The Influences of Low-Frequency Vorticity on Tropical Cyclone Formation Based on Systematic Model Simulations

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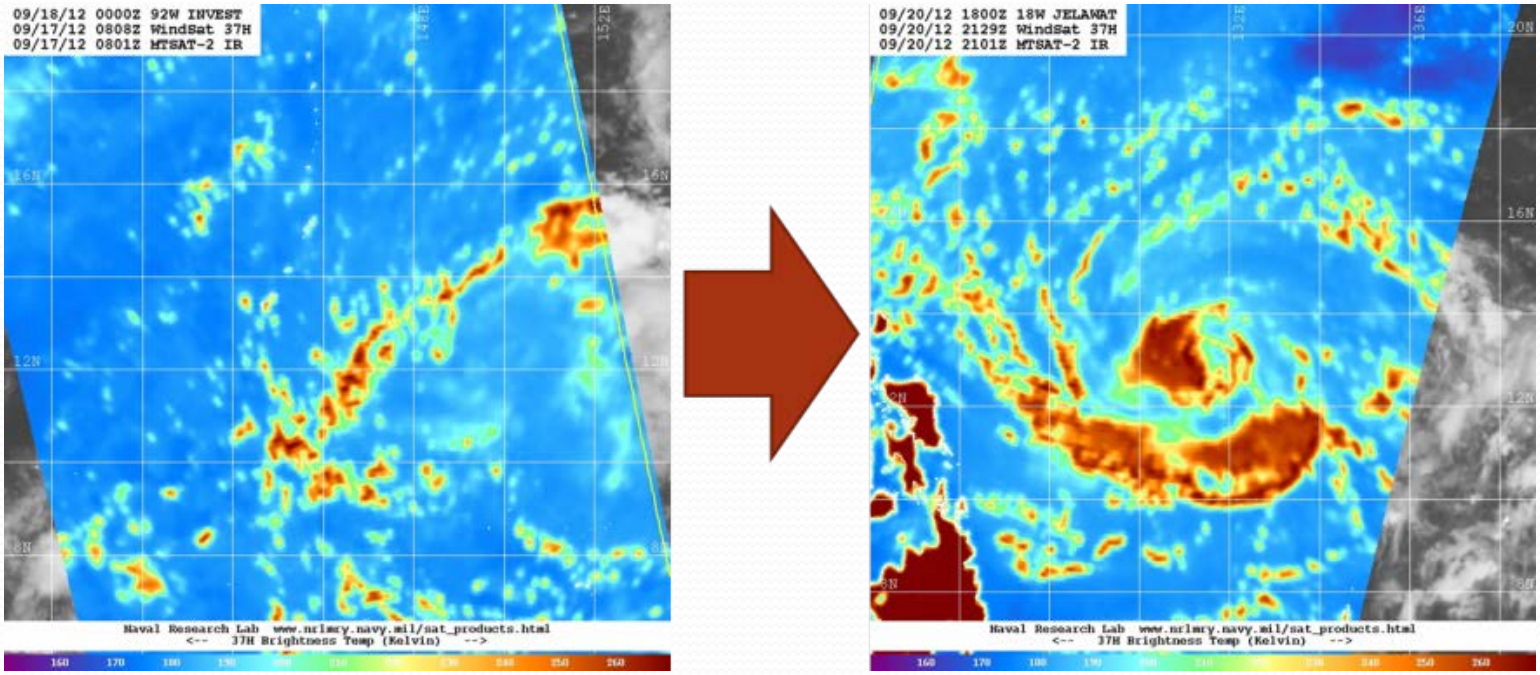
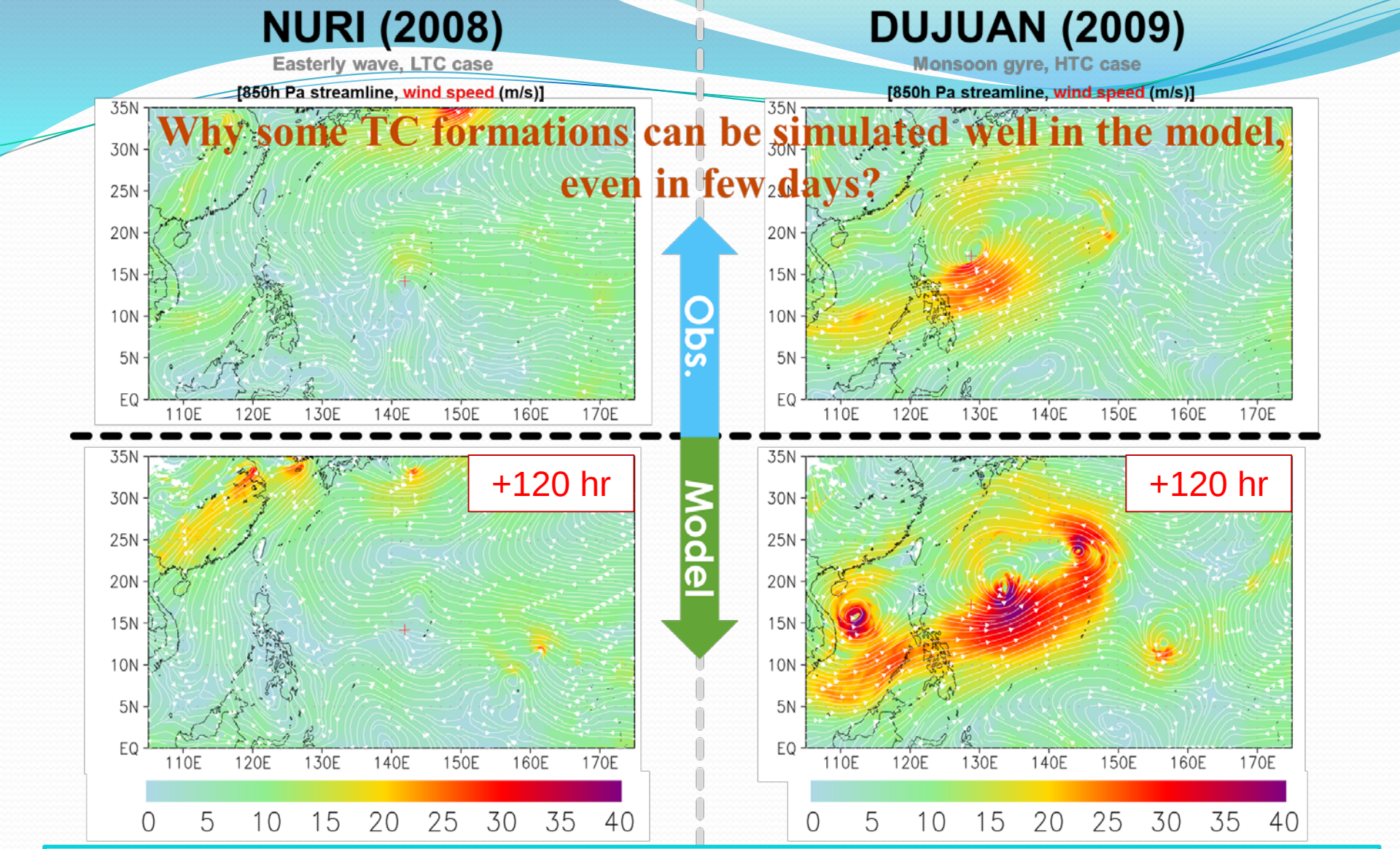
Tropical Cyclone Formation (Tropical Cyclogenesis)



...However, implicit in this operational genesis criterion is the expectation that the tropical storm will continue to develop from this point forward; that is, *that the storm will become self-sustaining*. This is the definition of genesis that we will use here: **tropical cyclogenesis has occurred when the tropical storm has become self-sustaining and can continue to intensify without help from its environment (external forcing).**

-The COMET® Program



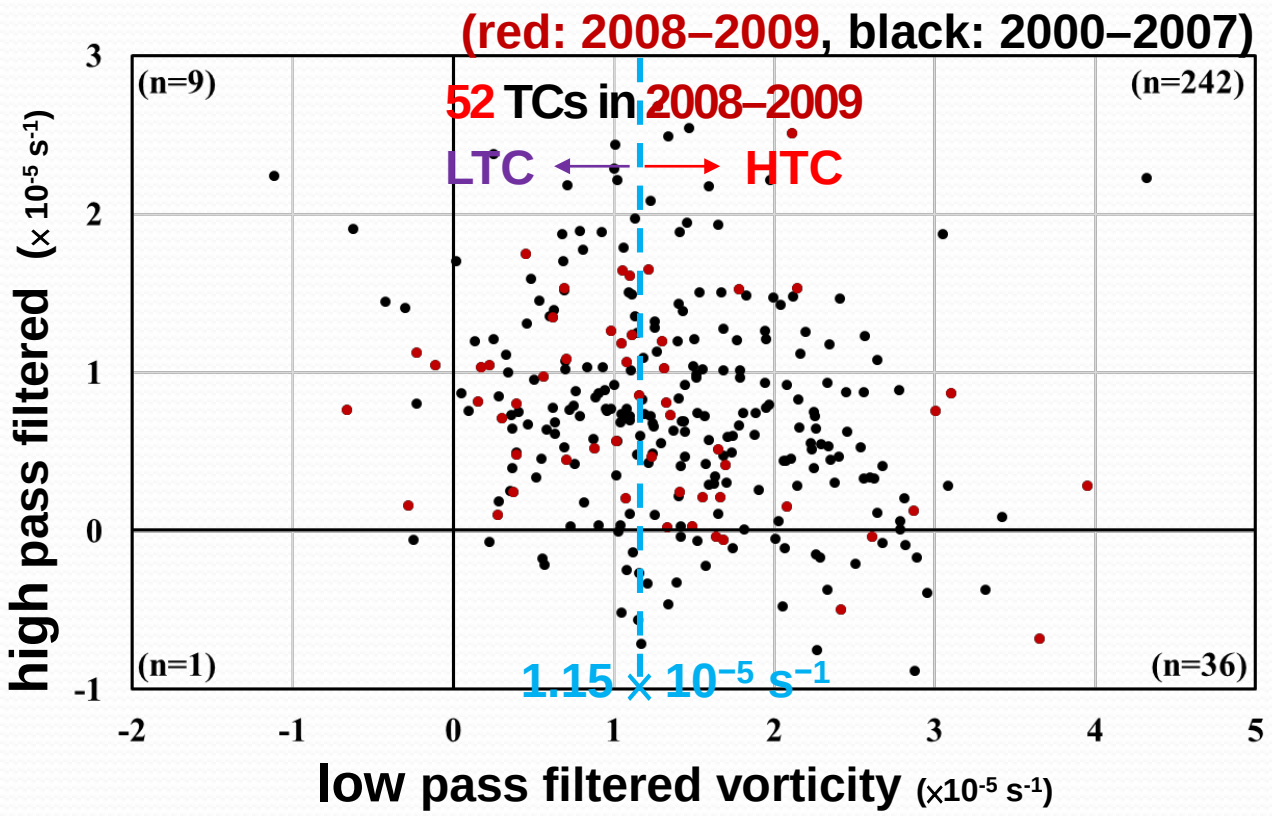
The 32-day ensemble forecast model of ECMWF was able to resolve the formation of most TCs (2009–2010), but some of the weak and short-lived TCs were missed.

- (Elsberry et al., 2010, 2011; Tsai and Elsberry, 2013; Elsberry et al., 2014)

Background 850-hPa vorticity of pre-TC disturbances

The 10-day*[2] low pass and high pass filters are applied to NCEP_FNL (2000-2009) data to obtained low/high pass filtered winds. - (*[2] Wu et al., 2013)

Use filtered winds to compute 850-hPa mean vorticity within 5° radius of the pre-TC disturbance in the WNP at 24-48h before the formation of TC (Vmax ~ 25kt).



TCs with Higher low-frequency vorticity, 26 HTCs - HTCs
TCs with Lower low-frequency vorticity, 26 LTCs - LTCs

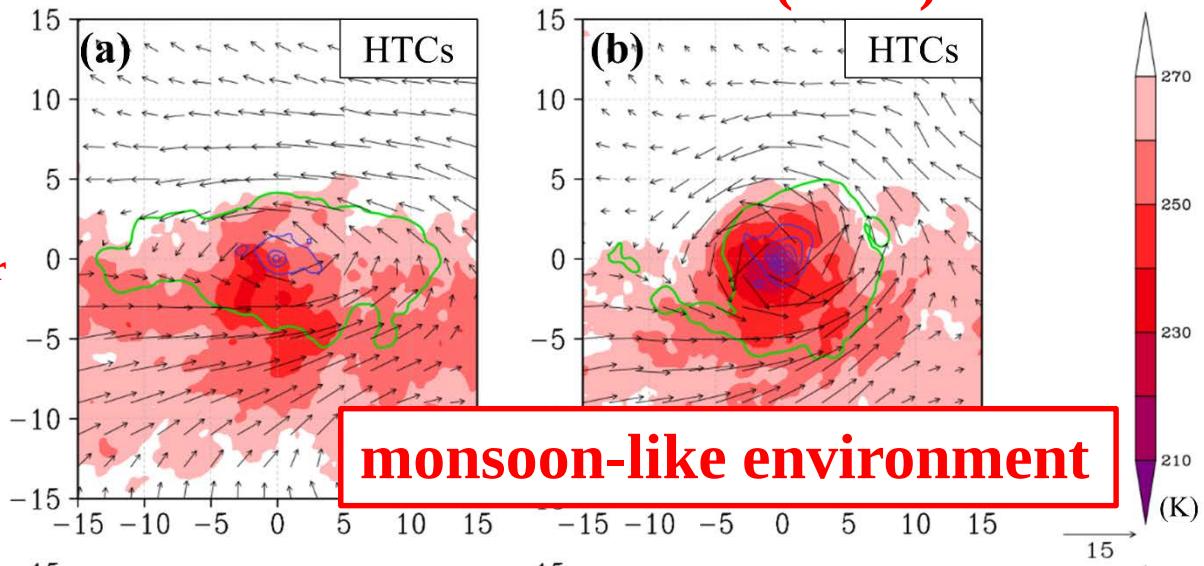
Synoptic environments during TC formation (850hPa)

- 48 h

0 h (25 kt)

HTCs

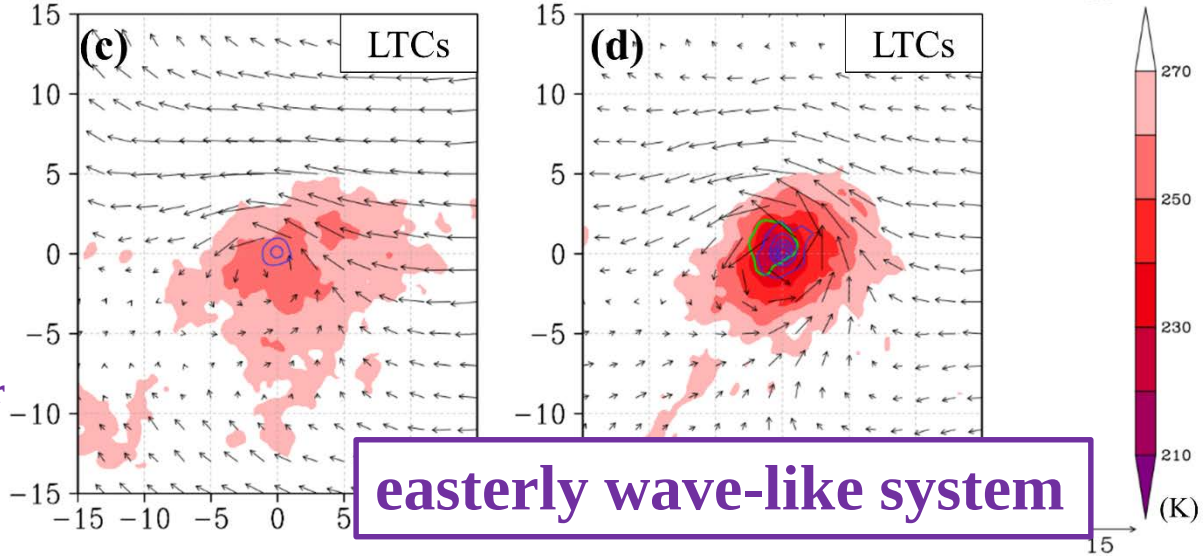
TCs with higher low-frequency vorticity



monsoon-like environment

LTCs

TCs with lower low-frequency vorticity



easterly wave-like system

Vorticity (~2x10^{-5}s^{-1}), wind vectors and cloud top temperature

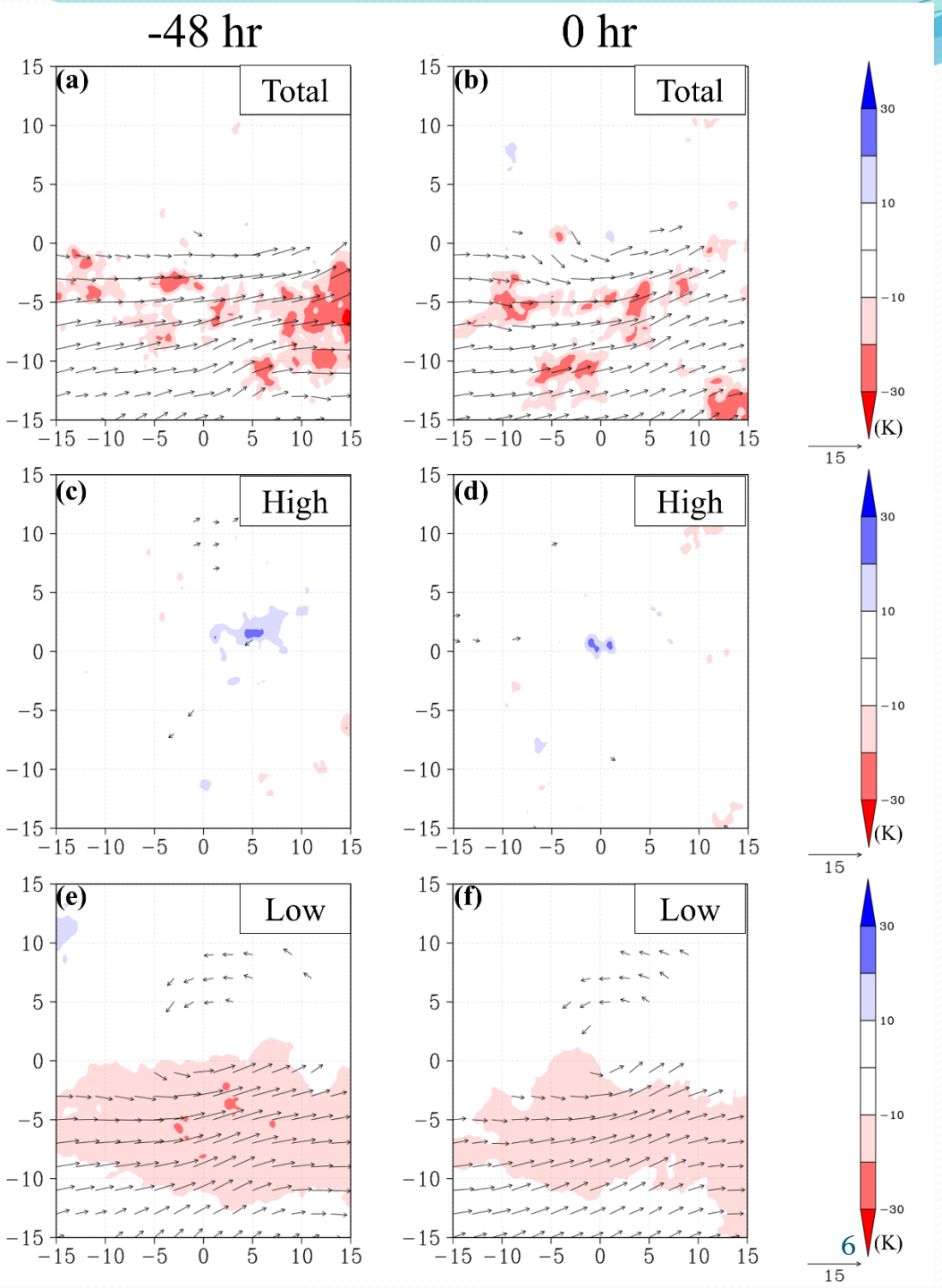
Difference of synoptic environments between HTCs and LTCs

HTCs – LTCs:

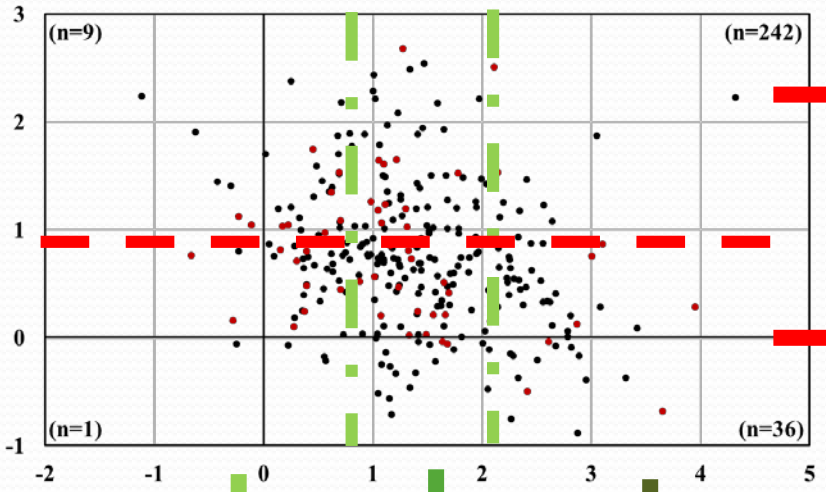
wind vectors, cloud top temperature

(pass 95% T-test)

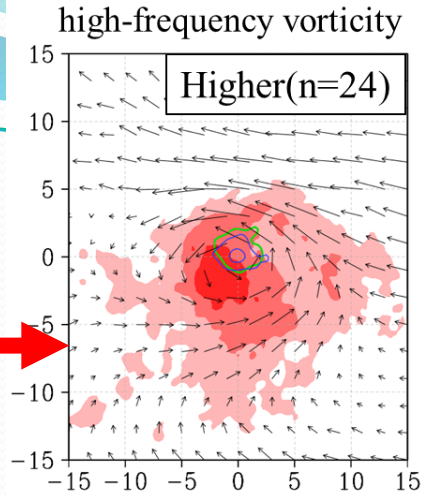
- The 850 hPa flow to the south of the circulation center is predominantly westerly for HTCs, but more easterlies for LTCs.
- This difference is mainly due to the difference in the 10-day low-pass filtered 850 hPa wind field (**pass T-test**)

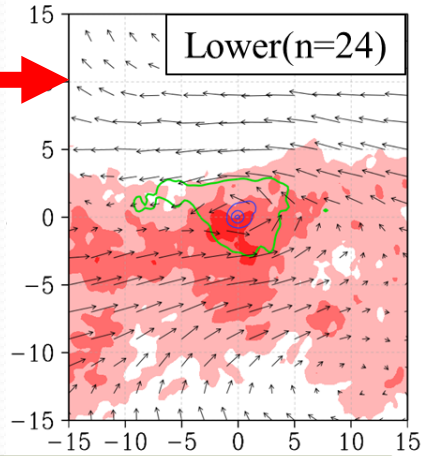


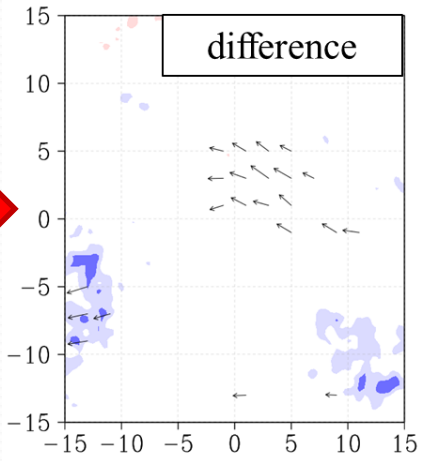
Synoptic environments during TC formation (850hPa)

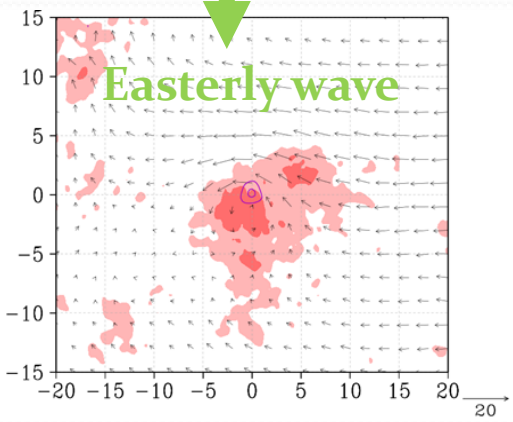


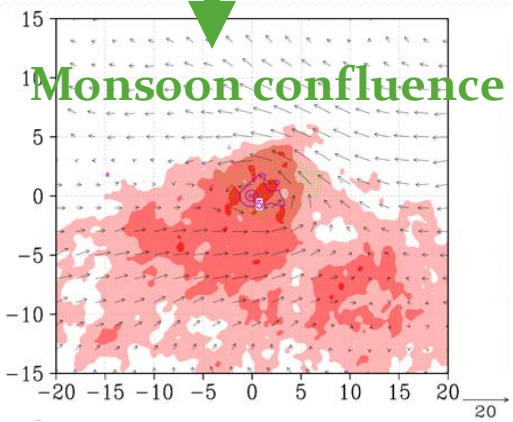
high-frequency vorticity

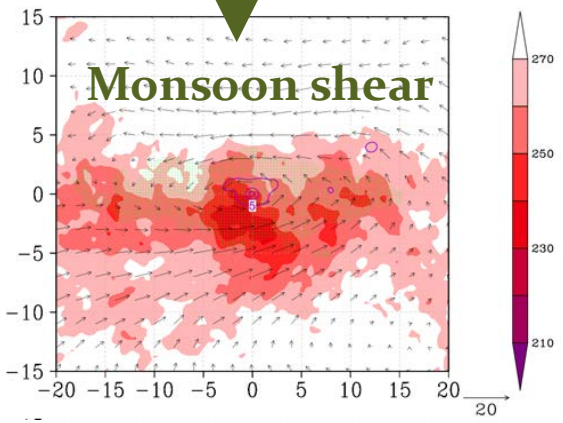












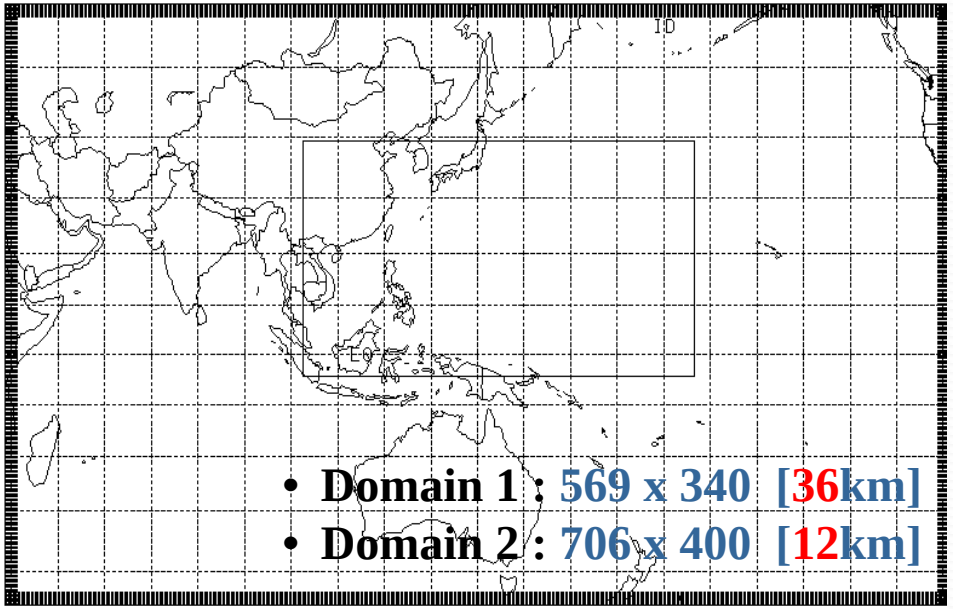
Model setup of systematic numerical simulations

Use WRF V3.2.1 to simulate
all 52 TCs in 2008 and 2009

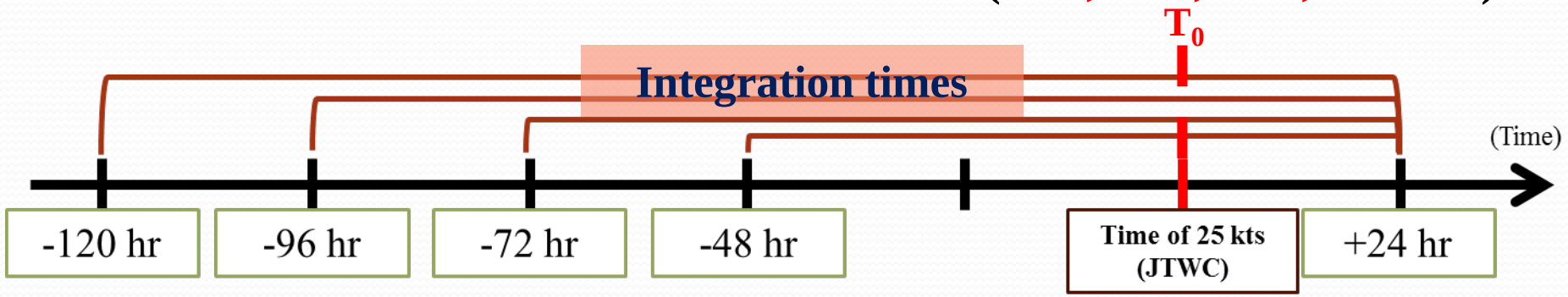
Cloud microphysics: WDM6
Cumulus scheme: Kain-Fritsch
PBL Physics : YSU

-Kieu and Zhang, 2008; Chiao and Jenkins, 2010; Wang et al., 2010; Crosbie and Serra, 2014; Li et al., 2014; Xu et al., 2014

Initial conditions:
NCEP_FNL &
EC_YOTC (available only in 2008-2009)



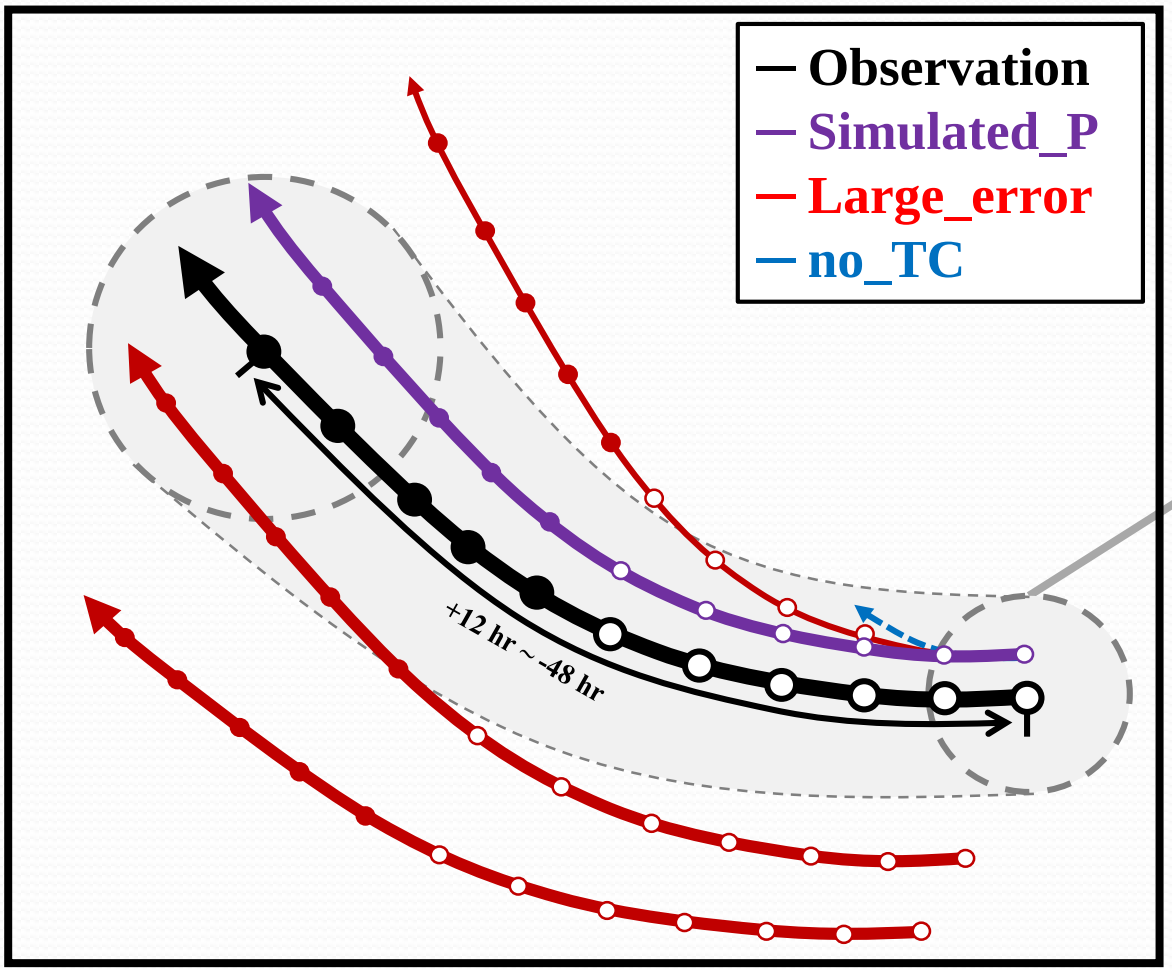
Simulations started at 4 distinct initial times (-48h, -72h, -96h, & -120h)



For each TC: 2 (initial conditions) x 4 (initial times) = 8 members

416 runs

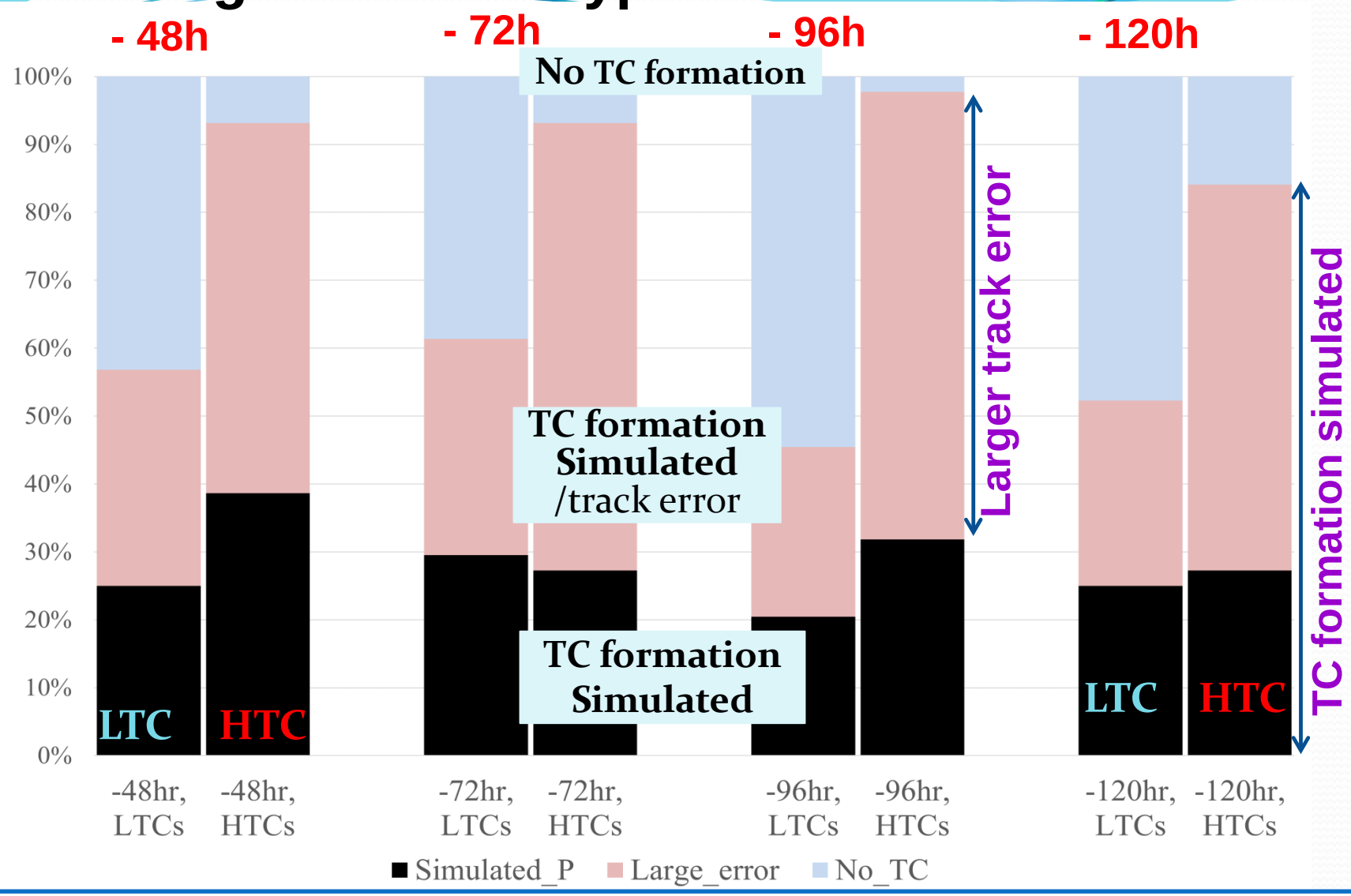
The classification of model simulated TCs



- Dashed circle – mean track error of all simulated TCs (varies with initial time)
  - -48h ~ 249 km,
  - -72h ~ 301 km,
  - -96h ~ 441 km,
  - -120h ~ 600 km,
- Continuous ≥ 3 (6-hourly)
- Discontinuous ≥ 4 (6-hourly)

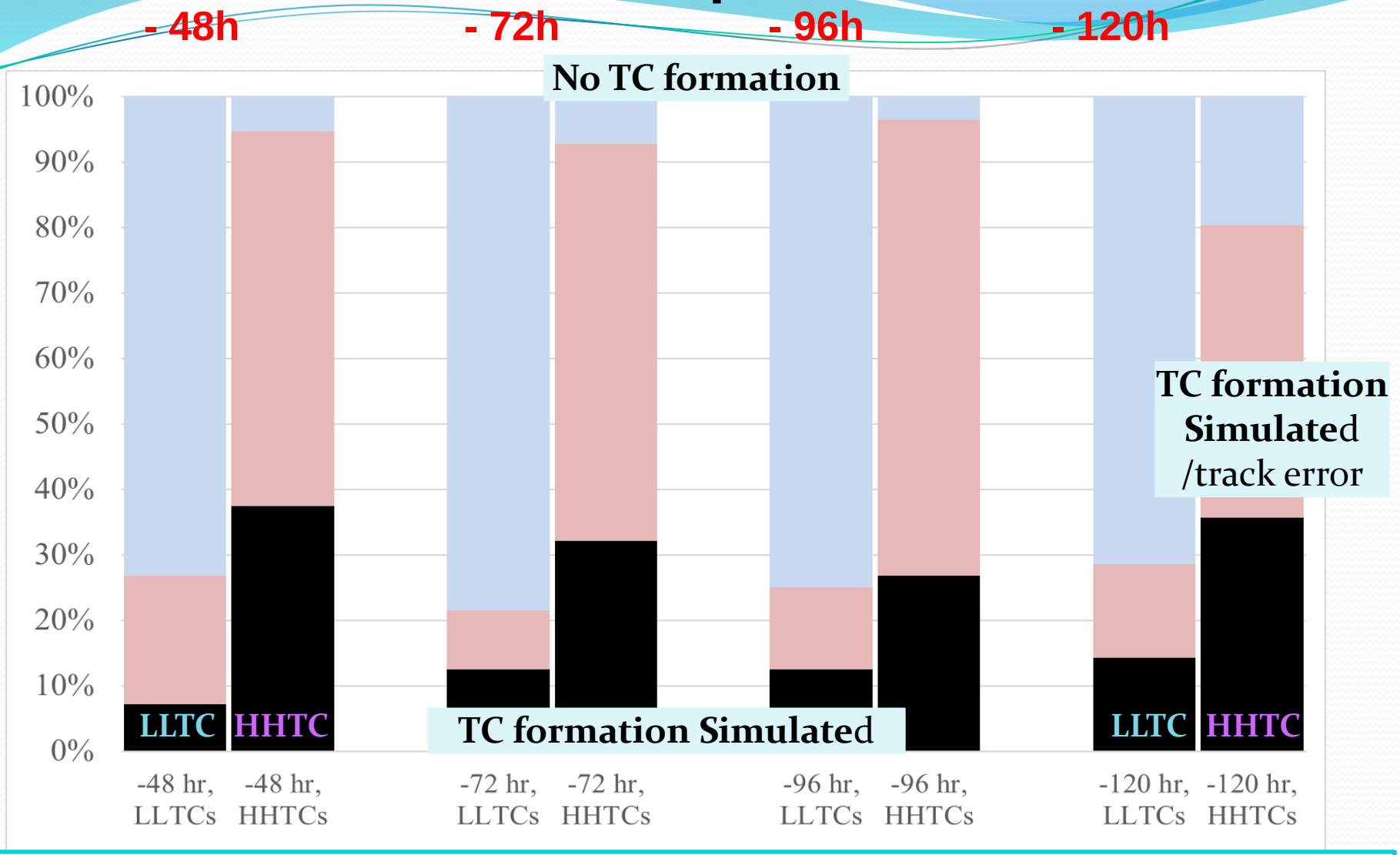
Classify all 416 simulations into 3 groups: No_TC, Simulated_P, Large_error (track error)

Percentages of three types of simulation results



Model is more capable of simulating the formation of a HTC, but w/larger location bias.
Model is less capable of simulating the formation of a LTC, but w/smaller location bias.

Cumulus experiment



The relative proportions of five simulation results for HHTCs and LLTCs are similar to those for HTCs and LTCs

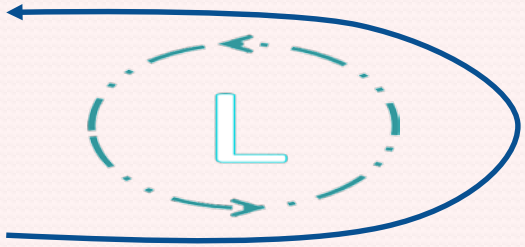
LTCs

Lower low-frequency vorticity

- easterly wave-like
- harder for TC formation (lower percentage)
- smaller track error
- Simulation results sensitive to the cumulus schemes

HTCs

Higher low-frequency vorticity



- monsoon-like
- easier for TC formation (higher percentage)
- larger track error
- Simulation results not too sensitive to the cu schemes

The convection process (cumulus scheme) is not the dominant factor for TC formation in an environment with large low-frequency vorticity, but very important if the environmental low-frequency vorticity is small.

(Hsieh et al. 2017, MWR, in press)

Model dependent?

To test the sensitivity of current results to the model used in the simulations, forecast results of 3 TIGGE members were analysed.

- **TIGGE**
  THORPEX Interactive Grand Global Ensemble
- **A major component of THORPEX:**
  a WMO World Weather Research Programme to accelerate the improvements in the accuracy of 1-day to 2-week high-impact weather forecasts

-Richard Swinbank and Masayuki Kyouda, 2013

- ✓ Three TIGGE members (EC, NCEP, BoM)
- ✓ The relative proportions of three simulation results in TIGGE forecasts are similar to those for HTCs and LTCs

→ ~~Model dependent~~

LTCs

HTCs

The convection process (cumulus scheme) is not the dominant factor for TC formation in an environment with large low-frequency vorticity, but very important if the environmental low-frequency vorticity is small. **(Hsieh et al., 2017, MWR, in press)**

convection might represent a critical low-level vorticity source

- **weak and short-lived TCs are difficult to simulate or predict in global models**
  - (Tsai et al. 2013; Elsberry et al. 2014; and Nakano et al. 2015)
- **an appropriate cumulus scheme and initial conditions are vital for accurate TC simulation.**
  - (Cheung and Elsberry 2006; Li et al. 2014; and Li and Pu 2014)
- **similar simulation results have been found for Atlantic easterly wave cases**
  - (Wang et al. 2010; Suzuki-Parker 2012; Thatcher and Pu 2013)

organized convection can easily concentrate vorticity

- **convection affect the timing and location of TC center development**
  - (Tory et al. 2006 ;Tory et al. 2007)
- **the initiation of convection and the stochastic nature of convection results in larger simulated TC track errors**
  - (Lee et al. 2008; Chang 2013)
- **Reasonably TC number when using the low-frequency background as initial conditions**
  - (Wu and Duan 2015)
- **False alarms**

Thanks for your attention

(red: non-formation, blue: formation)

future works