Sungkyunkwan University
Environment and Remote Sensing Lab.

Agricultural Drought Assessment over Australia from Multi Remote Sensors and Models Soil Moisture products

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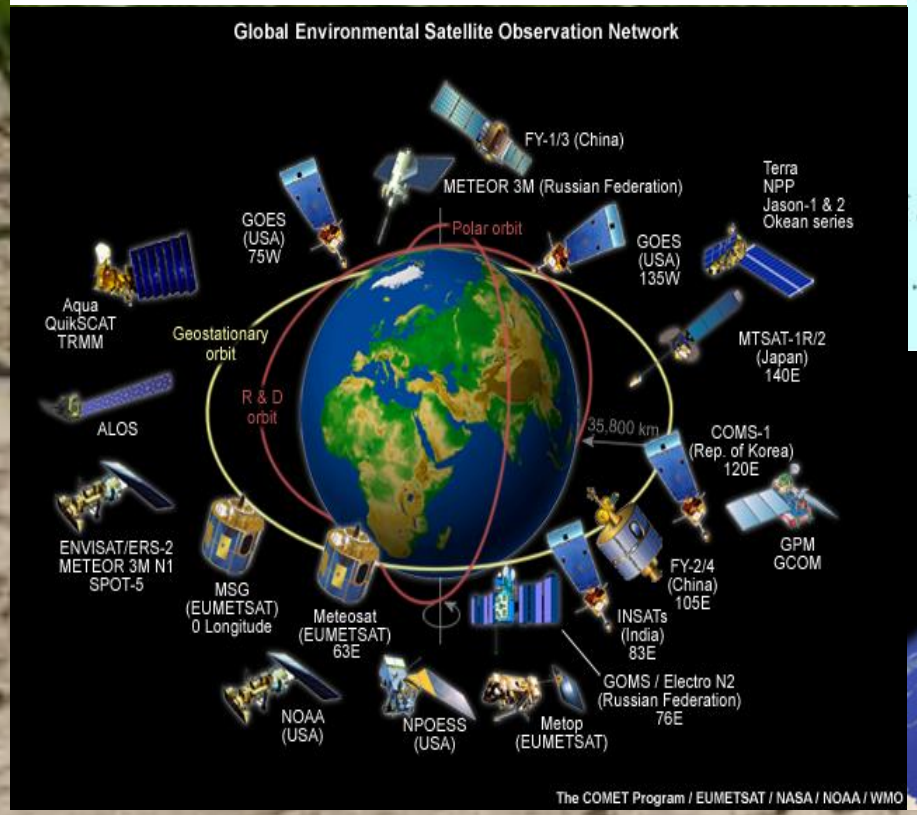
Contents

1. Introduction

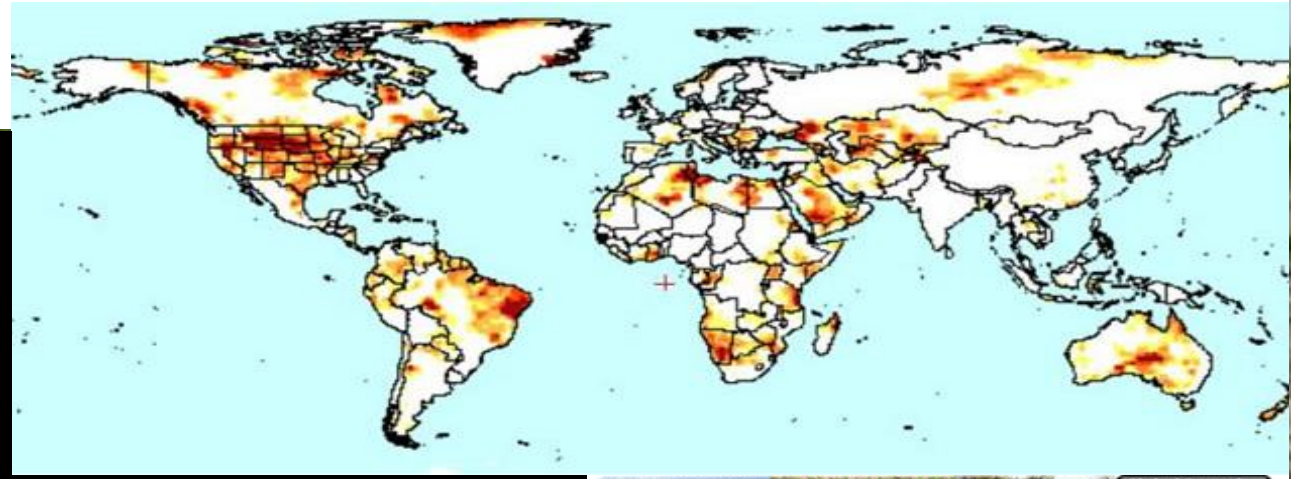
What is the Drought?

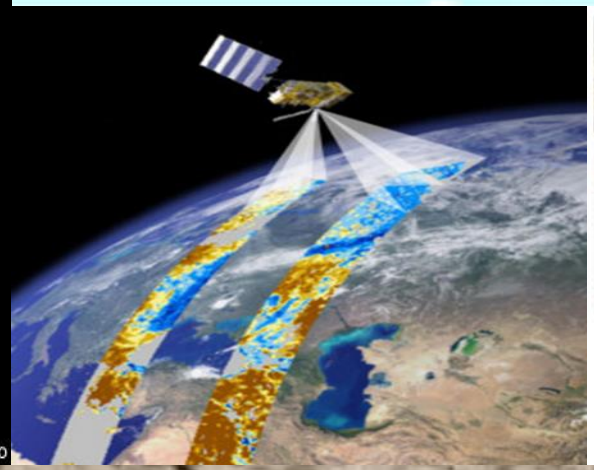
- Many definitions exists for drought
- Simplest: Deficiency of water due to lack of precipitation

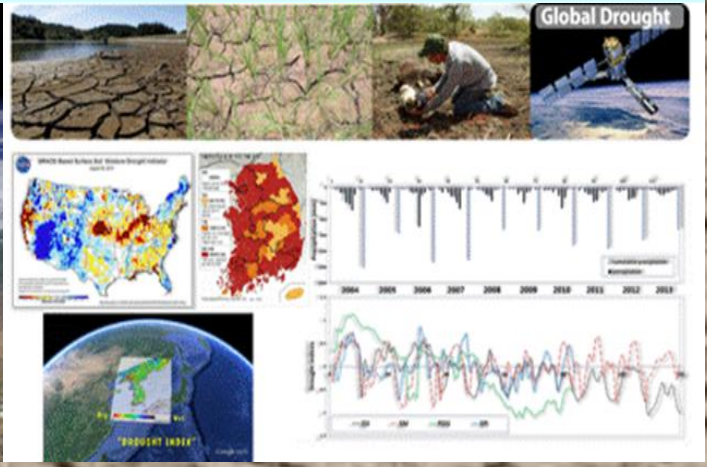


Remote sensing related Drought Analysis

- Remote sensing technology has provided an approach for analyzing drought events over broad regions.







Types of drought

Metrological

Shortfall in the magnitude of Precipitation (climatological drought)

Hydrological

Low water supply in streams, reservoirs, and groundwater levels

Agricultural

Availability of less soil moisture for crops production

Socio-Eco

The impact of drought on society and economy

Objectives

1. Evaluation of SM products
2. Assessment of agricultural drought (SWDI)
3. Comparing SWDI with widely used Atmospheric Water Deficit (AWD) index
4. Computation of drought detection accuracy

SM measurements

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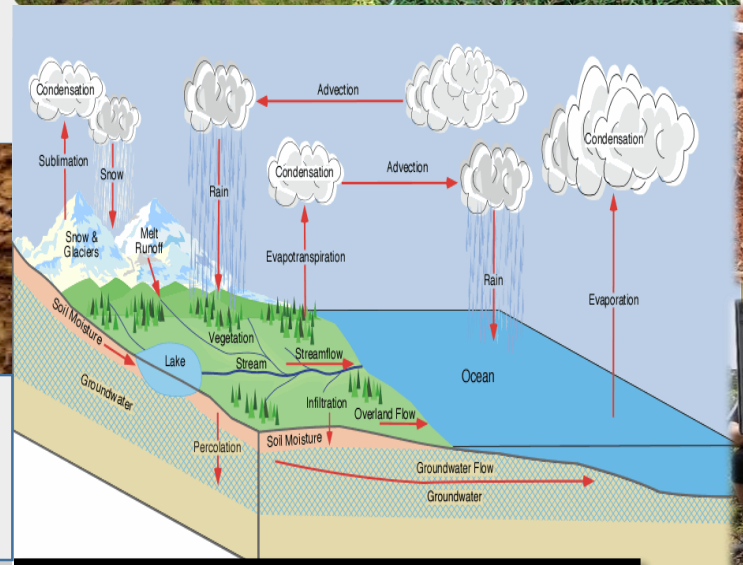
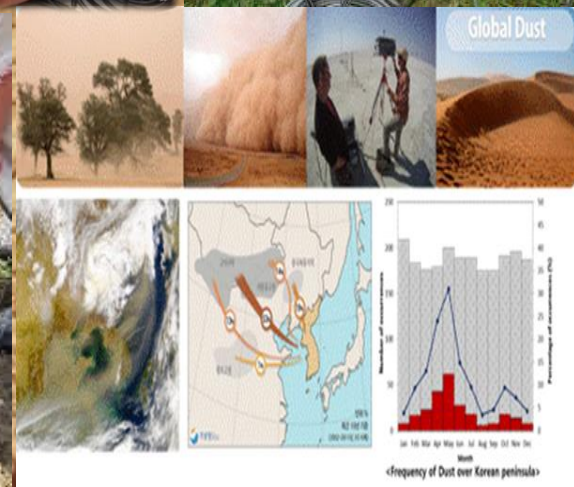
Ground observation
Remote Sensing
Hydrological Modelling

Ground observation (In-situ measurements i.e. point based data collection)

Hydrologic Modelling comprises of in situ and RS datasets to prepare an improved SM products

RS SM datasets used where in situ collection is difficult i.e. larger area, topographic constraints





2. Study Area

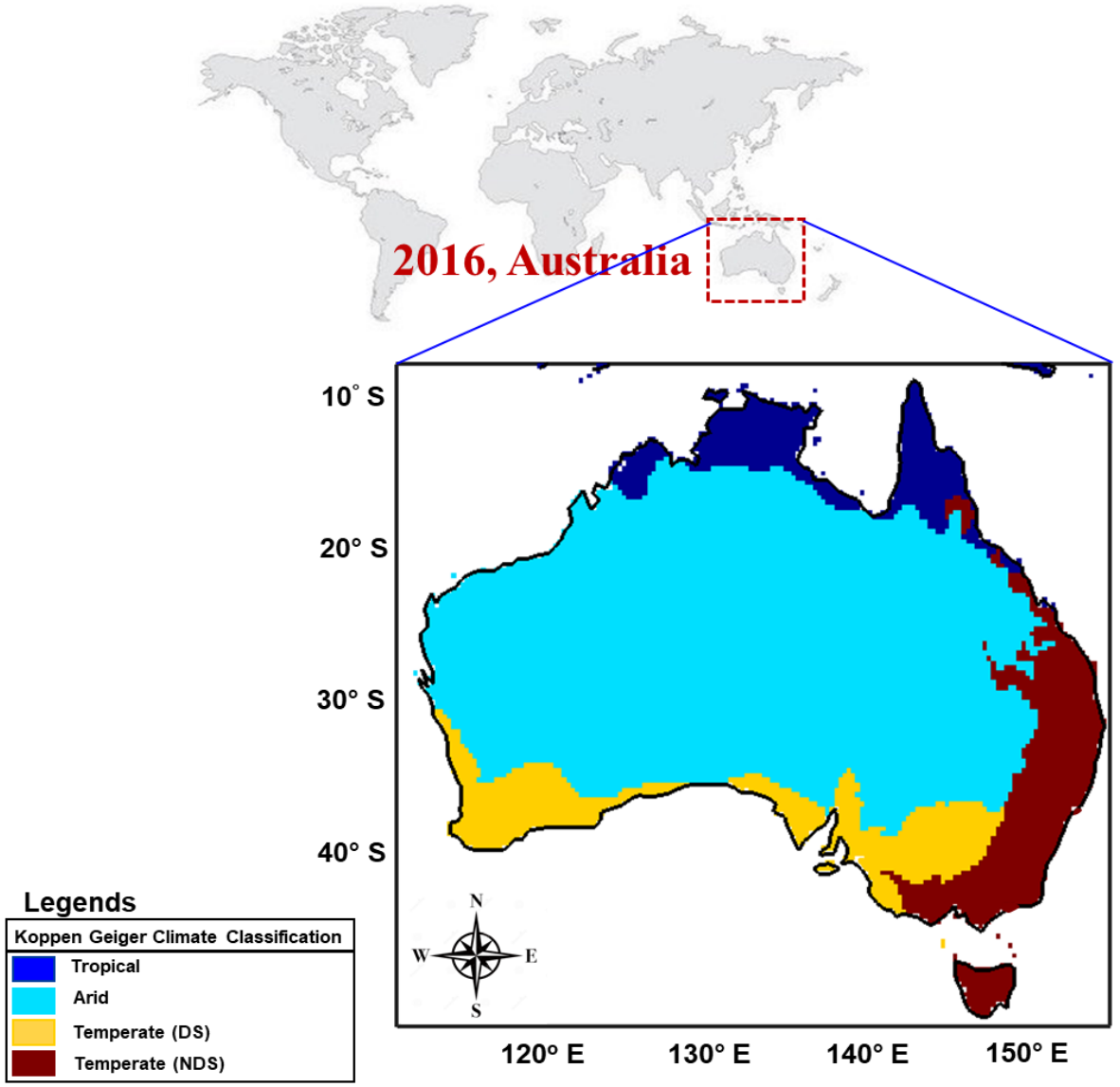
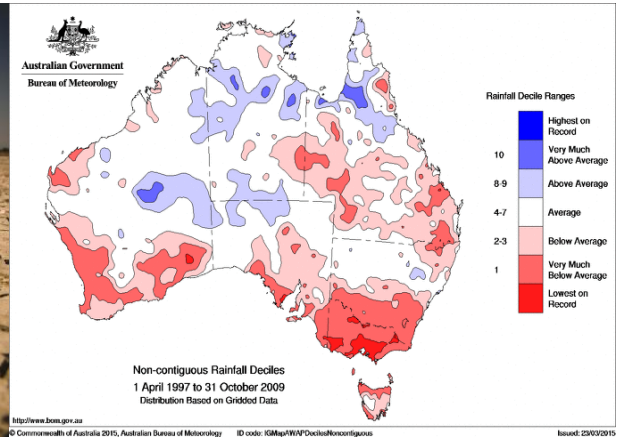
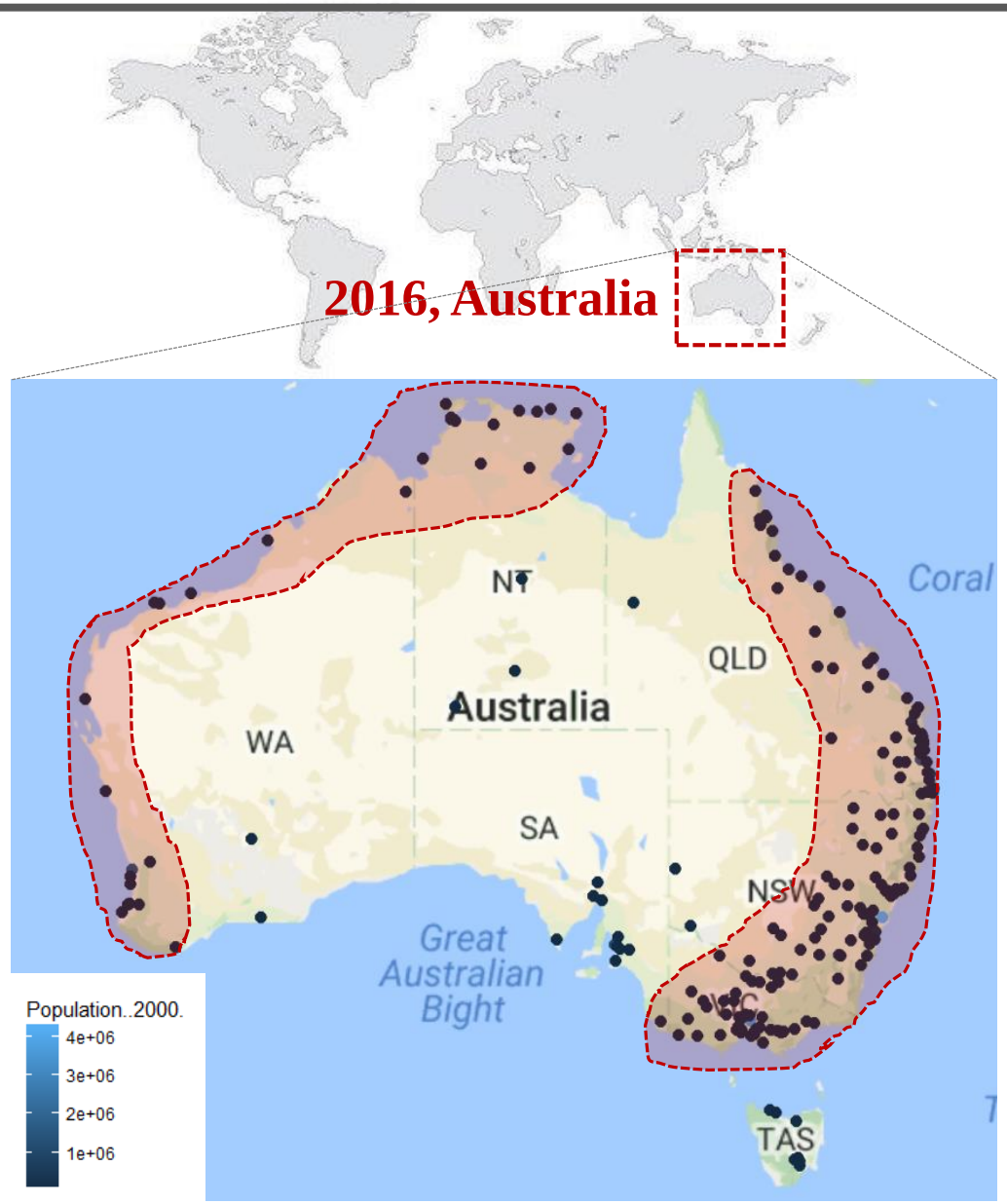


Fig. 1. Study area (Australia) and classification of four climate classes



- Location: 10° to 44° S and 112° to 154° E, consists of different ecological and clamatorial characteristics.
- Australia witnessed “Millennium drought” from 2001 to 2009.
- The “Millennium drought” as the worst drought on record that led to some economic losses by Dijk et al. (2013).

Study Area



Major Cities position

Top 24 population cities position

City	Population (2011)	Latitude	Longitude
Sydney	4029200	-33.87	151.21
Melbourne	3848000	-37.81	144.96
Brisbane	1977600	-27.46	153.02
Perth	1671900	-31.96	115.84
Adelaide	1198700	-34.93	138.6
Newcastle	546300	-32.92	151.75
Gold coast	457900	-28.07	153.44
Canberra	323100	-35.31	149.13
Wollongong	262500	-34.42	150.87
Sunshine	252000	-26.65	152.56
Hobart	201000	-42.85	147.29
Geelong	161500	-38.14	144.32
Townsville	139000	-19.26	146.78
Cairns	128500	-16.92	145.75
Launceston	99400	-41.45	147.13
Albury-wodonga	97300	-36.06	146.92
Darwin	95000	-12.43	130.85
Toowoomba	91800	-27.56	151.96
Ballarat	85300	-37.56	143.84
Shoalhaven	81600	-34.88	150.59
Bendigo	80400	-36.76	144.28
Burnie-devonport	78400	-41.06	145.89
Bathurst-orange	76600	-33.42	149.57
Mackay	72700	-21.14	149.18

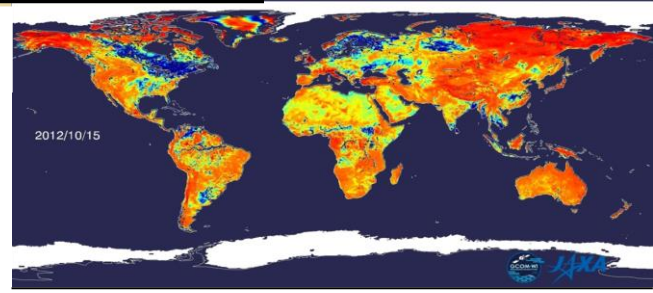
- Because there is dry desert area in the middle of the continent,
- Most cities are located near the coast.
- 5 cities with more than one million population

http://www.tageo.com/index-e-as-cities-AU.htm

3. Datasets

1. Advanced Microwave Scanning Radiometer 2 (AMSR-2)

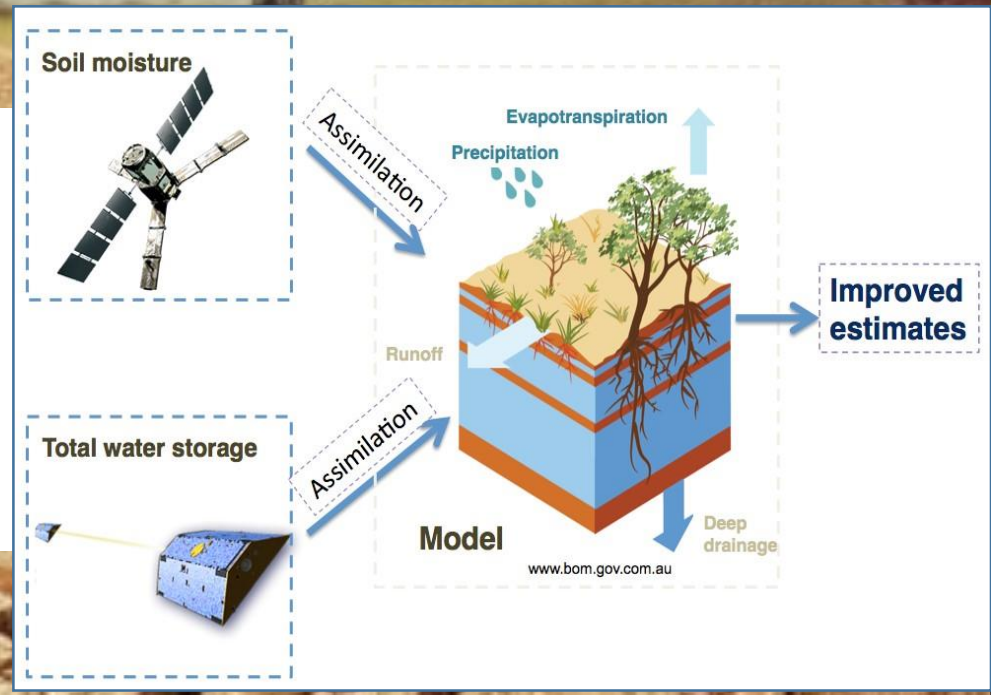
- Operated on JAXA's GCOM-W1 spacecraft,
- launched May 18, 2012
- Land Parameter Retrieval Model (LPRM) and JAXA algorithms (Wu et al., 2016)
- Spatial resolution : 25 km



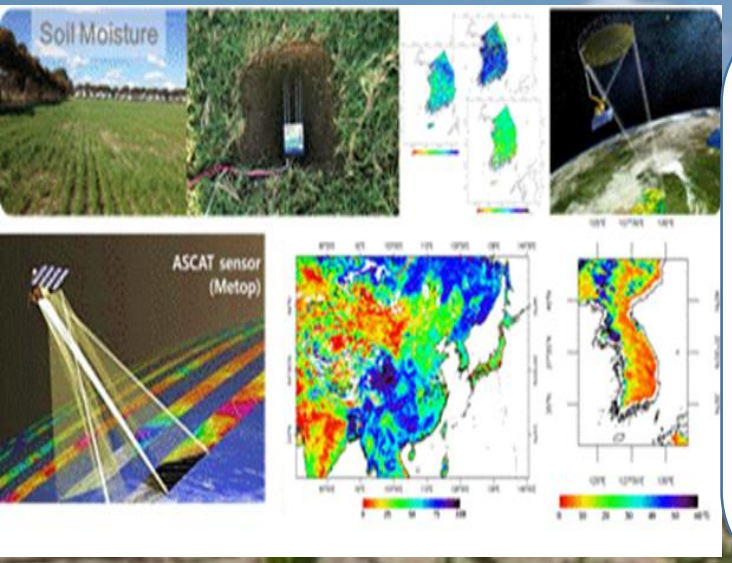
	AMSR-E	AMSR2
Launch Date	Jun, 2002 ~ 2011	Jun, 2012 ~
Spatial Resolution	25 km	10, 25 km
Overpass Time	13:30, 01:30	10:30, 22:30
Measuring Depth	~ 1 cm	~ 1 cm

2. AWRA-L (BoM, Australia)

- AWRA-L (the Australian Water Resource Assessment-Landscape Model) (Hafeez et al., 2015).
- Products : soil moisture, evapotranspiration, precipitation,
- Spatial Resolution : 5km (0.05 degree)
- Temporal Resolution : Daily

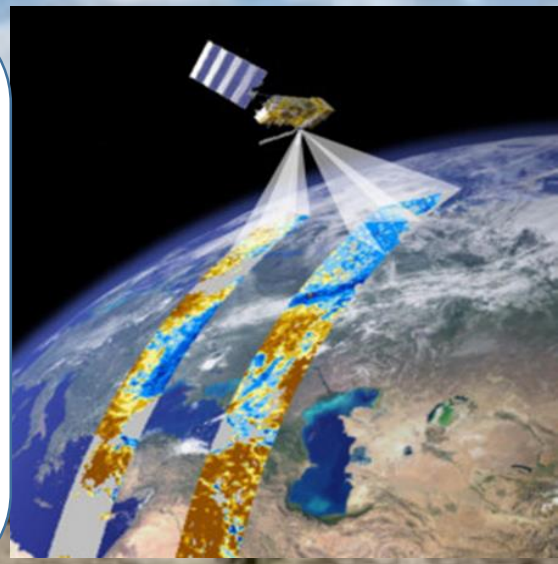


Datasets



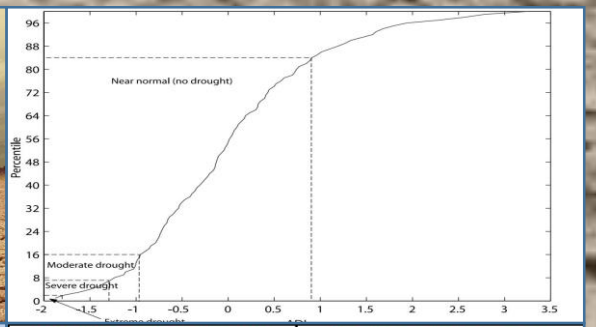
3. Advanced Scatterometer (ASCAT)

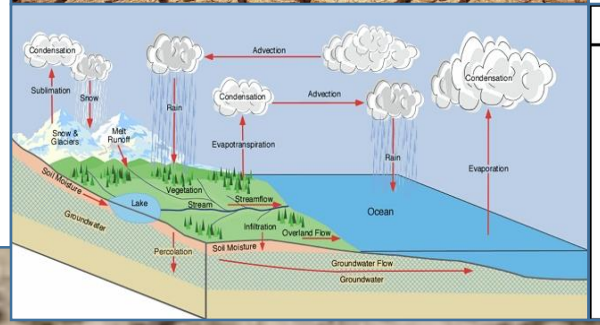
- Active Sensor on board of Meteorological Operational Platform (Metop) satellites
- Metop-A was launched in October 2006
- Resolution: 25 km
- Temporal coverage: 1.5 days (approx.) for global coverage
- Measures degree of saturation (percentage)

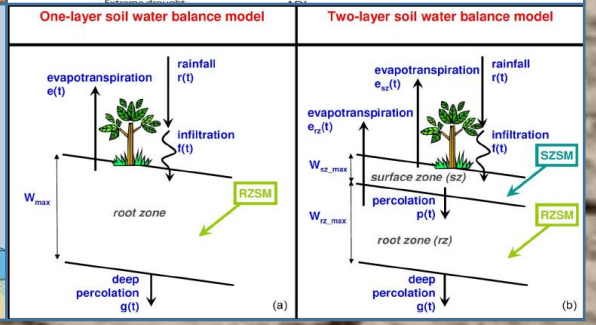


4. ERA-Interim

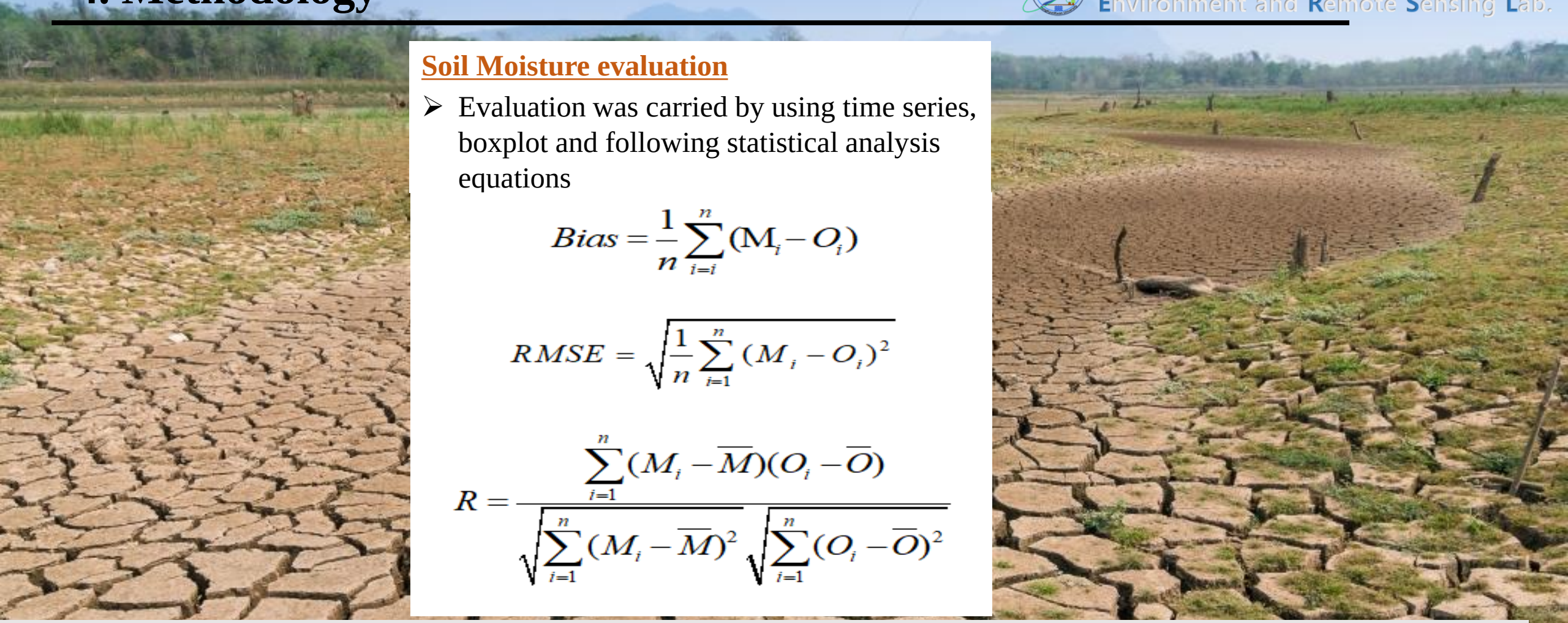
- European Centre for Medium Range Weather Forecasts (ECMWF) Interim Re-Analysis
- Provides essential land and atmospheric variables datasets since 1979
- Spatial resolution: 80 km
- Levels: Four soil moisture layers (surface to deep)







4. Methodology



Soil Moisture evaluation

- Evaluation was carried by using time series, boxplot and following statistical analysis equations

$$Bias = \frac{1}{n}\sum_{i=i}^{n}(M_i - O_i)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(M_i - O_i)^2}$$

$$R = \frac{\sum_{i=1}^{n}(M_i - \overline{M})(O_i - \overline{O})}{\sqrt{\sum_{i=1}^{n}(M_i - \overline{M})^2}\sqrt{\sum_{i=1}^{n}(O_i - \overline{O})^2}}$$

where, M and $\overline{M}$ are daily and mean soil moisture from RS or model products, respectively, O and $\overline{O}$ is the daily and mean reference soil moisture of BoM, respectively, i is number of day up to n number of days.

Methodology

Soil Water Deficit Index (SWDI)

- SWDI depends on soil moisture and soil characteristics

$$SWDI = \frac{(\theta - \theta_{fc})}{\theta_{\mathrm{AWC}}}$$

$$\theta_{AWC} = \theta_{fc} - \theta_{wp}$$

- Where θ is soil moisture (m^3/m^3),
- θ_{AWC} is available water content,
- θ_{fc} is field capacity, and θ_{wp} is wilting point

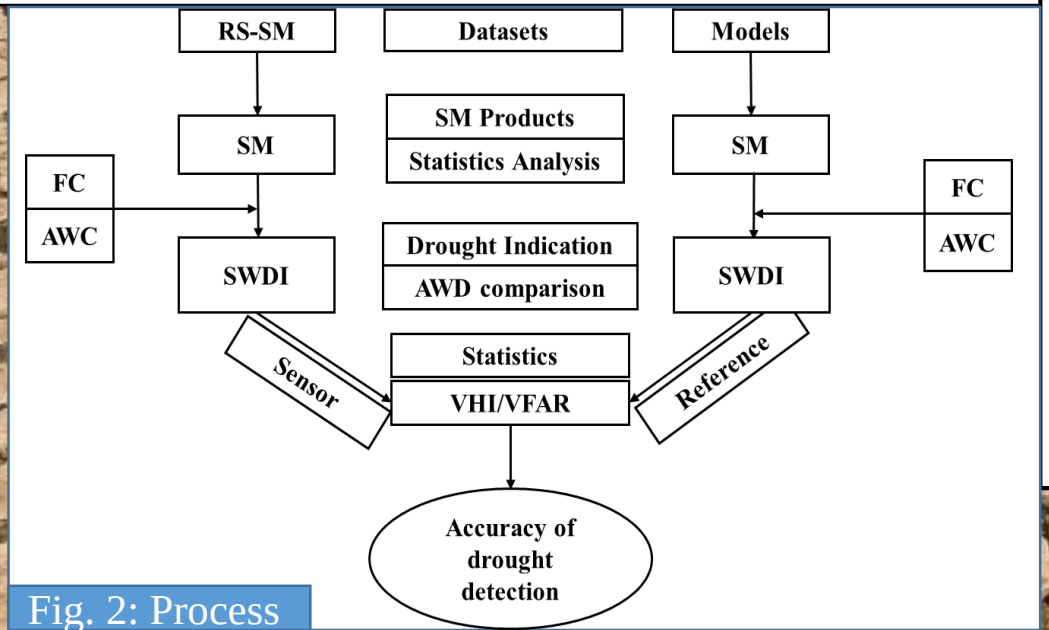


Fig. 2: Process

Atmospheric Water Deficit (AWD)

- AWD was calculated for verification of SWDI results for assessment of agriculture drought. The equation for AWD is,

$$AWD = P_{(\mathrm{Sum\_7days})} - ET_{o(\mathrm{Sum\_7days})}$$

Extended Volumetric Contingency Tables:

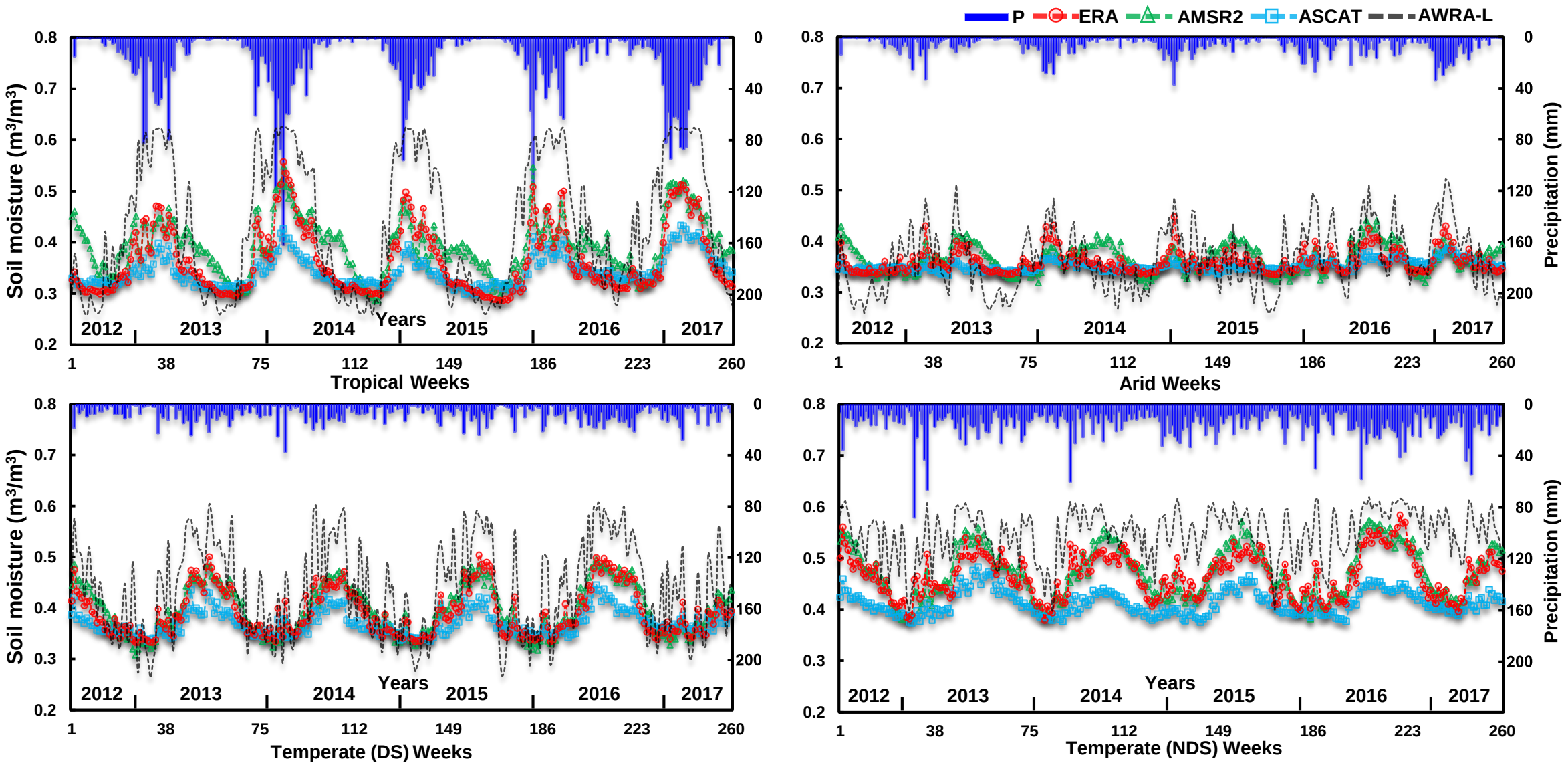
Volumetric Hit Index (VHI), Volumetric False Alarm Ratio (VFAR) and Volumetric Miss Index (VMI) were used for detection of drought.

$$VHI = \frac{\Sigma_{i=1}^{n}(Obs_i | Obs_i < t \& BoM_i < t)}{\Sigma_{i=1}^{n}(Obs_i | Obs_i < t \& BoM_i < t) + \Sigma_{i=1}^{n}(BoM_i | Obs_i \geq t \& BoM_i < t)}$$

$$VFAR = \frac{\Sigma_{i=1}^{n}(Obs_i | Obs_i < t \& BoM_i \geq t)}{\Sigma_{i=1}^{n}(Obs_i | Obs_i < t \& BoM_i < t) + \Sigma_{i=1}^{n}(BoM_i | Obs_i < t \& BoM_i \geq t)}$$

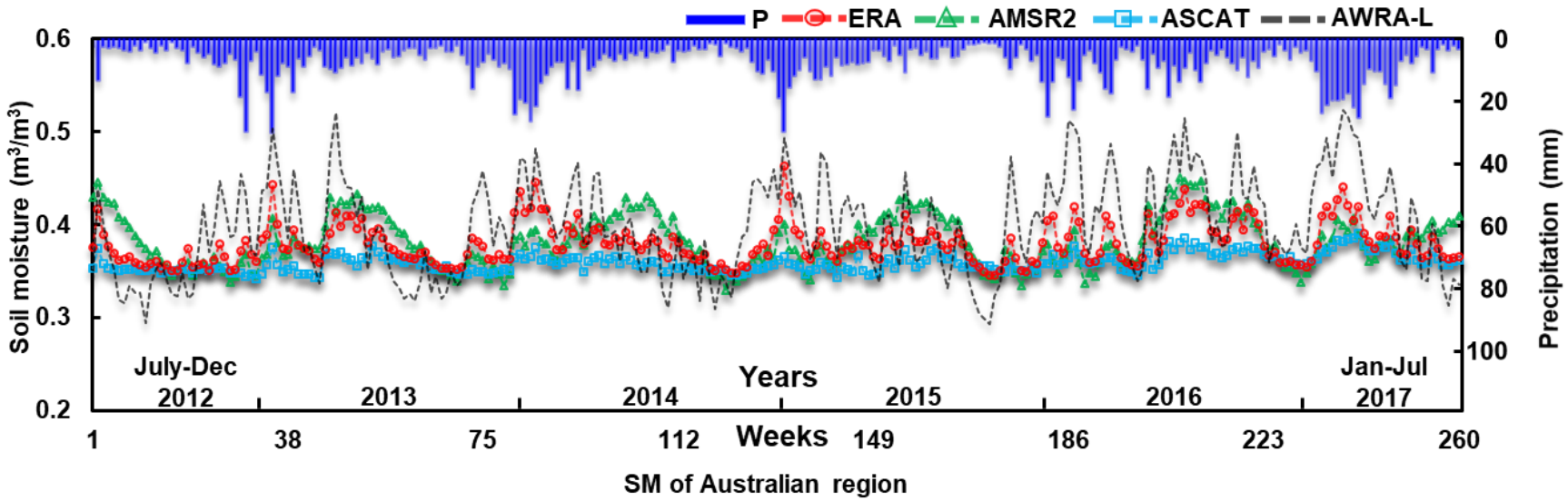
$$VMI = \frac{\Sigma_{i=1}^{n}(Obs_i | Obs_i \geq t \& BoM_i < t)}{\Sigma_{i=1}^{n}(Obs_i | Obs_i < t \& BoM_i < t) + \Sigma_{i=1}^{n}(BoM_i | Obs_i \geq t \& BoM_i < t)}$$

5. Results

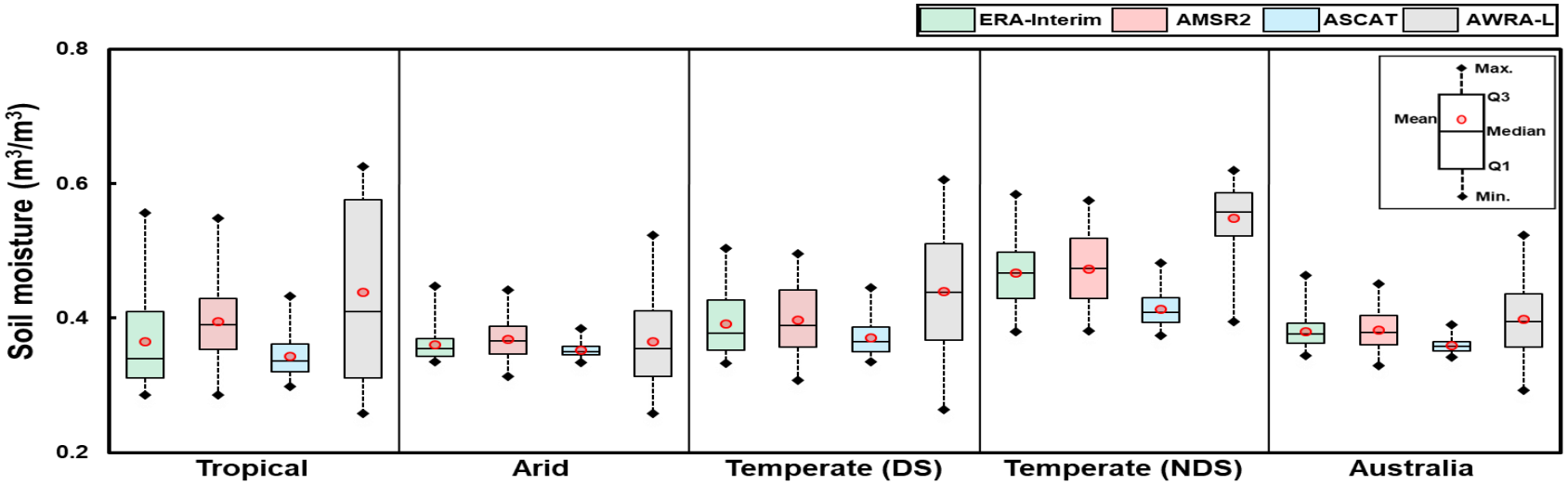


Time Series shows soil moisture comparison over various climate classes of Australia

Results

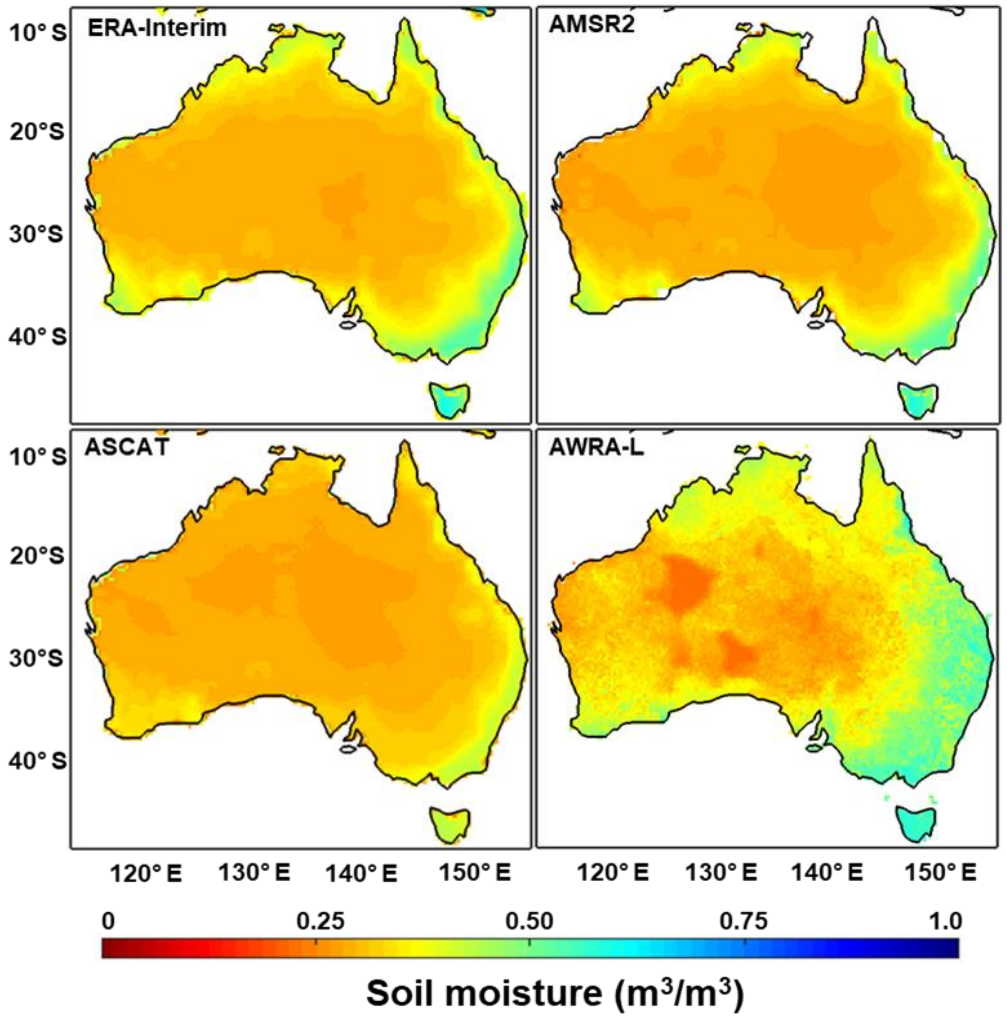


Time Series shows mean soil moisture comparison over Australia from various soil moisture products

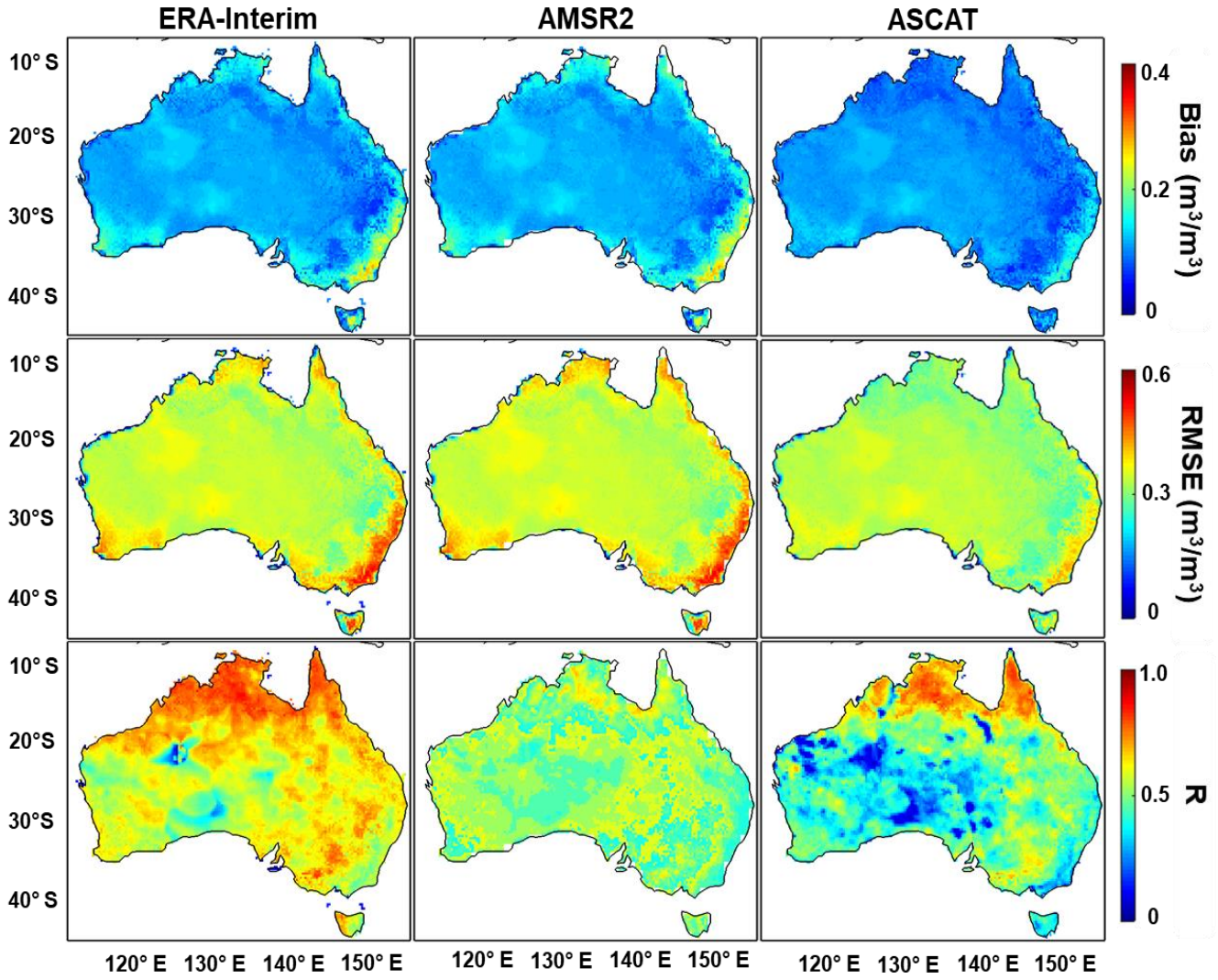


Boxplot shows soil moisture comparison over Australia from various soil moisture products

Results



Soil moisture spatial maps over Australia from various soil moisture products

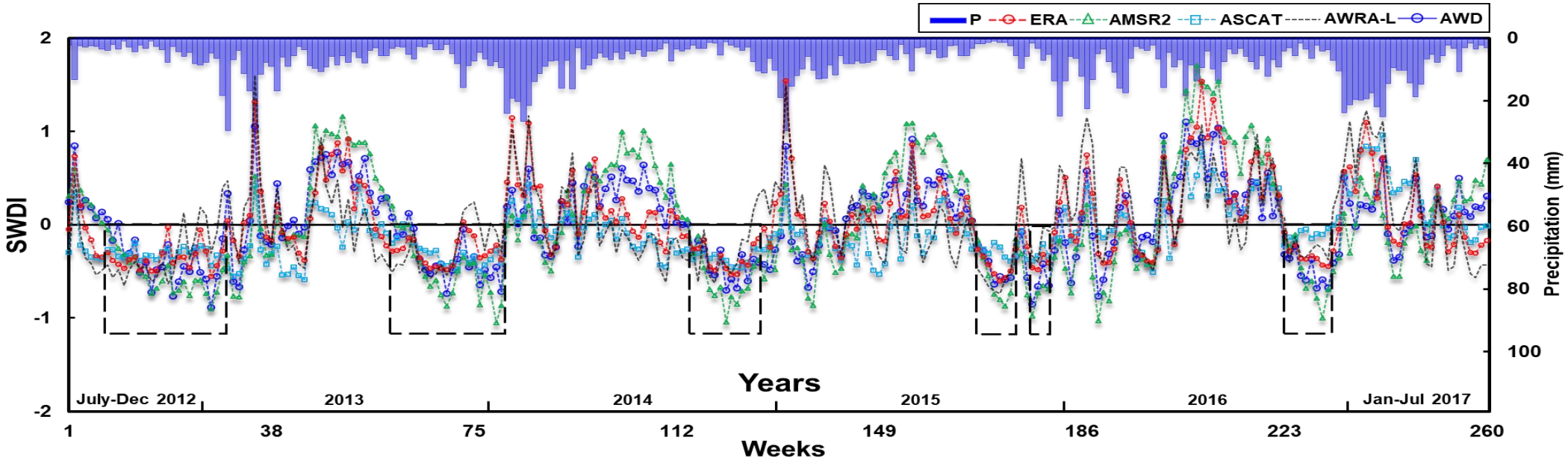


Statistical analysis (Bias, RMSE, and R) spatial maps are displayed for evaluation of ERA-Interim, AMSR2, and ASCAT SM against AWRA-L SM

Results

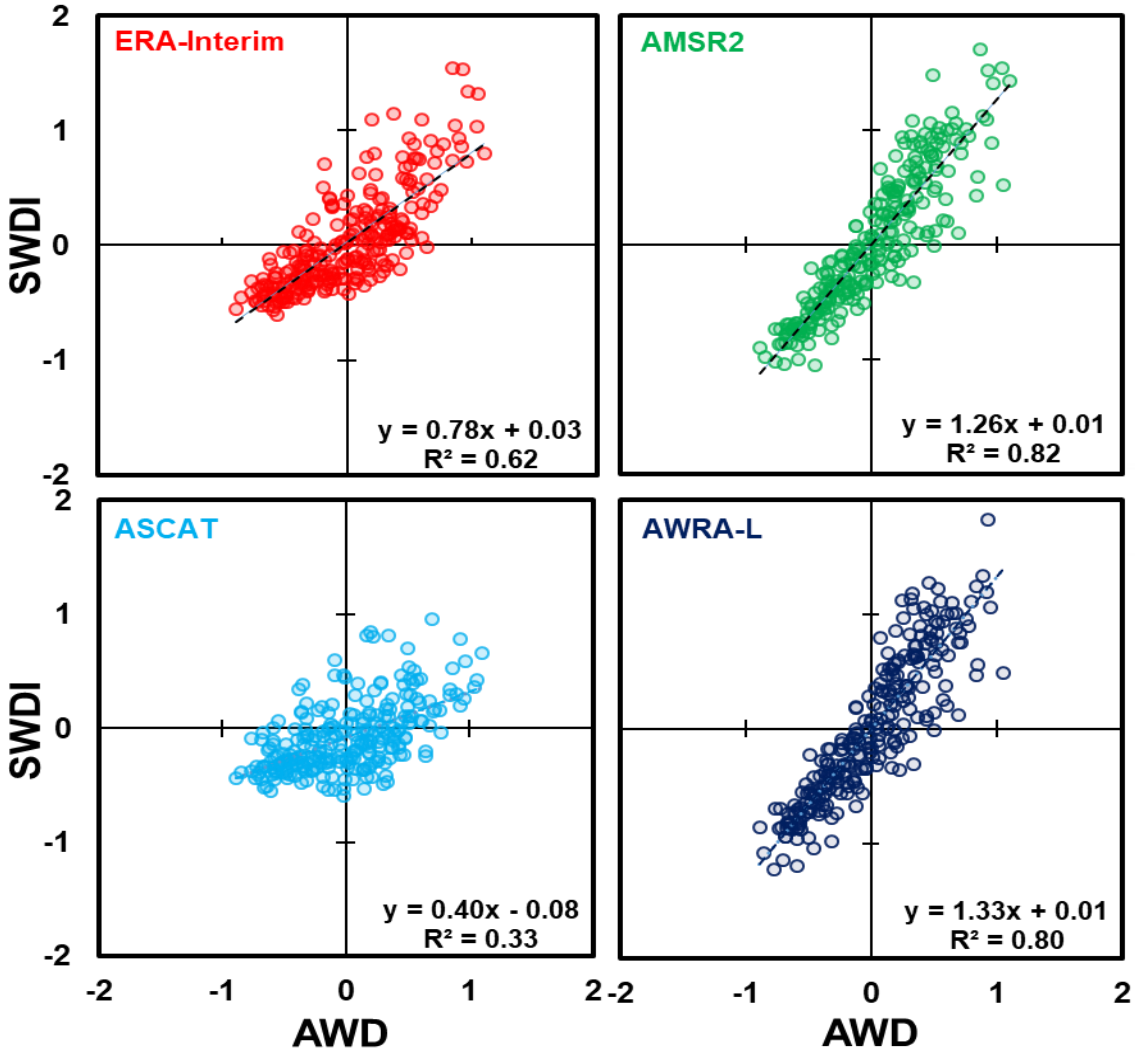
The mean values of statistical analysis (bias, RMSE, and R) of various SM products (ERA-Interim, AMSR2, and A SCAT) in reference to AWRA-SM over Australia and its climate classes.

Climate Class/ Region	ERA-Interim			AMSR2			ASCAT		
	Bias	RMSE	R	Bias	RMSE	R	Bias	RMSE	R
Tropical	0.12	0.32	0.74	0.13	0.34	0.58	0.09	0.28	0.62
Arid	0.11	0.33	0.60	0.11	0.33	0.43	0.10	0.32	0.28
Temperate (DS)	0.12	0.34	0.58	0.13	0.34	0.46	0.11	0.31	0.30
Temperate (NDS)	0.14	0.37	0.61	0.15	0.38	0.47	0.10	0.35	0.31
Australia	0.12	0.33	0.60	0.12	0.34	0.44	0.11	0.31	0.30

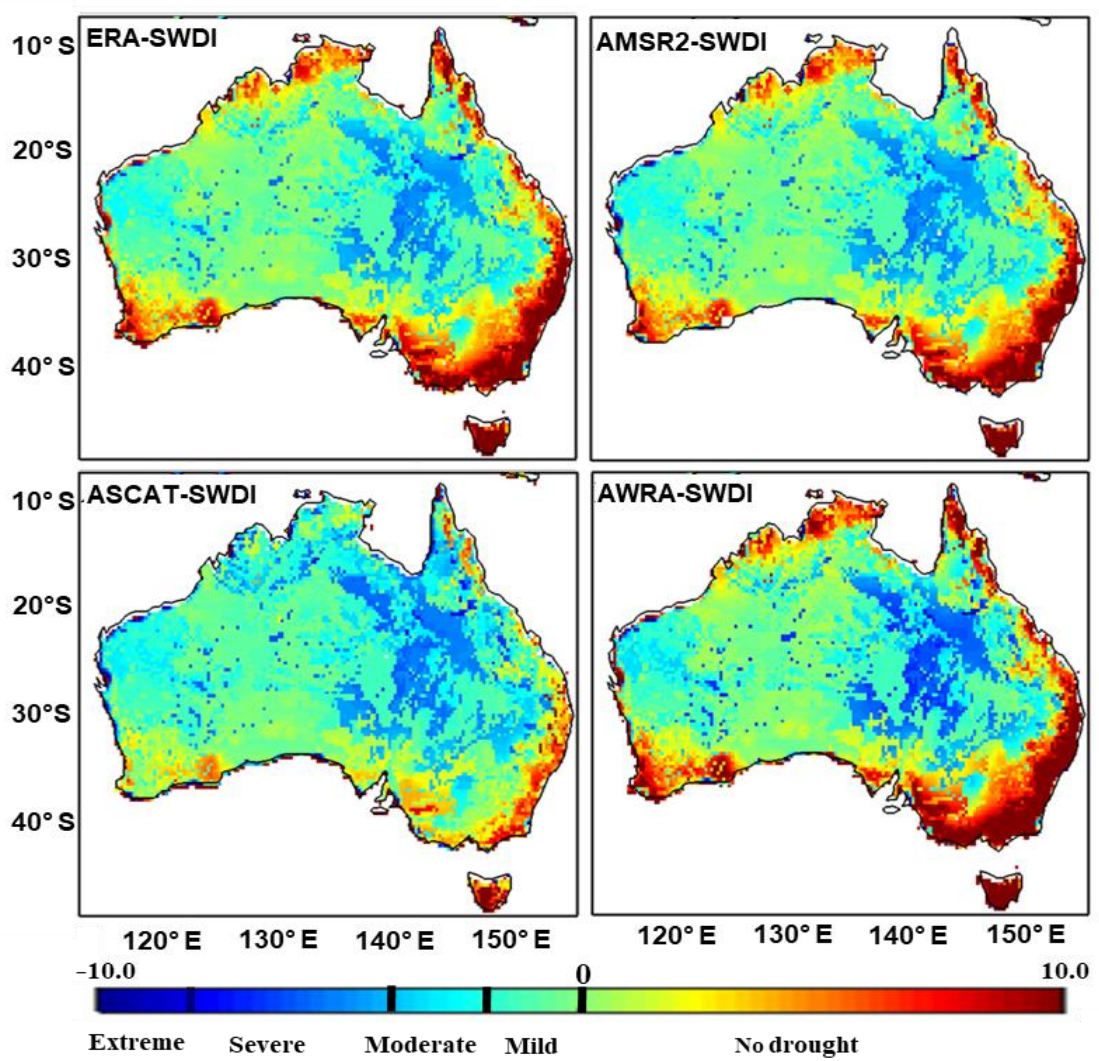


Soil Water Deficit Index (SWDI) calculated from various soil moisture products are compared with Atmospheric Water Deficit (AWD) index for assessment of agricultural drought over Australia from July 2012 to June 2017

Scatterplot and Spatial maps

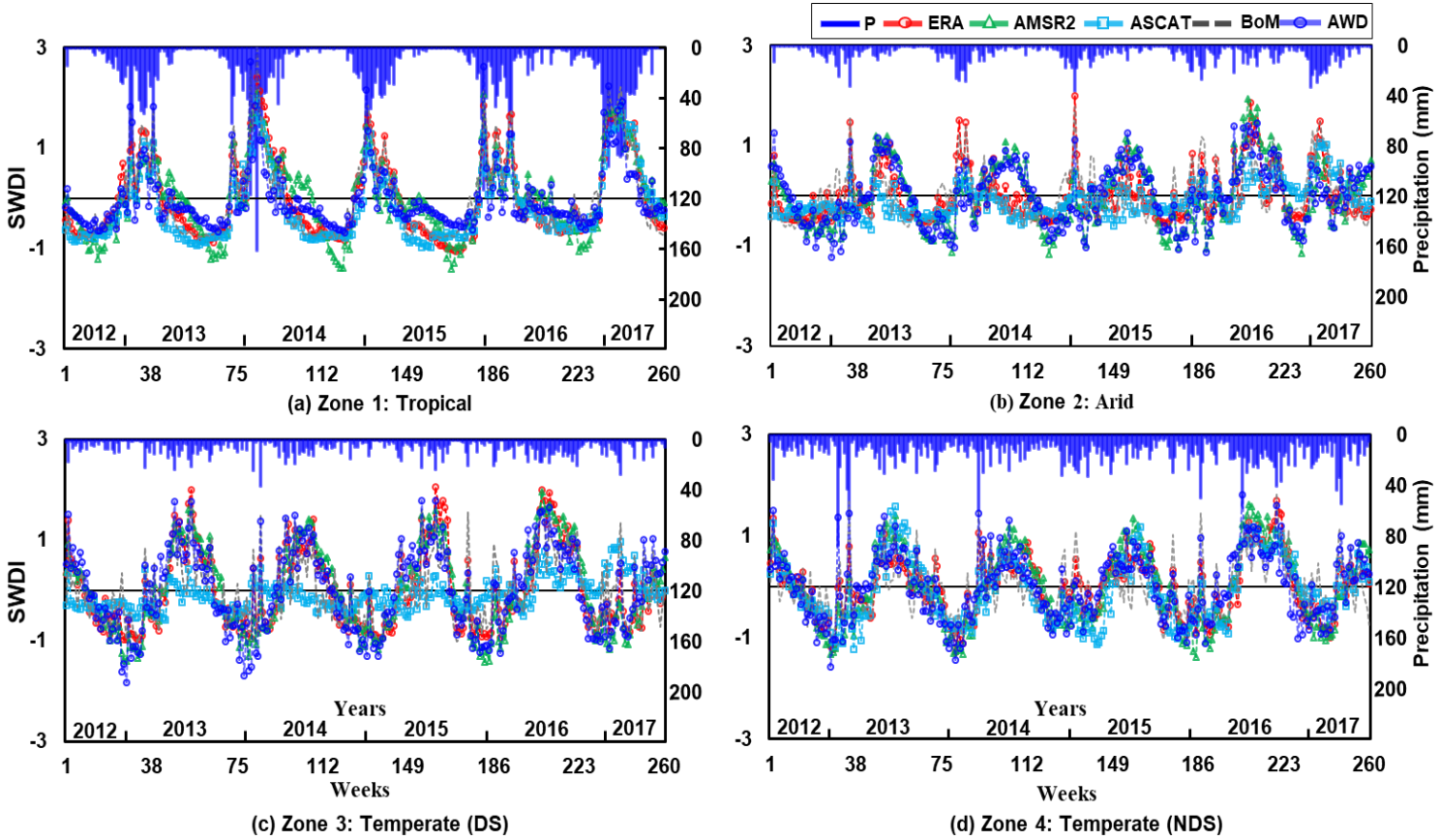


Scatterplot shows comparison of SWDI from ERA-Interim, AMSR-2 and ASCAT with Atmospheric Water Deficit Index (AWD)



Spatial maps of Soil Water Deficit Index (SWDI) from various products for assessment of agricultural drought

Drought in various climate classes



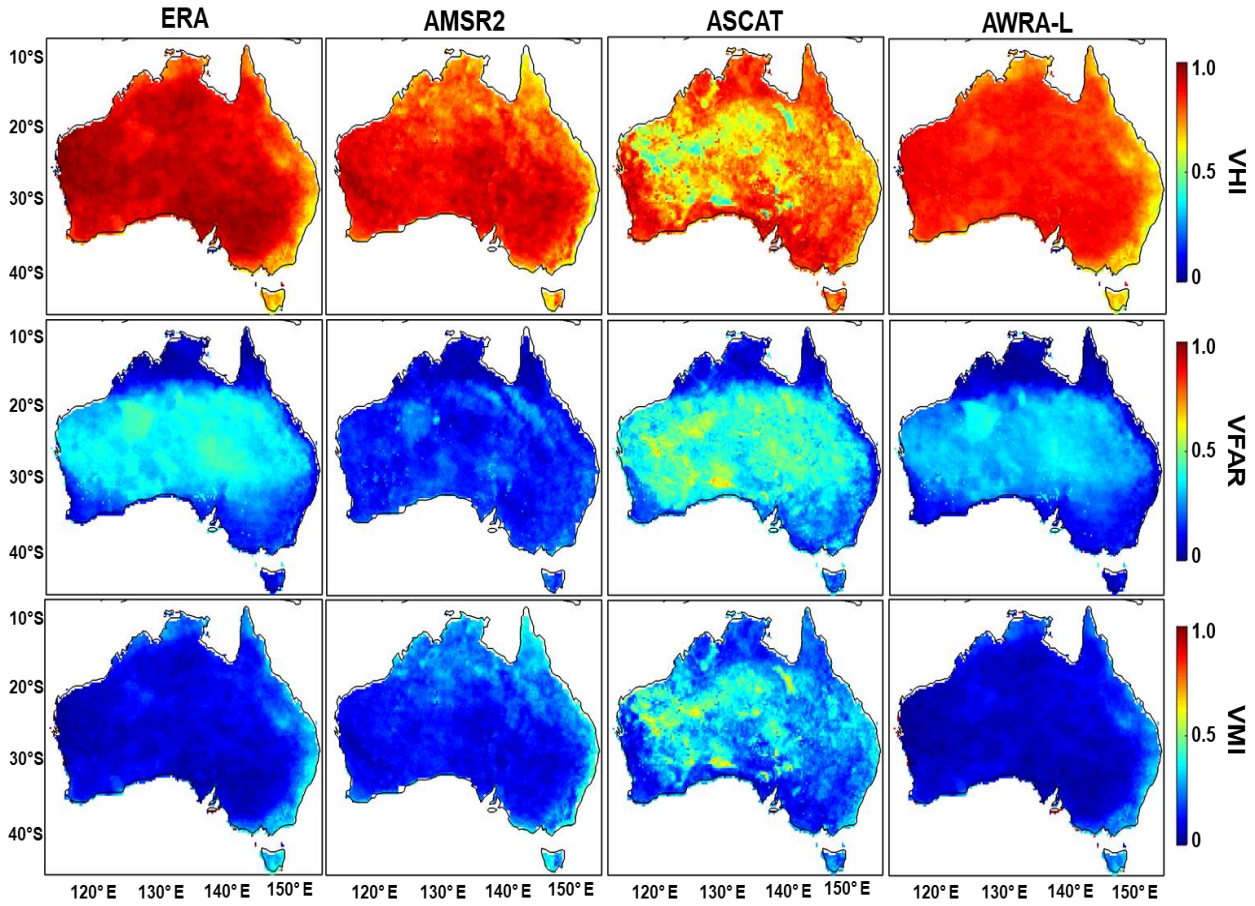
Temporal evaluation of Soil Water Deficit Index (SWDI) from various products in different climate classes

	ERA-Interim	AMSR2	ASCAT	AWRA-L	AWD	Mean
Tropical	107	102	116	105	118	110
Arid	166	154	199	162	213	169
Temp-DS	134	125	167	140	168	147
Temp-NDS	55	54	66	52	72	60
Australia	176	171	198	178	208	186

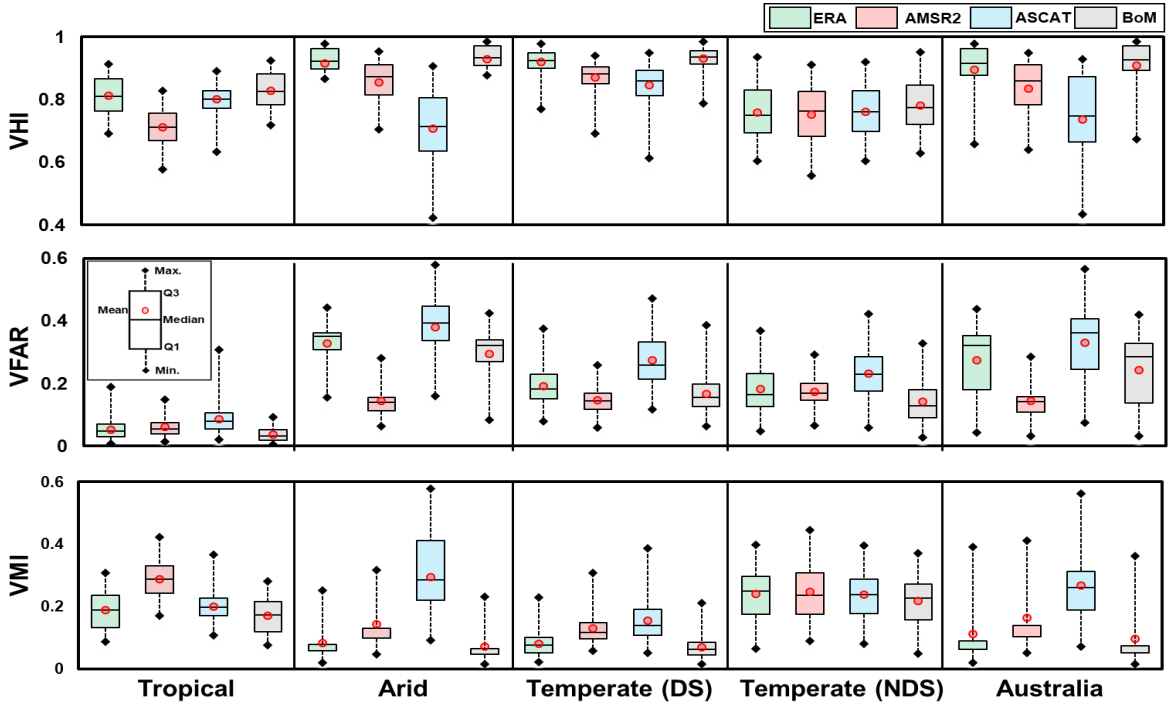
*Total 260 weeks (July 2012 to June 2017)

The number of drought weeks captured by Soil Water Deficit Index (SWDI) from various soil moisture products are compared with Atmospheric Water Deficit (AWD) during study periods.

Drought Detection Skills



Spatial maps of extended volumetric contingency tables were drawn for various platforms to assess agricultural drought detection



Boxplots show the range of extended volumetric contingency tables for agricultural drought assessment

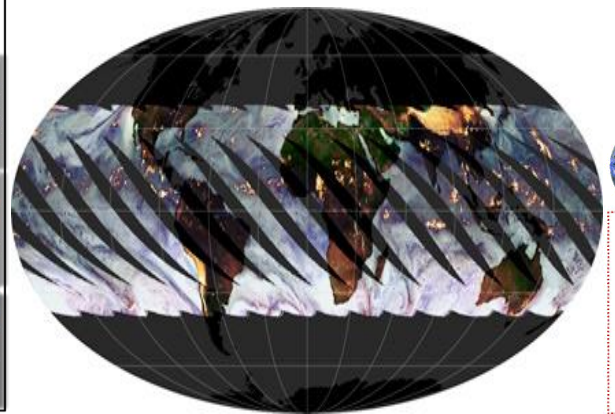
The statistical analysis of extended volumetric contingency tables over Australia

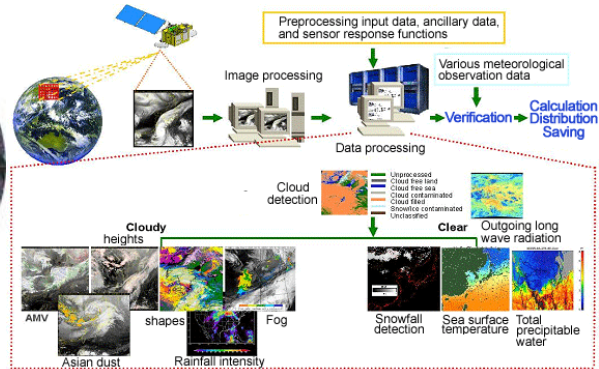
Product	VHI	VFAR	VMI
ERA-Interim	0.89	0.17	0.11
AMSR2	0.83	0.15	0.17
ASCAT	0.69	0.33	0.27
AWRA-L	0.90	0.14	0.10

*__VHI__ : Volumetric Hit Index, __VFAR__ : Volumetric False Alarm Ratio, __VMI__ : Volumetric Miss Index

Conclusion

1. SWDI can be accurately used to assess drought
2. ERA-Interim and AMSR-2 had high correlation AWRA-L SM datasets
3. ASCAT captured slightly more drought
4. SWDI estimated agricultural drought (water deficit) in six months (Oct-Dec) of each year
5. SWDI was accurately evaluated by AWD
6. VHI for ERA-Interim, AMSR-2 and AWRA-L were 89%, 83%, and 90%, respectively
7. VFAR showed that ASCAT had 33% false drought detection skills





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THANK YOU