Linkages between precipitation and discharge trends in Central Vietnam

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Introduction

Trend detection in precipitation and river discharge datasets can provide important insights into the impacts of climatic variability and change. Regions with poor observed hydrometeorological data coverage, often coincident with developing countries, are particularly prone to affects of changes in rainfall and temperature. In such regions, e.g. Central Vietnam, which are frequently affected by floods and droughts, knowledge about climate trends and their evolution over time is essential to project potential impacts on local water availability, agricultural productivity and risk analysis. Consequently, the quantification of the impact of global climate change in poorly gauged regions is of crucial importance for stakeholders and policy makers.

We analyse here changes in rainfall, temperature and river discharge over the last three decades in Central Vietnam. To overcome the limited data availability, the high resolution APHRODITE gridded dataset is used in addition to the existing rain gauges network. Finally, linkages between discharge changes and trends in rainfall and temperature are explored.

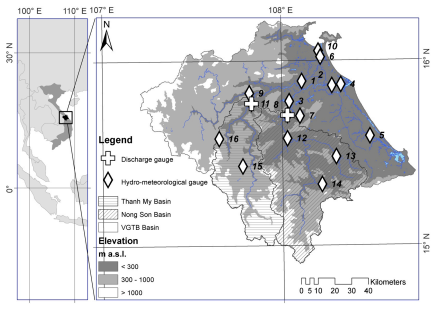

Fig 1: Location of the Vu Gia-Thu Bon (VGTB) basin in Central Vietnam (ca. 10,000km2).

Objectives

This works focuses mainly on:

1) Introducing detailed findings about variability and trends in rainfall and temperature in Central Vietnam.
2) Introducing a high resolution gridded rainfall product offering the first insights into potential orographic signals in trends in the region, a phenomenon generally missed by large scale studies and impossible while using the existing station network.
3) Exploring linkage of trends in rainfall and temperature with trends in discharge offers a useful opportunity to investigate the possible impacts of climate variability on floods in the region, conclusions which are, to the best of our knowledge, never been published at this level of spatial resolution in this area.

Consequently the study of historical trends in rainfall and temperature and their connection to discharge at the catchment's scale is of considerable interest for the climate change community. Equally, such trends can be linked with a likely increase in floods in Central Vietnam, which is important for future planning and flood mitigation in the region.

Methodology

The non-parametric Mann-Kendall trend test and Sen's slope method are used to detect monotonic trends in several precipitation indices (see table 1), temperature and river discharge. Thereafter two simple regression models (RG and APHRO) are set up to simulate river discharge in two pristine catchments (Nong Son and Than Mi). Such relatively simple multiple regression models provide useful information on how discharge responds to changes in climate processes and how trends would potentially evolve in the future.

Both models indicate good agreement (NSE>0.83) between simulated discharge and observed values (see Fig 4).

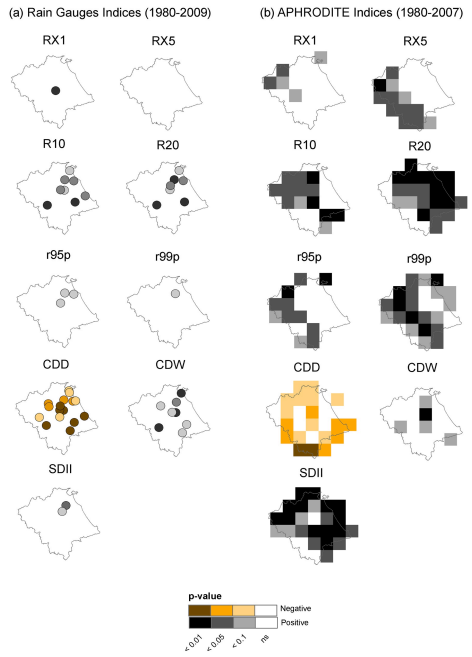

Fig 2: Trends in rainfall indices for (a) rain gauges and (b) Aphrodite datasets. Positive significant trends are represented by grey shades, whereas negative significant trends are displayed in colour scales. Non-significant trends (ns) are not displayed.

Table 1: Rainfall indices and their definition as used in this study

Index	Extended Name	Definition	Units
Rx1	Consecutive 1-Day Precipitation	Monthly maximum 1-day precipitation	mm
Rx5	Consecutive 5-Day Precipitation	Monthly maximum consecutive 5-day precipitation	mm
SDII	Simple Daily Precipitation Intensity Index	Ratio between daily precipitation amount and the number of wet days (Rainfall≥1mm)	-
R10	Days with Rainfall>10mm	Annual count of days when Rainfall>10mm	Days
R20	Days with Rainfall>20mm	Annual count of days when Rainfall>20mm	Days
CDD	Dry Spell	Maximum number of consecutive dry days (Rainfall<1mm)	Days
CDW	Wet Spell	Maximum number of consecutive wet days (Rainfall>1mm)	days
r95p	Annual 95th percentile total precipitation	Annual sum of precipitation for rainfall mount superior to the 95th percentile of precipitation in the 1980-1990 period	mm
r99p	Annual 99th percentile total precipitation	Annual sum of precipitation for rainfall mount superior to the 99th percentile of precipitation in the 1980-1990 period	mm

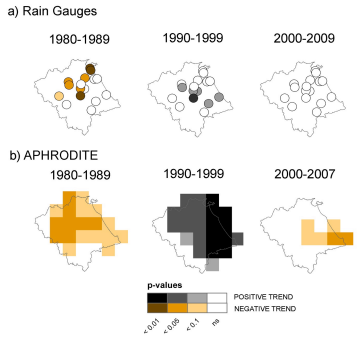

Fig 3: Decadal rainfall trends for the rain gauges and the APHRODITE datasets. P-values of significant increasing trends are displayed in grey shades and significant decreasing trends are represented in colour scales. Non-significant trends are displayed in white.

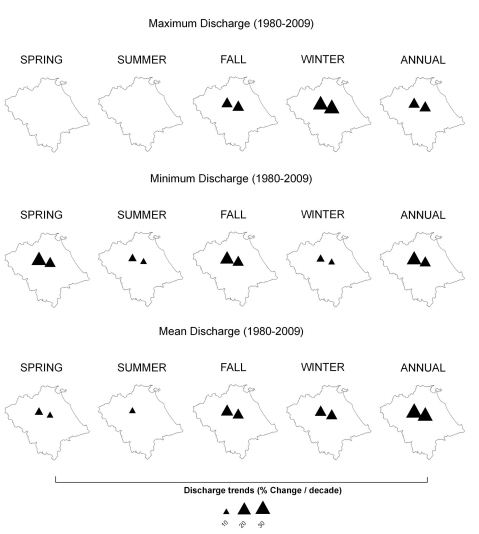

Fig 4: Seasonal and annual maximum, minimum and mean discharge trends in % the 30-year 1980-2009 period. Black arrows indicate trends at the 90% level. The size of the arrows is proportional to the magnitude of the trend.

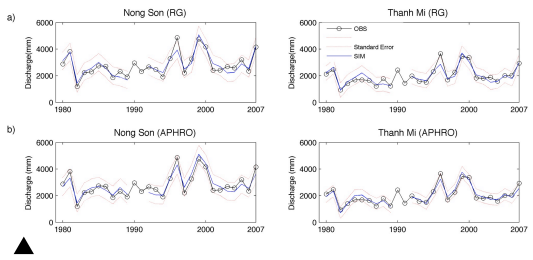

Fig 5: Observed and simulated annual hydrographs for the RG and APHRO regression models. Standard error is shown as a red dotted line.

Table 3: Percentage of change in discharge according to different trend scenarios. Percentage between brackets indicate how much of the expected increase in discharge is explained by the model

Scenario	% Change							
	Thanh My				Nong Son			
	RG		APHRO		RG		APHRO	
trend_ET	3.3%	*(9%)*	11%	*(33%)*	6%	*(17%)*	12.0%	*(34%)*
trend_P	19.9%	*(57%)*	25%	*(73%)*	20%	*(58%)*	18.8%	*(54%)*
trend_ET+P	23.4%	*(67%)*	29%	*(82%)*	26%	*(75%)*	30.8%	*(88%)*

Table 2: Decadal trends for discharge, significant at p=0.10 (+), p=0.05 (*), and p=0.01 (**):

	Station	Sen's slope [m³/year]				
		1980-1989		1990-1999		2000-2009
Qmax	NongSon	-370.0		**457.1**	+	233.3
	ThanhMy	**-213.3**	*	182.5		192.3
Qmin	NongSon	-0.1		-0.9		2.7
	ThanhMy	0.1		0.8		-0.7
Q	NongSon	-7.8		13.3		10.4
	ThanhMy	-3.4		7.2		4.5

Results

Results are indicative of an intensification of rainfall (+15%/decade), with more extreme and longer events. A significant increase in winter rainfall and a decrease in consecutive dry days provides strong evidence for a lengthening wet season in Central Vietnam. In addition, trends based on APHRODITE suggest a strong orographic signal in winter and annual trends (Fig 2). The oscillating decadal signal detected in rainfall mean, is possibly to be related to the EAM (East Asian Monsoon) and the observed decadal oscillation of tropical cyclones (ATCs) (Fig 3). Conversely, a weak signal is detected in the trend of minimum temperature (+0.2◦C/decade). River discharge trends show an increase in mean discharge (31% to 35%/decade) over the last decades. Between 54% and 74% of this increase is explained by the increase in precipitation (Table 3). The maximum discharge also responds significantly to precipitation changes leading to a lengthened wet season and an increase in extreme rainfall events (Fig 4).

Such trends can be linked with a likely increase in floods in Central Vietnam, which is important for future adaptation planning and management and flood preparedness in the region

The APHRODITE dataset

The Asian Rainfall-Highly-Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) is a daily gridded rainfall dataset covering a period of more than 57 years (1951-2007) which was created by collecting and analysing rain-gauge observation data across Asia (Yagatai et al., 2012). In this study a subset of the APHRO_V1101 daily dataset for Monsoon Asia (0.25° × 0.25° resolution: ca 25 x 25km at the Equator) is used over the 1980-2007 period. In the VGTB catchment, this subset includes 29 grid points. As reported by Yagatai et al. (2012), the APHRODITE average annual rainfall (1940mm) underestimates by ca 15% the gauge network annual rainfall (2240mm) over the 1980-2007 period. The variance of APHRODITE (342mm) is smaller than the variance of the gauged network (540mm). However, the annual correlation coefficient between the two dataset is 0.72 (p<0.01). Consequently, the gridded APHRODITE data set and the gauge network constitute two distinctive data sets but with the same order of magnitude.

Conclusions

This work provides new information for climate change adaptation in Central Vietnam:

1) the presence of an orographic gradient toward the coastline in rainfall trends shall should influence future policy in the area.
2) linkages between extreme rainfall and the lengthening wet season to river discharge suggest that flood mitigation policy should be further implemented with a focus on Fall and Winter.
3) we showed that a simple technique combining gridded data sets and trend analysis was meaningful to investigate linkages between hydro-climatological trends in ungauged or poorly gauged catchments.
4) In regions where the APHRODITE data set is not available (e.g. in South America and Africa), alternatives such as atmospheric re-analysis could be used. This simple technique constitutes therefore a very promising way of providing robust information for climate change adaptation policy.

Related literature

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