The influence of low-frequency variability on the life cycles of high-impact weather: simulations, predictions and observations

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Idealized Simulations

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The influence of planetary barotropic shear on idealized extratropical baroclinic life cycles

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Adrian Simmons
Huw Davies
Heini Wernli
John Methven

Huw Davies
Heini Wernli
Life Cycle 1 (LC1)

no shear \((A = 0)\)

cyclonic shear \((A = +0.2)\)

anticyclonic shear \((A = -0.2)\)
Fig. 3. Primitive-equation, spherical-domain simulations of two idealized cyclone life cycles at ~day 6. Left panels (a–c): The nonshear cyclone (LC1). Right panels (d–f): The cyclonic barotropic-baroclinic (-0.2 x 10^-4 s^-1) cyclone (LC2). Upper panels (a, d): Surface potential temperature at 5-K intervals. Middle panels (b, e): Surface relative vorticity at 10^-4 s^-1 intervals. Lower panels (c, f): Potential vorticity on the 300-K isentropic surface at 0.5-PVU intervals (Methven 1996).
The influence of low-frequency variability

El Nino Southern Oscillation

Arctic Oscillation
The influence of planetary time-mean flows on Rossby wave breaking

**Idealized and Observed Potential Vorticity (PV)**

Upper panels: idealised simulations under the influence of anticyclonic (left, LC3) and cyclonic (right, LC2) time-mean meridional barotropic shear (from Davies et al 1991). Lower panels: ECMWF observed PV at three isentropic levels for the cold and warm phases of ENSO, respectively; Shapiro et al. 2001 *QJRMS*.
Sensitivity of Large 72-hr Forecast Errors to Initial Conditions in Two Winters

Shading is the sensitivity calculated using the NOGAPS forecast and adjoint models. Contours are mean 500-mb ht. for January & February (courtesy Rolf Langland (NRL/Monterey).
ECMWF Medium-range forecast skill (anomaly correlation) and regime dependencies for North America

D+3  D+5  D+7

ENSO Index

ENSO

ECMWF Predictive Skill

El Nino  La Nina

1995  2000
Preliminary indications continue to suggest that winter temperatures are likely to be near or above average over much of Europe including the UK Winter 2009/10 is likely to be milder than last year for the UK, but there is still a 1 in 7 chance of a cold winter.

Britain facing one of the coldest winters in 100 years, experts predict Britain is bracing itself for temperatures hitting minus 16 degrees Celsius, forecasters have warned.
A wave of frigid air spilled down over Europe and Russia from the Arctic in mid-December, creating a deadly cold snap. According to [BBC.com](http://BBC.com), at least 90 people had died in Europe, including 79 people, mostly homeless, in Poland. In places, the bitter cold was accompanied by heavy snow, which halted rail and air traffic. This image shows the impact of the cold snap on land surface temperatures across the region from December 11–18, 2009, compared to the 2000–2008 average.
Arctic Oscillation Index:
1 Dec. 2009-16 Mar. 2010
250-mb Vector Wind Anomaly

Negative AO regime

1 Dec 2009 – 28 Feb 2010
250-mb Vector Wind Anomaly

Negative AO regime

1 Dec 2009 – 28 Feb 2010
700-mb Temperature
Long-Term Climatology
1 Dec–28 Feb
700-mb Temperature Mean

1 Dec 2009–28 Feb 2010

Negative AO regime
700-mb Temperature Anomaly
1 Dec 2009–28 Feb 2010

Negative AO regime
“Snow causes travel chaos in the UK, as the cold snap continues”

December  2010
26-27 December 2010

Northeastern US

Snow storm
Arctic Oscillation Index
Figure 1: **Arctic Oscillation (AO)** and **ECMWF 5-day anomaly correlation** of 500hPa height in the northern hemisphere (20°N-80°N), from 1 Sept 2010 to 27 Apr 2011. Note the period of high skill from mid-November to mid-January associated with negative AO phase. Forecast dropouts (low skill) occur during periods with positive AO phase and transitions between positive and negative AO phase; *Langland and Maue, NRLMRY*
North Atlantic 300-mb Height Mean and Anomaly (m)

11 Dec 2010–15 Jan 2011 (AO−)  
28 Jan–14 Feb 2011 (AO+)
North Atlantic 300-mb Height Mean and Anomaly (m)

11 Dec 2010–15 Jan 2011 (AO−)

28 Jan–14 Feb 2011 (AO+)
North Atlantic 850-mb Temperature Mean and Anomaly (K)

11 Dec 2010–15 Jan 2011 (AO−)

28 Jan–14 Feb 2011 (AO+)
250-hPa Meridional Wind Component (lat avg 30–60° N.)

Negative AO Regime

Positive AO Regime

Dec/01/10

10-12 Dec
Pacific NW heavy rains

18-22 Dec.
California heavy rain and snow

26-27 Dec
NE coastal storm

02Jan.11

20Jan.11

1-3 Feb
NE snow storm

Oklahoma snow storm

Record cold in Oklahoma

15Feb.11

Transient “wave packets”
associated with high-impact weather

Persistent blocking pattern
associated with high-impact weather

Hovmoller diagrams were computed using the NOAA/ESRL Physical Sciences Division Interactive Plotting and Analysis website
PV on 320 K Surface
Negative Phase AO

0600 UTC 27 Dec 2010
PV on 320 K Surface
Positive Phase AO

AO+

1200 UTC 2 Feb 2011
925-mb $\theta$ (K) and MSLP (mb)

0600 UTC 27 Dec 2010

Negative AO Phase

1200 UTC 2 Feb 2011

Positive AO Phase

Heavy snow region
Precipitable Water (mm) and MSLP (mb)

0600 UTC 27 Dec 2010

1200 UTC 2 Feb 2011

Negative AO Phase

Positive AO Phase
Precipitable Water (mm) and MSLP (mb)

0600 UTC 27 Dec 2010

1200 UTC 2 Feb 2011

Negative AO Phase

Positive AO Phase

Heavy snow region
72-h Backward trajectories starting at 1500 m. MSL

- LC2 during negative AO phase
- Air parcels near heavy snow region originate well north of warm front

- LC1 during positive AO phase
- Air parcels near heavy snow region originate in cyclone warm sector
- Direct tropical moisture feed

Starting at 0600 UTC 27 Dec 2010
Starting at 1200 UTC 2 Feb 2011
0600 UTC 27 December 2010
Water Vapor: GOES East
ERICA IOP- 4; 4 January 1989
WRF 18-h Forecast 4-km horizontal resolution forecast
Simulated radar reflectivity
500-m wind velocity; red > 50 ms⁻¹
3-D Trajectories
Potential Temperature
colored
50-mb Height Anomaly (m)

11 Dec 2010–15 Jan 2011 (AO−)

28 Jan–14 Feb 2011 (AO+)
T and Wind at 850hPa on 2011-DEC-27-00Z
W and Wind at 850hPa on 2011-DEC-27-00Z
GREENLAND FLOW DISTORTION EXPERIMENT
Feb.-Mar. 2007