Probabilistic Evaluation of Prediction and Dynamics of Super Typhoon MEGI (2010)

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Overview of Megi’s Activity and Forecasts

Megi’s best track (13-24 Oct. 2010)

Super Typhoon MEGI
strongest TC over the globe in 2010
peak intensity
max. winds: 72m/s
min. pressure: 890hPa

Megi’s peak intensity before striking Philippines
(infrared imagery at 18:05UTC, 17 Oct. 2010, NOAA-18)

Turning to the north since daytime of 20 Oct. 2010
(visible imagery at 03:00UTC, 20 Oct. 2010, FY-2E)
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Megi started turning to north since 0000 UTC 20 Oct.

Best track

CMA Official 5-day track Forecasts

2100UTC 17 Oct.  
(~2 days before turning)

2100UTC 18 Oct.  
(~1 day before turning)

1200UTC 19 Oct.  
(~half day before turning)
Official Forecasts by Different Typhoon Centers

All of three official forecasts show left-track bias after Megi entered the South China Sea, over-predicting the westward motion.
The questions are:

- How about the performance of ECMWF deterministic forecasts? Good enough?
- If the ECMWF ensembles tell us the “turning signal” ahead of the sharp turning?
Research Motivation

Truth:
- Official forecasts nearly **failed to predict the turning point** before the track sudden change.
- Some **good members** of ECMWF ensembles really showed turning signals at 1200UTC of 17 October, however, the **big uncertainty** due to broadly diverged spread of ensembles gave operational forecasters little confidence to draw an right decision.

Try to answer:
- what are the main reasons resulting in Megi’s sharp turning?
- What causes some “good” members to give off the right signal prior to the truly happened turning and others (“poor” members) not?
- What reasonable conclusion could be reached by forecasters facing big uncertainty from NWP guidance?
- What are the lessons learned from the unusual case of rapid change in TC track?
Data and Methodology

ECMWF Ensemble Data:
✓ thinned global Gaussian grid
✓ resolution of 0.28125 degrees in X, 640 levels in Y and 9 levels in Z
✓ 6-h interval
✓ twice per day for initial time of 0000 and 1200 UTC.

ECMWF Ensemble Tropical Cyclone Track Data:
✓ Cyclone XML (CXML) format
✓ TC center position in latitude/longitude
✓ minimum pressure and maximum wind near center
✓ with 6-h interval for deterministic forecast and 12-h for control and perturbations
✓ issued twice per day for initial time of 0000 and 1200 UTC

✓ Composite analysis
✓ Correlation analysis
✓ Dynamic diagnosis
good group:
the 10 ensemble numbers are 1, 2, 6, 7, 11, 19, 23, 31, 41, and 46 respectively

poor group:
the 10 ensemble numbers are 4, 5, 16, 17, 20, 28, 32, 36, 37 and 45 respectively

ensemble forecasts of 1200UTC 17 October

Composite analysis
Comparison Analysis between Good (blue) and Poor (red) Groups

500hPa height analysis based on 1712UTC ensemble fcsts with time interval 12h from 00h to 96h (blue contours are for good group and red for poor group). TC centers of the two group separate gradually as time goes forward.

Major differences:
1) Moving speed
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2) TC size
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**Major differences:**

1) Moving speed
2) TC size
3) Sub-tropical High strength
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**Major differences:**

1) Moving speed  
2) TC size  
3) Sub-tropical High strength  
4) Trough strength
Does the TC’s early movement really have relation with afterward track?

The first 24-h TC movements really have relationship with the afterward track forecast errors (or track turning effect).
Correlation and 120-h ensemble mean of 500hPa height based on initial time 1200 UTC 17 Oct.

Positive correlation of TC 24-h movement to 120-h 500hPa height covers areas of NE SCS, Taiwan island and SE China, that is really where Megi impacted later.
TC size analysis between good (blue) and poor (orange) group based on vortex-following framework (TC centers are shifted to one point)

12Z17OCT2010 700hPa HGT 0000h fcst good(blue) vs poor(orange)

12Z17OCT2010 700hPa HGT 0024h fcst good(blue) vs poor(orange)

12Z17OCT2010 700hPa HGT 0048h fcst good(blue) vs poor(orange)

12Z17OCT2010 700hPa HGT 0072h fcst good(blue) vs poor(orange)

Bigger-sized TC has stronger “erosion” impact on the size and strength of the sub-tropical high, resulting in a slower movement.
Turning Angle $\alpha = \arctg((\text{lon}_0-\text{lon}_1)/(\text{lat}_0-\text{lat}_1))$

Turning Angle has 120-h track forecast information.

Basically, the smaller the turning angle, the better the track

To calculate correlation of (earlier) height fields to (later)
Turning Angle based on Vortex-following framework
1) Within 1.5 degrees or even more less distance from TC center, the correlation value is small (+ 0.2 ~ - 0.2), meaning MEGI’s track sudden change has no big relation with the TC inner core intensity.

2) However, TC structure has really strong correlation with its later track change, especially on TC’s northern and western sides, where TC has strong interaction with environment.

3) Westerly trough really makes contribution to TC track change, due to its eastward movement, lowering the height in southern China and northern TC, which is favorable for TC’s track change to the north.
Correlation of 500hPa heights to turning angle based on the initial time of 1200 UTC 17 October

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Correlation of 500hPa heights to turning angle based on the initial time of 1200 UTC 17 October
- wrong guidance by ECMWF deterministic forecasts
- too much weight was put on low level steering flows
850hPa winds of ECMWF deterministic forecasts based on initial time of 1200 UTC 17 October, shaded are u winds, arrows are horizontal winds persistent and dominant northeast winds on the north side of TC center
Environmental Steering Flow

the average flow within the 5-7 degrees ring
Orange arrows for 51 members’ steering flows, blues for TC movements within the next 12h
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Megi’s track change has close relation with its earlier movement, a slower movement is favorable for its afterward turning to the north.

TC’s size or structure plays a very important role in its movement, bigger TC has stronger “erosion” on the strength of the Sub-tropical High, resulting in relatively weaker steering flows and then a slower TC movement.

Megi’s intensity has less impact on its track than its size or structure.

Westerly trough also makes contribution the Megi’s turning to the north, due to its interaction with Sub-tropical High and TC.

Upper level flows are the dominant steering flow in determining the TC track’s sudden change.
Thanks for your attention

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850hPa winds of ECMWF deterministic forecasts based on initial time of 1200 UTC 17 October, shaded are u winds, arrows are horizontal winds 

persistent and dominant northeast winds on the north side of TC center