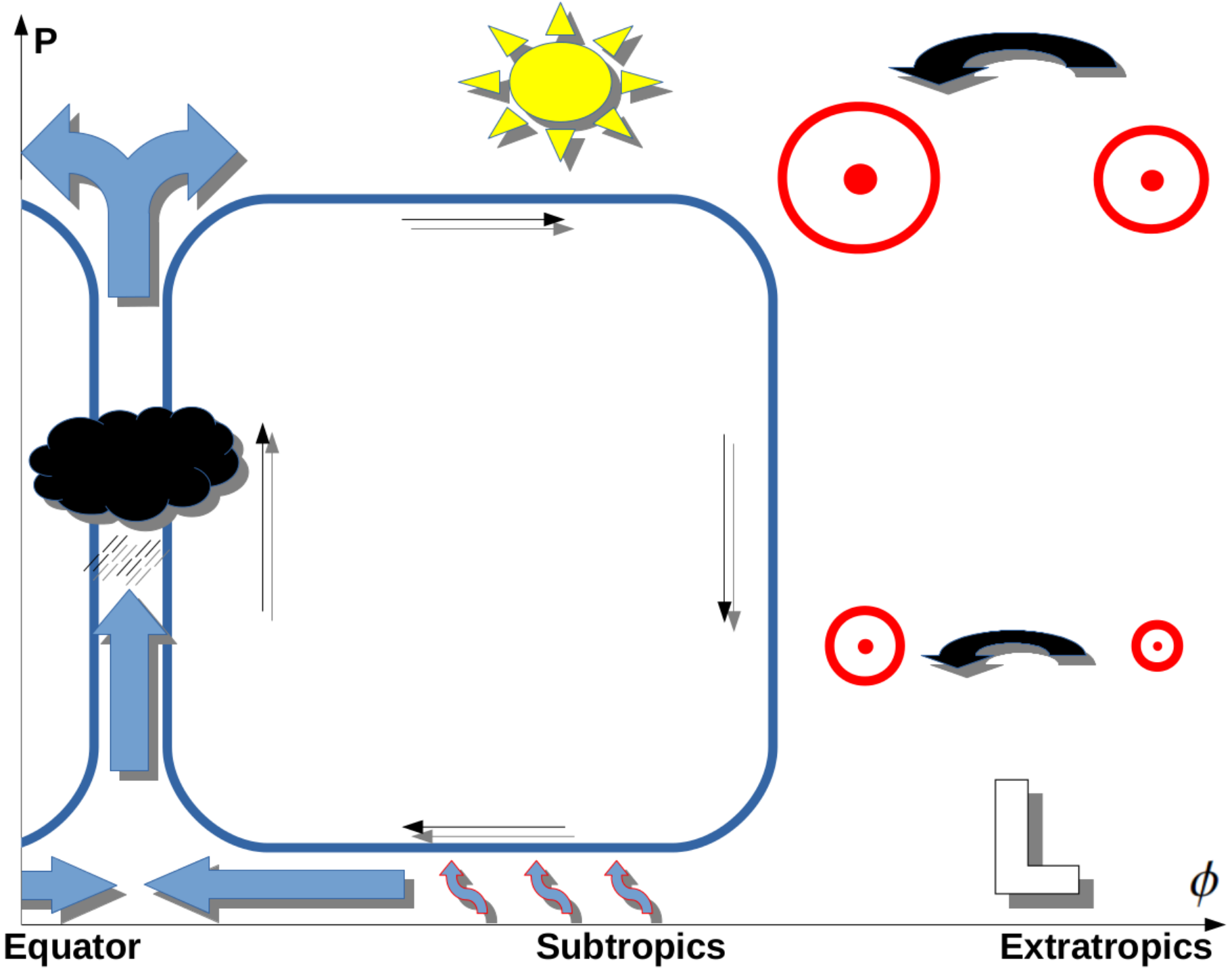
U300



Outgoing Longwave Radiation



Proposed Mechanism



Conclusions

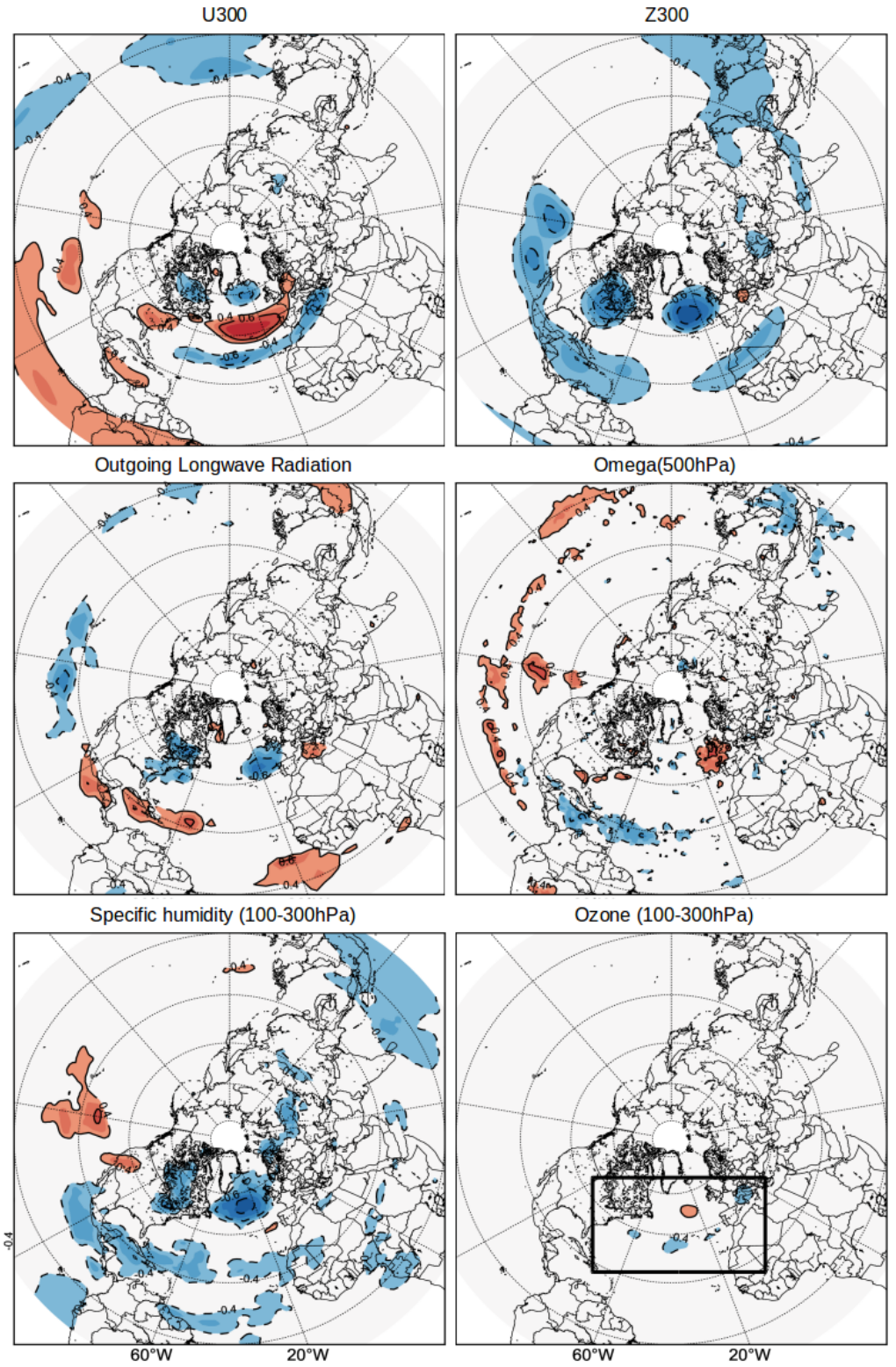
Contrasts in seasonal-mean static stability and the implications for differences in seasonal predictability.

The spatial and temporal distribution of mean static stability imply different seasonal spatial and temporal distributions of baroclinic sensitivity. These differences modulate the response of drivers that act through changing midlatitude baroclinicity.

Static stability, storm tracks, and North Atlantic sector variability.

Interannual variations in upper-level static stability suggests a tropical Atlantic driver of NAEU variability. Many actors operate but changes in the tropical overturning circulation should not be overlooked.

Extra Slides


U300
Z300
Outgoing Longwave Radiation
Omega(500hPa)
Specific humidity (100-300hPa)
Ozone (100-300hPa)
60°W
20°W
60°W
20°W