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Climate change in an Arctic mountainous area in the period 1900-2100 and the effect on permafrost and the ecosystem carbon stocks

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During the winter period at Zackenberg Research Station the solar energy input is low or equal to zero and radiative cooling of the snow-covered surface leads to monthly mean air temperatures (MMAT) below -20oC and daily minimum temperatures well below -30oC often occur (Hansen et al., 2008). Calm and weak winds (<2 m/s) combined with strong low-level temperature inversions are present 55-79 % of the time during the winter months. Cyclone activity over the Greenland Sea or over the Greenland Ice Sheet often takes place during the winter season and the majority (83 %) of the average annual accumulated precipitation on 261 mm w.eq. falls as snow. Snowfall in the area is most often connected with strong winds which easily lifts and redistributes the snow according to exposure and local topography, and huge snow drifts are generated on the south facing leeside in the terrain (Hinkler et al., 2008). n the snow-free summer period with continous daylight all around the clock, an almost constant weak sea breeze from south to southeast dominates the weather at Zackenberg. The MMAT vary between 3˚C and 7˚C in July and August, and the air temperature rarely gets below zero for 4-6 weeks during the warmest part of the summer season. Foehn events can occur and the wind speed and the wind speed can suddenly increase up to 20 m/s, when the air temperature remains above 20˚C for several hours, and the relative humidity drops well below 40 %. The observational time series from 1996-2008 have been used to downscale the time series of MMAT from 1900-2006 from the Climate Research unit (CRU) at Tyndall Centre for Climate Change Research (Hansen et al., 2008), while the time series of MMAT from the research project “Regional Climate Change in Greenland and Surrounding Seas” (Stendel et al., 2008) have been used for the period 2009-2100. The time series shows a fairly constant temperature level during the four season on -23, -15, -12 and 3 oC for respectively winter (DJF), spring (MAM), autumn (SON) and summer (JJA) for the period 1900-1980. In the period 1980-2008 the temperatures for the four seasons increase respectively -20, -12, -9 and 5 oC. The increase continues through the period 2008-2100 and ends on -15, -4,-5 and 8 oC for respectively winter, spring, autumn and summer. The large temperature increase is related to the retreat of sea ice along the Greenland’s east coast, which also causes a significant increase of 25-35% in the precipitation. The warmer climate generates a significant increase in the growing season from just below 90 days in the period 1900-1980 to 130-140 days in 2100. The majority of the increase is fund in the beginning of the growing season which started in the period 1900-1980 started in the 2nd week of June, while it in 2100 will start in the 1st week of May. The end of the growing season will be moved from 1st week of September to the 3th week September. Growing degree days (GDD) defined as the sum of positive mean daily air temperatures are often used in permafrost, snowmelt-runoff modelling and the GDD shows significant increase from 200-400 GDD in the period 1900-1980 to 600-800 in 2100. An important periglacial condition that is very important in the arctic ecosystem is the seasonal thaw progression of the active layer (Christiansen et al., 2008). The present active layer thickness varies between 50-65 cm at the moist Salix, Grassland and Fen sites which are placed in the lower parts of the terrain, to 65-80 cm at the drier Dryas and Cassiope heaths and continues to 80-90 cm or more at the dry Fell Fields and Barren Grounds. The Stefan solution provides a useful and simple method for predicting the depth of thaw (Z) in soils when little site-specific information is available. A basic version of the Stefan Solution has the form Z=EGDD), where E is the “edaphic factor” which varies thermal conductivity, the bulk density, soil water content and latent heat of fusion. In a period with no trends in the climate the edaphic factor is used as a soil/plant community specific constant and the variation in the active layer thickness is only caused by the annual variation in growing degree days. For period 1996-2007 a significant variation was found in the edaphic factors changing from high values in cold/dry years to lower values in wet/warm years. Using this variation on the GDD time series for the entire period 1900-2100 causes a 5 cm increase for the wet sites and a 10 cm increase for the dry sites at the end of the period. If the present constant edaphic factors was used the increase would have been 10 to 15 cm for respectively the wet and dry sites. This will lead to thawing of permafrost layers which have been stored carbon over 1000 of

years. These element stocks vary according to soil and vegetation type (Elberling et al., 2008). At dry sites (fell fields, Dryas and Cassiope heaths), C stocks are mainly found near the surface and vary between 6 and 9 kg soil-C m-2 within the upper 50 cm. In contrast, wetter sites (fen and grassland sites) holds more carbon (between 11 and 22 kg soil-C m-2) and most important know to hold the same amount in the upper part of the permafrost (Grøndahl et al., 2008). That means that dry sites may very well be the most sensitive in terms of thawing but the increaing mineralization of buried carbon will be limited, whereas a wetter site, thawing is more limited but more important in terms of mineralization rates. This become even more important considering the sum of all greenhouse gasses, as wet sites will produce both carbon dioxide and methan while dry sites only will produce carbon dioxide.

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