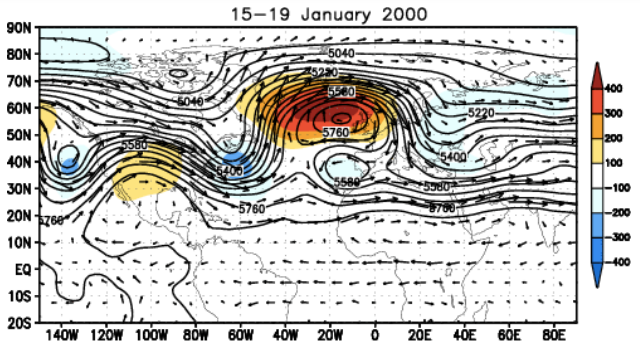
Atmospheric Blocking in the Community Earth System Model (CESM): Measure, Accuracy, Model Dependency

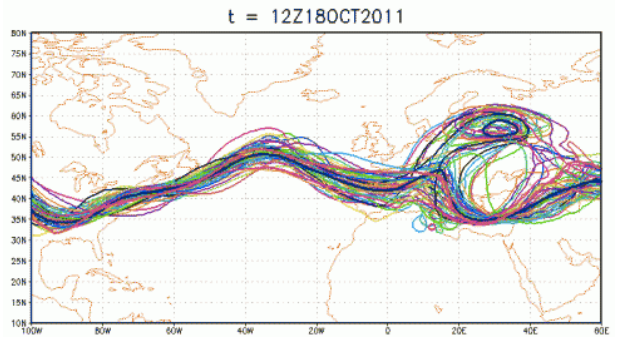
Rich Neale, Julio Bacmeister, Cecile Hannay

AMP/CGD

National Center for Atmospheric Research

Boulder, Colorado





NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NESL's Climate & Global Dynamics CGD

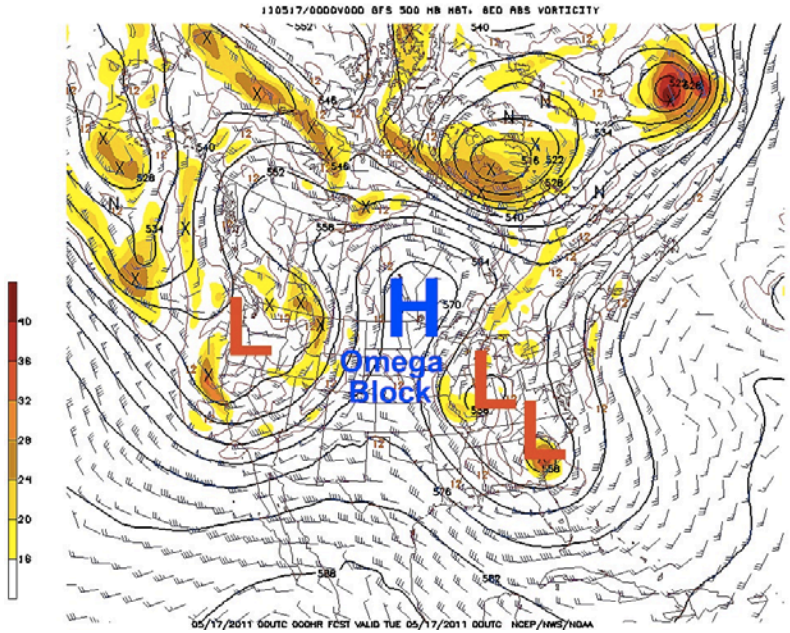
U.S. DEPARTMENT OF ENERGY

NSF

Blocking Pattern Characteristics

(A) Definition

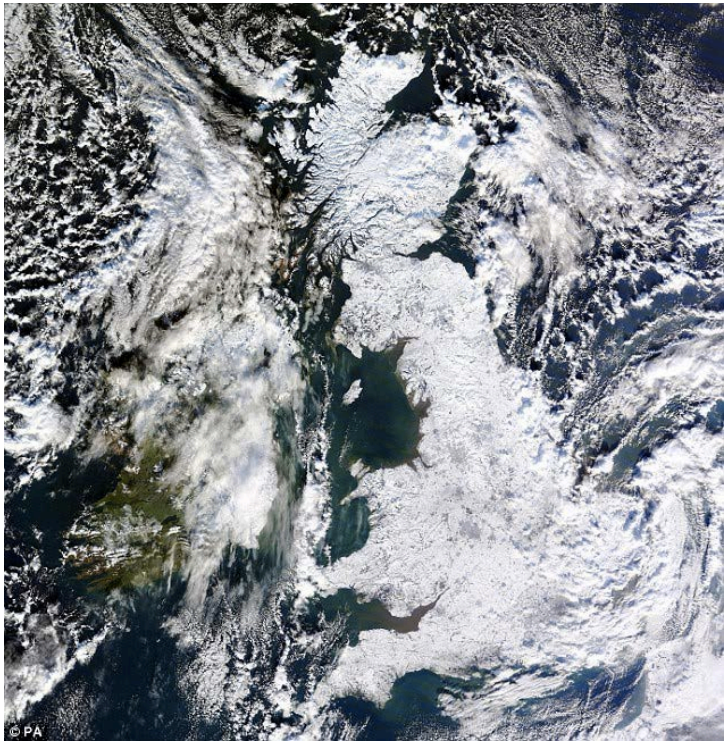
Blocks in meteorology are large-scale patterns in the atmospheric pressure field that are nearly stationary, effectively "blocking" or redirecting migratory cyclones. They are also known as blocking highs or blocking anticyclones (important for the global water cycle)



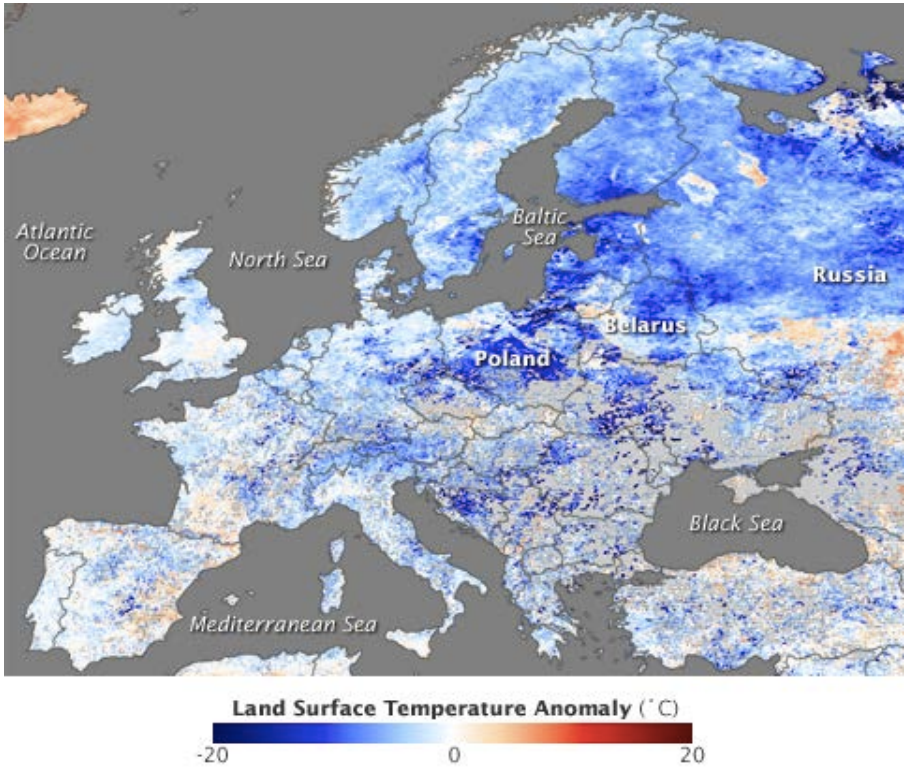
This talk

- *Brief blocking overview*
- *Blocking frequency*
- *Blocking strength*
- *Blocking composite patterns*
- *Event length distributions*
- *Role of topography*
- *Future changes (21st Century)*

Wintertime Atypical Extreme Event (2009/10)

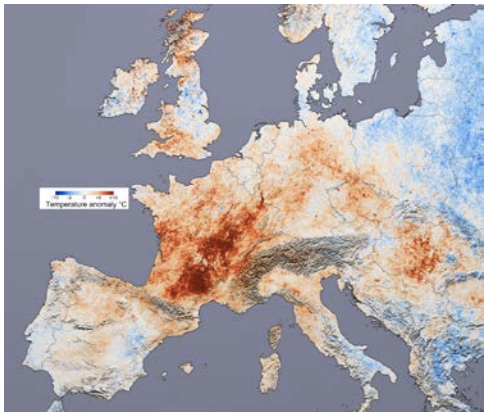


7 January, 2010

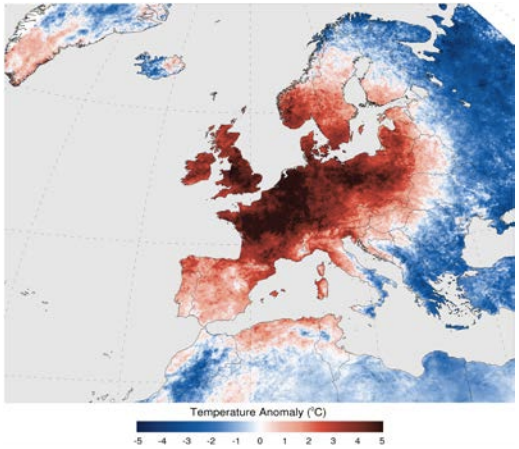


11-18 December, 2009

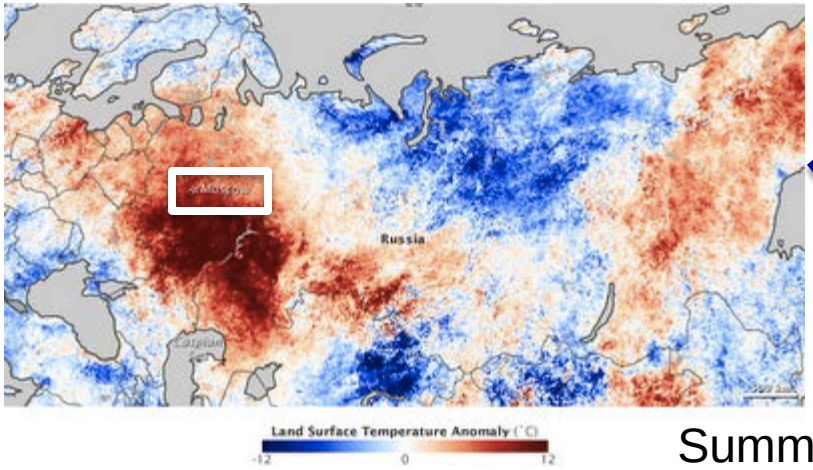
Summertime Atypical Extreme Event (2003/2006)



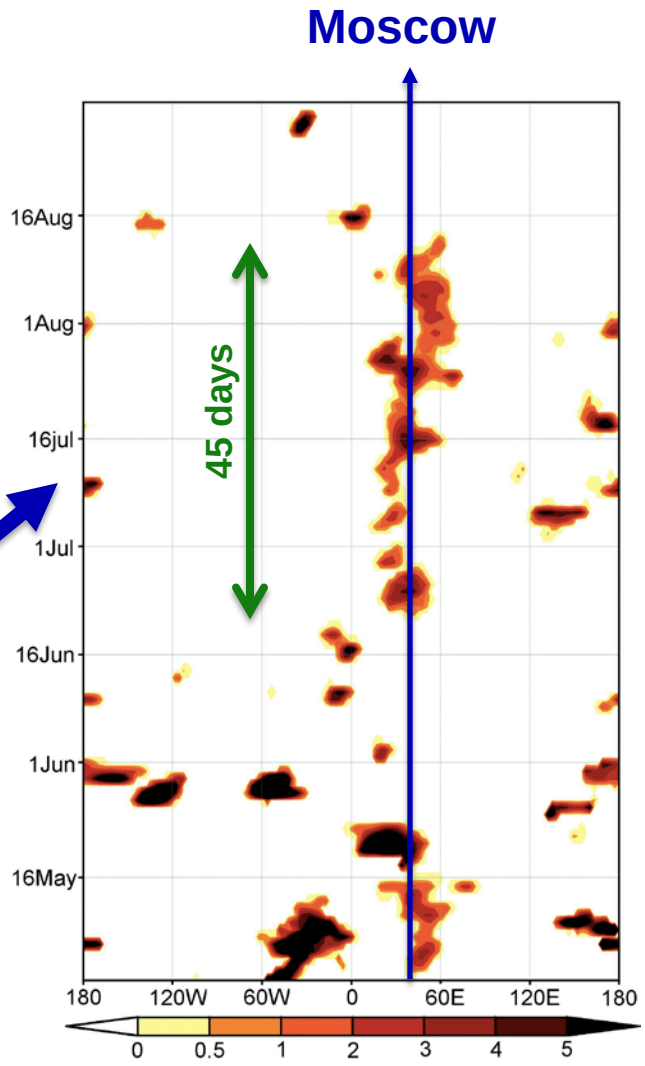
Summer 2003



Summer 2006



Summer 2010



Z500 metric – defined later

Observational and Model Output Data (CESM)

Obs/Model	1850	Present-day/20th Century (EMs)	Future (EMs)	Resolution
ERA-interim		1979-2010		1.5°
MERRA		1979-2010		0.5°
CAM3/4/5		1979-1999		1°-0.25°
CESM1-LE (Kay et al, 2014)	>1000 yrs	1920-2005 (30)	2006-2100 (30)	1°
CESM1-ME (Sanderson et al. 2015?)	""	""	2006-2080 (15)	1°
CCSM4	>1000 yrs	1850-2005 (30)	2006-2099 (2)	1°
CCSM3	~500 yrs	1870-1999 (9)	2000-2061 (29)	T85 (~1°)

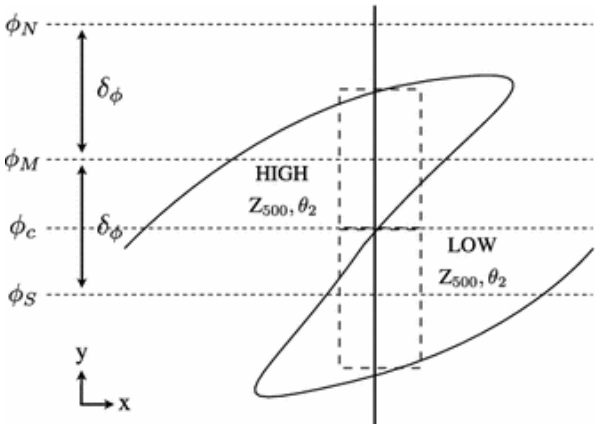
Measures of Blocking

500-mb geopotential height (daily means)

1-dimensional
(D'Andrea et al., 1998)

$$GHGN(\lambda_0) = \frac{Z500(\phi_N) - Z500(\phi_0)}{\phi_N - \phi_0}$$

$$GHGS(\lambda_0) = \frac{Z500(\phi_0) - Z500(\phi_S)}{\phi_0 - \phi_S}$$



$\phi_0 = 50N ... \phi_S = 41N ... \phi_N = 78N$

2-dimensional
(Daivni et al., 2012)

$$GHGN(\lambda_0, \phi_0) = \frac{Z500(\lambda_0, \phi_N) - Z500(\lambda_0, \phi_0)}{\phi_N - \phi_0}$$

$$GHGS(\lambda_0, \phi_0) = \frac{Z500(\lambda_0, \phi_0) - Z500(\lambda_0, \phi_S)}{\phi_0 - \phi_S}$$

$\phi_0, \phi_S, \phi_N \ldots \text{var}\, y$

Lat/lon Blocked if

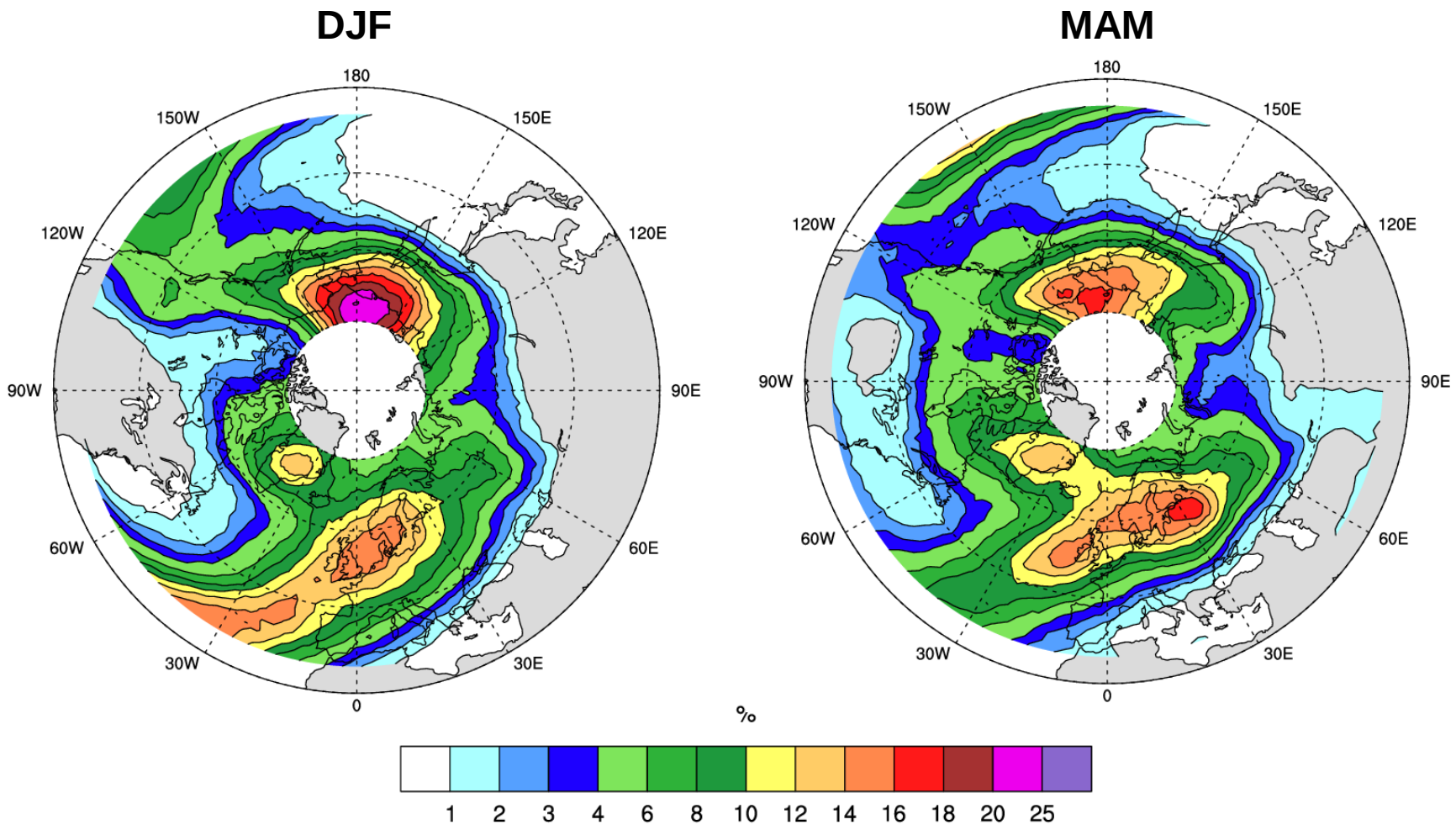
$$GHGN(\lambda_0, \phi_0) < -10m(^o lat)^{-1}$$

$$GHGS(\lambda_0, \phi_0) > 0$$

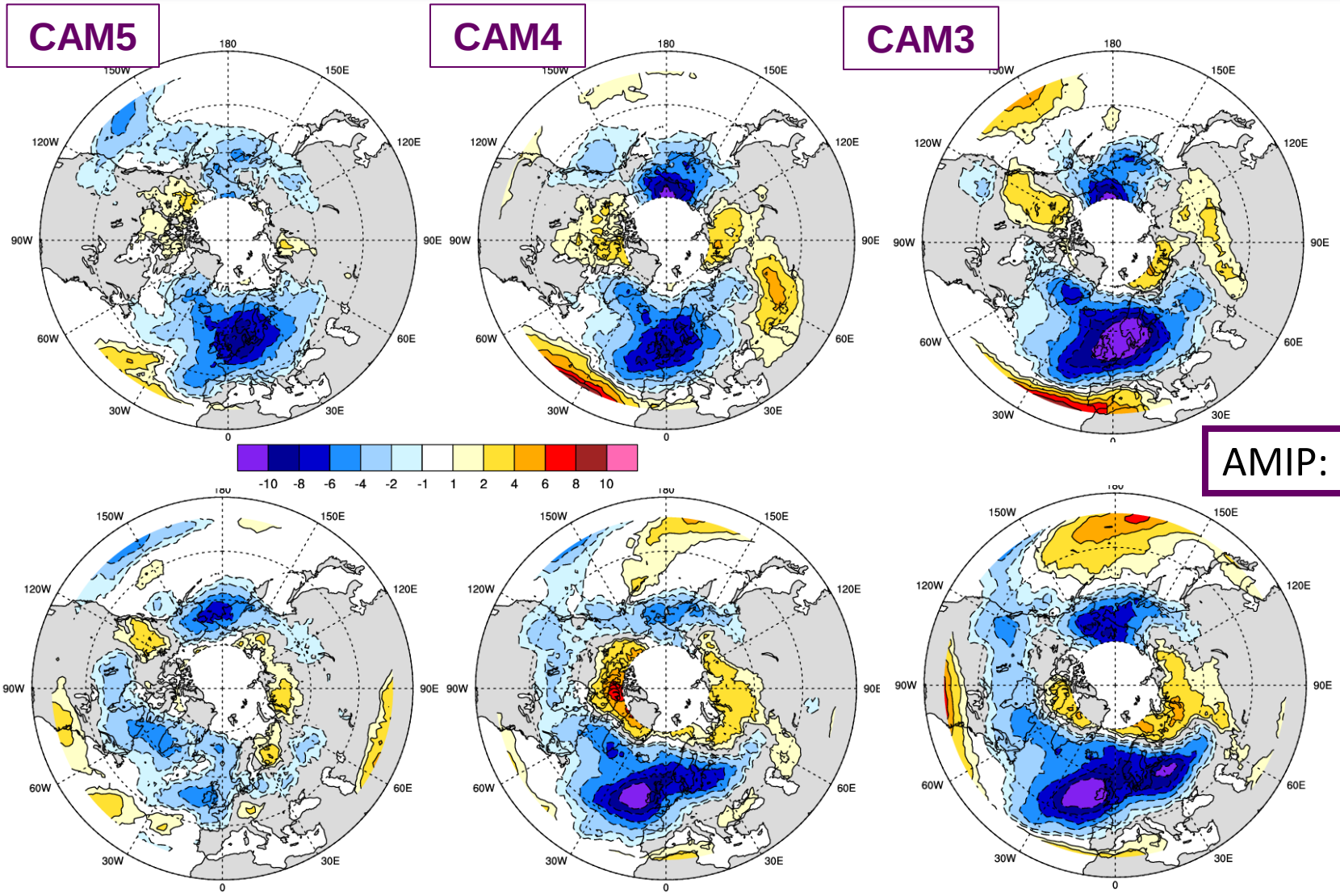
Lon Blocked strength

$$GHGS(\lambda_0) - GHGN(\lambda_0)$$

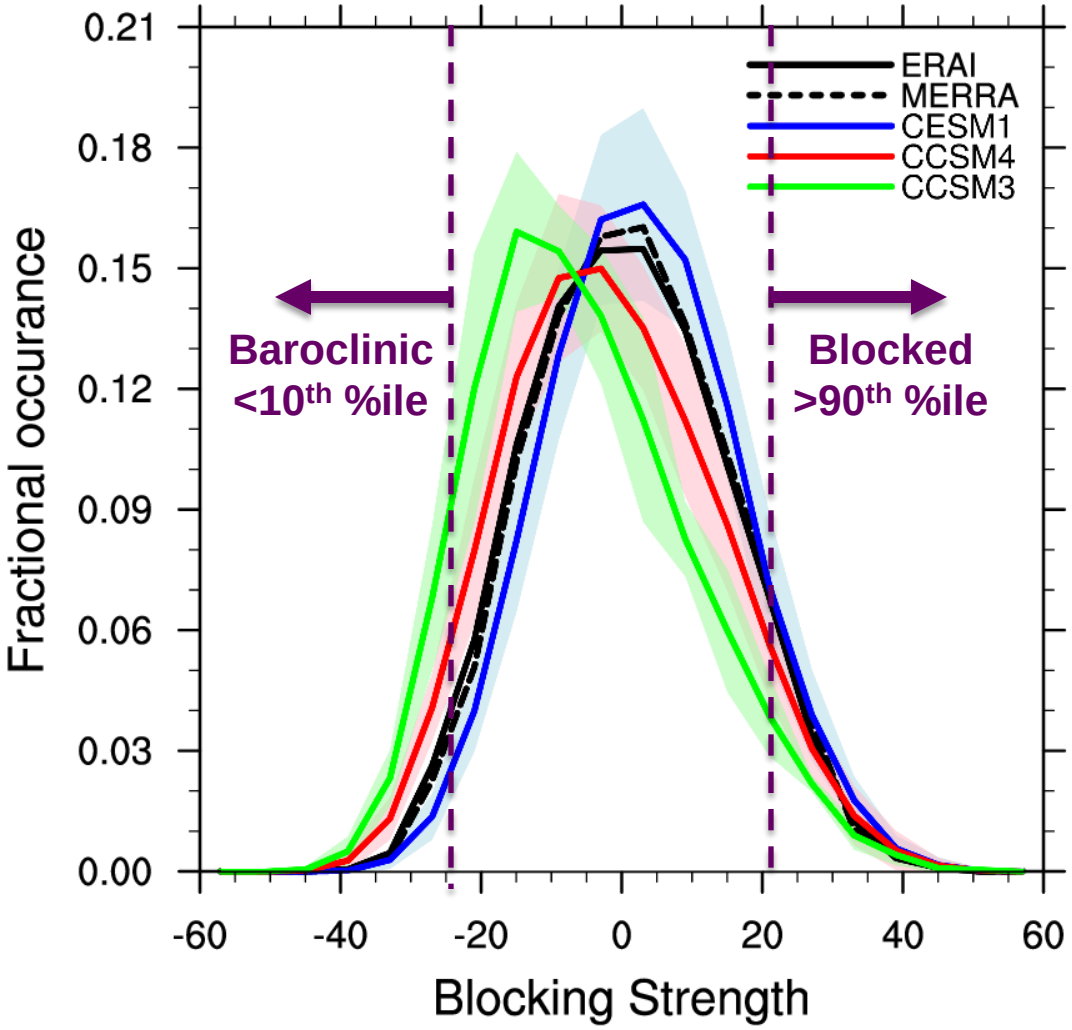
Climatological Blocking (2D) – ERA-interim



Evolution of Blocking Simulation in CESM – Model Version



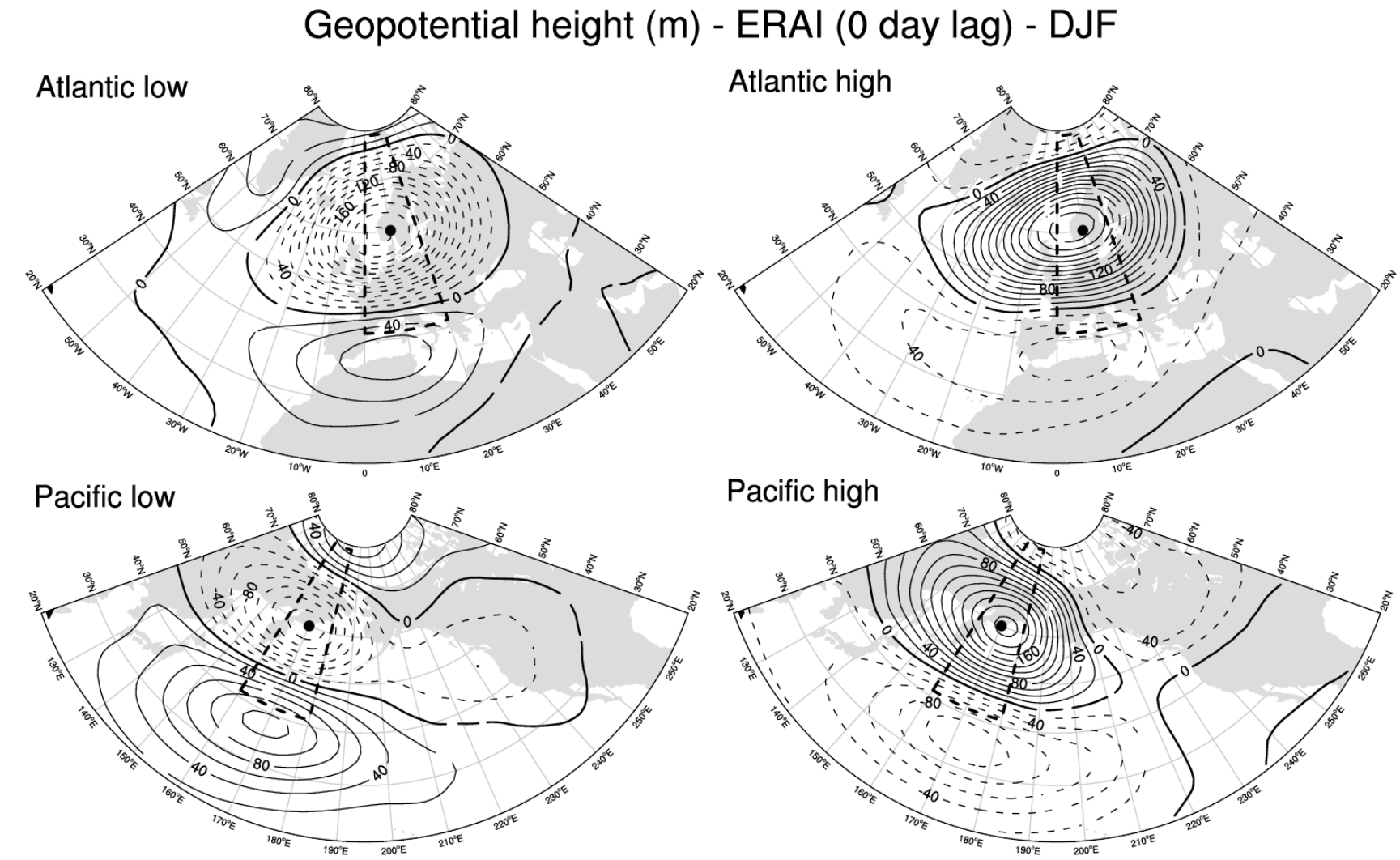
Composite Blocking Patterns – Description/Definitions



Blocking strength

- **Present day (1979-2005) coupled**
- **European and Pacific**
- **Seasonal averages**
- **Local and remote impacts**
- **Lagged responses**

Blocking Simulations in CESM – Composite Patterns (Z500)



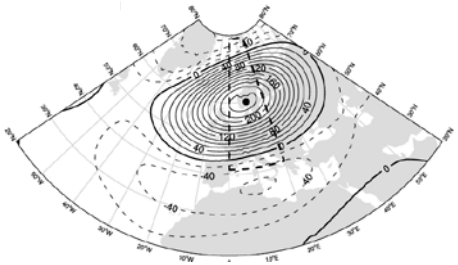
Blocking Simulations in CESM – LE DJF Composite Patterns

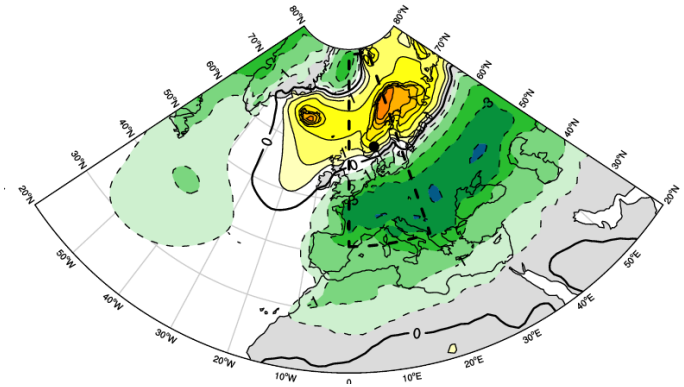
Z500

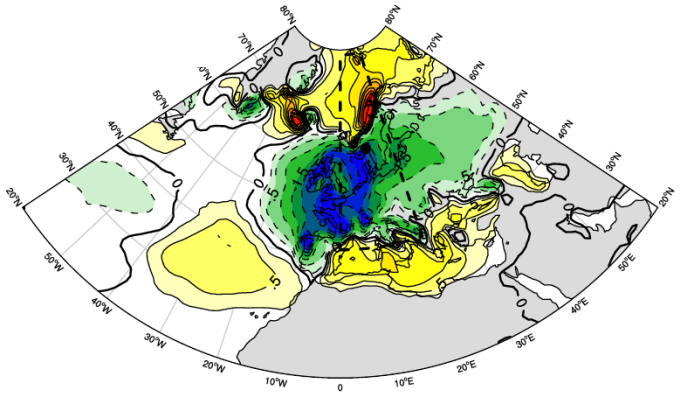
Surface Temperature

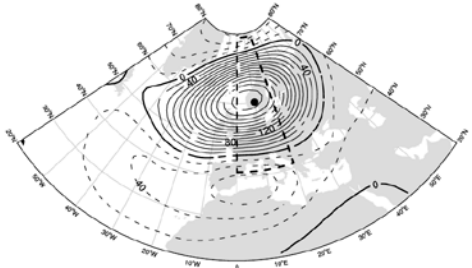
Precipitation

CESM1-LE

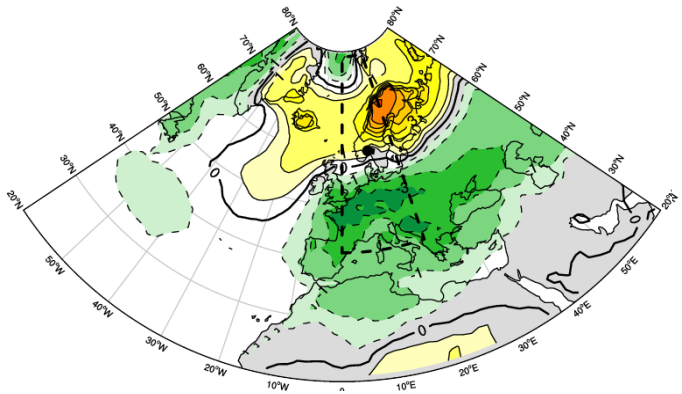


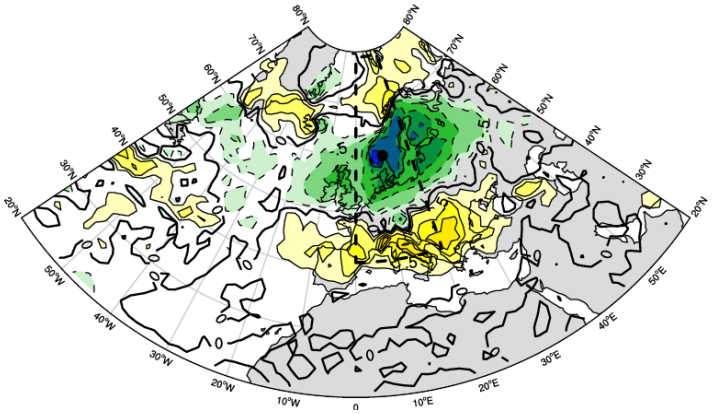


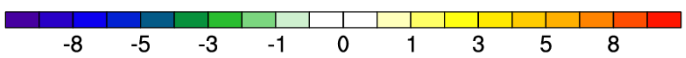


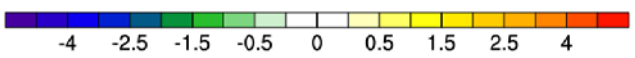


ERAI-interim









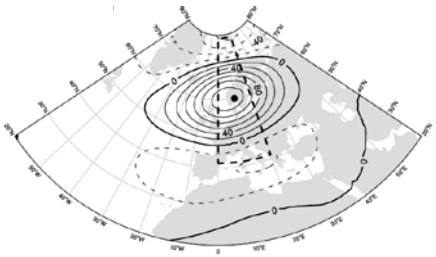
Blocking Simulations in CESM – LE JJA Composite Patterns

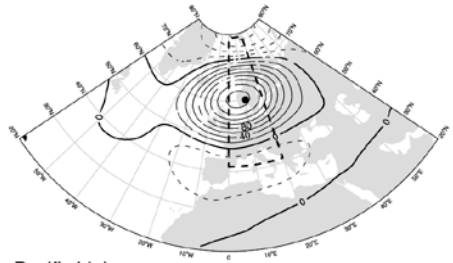
Z500

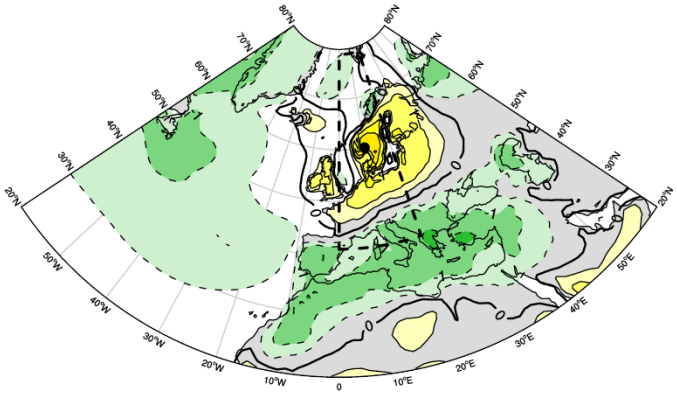
Surface Temperature

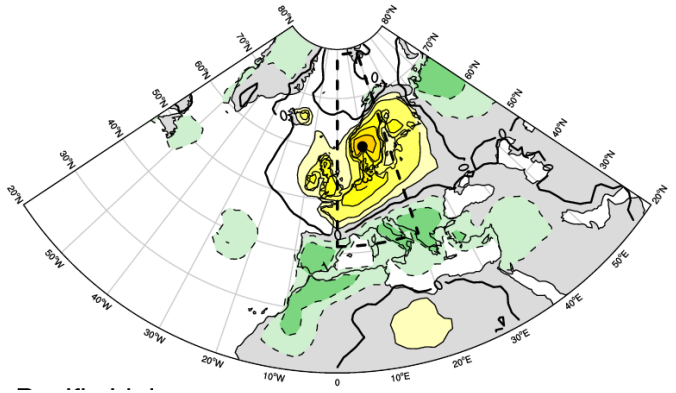
Precipitation

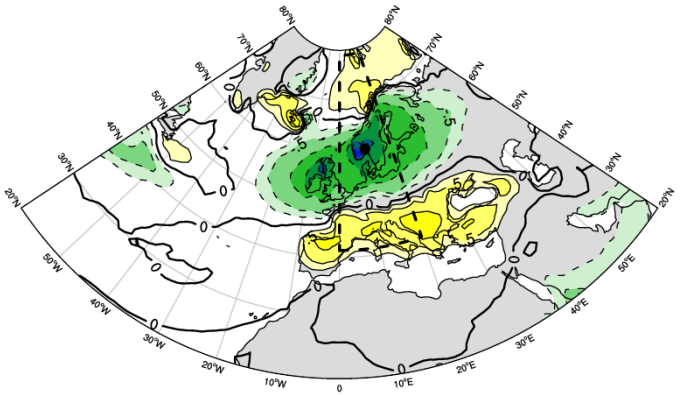
CESM1-LE

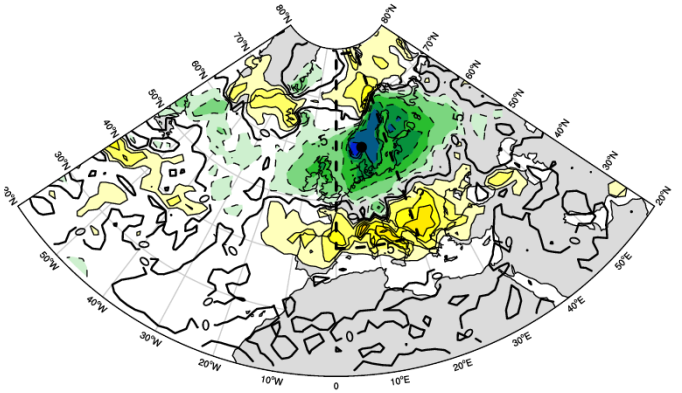




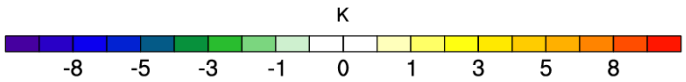


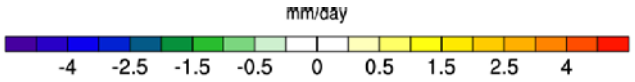




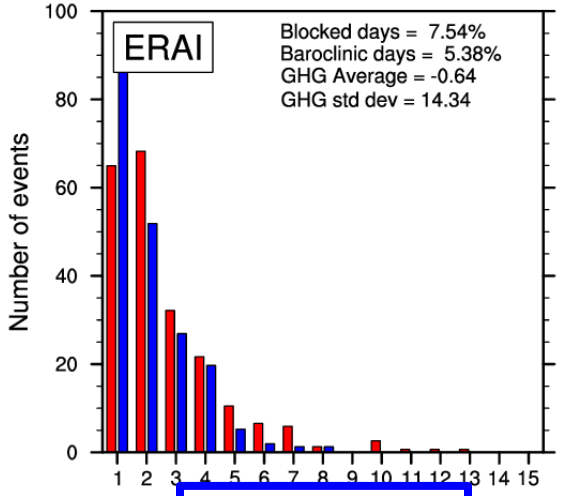


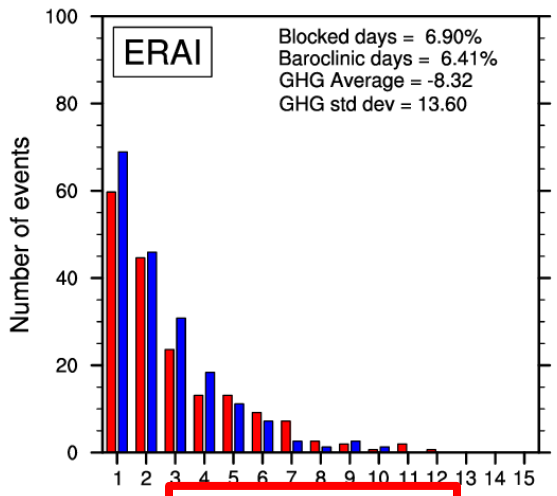
ERAI-interim

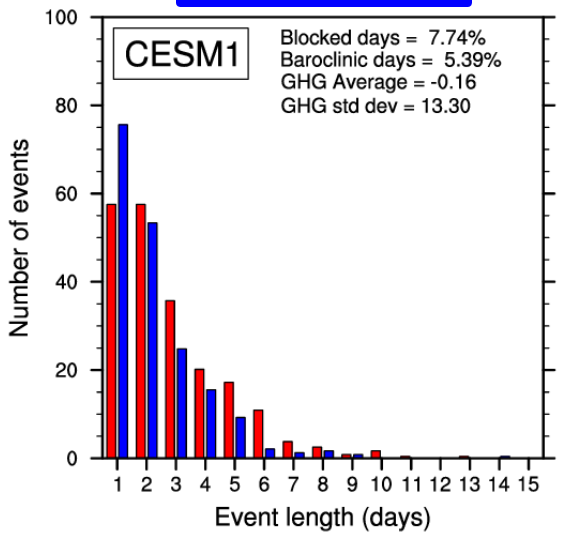


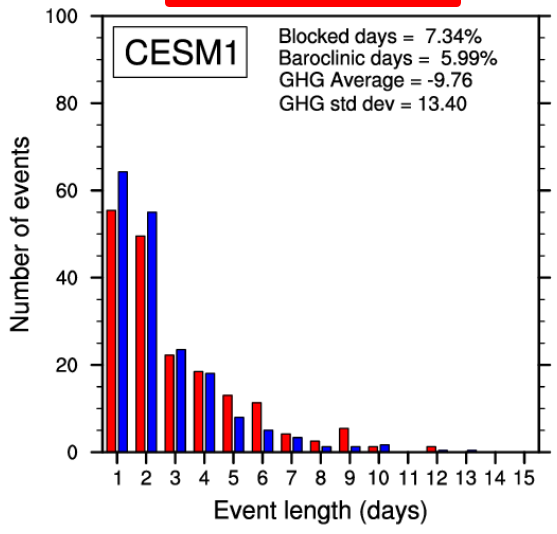


Blocking Simulations in CESM – Event Length (normalized)







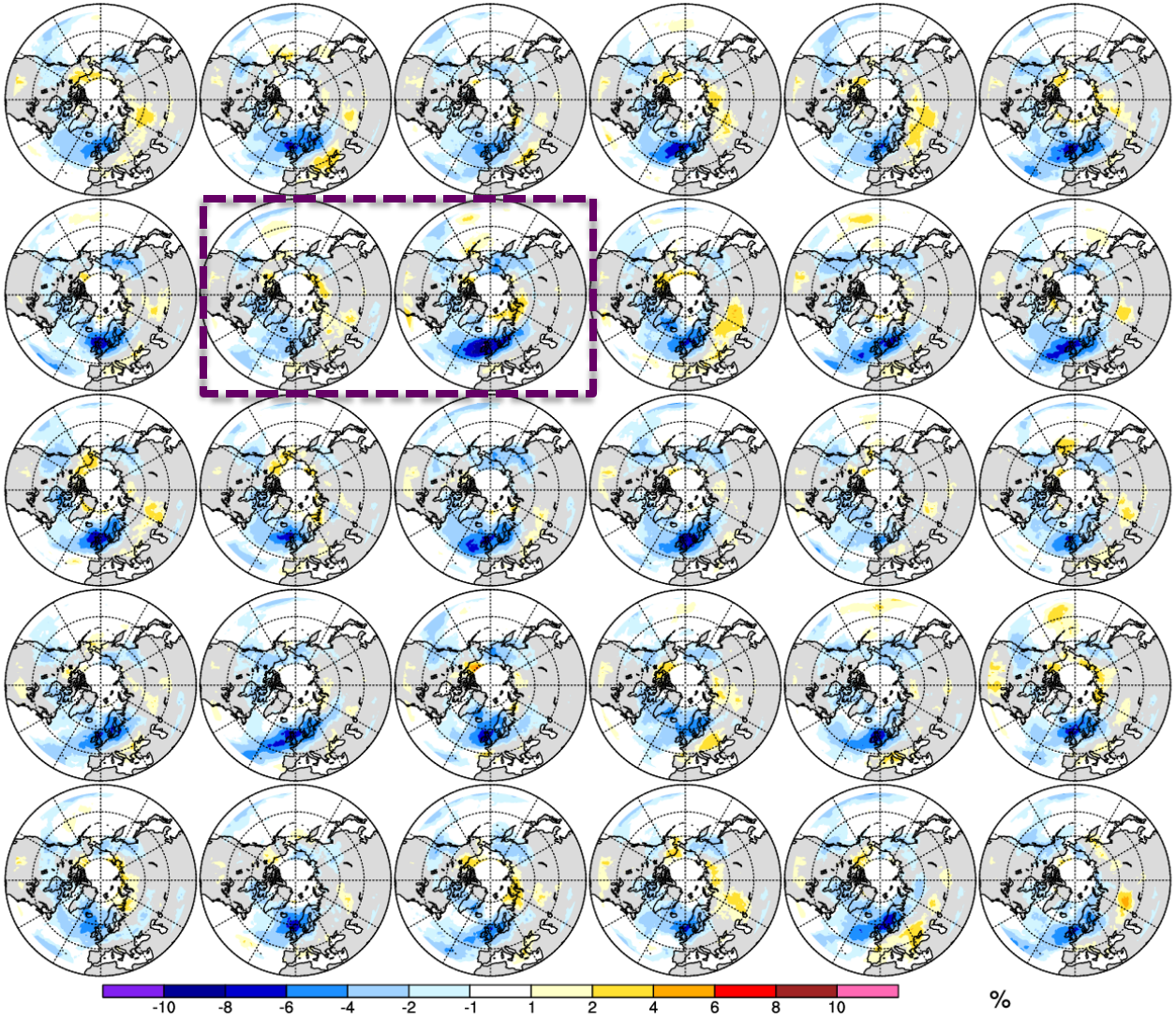


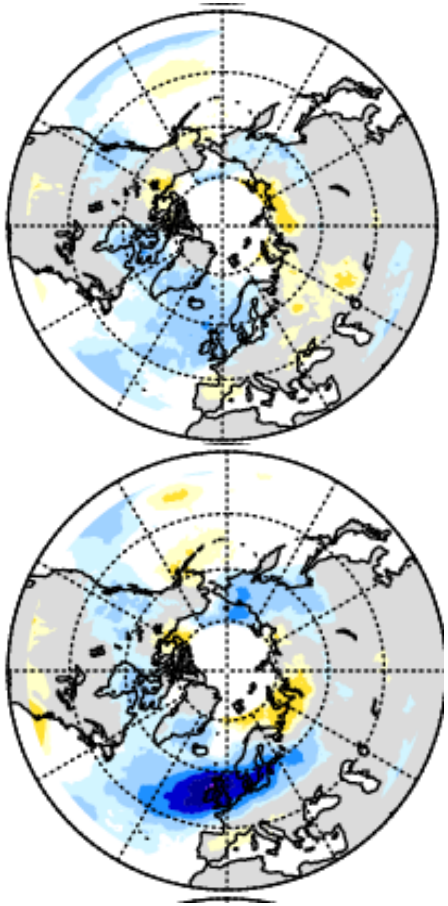
CESM obs. Agreement

- Consecutive days with blocking/baroclinicity
- Pacific has longer blocking events
- Europe has more shorter baroclinic events
- Total number of blocked days is greater over Europe.

CESM1 Large-Ensemble Variability in a Future Climate

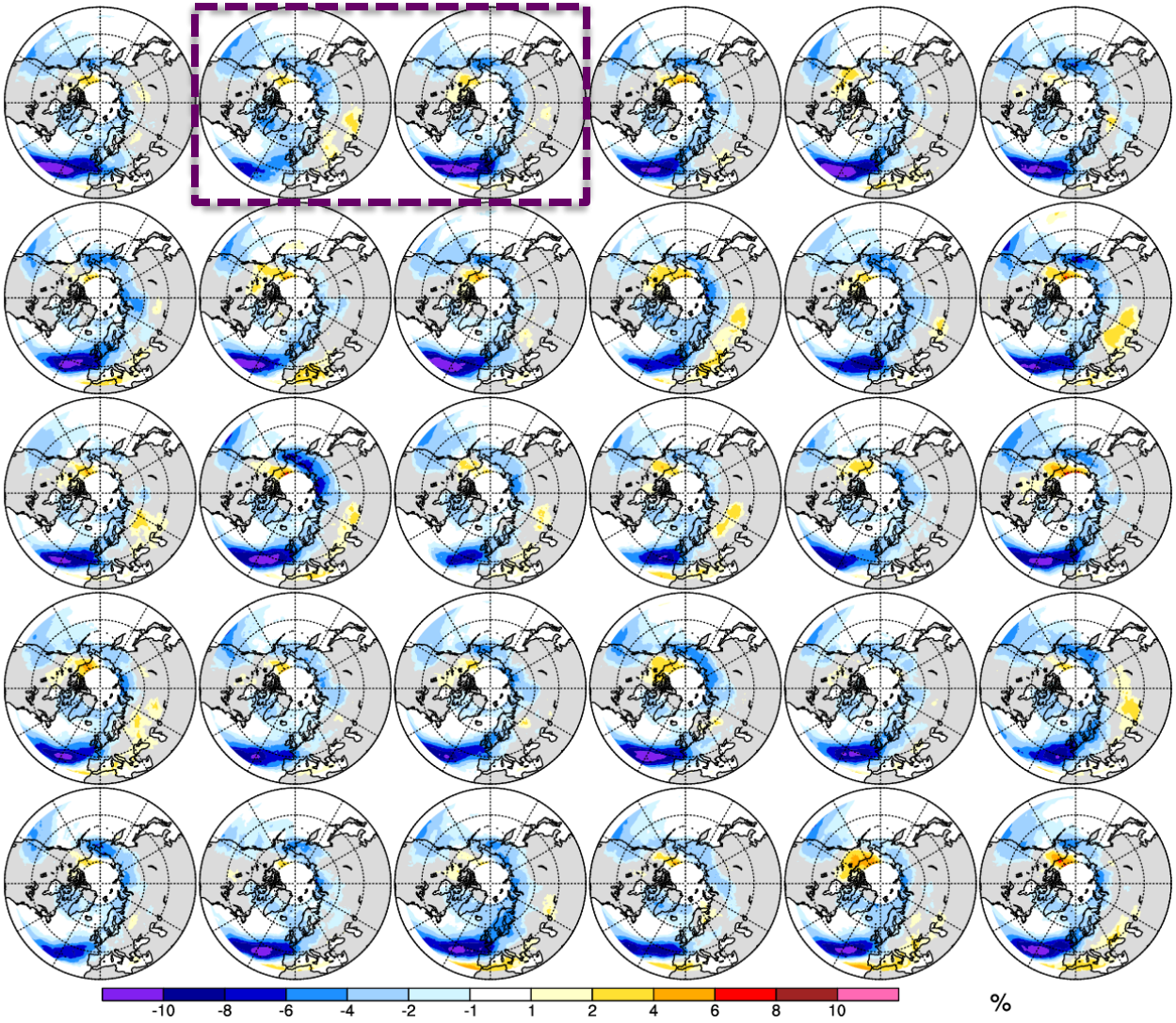
MAM – RCP8.5: 2081-2100 minus 1850 control

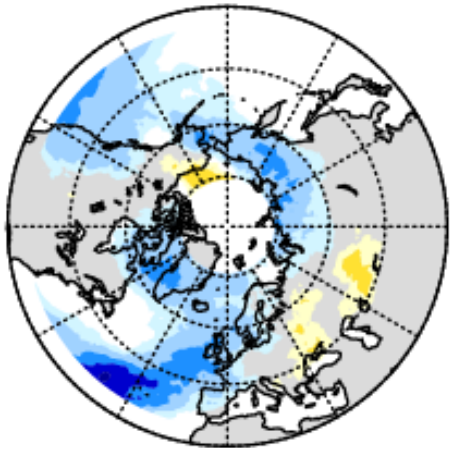


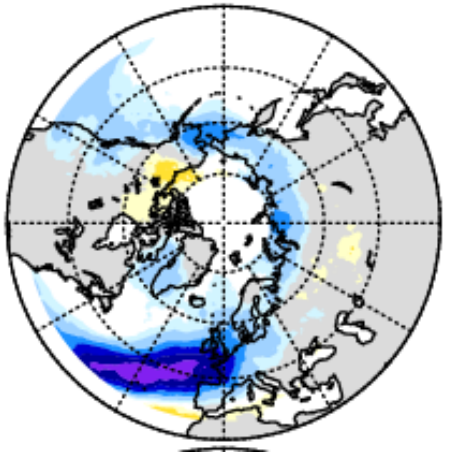


CESM1 Large-Ensemble Variability in a Future Climate

DJF – RCP8.5: 2081-2100 minus 1850 control







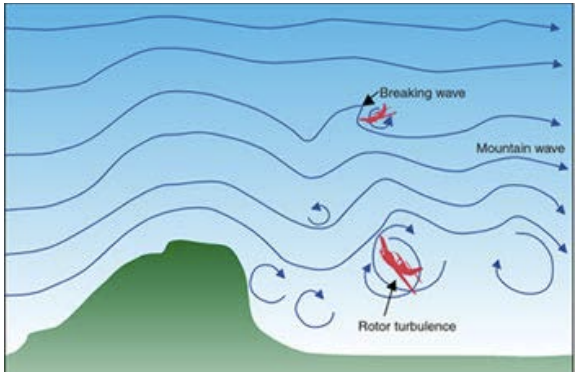
Sensitivity to Orography – Improved stress drag parameterizations

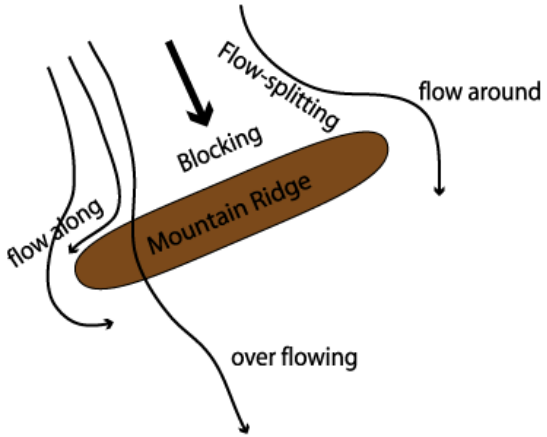
1.

- Smoother orography + ‘rougher’ sub-grid

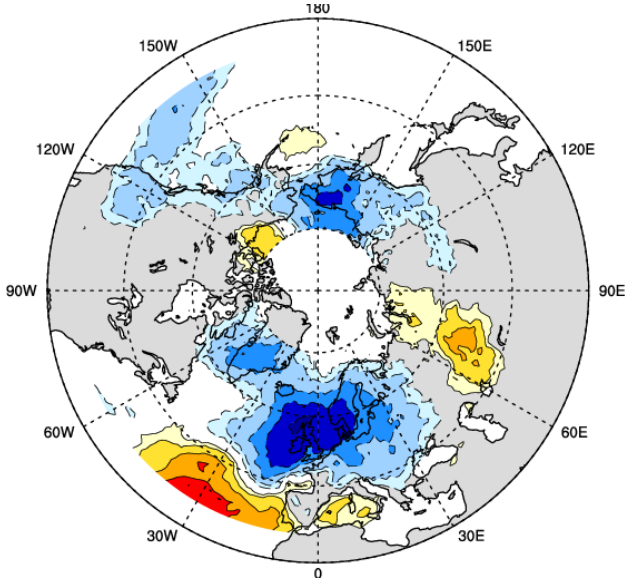
2.

- Anisotropic orography
- Low-level blocking
- Trapped lee-waves

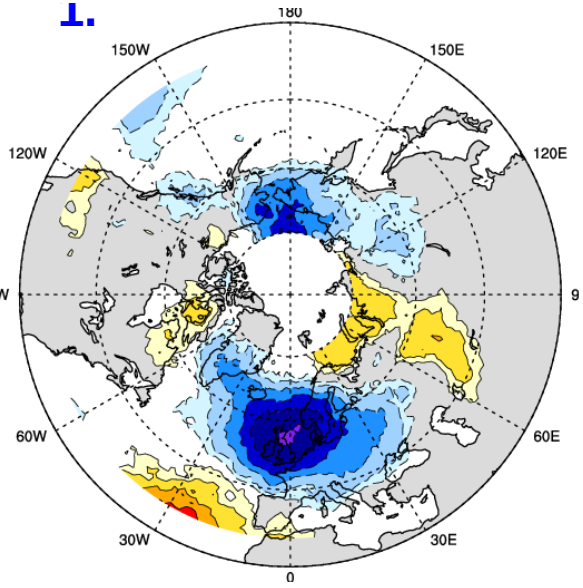




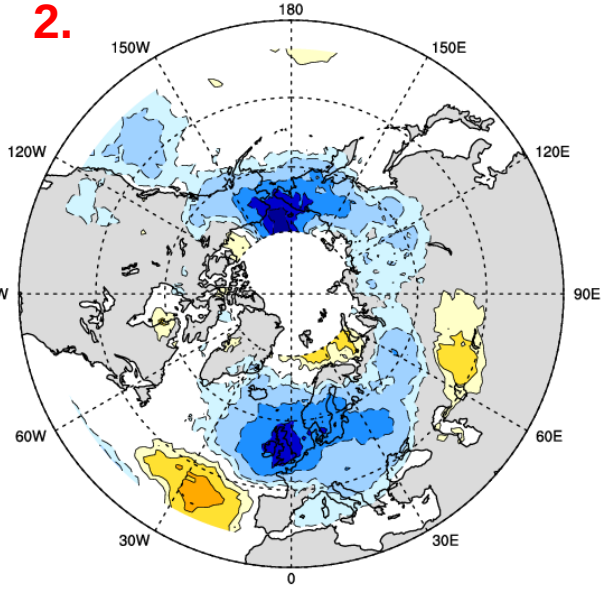
CAM5-CNTL



1.



2.



Summary

- Blocking characteristics
  - Loosely defined as asynoptic conditions with persistence
  - Association with local and non-local extreme events
  - Regional maxima: Western Europe, Greenland and N. Pacific
  - Increased ensemble forecast spread, poor forecast skill
  - Historically a difficult feature to simulate
- Model performance
  - Systematic improvement from CAM3->CAM5 (MAM/JJA, less DJF)
  - Tough to attribute changes
  - Distribution of blocking strength largely Gaussian
  - Accurate event length distribution
  - Composite event fields show accurate simulation of remote/local signals
  - Effect of blocking/lee wave parameterizations: Looks promising
  - Future reduced blocking frequency: Mostly W. Europe with RCP8.5


Thanks!