Systematic Errors in the ECMWF Forecasting System

Thomas Jung

ECMWF

Introduction

Two principal sources of forecast error:

➢ **Uncertainties in the initial conditions**

➢ **Model error**

How to identify model errors?

➢ **Relaxation experiments (Klinker)**

➢ **Budget diagnosis (*Klinker and Sardeshmukh*)**

➢ **Adjoint technique (see lectures on Sensitivity)**

➢ **Sensitivity experiments**

➢ **Diagnosis of *systematic errors***

Concept of Systematic Error

$$\hat{d}_{se}(f_t, o_t) = \hat{d}(f_t) - \hat{d}(o_t)$$

➢ **Relatively stratightforward to compute (simple maths)**

➢ **BUT there are pitfalls:**

  • **finite length (significance tests)**

  • **apparent systematic error for short time series (loss of predicatibility)**

  • **Observations might be biased**

Scope of the Study

Q: "Do we still have significant systematic errors in the ECMWF forecasting system?"

➢ If so, what are the main problems?

➢ How did systematic errors evolve over the years?

➢ How do systematic errors grow?

➢ How well do we simulate specific phenomena (e.g., blocking, extratropical cyclones)?

➢ How sensitive are systematic errors to horizontal resolution?

Data

- ➢ **Systematic errors and their growth**
  - **Operational forecasts (D+10)**
  - **ERA-40 forecasts (D+10)**
  - **EPS control forecasts (D+20)**
  - **Monthly forecasts (D+30)**
  - **Seasonal forecasts (beyond D+30)**

- ➢ **Evolution of systematic errors**
  - **Operational forecasts + analyses**
- ➢ **Verification (ERA-40, satellite products)**

Systematic Z500 Error Growth: Medium-Range (DJFM 1960-2001)
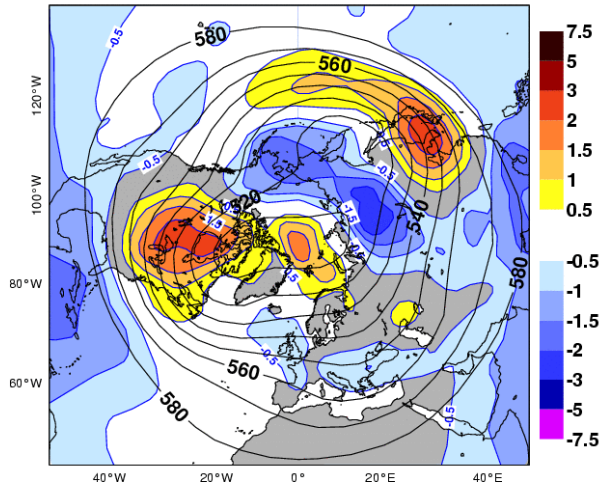

(a) Z500 Difference D+1 FC-ERA40 (DJFM 1960-2001)
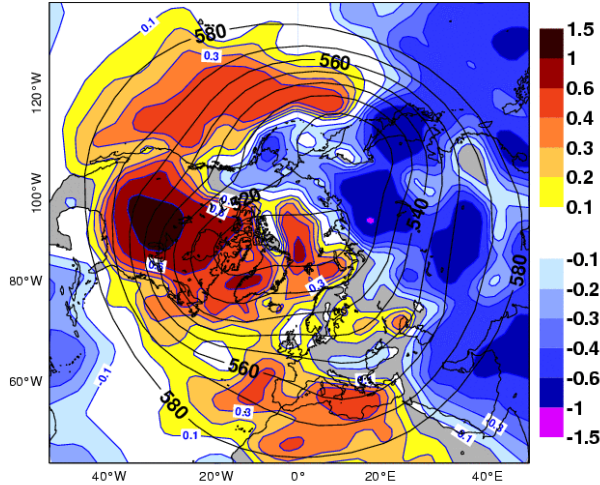
(b) Z500 Difference D+3 FC-ERA40 (DJFM 1960-2001)
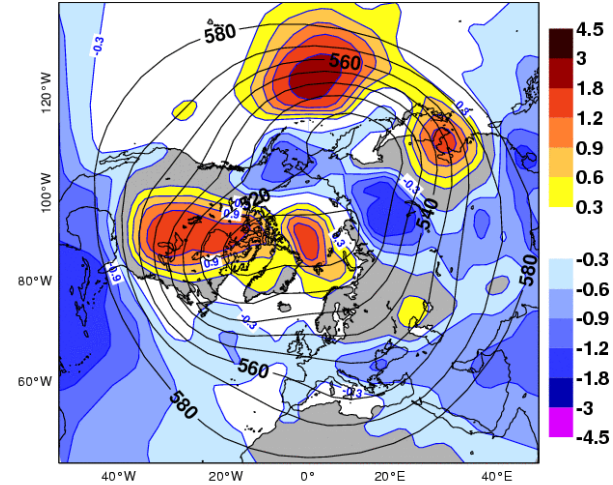
(c) Z500 Difference D+5 FC-ERA40 (DJFM 1960-2001)

(d) Z500 Difference D+10 FC-ERA40 (DJFM 1960-2001)
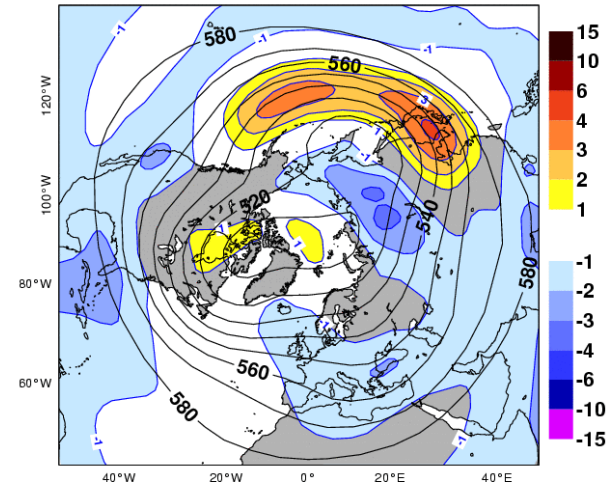
Asymptotic Z500 Errors (DJFM 1962-2001)

(a) Z500 Difference Cy26r1-ERA40 (Dec-Mar 1962-2001)
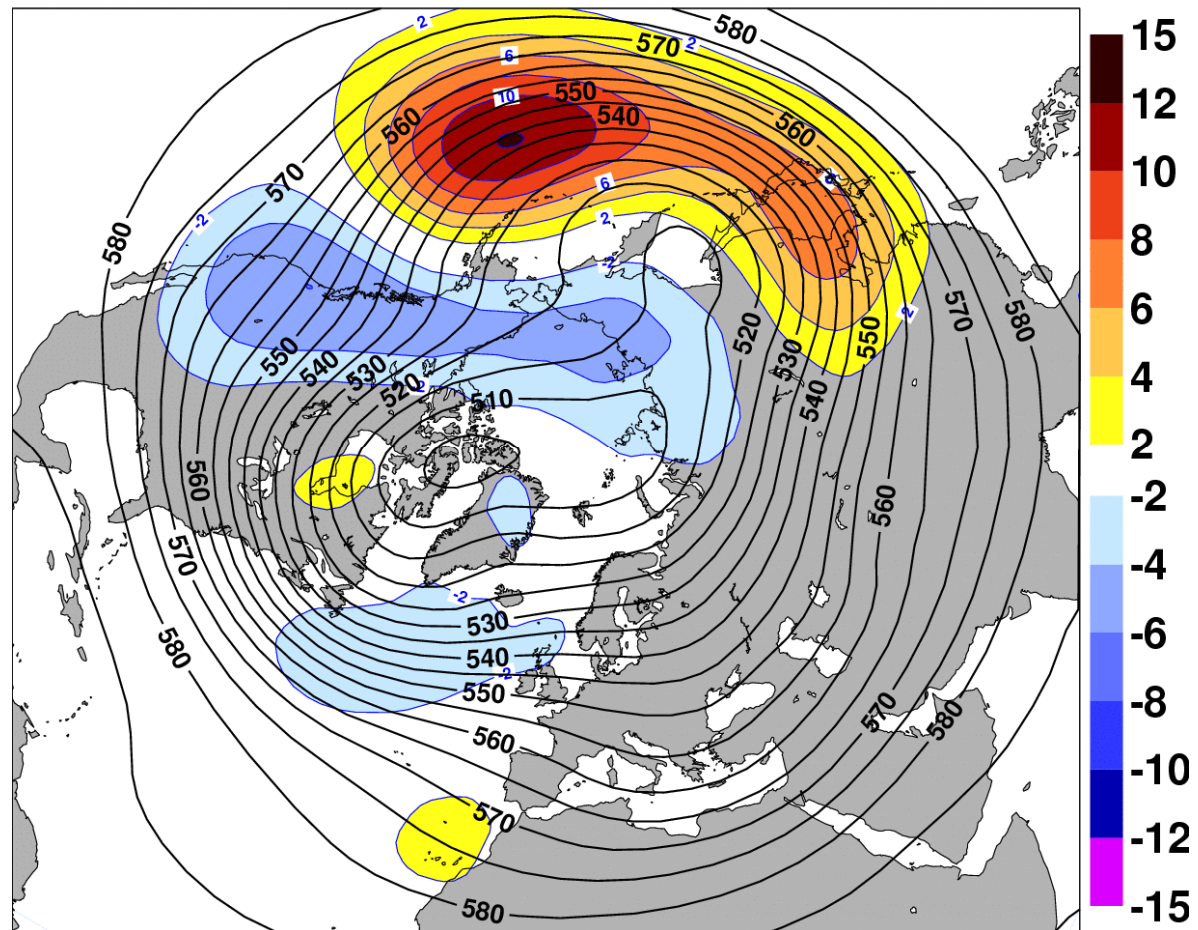
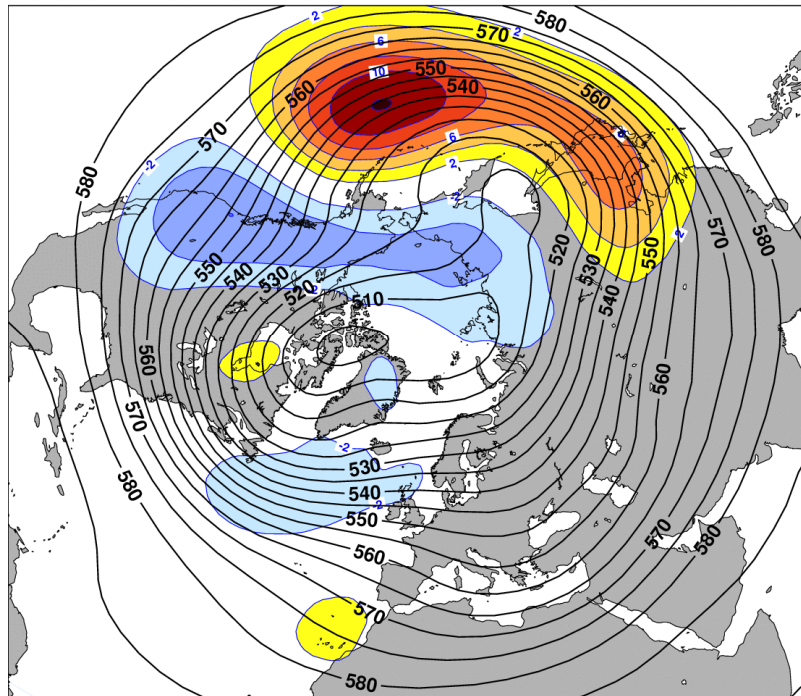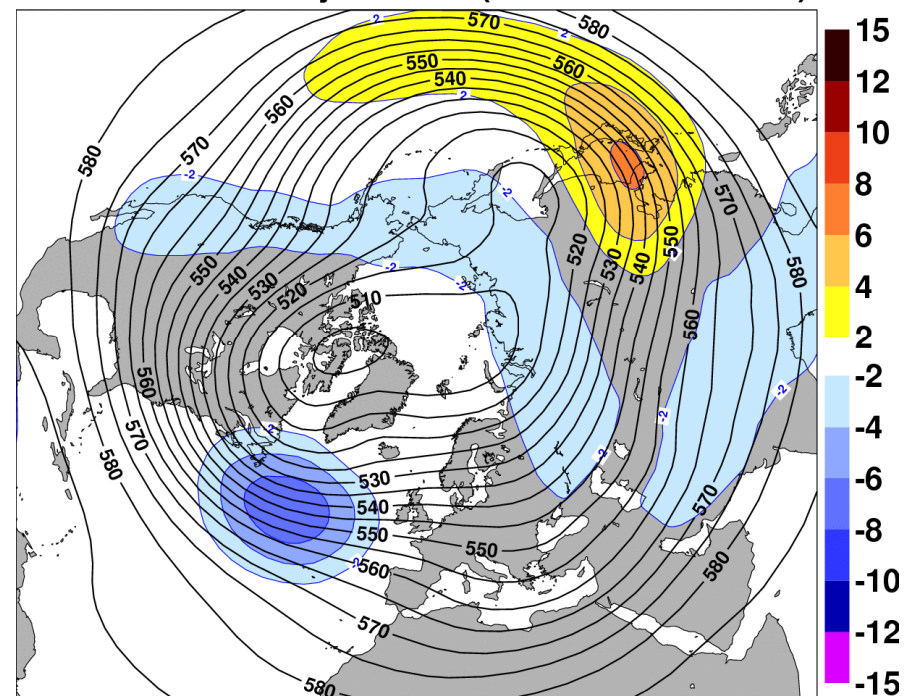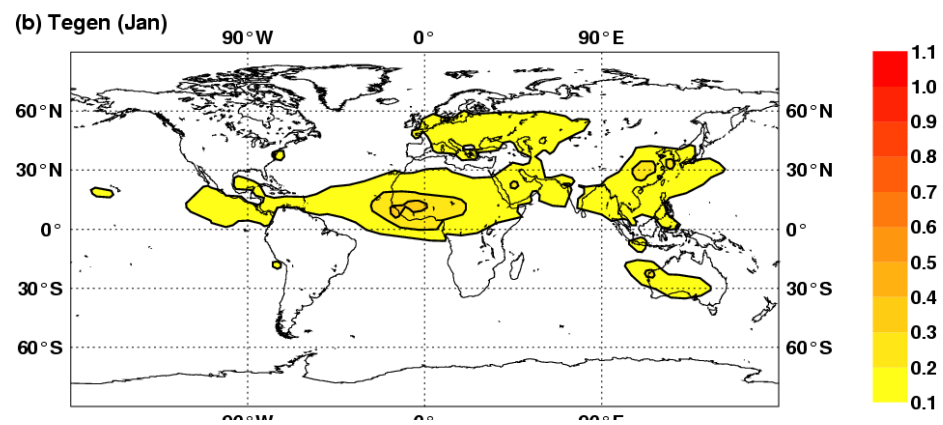# Asymptotic Z500 Errors (DJFM 1962-2001)

Cycle 26r1

Cycle 26r3

(a) Z500 Difference Cy26r1-ERA40 (Dec-Mar 1962-2001)

Z500 Difference ehjk-ERA40 (Dec-Mar 1962-2001)

Two Different Aerosol Climatologies

Tanre et al (1984) and Tegen et al (1997) aerosol optical thickness (at 550nm)

(a) Tanre (Annual)

(b) Tegen (Jan)
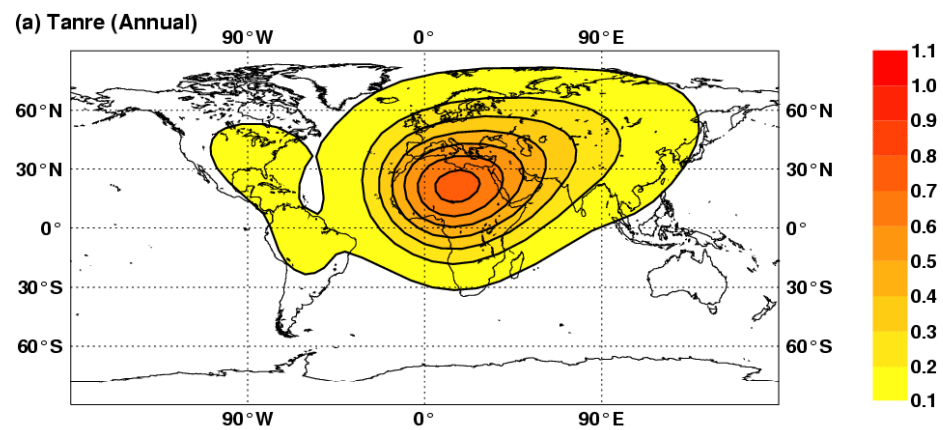
Systematic Error Growth: EPSC Z500 (DJFM 2000-03)

Forecast Range (hours)

Evolution of D+3 Systematic Z500 Errors

1986-1988   1993-1995   2001-2003

(a) Z500 Difference D+3 FC-Analysis (DJFM 1986-1988)
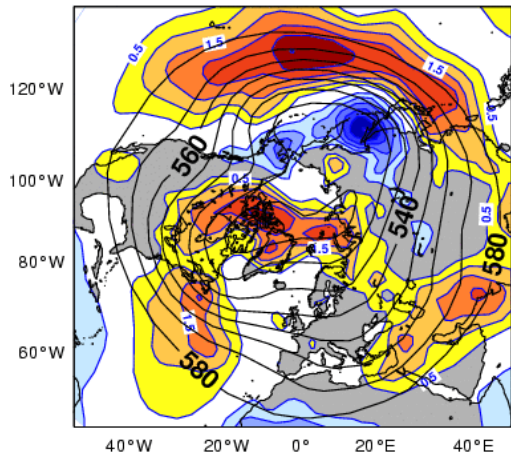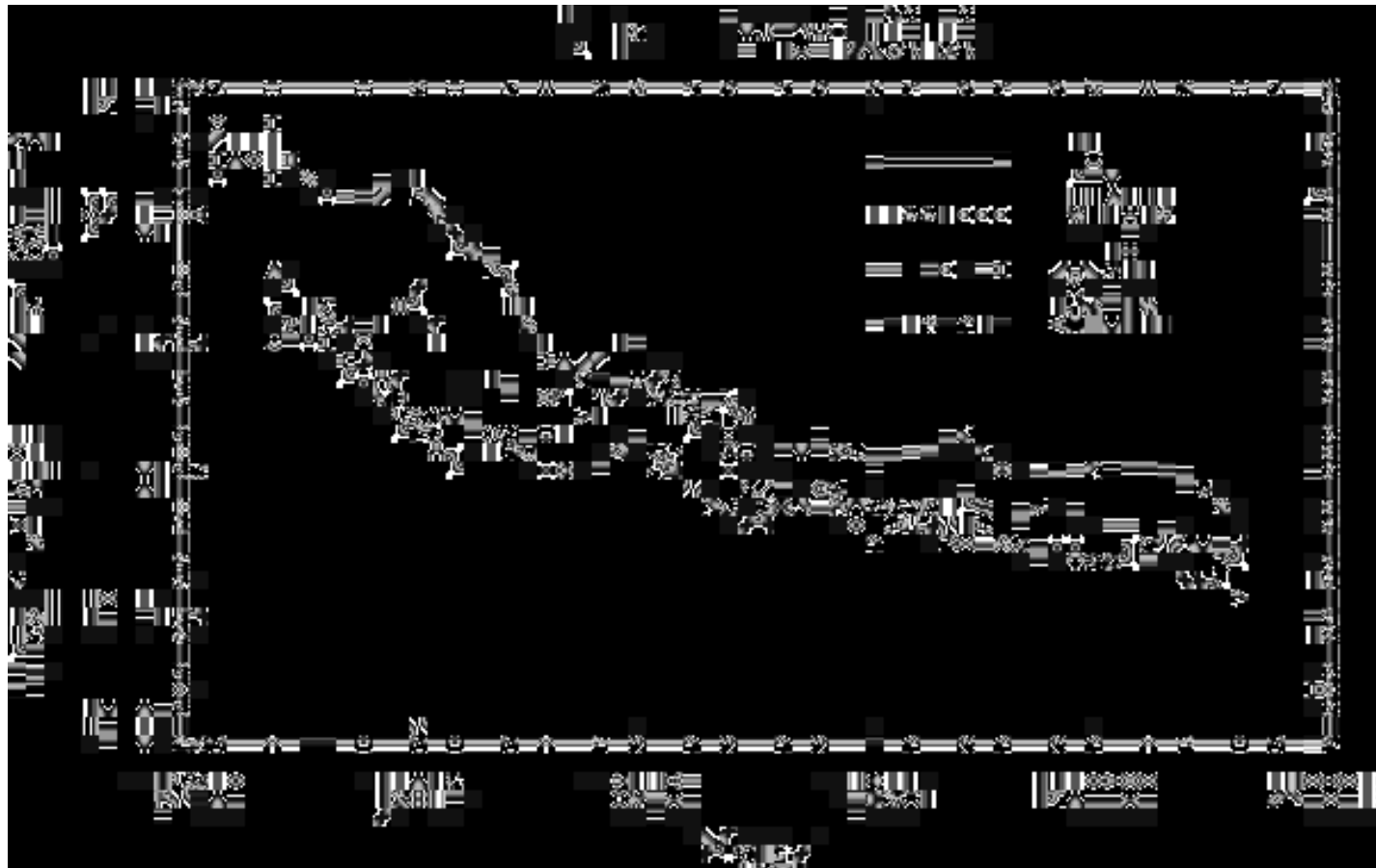
(b) Z500 Difference D+3 FC-Analysis (DJFM 1993-1995)
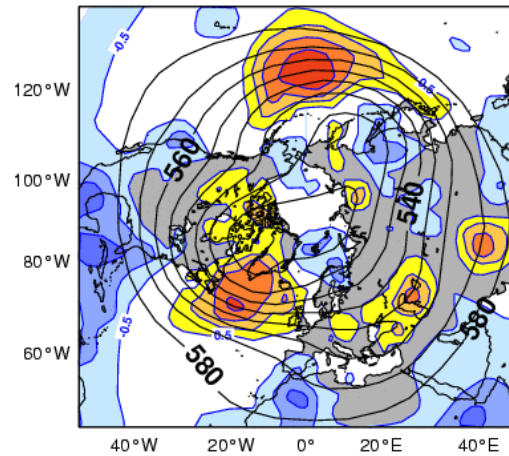
(c) Z500 Difference D+3 FC-Analysis (DJFM 2001-2003)
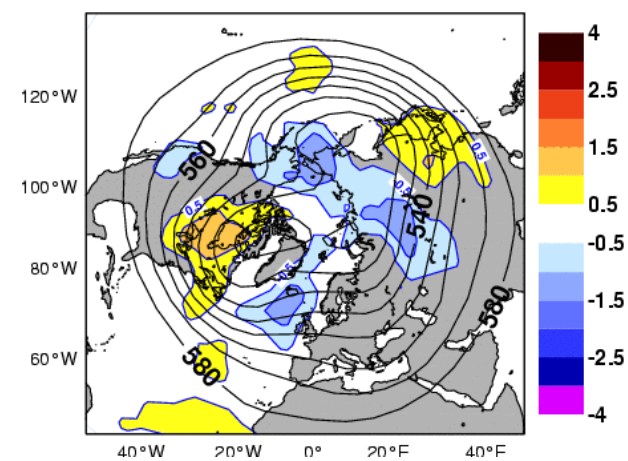
Reduction of Systematic Errors (1981-2003)
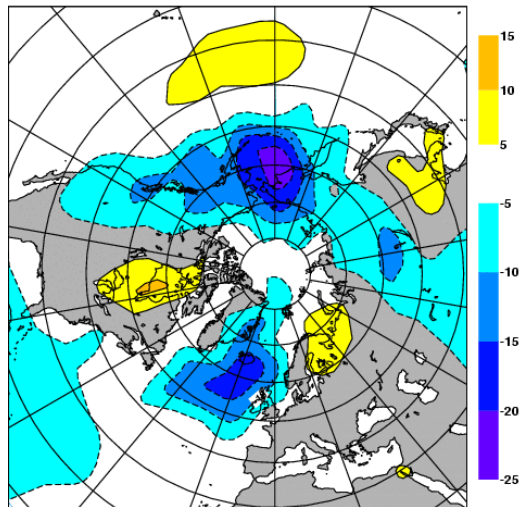
Systematic Errors: AMIP Models

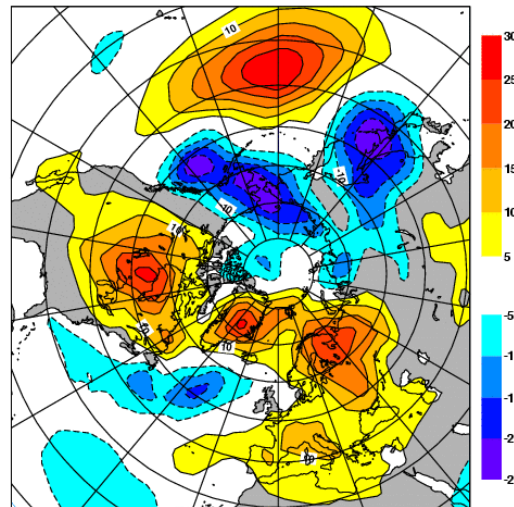(d) Ensemble error
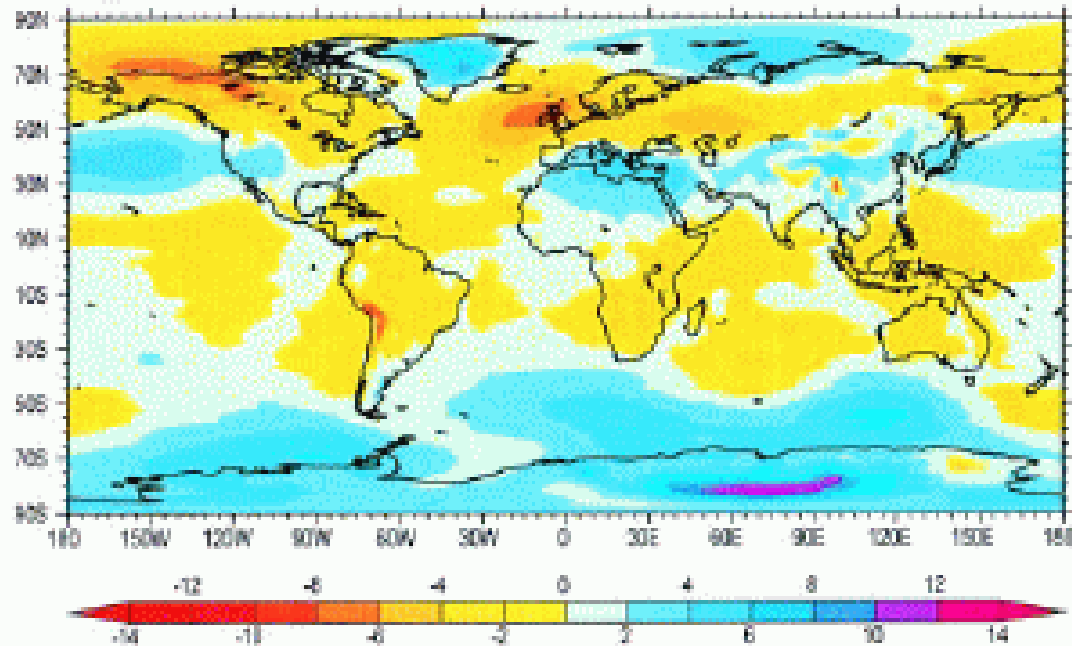
Systematic D+3 Z500 Errors: 3 NWP Models
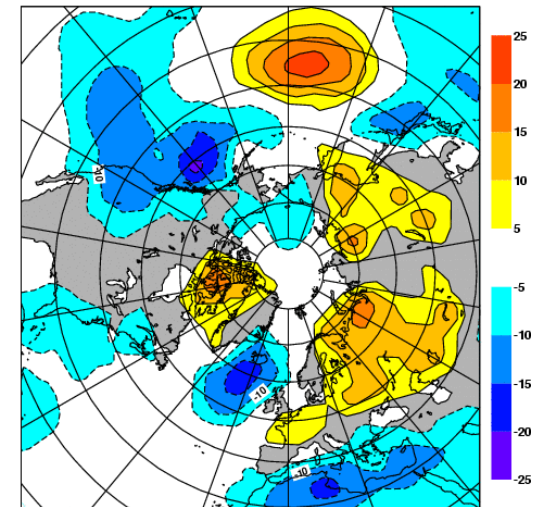
Blocking Methodology

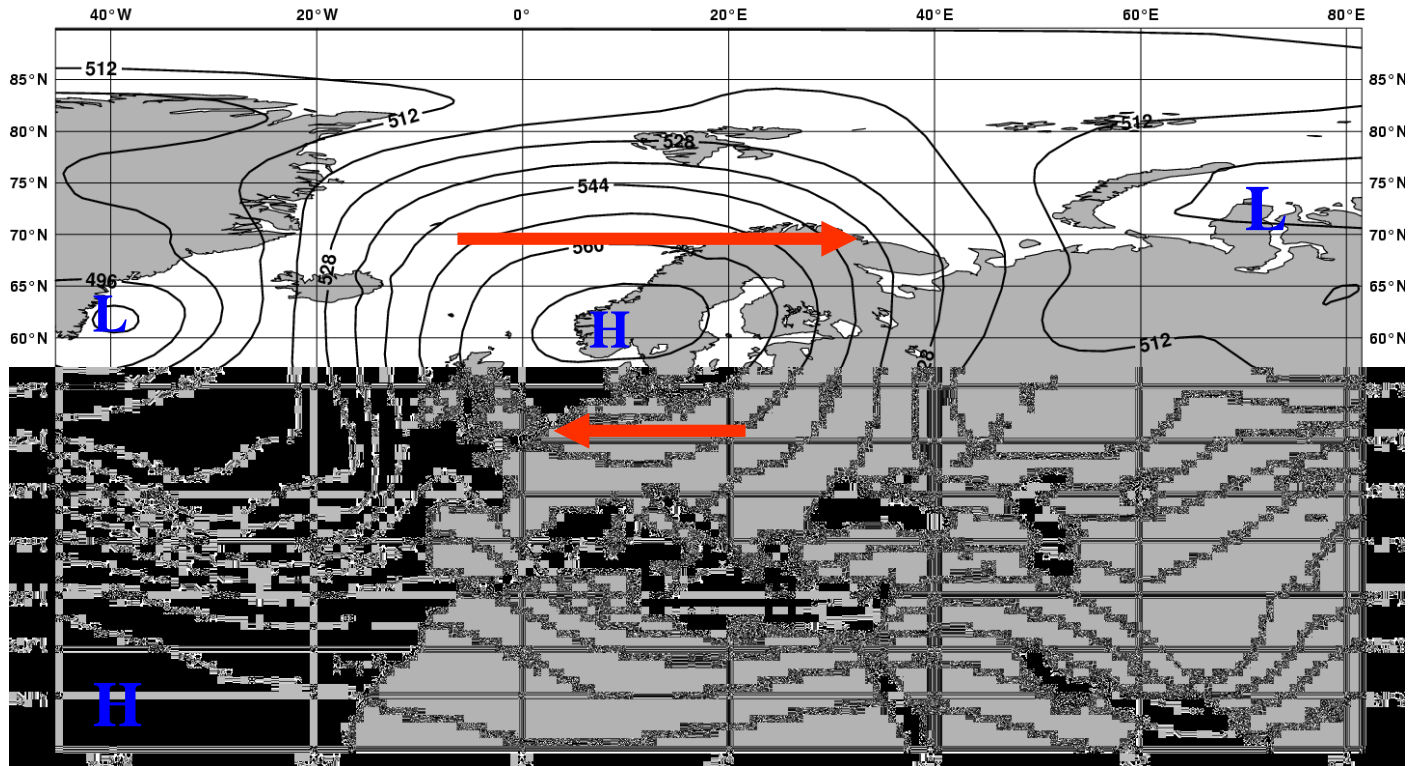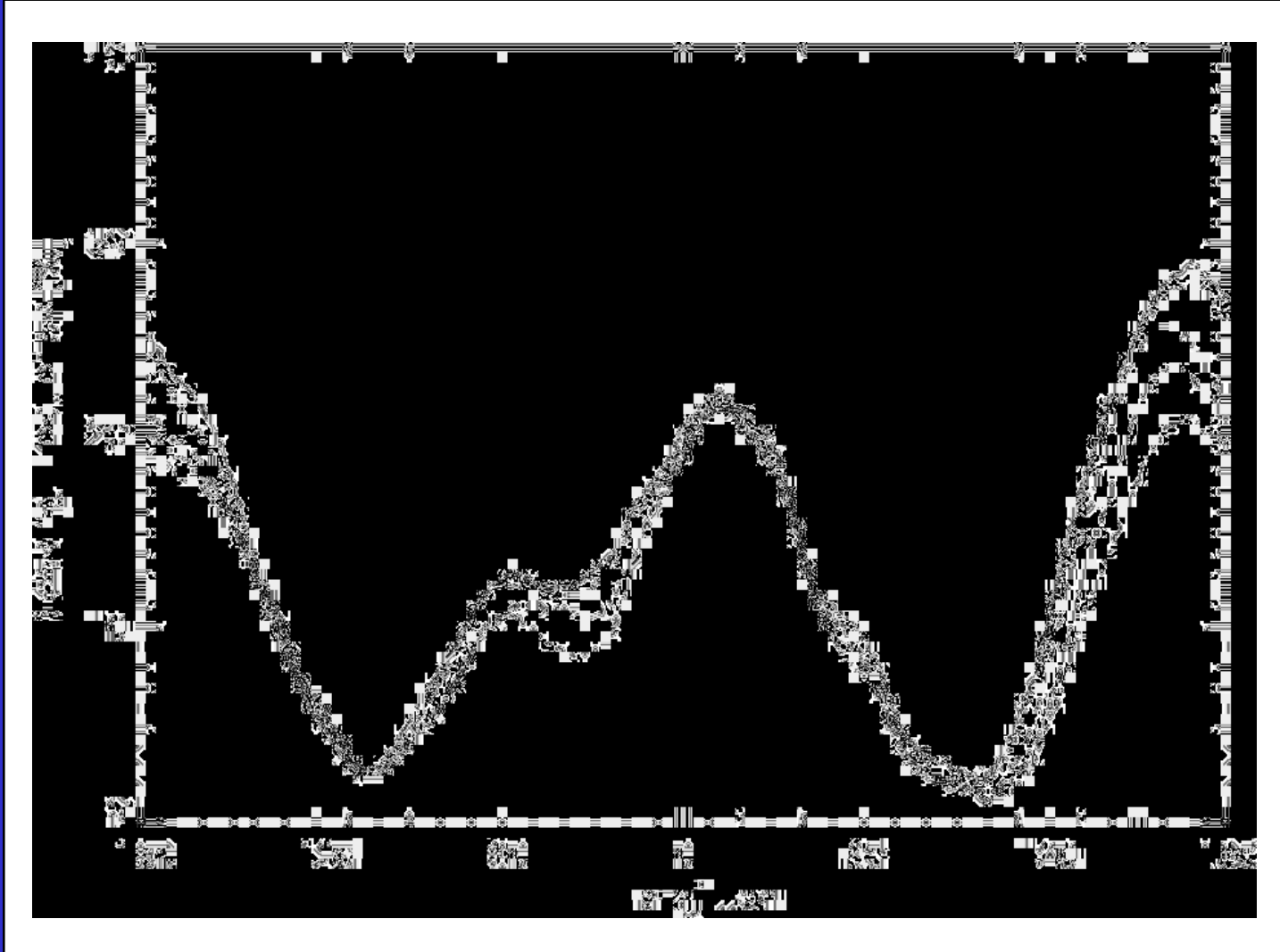ECMWF Analysis VT:Tuesday 18 February 2003 12UTC 500hPa geopotential height
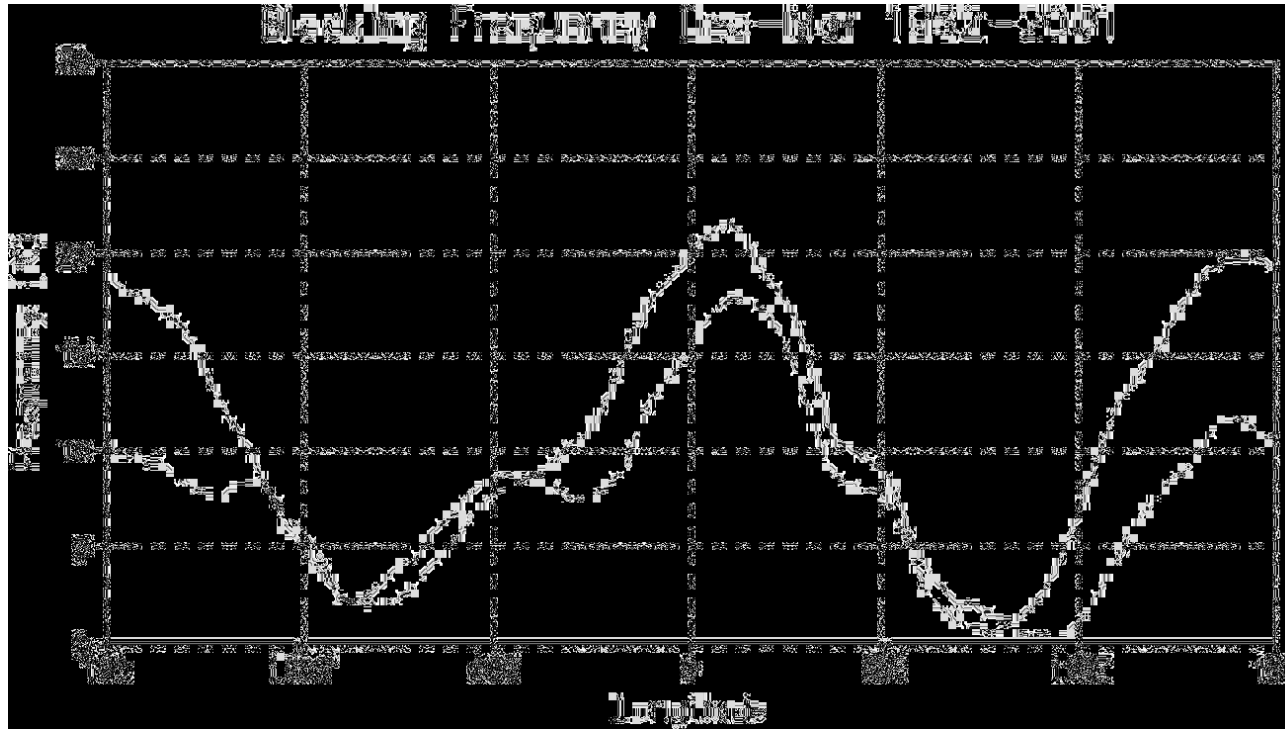
Blocking Frequency Biases (23r4)

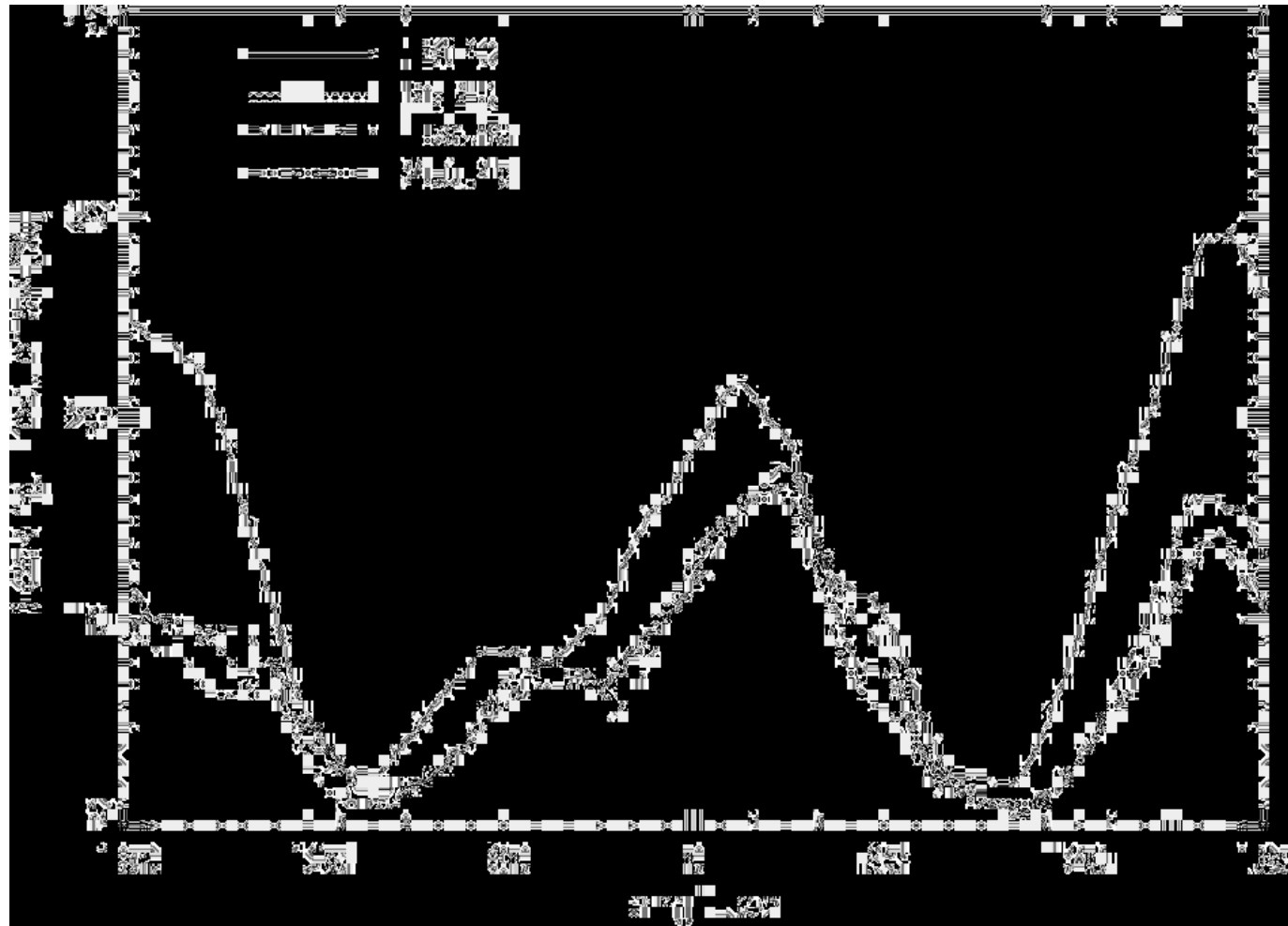DJFM 1960-2001

Asymptotic Systematic Errors

cy26r1

Blocking Episodes (DJFM 1962-2001)

|	n	4-6	7-10	11-15	16-20	21-30	>30
ERA-40	205	37.3	23.7	19.2	9.6	7.9	2.3
Model (26r1)	188	34.9	31.4	15.7	9.9	7.6	0.6

# Blocking and Horizontal Resolution

Stochastic Physics: The Rationale

➢ **Stochastic forcing from unresolved processes.**

➢ **Model tendencies due to parameterized physical processes have a certain coherence on the space and time scales associated, for example, with organized convection. A way to simulate this is to impose space-time correlation on the random numbers.**
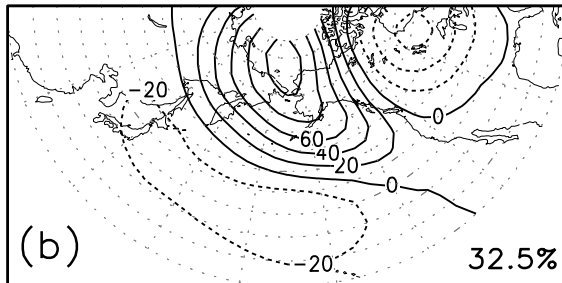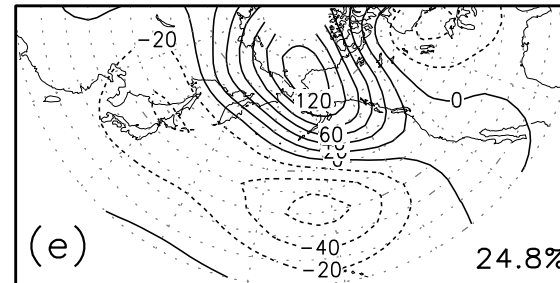
North Pacific Weather Regimes
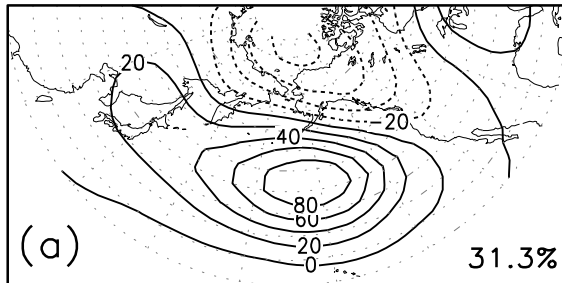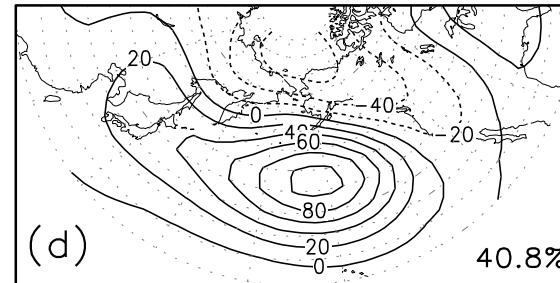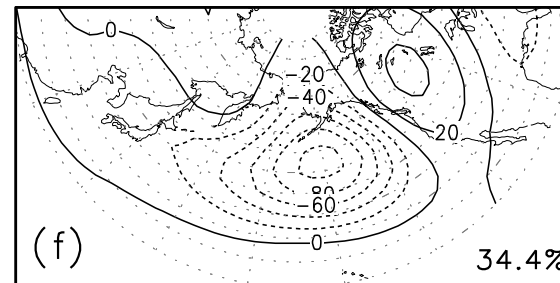
Influence of Stochastic Physics on North Pacific Weather Regimes
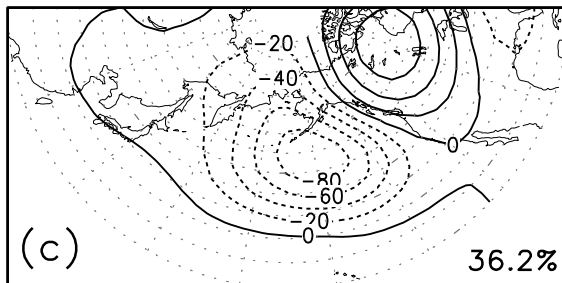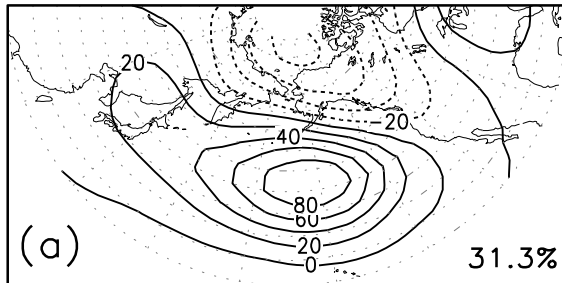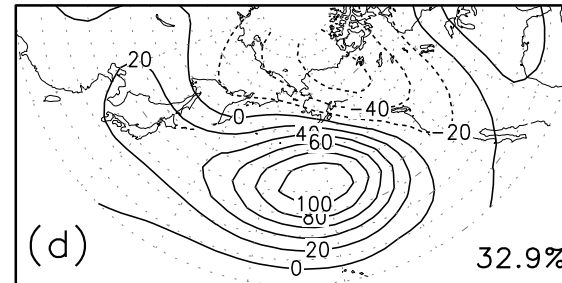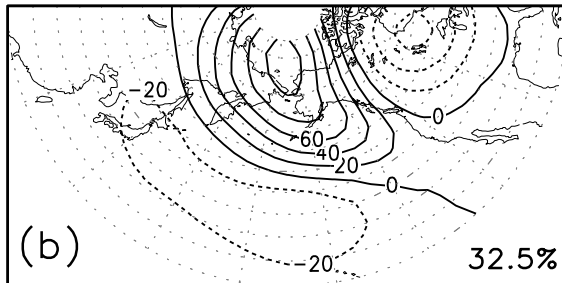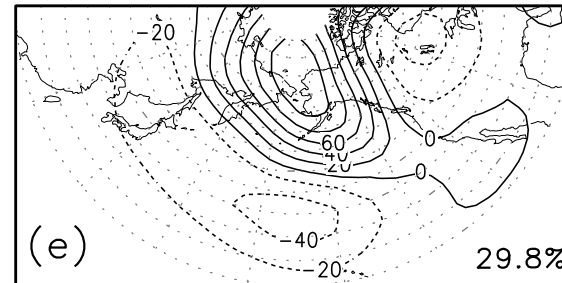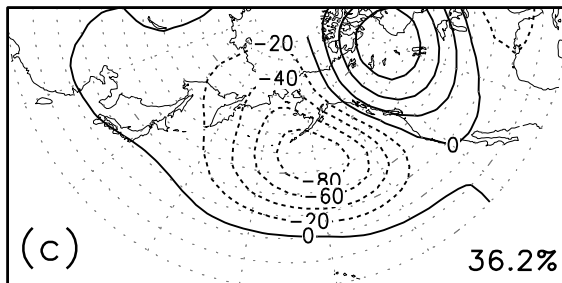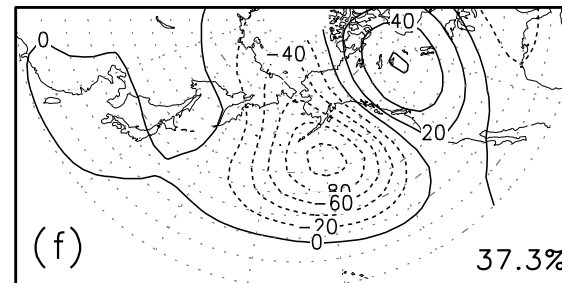
Schematic of the MJO
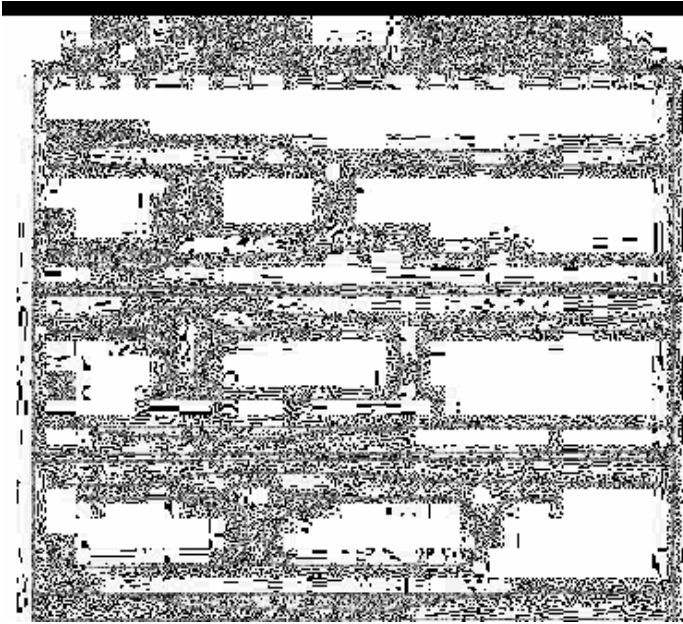
From Madden and Julian (1994)

The Madden and Julian Oscillation
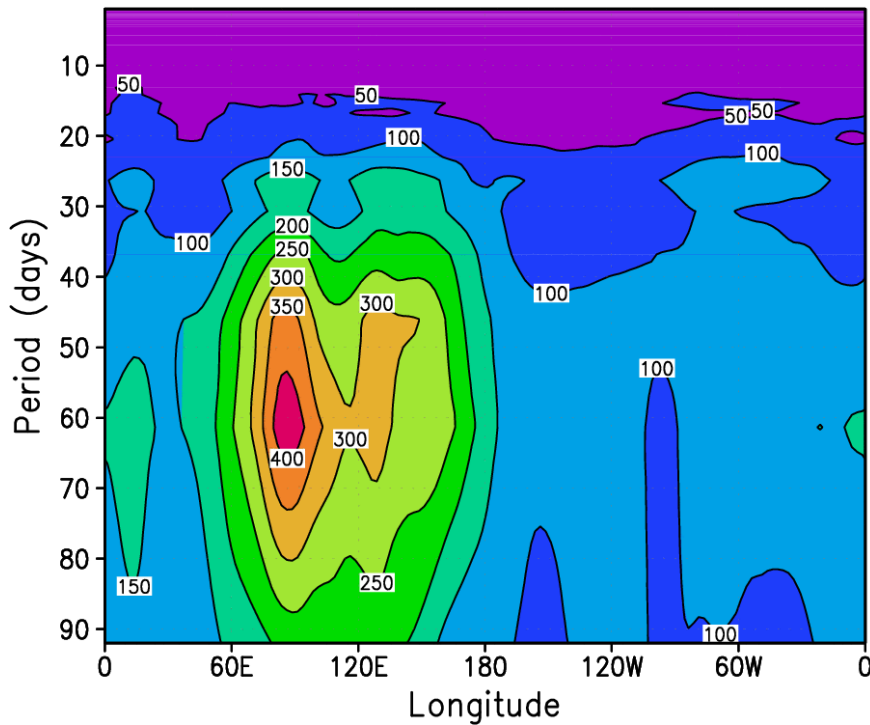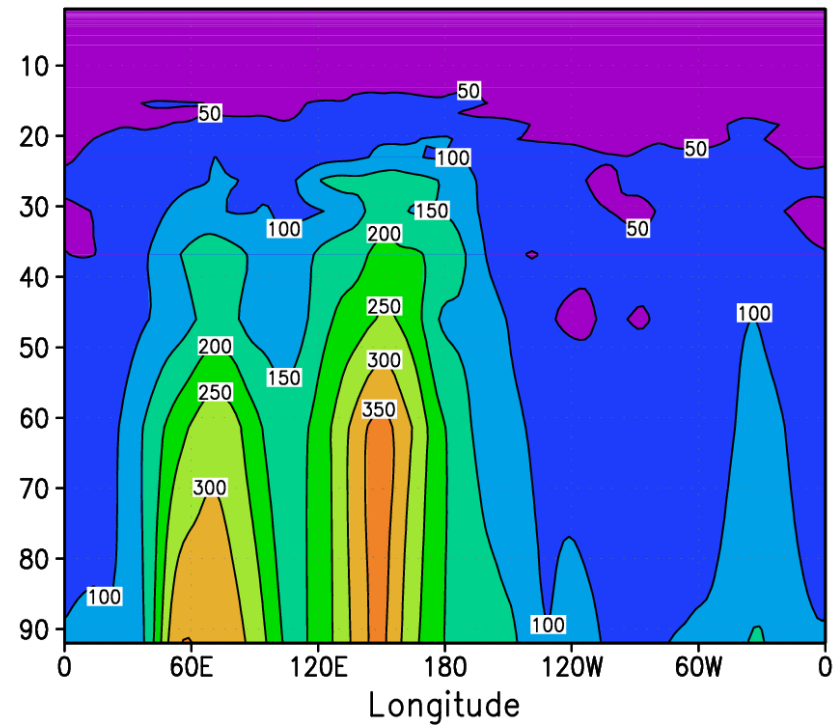
Extratropical Cyclones: Questions

- **How well do we simulate observed characteristics of extratropical cyclones?**
- **Cyclone tracking (do we learn something new?)**
- **How sensitive are the results to horizontal resolution?**

Extratropical Cyclones: Experiments

- **Four data sets:**
  - **ERA-40 for verification**
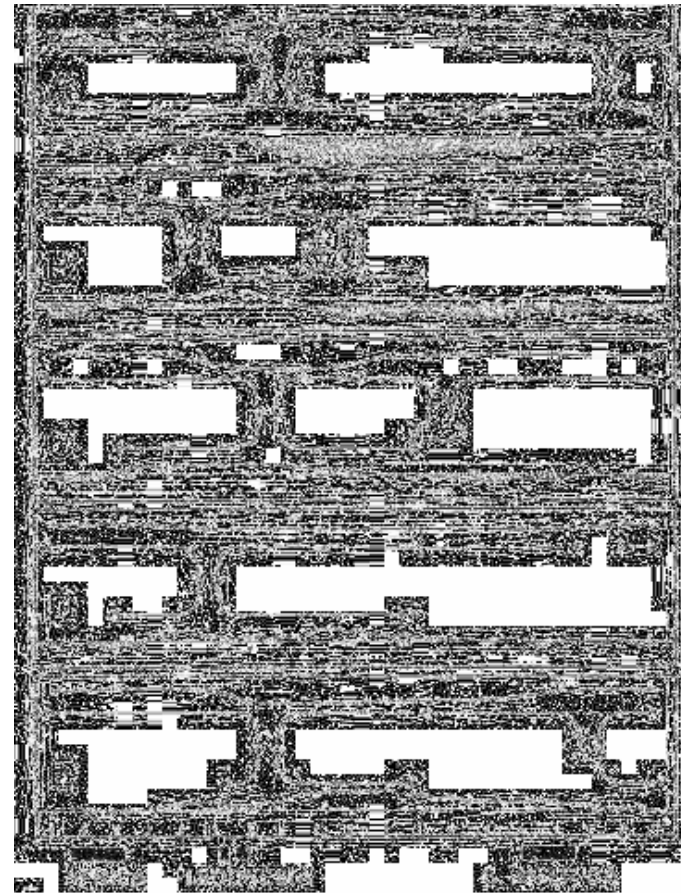 - **T95L60 run (29R1)**
  - **T159L60 run (29R1)**
  - **T255L40 run (29R1)**
- **6-hourly MSLP interpolated to a common 2.5x2.5 deg grid**
- **DJFM 1982-2001 (forecasts start 1st October)**

Tracking Software

- **Strategy: Searching for and tracking local minima in MSLP fields**

- **High temporal resolution required (6-hourly data)**

- **Data have been interpolated to 1-hourly data for tracking**

- **The accuracy of the software is very high**
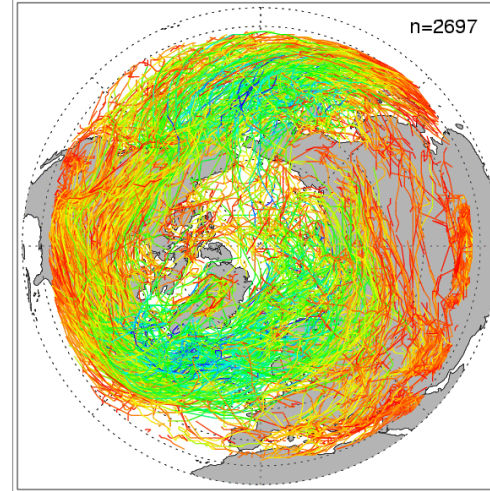
- **The software is fast**

Extratropical Cyclone Tracks (1995-2001)
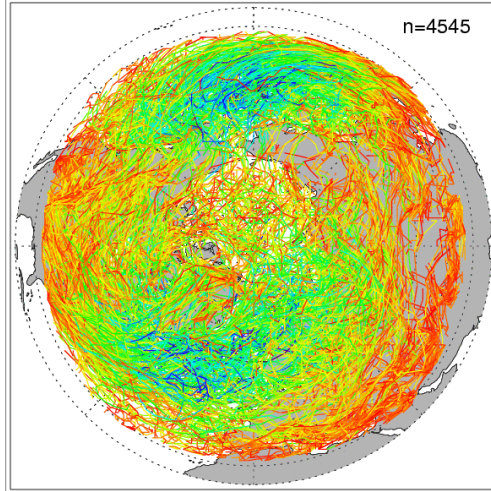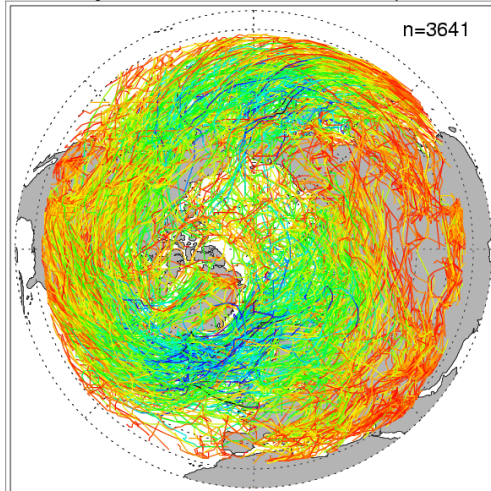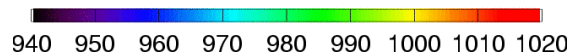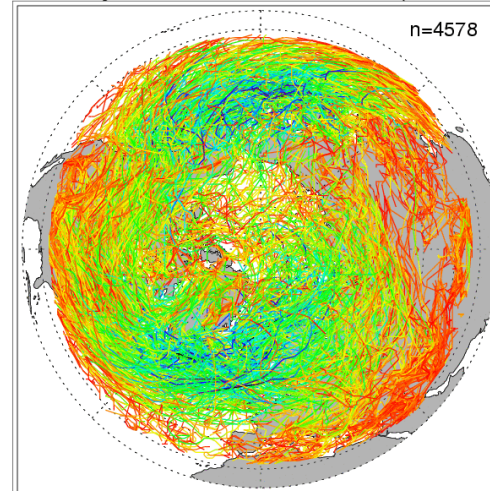
Number of Northern Hemisphere Cyclones
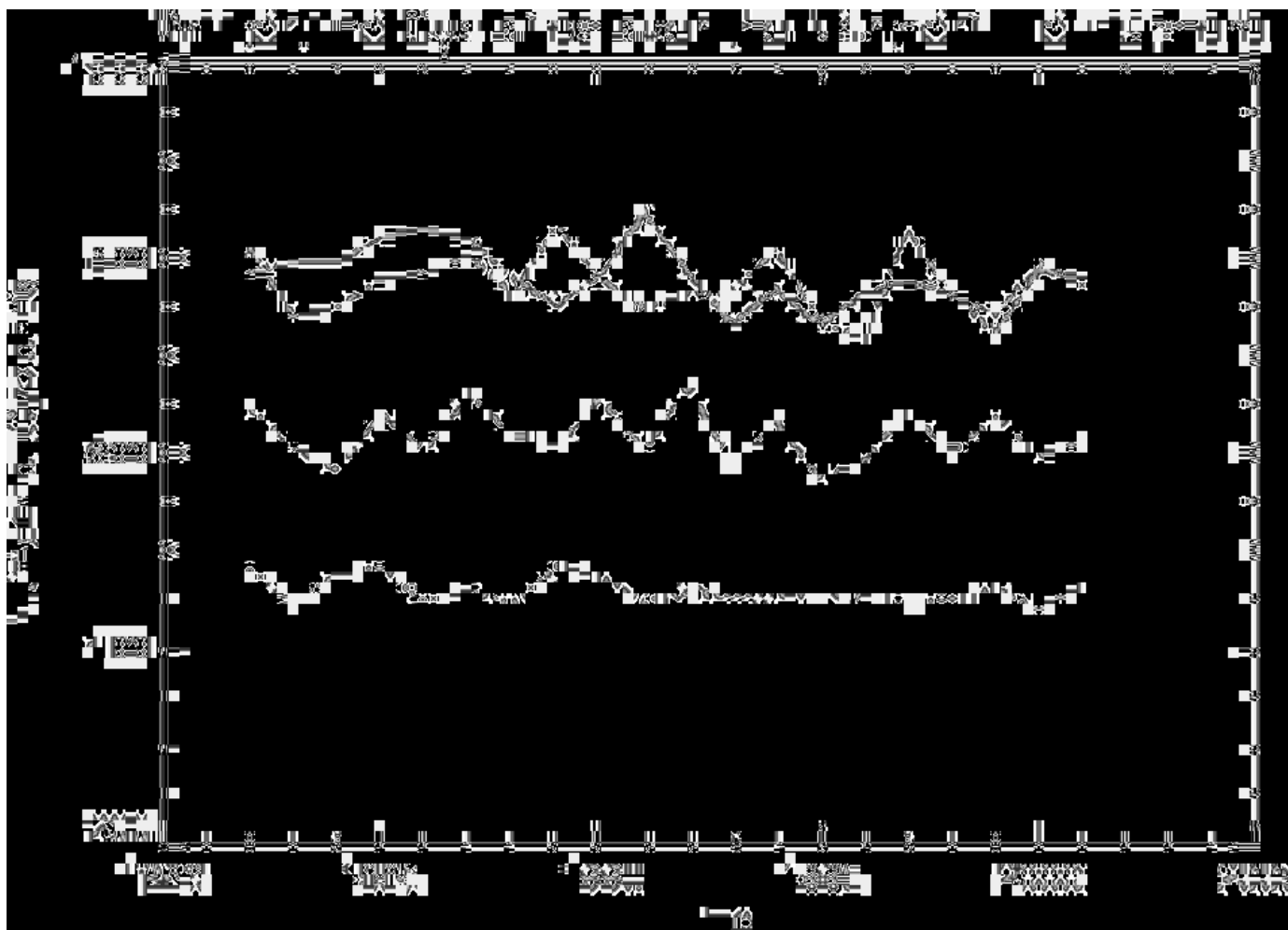
Number of Cyclones DJFM 1982-2001
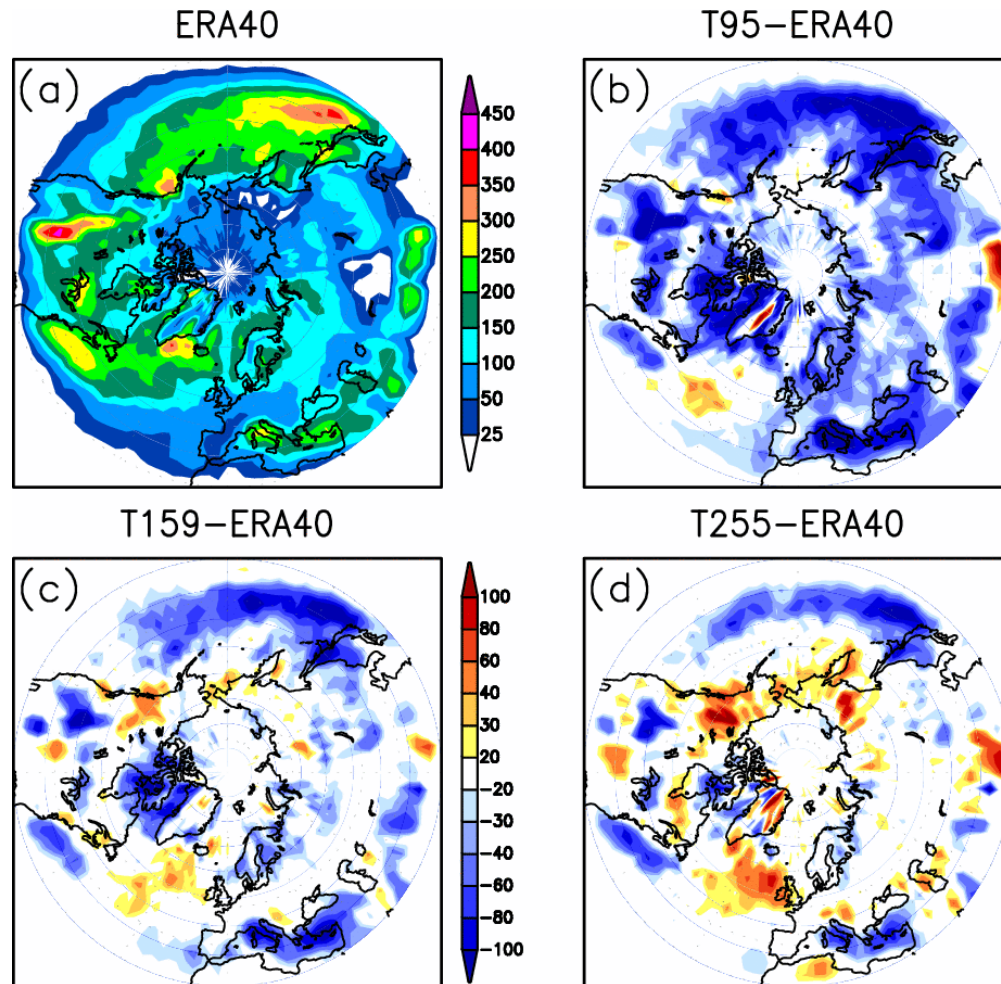
Synoptic Activity Bias II
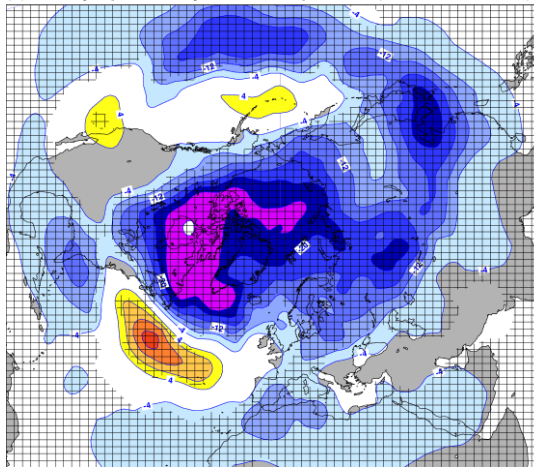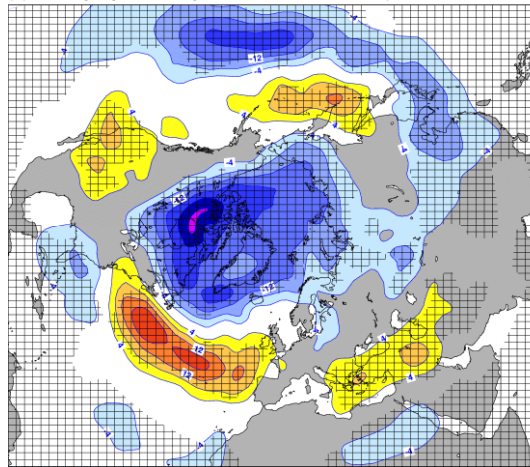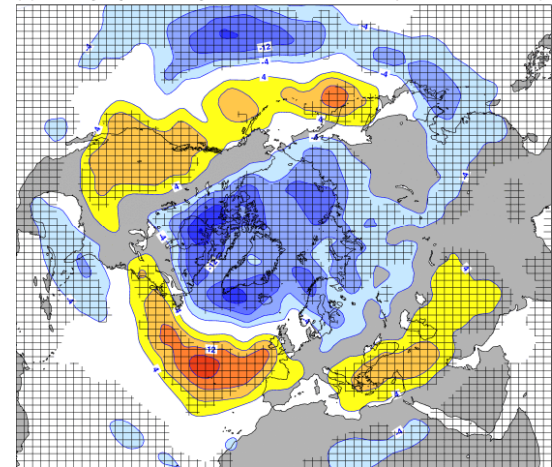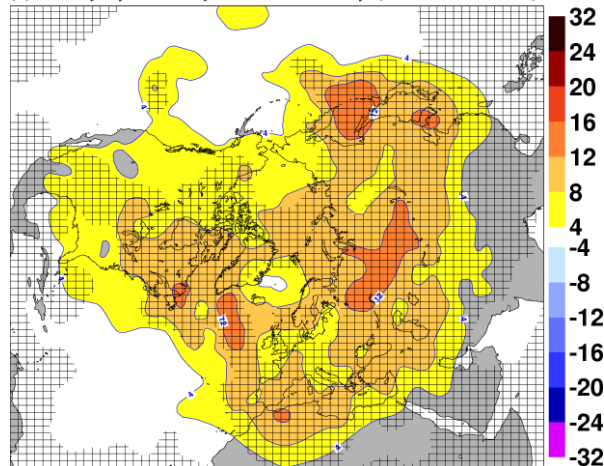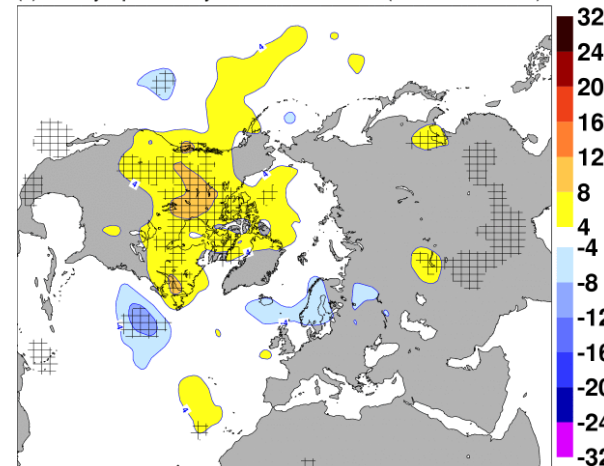
Conclusions (1)

Main systematic errors:

- ➢ **Atmospheric circulation over the North Pacific**

- ➢ **Synoptic activity**

- ➢ **Euro-Atlantic blocking**

- ➢ **Clouds**

- ➢ **Temperature in the stratosphere**

- ➢ **Specific humidity in the tropics**

- ➢ **KE of TE over the Northern Hemisphere**

- ➢ **Madden-and-Julian Oscillation**

Conclusions (2)

Did we improve in terms of systematic errors?

There is no straightforward answer. It depends on

➢ **the parameter/phenomenon,**

➢ **region,**

➢ **vertical level,**

➢ **season, and**

➢ **the forecast range being considered.**

Conclusions (3)

In general, though:

➢ **Improvements for most parameters, particularly in the short-range and near medium-range.**

➢ **Neutral for some parameters/phenomena.**

➢ **Only a few deteriorations.**

References

Jung, T. and A.M. Tompkins, 2003: Systematic Errors in the ECMWF Forecasting
  System. ECMWF Technicial Memorandum 422.
  http://www.ecmwf.int/publications/library/do/references/list/14

Jung, T., A.M. Tompkins, and R.J. Rodwell, 2004: Systematic Errors in the ECMWF
  Forecasting System. ECMWF Newsletter, 100, 14-24.

Jung, A.M. Tompkins, and R.J. Rodwell, 2005: Some Aspects of Systematic Errors
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Jung, T., T.N. Palmer and G.J. Shutts, 2005: Influence of a stochastic
  parameterization on the frequency of occurrence of North Pacific
  weather regimes in the ECMWF model. Geophys. Res. Lett., 32,
  doi:10.1029/2005GL024248, L23811.

Jung, T., 2005: Systematic Errors of the Atmospheric Circulation in the ECMWF
  Model. Quart. J. Roy. Meteor. Soc., 131, 1045-1073.

Jung, T., S.K. Gulev, I. Rudeva and V. Soloviov, 2006: Sensitivity of extratropical
  cyclone characteristics to horizontal resolution in the ECMWF model.
  Quart. J. Roy. Meteor. Soc., in press.

Gates and coauthors, 1999: An Overview of the Results of the Atmospheric
  Intercomparison Project (AMIP I). Bull. Amer. Meteor. Soc., 80, 29-55.

Hoskins, B.J. and K.I. Hodges, 2002: New Perspectives on the Northern Winter
  Storm Tracks. J. Atmos. Sci., 59, 1041-1061.

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  http://www.ecmwf.int/publications/library/do/references/list/14

Palmer, T.N., G. Shutts, R. Hagedorn, F. Doblas-Reyes, T. Jung, and M.
  Leutbecher, 2005: Representing Model Uncertainty in Weather and
  Climate Prediction. Ann. Rev. Earth. Planet Sci., 33, 163-193.

Impact of Stochastic Physics on Blocking
(Dec-Mar 1962-2001)
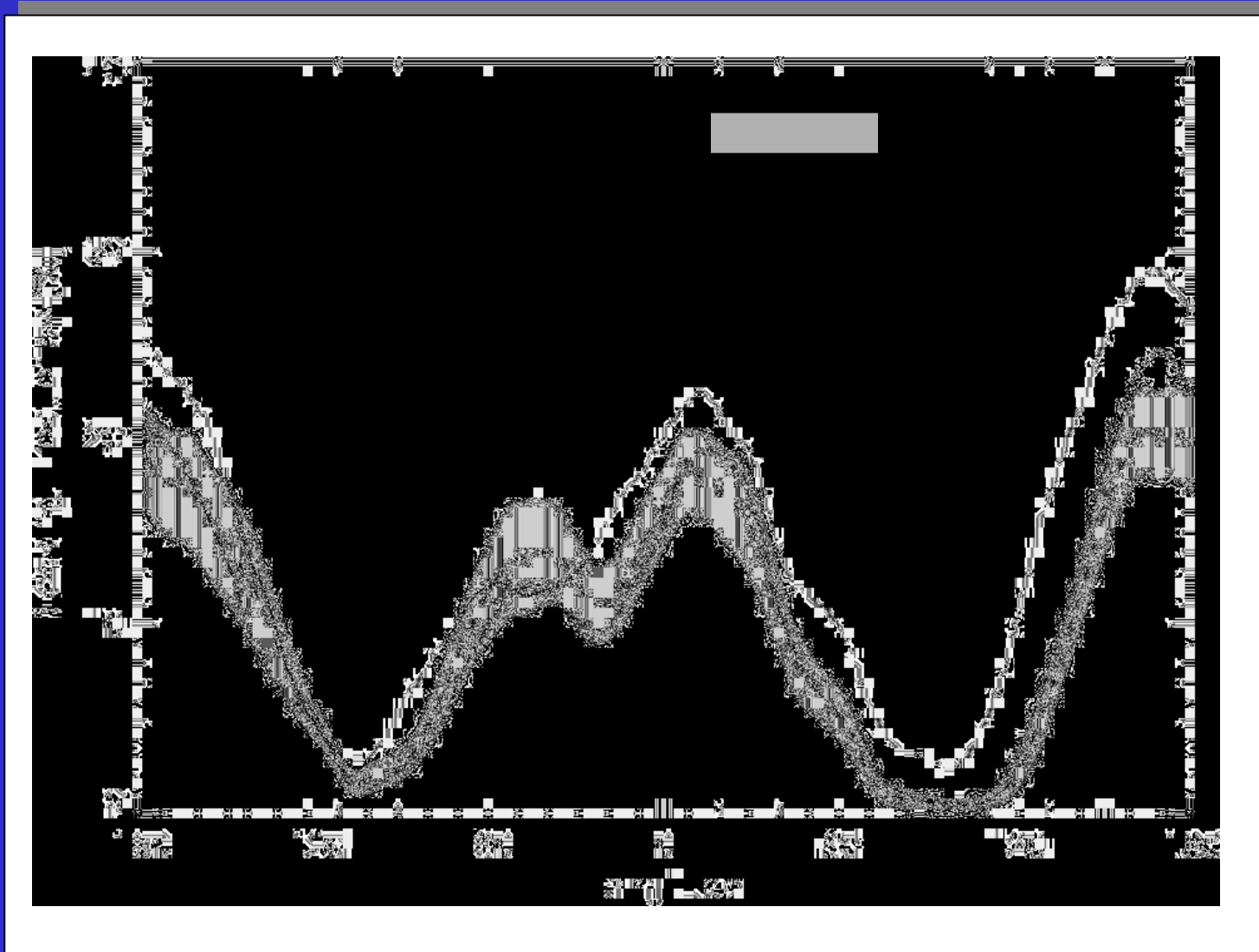
Number of Cases of Cyclo-Genesis DJFM 1982-2001