Recent Studies with HWRF Using the Hurricane Ensemble Data Assimilation System (HEDAS)

Sim Aberson

HWRF Meeting
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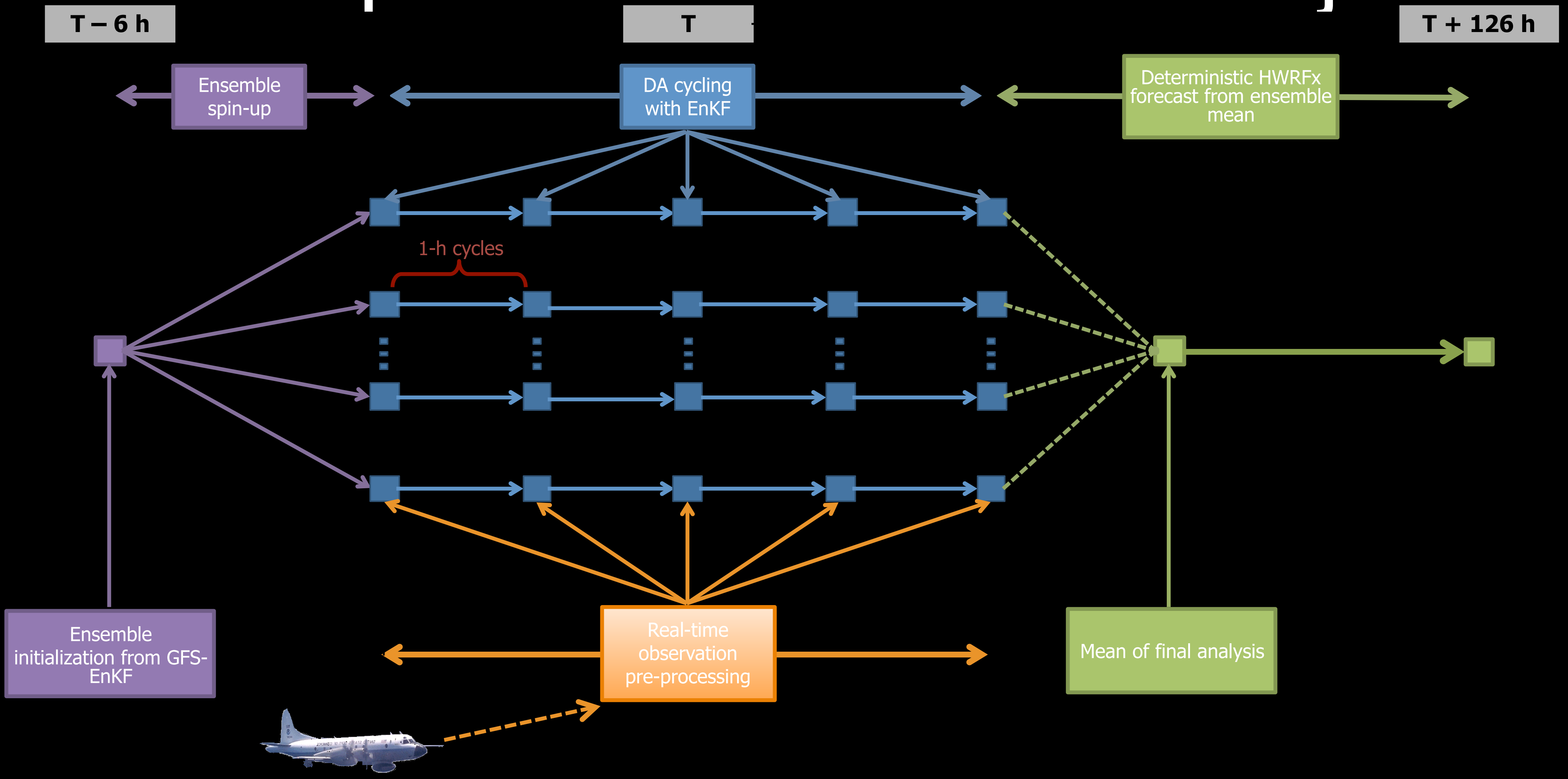
HEDAS Cycling Workflow

- Run for cases when NOAA Airborne Doppler Radar data were available (and a few other cases for research purposes - requests taken)
- Uses 1452 processors on NOAA's jet



- **Forecast model:**
  - A version of HWRF available spring 2015 provided by Sam Trahan
  - 2 nested domains (9/3-km horizontal resolution, 61 vertical levels)
  - Static inner nest to accommodate covariance computations
    - ➔ Inner nest size: ~10x10 degrees
  - Model integration begins at the time of the final analysis (2 h after synoptic time)
- **Ensemble system:**
  - Initialized from retrospective *GFS-EnKF* ensemble (since 2011), may use operational ensemble for earlier cases
  - Initial ensemble is spun up for 3-4 h before assimilation begins
  - 30 ensemble members

- **Data assimilation:**
  - Square-root ensemble Kalman filter, EnKF (Whitaker and Hamill 2002)
  - Assimilates realtime data on the inner nest in storm-relative coordinates
    - ➔ NOAA P-3, NOAA G-IV, USAF C-130, Global Hawk
      flight-level temperature, moisture, wind velocity
      dropsonde temperature, moisture, wind velocity at correct location
      stepped-frequency microwave radiometer surface wind speed
      Airborne Doppler radial superobs
    - ➔ CIMSS high-density AMVs
    - ➔ ACARS temperature, humidity, wind velocity
    - ➔ AIRS retrievals
    - ➔ GPS radio occultation retrievals
    - ➔ Global Hawk HAMSR data
    - ➔ Airborne wind LIDAR
    - ➔ Coyote temperature, humidity, wind velocity
    - ➔ Satellite radiance CCV data
  - Covariance localization (Gaspari and Cohn 1999) - variable depending on data type

Currently six sets of model runs (214 cases since 2008)

1. No DA control (HECT) as a baseline
2. All observations (HEAD)
3. All observations except Airborne Doppler radar superobs (HEND)
4. All observations except G-IV Airborne Doppler radar superobs (HENG)
5. All observations except high-density AMVs (HENA)
6. All observations except UAS (Global Hawk) data (HENU)

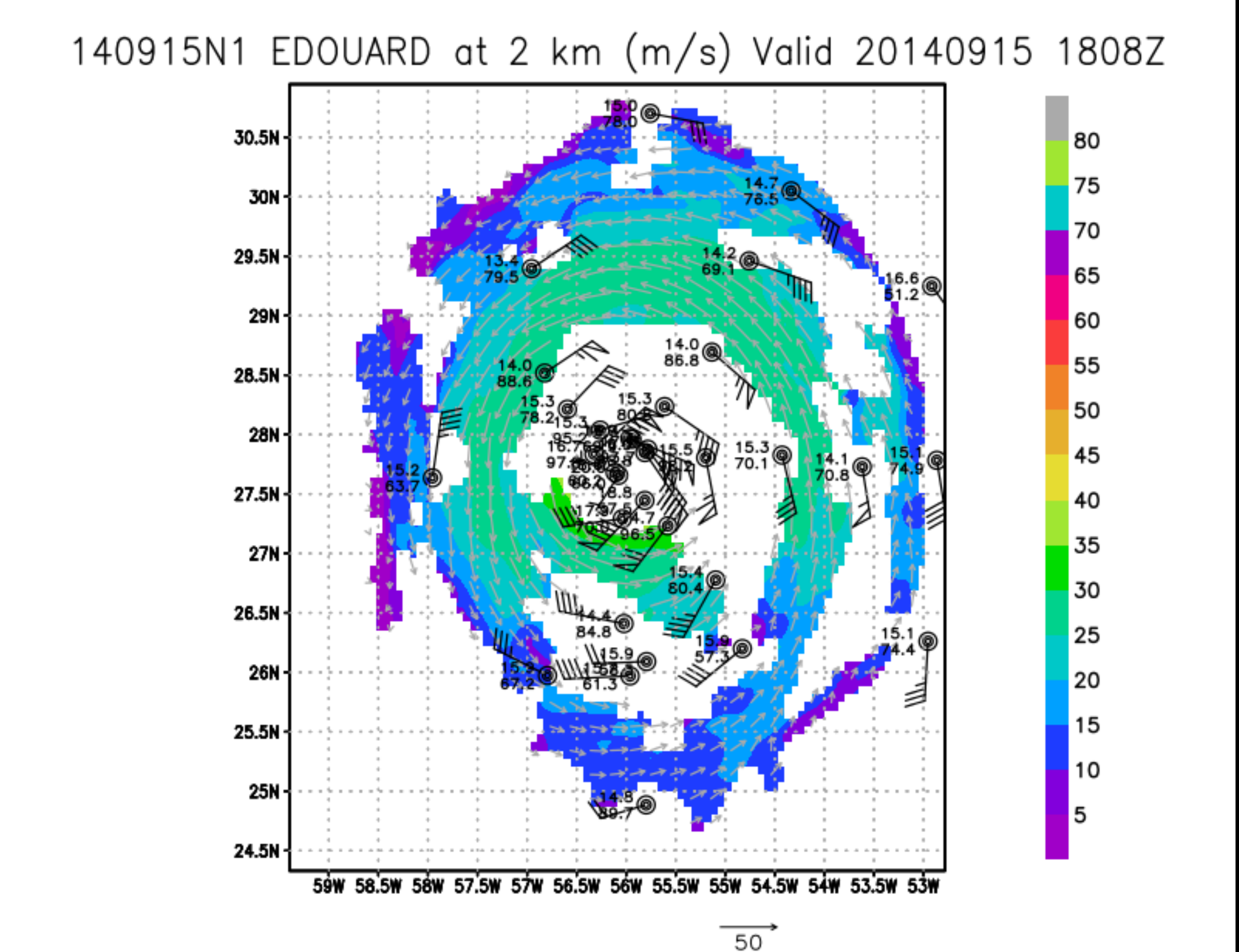
Impact of assimilation dropwindsondes at the correct location

Dropwindsonde data are currently transmitted from aircraft in World Meteorological Organization (WMO) format known as TEMPDROP.

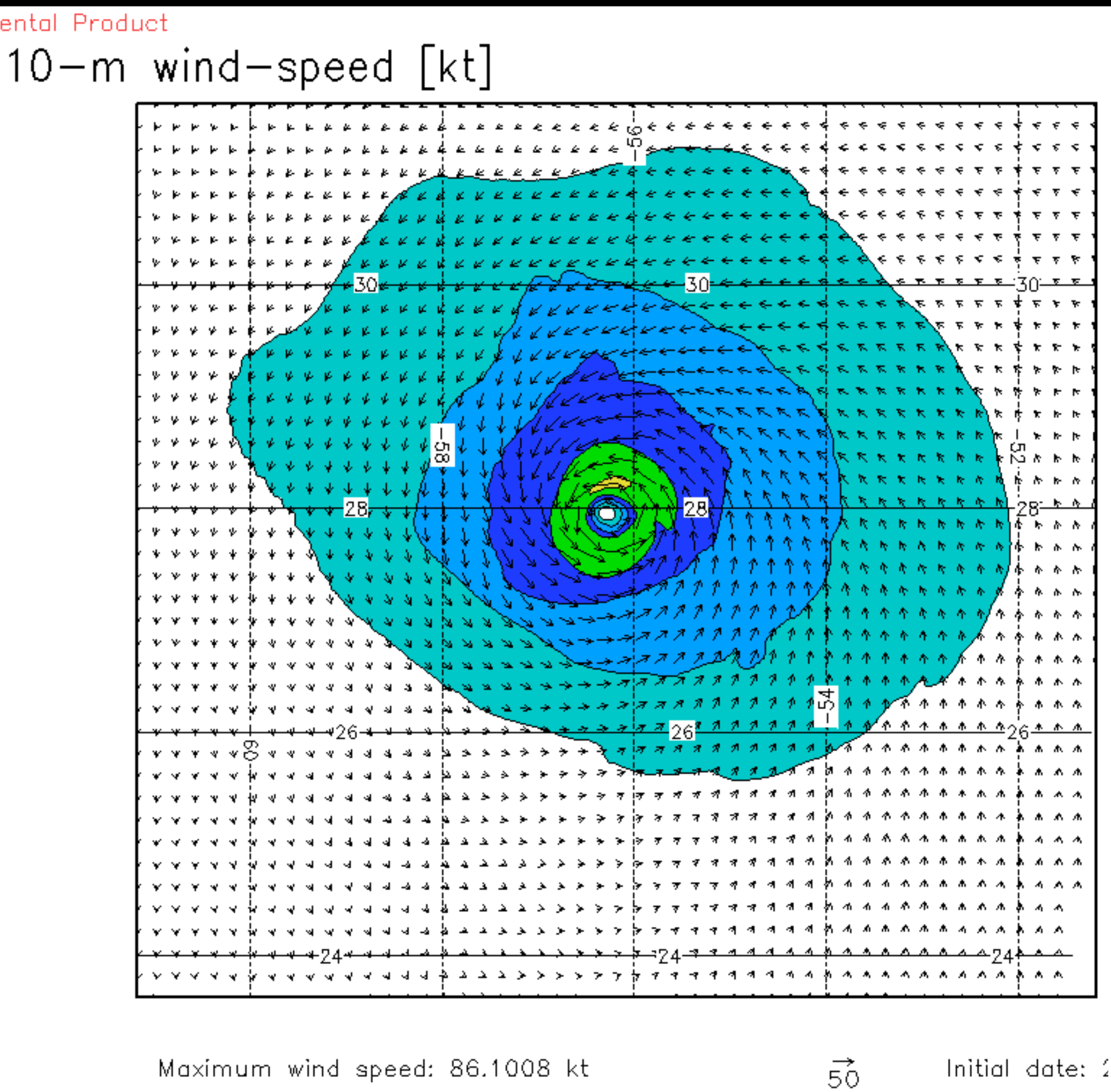
The release time and location are available to the nearest hour and 0.1 degrees latitude and longitude.

All dropwindsonde data are also sent with information to calculate the time and location of each level's data within 0.5 km and 30 s. Only data available in realtime are necessary for this calculation.

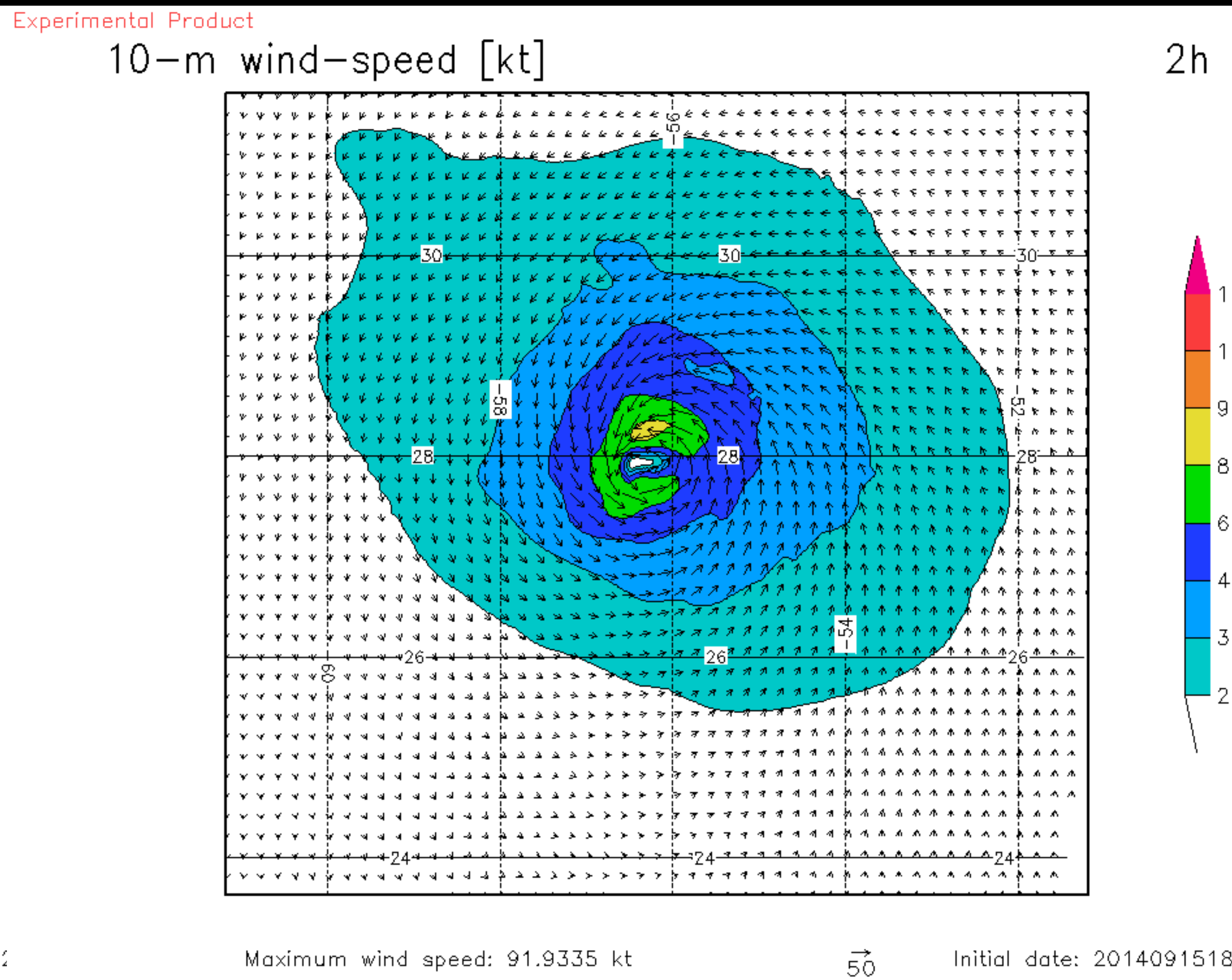
Edouard 2014091518 was chosen because of the large number of dropwindsondes and Doppler radials from three NOAA aircraft (only G-IV radar analysis shown)



Wind impact is expected because directions are incorrect

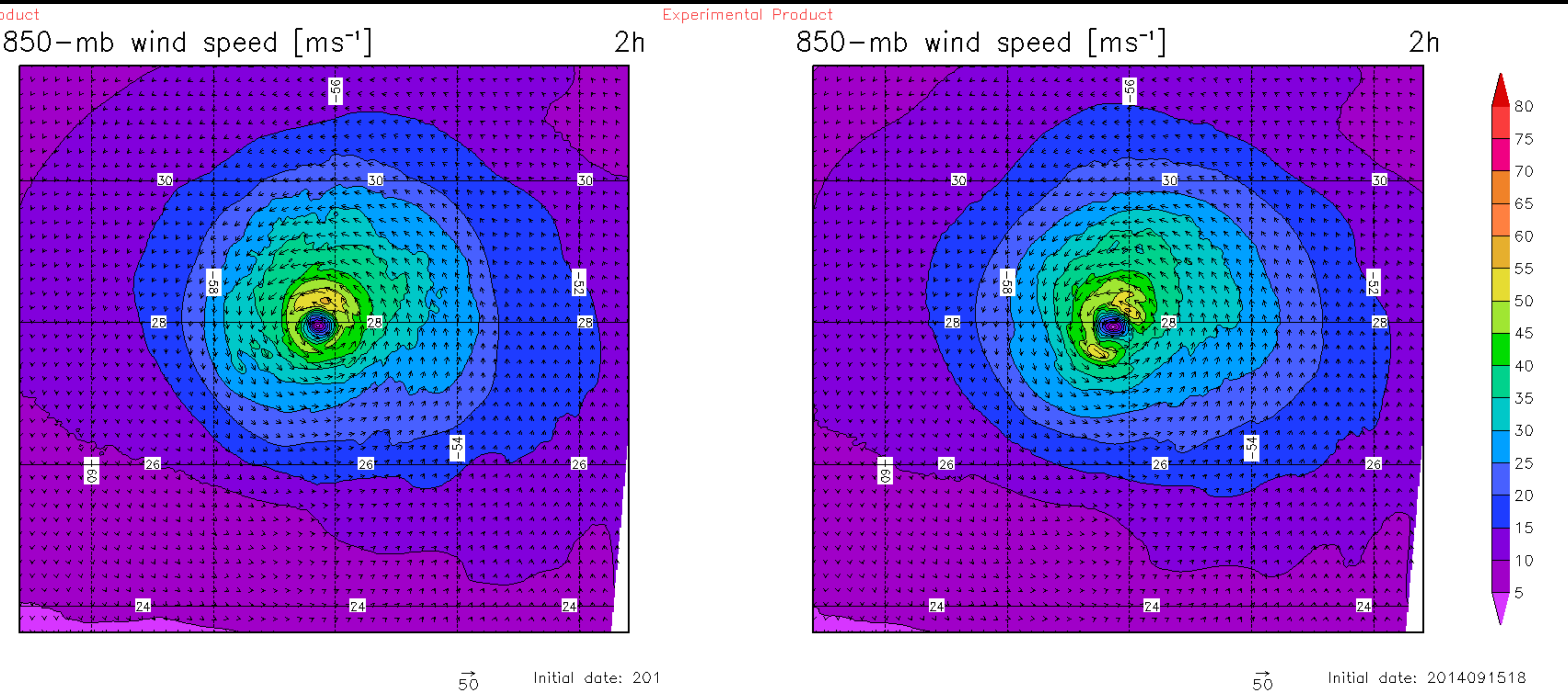


With drift



Without drift

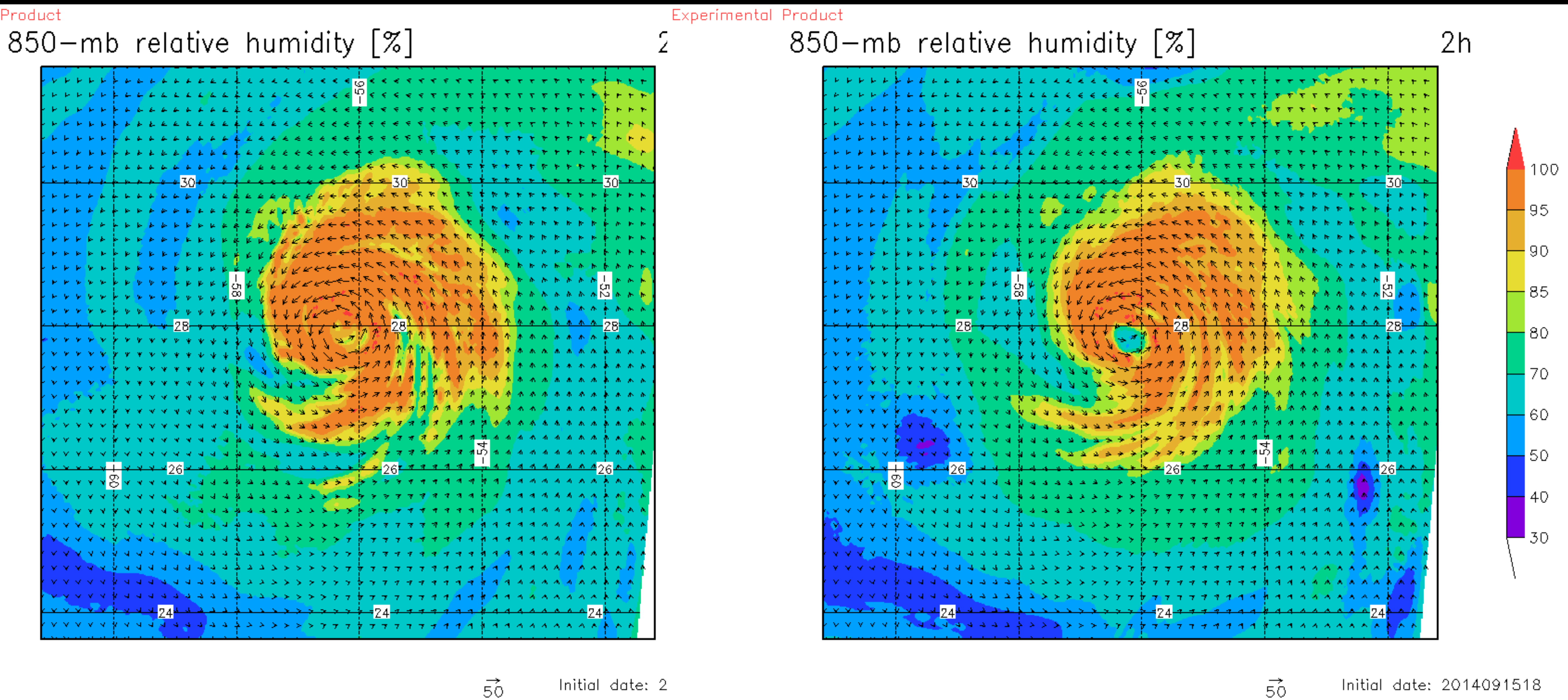
Wind impact is expected because directions are incorrect



With drift

Without drift

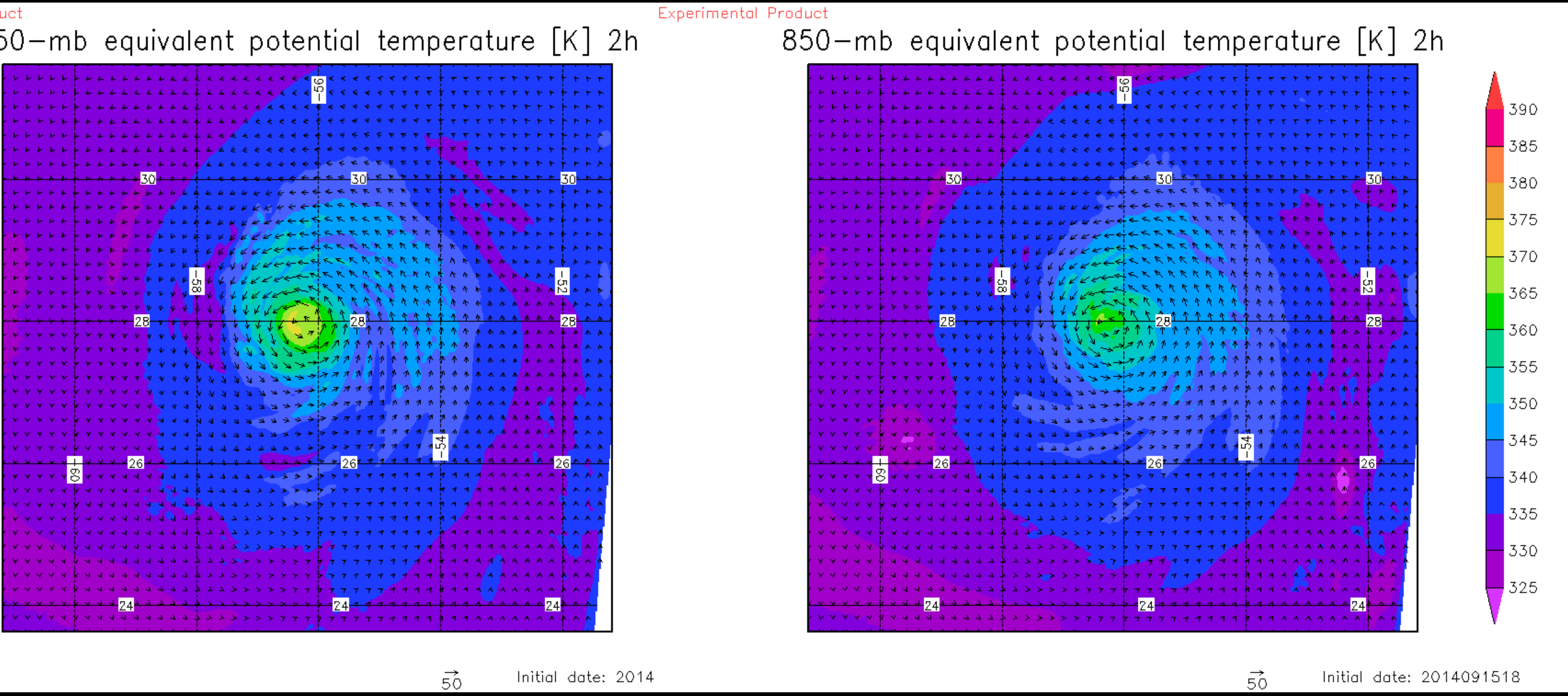
Large asymmetric increments put very low humidity in southeastern eyewall



With drift

Without drift

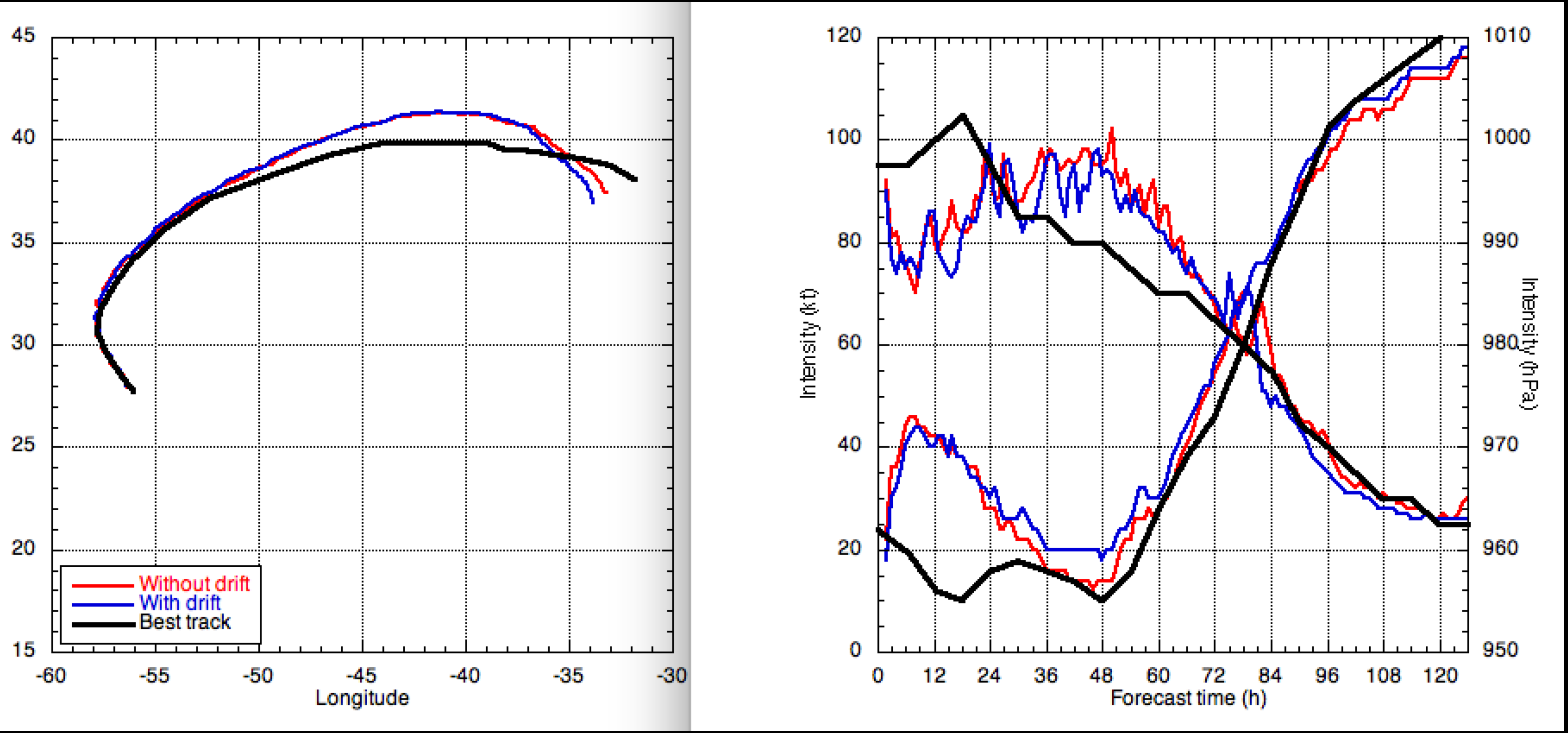
Large temperature impacts due to not accounting for location



With drift

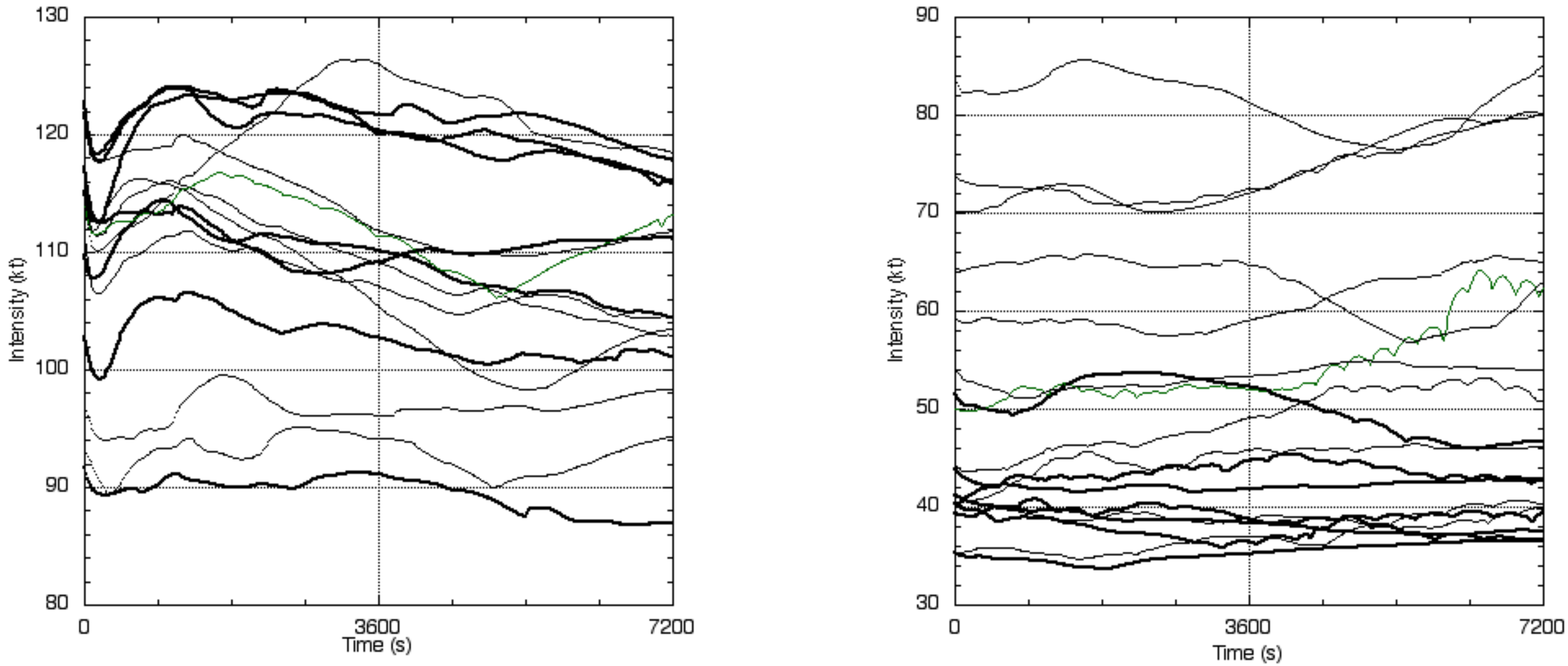
Without drift

Some differences in initial condition and forecast with and without dropwindsonde drift



Forecast differences are not large in this case, though initial conditions are somewhat degraded without calculated drift. This calculation can be done with current data and does not require additional data to be transmitted from aircraft.

Vortex initial conditions



Two Earl cases, old HEDAS 30-member ensemble intensity

If spin-down/spin-up happens on such short time scales, does this negatively impact cycled DA systems?

Old HEDAS used wrfout files to start each run. In wrf-nmm, the vertical velocity variable is a form of dw/dt, but that variable is not in wrfout. Each run was thus starting with a uniform base value of dw/dt at each cycle time.

NMM Solver Scientific Documentation, page 19, it states that if there are vigorous convective storms, it takes O(1000s) for the vertical velocity to grow to O(10m/s).

TCs are comprised of "vigorous convective storms," suggesting that WRF-NMM will take that amount of time to develop sufficient vertical velocity to sustain the secondary circulation.

In discussion with Zavisa Jancic, he stated “For the nonhydrostatic component of motion, it would be useful if you had initial dw/dt, or some approximation of it.”

As a result, HEDAS was upgraded to use wrfrst files which do have dw/dt, and dw/dt is now updated in the HEDAS runs.

What is the impact of using dw/dt updated with a DA system?

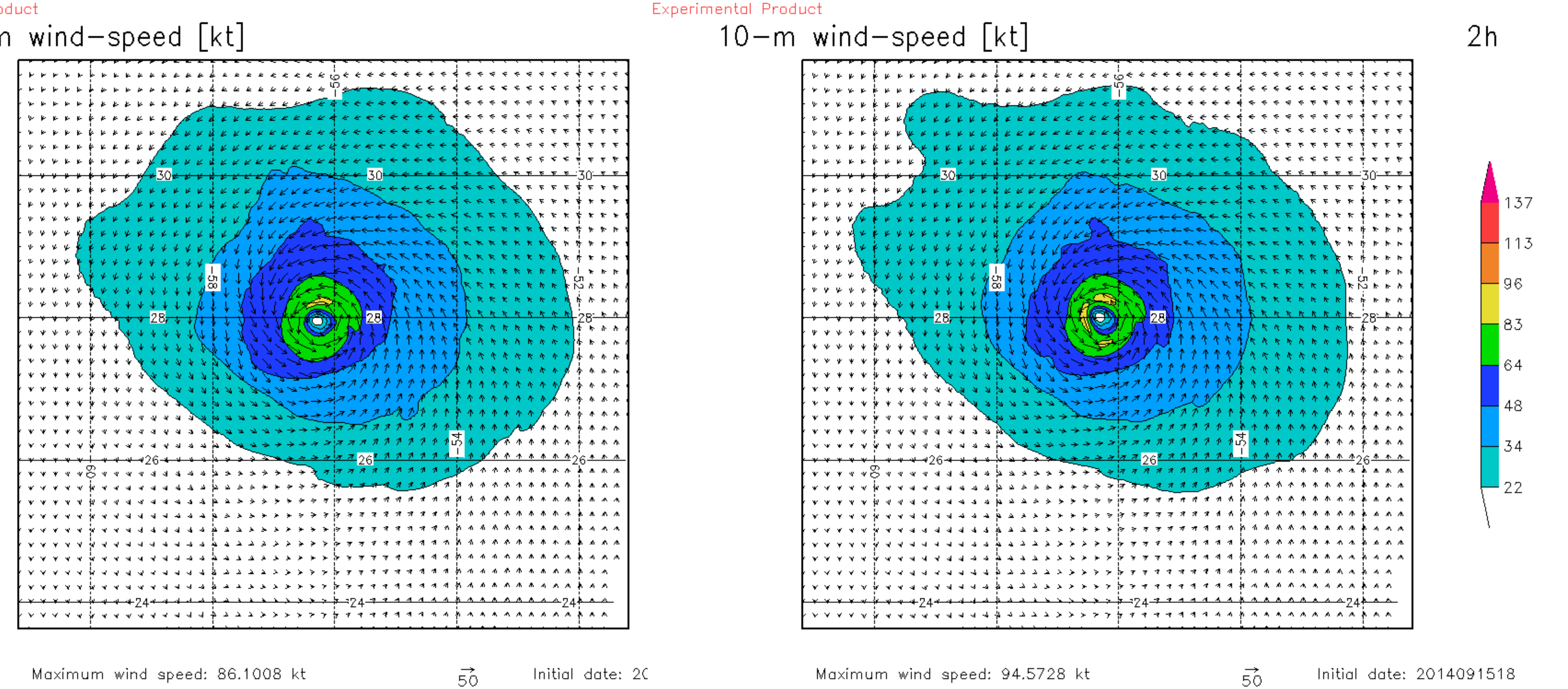
Hypothesis 1: dw/dt variable is necessary to reduce the spin-down issue and improve vortex initial conditions.

Hypothesis -1: dw/dt varies so little that updating it will have little impact on forecasts.

The same Edouard case was run without updating dw/dt.

In this run, dw/dt is left at the value of the prior, so there are values of dw/dt available. This is different from the original HEDAS case in which dw/dt is ‘zeroed’ out in the initial condition. So, this run will likely have values of dw/dt with the correct sign in the eyewall, and the answer will not be definitive.

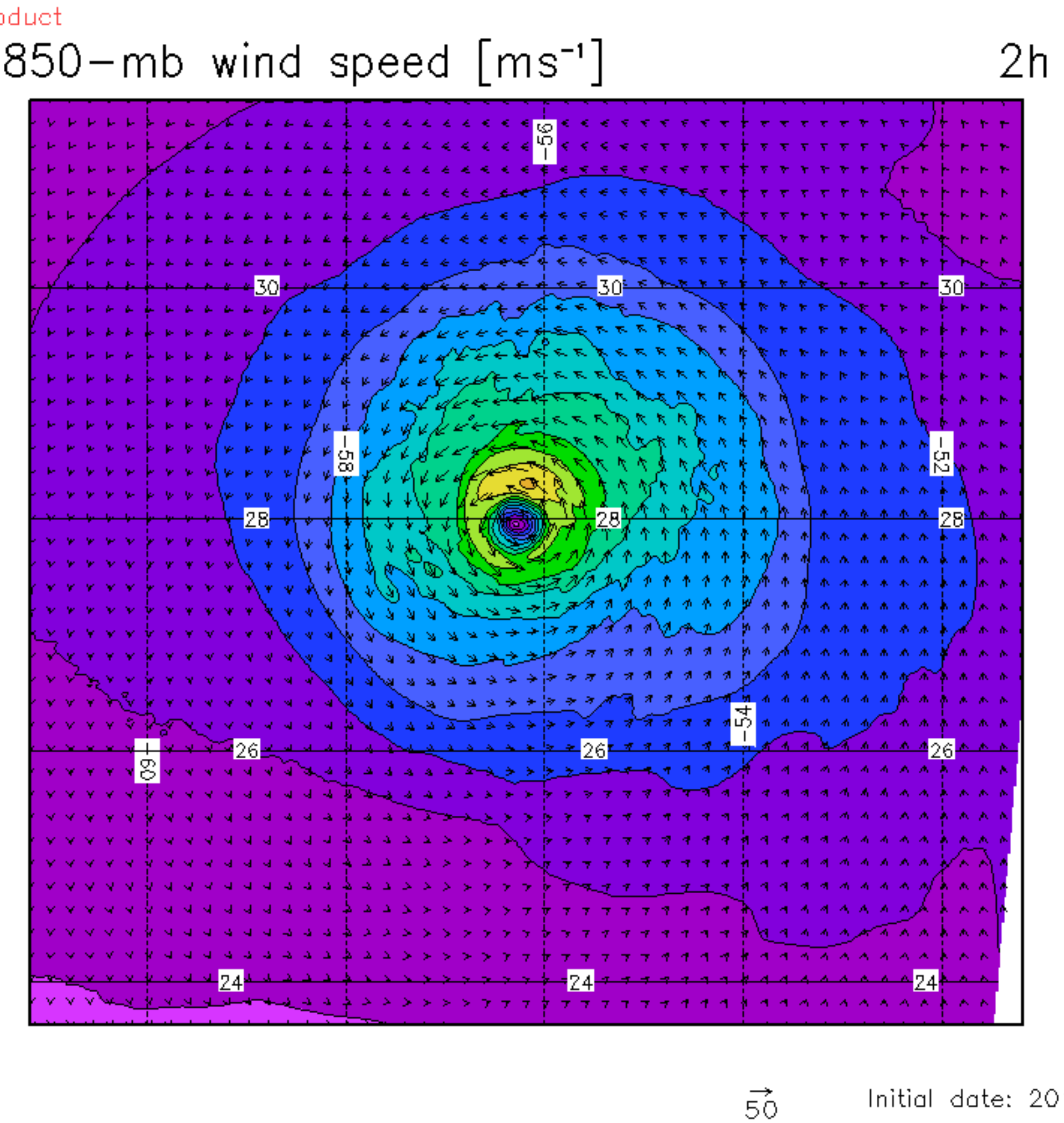
We hope to develop the capability to do this soon.



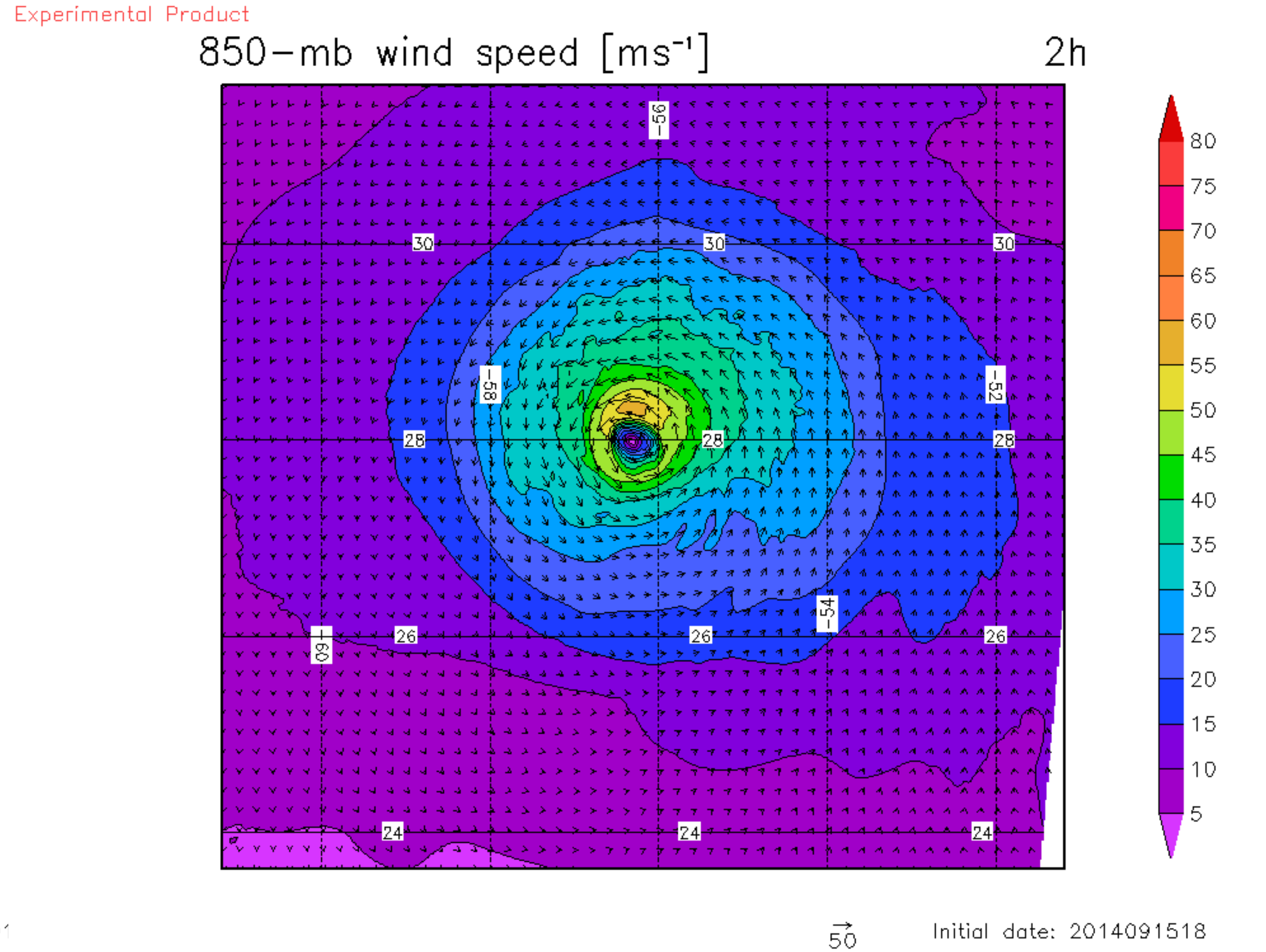
dw/dt update

No dw/dt update

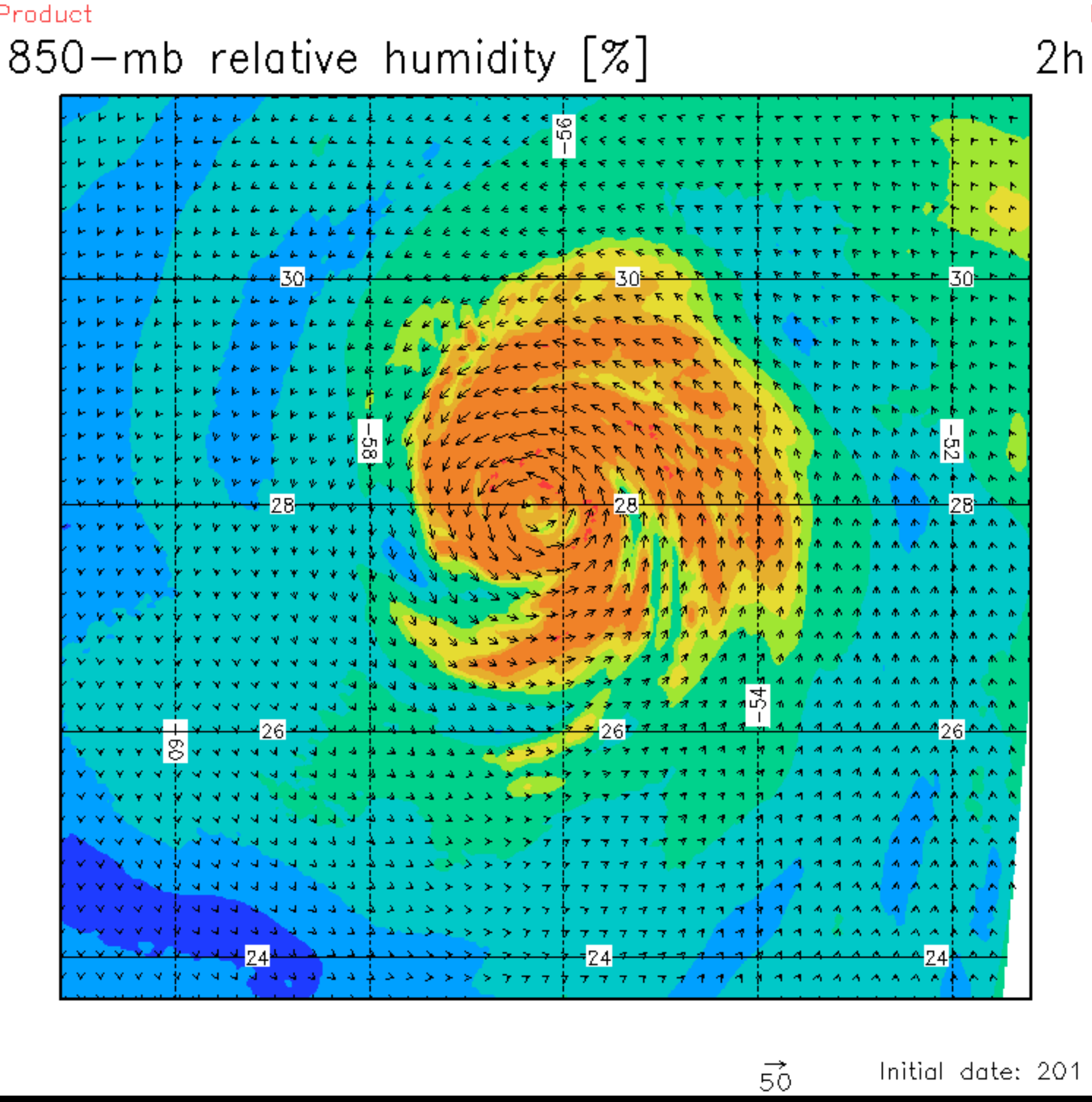
Updating dw/dt has an impact, but makes initial conditions slightly weaker than without the update in this case.



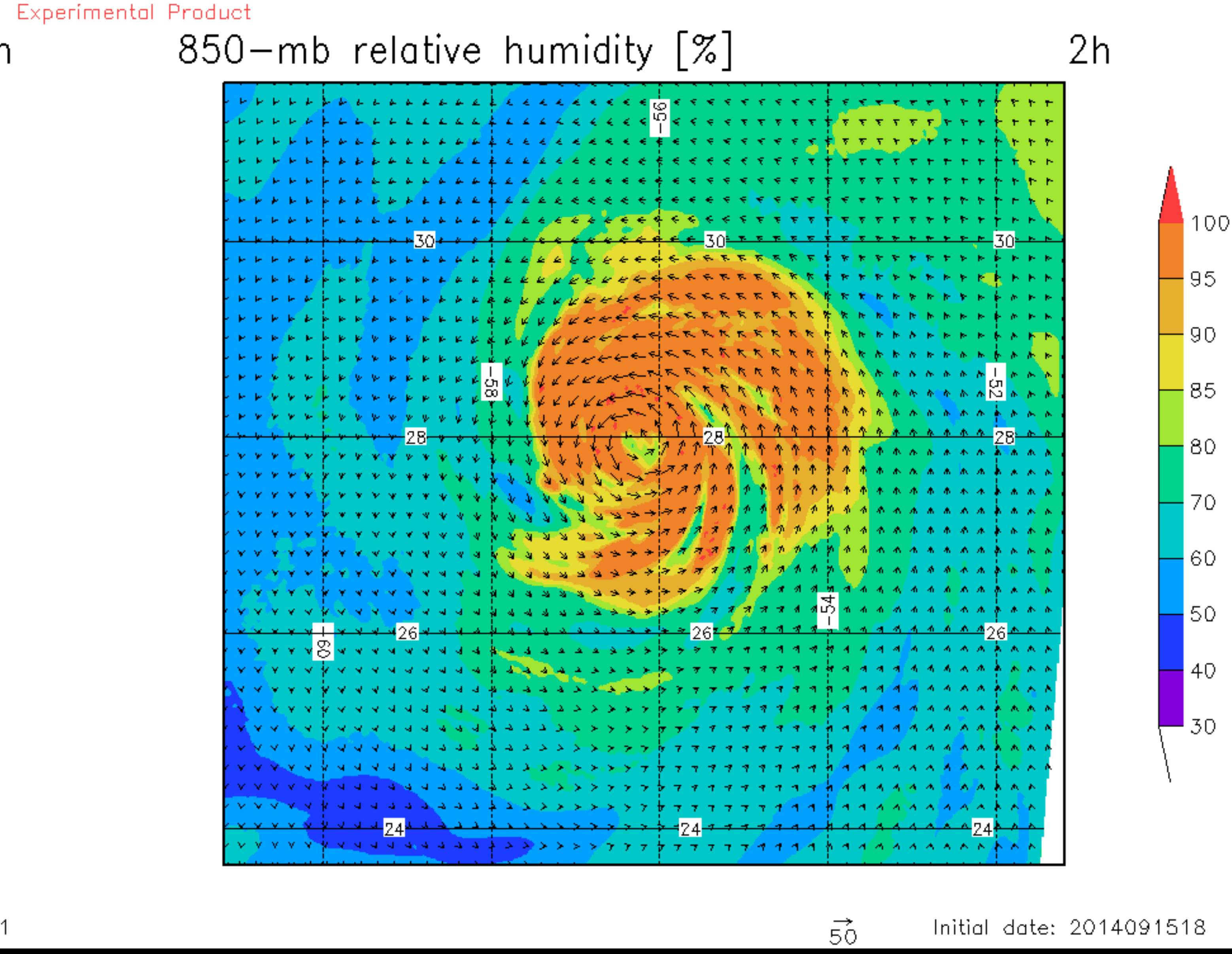
dw/dt update



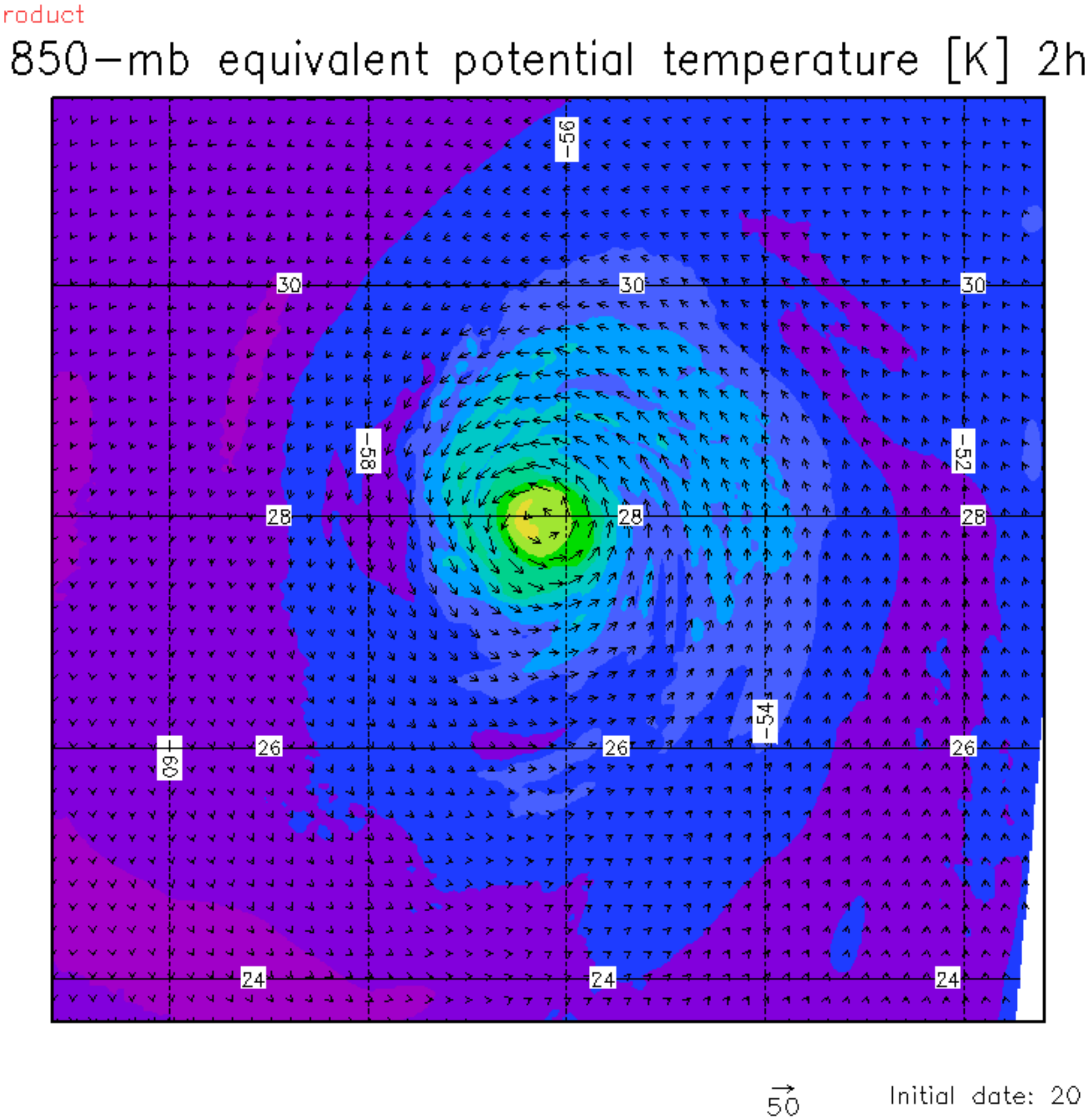
No dw/dt update



dw/dt update



No dw/dt update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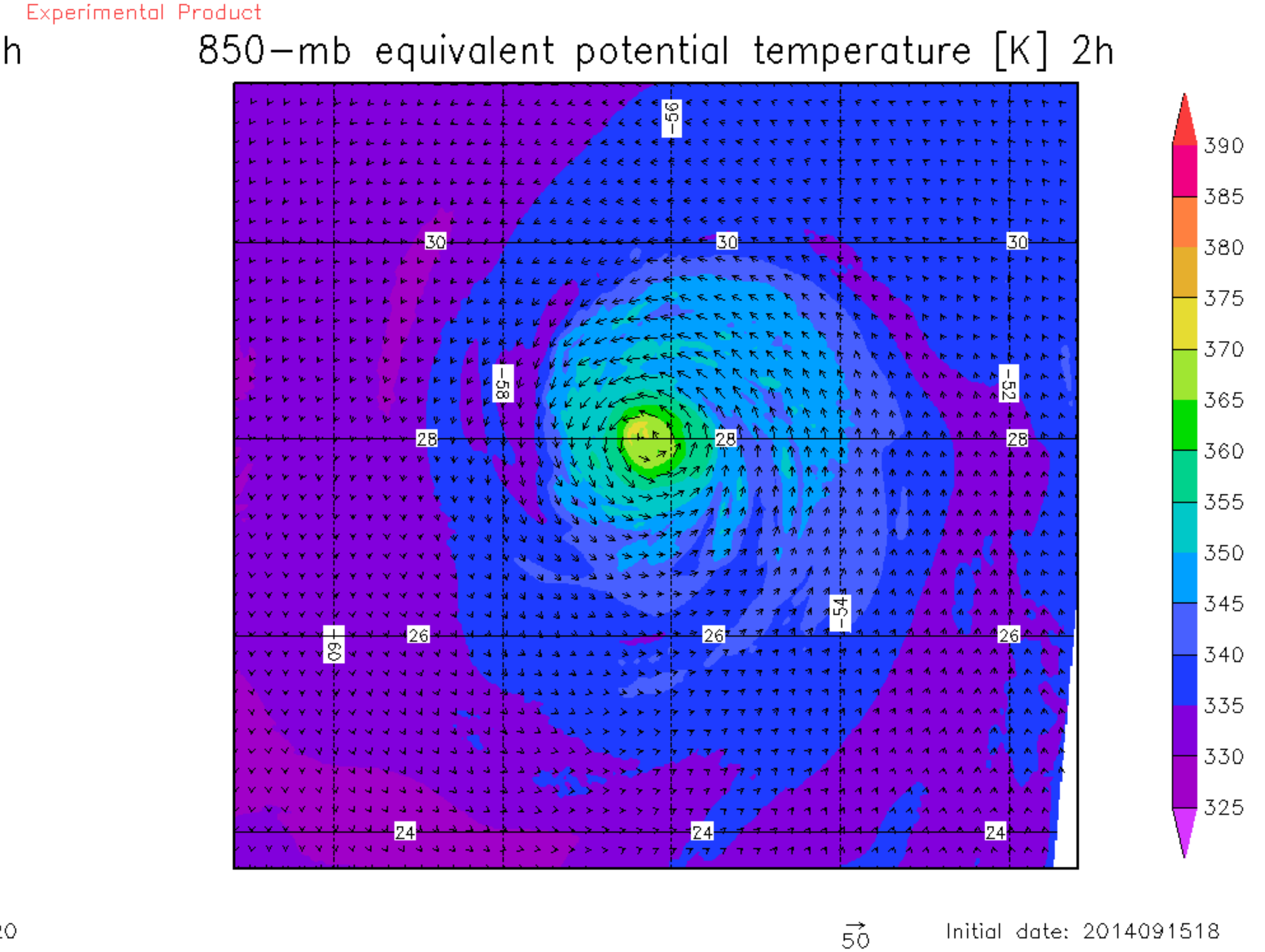
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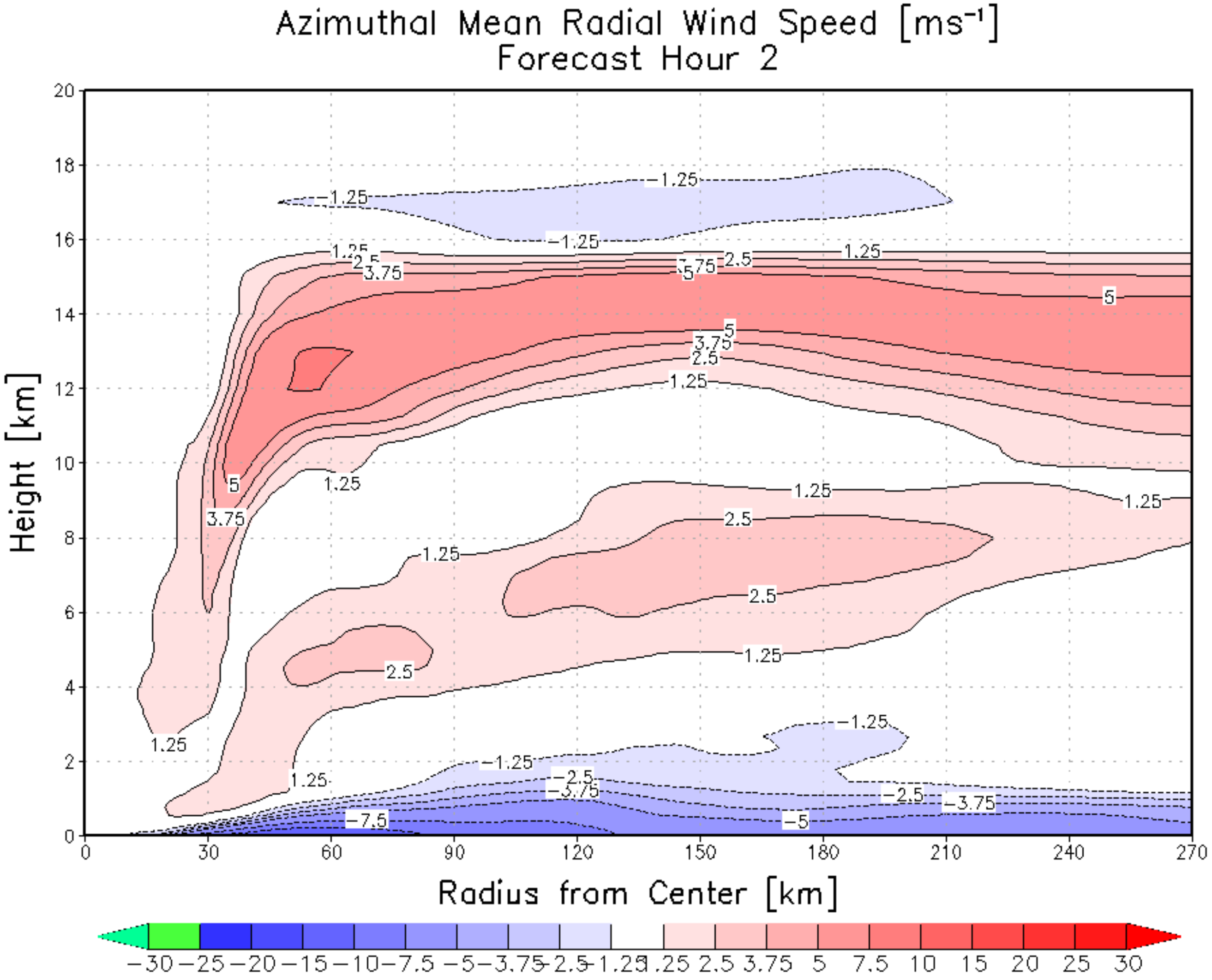
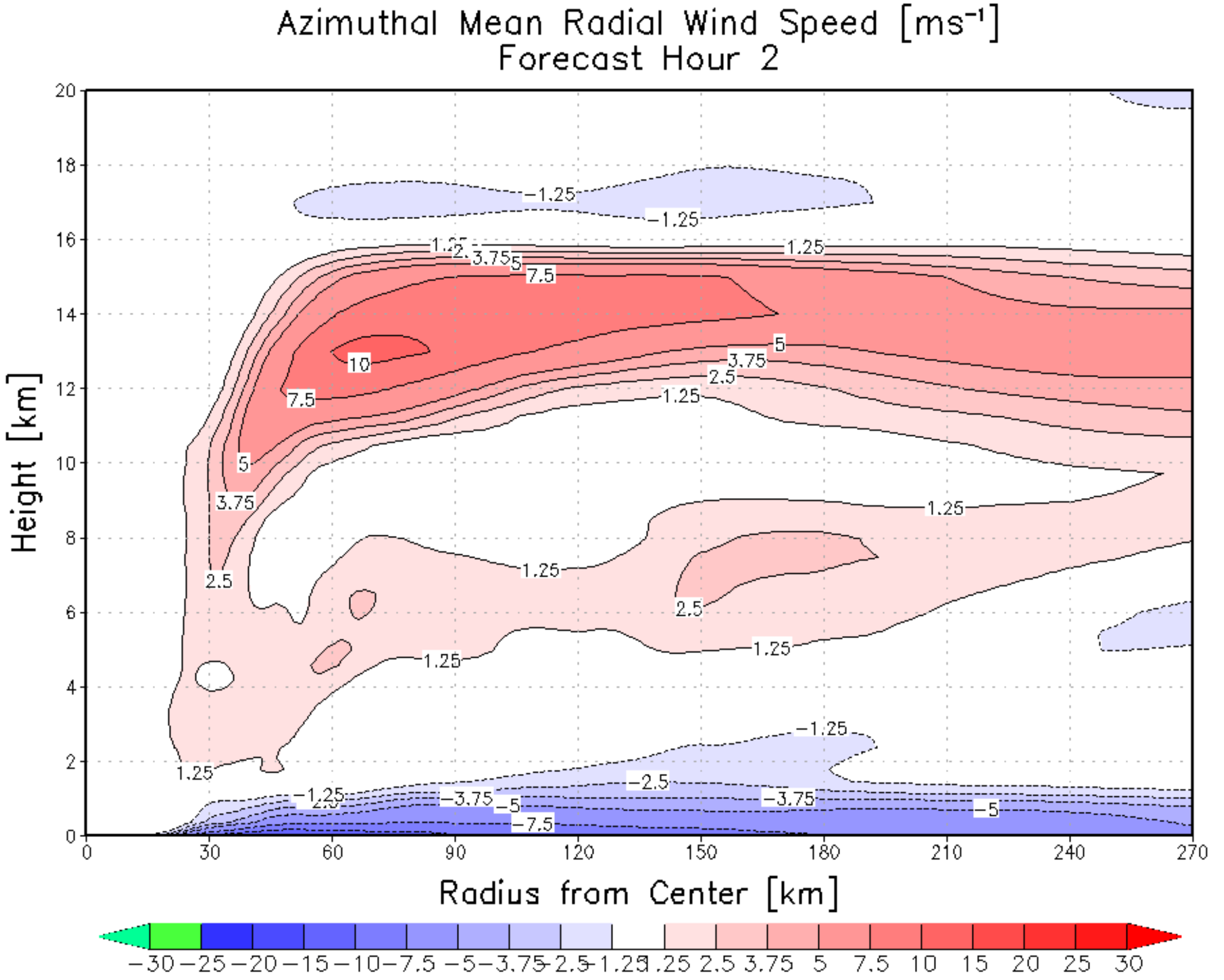
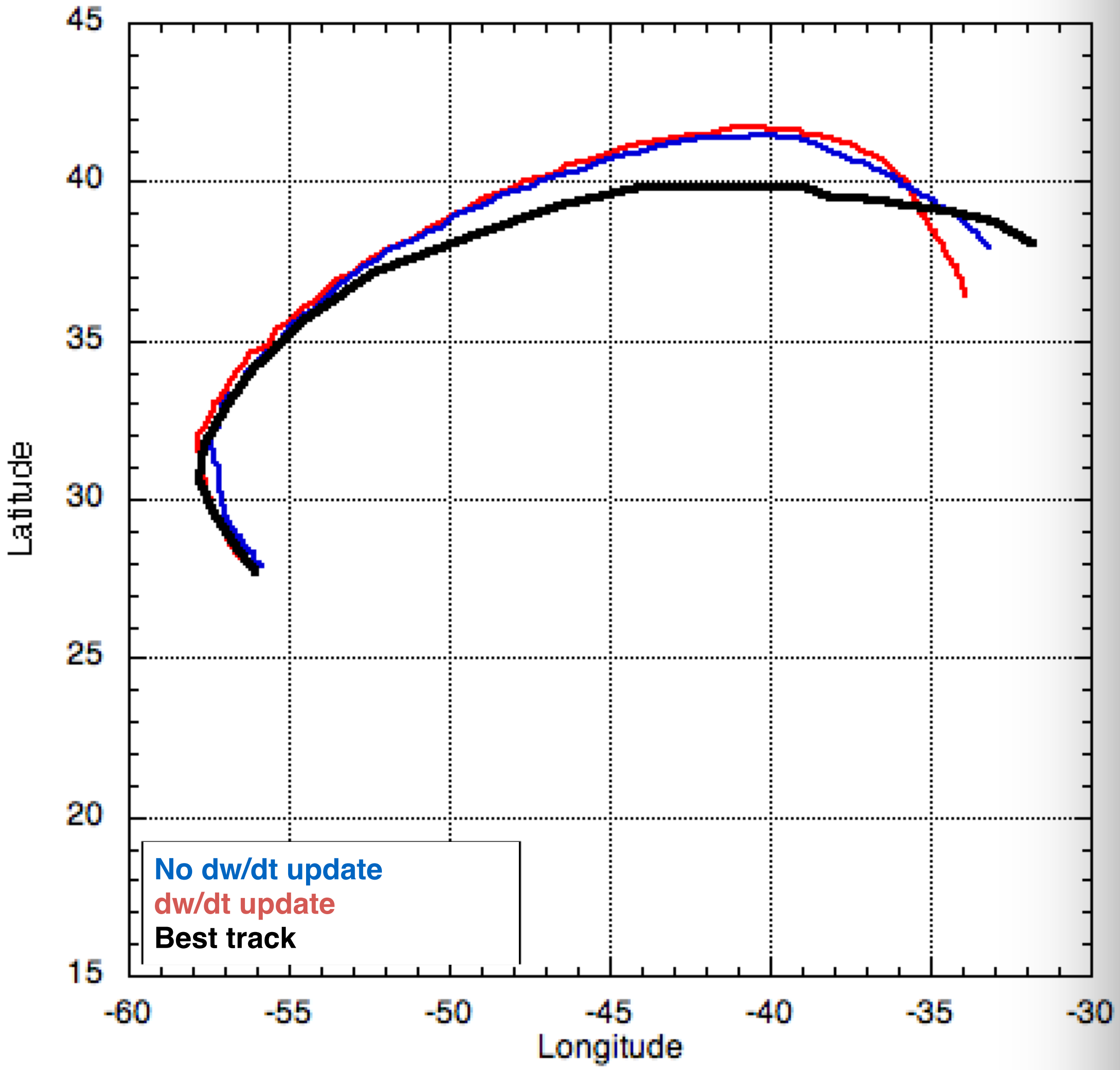
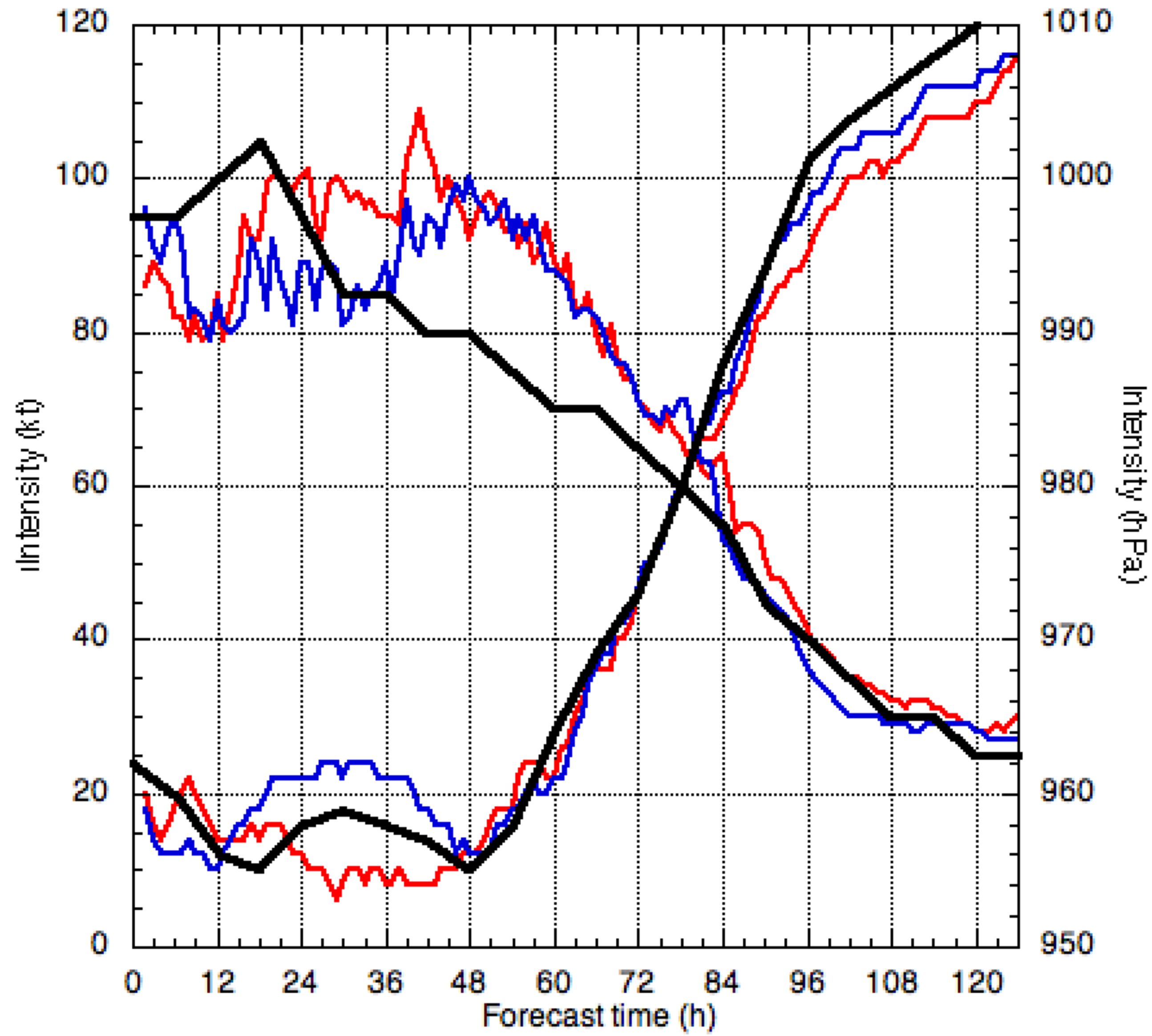


dw/dt update



No dw/dt update





No dw/dt update
dw/dt update

There are large differences in the forecasts with the only difference the dw/dt update.

Conclusion

Test of observation types (2008) 2011-2015 ongoing, and will hopefully be complete in a few months:

1. Doppler radar data from NOAA aircraft
2. Doppler radar data from G-IV
3. CIMSS high-density AMVs
4. Data from NOAA SHOUT

Other data (HAMSR, P3 wind lidar, satellite radiance CCV) to be tested soon.

Further testing of dropwindsonde drift and initialization with other cases.

HEDAS upgrade to MPI.