We highly appreciate and would like to thank you and the reviewers for positive comments and suggestions to improve our manuscript. We have carefully revised the manuscripts as per their every comments and suggestions as described below. The editor and reviewers' comments are in black and authors' replies in blue and modified /inserted text in the revised manuscript (red color). For clarity and ease, we have provided the line numbers (from track change mode manuscript) where particular changes have been made in the main manuscript as well as provided the change as a response below the comment. We believe that the revised manuscript has incorporated the concerns and suggestions given by the reviewers.

Reviewer #2 The title, abstract, and introduction of the study ``Insight into seasonal aerosol concentrations, meteorological influence, and transport over the Pan-Third Pole region using multi-sensors satellite and model simulation" by M. Rai et al. suggest an investigation of the seasonal properties and the origin of aerosol over the Pan-Third-Pole my means of satellite observations and model simulations. However, the study mainly presents seasonal means of PM2.5, PM10, and AOD at 10 AERONET stations and an unidentified number between 8 to 12 stations in China, a WRF simulation, CAMS data, MERRA-2 reanalysis, and VIIRS satellite measurements for a single year. While the motivation and envisaged scope of the manuscript would fit the scope of ACP the presented data and analyses do not. In my opinion this manuscript is just a collection of arbitrarily selected data. The data sets do not agree quantitatively, and in case of the WRF simulation not even qualitatively. Despite these discrepancies no attempt was made to assess the uncertainties of the simulation and measurement data to identify the source of the discrepancies.

1) In this study 3 different reanalysis were used: NCEP/FNL with WRF, MERRA-2, and GDAS with HYSPLIT. What was the motivation to do this? It is known that reanalysis differ. In my opinion using multiple reanalysis is a source for discrepancies. This should be taken into account when estimating the uncertainties and comparing the results/data sets.

Response: We appreciate the concern raised by the reviewer. We acknowledge the fact of the discrepancy in our study. Carrying out model simulation in a geographical complex region is challenging itself as our study area possesses diverse geographical features where observation data sets are very limited. Thereby we wanted to leverage other available data sources to assess, compare, and draw the conclusion in our study. The motivation for using the reanalysis data set in our study is to provide meteorological initial boundary conditions in the model, compare it with the model and reanalysis data set, and perform footprint analysis. To assess the model performance, we performed statistical metrics analysis of different pollutants and compared between model, observation, and reanalysis data (l 243-245, 278-288). The detailed comparison of AOD observation versus model and reanalysis data sets are provided in Table S2.

2) The methods section (Section 2) is rather a description of the models used, but not of the data. Moreover, it is not clear how the models were set up and used and how the data was prepared. Concerning WRF, what is the purpose of the used models? Why have they been selected? Which parameters were used from the MERRA-2 data? What was the ``further treatment" of the AERONET data? A description of the Chinese stations is completely missing. Figure 1 indicates 12 stations in China, but according to the manuscript only 8 stations were used (l 205). Which stations and why were four left out? I have the impression that the data and methods are not sufficiently described to reproduce the results.

Response: We have discussed the data used in section 2.4. Regarding the model set-up and data preparation, we have discussed in 2.1 section. Further, key parameterization schemes adopted in our study are included in Table S1. The WRF-Chem model is selected because of its dynamic abilities such includes numerical consistency, meteorology-chemistry feedback, capable of simulating and predicting pollutant concentration with physical and chemical options. As our model is forced to run in a diverse geographical region (i.e. flat land, arid, semi-arid, and mountain region) it may require to have more represented parameterization schemes which should have more realistic presentation of different processes like advection, convection, diffusion, dry deposition, wet scavenging, aqueous and gas phase reaction, photolysis rates, other microphysics. We have used AOD and dust from MERRA-2. ‘Further treat’: we mean to say that we have used level 2 AERONET data however, due to the data gap we further fill this void using Level 1.5 data. Now, the description of the China station is included (l211-214).

3) Did the WRF simulation really produce negative PM2.5 concentrations? E.g. in Xi'an 66.5µg m-3 were measured, whereas the WRF simulation underestimated it by 93.6µg m^{-3} (ll 235-237). - This should be clarified in the text.

Response: Thank you for pointing out this issue. We have gone through the code and found out there was a typo in the code. We have modified and presented the right values in (l243-246)

4) Concerning the differences between the WRF simulation and the measurement the authors stated repeatedly some speculation (e.g. l243-246, 248-246). To investigate the effect of e.g. the meteorological data, a sensitivity test with a different reanalysis, which is obviously at hand, could be performed.

Response: We agree. Taking the notion of model reproducibility over complex terrain, a previous study by Rai et al. (2022) explicitly carried out comprehensive model validation using different meteorological reanalysis data sets over the same domain. In that study, one should note that the entire simulated period is categorized into monsoon and non-monsoon periods. Study found that temperature WRF-CRU (Rm = 0.82, Rnm = 0.96) and WRF-ERA5 (Rm = 0.90, Rnm = 0.93) reproduced better than precipitation WRF-TRMM (Rm = 0.80, Rnm = 0.63) and WRF-ERA5 (Rm = 0.30, Rnm = 0.40) respectively. Note: Rm = correlation coefficient in monsoon, Rnm = correlation coefficient in non-monsoon. Additionally, the model was able to reproduce reasonably well with NCEP and ERA5 data. Here we have provided additional statistical metrics to showcase the meteorological data relation with the model. During monsoon, a model produced cold biased with ERA5 while there is a higher precipitation bias with ERA5 than TRMM. Detailed statistical scores are presented in Table S4.

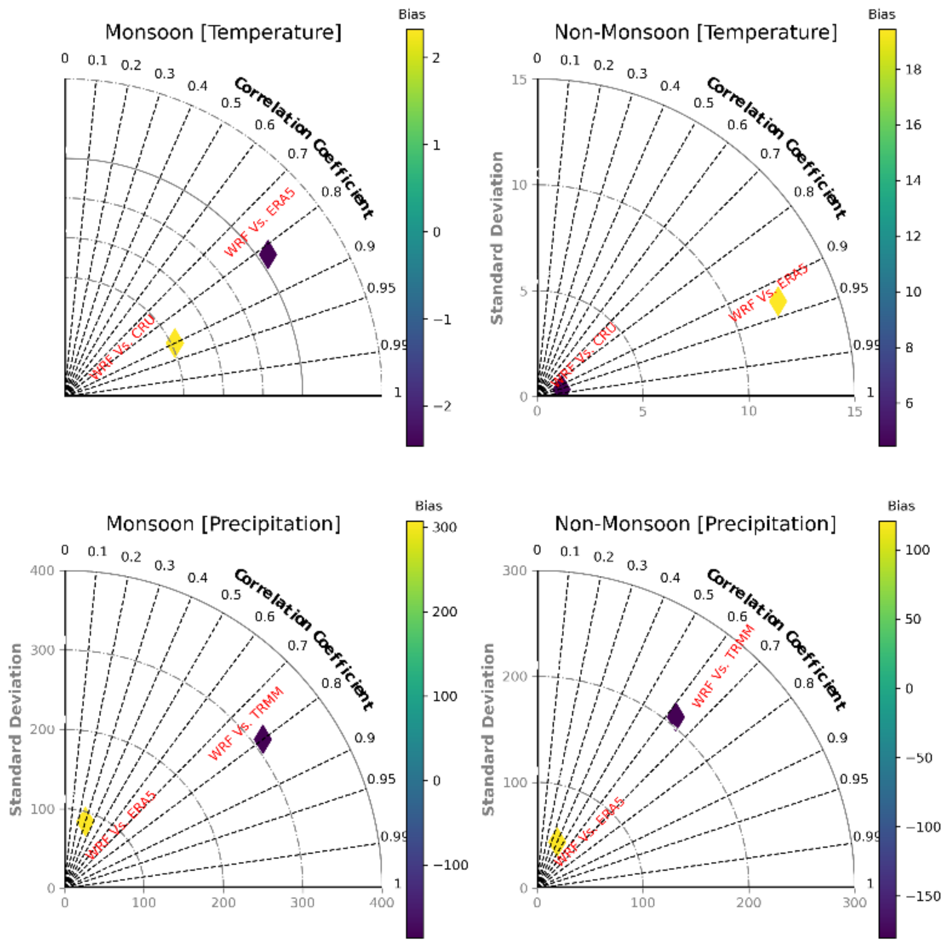

Figure S1 . Taylor diagram showing different statistical metrics in relation to different reanalysis dataset with model.

5) Figure 5 gives the impression that the WRF simulation does not perform well in reproducing the AOD. In winter and spring it underestimates the AOD and in summer and autumn it overestimates the AOD. In the text mainly the problems in simulating dust are discussed. However, given the large (a difference plot WRF-observations would be helpful) discrepancies between simulation and observations, I have little confidence in the further results derived from the WRF simulation.

Response: We appreciate the reviewer's concern and concur that our model simulation significantly understates the AOD, particularly in the winter and spring. However, we also conducted a comparison of model AOD data with AOD data from a number of additional data sources, including AERONET (limited but accessible locations), MERRA-2, and CAMS reanalysis datasets, in order to assess the confidence in the simulation results. The time series plot of AOD from the model (WRF-Chem) and observation (AERONET), as well as CAMS and MERRA-2, have displayed in Figure 3. We employed the datasets further for our research with the help of statistical analysis, which demonstrated good agreement between the dataset and also with the trend and distribution for the majority of the period.

6) I wonder why the seasonal pattern for PM2.5 and PM10 with maximum concentrations in winter and minimum concentrations in summer (Fig 4, first and second column) is the opposite to AOD with the maximum AOD in summer and the minimum AOD in winter (Fig5, top row).

Response: We thank the reviewer for the comment. This discrepancy could arouse by several reasons. First, while AOD is the sum of the extinction coefficient times thickness that is integrated over the atmospheric vertical layer, PM represents surface concentration. Our study is set up by default with 40 vertical sigma levels from the level's surface to its peak. Because of the thin depth of the atmospheric layer and the poorer geographic resolution used in our analysis, we believe that the AOD was underestimated despite the high surface concentrations during winter and spring. Second, according to Pan et al. (2015), inadequate representation of anthropogenic and biofuel emissions as well as relative humidity (RH) may all contribute to the underestimating of AOD during the winter. This part is overlooked in this study however we envisioned carrying out the effect of such factors in AOD underestimation in near future. Surprisingly, higher AOD during summer was found. This is partly due to aerosol long-range transport through the low-level jet and tropical easterly jet that persist especially over South Asia (Ratnam et al., 2021). Another reason could be modulated by enhanced temperature and RH during summer monsoon that intensified hygroscopic growth of aerosols which consequently yields high AOD. The detail is given in (l379-392).

7) It is still not clear to me how the trajectory analysis was performed. What was the purpose of doing forward and backward trajectories? Where were the forward and backward trajectories started?

Response: We have briefly stated the trajectory analysis in section 2.3. The air trajectory essentially measures the dynamic processes occurring in the atmosphere. The trajectory can be forward, indicating the impending path taken by the particles, or backward, indicating the historical path the particles had travelled along their trajectory. The calculations of the air trajectories take wind and weather patterns seriously. The purpose of the trajectories analysis was to provide essential information especially aerosol transport mechanism and source-receptor relationship over the study region. We computed trajectories at Langtang station (28.21° N, 85.61° E; 4900 m a.s.l). In this study, we consider the endpoint of the backward trajectory is the starting point of the forward trajectory. 7-day trajectories at 6-hour intervals were simulated in the study.

8) While the title suggests that the focus of this study is put on the Pan-Third-Pole this study mainly presents and discusses the high aerosol load in densely populated regions (Indo- Gangetic Plain and East China) known for strong aerosol sources. The possible impacts of aerosol on the Pan-Third-Pole are stated in the introduction, but throughout the manuscript the authors avoid presenting the current knowledge on the sources and transport pathways and comparing it with their findings. They rather name studies (e.g. ll460 - 464; ll467-469) and remain vague. In my opinion the authors should contrast the state-of-the-art knowledge with their findings to make the advancements in their study clear.

Response: Thank you for the suggestions. Most of the past study focuses either on South Asia or East Asia. In this study, we presented the synoptic scale analysis on aerosol concentration, transport dynamics, and meteorological influence by leveraging satellite data, reanalysis data, and model over the interest of a global important region (i.e. PTP). As the region is susceptible to air pollution and environmental impact perspectives. Over this complex geographic region, this study started off with model validation, presented Spatio-temporal variation of aerosol and AOD, provided a vertical profile of aerosol, and carried out the source-apportionment analysis. Exclusively, we extended the atmospheric river concept in terms of aerosol which is first of its kind if not otherwise stated. In this study, we discussed the inability of a model in AOD simulation which further needs to be taken into consideration. An interesting finding from integrated aerosol transport calculation shows significant aerosol transport over South East Asia. To enhance the knowledge of such methods and process inclusion of more variables with a finer resolution of reanalysis products is warranted. Further to resolve the vertical structure of the transport process across complex terrain like the Himalayas and Tibetan Plateau, the finer resolution of model simulation is anticipated with the aerosol-climate feedback mechanism.

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