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

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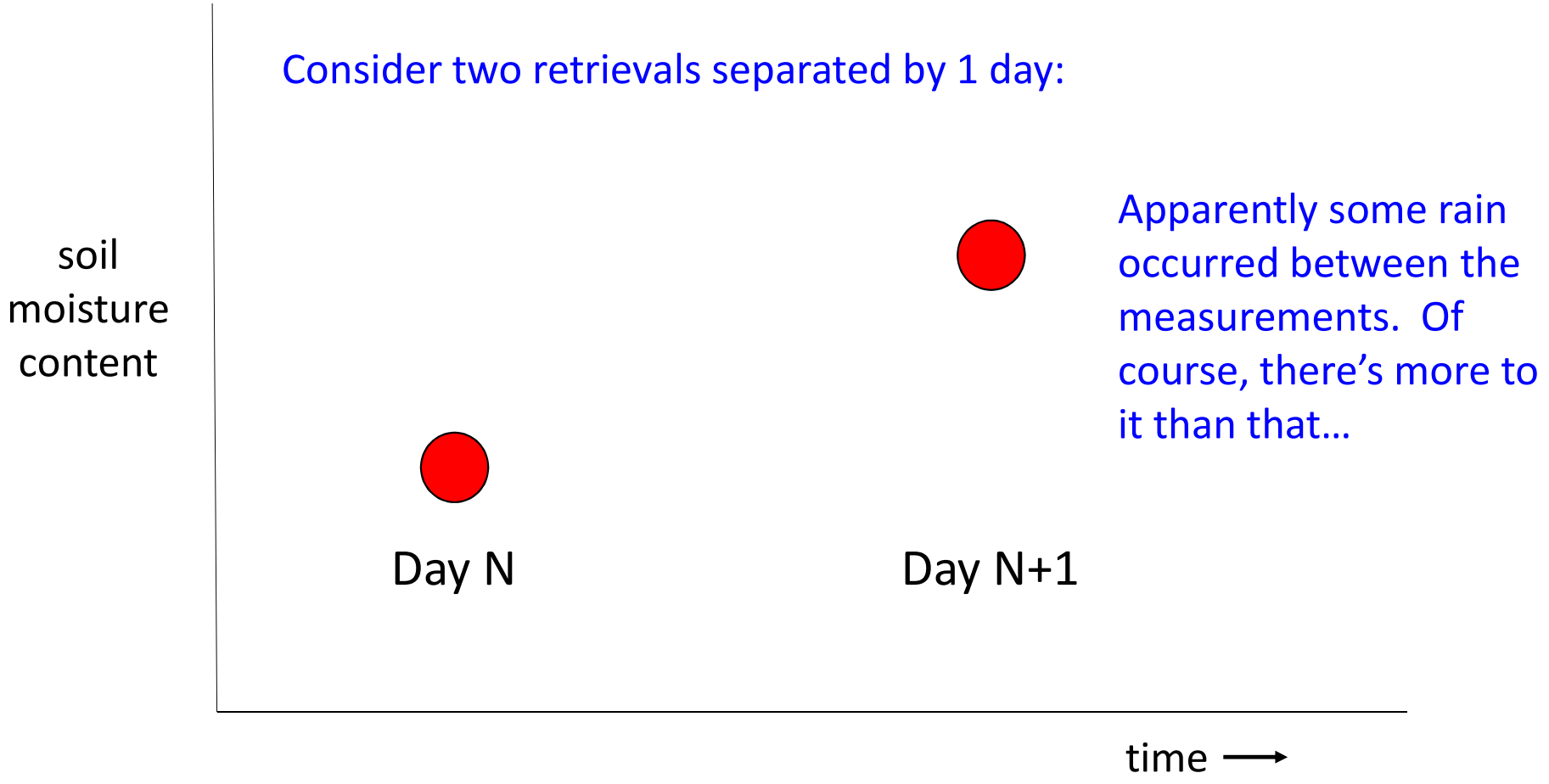
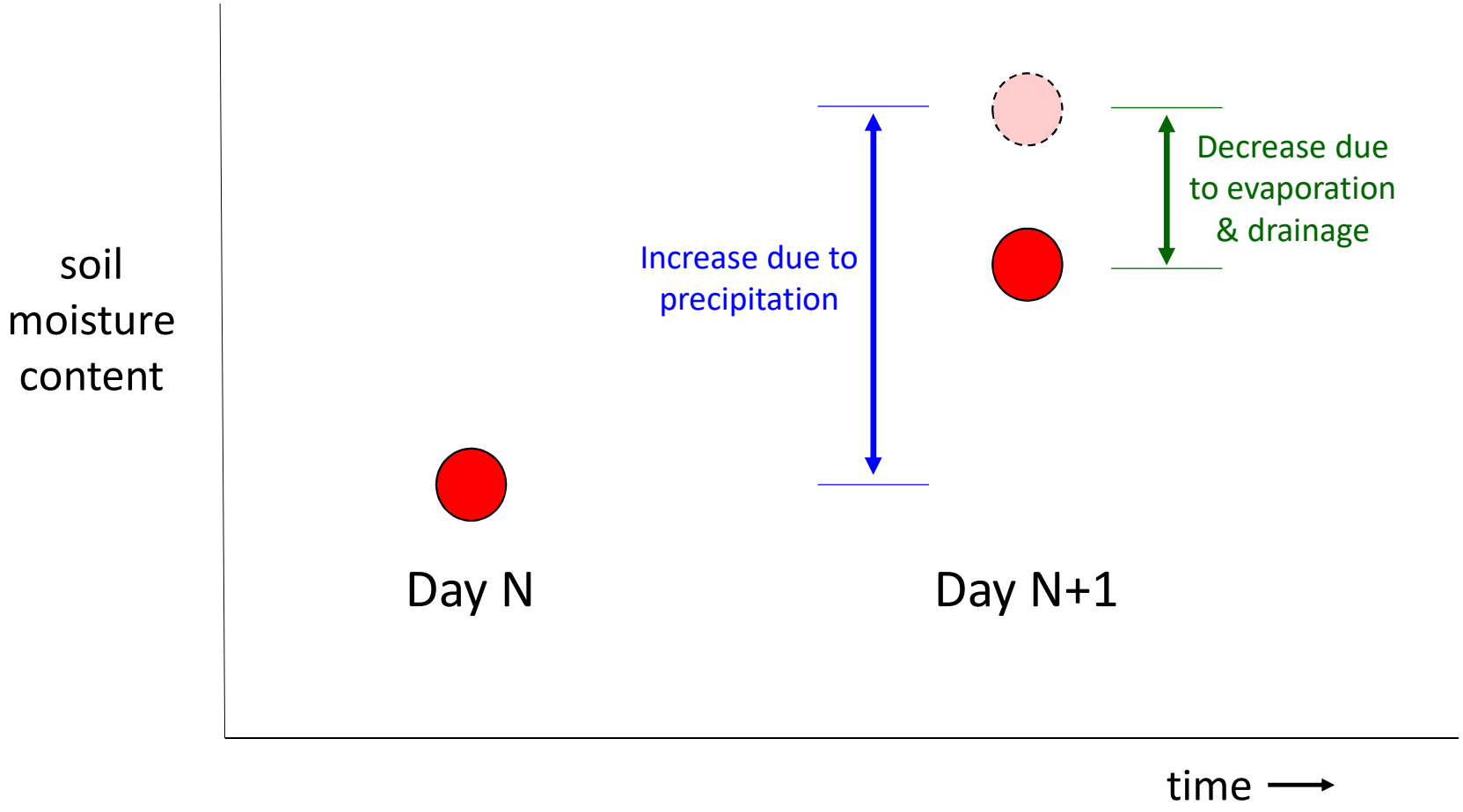
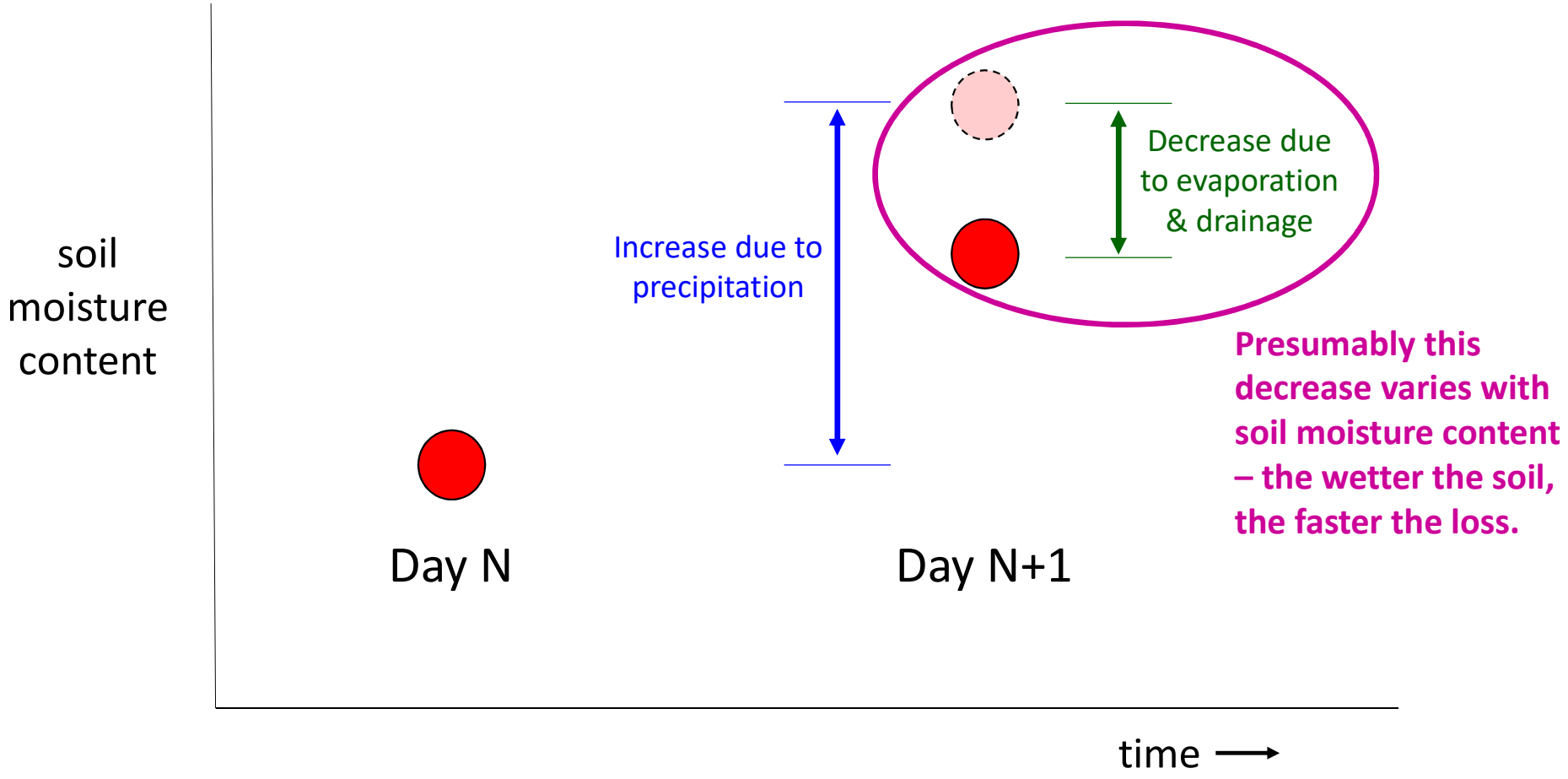
Question 1: What is a loss function?

Consider two retrievals separated by 1 day:



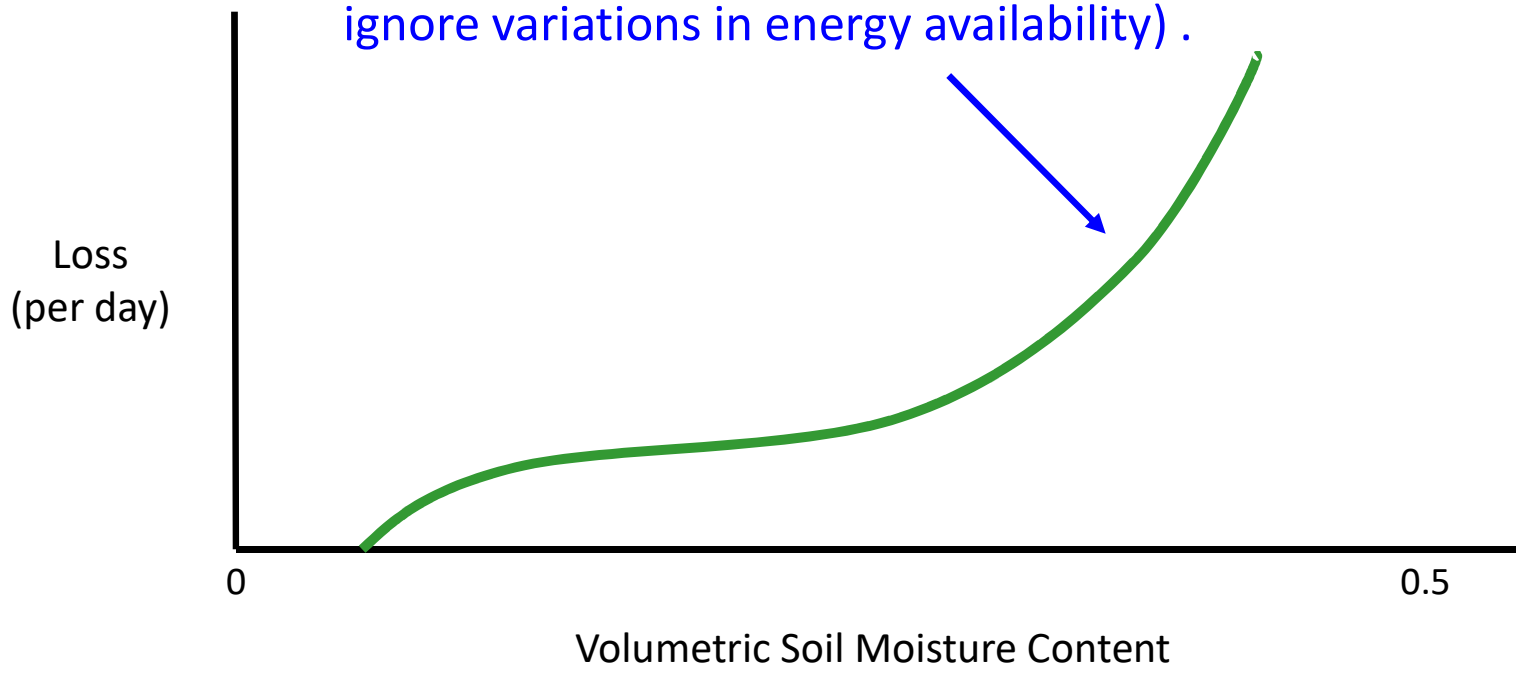
Apparently some rain occurred between the measurements. Of course, there's more to it than that…


soil
moisture
content
Increase due to
precipitation
Decrease due
to evaporation
& drainage
Day N
Day N+1
time



Presumably this decrease 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…

nainly on cipitated water eventually runs off by various routes.
porability After adopting these accretion relations verified by the
elow W_K, authors mentioned above and after taking into con-
hereupon sideration the effect of evaporation, the rate of the change
e amount of soil moisture can be expressed by the following
equations:

vs:

if $W=W_{FC}$ and $R_A>E_0$, $\partial W/\partial t=0$ and $r_f=R_A-E_0$

(18) and (21)

if $W<W_{FC}$, $\partial W/t=R_A-E$

where R_A is the rate of rainfall and r_f is that of runoff.

(19) The field capacity of soil varies widely and depends very much upon the kind of soil (for example, the U.S. Department of Agriculture, 1955). It was decided, how-

Manabe, Monthly Weath. Rev., 97,739-774, 1969

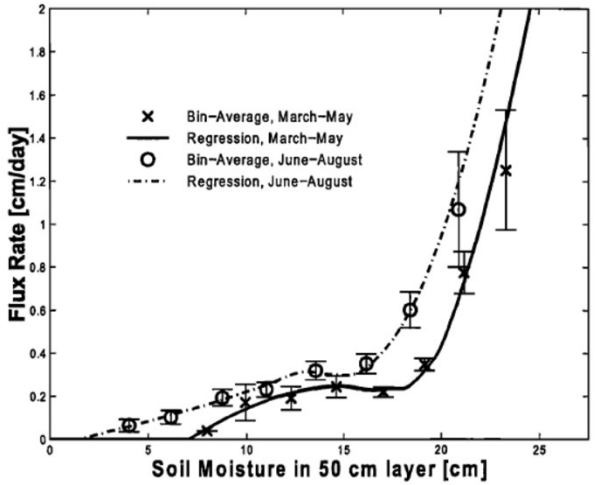


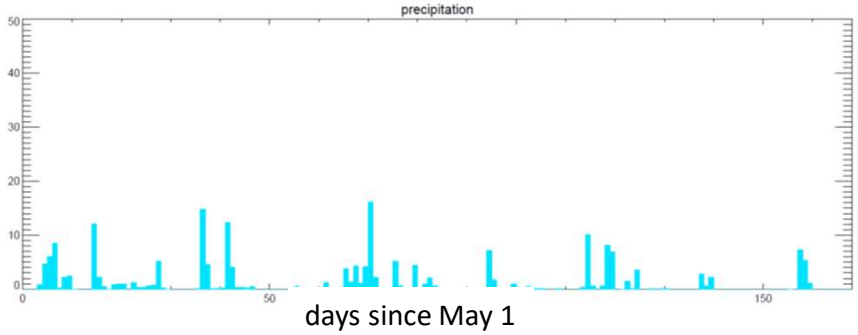
Figure 3. Estimation of moisture-dependent water loss from conditional mean precipitation for sites in Illinois. Note the plateau, presumably corresponding to potential evapotranspiration, and the sharp rise near saturation, presumably corresponding to percolation.

Salvucci, Water Resour. Res., 37,1357-1365, 2001

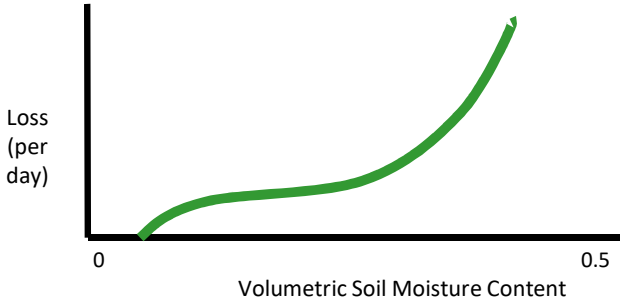
… and its determination has been a chief scientific motivation for the SMAP mission.

Question 2: What is a simple way of determining a loss function from SMAP Level 2 soil moisture retrievals?

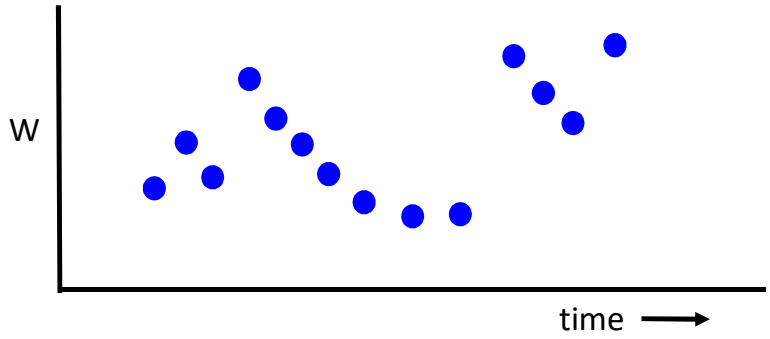
For a given time series of precipitation…



…and an assumed loss function…

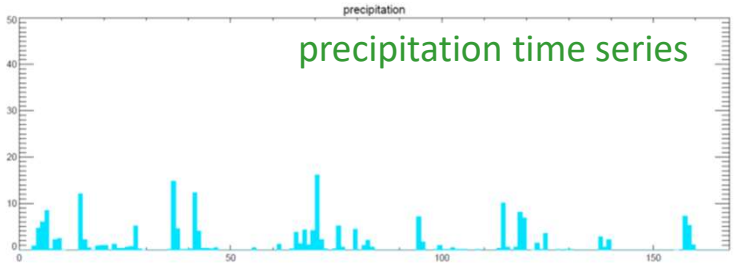


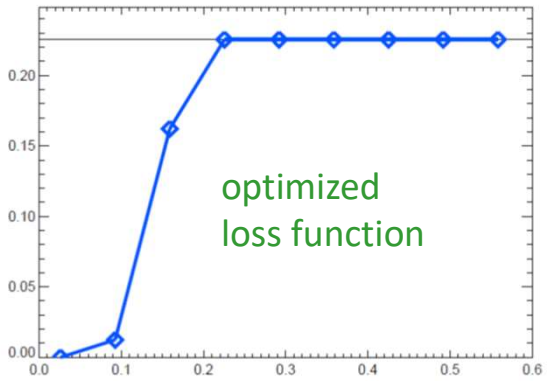
… we can generate a time series of soil moisture contents:

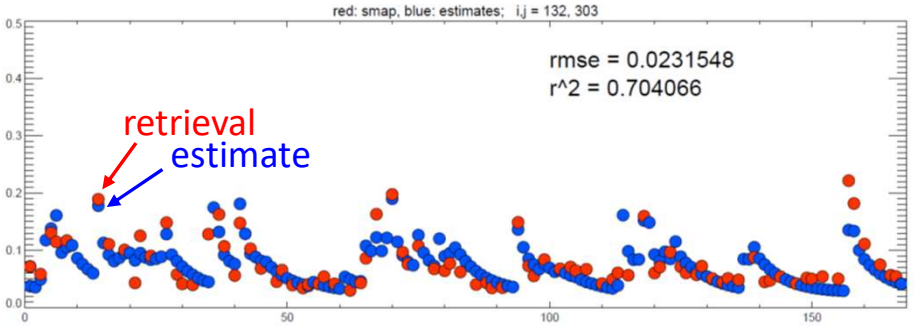


(generated with P data and assumed function alone – no retrievals used)

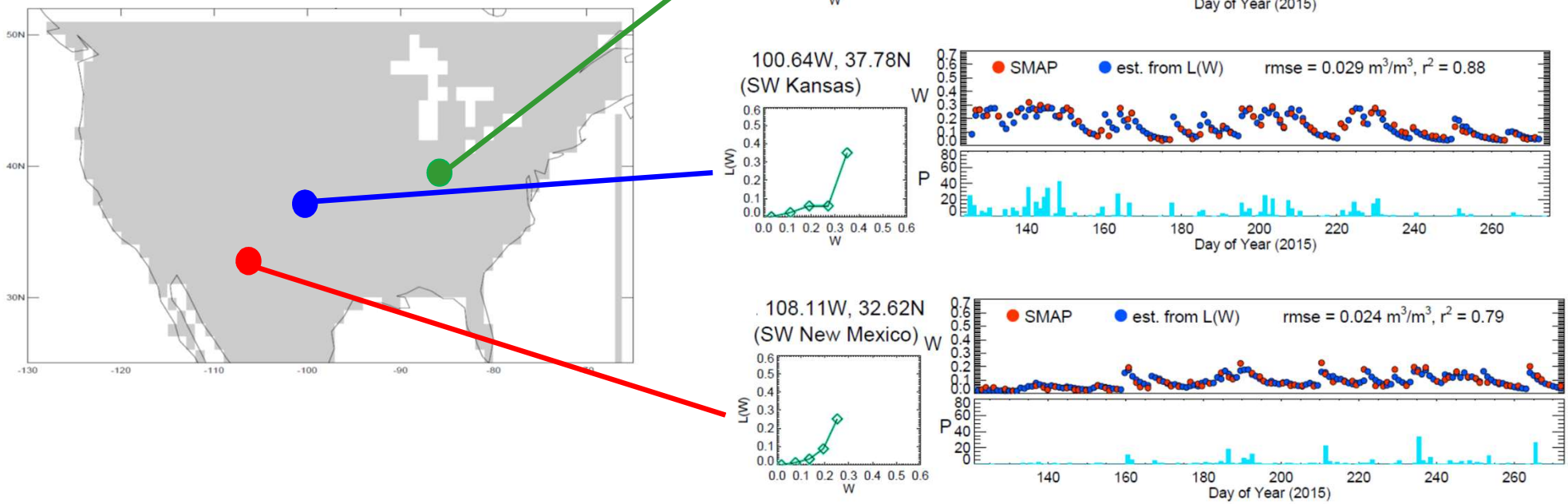
Procedure: through brute force, we find the loss function that produces the best reproduction (in terms of RMSE) of the SMAP Level 2 soil moisture time series.







Examples of Loss Functions

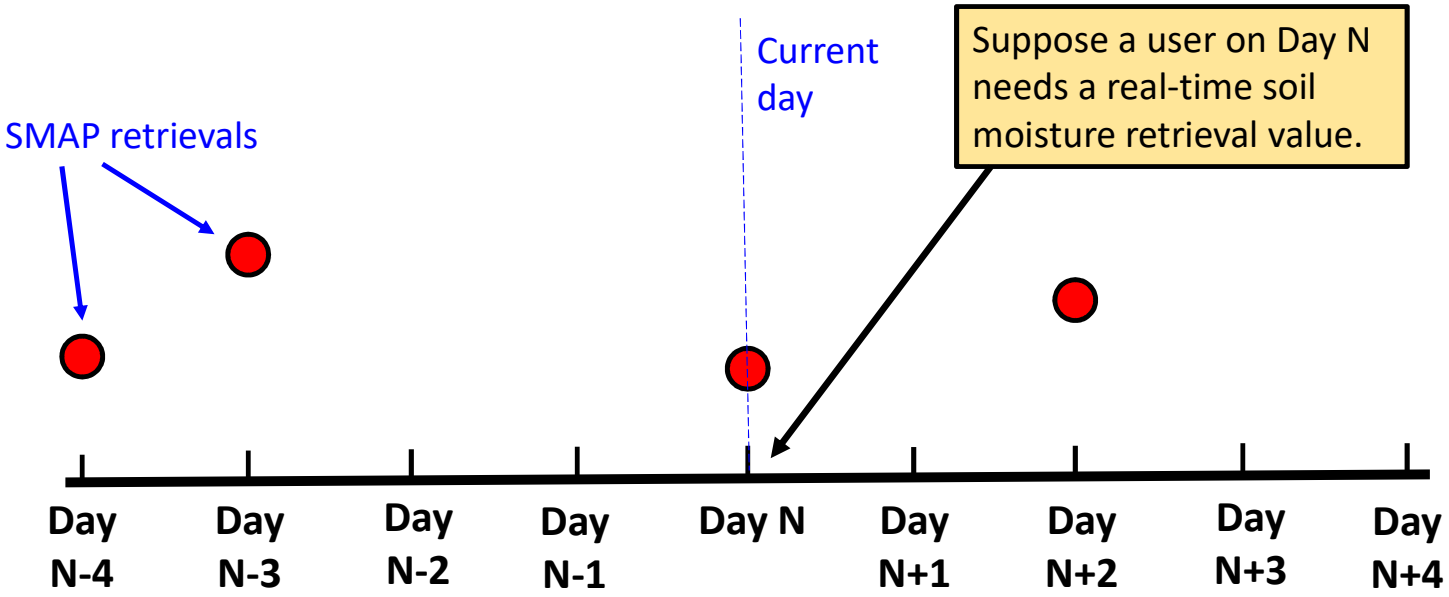


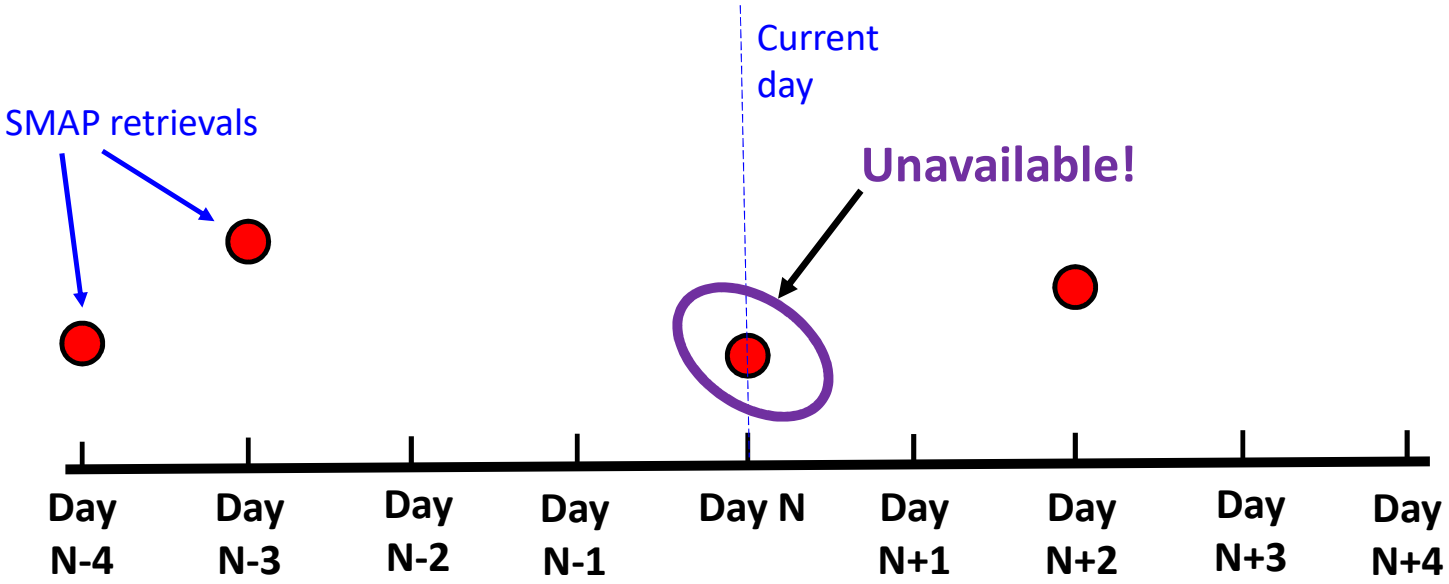
Question 3: What can we do with these loss functions?

Answer: *Many things. Discussed here:*

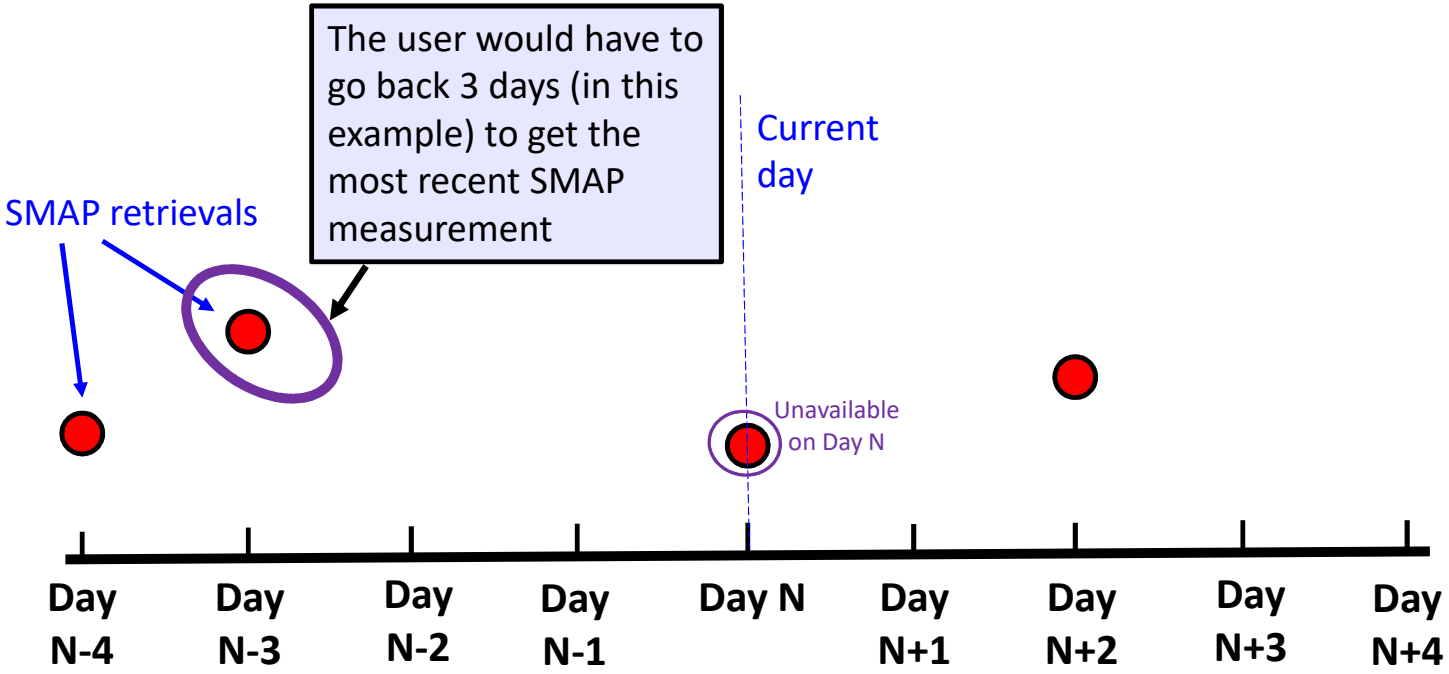
-- Decreasing the latency of SMAP retrieval information

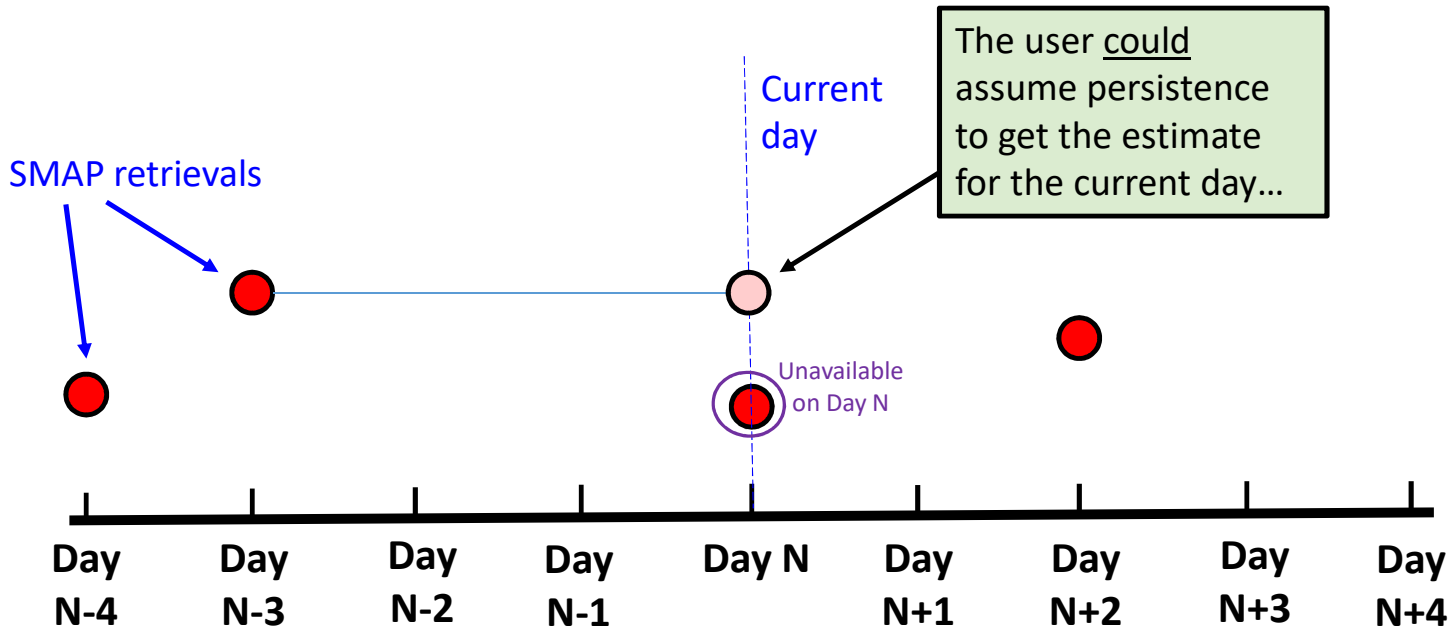
-- Providing soil moisture forecasts

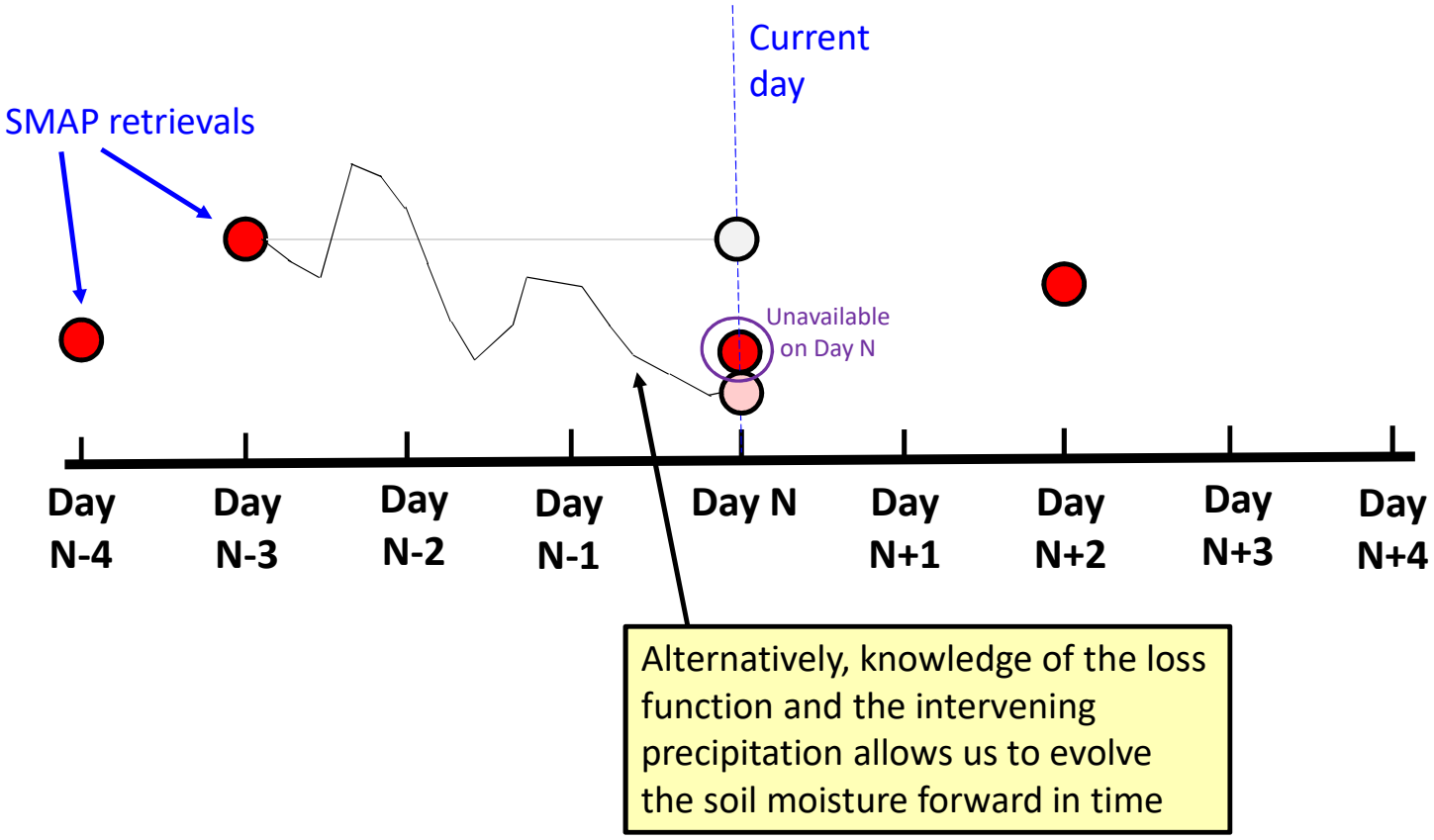

SMAP retrievals
Current day
Suppose a user on Day N needs a real-time soil moisture retrieval value.
Day N-4
Day N-3
Day N-2
Day N-1
Day N
Day N+1
Day N+2
Day N+3
Day N+4

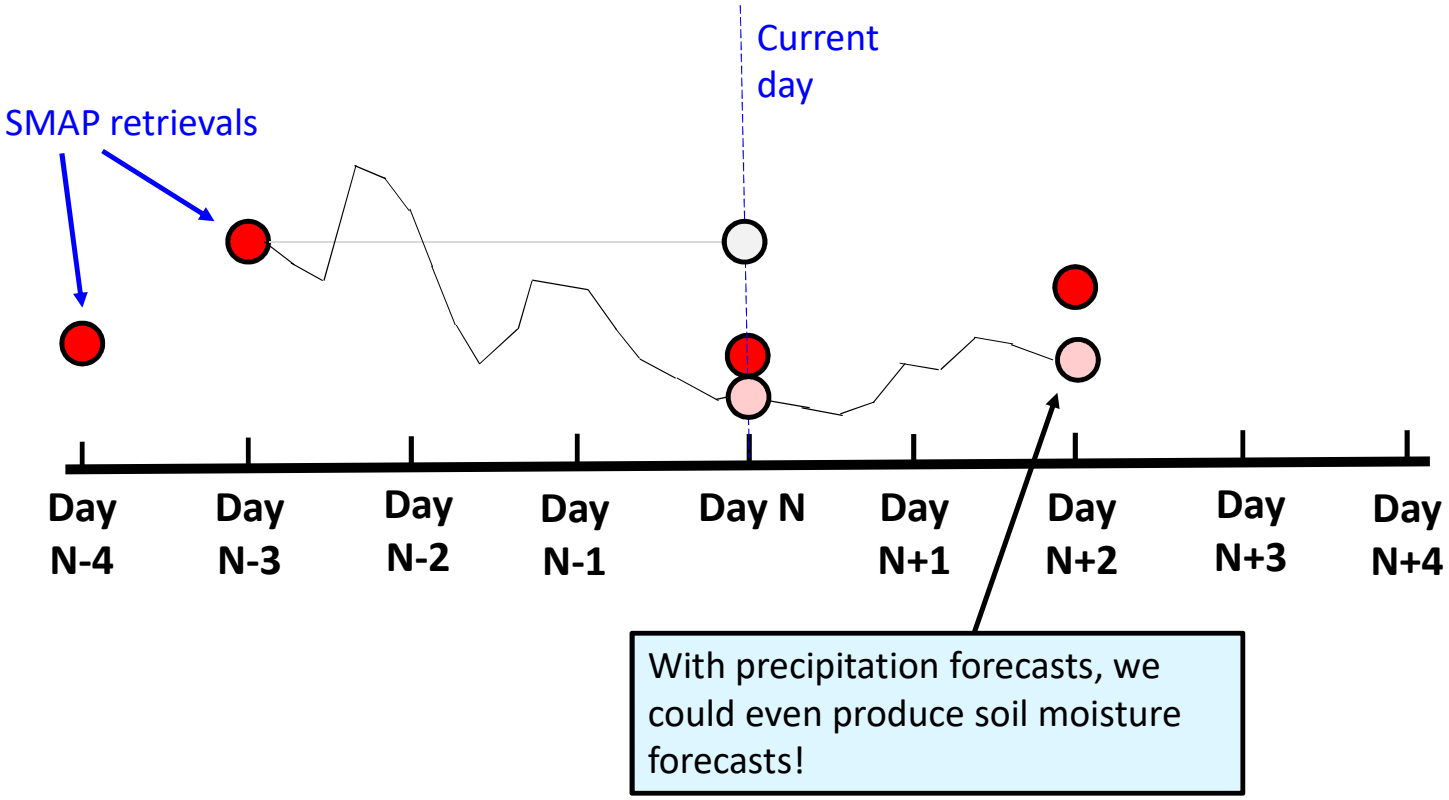


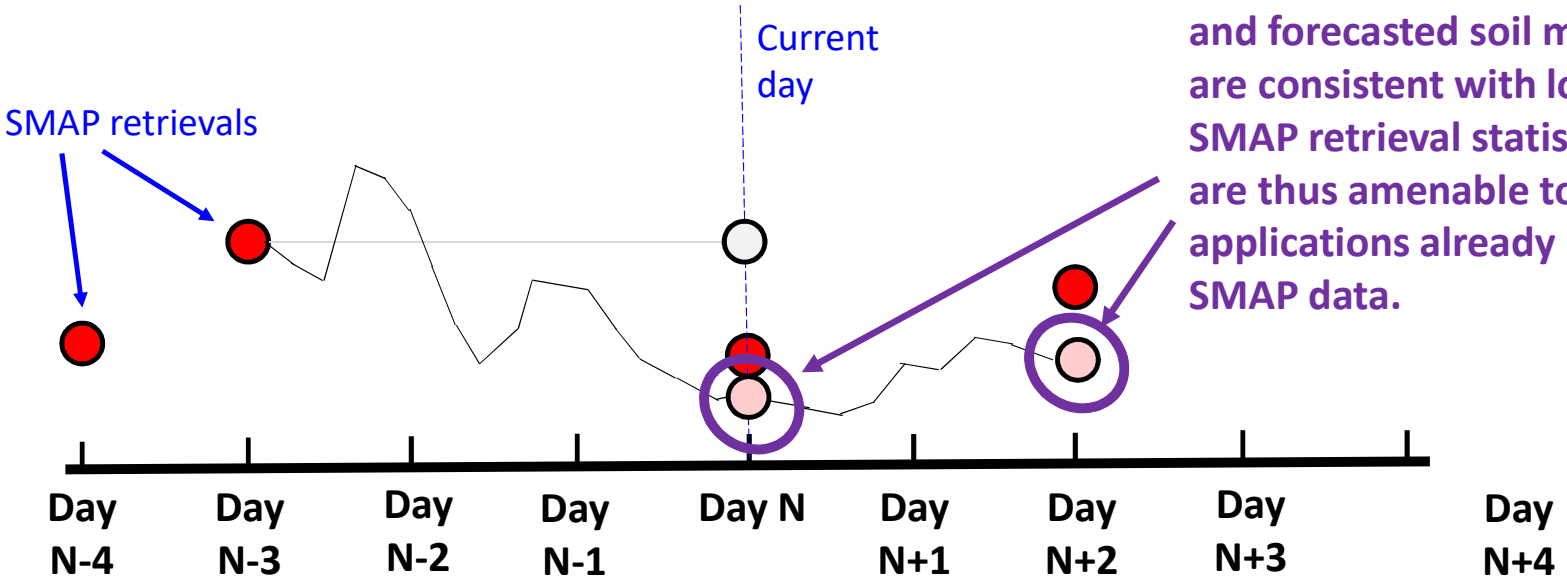
Given product latency, this retrieval value would not be available until Day N+1


The user would have to go back 3 days (in this example) to get the most recent SMAP measurement
Current day
SMAP retrievals
Unavailable on Day N
Day N-4
Day N-3
Day N-2
Day N-1
Day N
Day N+1
Day N+2
Day N+3
Day N+4


SMAP retrievals
Current day
The user could assume persistence to get the estimate for the current day…
Unavailable on Day N
Day N-4
Day N-3
Day N-2
Day N-1
Day N
Day N+1
Day N+2
Day N+3
Day N+4


Current day
SMAP retrievals
Unavailable on Day N
Day N-4
Day N-3
Day N-2
Day N-1
Day N
Day N+1
Day N+2
Day N+3
Day N+4
Alternatively, knowledge of the loss function and the intervening precipitation allows us to evolve the soil moisture forward in time


Current day
SMAP retrievals
Day N-4
Day N-3
Day N-2
Day N-1
Day N
Day N+1
Day N+2
Day N+3
Day N+4
With precipitation forecasts, we could even produce soil moisture forecasts!

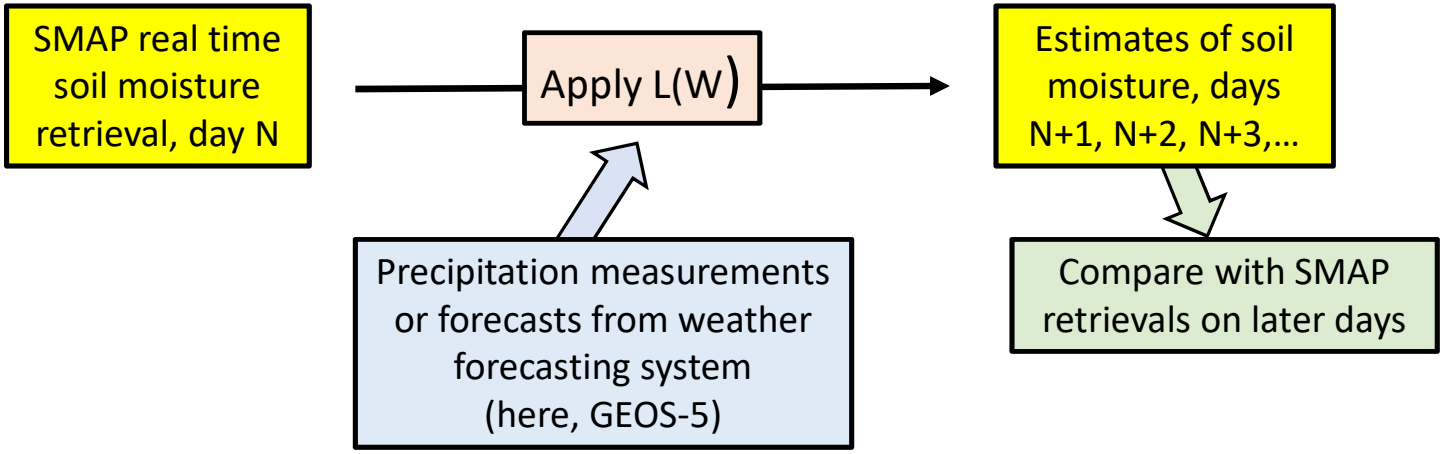


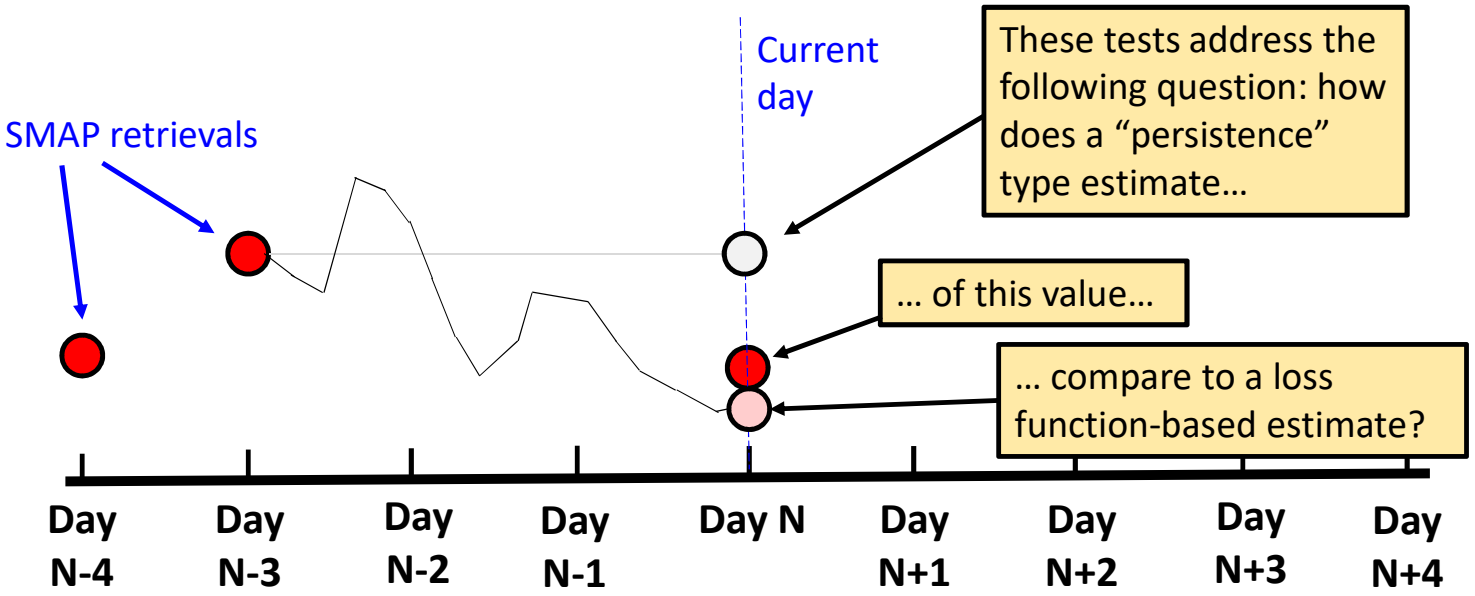
The estimates of real-time and forecasted soil moistures are consistent with local SMAP retrieval statistics and are thus amenable to applications already using SMAP data.

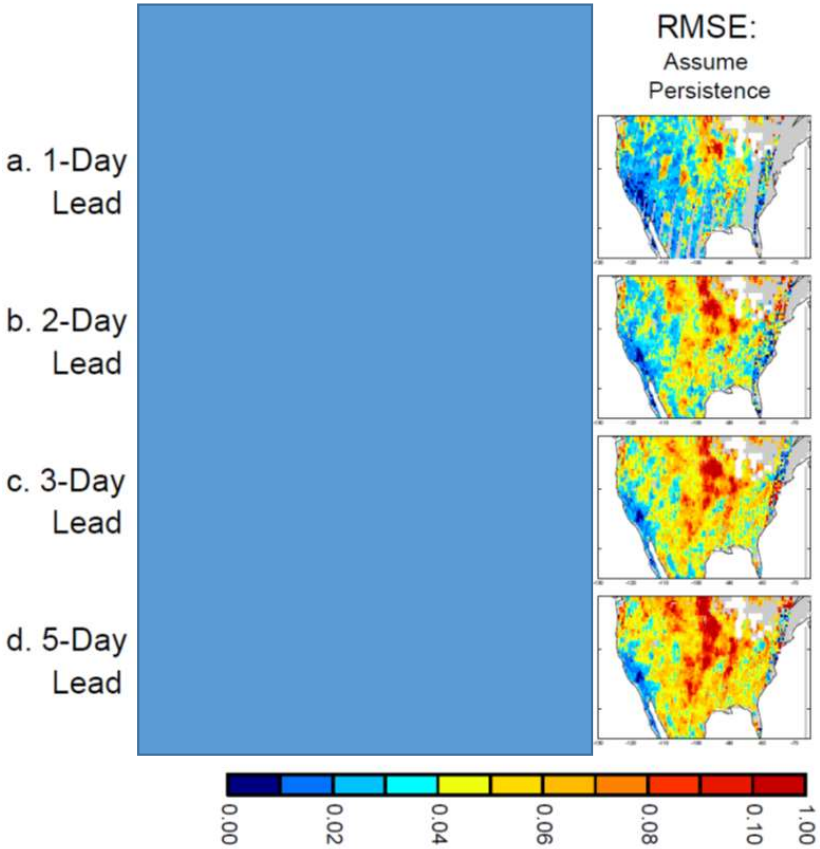
Overall strategy to test such soil moisture estimation:

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.):



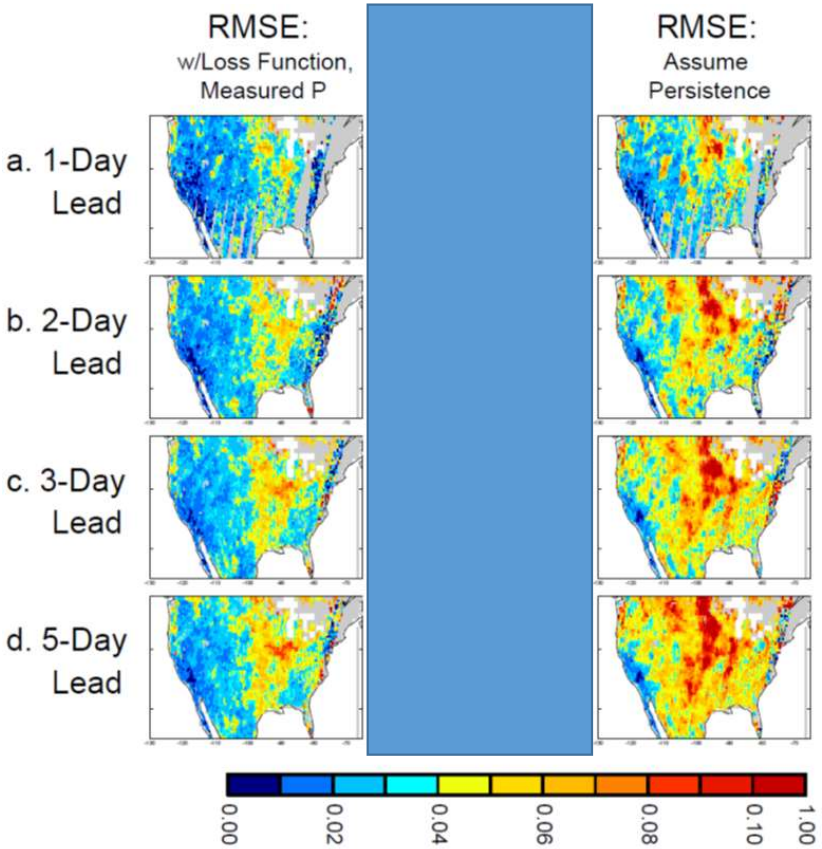

SMAP retrievals
Current day
These tests address the following question: how does a "persistence" type estimate…
… of this value…
… compare to a loss function-based estimate?
Day N-4
Day N-3
Day N-2
Day N-1
Day N
Day N+1
Day N+2
Day N+3
Day N+4



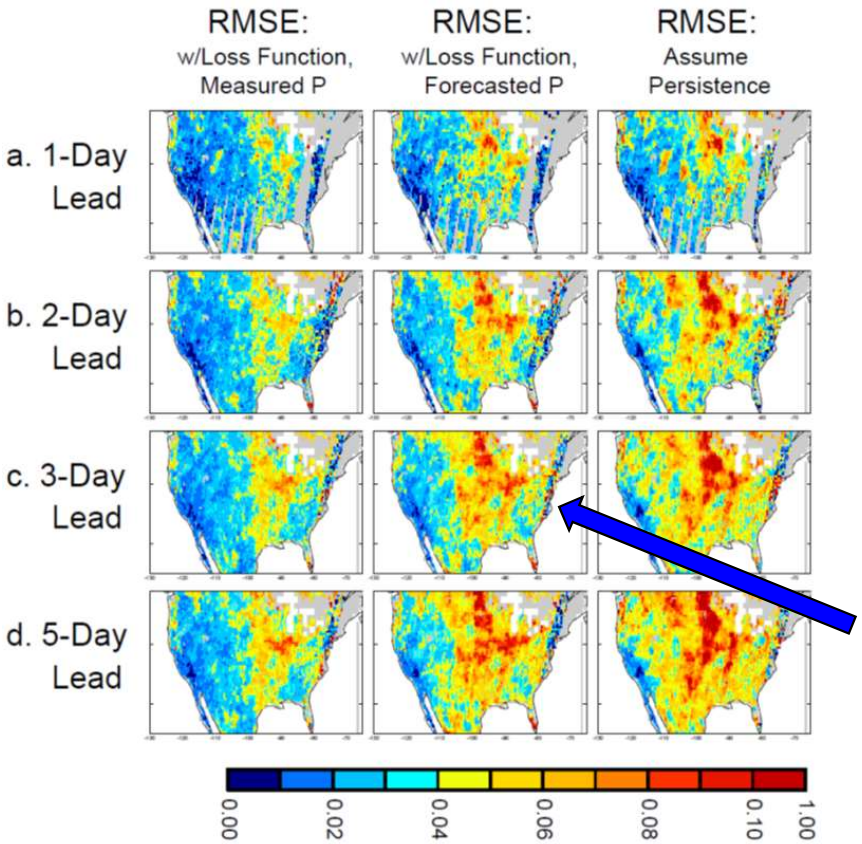
Persistence: If you assign the most recent SMAP retrieval value to the current day, these are the errors you obtain.

Units: m^3/m^3 (volumetric soil moisture)

Loss function: The errors go way down if you use loss functions in conjunction with precipitation information (for real-time estimates)….

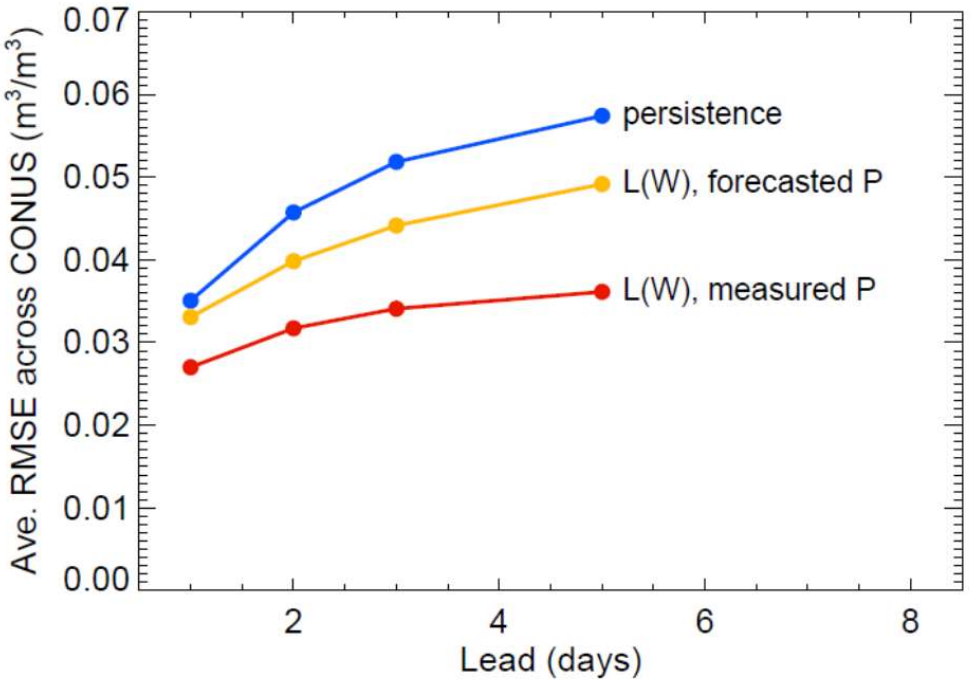


Units: m^3/m^3 (volumetric soil moisture)



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).

  → A potentially high impact on applications!