Assimilation of SMAP soil moisture in an ecosystem model for improving global GPP simulation

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SMAP-Canada Workshop, University of Guelph, May 17, 2017

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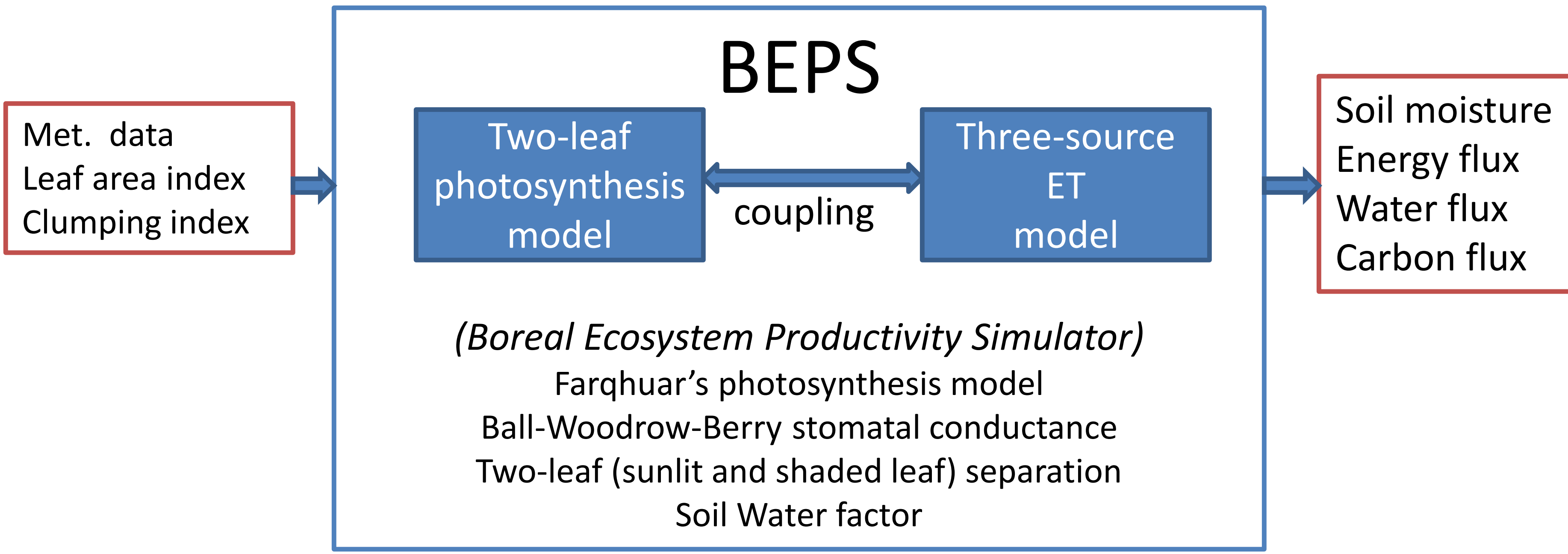
He et al., JGR-BGS, in Revision

Background: the BEPS model



Chen J. et al. (1999), Liu J. et al. (2003),
Ju W. et al. (2006), Chen B. et al. (2007),
Chen J. M. et al. (2012), He et al. (2014)

Leaf-level Photosynthesis Model

Farquhar's Model

$$W_c = V_m \frac{C_i - \Gamma}{C_i + K}$$

$$W_j = J \frac{C_i - \Gamma}{4.5C_i + 10.5\Gamma}$$

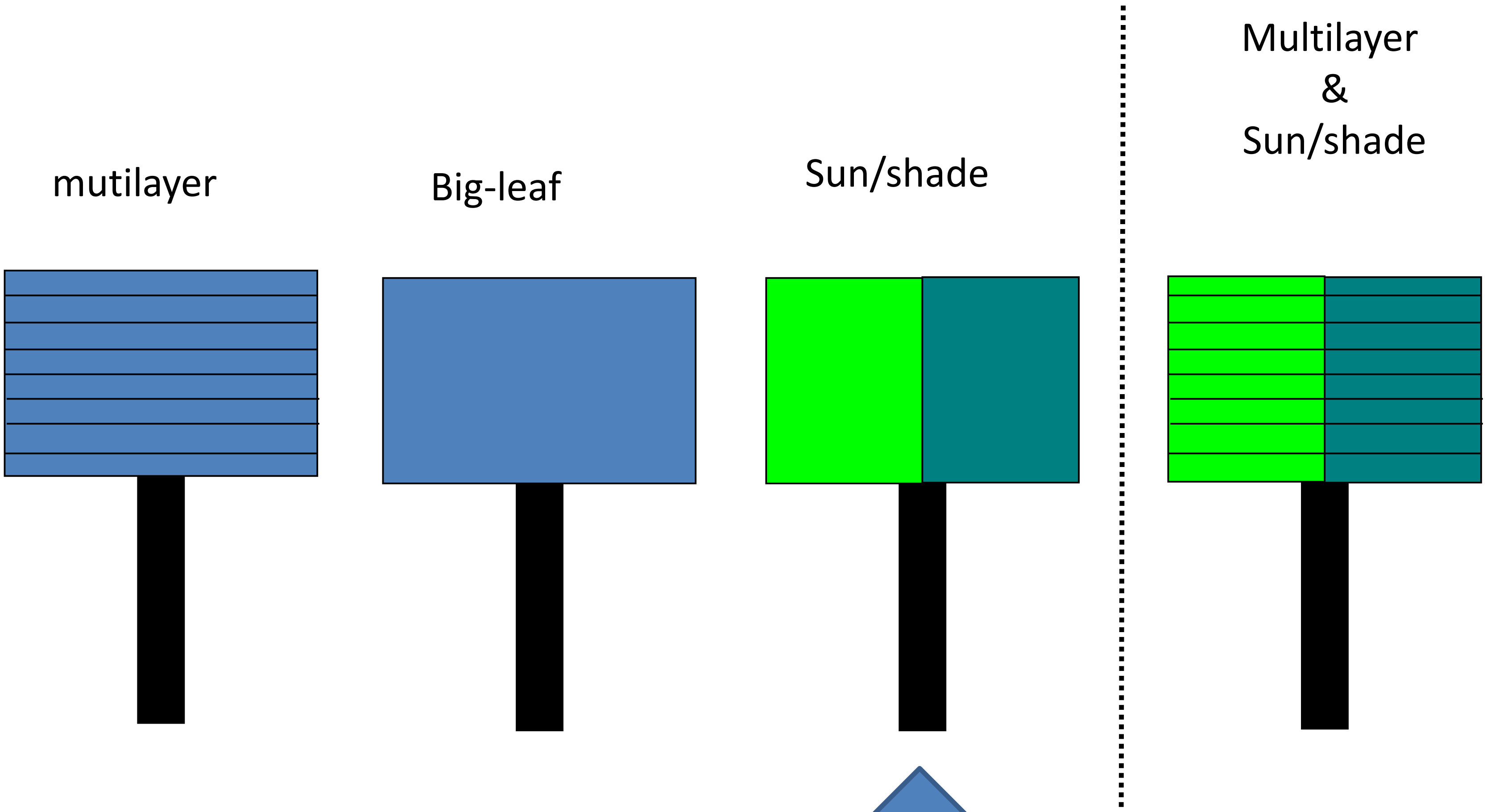
$$GPP = \min\,(W_c, W_j) - R_d$$

Sunlit Leaf

Shaded Leaf

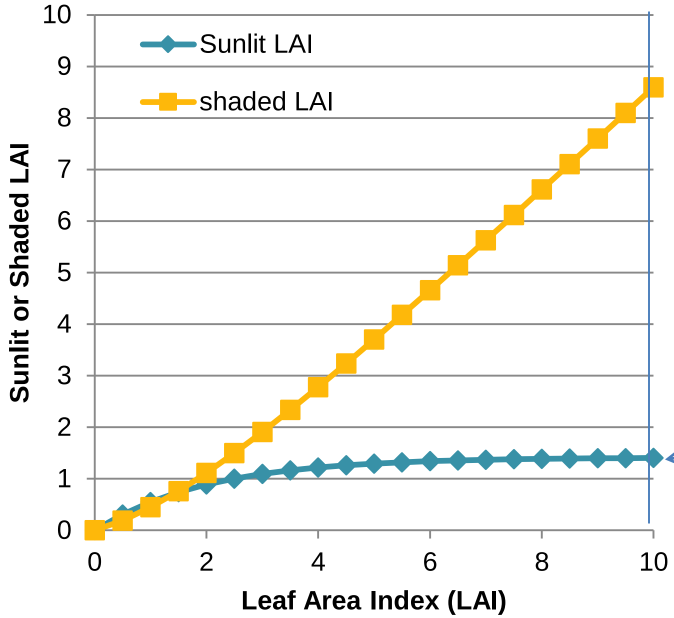
W_c and W_j are temperature/nutrient-limited and light-limited gross photosynthesis rates

Scaling from leaf to canopy



$$GPP = GPP_{sun} L_{sun} + GPP_{shaded} L_{shaded}$$

Importance of Shaded Leaves

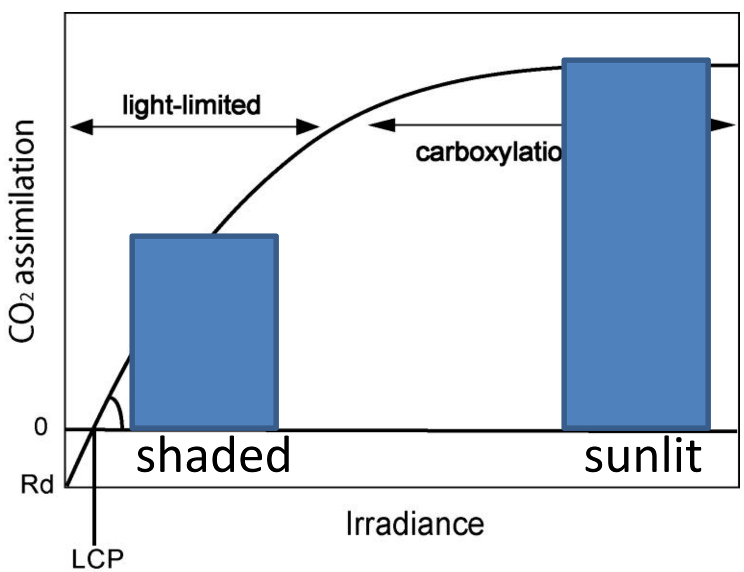


$$L_{sun} = \frac{\cos\theta}{G(\theta)}[1 - e^{-G(\theta)L\Omega/\cos\theta}]$$

$$L_{shaded} = L - L_{sun}$$

Assuming Ω=0.7 and θ=45º

Although GPP of shaded leaves is 2-3 times lower than that of sunlit leaves, shaded LAI may be 2-3 times more than sunlit LAI.



Assimilation of SMAP soil moisture for improving BEPS performance

g: stomatal conductance

A: net photosynthesis rate

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

f_w = f(**soil moisture in root zone)**

$\Updownarrow$

Ensemble Kalman filter (EnKF)

$\Uparrow$

SMAP L2 soil moisture

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The design of experiment

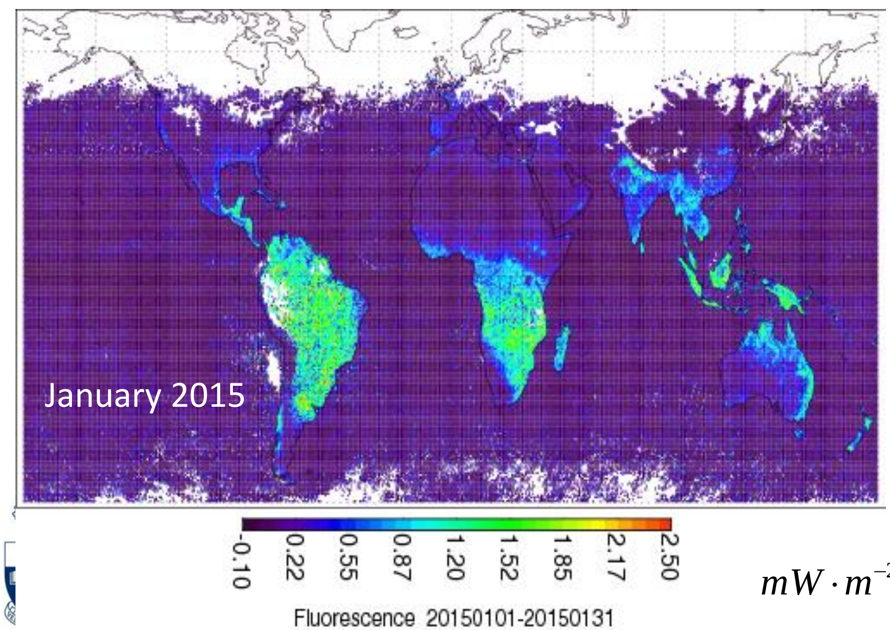
Start with the same initial status

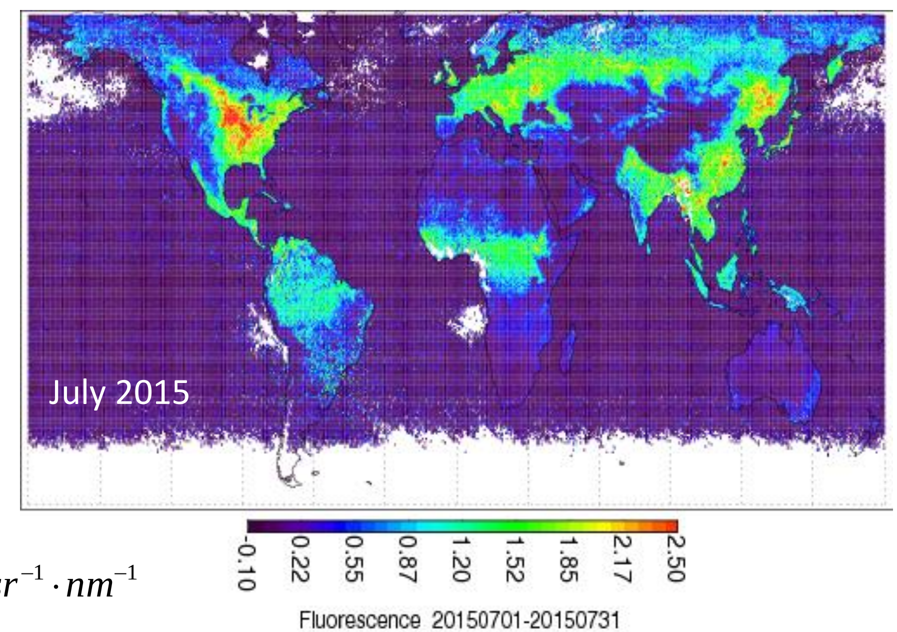
Open-loop run (w/o SMAP)

EnKF run (w. SMAP)

Compare with SIF data
temporal correlation (r)

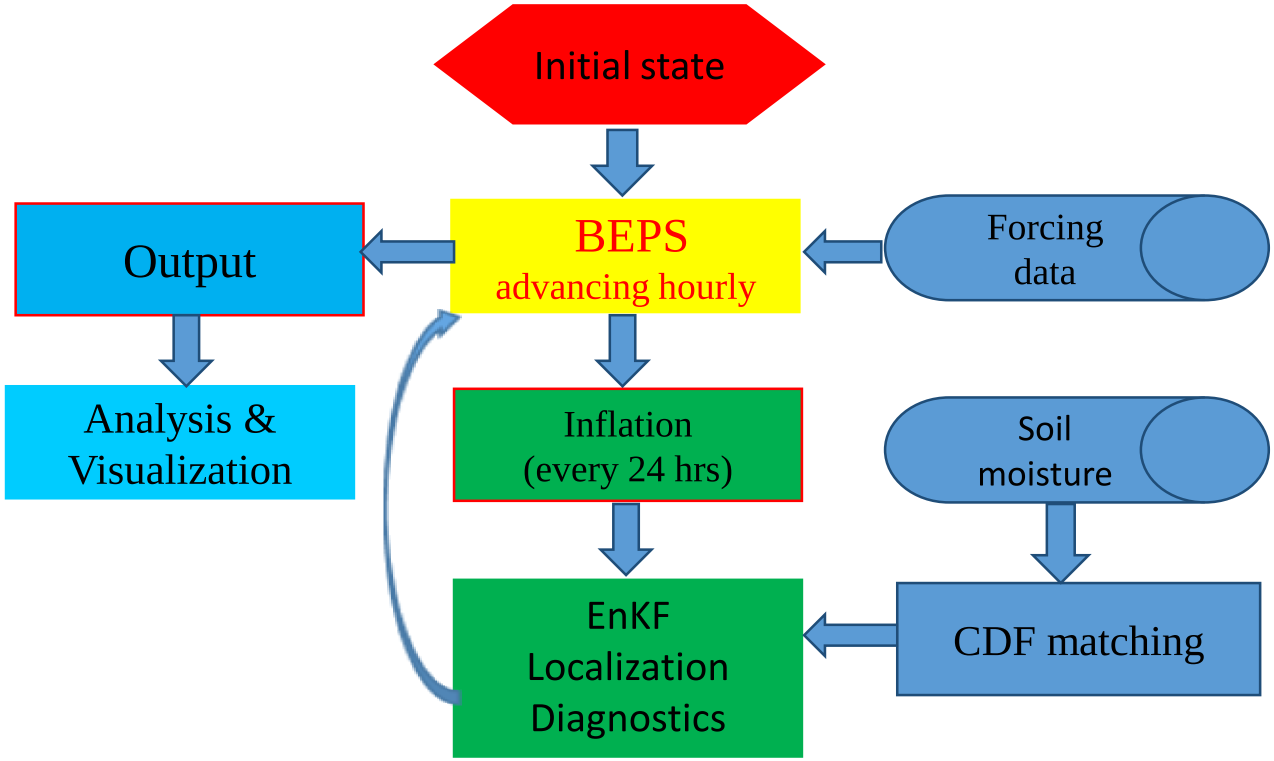
Solar-Induced chlorophyll Fluorescence (SIF) from GOME-2





$mW \cdot m^{-2} \cdot sr^{-1} \cdot nm^{-1}$

Data Assimilation of soil Moisture in Parallel (DAMP)



Liming He, Jing M. Chen, Jane Liu, Stéphane Bélair, Holly Croft, Xiangzhong Luo, Gang Mo, Bin Chen, A Parallel Package for Data Assimilation of Soil Moisture into a Land Surface Model, submitted to *Environmental Modelling & Software*

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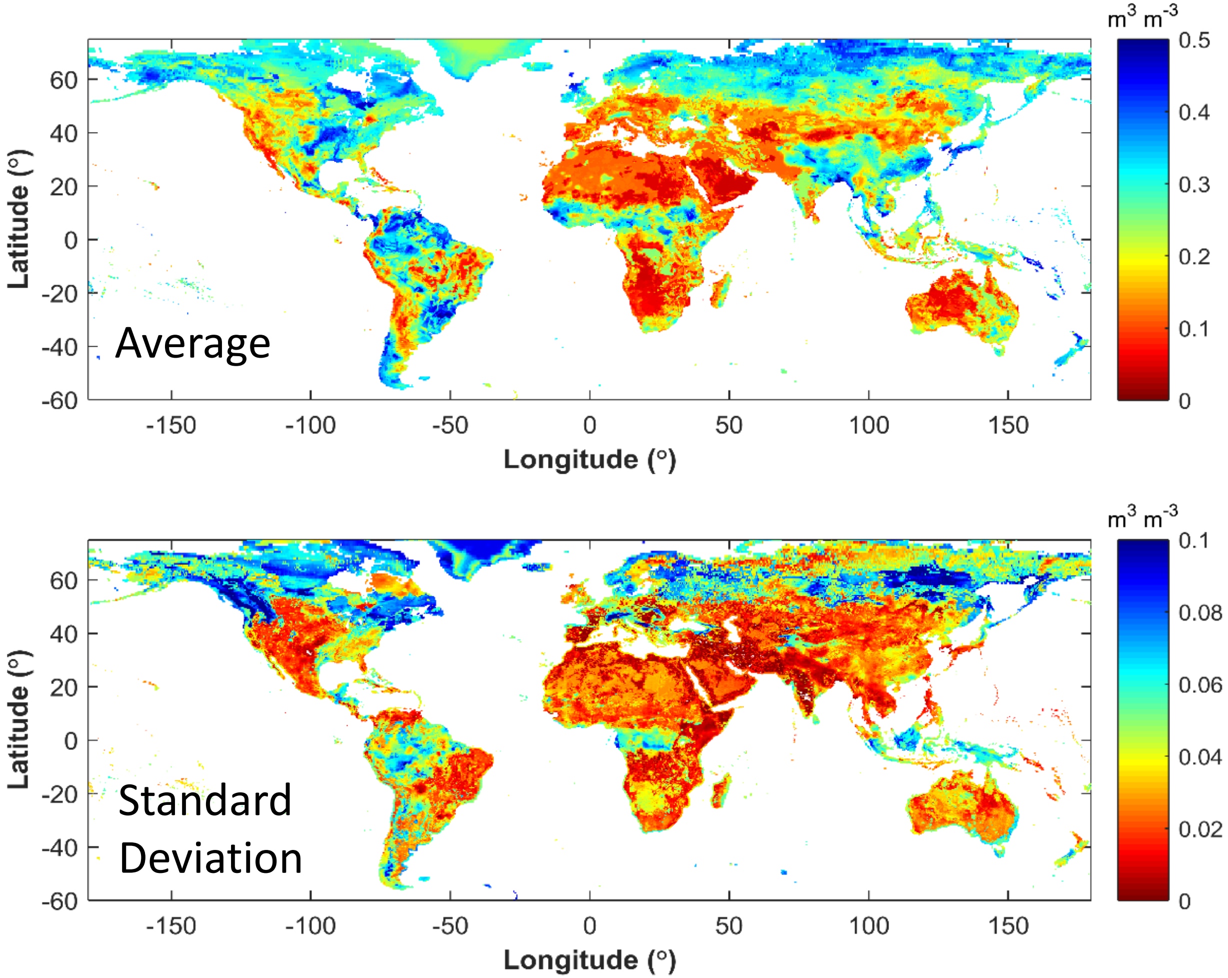
Global Datasets for GPP simulation

- Leaf Area Index (10 days), 2015
- Clumping index (2006)
- Met. (MERRA2 re-analysis data from GSFC,hourly)
- Other parameters (Vcmax, C3/C4, soil texture et al.)

- SMAP L2 soil moisture in 36 km (2-3 days, 2015)
- GOME-2 SIF data in 40 km resolution (monthly, 2015)

- Data assimilation (DAMP) conducted with the general purpose cluster in SciNET
- ~3000 CPU-hours for 100 BEPS replicates per experiment

Example: Surface Soil Moisture Estimates in DAMP
at a given time step (at 11 am, July 7, 2015)



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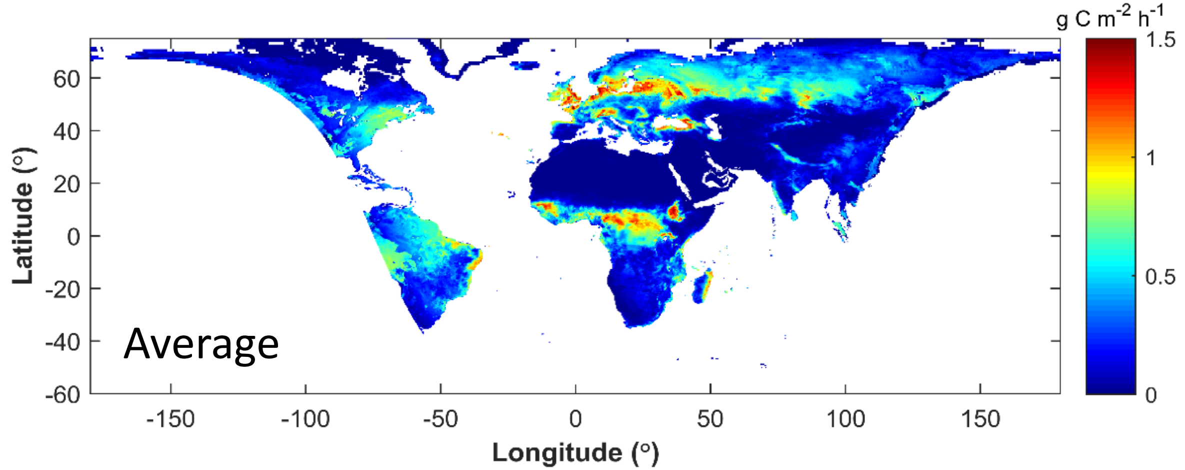
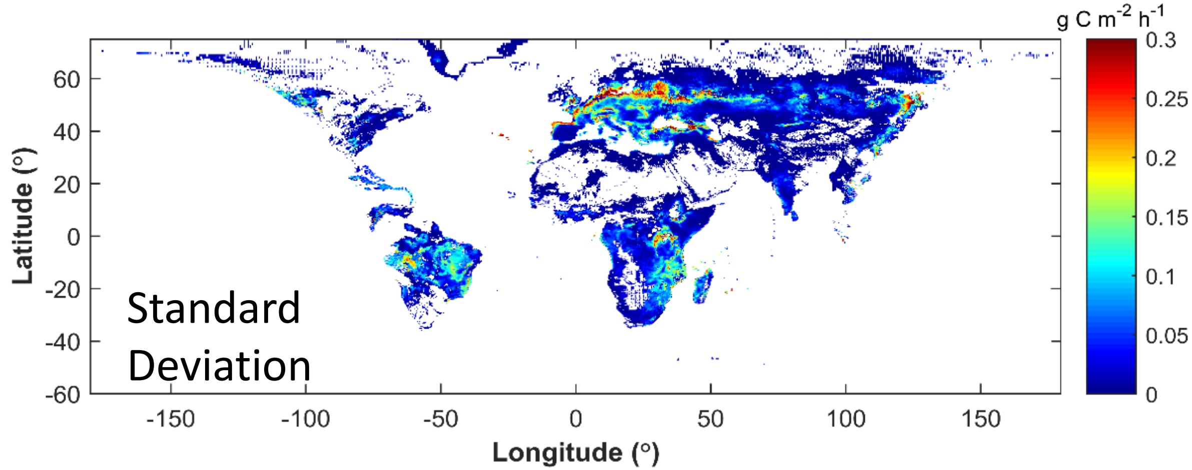
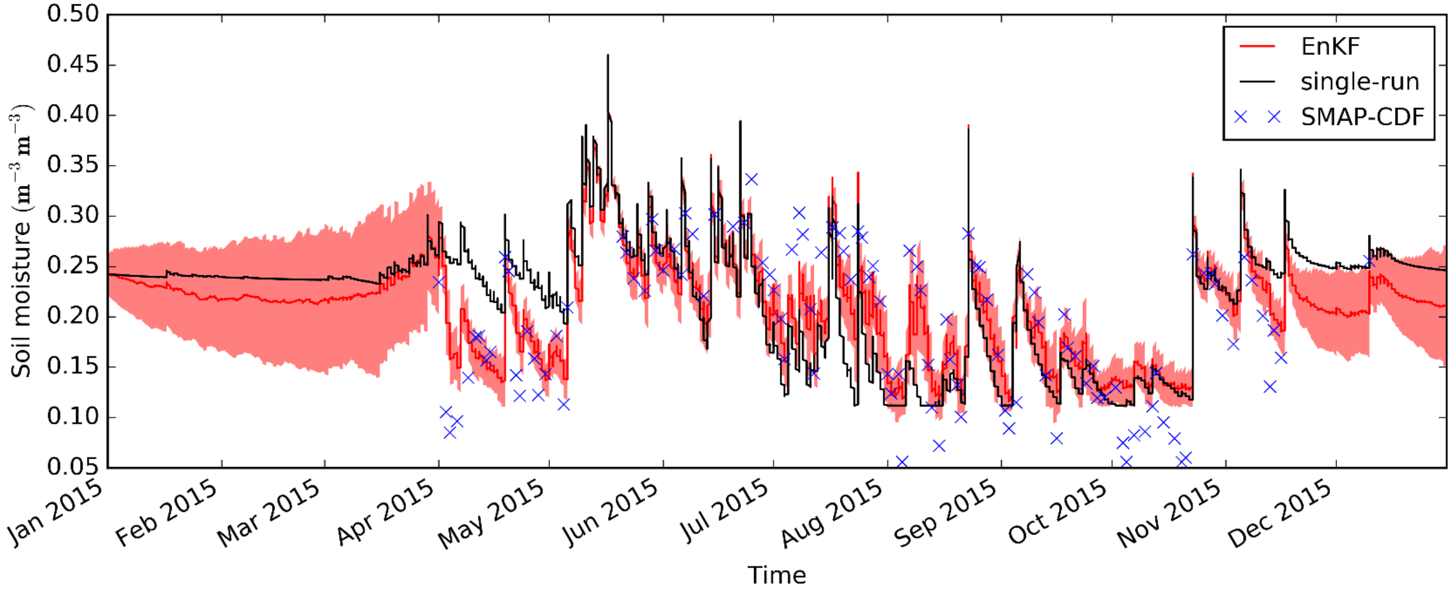
Example: GPP in DAMP
at a given time step (at 11 am, July 7, 2015)





The simulation of soil moisture in top layer (5 cm)
by EnKF and a single-run for a pixel in Canada
(47.3233N, 98.0290W)



"SMAP-CDF" indicates the SMAP soil moisture that has been adjusted using the CDF matching approach. The red background color indicates one standard deviation of soil moisture simulated from the EnKF

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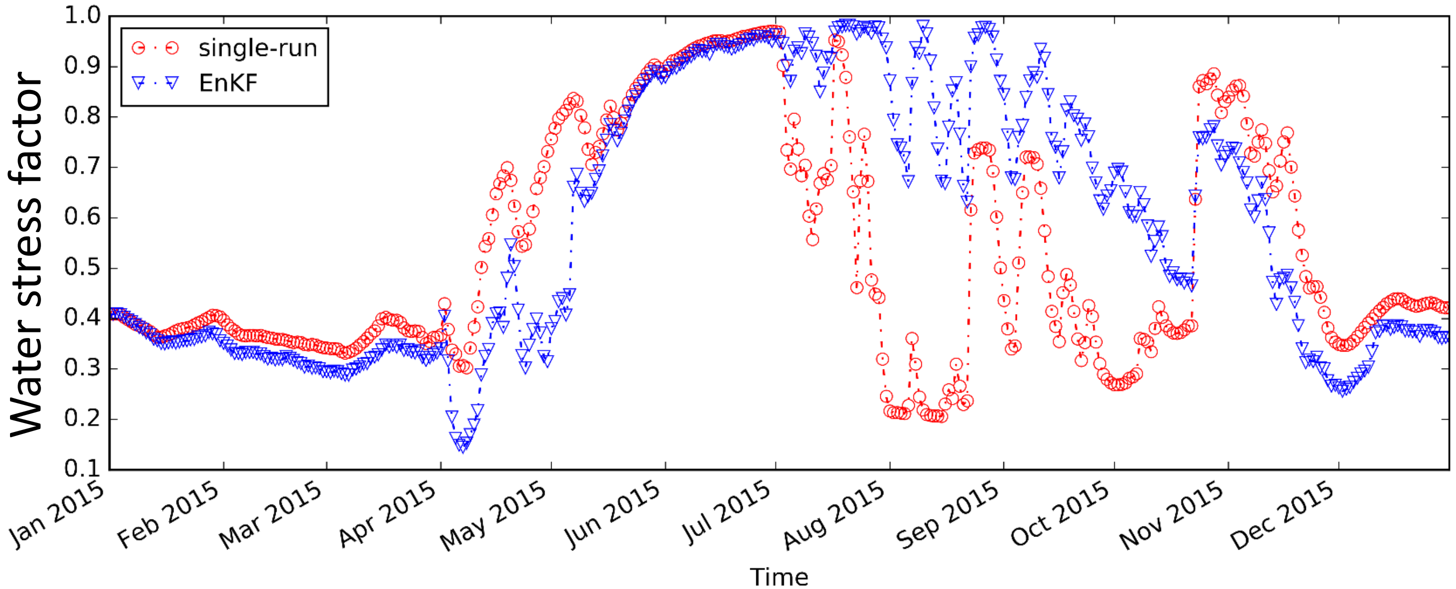
Soil water stress factor (f_w)
by EnKF and single-run for a pixel in Canada (47.3233N, 98.0290W)



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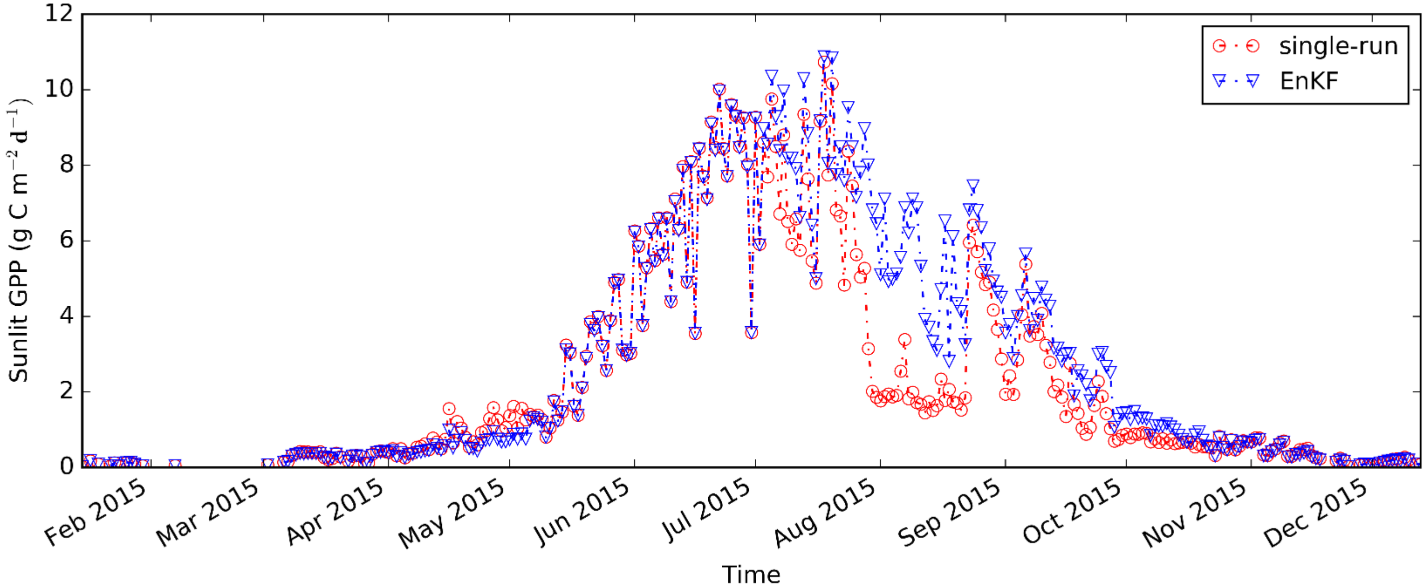
Time series of sunlit GPP estimates
by EnKF and single-run for a pixel in Canada
(47.3233N, 98.0290W)



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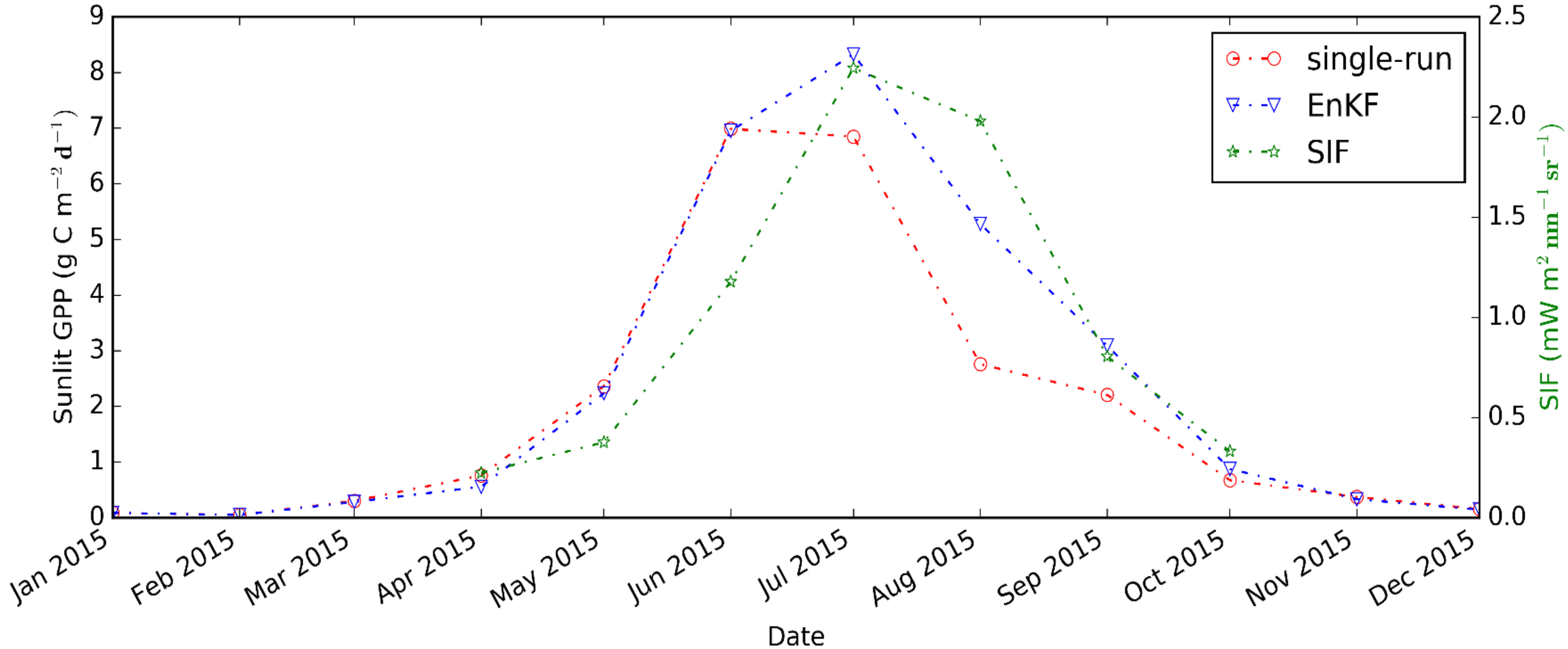
Monthly time series of SIF, sunlit GPP estimates
by EnKF and single-run for a pixel in Canada
(47.3233N, 98.0290W)



The left y-axis indicates the monthly-averaged daily sunlit-GPP estimation. The overestimation of sun-GPP in early growth season may be attributed to a constant Vcmax value used in the model.

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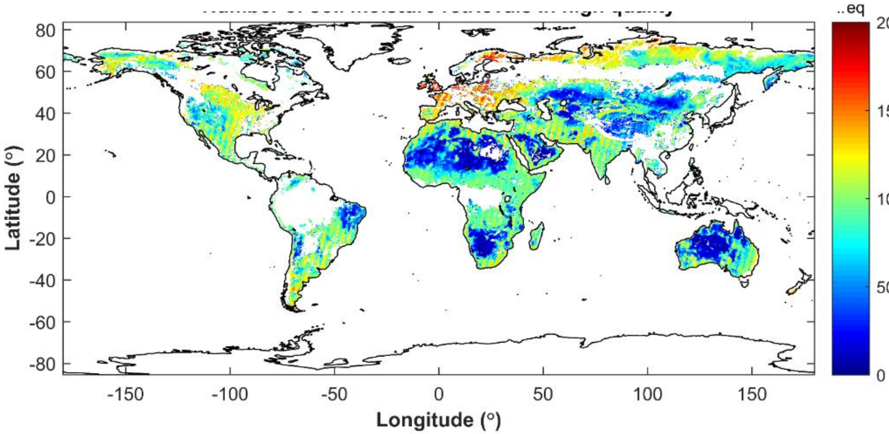
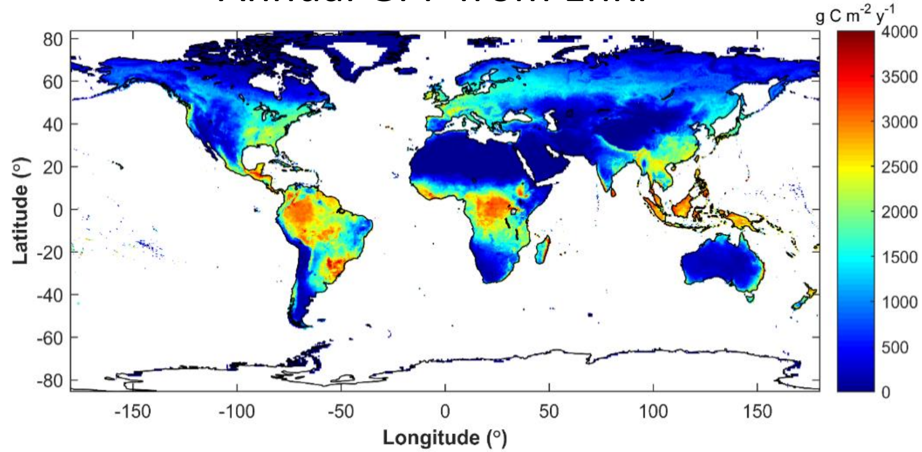
Evaluation of model improvement from data assimilation in 2015

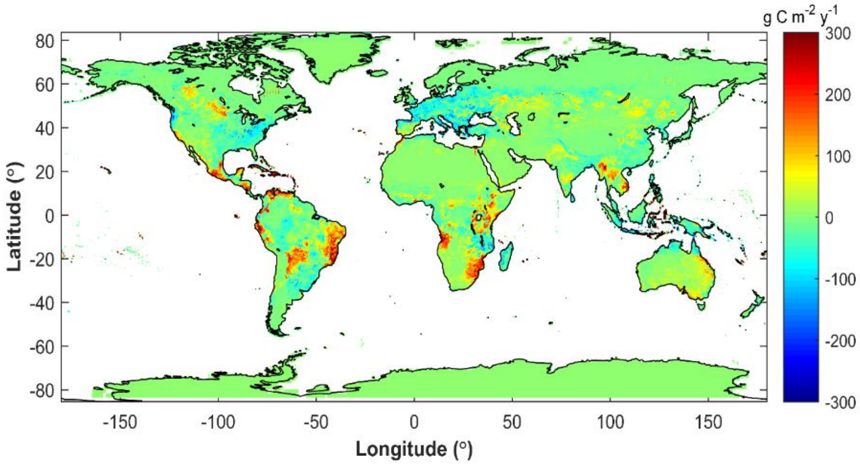
No. of SM retrievals with high quality



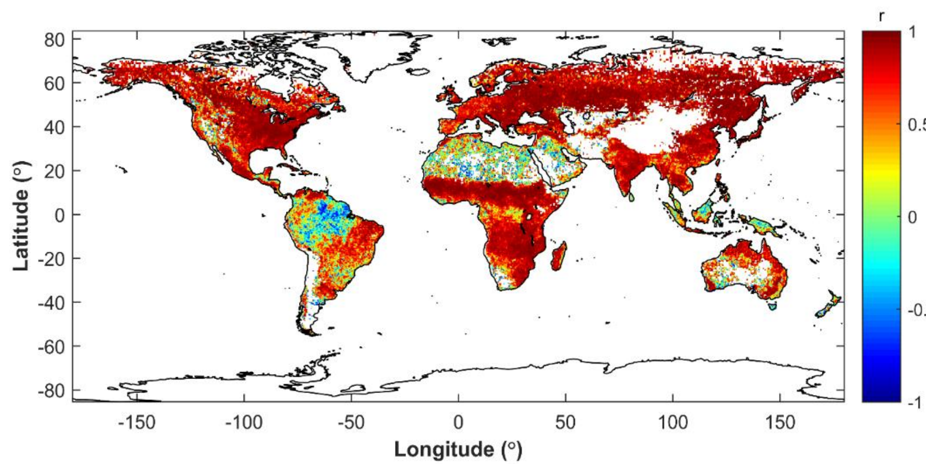
Annual GPP from EnKF



GPP diff. between EnKF and ref. runs



r between SIF and EnKF-GPP



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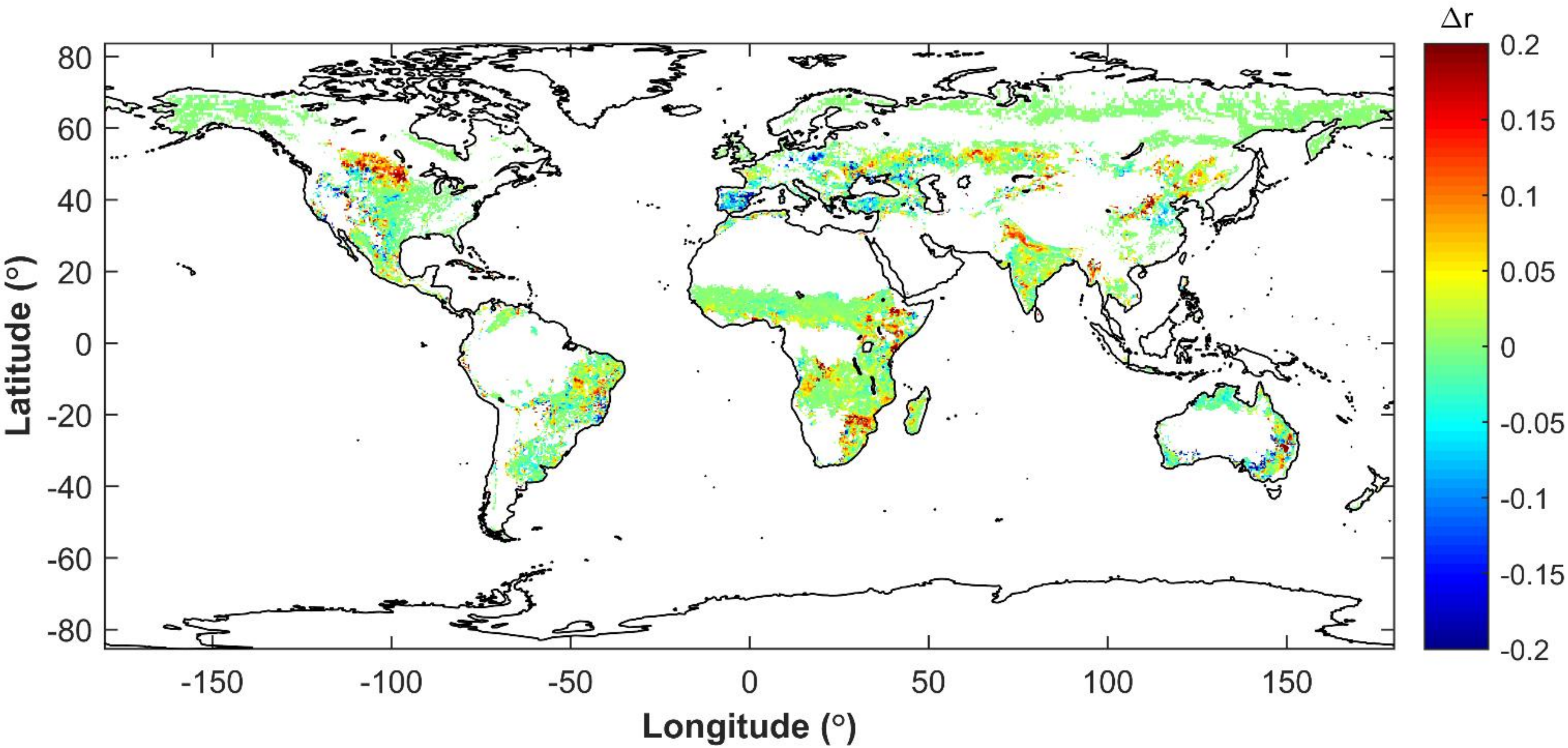
The Δr (SIF vs. Sunlit GPP) between EnKF and single-run

Positive values indicate that the simulation of sunlit GPP is improved after assimilating SMAP data.



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Change in the correlation coefficient (Δr) between SIF and sunlit GPP after using SMAP soil moisture for data assimilation

	Asia	North America	Europe	Africa	South America	Australia	All continents
Evergreen Needle-leaf trees	0.0%	-0.9%	-0.2%				-0.6%
Evergreen Broadleaf trees	3.6%**	-0.4%		1.6%*	0.6%		1.5%*
Deciduous Needle-leaf trees	0.1%						0.1%
Deciduous Broadleaf trees	3.5%**	0.9%	1.1%	2.0%**	-0.6%	-0.7%	1.6%**
Shrub	0.0%	0.0%	-1.9%	2.0%**	1.2%*	0.8%	0.5%*
Grass	1.3%**	0.1%	-0.7%	1.7%**	0.4%*	-0.6%	0.9%*
Cereal crops	2.2%**	9.0%**	-0.8%	0.3%*	-0.7%	-0.2%	1.5%**
Broad-leaf crops	2.3%**	0.8%*	-0.3%	1.1%*	-0.9%		1.0%*
All Land cover	1.3%**	1.3%**	-1.2%	1.6%**	0.3%*	0.1%	1.0%*

Note: The mark "*" or "**" indicates that the t-test for the improvement with SMAP data assimilation is significant at the 5% or 1% level.

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Summary of the improvements from data assimilation

Regions	Significance of improvement (Δr)	Reasons
Global land surface	No significant improvement (0.01).	Use of gauge-corrected precipitation in reanalysis forcing data; Bias in SMAP data and short data period for CDF correction; Large areas without water stress.
Cropland in single-cropping system	Significant improvement (0.09 in North America, 0.02 in Asia)	Strong SIF variation for validation; explanation of irrigation practices in SMAP product.
Cropland in multi-cropping system	None or negative improvement	Errors due to the use of constant Vcmax value across seasons.
Shrubland	Minor improvement (0.02 in Africa, 0.01 in South America)	Low SIF variation; use of gauge-corrected precipitation.
Grassland	Minor improvement (0.02 in Africa, 0.01 in Asia)	Low SIF variation; use of gauge-corrected precipitation.
Mountain	None or negative improvement	Low soil moisture accuracy but not masked in the product.
Tundra	No improvement	Water is usually not a stress factor in these area.
Forest	No evaluation except some sparse forests in Africa and mixed forests in Asia	Limited number of soil moisture in high quality due to high vegetation water content.

Conclusion

- Improvements in GPP estimation from SMAP data assimilation vary among land cover types and regions
- Significant improvement is found in the single-cropping agricultural land (irrigation is captured by SMAP)
- Limited usefulness for tropical, temperate and boreal forests
- Further improvement is possible

Thanks!

Questions?

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Acknowledgement:

CSA ASC

Environment and Climate Change Canada
Environnement et Changement climatique Canada

SciNet

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