Introduction
Mid-latitude cyclones play an essential role in maintaining the global atmospheric energy balance by the exchange, transport and transformation of mass and energy. These weather systems are associated with different, local weather phenomena affecting every day’s life, especially in case of extreme windstorms and extreme precipitation. As early as 1891 W. J. van Bebber recognized and described the importance of specific cyclone track types in generating heavy, large-scale precipitation in winter snowstorms in Central Europe (Van Bebber, 1891). He attributed several of these events to cyclones which are propagating from Northern Italy to the Northeast, leaving the Alps on the left. Especially this specific cyclone track named “Vb” is still well known, since some of the most devastating Central European floods have been associated with this type like in August 2002 (Ublrich et al., 2003) or with a comparable type in June 2013 (Hofstätter, 2014; Schröter et al., 2014; Blöschl et al., 2013).

The aim of this work is to assess different propagation paths of atmospheric cyclones in terms of a systematic relation to large scale extreme precipitation events over Central Europe and examine future changes of such precipitation extremes. The main focus is on the few cyclone tracks affecting the Alpine region most, and especially Vb.

Data
Precipitation
• HYRAS (including Germany, Czech Republic and Switzerland; Raustie et al., 2013)
• GWMF (a completely new, gridded precipitation data set, which was calculated from daily station data for Austria, ZAMG)

Each of these two data sets has been interpolated on a common 0.5°x0.5° grid and merged with an overlap of “Silkman width at the border of Austria to neighboring countries. The final data set provides daily gridded precipitation data at a temporal resolution of 24 hours for the time period 1951 to 2007.

Cyclone tracks (MSLP and 700hPa GPH)
Cyclones over Europe are classified into nine types, based on the geographic regions the cyclones traverse before entering Central Europe (Hofstätter et al., 2015 – under review).

• Re-analysis: ERA-40
• Global Climate Models: ECHAM5, MPI-ESM (ECHAM5), EC-Earth

Figure 2: Track density map for cyclone tracks at 700hPa GPH (1951-2006). Black arrows: mean direction of rainfall propagation, blue or red arrows: idealized track motion vector. Colors: track frequency for each grid point relative to the overall frequency of each track type. Numbers in the color bar: absolute number of tracks within the time period.

Results
The results show, that changes of the amount of extreme precipitation as well as their frequency of occurrence are large in some cases. The climate signal (increase/decrease) is not always in accordance between the GCMs. Moreover, the changes are generally stronger at 700hPa GPH than at MSLP (see Table 3), and indicate a stronger increase in the second period (Figure 8).

Since Vb tracks play an important role, they have been analyzed in a more detailed way. The results show, that there is an increase of extreme events in the second period, especially during the summer months (see Figure 9 and Figure 10).

Figure 3: Regional changes of extreme event precipitation amounts [%] for all tracks (reference period: 1971-2000). The grey boxes enclose regions of significance (p < 0.05).

The GCM signals are not always in accordance.

• Changes in RCP 4.5 are stronger than in RCP 8.5.
• Strong increase in the second period, when looking upon all tracks, but not for the summer season!
• Vb tracks point out an increase of extreme events during summer months.
• Not only the amount of extreme precipitation is increasing in the second period, but also the occurrence of such extreme events.
• Only a few results show significant changes (reference period: 1971-2000, projection period: 2021-2050 and 2071-2100).

Conclusions
The GCM signals are not always in accordance.

• Changes in RCP 8.5 are stronger than in RCP 4.5.
• Strong increase in the second period, when looking upon all tracks, but not for the summer season!
• Vb tracks point out an increase of extreme events during summer months.
• Not only the amount of extreme precipitation is increasing in the second period, but also the occurrence of such extreme events.
• Only a few results show significant changes (reference period: 1971-2000, projection period: 2021-2050 and 2071-2100).

Table 2: Thresholds of extreme precipitation events (%95th percentile)

<table>
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<th>500hPa</th>
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Table 3: Thresholds of all tracks together and the most relevant cyclone tracks for each region. Each track was divided into its own regions. Cyclone tracks generate high precipitation amounts.

References

