Point-to-point responses to the reviewers' comments

on "A Global Surface Turbulence Heat Flux Dataset resolving tropical cyclones"

We are grateful to the editor and two anonymous reviewers for the valuable time, careful reading and crucial comments on our manuscript. Following the comments, we have substantially revised our paper. This document addresses reviewers' comments point-by-point. Reviewer comments are presented in **black**, our response in blue, and revised manuscript text in orange.

Response to Reviewer #1:

Comments:

1. Various global datasets for air-sea latent and sensible heat fluxes have been available in recent years. This database is particularly original in its approach to representing air-sea latent and sensible heat flux within tropical cyclones. However, unfortunately, at the time of review, I was unable to access the site (https://doi.org/10.57760/sciencedb.24400).

Response: We appreciate these positive and encouraging evaluations, as well as crucial comments, following which we have carefully modified the manuscript accordingly.

Regarding the concern about accessing the data via the provided DOI (https://doi.org/10.57760/sciencedb.24400), we have re-checked the link from multiple network environments and confirm that it is available and directs to the publicly accessible dataset page on the Science Data Bank.

We suspect the access issue might have been caused by a temporary network instability or firewall-related factors. We will keep in active touch with the editorial office to ensure its public access.

2. I would like to commend the efforts regarding the tropical cyclone area, particularly the strong wind distribution. On the other hand, I would like to confirm whether the average wind speed used for evaluating latent and sensible heat fluxes is a 1-minute average or a 10-minute average. In the IBtRACS dataset, the World Meteorological Organization (WMO) standard dataset uses 10-minute average wind speeds. However, 1-minute average wind speeds are commonly used when dealing with Atlantic and Eastern Pacific hurricanes. At the very least, this paper should clearly indicate to users which average time scale was used, or whether a 2-minute average was adopted following the China Meteorological Administration's definition.

Response: Thanks for the positive encouragements and this insightful suggestion. The 10-min average wind speeds of the World Meteorological Organization (WMO) standard dataset have been used to construct the TC-permitted wind field together with the Cross-Calibrated Multi-Platform (CCMP) Version 3.1 dataset (Atlas et al., 2011), which is a 10-m wind field. This information has been clarified in Line 70-71, Page 3, reproduced as follows.

The IBTrACS (Gahtan et al., 2024; Knapp et al., 2010; Knapp, 2018) is used to provide the TC information and construct the wind field from 1993 to 2023. Specifically, we utilize the WMO-standardized 10-minute average maximum wind speed and the radius of maximum wind in IBTrACS dataset, to integrate TC wind speeds into the CCMP dataset.

3. The results of numerical simulations should describe the specifications used in the simulation (such as the model adopted—whether it is an atmosphere-ocean coupled model—and the horizontal resolution). It is desirable to explicitly state the differences from COARE3.6. In addition to sensible and latent heat fluxes, it is desirable to make comparisons of 2-m air temperature, 2-m specific humidity, and 10-m wind speed. For simulations using an atmosphere-ocean coupled model, comparison of salinity concentrations would be also possible.

Response: Following the comments, the details of the numerical simulations have been supplemented in Line 209-217, Page 12. The atmosphere-ocean coupled model has been used for the simulation, with a horizontal resolution of 3 km. The bulk formula with surface drag coefficient (Cd) leveling off at high winds (33 m/s) has been used to calculate the latent and sensible heat flux.

Figures 9 and 10 present the plan views of different flux products and high-resolution case simulation of Typhoon Francisco, based on the simulation results in Ma (2020). The simulations are conducted using the coupled Weather Research and Forecasting (WRF) model with the Stony Brook Parallel Ocean Model (sbPOM). Two domains are configured with dimensions of 350 × 402 and 217 × 217, and horizontal resolutions of 9 and 3 km, respectively. The internal grid moves with the vortex center. In the WRF model, The Yonsei State University (YSU) scheme(Hong et al., 2006) is used to parameterize boundary layer processes. For the surface-layer scheme, the “isftcflx51” option is chosen, ensuring that the surface drag coefficient levels off at hurricane-force wind speeds (33 m s^{-1}) (Donelan et al., 2004). Microphysical processes are parameterized by the Lin scheme (Lin et al., 1983). Radiation schemes are the RRTM longwave scheme (Mlawer et al., 1997) and the Dudhia shortwave (Dudhia, 1989) scheme. The Kain-Fritsch cumulus scheme (Kain, 2004) is utilized in the outermost domain. In the sbPOM model, a total of 40 levels are distributed as default, with 20 levels in the upper 100 m.

Both algorithms of heat flux of WRF model and COARE 3.6 are based on the applications of Monin－Obukhov similarity theory (MOST), where the turbulent fluxes of sensible heat and latent heat are expressed with state variable magnitudes associated with surface friction-t_*, $q_*$and $u_*$for air temperature, specific humidity, and horizontal wind velocity, respectively. Differences among the algorithms are primarily how they estimate $\Psi_{M,\theta,q}(\zeta)$, z_o, z_{ot} and z_{oq}. In the coupled model, the stability functions used in the surface layer scheme follow Paulson (1970) for unstable conditions and Chenge et al. (2005) for stable conditions. The COARE 3.6 employs stability functions based on Beljaars et al. (1991) under stable stratification, while under unstable conditions it adopts a combination of the forms of Businger et al. (1971) with additional convective adjustment (Fairall et al., 2003). Regarding surface roughness lengths, our model calculates the momentum roughness length z_o using the parameterization of Davis et al. (2008), whereas the scalar roughness lengths for heat and moisture (z_{ot} and z_{oq}) are computed following the COARE 3.0 (Fairall et al., 2003). In COARE 3.6, the momentum roughness length is based on a modified Charnock parameter that has been retuned against a comprehensive set of field observations (Edson et al., 2013). Moreover, the scalar roughness lengths z_{ot} and z_{oq} in COARE 3.6 have also been refined using a broader observational database.

The 2-m air temperature, 2-m specific humidity, and 10-m wind speed between simulations and the GHFD have been compared, shown as Figure S16. Relevant discussion is in Lines 225-227, Page 12, reproduced below. We understand that the salinity affects surface flux by modulating sea surface temperature response, so that this analysis has not been added to the manuscript yet. We appreciate these crucial suggestions.

In addition to heat flux, we also compare the 2 m air temperature, 2 m specific humidity, and 10 m wind speed of the simulation with the corresponding variables in GHFD. As illustrated in Figure S16, the mean bias is nearly 0.5 K for 2 m air temperature, about 1.6 g kg^{-1} for 2 m specific humidity, and roughly 5.0 m s^{-1} for 10 m wind speed.

4. Carefully include captions for both the main text and supplementary material to ensure that readers can easily understand. For supplementary material, do not simply list figures and tables; explain which part of the main text they supplement.

Response: Thanks for this comment. The captions in the main text have been re-checked and revised carefully to ensure they are in a standard format. A supplementary text has been added to clarify which part of the main text is explained by these supplementary figures and tables.

5. There is a scarcity of in-situ observational data beneath tropical depressions for calculating latent and sensible heat fluxes, leaving questions about the reliability of satellite-based estimates. Even with current technology, direct observations using sail drones remain challenging, particularly due to the effects of sea spray and platform sway. In this sense, explaining the significance of releasing this dataset in the introduction serves as a consideration for the general reader to prevent misunderstandings.

Response: Thanks for the insightful comment. We have followed the suggestion to add statements explaining the significance of releasing this dataset for the general reader to prevent misunderstandings in Line 40-42, Page 2, as follows.

This large uncertainty is because that there is a scarcity of in-situ observational data beneath TCs for calculating latent and sensible heat fluxes. Direct observations using sail drones are also challenging, particularly due to the complex states of the air-sea interface under TC conditions.

Response to Reviewer #2:

General comments:

The current flux datasets are commonly associated with substantial uncertainties under tropical cyclones. This manuscript presents a new dataset of surface turbulent heat fluxes resolving tropical cyclones by merging various data sources of best track, satellite SST, blended surface winds, and reanalysis datasets using the COARE3.6 algorithm. Validations against observational data and high-resolution simulations show an evident improvement under tropical cyclone conditions compared with other limited-flux datasets. Overall, the work is scientifically meaningful, and the writing is clear and well-organized. It contributes to the community with an improved tropical cyclone-resolved flux data product that can be used for either tropical cyclone or global energy cycle studies. I only have a couple of minor concerns for the authors to consider to improve the work.

Response: We are grateful to the reviewer for positive evaluations and crucial comments. We have followed the detailed comments to modify the manuscript carefully. Detailed comments are replied one by one below.

Specific comments:

1. This dataset is especially useful for tropical cyclone analysis, where the wind speeds are high. The latent and sensible heat fluxes are calculated using Equations 11 and 12, in which Ch and Cq are used, Then, what are the relationships between the two variables and the wind speed? In other words, how do the authors determine the Ch and Cq in a high wind speed?

Response: Following the comments. Both the Ch and Cq in our study are calculated using the state-of-the-art COARE 3.6 bulk flux algorithm. They are not prescribed as direct empirical functions of wind speed. Instead, they emerge from the iterative solution of the Monin–Obukhov similarity theory (MOST) together with physically based roughness length schemes.

In COARE 3.6, the transfer coefficients are defined as:

$$C_h = \frac{-u_* t_*}{U(\Delta T - \Delta T_{cool})}, \quad \text{and} \tag{1}$$

$$C_q = \frac{-u_* q_*}{U(\Delta q - \Delta q_{cool})}, \tag{2}$$

where u_* is the friction velocity, t_* and q_* are the temperature and specific humidity scaling parameter, ΔT is the air-sea temperature difference, Δq is the air-sea specific humidity difference, ΔT_{cool} and Δq_{cool} accounts for the cool-skin effect. The friction velocity and scaling parameters are also functions of wind speed. The robustness of these parameterizations is supported by extensive observational validation (Edson et al., 2013; Fairall et al., 2003), providing strong assurance of the reliability of Ch and Cq in high-wind regimes.

2. The manuscript states the importance of global energy budget, especially in a warming climate. How large are the global mean (e.g., 60S-60N) latent and sensible heat fluxes? Please compare with other datasets.

Response: Following the suggestion, we have calculated the global-mean latent and sensible heat fluxes (60S-60N) from different datasets. The surface latent heat flux is estimated at 113.4 W m^{-2} for GHFD, 98.7 W m^{-2} for J-OFURO 3, 92.4 W m^{-2} for OAFlux and 90.6 W m^{-2} for ifremerflux, while the surface sensible heat flux is estimated at 16.6 W m^{-2} for GHFD, 6.8 W m^{-2} for J-OFURO 3, 10.4 W m^{-2} for OAFlux and 19.1 W m^{-2} for ifremerflux. The relative discussion is in Line 165-168, Page 9, reproduced below.

The global mean (60°S-60°N) surface latent heat flux is estimated at 113.4 W m^{-2} for GHFD, 98.7 W m^{-2} for J-OFURO 3, 92.4 W m^{-2} for OAFlux and 90.6 W m^{-2} for ifremerflux, while the surface sensible heat flux is estimated at 16.6 W m^{-2} for GHFD, 6.8 W m^{-2} for J-OFURO 3, 10.4 W m^{-2} for OAFlux and 19.1 W m^{-2} for ifremerflux.

3. Some variables are obtained from different heights, such as 2 m and 10 m. Then the COARE algorithm was used to construct the dataset. There is no depiction of how these variables at different heights are used for the flux calculation. Have the authors conducted a standardization? If not, simply merging them together would introduce bias, though presumably not significantly. If so, an illustration is needed for this procedure.

Response: Thanks. In the COARE 3.6 framework used in this work, the heights of related variables need not be standardized in advance. The COARE 3.6 itself will handle these variables at different heights to calculate the surface flux.

4. Figure 1: Please do not use a yellow background and white font together. The text cannot be well identified. IBTrACs in the blue bottom may change to TC data.

Response: Thanks. Figure 1 has been revised as suggested. The revised picture is shown in Page 3.

5. Figure 7: The 'two white dotted lines' are not identifiable to me. Please polish this figure or adjust the caption to make them consistent.

Response: Thanks. "The intersection of the two white dotted lines marks the center of the TC" in the caption has been deleted.

6. Figure 8c: Is '$\times 10^{-3}$' correct here?

Response: Thanks for pointing it out. It's a typo and has been deleted from the Figure 8c.

7. Related to equations: Not all the symbols are sufficiently defined, such asVi and Vo. Please double-check them carefully.

Response: V_i and V_o have been defined clearly, as Eq.(1) and Eq.(2) in Line 90-91, Page 4. We have double-checked the manuscript carefully to ensure all symbols are clearly defined.

8. Line 7: Replace 'daily available from 1993 to 2023' with 'available daily from 1993 to 2023'.

Response: As suggested, we have replaced ‘daily available from 1993 to 2023’ with ‘available daily from 1993 to 2023’.

9. L56, please full spell the CCMP here.
Response: Thanks. We have added the full spelling of “CCMP” in Line 60-61, Page 2 as: “Cross-Calibrated Multi-Platform (CCMP)”.

10. L35-37, some references should be added.
Response: The reference of Andersen et al. (2013), Song et al. (2021) and Xie et al. (2024) has been added in Line 38-39, Page 2.

11. While most part of the manuscript is well written, I do find several places of typos or writing problems, as listed below. Please proofread the manuscript much more carefully during the revision:
Response: Thanks for the careful review. All these points have been addressed accordingly. We have also proofread the manuscript carefully.

Line 77: Change ‘origin’ to ‘original’.
Response: Done.

Line 175-176: Please rewrite this sentence.
Response: The sentence has been rewritten as:
Among the four datasets, GHFD yields the smallest bias in surface sensible heat flux. As for surface latent heat flux, GHFD performs better than OAFlux, with comparable but marginally larger bias than J-OFURO 3.

Line 197: Change ‘magnitude’ to ‘magnitudes’, or replace ‘are’ with ‘is’.
Response: Thanks. ‘magnitudes’ has been changed to ‘magnitude’.

Line 203-204: Consider rewriting this sentence.
Response: Thanks. The sentence has been rewritten as:
The peak surface latent heat flux of Earl is approximately 900 W m^{-2}, and the surface sensible heat flux is approximately 250 W m^{-2}. The GHFD values are closer to those of Earl compared with the other products.

Line 207: Delete ‘The max’.
Response: Deleted

Line 224: Delete ‘under high wind speed conditions’.
Response: Deleted

Line 233: Should it be ‘Francisco’?
Response: Yes. Revised.

Line 233-235: Too long a sentence. Please rewrite it.

Response: Thanks. It has been rewritten as:

Compared with other products, GHFD shows better performance under TC conditions. A comparison of each parameter indicates that the bias of GHFD is significantly smaller than that of other products.

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