Synoptic-scale controls of fog and low clouds in the Namib Desert: Response to Reviewer 3

Hendrik Andersen, Jan Cermak, Julia Fuchs, Peter Knippertz, Marco Gaetani, Julian Quinting, Sebastian Sippel, and Roland Vogt

contact: hendrik.andersen@kit.edu

We would like to thank reviewer 3 for her/his review of the manuscript and the valuable comments. Comments by the referee are colored in black, our replies or comments are colored in blue and written in italics.

This is a well-written article. The authors are to be congratulated.

However, It has long been known that fog and low cloud in the coastal zone of the Namib and the South African west coast are largely due to a local/meso-scale phenomenon called a coastal low. This is a weak low pressure system trapped between the western escarpment to the east and the Benguela current to the east. It only extends to just above the height of the escarpment. The diameter of the coastal low and the extent of the cold water upwelling region often determines whether fog occurs or not. An interplay between an approaching cold front and a HIGH pressure system over the continent is thought to cause the coastal low and associated fog to move southwards from the Namibian coast, down the South African west coast, around the tip of South Africa and northwards towards Kwazulu-Natal. It is unclear why the authors need to work at synoptic scale when the phenomenon occurs at a much smaller scale. The role of a cut-off low in fog occurrence is really surprising.

We agree with referee 3 that the connection between coastal lows and fog occurrence has been suggested for a long time, to our knowledge the main paper on this is titled "The influence of upwelling extent upon fog incidence at Lüderitz, southern Africa" by Olivier and Stockton (1989), which is discussed on pages 7 and 8 of the original manuscript. In this very interesting study, on the basis of two years (1983 & '84) of satellite observations, Olivier and Stockton find that fog occurrence in Lüderitz is mostly associated with coastal lows, especially in austral summer, while during winter, it is associated with cold fronts. They go on to assume that as coastal lows often precede the passage of cold fronts (observed to be associated with fog during winter), a coastal low "was present, but unobserved, during these conditions." (p. 71). While their paper is focused on fog occurrence in Lüderitz, southern Namibia, this concept is extended to other regions along the southern African coast, based on two conference papers (Estie 1984, Sciocatti 1984). Both of these publications could not be found in the usual online publication data bases and are therefore not cited in the manuscript.

However, other hypotheses also exist:

1. *Seely and Henschel (1998) suspect that the onshore advection of 'high fog' is enhanced by the plain-mountain wind.*

2. *Lancaster et al. (1984) hypothesize that the seasonal occurrence patterns of fog in the central Namib is influenced by the continental high pressure system, pointing to a synoptic-scale influence.*
3. *In the last few years, several papers have been published that question the described mechanism, and typify most fog events as locally generated radiative fog (e.g., Kaseke et al. 2017, 2018).*

Therefore, we believe that substantial knowledge gaps do still exist and that good reasons exist to study the mechanisms driving variability of fog and low clouds along the south western African coastline on the basis of an extensive observational data set as done here. Also, many of the anomaly patterns that we find are actually on synoptic scales (e.g., moisture transport), underscoring the relevance of this scale to gain a more complete understanding of mechanisms influencing the Namib-region FLC system.

The note of the cut-off low, however, was a mistake on our part, and is now corrected in the updated version of the manuscript.

It is suggested that much more information is provided on the research that has already been conducted on the occurrence of fog along the southern African west coast.

We thank reviewer 3 for this useful suggestion. We have now added a much more detailed discussion on coastal lows in different sections of the manuscript.
In the introduction:
" In Olivier and Stockton (1989), a coastal low is described as the mechanism that, in case of a narrow coastal upwelling region, drives the onshore advection of foggy air masses into the region of Lüderitz in southern Namibia during austral summer, while during winter they find fog to be associated with cold fronts. However, they assume that, while undetected, coastal lows were also present in the case of cold fronts, as they typically precede the passage of a cold front (Olivier and Stockton, 1989; Reason and Jury, 1990)."
In section 3.1:
"Coastal upwelling, which has been shown to determine marine sea fog patterns along the Namibian coastline (Dorman et al., 2019), in combination with the presence of a coastal low that drives the onshore advection of foggy air masses have been found to be major drivers of fog occurrence in southern Namibia during austral summer (Olivier and Stockton, 1989). One should note though that the relationship between SSTs and Namib-region fog is complex, as Olivier and Stockton (1989) point out that a too large upwelling extent can also lead to less fog in southern Namibia."
In section 3.2:
"While a coastal low that has been described in Olivier and Stockton (1989) as a local feature that can determine onshore flow may still be present on FLC days, at least in some of the cases, the composite differences between FLC days and clear days do not provide a clear indication of an increase in its presence on FLC days. However, as Reason and Jury (1990) describe, the coastal low is frequently followed by a frontal passage, which is a synoptic-scale signal observed here (Fig. A1)."

We believe to now extensively discuss the existing literature on fog along the southern African west coast, and in the updated version of the manuscript also discuss in much more detail links to comparable upwelling systems, but if reviewer 3 knows of an important paper on the regional mechanisms that is still missing, we would kindly ask her/him to point us to this publication.

References

Dorman, C. E., Mejia, J., Koracin, D., and McEvoy, D.: World marine fog analysis based on 58-years of ship observations, International Journal of Climatology, pp. 1–24, https://doi.org/10.1002/joc.6200, 2019.

Estie, K. E.: ‘Forecasting the formation and movement of coastal lows’, Paper presented at the Coastal Low Workshop held at the Institute of Marine Technology, Simonstown, 15 and 16 March 1984, 17-27, 1984.

Kaseke, K. F., Wang, L., and Seely, M. K.: Nonrainfall water origins and formation mechanisms, Science Advances, 3, e1603 131, https://doi.org/10.1126/sciadv.1603131, http://advances.sciencemag.org/lookup/doi/10.1126/sciadv.1603131, 2017.

Kaseke, K. F., Tian, C., Wang, L., Seely, M., Vogt, R., Wassenaar, T., and Mushi, R.: Fog spatial distributions over the central Namib Desert - An isotope approach, Aerosol and Air Quality Research, 18, 49–61, https://doi.org/10.4209/aaqr.2017.01.0062, 2018.

Lancaster, J., Lancaster, N., and Seely, M. K.: Climate of the central Namib desert, Madoqua, 14, 5–61, 1984.

Olivier, J. and Stockton, P. L.: The influence of upwelling extent upon fog incidence at Lüderitz, southern Africa, International Journal of Climatology, 9, 69–75, https://doi.org/10.1002/joc.3370090106, 1989.

Reason, C. J. and Jury, M. R.: On the generation and propagation of the southern African coastal low, Quarterly Journal of the Royal Meteorological Society, 116, 1133–1151, https://doi.org/10.1002/qj.49711649507, 1990.

Sciocatti, B.: The effect of sea surface temperatures on the formation or disposal of advection fog with the passage of a coastal low, Paper presented at the Coastal Low workshop, held at the Institute of Marine Technology, Simonstown, 15 and 16 March 1984, 51–52, 1984.

Seely, M. K. and Henschel, J. R.: The Climatology of Namib Fog, Proceedings, First International Conference on Fog and Fog Collection, Vancouver, Canada, pp. 353–356, 1998.