What does a cloud-resolving model bring during an extratropical transition?

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Motivation

- Forecasting the interaction between a Rossby Wave Train (RWT) and a cyclone during its Extratropical Transition (ET) is a challenge.
- The interaction involves strong diabatic processes from the cyclone outflow and frontal precipitation (Riemer et al. 2010, Torn 2010, Grams et al. 2011).
- RWTs can trigger high-impact weather downstream (e.g. Martius et al. 2008).
- Diabatic processes are parametrised in global models, only a few studies of ET used a cloud-resolving model.

*What does a cloud-resolving model bring during ET?*
Period of interest: September 2006
High-impact weather on Europe during 3 successive Atlantic ETs

- Heavy rain in the Mediterranean downstream of ET Florence
- Strong winds on the European coasts from ET Gordon
- Medicane (Mediterranean hurricane) downstream of ET Helene

ECMWF analysis, 40-60°N average

ECMWF ensemble forecast, 40-60°N average
Interaction of Florence and Helene with RWTs

IR and ECMWF 9 Sep 00 UTC

Globally merged InfraRed observation and 2-PVU contour at 250 hPa from ECMWF analysis

merg_all.gif  movie_IR.mpg
High-impact weather triggered from RWTs

Cut-off low
downstream of Florence (ET+96h):
24-h precipitation accumulation > 100 mm
(www.wettergefahren-fruehwarnung.de)

Potential vorticity streamer
downstream of Helene (ET+96h):
Medicane intensification by jet crossing
(Chaboureau et al, QJRMS 2012)

Infrared observation from MSG
on 1527 UTC 26 September

Precipitation rate (shading, mm/h) from AMSU-B
and 250-hPa potential vorticity (contour at 2 PVU)
on 1200 UTC 16 September
Model configuration

Mesoscale model Meso-NH
- Initialisation ECMWF analysis
- Run Florence 12-17 September
- Run Helene 22-27 September

Sensitivity to model resolution
- Cloud-resolving HiRes dx = 4 km
- Regional mode LowRes dx = 24 km
- Deep and shallow convection schemes
ET Florence: results of simulations

- Strong intensification during wrap-up of trough from RWT
- Good track until end of wrap-up then southeastward drift
- HiRes and LowRes show very close track and precipitation
ET Helene: results of simulations

- 3 intensifications during wrap-up of 3 PV filaments from RWT
- Good track until 3rd wrap-up then **bifurcation LowRes vs. HiRes**
- More precipitation LowRes than HiRes during 3rd intensification
ET Helene: precipitation in HiRes & LowRes

- Observation: rainband north of Helene and front to the northeast
- HiRes & LowRes similar, both underestimate frontal precipitation

*Origin of the bifurcation in the track of Helene in LowRes vs. HiRes?*
ET Helene: high sensitivity in phasing with RWT

1200 UTC 24 Sep (t+60)

1200 UTC 25 Sep (t+84)

MSLP (green contours) and 250-hPa wind (blue arrays over 30 m/s)
ET Helene: forecast of the Medicane

- HiRes & LowRes miss the elongation of a trough into PV streamer
- As a consequence, both miss the development of the Medicane
- The improvement of track in HiRes has no impact downstream
- But a strong impact is found when Helene is removed at initialisation

10500-m contour of the 250-hPa geopotential height
What does a cloud-resolving model bring during an extratropical transition?

- Weak impact on precipitation of Florence and Helene
- Improvement of track Helene from a better phasing with RWT
- No improvement on the development of a Medicane downstream

How can we improve the downstream development?

- Convection partially resolved at 4 km -> increase of resolution
- Lack of frontal precipitation -> perturbation of microphysics
- Sensitivity of phasing -> perturbation of initial conditions
Sensitivity to model resolution

- ET Florence: 24-h run at 1-km resolution for fully explicit convection
- Similar frontal precipitation and downstream ridge than 4-km run

Precipitation (shading, mm/h), 925-hPa $\theta_e$ (red contours each 10 K) and 925-hPa wind (arrows over 10 m/s)
Sensitivity to model microphysics

- ET Helene: increased latent heat in order to increase ridge building
- Cloud structure improved along front to the northeast of Helene (on-going work...)

Radar reflectivity (shading, dBZ), normal wind (blue contours over 30 m/s) and tangent wind (arrows over 30 m/s) in south-north vertical cross-sections through the warm front to the northeast of Helene
Sensitivity to initial conditions

- Perturbations from the ECMWF Ensemble Prediction System (EPS)
- Select member with the Medicane and the best position of Helene
- Meso-NH run from targeted initial perturbations at 0000 UTC 22 Sep

- Perturbed phasing: stronger wrap-up of trough accelerates Helene
- Increased ridge building improves elongation of downstream trough
Medicane forecast in perturbed Meso-NH run

- Perturbed Meso-NH run matches observation and MSLP analysis
- Medicane intensifies by jet crossing, rotates around larger-scale low
- No Medicane when initial perturbations on complementary domain

The forecast of the Medicane at t+108 is possible in a Meso-NH run from perturbations on Helene and the upstream trough only
Predictability of the Medicane in EPS

- 8, 7, 5 members forecast the Medicane at 60-h, 84-h, 108-h lead time

**What increases the predictability of the Medicane?**

- Method: clustering of all EPS members from 00 UTC 20-23 Sep based on synoptic conditions over western Europe at 12 UTC 26 Sep
- Two patterns found: trough-ridge-trough vs. broad trough and low

*Shading: target field for hierarchical clustering. Black contours: MSLP*
Joint predictability of Helene and the Medicane

Helene in cluster 1
- Correct track until 25 Sep
- Good phasing with RWT

11 Medicanes

Helene in cluster 2
- Bifurcation before 25 Sep
- Missed phasing with RWT

1 Medicane only

The forecast of the Medicane requires a correct forecast of ET Helene
Conclusions I: deterministic forecast

- The ET of Helene was unique
  - 3 regular intensifications occurred during the wrap-up of 3 filaments of potential vorticity from a Rossby wave train
  - A small difference in the phasing with the Rossby wave train led to the bifurcation of the track of Helene after ET
  - The Rossby wave train triggered the development of a Medicane downstream of ET

  Pantillon et al. « On the role of a Rossby wave train during the extratropical transition of Helene » QJRMS, in press

- The downstream development was not improved by an increase of resolution, which had a small impact on the precipitation during ET

*Is the uncertainty too high during ET for a deterministic forecast?*
Conclusions II: ensemble forecast

- The Medicane was forecast at midrange
  - 8, 7 and 5 out of 50 members of the ECMWF ensemble were successful at 60-h, 84-h and 108-h lead time
  - A correct phasing of Helene with the Rossby wave train during ET was necessary to forecast the Medicane
  - Initial perturbations targeted on Helene and an upstream trough led to the development of the Medicane at t+108

Pantillon et al. « Predictability of a Mediterranean tropical-like storm downstream of the ET of Helene », MWR, to be submitted

*Can an alert for high-impact weather downstream of ET be issued at midrange from 10-20% of ensemble members?*
If you travel to Italy in September, check the ensemble forecast!
Operational forecasts of Helene and Medicane

Day of initialization
25 Sep 24 Sep 23 Sep 22 Sep 21 Sep 20 Sep

Lead time (h)
36 60 84 108 132 156

Potential temperature on the 2-PVU surface (K)
Downstream propagation of uncertainty
Principal component analysis