MONASH University

Engineering

Towards Validation of SMAP Downscaled Soil Moisture

J Walker, R DeJeu, D Entekhabi, TJ Jackson, E Kim, O Merlin, A Monerris, L Renzullo, C Rüdiger, F Winston, X Wu, N Ye




VU UNIVERSITY AMSTERDAM

MIT

USDA United States Department of Agriculture

NASA Goddard

CESBIO

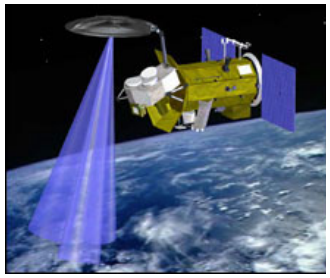
CSIRO

Soil moisture missions (L-band)

SMOS (Soil Moisture and Ocean Salinity)

launched Nov 2009

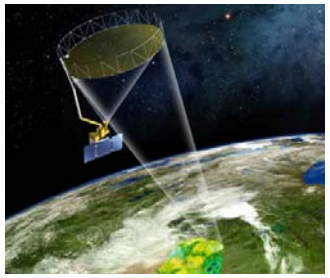
40km with 3days repeat;
synthetic aperture radiometer



Aquarius (Ocean Salinity and Soil Moisture)

launched Jun 2011

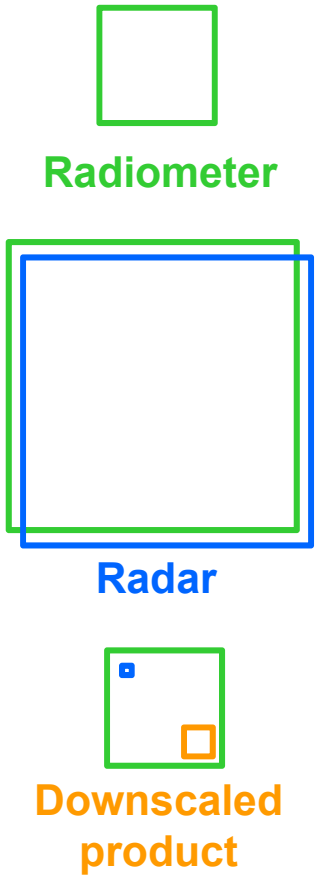
~100km with 7days repeat;
"traditional" radar and radiometer



SMAP (Soil Moisture Active and Passive)

launch Nov 2014

40-10km with 3days repeat;
high resolution radar and radiometer



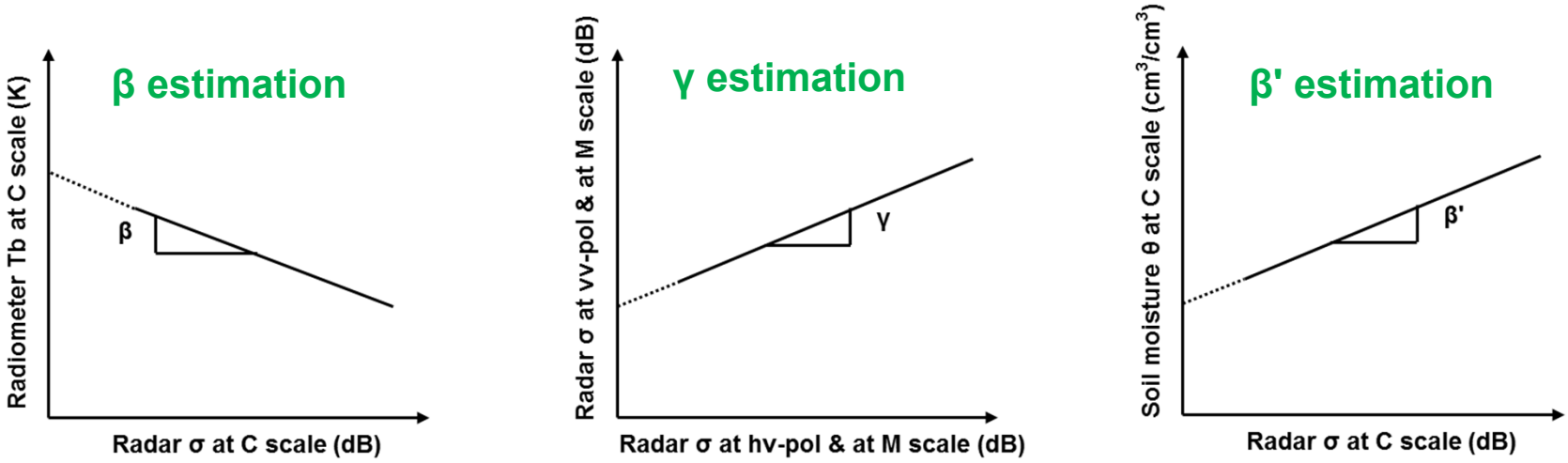
Target accuracy: 4% volumetric for top 5cm soil under moderate vegetation

SMAP downscaling algorithms

1. Baseline downscaling algorithm for SMAP

➢ $Tb_p(M_j) = Tb_p(C) + \beta(C) \times \{[\sigma_{pp}(M_j) - \sigma_{pp}(C)] + \gamma \times [\sigma_{pq}(C) - \sigma_{pq}(M_j)]\}$.

Soil moisture retrieval from downscaled Tb and ancillary parameters



2. Optional downscaling algorithm for SMAP

➢ $\theta(M_j) = \theta(C) + \beta'(C) \times \{[\sigma_{pp}(M_j) - \sigma_{pp}(C)] - \gamma \times [\sigma_{pq}(C) - \sigma_{pq}(M_j)]\}$.

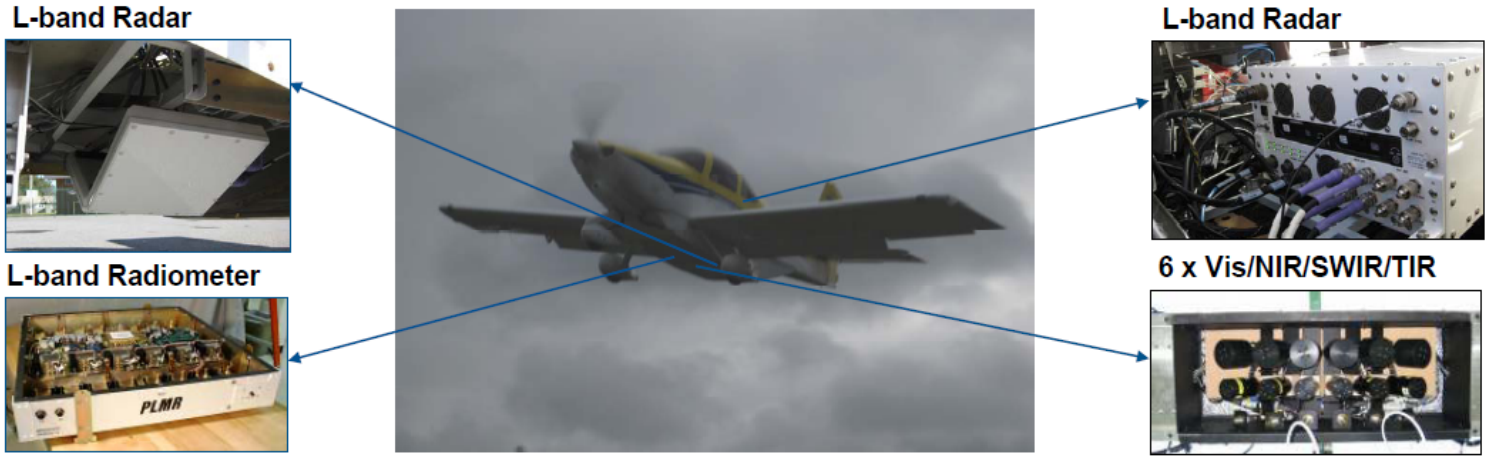
Source: SMAP ATBD

Motivation

Algorithm validation is largely based on synthetic studies & few experimental data sets

36km brightness temperature (Tb) from radiometer

1km backscatter coefficient (σ) from radar



PLMR:
Polarimetric L-band Multi-beam Radiometer

Frequency/bandwidth: 1.413GHz/24MHz

Polarisations: V and H

Resolution: ~1km at 10,000ft flying height,

Incidence angles: ±7°, ±21.5°, ±38.5° across track

Antenna type: 8x8 patch array

PLIS:
Polarimetric L-band Imaging SAR

Frequency/bandwidth:1.26GHz/30MHz

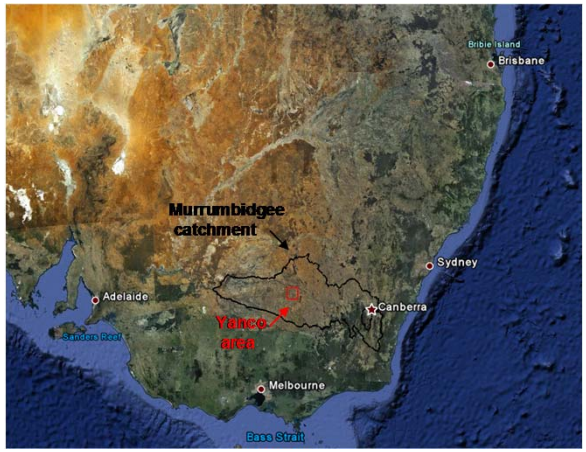
Polarisations: VV, VH, HV and HH

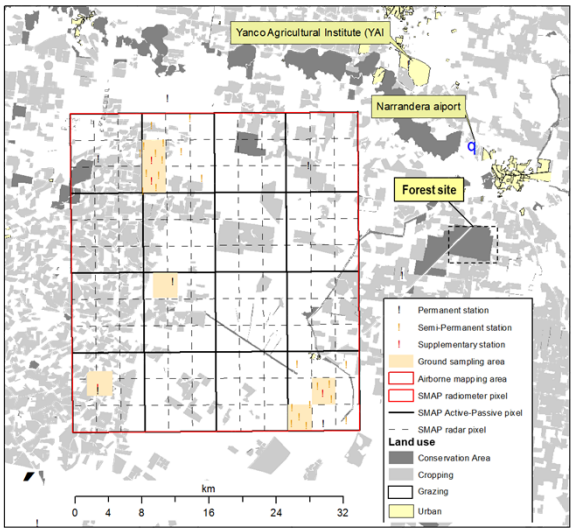
Resolution: ~10m

Incidence angles: 15º - 45º on both sides of aircraft

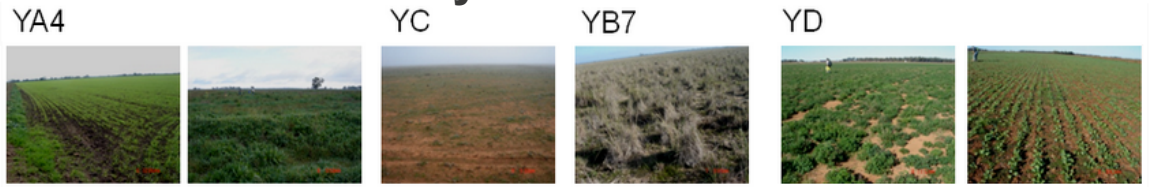
Antenna type: 2x2 patch array

SMAP Experiments (SMAPEx)

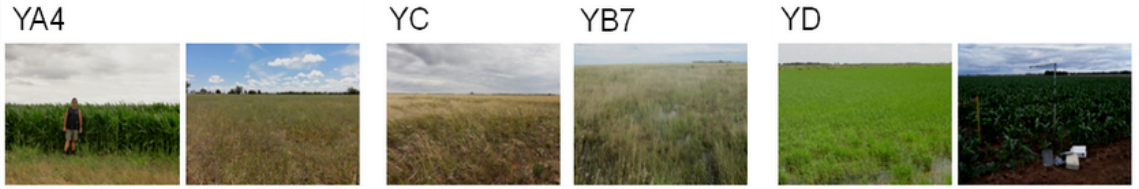




SMAPEx-1: 5-10 July 2010



SMAPEx-2: 4-8 December 2010

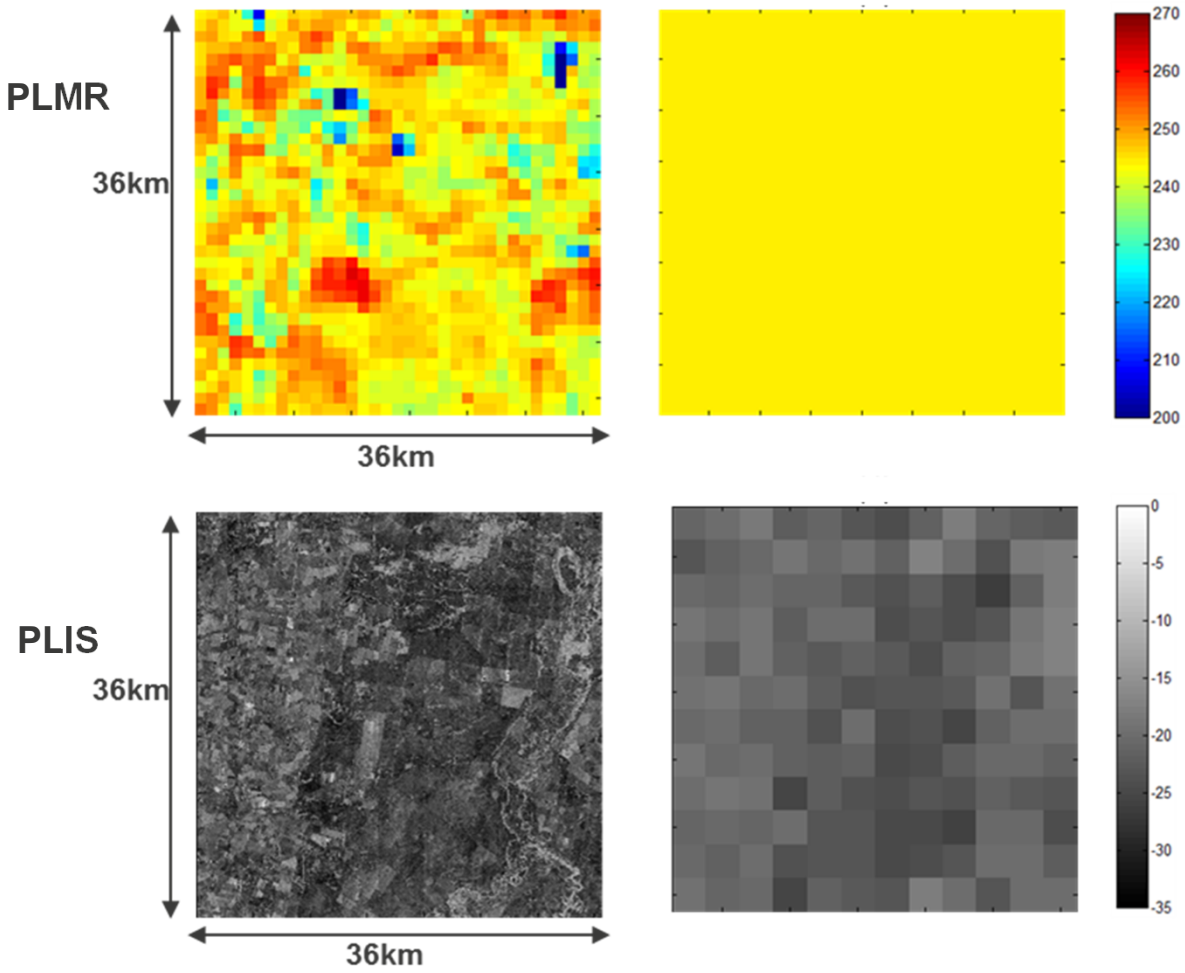


SMAPEx-3: 5-23 September 2011

- **Downscaling of radiometer observations using radar data.**
- Radiometer retrieval using radar-derived parameters.
- Development of an Australian cal/val site for SMAP.
- Testing of radar retrieval algorithms.

Panciera, Walker, Jackson, et al., 2014. The Soil Moisture Active Passive Experiments (SMAPEx): Towards Soil Moisture Retrieval from the SMAP Mission. *TGRS*, **52**(1): 490-507.

Example of simulated data



Incidence-angle normalized to 40°;

PLMR Tb upscaled to 36km;

PLIS σ upscaled to 3km

(Data collected on 7th Sept. 2011)

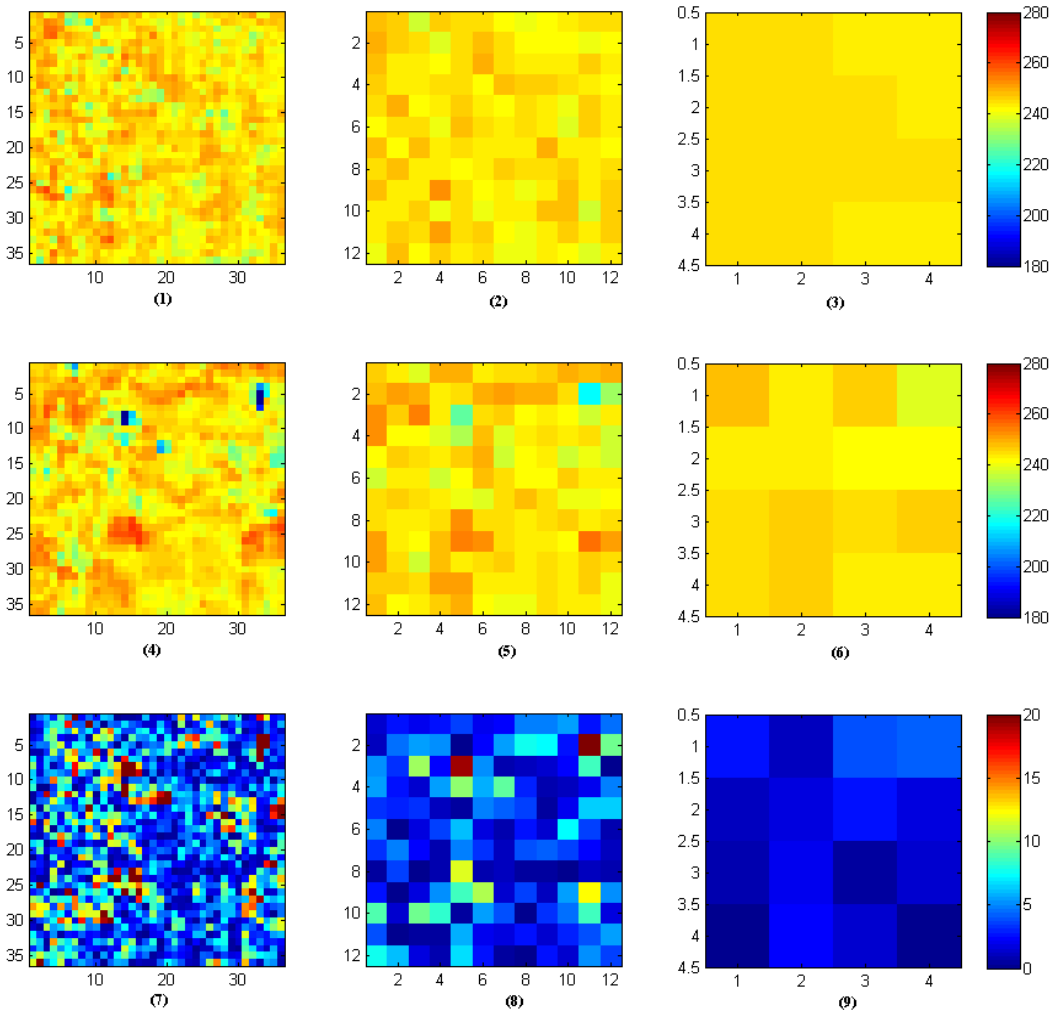
Wu, Walker,, Rüdiger, Panciera, and Gray. Simulation of the SMAP Data Stream from SMAPEx Field Campaigns in Australia, *TGRS*, In Review

Downscaled brightness temperature

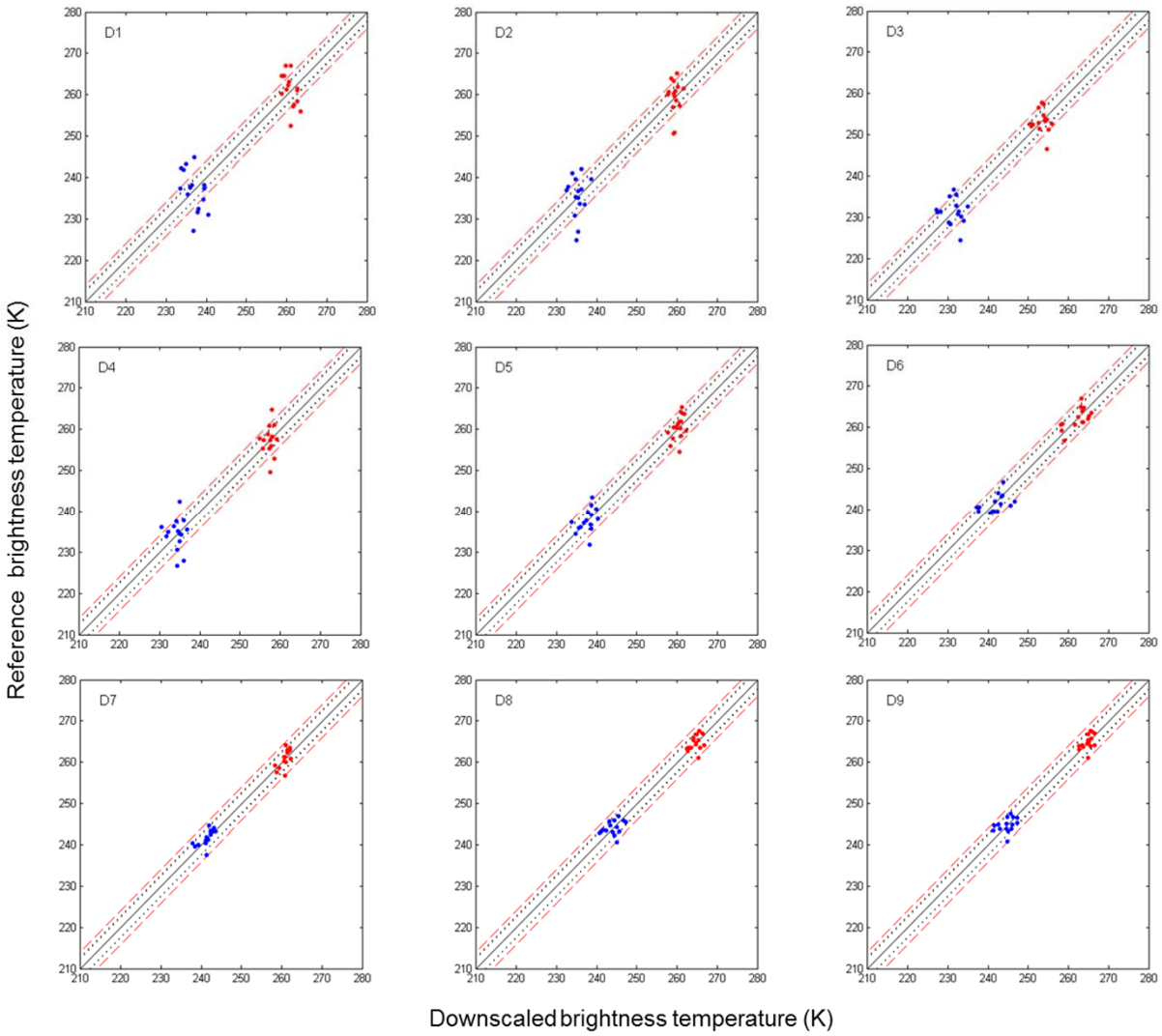
Downscaled Tb

Reference Tb

Difference



1km **3km** **9km**



- **Resolution: 9km**
- **Polarization: H (in blue) and V (in red)**
- **Red dashed lines: SMOS target 4K; black dashed lines: SMAP target 2.4K**
- **Water-body removed (0.7K lower in RMSE than un-removed)**
- **5 of 9 days: RMSE ~2.4K, error target for SMAP**

	Average RMSE(K)		
		h-pol	v-pol
1km	A1	9.5	7.2
	A2	8.2	6.6
3km	A1	6.6	4.9
	A2	5.5	4.5
9km	A1	3.9	2.9
	A2	3.1	2.6

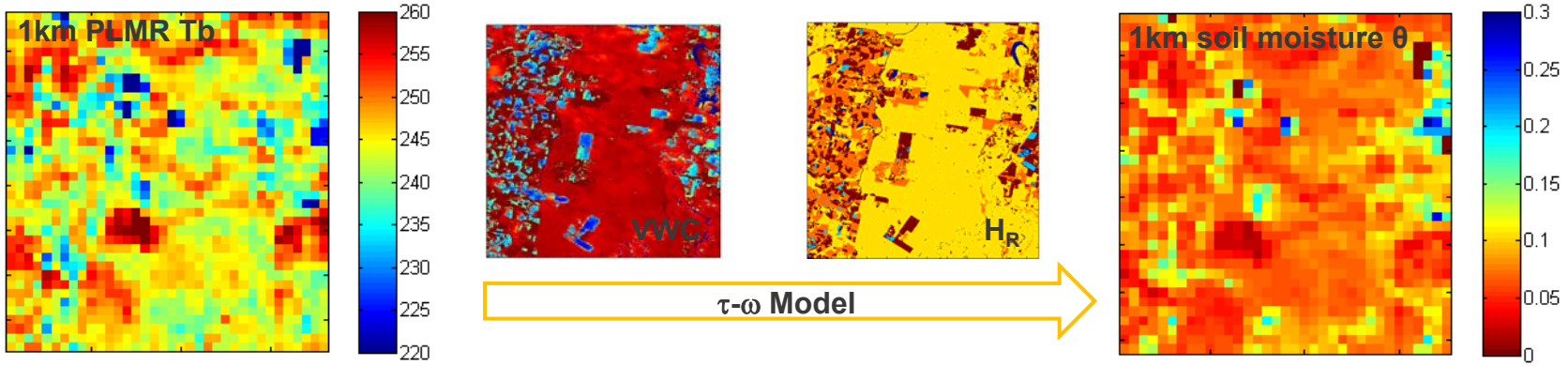
A1: γ=0; A2: γ≠0

Wu, Walker, Das, et al., Evaluation of a Brightness Temperature Downscaling Algorithm using Active and Passive Microwave Observations, *Remote Sensing of Environment*, In Press

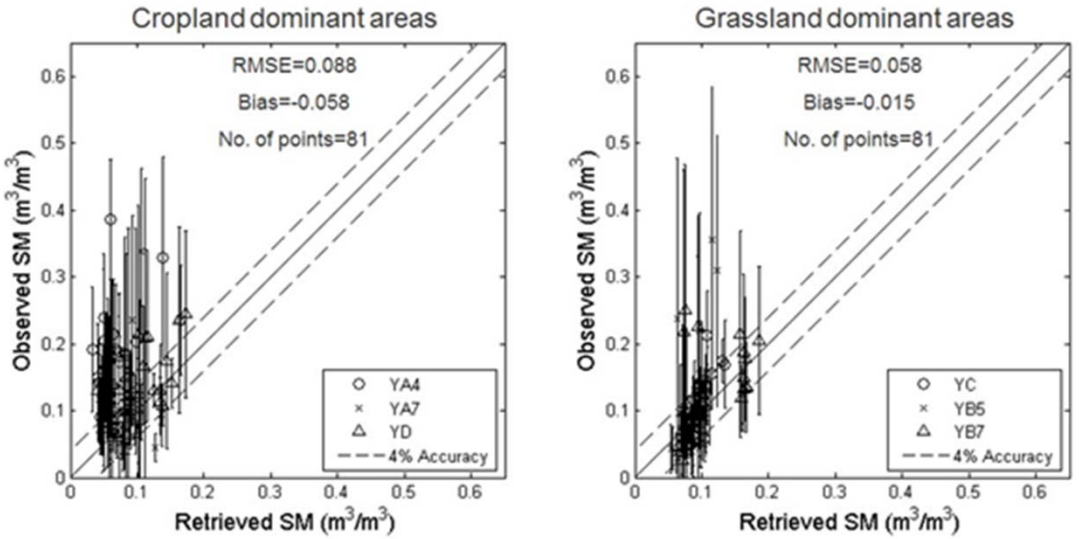
Reference soil moisture

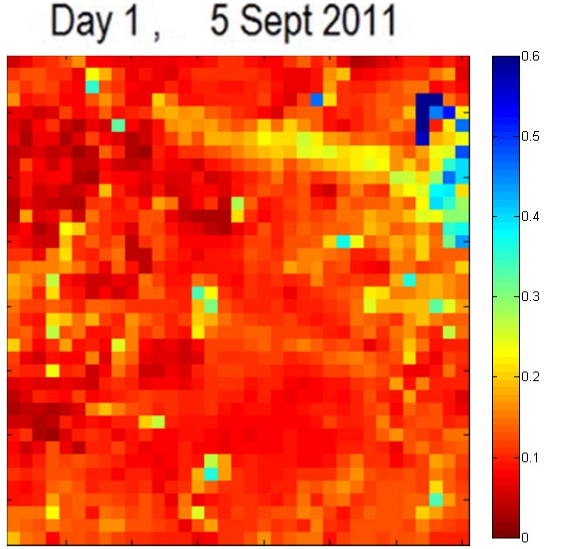
- Passive microwave retrieval model

(Courtesy of Ying Gao)

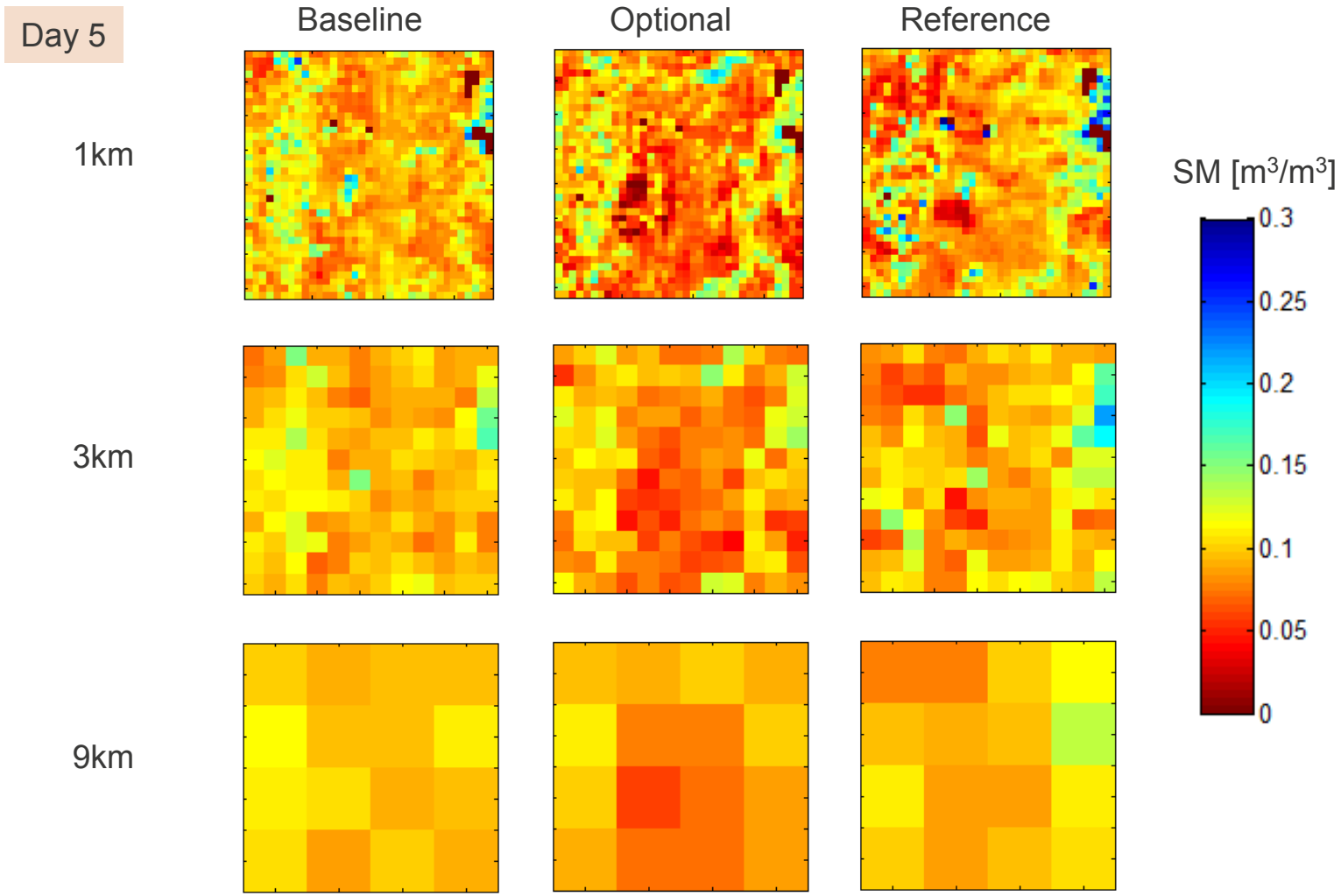


- Validation against ground soil moisture

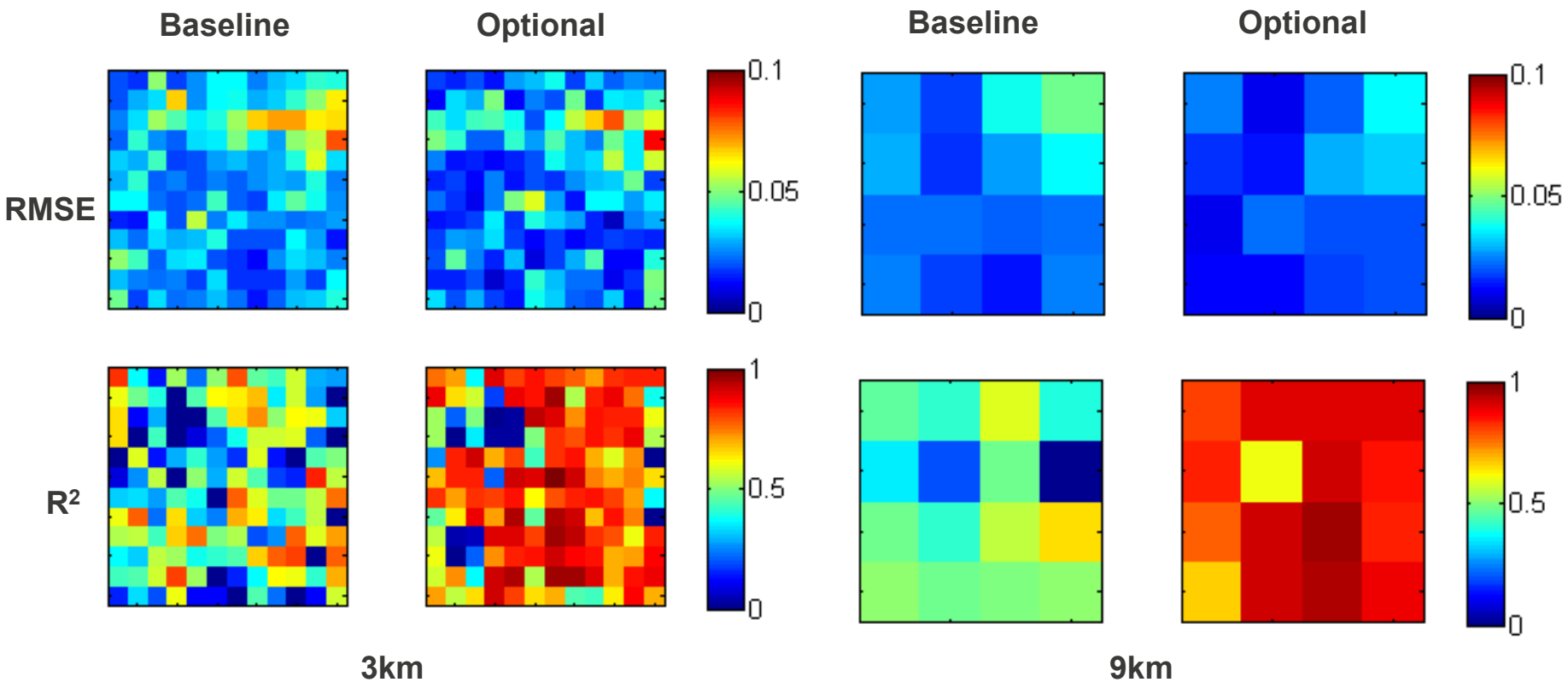




Downscaled soil moisture



Spatial plots of RMSE and R^2 @ 3 & 9km

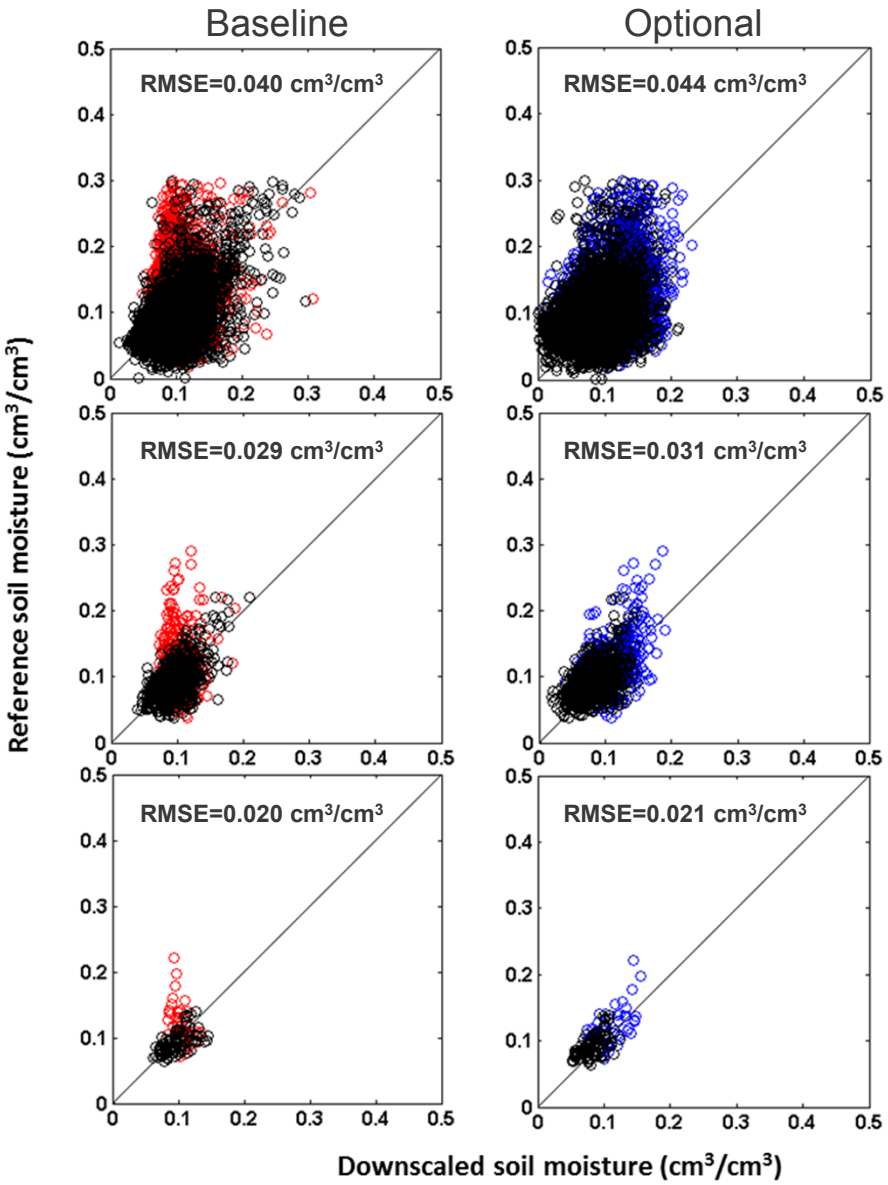


All 9 days

1km

3km

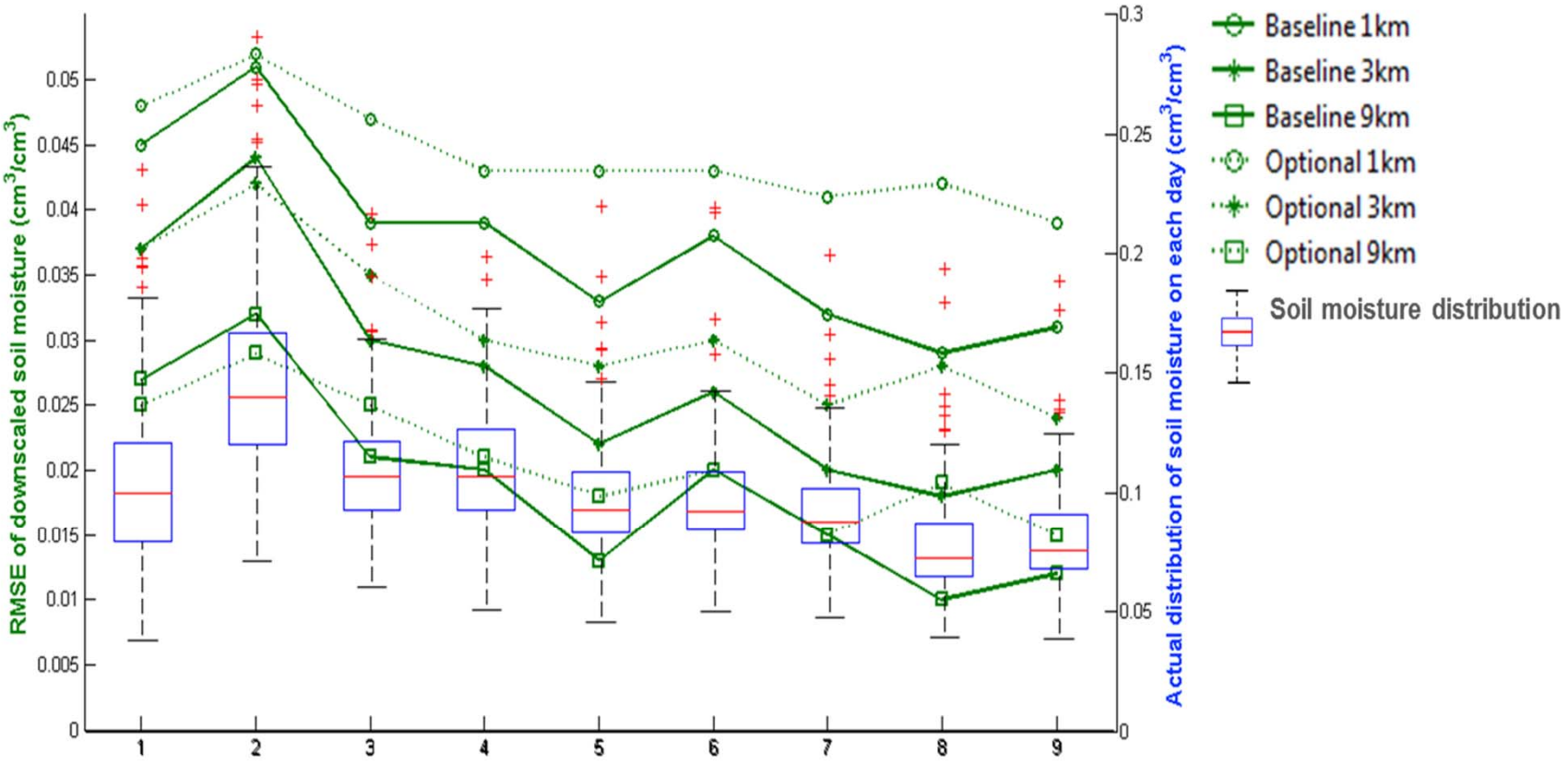
9km



Red/Blue: first 3 days;

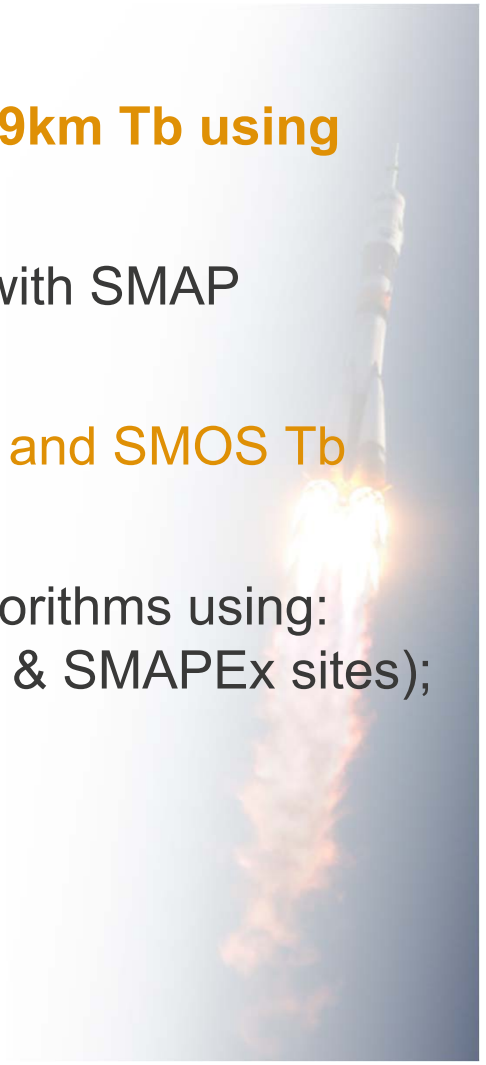
Black: remaining days.

Temporal evolution across 9 days

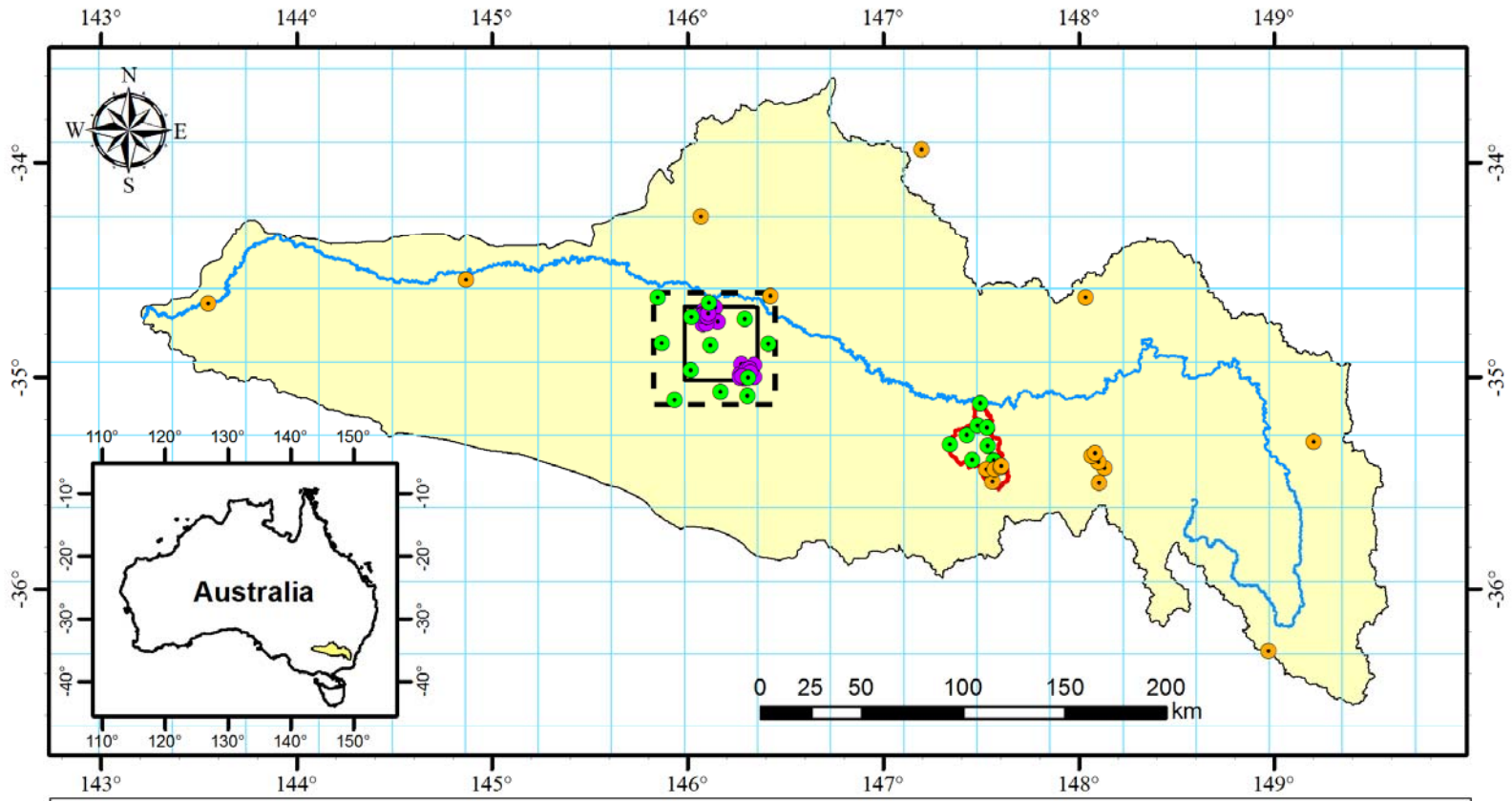


SMAPEx-4/-5 objectives

- **Evaluation of SMAP active-passive downscaled 9km Tb using PLMR Tb observations.**
- Comparison of PLMR Tb and PLIS σ observations with SMAP radiometer and radar observations respectively.
- Inter-comparison between PLMR, SMAP, Aquarius, and SMOS Tb observations.
- Validation of SM_P, SM_A and SM_AP retrieval algorithms using:
  - Coarse and dense monitoring network (OzNet & SMAPEx sites);
  - Airborne retrievals (SMAPEx campaigns).
- Radar only SM retrieval algorithm developments.
- RFI detection and elimination.



Monitoring station network



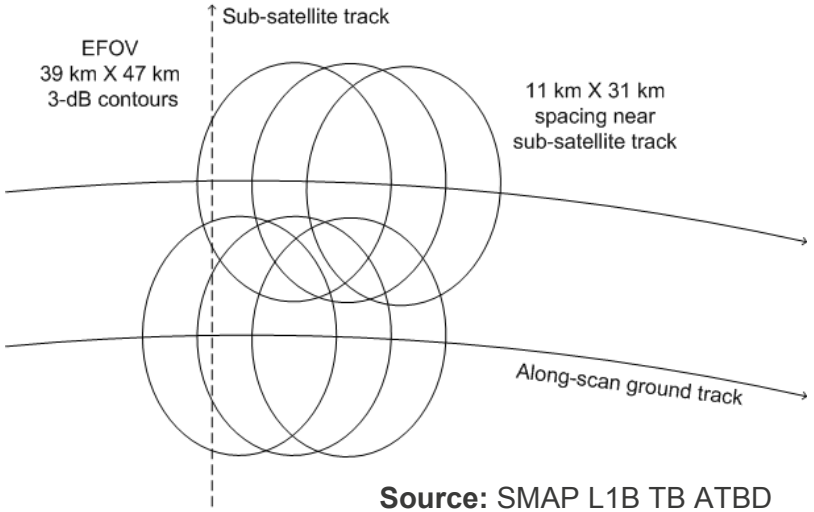
SMAP overpass

Orbit	Ascending/ Descending	Date Time	Distance to nadir
00010	A	2014-01-02T08:36:31.556	-50.00
00016	D	2014-01-02T19:35:58.543	370.00
00031	D	2014-01-03T20:12:33.555	-460.00
00054	A	2014-01-05T08:48:42.742	220.00
00060	D	2014-01-05T19:48:09.729	100.00
00083	A	2014-01-07T08:24:20.372	-330.00
00098	A	2014-01-08T09:00:52.481	490.00
00104	D	2014-01-08T20:00:20.923	-180.00

Based on Nov 5 launch date

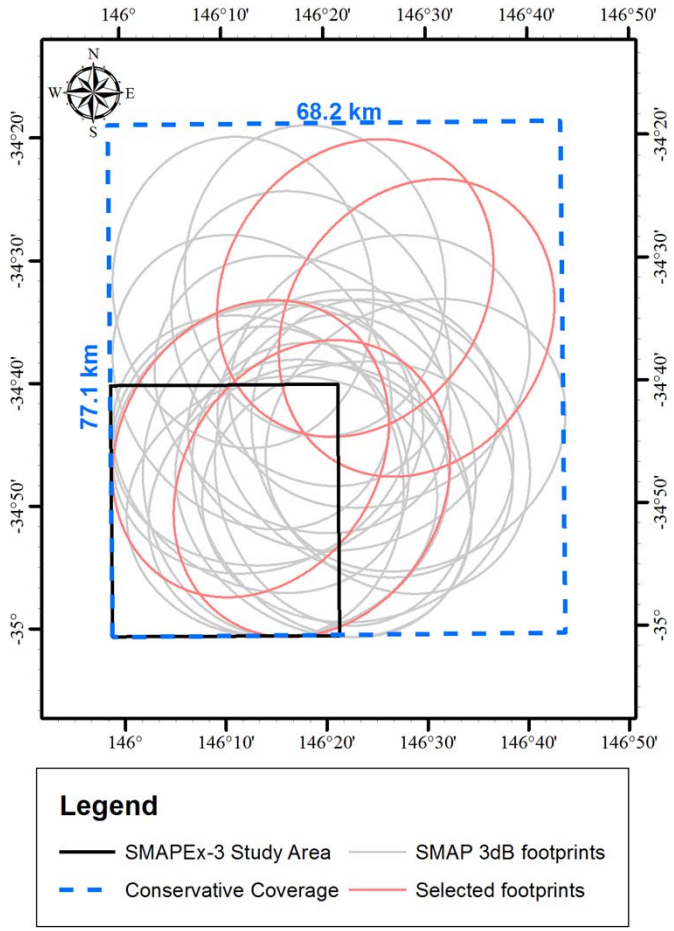
SMAP has an 8-day exact repeat

Conservative coverage for SMAP



Source: SMAP L1B TB ATBD

Distance to nadir [km]	Scan angle [°]	Spacing [m]	Azimuth [°]	Looking	Minimum extent	
					width [m]	length [m]
370	48.6	20,175	60.6	F	**68,178**	60,558
			143.6	B	62,817	67,114
-460	66.9	11,578	-54.9	F	60,312	57,472
			-101.1	B	60,207	52,349
-180	21.1	28,857	-9.1	F	54,645	**77,050**
			-146.9	B	66,521	74,945



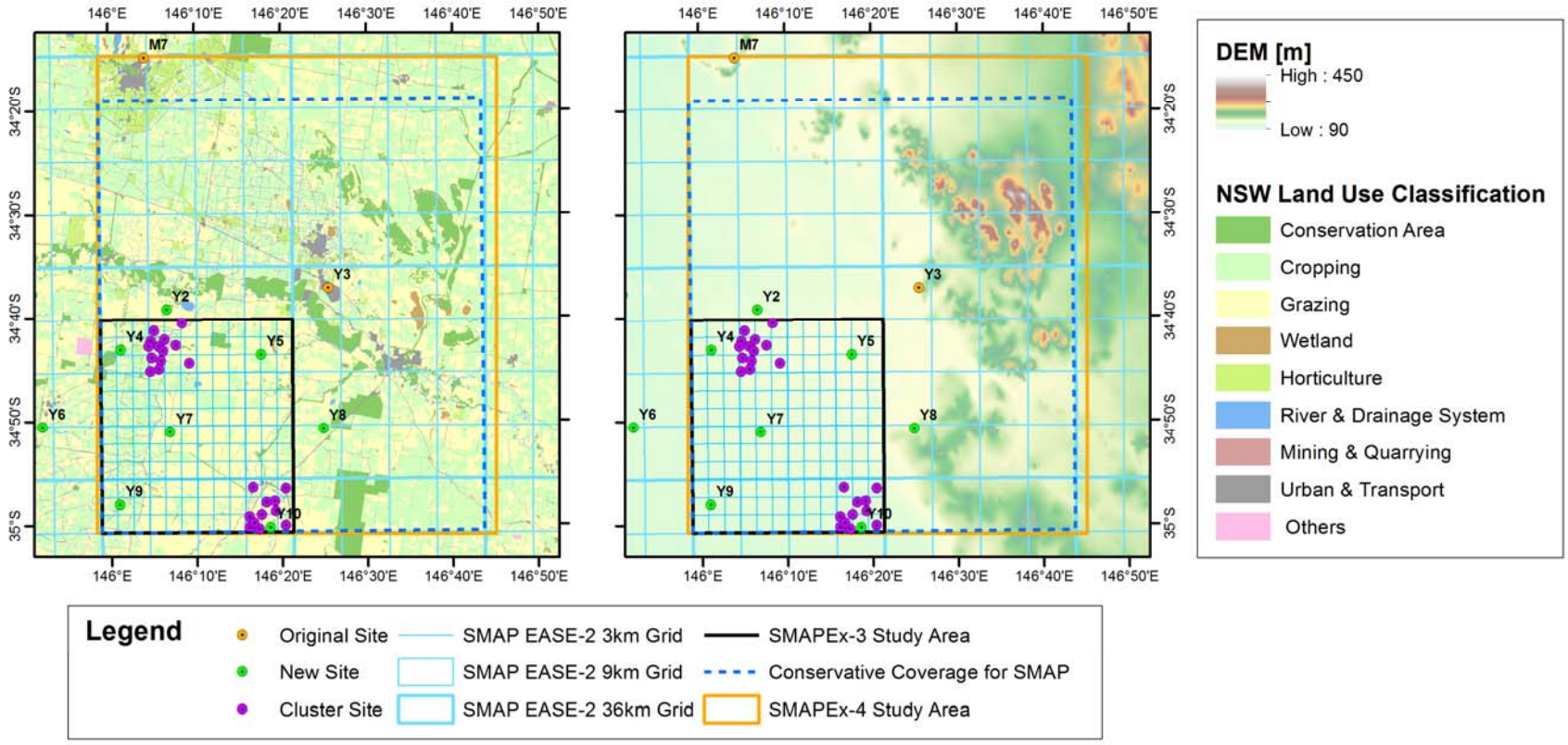
SMAPEx-4 flight area for SMAP

Land Use

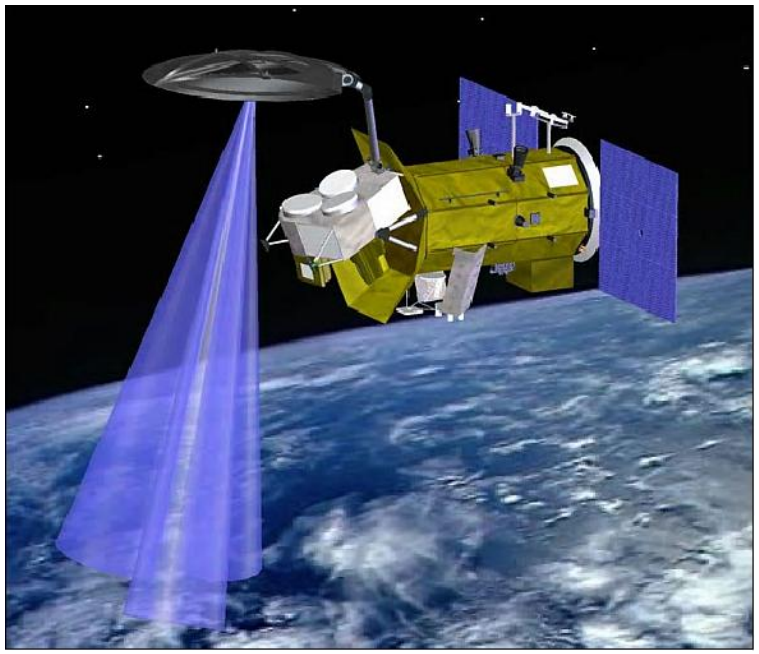
Topography

71 km

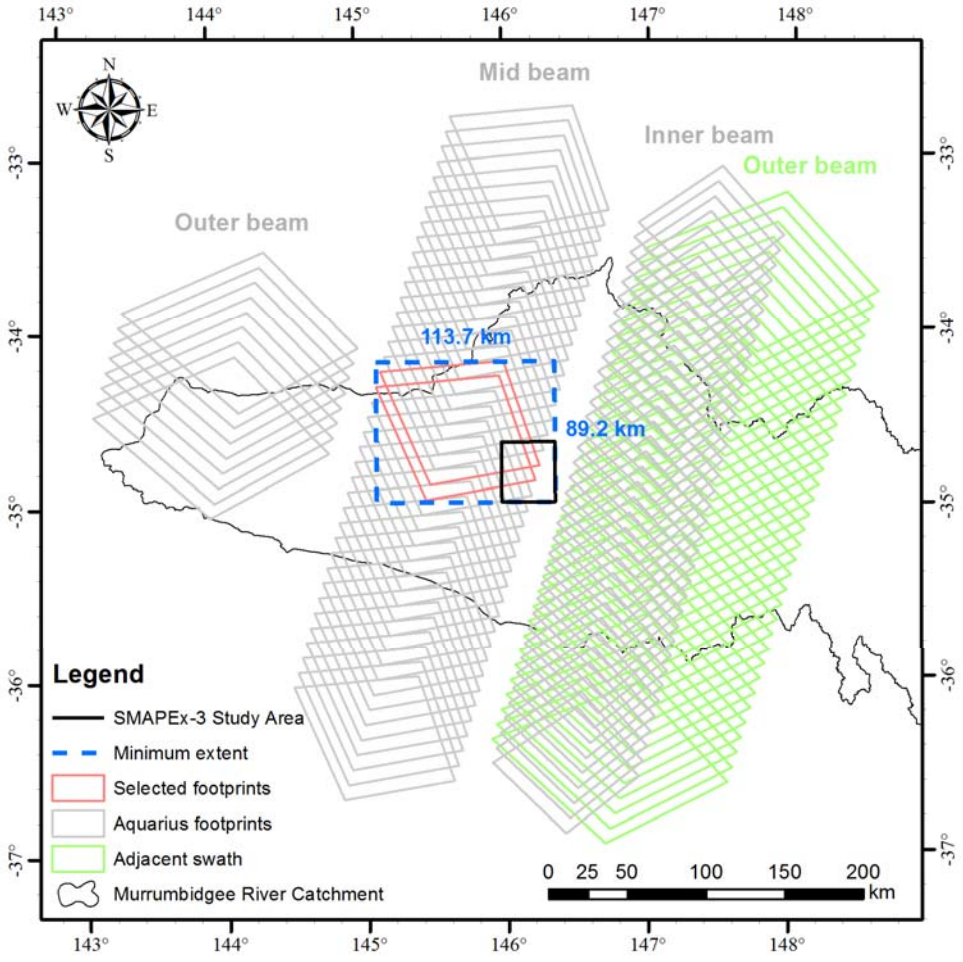
85 km



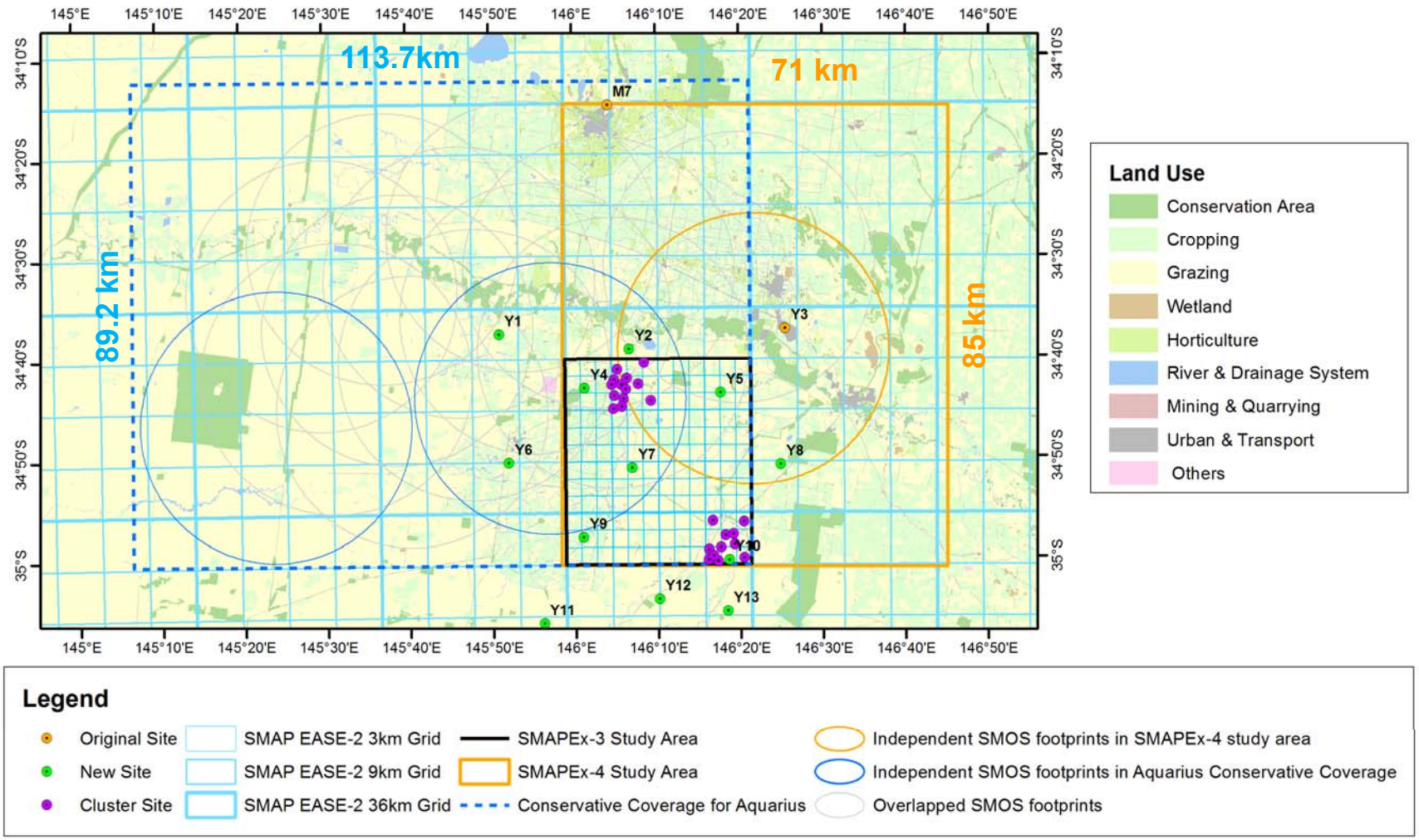
Conservative coverage for Aquarius



Revisit time	Exact 7 days
Beam number	3
Incidence angle [°]	28.7, **37.8**, 45.6
Foot print size [km]	74 × 94, **84 × 120**, 96 × 156
Minimum extent width [km]	113.7
Minimum extent length [km]	89.2



SMOS footprints



SMAPEx-4 & -5 schedule

Feb	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
SMAP				●		●	●					●		●	●					●		●	●					●
SMOS	●			●		●	●		●			●		●			●		●			●		●	●		●	
Aquarius		●							●							●							●					

Sep	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
SMAP		●	●					●		●	●					●		●	●					●		●	●			
SMOS		●		●			●		●			●		●	●		●			●		●			●		●			●
Aquarius							●							●							●									

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Oct	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SMAP		●		●	●					●		●	●					●		●	●					●		●	●		
SMOS		●			●		●	●		●			●		●			●		●			●		●			●		●	●
Aquarius							●							●							●							●			

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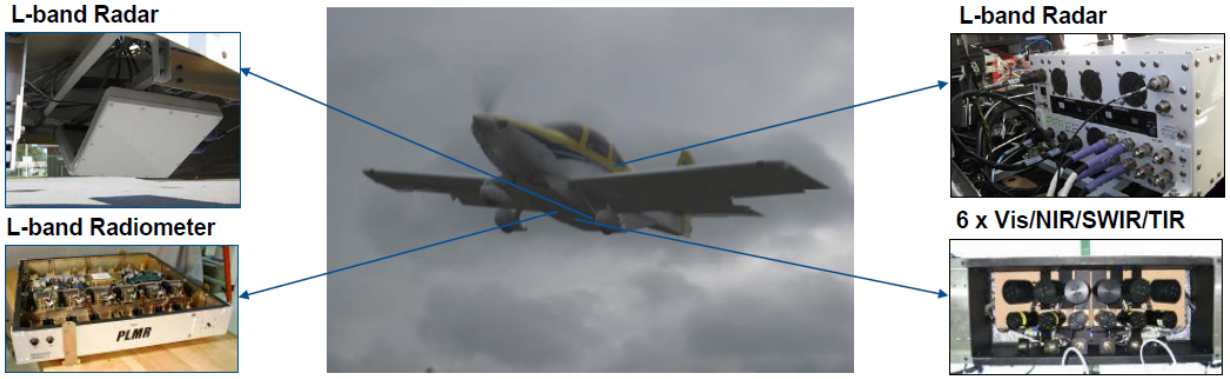
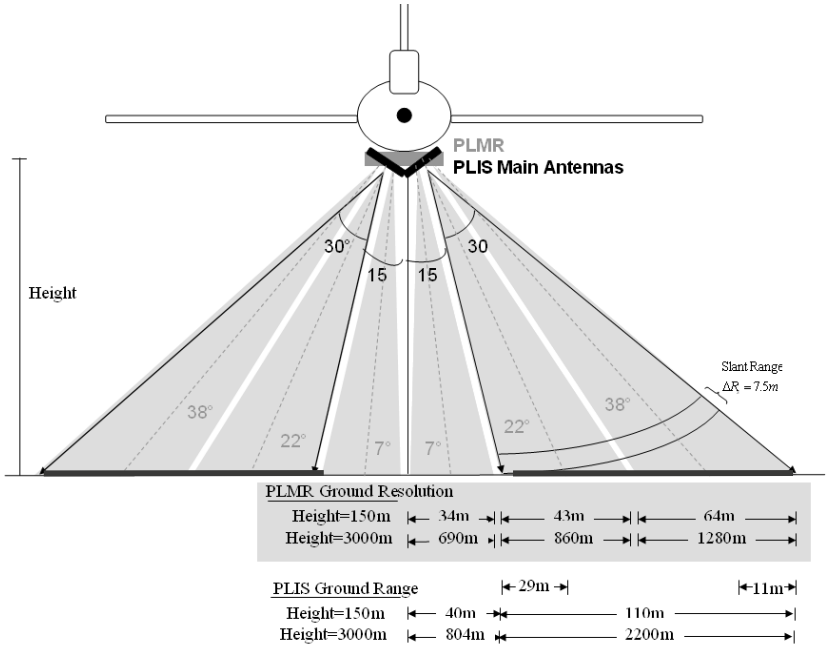
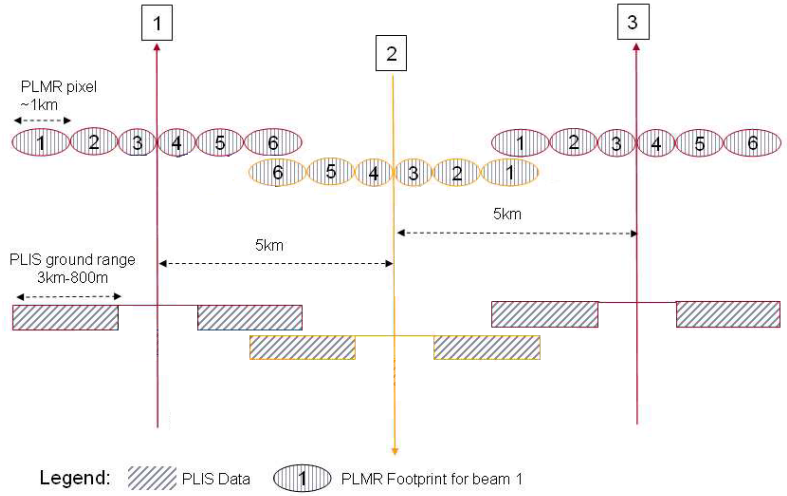
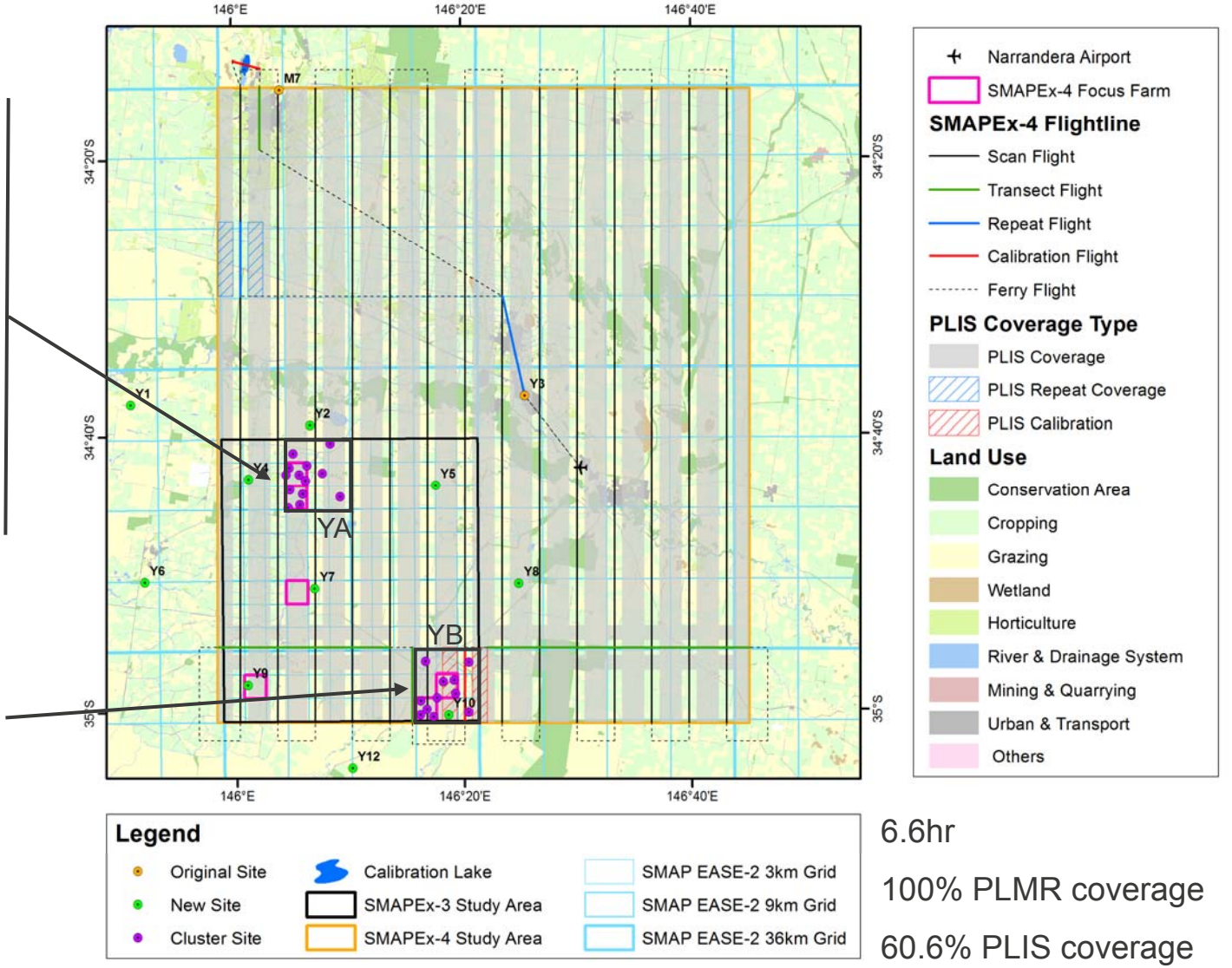
Airborne sampling







SMAPEx-4 flight line for SMAP



6.6hr

100% PLMR coverage

60.6% PLIS coverage

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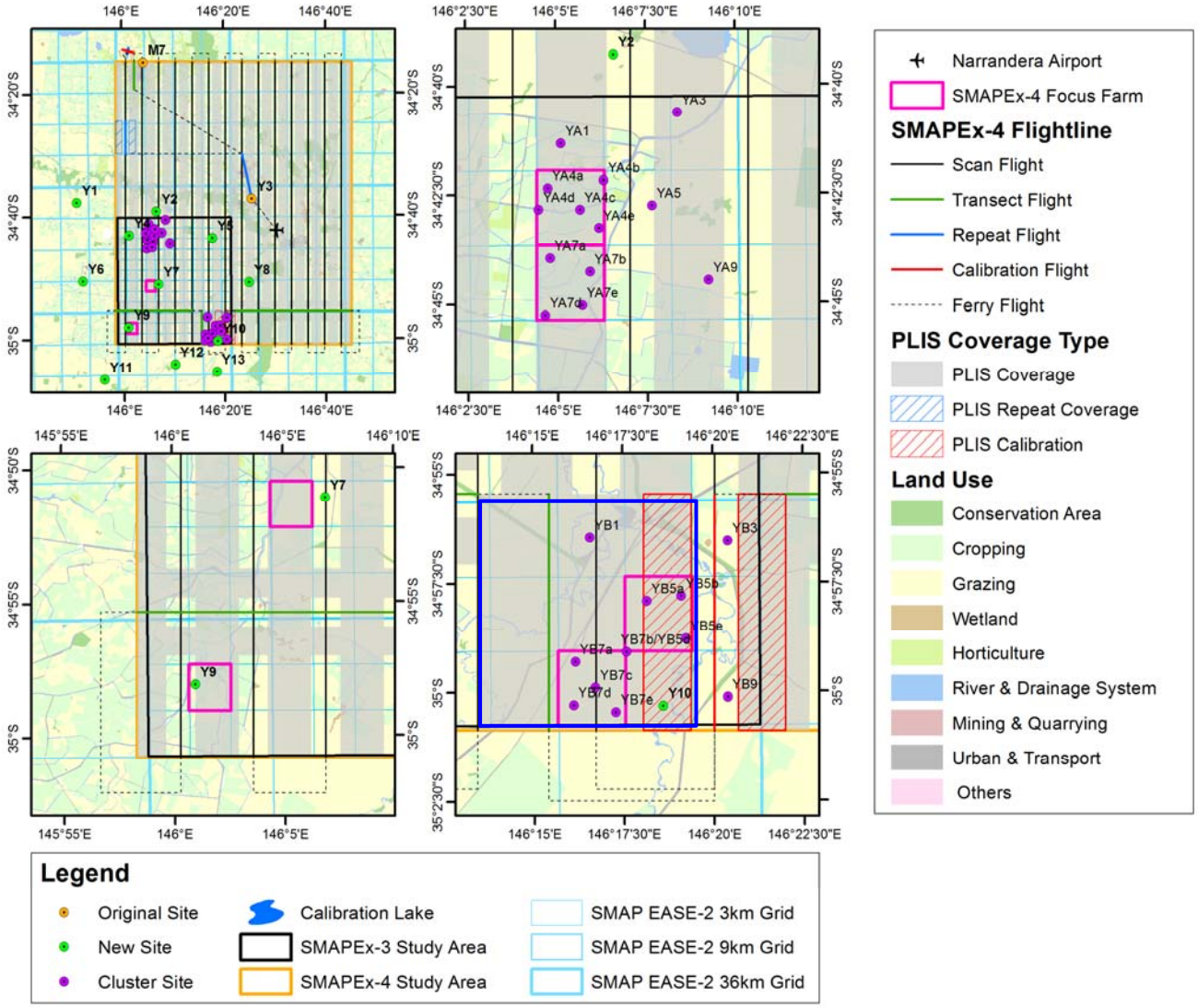
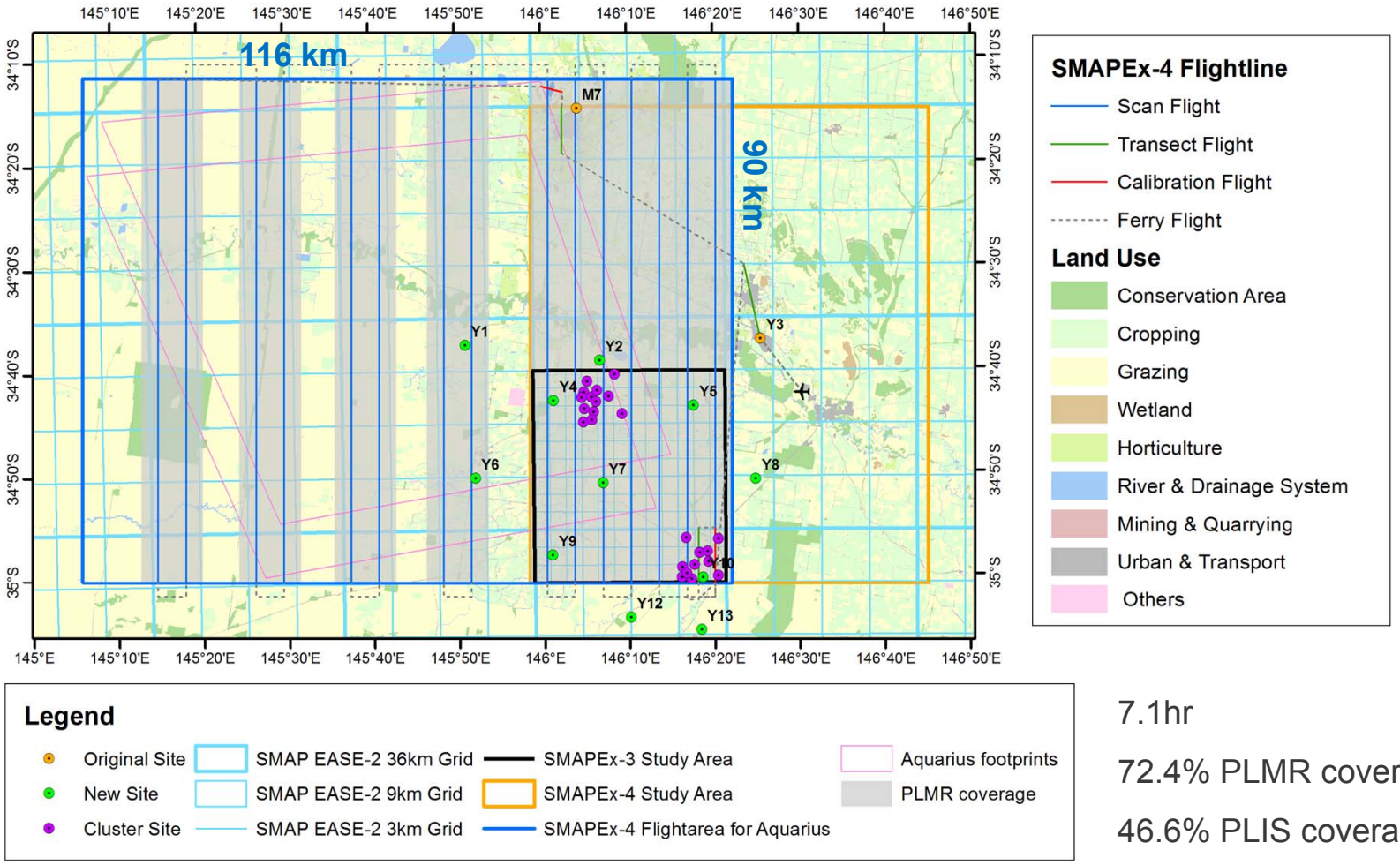
SMAPEx-4 focus farm coverage for SMAP



SMAPEx-4 flight line for Aquarius



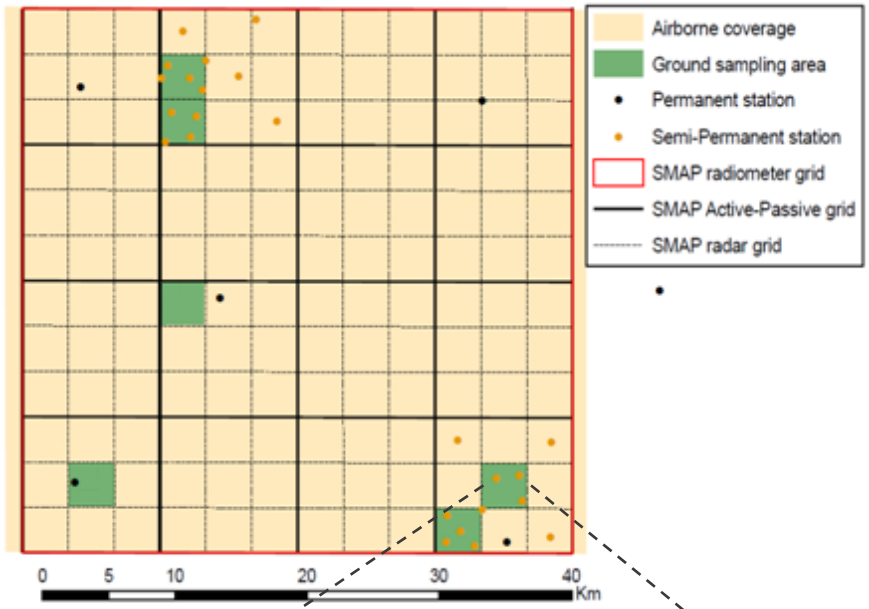
7.1hr

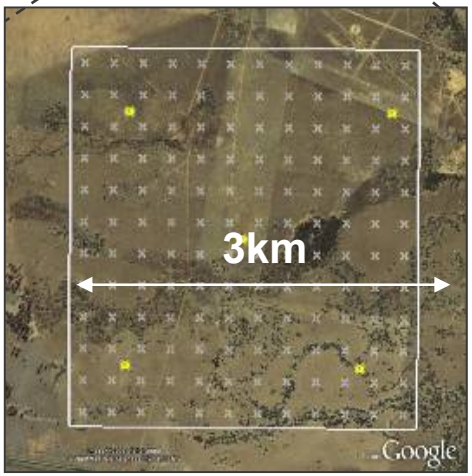
72.4% PLMR coverage

46.6% PLIS coverage

SMAPEx ground monitoring strategy

- Ground validation data
  - Continuous soil moisture at 29 sites
  - Continuous TIR/leaf wetness/soil temperature at 4 sites
  - Roving “regional” measurements on off-overpass days (scaling)
  - Six 3km x 3km focus areas
    - Soil moisture @ 250m spacing
    - Vegetation biomass, water content, LAI, reflectance @ 5 sites per dominant vegetation type
    - Surface roughness @ 3 sites per dominant vegetation type
    - Supplementary data from GPR, L-band Rover, etc





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Conclusions

- Baseline method showed (slightly) better RMSE but optional showed better correlation;
- Results are within target accuracy at 9km;
- RMSE of both methods reduced for drier conditions, meaning spatial variability of soil moisture will likely affect the accuracy of downscaling;
- The estimated error of downscaling here may be larger than reality due to a non-perfect simulation of SMAP data and non-perfect reference soil moisture;
- **There is a need to further validate downscaled Tb and derived soil moisture from SMAP post launch.**

SMAPEX

February & September/October 2015

3-week campaign, Yanco, NSW, Australia

Contact: Prof Jeff Walker

jeff.walker@monash.edu