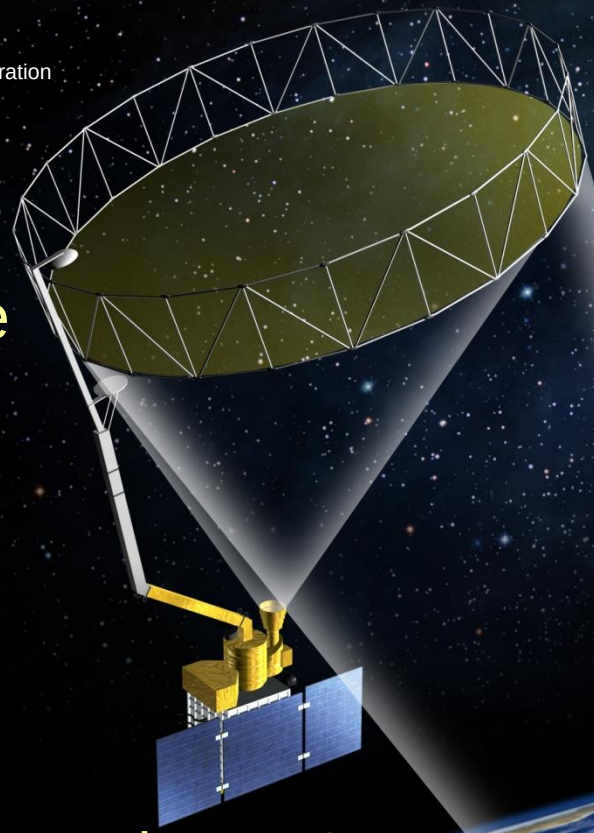
National Aeronautics and Space Administration

Soil Moisture Active Passive Mission

SMAP



Regularized Dual-Channel Algorithm

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Outline

- Motivation
- Tau-omega model overview and mixed dual-channel algorithm (MDCA)
- T16100 (OASIS) test results
- Regularized dual-channel algorithm (RDCA)
  - Implementation
  - First results
- Conclusion

Motivation

DCA cost function (Currently in the product):

$$F = \underbrace{(TBV_{obs} - TBV_{model})^2}_{\text{SCAV}} + \underbrace{(TBH_{obs} - TBH_{model})^2}_{\text{SCAH}}$$

Regularized DCA (RDCA) cost function:

$$F = \frac{(TBV_{obs} - TBV_{model})^2}{dtv^2} + \frac{(TBH_{obs} - TBH_{model})^2}{dth^2} + \lambda^2(tau - tau^*)^2$$

tau* is a priori estimated tau

- RDCA results depend strongly on a good estimation of *tau**
- Estimation of *tau** based on DCA tau requires improvement of DCA algorithm

Tau-Omega Model

- In the tau- omega model the roughness effects are introduced by the reflectivity equation

$$\Gamma_p(\theta) = \left[(1-Q)\Gamma_p^*(\theta) + Q\Gamma_q^*(\theta)\right]e^{\left(-hcos^N(\theta)\right)}$$

where $\Gamma_p^*(\theta)$ is the smooth surface reflectivity for the polarization *p* or *q*

- Current Q-h model : $h = 0.01s$, *s* is the root-mean-square of the surface height, $Q = 0, N = 2$

- In this presentation we show results obtained by the use of a new roughness model (mixed double channel algorithm - MDCA) and a modified omega parameter

$$h = \left(\frac{0.9437s}{0.8865s+2.2913}\right)^6 \text{ , } Q = 0.1771h \text{ , } N = 2.$$

References

J. Wigneron, A. Chanzy, Y. Kerr, H. Lawrence, J. Shi, M. Escorihuela, V. Mironov, A. Mialon, F. Demontoux, P. de Rosnay, and K. Saleh- Contell, "Evaluating an improved parameterization of the soil emission in L-MEB," *IEEE*

Lawrence, H., Wigneron, J. -P., Demontoux, F., Mialon, A., & Kerr, Y. H. (2013). Evaluating the semiempirical H - Q model used to calculate the L-band emissivity of a rough bare soil. IEEE Transactions on Geoscience and Remote Sensing, 51(7), 4075–4084.

Zheng Donghai , Wang Xin , Van Der Velde, Rogier, Ferrazzoli P, Wen Jun, Wang Zuoliang, Schwank Mike , Colliander Andreas , Bindlish Rajat , Su Bob. (2018). Impact of surface roughness, vegetation opacity and soil permittivity on L-band microwave emission and soil moisture retrieval in the third pole environment. Remote Sensing of Environment. 209. 10.1016/j.rse.2018.03.011.

Q-h Parameters

Current product

$s = 100h$

Site	Land type	Q	h	s (mm)	new Q	new h
ReynoldsCreek	Grasslands	0	0.15567	15.567	0.10	0.58
WalnutGulch	Shrub open	0	0.1312	13.12	0.08	0.50
TxSON	Grasslands	0	0.156	15.6	0.10	0.58
FortCobb	Grasslands	0	0.153	15.3	0.10	0.57
LittleWashita	Grasslands	0	0.156	15.6	0.10	0.58
SouthFork	Croplands	0	0.108	10.8	0.07	0.40
LittleRiver	Cropland/natural mosaic	0	0.1286	12.86	0.085	0.48
Kenaston	Croplands	0	0.1093	10.93	0.07	0.40
Carman	Croplands	0	0.108	10.8	0.07	0.40
MonteBuey	Croplands	0	0.108	10.8	0.07	0.40
REMEDHUS	Croplands	0	0.108	10.8	0.07	0.40
Yanco	Grasslands	0	0.13	13	0.08	0.49

Omega

Site	Land type	Current Omega	New Omega
ReynoldsCreek	Grasslands	0.05	0.09
WalnutGulch	Shrub open	0.05	0.09
TxSON	Grasslands	0.05	0.09
FortCobb	Grasslands	0.05	0.09
LittleWashita	Grasslands	0.05	0.09
SouthFork	Croplands	0.05	0.062
LittleRiver	Cropland/natural mosaic	0.062521	0.14
Kenaston	Croplands	0.05062	0.062
Carman	Croplands	0.05	0.062
MonteBuey	Croplands	0.05	0.062
REMEDHUS	Croplands	0.05	0.062
Yanco	Grasslands	0.05	0.09

Multi-Temporal Dual Channel Algorithm (MTDCA)

Global albedo map

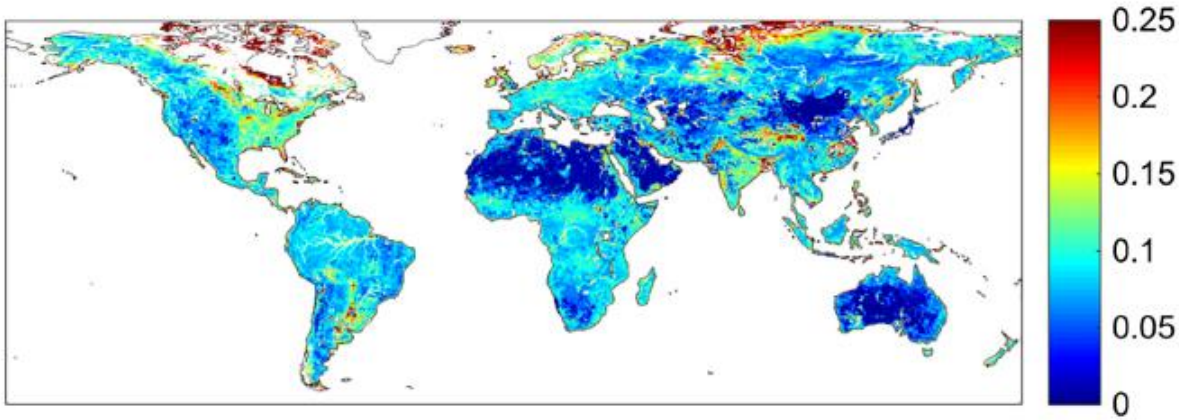


Fig. 5. Retrievals of the effective scattering albedo ω (dimensionless) based on one year of SMAP radiometer measurements and the multi-temporal dual-channel algorithm.

Author provided omega at coresite locations for comparison with our tuned omegas

Reference

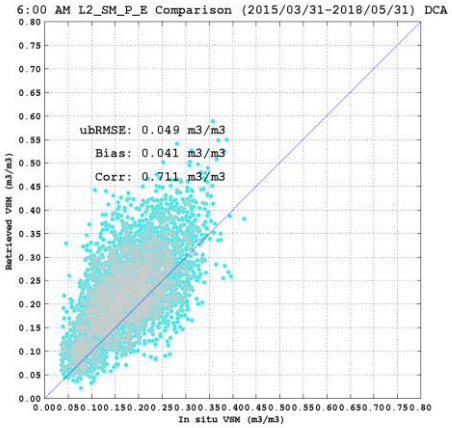
L-band vegetation optical depth and effective scattering albedo estimation from SMAP. Konings, Alexandra G, Piles, Maria, Das, Narendra, Entekhabi, Dara

Omega

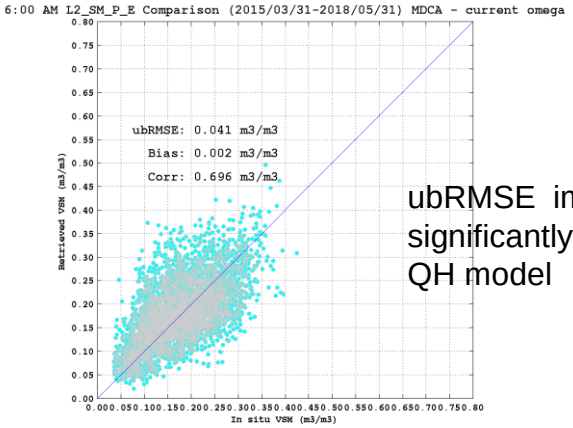
Site	Land type	Current Omega	Tuned Omega	MTDCA
ReynoldsCreek	Grasslands	0.05	0.09	0.08
WalnutGulch	Shrub open	0.05	0.09	0.11
TxSON	Grasslands	0.05	0.09	0.08
FortCobb	Grasslands	0.05	0.09	0.10
LittleWashita	Grasslands	0.05	0.09	0.08
SouthFork	Croplands	0.05	0.062	0.20
LittleRiver	Cropland/natural mosaic	0.062	0.14	0.16
Kenaston	Croplands	0.05	0.062	0.35
Carman	Croplands	0.05	0.062	0.22
MonteBuey	Croplands	0.05	0.062	0.062
REMEDHUS	Croplands	0.05	0.062	0.08
Yanco	Grasslands	0.05	0.09	0.09

Q-h-Omega Evaluation

Baseline DCA

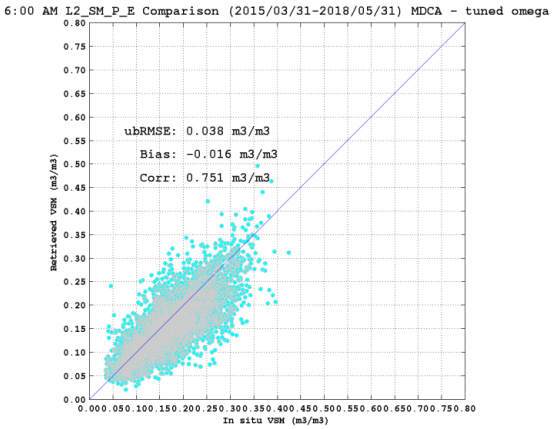


MDCA with current Omega



ubRMSE improves significantly with new QH model

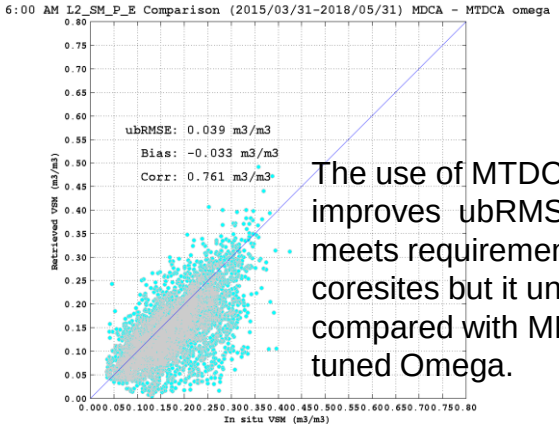
MDCA with tuned Omega



By tuning Omega we improve ubRMSE which meets requirement over coresites

SouthFork	0.049	-0.063	0.080	0.637
Carman	0.060	-0.066	0.089	0.504

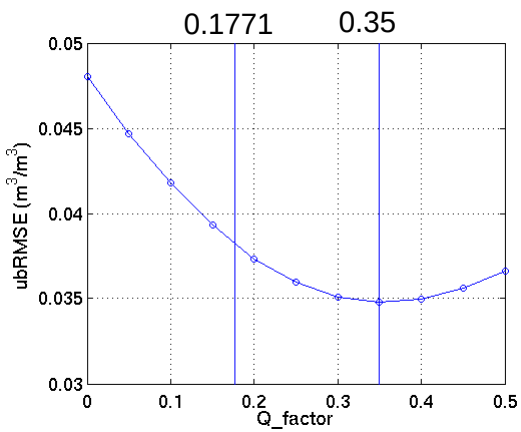
MDCA with MTDCA Omega

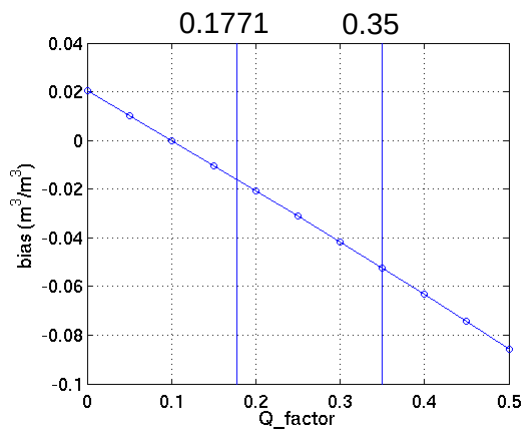


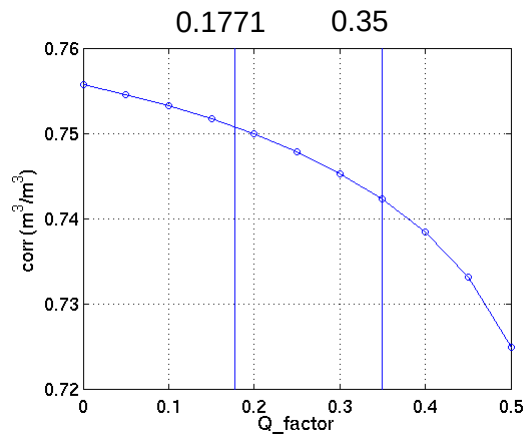
The use of MTDCA Omega improves ubRMSE which meets requirement over coresites but it underperforms compared with MDCA and tuned Omega.

SouthFork	0.058	-0.115	0.129	0.606
Carman	0.067	-0.114	0.132	0.506

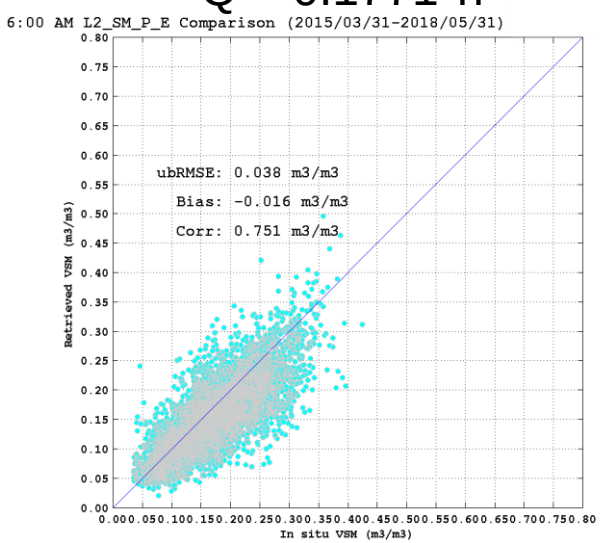
Q = factor*h



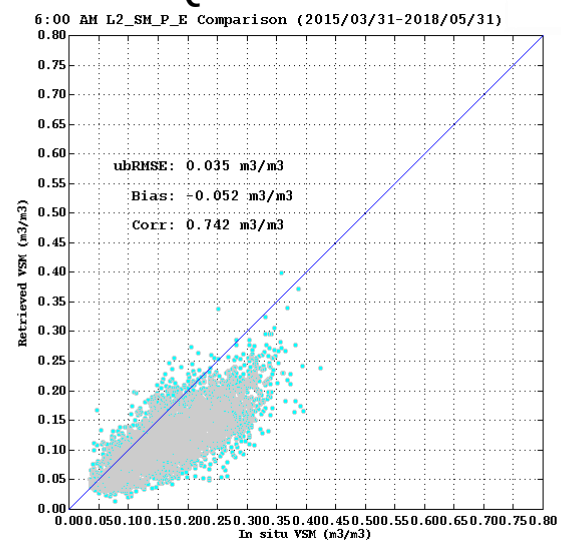




Q = 0.1771*h



Q = 0.35*h



OASIS Test of Q-h New Model

- The Q-h model was incorporated into the L2_SM_P_E code and tested on OASIS.
- 38 months of data were generated (T16100)
- We compared the data with T16010 (new soil texture)
- Current Q-h model : $h = 0.01s, Q = 0$, s is the root-mean-square of the surface height
- New model (mixed double channel algorithm - MDCA):

$$h = \left(\frac{0.9437s}{0.8865s+2.2913}\right)^6 \qquad Q = 0.1771h$$

References

J. Wigneron, A. Chanzy, Y. Kerr, H. Lawrence, J. Shi, M. Escorihuela, V. Mironov, A. Mialon, F. Demontoux, P. de Rosnay, and K. Saleh- Contell, “Evaluating an improved parameterization of the soil emission in L-MEB,” *IEEE*

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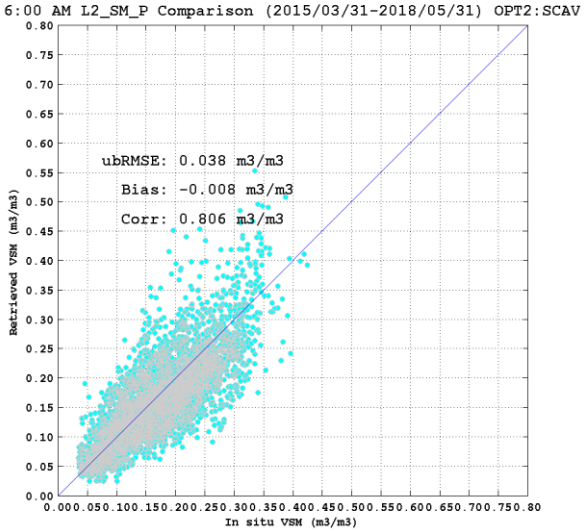
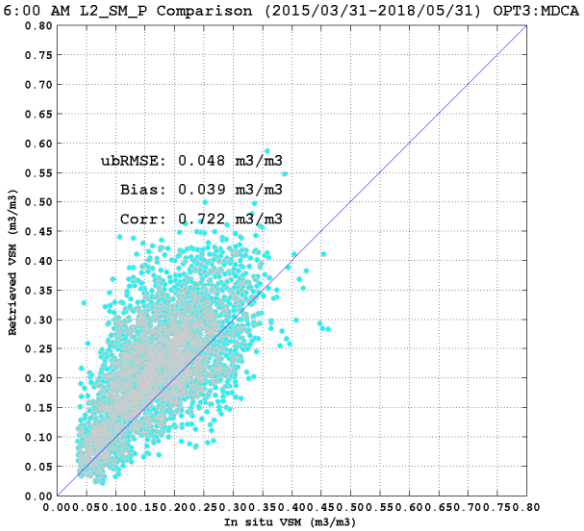
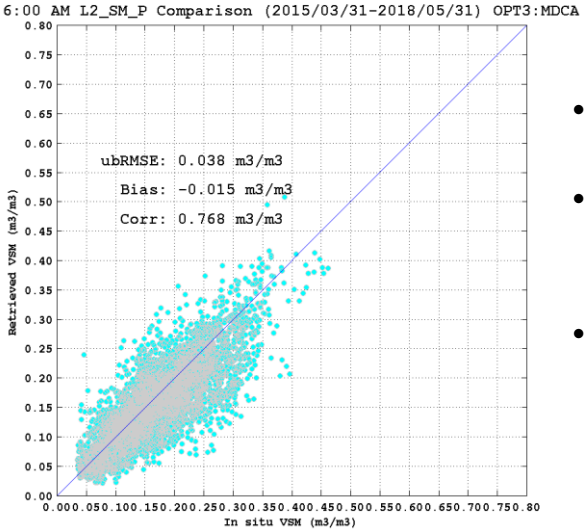
Results

T1601





T16100



- SCAV and MDCA get the same ubRMSE
- SCAV results in smaller bias and higher correlation
- MDCA shows less scatter at higher sm values

Results at Coresites

T16010

9 Coresites satisfy the 0.040 requirement

	ubrmse	bias	rmse	rho
ReynoldsCreek_04013302	0.040	-0.023	0.046	0.638
WalnutGulch_16013302	0.024	0.021	0.032	0.835
TxSON_48013301	0.032	-0.007	0.033	0.941
FortCobb_16033302	0.028	-0.044	0.052	0.881
LittleWashita_16023302	0.022	-0.014	0.026	0.913
SouthFork_16073302	0.055	-0.049	0.073	0.670
LittleRiver_16043305	0.036	0.066	0.075	0.792
Kenaston_27013301	0.027	0.012	0.030	0.799
Carman_09013311	0.066	-0.049	0.082	0.588
MonteBuey_19023301	0.049	-0.012	0.050	0.838
REMEDHUS_03013302	0.037	-0.007	0.037	0.852
Yanco_07013301	0.035	0.011	0.036	0.926
***** AVERAGE OPT2:SCAV *****	0.038	-0.008	0.048	

No coresites satisfy the 0.040 requiremen

	ubrmse	bias	rmse	rho	
ReynoldsCreek_04013302	0.054	0.023	0.059	0.591	141.000
WalnutGulch_16013302	0.042	0.056	0.070	0.817	183.000
TxSON_48013301	0.041	0.091	0.099	0.842	349.000
FortCobb_16033302	0.044	0.012	0.046	0.809	417.000
LittleWashita_16023302	0.043	0.059	0.073	0.813	397.000
SouthFork_16073302	0.055	-0.023	0.060	0.628	265.000
LittleRiver_16043305	0.049	0.149	0.157	0.599	420.000
Kenaston_27013301	0.041	0.063	0.075	0.582	188.000
Carman_09013311	0.069	-0.025	0.073	0.510	250.000
MonteBuey_19023301	0.043	0.003	0.043	0.778	196.000
REMEDHUS_03013302	0.050	0.020	0.053	0.828	338.000
Yanco_07013301	0.049	0.044	0.066	0.863	289.000
***** AVERAGE OPT3:MDCA *****	0.048	0.039	0. 73	0.722	

T16100

9 Coresites satisfy the 0.040 requirement

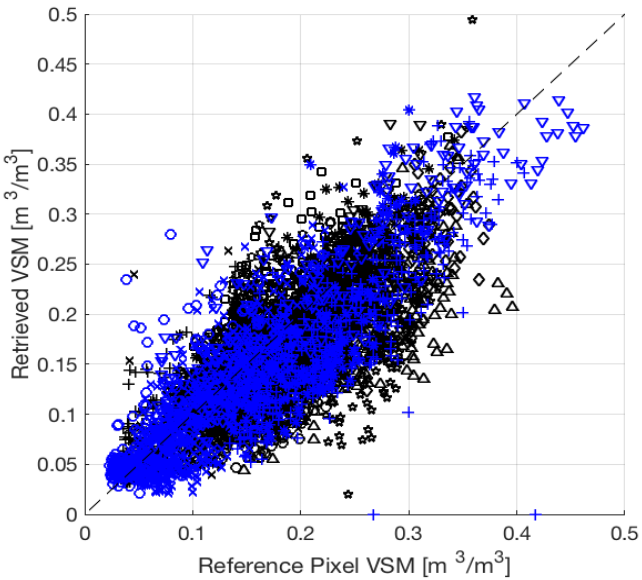
	ubrmse	bias	rmse	rho	
ReynoldsCreek_04013302	0.044	-0.020	0.049	0.602	141.000
WalnutGulch_16013302	0.030	0.024	0.038	0.828	183.000
TxSON_48013301	0.032	0.009	0.033	0.902	356.000
FortCobb_16033302	0.031	-0.043	0.053	0.866	419.000
LittleWashita_16023302	0.030	-0.010	0.032	0.860	402.000
SouthFork_16073302	0.049	-0.064	0.081	0.646	265.000
LittleRiver_16043305	0.032	0.015	0.036	0.816	420.000
Kenaston_27013301	0.036	0.021	0.041	0.611	188.000
Carman_09013311	0.060	-0.064	0.087	0.524	250.000
MonteBuey_19023301	0.036	-0.041	0.054	0.803	197.000
REMEDHUS_03013302	0.038	-0.007	0.039	0.830	339.000
Yanco_07013301	0.037	0.005	0.037	0.934	309.000
***** AVERAGE OPT3:MDCA *****	0.038	-0.015	0.048	0.768	

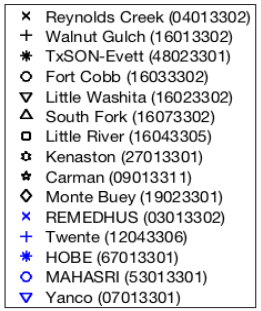
L2_SM_PE-Opt 3 (T16100-199)

2015/04/01 - 2018/11/05

Performance Metrics: DCA

Ref Pixel	ubRMSE	Bias	RMSE	R	Slope	N
Reynolds Creek (0401-33-02)	0.044	-0.020	0.049	0.601	0.580	141
Walnut Gulch (1601-33-02)	0.030	0.022	0.038	0.829	1.432	193
TxSON-Evett (4802-33-01)	0.028	-0.003	0.028	0.890	0.975	434
Fort Cobb (1603-33-02)	0.032	-0.047	0.057	0.856	0.999	474
Little Washita (1602-33-02)	0.029	-0.011	0.031	0.865	1.034	444
South Fork (1607-33-02)	0.049	-0.062	0.079	0.640	0.614	282
Little River (1604-33-05)	0.032	0.012	0.035	0.806	0.962	479
Kenaston (2701-33-01)	0.036	0.021	0.042	0.611	0.617	187
Carman (0901-33-11)	0.059	-0.066	0.089	0.525	0.717	251
Monte Buey (1902-33-01)	0.036	-0.041	0.054	0.804	0.929	197
REMEDHUS (0301-33-02)	0.038	-0.005	0.039	0.838	1.227	389
Twente (1204-33-06)	0.037	-0.047	0.060	0.879	1.036	348
HOBE (6701-33-01)	0.048	-0.048	0.068	0.775	1.344	117
MAHASRI (5301-33-01)	0.033	0.015	0.036	0.796	1.120	264
Yanco (0701-33-01)	0.037	0.005	0.038	0.929	0.874	341
MEAN:	**0.038**	**-0.018**	**0.049**	**0.776**	**1.022**	





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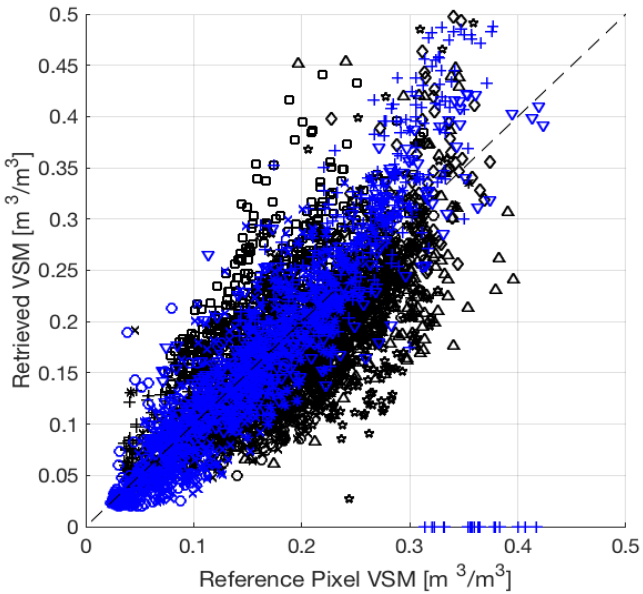
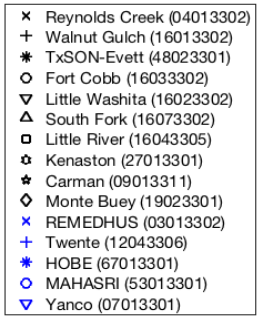
L2_SM_PE-Opt 2 (T16100-199)

2015/04/01 - 2018/11/05

Performance Metrics: SCA-V

Ref Pixel	ubRMSE	Bias	RMSE	R	Slope	N
Reynolds Creek (0401-33-02)	0.040	-0.023	0.046	0.638	0.485	141
Walnut Gulch (1601-33-02)	0.024	0.020	0.032	0.836	1.251	193
TxSON-Evett (4802-33-01)	0.022	-0.019	0.029	0.929	0.764	434
Fort Cobb (1603-33-02)	0.029	-0.047	0.055	0.876	0.992	474
Little Washita (1602-33-02)	0.021	-0.016	0.027	0.912	0.990	444
South Fork (1607-33-02)	0.054	-0.049	0.073	0.669	0.805	282
Little River (1604-33-05)	0.036	0.062	0.072	0.782	1.008	478
Kenaston (2701-33-01)	0.027	0.012	0.030	0.801	0.892	187
Carman (0901-33-11)	0.067	-0.054	0.086	0.562	0.918	251
Monte Buey (1902-33-01)	0.049	-0.012	0.050	0.838	1.362	193
REMEDHUS (0301-33-02)	0.038	-0.003	0.038	0.853	1.280	387
Twente (1204-33-06)	0.051	0.042	0.066	0.889	1.344	332
HOBE (6701-33-01)	0.036	0.002	0.036	0.860	1.330	117
MAHASRI (5301-33-01)	0.029	-0.003	0.029	0.809	0.951	187
Yanco (0701-33-01)	0.035	0.010	0.036	0.919	0.960	318
MEAN:	**0.037**	**-0.005**	**0.047**	**0.812**	**1.022**	





Andreas Colliander

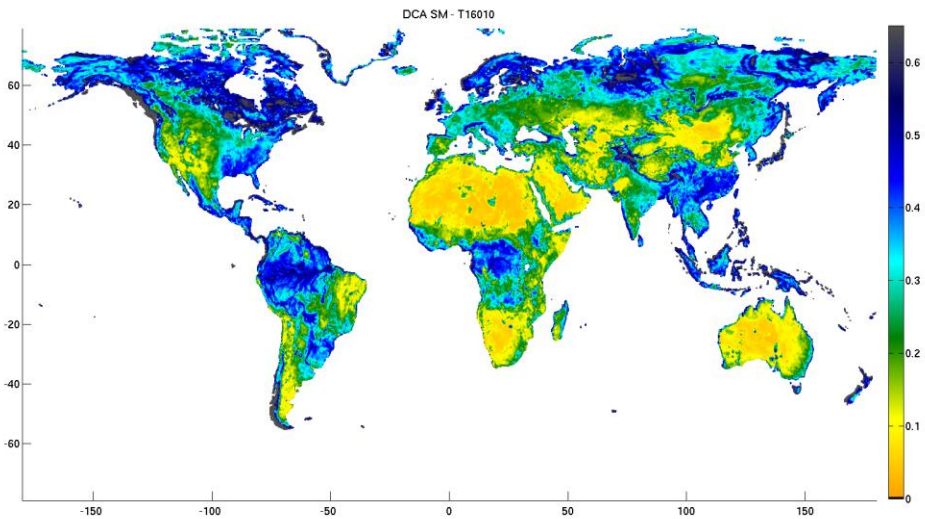
Sparse Networks

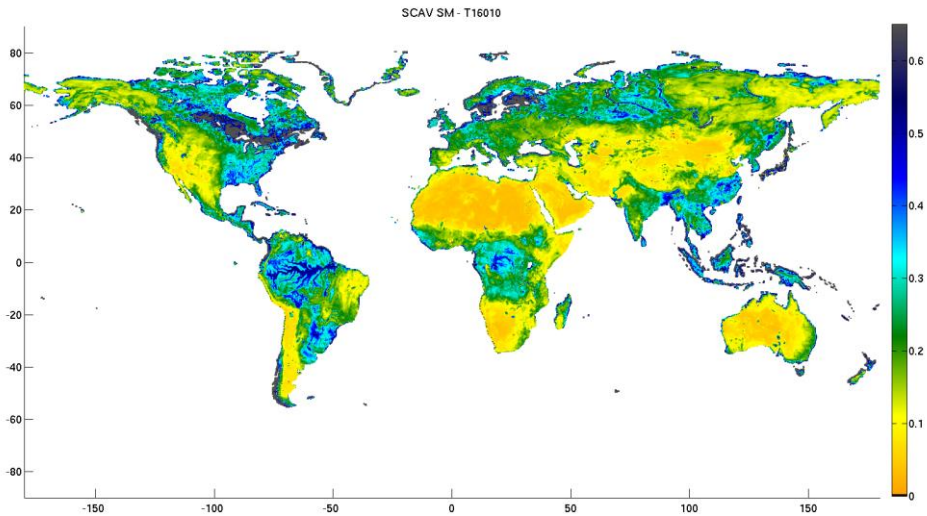
	ubRMSE(m^3/m^3)			Bias (m^3/m^3)			MABias (m^3/m^3)			RMSE (m^3/m^3)			R			N
AM	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	
Evergreen needleleaf forest	0.034	0.044	0.062	0.027	0.065	0.139	0.042	0.067	0.139	0.048	0.078	0.152	0.737	0.715	0.647	2
Mixed forest	0.057	0.059	0.066	-0.017	-0.026	0.042	0.049	0.052	0.060	0.06	0.065	0.078	0.655	0.63	0.583	1
Open shrublands	0.041	0.045	0.051	-0.003	0.01	0.049	0.046	0.049	0.069	0.056	0.061	0.081	0.552	0.552	0.545	45
Woody savannas	0.057	0.067	0.073	0.028	0.039	0.107	0.08	0.088	0.126	0.092	0.103	0.143	0.72	0.56	0.507	19
Savannas	0.031	0.032	0.041	-0.008	-0.001	0.014	0.043	0.044	0.053	0.05	0.051	0.063	0.874	0.857	0.865	3
Grasslands	0.05	0.053	0.059	-0.032	-0.022	0.031	0.062	0.061	0.069	0.073	0.074	0.084	0.687	0.668	0.639	240
Croplands	0.065	0.065	0.071	-0.016	-0.024	0.029	0.086	0.085	0.091	0.1	0.1	0.106	0.611	0.562	0.527	61
Crop/Natural vegetation mosaic	0.06	0.059	0.071	0.009	-0.035	0.079	0.075	0.085	0.105	0.088	0.098	0.122	0.68	0.683	0.569	23
Barren/Sparse	0.022	0.025	0.029	0.014	0.026	0.058	0.032	0.039	0.061	0.036	0.044	0.067	0.61	0.61	0.550	6
Average	**0.046**	**0.05**	**0.058**	**0**	**0.004**	**0.061**	**0.057**	**0.063**	**0.086**	**0.067**	**0.075**	**0.100**	**0.681**	**0.649**	**0.604**	**400**
PM	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	**SCA-V**	**MDCA**	**DCA**	
Evergreen needleleaf forest	0.037	0.05	0.064	0.03	0.074	0.160	0.046	0.077	0.160	0.053	0.089	0.172	0.626	0.585	0.500	2
Mixed forest	0.054	0.053	0.057	-0.01	-0.023	0.046	0.045	0.048	0.061	0.055	0.058	0.073	0.716	0.731	0.694	1
Open shrublands	0.041	0.045	0.051	-0.005	0.008	0.052	0.045	0.049	0.072	0.055	0.06	0.084	0.526	0.509	0.472	45
Woody savannas	0.057	0.068	0.073	0.038	0.036	0.105	0.082	0.087	0.124	0.094	0.102	0.141	0.699	0.5	0.459	19
Savannas	0.034	0.034	0.042	-0.003	-0.001	0.018	0.045	0.047	0.057	0.053	0.054	0.067	0.849	0.817	0.827	3
Grasslands	0.05	0.052	0.057	-0.03	-0.023	0.028	0.061	0.062	0.070	0.073	0.075	0.084	0.694	0.666	0.629	240
Croplands	0.063	0.063	0.069	-0.011	-0.028	0.021	0.086	0.086	0.089	0.1	0.1	0.104	0.611	0.551	0.515	61
Crop/Natural vegetation mosaic	0.059	0.059	0.070	0.024	-0.032	0.072	0.076	0.084	0.099	0.088	0.097	0.116	0.673	0.654	0.545	23
Barren/Sparse	0.024	0.026	0.033	0.014	0.028	0.066	0.032	0.04	0.068	0.037	0.046	0.075	0.49	0.48	0.389	6
Average	**0.046**	**0.05**	**0.057**	**0.005**	**0.004**	**0.063**	**0.058**	**0.064**	**0.089**	**0.068**	**0.076**	**0.102**	**0.654**	**0.61**	**0.559**	**400**

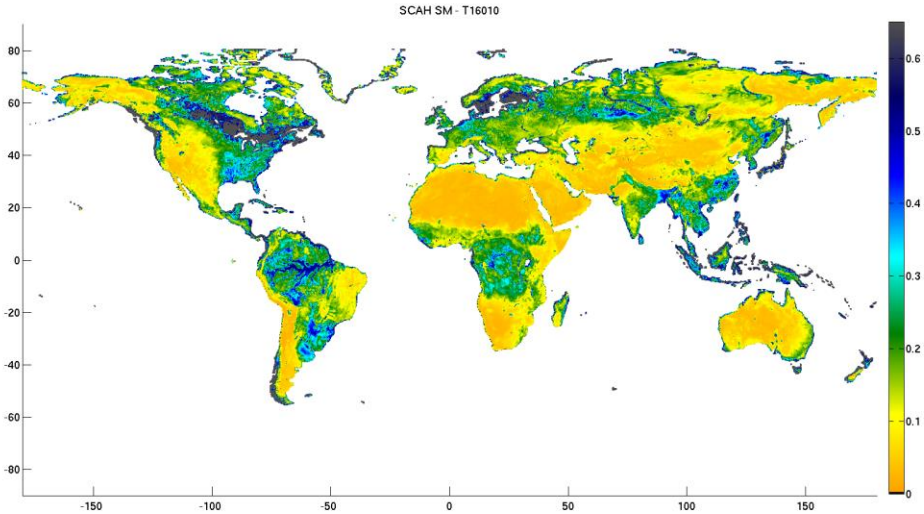
- SCAV provides the best results
- MDCA outperforms DCA for all the parameters

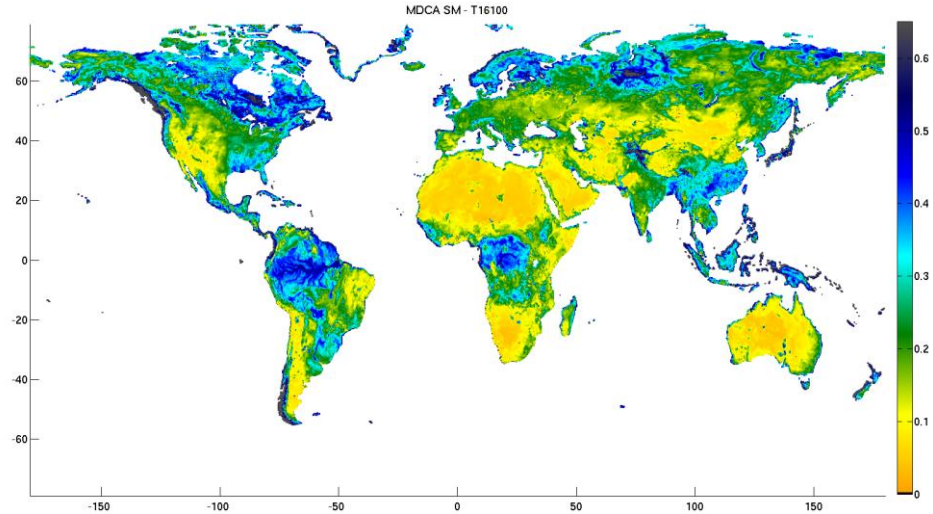
Fan Chen

One Full Annual Cycle
April 1, 2015 to March 31, 2016





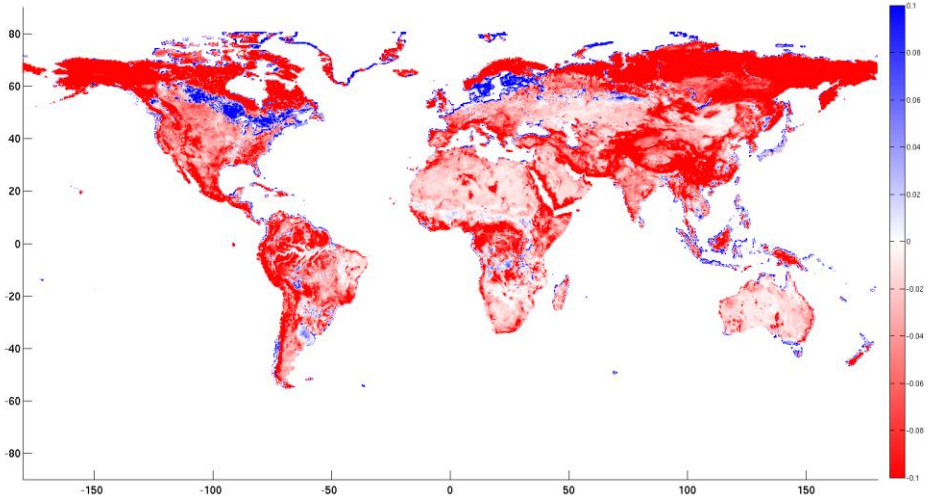




DCA(MDCA)-SCAV

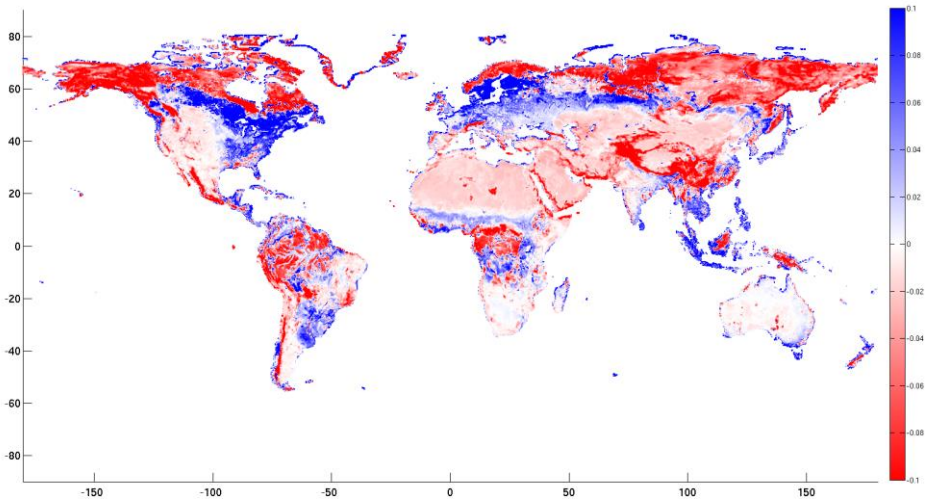
One full annual cycle April 1, 2015 to March 31, 2016.

SCAV - DCA



Mean = -0.0661 m^3/m^3
Std = 0.0899 m^3/m^3
Mean absolute difference = 0.0765 m^3/m^3

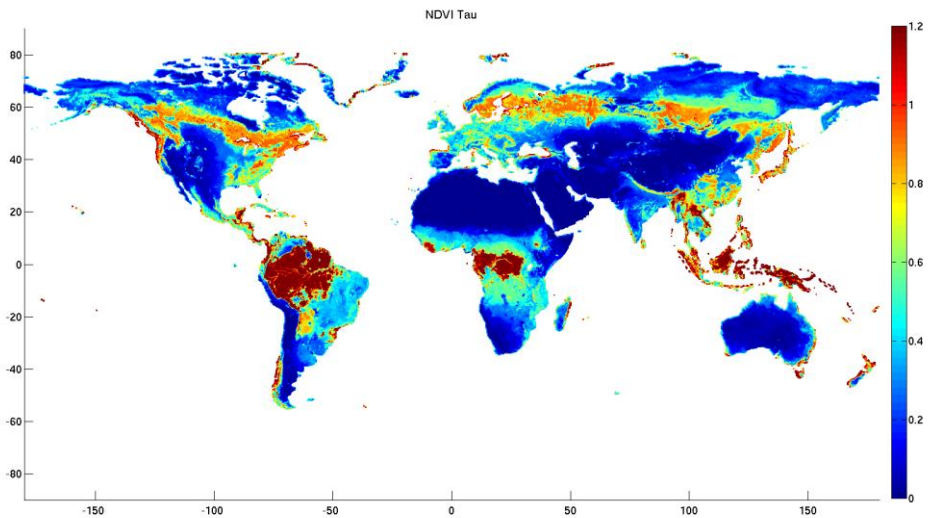
SCAV - MDCA

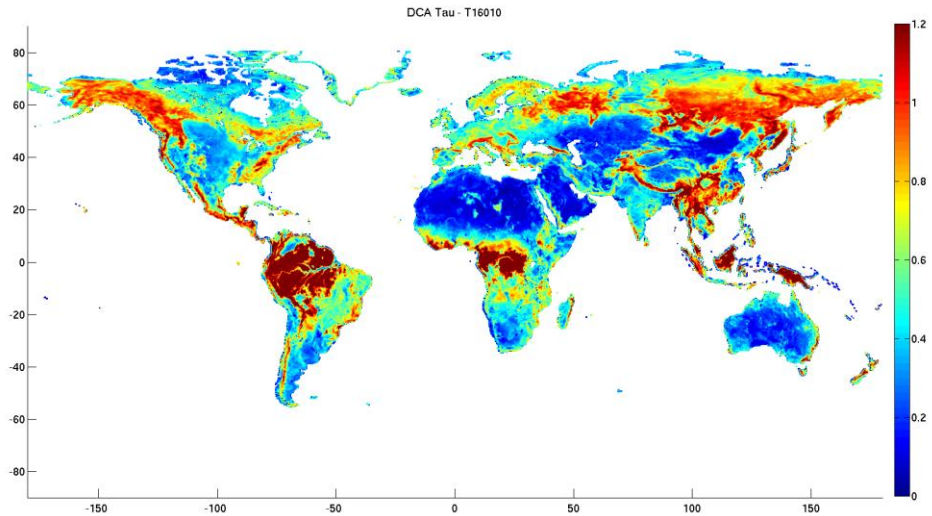


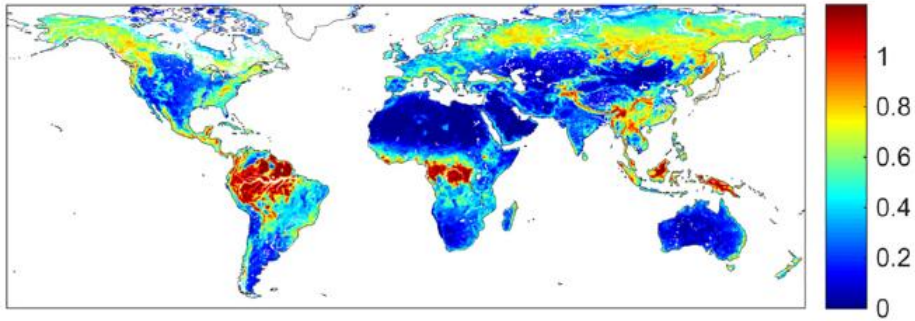
Mean = -0.0121 m^3/m^3
Std = 0.0735 m^3/m^3
Mean absolute difference = 0.0461 m^3/m^3

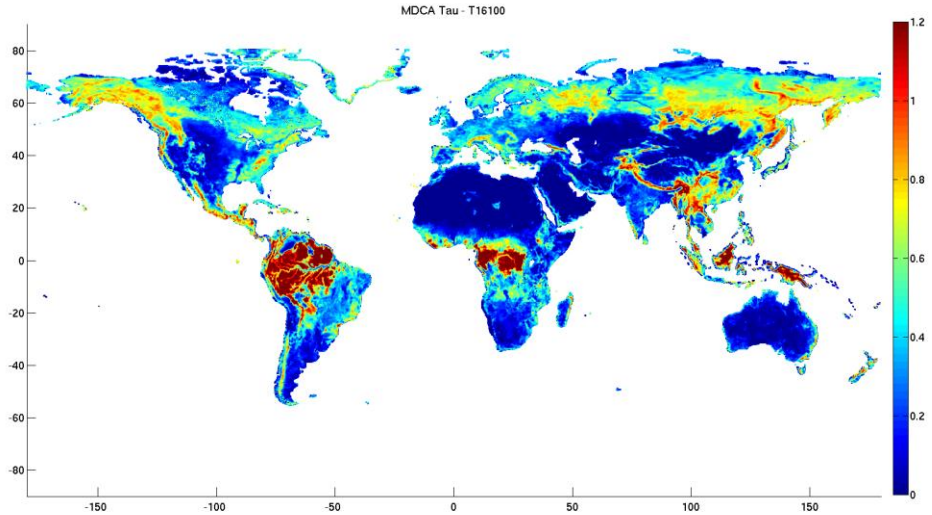
- DCA shows a wet bias with respect to SCAV over the globe except for some locations.
- MDCA reduces the bias with respect to SCAV. MDCA shows wet bias over forest and boreal regions and dry bias in parts of North America and Northern Europe.

One full annual cycle
April 1, 2015, to March 31, 2016









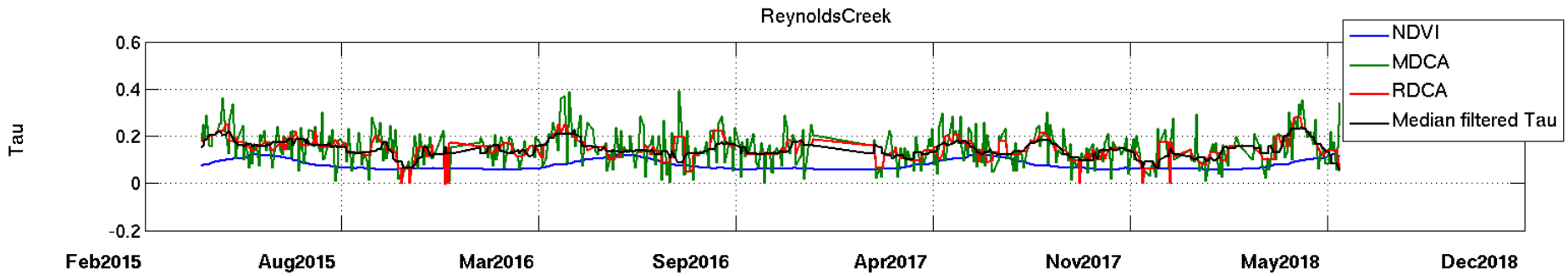
- DCA tau is higher than MDCA and MTDCA
- MDCA tau seems to follow MTDCA patterns and shows slightly higher values, particularly in higher latitudes.

RDCA

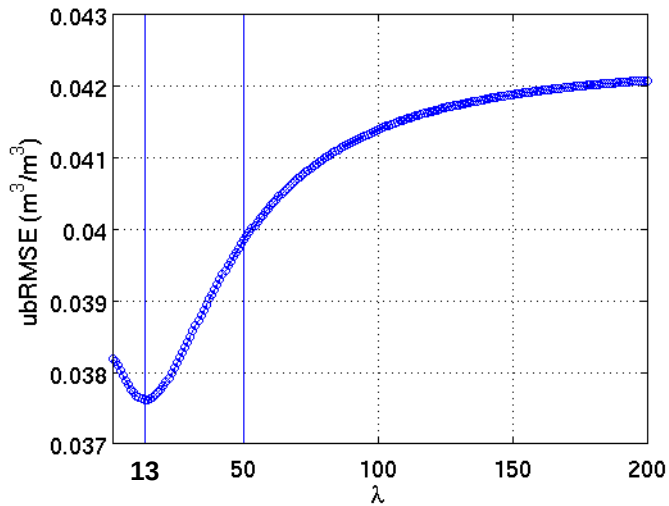
Regularized DCA (RDCA) cost function:

$$F = \frac{(TBV_{obs} - TBV_{model})^2}{dtv^2} + \frac{(TBH_{obs} - TBH_{model})^2}{dth^2} + \lambda^2 (tau - tau^*)^2$$

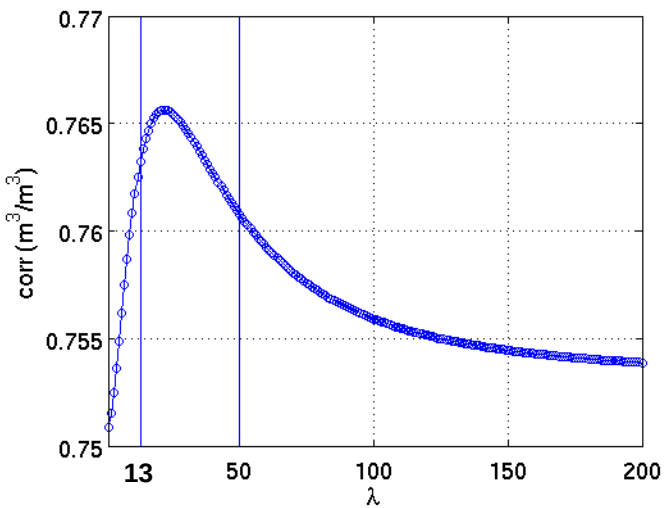
tau* estimated tau computed using a median filter over MDCA timeline tau

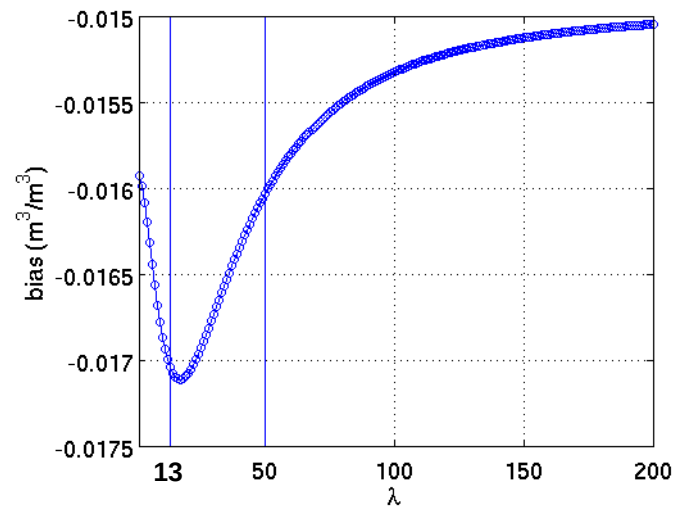


λ Selection



- RDCA meet requirements if $\lambda < 50$
- $\lambda = 13$ results in smaller ubRMSE

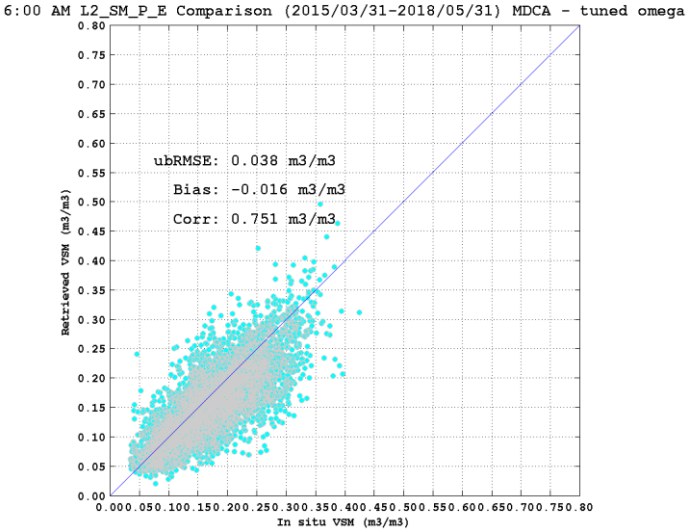




RDCA test results

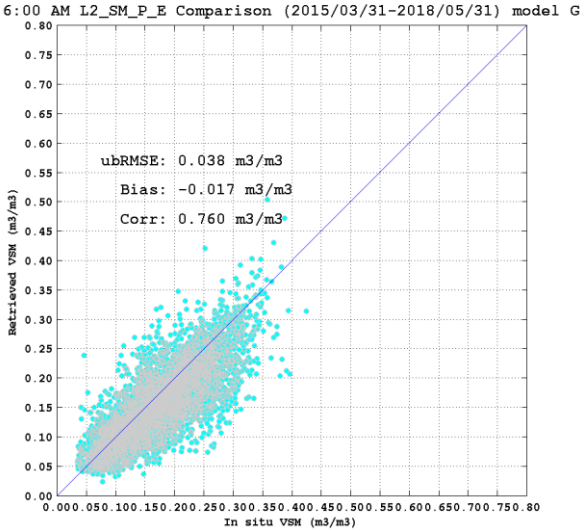
	ubrmse	bias	rmse	rho
ReynoldsCreek	0.048	-0.021	0.053	0.528
WalnutGulch	0.030	0.029	0.042	0.812
TxSON	0.031	0.009	0.032	0.898
FortCobb	0.032	-0.050	0.059	0.838
LittleWashita	0.029	-0.010	0.031	0.864
SouthFork	0.049	-0.063	0.080	0.637
LittleRiver	0.033	-0.001	0.033	0.806
Kenaston	0.036	0.021	0.041	0.613
Carman	0.060	-0.066	0.089	0.504
MonteBuey	0.035	-0.042	0.055	0.792
REMEDHUS	0.039	-0.001	0.039	0.813
Yanco	0.036	0.004	0.037	0.904
***** AVERAGE :MDCA *****		0.038	-0.016	0.049	0.751

9 sites meet requirements



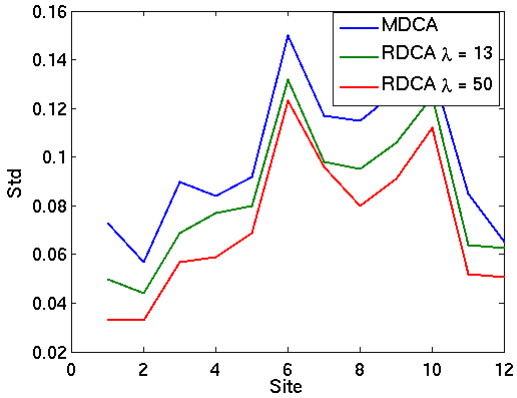
	Ubrmse	bias	rmse	rho
ReynoldsCreek	0.048	-0.022	0.053	0.535
WalnutGulch	0.030	0.029	0.042	0.812
TxSON	0.029	0.008	0.030	0.914
FortCobb	0.032	-0.050	0.059	0.847
LittleWashita	0.027	-0.011	0.030	0.878
SouthFork	0.048	-0.065	0.080	0.661
LittleRiver	0.033	-0.001	0.033	0.810
Kenaston	0.035	0.020	0.040	0.638
Carman	0.061	-0.067	0.090	0.507
MonteBuey	0.034	-0.043	0.055	0.804
REMEDHUS	0.040	-0.001	0.040	0.814
Yanco	0.036	0.002	0.036	0.907
***** AVERAGE : ***		0.038	-0.017	0.049	0.760

9 sites meet requirements



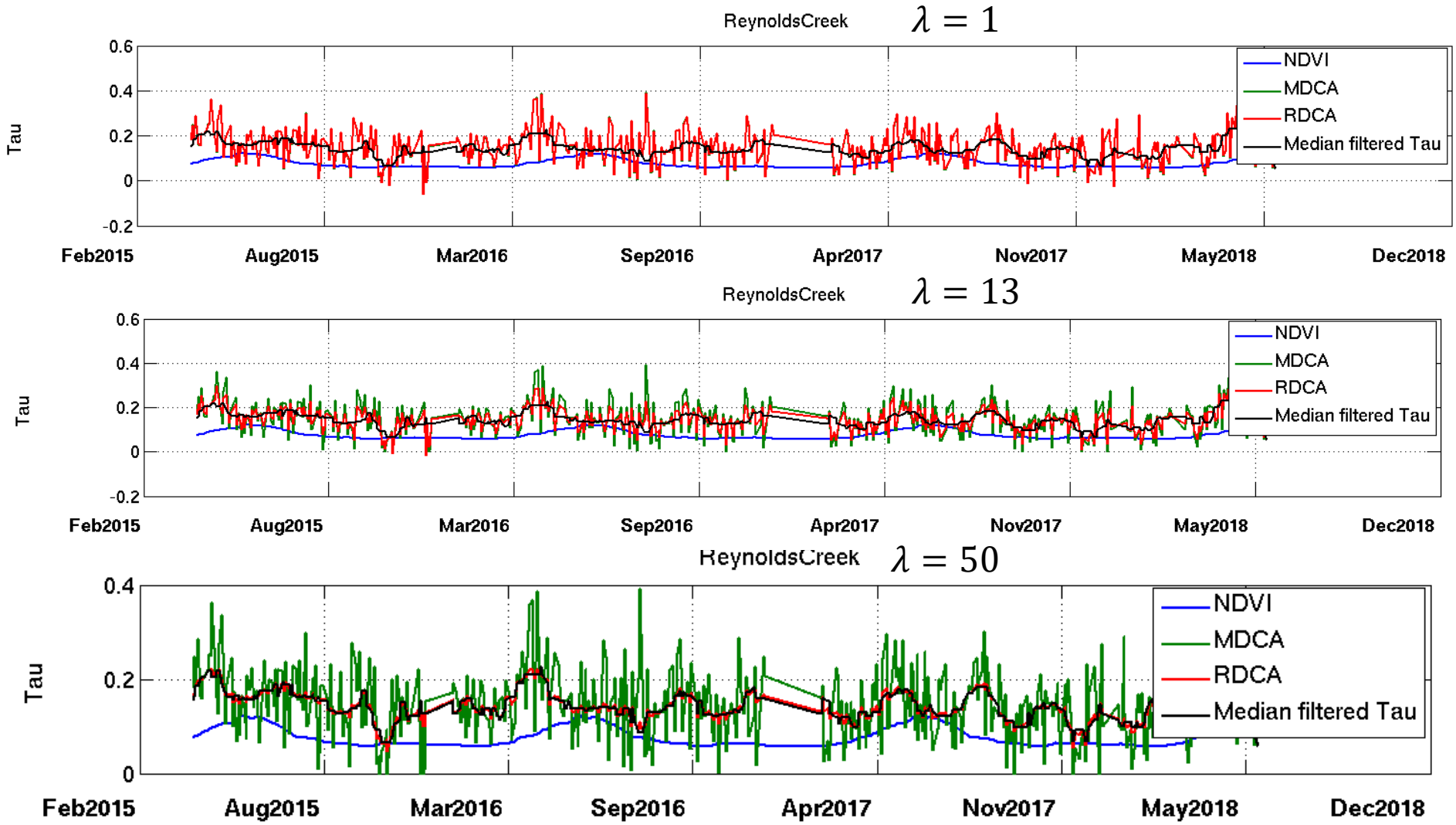
λ effect

	MDCA tau			RDCA tau $\lambda = 13$			RDCA tau $\lambda = 50$		
	Mean	Std	RMS	Mean	Std	RMS	Mean	Std	RMS
ReynoldsCreek	0.147	0.073	0.164	0.144	0.050	0.153	0.144	0.033	0.148
WalnutGulch	0.073	0.057	0.092	0.069	0.044	0.081	0.068	0.033	0.075
TxSON	0.257	0.090	0.272	0.253	0.069	0.262	0.253	0.057	0.260
FortCobb	0.110	0.084	0.138	0.099	0.077	0.125	0.099	0.059	0.115
LittleWashita	0.143	0.092	0.169	0.139	0.080	0.160	0.137	0.069	0.153
SouthFork	0.224	0.150	0.270	0.214	0.132	0.252	0.210	0.123	0.243
LittleRiver	0.395	0.117	0.412	0.386	0.098	0.398	0.389	0.096	0.401
Kenaston	0.194	0.115	0.225	0.184	0.095	0.207	0.182	0.080	0.199
Carman	0.186	0.127	0.226	0.174	0.106	0.204	0.170	0.091	0.193
MonteBuey	0.160	0.136	0.210	0.152	0.125	0.196	0.150	0.112	0.187
REMEDHUS	0.138	0.085	0.162	0.134	0.064	0.149	0.132	0.052	0.142
Yanco	0.068	0.065	0.094	0.071	0.063	0.095	0.062	0.051	0.080



RDCA reduces the level of noise

λ Selection



RDCA reduces the level of noise

Conclusion

- MDCA shows significant improvement with respect to DCA.
- SCAV still shows slightly better results than MDCA.
- MDCA provides tau.
- RDCA performs as MDCA but provides smooth tau.
- Andreas' assessment is in agreement with this assessment.
- We encourage everybody to look into T16100 (OASIS) and provide feedback