



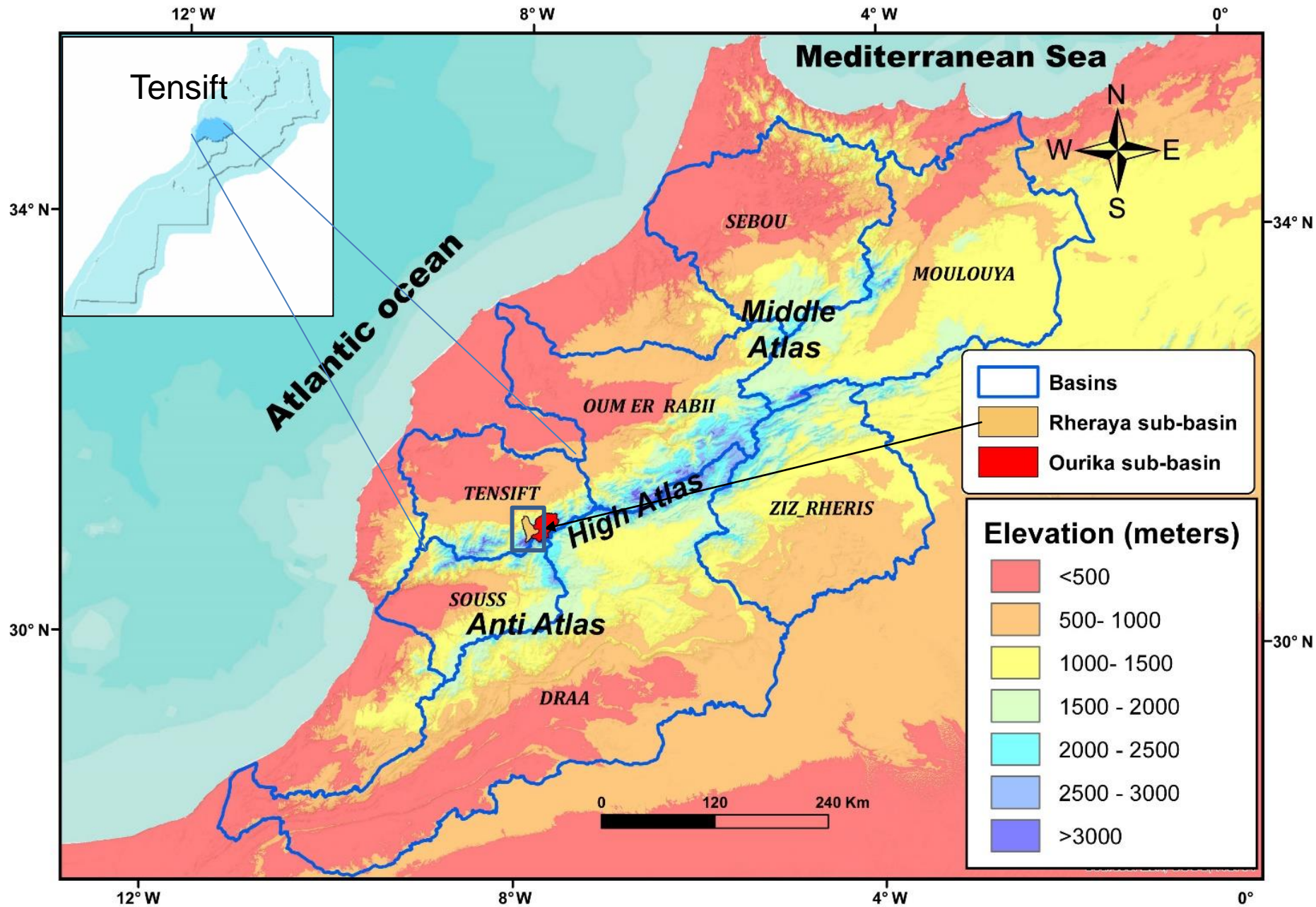
INARCH Workshop, Baños de Panticosa, Spain
October 18-20, 2022

Hydro-climatic observatory of the Rheraya watershed in the Moroccan High Atlas Mountains

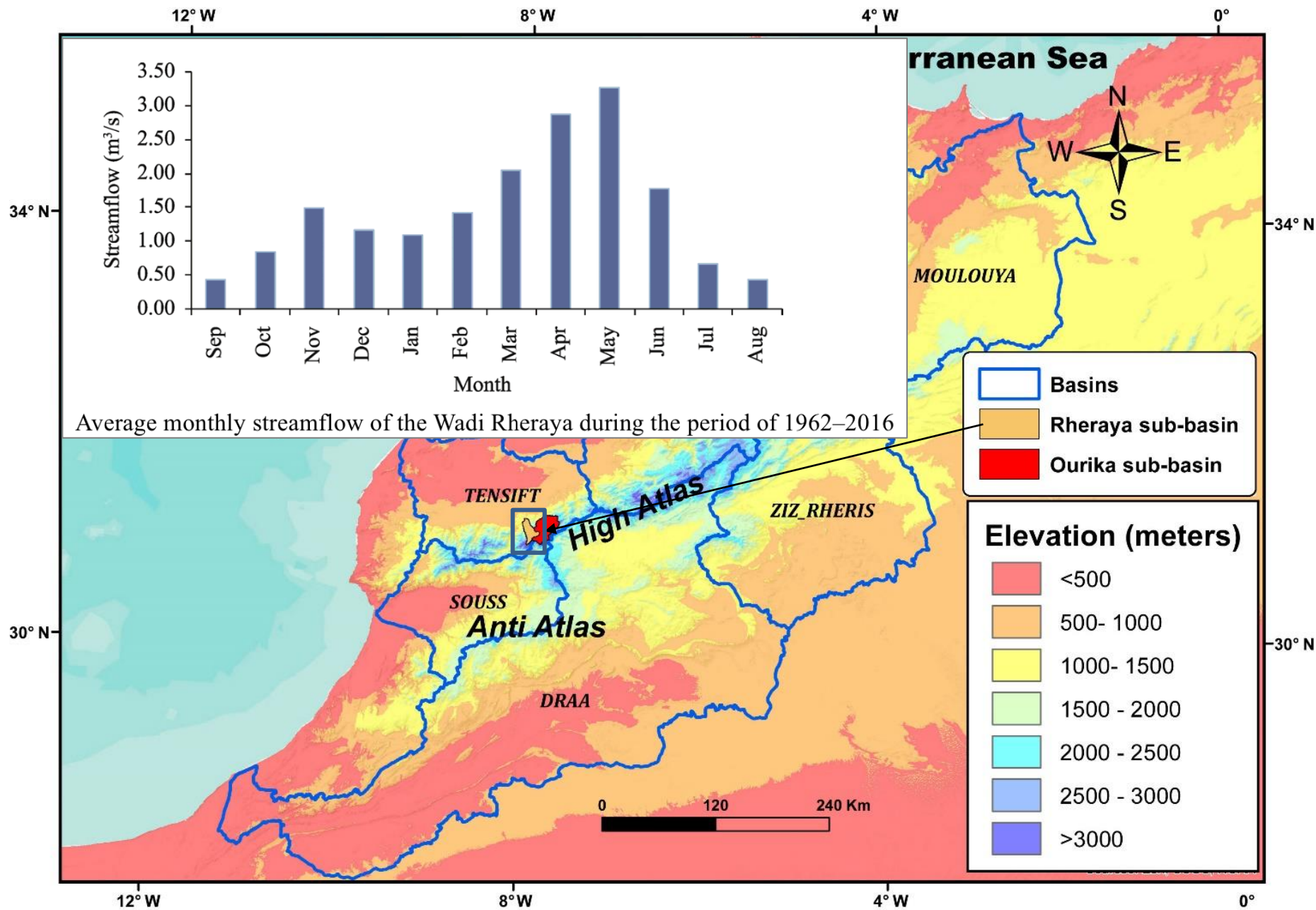
Lahoucine Hanich, Simon Gascoin and Vincent Simonneaux



Rheraya: a mountain catchment of 225 km² in the Tensift river basin (20,000 km²)



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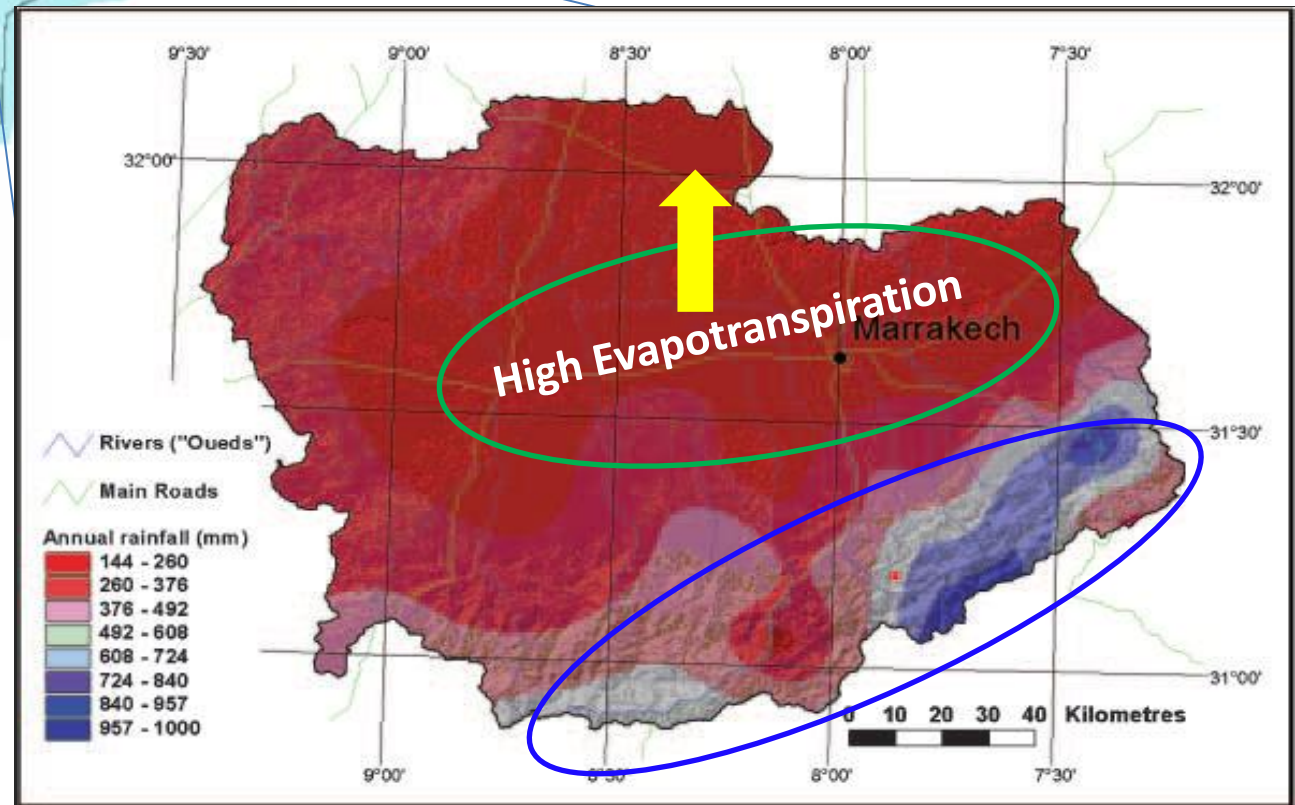
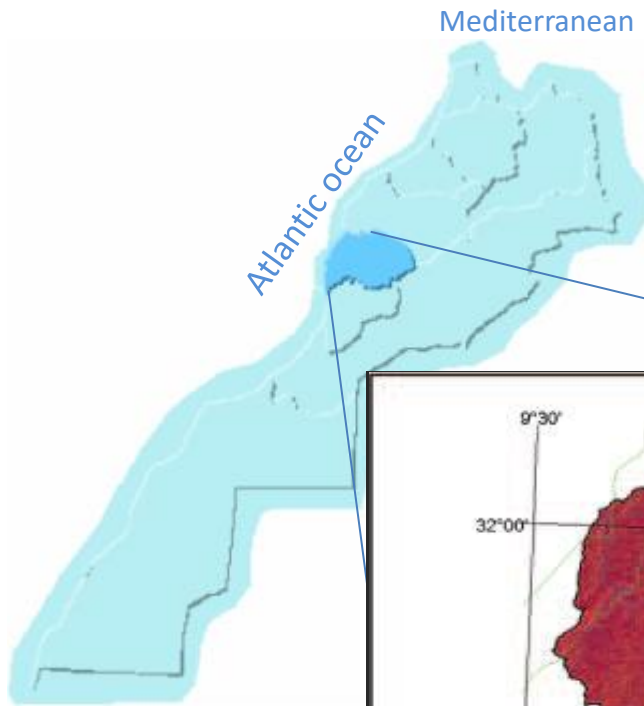


Tensift basin: typical basin of the southern Mediterranean

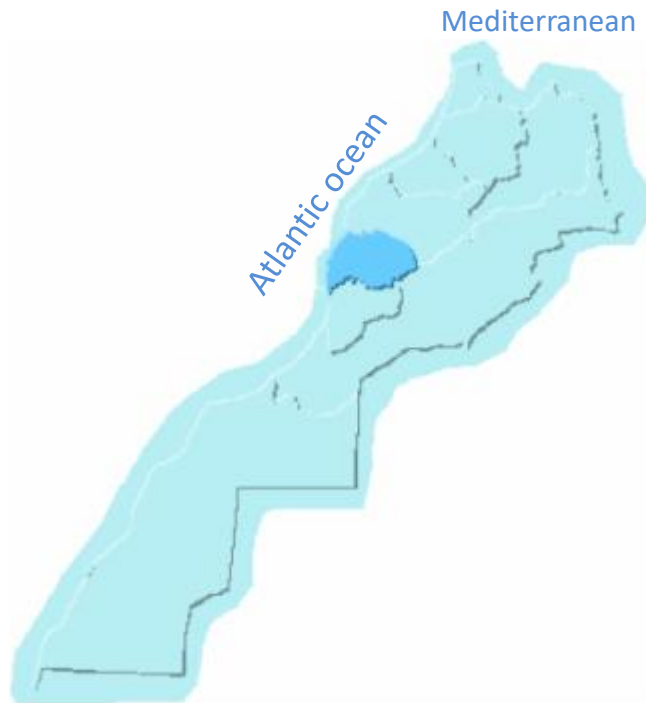
Population: **3.5M inhabitants**

Contrasted precipitation

Mountain	1000 mm/an
Plain	200 mm/an

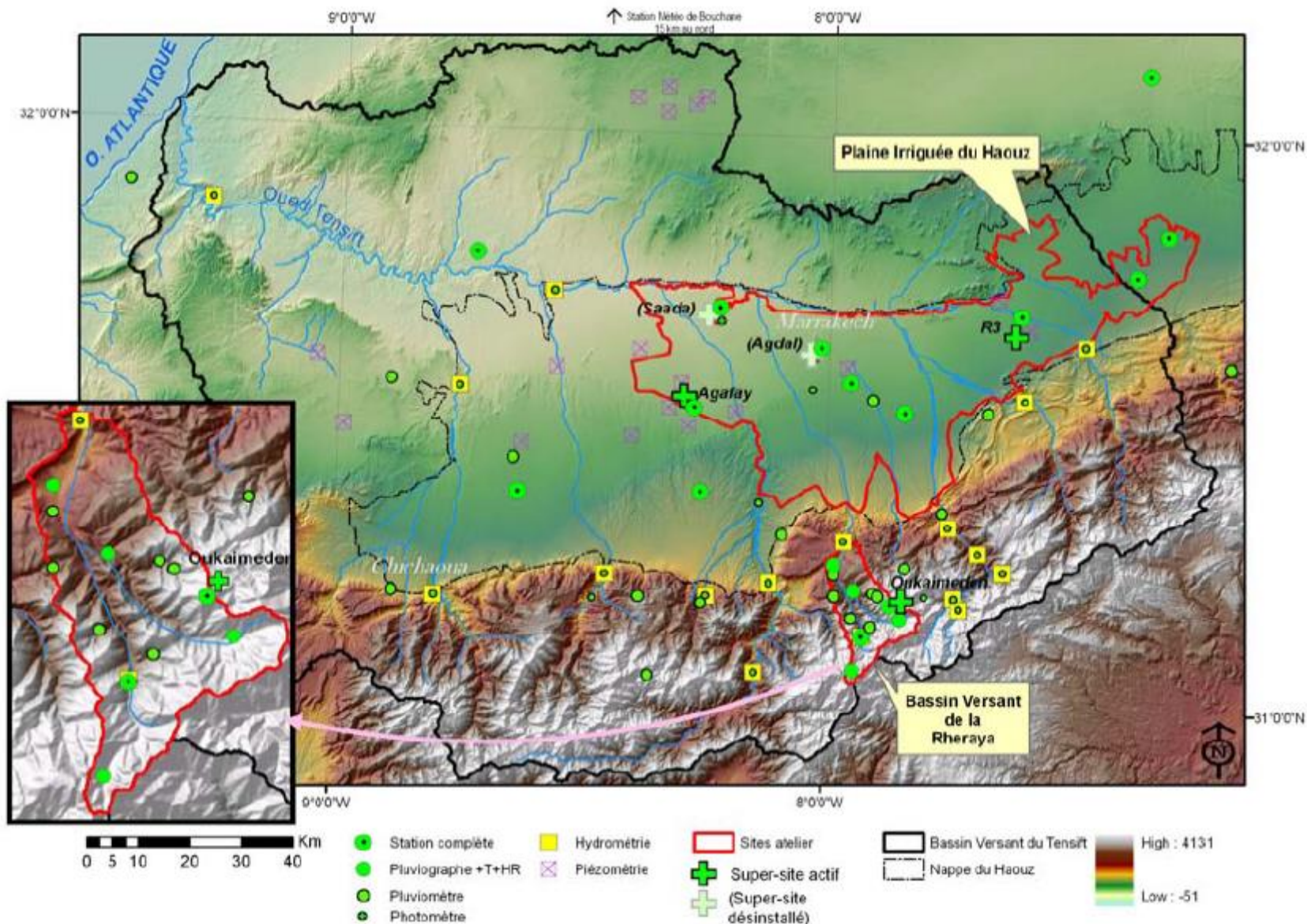


Tensift basin: typical basin of the southern Mediterranean

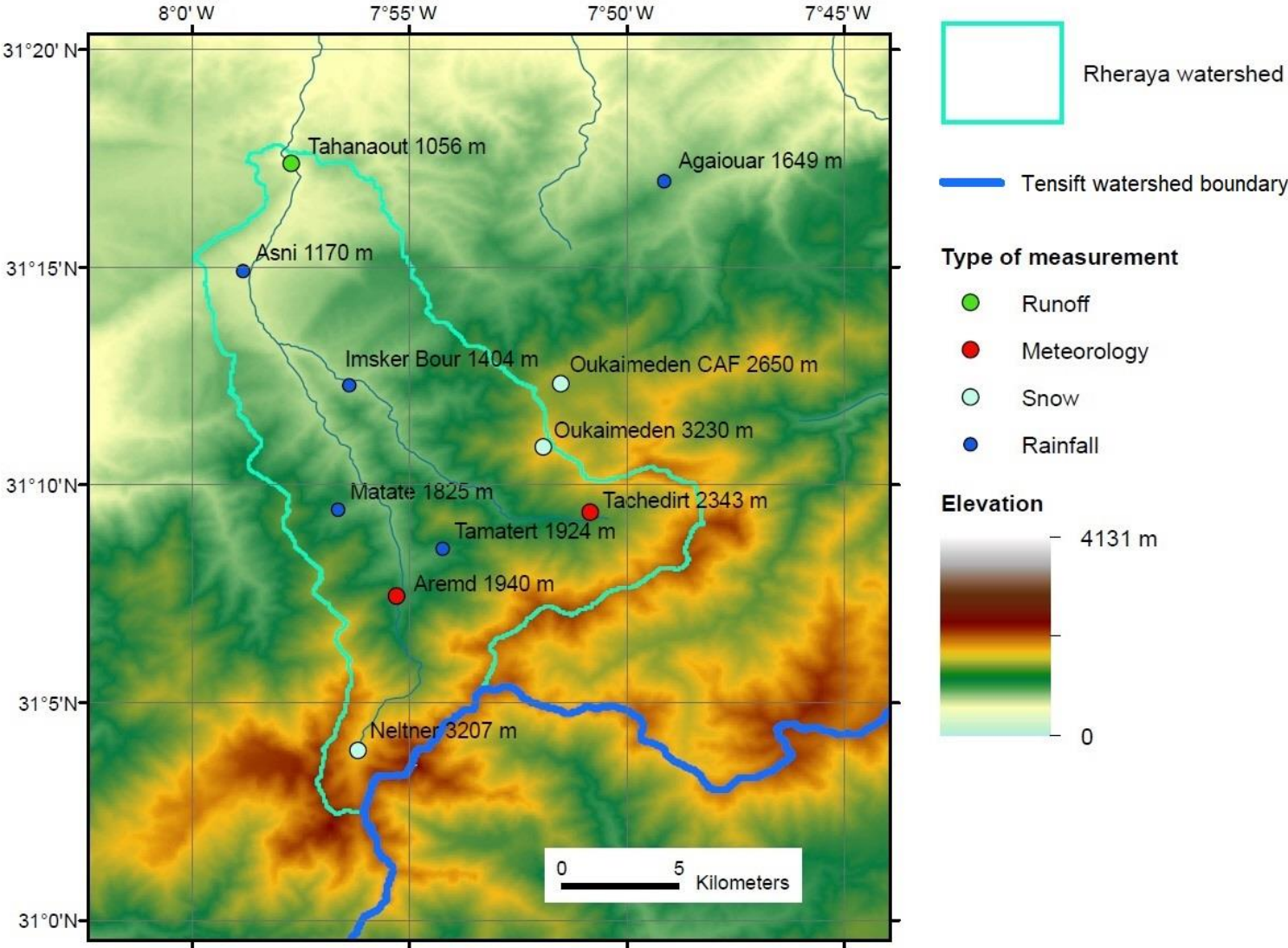


- **Low and limited water resources:**
 - 580 m³/inhab/year in 2010
 - 450 m³/inhab/year in 2030
- **Irregular spatio-temporal distribution;**
- **Fast increasing water demand (>>resources)**
- **Agricultural sector uses 85% of water**
- **Overexploitation of groundwater**
- **Climate change in Morocco: increase in temperature and decrease of precipitation.**

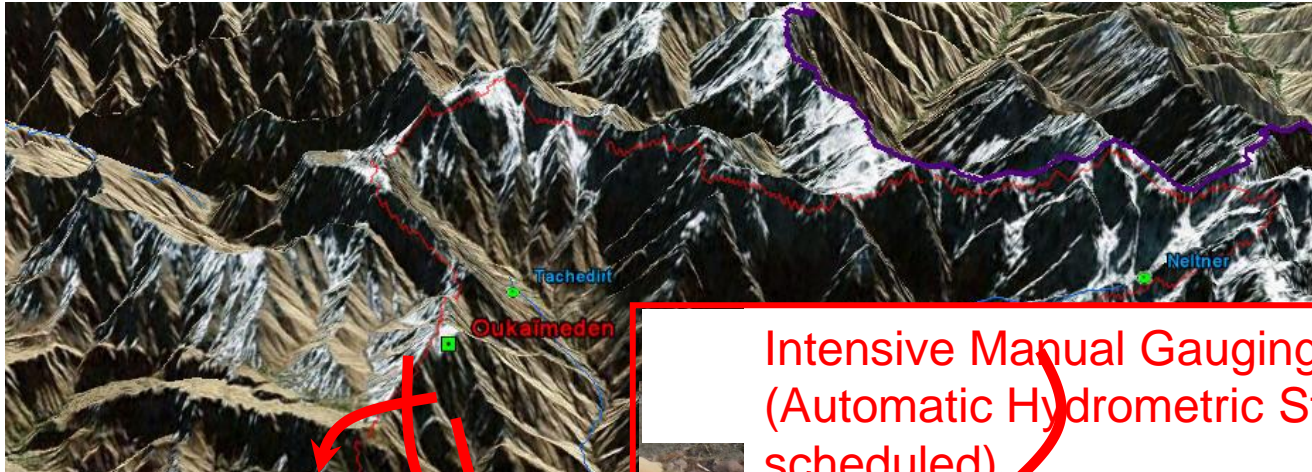
Rheraya watershed: a pilot catchment in the Tensift observatory



Location of the measurement sites in the Rheraya watershed



ATLAS: Rheraya watershed (240 km²)



Intensive Manual Gauging
(Automatic Hydrometric Station
scheduled)

Automatic and Manual Stations



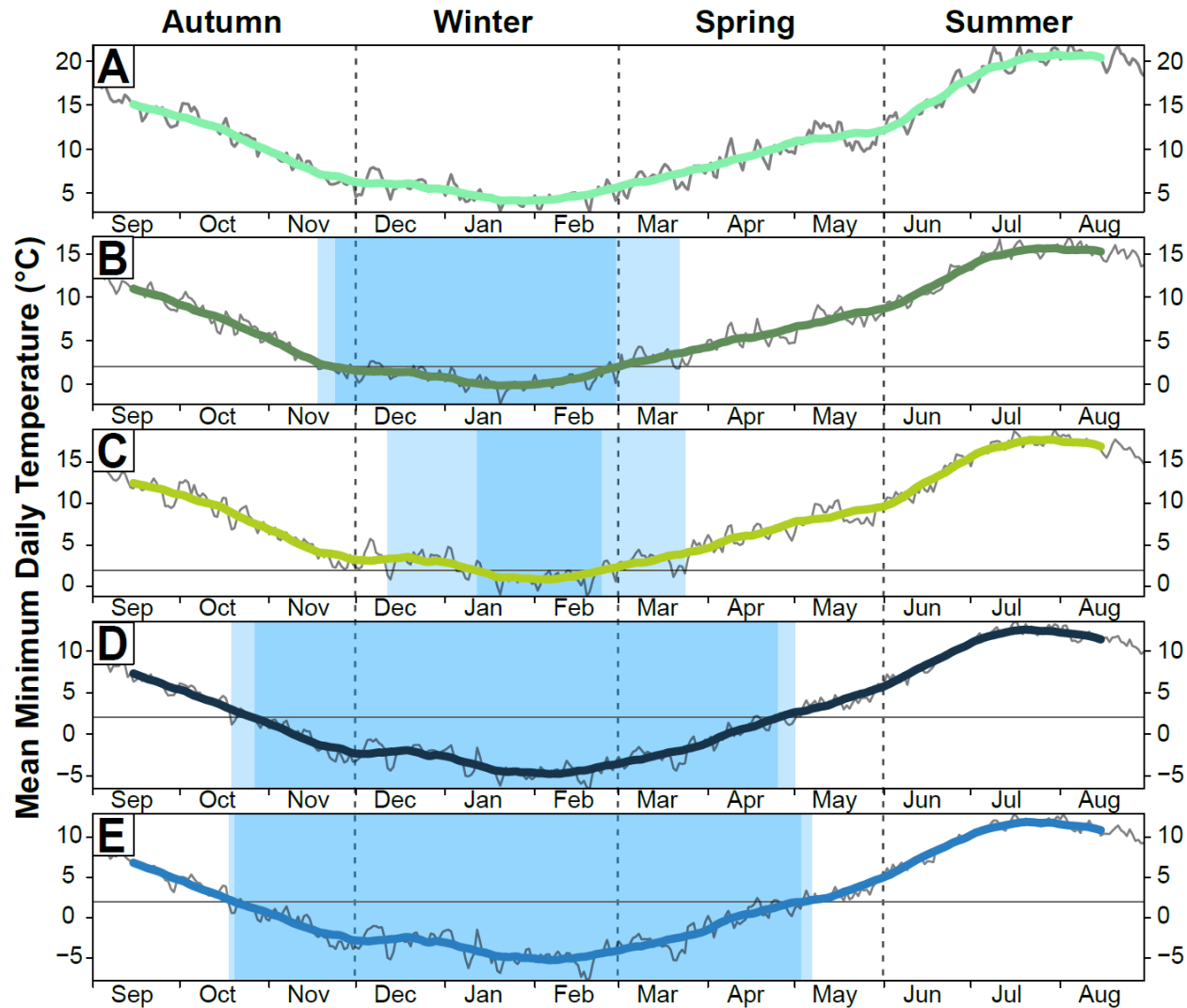
⑥ Automatic P-T-RH Stations



ations

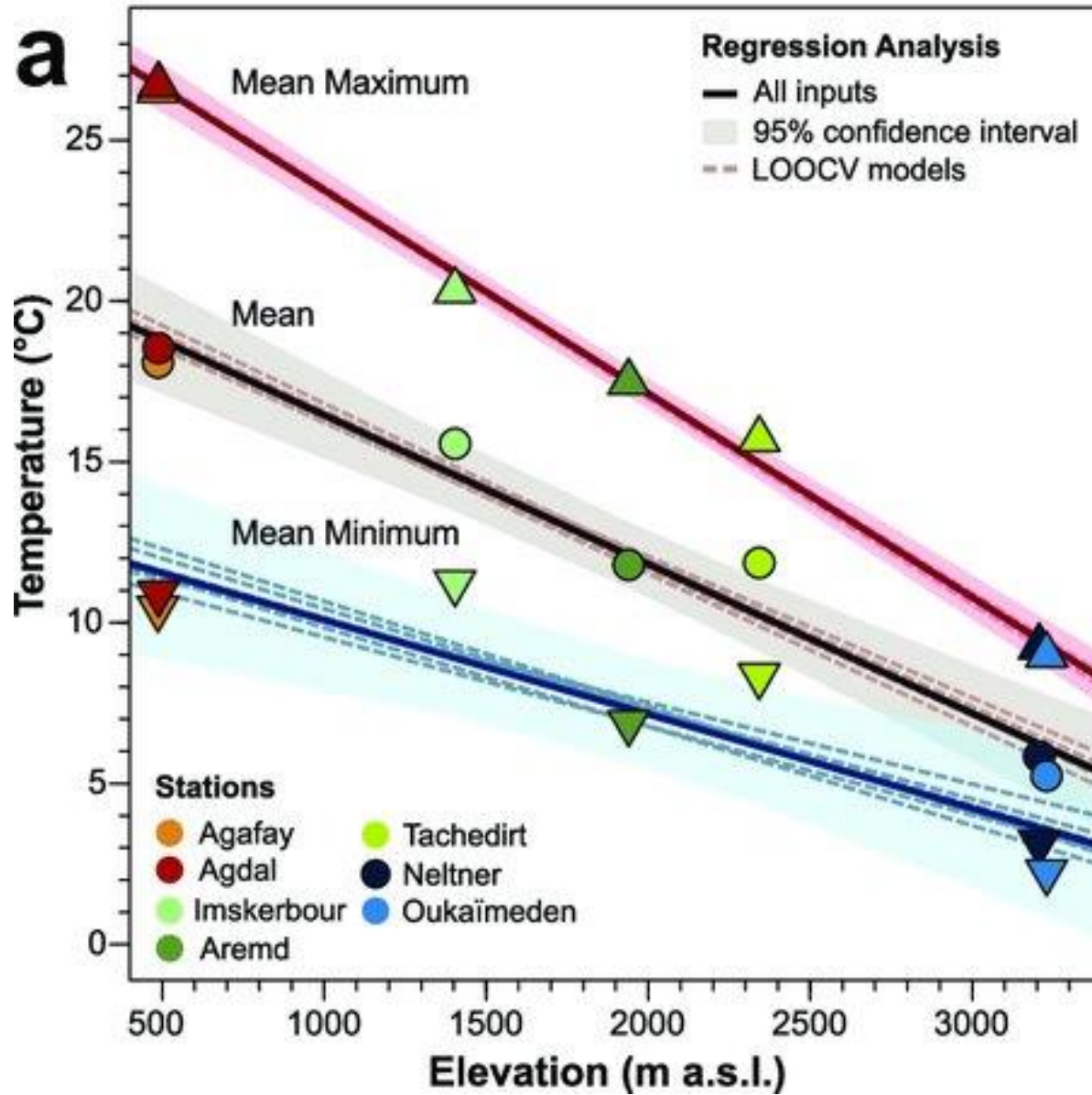
Mean minimum daily temperatures for the Rheraya stations (period 2008 to 2018) :

A) Imskerbour; B) Aremd; C) Tachedirt; D) Neltner; and E) Oukaïmeden



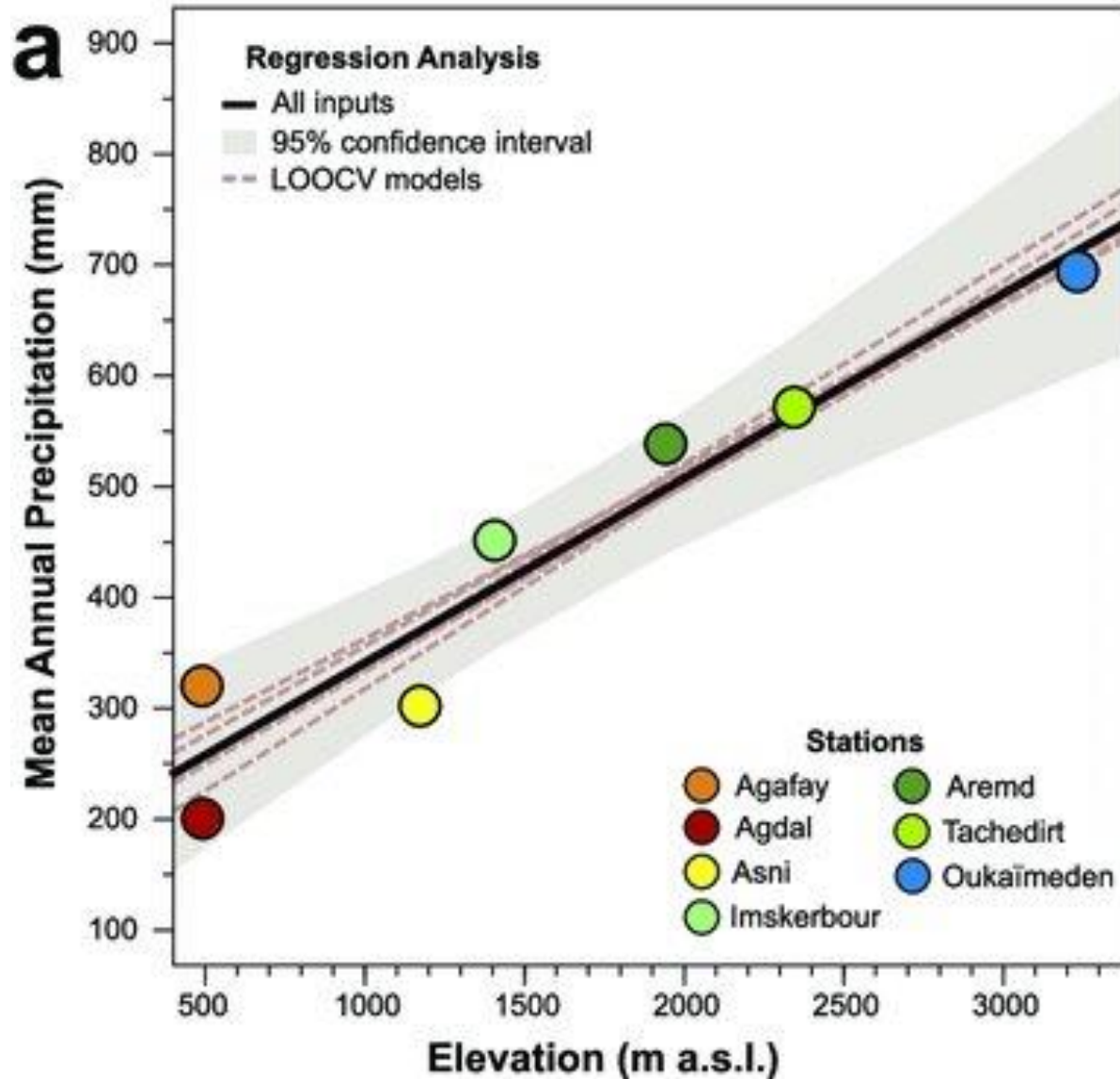
Temperature lapse rate

The mean annual near-surface temperature lapse rate is $-4.63^{\circ}\text{C km}^{-1}$



Precipitation gradient

The mean annual precipitation increases by 166 mm km^{-1}



Selected previous studies

Remote sensing

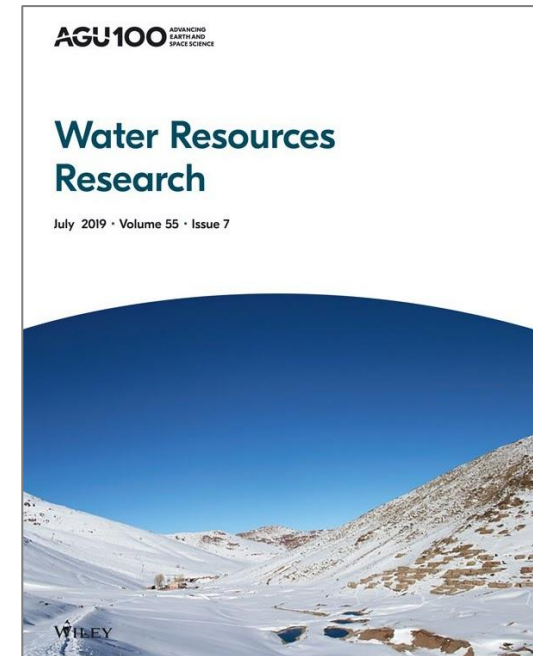
- Marchane, A. *et al.* Assessment of daily MODIS snow cover products to monitor snow cover dynamics over the Moroccan Atlas mountain range. *Remote Sensing of Environment* (2015).
- Bouamri *et al.* MODIS does not capture the spatiotemporal heterogeneity of snow cover induced by solar radiation. *Front. Earth Sci.* (2021).

Energy balance modelling

- Boudhar *et al.* Energy fluxes and melt rate of a seasonal snow cover in the Moroccan High Atlas. *Hydrological Sciences Journal* (2016).
- Baba *et al.* Effect of Digital Elevation Model Resolution on the Simulation of the Snow Cover Evolution in the High Atlas. *Water Resources Research* (2019).

Review

- Hanich *et al.* Snow hydrology in the Moroccan Atlas Mountains. *Journal of Hydrology: Regional Studies* (2022).



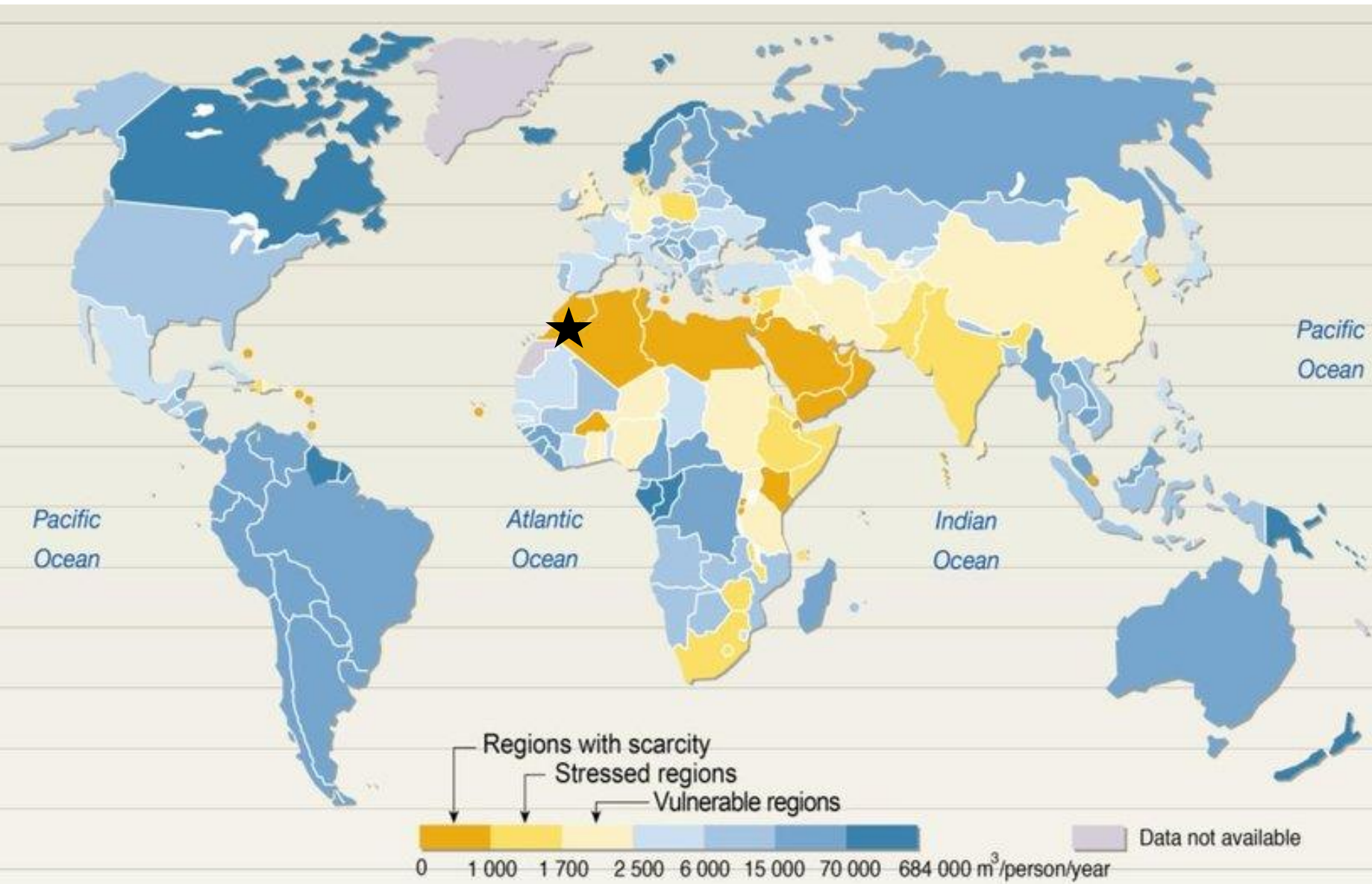


Oukaimdem Snow Monitoring Station, 3239m, 05/03/2010 (photo F. Bourgin)

THANK YOU FOR YOUR ATTENTION

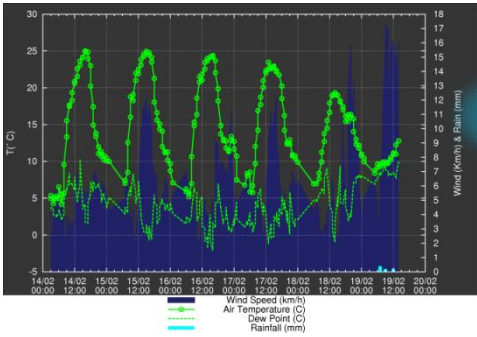
List of the main in situ variables measured within the Rheraya watershed

Data type	Variable	Instrument	Sampling time step	Neltner (3207 m)	Aremd (1940 m)	Tamatert (1924 m)	Tachedirt (2343 m)	Matate (1825 m)	Oukaïmeden (CAF Hut) (2650 m)	Oukaïmeden (3230 m)	Imsker Bour (1404 m)	Agalouar (1649 m)	Asni (1170 m)
Meteorology	Rain	Rain gauge	30 mn	2007-	2003-	2012-	2007-	2012-	1989-2009 (daily, manual)	2003-	2007-	2016-	2007-
	Temperature / Humidity	CS215 Sensor	30 mn	2007-	2003-		2007-		1989-2009 (T only, daily, manual)	2003-	2007-		
	Wind speed	Anemometer	30 mn	2013-	2003-					2003-			
	Solar radiation	Pyranometer	30 mn		2003-					2003-			
	Net Radiation	CNR1, NR0 Radiometer	30 mn							2003-			
Snow	Snow depth	Ultrasonic probe Manual samples	3-5 campaigns of 6-10 points/year						1989-2009 (daily, manual)	2003-			
	Rain + Snow	GEONOR (Weighting pluviometer)	30 mn	2013-						2013-			
	Snow density	Core tube / manual	3-5 campaigns of 6-10 points/year							2007-2016			
Soil	Soil moisture	Theta probes / CS655	30 mn		2013-					2019-			
Hydrology	Streamflow	Gauging	Monthly	From the 1970s at the outlets of the main watersheds (cf. Figure 1)									
	Height	Scale reading Hydro station	3 per day 10 min										
Hydrochemistry and isotopy (water and snow)	¹⁸ O and ² H	Laboratory analysis	Monthly	From 2011 to 2014 and from 2018 on the Ourika Watershed (cf. Figure 1)									

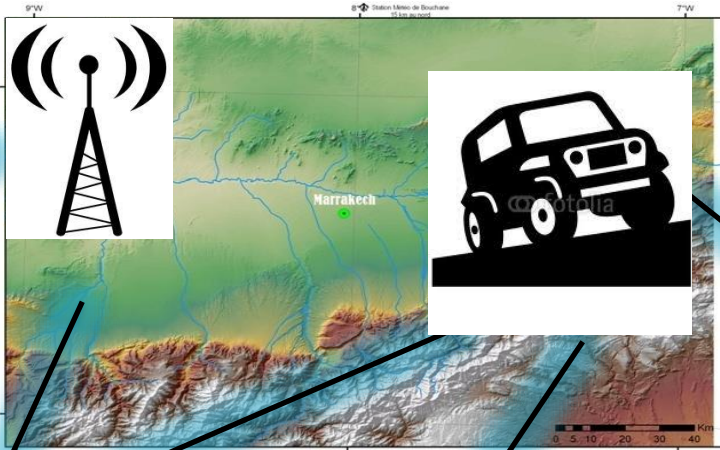


Observatory database

Website



Telemetry
RT



15 days
collect

Field campaigns

