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Reply on RC1

Tiago Silva et al.

Author comment on "A 25-year climatology of low-tropospheric temperature and humidity inversions for contrasting synoptic regimes at Neumayer Station, Antarctica" by Tiago Silva et al., Weather Clim. Dynam. Discuss., <https://doi.org/10.5194/wcd-2021-22-AC1>, 2021

We thank RC1 for the fast review with helpful comments. We will now answer to all single points:

- *My main concern is that the concept of the manuscript is based on division between "cyclonic" and "non-cyclonic" conditions at the station, defined from the SYNOP weather codes. In practice, these weather codes used tell whether there is/has been precipitation or not.*

This point was also of concern for RC2, and we realize that we have to explain our choice of definition and terms in more detail. "Cyclonic vs. non-cyclonic" has not been our first try, but we came to the conclusion that it describes our defined synoptic situation as closely as possible. "Precipitation vs. non-precipitation", as the RC2 states, too, is difficult because diamond dust is also precipitation, but definitely falls into the non-cyclonic class. Also, "fair weather" vs. "bad/stormy weather" is not a good choice since fog would not belong to the bad weather category while it is not exactly what one would call fair weather. Non-cyclonic conditions would not occur when the area is under the influence of low pressure (except for a short transition period, we discussed this difficulty already in the original text).

- *They do not indicate anything about circulation, and they should not be referred as cyclonic/non-cyclonic. If the authors want to classify circulation, they should use reanalysis/numerical model pressure fields for that or at least utilize more the wind direction information (which is also available from radiosoundings). As far as I understand the classification made in this manuscript, it practically only separates precipitation events from non-precipitation events.*

Different from the Arctic, weather and climate at Antarctic coastal stations is strongly influenced by the circumpolar trough, a climatological low-pressure area that results from several cyclones that regularly develop and move eastwards above the Polar Ocean. Weather at Neumayer thus has a fairly "binary" character: either overcast conditions with precipitation (and or blowing/drifted snow) and high wind speeds from easterly to NNELY directions related to a cyclone passing in the north of the base, or, between two cyclones, fair weather conditions with south to southwesterly winds and low cloudiness. This knowledge comes from personal experience (ES has wintered at Neumayer and lived in the area for almost 2 years) and is also confirmed in the literature (e.g. König-Langlo and

Loose, 2007: The Meteorological Observatory at Neumayer Stations (GvN and NM-II) Antarctica. *Polarforschung* 76 (1-2), 25 – 38, 2006, König-Langlo et al., 1998: Climatology of the three coastal Antarctic stations Dumont d'urville, Neumayer, and Halley. *J. Geophys. Res.* VOL. 103, NO. D9, PAGES 10,935-10,946).

Thus, a classification based on model pressure fields, wind direction or cloudiness, as the referee suggests, would basically lead to the same results as our classification based on SYNOP observations. We added this information in the revised version of the manuscript.

- *This leads to my second serious concern: what is the motivation to study inversion characteristics in precipitation events, when we know that radiative cooling, which is largely controlled by clouds, subsidence and horizontal advection are the main factors affecting the inversion properties? Clouds and advection can occur without precipitation. Radiative cooling, both at the surface and on the cloud tops, is almost neglected in this study (including the Introduction section), even if it is the main mechanism behind the temperature inversions. Specific humidity inversions close to the surface are largely affected by this radiative cooling, and saturation takes place in the lowermost cold layer and leads to specific humidity inversions.*

The original motivation for the study of Antarctic inversions stems from ice core studies, where paleotemperatures are derived from stable water isotopes of the ice. The stable isotope ratio of the ice is the result of a complex precipitation history (isotopic fractionation during evaporation and condensation processes), and the derived temperature mainly represents the condensation temperature of the last precipitation. The relationship between surface temperature, condensation temperature and temperature at the top of the inversion is still a fairly unknown subject. For the deep ice cores in the interior of Antarctica, which yield information about the last 800,000 years, of course, the surface-based inversions are most important, and about half of the precipitation falls in the form of diamond dust. However, there are also cores close to the coast (e.g. Law Dome, e.g. Souney et al., 2002) and also the interior cores get precipitation related to warming events with advection of relatively warm and moist air from lower latitudes at higher levels.

Different from many deep drilling locations, Neumayer Station has an abundance of meteorological data and thus was chosen for the presented study for a first climatology of temperature and humidity inversions. In a second publication that also includes the inland station Dome C, a deep drilling location, we will present a more elaborated study of the relationship between condensation temperature, surface temperature and temperature at the top of the inversion, which has been used as approximation to the condensation temperature in ice core studies for many years, simply due to lack of better knowledge. We had mentioned the ice core related motivation already in the original version but elaborate it in more detail in the revised manuscript.

We agree that clouds or warm air advection without precipitation can be very important in the formation or destruction of inversions, however, this is more important in the interior of the Antarctic continent (e.g. Hirasawa et al., 2000) and of minor importance at Neumayer. Cloudiness would be a difficult variable as there are no eye observations at night and, during the polar night, observation of clouds is difficult and not reliable. At Neumayer, as we state in our study, the cyclones (that bring precipitation) are very important for the formation of elevated inversions since they are usually associated with advection of relatively warm and humid air masses.

We also stated that surface-based humidity inversions are caused by deposition of hoar frost which is caused by radiative cooling. Arctic and coastal Antarctic conditions are very different, and there are clearly more studies available for the Arctic than for the Antarctic. We would like to stress that our study is the first in Antarctica to investigate humidity and temperature inversions at different levels and for different weather conditions and by far for the longest time period (25 years). Seasonality of various inversion features were studied in detail and their relationships with each other, and different formation

mechanisms were discussed.

As we state in the conclusion, more detailed studies including the surface energy balance and advection terms from models are recommended, but beyond the scope of our study. In particular, the formation and destruction of inversions could be studied with the abundance of data available at Neumayer, but this would be better done in numerous case studies than for a complete 25-yr data set.

- *Formation mechanisms of inversions are not adequately taken into account in the analyses, and the authors do not utilize what is known about inversions in the other polar region, i.e. Arctic.*

We used the suggestions of the referee to improve our introduction and Data and Methods sections, including a more detailed comparison with Arctic conditions. In particular, we stressed the differences between Arctic and coastal Antarctic climate that also would lead to different classifications of synoptic situations for a study of inversions in the Arctic. Also, the highly complex interactions between surface inversions, elevated inversions, and low-level clouds and the involved long-wave radiation fluxes are very important in the Arctic, but only of minor importance at Antarctic coastal stations due to the vastly different climatic/synoptic conditions.

- *Interpretation of the results is not deep in the manuscript, and it is mostly at the level of a "data report". The data analyses made do not really provide support for physical interpretation, especially because they do not give reliable estimates of the synoptic conditions/atmospheric circulation. The abstract the Discussion/conclusions section should be able to convince a reader that this manuscript has provided some new valuable results, but unfortunately this value is not clearly visible in the current version of the manuscript.*

The study was mainly planned as a climatology. It covers the longest time period of radiosonde measurements used in a study of inversions in Antarctica, at least to our knowledge. We explain the synoptic conditions and our choice of definition in more detail in the Data and Methods section now, based on a more elaborated introduction about weather conditions at a coastal Antarctic station and the differences to Arctic conditions. We also added a new Figure (Fig. 15) for a more thorough discussion of the composite temperature and humidity profiles including the vertical wind profile.

- *I have two suggestions to the authors: (1) if you want to define the states based on circulation (cyclonic/non-cyclonic), define the weather states based on reanalysis/numerical model fields, and utilize those data also to address advection, or (2) if you want to limit the study to observational data, utilize more comprehensively the wind speed/direction information of radiosondes, cloud cover observations and surface radiation observations (if available). Instead of dividing the data between precipitation/non-precipitation cases, divide the data based on cloud conditions (which are known to have a large impact on the inversions), radiative fluxes at the surface, and wind direction.*

Neumayer weather conditions are strongly determined by cyclonic activity in the circumpolar trough. The weather is characterized by cyclones passing from west to east with the general westerly flow, with anticyclonic conditions for shorter or longer periods between two cyclones. The semi-annual oscillation can lead to longer anticyclonic periods in summer and winter when the trough and thus the position of the frontal zone moves northwards. This is also indicated by the main wind directions. For the majority of the time Neumayer Station experiences relatively strong easterly, to ENEly winds, related to the clockwise rotation of the passing cyclones. Weaker winds from southerly or SWly directions prevail under high pressure. We add a figure of the mean Neumayer wind direction in the supplemental material. Also, clouds are of much less importance for

inversions at Neumayer than at Arctic or interior Antarctic stations. A study by Hirasawa et al. (2000) showed that at Dome Fuji, advection of relatively warm and moist air lead to formation of low clouds, which were not sufficient to produce precipitation but increased downward longwave radiation, which, together with increased wind speed destroyed the prevailing inversion. At Neumayer, the increased wind speeds, thus turbulence associated with an approaching cyclone remove an inversion very quickly.

We explained our definition of the two-weather situation typical at Neumayer in more detail in the Data and Methods section and also gave more general information about the climate of Neumayer as an Antarctic coastal station in contrast to interior Antarctica or most Arctic stations in the introduction.

References:

Hirasawa, N., H. Nakamura, and T. Yamanouchi, 2000. Abrupt changes in the meteorological conditions observed at an inland Antarctic station in association with wintertime blocking. *Geophys. Res. Lett.*, Vol. 27 No. 13, 1911/1914.

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