NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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Local Fidelity and Remote Teleconnection Influences on Atmospheric Blocking in the Community Earth System Model (CESM)

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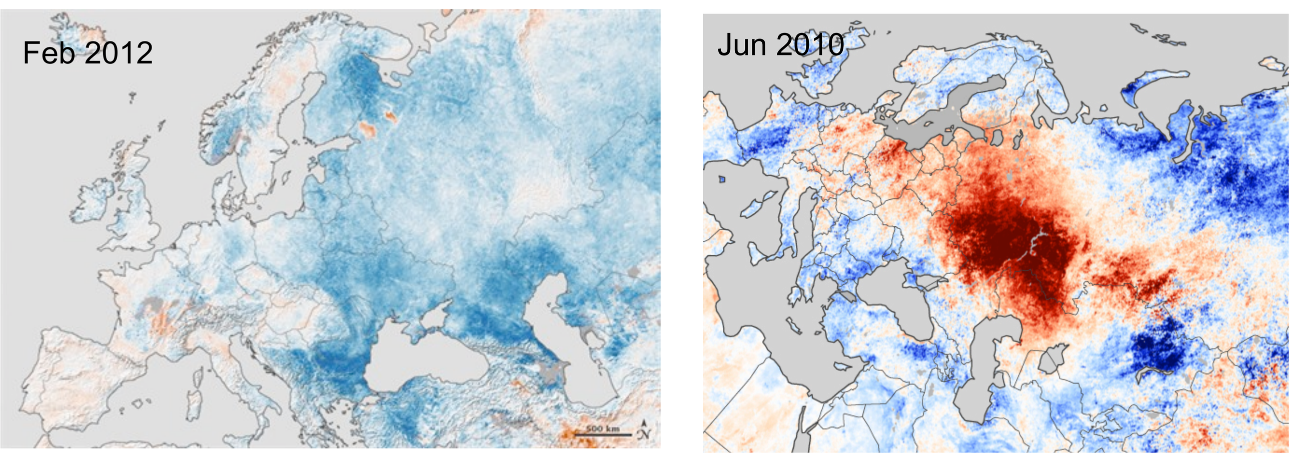
Introduction

Atmospheric blocking is a climate regime that can lead to persistent, atypical and often severe weather patterns. In the northern hemisphere winter time blocking is associated with prolonged periods of cold weather and significant snow events, predominantly in the North Atlantic and Western European regions. In summer time blocking events can lead to significant drought impacts and associated fire-danger and air-quality events. Recent events of note are the European Winter of 2012 and the Russian heat wave of 2010.

This study shows the current performance of the Community Earth System Model (CESM) in simulating realistic blocking statistics using a range of model simulations, configurations and blocking metrics.



Experiments and Metrics

This work involves an analysis of sets of ensemble experiment members (EM) available for CCSM3 through CESM1;

CCSM3: 20th C (9 EM), A1B (30 EM)
CCSM4: 20th C (30 EM), RCP8.5 (2 EM)
CESM1: 20th C (30 EM), RCP8.5 (30 EM)

Blocking index and composites are based on the D'Andrea et al (1998) metric; an analysis of poleward gradients of 500-mb geopotential height.

$$GHGS = \frac{Z(\phi_0) - Z(\phi_S)}{\phi_0 - \phi_S}$$

$$GHGS = \frac{Z(\phi_n) - Z(\phi_0)}{\phi_n - \phi_0}$$

$\phi_n = 78.75°N + \Delta$
$\phi_0 = 60°N + \Delta$ (3)
$\phi_S = 41.25°N + \Delta$
with
$\Delta = -3.75°, 0°, 3.75°$.

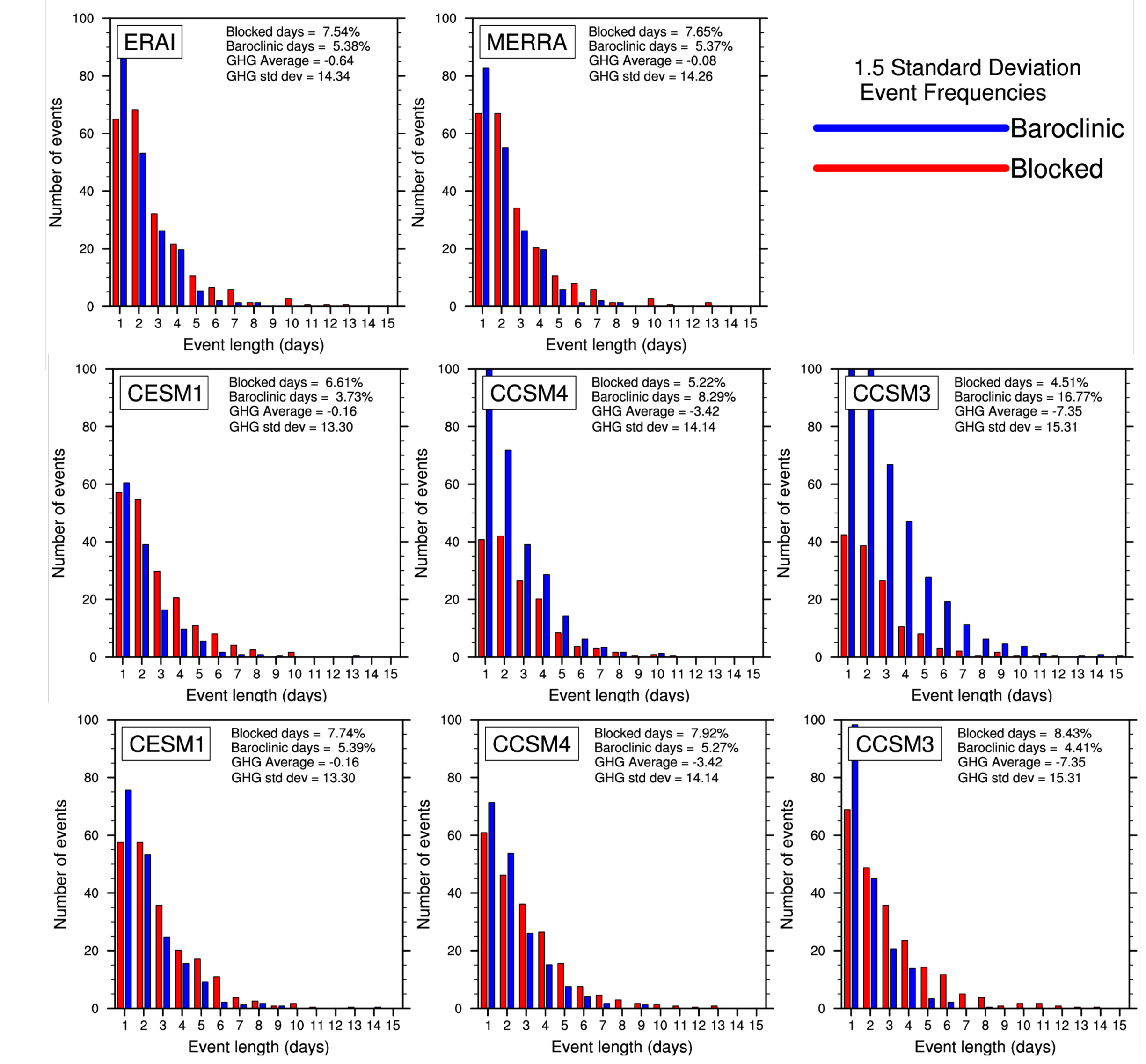
A given longitude is then locally defined as blocked on a specific day if the following conditions are satisfied (for at least one of the three values of Δ):

$GHGS > 0$, (4)
$GHGN < -5$ m/deg lat, (5)

Main Conclusions

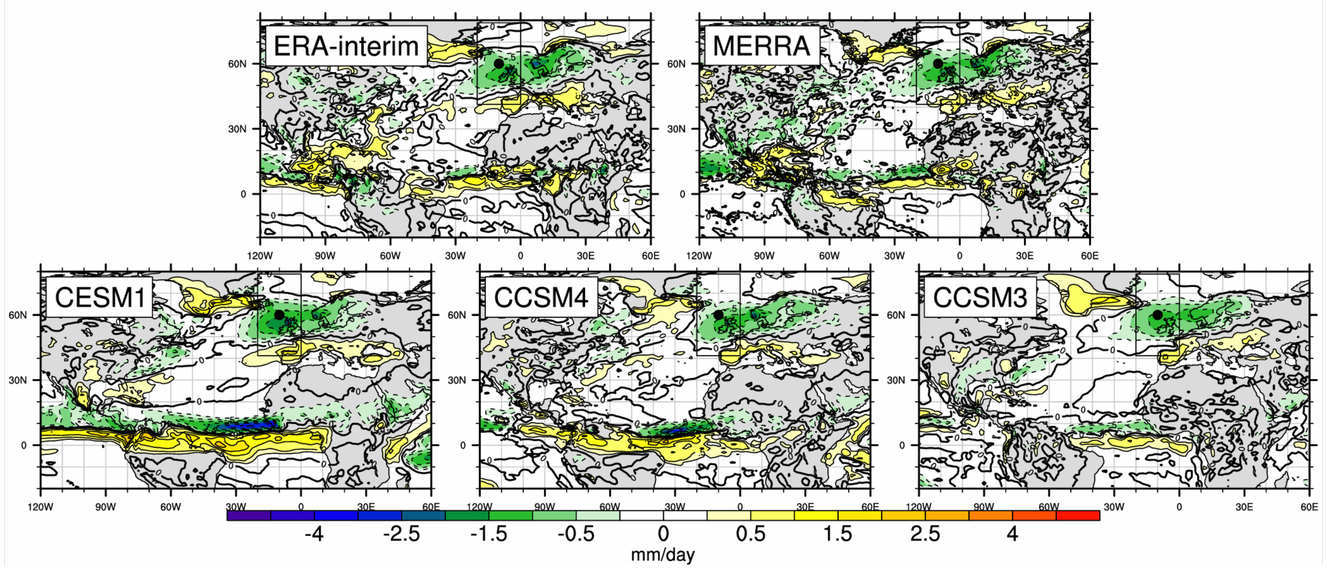
- Simulations exhibit significant skill for blocking metrics
- CESM large ensembles are required to separate model skill
- Largest remaining bias is a deficit of blocking activity during DJF over Eastern Atlantic
- Progressive improvements are seen from CCSM3 to CESM1
- Blocking strength distribution is essentially Gaussian
- Summer and Winter regional composite blocking patterns are well captured
- Un-normalized blocking length distributions agree with obs.
- Remote influences: Strong tropical Atlantic rainfall signal
- Model sensitivities: Greatest for turbulent mountain stress in JJA, deep convective entrainment in DJF
- Future climate shifts are slightly baroclinic and PDF is skewed and does not 'translate'

Event Length



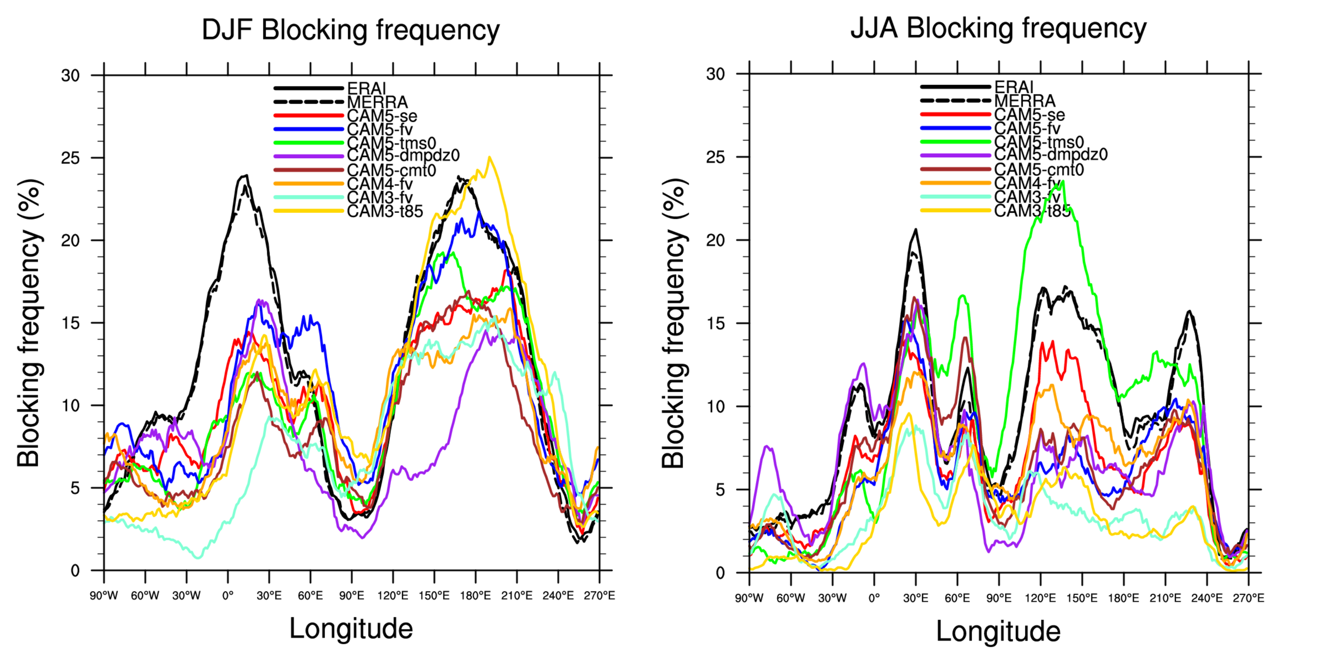
Distribution of blocking and baroclinic event length in days for DJF. Events determined as greater than +/- 1.5 standard deviations from pdf of blocking index strength. Shown for reanalyses (top), normalized to ERA-interim (center) and un-normalized (Bottom)

Remote Influences?



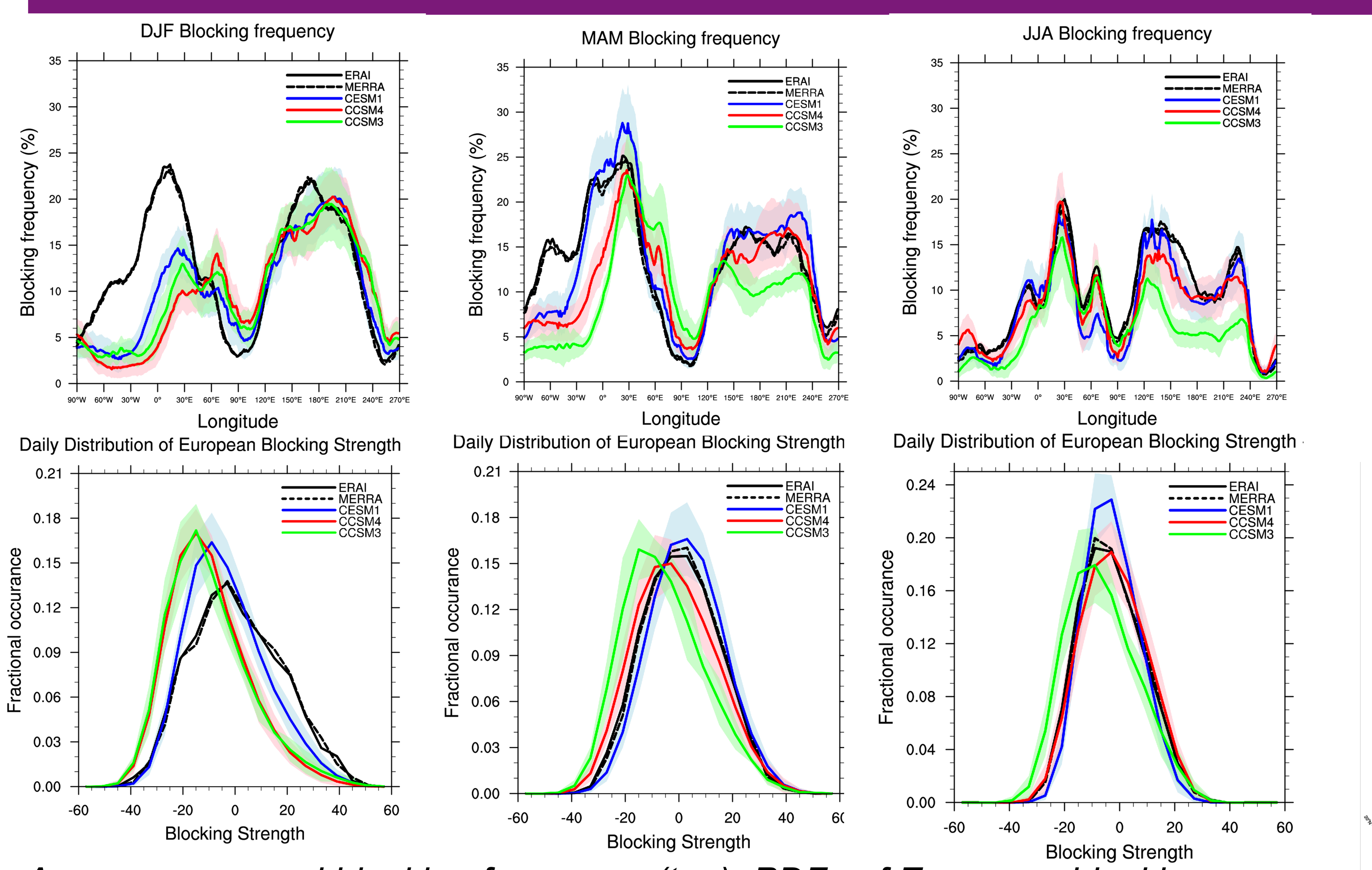
Composite remote precipitation patterns for strong European blocking in JJA. All model versions capture the associated tropical Atlantic ITCZ shift, consistent with observations.

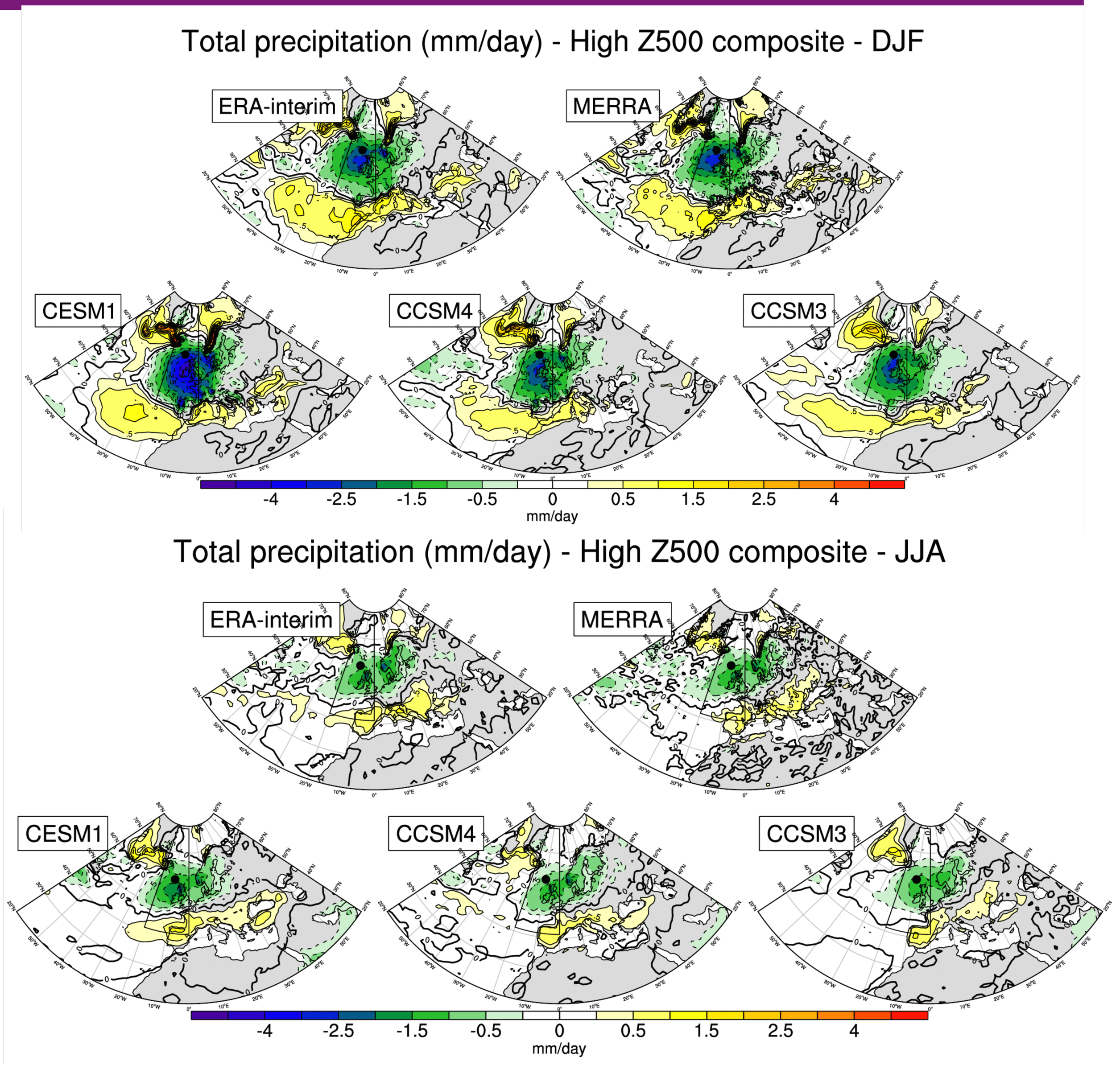
Model Dependencies



Spread of blocking frequencies from 20-year AMIP simulations spanning the major atmospheric physical and dynamical increments from CAM3 to CAM5.

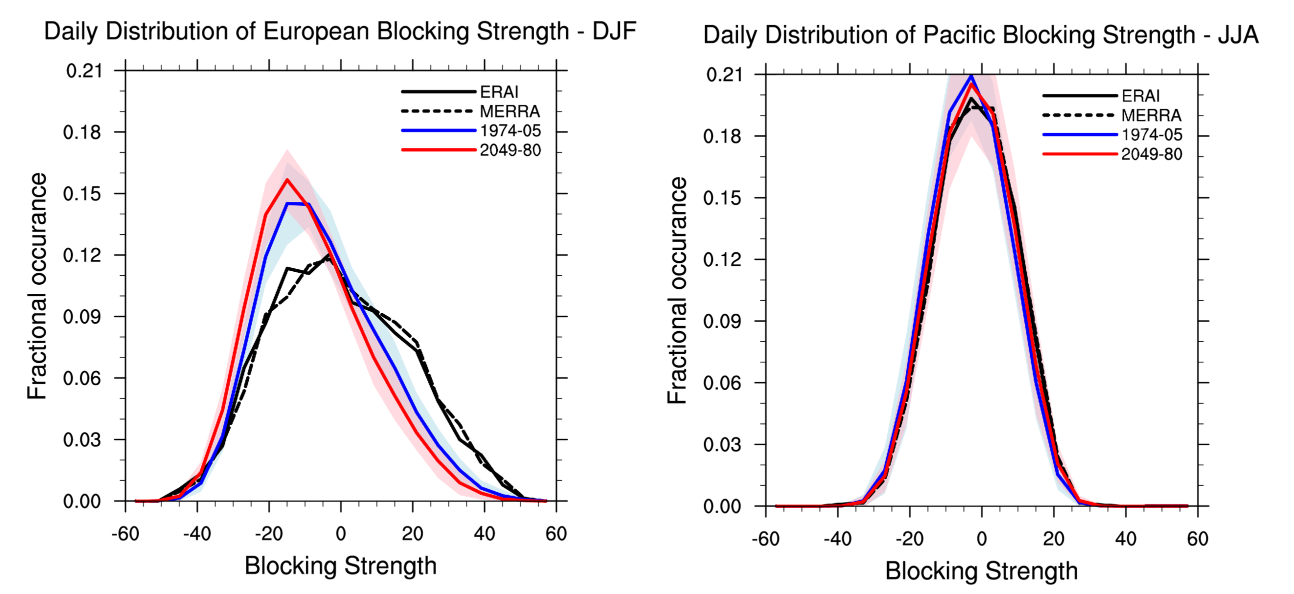
Model Skill





Average seasonal blocking frequency (top), PDFs of European blocking strength (bottom). Shading shows +/- 2 standard deviations for each ensemble. Seasonal blocking precipitation composite patterns over Europe at right.

Future Climate



Seasonal change in the PDF of European blocking frequency from the end of the 20th century to the mid-21st century. The change is a shift towards greater mean baroclinity, particularly in DJF.