Comparing limited-area 3DVAR and hybrid variational-ensemble data assimilation methods for typhoon track forecasts

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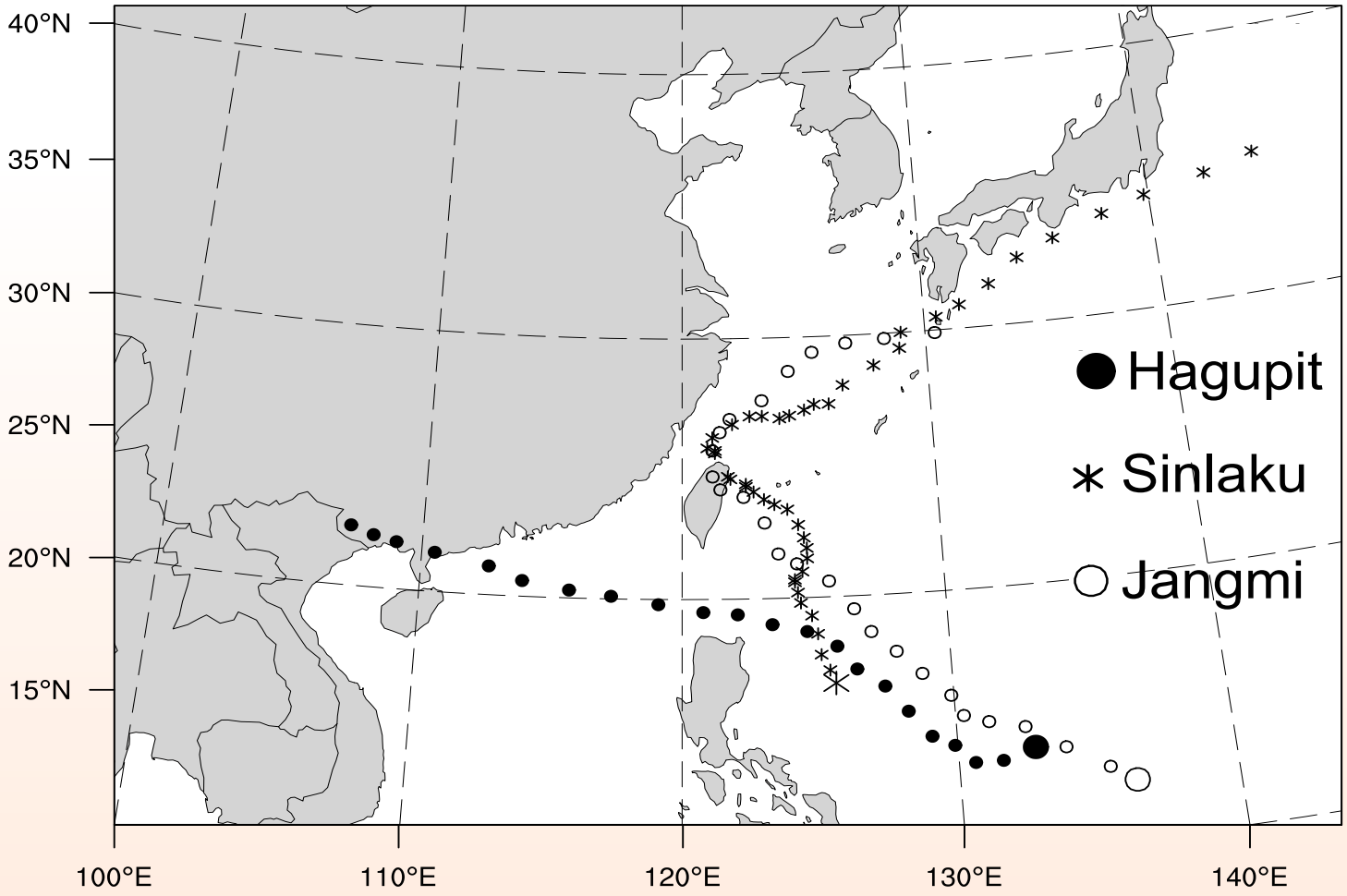
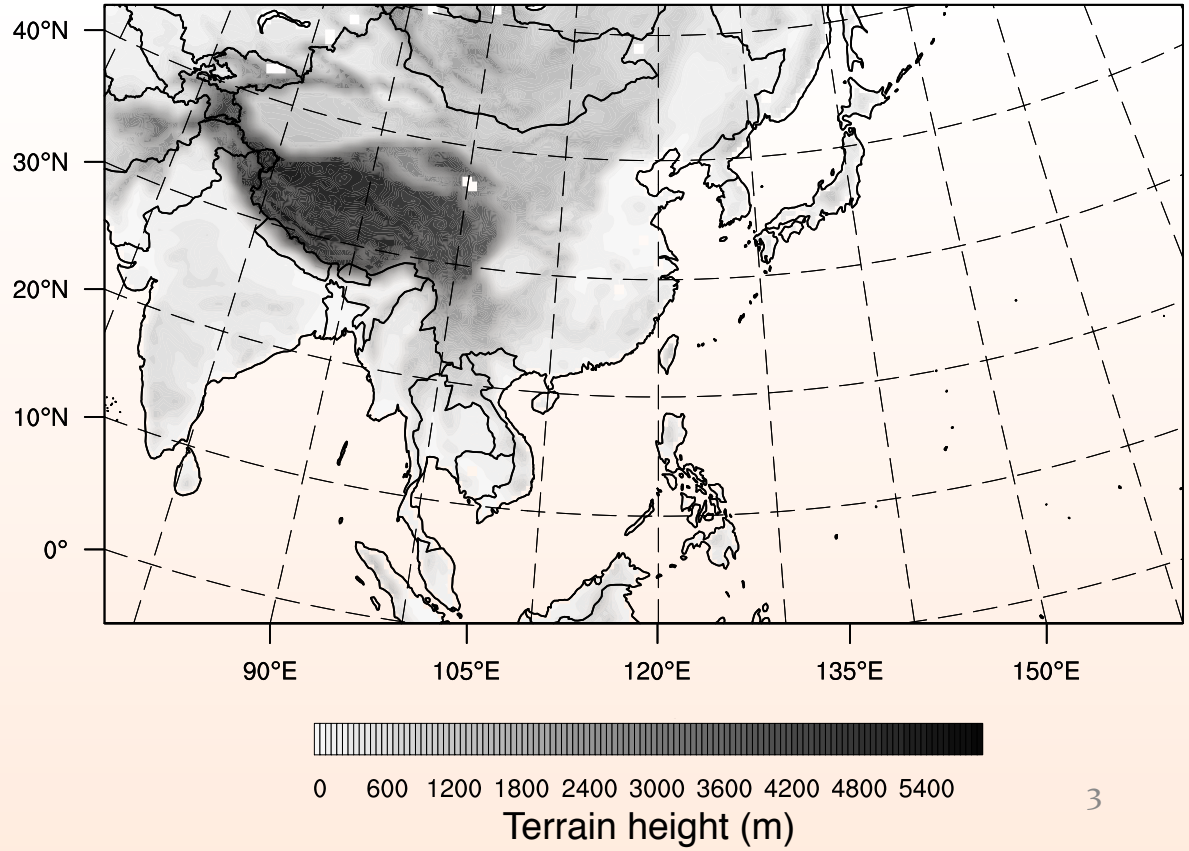
Typhoon tracks

- Best track positions from Taiwan Central Weather Bureau (CWB)
- September 2008; positions plotted every 6-hrs



Model configurations

- Version 3.3.1 of WRF and WRFDA
- 45-km horizontal grid spacing, 45 vertical levels, 30 hPa top
- Lateral boundary conditions from GFS forecasts



Experimental design

- Four cycling experiments with different initialization approaches:
  - WRFDA-3DVAR with 1 outer loop ("3DVAR-1OL")
  - WRFDA-3DVAR with 3 outer loops ("3DVAR-3OL")
  - WRFDA-Hybrid with 1 outer loop ("HY-1OL")
  - WRFDA-Hybrid with 3 outer loops ("HY-3OL")

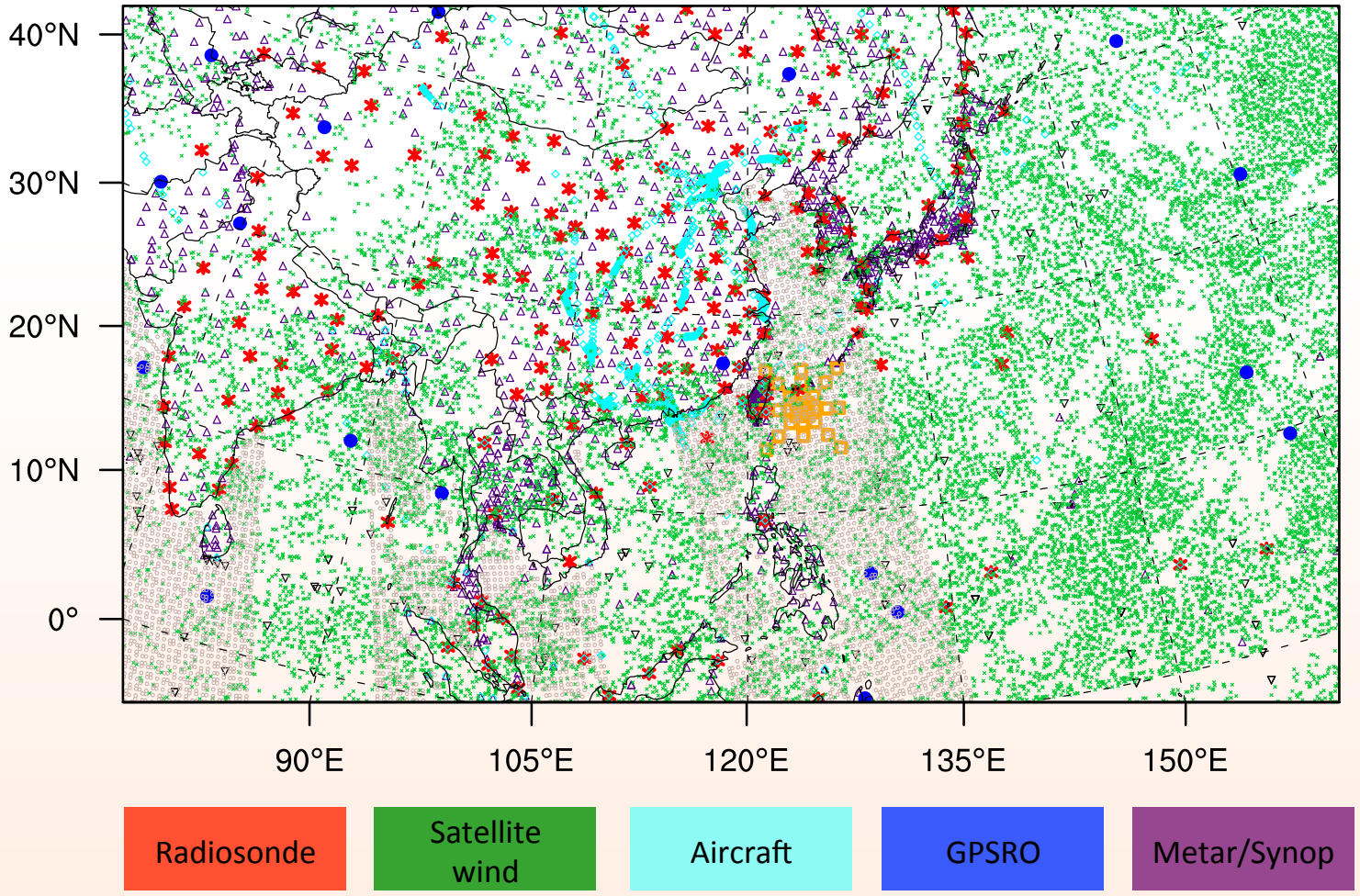
- An EnKF was employed in the hybrid to update the ensemble

- Fully-cyclic data assimilation (6-hr period) from 4-28 September 2008

- 72-hr WRF-ARW forecasts initialized from each analysis beginning 1800 UTC 8 September (78 total forecasts)

Observation coverage

- Snapshot of available observations at 0000 UTC 12 September



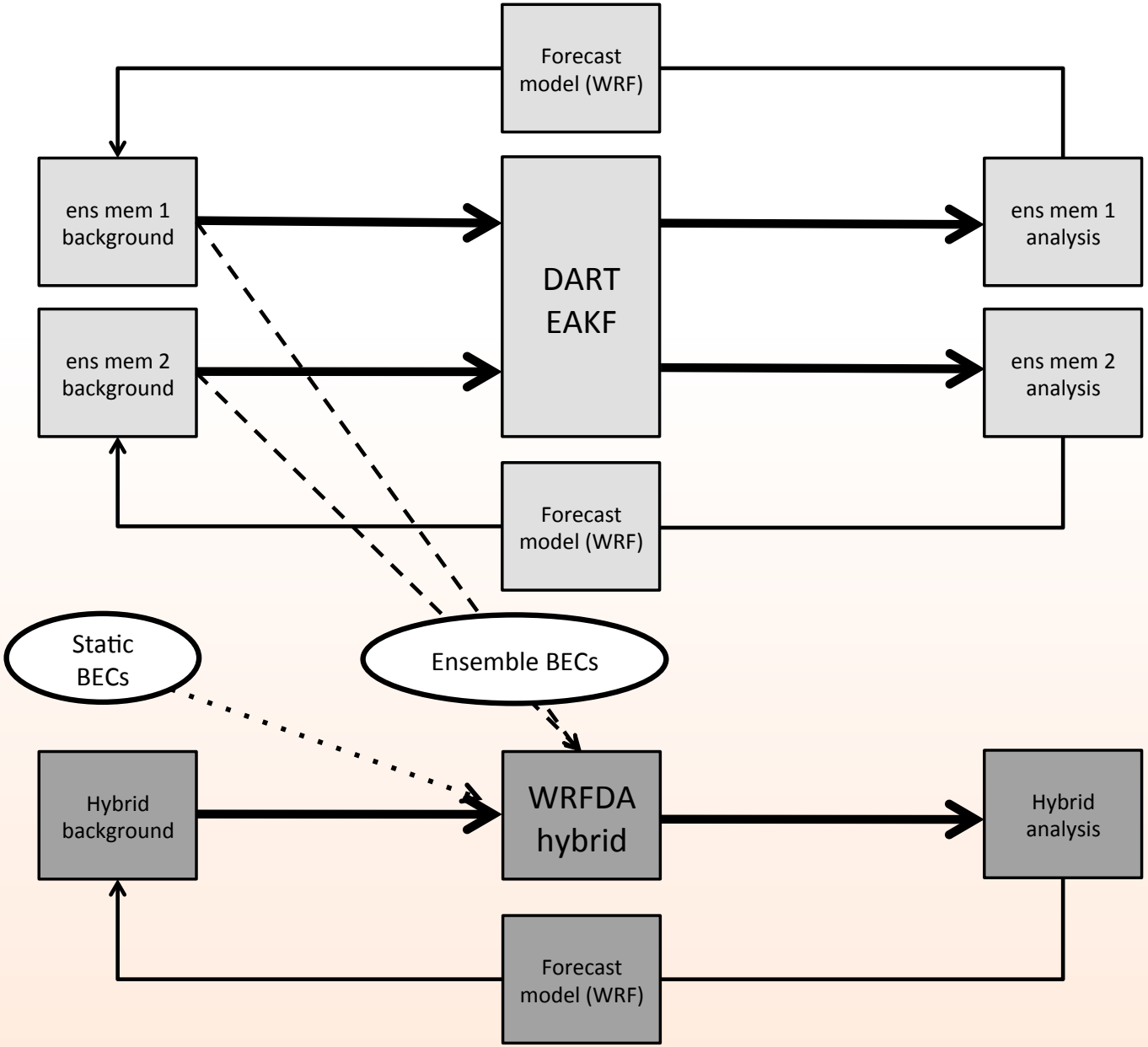
EnKF assimilation parameters

- The Data Assimilation Research Testbed (DART) software
  - Ensemble adjustment Kalman filter (EAKF)
- 32 ensemble members
- Horizontal localization: Increment forced to zero 1280 km from ob
- Vertical localization: Increment forced to zero ~10 km from ob
- Prior adaptive inflation to maintain ensemble spread
- Stochastic kinetic-energy backscatter scheme used within WRF during cyclic model advances

Hybrid assimilation parameters

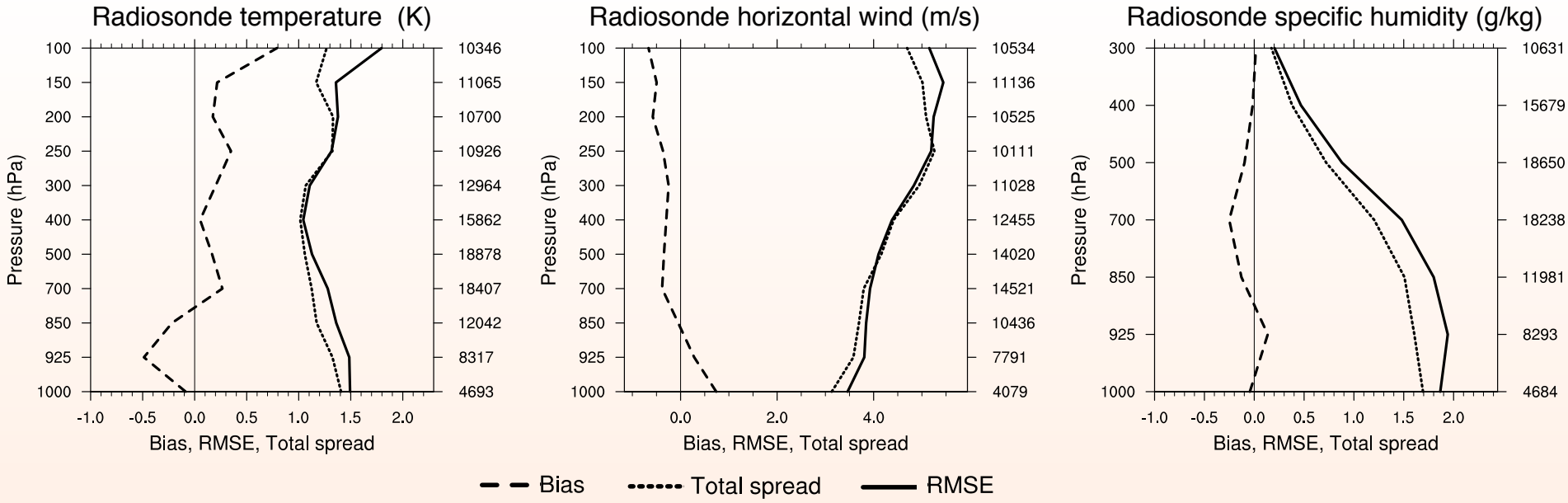
- 75% ensemble, 25% climatological ratios for background error covariances
- Horizontal localization: Similar as EnKF
- Vertical localization: Achieved using EOFs with length-scale increasing with height

Hybrid/EnKF flowchart



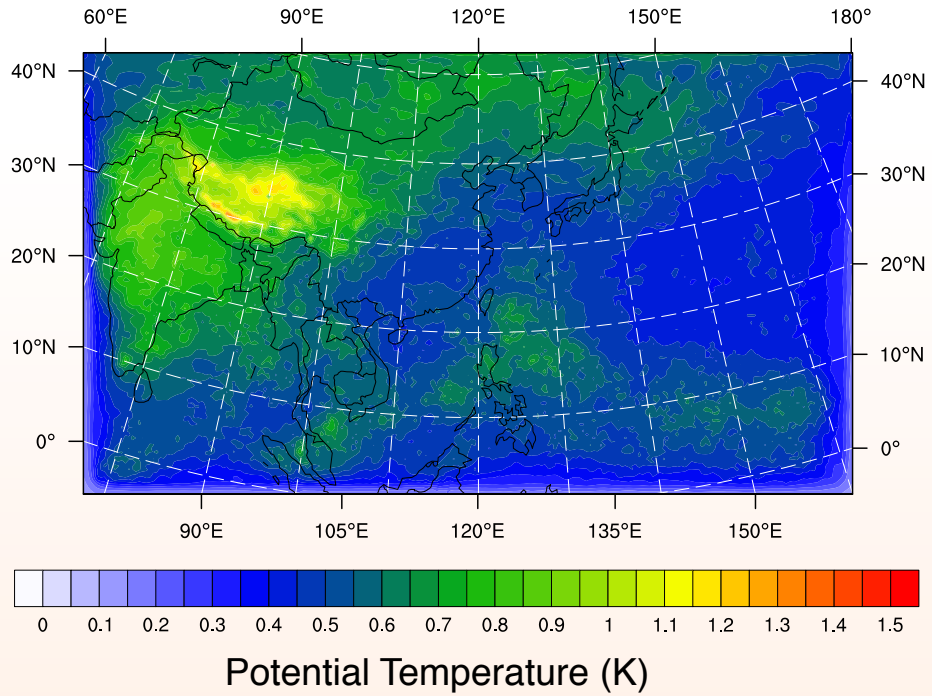
Ensemble performance

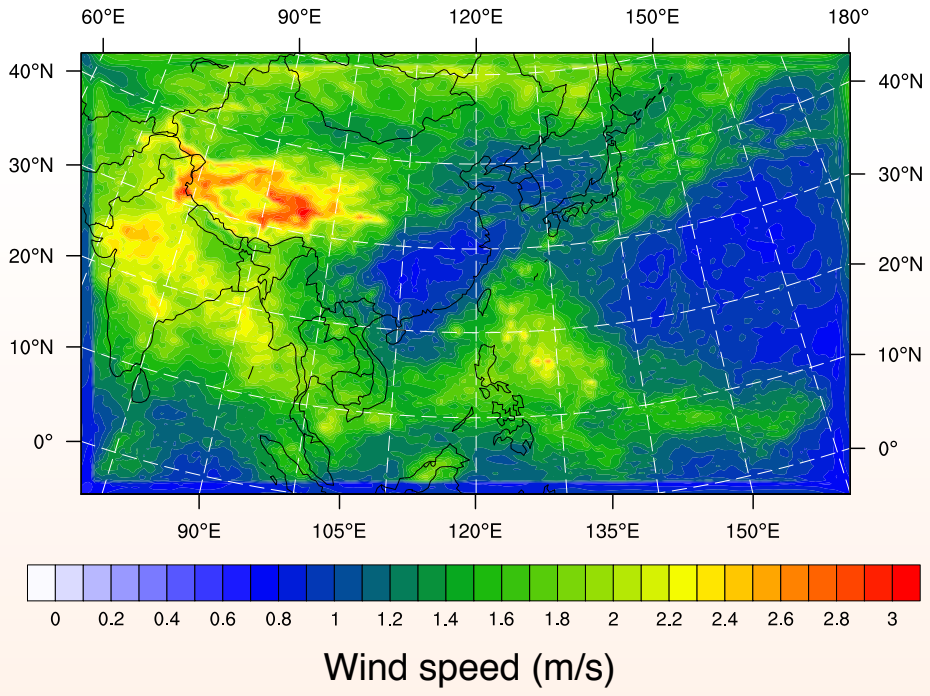
- In a well-tuned ensemble, the total spread should be similar to the mean RMSE
  - Total spread is the square root of the sum of the ensemble and observation error variances



Ensemble spread

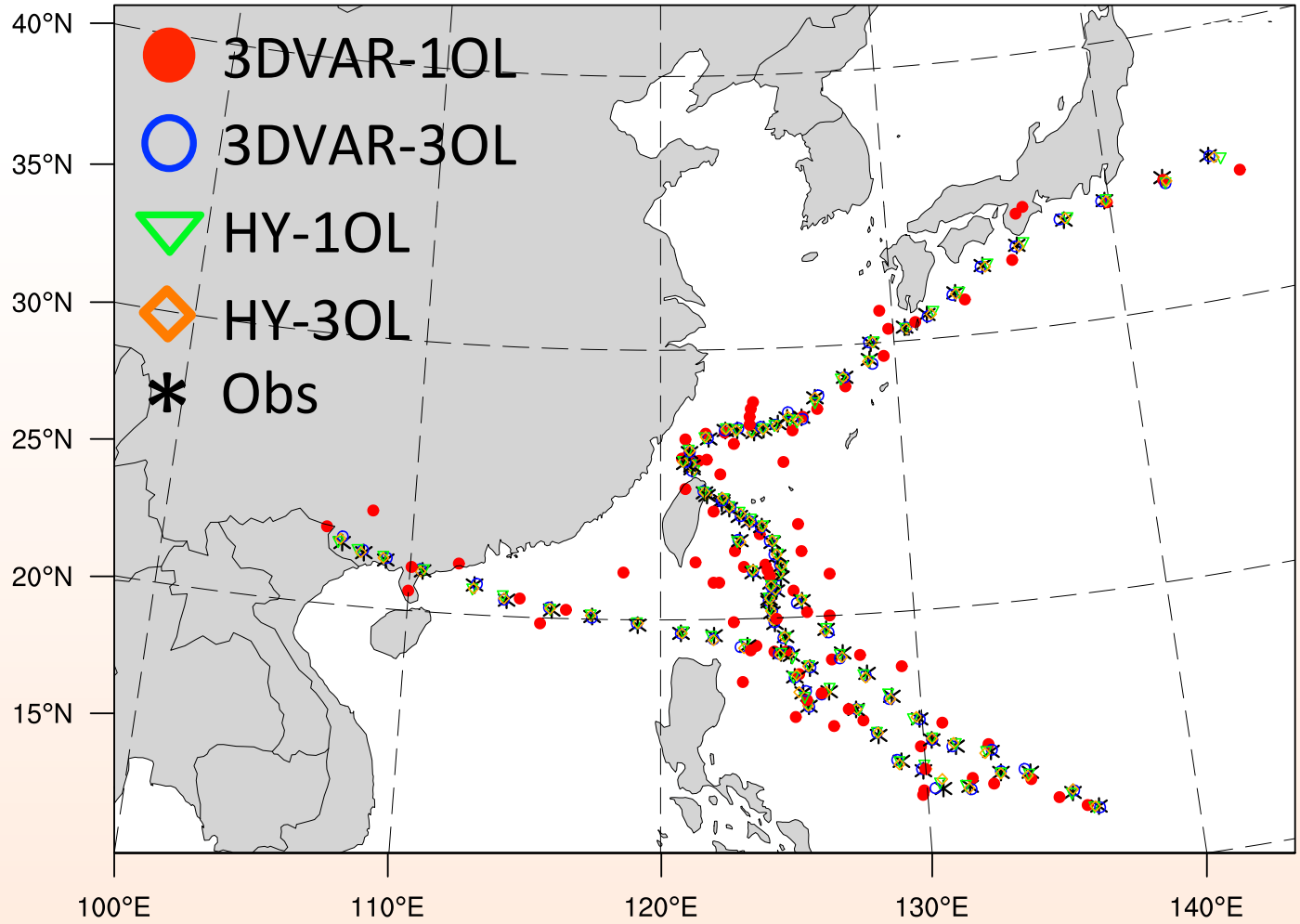
- Mean 6-hr forecast ensemble standard deviation of 500 hPa potential temperature and wind speed at 0000 UTC





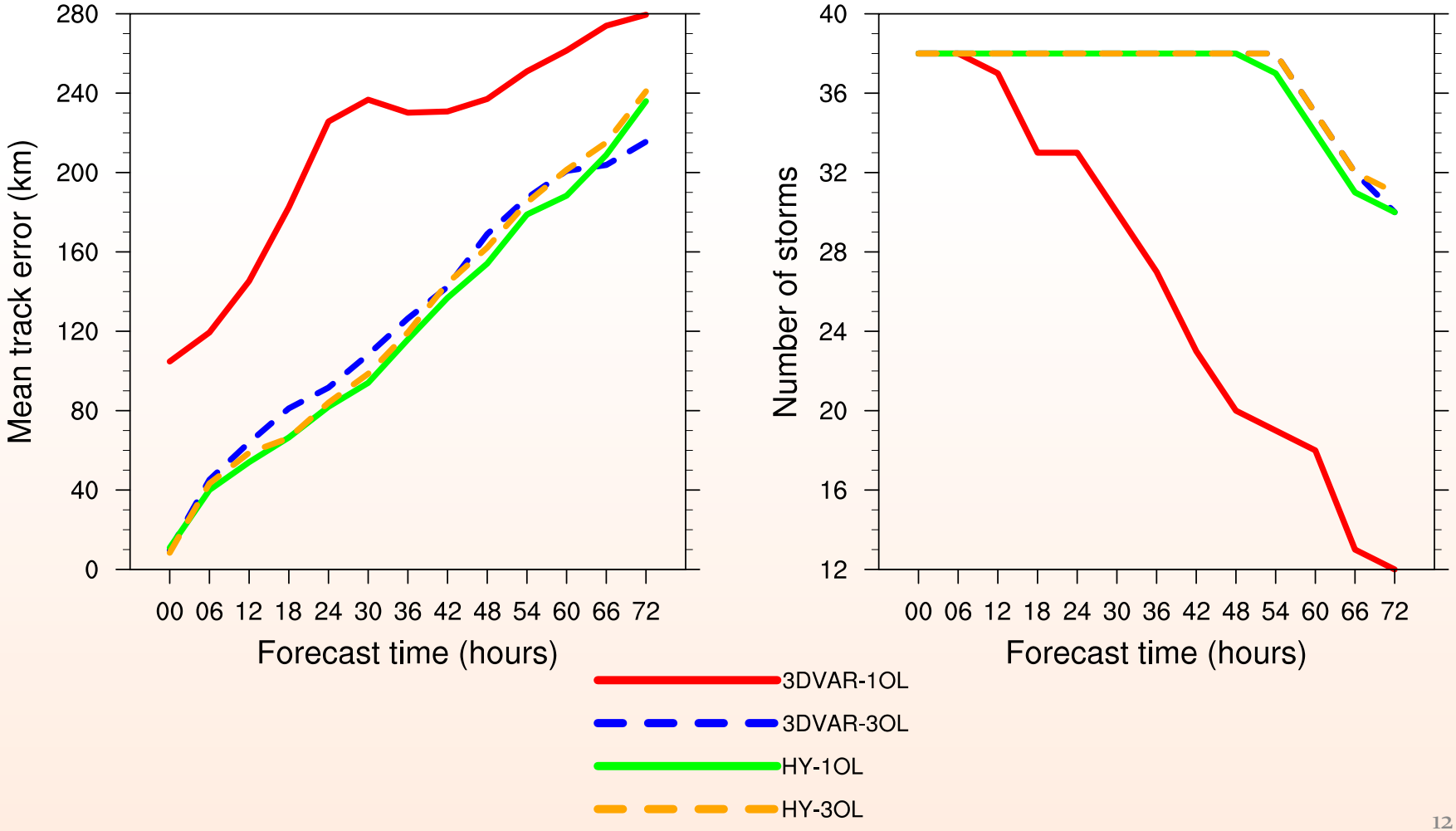
Analysis positions

•Best track and initial analysis positions between 1800 UTC 8 September and 0000 UTC 28 September (every 6-hrs)



Mean track errors for Sinlaku

- Inhomogeneous comparison to keep sample sizes larger



Mean track errors for Hagupit

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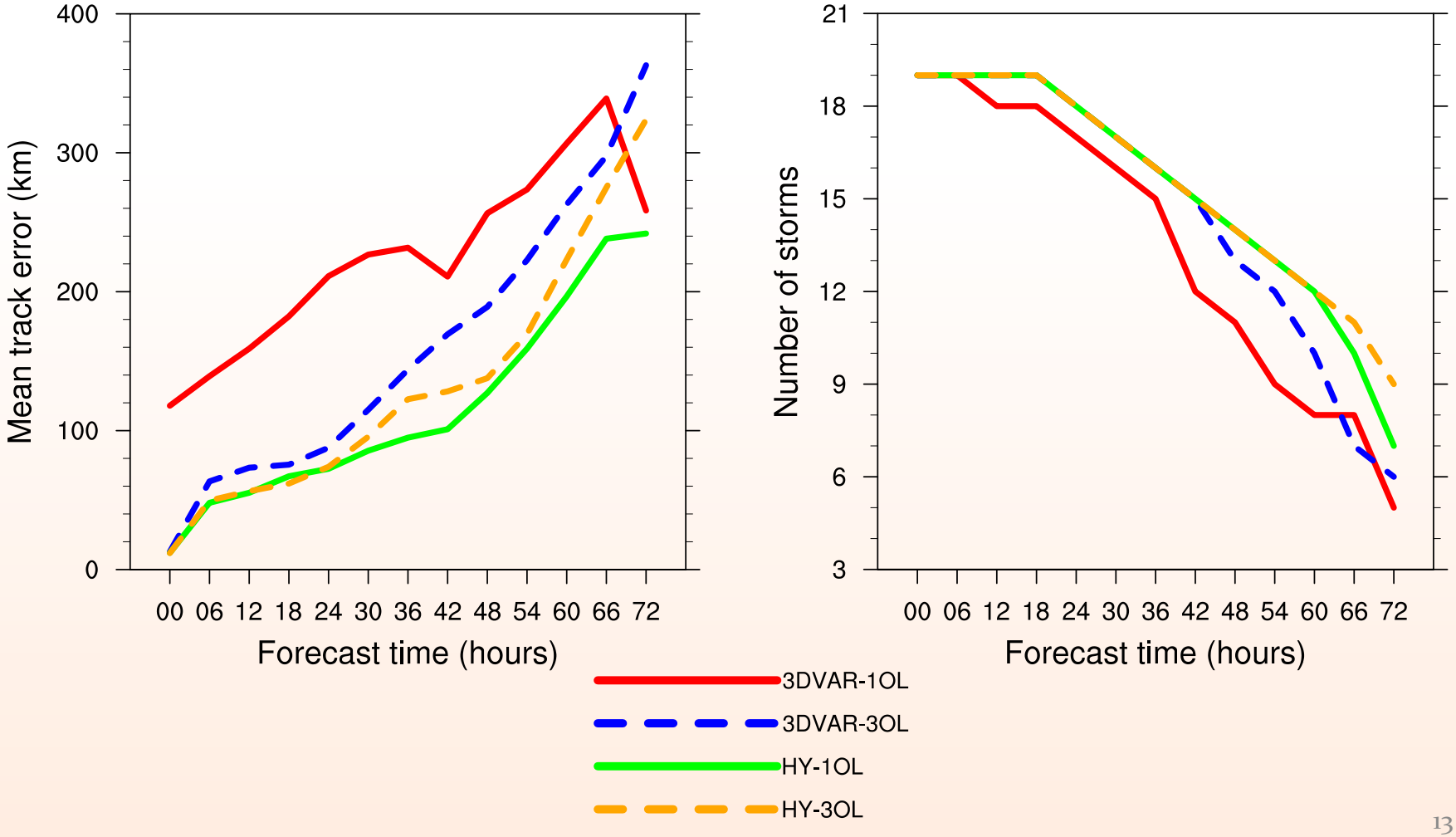

Mean track errors for Jangmi

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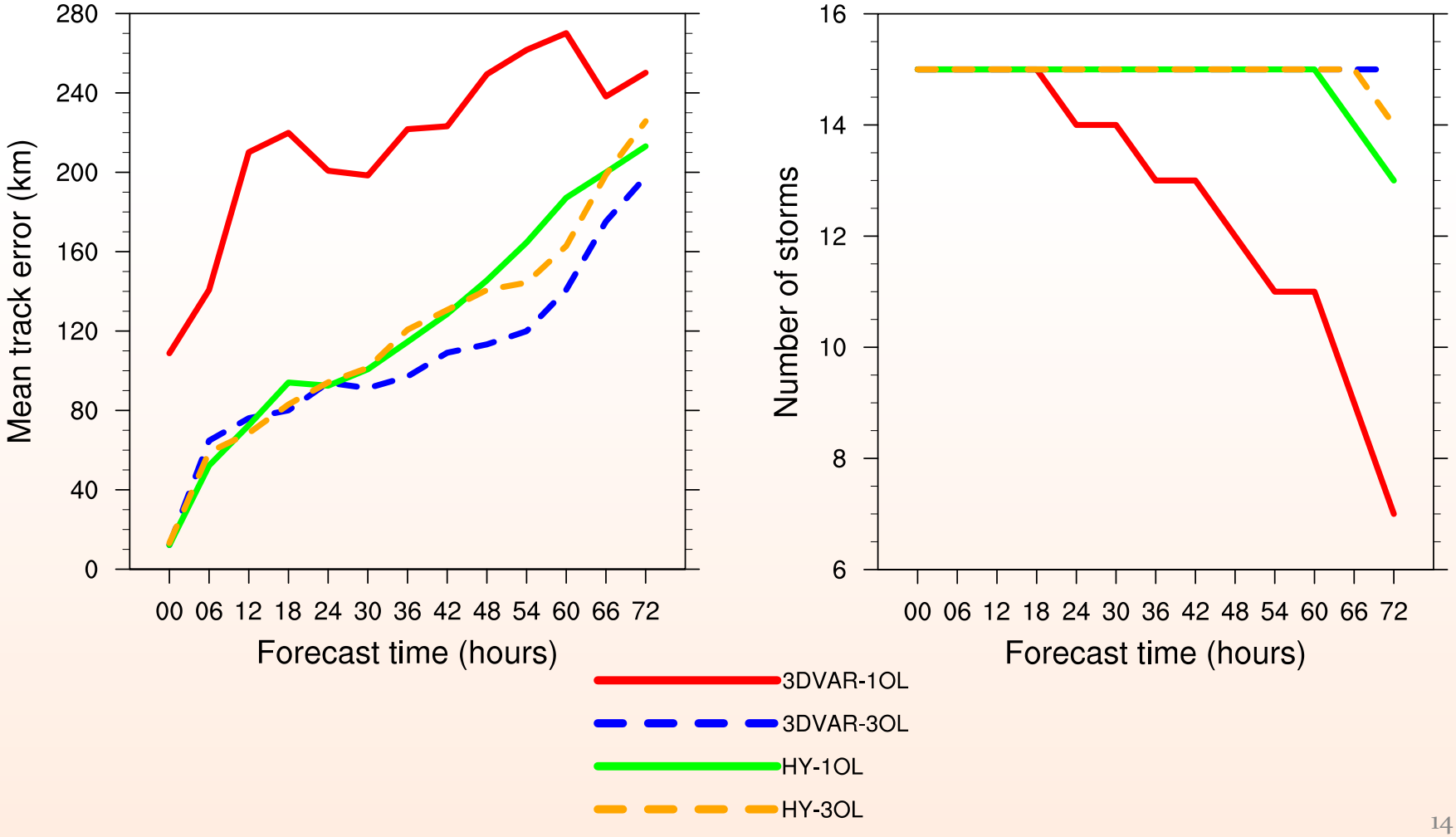
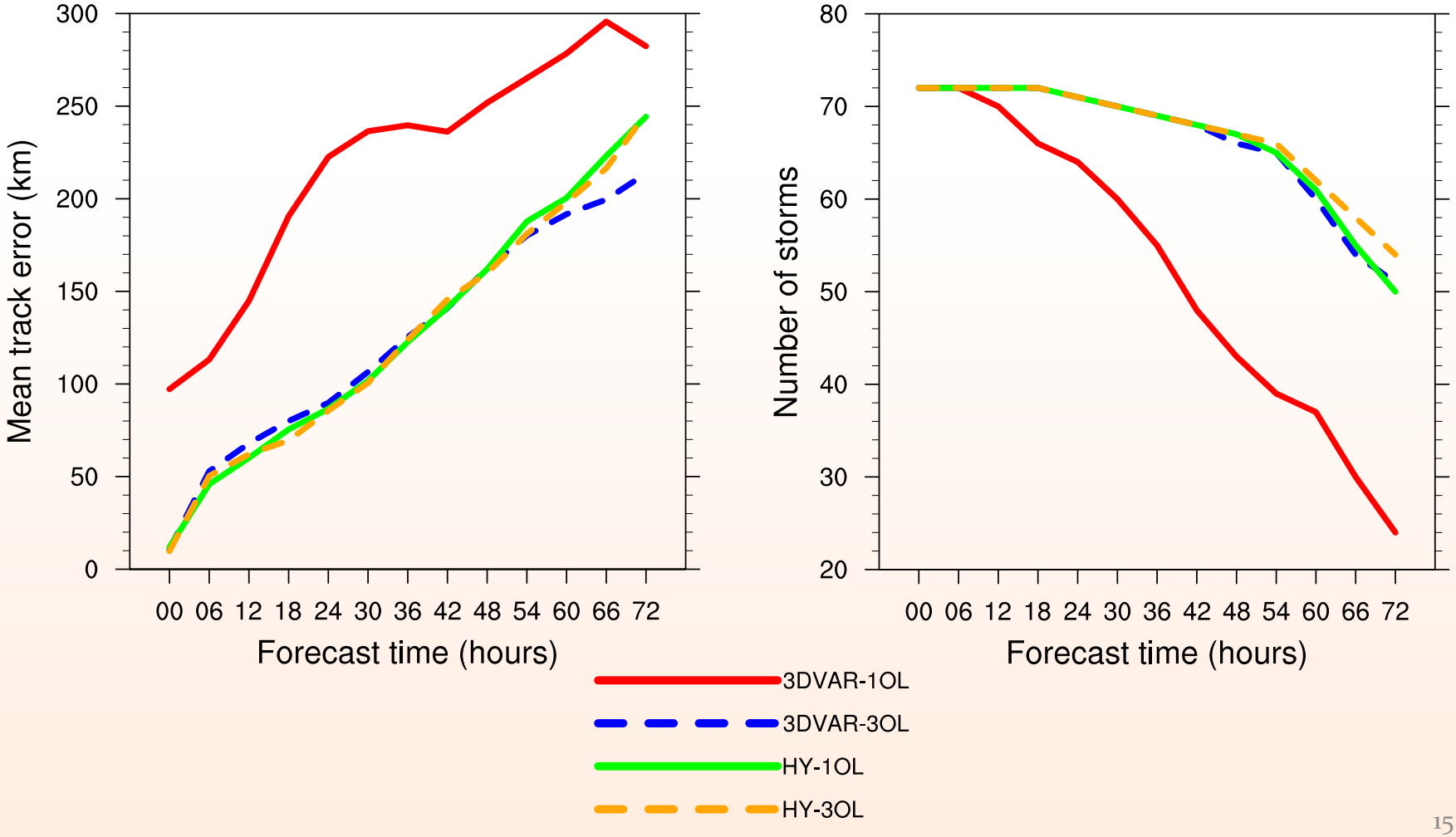


Mean track errors: All Storms

- Inhomogeneous comparison to keep sample sizes larger



How to use multiple OLs in WRFDA

- Very easy—namelist controlled

- WRFDA namelist "max_ext_its" variable

- For 1 OL:

```
&wrfvar6
  max_ext_its = 1
```

- For 3 OLs:

```
&wrfvar6
  max_ext_its = 3
```

Summary

- When just 1 OL was used during minimization, the hybrid produced superior tropical cyclone track forecasts than 3DVAR

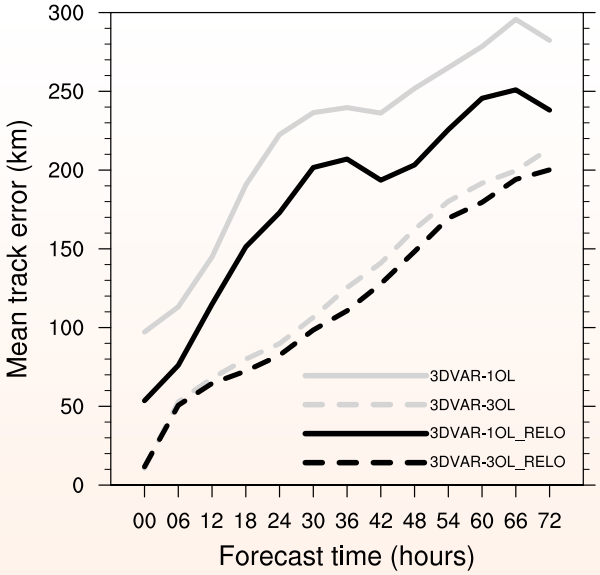
- Using multiple OLs greatly improved 3DVAR typhoon forecasts

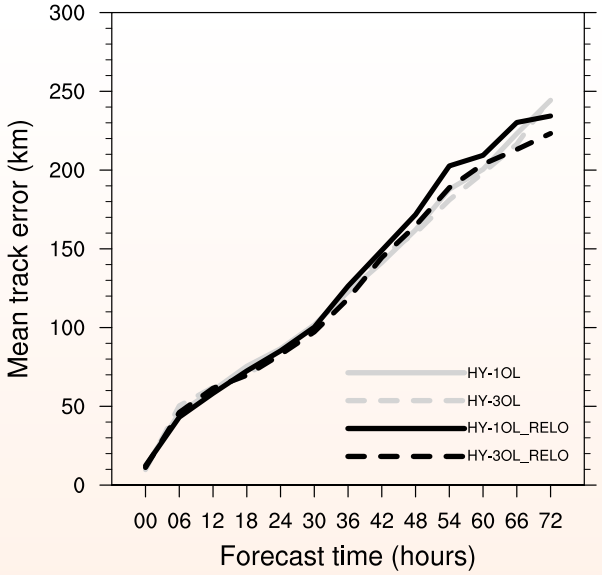
- On average, hybrid forecasts unaffected by using multiple OLs

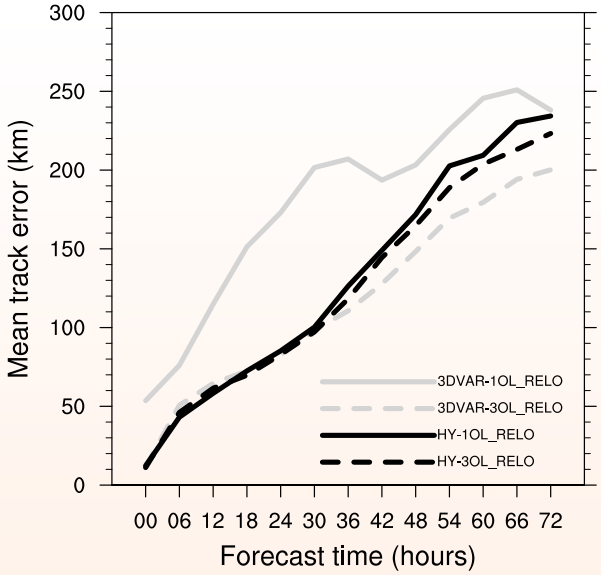

NESL

Impact of TC relocation

•3DVAR and hybrid experiments were re-run but with a TC relocation scheme applied before each analysis







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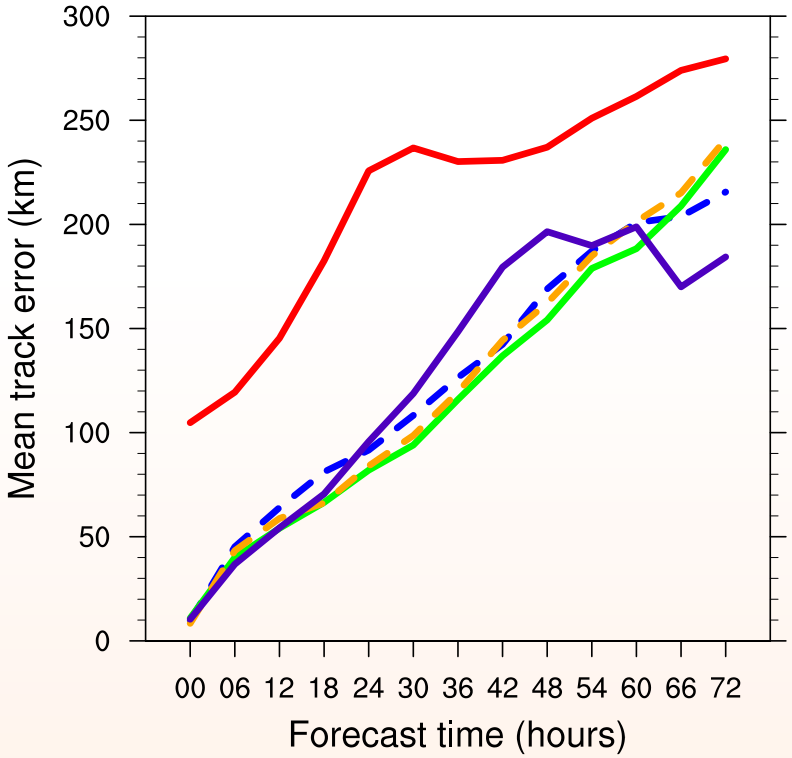

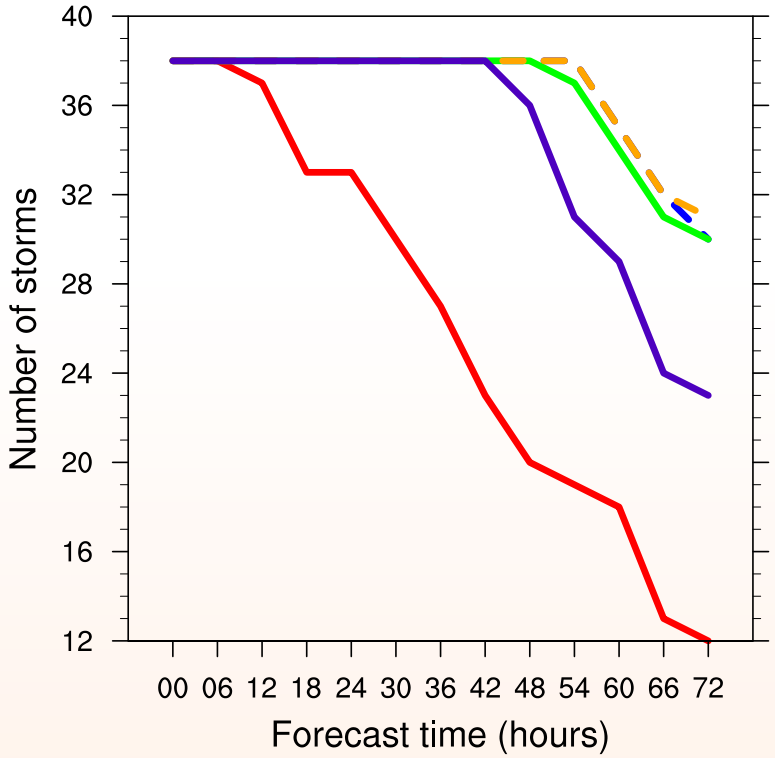

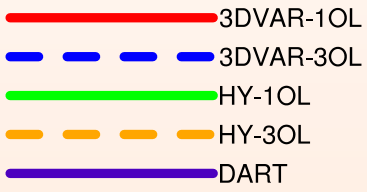

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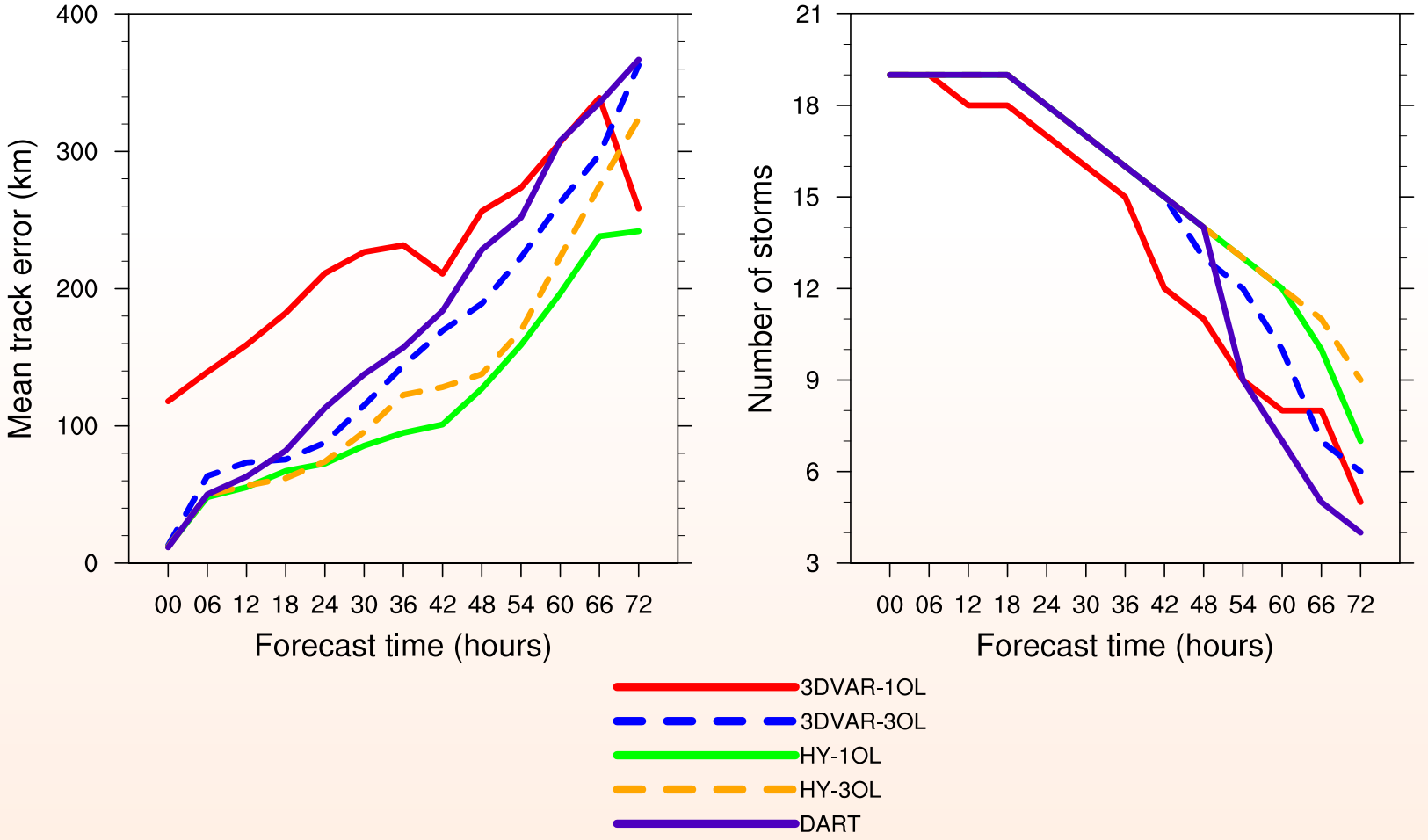

Mean track errors for Jangmi

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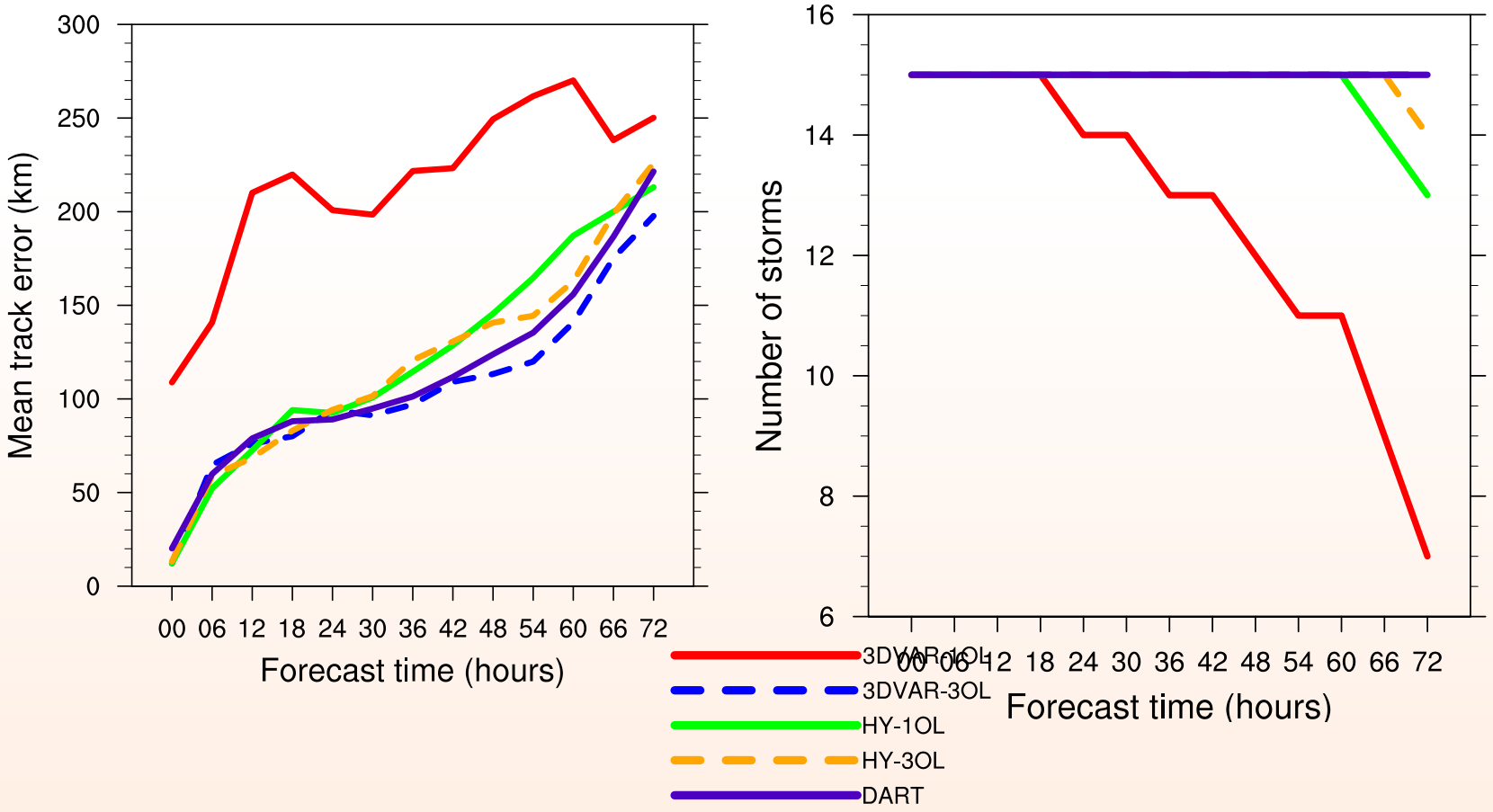

Mean track errors All Storms

- Inhomogeneous comparison to keep sample sizes larger