# Assimilation of Soil Moisture in an Ecosystem Model for SMAP Applications

## Testing in Old Jack Pine site

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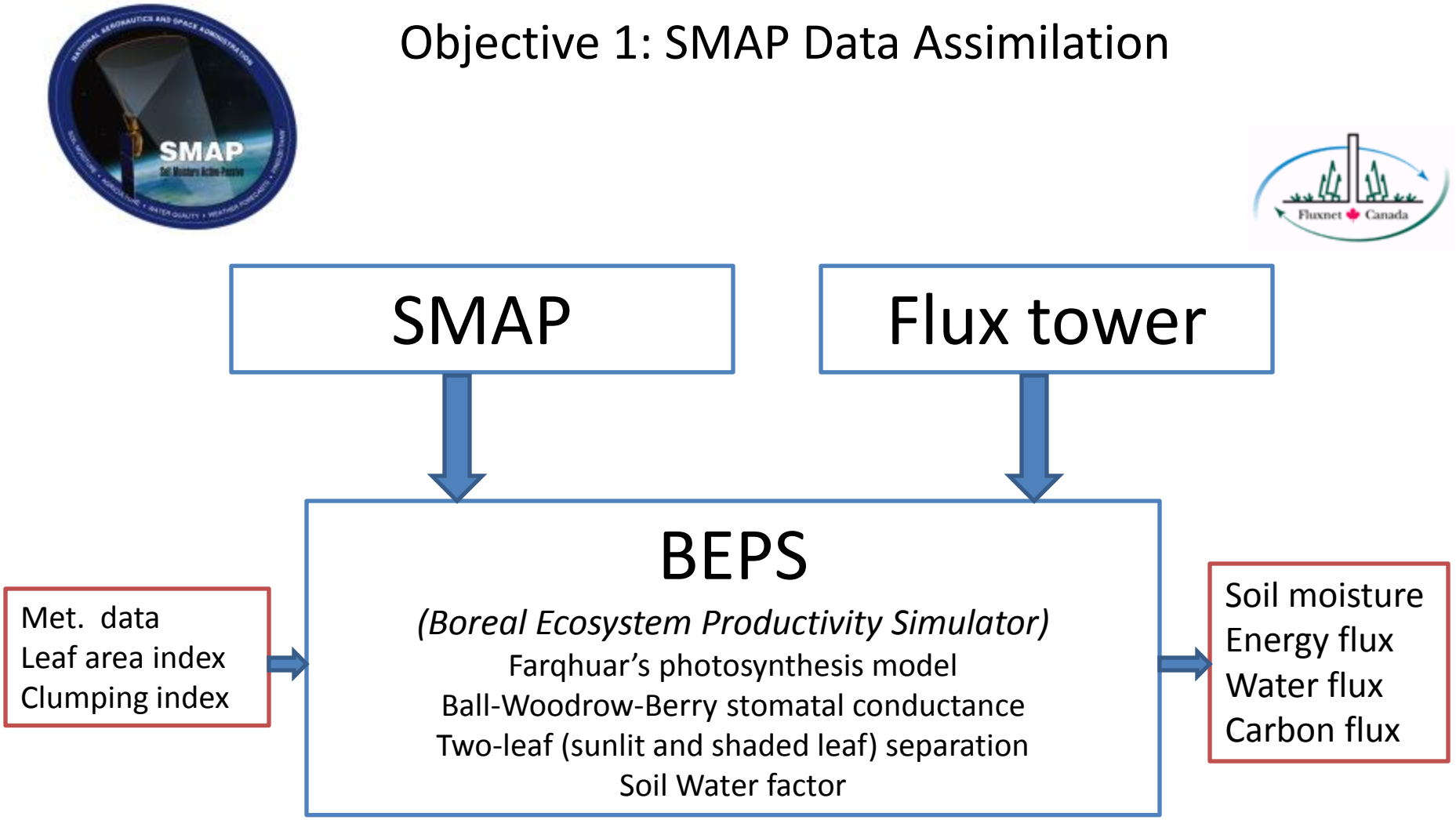
# Outline

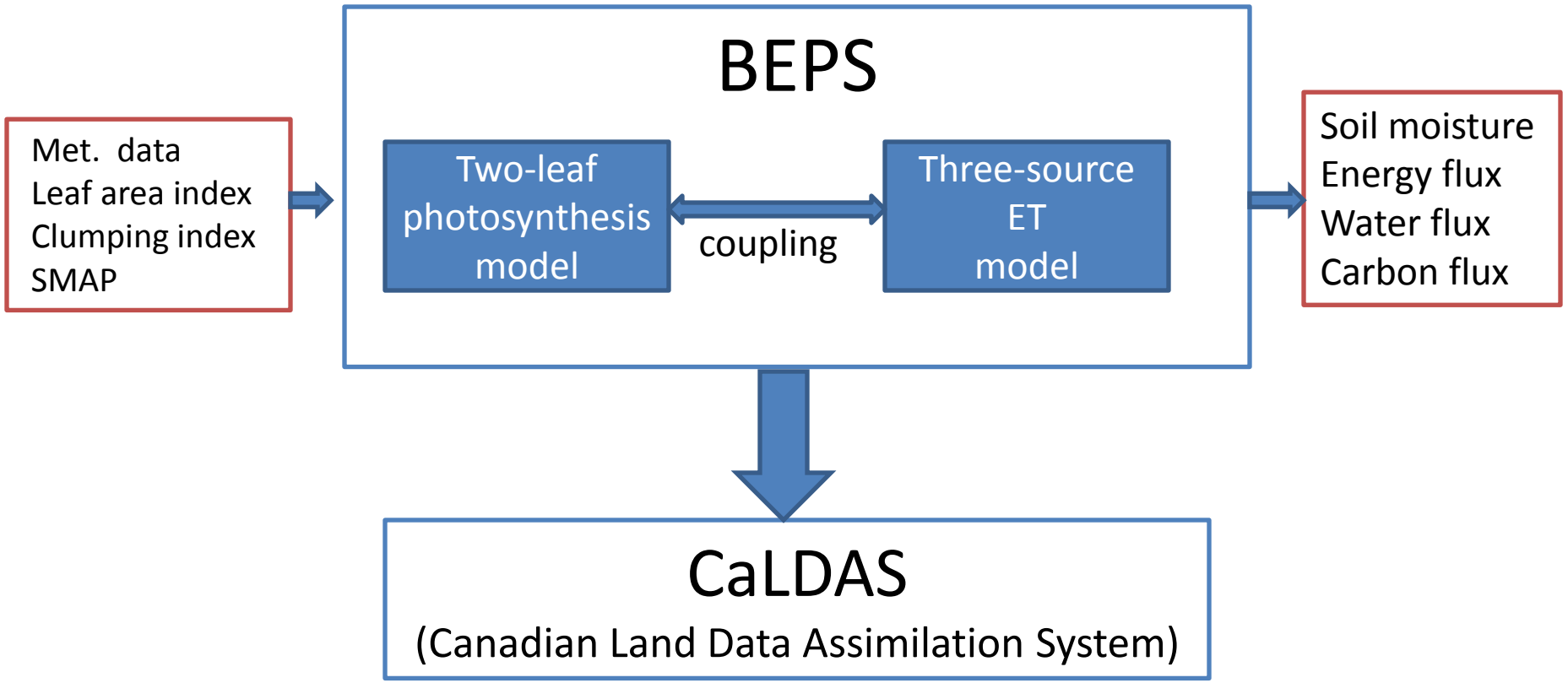
- Objectives
  - To assimilate SMAP data in an ecosystem model to improve carbon and water cycle estimation
  - To assist in the development of CaLDAS (Stephane Belair)
- Site descriptions
  - Old Jack Pine Site
- Methodology
  - Ensemble Kalman Filter
- Result
  - Soil moisture simulation
  - Data assimilation
  - Parameter optimization
- Conclusion

# Objective 1: SMAP Data Assimilation



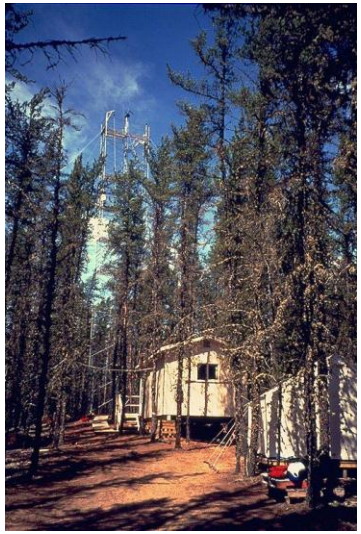

Chen J. et al. (1999), Liu J. et al. (2003), Ju W. et al. (2006 ), Chen B. et al. (2007)

# Objective 2: Linking BEPS with CaLDAS




Chen J. et al. (1999), Liu J. et al. (2003), Ju W. et al. (2006 ), Chen J. M. et al. (2012)

# The Southern Old Jack Pine site

- Coordinates: 53.92° , -104.69°
- Elevation: 579.27 m
- Evergreen Needle leaf Forest
- Soil texture: sandy, very good drainage
- Topography: undulating
- Mean annual air temperature: 0.4° C
- Mean total annual precipitation: 467.2 mm
- Overstory cover: mature jack pine (established 1914)
- Understory: very sparse green alder ( predominantly lichen ground cover).
- Organic layer:  10-15cm deep
- Soil moisture measured at 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm, 90-120 cm, and 120-150 cm.

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**Pictures from the SSA-OJP Site**
**The BOREAS Information System**
http://daac.ornl.gov/BOREAS/bhs/sites/SSA-OJP.html

# Methodology: EnKF

$$X_k^a = X_k^f + K\left(Y_k - H\left(X_k^f\right)\right)$$

$$K = P_k^f H^T \left(HP_k^f H^T + R_k\right)^{-1}$$

$P_k^f H^T$ : forecast cross covariance between any given state and $H\left(X_k^f\right)$

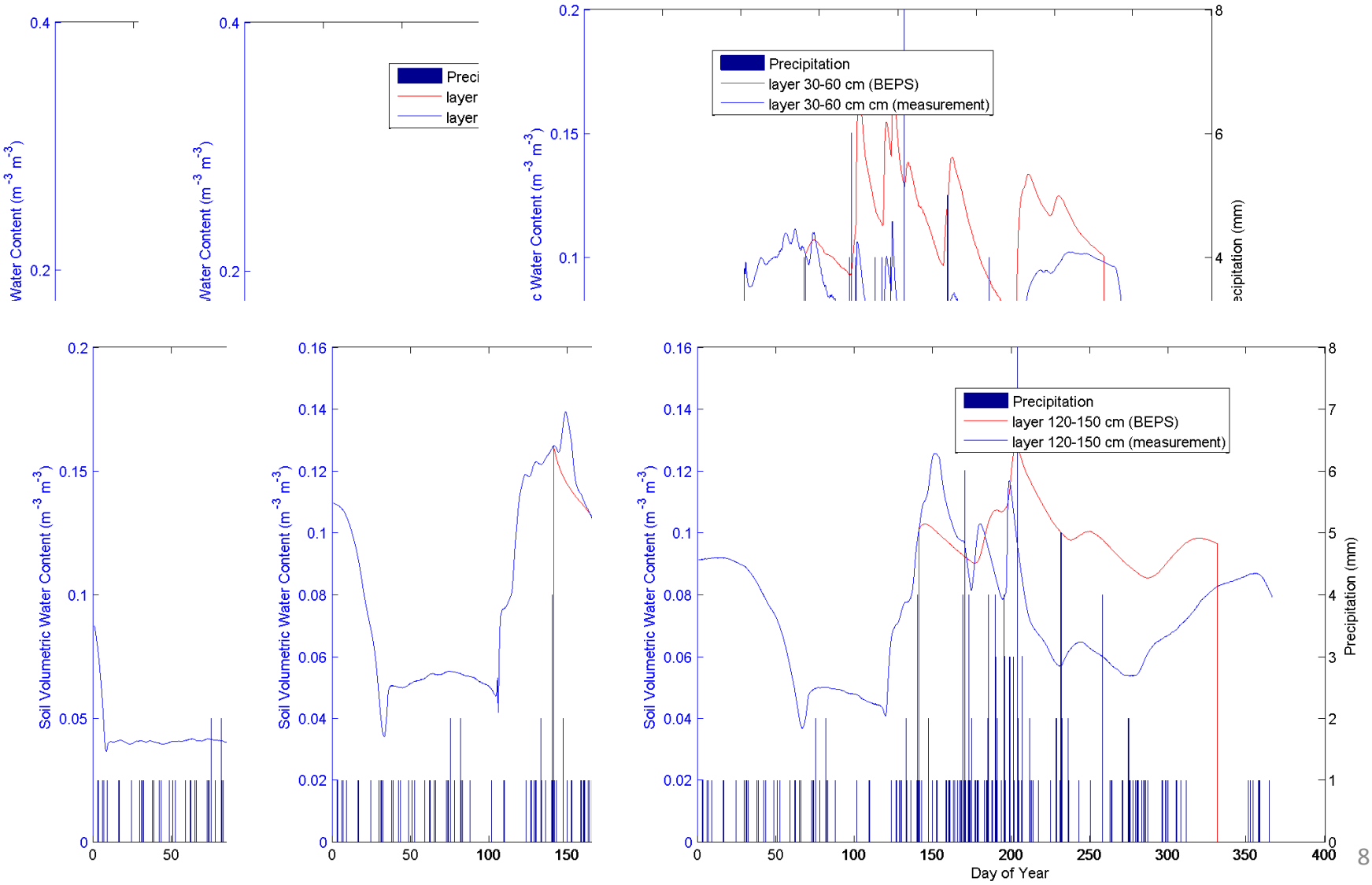
$HP_k^f H^T$ : forecast error covariance

$R_k$ : covariance of uncertainty for the observations.

# The result

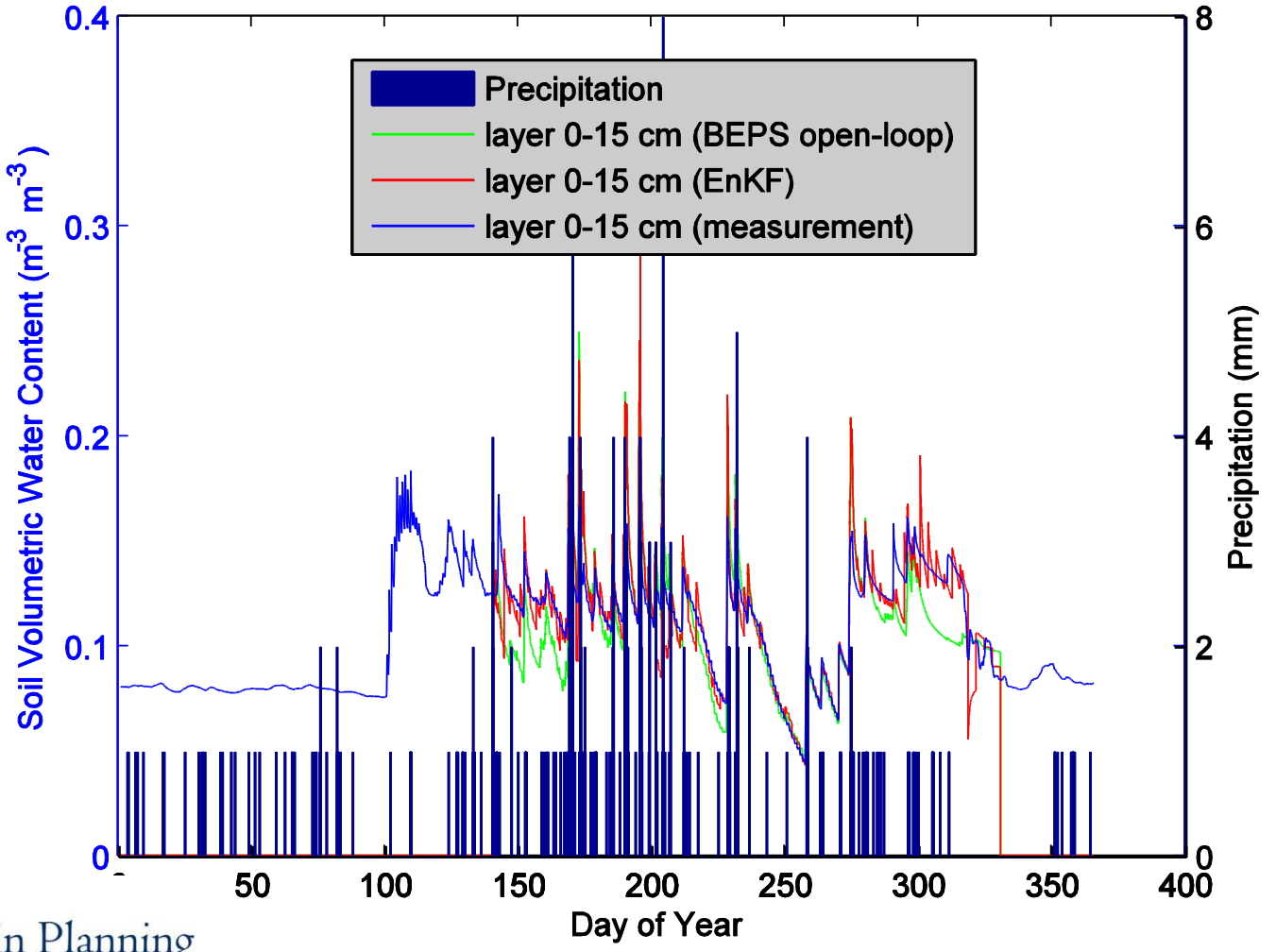
- Soil moisture simulation (open loop)
- Data assimilation of top layer soil moisture
- Parameter optimization

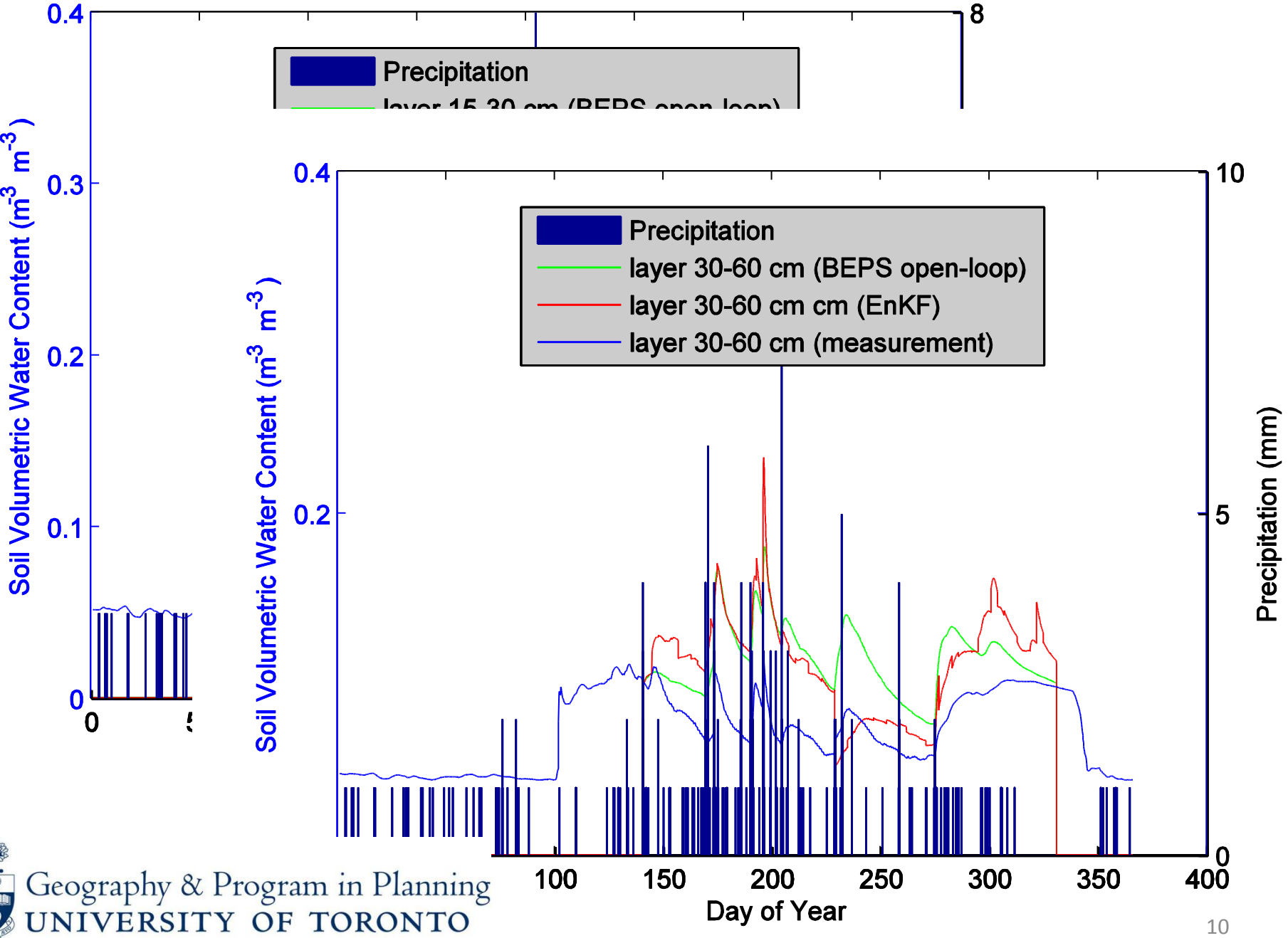
# Result 1: Soil moisture simulation

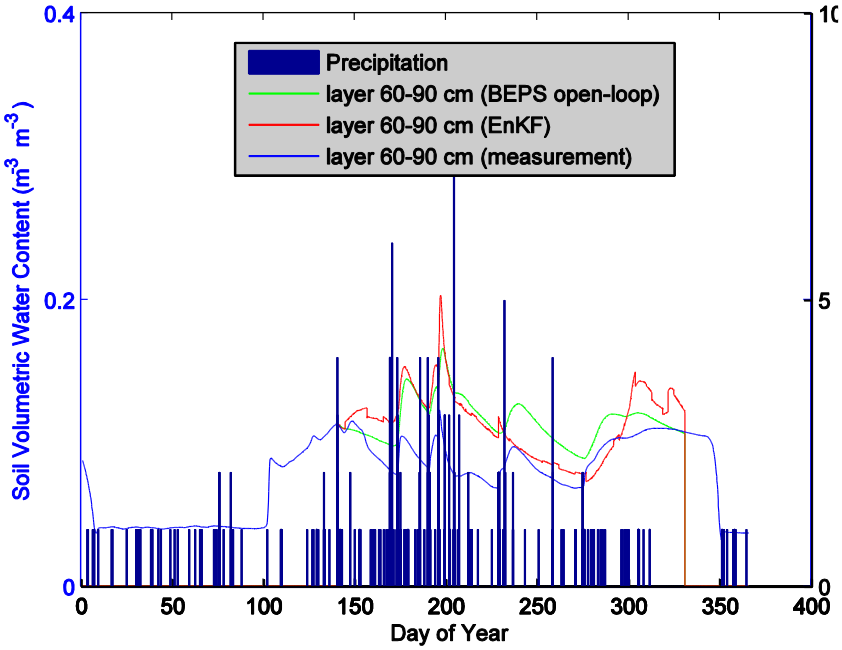


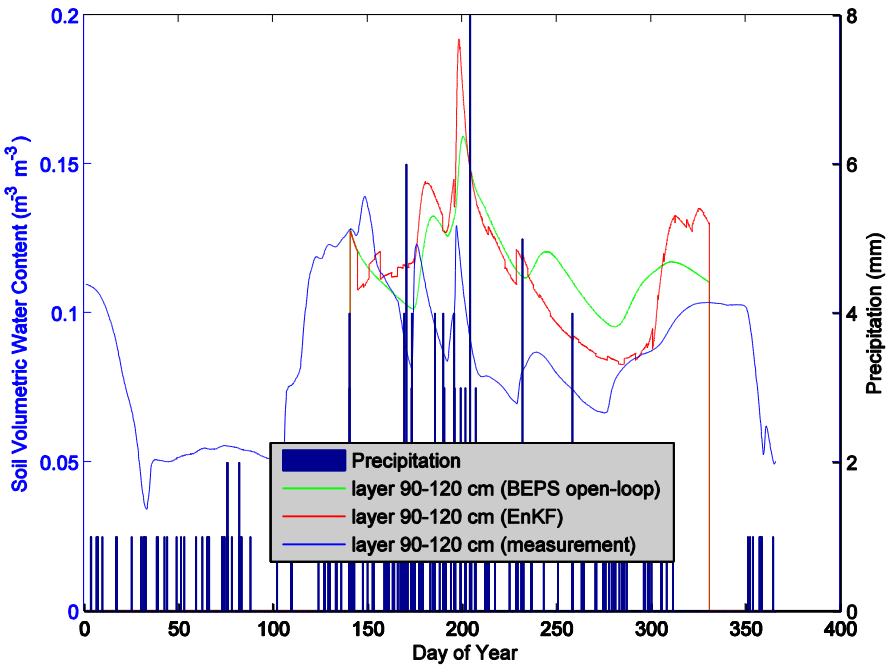
# Result 2: Data assimilation of soil moisture

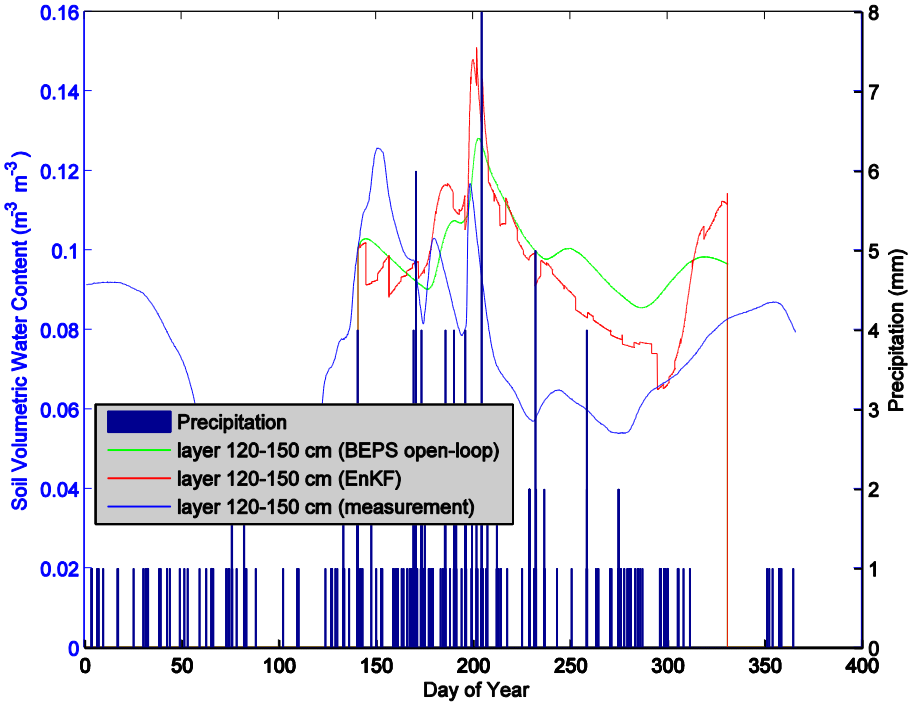
- Obs. @ top layer
- Obs. Error: 0.02
- Status vector: 6
- DA conducted in 3 days




Precipitation
layer 30-60 cm (BEPS open-loop)
layer 30-60 cm cm (EnKF)
layer 30-60 cm (measurement)
Soil Volumetric Water Content (m-3 m-3)
Precipitation (mm)
Day of Year
0.4
0.3
0.2
0.1
0
8
10
5
100
150
200
250
300
350
400

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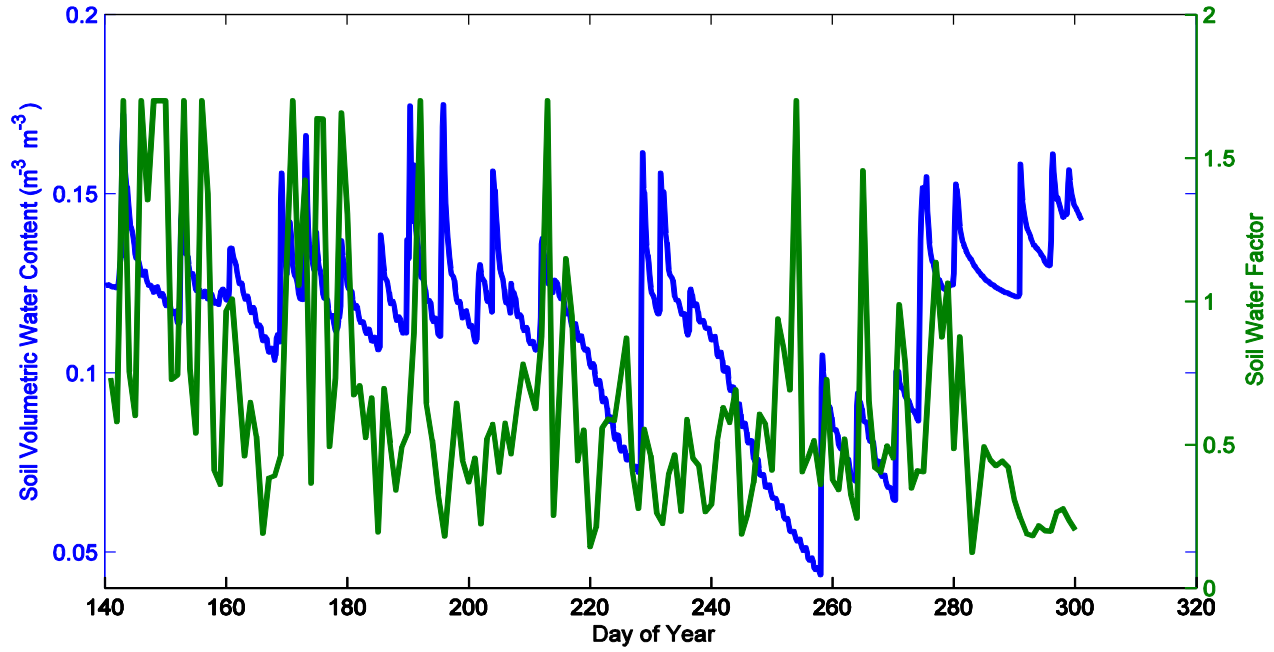
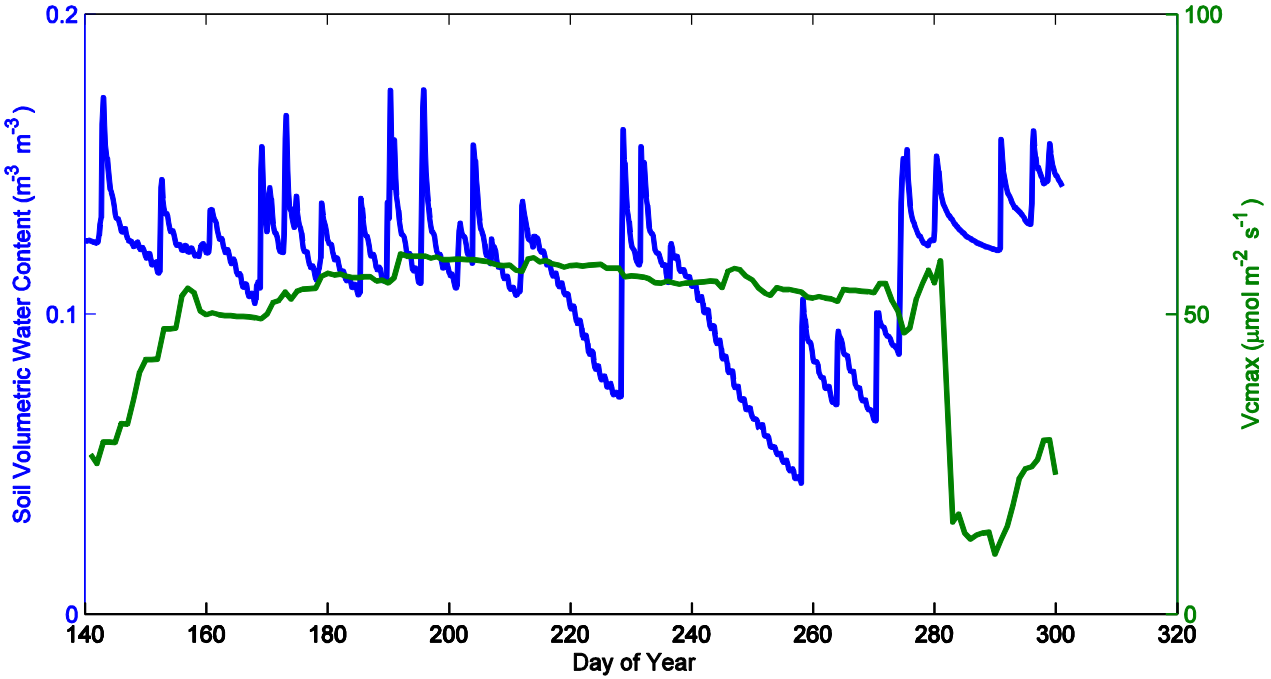
# Result 3: Parameter optimization
# Soil water factor & Vcmax

$$g = f_w\left(m\frac{Ah_s}{C_s}\right)+b$$

Vcmax @ 25 °C in Farquhar's model

*--maximum rate of Rubisco carboxylase activity*



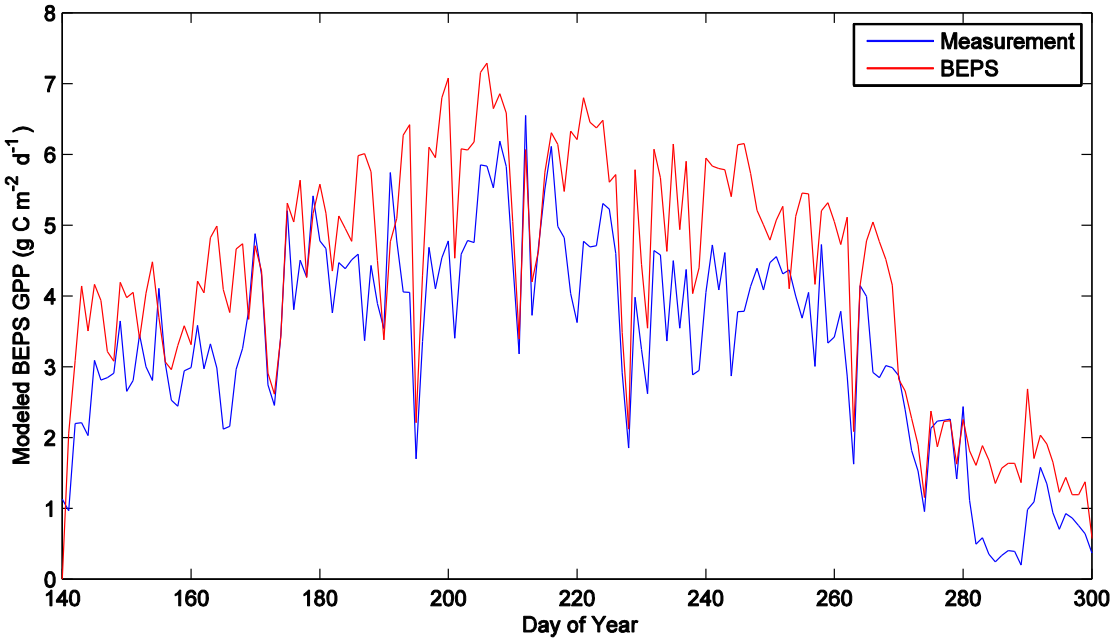

- Obs. : GPP flux
- Obs. Error: 15%
- Status vector: 2
- DA conducted daily

- $f_w$ is closely related to soil moisture dynamics
- Small lag in $f_w$
- Not all variance can be explained by $f_w$
- nonlinear relationship between water stress and soil moisture

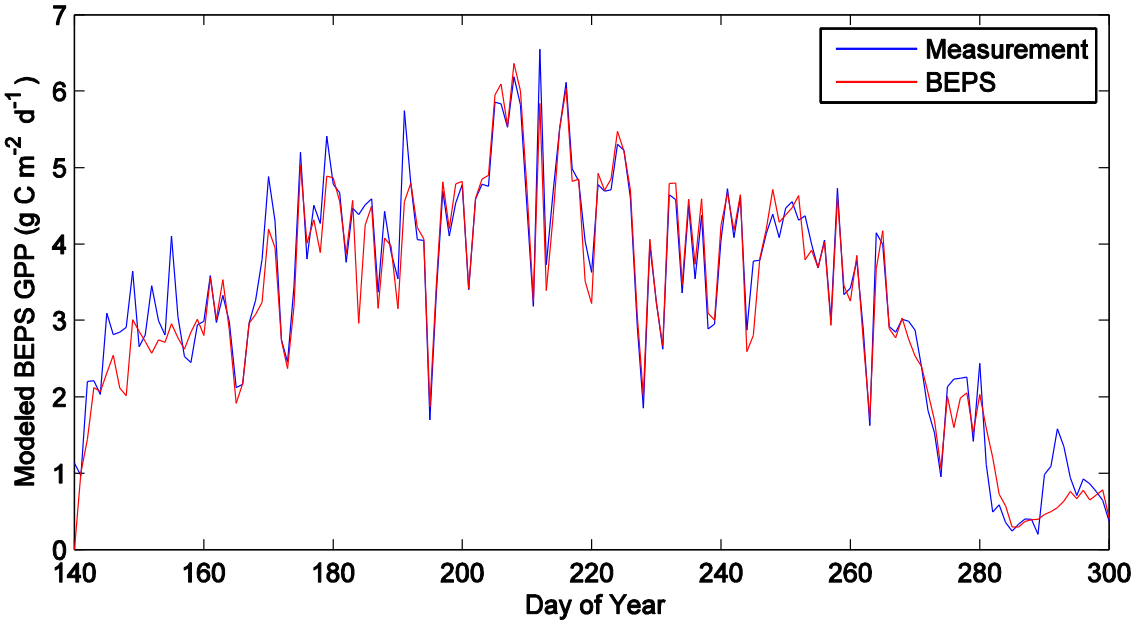
- Slow change of Vcmax

# The simulated GPP using optimized parameters

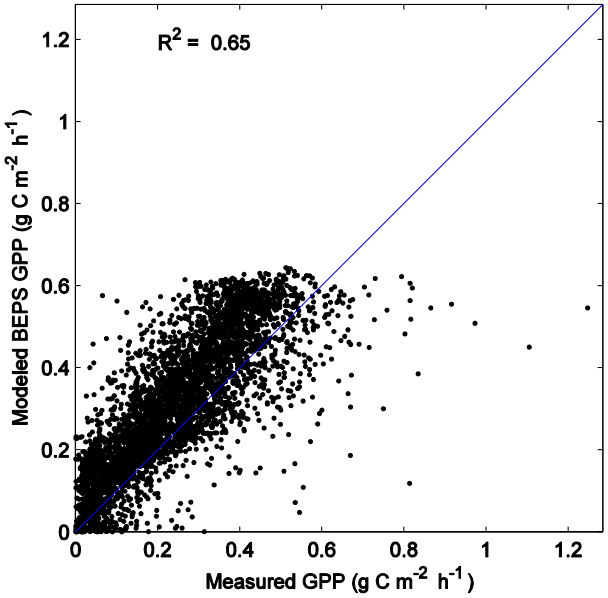
Before

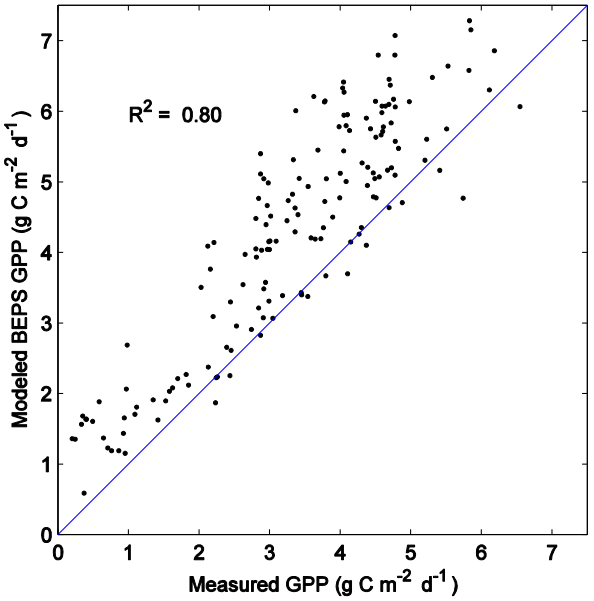



After

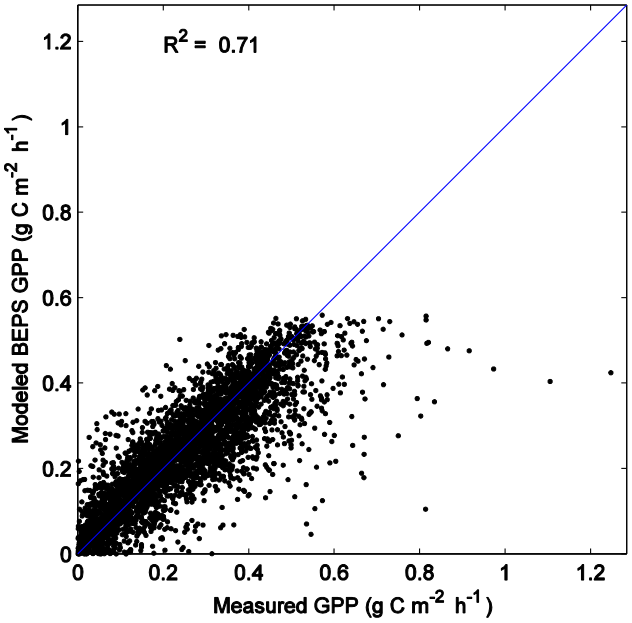


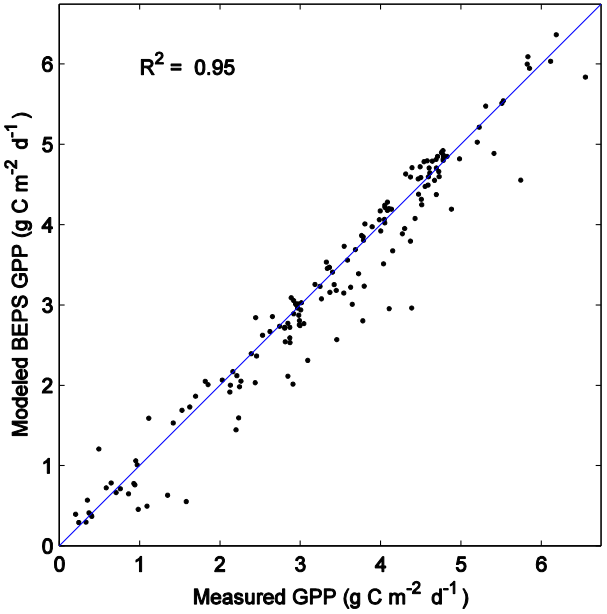
Before




After



# The problems in the parameter optimization

- The setup of parameters
  - How to set standard errors and ranges of parameters
- The correlation between parameters
  - The variance may be explained by one and/or more parameters
- Information projected from other parameters
  - How to determine the parameters to be optimized

# Conclusion

- Soil moisture is successfully simulated on the SOJP site.
- Assimilation of top layer (SMAP) soil moisture in the BEPS model via EnKF is feasible.
- Parameter optimization:
  - The scheme (EnKF) works but with lots of limitations to overcome.
  - Accurate parameter optimization relies on our understanding of the model structure and parameter distribution.

# Thanks!

# Questions?

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