European ECOSTRESS Hub for mapping land surface temperature and evaporation over Europe and Africa

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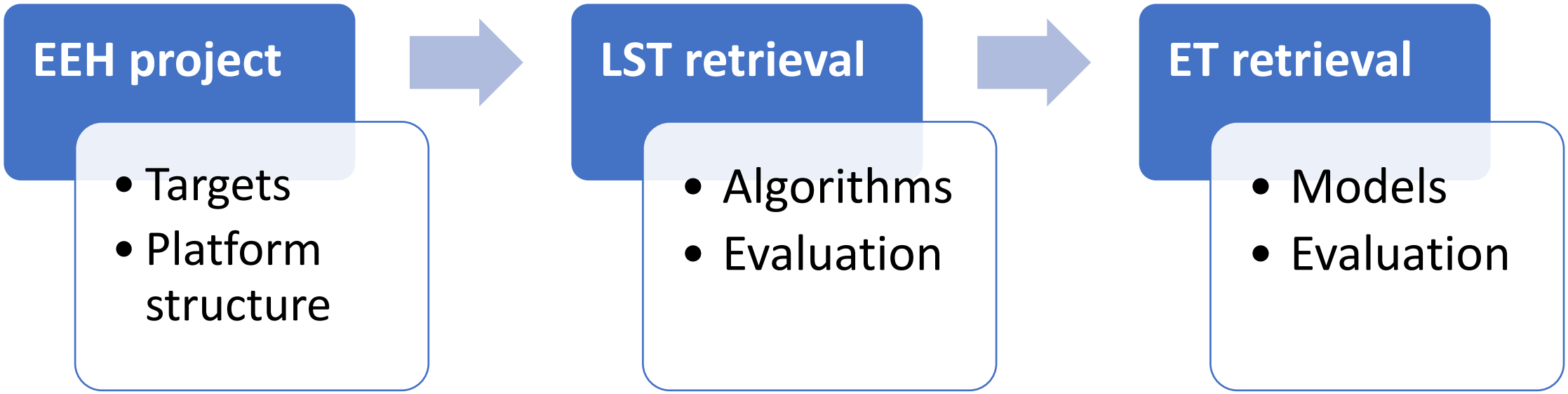
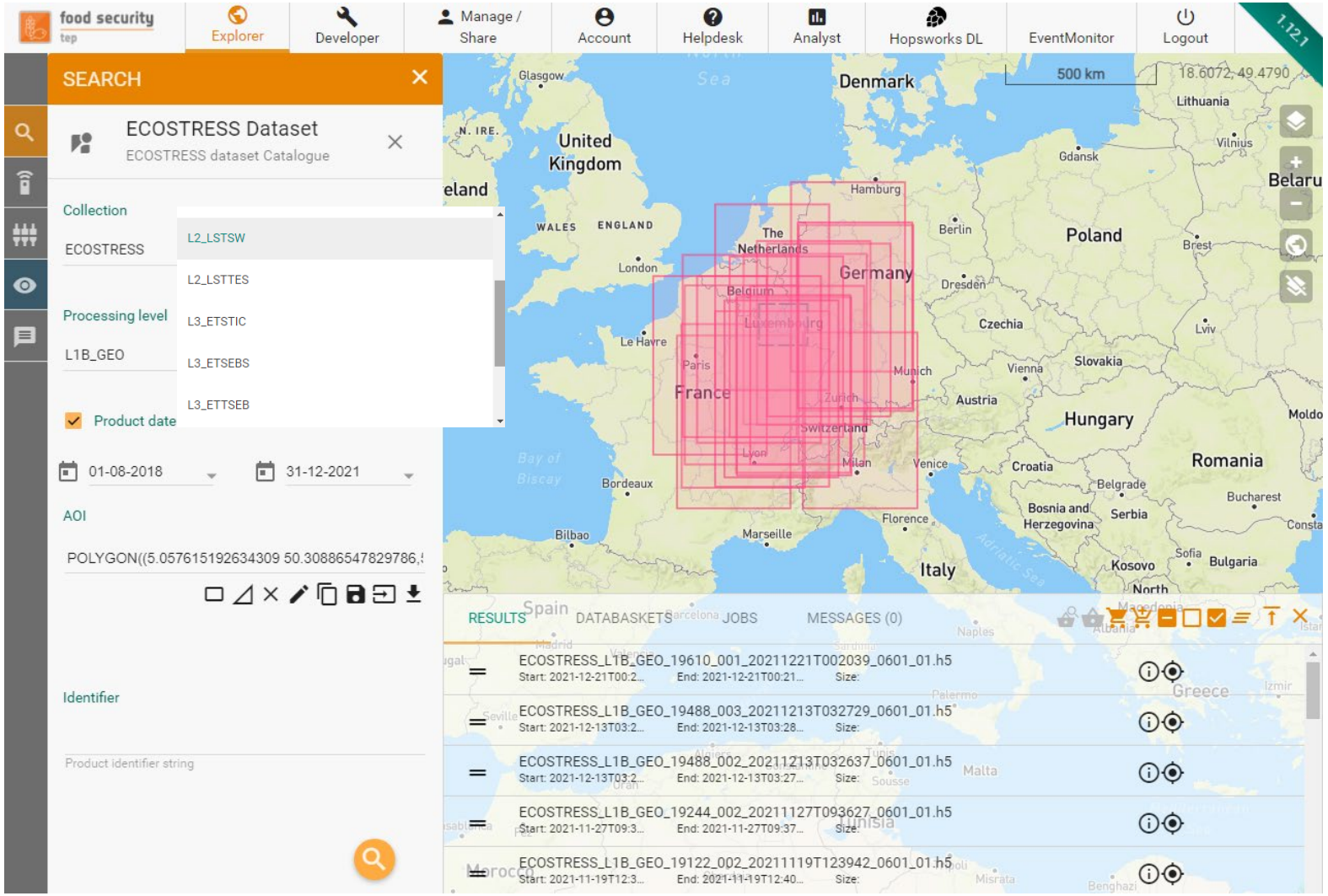
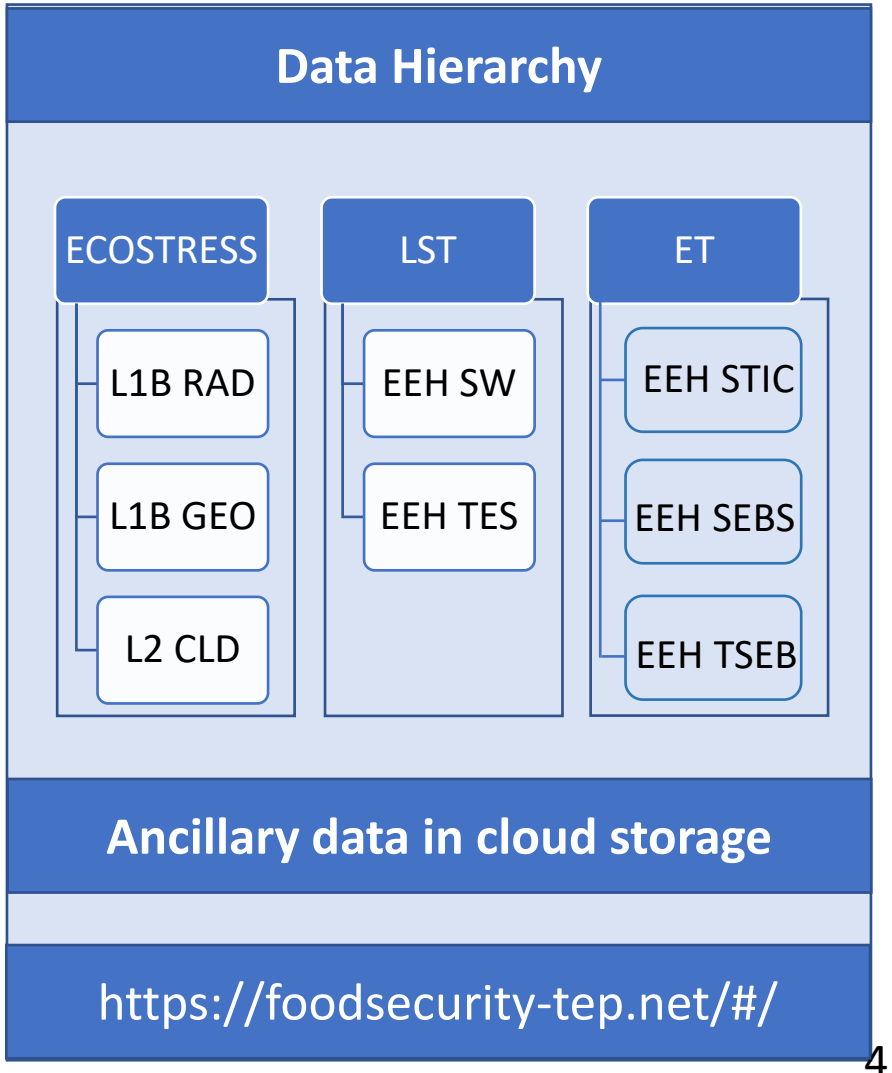

EEH project
• Targets
• Platform structure
LST retrieval
• Algorithms
• Evaluation
ET retrieval
• Models
• Evaluation

European ECOSTRESS Hub (EEH)

- Generating publicly accessible LST and ET products (**08/2018 – 12/2021**) for ECOSTRESS over Europe and Africa from multiple models (same inputs)
- Providing a user-interactive interface (FS-TEP) for running the models with customized model coefficients





EEH SW Flowchart

(a) Emissivity

ASTER GED V3

AST_EMI 10-14, mean NDVI

Copernicus Global Land Service

FVC, LULC, SCE

Emissivity Estimation

(b) SW coefficients

SeeBor v5.0 + ASTER spectral library

p, q, t, emi

SW Coefficient Simulation using RTTOV 12

SW coefficients

(c) Input parameters

ECO1B_GEO

Land/Sea Mask, Elevation, VZA, SZA, Lat, Lon

ECO1B_RAD

TOA Radiances (Bands 2,4,5)

ERA5 hourly atmospheric single-level

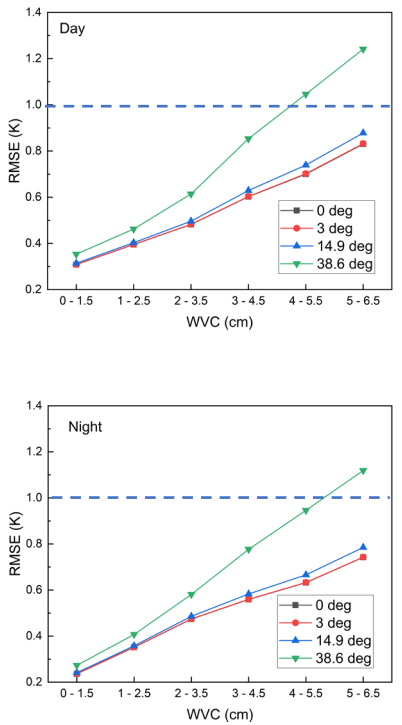
WVC

Emissivity map

SW Algorithm

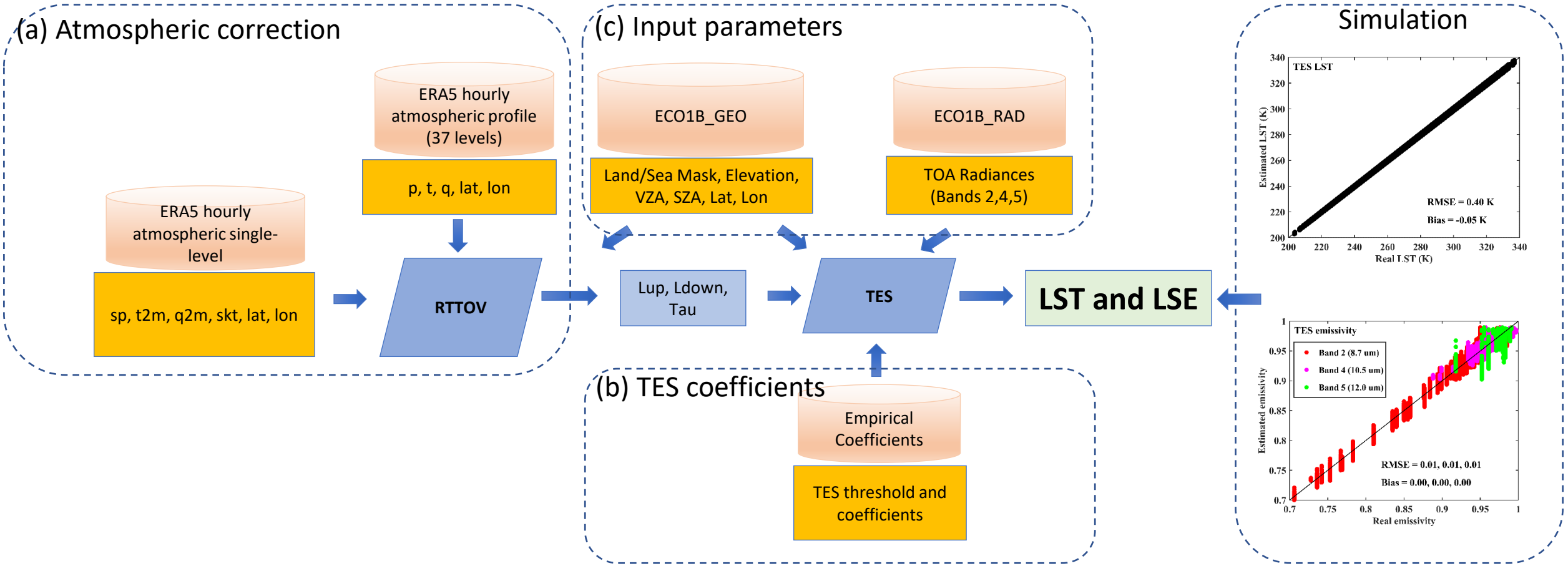
LST

Simulation



Assumptions:
Accurate WVC and emissivity retrieval

EEH TES Flowchart



Assumptions:
Perfect atmospheric correction (RTM and atmospheric profile)

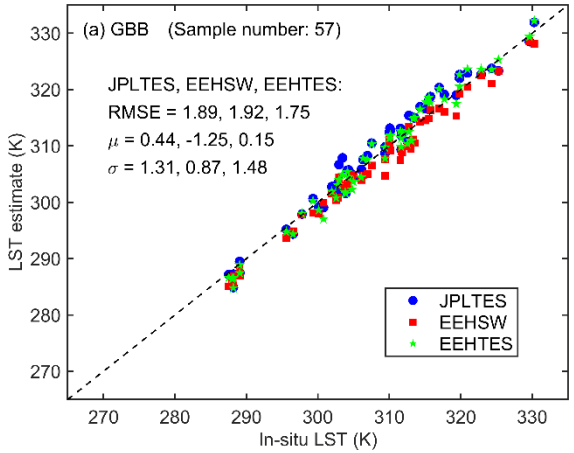
Data used in the evaluation

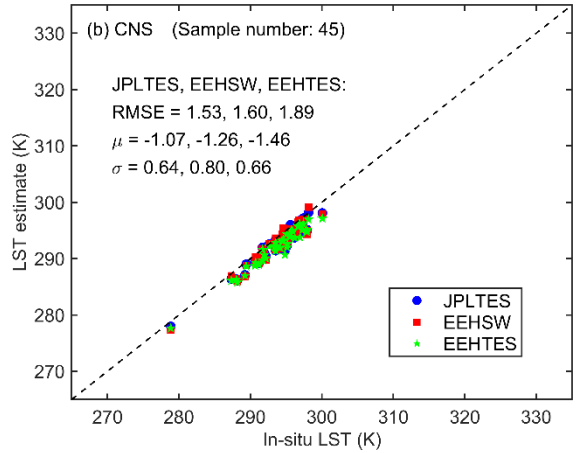
Satellite Data (2018/08/01 to 2021/12/31):

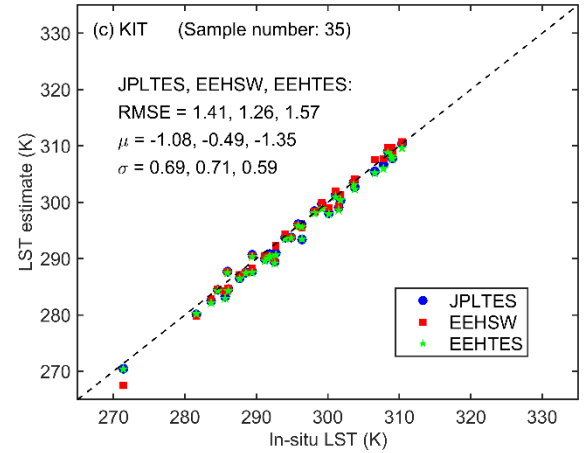
ECOSTRESS LST (JPL LST, EEHTES LST, EEHSW LST), Landsat LST, ASTER LST

Ground sites (9 different land surface types):

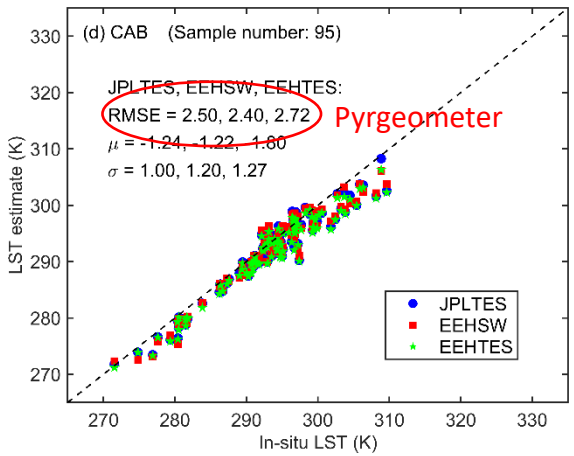
Site No.	Site location	Site ID	Network	Latitude	Longitude	Surface type	Emissivity
1	Gobabeb wind tower, Namibia	GBB	KIT	23.551° S	15.051° E	Barren/sparsely vegetated	0.940 Hulley et al. (2021)
2	Lake Constance, Germany	CNS	KIT	47.605° N	9.444° E	Water	0.973 Hulley et al. (2021)
3	KIT Forest, Germany	KIT	KIT	49.091° N	8.425° E	Mixed forest	0.988 Freitas et al. (2010)
4	Cabauw, Netherlands	CAB	BSRN	51.971° N	4.927° E	Grassland	From ECOSTRESS
5	Fuente Duque, Donana, Spain	FDU	GCU	36.998° N	6.434° W	Marshland	Measurements Sobrino and Skoković (2016)
6	Balsa Blanca, Cabo de Gata, Spain	CDG	GCU	36.939° N	2.034° W	Woody savannas	Measurements Sobrino and Skoković (2016)
7	Fontainebleau-Barbeau, France	FON	ICOS	48.476° N	2.780° E	Deciduous broadleaf forest	From ECOSTRESS
8	Lison, Italy	LSN	ICOS	45.740° N	12.750° E	Cropland	From ECOSTRESS
9	San Rossore 2, Italy	SR2	ICOS	43.732° N	10.291° E	Evergreen needleleaf forest	From ECOSTRESS

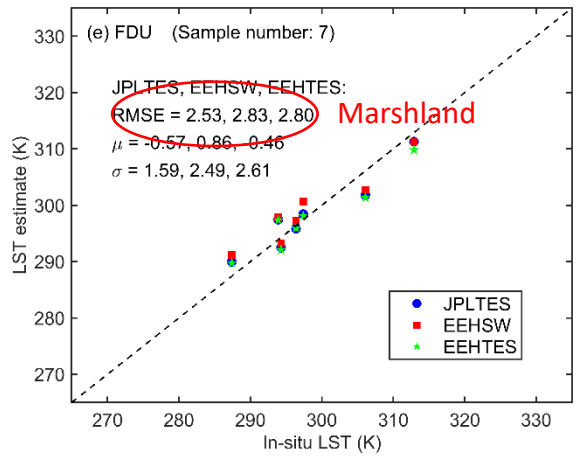


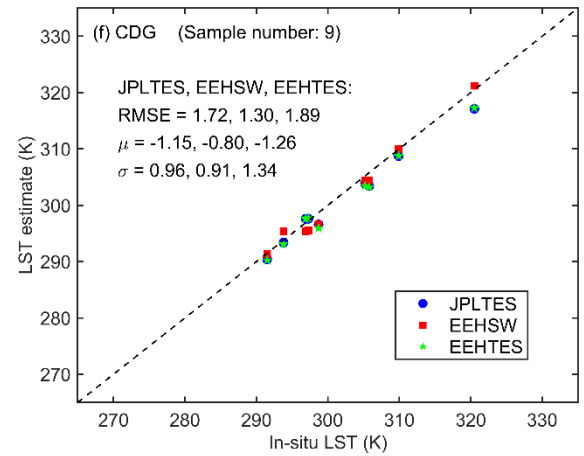




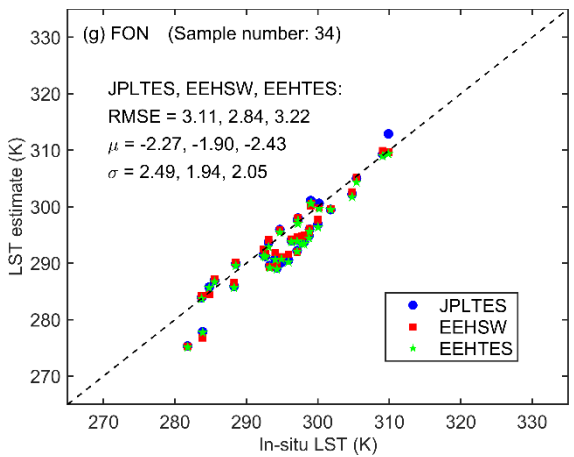
Good accuracy (homogeneous landscape)

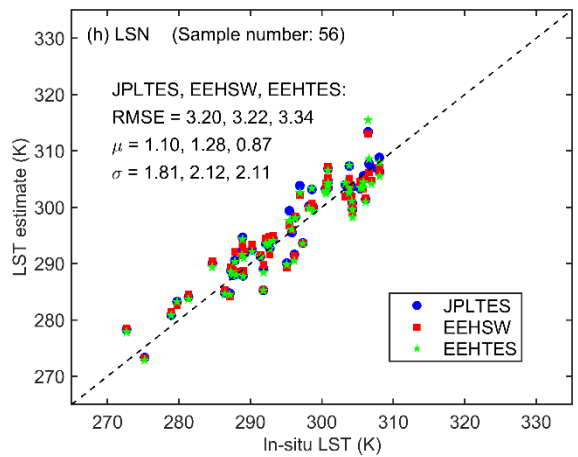


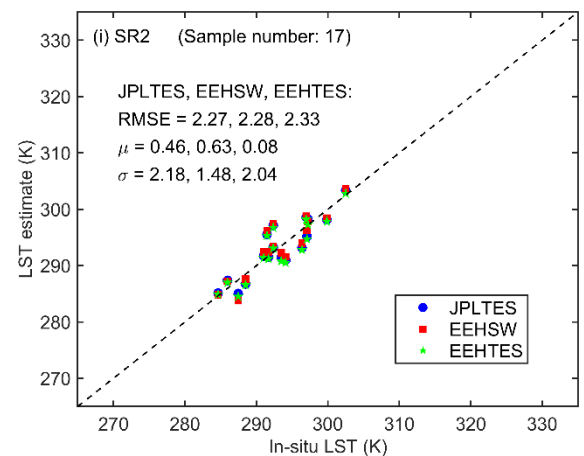




Acceptable accuracy

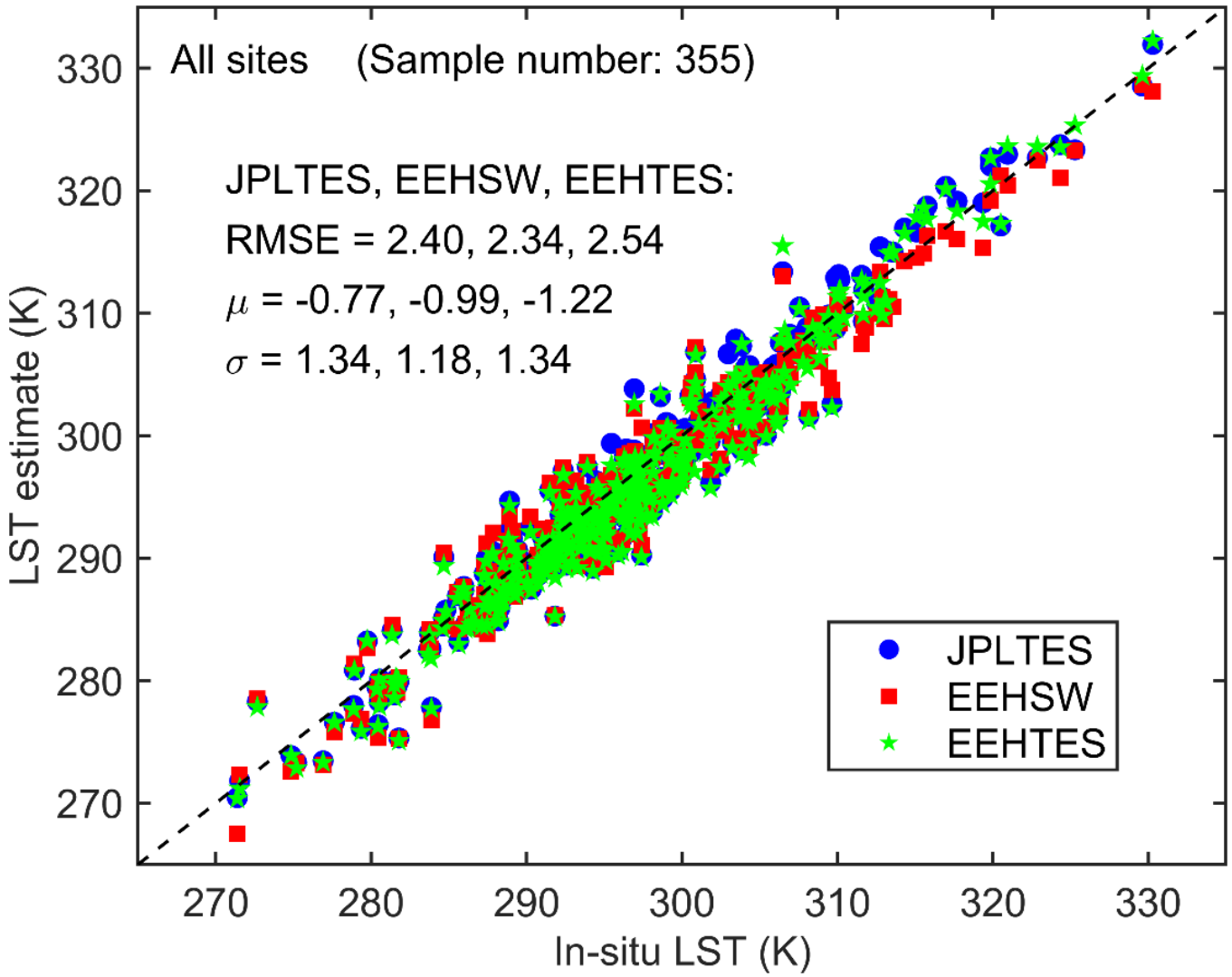






Unsatisfying Accuracy (30 min sampling frequency and pyrgeometer)

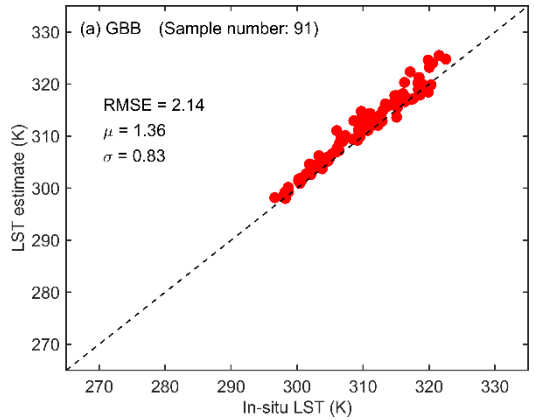
Similar performances of the three ECOSTRESS LST products

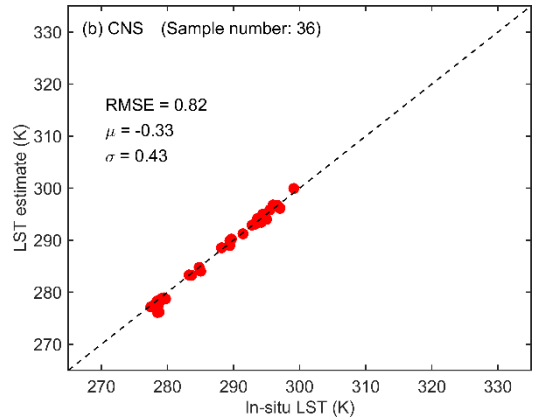


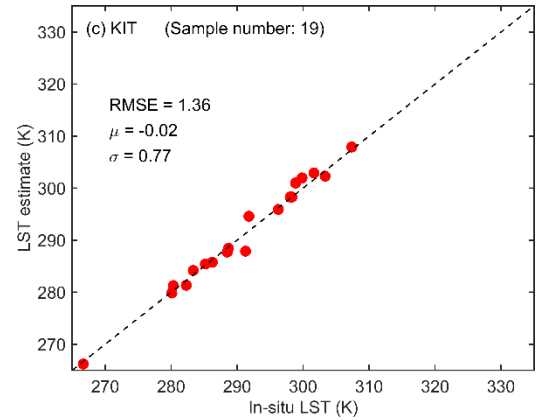
Marginal difference between TES and SW overall

Sites	JPLTES			EEHSW			EEHTES		
	RMSE	μ	σ	RMSE	μ	σ	RMSE	μ	σ
GBB	1.89	0.44	1.31	1.92	-1.25	0.87	1.75	0.15	1.48
CNS	1.53	-1.07	0.64	1.60	-1.26	0.80	1.89	-1.46	0.66
KIT	1.41	-1.08	0.69	1.26	-0.49	0.71	1.57	-1.35	0.59
CAB	2.50	-1.24	1.00	2.40	-1.22	1.20	2.72	-1.80	1.27
FDU	2.53	-0.57	1.59	2.83	0.86	2.49	2.80	-0.46	2.61
CDG	1.72	-1.15	0.96	1.30	-0.80	0.91	1.89	-1.26	1.34
FON	3.11	-2.27	2.49	2.84	-1.90	1.94	3.22	-2.43	2.05
LSN	3.20	1.10	1.81	3.22	1.28	2.12	3.34	0.87	2.11
SR2	2.27	0.46	2.08	2.28	0.63	1.48	2.33	0.08	2.04
ALL	**2.40**	**-0.77**	**1.34**	**2.34**	**-0.99**	**1.18**	**2.54**	**-1.22**	**1.34**

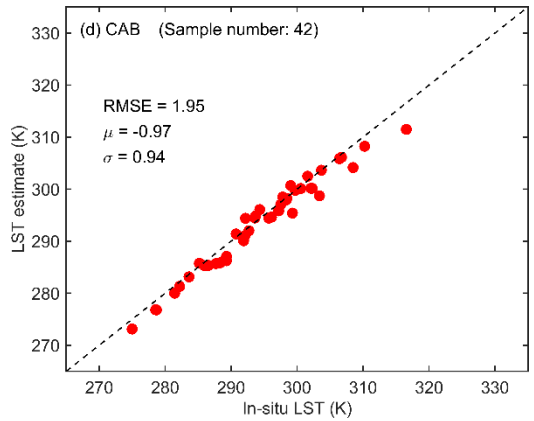
Landsat

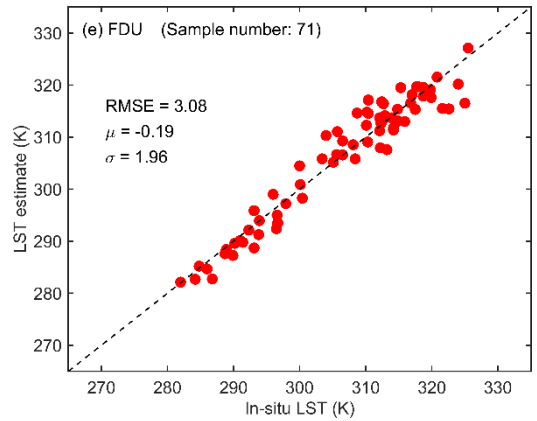


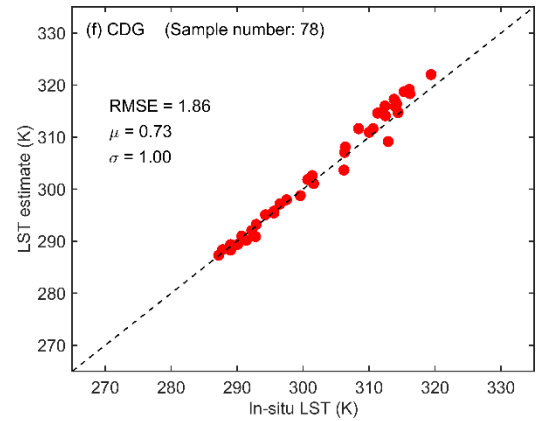




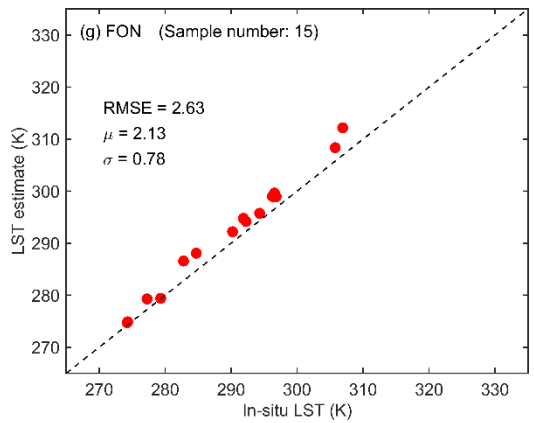
Good accuracy (homogeneous landscape)

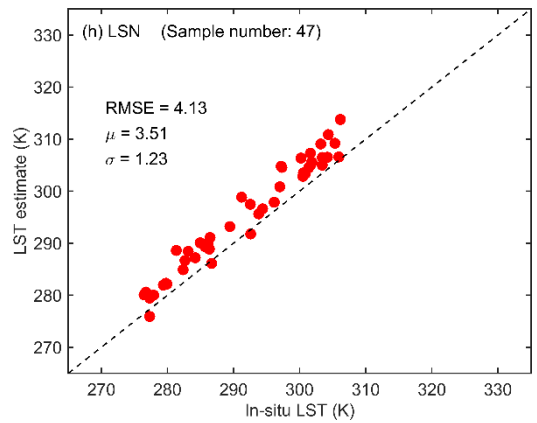


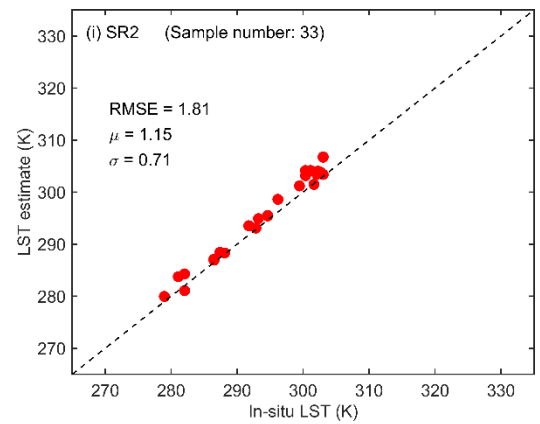




Large uncertainty at FDU

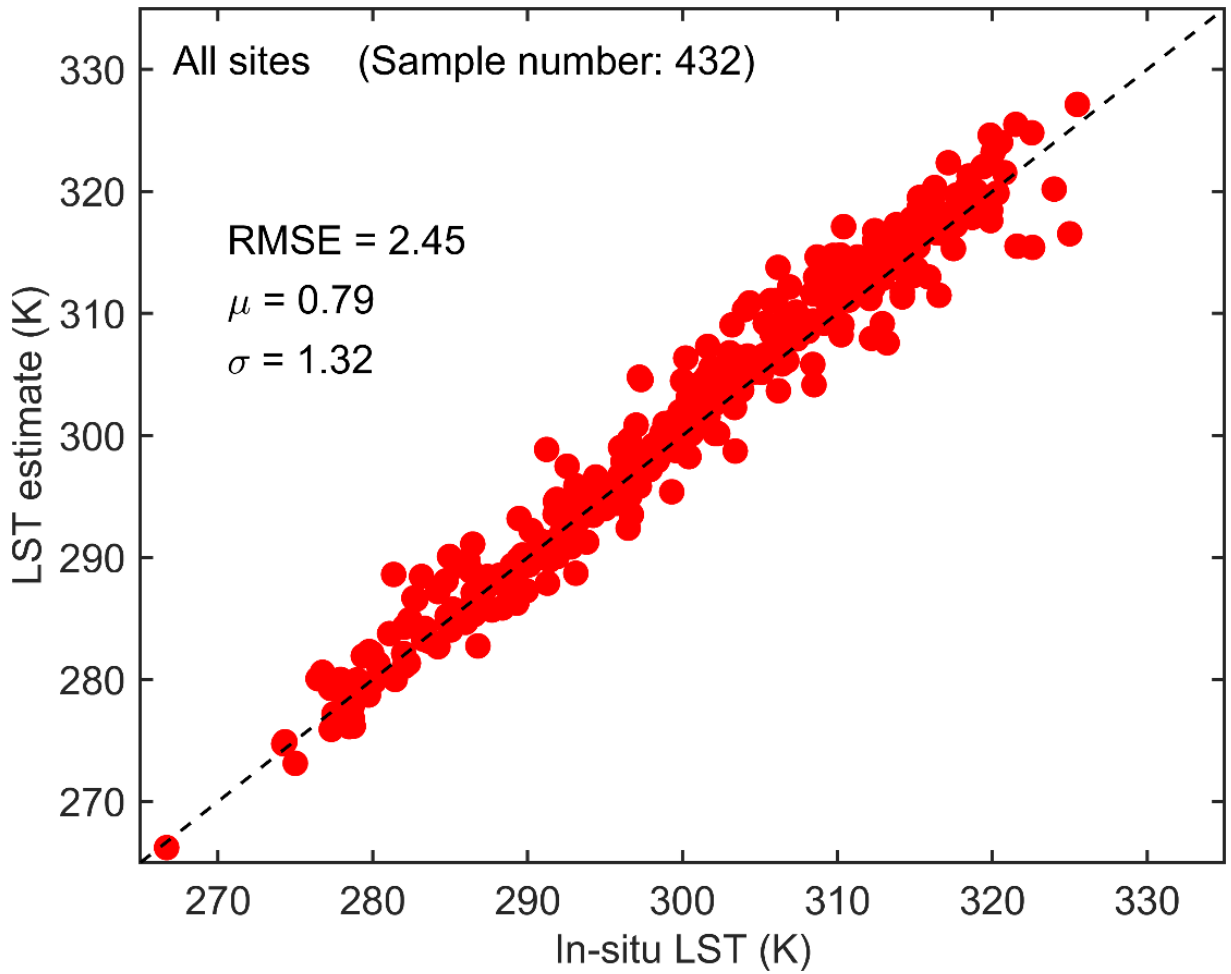




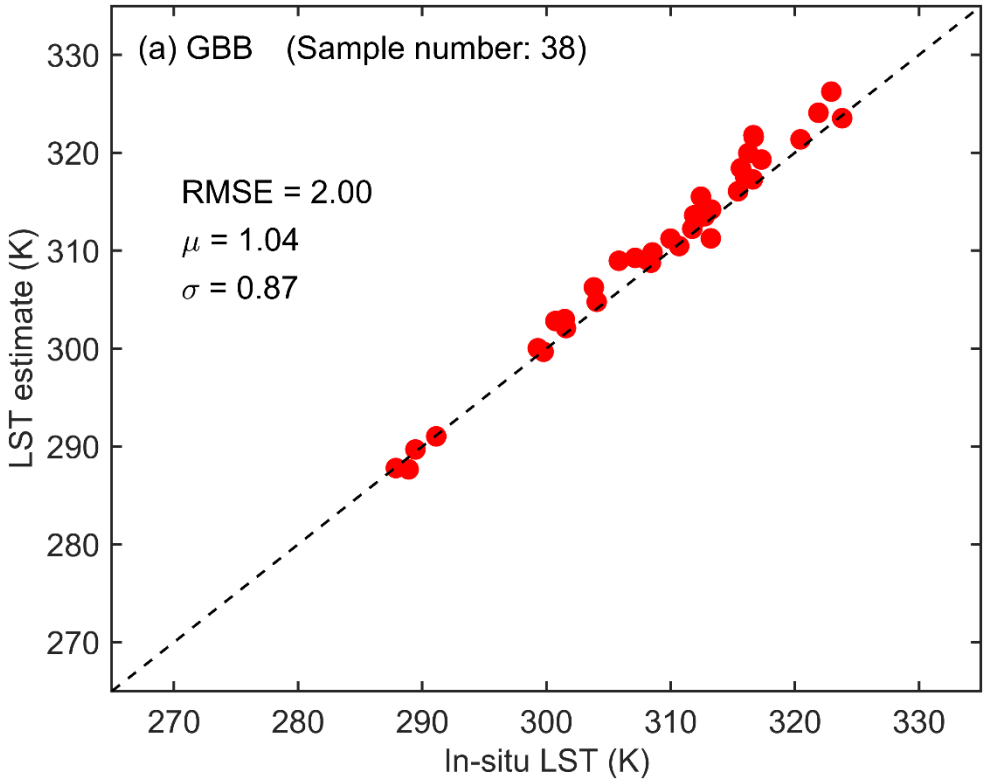


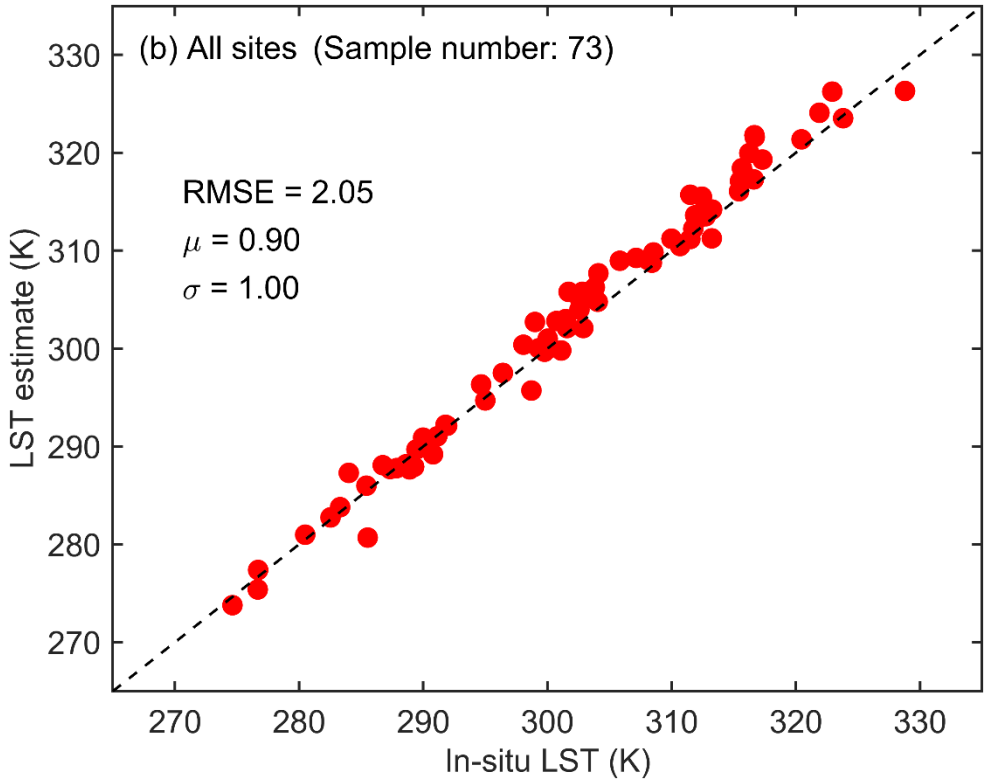
Largest uncertainty at LSN

Similar accuracies for ECOSTRESS and Landsat LST



Slightly better performance (RMSE) of ASTER LST



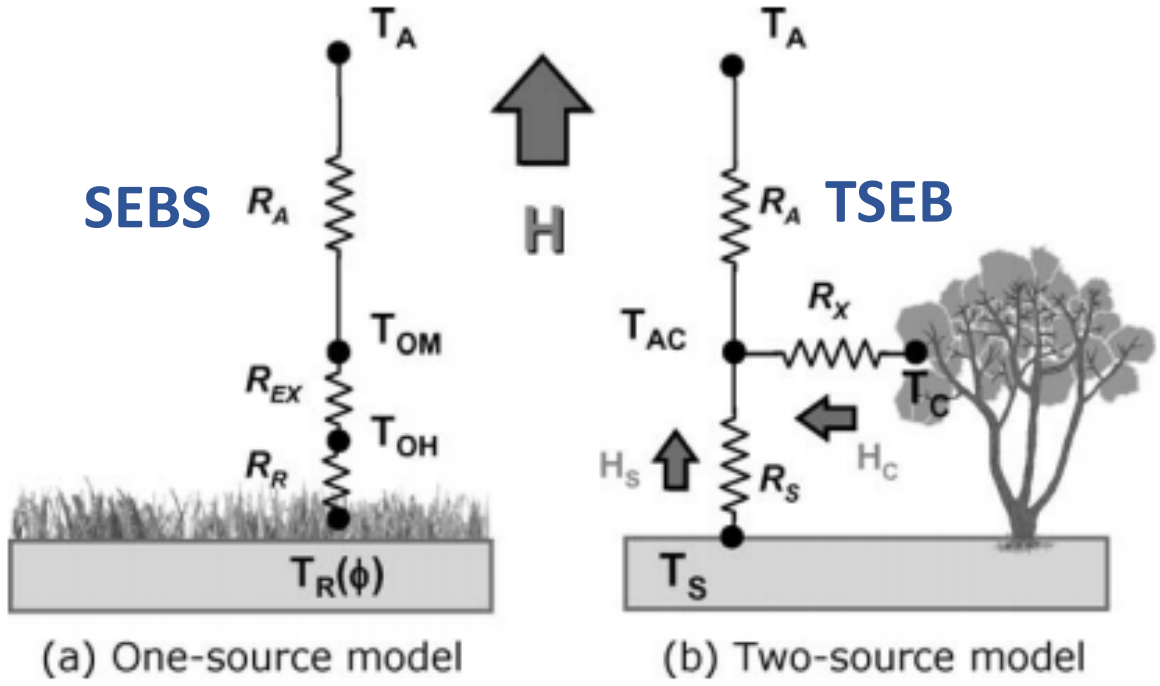


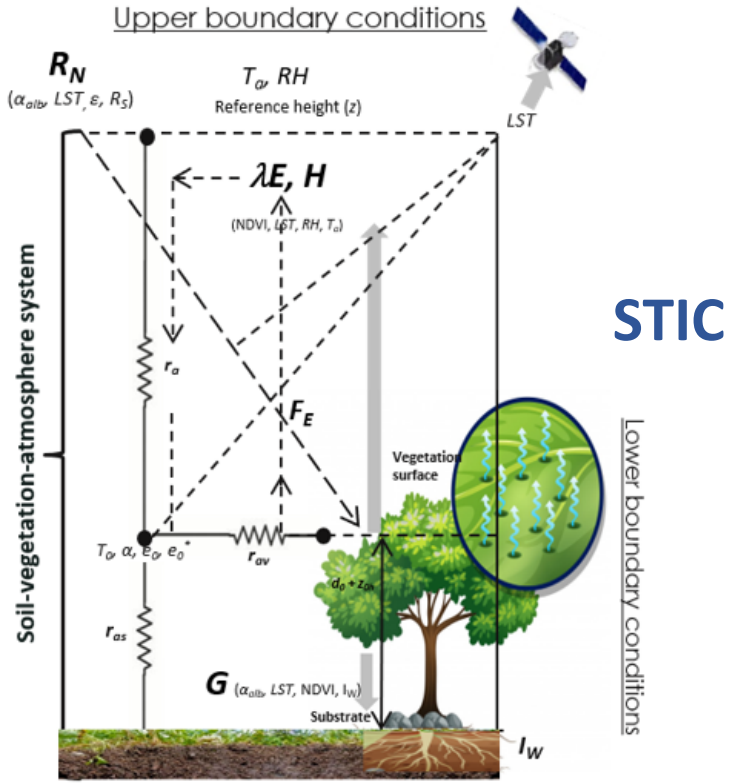
Marginal difference between ECOSTRESS, Landsat and ASTER LST products

Sites	Landsat			ASTER		
	RMSE	μ	σ	RMSE	μ	σ
GBB	2.14	1.36	0.83	2.00	1.04	0.87
CNS	0.82	-0.33	0.43	-	-	-
KIT	1.36	-0.02	0.77	-	-	-
CAB	1.95	-0.97	0.94	-	-	-
FDU	3.08	-0.19	1.96	-	-	-
CDG	1.86	0.73	1.00	-	-	-
FON	2.63	2.13	0.78	-	-	-
LSN	4.13	3.51	1.23	-	-	-
SR2	1.81	1.15	0.71	-	-	-
Mean	**2.45**	**0.79**	**1.32**	**2.05**	**0.90**	**1.00**

	JPLTES			EEHSW			EEHTES		
ECO	2.40	-0.77	1.34	2.34	-0.99	1.18	2.54	-1.22	1.34

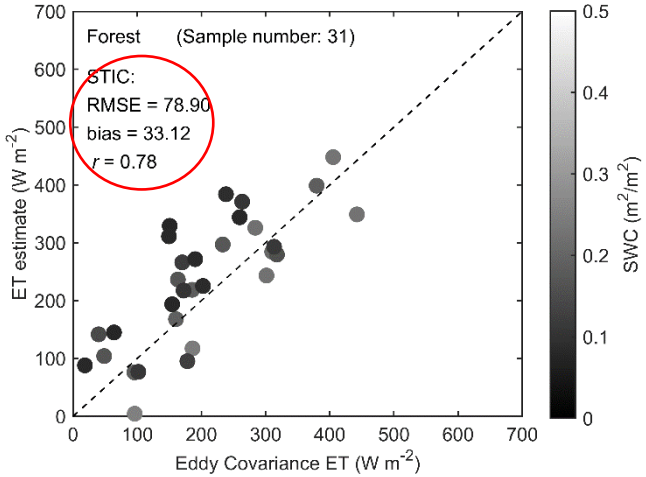
EEH ET models

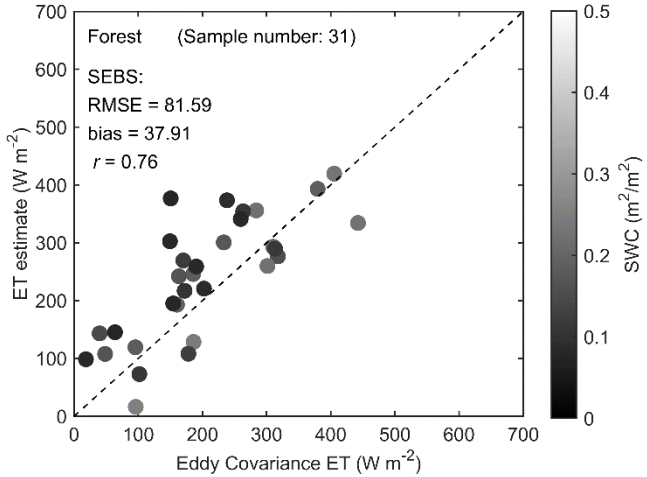


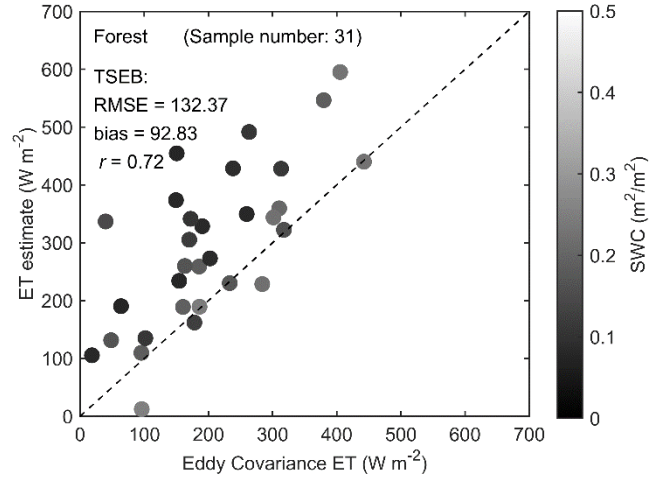


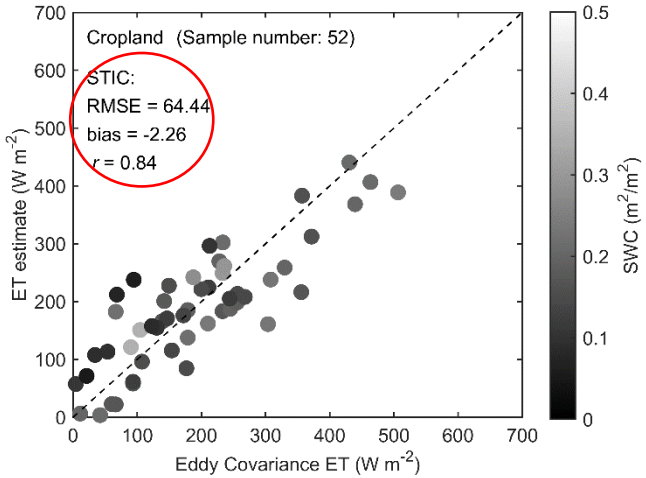
Credit to W. Kustas et al. (2009)

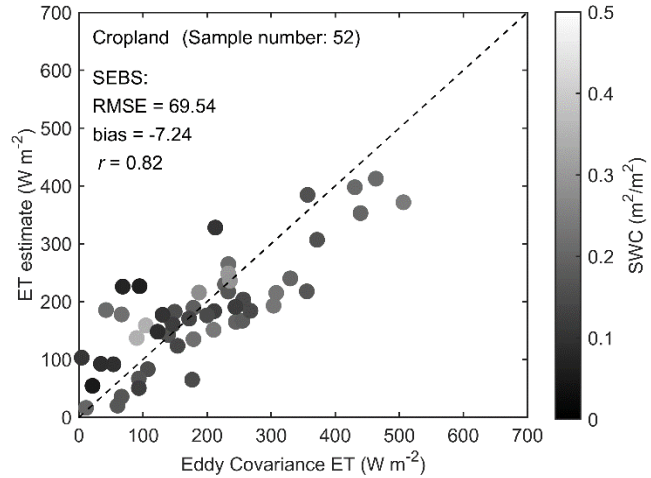
- **STIC**: Non-parametric; physical link of surface and aerodynamic conductance with surface water stress (driven by LST)
- **SEBS** and **TSEB**: Parameterisation of aerodynamic resistances, atmospheric stability and aerodynamic roughness length parameters
- **SEBS**: PBL height, canopy height, excess resistance to accommodate T_0 versus T_R inequality
- **TSEB**: f_g (green leaf fraction), KB^{-1} (connecting momentum and heat roughness lengths), α (PT constant), canopy height

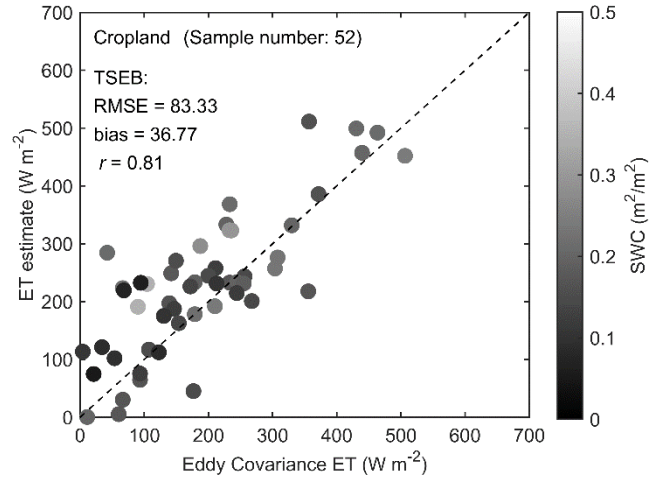

Forest (Sample number: 31)
STIC:
RMSE = 78.90
bias = 33.12
r = 0.78
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

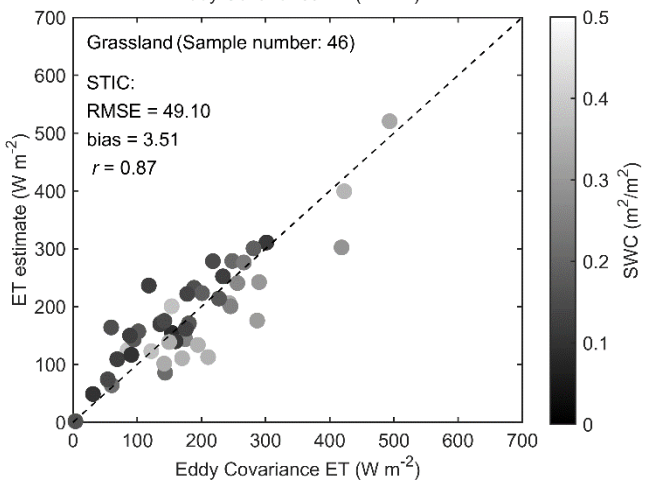

Forest (Sample number: 31)
SEBS:
RMSE = 81.59
bias = 37.91
r = 0.76
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

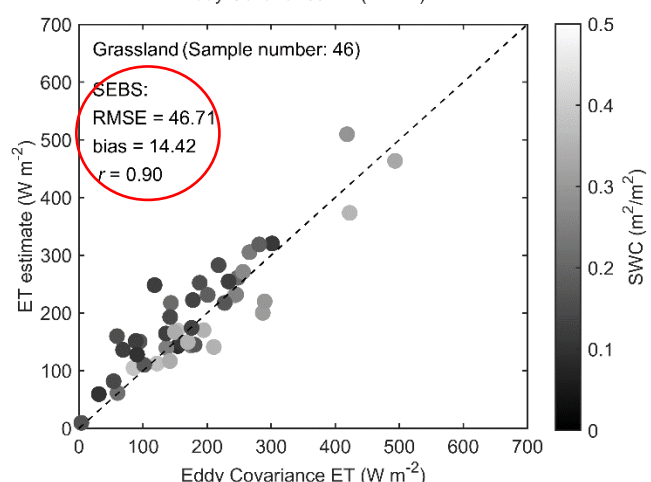

Forest (Sample number: 31)
TSEB:
RMSE = 132.37
bias = 92.83
r = 0.72
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

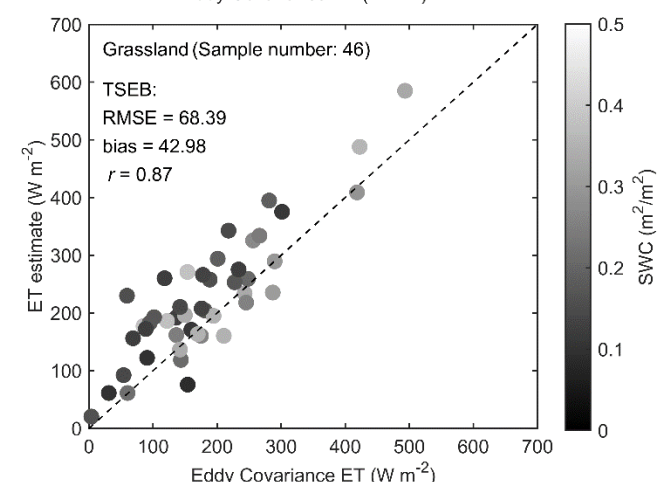

Cropland (Sample number: 52)
STIC:
RMSE = 64.44
bias = -2.26
r = 0.84
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

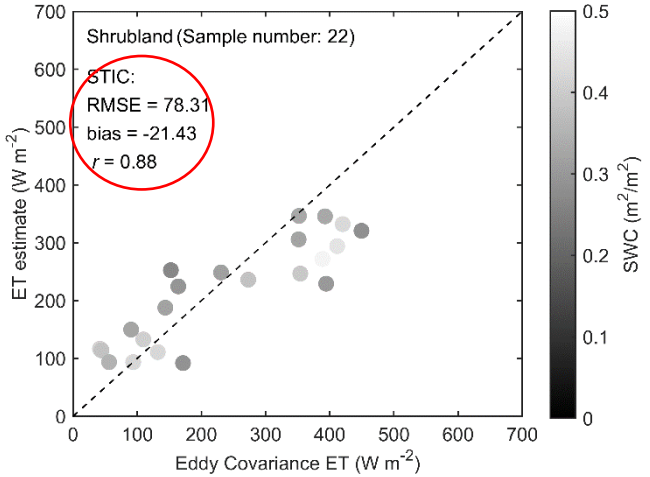

Cropland (Sample number: 52)
SEBS:
RMSE = 69.54
bias = -7.24
r = 0.82
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

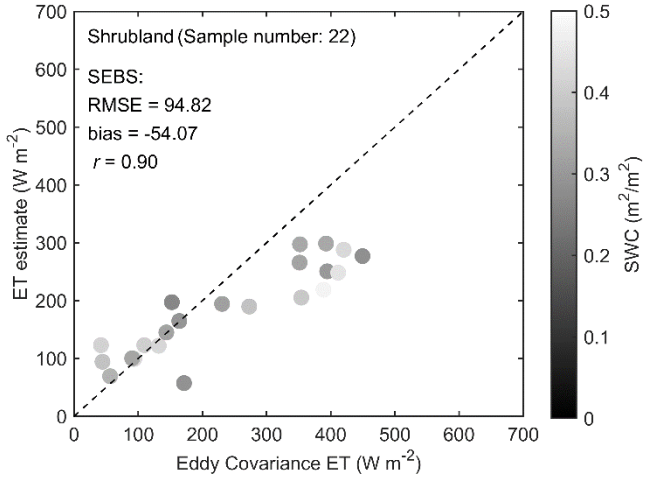

Cropland (Sample number: 52)
TSEB:
RMSE = 83.33
bias = 36.77
r = 0.81
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

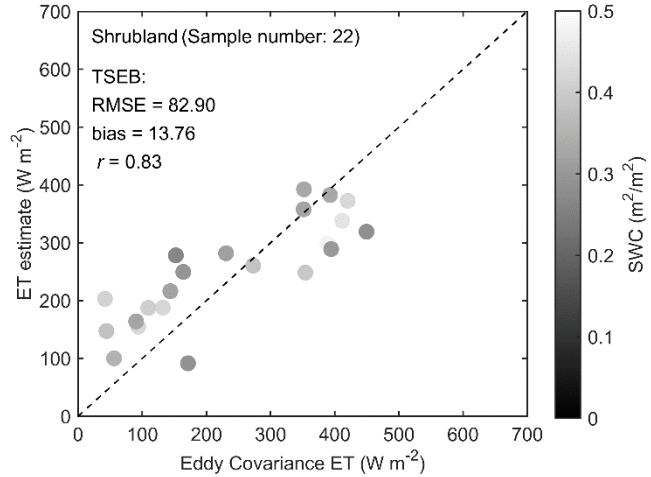

Grassland (Sample number: 46)
STIC:
RMSE = 49.10
bias = 3.51
r = 0.87
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

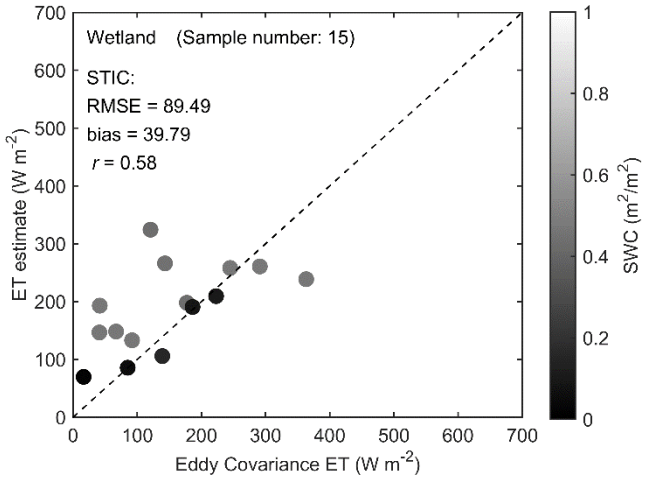

Grassland (Sample number: 46)
SEBS:
RMSE = 46.71
bias = 14.42
r = 0.90
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

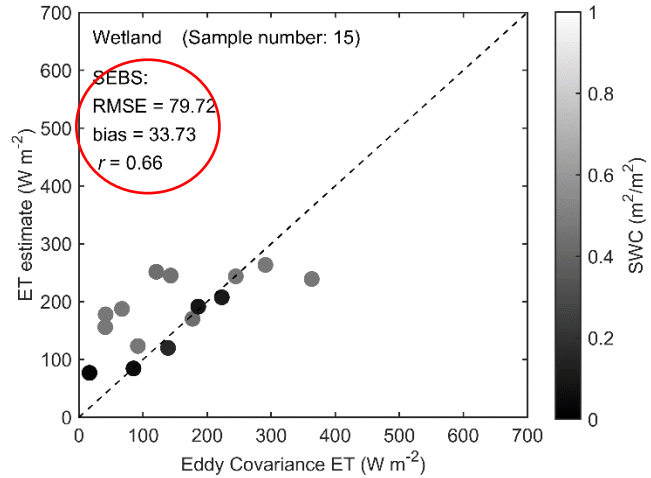

Grassland (Sample number: 46)
TSEB:
RMSE = 68.39
bias = 42.98
r = 0.87
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

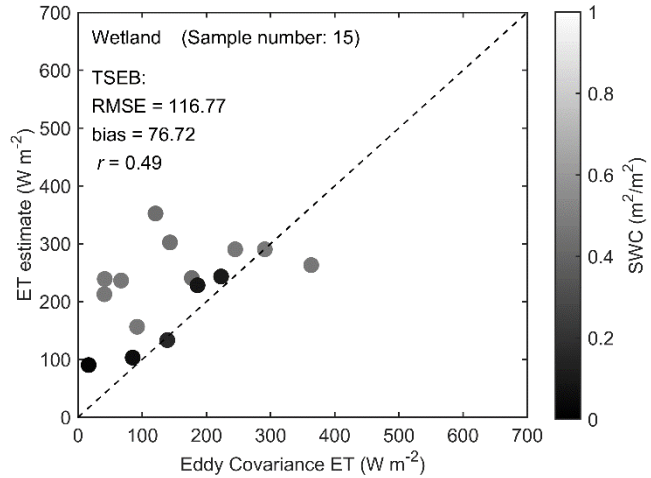

Shrubland (Sample number: 22)
STIC:
RMSE = 78.31
bias = -21.43
r = 0.88
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

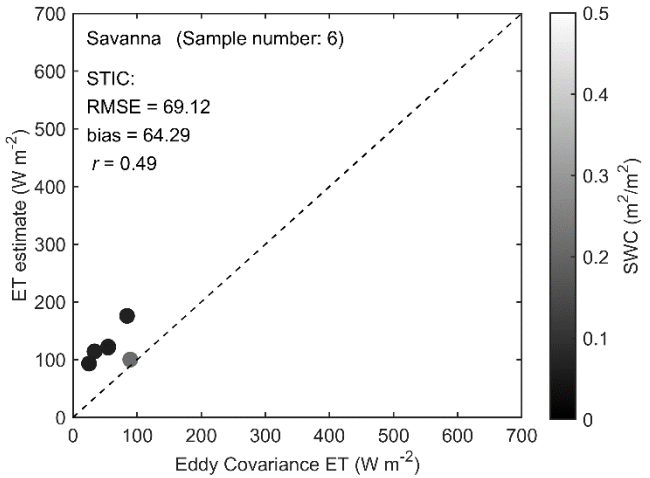

Shrubland (Sample number: 22)
SEBS:
RMSE = 94.82
bias = -54.07
r = 0.90
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

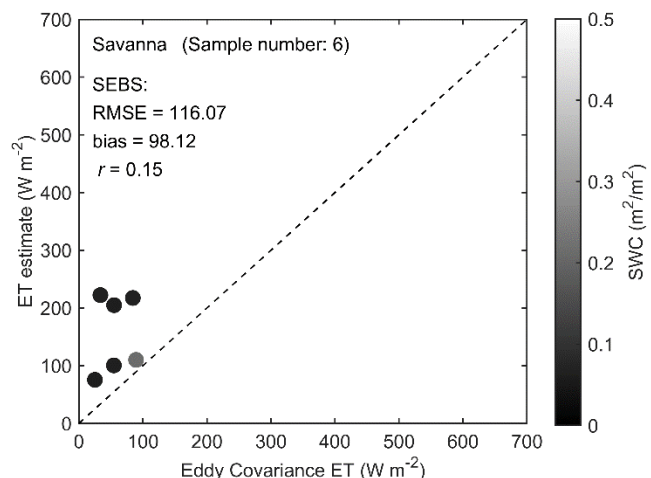

Shrubland (Sample number: 22)
TSEB:
RMSE = 82.90
bias = 13.76
r = 0.83
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

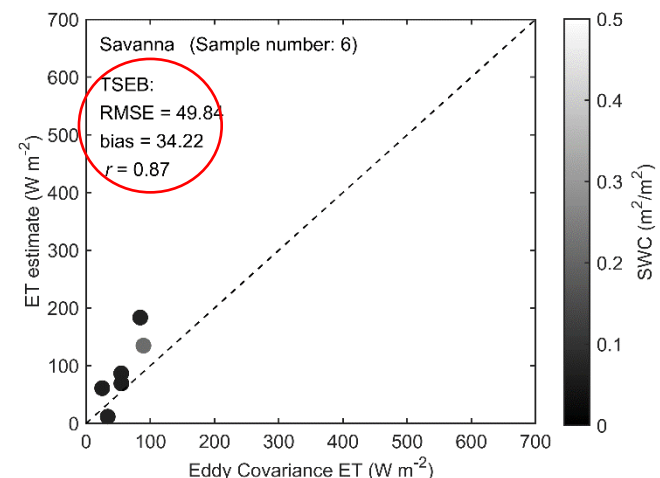

Wetland (Sample number: 15)
STIC:
RMSE = 89.49
bias = 39.79
r = 0.58
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)


Wetland (Sample number: 15)
SEBS:
RMSE = 79.72
bias = 33.73
r = 0.66
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

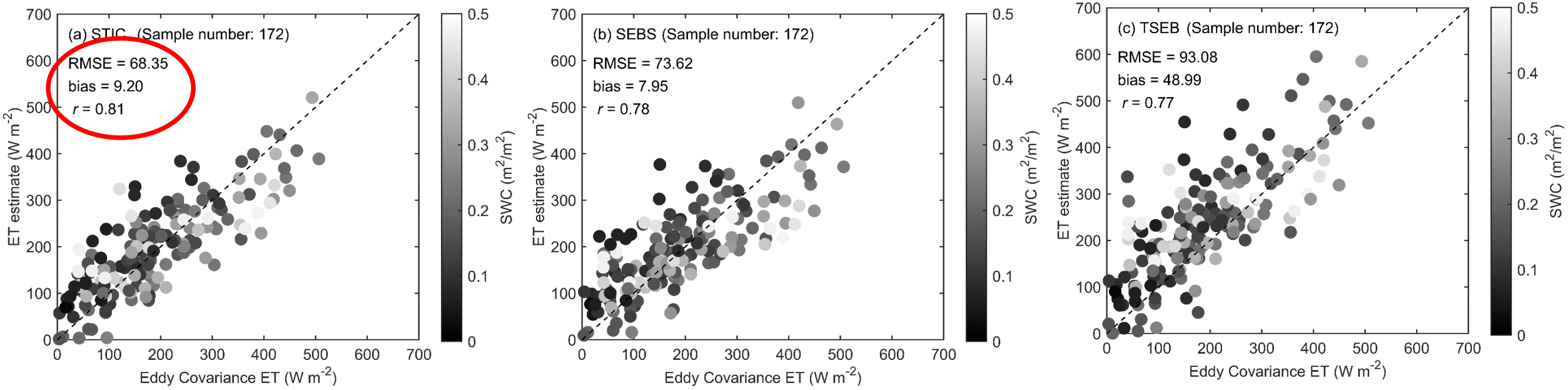

Wetland (Sample number: 15)
TSEB:
RMSE = 116.77
bias = 76.72
r = 0.49
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)


Savanna (Sample number: 6)
STIC:
RMSE = 69.12
bias = 64.29
r = 0.49
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

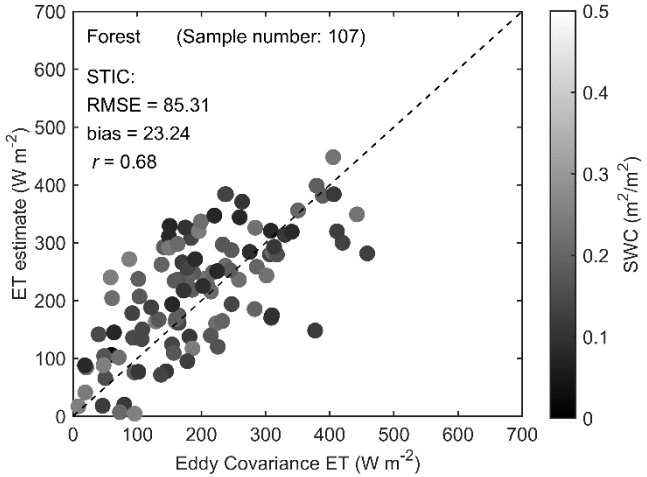

Savanna (Sample number: 6)
SEBS:
RMSE = 116.07
bias = 98.12
r = 0.15
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

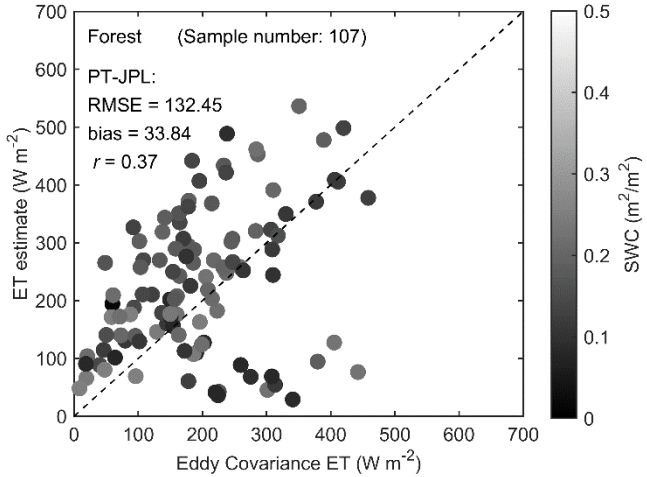

Savanna (Sample number: 6)
TSEB:
RMSE = 49.84
bias = 34.22
r = 0.87
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

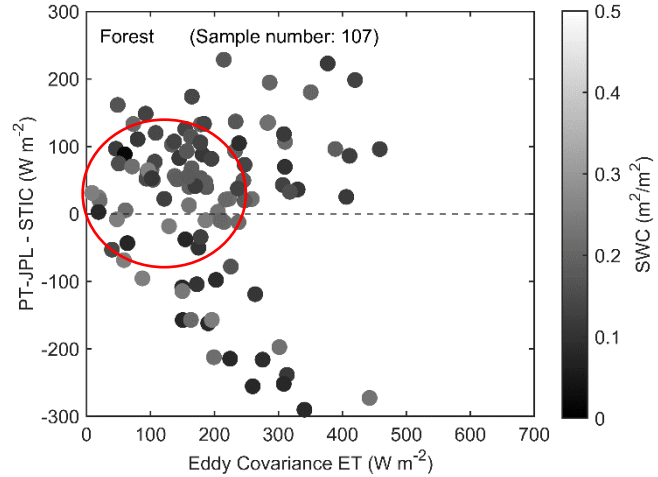
Best performance of STIC overall, close to SEBS

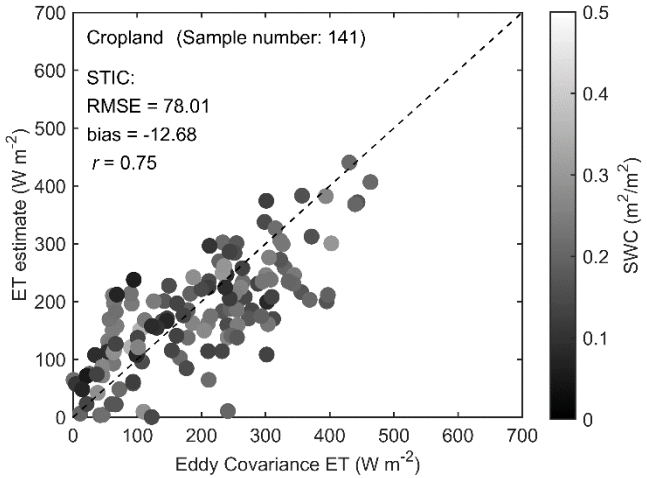


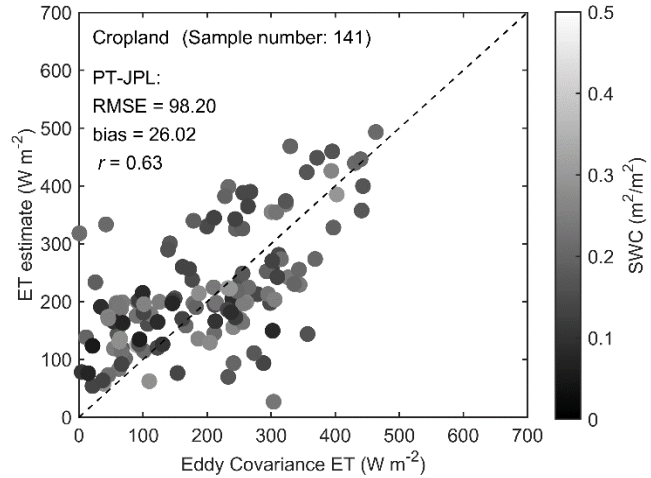
How EEH ET compares with official NASA ECOSTRESS ET?

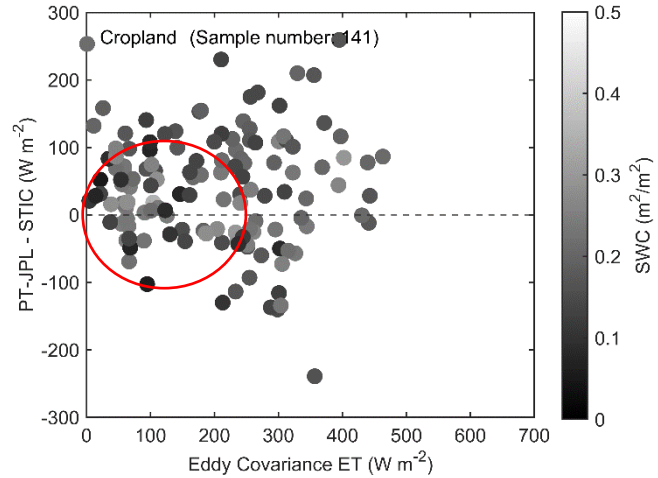

Forest (Sample number: 107)
STIC:
RMSE = 85.31
bias = 23.24
r = 0.68
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

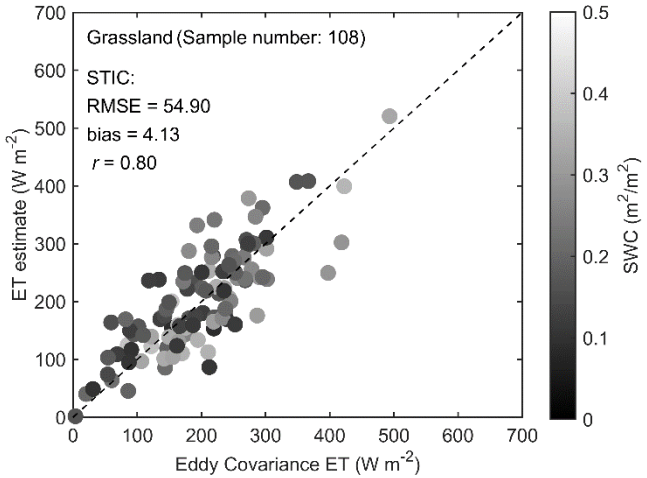

Forest (Sample number: 107)
PT-JPL:
RMSE = 132.45
bias = 33.84
r = 0.37
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

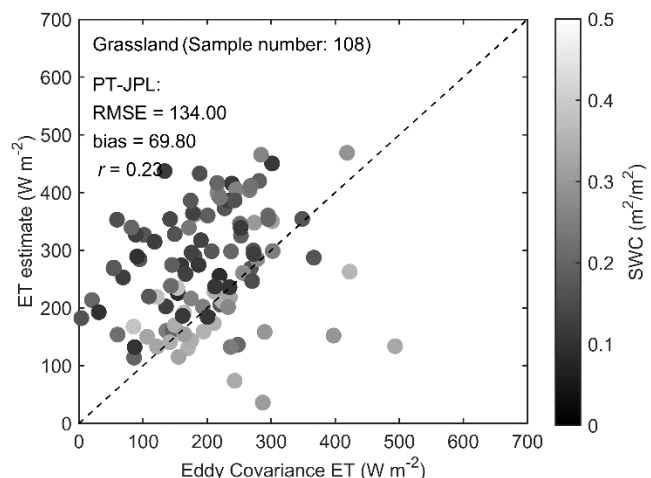

Forest (Sample number: 107)
PT-JPL - STIC (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

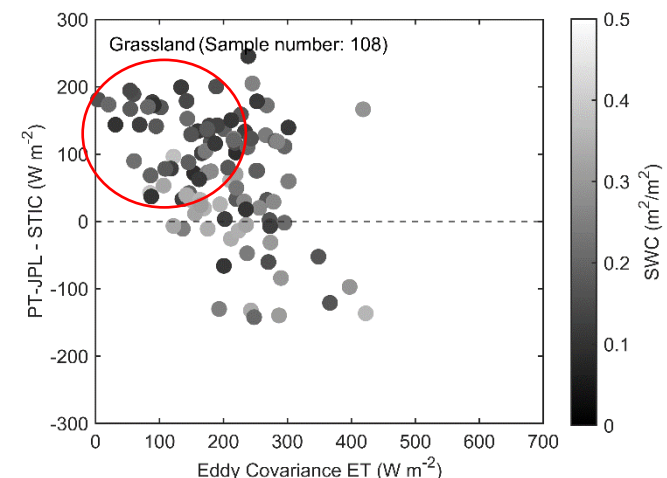

Cropland (Sample number: 141)
STIC:
RMSE = 78.01
bias = -12.68
r = 0.75
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

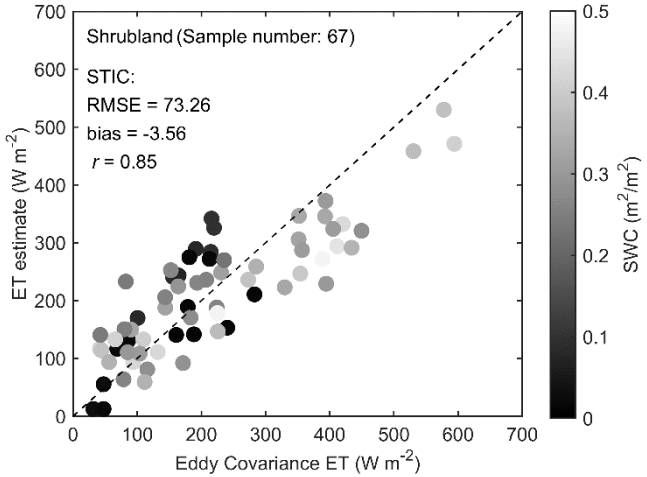

Cropland (Sample number: 141)
PT-JPL:
RMSE = 98.20
bias = 26.02
r = 0.63
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

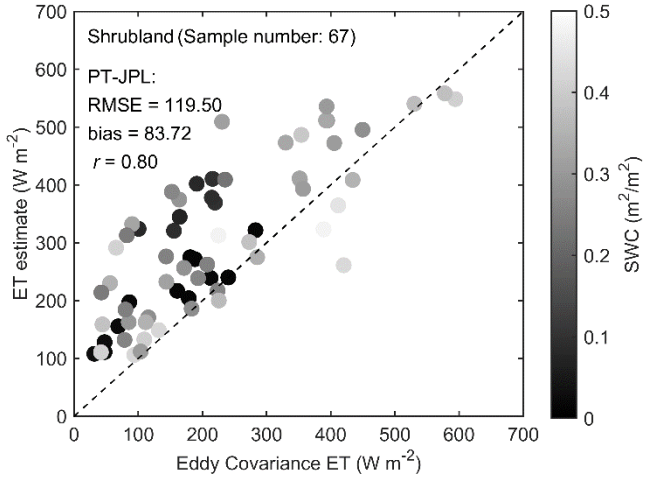

Cropland (Sample number: 141)
PT-JPL - STIC (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

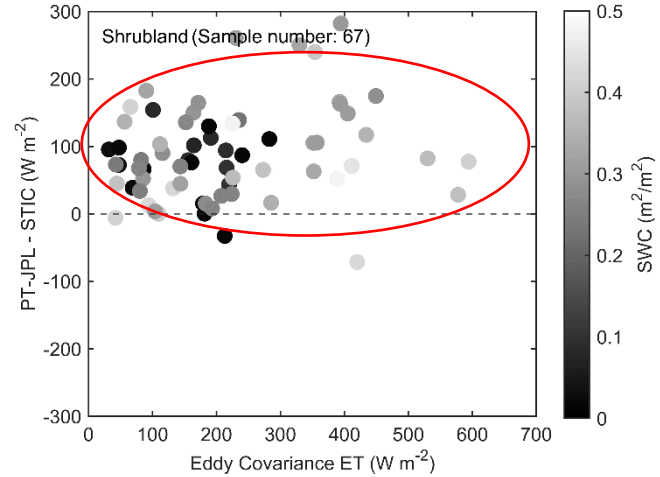

Grassland (Sample number: 108)
STIC:
RMSE = 54.90
bias = 4.13
r = 0.80
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

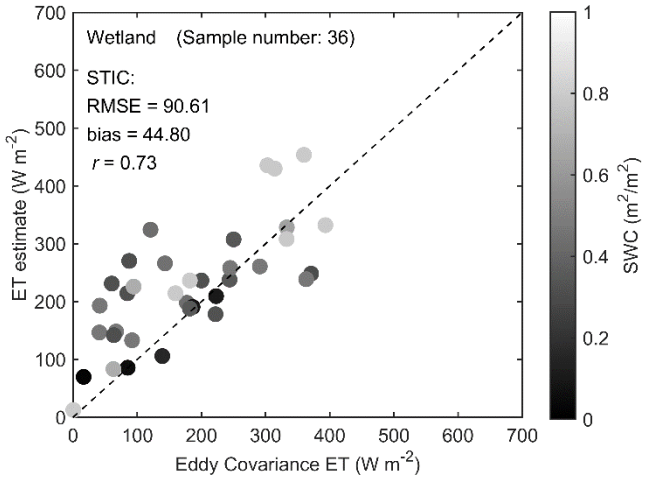

Grassland (Sample number: 108)
PT-JPL:
RMSE = 134.00
bias = 69.80
r = 0.23
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

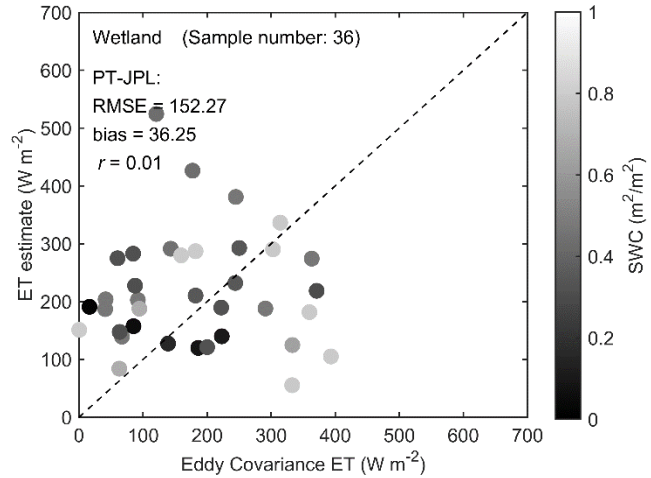

Grassland (Sample number: 108)
PT-JPL - STIC (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

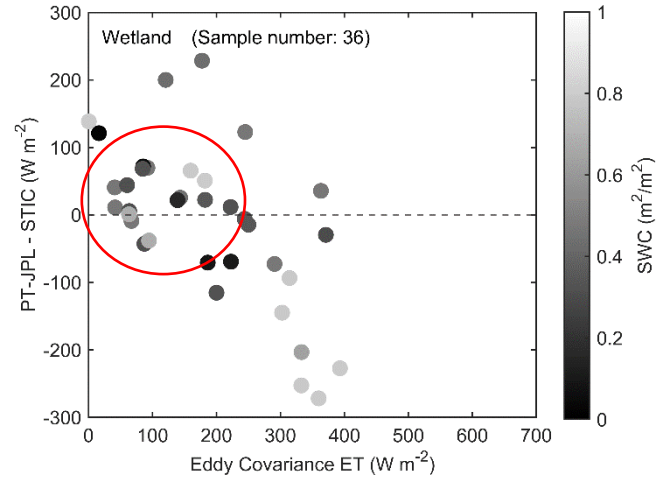

Shrubland (Sample number: 67)
STIC:
RMSE = 73.26
bias = -3.56
r = 0.85
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

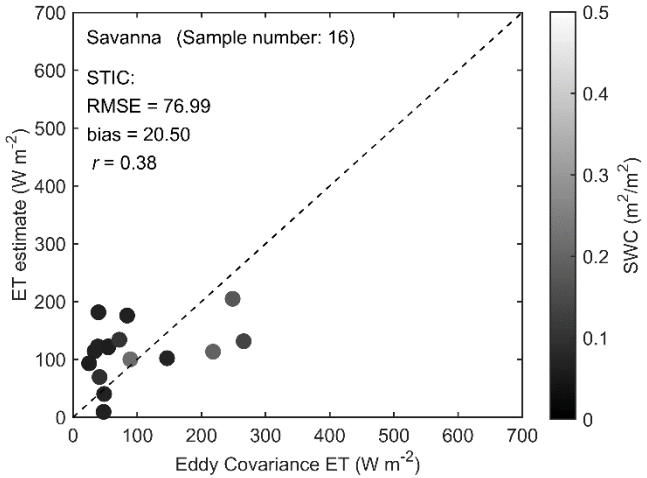

Shrubland (Sample number: 67)
PT-JPL:
RMSE = 119.50
bias = 83.72
r = 0.80
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

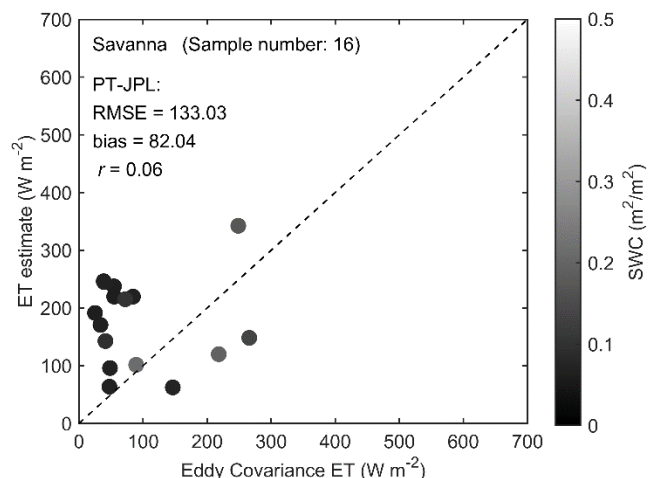

Shrubland (Sample number: 67)
PT-JPL - STIC (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

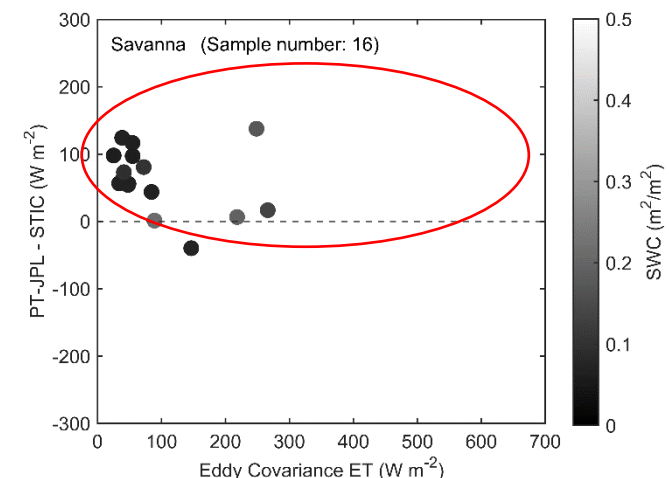

Wetland (Sample number: 36)
STIC:
RMSE = 90.61
bias = 44.80
r = 0.73
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)


Wetland (Sample number: 36)
PT-JPL:
RMSE = 152.27
bias = 36.25
r = 0.01
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

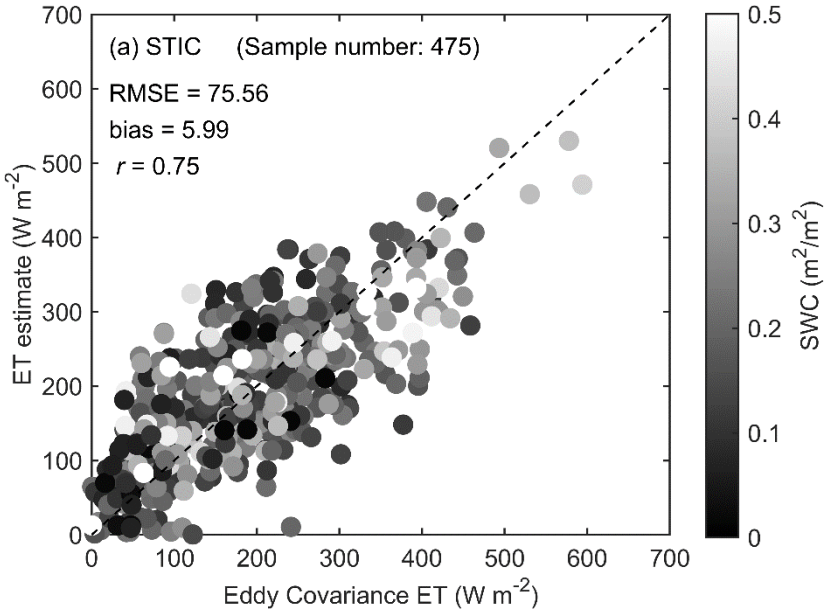

Wetland (Sample number: 36)
PT-JPL - STIC (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

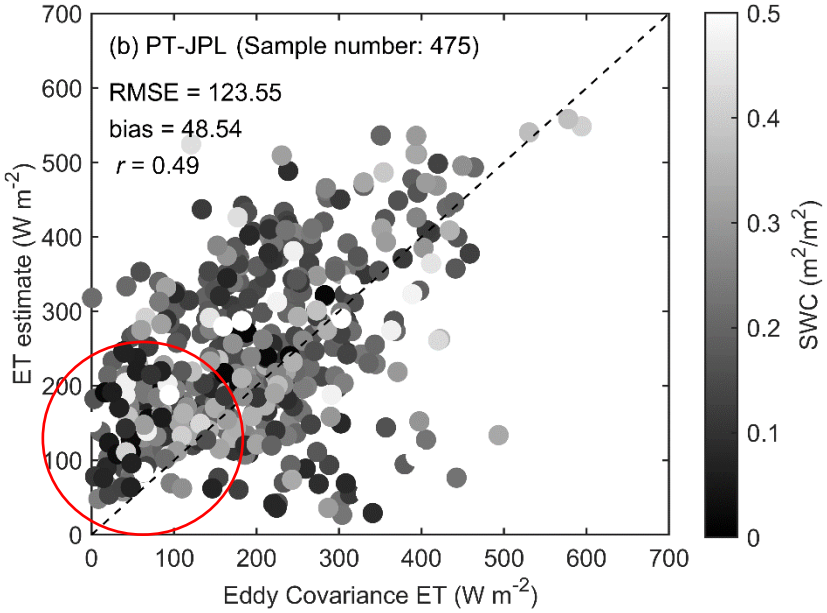

Savanna (Sample number: 16)
STIC:
RMSE = 76.99
bias = 20.50
r = 0.38
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

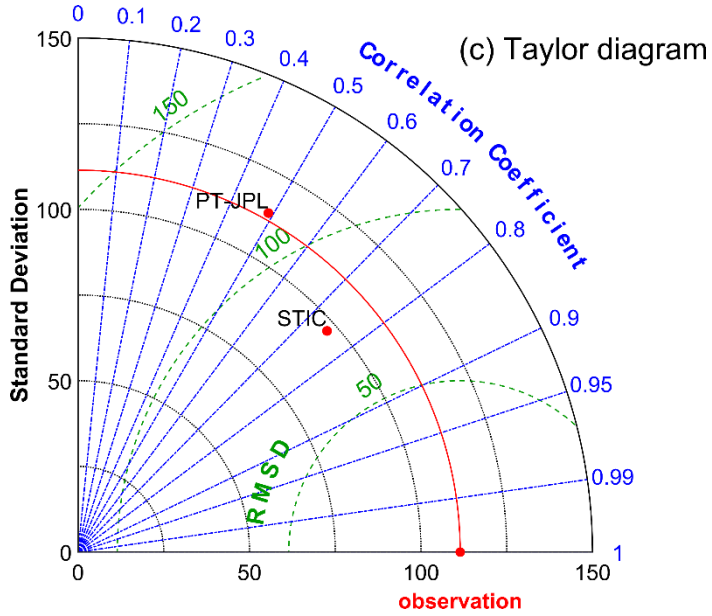

Savanna (Sample number: 16)
PT-JPL:
RMSE = 133.03
bias = 82.04
r = 0.06
ET estimate (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)


Savanna (Sample number: 16)
PT-JPL - STIC (W m-2)
Eddy Covariance ET (W m-2)
SWC (m2/m2)

Clear advantage (~50 W m^{-2}) of STIC over PT-JPL overall







Consistent overestimation of NASA ET products under water stress (weak LST constraint)

Conclusions

- Similar accuracy of three ECOSTRESS LST products, around 2.4 K (RMSE), marginal difference between SW and TES (even from SC), empowered by ASTER GED
- Close accuracies of three operational high resolution LST (ECOSTRESS, Landsat, ASTER), between 2 and 2.5 K (RMSE)
- Better performance of STIC and SEBS than TSEB, highest accuracy of STIC (~68 W m^{-2})
- Clear advantage (uncertainty 50 W m^{-2} lower) of STIC over PT-JPL

Acknowledgement: ESA EOEP-5 (Earth Observation Envelop Programme), scientists involved in ECOSTRESS mission and ground measurement collection