Numerical modelling for soil moisture monitoring and forecasting

Keshav Parameshwaran S[1]*, Paul Bullock[2], Hartmut M. Holländer[1], Steven Frey[3] and Timi Ojo[2],[4]

[1]Civil Engineering Department, University of Manitoba, Winnipeg, Manitoba, Canada.; [2]Department of Soil Science, University of Manitoba, Winnipeg, Manitoba, Canada; [3]Aquanty Inc., Waterloo, Ontario, Canada; [4]Manitoba Agriculture and Resource Development, Winnipeg, Manitoba, Canada

INTRODUCTION

- Soil moisture is highly variable in space and time
- Accurate soil moisture forecasting will provide reliable information on crop yield to improve decision making
- Forecasting helps in crop management, flood risk drought severity and many other applications

OBJECTIVE

- Simulating historic soil moisture conditions across Brunkild catchment using HydroGeoSphere (HGS) and evaluating the model's ability for soil moisture forecasting

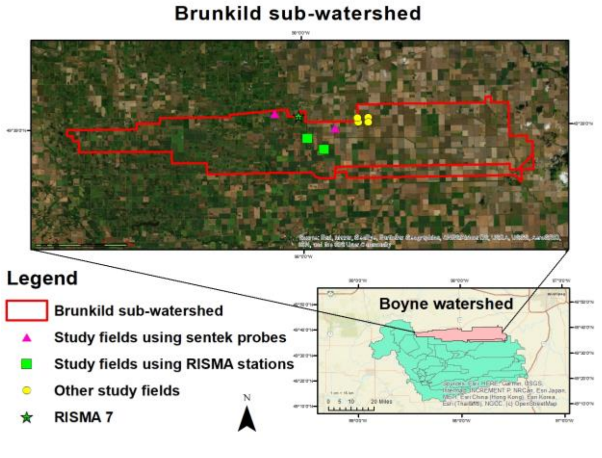

Figure 1: Study Area – Brunkild sub-watershed

MATERIALS AND METHODS

Field Work:

- Eight sites were selected inside the catchment for soil moisture monitoring (Figure 1)
- The crops in the study fields in 2020 were soybean (sand) and canola (clay)

Continuous soil moisture measurements at single points :

- Sentek soil moisture sensors were installed in two fields (June – August, 2020)
- Two Real-Time In Situ Soil Moisture (RISMA) monitoring stations in two fields

Time-specific area measurements of surface soil moisture :

- POGOs were used to measure the surface soil moisture (0 to 5 cm) in all 8 fields
- Three measurements were made, one each in June, July and August 2020

MATERIALS AND METHODS

Data collection:

Data type	Source
Precipitation and all climatology data	RISMA 4,5 & 7
Groundwater, streamflow	Manitoba ARD
Snow melt	SNODAS

- Model calibration is underway for the 2010 – 2019 time period
- Double mass curve technique is used to infill the missing model input data
- Field data from 2020 – 2021 will be used for model validation
- Sensitivity analysis of soil hydraulic parameters is currently underway

Model :

- HGS is a 3D, physically based hydrological model.
- It describes water balance components and their processes for separate domains linked by interaction terms (Cornelissen et al., 2013)

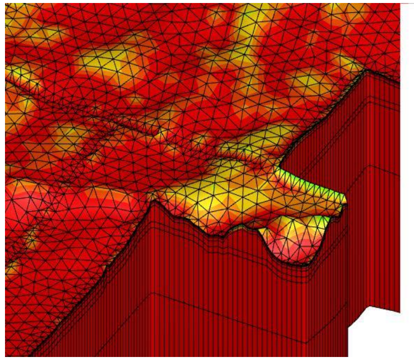

Figure 2(a): 3D model displaying finite element grid & %saturation

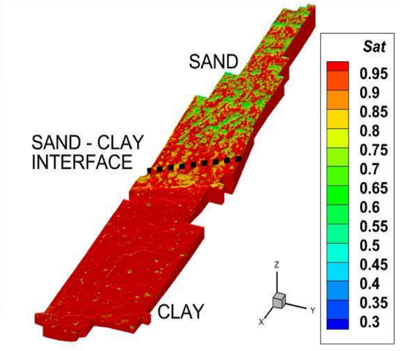

Figure 2(b): %Saturation level using 13 years (2002 -2014) of MERRA2 data & sand-clay interface

- Algomesh was used to generate unstructured finite element grid (Figure 2a)
- Grid refinement was highest along channels, ditches and roadways (Figure 2a)
- LiDAR was used to create DEMs and the subsurface layers are developed using processed ASCII files that represent hydrostratigraphic surfaces
- The sub-catchment was discretized with 45929 nodes per 2D mesh sheet
- Precipitation, hydraulic head (Dirichlet), liquid water influx (rainfall + snowmelt) are primary boundary conditions
- PET was calculated with the Hargreaves method (Sentelhas et al. 2010)
- The van Genuchten parameters were determined using Rosetta v3 for finding the hydraulic properties of different soil types (Zhang and Schaap 2017)

PRELIMINARY RESULTS

- Preliminary results using long-term global reanalysis weather data (MERRA2) as climate forcing showed a strong fit for all soil moisture in sandy soil and a good fit for all clay soil for both daily and monthly simulations (Figure 3)

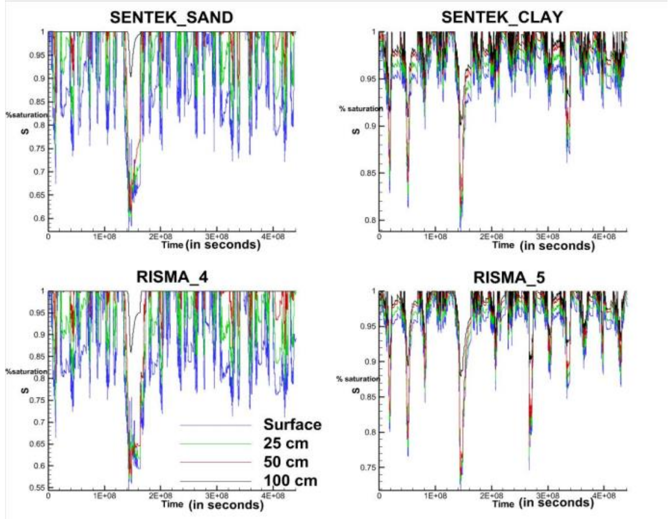

Figure 3: % saturation at surface, 25 cm, 50 cm & 100 cm depth in field sites

FUTURE WORK

- Observed weather data from the RISMA stations are more accurate than MERRA 2, hence the model will be recalibrated using the RISMA weather data
- 14-day forecasts of soil moisture in the Brunkild catchment will be generated for the 2021 growing season
- RMSE and correlation coefficient techniques will be used to quantify the forecasting skills
- Testing of various model inputs relating to climatology and soil parameterization will be conducted again to improve the HGS model skill

REFERENCES

- Cornelissen, T., Diekkrüger, B., & Bogena, H. (2013). Using HydroGeoSphere in a Forested Catchment: How does Spatial Resolution Influence the Simulation of Spatio-temporal Soil Moisture Variability? *Procedia Environmental Sciences*, *19*(0), 198–207. https://doi.org/10.1016/j.proenv.2013.06.022
- Sentelhas, P.C., Gillespie, T.J., and Santos, E.A. 2010. Evaluation of FAO Penman-Monteith and alternative methods for estimating reference evapotranspiration with missing data in Southern Ontario, Canada. Agricultural Water Management, **97**(5): 635–644. Elsevier B.V. doi:10.1016/j.agwat.2009.12.001.
- Zhang, Y. and M. G. Schaap (2017). "Weighted recalibration of the Rosetta pedotransfer model with improved estimates of hydraulic parameter distributions and summary statistics (Rosetta3)." Journal of Hydrology 547: 39-53.