Multi-scale monitoring of water use from multi-sensor remote sensing: two recently initiated studies over ACCWA sites

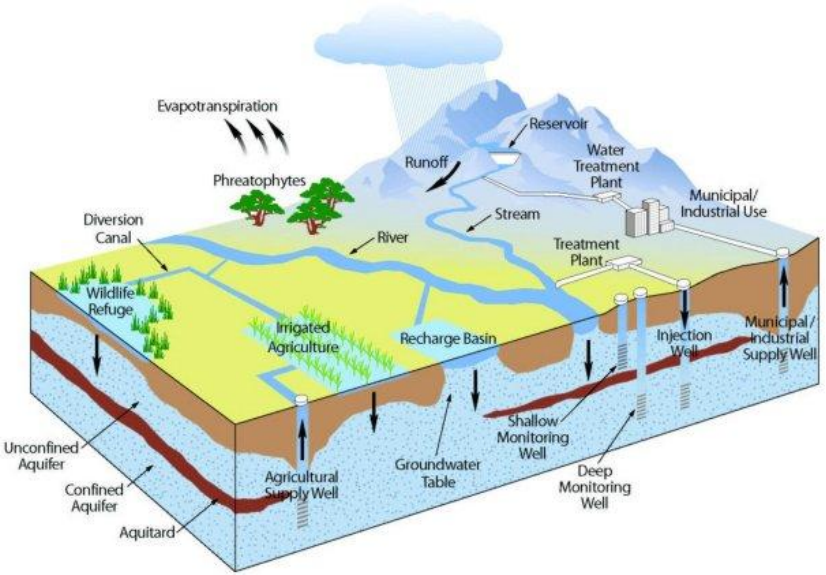
Olivier Merlin for the IRD ACCWA team

Plan

- Introduction
- Retrieving irrigation at the field scale
- Monitoring groundwater level changes at regional scale
- Conclusions and prospects

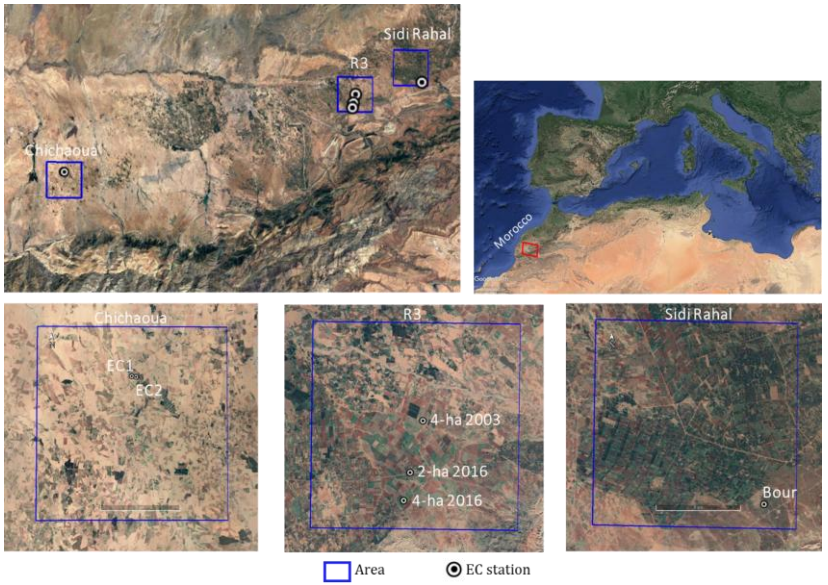
Introduction

- Monitoring the water uses by agriculture within Mediterranean basins for helping manage water in a context of global changes
- Irrigation
- Groundwater extraction
- Multi-scale: field, irrigated perimeters, pumping areas, basin



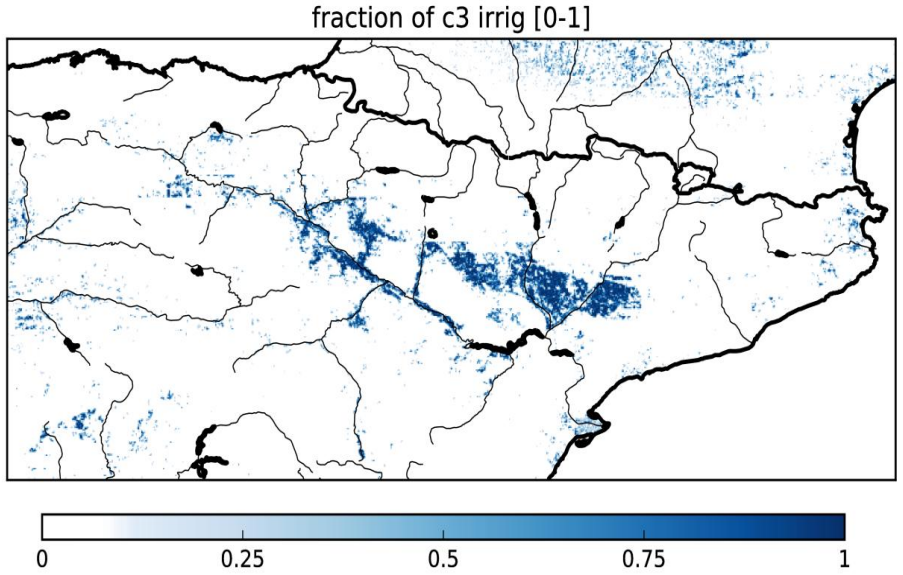
Site 1: Haouz plain

- Haouz, Morocco
- Arid area
- 85% of resources mobilized for irrigating crops (mainly wheat, olive trees, etc.)
- Mainly flood but conversion to drip



Site 2: Ebro basin

- Ebro basin, Spain
- Semi-arid area
- Study area composed of old and modern irrigation perimeters

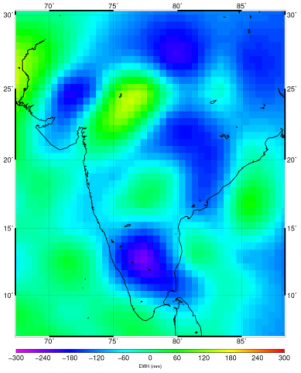


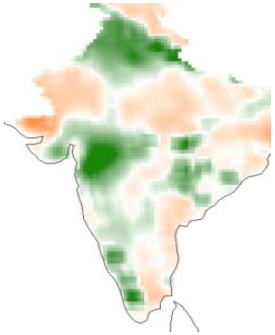
Meier et al., 2018

Site 3: Southern India

- Telangana region, India
- Semi-arid area
- Water storage renewed annually by monsoon
- 90% of ressources mobilized for irrigation (rice)

GRACE water storage	SMOS soil moisture	MODIS ET	Water surfaces and crop types





300 km → 10-20 m

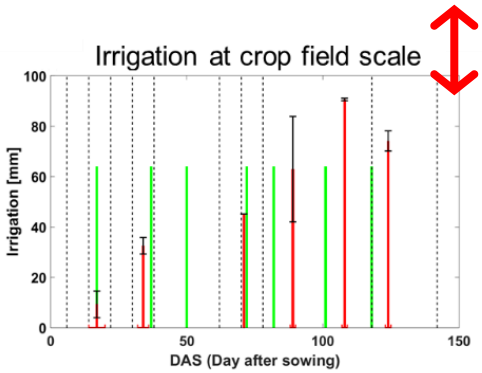
On going PhD theses

- Luis Olivera (Co-Dir. Salah Er-Raki, Co-Dir. Olivier Merlin; 3rd year): was seconded to isardSAT. **Monitoring the water resources of irrigated crops from multi-spectral (optical/thermal) remote sensing data (Landsat, FAO modeling).**

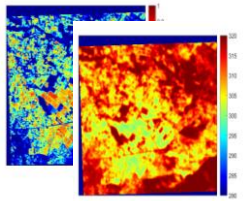
- Yann Pageot (Dir. Valérie Demarez; 2nd year): will be seconded to isardSAT/LabFerrer. **Improving classification techniques to map irrigated crops during the agricultural season (Sentinel-1, AI).**

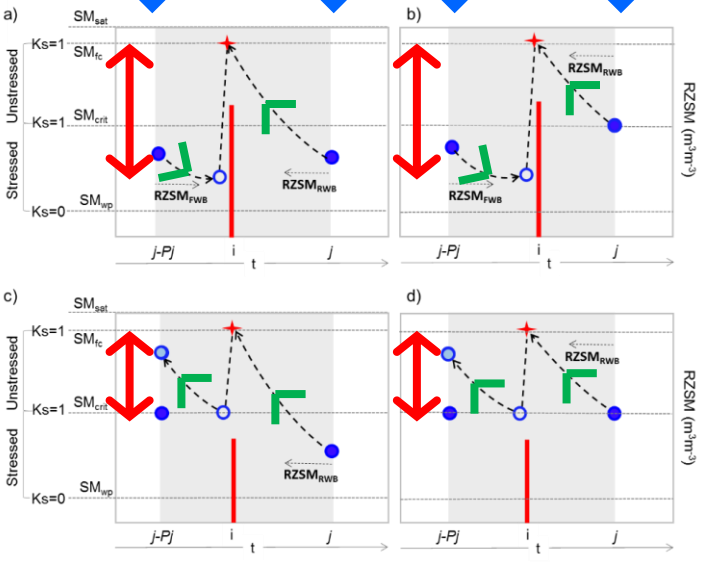
- Claire Pascal (Co-Dir. Sylvain Ferrant, Co-Dir. Olivier Merlin; 1 st year): will be seconded to UCAM and isardSAT. **Multi-scale mapping of water resources over irrigated regions: disaggregation of GRACE data (Multi-sensor, AI).**

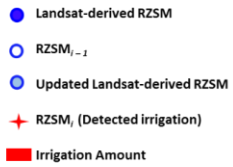
Retrieving irrigation at the field scale

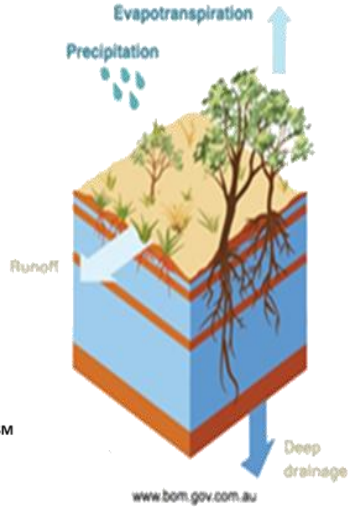


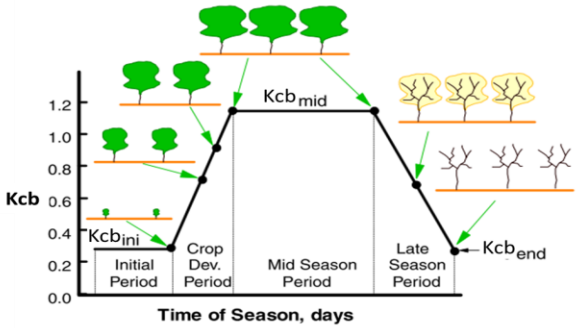
Landsat data





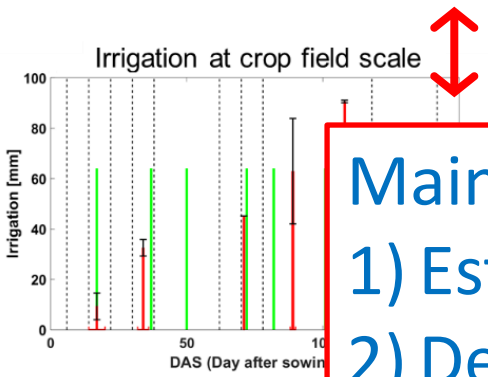


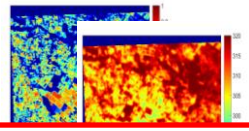


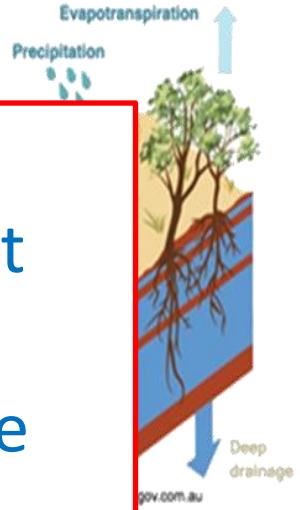


FAO-2Kc model

Retrieving irrigation at the field scale

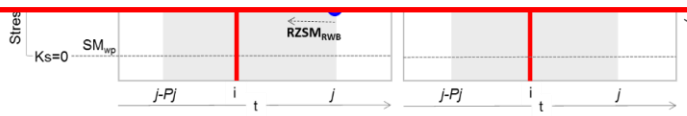


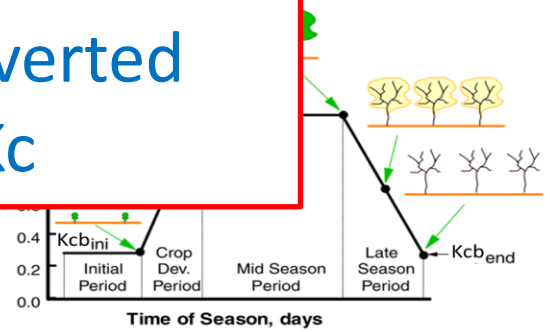




Main steps of the method:

1) Estimating the crop stress coefficient
2) Deriving the root zone soil moisture
3) Retrieving irrigation at the pixel scale
4) Aggregating at the field scale
5) Re-analyzing fluxes by using inverted irrigations as forcing to FAO-2Kc

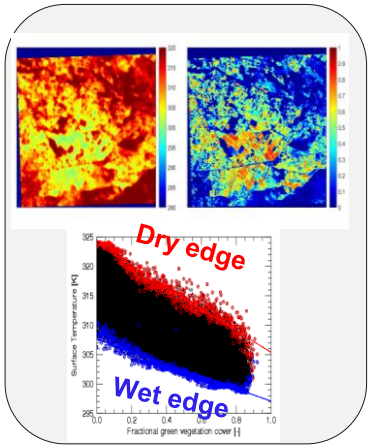


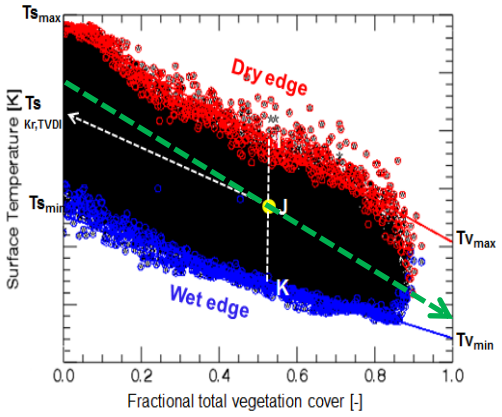


FAO-2Kc model

1) Estimating a stress coefficient

Time series of Landsat-derived
Land surface temperature
Fractional vegetation cover

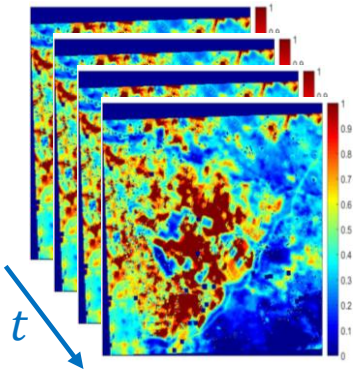




Partitioning method

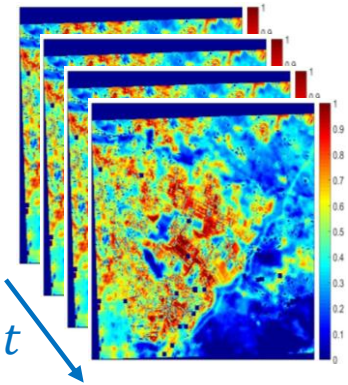
Time series of Landsat-derived
Stress coefficient

Vegetation



$$K_s = \frac{Tv_{max} - Tv}{Tv_{max} - Tv_{min}}$$

Soil



$$K_r = \frac{Ts_{max} - Ts}{Ts_{max} - Ts_{min}}$$

$$ET = (Ks.Kcb + Ke)ETO$$

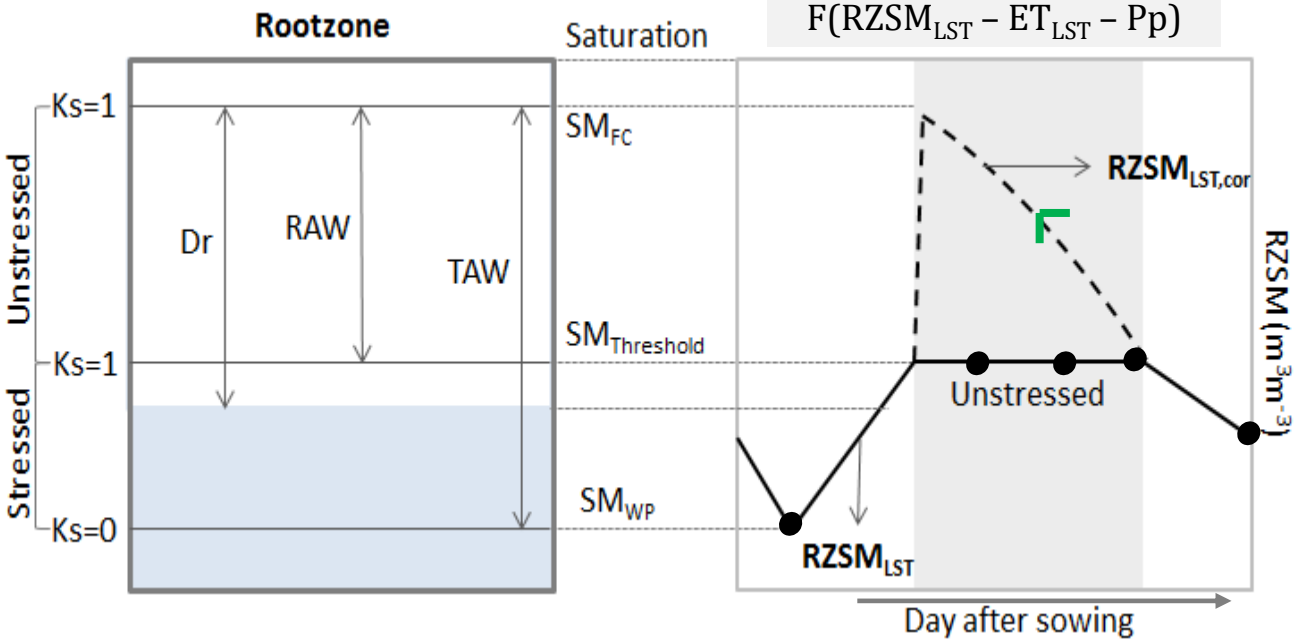
2) Deriving the root zone soil moisture

Non-linear relationship between Ks and RZSM!

Ks < 1

$$RZSM = SM_{WP} + K_s(1-p)(SM_{FC} - SM_{WP})$$

$$p = RAW/TAW$$



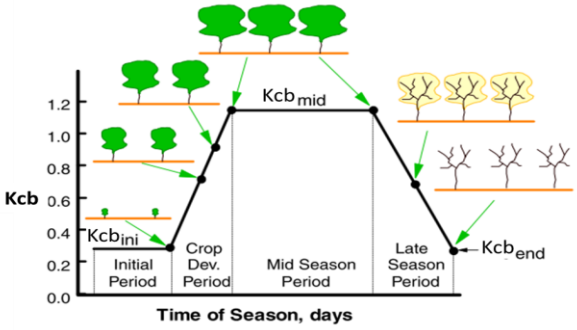
Ks =1

Re-construct the RZSM dynamics

Water Budget:
$F(RZSM_{LST} - ET_{LST} - Pp)$

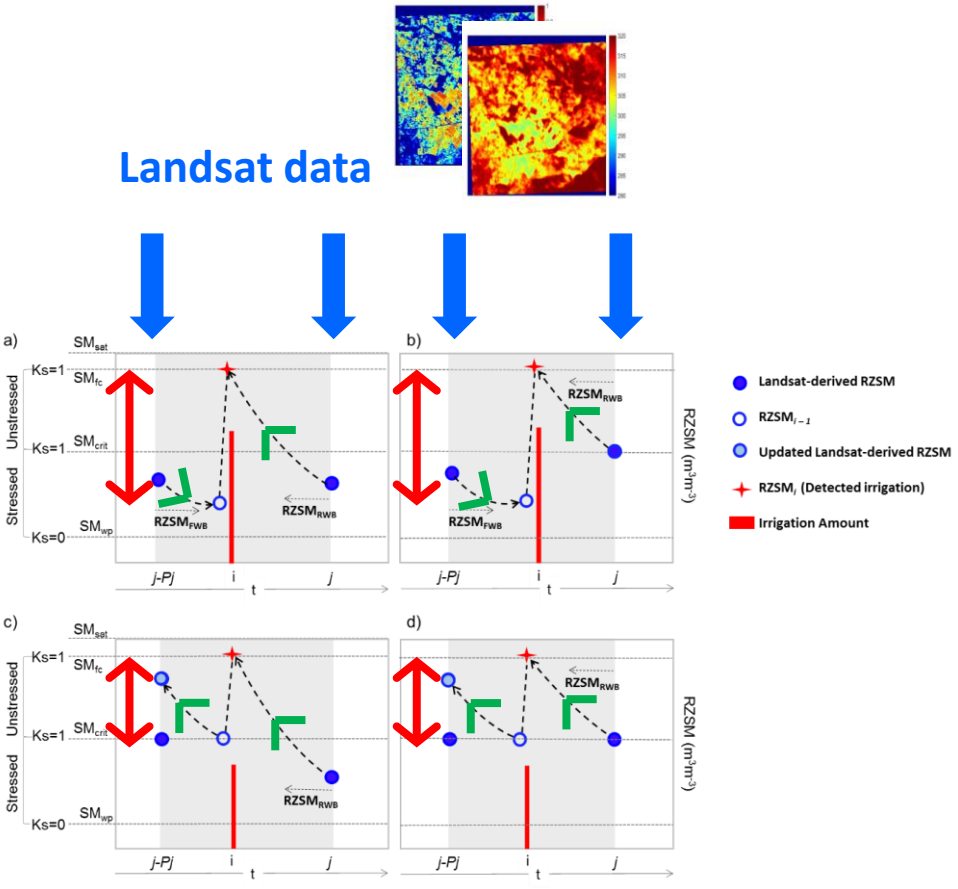
3) Pixel-scale retrieval of irrigation

Four cases depending on the stress/unstress situation on two successive Landsat overpass dates

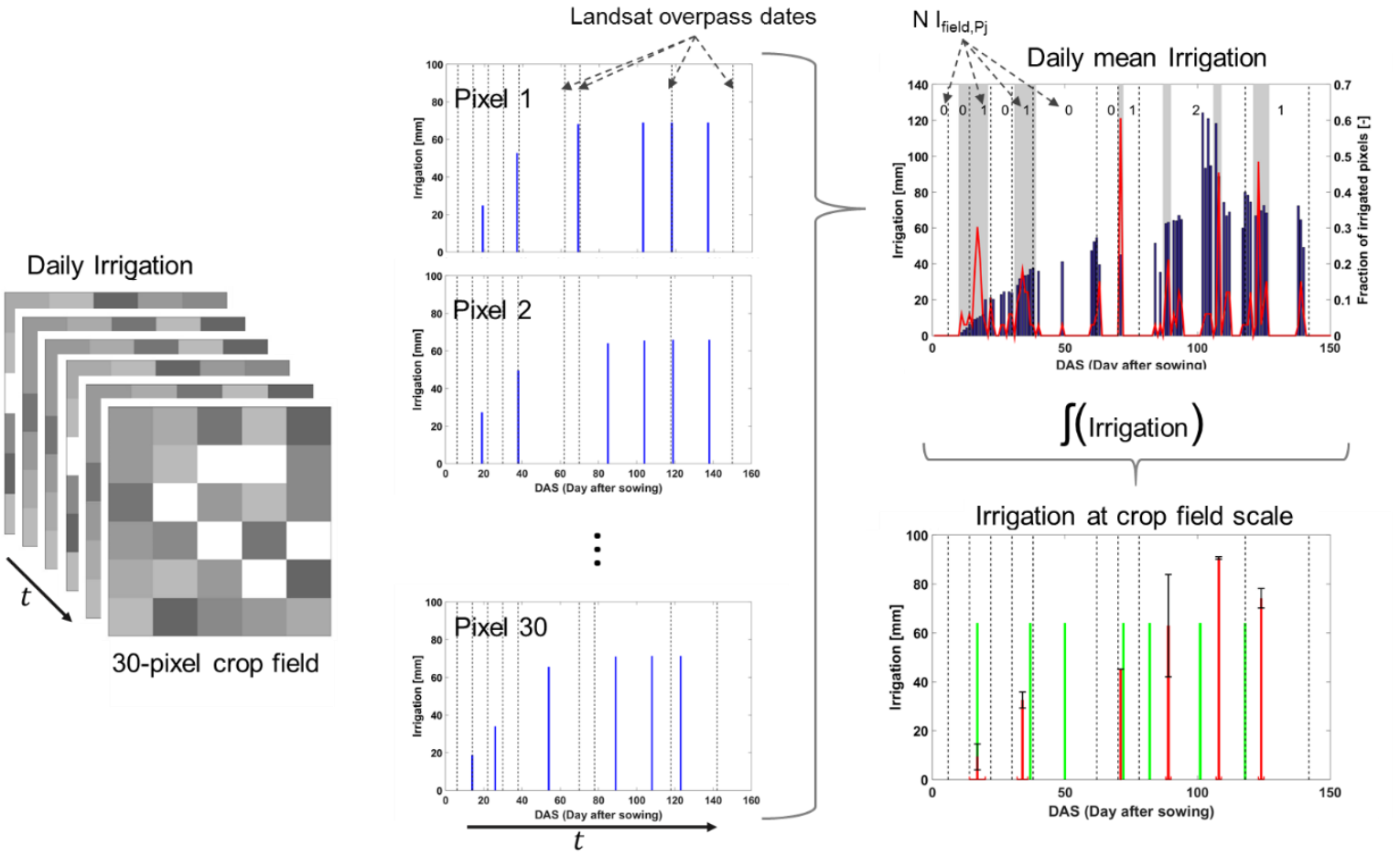


FAO-2Kc model

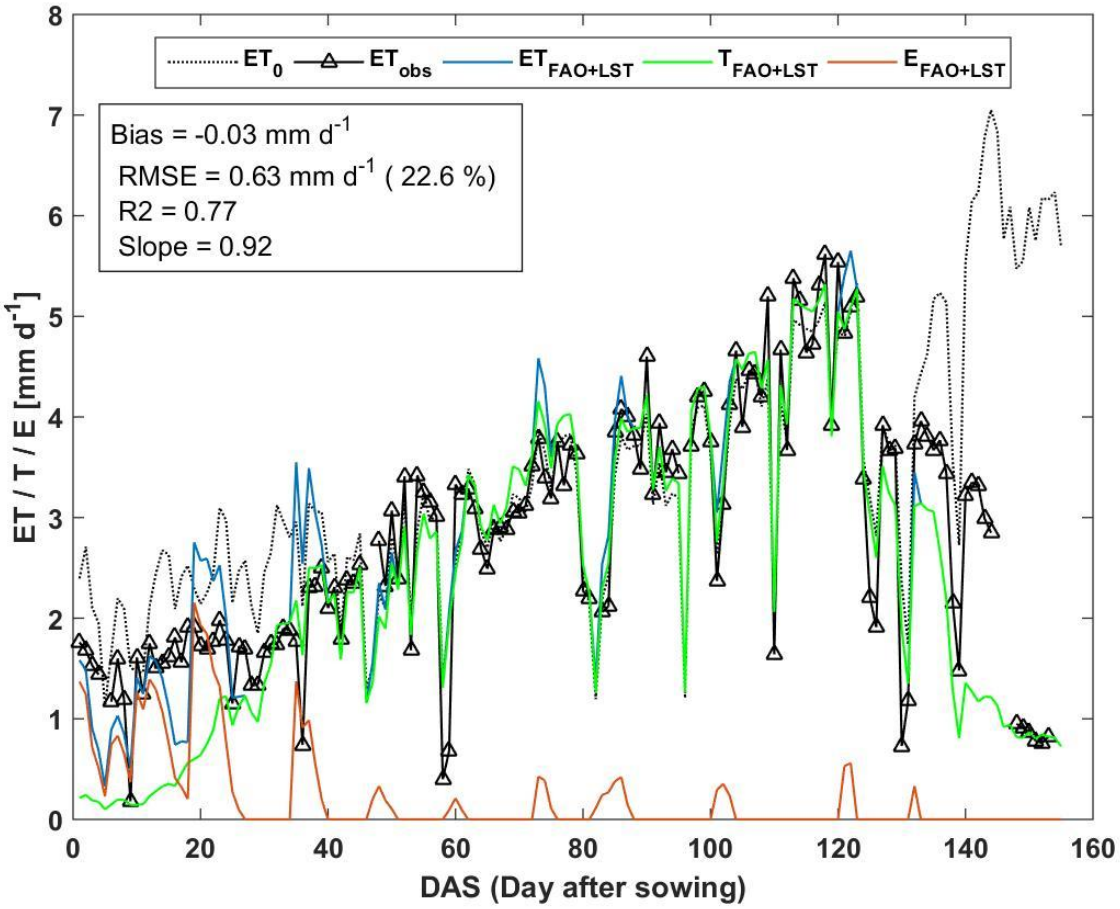
Landsat data



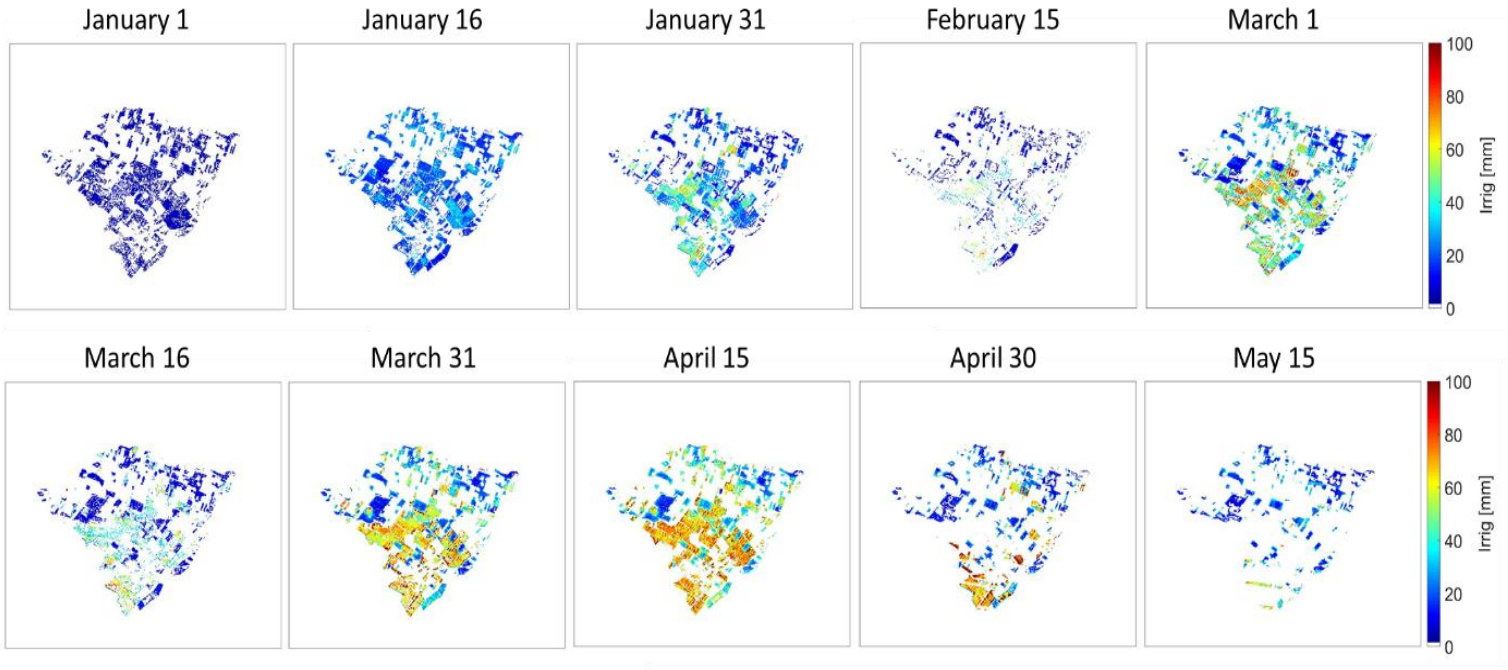
4) Field-scale retrieval of irrigation



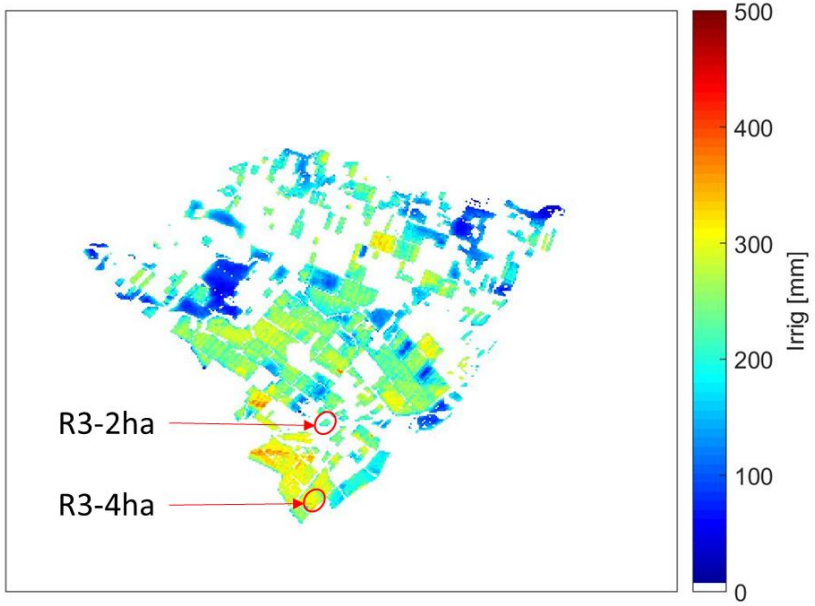
5) Final run of the FAO-2Kc using retrieved irrigation

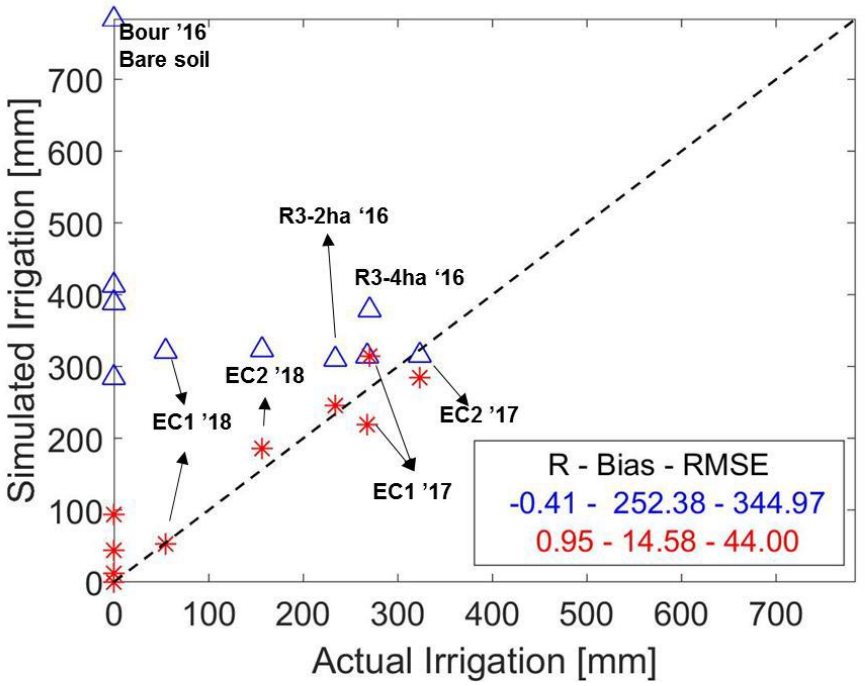


Results

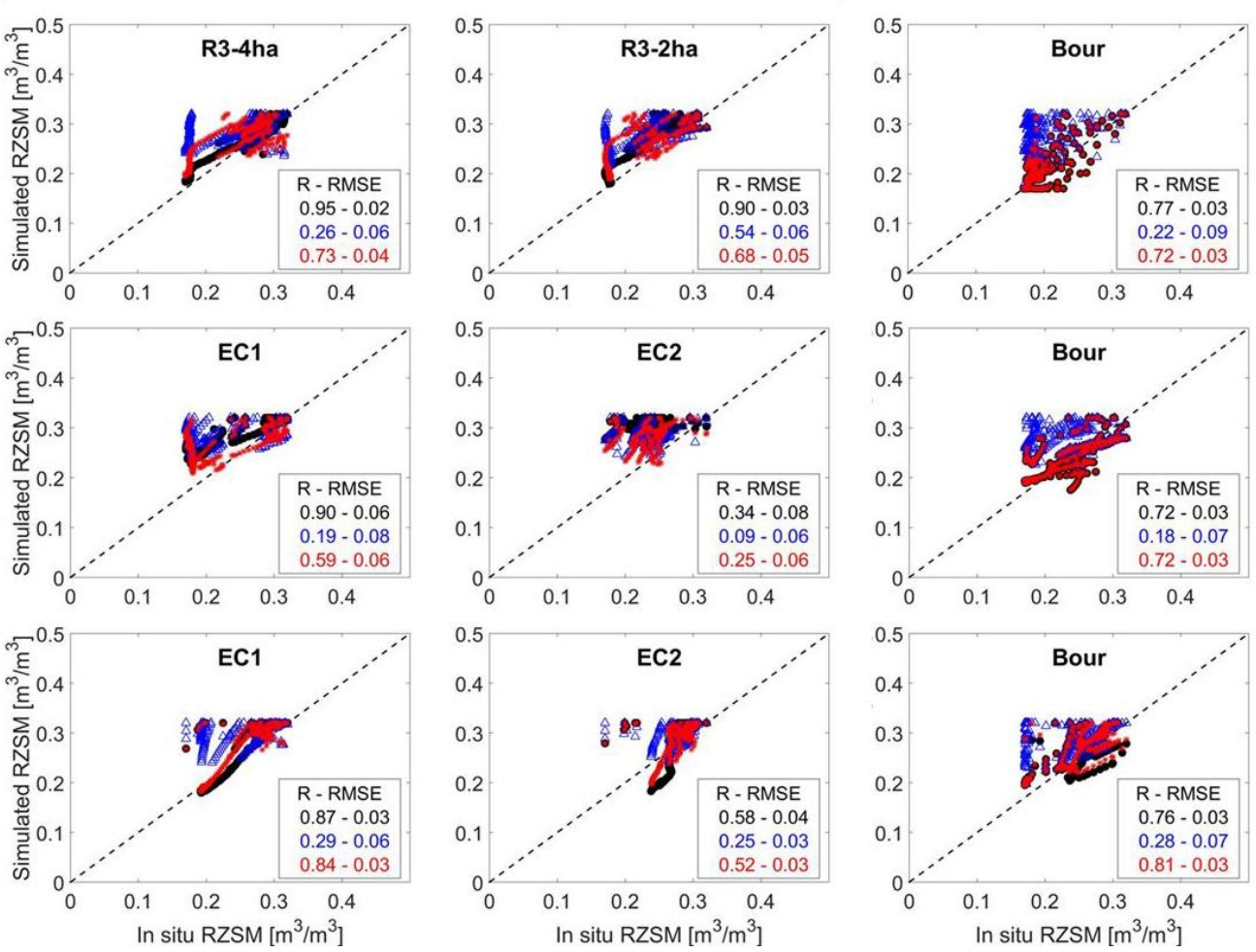

January 1
January 16
January 31
February 15
March 1
March 16
March 31
April 15
April 30
May 15
100
80
60
40
20
0
Irrig [mm]

Results

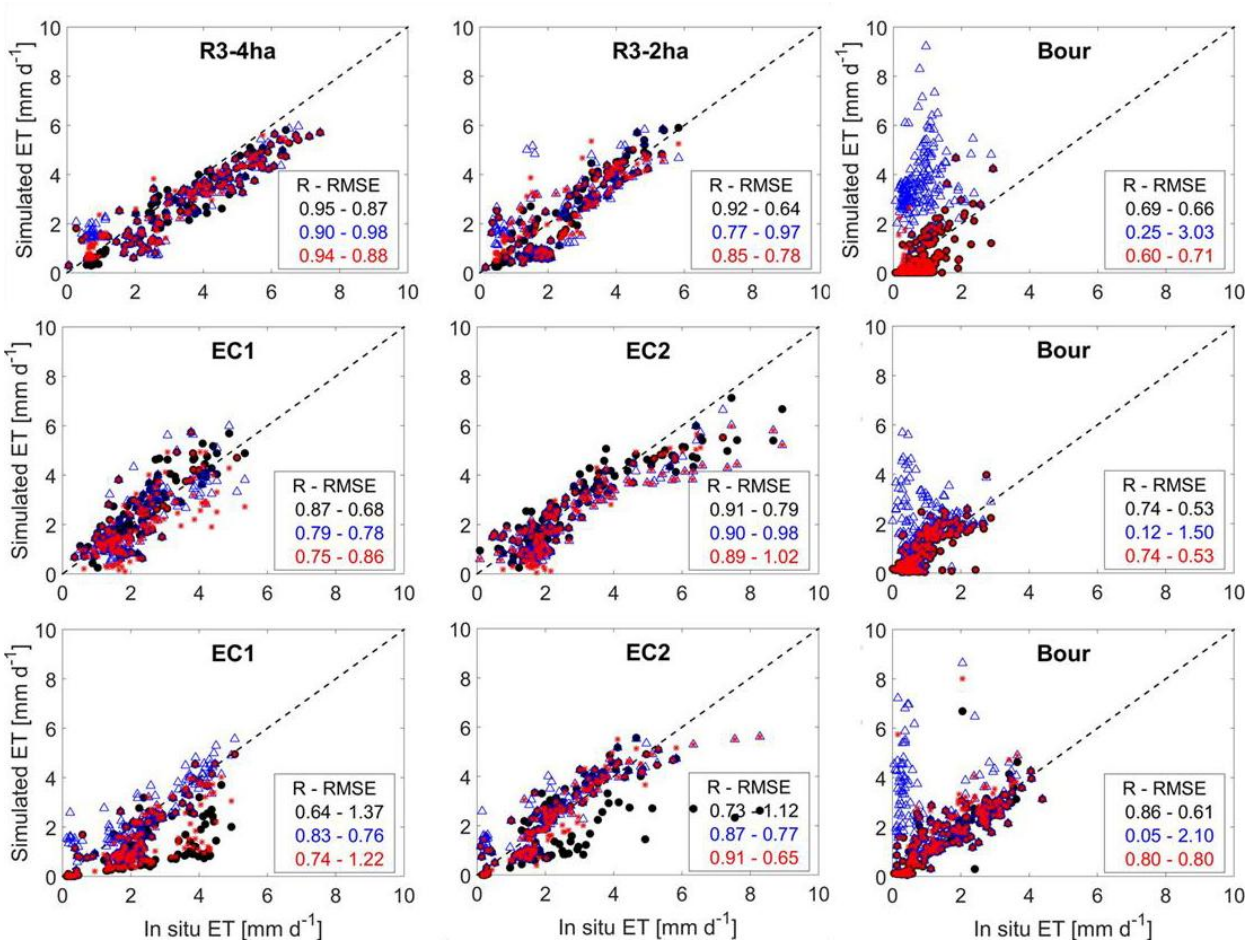

R3-2ha
R3-4ha
500
400
300
200
100
0
Irrig [mm]


Bour '16
Bare soil
R3-2ha '16
R3-4ha '16
EC2 '18
EC1 '18
EC2 '17
EC1 '17
R - Bias - RMSE
-0.41 - 252.38 - 344.97
0.95 - 14.58 - 44.00
Simulated Irrigation [mm]
Actual Irrigation [mm]
0
100
200
300
400
500
600
700

Results

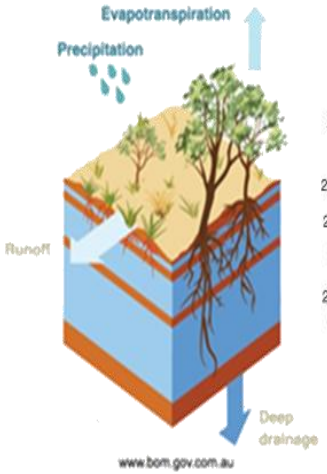

R3-4ha
R - RMSE
0.95 - 0.02
0.26 - 0.06
0.73 - 0.04
R3-2ha
R - RMSE
0.90 - 0.03
0.54 - 0.06
0.68 - 0.05
Bour
R - RMSE
0.77 - 0.03
0.22 - 0.09
0.72 - 0.03
EC1
R - RMSE
0.90 - 0.06
0.19 - 0.08
0.59 - 0.06
EC2
R - RMSE
0.34 - 0.08
0.09 - 0.06
0.25 - 0.06
Bour
R - RMSE
0.72 - 0.03
0.18 - 0.07
0.72 - 0.03
EC1
R - RMSE
0.87 - 0.03
0.29 - 0.06
0.84 - 0.03
EC2
R - RMSE
0.58 - 0.04
0.25 - 0.03
0.52 - 0.03
Bour
R - RMSE
0.76 - 0.03
0.28 - 0.07
0.81 - 0.03
Simulated RZSM [m3/m3]
In situ RZSM [m3/m3]

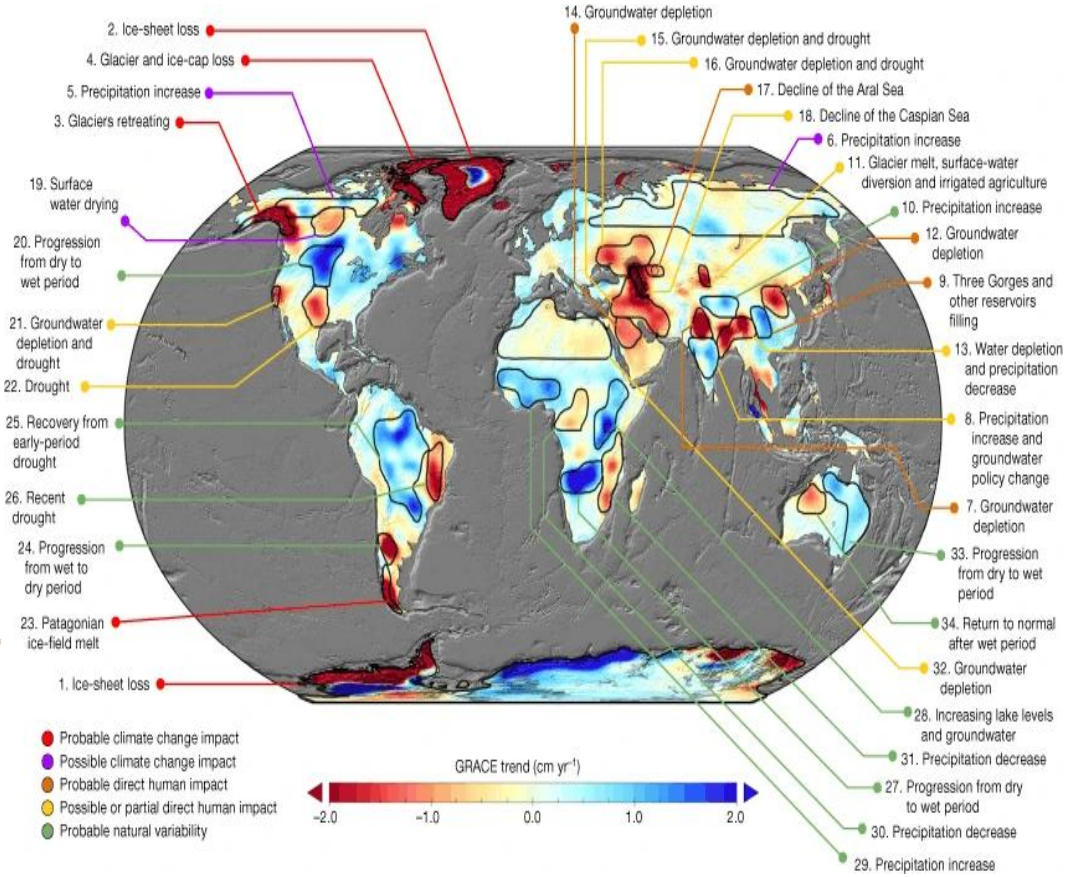
Results

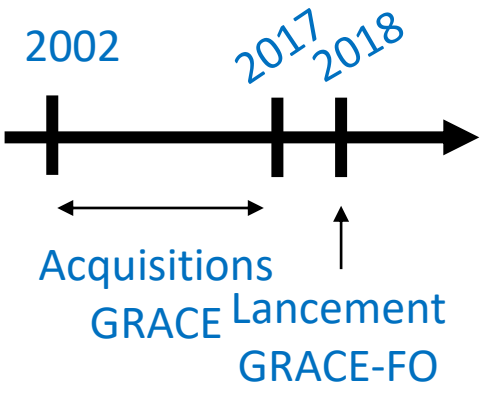

R3-4ha
R - RMSE
0.95 - 0.87
0.90 - 0.98
0.94 - 0.88
R3-2ha
R - RMSE
0.92 - 0.64
0.77 - 0.97
0.85 - 0.78
Bour
R - RMSE
0.69 - 0.66
0.25 - 3.03
0.60 - 0.71
EC1
R - RMSE
0.87 - 0.68
0.79 - 0.78
0.75 - 0.86
EC2
R - RMSE
0.91 - 0.79
0.90 - 0.98
0.89 - 1.02
Bour
R - RMSE
0.74 - 0.53
0.12 - 1.50
0.74 - 0.53
EC1
R - RMSE
0.64 - 1.37
0.83 - 0.76
0.74 - 1.22
EC2
R - RMSE
0.73 - 1.12
0.87 - 0.77
0.91 - 0.65
Bour
R - RMSE
0.86 - 0.61
0.05 - 2.10
0.80 - 0.80
Simulated ET [mm d-1]
In situ ET [mm d-1]

Groundwater monitoring

from Gravity Recovery and Climate Experiment (GRACE)



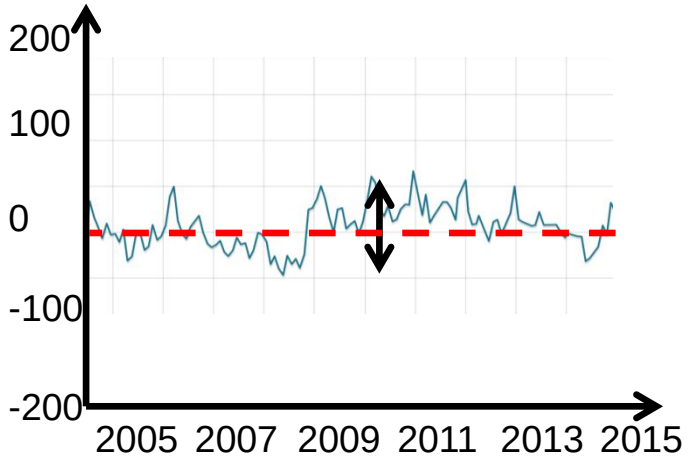




Total water storage change at global scale from GRACE signal (Rodell et al., 2018)

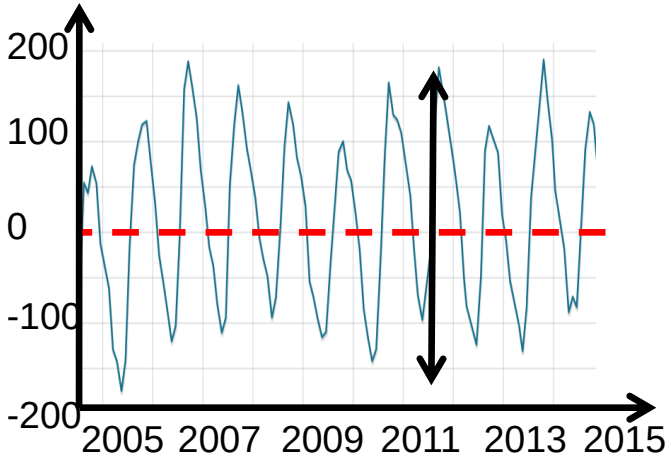
Irrigation impact on GRACE signal

Morocco, Haouz, arid



Variations =
Climate
+ Irrigation

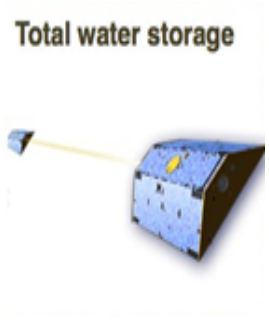
India, Deccan, semi-arid



2 issues:

- Quantifying the impact Ground Water Storage (GWS) on the evolution of Total Water Storage (TWS)
- Disaggregating GRACE et GRACE-FO data (TWS at ~300 km resolution)

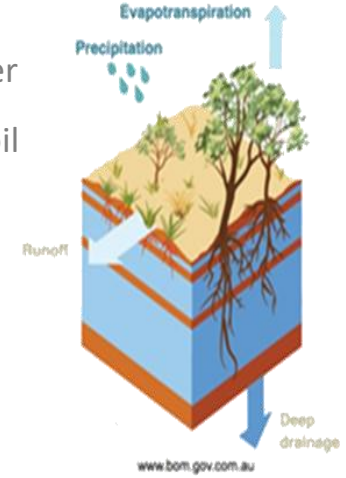
- Disentagling TWS and GWS in time



Snow
Surface water

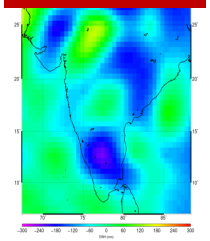
Root zone soil moisture

Ground Water Storage

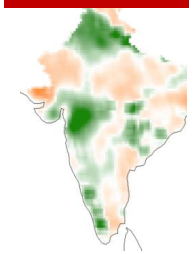


- Distributing GWS in space

GRACE water storage

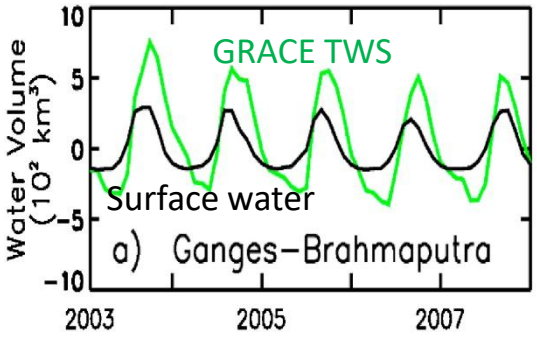


SMOS soil moisture



MODIS ET

Water surfaces



Gange–Brahmaputra basin (Papa et al., 2015)

→Residual term of water budget

Remote sensing
SMOS, Sentinel, MODIS, TRMM…

300 km → 10-20 m

→Deep learning
→Contextual methods

Conclusion

- Method to retrieve irrigation (Luis's PhD) is cutting edge, but need to test applicability in a range of agricultural conditions (crop type, irrigation techniques, etc.).
- A challenging research is proposed to apply GRACE data to the monitoring of water resources at 1 km resolution (Claire's PhD).

Prospects

- Retrieving irrigation:
  - from the field to irrigated perimeters
  - Integrating Sentinel-1 data to better constrain the timing of irrigation dates (and hence the retrieved volumes)
- Monitoring groundwater:
  - Disentangling the various contributions to GRACE signal
  - Disaggregating GRACE observation at scales useful for water resources monitoring