Оценка использования реанализов для диагностики лавинной опасности в горах Кавказа.
Assessment of the use of reanalyses for the diagnosis of avalanche hazard in the Caucasus mountains.

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Аннотация: Работа посвящена оценке использования реанализов для диагностики лавинной опасности на примере Кавказских гор – данный метод применим к целым горным регионам, а не отдельным склонам, и использует результаты как наблюдений, так и численного моделирования атмосферы. На основе классификации зим по температуре воздуха и осадкам для оценки лавинной опасности выполнено сравнение данных наблюдений и реанализов Era-Interim, CFSR и NCEP-NCAR, дана оценка их точности и проанализированы степени влияния температуры и осадков на лавинную опасность.

Abstract: The work is devoted to assessing the use of reanalyses for diagnosing avalanche danger using the example of the Caucasus Mountains – this method is applicable to entire mountain regions, not individual slopes, and uses the results of both observations and numerical modeling of the atmosphere. A comparison of observational data and reanalyses of Era-Interim, CFSR and NCEP-NCAR was performed, based on the classification of winters by air temperature and precipitation to assess the avalanche hazard. An assessment of their accuracy was given, and the degree of influence of temperature and precipitation on avalanche hazard was analyzed.
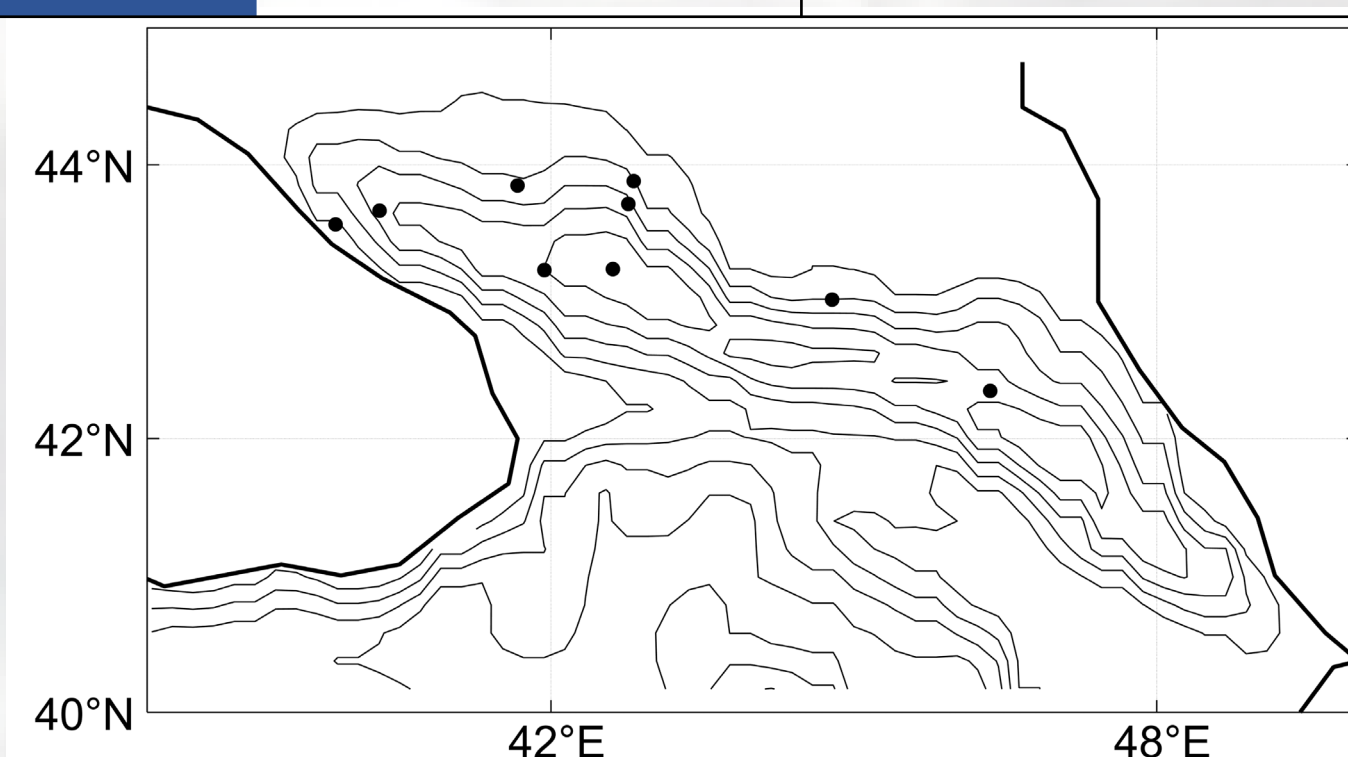
Motivation

- High population density in the Caucasus region causes an **increased avalanche danger for people and infrastructure** – this necessitates diagnosis and forecasting

Problems of existing methods:

- Methods that use numerical modeling and are suitable for forecasting are used only for individual slopes and **cannot cover the whole region**
- Methods for estimating avalanche hazard at the regional scale are usually used with only small sets of scattered observational data and without numerical modeling, which **does not allow their use for forecasting**.
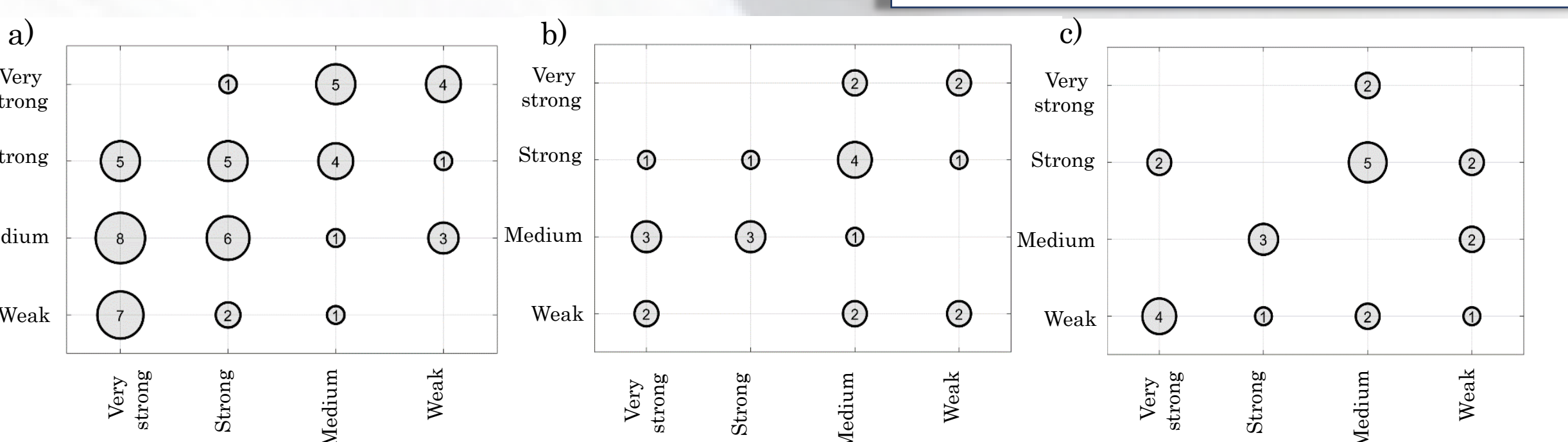
It is necessary to use reanalysis and modeling data with a method working on a regional scale.

The chosen method [Olejnikov, 2002] makes it possible to diagnose avalanche hazard based on the ratio of air temperature and precipitation during the cold period.

Winter avalanche hazard matrix [Olejnikov, 2002]

Materials and methods

Name reanalysis	Time	Grid step
NCEP-NCAR	1948-2020	2.5° x 2.5°
CFSR/CFS	1979-2010/2010-2019	Temperature: 0.312° x ~0.312°/ 0.205° x ~0.204° Precipitation: 0.5° x 0.5°
Era-Interim	1979-2019	0.703° x ~0.702°

Station data obtained from the network of meteorological stations of Roshydromet

## Results:avalanche hazard by reanalysis

Comparison of the degree of avalanche activity according to the reanalyses of NCEP-NCAR (a), Era-Interim (b), and CFSR (c) with the Terskol meteorological station. The numbers indicate the number of cases.

- Reanalyses reproduce well the actual data and temporal dynamics of seasonal temperature, but less accurate in seasonal precipitation amounts
- Over the past 20 years, there has been a decrease in the frequency of winters with conditions for the occurrence of extreme avalanches.
- In most cases, the degree of avalanche hazard according to measurements at Terskol station and reanalysis is the same. NCEP-NCAR reanalysis often overestimates avalanche hazard
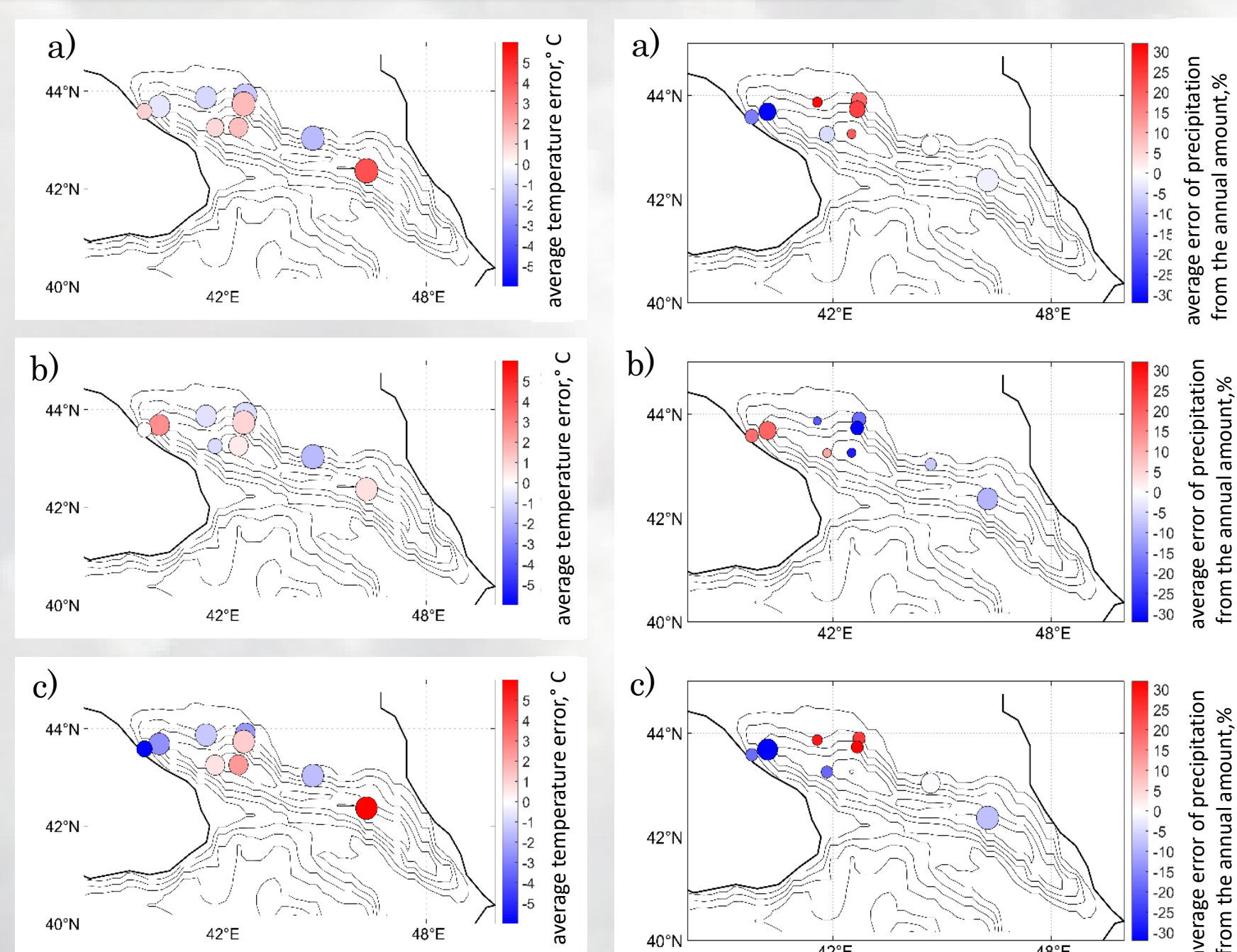
Reanalysis error Era-Interim (a), CFSR (b), and NCEP-NCAR (c) with station data on air temperature at 2 meters (left) and total precipitation (right) for the cold period. The size shows the correlation coefficient.

Results:atmospheric parameters
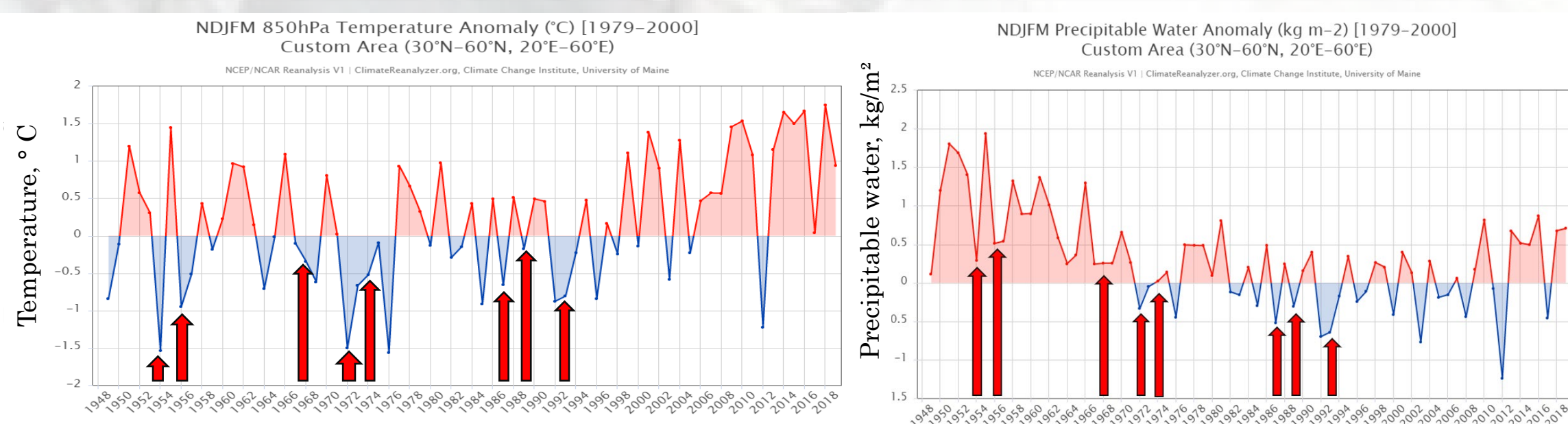
According to the results of the analysis of the main characteristics of the free atmosphere, winters with a large number of catastrophic avalanches were associated exclusively with the negative temperature anomaly at heights of 850, 700 and 500 hPa, and in all cases, the negative moisture anomaly coincided

Conclusions

1. Reanalyses reproduce the avalanche hazard assessment in the Caucasus Mountains with acceptable accuracy. The absence of large deviations was noted in the NCEP-NCAR reanalysis.
2. Decrease in the number of winters with conditions for extreme avalanches has been observed over the past 20 years due to an increase in the frequency of warm winters and a shift in the maximum precipitation from winter months to March.
3. The key factor in the increased avalanche danger in the Central Caucasus is the effect of temperature, not precipitation.