Reviewer #2

This manuscript offers an opinion on "new directions in atmospheric research offered by research infrastructures (RIs) combined with open and data-intensive science". The European author group is well qualified to discuss the present and future of research infrastructures based on their involvement and experience. Recognizing the current state of affairs of observations, data and models related to climate resilience and anticipating future needs and demands on the RIs of the world is the basis of a valuable narrative. The manuscript is suitable for publication after the authors consider the following comments.

1) The manuscript would be improved by substantially shortening its length. It is a slow read given the abundance of detail that is primarily background material to the main thesis. In shortening, I suggest a focus on the promised 'new directions', ie to make them standout better in this narrative.

Reply: To make the key messages more visible, we moved the entire former Section 3 on Research Infrastructures into an Appendix. However, we do not delete this section completely since from our discussions at multiple dissemination events in our research communities, we still recognized that not many scientists and in particular young researchers are aware of what research infrastructures are and how they can make use of them.

By rearranging the manuscript, the key message appears now much earlier, but the background information on Research Infrastructures is still available for those who are not familiar with this new tool.

2) The figures (except 6 and 7) and Table 2 seem to be unnecessary information for this opinion piece; hence I suggest the authors considering deleting.

Reply: See reply to Comment 1. The illustrations and tables referred to have been moved to the Appendix.

3) The most interesting and relevant text was in sections 4 and 5 where the reader finds the most new thinking about this topic.

Reply: Former Sections 4 and 5 are ow Sections 3 and 4, to give them more weight.

4) The recommendation that the GCIs be modified to include SLCFs appears rather casually on ln 337. The GCIs are formally put forth by WMO/GCOS so a change would be a major consideration. While a quite reasonable suggestion, this proposed change could alone be the topic of an opinion piece. In the present context, it is not clear what the authors would like the reader to think about this proposal, eg what is the next step in advancing this idea or is it only meant to be a marginal comment?

Reply: Given the formal nature of the set of GCIs and the consequent major consideration to changing this figure, we agree to use the original figure here. The sentence describing this figure has been adapted. The reason for adding short-lived climate forcers here was that reducing the changing atmosphere to its CO_2 content appears to be a simplification and neglects all the processes triggered by short-lived climate forcers.

To make the difference between GCIs and ECV – which include short-lived climate forcers – clearer, we rephrased this paragraph to:

"To transform the challenging task of integrated Earth observation into a concept towards a global climate observation system, WMO/GCOS has defined a set of global climate indicators (WMO-GCI), which stretches beyond the boundaries of traditional scientific disciplines like, e.g., atmospheric sciences, ocean sciences, or biology; see **Fehler! Verweisquelle konnte nicht gefunden werden.**. This set of GCIs defines the indicators which point to long-term changes in the Earth system. Consequently, WMO requests the continuous observation of these indicators for monitoring the state of Earth's climate. However, this undertaking requires a largely interdisciplinary approach.

To further develop this interdisciplinary approach towards a global climate observation system, WMO has introduced the concept of essential climate variables supplementary to the GCIs. Essential climate variables for atmospheric composition are defined as a physical, or chemical variable or a group of linked variables that critically contributes to the characterization of the atmospheric composition. This set of variables includes the long-living greenhouse gas CO_2, but also many of the short-lived climate forcers."

5) Another casual remark is on ln 430 : 'One prime example for research-based information for climate policy is the validation of emission reductions required as part of the COP21 Paris Climate Agreement of 2015.' The failure to achieve GHG emissions and concentration reductions in the next 2 decades is perhaps the greatest threat to the future health of human society and ecosystems. The role of RIs is essential to have an efficient, effective and verifiable global emissions reductions. I could easily see an opinion piece focused on this essential RI role under the label of New Directions and hence standout more in this opinion piece.

Reply: We appreciate this suggestion and implemented it in the manuscript. In current section 2.2 on the impact of cross-disciplinary research supported by ATMO-Ris, we supplemented the paragraph on the role of CO2 observations for the 2021 Physics Nobel Prize by the statement on the relevance of RI long-term observations of the validation of CO_2 emissions. Now, this important role of RI contributions appears at a prominent place of the article. The full text reads now:

"The scientific importance of long-term greenhouse gas observations as conducted since many years by the ENVRI RI ICOS, and since recently, by IAGOS, has been confirmed in the Scientific Background document on the 2021 Physics Nobel Prize which went to Klaus Hasselmann, Syukuro Wanabe and Giorgio Parisi "For ground breaking contributions to our understanding of complex physical systems". In Chapter IV, the Nobel Committee writes: "From the perspective of laboratory science, using experimental measurements to test theory is such a self-evident step in the scientific method that it goes without saying. However physical cosmology and physical climatology are observational sciences – practitioners observe that which nature allows."

Moreover, failure to reduce greenhouse gas emissions and concentrations over the next two decades is perhaps the greatest threat to the future health of human society and ecosystems. The role of the ATMO-RI is critical to achieving efficient, effective and verifiable global emission reductions, particularly for the validation of emission reductions required as part of the COP21 Paris Climate Agreement of 2015. The mitigation measures and the speed of their implementation need to be checked by independent methods and closely monitored, while the influence of natural feedback due to the ongoing climate change will require attention, as this may force a change in the speed of implementation of mitigation measures and adaptation. The contribution of ATMO-RIs to the validation exercise of emission reductions is described by Vermeulen et al. (2020)."

6) Para at ln 249. It is important to note that using long timeseries of observations for trend analysis requires a measurement infrastructure that guarantees intercomparability regarding observation precision and accuracy over the time period of interest. Such intercomparability generally requires constant vigilance and support.

Reply: Thank you very much for this suggestion which we implemented. The text covering this topic is now in the appendix. The full paragraph reads now:

"Another major achievement of the ATMO-RIs which deserves explicit mentioning is the conservation of long-term atmospheric observation stations and time series which were in danger during the transition process from research projects to research infrastructures. The detection of trends and seasonality in the presence of greenhouse gases and short-lived climate-active atmospheric constituents is an important aspect of climate science. An accurate description of trends relies heavily on the ability to place the measurements of all kinds of climate-active atmospheric constituents in a historical context, i.e., to compare measurements against measurements from the same location in preceding years and decades. From a scientific perspective, longer timeseries reduce the uncertainties in the interpretation of current measurements. The length of timeseries which are produced by the different ATMO-RIs is therefore a good indicator of how well these data meet the requirements of climate scientists. It is important to note that the use of long time series of observations for trend analysis requires a measurement infrastructure that guarantees inter-comparability in terms of observation precision and accuracy over the period of interest. Such inter-comparability generally requires constant vigilance and support which operational RIs secure."

7) Minor point: suggest replacing 'periodicity' with 'seasonality' since the former is non-standard usage.

Reply: Thank you for this suggestion, we use now seasonality instead of periodicity.