

A satellite image of a storm system over the Atlantic Ocean and Europe. The storm is a large, swirling mass of clouds, with a distinct eye-like structure. The colors range from dark blue (low cloud cover) to bright yellow and white (high cloud cover). The landmasses of Europe and Africa are visible in the lower right and bottom center, respectively. The text is overlaid on the top half of the image.

# Vortex-vortex interaction between Hurricane Nadine (2012) and an Atlantic cutoff dropping the predictability over the Mediterranean

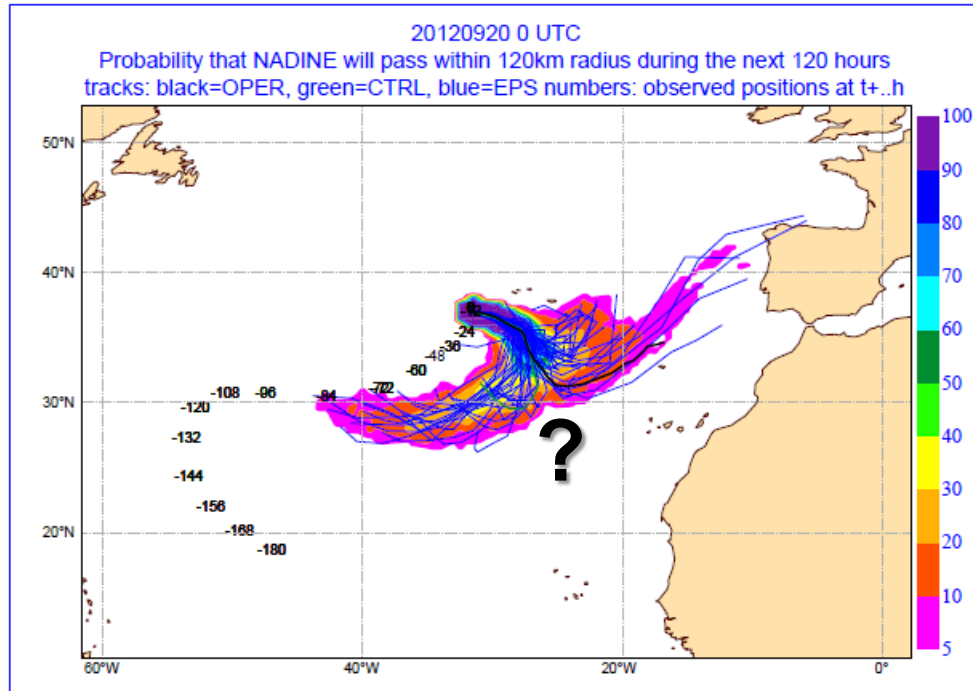
**Florian Pantillon**<sup>1,2</sup> Jean-Pierre Chaboureau<sup>1</sup> and Evelyne Richard<sup>1</sup>

<sup>1</sup> *Laboratoire d'Aérodynamique, University of Toulouse and CNRS*

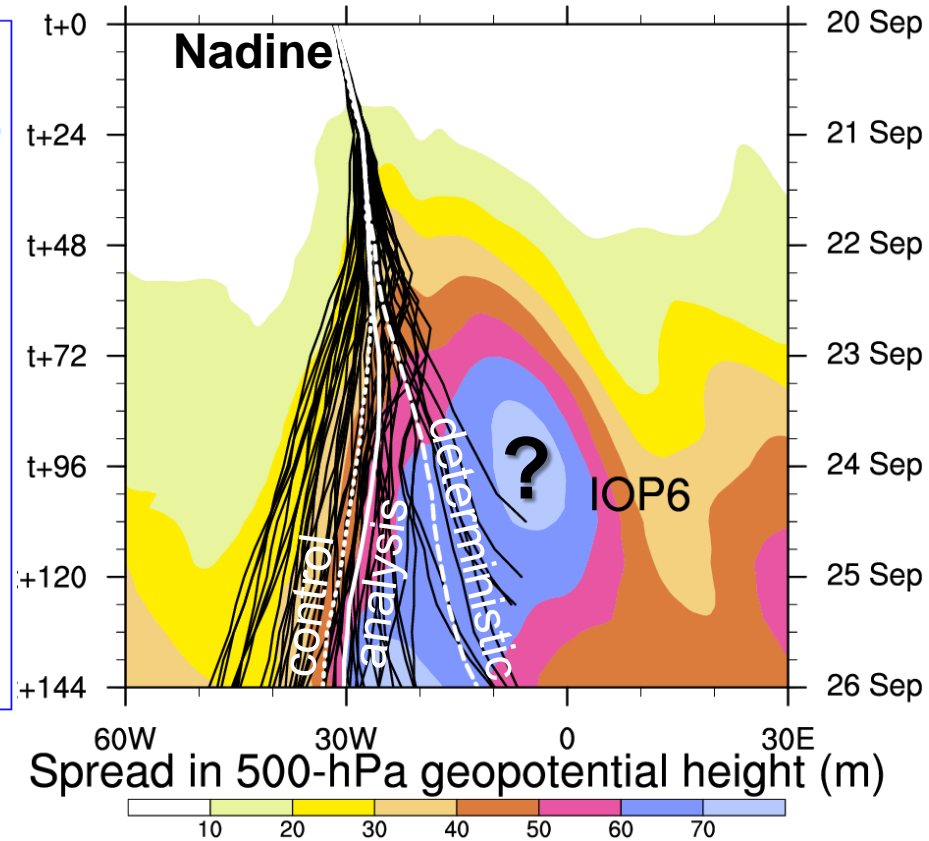
<sup>2</sup> *Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology (KIT)*

# Low predictability Nadine and downstream

ECMWF ensemble forecast initialized at 0000 UTC 20 September 2012



Track of Hurricane Nadine



Double predictability issue during HyMeX SOP1

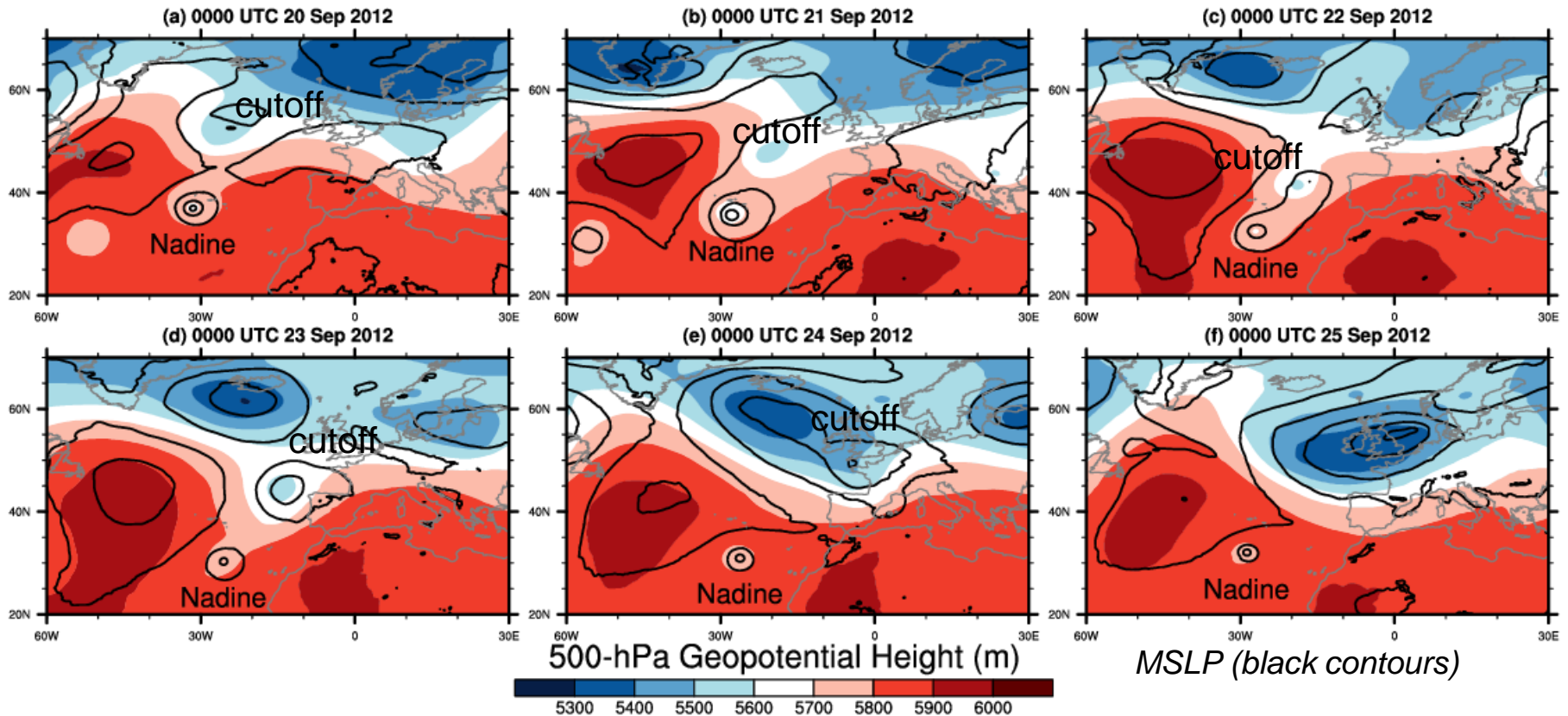
1. Landfall Nadine over Iberian Peninsula?
2. Synoptic conditions over western Europe?



# Synoptic evolution in the analysis

Track of post-tropical storm Nadine over the eastern North Atlantic

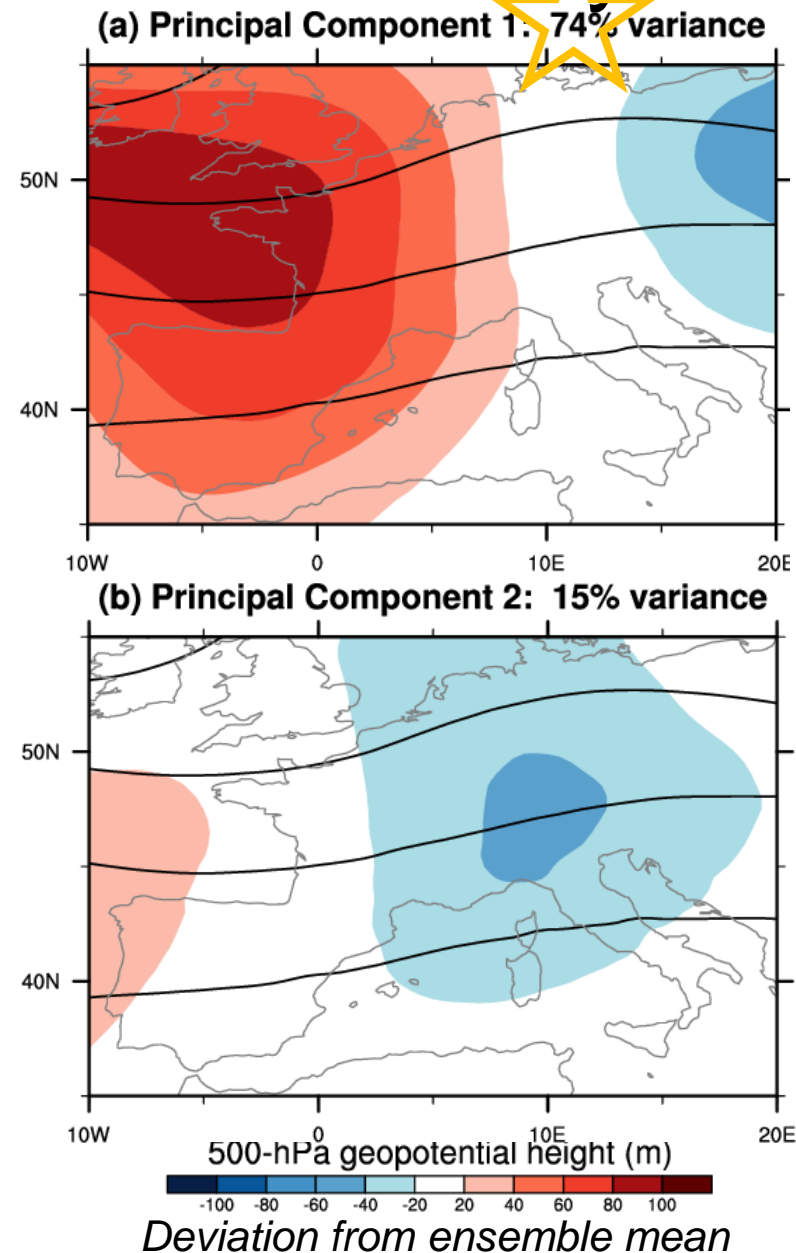
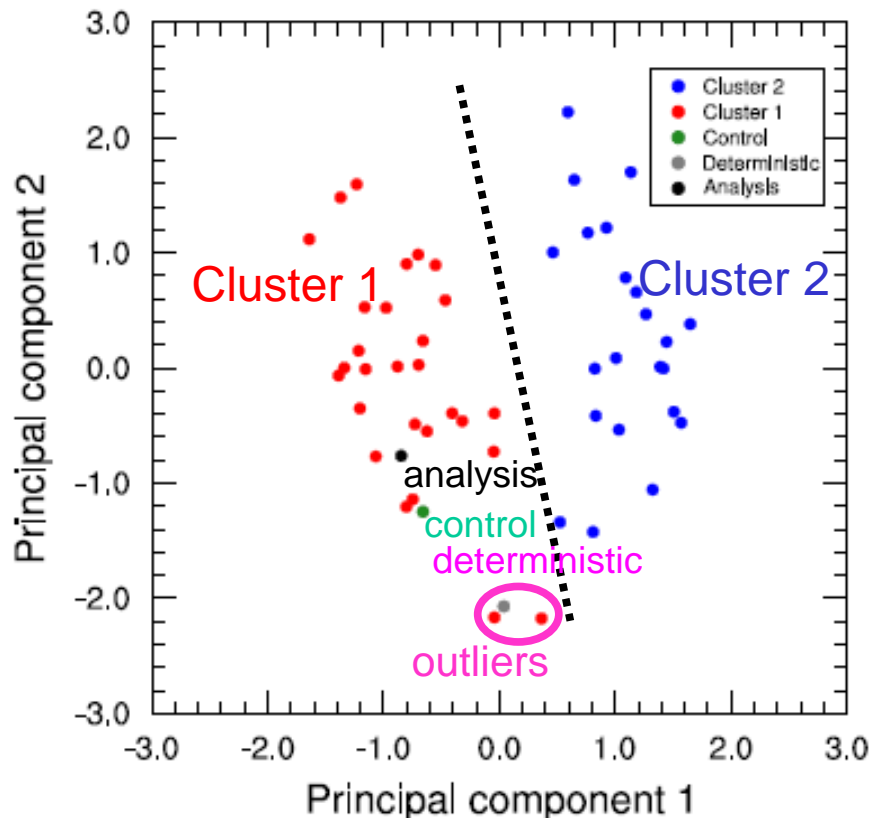
- Nadine moves slowly while a cut-off approaches from the north
- The cut-off is steered by a trough and moves eastward
- Nadine is steered by a ridge and turns westward



# Investigating the forecast uncertainty I

50 members ECMWF ensemble forecast  
initialized at 00 UTC 20 September

- 1) Principal Component Analysis  
at 00 UTC 24 September (t+96)
- 2) Ascending hierarchical classification  
with 2 clusters (arbitrary number)



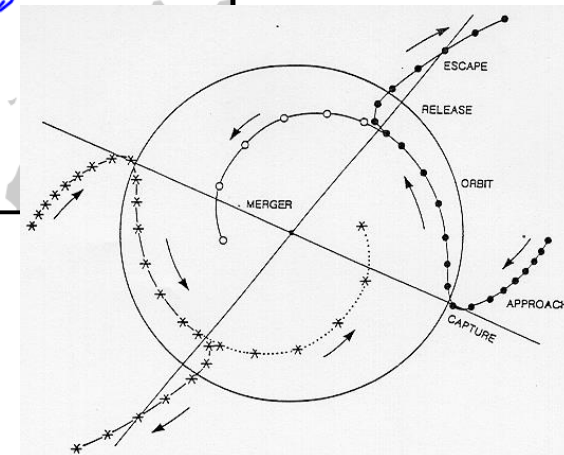
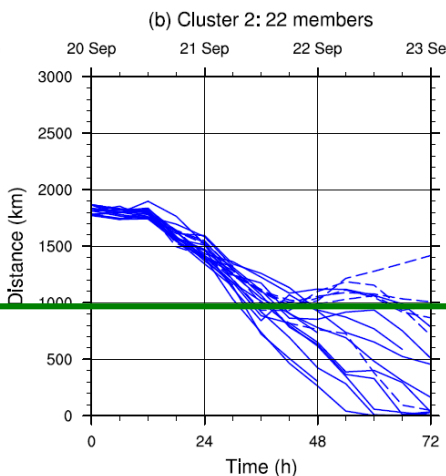
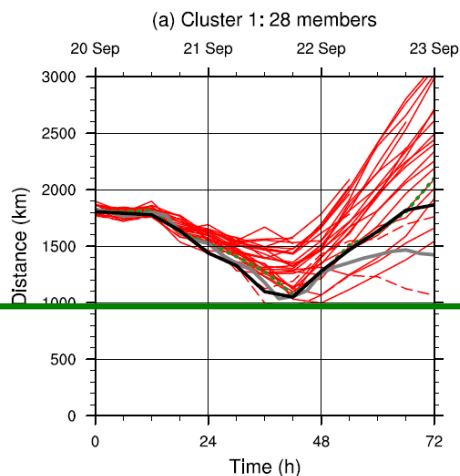
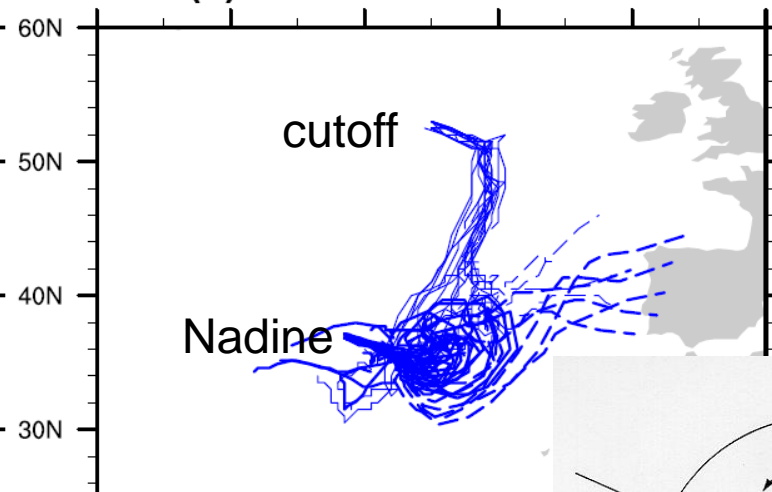
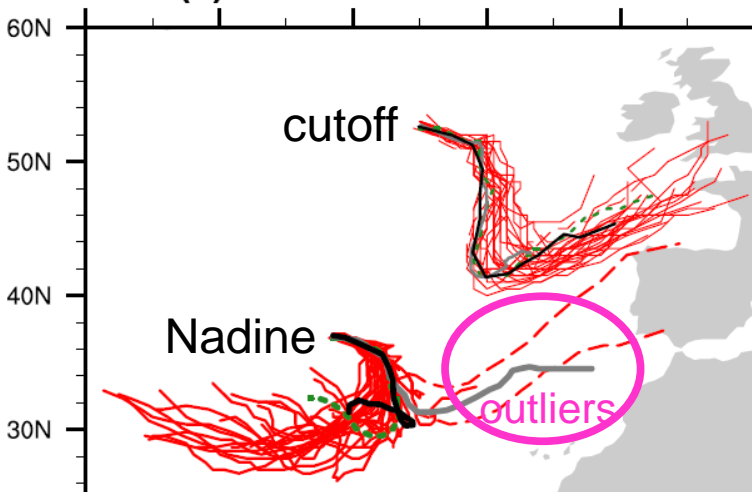
# Two scenarios for interaction Nadine-cutoff

**Cluster 1: weak interaction**  
Nadine moves westward  
The cutoff moves eastward

(a) Cluster 1: 28 members

**Cluster 2: strong interaction**  
Nadine merges with the cutoff  
or escapes and makes landfall

(b) Cluster 2: 22 members



*Matches vortex-vortex interaction  
between two tropical cyclones*

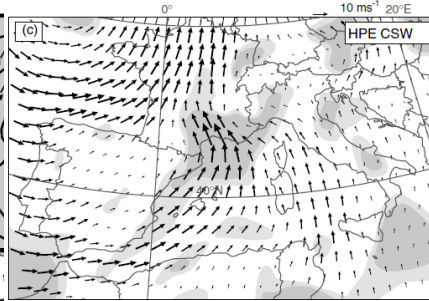
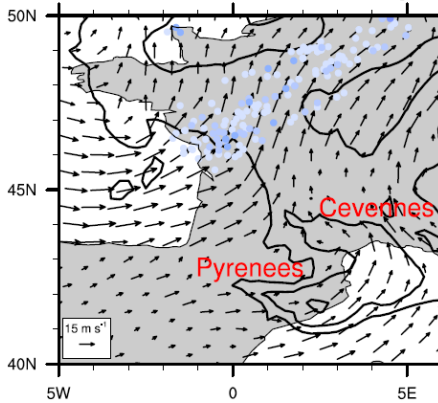
*Lander and Holland 1993, QJRMS*

# Impact on the Mediterranean

Obs: cutoff → cyclonic flow  
 → Moisture towards Cévennes  
 + orographic forcing  
 = 70 mm / 6 h

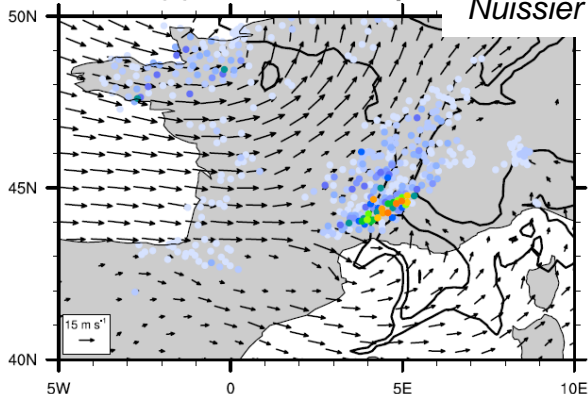
Cluster 1: cyclonic flow → moisture → precipitation

(a) 0000 UTC 24 Sep 2012

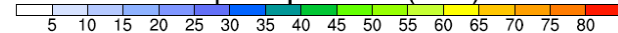


Typical situation of heavy precipitation  
*Nuissier et al. QJRMS 2011*

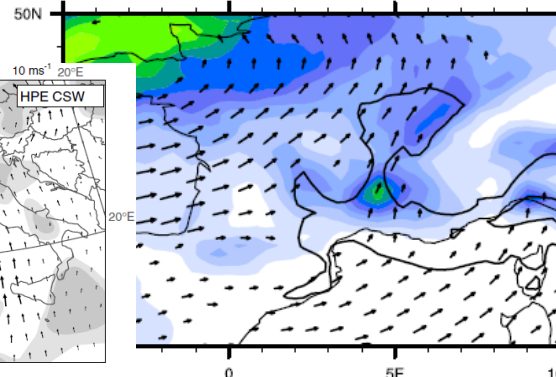
(b) 0600 UTC 24 Sep 2012



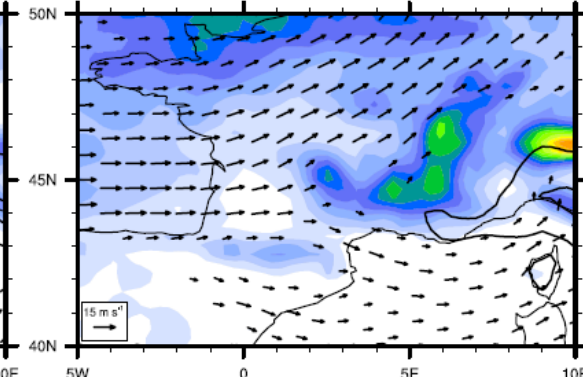
6-h precipitation (mm)



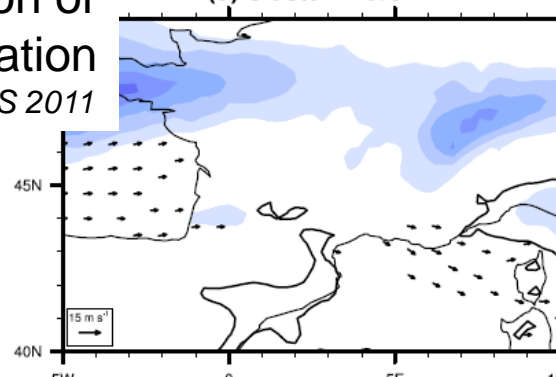
(a) Cluster 1: t+84



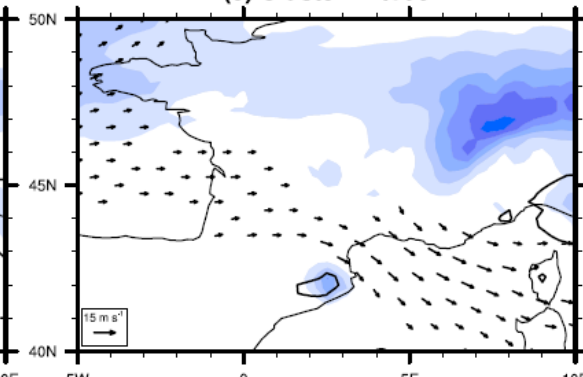
(b) Cluster 1: t+96



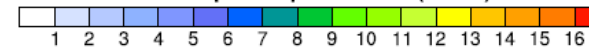
(d) Cluster 2: t+84



(e) Cluster 2: t+96



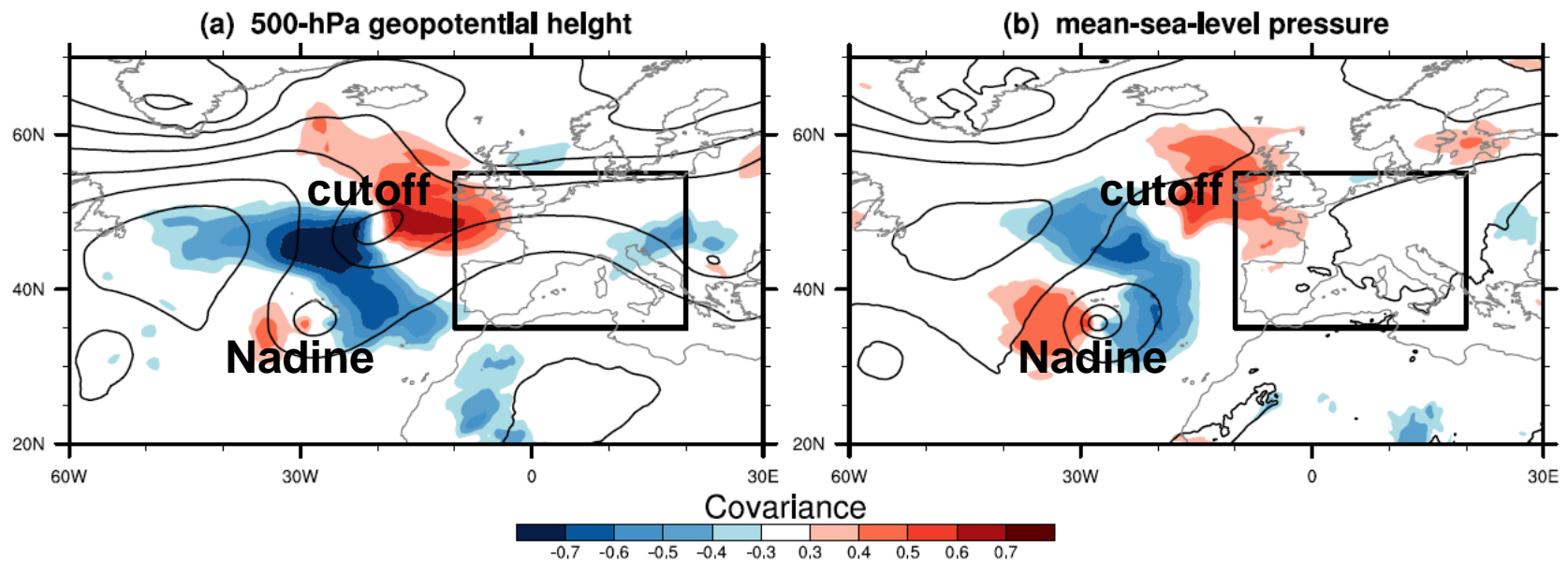
12-h precipitation (mm)



Cluster 2: no cyclonic flow → no precipitation

# Investigating the forecast uncertainty II

1. Ensemble sensitivity analysis (*Torn and Hakim 2008*) at t+24:  
at each point, covariance with principal component 1 among 50 members  
→ **sensitivity to east/westward shift in position Nadine and cutoff**

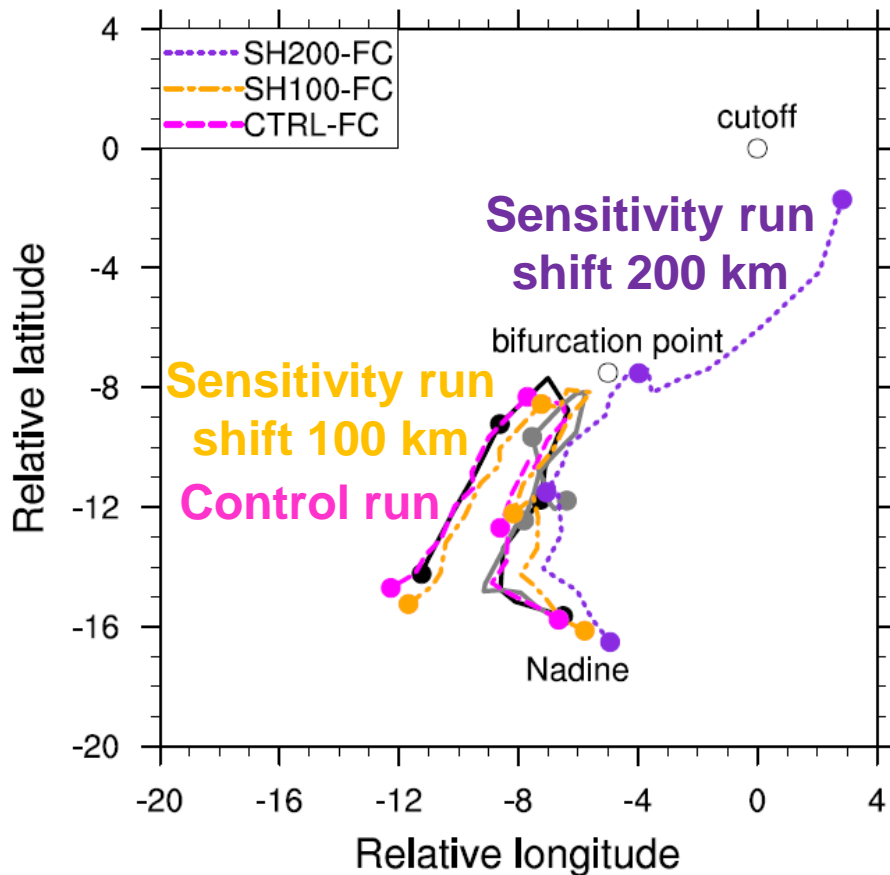


but based on linear assumptions...

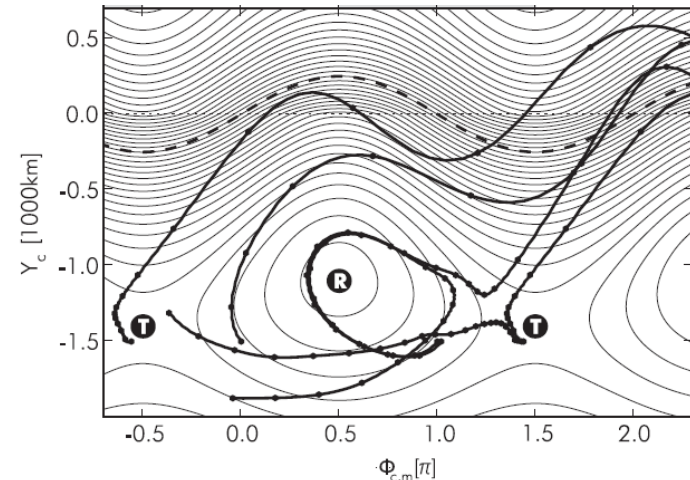
2. Numerical experiments with the Meso-NH model:
  - control run initialized from the ECMWF analysis at 00 UTC 20 September
  - sensitivity runs with initial location of Nadine shifted 100/200-km eastward



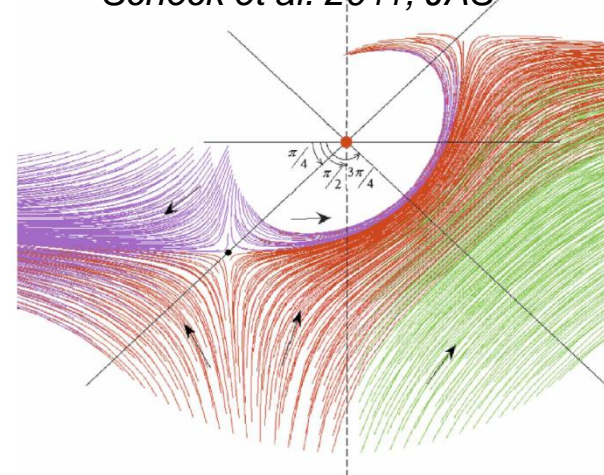
# Bifurcation point in position relative to cutoff



*High sensitivity to relative position  
→ high uncertainty in ensemble forecast!*



**Similar:** bifurcation point in environmental flow cyclone during interaction with trough  
*Scheck et al. 2011, JAS*



**Best match:** bifurcation point in relative position during vortex-vortex interaction in background flow  
*Liu and Roebber 2008, JAS*



# Conclusion

Double predictability issue related to Hurricane Nadine during HyMeX SOP1

- **Uncertain track** of Nadine with possible landfall over Iberian Peninsula
- **Uncertain synoptic conditions** over western Europe downstream

Clustering ECMWF ensemble forecast + Meso-NH sensitivity experiments

- **Two scenarios** of weak vs. strong interaction between Nadine and cutoff
- **Critical distance** ~1000 km and **bifurcation point** in relative position  
→ Matches **vortex-vortex interaction** between two tropical cyclones

*The landfall of Nadine did not occur, does it belong to the model world only?*

- Landfall possible as tropical cyclone (Vince 2005) or after ET (Gonzalo 2014)
- Landfall hurricanes more likely in future climate (Haarsma et al. 2013)  
→ *Scenarios of landfall should be considered during vortex-vortex interaction!*

# Future work

Within DFG project Waves to Weather:  
“Forecast uncertainty for peak surface gusts associated with European cold-season cyclones”

Multiscale approach

for predictability windstorms

- **Synoptic scale:** track and intensity storms in global ensemble forecast
- **Mesoscale:** e.g. cold pools and sting jets in regional ensemble forecast
- **Turbulent scale:** downward mixing of momentum in large-eddy simulations

***Comments and suggestions  
are welcome!***

