EFFECTS OF THE EL NIÑO – SOUTHERN OSCILLATION (ENSO) ON HEAVY PRECIPITATION AND ASSOCIATED LOSSES AT THE NORTH AMERICAN WEST COAST

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I. INTRODUCTION

According to NatCatSERVICE®-data on average 45 people per year died in the western parts of the USA and North Mexico between 1997 and 2007 due to catastrophes where heavy precipitation was involved. Estimated material losses summed up to about 800 Mio. US$ per year. Besides its devastating effect, heavy precipitation also contributes largely to annual rainfall (Gershunov und Barnett, 1998). At the same time the rainfall distribution and also the number of heavy precipitation events in America is biased by ENSO (e.g. Gershunov und Barnett, 1998; Cayan et al., 1999)). With growing knowledge this effect may be exploited to minimize losses due to severe precipitation events.

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II. PRESENTATION OF RESEARCH

In this work we analyse to what extend it is possible to infer seasonal estimates for extreme precipitation (EP) and associated losses exploiting SST-measurements with statistical means. The analysis is limited to extremes in the cold season, defined as the months Nov., Dec., Jan. and Feb., where the influence of ENSO is strongest.

The NCEP "US-MEX"-dataset which covers 1948-2005 is the basis of this study. It is a 1°x1°-gridded precipitation dataset derived from rain gauge measurements. Additionally excerpts of the NatCatSERVICE®-catastrophe-database are used. We analyse the connection between the frequency of EP-events and SST-anomalies of the previous months in three distinct regions of the Pacific. These anomalies are known as the Niño3-, the Niño3.4- and the Niño4-index.

As threshold for "extreme precipitation" we use the local 99.7th percentile of the daily precipitation amounts. This allows an assessment of the problem affecting different climatic regions. The choice of the 99.7th percentile is arbitrary, and is a result of balancing severity against number of detected events. It causes extreme events to be identified on long time average about once a year at every location. Evaluating climatological timescales of several decades in the period from 1950 to 2008, we find this to be a reasonable trade-off.

At first an ENSO-state was determined for every month out of each of the three Niño-indices. If the SST-anomaly of a month exceeded the 75th percentile of 1950-2008, this month was labelled El Niño (+), if the SST-anomaly lay below the 25th percentile, it was labelled La Niña (-). The remaining months were considered neutral (0). The results are three time-series of monthly ENSO-status, one for each Niño-index.

Calculating the frequency of EP for each grid point of the precipitation dataset, reveals an area covering South California, New Mexico, Arizona and northern parts of Mexico, which was more prone to EP in winter months that were labelled (+) according to the Niño3.4-index than in neutral ones. Less EP-events were registered in months labelled (-) than in neutral ones respectively. The study focuses on this geographic area (investigation area, IA) which is marked by the black rectangle in Fig. 1.

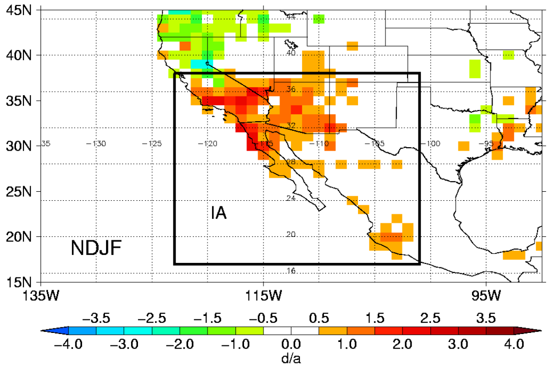

FIG. 1: Difference between El Niño- and La Niña-anomaly of EP-frequency in Nov., Dec., Jan. and Feb.. The investigation area (IA) is framed by a black rectangle.

We distinguish winter-seasons by the ENSO-status of one single month with a defined lead time. For example we compare all the cold-seasons where the ENSO-status with a lead time of five months (June) is positive (L5=+1) to all the cold-seasons where the ENSO-status with the same lead is negative (L5=-1). Another example would be comparing the winters where the month without any lead time (Nov.) is positive (L0=+1) to the (L0=0)-winters.

The labelling and therefore the comparison of the winters, is done separately for all of the three Niño-indices (Niño3, Niño3.4, Niño4). This allows assessment of which index is best suited to estimate the trend of an upcoming winter.

In general we found the count of EP-events to be higher in series of El Niño-labelled winters than the average count. To verify that this result is not by chance the Wilcoxon-Rank-Sum-Test on significance (e.g. Wilks, 2005) was used. It was performed for lead times ranging from zero to ten months and for all three Niño-indices. Also the EP-attenuating effects of La Niña were examined.

The differences in winterly EP-counts between positive labelled subsets and the whole series are quite remarkable in many cases. Thus we also computed the confidence levels of the El Niño average EP-count not just being higher than the overall average but also being higher than a defined threshold (115%, 130%, 145%, 160%). Fig. 2 shows the confidence-level for each threshold (different line-styles) for different lead times (x-axis).

Interpreting Fig. 2 in predictive sense one could say, if the July SST-anomaly in the Niño4-region is so warm that we can call July an El Niño-month, there is a chance of some 95% that in N, D, J, F the EP-count will exceed at least 145% of the average in the investigation area.

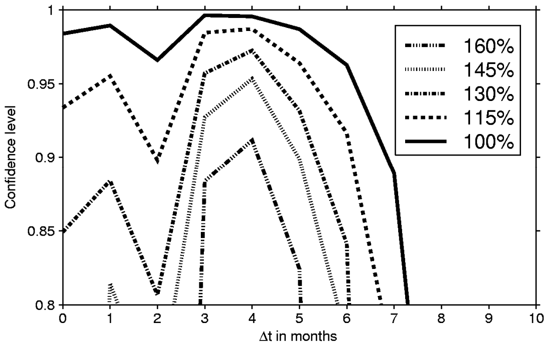

FIG. 2: Probability of EP-count in El Niño-winters being higher than the average multiplied by five different percentages when ENSO status is derived at lead time Δt.

Concerning the reinsurance loss data a similar scheme is applied. A series of an annual winter-damage-index is constructed. This index is based on the number of reported events with medium-severe to severe damage to infrastructure and/or death tolls ranging from 20 to 500 fatalities (NatCat-category three and four). In the aspect of reinsurance these are medium-severe events. The limitation to Cat3&4-events is a trade-off between a desired level of severity and a sufficient number of reports to make statistics. Comparing the El Niño-winters with the whole series yields similar results to that shown in Fig. 2. Only reports after 1975 are used, so the sample size is reduced to 32 years. This implies that for the same effect lower confidence-levels are to be expected. Nevertheless, we find that the damage-index is 15% higher than normal if El Niño conditions are met in the Niño4-region in July with a confidence of 95%.

One-point-correlation maps between monthly SST-anomalies out of a gridded dataset (EERSTv.3) and the winterly EP-frequency are calculated for different lead times for the period from 1951 to 2004. This suggests most preferable areas where SSTs should be monitored to gain the most value for estimating EP-frequency. Fig. 3 depicts the one-point-correlations between June-SST-anomalies and winterly EP-counts.

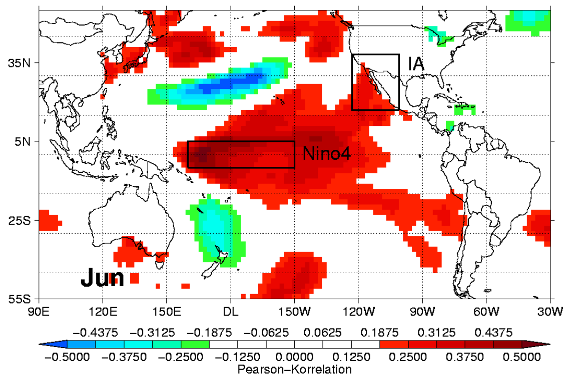

FIG. 3: Correlation-map of 1951-2004 June-SST-anomaly with winterly EP-frequency in the investigation area (IA). The Niño4-area is marked by the wide rectangle.

It reveals that the Niño4-region encloses a region of high correlation very well. The maps for increasing lead times show that the red area of high correlation is shrinking from east to west, so that the Niño4-area contains high correlation values longest compared to the other Niño-areas (Reinhardt, 2009).

Cox regression models are used for further analysis as suggested by Maia and Meinke (2008). The advantage over linear regression is that Cox models provide a) probabilistic results in terms of probabilities for the EP-frequency to exceed thresholds as well as related confidence intervals and b) a judgement if the used covariates (i.e. the different Niño-indices at different lead times) are appropriately chosen. Verification of the regression results identify the limitations of seasonal forecasts based on one single Niño-index value. For lead times between zero and five months one can expect 70%-75% correct forecasts in the sense of predicting winterly EP-activity above or below average. Computed probabilities of occurrence of very severe winters are connected with the highest uncertainty. This is also due to the low number of observations of such winters.

III. RESULTS AND CONCLUSIONS

In this work it is shown that exploiting the “July-or-later”-SST-anomalies in the Niño4-region yields a hint of above- or below-average precipitation in the winter-season. But it is also shown that Central-Pacific SSTs account merely for about a fifth of the variability of wintertime extreme precipitation.

A connection between the Central-Pacific SSTs and NatCat events exists but could only be detected at lower significance than for the extreme precipitation events.

Cox-type regression as suggested by Maia and Meinke (2008) can be applied quickly to detect weaknesses or limitations in the covariate selection. However, more research on the matter is needed if one wants to use this regression type operationally since the Cox-type approaches and associated methods are not as illustrative as plain tests on significance.

IV. AKNOWLEDGMENTS

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