The 1st Review Opinion for "Development Processes of the East Asian Cyclones over the Korean Peninsula" (WCD-2020-65)

by Joonsuk M. Kang, Seok-Woo Son

(08 February 2021)

General Comments:

By using the six-hourly ERA-Interim data interpolated onto 1.5° × 1.5° latitude-longitude grids, this manuscript aims to quantitatively evaluate the development processes of the extratropical cyclones (ETC) passing the Korean Peninsula from 1979 to 2017 by using the potential vorticity (PV) tendency equation. A feature tracking algorithm using the relative vorticity at 850 hPa is applied to objectively identify the so-called northern- and southern-track (NT and ST) cyclones affecting the Korean Peninsula region in the cold season (October to May). The dynamic and thermodynamic contributions to the development of these two categories of cyclones are then comparatively assessed from the PV tendency equation. The results suggested that East Asian cyclones passing the Korean Peninsula had different development processes depending on their tracks. Generally, the structure of this manuscript is fine, and its English language is better being non-native authors, as most sentences can be understood easily without any difficulties. However, it is necessary to indicate that, this manuscript at the present stage, didn't supply new and sharp insights into to deeply understand extratropical cyclones, and it is lack of sufficient explanation of physics for those two types of extratropical cyclones passing over the Korean Peninsula. Thus, it is very hard for referee to recommend this manuscript to be acceptable before the authors make clearer clarifications to the following key questions. It strongly suggests that this manuscript needs MAJOR REVISION before its potential publication in WCD.

Major Comments:

1. The background and methods of tracking ETCs were not introduced

adequately. There were a great number of methods of tracking ETCs. As indicated by Neu et al. (2013) “Identifying and tracking extratropical cyclones might seem, superficially, to be a straightforward activity, but in reality it is very challenging” (line 1-3 in right half, P529). The use of vorticity at 850 hPa for cyclone tracking is only one of 22 methods to identify ETCs as indicated by Neu et al. (2013) (see their Table 1 in P532). Different tracking methods may produce great quantitative differences in the total numbers of ETC (line 24-line 32 in right half page, P535) from 5~6 thousands to 21~28 thousands in two hemispheres. The present manuscript is lack of introducing the background as well as the advantage/disadvantage of using relative vorticity at 850 hPa for cyclone tracking.

2. The present title of this manuscript “Development Processes of the East Asian Cyclones over the Korean Peninsula” is not consistent with its content. More previous studies had indicated, and even the present authors admitted, that the development processes of ETCs involved in more complicated physics processes such as baroclinic process, upper-level trough, latent heating and so on. This manuscript only examines the development (intensifying/deepening) processes from one of various angles: PV perspective. Thus, it is suggested to use “PV Perspective of Development Processes of the East Asian Cyclones over the Korean Peninsula” or “Development Processes of the East Asian Cyclones over the Korean Peninsula: A Potential Vorticity Perspective” or other suitable title if the authors insisted on using PV analysis. It is much better to leave more rooms for other researchers.

3. The data and methods used in the present study is strongly argued. The present authors employed the six-hourly ERA-Interim data during the period from 1979 to 2017 which were interpolated onto $1.5^{o} \times 1.5^{o}$ (same data with K20), and the ETCs under investigation were identified on the 850-hPa relative vorticity field “Note that these ETCs fall into the categories of rapidly intensifying cyclones in K20” (line 89). Why did not the present authors use

more high-resolution data, for instance, ERA5 data (issued by ECMWF) with horizontal resolution $0.25^o \times 0.25^o$ and 1 hour interval? Or even FNL data (issued by NCEP) with horizontal resolution $1^o \times 1^o$ and 6 hour interval? As indicated by authors "The PV is calculated from horizontal winds and temperature by approximating partial differentials with second-order finite differencing" (line 65). What an error will be produced in the calculation of relative vorticity field at 850 hPa, then PV, from horizontal winds by approximating partial differential? As the target domain is 120^oE-135^oE, 33^oE-48^oN (line 78) with a region 15 $^o\times$ 15^o, it suggests that whole domain only covers 5 × 5 PV values if the authors employed the "central finite differencing" scheme to calculate the PV from horizontal winds. How to calculate the geopotential tendency limited by the boundary conditions?

4. It is not convincing that two important references supporting WCD-2020-65 properly. The authors indicated at "In East Asia, cyclogenesis is remarked over Mongolia and East China (Chen et al., 1991; Adachi and Kimura, 2007" (line 29). This citation plays quite important role for WCD-2020-65. We examined carefully the detailed information from words and figures in the aforementioned two papers (named as "Chen1991" and "AK2007", respectively), and found a great discrepancy between Fig. 2 of "Chen1991" (see Figure A) and Fig.1a of WCD-2020-65 (see Figure B). It is OK that "N region" is Figure A can be seen in Figure B correspondingly. But it is very strange that "S region" (the high cyclogenesis density region) in Figure A can not be found in Figure B. This may be perhaps explained that they used different period data with different resolution. "Chen1991" used the twelve-hourly historic weather maps from 1958 to 1987, and $2.5^o \times 2.5^o$ latitude-longitude (coarse-resolution data) for cyclogenesis frequency counting. WCD-2020-65 used six-hourly $1.5^o \times 1.5^o$ ERA-Interim data (fine-resolution data) from 1979 to 2017. The overlapping period of these two data is INDEED 9 years (from 1979 to 1987). It is very hard

for referee to understand the important feature of “high cyclogenesis density region” in “Chen1991” (coarse-resolution data) disappeared in WCD-2020-65 (fine-resolution data). Is it suggested this great discrepancy hint that the method of using vorticity at 850 hPa for cyclone tracking is questionable? Moreover, the present referee failed to find “cyclogenesis is remarked over East China”. In “Chen1991” paper, we didn’t find the term “East China” but “East China Sea”. In AK2007 paper, they mentioned “East China Sea” several times, but not “East China”. It is strongly expected that the authors could clarify this issue.

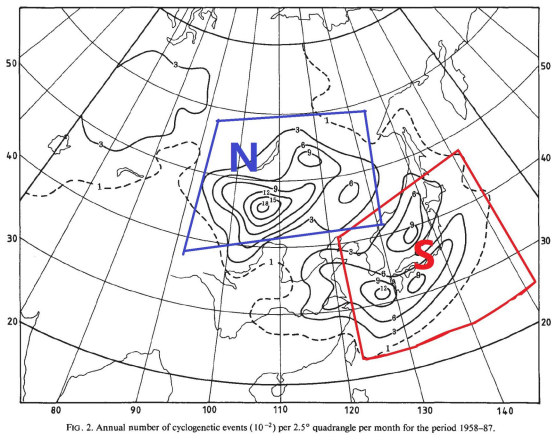

FIG. 2. Annual number of cyclogenetic events (10^{-2}) per 2.5° quadrangle per month for the period 1958–87.

Figure A: This figure was cited from Figure 2 in page 1409 of “Chen1991”. “FIG.2 Annual number of cyclogenetic events (10^{-2}) per 2.5° quadrangle per month for the period 1958-87”.

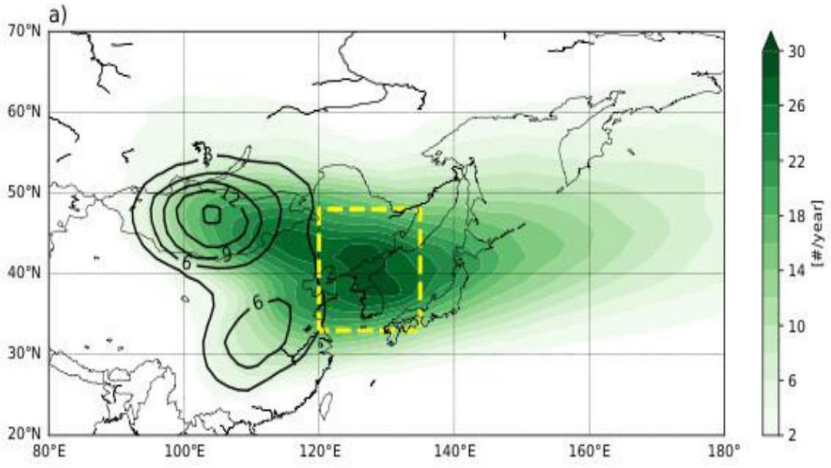

Figure B: This figure was cited from Figure 1a in page 15 of WCD-2020-65. “Figure 1. (a) Track (shading, units: number per year) and cyclogenesis density (black, units: number per year) of the cold season ETCs passing the target domain (yellow box)”.

5. In the present study, the PV tendency equation is a very important tool for analysis. The authors also described this equation from term to term (line 95-103) as follows:

"The first term on the rhs of Eq. (1), representing the horizontal PV advection, describes the effects of the propagation and interaction of the upper-level trough and lower-level cyclonic circulation. The second term, representing the vertical PV advection, is physically related to the vertical change of adiabatic cooling which generally weakens ETC development. The third and fourth terms respectively stand for local PV changes from latent heating and other non conservative processes such as friction and cloud radiation". It is very strange that "in terms of the relative vorticity tendency resulting from the PV tendency inversion" (line 10). How about "relative vorticity tendency resulting from PV tendency inversion" ? If there exists a "relative vorticity tendency" term in PV tendency inversion, please describe it to all readers.

6. It is very hard for referee to understand the theory described from line 104 to line 130. What is(are) the scientific purpose(s) to establish "large theoretical framework" ? If the authors need the information of relative vorticity tendency (ζ_t) (line 182), it is easy to calculate this term according to the following relative vorticity equation:

$$\frac{\partial \zeta}{\partial \mathrm{t}} = -\vec{V} \cdot \nabla(\zeta + f) - \omega \frac{\partial \zeta}{\partial p} - (\zeta + f)\nabla \cdot \vec{V} + \vec{k} \cdot (\frac{\partial \vec{V}}{\partial p} \times \nabla \omega) \qquad (4.21)$$

Please see details about the relative vorticity equation (4.21) in page 103 of Holton's book "An Introduction to Dynamic Meteorology" (4th edition).

7. Is it suitable to define the "cold season" from October to May (8 months of one year)? Usually, in mid-latitude region from 30°N to 50°N, May belongs to the early summer season. Are there any references from other scholars to support this definition about "cold season"?

Specific Comments:

1. Line 11-12, "It is quantified through inversion that the NT cyclones develop

87.9% dynamically and 6.2% thermodynamically. In contrast, the respective contributions to the ST cyclones are 71.8% and 43.5% for the ST cyclones". Sorry, we didn't understand the meaning of "percentage" in this sentence. Does it refer to the "number of ETS" or "the percentage of dynamic mechanism and thermodynamic mechanism" ? Now the sum of them is not 100%.

2. Line 64, " ... specific humidity, and pressure velocity data during 39 years ..." . It seems more appropriate to express "pressure velocity" as "vertical velocity in pressure coordinate".

3. Line 69, " ... the Hodges (1995,1999) algorithm ..." Here, a space is required after the comma in the sentence.

4. Line 70, "The spatial filtering is made to focus on synoptic-scale circulation". What kind of spatial filtering method is used in this paper?

5. Line 84, "the top 10% maximum intensification rate". Why did the authors select "top 10% maximum"?

6. Line 85, "The intensification rate is calculated as the 12-hour difference of relative vorticity". On which layer did the author calculate the relative vorticity?

7. Line 87-88 "The average tracks of these NT and ST cyclones are depicted in Fig.1b". How to define the average tracks of these NT and ST cyclones? What is(are) the scientific purpose(s) to do them? Unfortunately, we only find "one red track" and "one blue track" in Fig.1b (not many tracks).

8. Line 89, "Note that these ETCs fall into the categories of rapidly intensifying cyclones in K20.." There are two periods after the sentence.

9. Line 92, "the PV tendency inversion method (KS20)". We did not find the "KS20" paper at all. Even the "*Kang, J. M., and Son, S.-W.: Development processes of explosive cyclones over the Northwest Pacific: Potential vorticity perspective, J. Atmos. Sci., revised*" can be found, it is not suitable to work as a formal reference, because it is under revision.

10. Line 106, "The overbar denotes the mean, which is the monthly climatology

during the analysis period". The average physical quantity used by the authors in the calculation process is monthly mean, while the life cycle of extratropical cyclones is only about one week. Are these two different time scales suitable for study together ?

Key References:

Adachi, S., and F. Kimura, 2007: A 36-year climatology of surface cyclogenesis in East Asia using high-resolution reanalysis data, *SOLA*, **3**, 113-116.

Chen, S.-J., Y.-H. Kuo, P.-Z. Zhang, and Q.-F. Bai, 1991: Synoptic climatology of cyclogenesis over East Asia, 1958-1987. *Mon. Wea. Rev.*, **119**, 1407-1418.

Holton, J. R., 2004: An Introduction to Dynamic Meteorology (4th Edition), *Elsevier Academic Press*, 529.pp

Neu, U, and Coauthors, 2013: IMILAST: A Community Effort to Intercompare Extratropical Cyclone Detection and Tracking Algorithms, *Bull. Amer. Meteor. Soc.*, **94(4)**, 529-547.

https://journals.ametsoc.org/view/journals/bams/94/4/bams-d-11-00154.1.xml