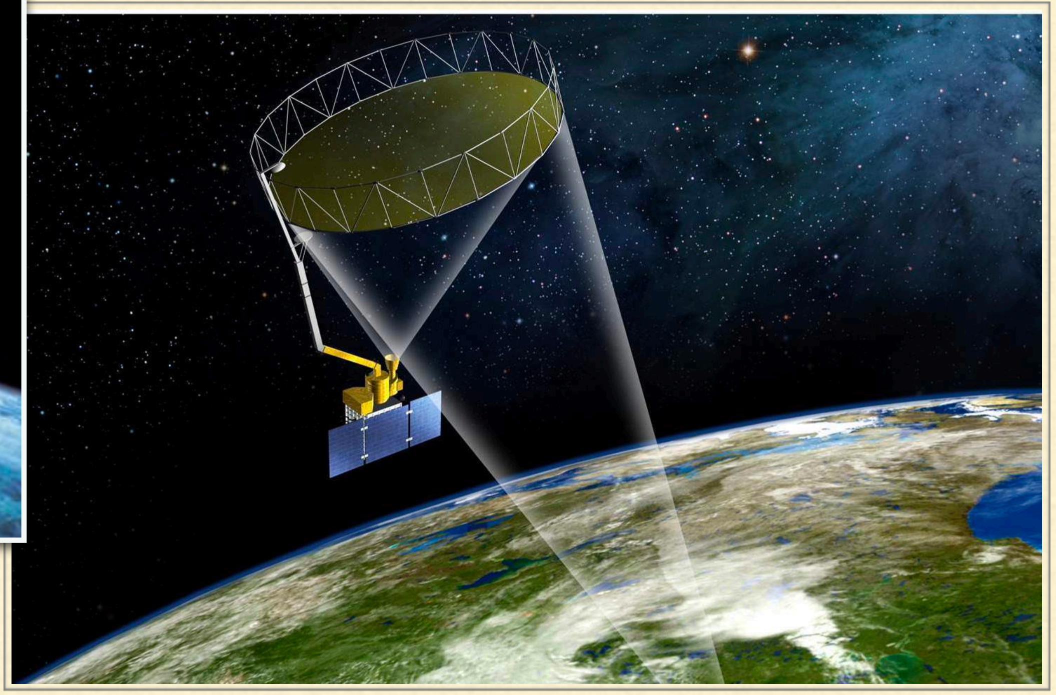
GLOBAL NEAR-REAL-TIME DROUGHT MONITOR USING INTEGRATED SMOS-SMAP SOIL MOISTURE DATA



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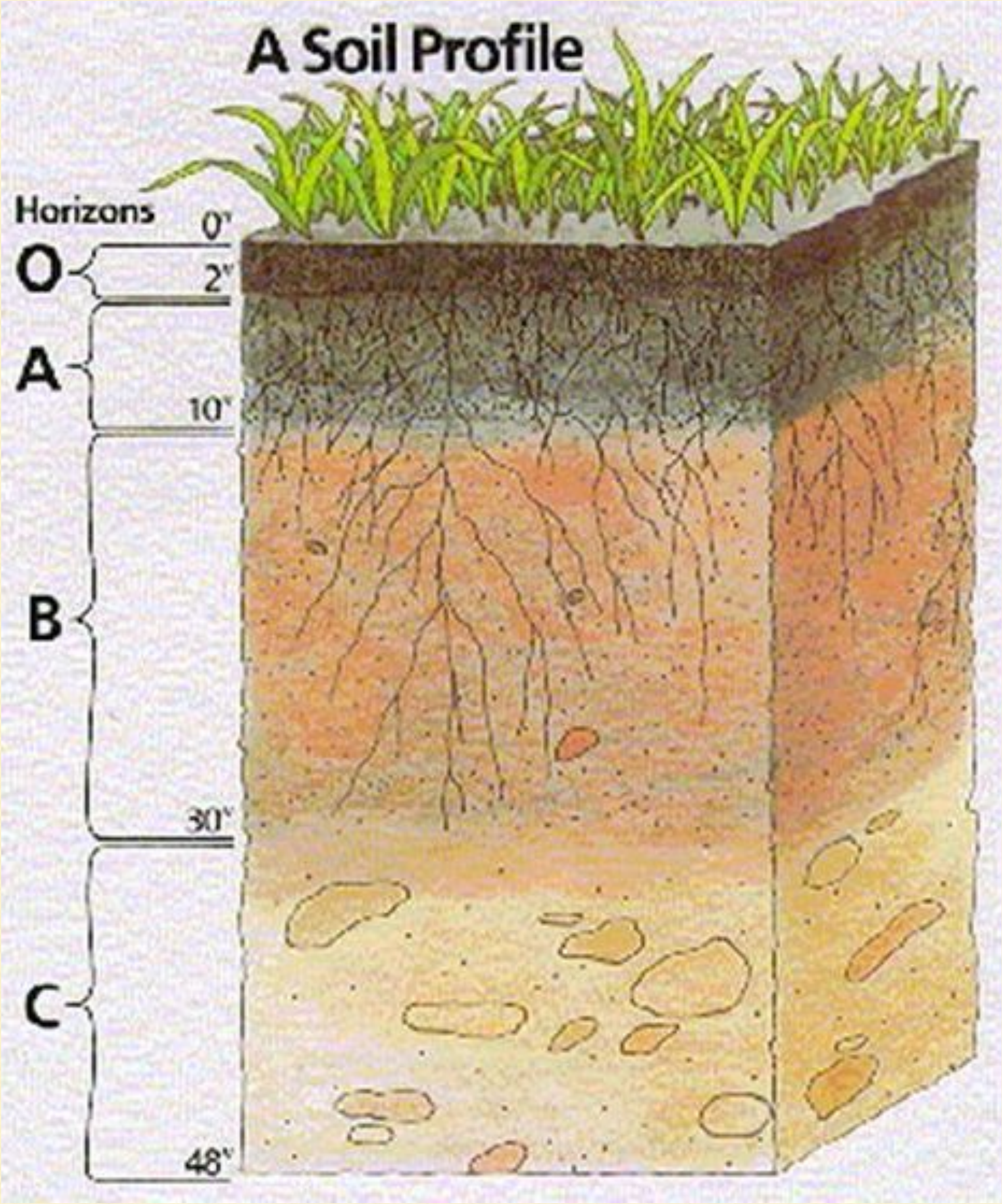
PRINCETON UNIVERSITY

INTRODUCTION

- A global representation of soil moisture conditions is useful for:
    - Agricultural growing conditions and food security
    - Improve forecasting of both droughts and floods
    - Farm insurance and policies
    - Agricultural crop planning
- Agricultural drought is typically defined at Zone B (Sanchez et al., 2016), but …
- It begins at the soil surface when Actual Evapotranspiration drops to only a small fraction of the Potential Evapotranspiration rate (WMO, 1992)



MOTIVATION & OBJECTIVES

- None of the globally defined indices (SPI, PDSI, CMI, SMDI, ETDI, ESA's ESSMI, VIC, etc) uses satellite observations and in a near-real-time capacity and as an operational tool.
- **Our goal** is to develop a global monitoring product, based on integrated SMOS-SMAP, that monitors SSM in terms of probability percentiles for dry and wet conditions.
- Integrated SMOS and SMAP has an increased global revisit frequency (1 day) and period of record from 2010 to the present.

METHODOLOGY

Integrating SMAP+SMOS

Fitting 4-parameter beta distribution

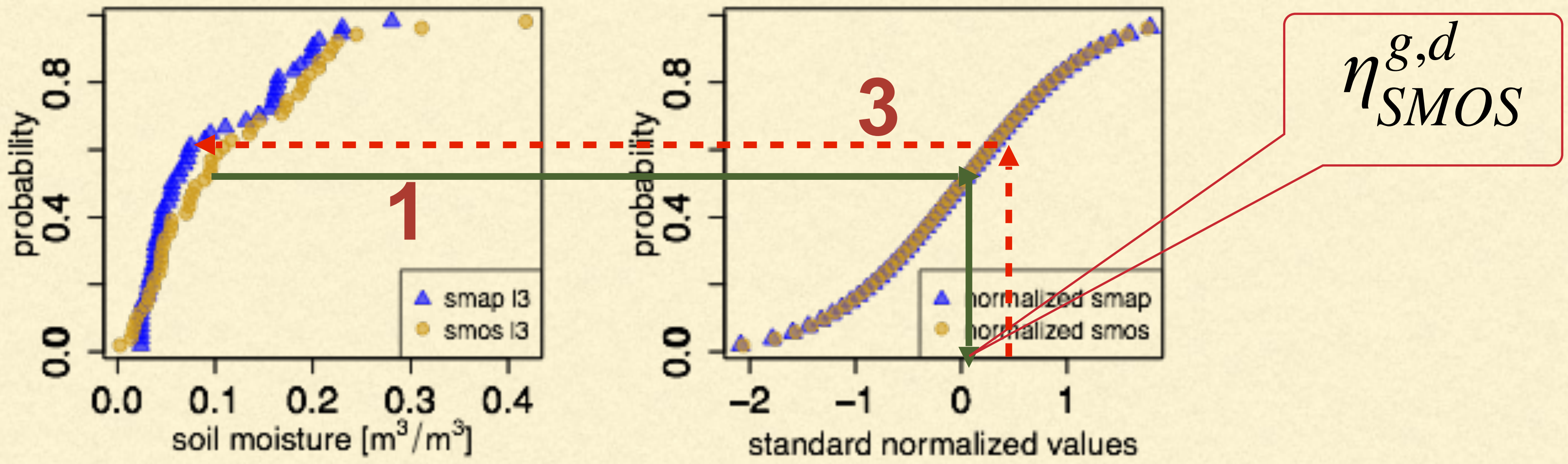
Determining drought index using SMOS-SMAP observations

Publishing a global map of drought and pluvial conditions online every 24 hours

GLOBAL SOIL MOISTURE DATA USED

SSM dataset	type	Depth (cm)	period	Sp. res. (km)	Temp. res.	Considered period for fitting Beta	Considered period for validation
SMAP L3SMP	Remotely sensed	5	2015-2018	36	Every 3-4 days	-	-
SMOS L3SM	Remotely sensed	5	2010-2018	25	Every 7-8 days	-	-
SMOS-SMAP	Integrated	5	2010-2018	36	Daily	2010-2018	2012-2016
ECV SM04.2	Integrated	0.5-2	1978-2016	25	Daily (not-near-real-time)	1979-2016	2012-2016
VIC	LSM	5-10	1979-2018	36	Daily	2010-2018	2012-2016

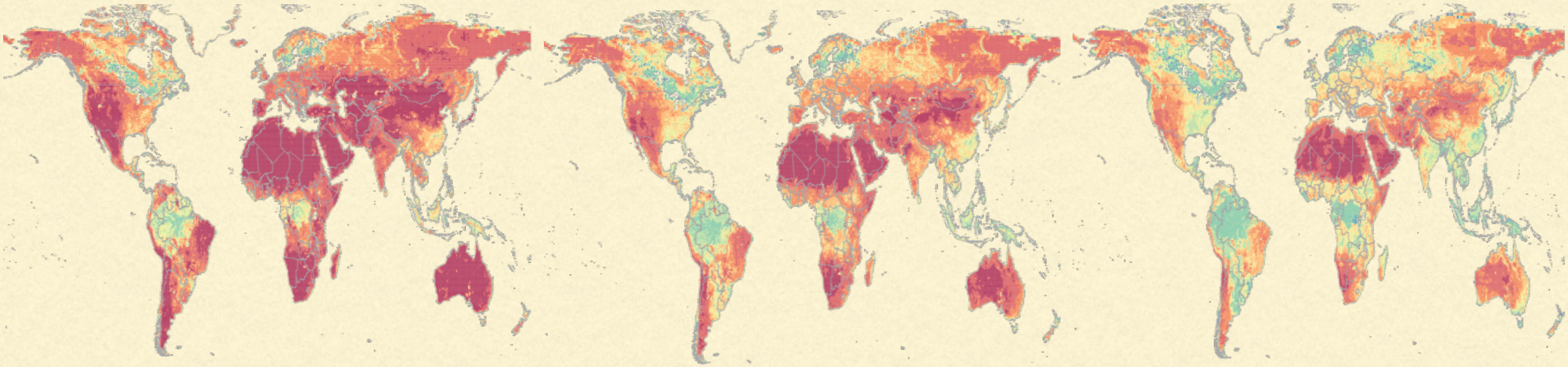
Integrating SMAP+SMOS



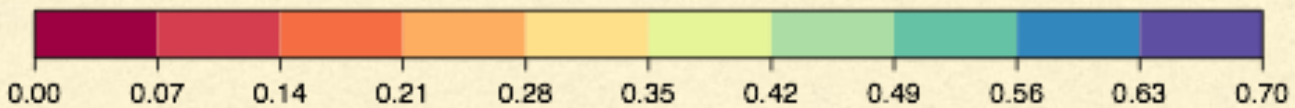
- For every day *d*, if grid *g's* $SMAP^{g,d}$ is missing, but $SMOS^{g,d}$ not:

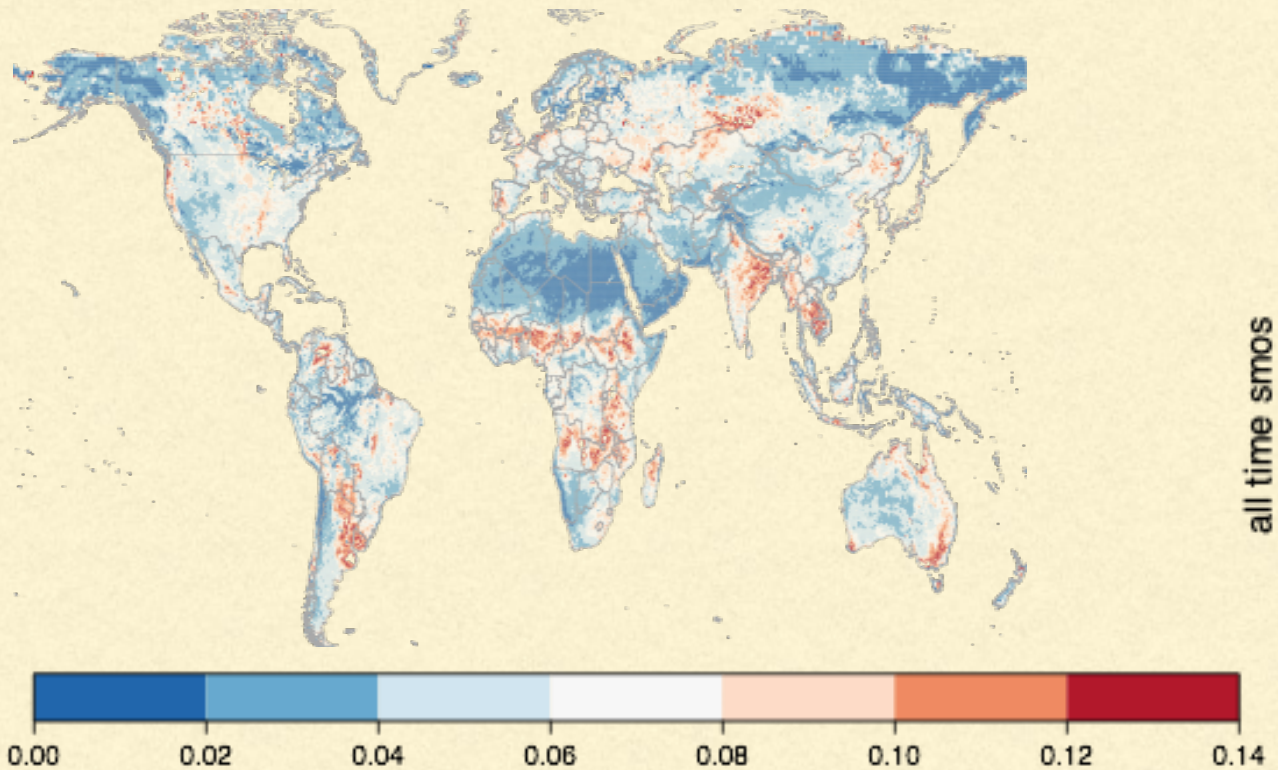
  1. Find the realization of SMOS in normal space ($\eta_{SMOS}^{g,d}$)
  2. Draw a random number from joint bivariate distribution:
     $$\mu = \rho^{g,m} \times \eta_{SMOS}^{g,d} \qquad \sigma^2 = 1 - (\rho^{g,m})^2$$
  3. Use the inverse of NQT and that is $SMAP^{g,d}$

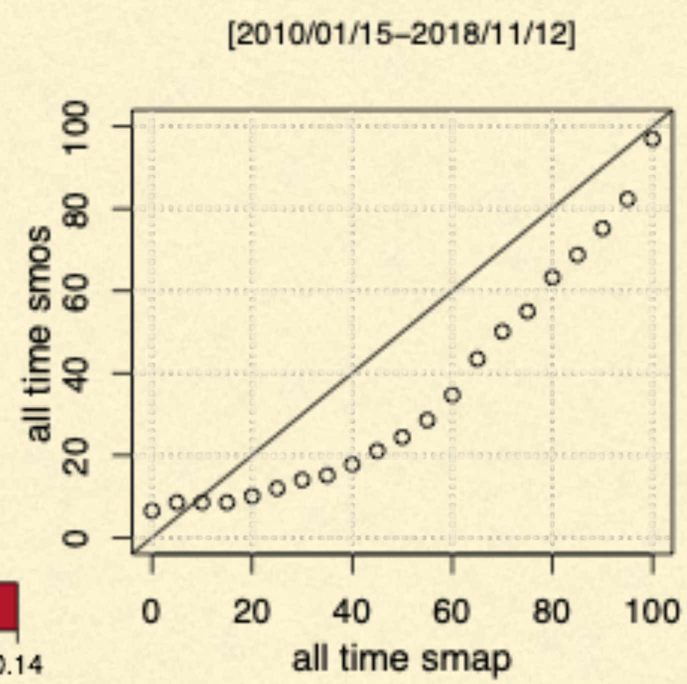
SMOS-SMAP Climatology [2010-2018]

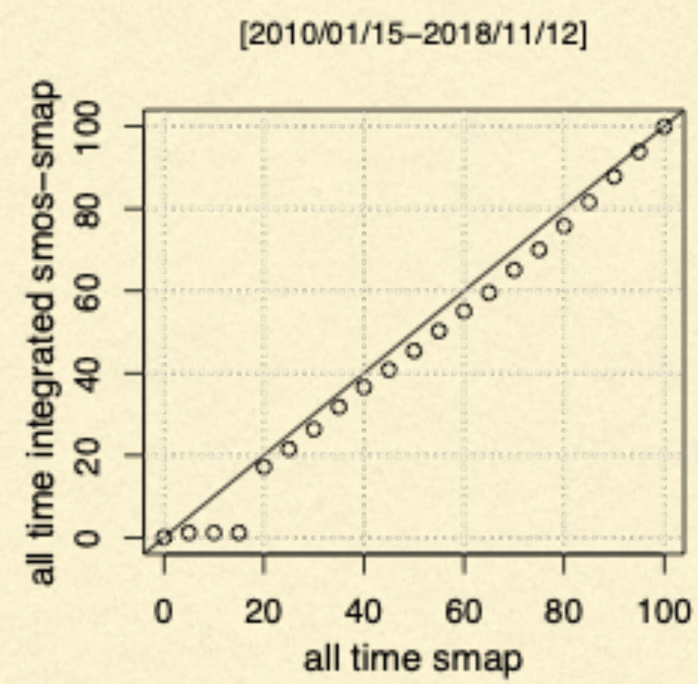


10% [avg: 0.16]   50% [avg:0.22]   90% [avg: 0.30]









Grid point in Bahia, Brazil (Lon:-38.27799, Lat:-10.07724) in the month of September between the period of 2010-2018.

Fitting 4-parameter beta distribution

- Generalized beta distribution has lower/ upper bounds a, b rather than 0, 1:

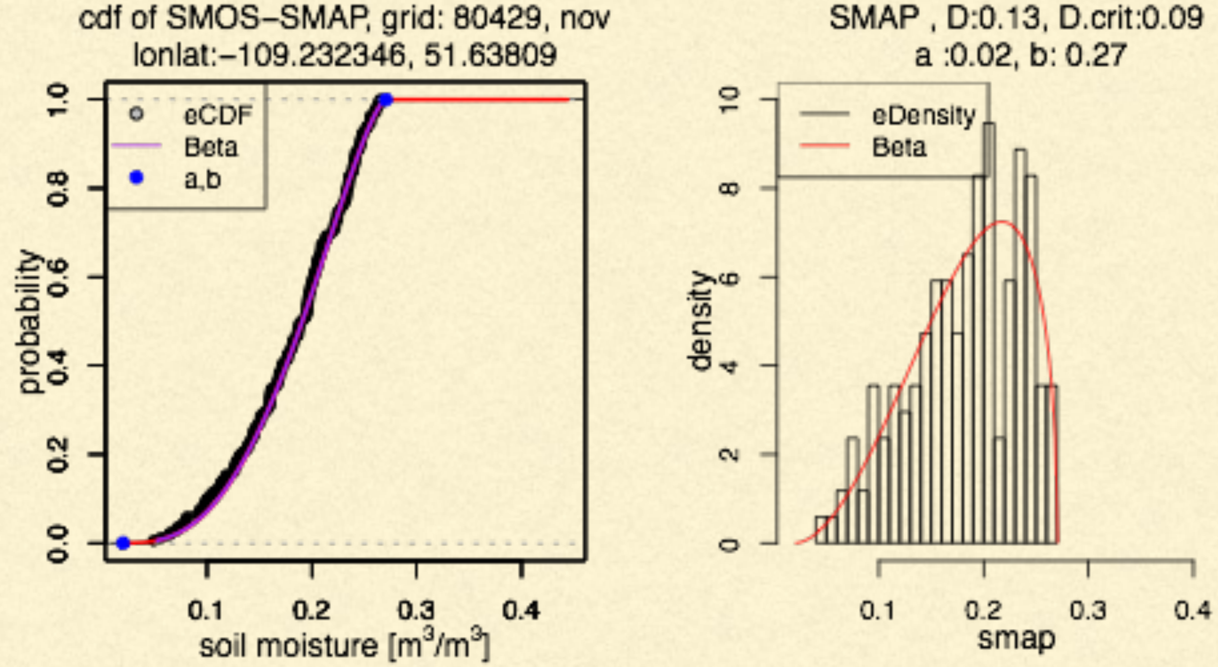
$$f(x; a, b, p, q) = \frac{(x-a)^{p-1}(b-x)^{q-1}}{B(p,q)(b-a)^{p+q-1}} \qquad a \le x \le b; p, q > 0$$

(1) Find *a*, *b* using a new technique (asymptotic model endpoints using log-log fit):

$$x : log(\hat{x}_i - a) \quad y : log(i/n)$$

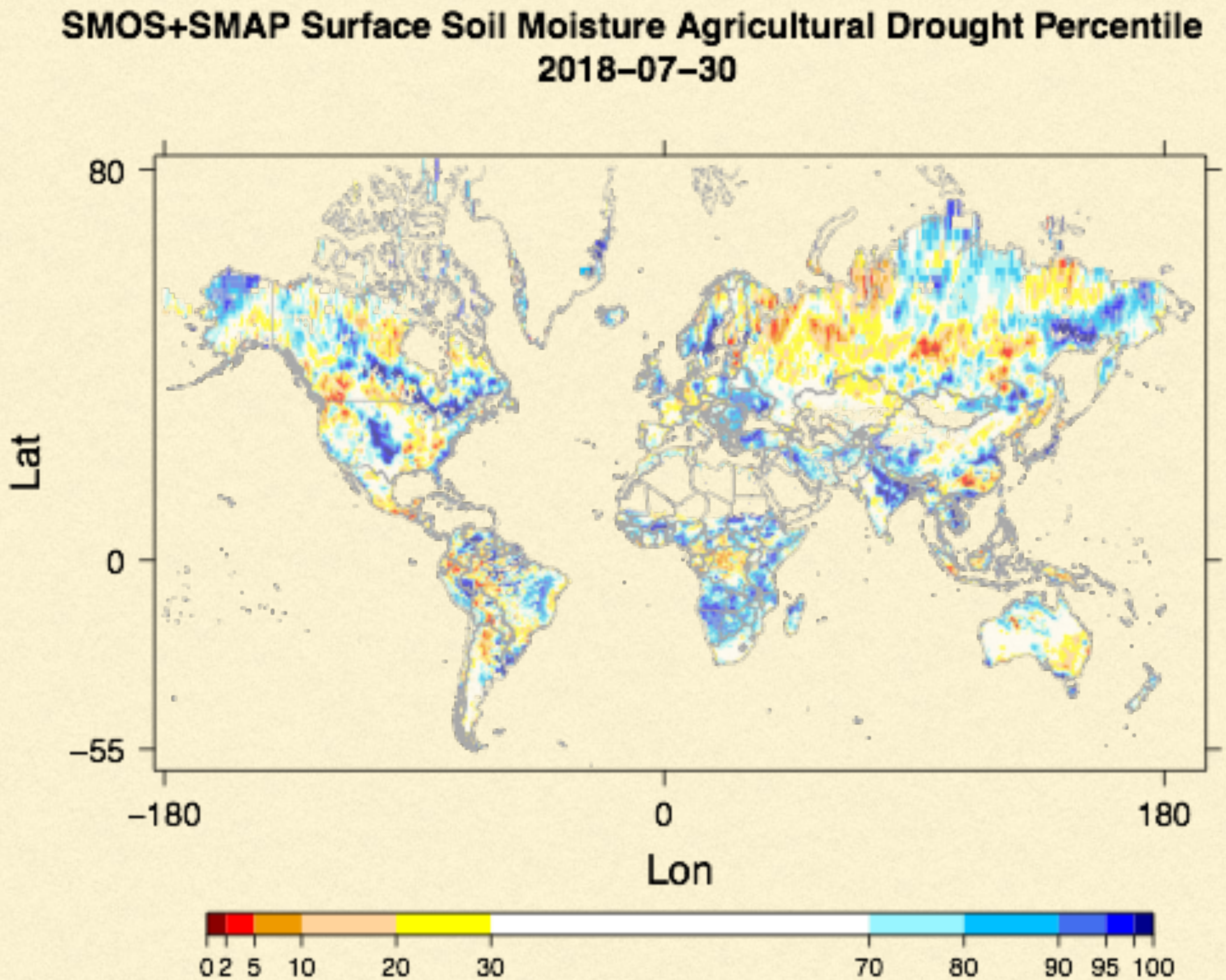
$$x : log(b - \hat{x}_j) \quad y : log(j/n)$$

(2) Fit *p*, *q* using method of moments.



Example from: All Novembers at a grid point in SK, Canada (*109.23 W, 51.63 N*)

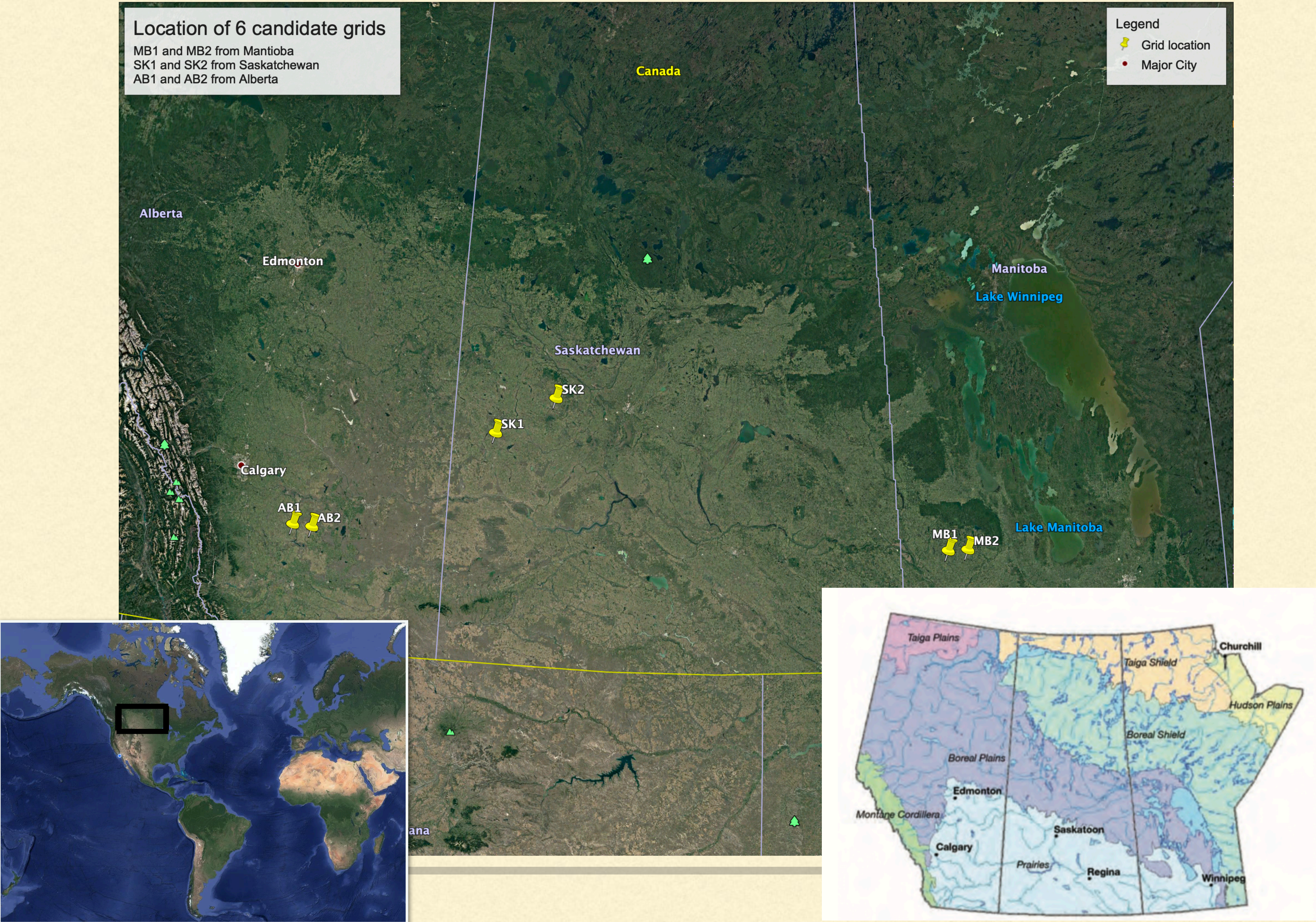
Global Map of Soil Moisture Probability Percentiles



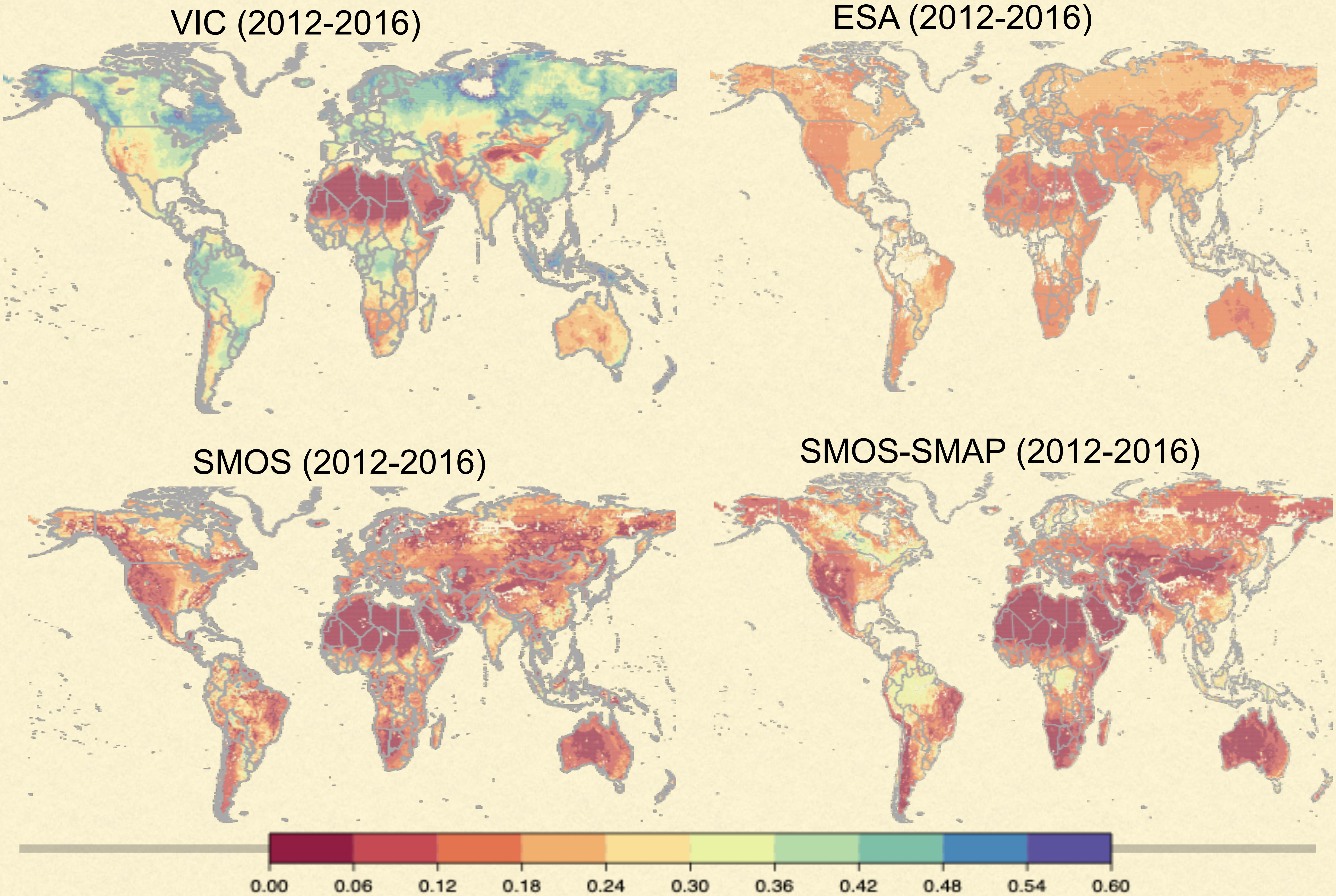
VALIDATION

1. We compared the index from daily SSM of the integrated SMOS-SMAP with those from ESA and VIC for the common period of 2012-2016.

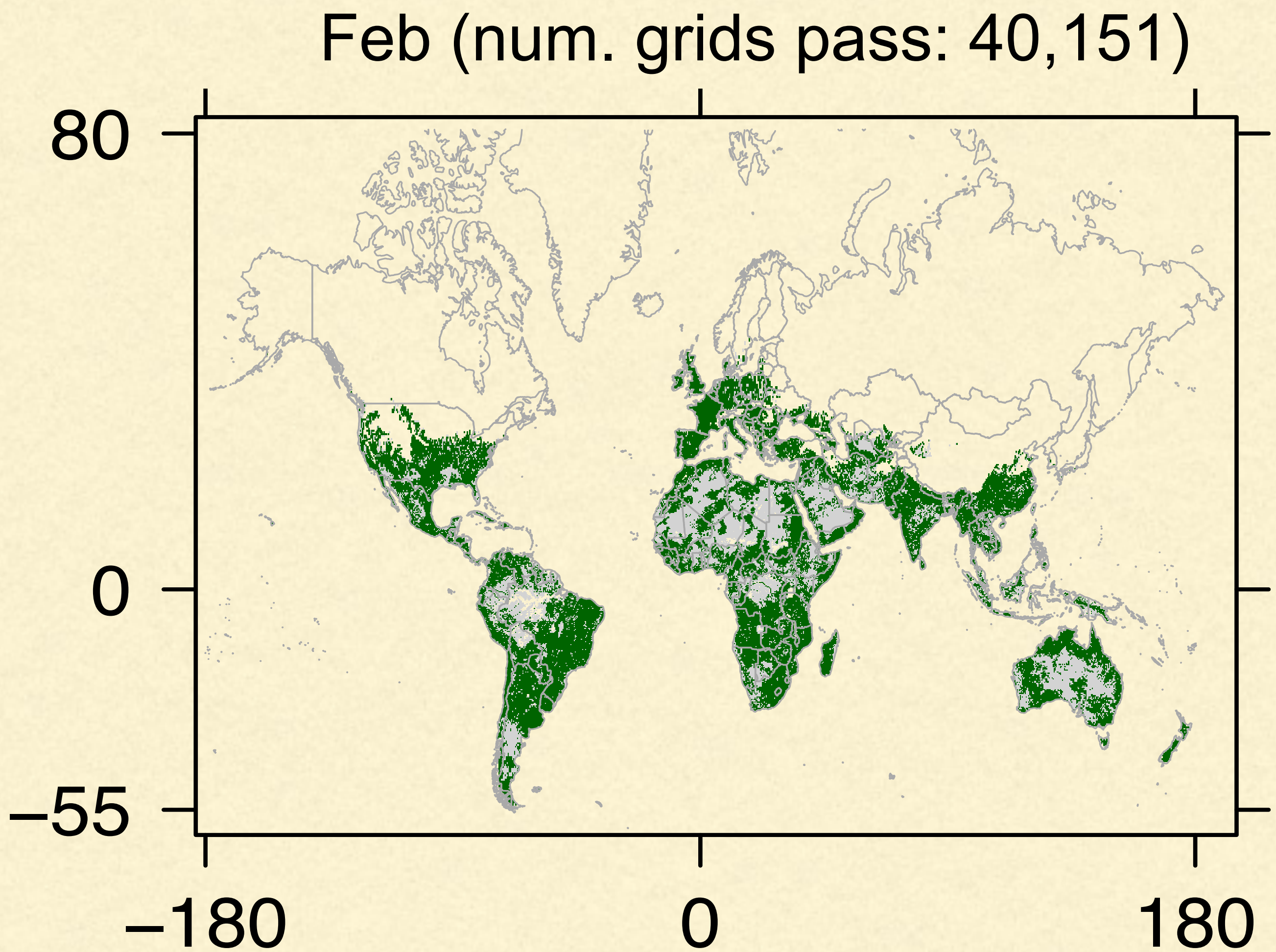
2. We combined the results from SMOS-SMAP with satellite-derived (GPM) observations of precipitation and SPI-1 for detection of drought events.

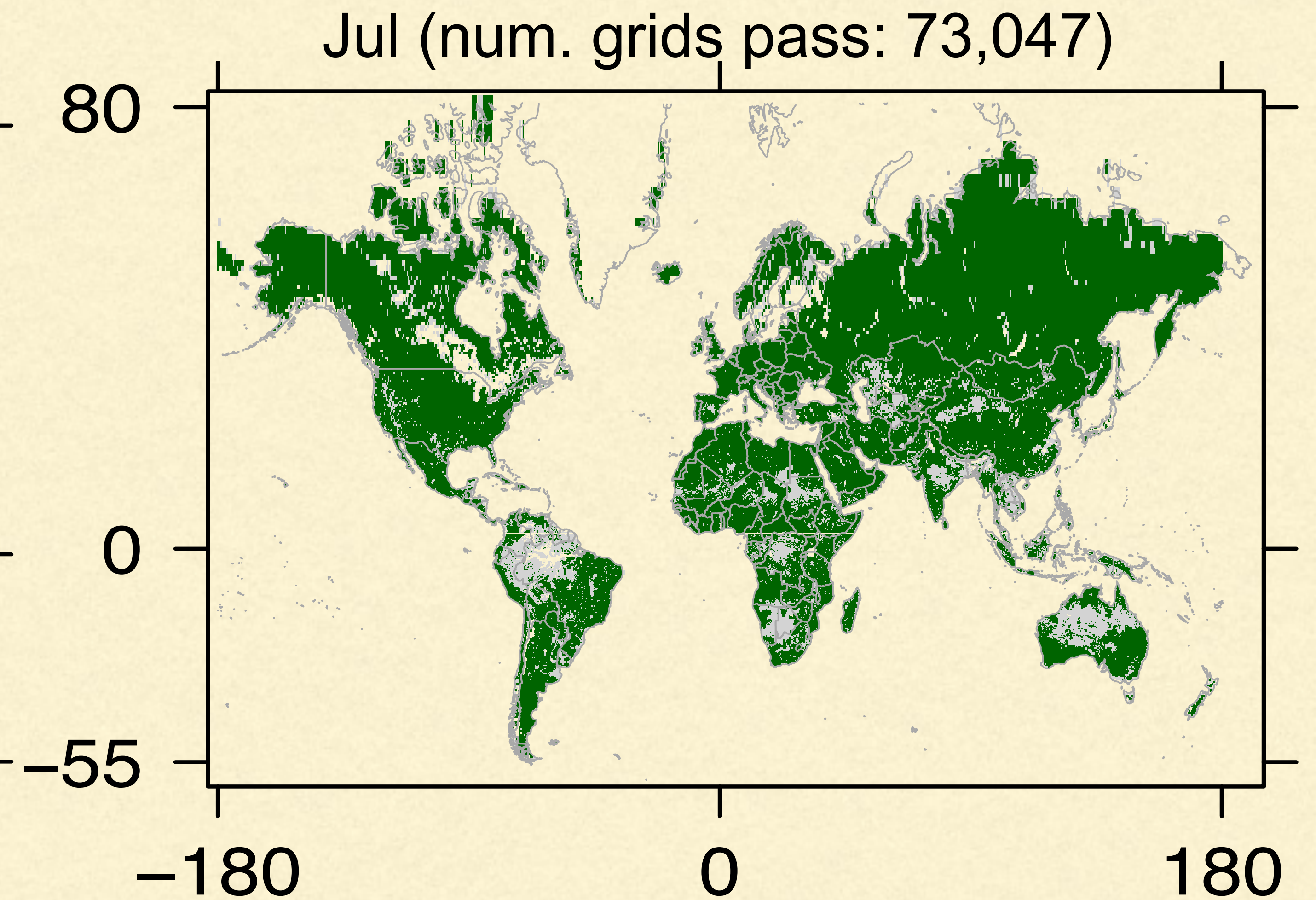

Location of 6 candidate grids
MB1 and MB2 from Mantioba
SK1 and SK2 from Saskatchewan
AB1 and AB2 from Alberta
Legend
Grid location
Major City
Canada
Alberta
Edmonton
Saskatchewan
Manitoba
Lake Winnipeg
Lake Manitoba
Calgary
AB1
AB2
SK1
SK2
MB1
MB2
ana
Taiga Plains
Taiga Shield
Churchill
Hudson Plains
Boreal Shield
Boreal Plains
Edmonton
Montane Cordillera
Saskatoon
Calgary
Prairies
Regina
Winnipeg

MEDIAN SSM CLIMATOLOGY



BETA FITTING

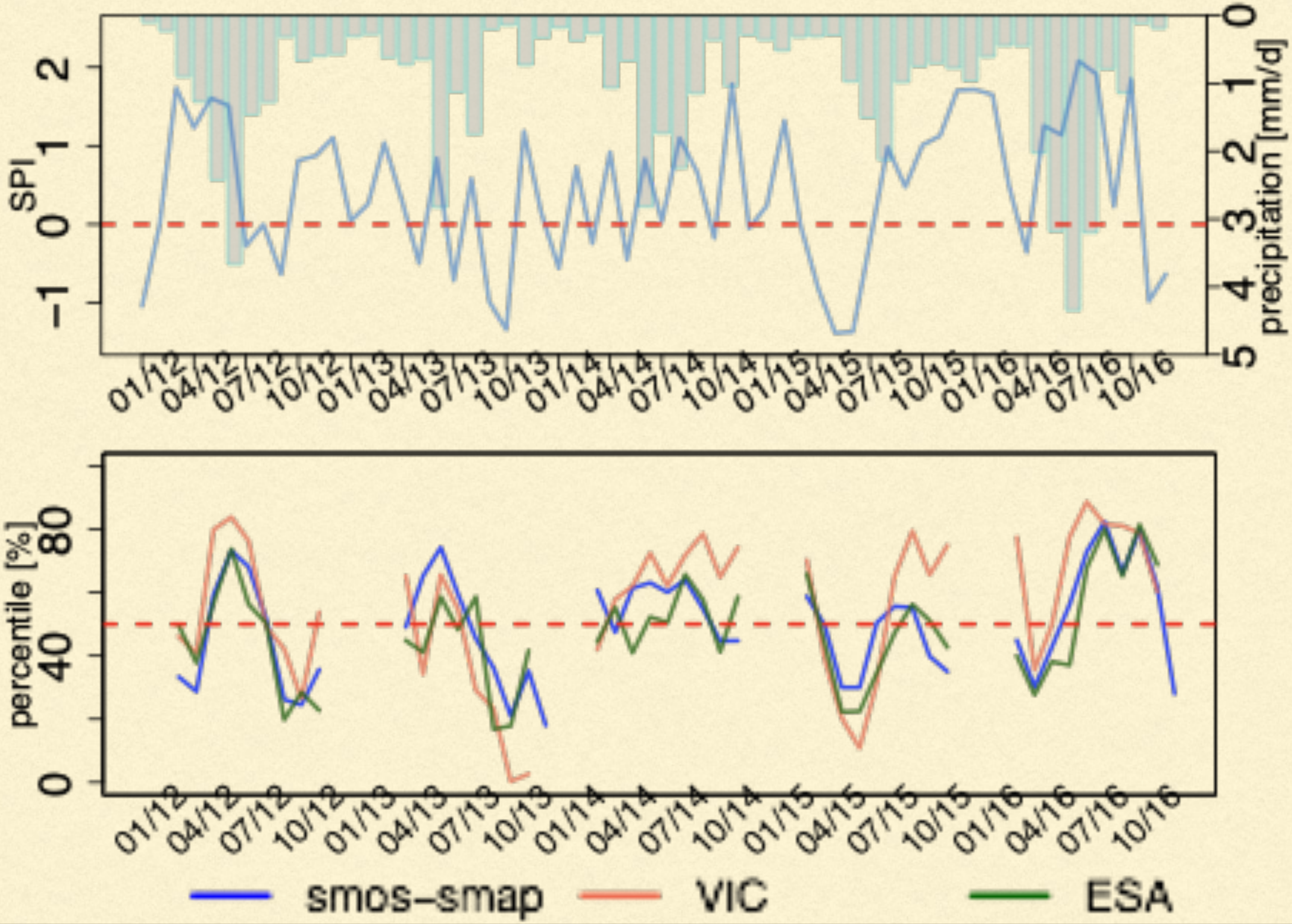




Global	Pass KS test [100,500 grids]	w/o Deserts* [81,628 grids]	**The Prairies**	Pass KS test [382 grids]
SMOS-SMAP	74%	76%	SMOS-SMAP	96%
VIC	62%	70%	VIC	66%
ESA	-	-	ESA	99.6%

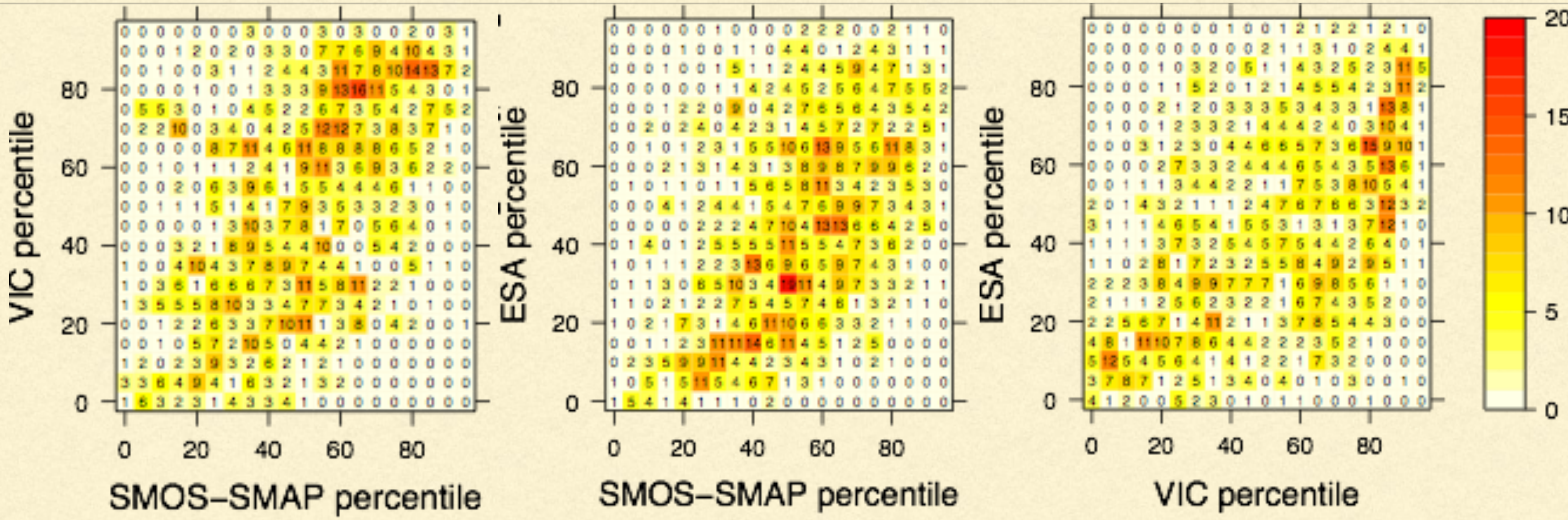
* 18,872 grids are bare soil, only 4 are in the Canadian Prairies

SK1(-109.2 W,51.6 N) period:[2012-2016]



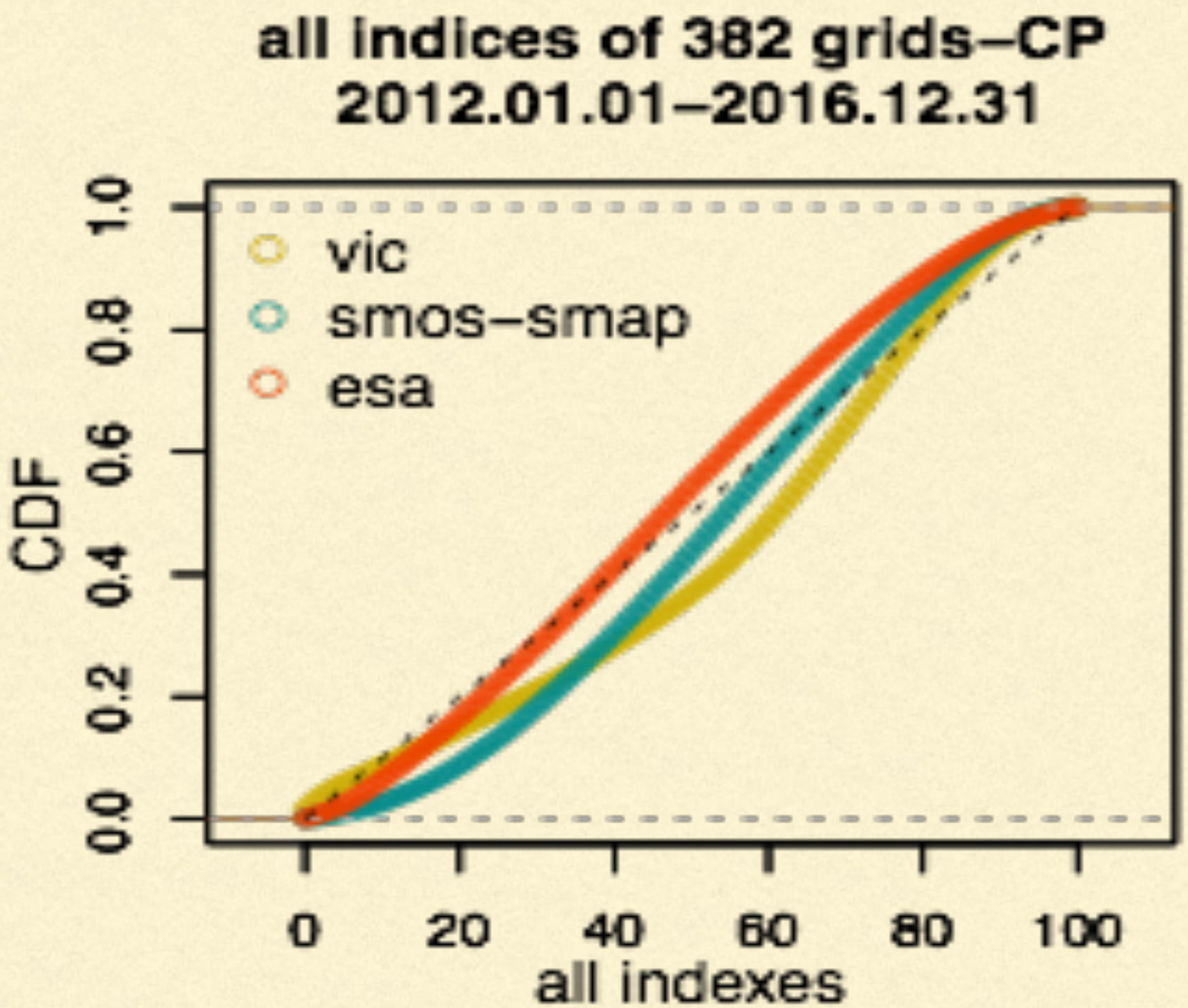
Joint Distribution Heat Map [2012-2016]

AB1



- Heat maps: to understand the similarity of the actual daily indices from SMOP-SMAP, VIC, and ESA in a two-by-two comparison.
- Better compatibility between VIC and ESA and VIC and SMOS-SMAP in higher percentiles.
- Similar recognition of drought between ESA and SMOS-SMAP

Index properties of all indices-382 grids in CP [2012-2016]



- Any ideal index should have uniform distribution on 0%-100% (per grid + month: fit 1:1 line, median 50%)
- ESA is closest to ideal, SMOS-SMAP second closest; ESA slight low bias, others bias high

CONCLUSION

- ESA performed better than SMOS-SMAP in terms of an index, but it is not a real time product. SMOS-SMAP is almost near-real-time and showed a great potential to be used as a global drought monitor/forecast for food security.
- Currently SMOS (CESBIO) has a 7-8 days latency while SMAP has only 2-3 days. The integrated product, therefore, is forced to be 7-8 days late which can be solved if SMOS is provided in higher temporal resolution.
- Future studies
  - integrating SMOS-SMAP with ESA
  - studying the index validation in other regions of the world
  - downscaling soil moisture and its indices to higher resolutions
  - finding relationship between Beta distribution fitting variability and reasons for that globally
  - adding a layer of bias correction to SMOS-SMAP data to fit 1:1 line and re-run the analysis

ACKNOWLEDGEMENT

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