ETH zürich

IfU Institut für Umweltingenieurwissenschaften Institute of Environmental Engineering

hydrosolutions

PREDICTING SUMMER RUNOFF IN THE HEIHE RIVER WATERSHED IN CHINA ON THE BASIS OF MODIS SNOW COVER DATA

Jules Henze[1,2], Haijing Wang[1], Wolfgang Kinzelbach[2]

[1]hydrosolutions Ltd.; [2]ETH Zürich; henzej@student.ethz.ch

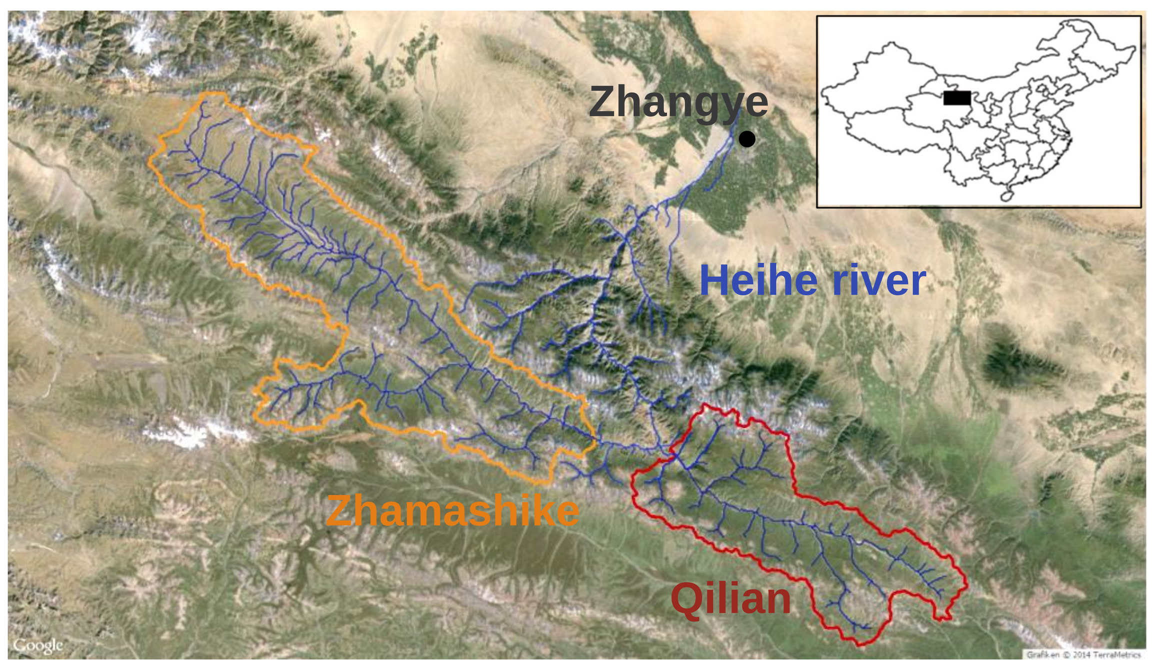
1. ABSTRACT

This study looks into the relationship between the total runoff volume in summer and the snow covered area during winter months of the Heihe river watershed. The snow covered area is derived from MODIS Terra and Aqua Snow Product MOD10A1 and MYD10A1 for the year 2001 to 2011. Two cloud correction methods were applied in order to receive continuous time series of snow cover. Gauging station observations were used to calculate runoff volume. A linear relation between runoff volume and integrated negative change of the SCA was confirmed with reasonable correlation values of r=0.85 (Qilian) and r=0.67 (Zhamashike).

2. INTRODUCTION & OBJECTIVE

Research area

- Heihe watershed, located in the Qilian mountains.
- The upper watershed includes two main sub-catchments: Qilian and Zhamashike.
- Heihe river is mainly fed by snow melt water[1].



Motivation

- Mid-reach river oasis Zhangye is heavily depending on irrigation water supplied by Heihe river.
- Zhangye is an important agricultural producer.
- Better knowledge about variation in annual runoff volume can enhance water management practices.

Study objective

- Examining the relationship between snow covered area during winter and runoff volume in summer of both sub-catchments Qilian and Zhamashike.

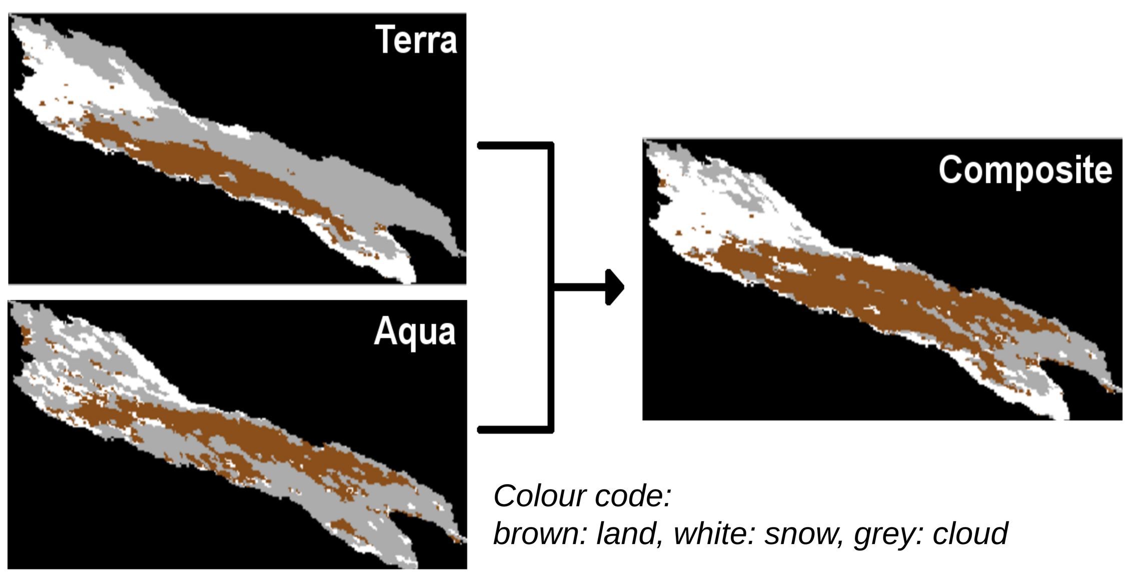
3. METHODS

Data

- MODIS Snow Cover Product MOD10A1 (Terra) and MYD10A1 (Aqua) version 5 from 2001 to 2011
- Runoff data from gauging stations
- Daily data

Cloud correction I

- 45% of MODIS observations are classified as cloud.
- Composite of Terra and Aqua images from the same day reduces cloud cover by 10%

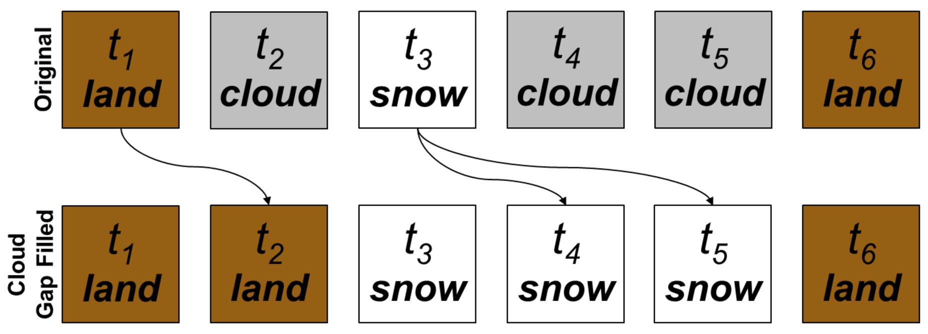


Colour code: brown: land, white: snow, grey: cloud

… METHODS

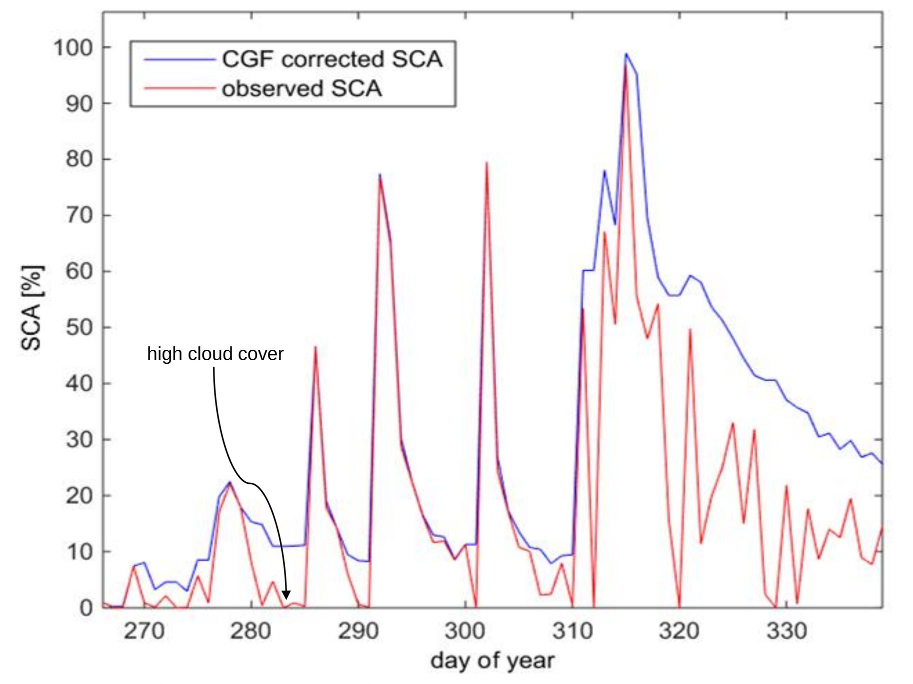
Cloud correction II

- Goal: continuous time series of snow covered area (SCA). The most important information is the change of SCA.
- To pixels with no ground information for the current time step due to cloud cover, the value of their last known observation is assigned. (Cloud Gap Filled method, GCF)[2]



- → All available observations are part of the corrected time series. The course of SCA does not react to cloud cover anymore.

SCA time series with / without Cloud Gap Filled correction



Linear correlation analysis

- *Summer runoff volume V* is defined as the integrated water discharge, measured by the gauging station, from March 12th to October 21st.
- From the SCA time series, the variable *melted snow area P_M* is derived. It is defined as the integrated negative change of SCA.
- The relevant winter weeks for snow melt are unknown. Correlation Analysis is therefore done for different starting dates & end dates.
- The following linear relation is assumed:

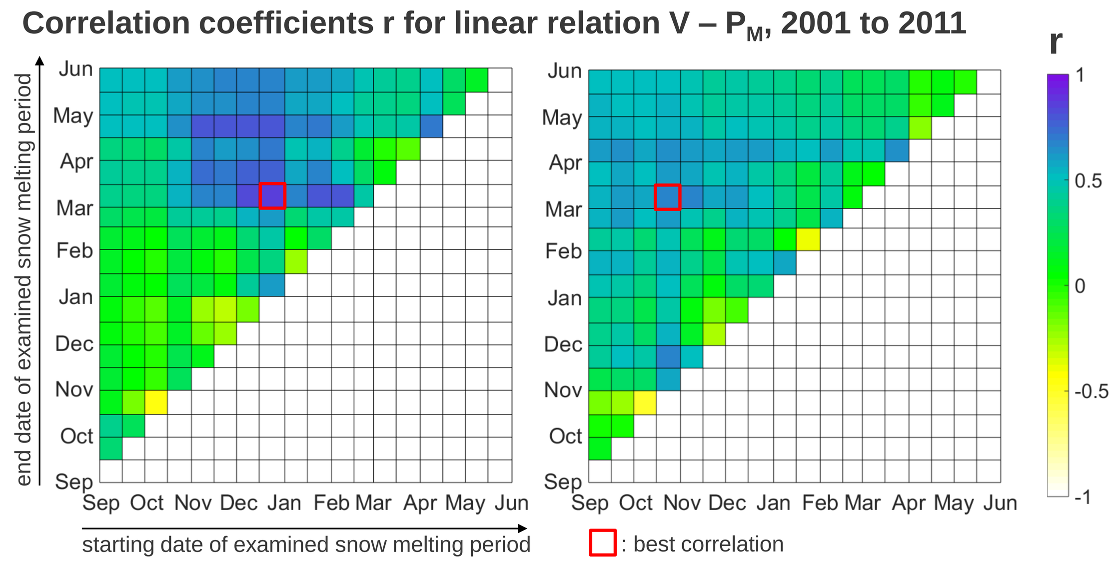
$$V = a + b * P_M$$

4. RESULTS

Correlation

- Qilian: The best correlation is found for P_M calculated from *Dec 16th to March 1st* with r=0.85
- Zhamashike: The best correlation is found for P_M calculated from *Oct 16th to March 1st* with r=0.67

Correlation coefficients r for linear relation V – P_M, 2001 to 2011



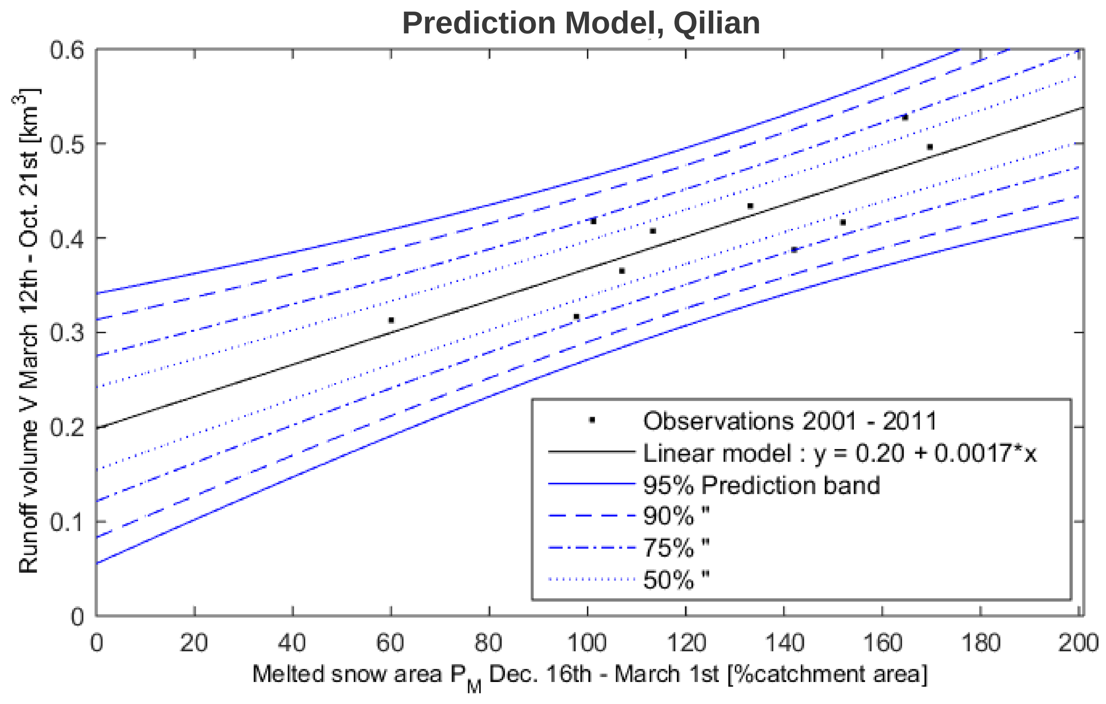
- From the statistical viewpoint, the snowmelt in October already contributes to runoff formation for the next summer in Zhamashike. A strong retention of snow melt water is a possible explanation. Retention is weaker in the case of Qilian, what might be the effect of its shorter shape.

… RESULTS

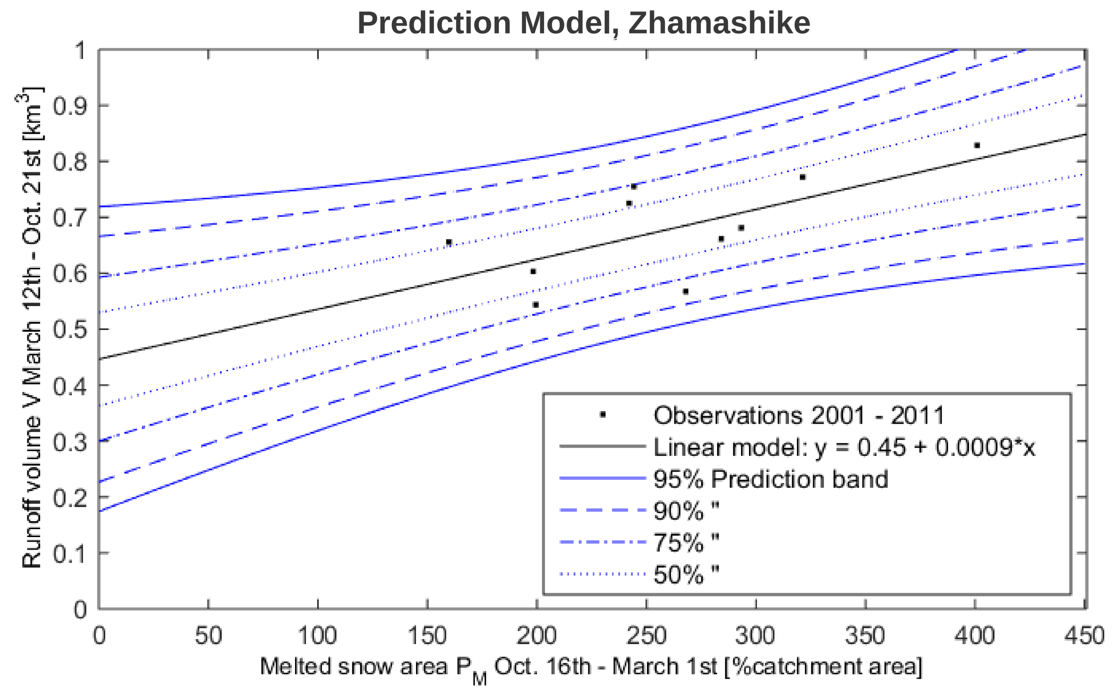
Prediction model

- Based on the best correlation found, a prediction model with a Student's t-distribution was created.
- Here, the magnitude of summer runoff volume for any year can be read, given P_M for the preceding winter of that same year.
- Example: P_M in Qilian for the last winter season was observed to be 120% of the catchment area. With a probability of 75%, the summer runoff volume will be in between 0.35 and 0.45 km³

Prediction Model, Qilian



Prediction Model, Zhamashike



5. CONCLUSION

- Although cloud cover poses a difficulty for the use of MODIS Snow Cover maps, two simple correction methods helped to produce continuous time-series of SCA with minimal cloud interference.
- The correlation analysis has shown, that already in late October, snow melt in Zhamashike contributes to runoff formation for the next summer. This leads to the conjecture, that melt water is strongly retained in the catchment, possibly due to permafrost layers[3].
- A deeper look into runoff processes in the Qilian mountains should be considered in order to prove the above theory.
- The generated prediction model can help to support risk assessments for irrigation water management with only MODIS Snow Cover maps as input[4].
- The results could be strongly enhanced by the measurement or estimation of snow water equivalents, which were not available for this study.

6. MAJOR REFERENCES

1. H. Zhang, B. Zhang, C. Zhao und C. Wang, ***Characteristic Analysis of Baseflow Change and Its Response to Global Change in the Upper Reaches of Heihe River Basin, Northwestern China***, 18th International Conference on Geoinformatics, 18.-20. 6. 2010
2. D. K. Hall, G. A. Riggs, J. L. Foster und S. V. Kumar, ***Development and evaluation of a cloud-gap-filled MODIS daily snow-cover product***, Remote Sensing of Environment Vol.114 Issue 3, pp. 496-503, 15. 3. 2010
3. G. Wang, H. Hu und T. Li, ***The influence of freeze–thaw cycles of active soil layer on surface runoff in a permafrost watershed***, Journal of Hydrology Vol. 375 Issues 3-4, pp. 438 - 449, 15. 9. 2009
4. D. K. Hall, G. A. Riggs und V. V. Salomonson, ***MODIS/Terra and Aqua Snow Cover Daily L3 Global 500m Grid V005 2000-2011***, Boulder, Colorado USA: National Snow and Ice Data Center, 2006, updated daily