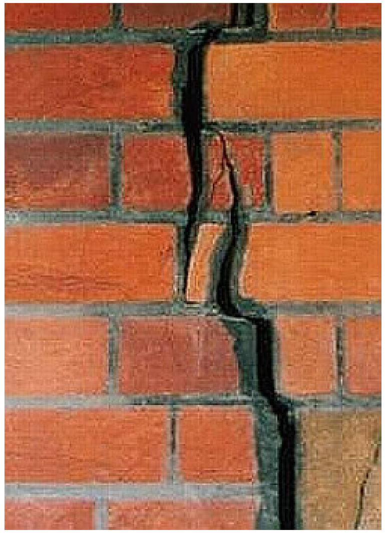

Courtesy of G Birch, Network Rail

Projections of climate change on the behaviour of clays in the UK

Derek Clarke and Joel Smethurst

Faculty of Engineering and the Environment

University of Southampton, UK

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PAPER OVERVIEW:

Volume sensitive clays cause a variety of impacts at differing scales such as seasonal displacement or long term progressive failure of slopes.

In this paper, daily changes in soil moisture content in the surface layers of a clay slope west of London, UK are simulated using a water balance model.

The impacts of anticipated climate change on soil water contents and equivalent pore water pressures are evaluated for the 21st century.

Results indicate that recent dry summers are likely to become the average condition later in the 21st century.

Although winter rainfall is predicted to increase, average winter runoff will remain the same

The implications for the design and maintenance of clay slopes and embankments are discussed.

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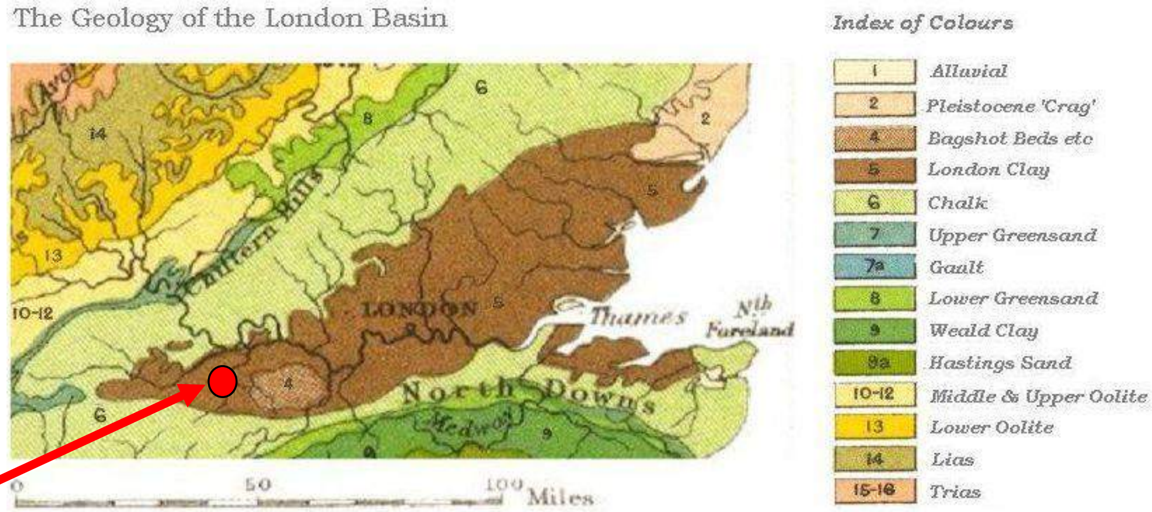
Long term monitoring in a London Clay cutting at Newbury



Continuous records since 2002 :

- Pore water pressure (17 vibrating wire sensors, 10 tensiometers)
- Soil moisture content (7 TDR sensors)
- Runoff (flow gauge)
- Climate station

Intermittent measurements

- Gravimetric sampling
- 6 Neutron probe tubes
- 2 Infiltrometer sites
- Bailout tubes
- LiDAR surveys

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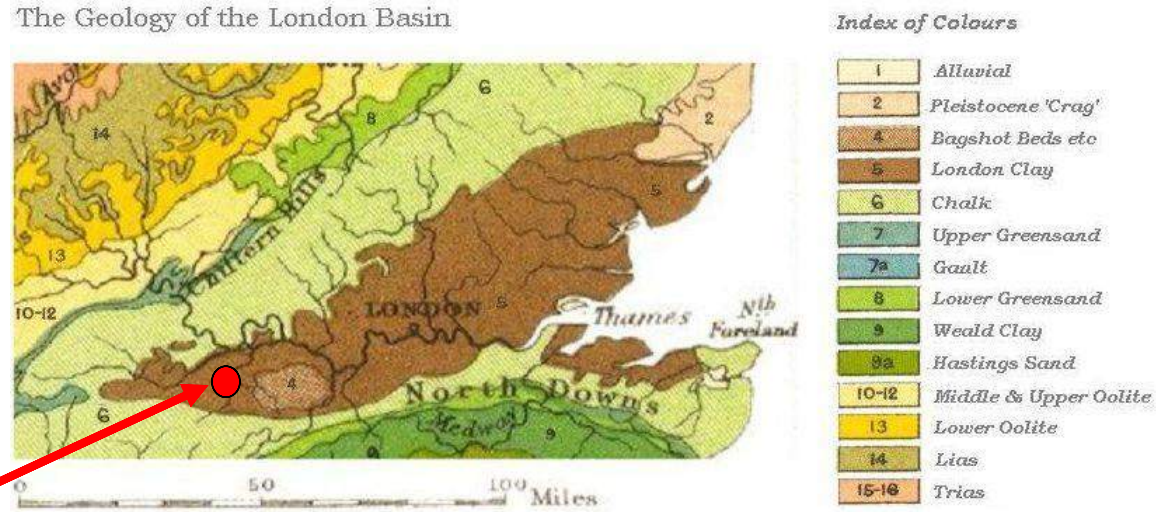

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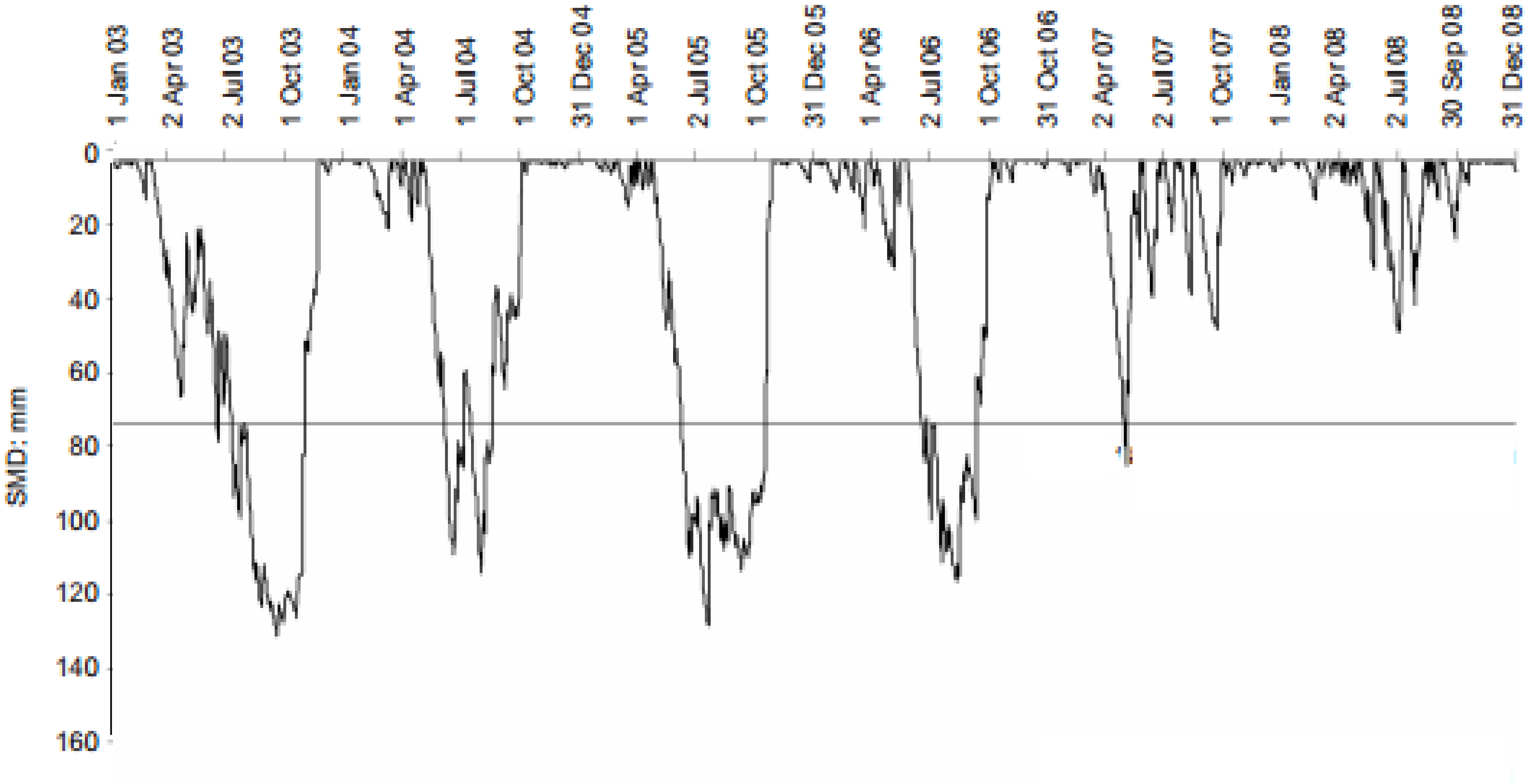
Newbury – measured soil moisture deficit in grey clay



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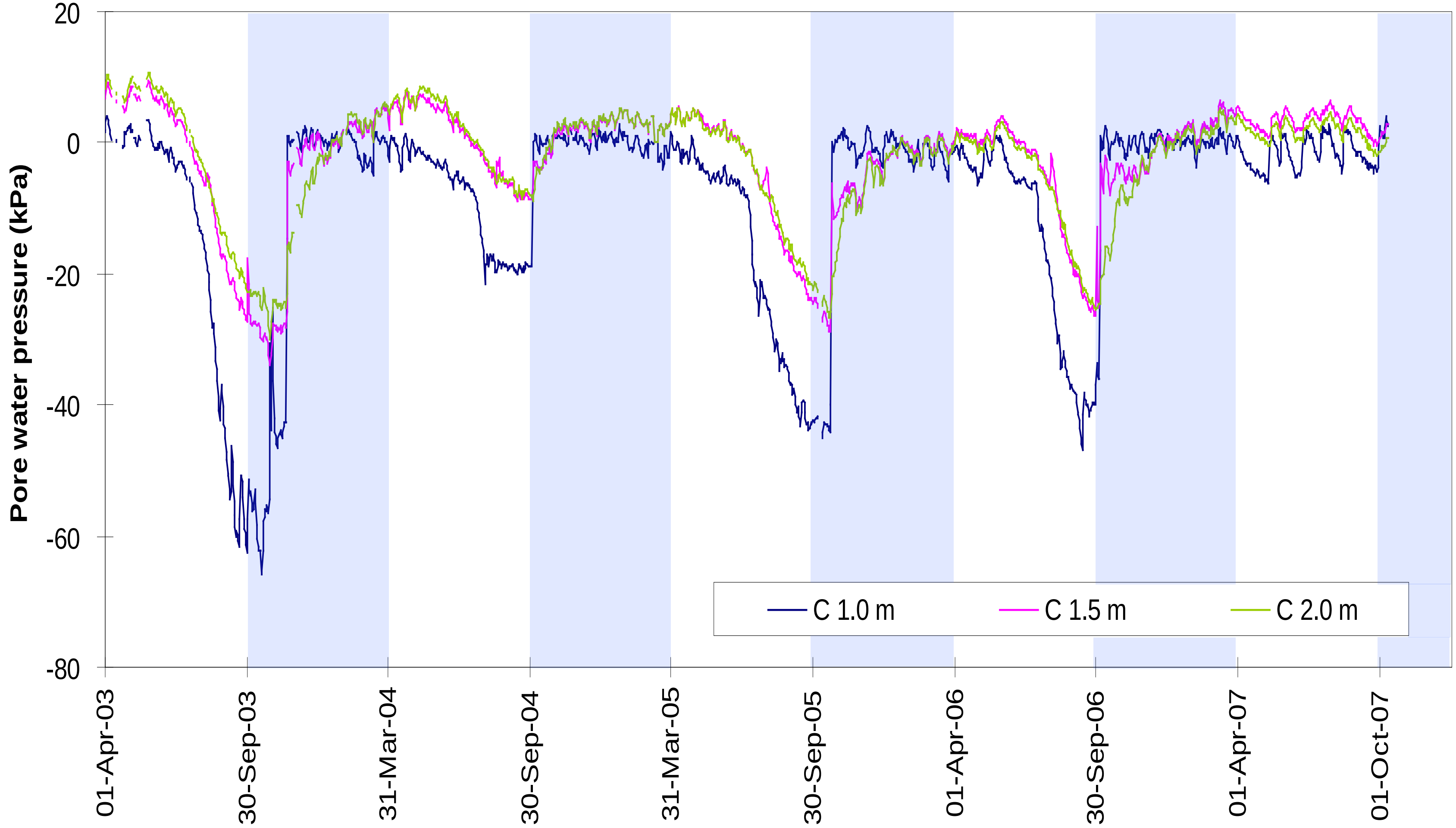
Newbury – measured pore water pressures in grey clay



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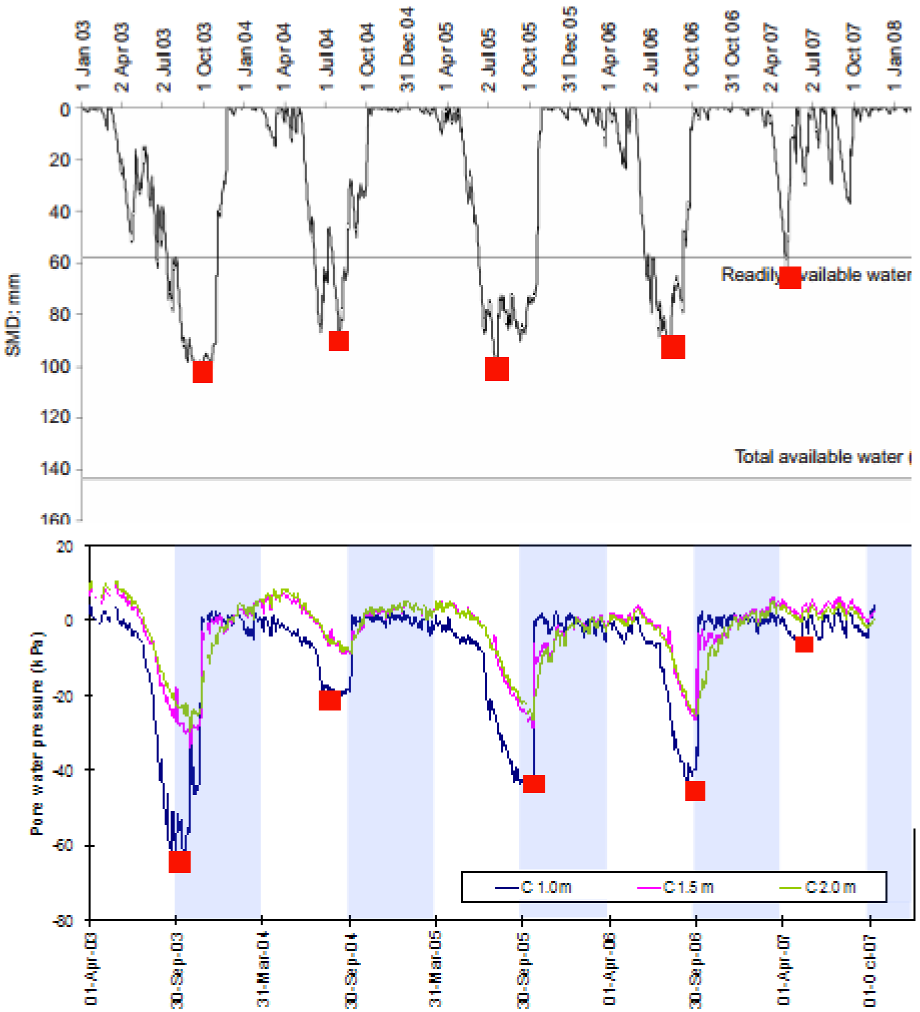
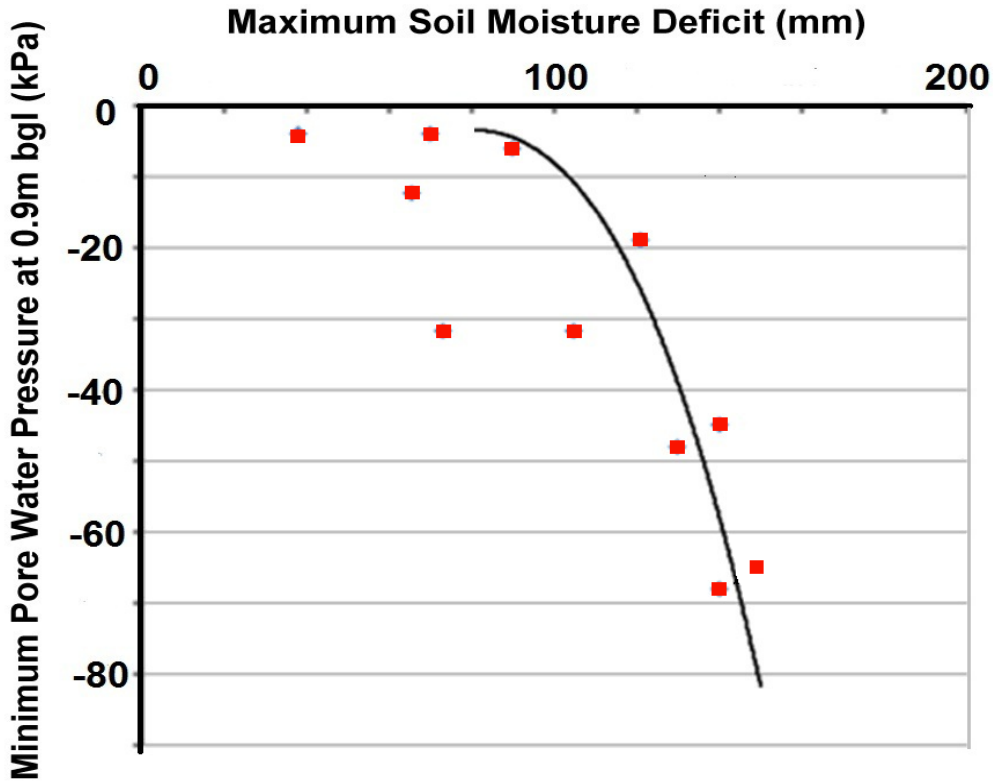
Newbury – peak soil moisture deficit vs max pore water pressure (drying)





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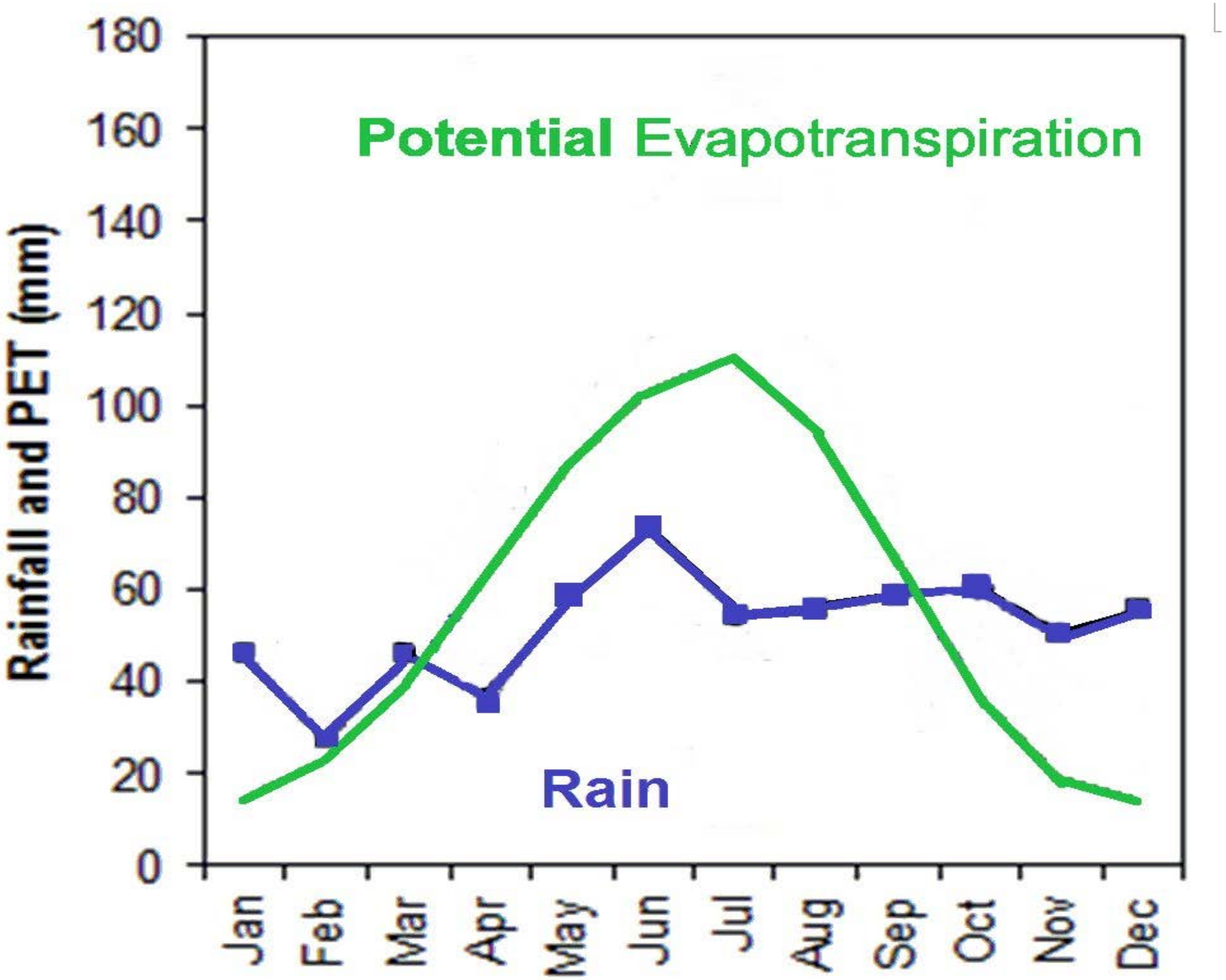
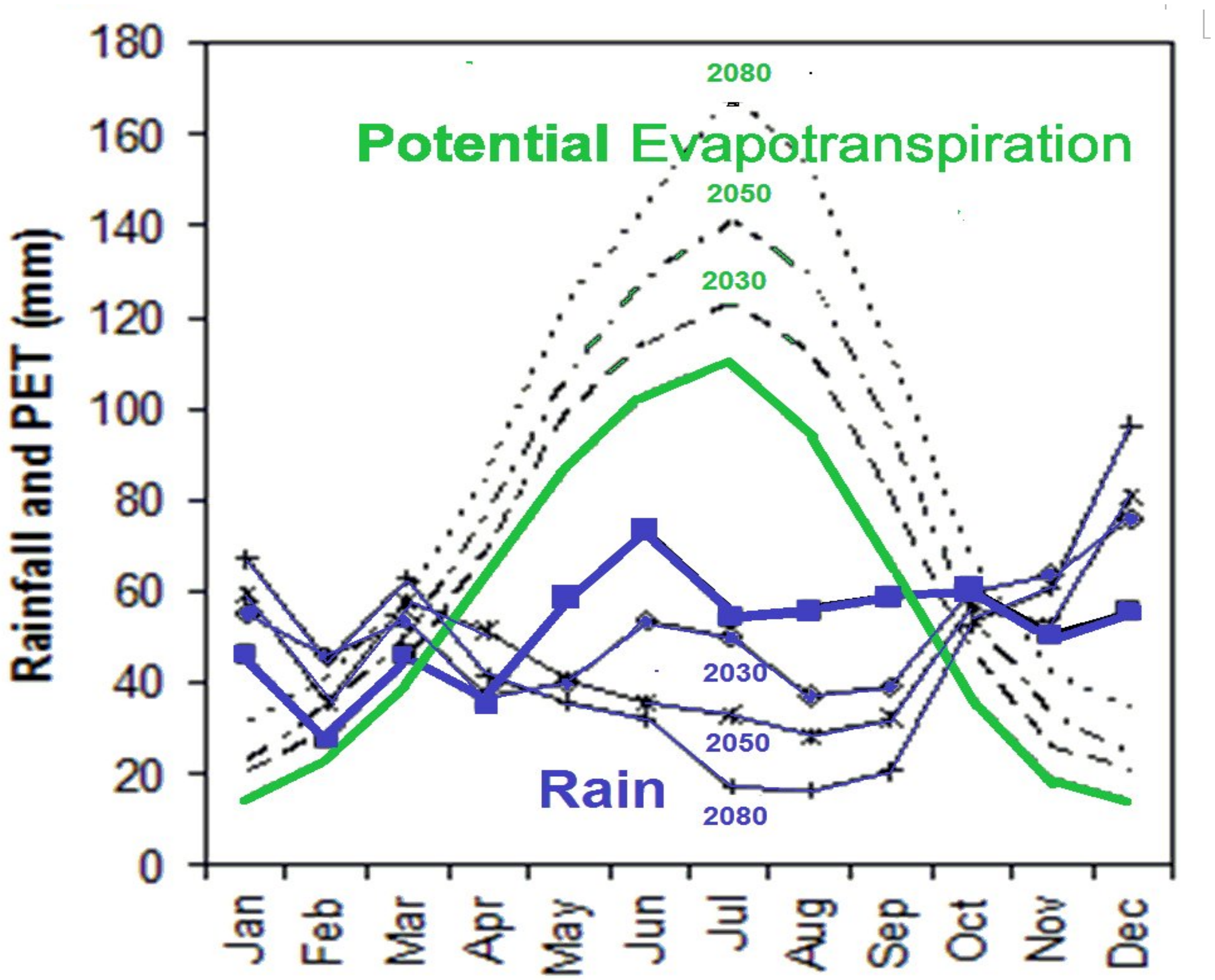
CLIMATE - VEGETATION – SOIL MOISTURE DEFICIT (1961-1990)



CLIMATE - VEGETATION – SOIL MOISTURE DEFICIT (**up to 2080**)



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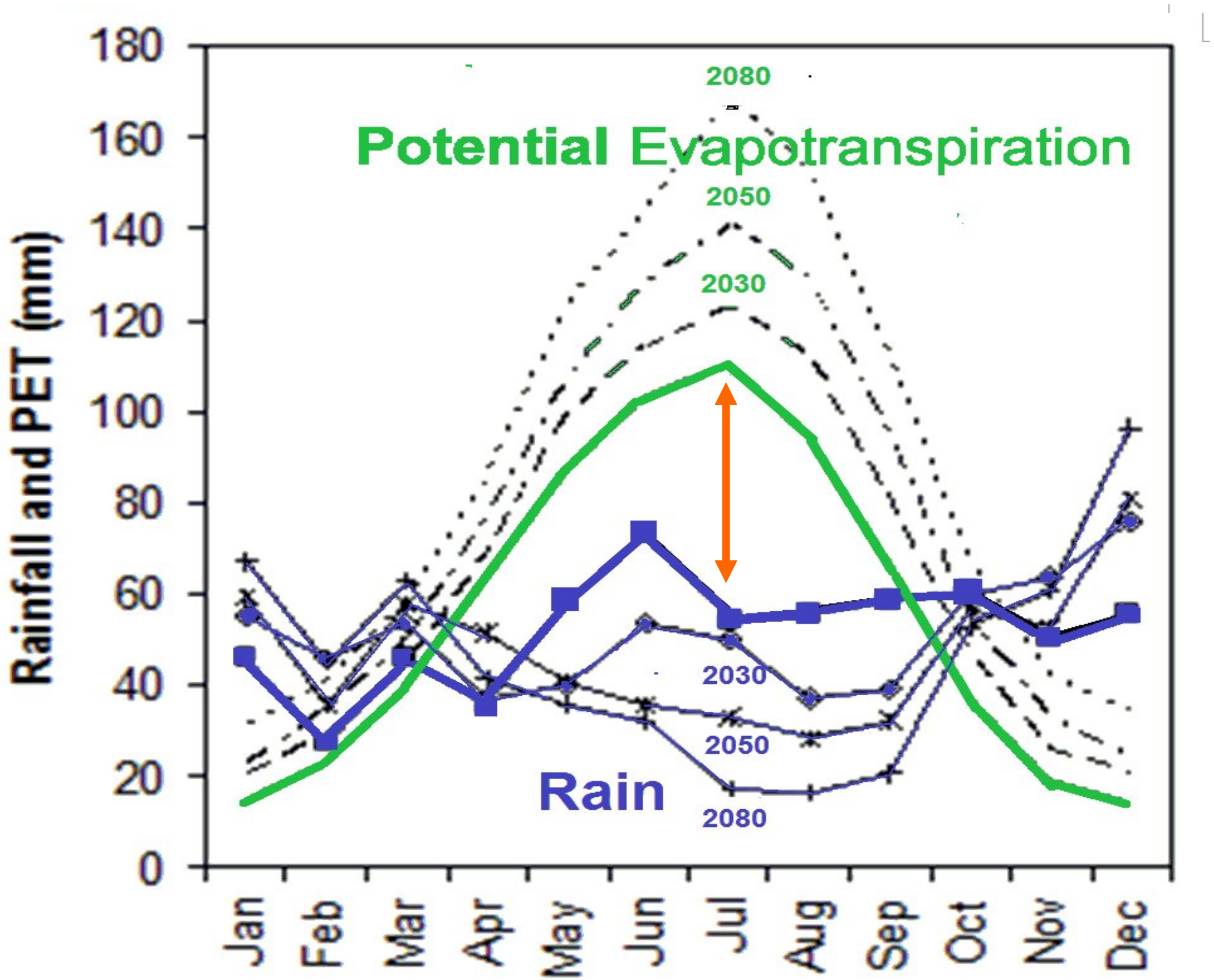
CLIMATE - VEGETATION – SOIL MOISTURE DEFICIT



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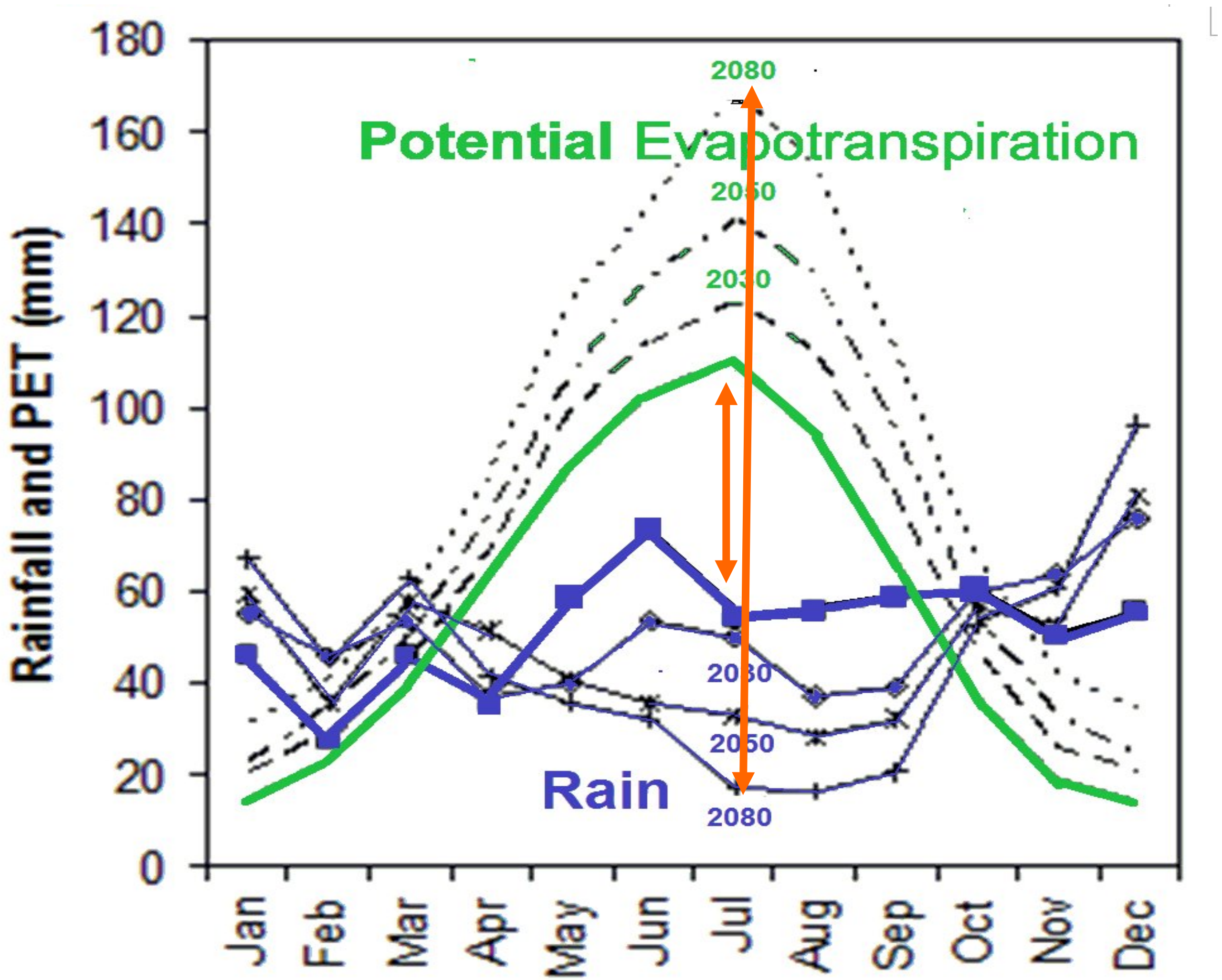

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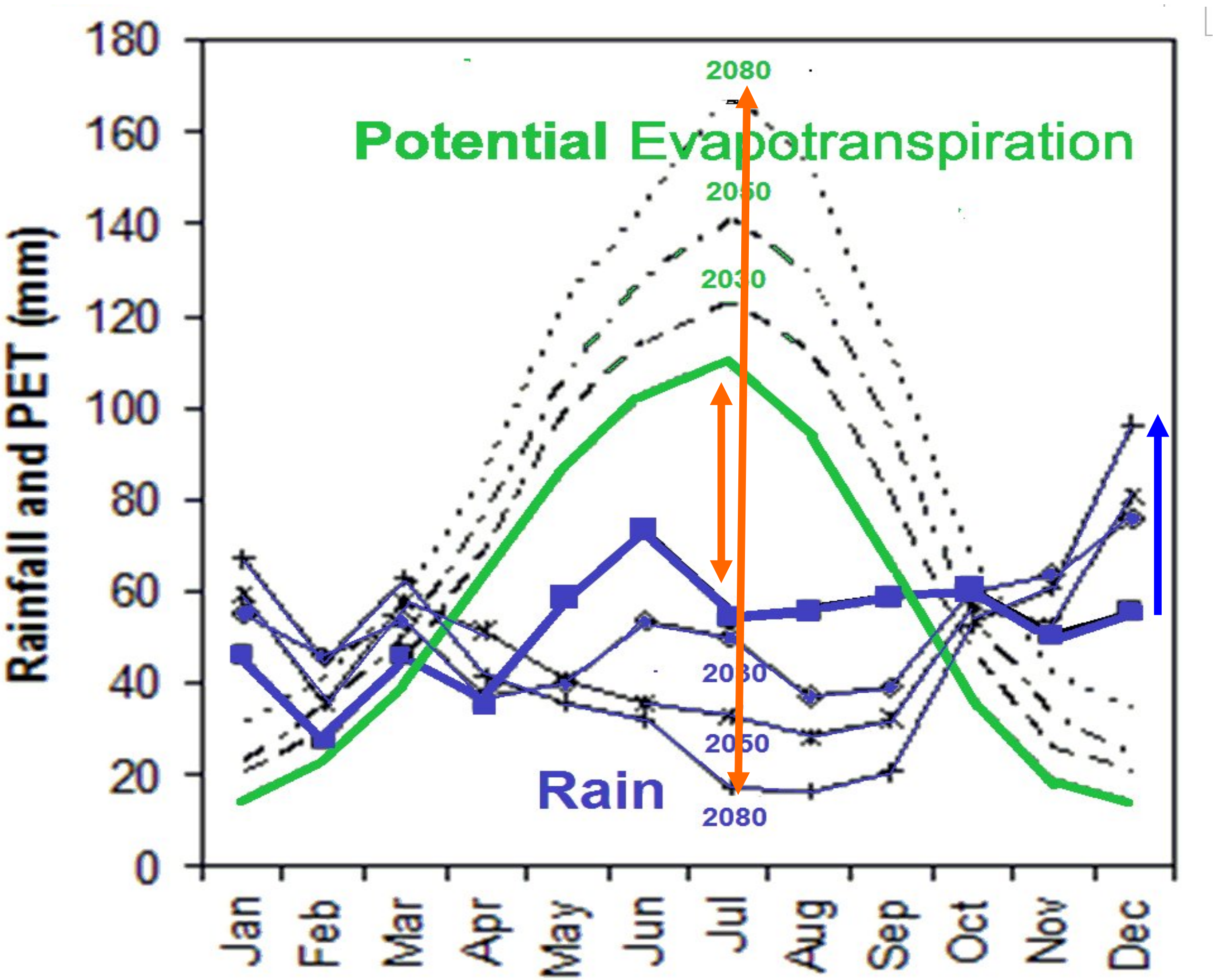
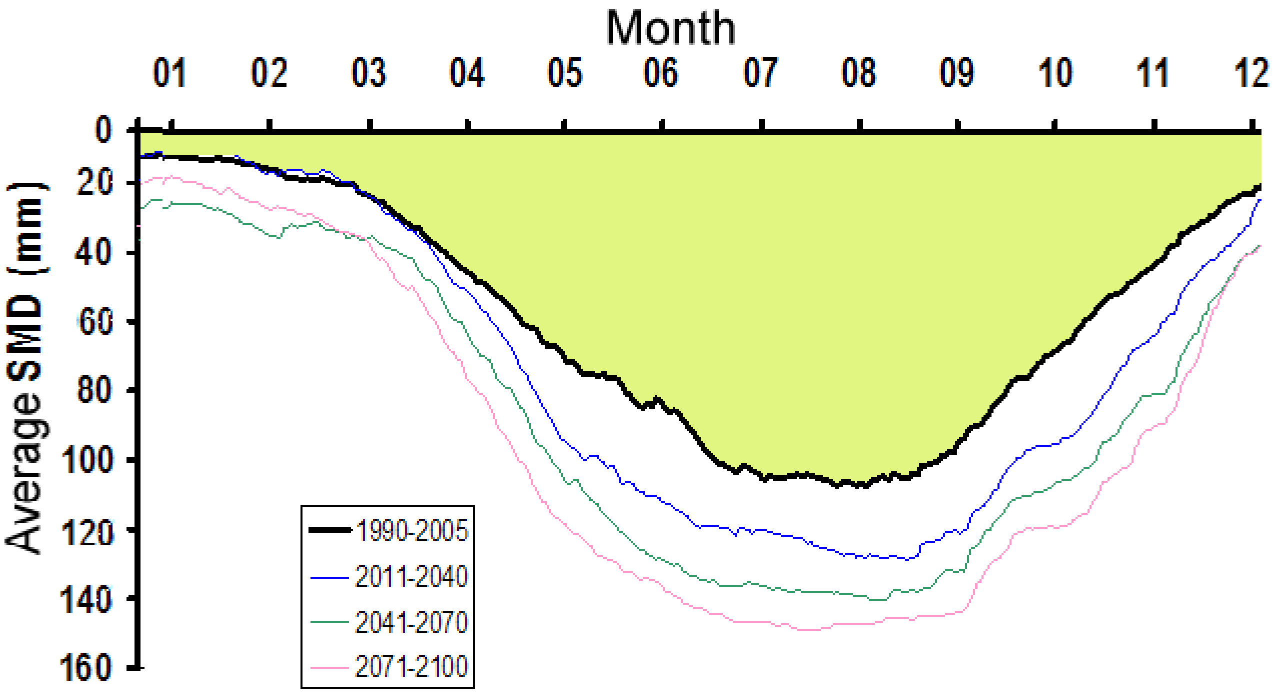


Simulating Soil Moisture Deficits

- Daily Soil Moisture Deficits (SMDs) were calculated using observed climate data 1990-2005 using a 1-D water balance model. The model was validated against field measurements as described by Smethurst *et al* (2006).
- The model used rainfall, potential evapotranspiration and an algorithm to estimate Actual Evapotranspiration when the soil is dry and the vegetation becomes stressed.
- Future daily climate "data" was obtained from the UK Climate Impacts Programme Weather Generator, which provides data in 30 year time slices .



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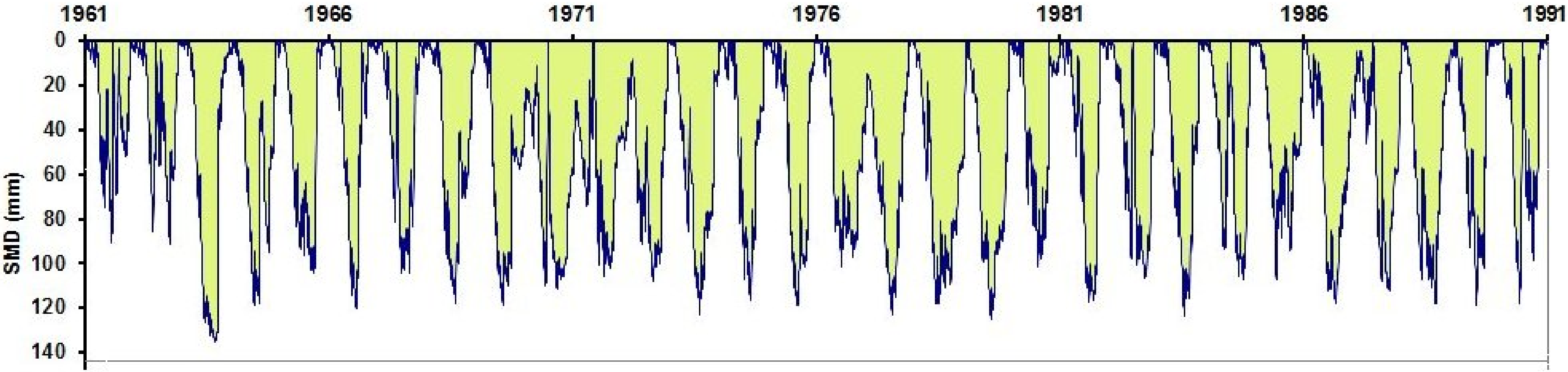
Soil Moisture Deficit simulations over baseline period

30-year simulation using daily rainfall and potential evapotranspiration data.

Soil model parameters assume 0.9m root depth, total available water 144mm and plant stress reducing potential evapotranspiration when SMD > 57mm



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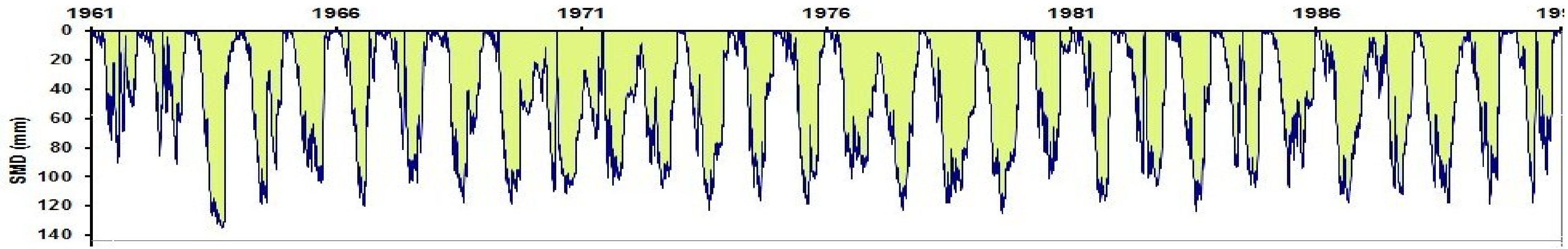
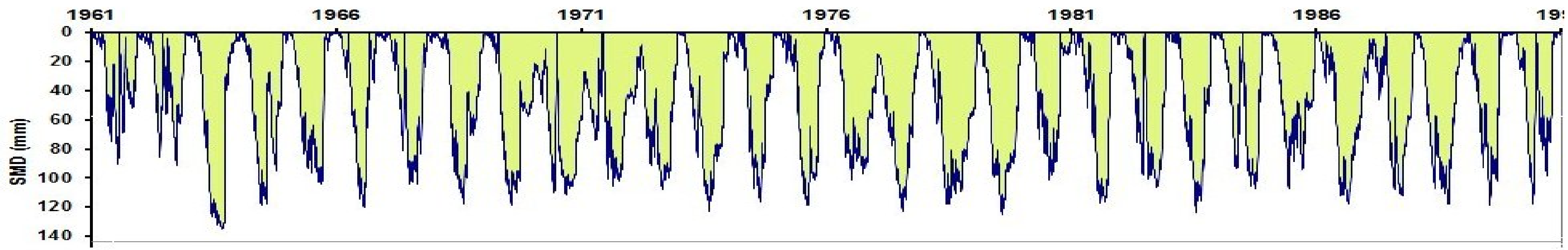
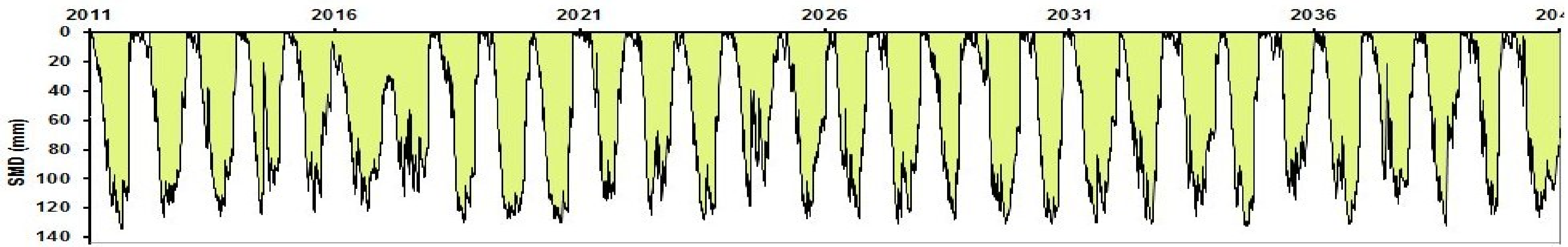


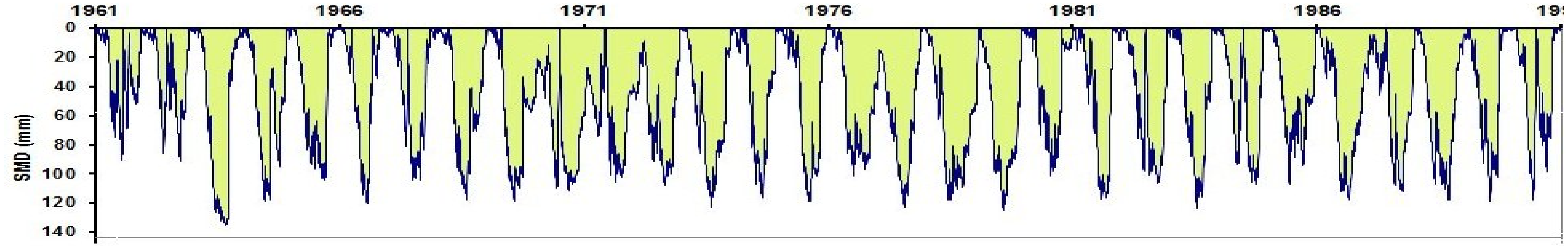
1961-1991



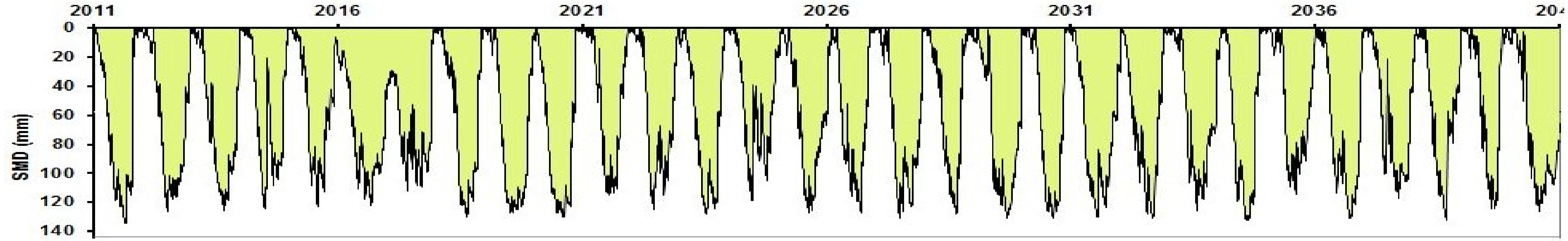
1961-1991



2011-2040



1961-1991



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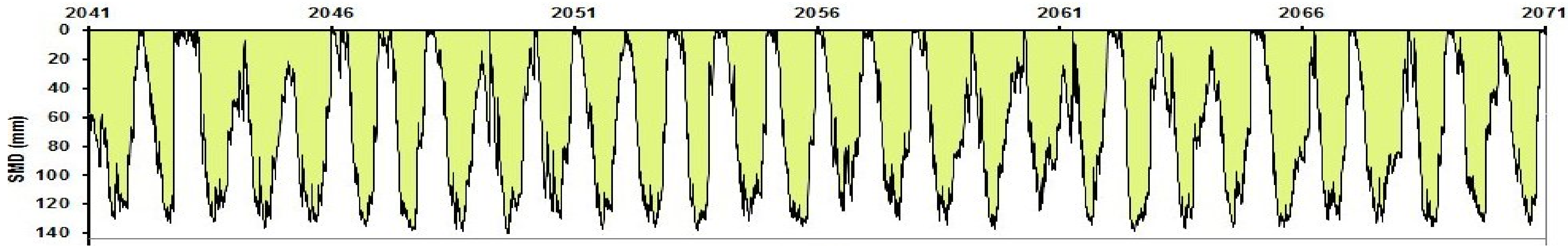
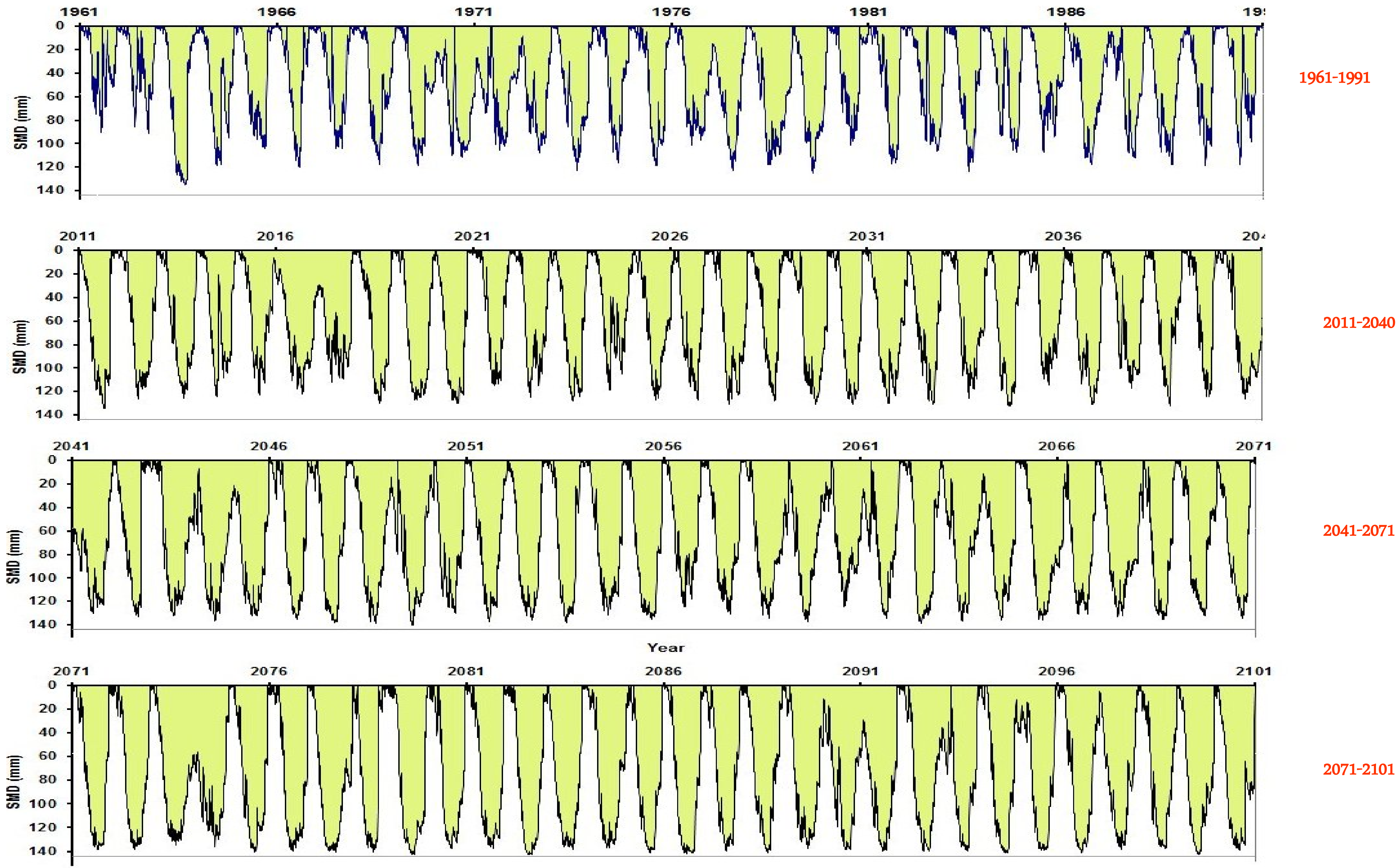


2041-2071



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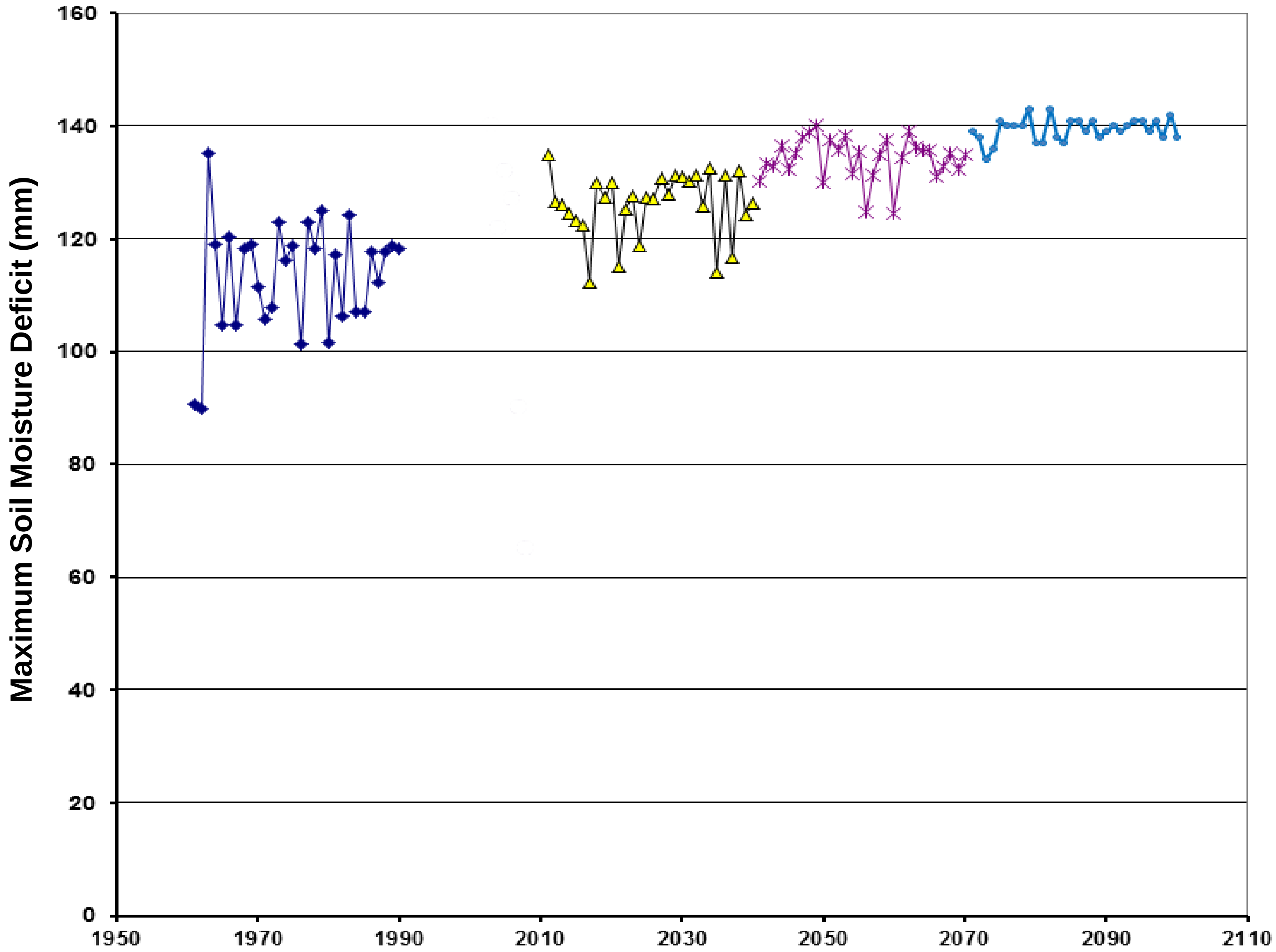
Evolution of maximum Soil Moisture Deficit

The baseline period 1961-1990 shows typical summer maximum SMDs around 110mm.

The modelled SMD increases in the future simulations to 140mm, which is close to the total available moisture in the vegetation root zone.



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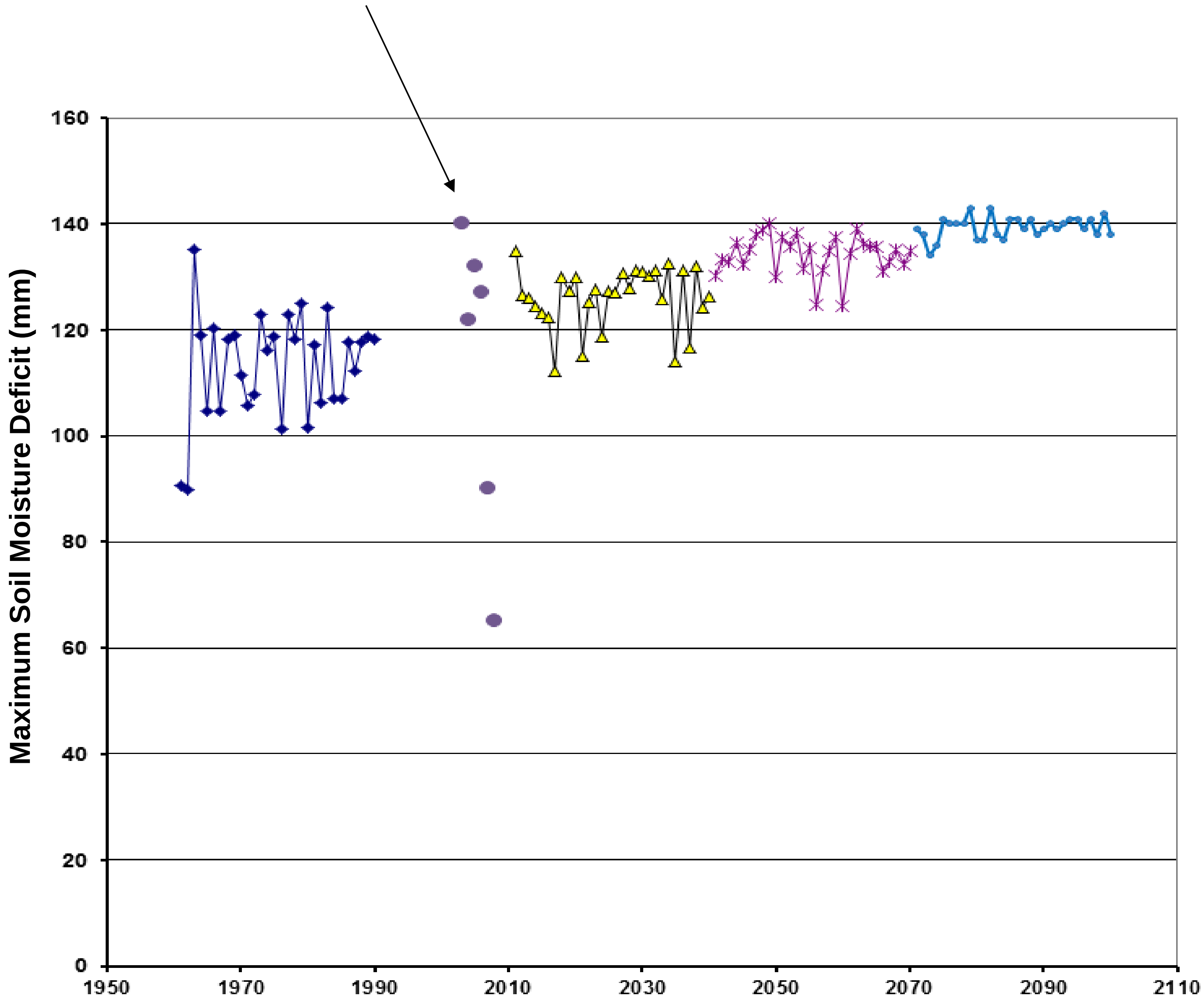
Measured maximum Soil Moisture Deficit

Field work at Newbury has observed a larger range of maximum SMD in the early 2000’s.

This period contained a 1:30 / 1:50 year drought in 2003 and several exceptionally wet summers.

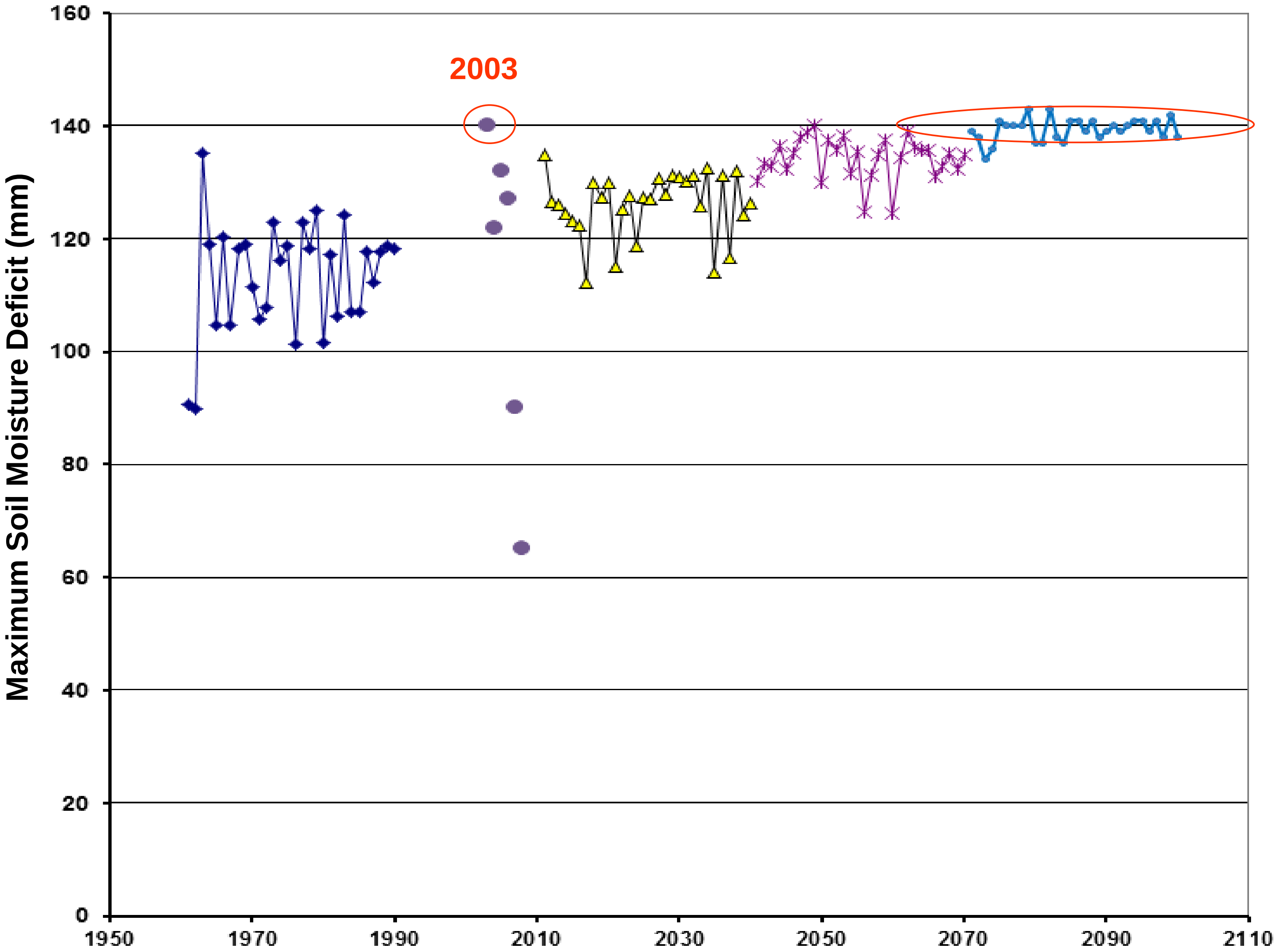
It appears that currently, the inter-annual variability may be more important than climatic “change”.



Future maximum Soil Moisture Deficit

If the simulations are correct then **average** summer SMD at the end of the 21st Century will be similar to the **extreme drought** year of 2003.

This suggests that the current grass vegetation cover will be replaced by bare soil and more Mediterranean plant types..



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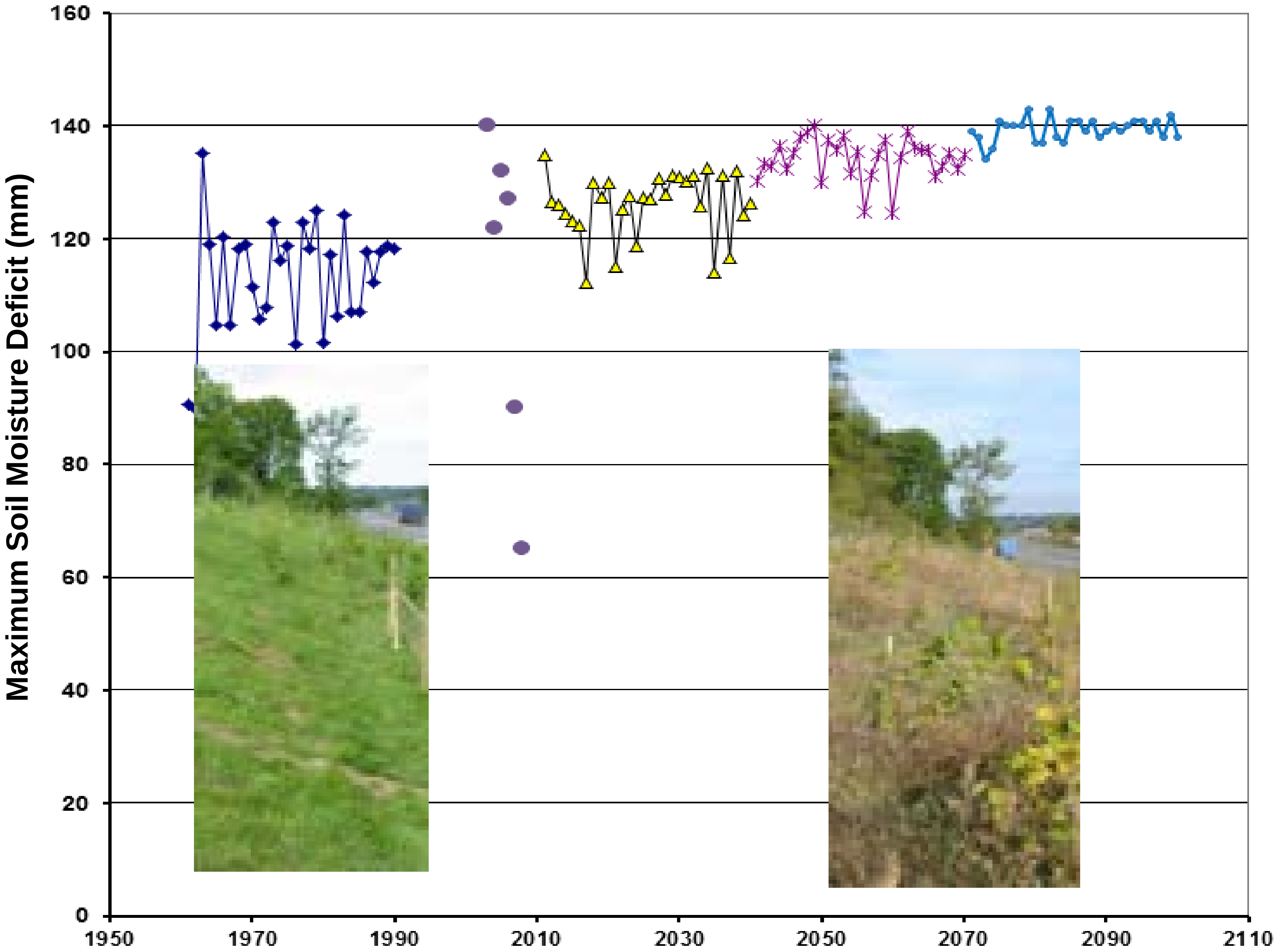

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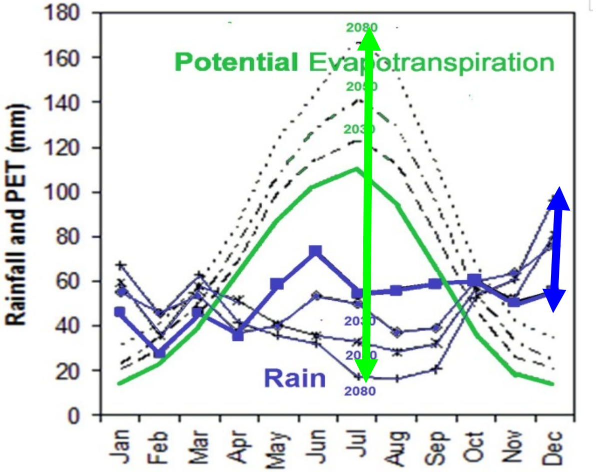
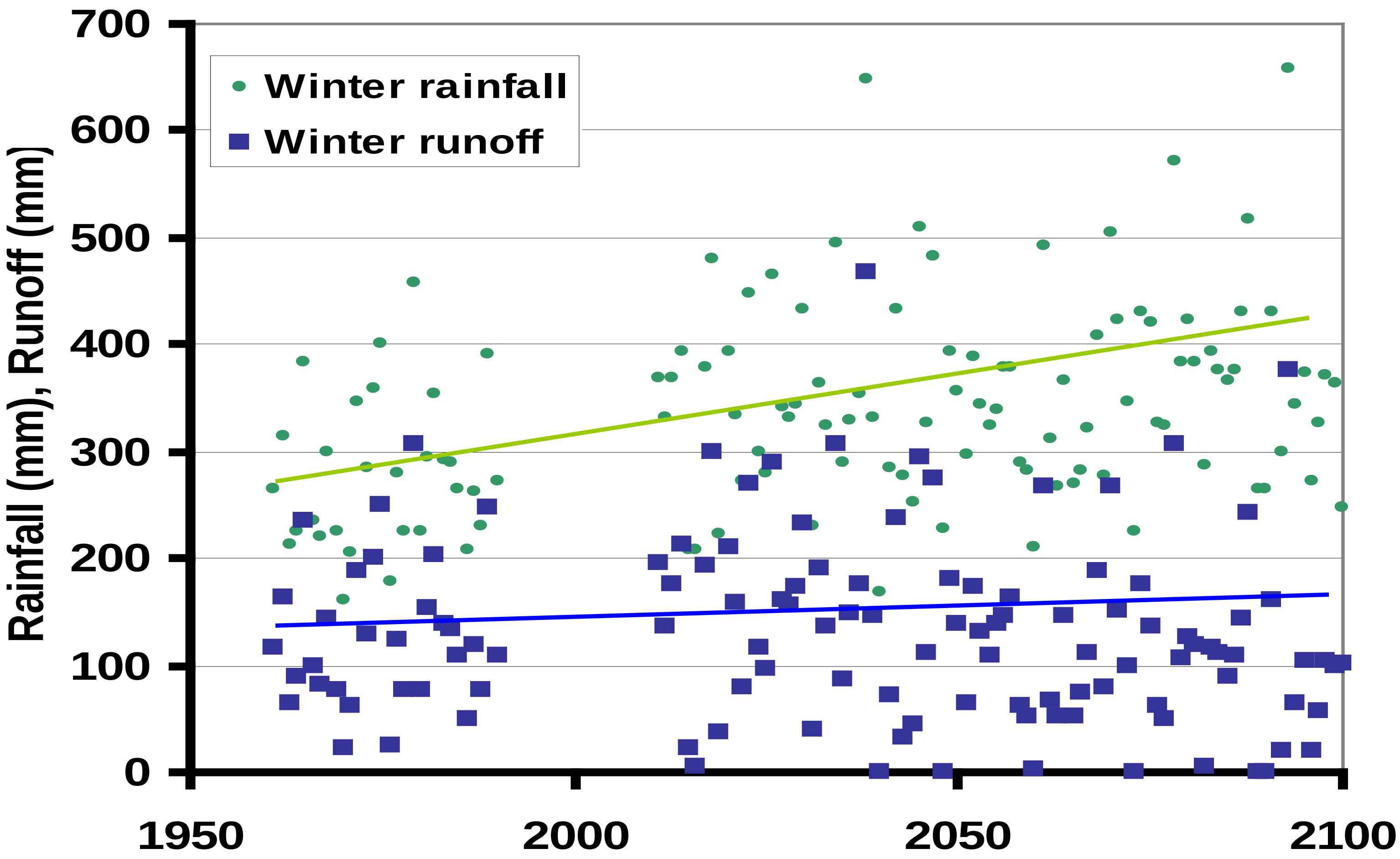
Future surface runoff and drainage

If the simulations are correct, wetter winters may not cause increased runoff because of the longer drier summers.





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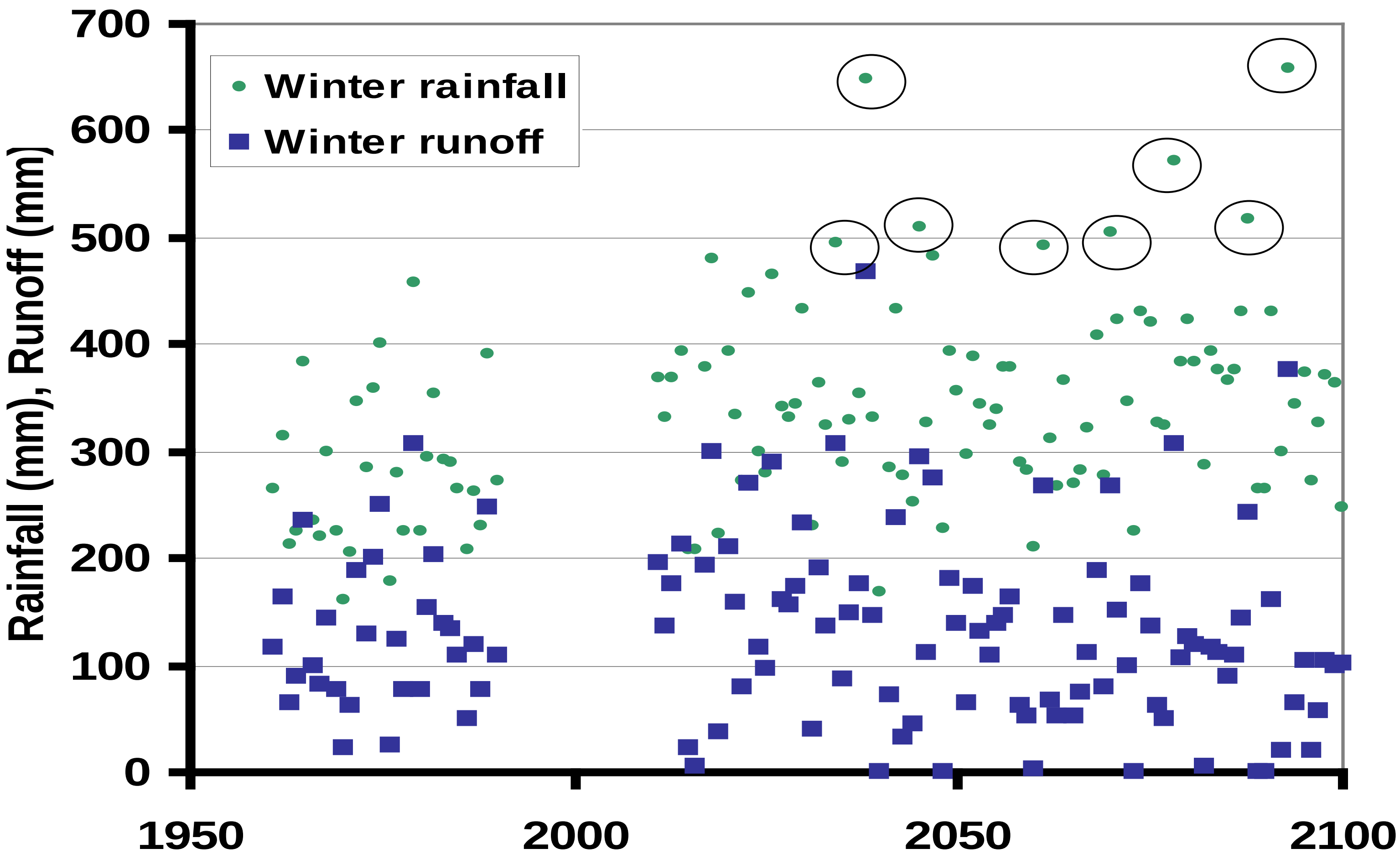
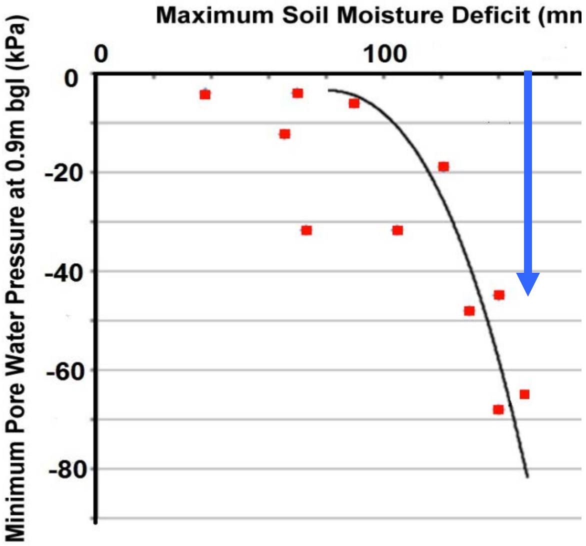
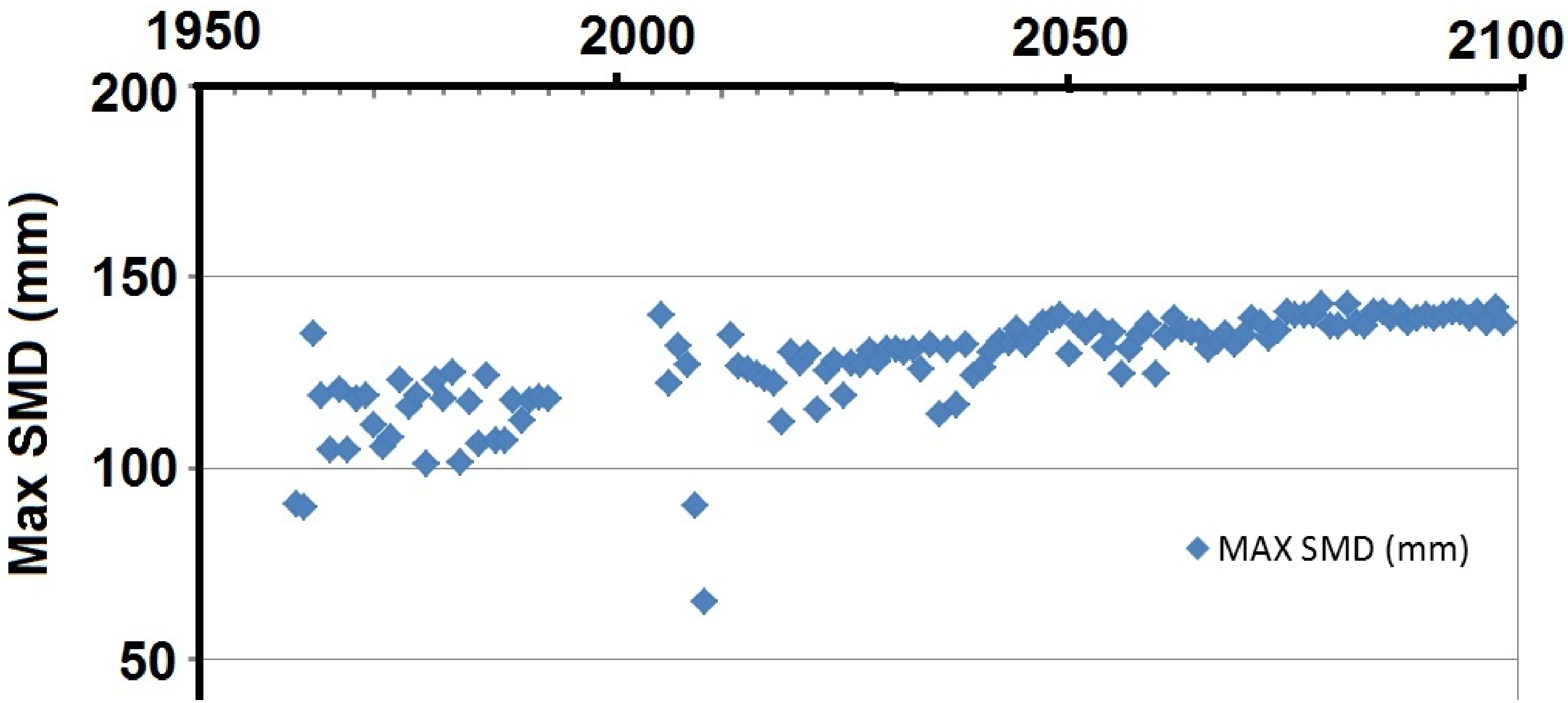
Future surface runoff and drainage

However more extreme winter rainfalls on slopes with reduced vegetation cover may cause increased soil erosion.



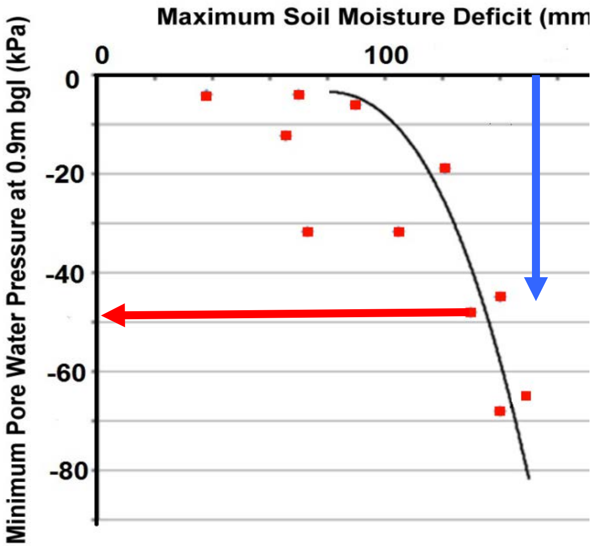
Linking future pore water pressures to simulated SMD

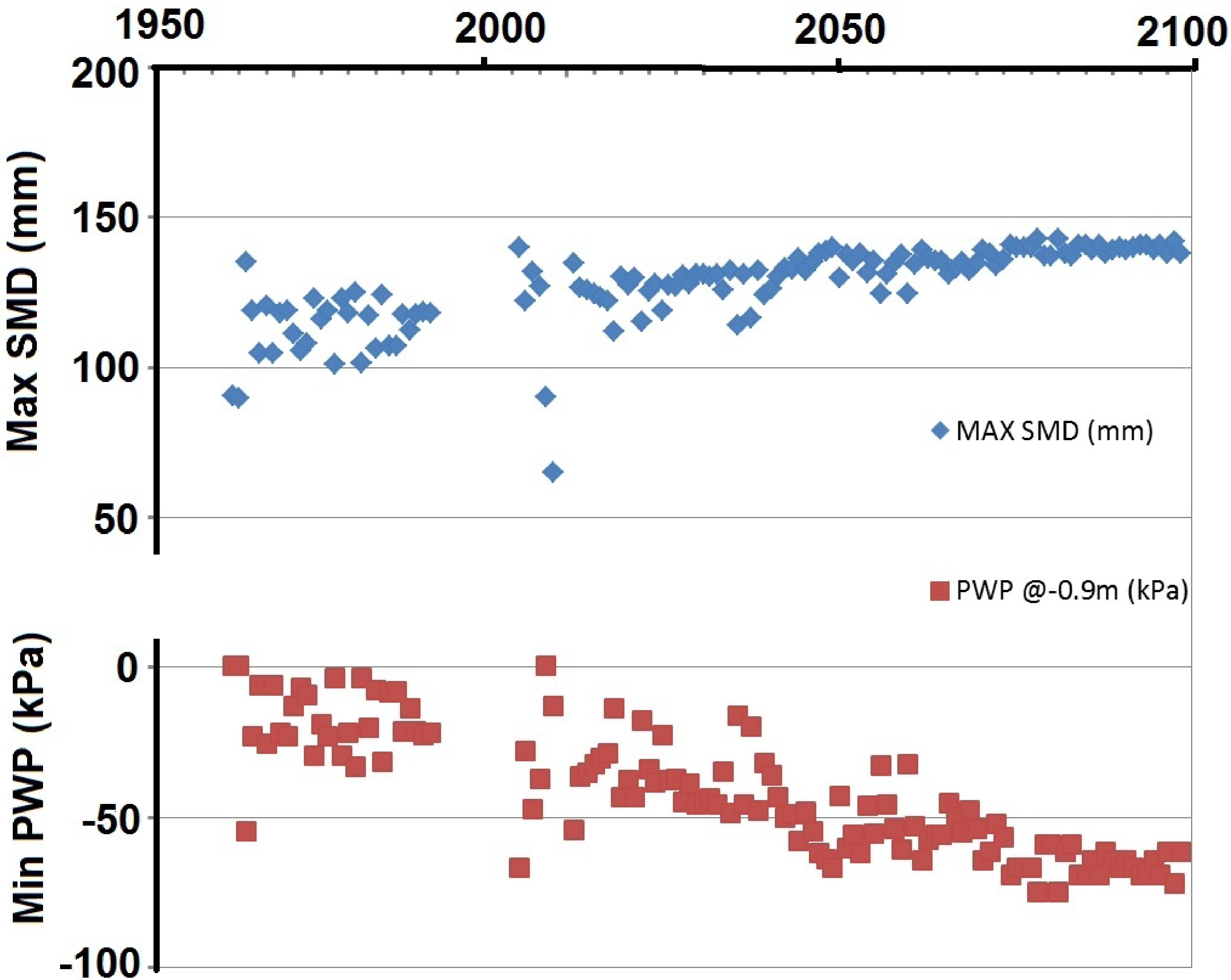




Using field observations to link pore water pressures to SMD in the drying phase.

Linking future pore water pressures to simulated SMD





Increased summer SMDs results in extended drying and increases in negative pore water pressures.

This suggests higher slope stability in the future.

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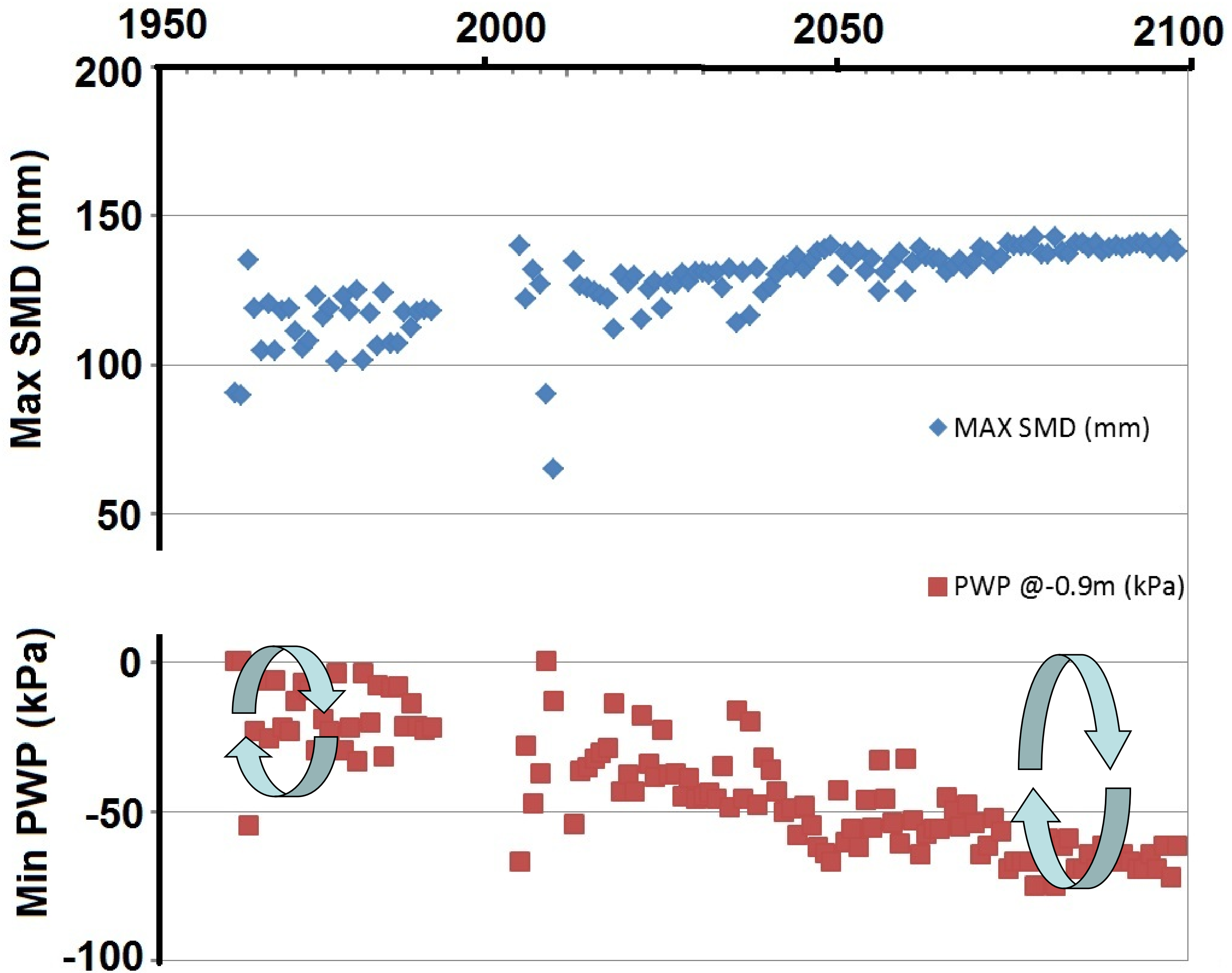
Future pore water pressure cycle size increases

However the larger annual cycle of wetting drying results in enhanced cycling of pore water pressures.

These larger cycles have been linked to strain softening and potential slope failure



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Larger pore water pressure cycle can cause strain softening

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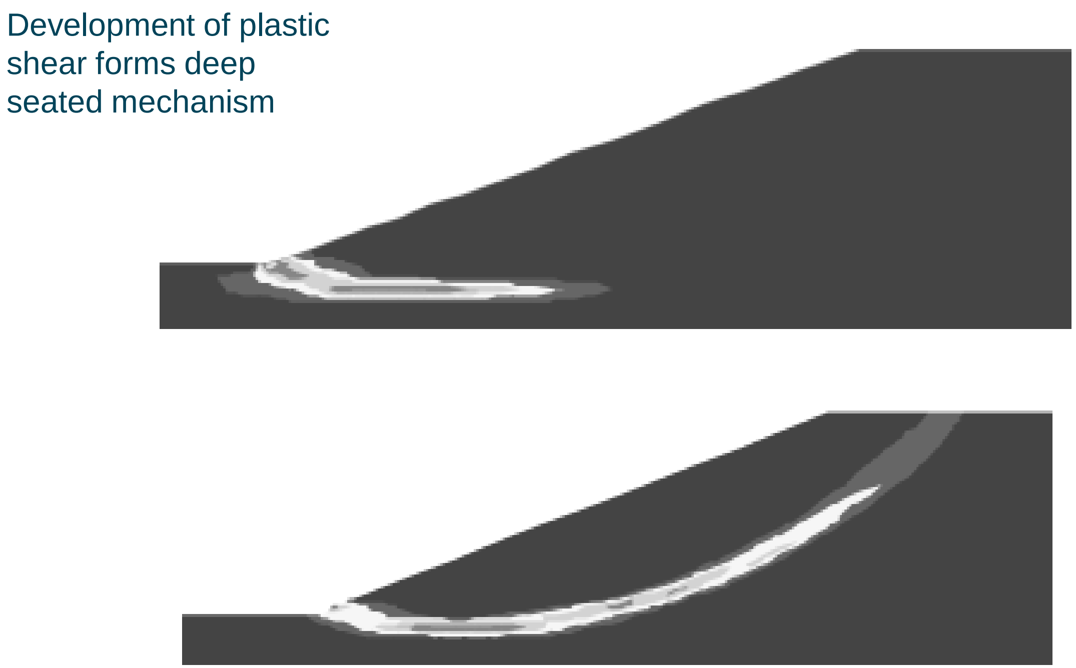
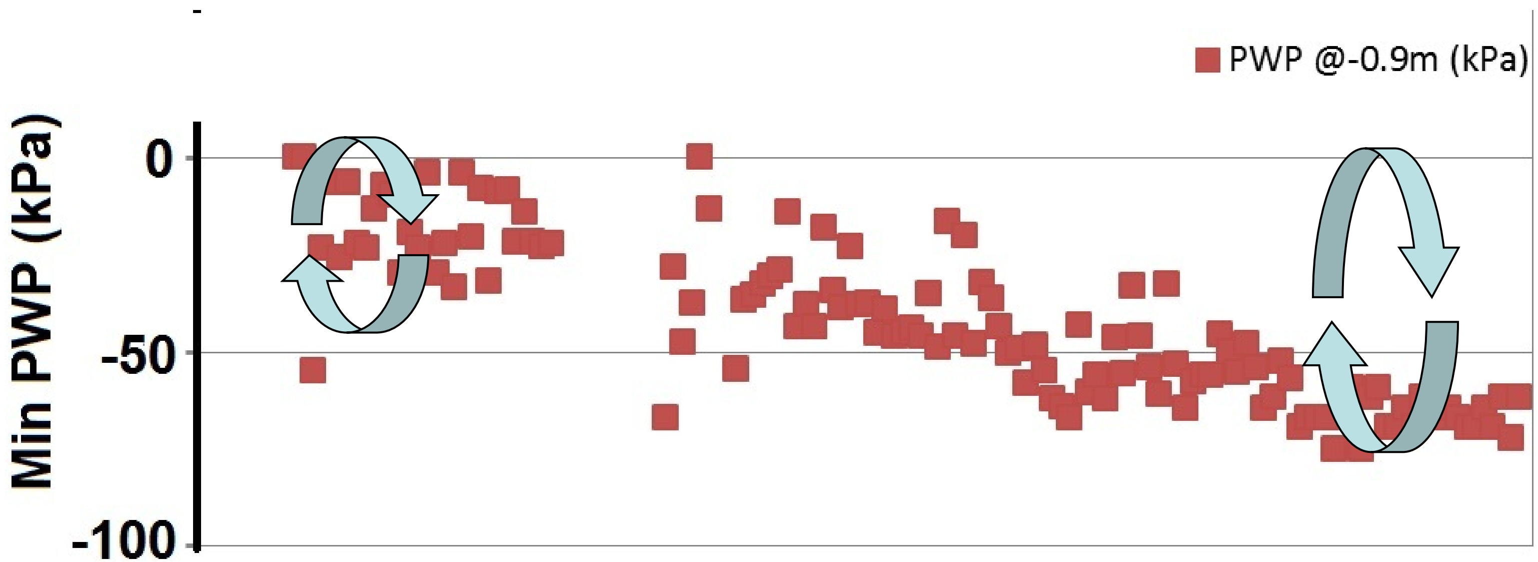
Ellis and O'Brien (2007)



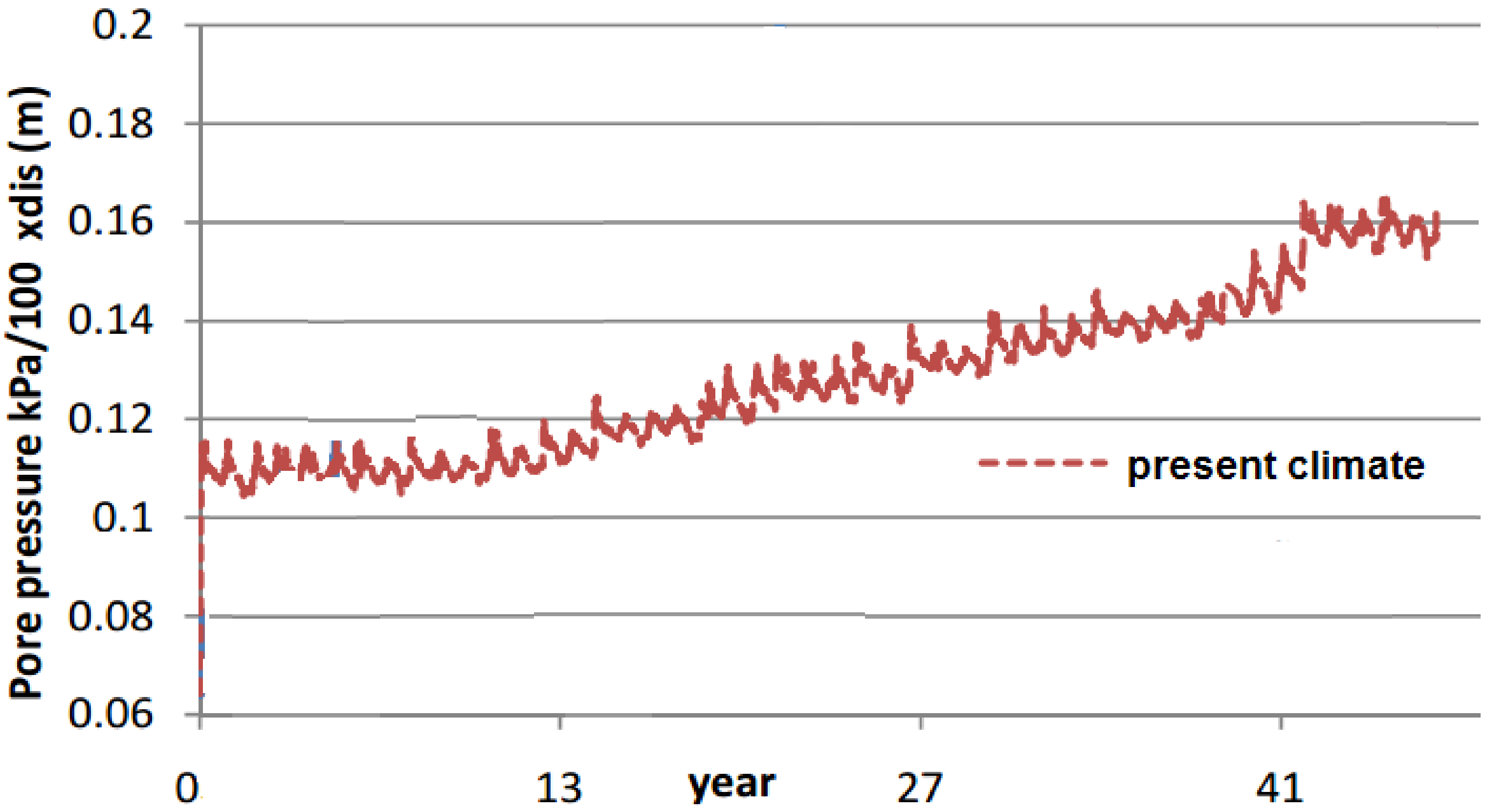


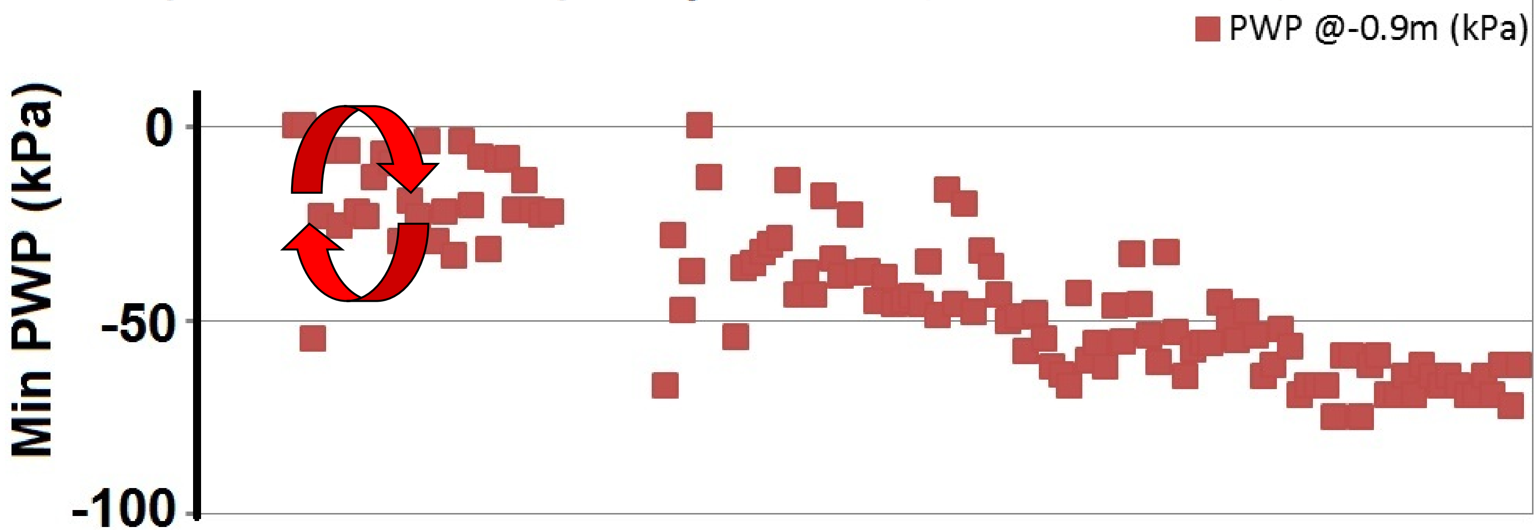
Modelled displacements (present day climate)

However the larger annual cycle of wetting drying results in enhanced cycling of pore water pressures.

These larger cycles have been linked to strain softening and potential slope failure

(Thanks to iSMART project/Newcastle University, UK)





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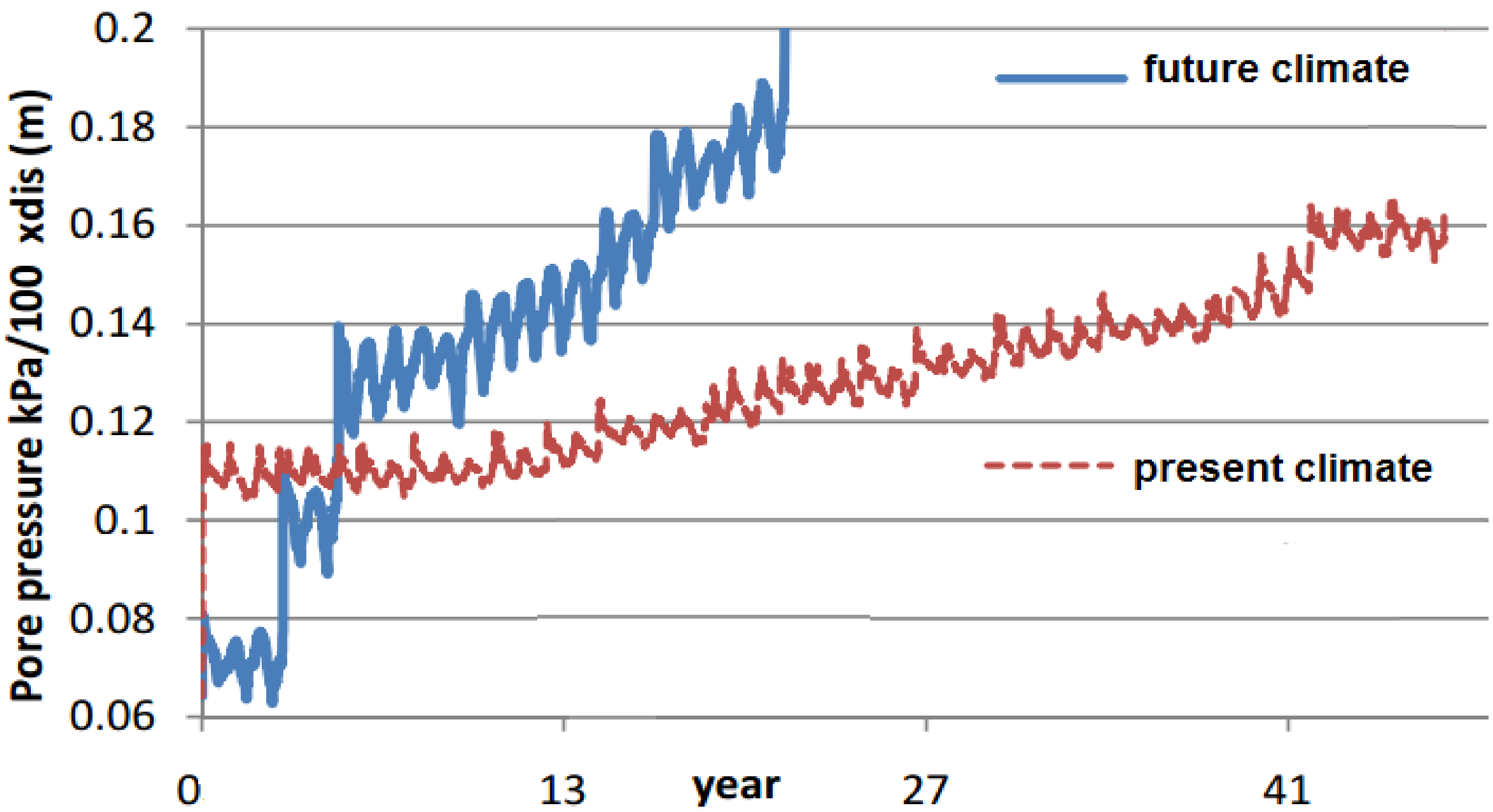
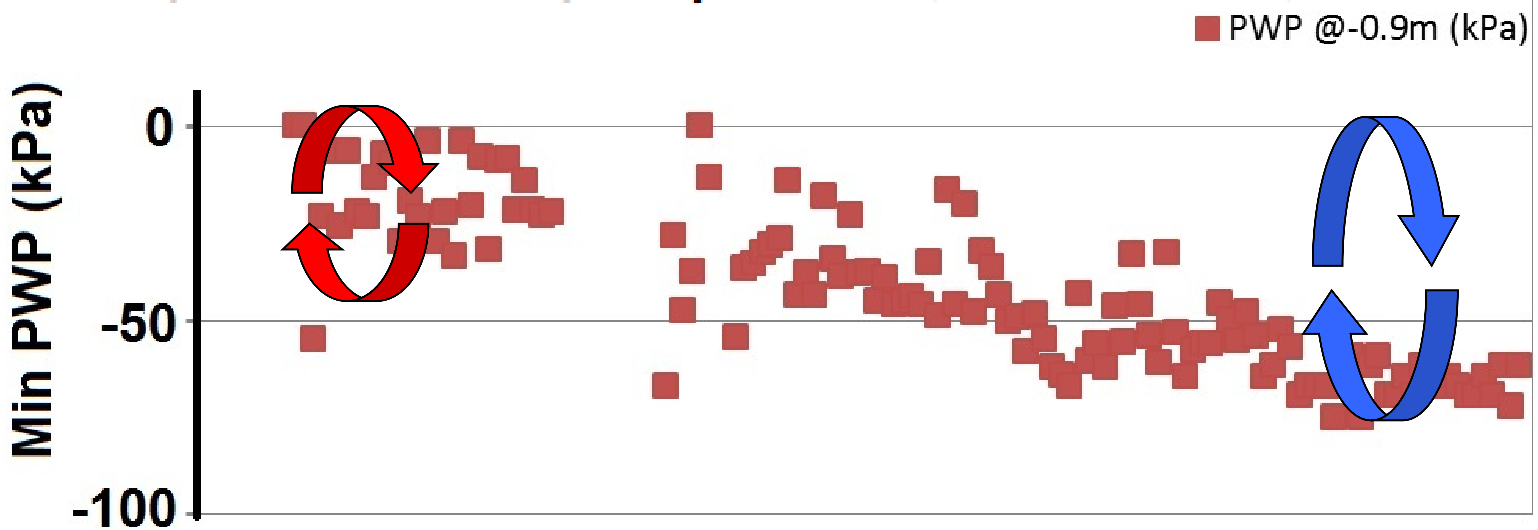
Future climate suggests larger modelled displacements and onset of slope failure

However the larger annual cycle of wetting drying results in enhanced cycling of pore water pressures.

These larger cycles have been linked to strain softening and potential slope failure

(Thanks to iSMART project/Newcastle University, UK)





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Some useful Publications

Briggs, K.M., Smethurst, J.A., Powrie, W. and O'Brien, A.S. (2013) Wet winter pore pressures in railway embankments. Proceedings of the ICE - Geotechnical Engineering (doi:10.1680/geng.11.00106).

Smethurst, J., Clarke, D. and Powrie, W. (2012) Factors controlling the seasonal variation in soil water content and pore water pressures within a lightly vegetated clay slope. Geotechnique, 62, (5), 429-446. (doi:10.1680/geot.10.p.097).

Clarke, D. and Smethurst, J. (2010) Effects of climate change on cycles of wetting and drying in engineered clay slopes in England. Quarterly Journal of Engineering Geology and Hydrogeology, 43, (4), 473-486. (doi:10.1144/1470-9236/08-106).

Loveridge, F.A., Spink, T.W., O'Brien, A.S., Briggs, K.M. and Butcher, D. (2010) The impact of climate and climate change on infrastructure slopes, with particular reference to southern England. Quarterly Journal of Engineering Geology and Hydrogeology, 43, (4), 461-472. (doi:10.1144/1470-9236/09-050).

Smethurst, J., Clarke, D. and Powrie, W. (2006) Seasonal changes in pore water pressure in a grass covered cut slope in London clay. Geotechnique, 56, (8), 523-537. (doi:10.1680/geot.2006.56.8.523).

Useful resources

climate impact forecasting for slopes

CLIFFS

CLIFF*S* is a network based at Loughborough University that brings together academics, R&D agencies, stakeholders, consultants and climate specialists to improve forecasting of slope instability in the context of progressive climate change

http://cliffs.lboro.ac.uk/

iSMART PROJECT:

INFRASTRUCTURE SLOPES: SUSTAINABLE MANAGEMENT AND RESILIENCE ASSESSMENT

http://www.ismartproject.org/