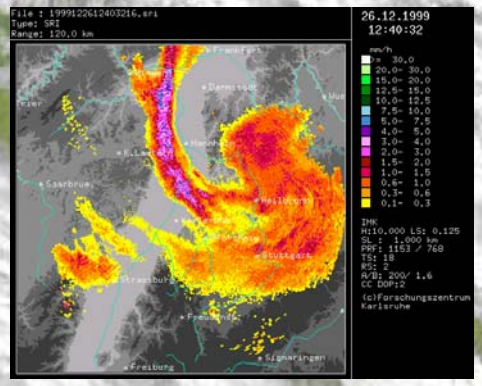
# European windstorms: diagnostics, downscaling and climate change



Thanks: Patrick Ludwig, Kai Born, Andreas H. Fink, Dominique Yuen

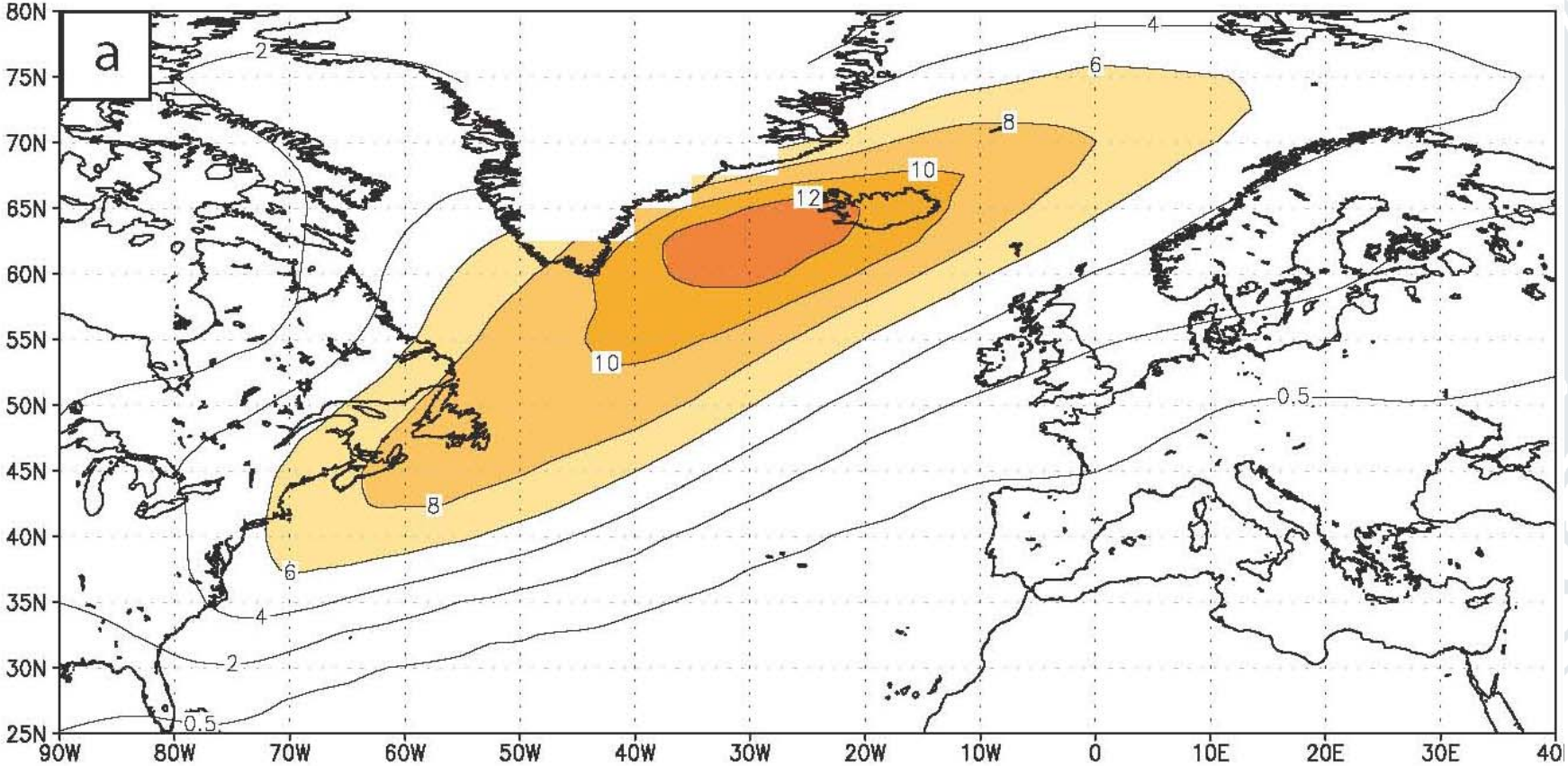
Exeter 06.09.2011

# European windstorms: diagnostics, downscaling and climate change

Outline:

- Introduction
- Unusual extreme cyclones in recent years
- Xynthia: diagnostic and modeling studies
- Climate change
- Key Messages

# Extreme Cyclones

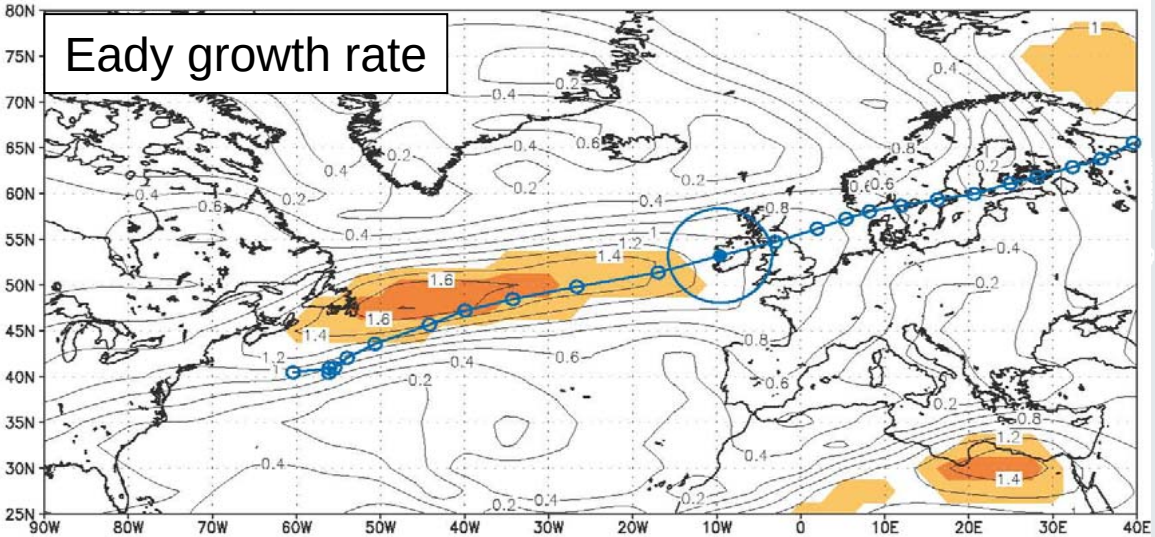


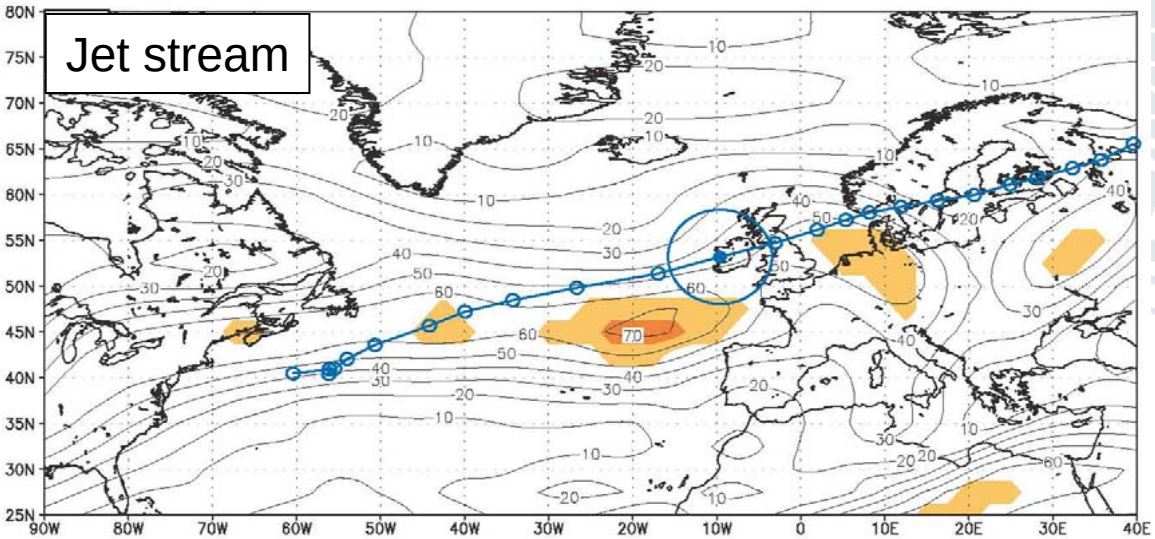

10 % strongest cyclones ($\nabla^2 p$), cyclone trackdensity, October-March

**Frequent over North Atlantic Ocean, e.g. South of Greenland, rarer over Europe**

*Source: Pinto et al. (2009) Clim Dyn*

# Assignment of cyclones to environmental variables




Climatological approach:

Identify 24-hour period of maximum intensification

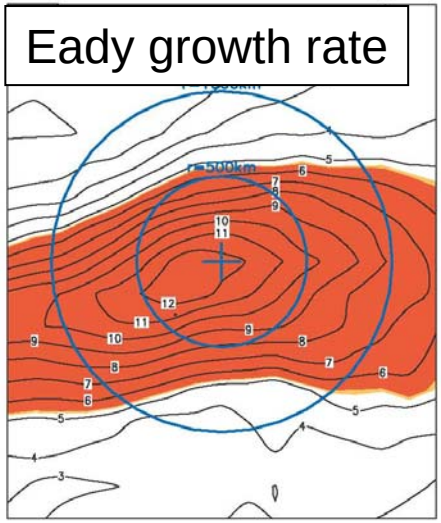
relate to

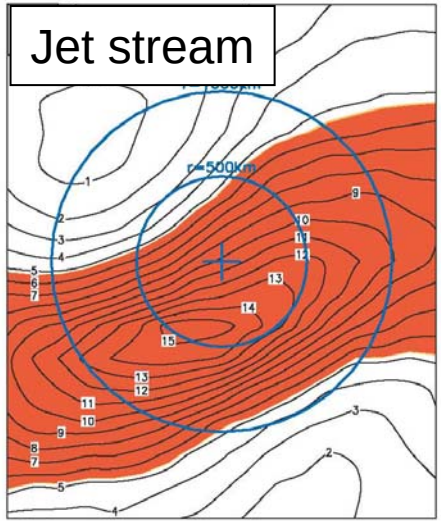
Latent Heat
($\Theta_e$ 850 hPa)
Divergence 250 hPa
Eady growth rate 400 hPa
Jet Stream 250 hPa

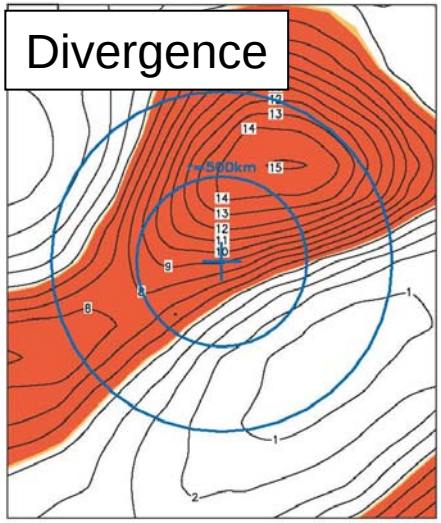
Daily NAO-index

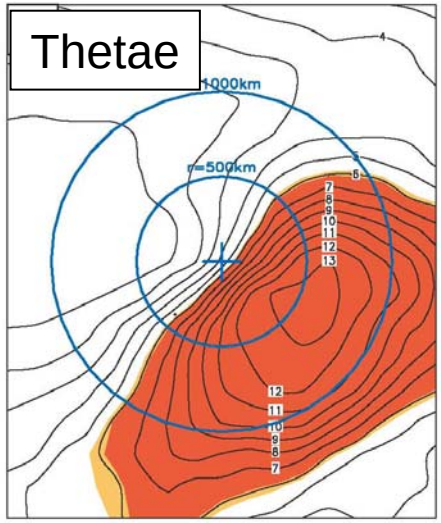
*Source: Pinto et al. (2009) Clim Dyn*

# Assignment of cyclones to environmental variables



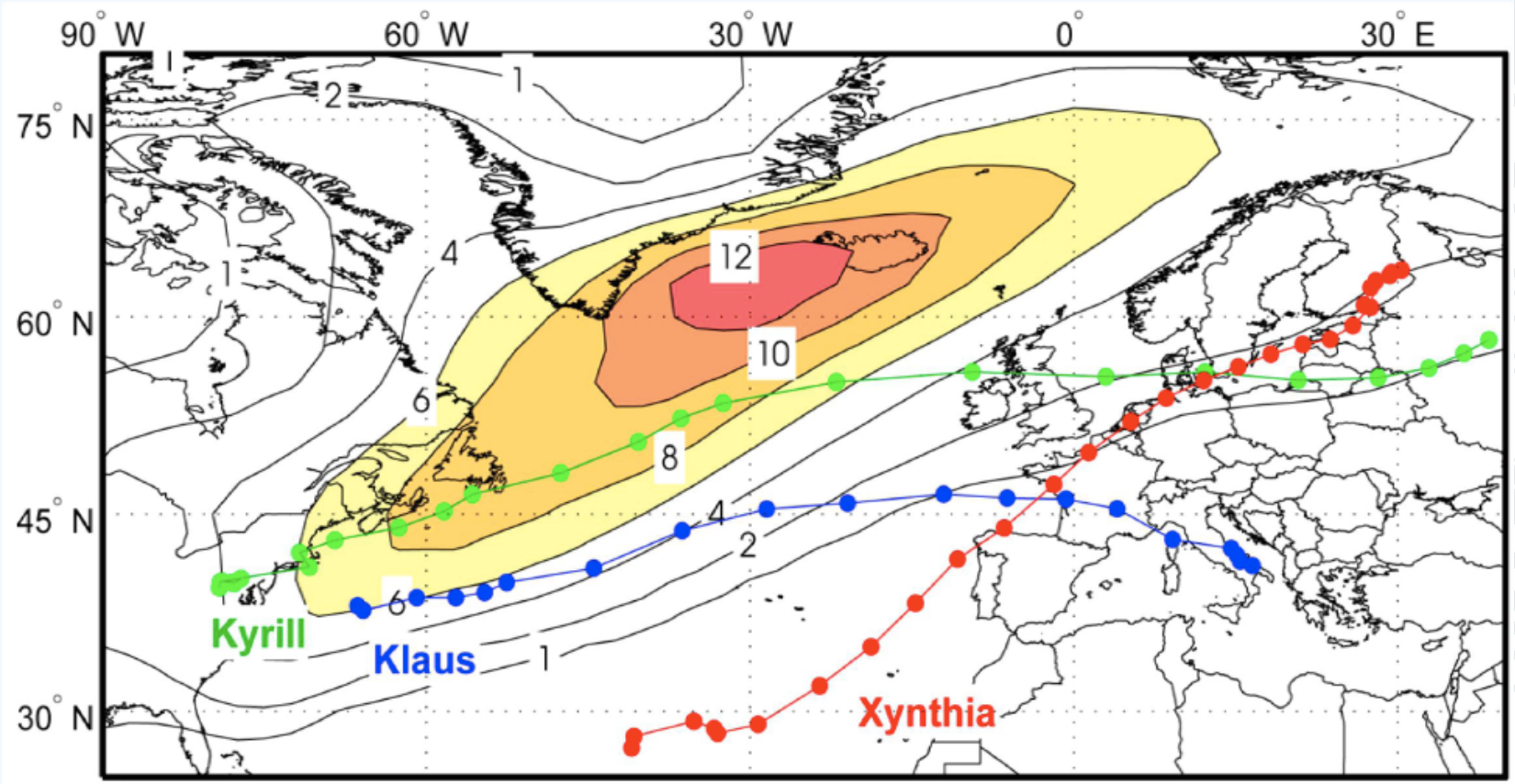

| Phase: | extreme cyclones | | | |
|---|---|---|---|---|
| | $\sigma_{400}$ | $jet_{250}$ | $div_{250}$ | $\theta_e$ |
| NAO-- | 49 | 40 | 96 | 62 |
| NAO - | 47 | 40 | 98 | 61 |
| NAO 0 | 47 | 46 | 97 | 68 |
| NAO + | 45 | 47 | 94 | 64 |
| NAO++ | 44 | 66 | 95 | 71 |
| **NAOall** | **46** | **47** | **96** | **66** |

Extreme cyclones: extreme values of environmental variables found near the cyclone cores during the most intensive development phase

Lower frequency for non-extreme cyclones

*Source: Pinto et al. (2009) Clim Dyn*

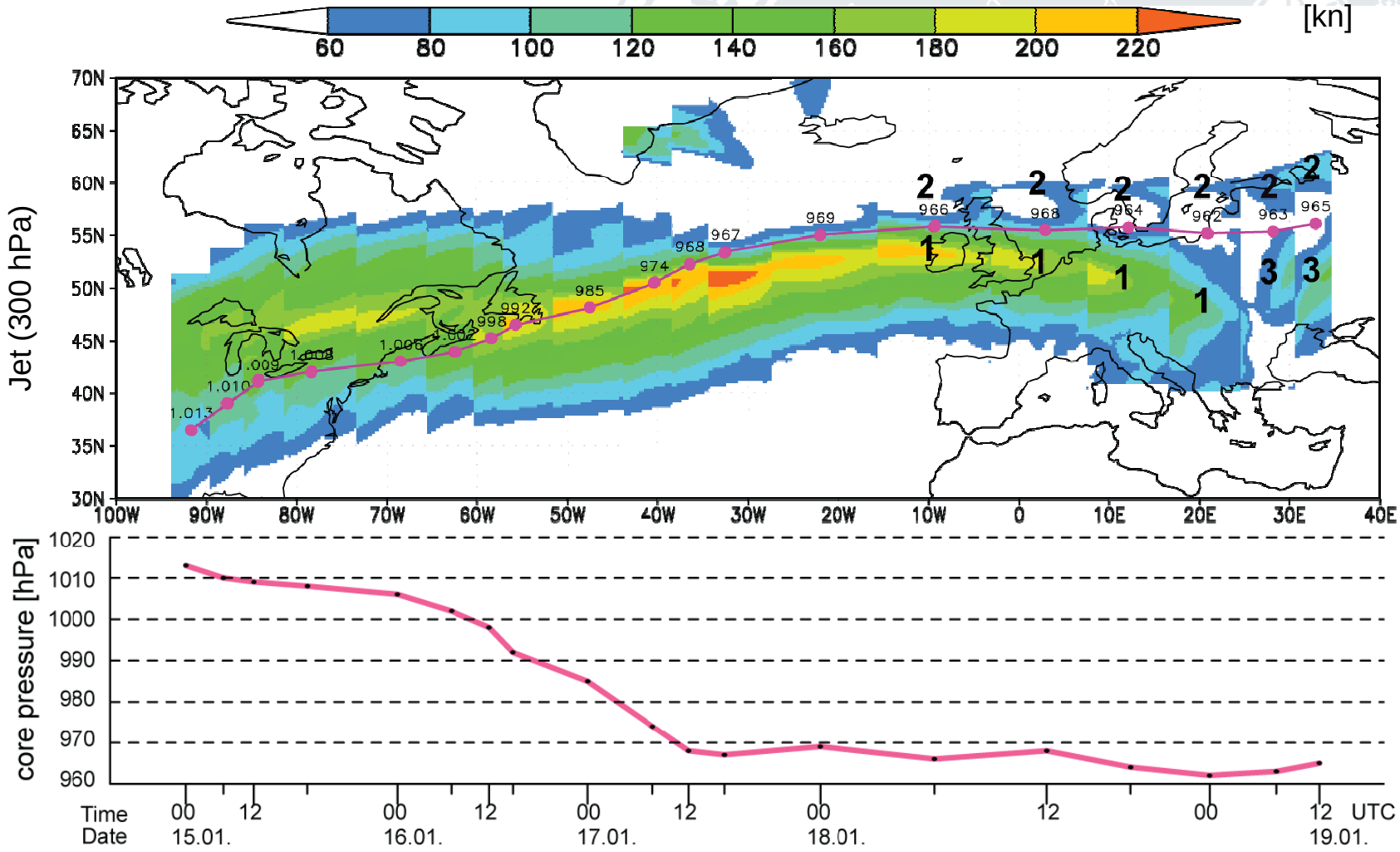
# Unusual windstorms in recent years




10 % strongest cyclones ($\nabla^2 p$), cyclone trackdensity, October-March

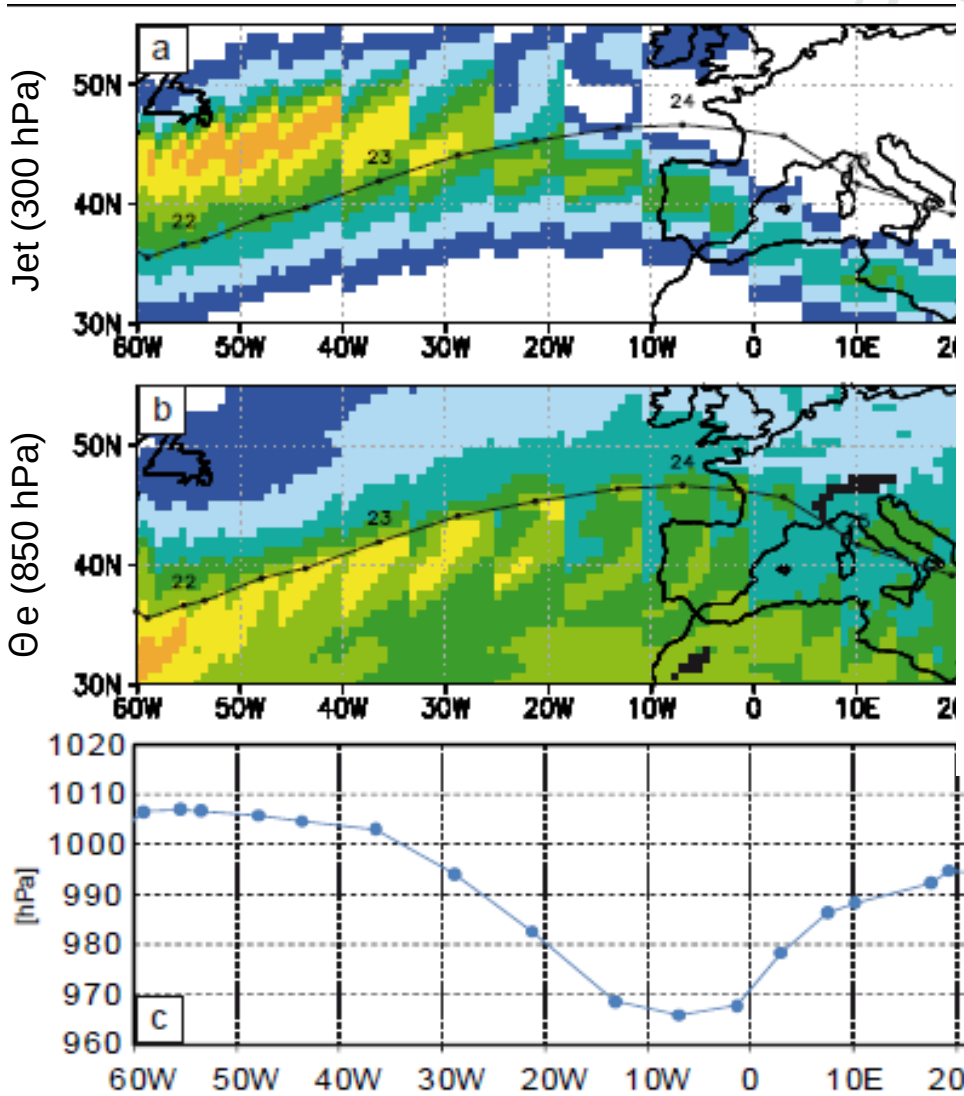
*Source: Pinto et al. (2009) Clim Dyn, adapted*

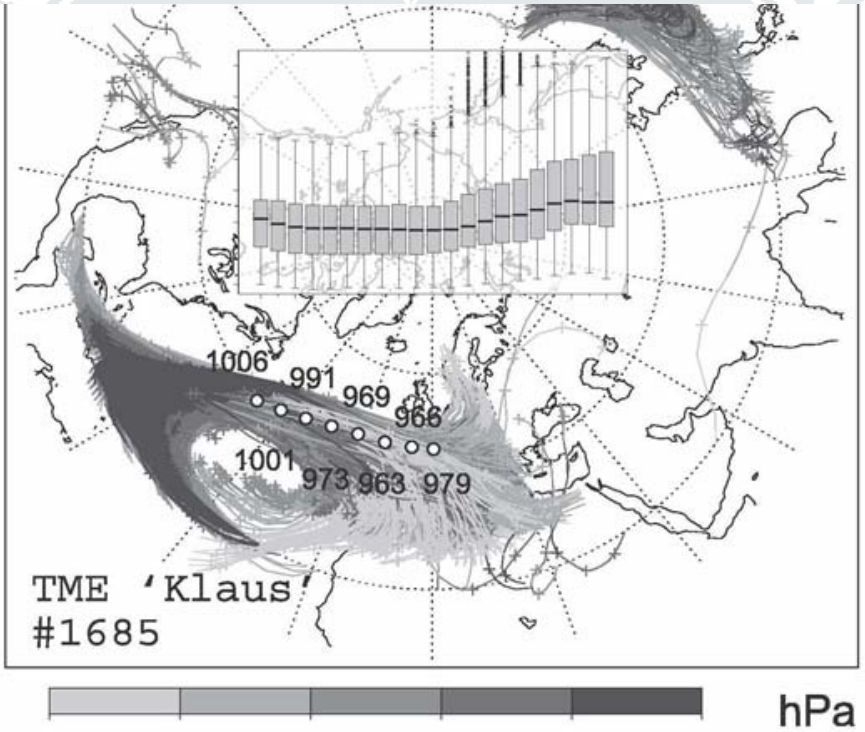
# Development of storm Kyrill: Diagnostics




*Source: Fink et al, 2009; NHESS*

# Development of storm Klaus: Diagnostics



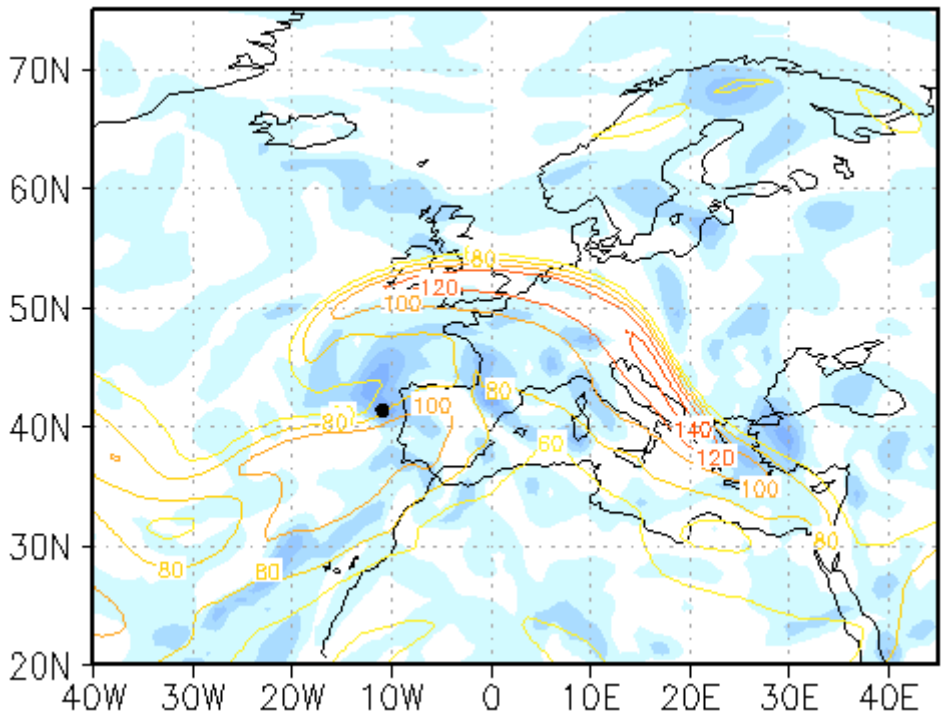




Tropical moisture export associated with storm Klaus

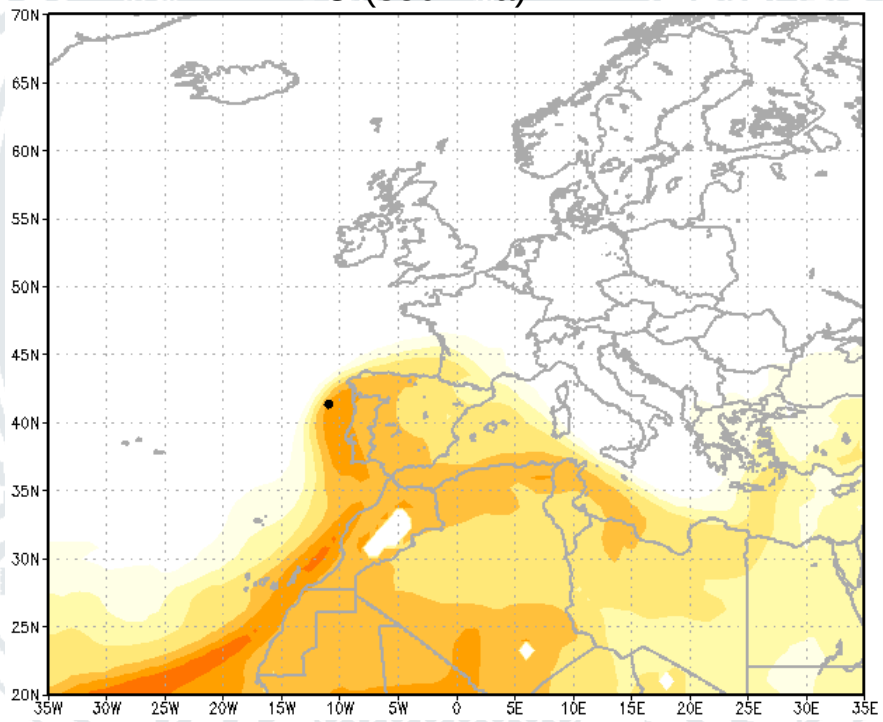
*Source: Fink et al, 2011; GRL, in prep.; Knippertz & Wernli, 2010, J Clim.*

# Development of storm Xynthia: Diagnostics

Jet and Divergence (300 hPa)




$\Theta e$ (850 hPa)



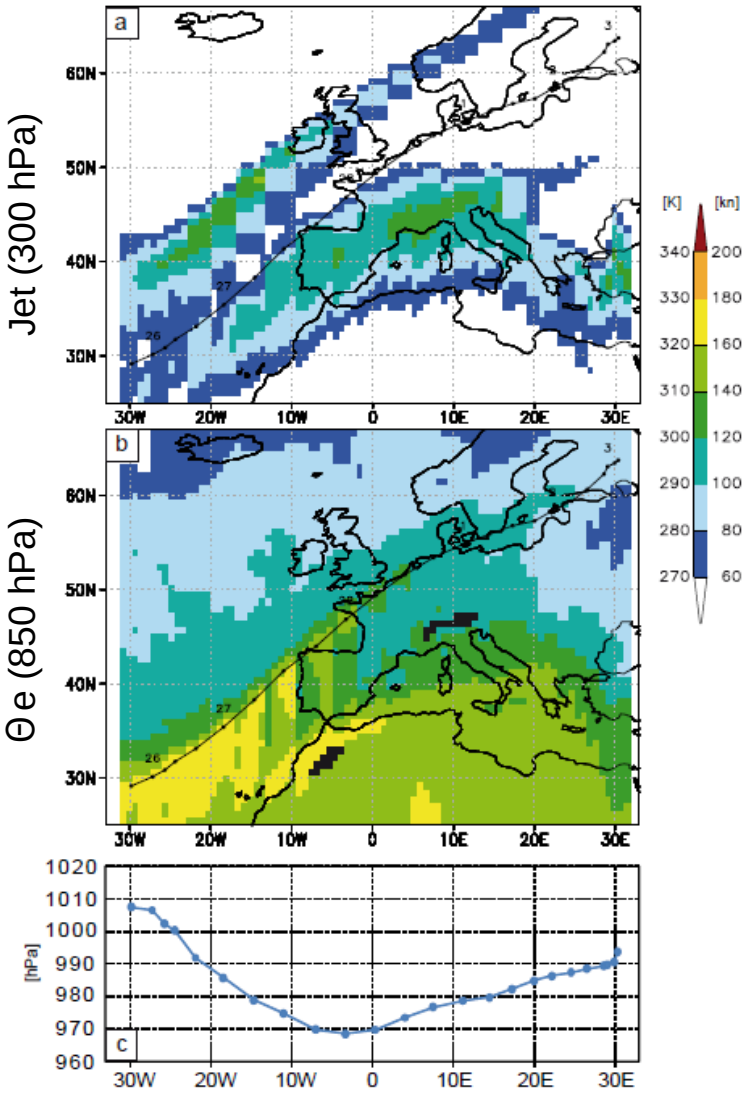

27.02.2010 12 UTC

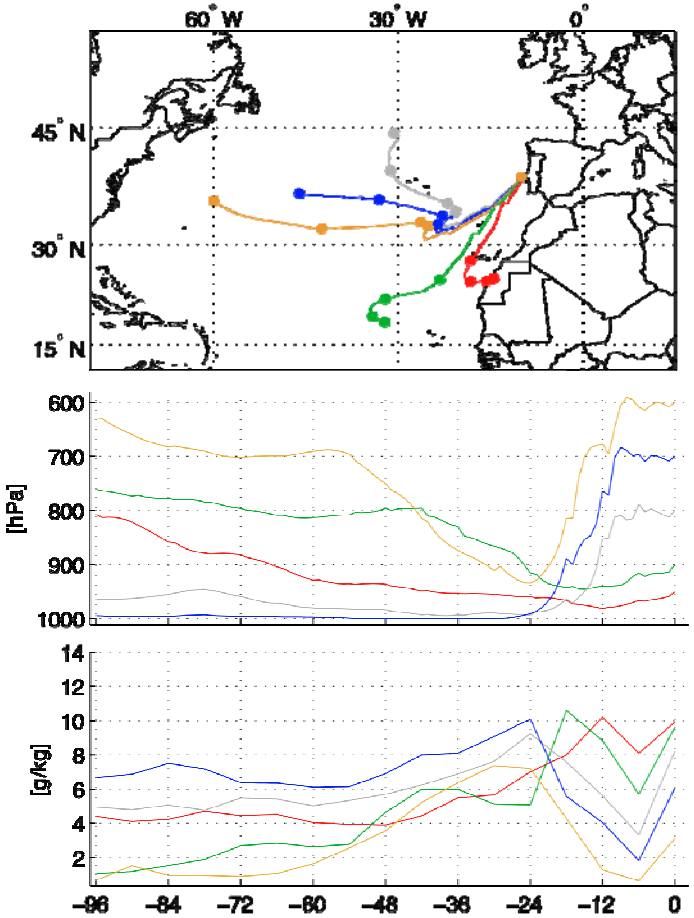
Xynthia does not cross the jet at any time, but remains in divergence zone between two jet streaks

Tongue with strong $\Theta_e$ (latent heat), associated with Xynthia's warm sector

*Thanks: D. Yuen, S. Pohle*

# Development of storm Xynthia: Diagnostics



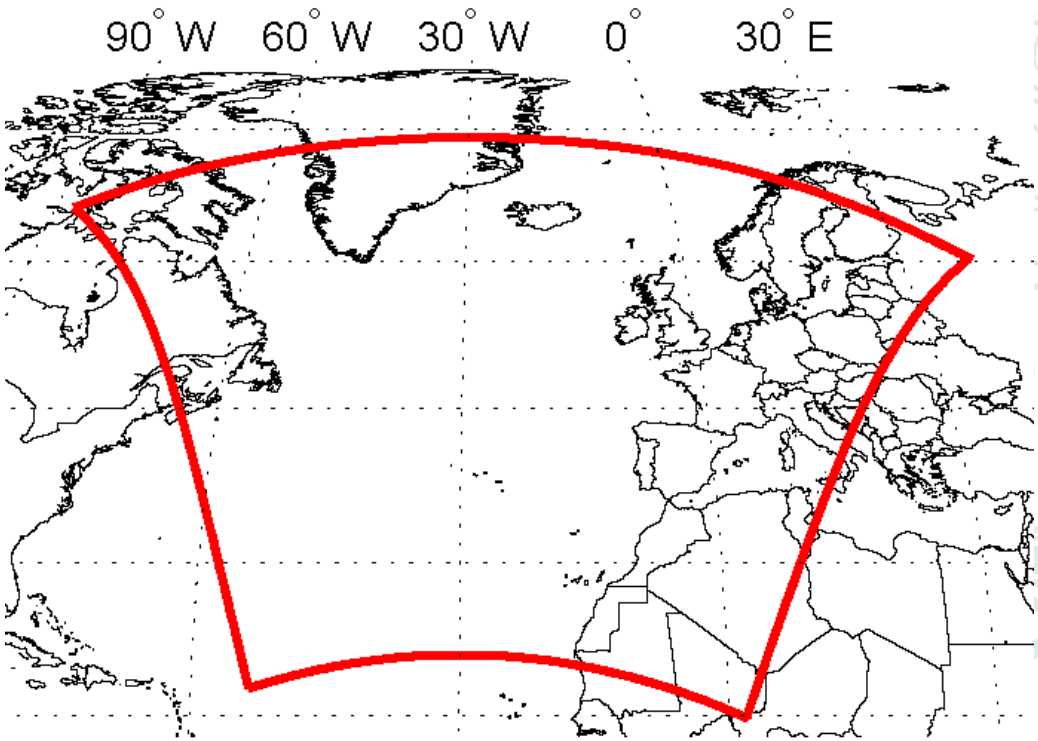




4-day air-parcel backtracing

Strong diabatic character, evaluated with new diagnostic method (see poster)

*Source: Fink et al, 2011; GRL, in prep.; P. Ludwig*

# Modeling studies with COSMO-CLM




COSMO-CLM 4.8 (CCLM)

Joint initiative to develop a RCM from COSMO (DWD)

Grid: 0.22° (25 km)

Vertical: 32 Levels

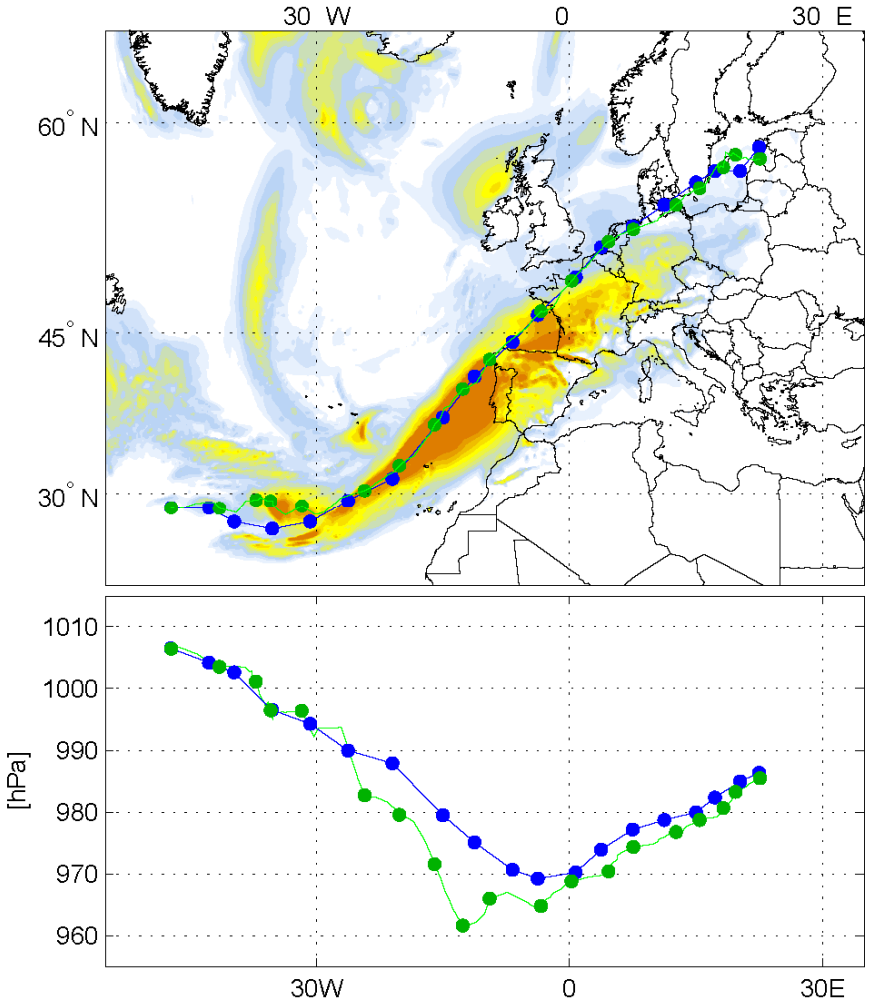
Runge-Kutta integration scheme, time step (150s)

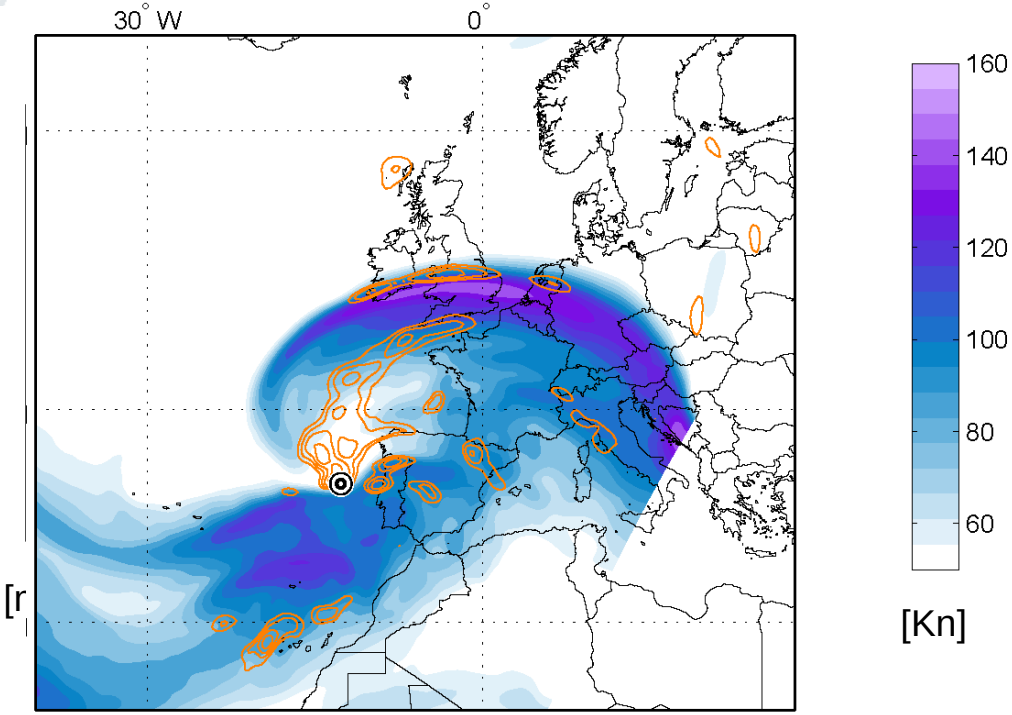
3 Wind gust schemes: DWD, TKE, Brasseur (Born et al., 2011)

Forced with ERA-Interim Data

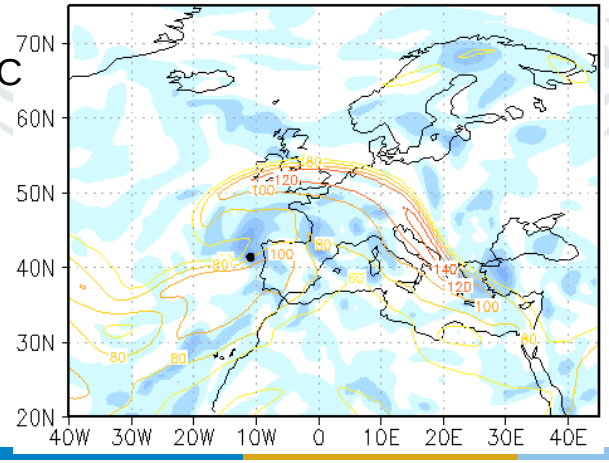
*Ref: Born et al., 2011, Tellus A, revised*

# Storm Xynthia: Wind Gusts and Jet Stream 300 hPa



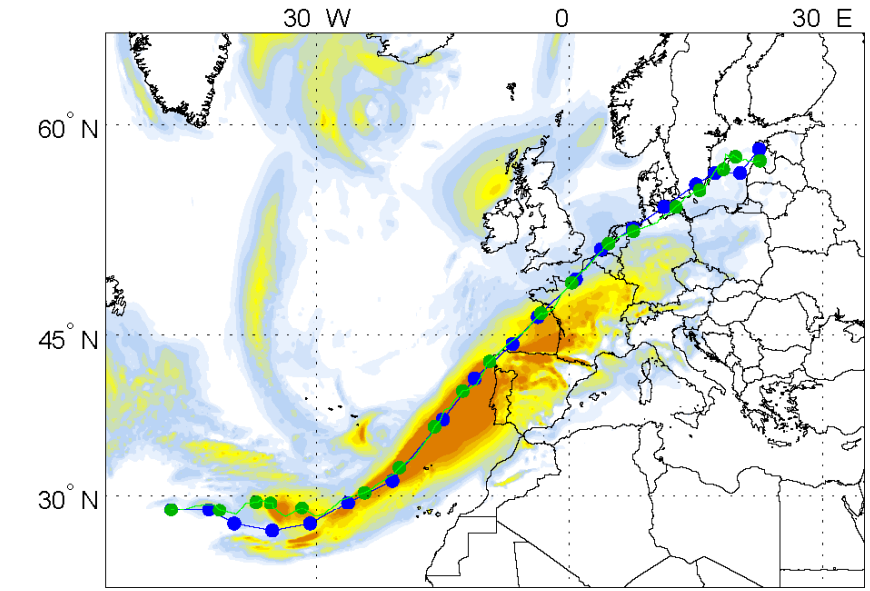

27.02 12 UTC

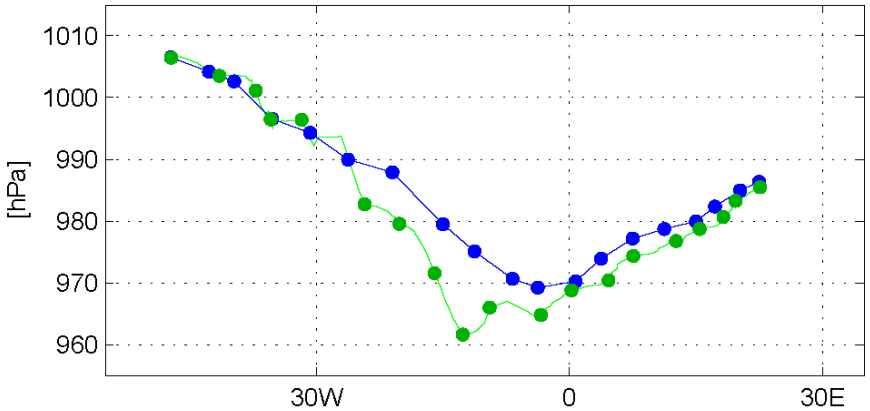



Blue: ERA-Interim; Green: CCLM

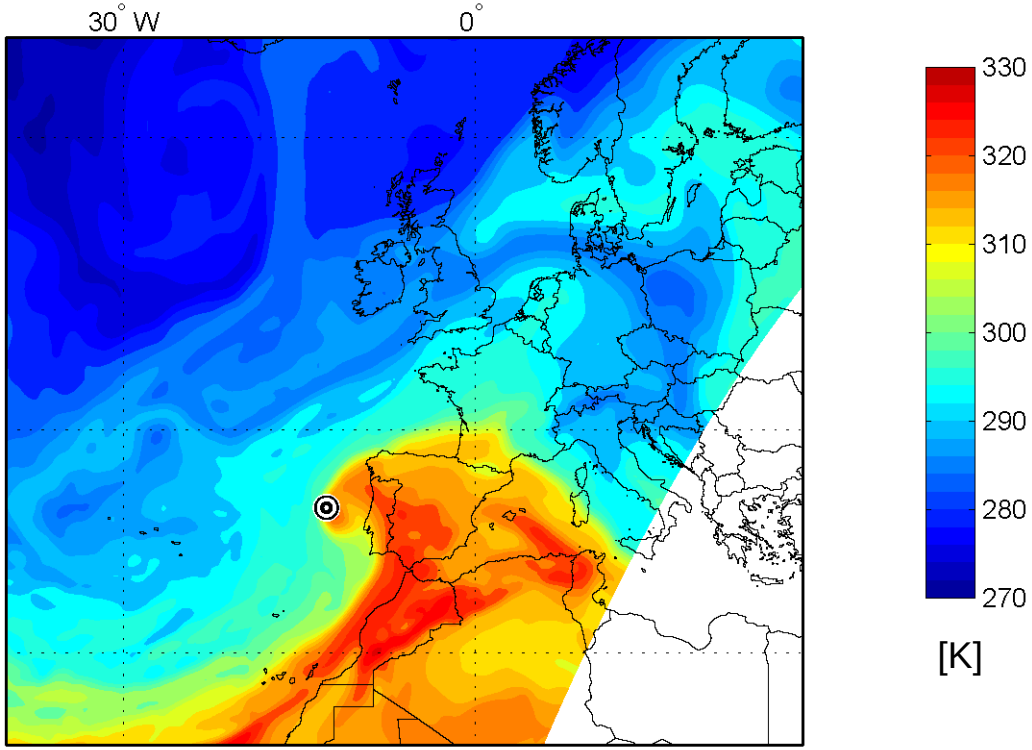
*Thanks: P. Ludwig*

# Storm Xynthia: Wind Gusts and Θe 850 hPa




Blue: ERA-Interim; Green: CCLM

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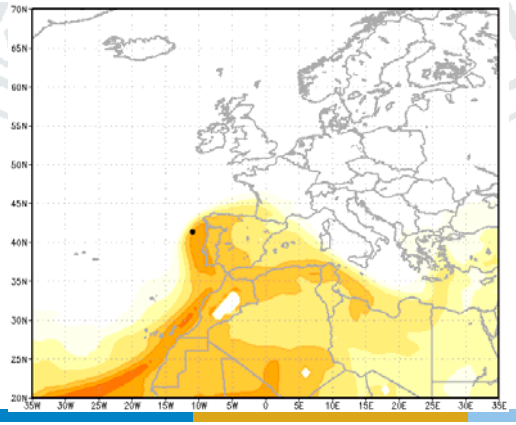
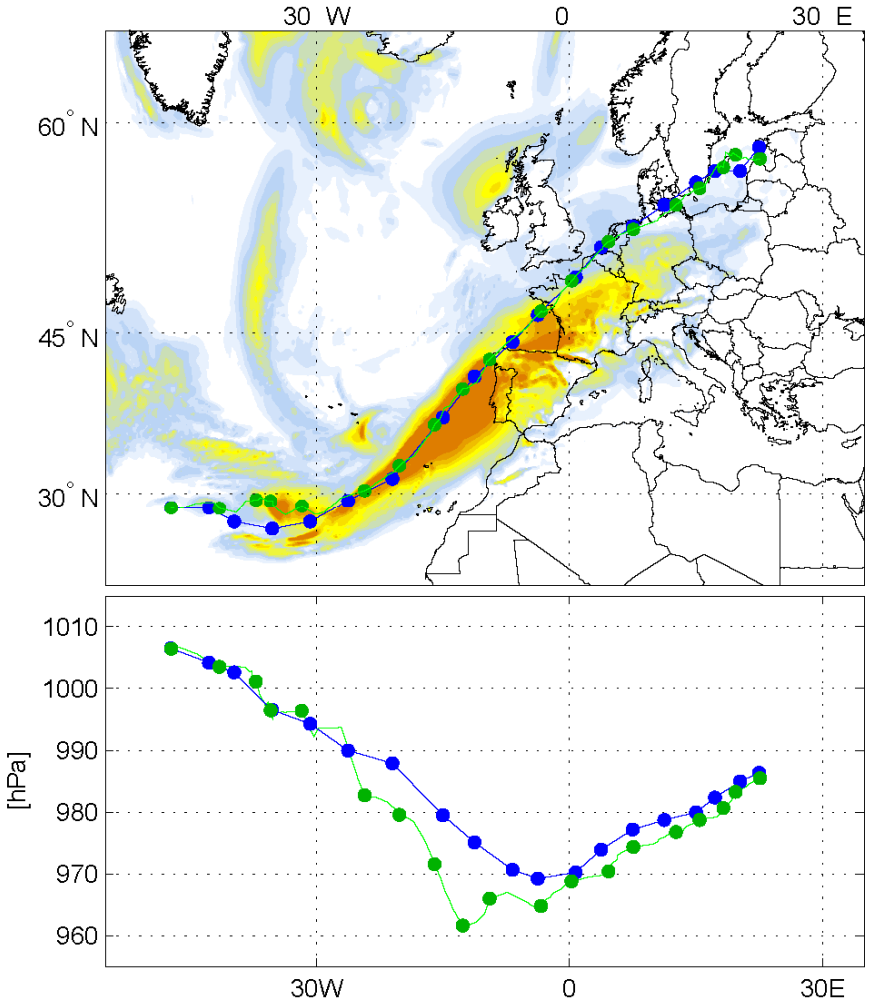
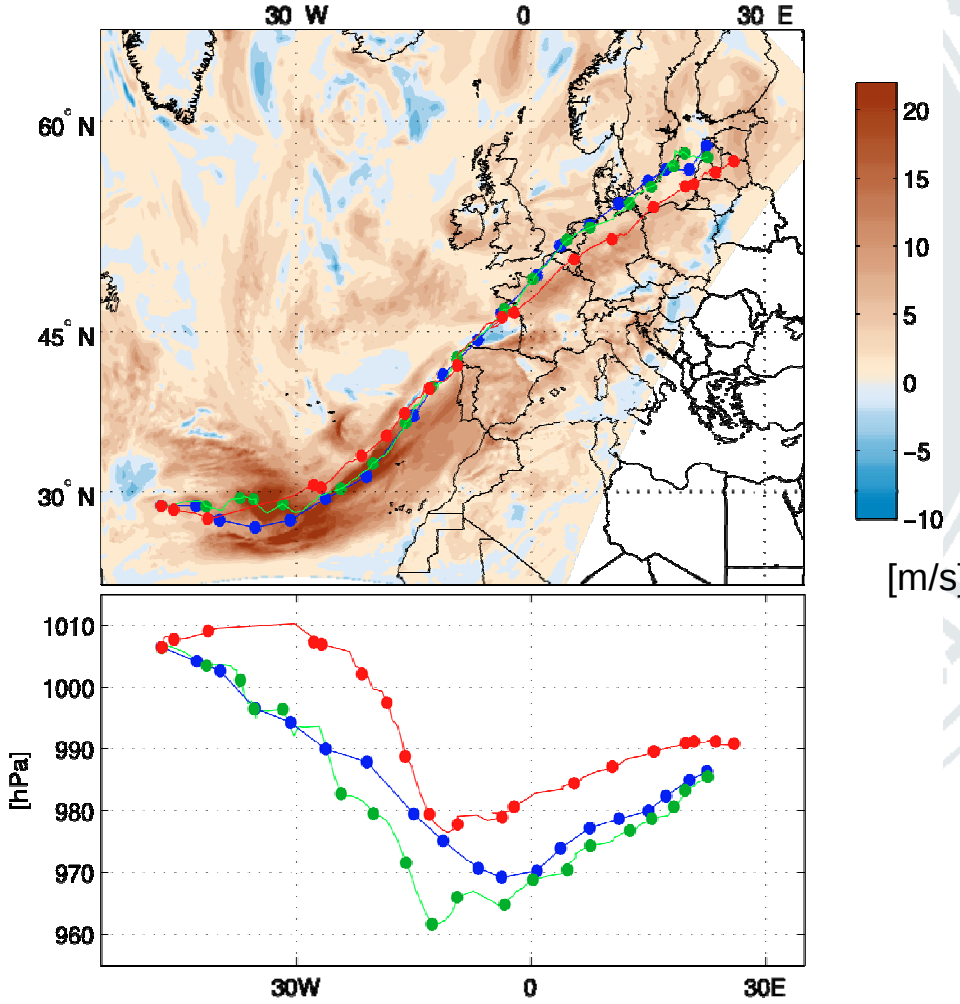


*Thanks: P. Ludwig*

# Storm Xynthia: Dry vs. Normal (Tracks and Wind Gusts)



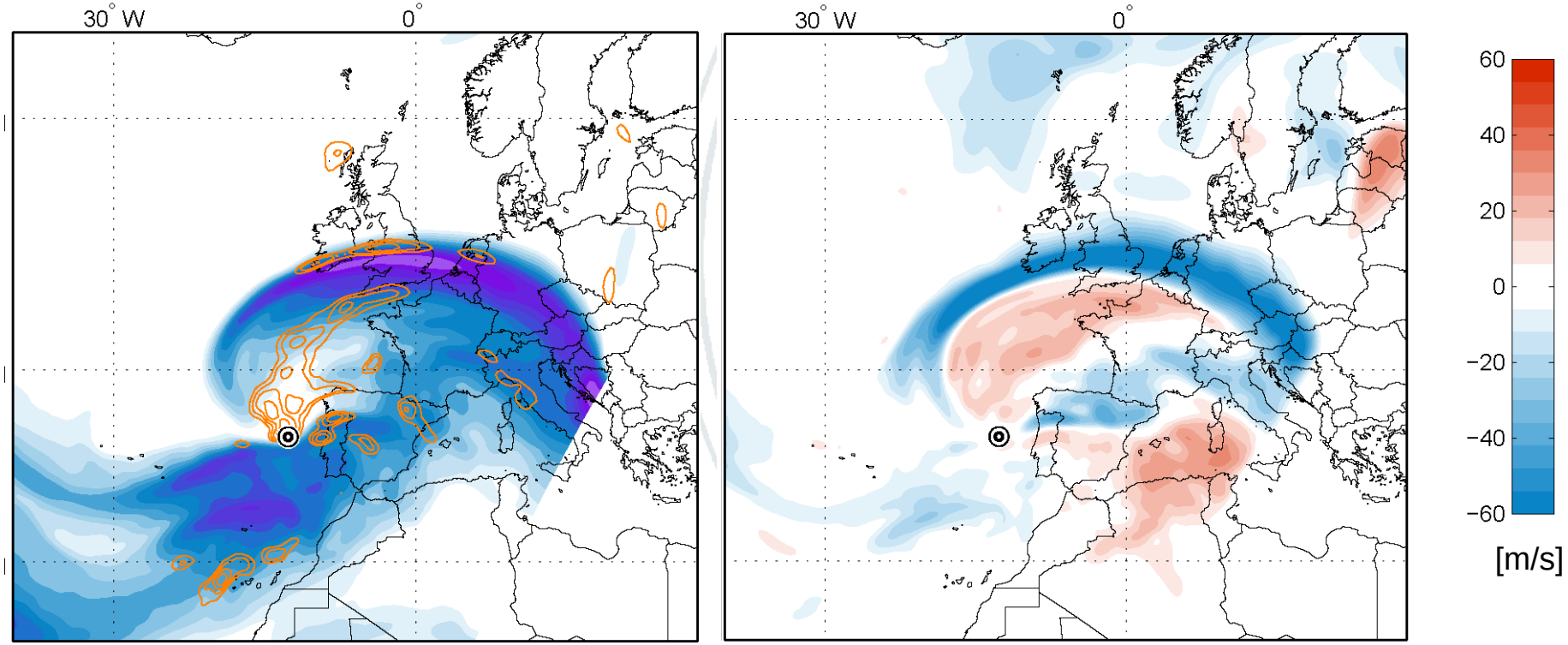

Blue: ERA-Interim; Green: CCLM

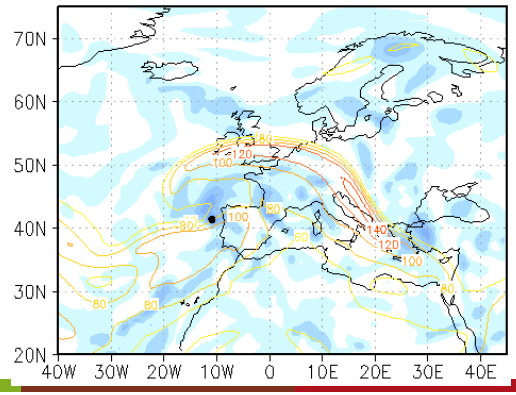



Red: CCLM-dry (50% humidity)

*Thanks: P. Ludwig*

# Storm Xynthia 27.02 12 UTC: Dry vs Normal (Jet stream 300 hPa)

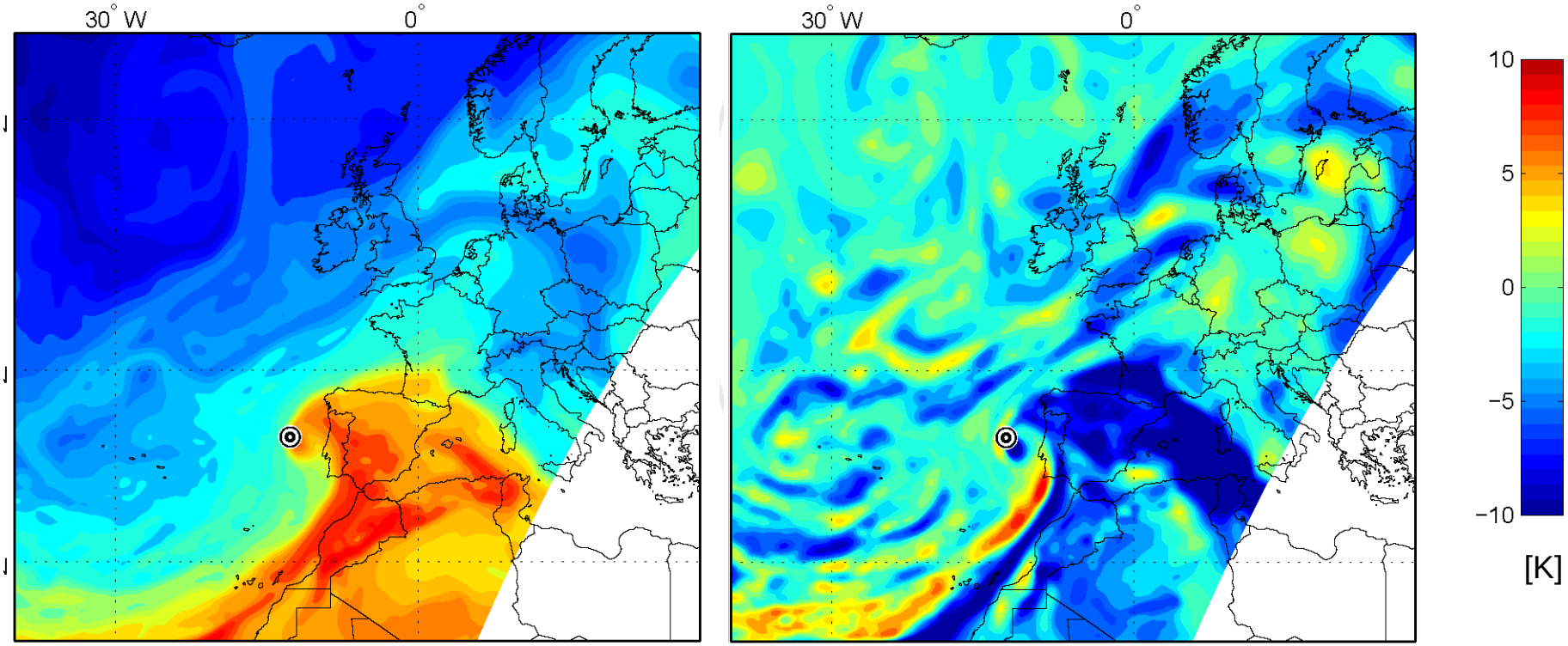


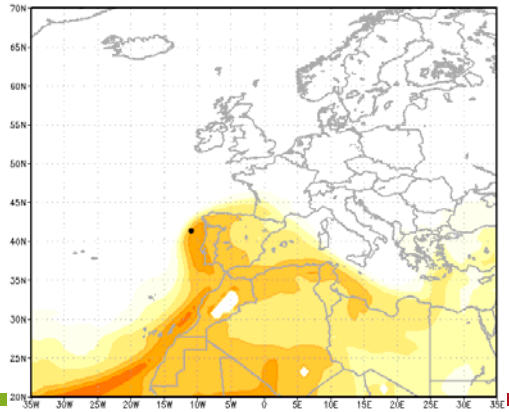




Jet streaks have similar intensity and structure; northern streak slightly shifted south

*Thanks: P. Ludwig*

# Storm Xynthia 27.02 12 UTC: Dry vs Normal (Θe 850 hPa)



Θe field has similar structure, lower Θe values in warm sector (-10 K)

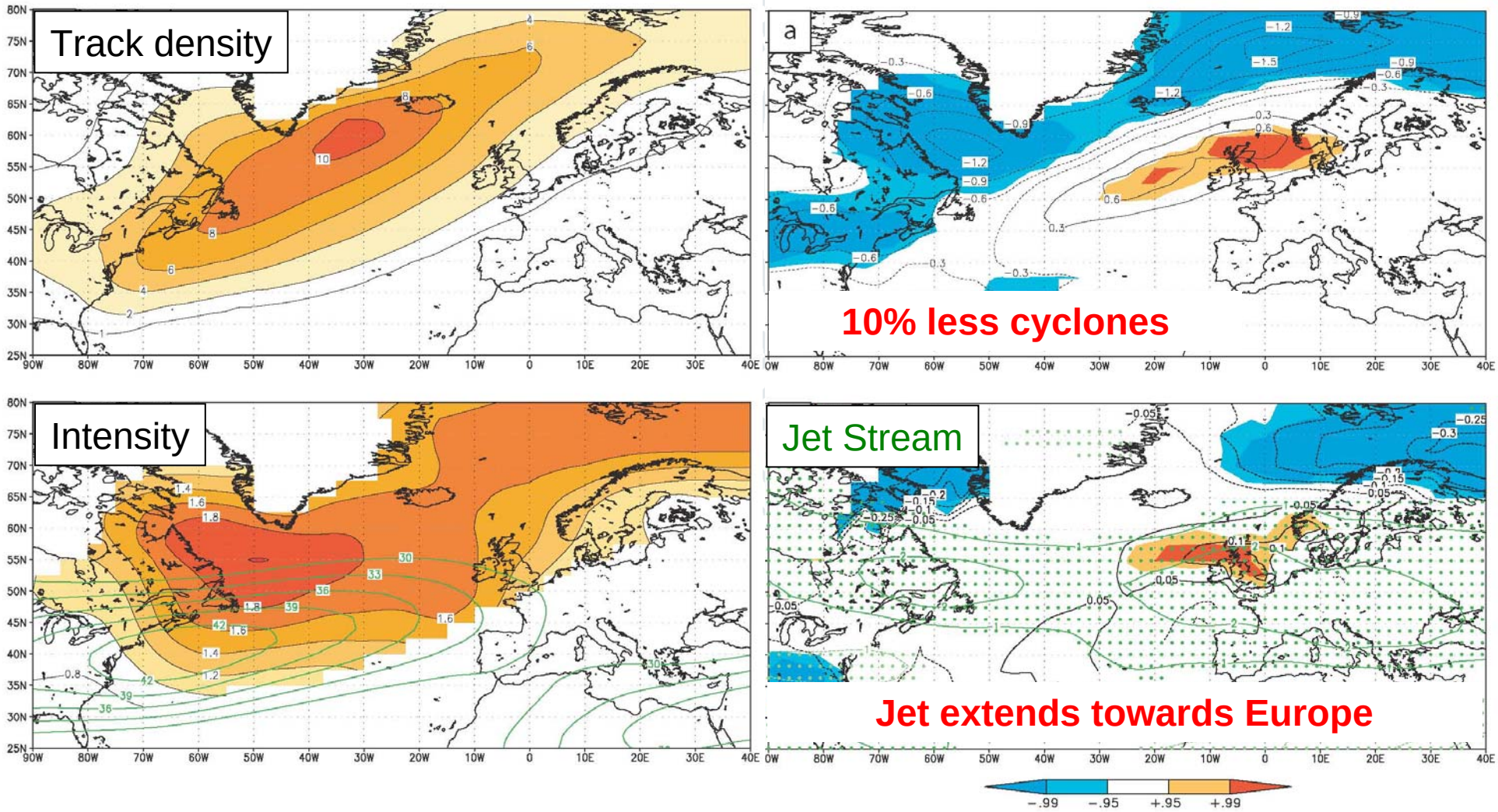
Delayed development, weaker, only reaches 978 hPa (normal: 962 hPa).

*Thanks: P. Ludwig*

# Climate change signal: Extreme cyclones in ECHAM5/OM1

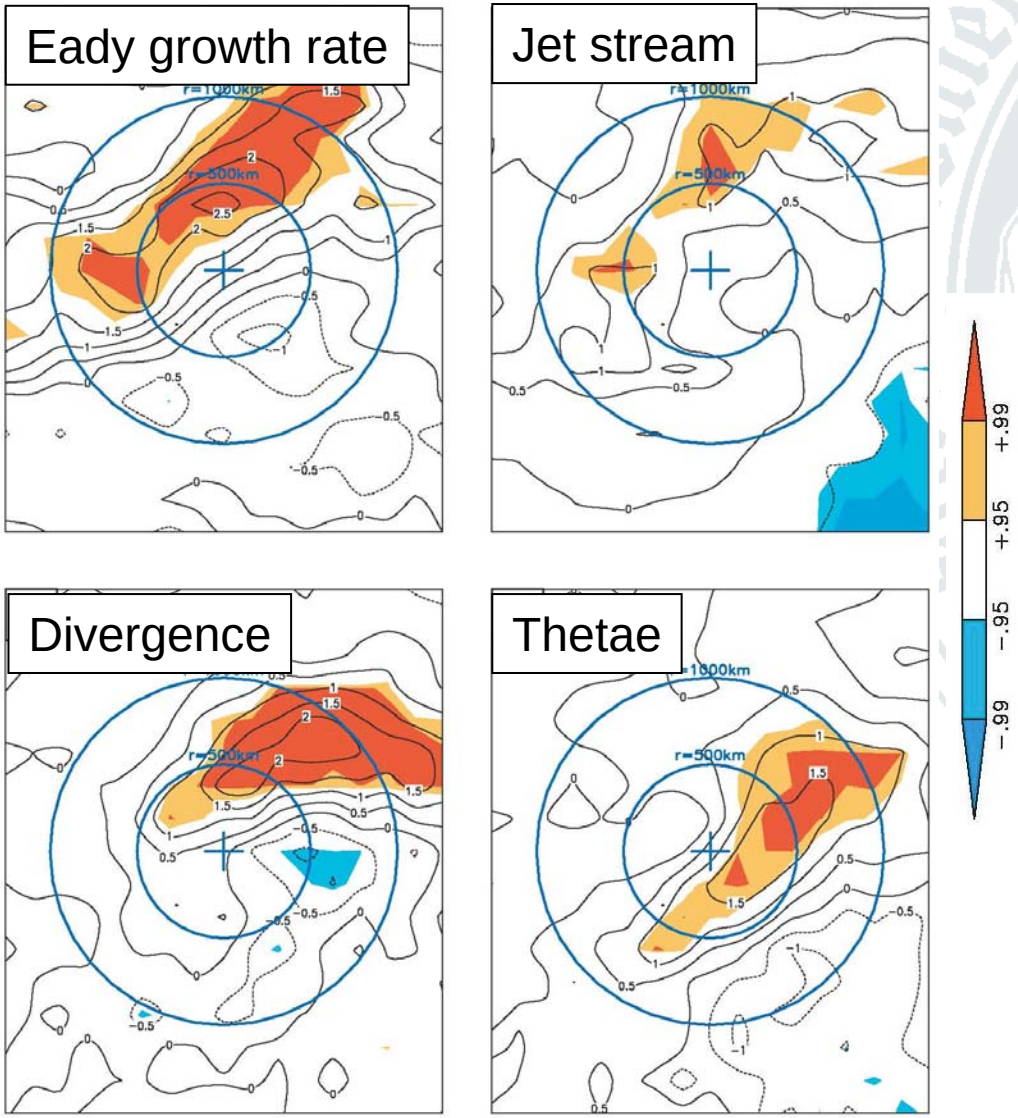
20C [1960-2000]

A1B [2060-2100] vs 20C




*Source: Pinto et al. (2009) Clim Dyn*

# Climate change signal: Enviromental factors




*Source: Pinto et al. (2009) Clim Dyn*

A1B [2060-2100] - 20C [1960-2000]

More frequent extreme values under future climate conditions

If 20C percentiles are considered, changes are even larger, in particular for $\Theta_e$

Indication of better conditions for extreme cyclone developments with enhanced GHG forcing

**More developments like Xynthia?**

# Key Messages

- Strong intensification of cyclones is associated with extreme values of $\Theta e$ (latent heat), divergence, jet stream and Eady growth rate.
- In recent years we had some cyclones with unusual characteristics, like Xynthia, with a strong diabatic influence.
- Climate change:
  - Reduced number of total cyclones, but more extreme cyclones over Eastern North Atlantic / British Isles
  - Better environmental conditions for extreme cyclone development
  - Enhanced number of explosive developments over southern North Atlantic with a strong diabatic character **?**
- **Important to analyse developments like Klaus and Xynthia in detail**

# European windstorms: diagnostics, downscaling and climate change

## Questions?

Contact: jpinto@meteo.uni-koeln.de