Impact of Hurricane Nadine on the predictability of severe weather in the Mediterranean

The extraordinary life of Hurricane Nadine

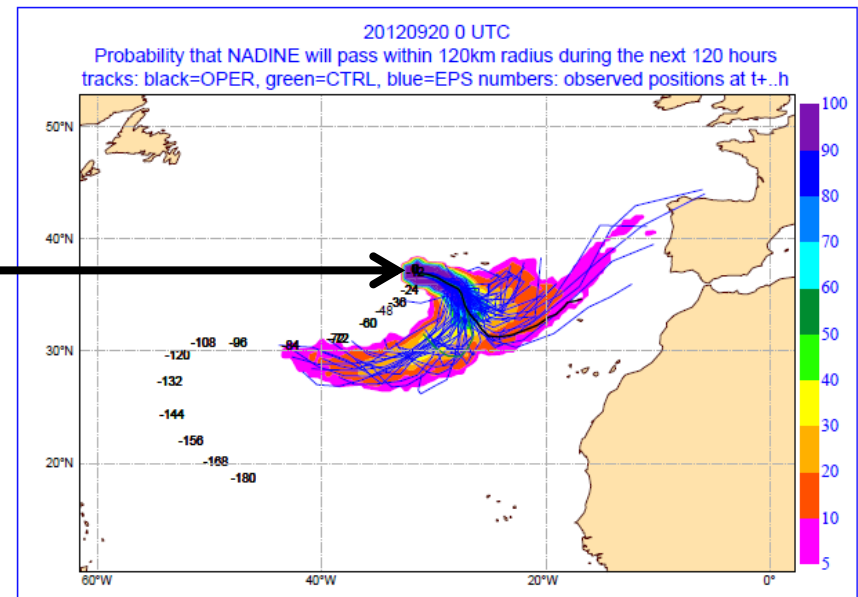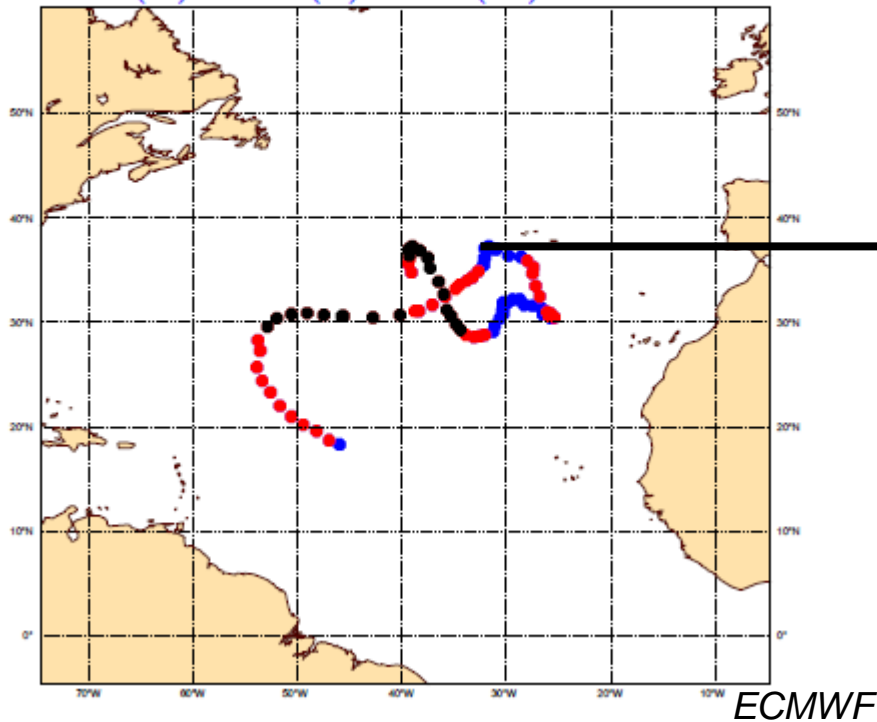Unusual long and complex life cycle in September-October 2012
- 22 days (4th longest in history)
- Loops over the eastern Atlantic
- 2 periods with hurricane strength

Low predictability over the eastern Atlantic
- **bifurcation** in operational forecasts between eastward and westward tracks
- similar to bifurcation in cyclone tracks during interaction with upper-level trough *(Scheck et al. 2011, Grams et al. 2013, Pantillon et al. 2013, Riemer and Jones 2013)*

OBSERVATION TRACKING FOR NADINE (14L)
CYCLONE LIFETIME : 20120912 TO 20121002

● 1 (TD)   ● 2 (TS)   ● 3 (STS)   ● 4 (TYP/HUR)

ECMWF

20120920 0 UTC
Probability that NADINE will pass within 120km radius during the next 120 hours
tracks: black=OPER, green=CTRL, blue=EPS numbers: observed positions at t+..h

ECMWF ensemble forecast initialised at 00 UTC 20 Sep

HyMeX field campaign in Autumn 2012

HyMeX
HYdrological cycle in Mediterranean EXperiment
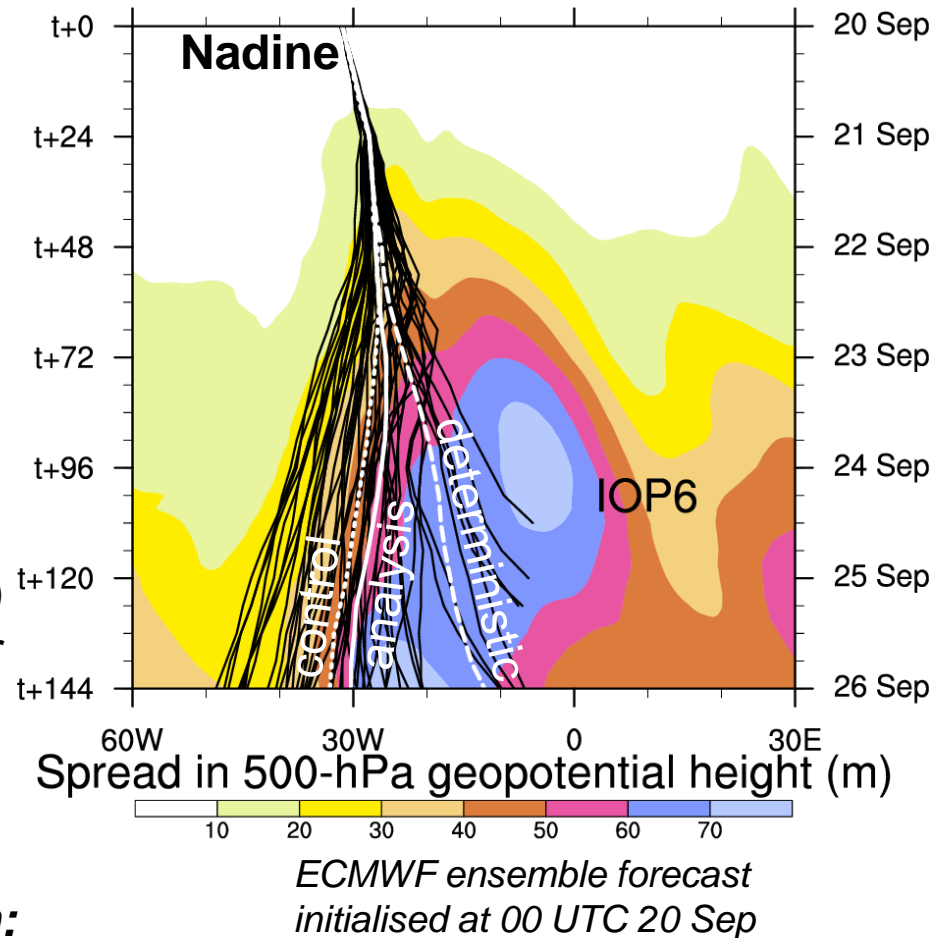
Special Observation Period 1 (SOP1)

- Area: northwestern Mediterranean

- Target: heavy precipitation
  and flash floodings

- Period: September-October 2012

Predictability during SOP1:
  Highest spread (= lowest predictability)
  in ensemble forecast on 24 September

1. downstream of Hurricane Nadine

2. upstream of heavy precipitation:
   Intense Observation Period 6 (IOP6)

impact of Nadine on the Mediterranean:
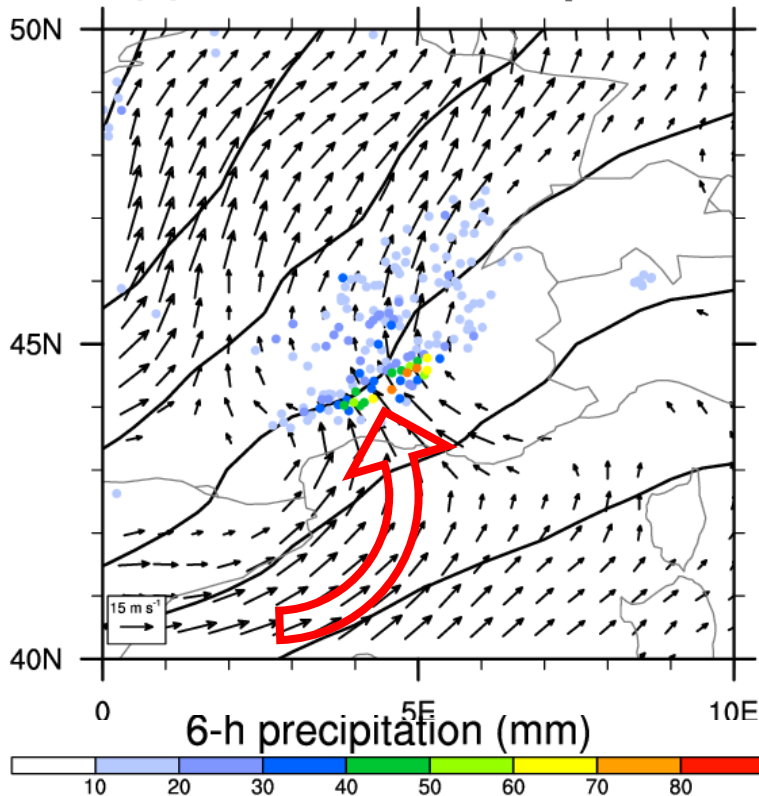
predictability issue during HyMeX SOP1

Spread in 500-hPa geopotential height (m)

*ECMWF ensemble forecast
initialised at 00 UTC 20 Sep*

IOP6: episode of heavy precipitation

Convective line on 24 September

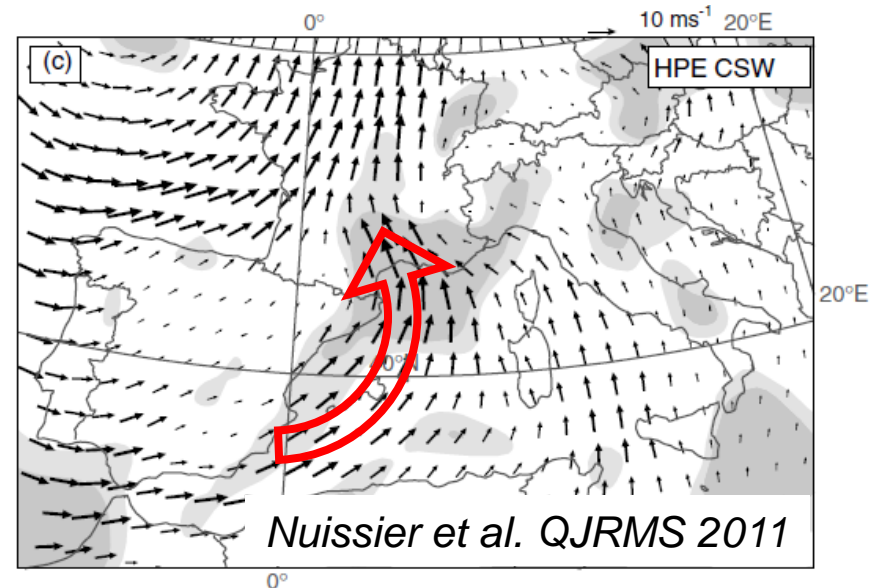- >70mm/6h over the Cévennes

- 184mm over northeastern Italy

Synoptic conditions

- trough over southwestern Europe

- strong low-level moisture flux towards the topography

Precipitation observation from HyMeX database
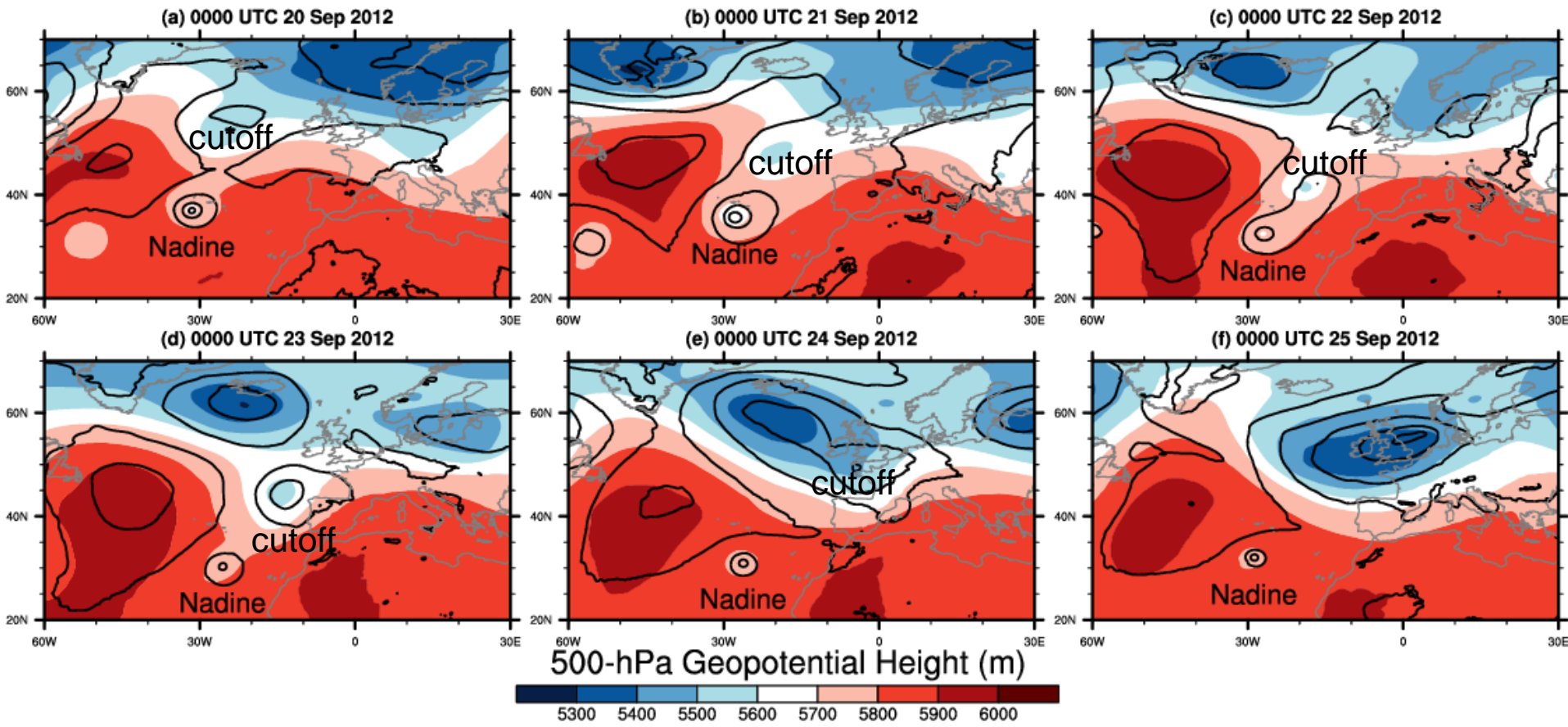*500-hPa geopotential and 925-hPa wind from ECMWF*

Nuissier et al. QJRMS 2011

typical conditions for heavy precipitation in the northwestern Mediterranean

Synoptic evolution 20-25 September

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
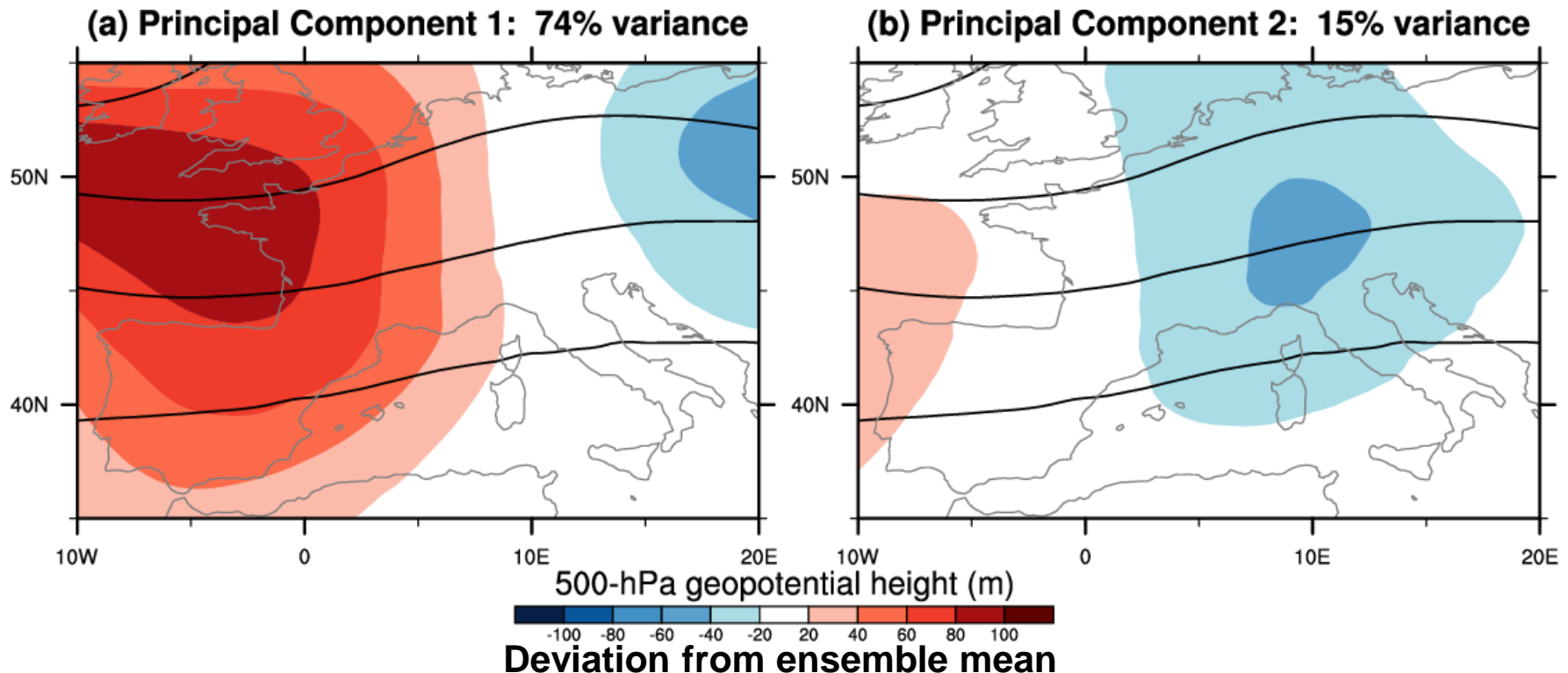

500-hPa Geopotential Height (m)

Understanding the forecast uncertainty I

ECMWF ensemble forecast (dx=30km)
initialized at 00 UTC 20 September

- 50 perturbed members + 1 control
- Initial perturbations: singular vectors
- Also perturbed physics during run

Principal Component Analysis

- Target: 00 UTC 24 September (t+96)
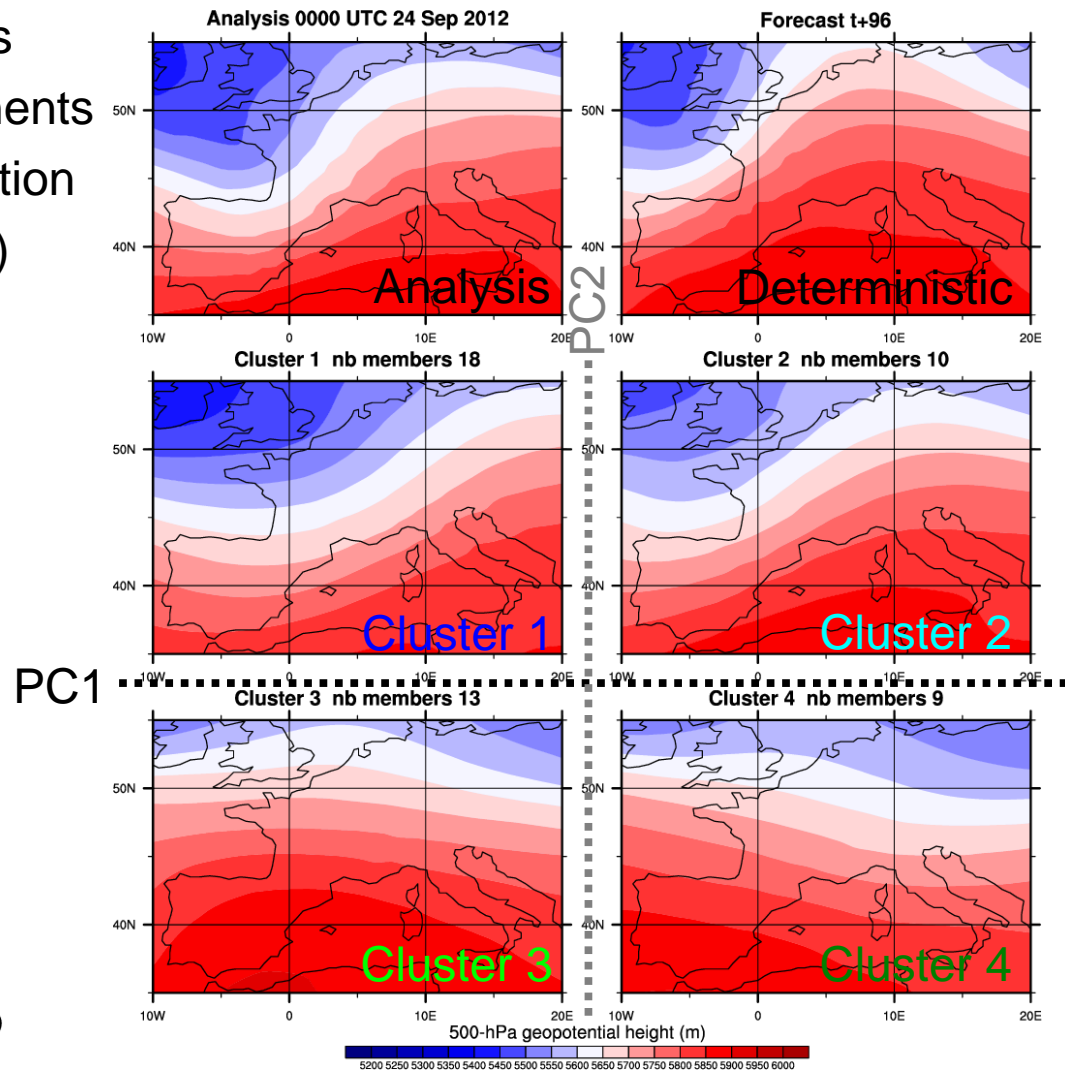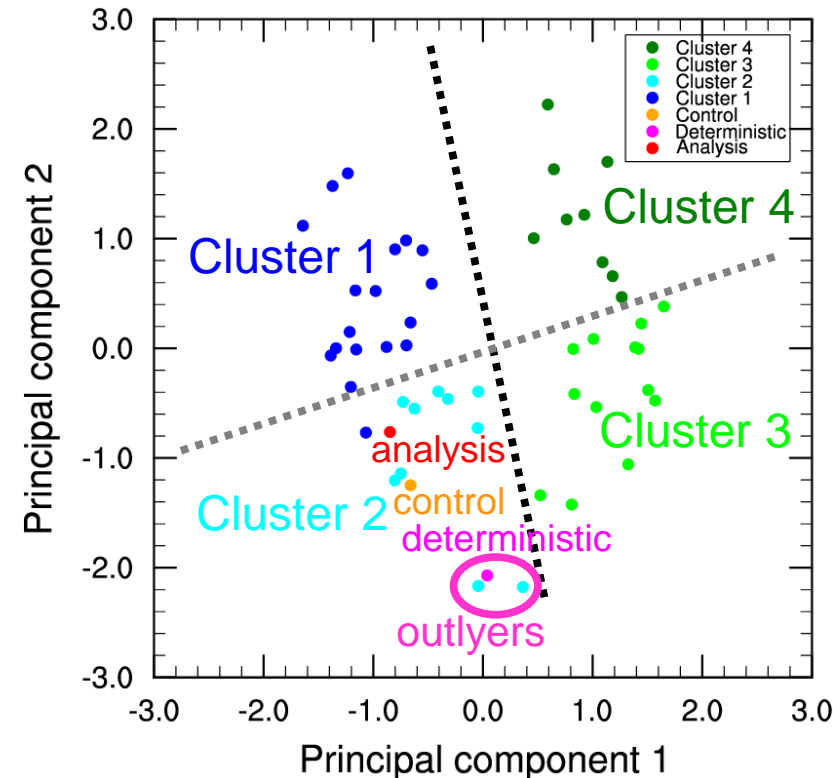- Field: 500-hPa geopotential height
- Area: northwestern Mediterranean

PC1 accounts for 3/4 of variance!

(a) Principal Component 1: 74% variance
(b) Principal Component 2: 15% variance

500-hPa geopotential height (m)
-100 -80 -60 -40 -20 20 40 60 80 100
Deviation from ensemble mean

Understanding the forecast uncertainty II

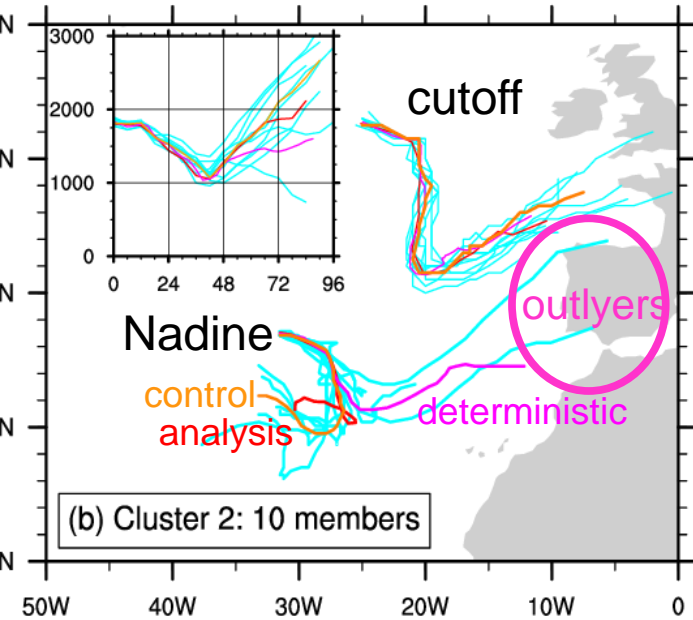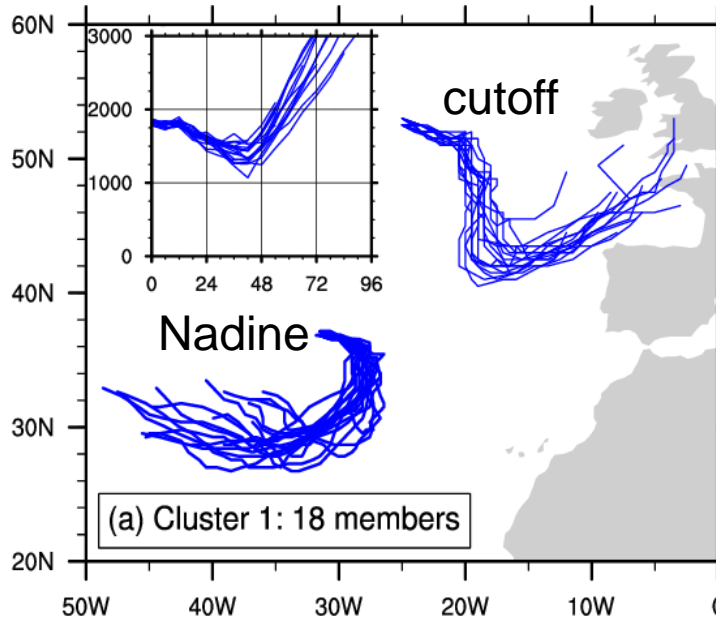Clustering of 50 ensemble members

- projection on 2 principal components
- ascending hierarchical classification
- number of clusters = 4 (arbitrary)

cf. Harr et al. (2008), Anwender et al. (2008):
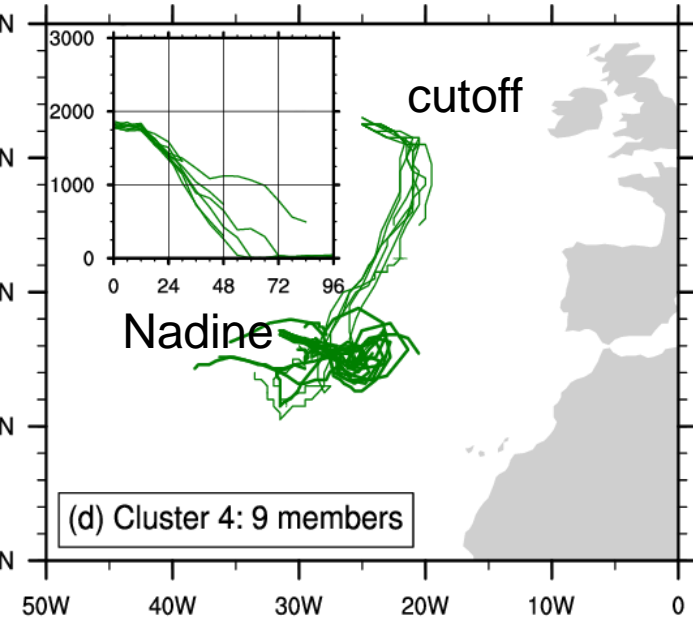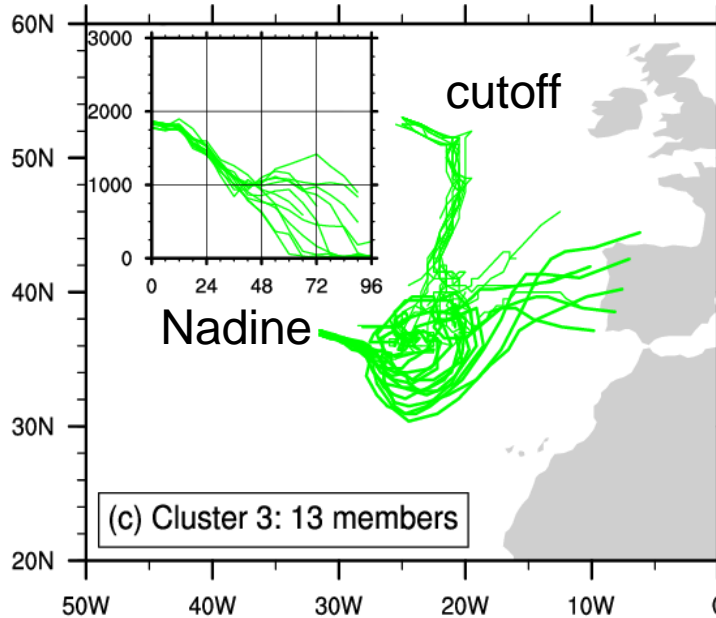*downstream impact of cyclones during extratropical transition*

4 scenarios for Nadine-cutoff interaction

1. weakest interaction
Nadine moves westward
cutoff moves eastward

(a) Cluster 1: 18 members

2. weak interaction
Nadine moves slower
cutoff moves slower

(b) Cluster 2: 10 members

control
analysis
deterministic
outlyers

3. strong interaction
Nadine makes landfall
cutoff moves southward

(c) Cluster 3: 13 members

4. strongest interaction
Nadine merges with cutoff

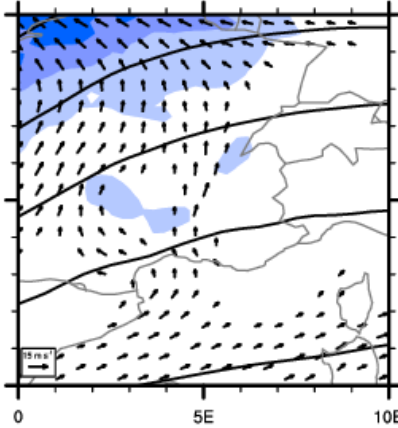(d) Cluster 4: 9 members

cutoff
Nadine

Predictability of precipitation during IOP6

1. weakest interaction cutoff over Europe
2. weak interaction delayed cutoff
3. strong interaction no cutoff
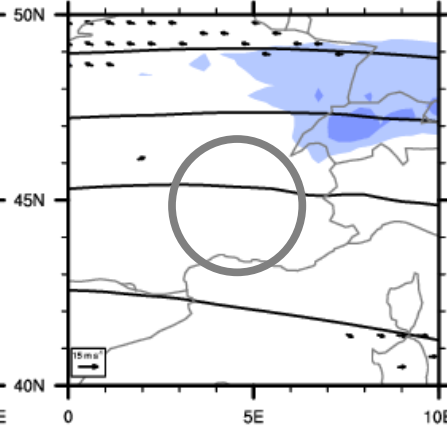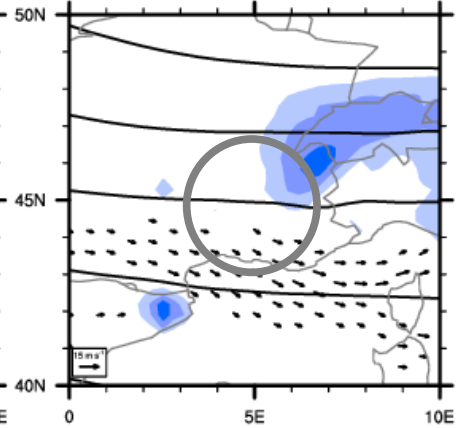4. strongest interaction no cutoff

Precipitation but too early

Good timing of precipitation

No precipitation over the Cévennes

Conclusions

Double predictability issue during HyMeX SOP1 in Autumn 2012

- Forecast uncertainty in the track of Hurricane Nadine

- High ensemble spread over southwestern Europe

Cluster analysis -> **crucial interaction of Nadine with a cut-off low**

1. Weak interaction: the cut-off low moves eastward and triggers heavy precipitation during HyMeX IOP6 (actual scenario)

    -> Cluster analysis supports interpretation in case of low predictability

2. Strong interaction: Nadine makes landfall over the Iberian Peninsula (in model world only… is it realistic?)

    -> Vince 2005 *(Tapiador et al. 2007)* and 1842 cyclone *(Vaquero et al. 2008)*

    -> More common landfall of hurricanes as extratropical cyclones

    -> Higher risk of hurricane landfall in future climate *(Haarsma et al. 2013)*

Beyond the cluster analysis: understanding Nadine-cutoff interaction

    -> PV inversion to quantify their mutual impact *(e.g. Wu et al. 2002)*