Local climate assessments in data scarce mountain areas; for example Kullu district, Himachal Pradesh, India

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INTRODUCTION

High-mountain regions like the Himalayas and their adjacent downstream areas are often highly affected by climatic changes, climate variability and/or related extremes. As a result of cascading effects of rising air temperatures, melting glaciers, thawing permafrost – as well as anthropogenic water usage or changes in forest and agro-biodiversity – potential impacts on people's livelihood has broadened and increased. However, climate impacts assessments on physical and societal systems are often limited due to the scarcity of reliable long-term observations, particularly in remote high-mountain regions, which additionally also hampers robustness of future projections. Since livelihoods in remote high-mountain regions are particularly vulnerable to climate related impacts, and have typically only low adaptive capacities, studies assessing climate variability pattern of the past and for the future are an important basis for sound impact assessments, and as such for preparing and planning adequate adaptation measures. Key for such studies and measures are climatic baselines.

Within the Indian Himalayas Climate Adaptation Programme (IHCAP) integrated vulnerability and hazard and risk assessments are on the way for the Kullu district in Himachal Pradesh, India, for the sake of supporting adaptation planning there. Related to these studies, the present work aims to provide an approach and according results for climatological baseline generation for regions without respective observations available or accessible.

STUDY SITE

The area of interest of this study is the Kullu District in Himachal Pradesh, India, which is located in the monsoon-arid transition zone, and thus influenced by both the Indian summer monsoon and the westerlies. This district is mainly characterized by the Kullu valley drained by the Beas river, where the main settlements are found at elevations between 1000 and 2000 m a.s.l.; and the Parvati and the Sainj valley, both leading up to high glacierized mountains with altitudes up to 6000 m a.s.l. The study site can be framed by a 1 by 1 degree box spanning 31,4 to 32,4°N and 76,9 to 77,9°E (cf. Fig. 1).

Fig. 1: Kullu district (boundary in yellow) is located in the center of Himachal Pradesh (boundary in green). The dashed square (bright green) marks the 1 by 1 degree box covering Kullu. All other boxes mark the boxes from the Reanalyses that have been used to average the mean seasonal time series. The inset map shows the Kullu district on a larger scale. The green dots show the location of the meteo stations used.

DATA and METHODS

As the baseline data for this study we used Reanalyses, observational gridded data sets and the records from the meteo stations in Srinagar (34.1N, 74.8E, 1587 m a.s.l.) and Bhuntar (31.8N, 77.2E, 1093 m a.s.l.) (cf. Fig. 1 and Table 1). The gridded datasets (observational and Reanalyses) are used to provide spatially and temporally continuous data for the Kullu district. From these datasets the average monthly mean time series of temperature and precipitation of the grid box(es) covering the Kullu district were taken. The timeframe of the datasets cover all different timespans. In order to make it comparable, we choose a 30-year window from 1981 to 2010. For the observational data air temperatures at the surface are analysed, whereas from the Reanalyses additionally the temperatures at a level of 500 and 700 hPa are included. This corresponds approximately to elevations of about 3000 m (700 hPa level) where still people live, or 5000 m (500 hPa level) where the glaciers are located. The Srinagar air temperature data are measured by the Indian Meteorological Department for more than 100 years as a part of the world's synoptical network. Srinagar is situated at 1587 m a.s.l. in a large valley surrounded by mountain chains culminating at more than 4000m a.s.l. about 300 km NW of Kullu. The Bhuntar observatory is located in the main valley of the Kullu district at an elevation of 1093 m a.s.l. where temperature and precipitation are recorded since 1969. However, from this meteo station only minimum/ maximum temperature and precipitation from 2001 onwards were available. For all the time series (within the defined time window 1981-2010) the monthly means have been grouped to seasonal means (spring = MAM (March, April, May); summer = JJA (June, July, August); autumn = SON (September, October, November); winter = DJF (December, January, February)). From the seasonal time series per dataset a linear trend is derived and the values are filtered with a seven elements Gauss filter. These curves were plotted for every dataset, season and variable (cf. Table 1).

Table 1: Used climatological datasets, whereas Stat = station data, Obs = gridded observational data, Rea = Reanalyses, T 2m = 2 m air temperature, T 700 hPa = air temperature at a pressure level of 700 hPa and T 500 hPa = air temperature at a pressure level of 500 hPa.

dataset	timeframe	Stat	Obs	Rea	T 2m	T 500 hPa	T 700 hPa
Srinagar	1880-2015	x			x		
Bhuntar	2001-2014	x			x		
Delaware	1901-2010		x		x		
CRU TS3.22	1901-2013		x		x		
GPCC	1966-now		x				
GPCP v2.2	1979-now		x				
TRMM	1998-now		x				
ERA-20C	1900-2010			x	x		
JRA-55	1958-2014			x	x	x	x
NCEP CFSR	1979-2010			x	x	x	x
ERA-interim	1979-now			x	x	x	x
NCEP/NCAR R1	1948-now			x	x	x	x

DISCUSSION

Even though with Bhuntar there is a meteo station in the study area, which records temperature and precipitation data since 1969, only a minor subset (from 2001 onwards) with large gaps was available. Unfortunately this dataset can't be used for validation as it does not cover a long enough time line. Hence we used the meteorological records from Srinagar. Srinagar is about 300 km NW of Kullu, but located in a similar situation in terms of climate and topography. With the data from Srinagar, the trends from the gridded data over Kullu can be confirmed. However, when looking at Fig. 3 the curves of the gridded observational data closely follow the temperature curve of Srinagar. It is obvious that this station, which is one of the closest to Kullu has been used when compiling the gridded datasets.

As gridded datasets are prone to inhomogeneities, an 'ensemble' of observational and Reanalyses datasets are analysed and possible uncertainties have to be discussed. In conclusion it is important to state that global observational datasets and Reanalysis are not a surrogate for ground and upper air in-situ measurements and allow only a very coarse estimation of air temperature and precipitation trends. Nevertheless, it often remains the only option for local studies.

RESULTS

The analyses reveal that the mean annual air temperatures over all levels and datasets have generally increased within the time window of 1981 to 2010. Considering the seasonal plots, striking is the increase of the spring temperatures. The trend for the summer temperatures is stagnant or even decreasing, whereas for the autumn and winter temperatures there is no relevant linear trend.

In Fig. 2 the spring and summer seasonal valuesfor Reanalyses, and in Fig. 3 the spring and summer curves for station and gridded observational data are plotted. All plots clearly reveal the positive linear trends for spring temperatures over Kullu, with increasing altitude the trend is even more positive. Contrary are the summer plots, where the linear trends are stagnant or even decreasing.

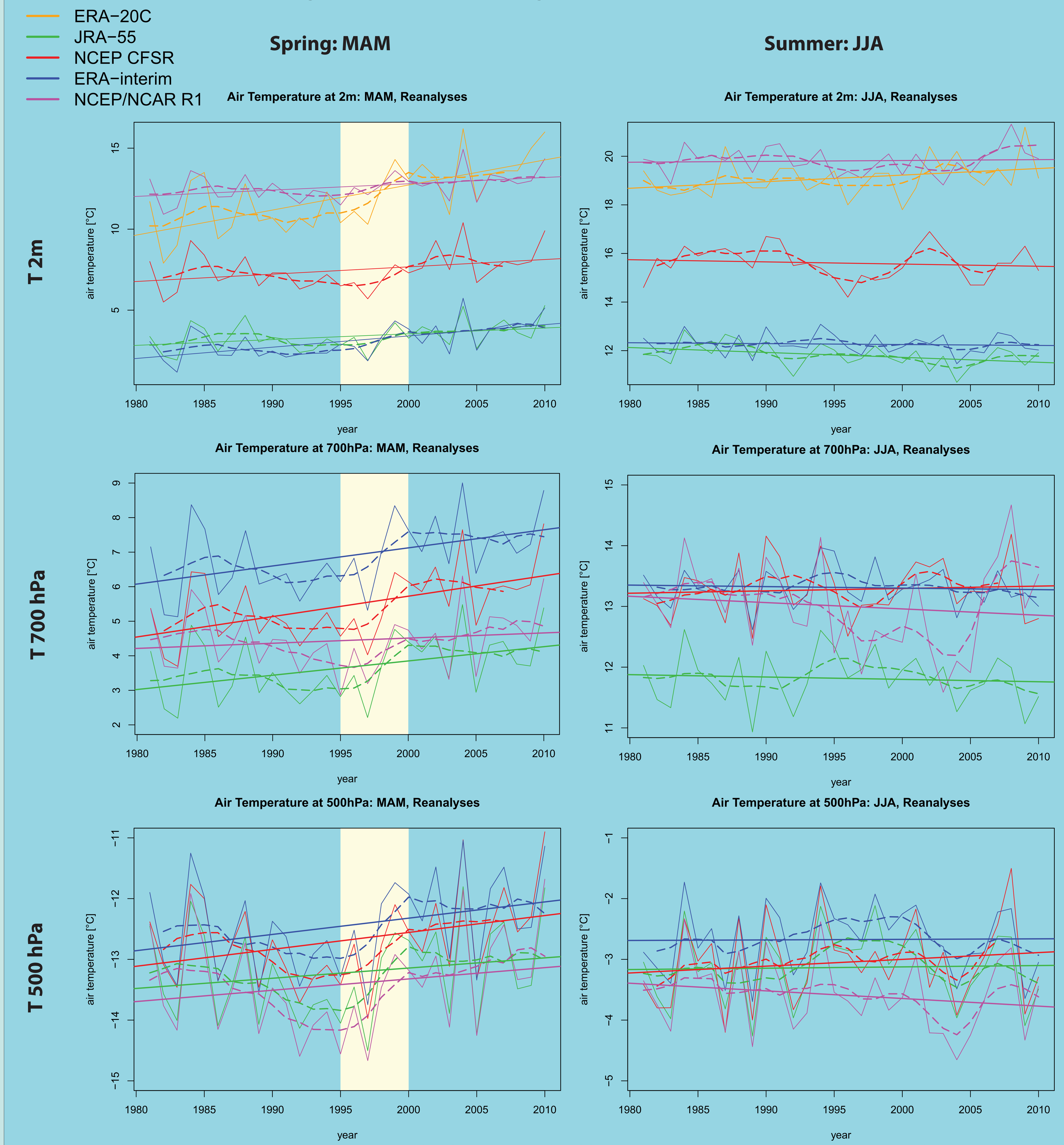


Fig. 2: Seasonal means for air temperature at 2m 700 hPa level and 500 hPa level for spring (MAM) and summer (JJA) from Reanalyses.

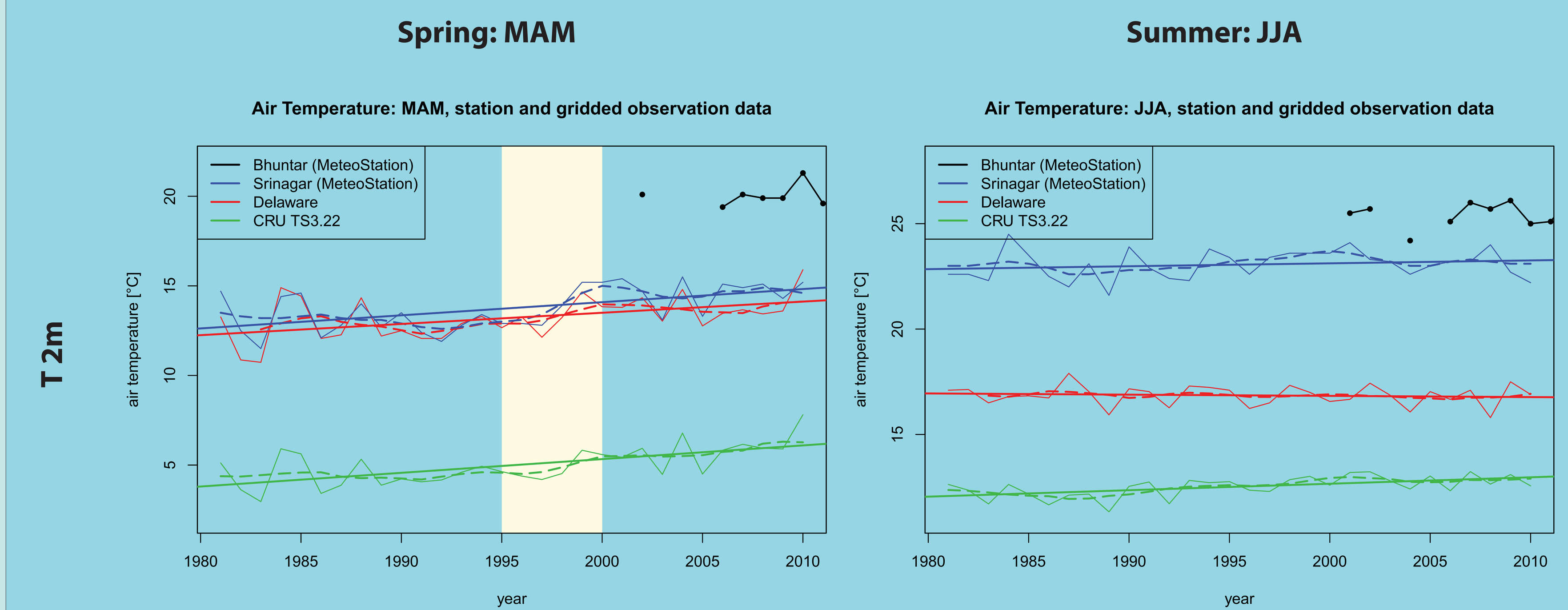
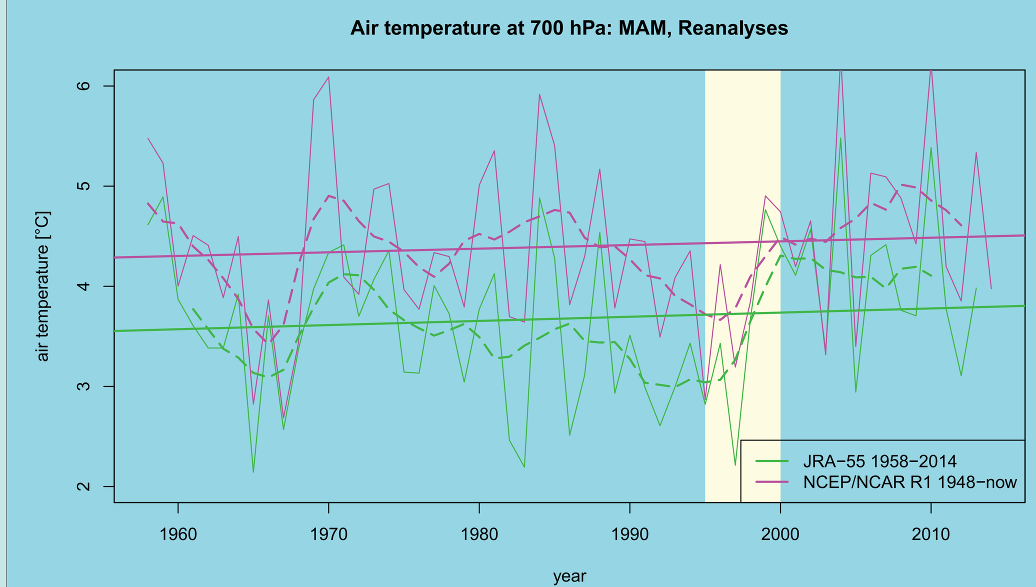


Fig. 3: Seasonal means for air temperature for spring (MAM) and summer (JJA) from station and gridded observational data.



All data sets (observation and Reanalyses) show a shift of about 1-2°C for mean spring temperature for the time between 1995 and 2000 (cf. curves with Gauss filtered values in Fig. 2 and Fig. 3). Beginning with the new century in 2000, the temperatures remain at about the same level. This temperature shift seems to be the main reason for the strong positive spring trend. However, when considering a longer time window (e.g. from 1958 to 2014) the trend for spring temperatures stays positive, but with a gentler gradient (Fig. 4)

Fig. 4: Comparison of Spring air temperature on the 700 hPa pressure level over Kullu for the reanalyses products NCEP/NCAR R1 and JRA-55.

CONCLUSION

The local climate assessment based on gridded observational and Reanalyses data for the Kullu district in Himachal Pradesh, India for the time window 1981-2010 revealed:

- **A positive linear trend for spring temperatures of about 1°C over 30 years (~0.35°C per decade).**
- **A stagnant (or even decreasing) trend for summer temperatures.**
- **No relevant linear trends for autumn and winter temperatures.**

IIncreasing temperatures in spring may lead to an upwards shift of the snow line with related impacts on precipitation, snow melt, glacier mass balance and hazards from the high mountain environment. The stagnant temperatures in summer imply that the snow line did presumably not further increase in summer.

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IHCAP Indian Himalayas Climate Adaptation Programme