REFEREE 1

We would like to thank the anonymous referee for providing his careful and very constructive comments on our manuscript. We think to be able to address his suggestions and without doubt his contribution has resulted to significant improvement of the manuscript.

General comments:

The paper deals with an investigation of temperature and precipitation trends in the south slopes of Mt Everest in the last two decades. In particular the paper considers how the changes in temperature and precipitation have affected the glaciers size. The paper is well written and presents unique data collected in the Region.

If think that in the paper it should be better specified what the authors mean for high and low elevation, since these are concepts which depends strongly on the geographical context.

Response:

"for high and low elevation" we use the threshold of 5000 m a.s.l. We revised the paper specifying better this altitudinal limit.

Moreover I think it should be better specified (because the data come from different networks) what are the characteristics of sensors used and how the functioning of sensors is periodically certified.

Response:

The quality insurance of these meteorological data is ensured considering that they are used as part of global and regional networks including for instance APHRODITE (Asian Precipitation–Highly Resolved Observational Data Integration Towards Evaluation of Water Resources) (Yasutomi et al., 2011) and GHCN (Global Historical Climatology Network) (Menne et al., 2012).

Moreover I think it should be better underlined that this paper deals only with liquid precipitation, without taking into consideration the snowfall, that in the area in particular at elevations greater than 5000 m a.s.l. could be considerable, in association with tropical cyclones and westerly disturbances.

Response:

We followed the suggestion specifying in many part of the text this concept.

Specific comments:

Reply to all specific comments are reported directly point to point in the attached pdf file. Moreover the revised paper including all comments and revisions provided by anonymous referee #1 and with the "short comment" have been annexed at the end of the same pdf file.

REFEREE 2

We would like to thank the anonymous referee for providing his careful and very constructive comments on our manuscript. We think to be able to address his suggestions and without doubt his contribution has resulted to significant improvement of the manuscript.

<u>General comments</u>:

The authors present a very interesting study on precipitation and temperature trends in the Everest region between 1994 and 2013. They analyze high altitude datasets gathered by the EV-K2-CNR project and they compare those high altitude data to other datasets which are regionally available. They draw several interesting conclusion: (i) The minimum temperature increases much stronger than the maximum temperature at high altitude, (ii) the temperature trends are stronger than for the surrounding areas; (iii) there is a significant negative trend in precipitation. This factors combined will have a very strong impact on the glaciers in the region, which is supported by recent observations of geodetic mass balances and flow velocities of the glaciers in the Khumbu region. The paper is generally well written and it is suitable for publication in the Cryosphere.

Thanks very much for the positive feedback.

The detection of precipitation trends is essential; however those measurements are conducted using tipping buckets, which are unreliable for snow fall. The authors touch upon this topic briefly (p5917), however I do not find this discussion convincing. Temperatures at the 5050 reference altitude only above zero for a limited period of time. The authors state that more than 90% of annual precipitation falls during the monsoon, but how can this be proven if only observation during the monsoon months can be trusted. It could be that there has been a shift in precipitation from the monsoon to other (colder) seasons which remains undetected because of the tipping buckets. This should be more extensively discussed.

Response:

We followed the suggestion adding some new analysis and writing a new paragraph in the data section. Moreover we provided new supporting materials (3) in order to increase the clarity on the magnitude of the possible underestimation of the solid phase of precipitation at the PYRAMID station.

"The Prec sensors at these locations are conventional heated tipping buckets which may not fully capture the solid Prec. Therefore, solid Prec is probably underestimated, especially in winter. However, in order to know the magnitude of the possible underestimation of the solid phase, we compared the monthly mean Prec of the reconstructed PYRAMID series (1994-2013 period) with the Prec of a station located downstream at 2619 m a.s.l. (Chaurikhark, ID 1202), (Fig. 1b, Table 2) which presents monthly mean temperature above 0 °C even during the winter and thus a high prevalence of liquid Prec also during these months. This comparison, supported by the elevated correlation existing between the monthly Prec of the two stations, shown a slight underestimation of the PYRAMID snow (about 3±1% of total annual precipitation registered at PYRAMID, see Supplementary material 3 for more details). Therefore, being much reduced the underestimation, we decided not to manipulate data."

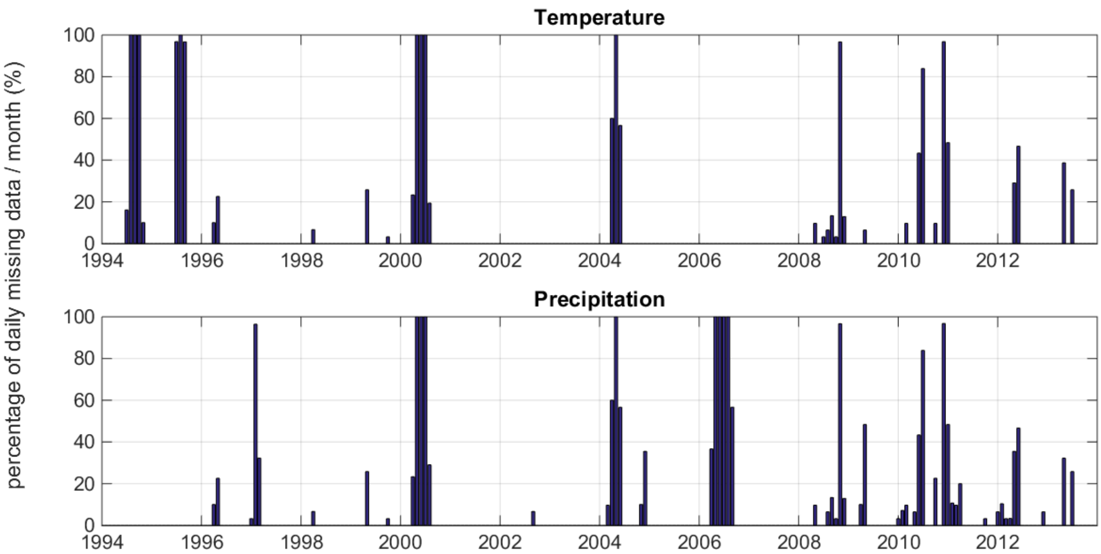
The authors reconstruct a P and T series at an altitude of 5050 and they use a quantile mapping approach to fill in missing data. It would be interesting to know how the percentage of missing data progresses with time, so it can be excluded that false trends may be attributed to trends in missing data occurrence.

Response:

We fully agree that missing data are a key issue in the assessment of the non-stationarity. To be sure about false trends possibly attributable to missing data, we dedicated several efforts to address this potential issue. In fact, the authors consider suitably the impact of missing data computing both the daily and monthly uncertainty. The applied methodology and the impact on missing data on the estimated trends is fully detailed in the supplementary materials. All uncertainty values are reported in table S3, S4 and S5. Moreover, figure S1 gives an overview of the missing data for the overall dataset used for the reconstruction.

To explicitly address the reviewer concern, the following figure reports (at monthly scale) the number of missing daily values at Pyramid both for temperature and precipitation. Concerning temperature, missing data clearly decrease after 2000, while precipitation have a maximum of missing data during the early and mid-2000s.

p.s. this new figure will be not inserted in the manuscript.



Very limited information is provided about the sensors which have been to measure the temperature and precipitation and whether they have been the same for the entire period or whether replacements have been made that may have interrupted the data series.

Response:

We followed the suggestion inserting the information related to the sensors used in the reconstruction in the Supplementary material (Table S2).

The minimum temperature trends seem extremely large (_ 0.2 degrees Celsius / year) for some months. I am not sure if this is realistic.

Response:

Yes, it is impressive! … this increase has been experienced as unbelievable for us too (even + 4 °C over twenty years). However we completely exclude a systematic error confined to the minimum temperature and just to few months.

p.s. a curiosity: consider that our temperature trend are personally experienced by the Pyramid staff which reports that, in the recent years in November and December, outside the laboratories (5050 m) the temperature during the day, but also during the night, is often above zero (experienced as .. “a milder climate during those months in the last years”).

I really appreciate Figure 4, but I suggest for precipitation the color scheme is change. Now blue = drying , which is counterintuitive.

Response:

We appreciate the compliments, and we are working to make available the Matlab© script creating this figure for the community. We can understand that the color codes are counterintuitive for precipitation, but we think it is better to keep the same codes for both precipitation and temperature rather than two different color codes (if we reverse the color code for both, we will obtain blue = warming for temperature). It is also interesting to note that the color codes refer to the trend significance rather than the amplitude, having thus no units.

The P-H relation in Figure 5 is also very interesting, but it could be related a bit more to other studies in this field , the regional context and the underlying patterns that would explain this relation.

Response:

We followed the suggestion inserting this new paragraph:

“Physically, we can interpret the Prec gradient of Fig. 5a considering that when the humid air masses coming from the Bay of Bengal collide with the orographic barrier, heavy convections induce huge quantity of rain below 2500 m a.s.l.. The topographic barrier of the Himalayan mountain range causes the mechanical lift of the humid air, the cooling of the air column, the condensation and the consequent rainfall. The further increase in relief induces a depletion of the moisture content resulting in a severe reduction of Prec at higher altitudes. Our study, based on ground stations, confirms the general Prec gradient detected with the TRMM microwave observations, even if we did not identified a marked double maximum Prec peak as observed generally for the whole central Himalaya by Bookhagen and Burbank, 2006. In fact these author report for our specific case study (profiles 14 and 15 of their Fig.1(b)) a single step increase in relief associated with a single Prec maximum.”