Can we use soil moisture loss functions to improve the timeliness of SMAP Level-2 data availability?

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Question 1: What is a loss function?
Consider two retrievals separated by 1 day:

- Day N
- Day N+1

Apparently some rain occurred between the measurements. Of course, there's more to it than that...
soil moisture content

Day N

Increase due to precipitation

Day N+1

Decrease due to evaporation & drainage

time →
Soil moisture content increases due to precipitation on Day N. However, there is a decrease due to evaporation and drainage, which presumably varies with soil moisture content. The wetter the soil, the faster the loss.
Assume that some monotonic loss function operates on the soil moisture whether or not precipitation falls during an interval. (We focus on the warm season and thus ignore variations in energy availability).
The idea of the “loss function” is not new...


... and its determination has been a chief scientific motivation for the SMAP mission.
Question 2: What is a simple way of determining a loss function from SMAP Level 2 soil moisture retrievals?
For a given time series of precipitation...

...we can generate a time series of soil moisture contents:

...and an assumed loss function...

(generated with P data and assumed function alone – no retrievals used)
Procedure: through brute force, we find the loss function that produces the best reproduction (in terms of RMSE) of the SMAP Level 2 soil moisture time series.
Examples of Loss Functions
Question 3: What can we do with these loss functions?

Answer: *Many things. Discussed here:*
-- Decreasing the latency of SMAP retrieval information
-- Providing soil moisture forecasts
Suppose a user on Day N needs a real-time soil moisture retrieval value.
SMAP retrievals

Given product latency, this retrieval value would not be available until Day N+1
The user would have to go back 3 days (in this example) to get the most recent SMAP measurement.
SMAP retrievals

The user could assume persistence to get the estimate for the current day...

Unavailable on Day N
Alternatively, knowledge of the loss function and the intervening precipitation allows us to evolve the soil moisture forward in time.
With precipitation forecasts, we could even produce soil moisture forecasts!
The estimates of real-time and forecasted soil moistures are consistent with local SMAP retrieval statistics and are thus amenable to applications already using SMAP data.
Overall strategy to test such soil moisture estimation:

STEP 1: Derive loss function, $L(W)$, from 2015 precipitation and SMAP data (warm season, May-Sept) over the US.

STEP 2: Utilize this function to predict 2016 soil moisture (again, May-Sept.):
These tests address the following question: how does a “persistence” type estimate...

... of this value...

... compare to a loss function-based estimate?
Persistence: If you assign the most recent SMAP retrieval value to the current day, these are the errors you obtain.

Units: m³/m³ (volumetric soil moisture)
**Loss function:** The errors go way down if you use loss functions in conjunction with precipitation information (for real-time estimates)....

Units: m³/m³ (volumetric soil moisture)
They also go down, though not as much, if you use loss functions in conjunction with precipitation forecasts (for soil moisture forecasts)....
Average error across CONUS
Overall findings:

- Loss functions (descriptions of how soil moisture decreases with evaporation and drainage) can be derived from joint analysis of SMAP data and precipitation data.

- Using these functions along with precipitation measurements and/or precipitation forecasts, we can produce skillful soil moisture estimates with 0-day latency and even negative latency (soil moisture forecasts).
  
  \[\rightarrow\] A potentially high impact on applications!