The CYCAS–MED project: analysis of weather data in Morocco for statistical weather yield function

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Summary

- Analysis of weather data: a few issues
- Data analysis
  - temperature: normal values and trend
  - rainfall: missing data...
- Weather yield function from observational data
  - Simulated weather data
  - Future work

The analysis of weather data...

... a few issues:

- long time series
- normal values: 30–yr standard period (1961–1990, 1971–2000), with at least 20 years of complete data
- indexes

The analysis of weather data...

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- long time series
- normal values: 30–yr standard period (1961–1990, 1971–2000), with at least 20 years of complete data
- indexes
  - T_{min}, T_{max}, T_{day}
  - daily, monthly, seasonal, etc. rainfall
  - max. number of consecutive dry days, heat wave duration index, etc.
  - . . .

The analysis of weather data...

... a few issues:

- long time series
- normal values: 30–yr standard period (1961–1990, 1971–2000), with at least 20 years of complete data
- indexes
  - potential evapotranspiration, ET_0
  - length of the growing period (with temp. thresholds)
  - Growing degree days (single sine method; Allen, 1976)
  - . . .

The analysis of climatic data...

...the problem of missing data

- temperature data:
  - low variability
  - *linear* relationship

  $\Rightarrow$ data imputation up to 4 consecutive days by linear interpolation

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- temperature data:
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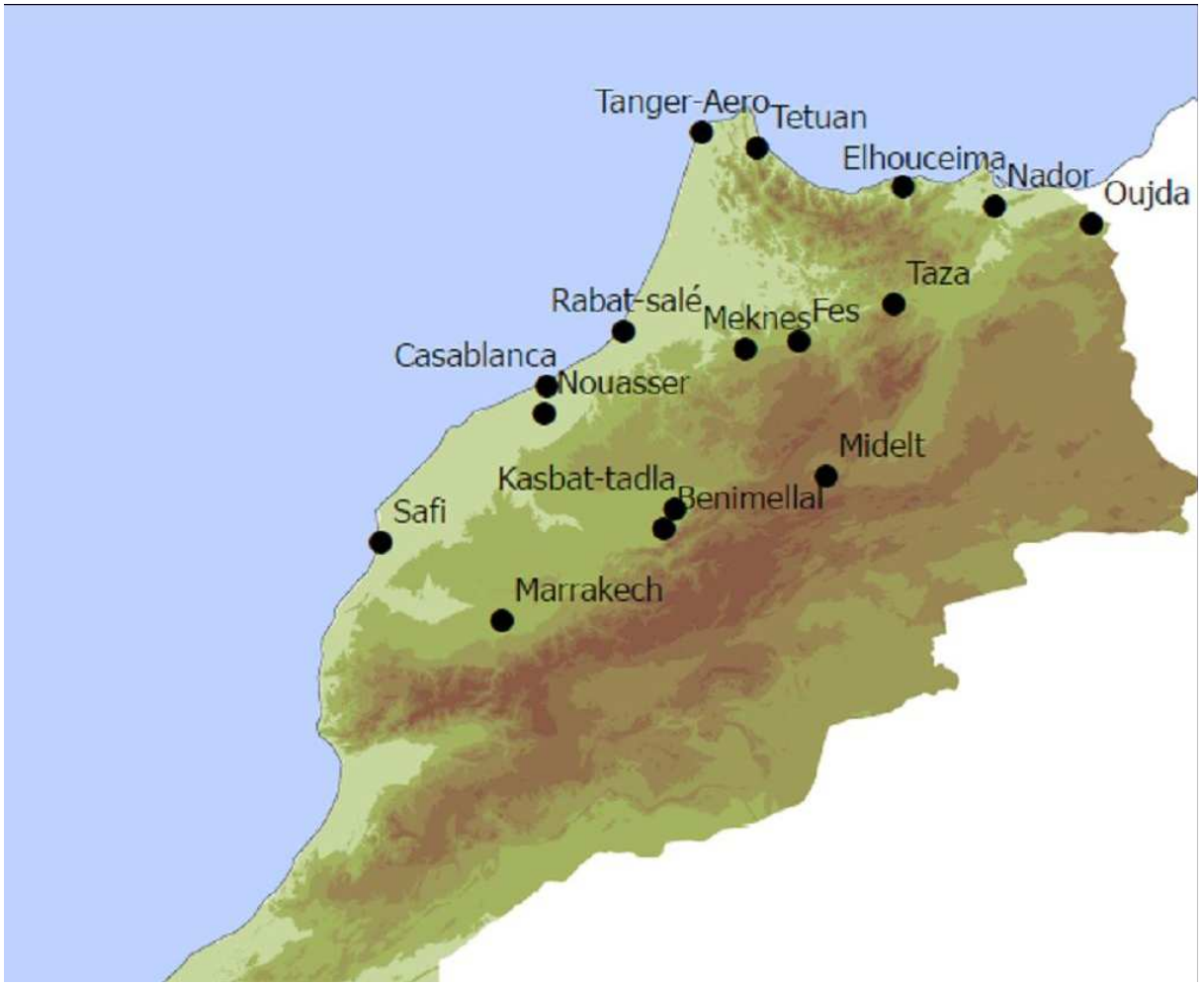
- rainfall data:
  - high variability
  - singletons
  - imputation can destroy data autocorrelation

  $\Rightarrow$ **no daily** data imputation (*but* still some kind of imputation...)

Study area



16 sites; Source: Ministry of Agriculture

Morocco temperature data

	Normal values, after imputation standard period (SP): 1971–2000						
Station	tot nr. years	nr. SP years	T_{min} (°C)	T_{max} (°C)	T_{day} (°C)	Tn90 (%)	Tn90* days
Marrakech	32	28	13.3	26.7	20.0	10.2	37.2
Casablanca	28	25	13.9	21.6	17.7	9.8	35.8
Meknes	25	21	11.2	23.3	17.3	9.7	35.2
Nouasser	32	28	11.4	23.5	17.5	9.4	34.3
Oujda	26	22	10.2	23.5	16.8	10.7	39.0
Safi	26	24	13.7	23.3	18.5	10.5	38.3
Taza	24	23	12.6	23.8	18.2	9.9	36.1
Rabat	32	28	12.7	22.2	17.4	10.7	39.0
Tanger	30	27	13.4	22.1	17.7	10.9	39.8

Tn90: Percent of time Tmin $>$ 90th percentile of daily minimum temperature (warm nights). Tn90* = Tn90 $\times$ 365.

Morocco temperature data

Station	TREND (Mann–Kendall test) T_{min} (°C)	T_{max} (°C)	T_{day} (°C)	Tn90 (%)
Marrakech	+1	+1	+1	0
Nouasser	+1	+1	+1	+1
Rabat	0	+1	+1	+1
Tanger	0	+1	+1	+1

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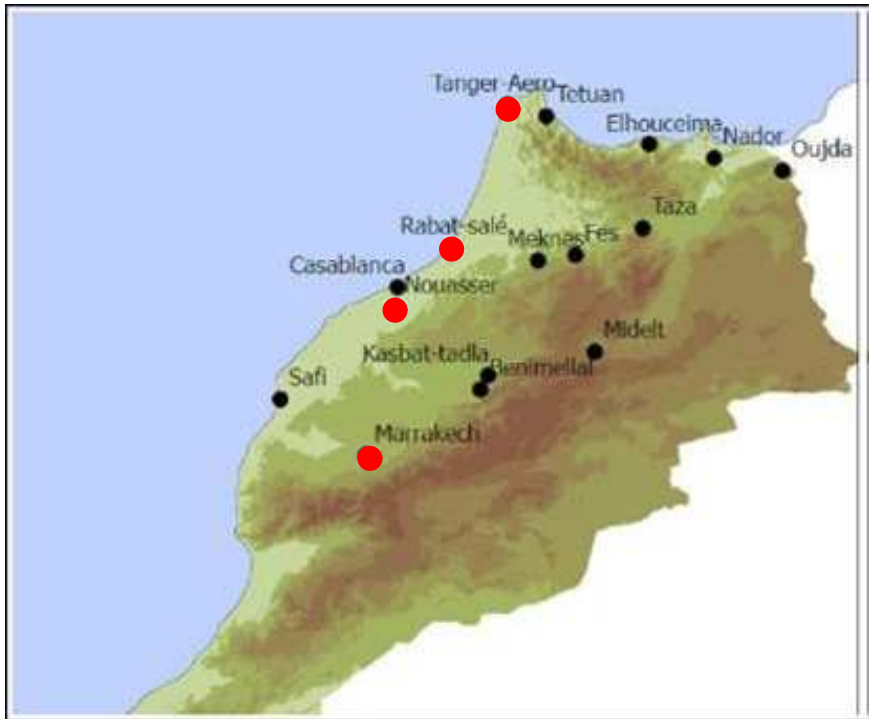

Morocco temperature data

	Variation per 10 years (Sen's slope)			
Station	T_{min} (°C)	T_{max} (°C)	T_{day} (°C)	Tn90 (%)
Marrakech	0.46	0.37	0.44	–
Nouasser	0.60	0.55	0.59	13.5
Rabat	–	0.43	0.40	5.8
Tanger	–	0.32	0.44	5.8

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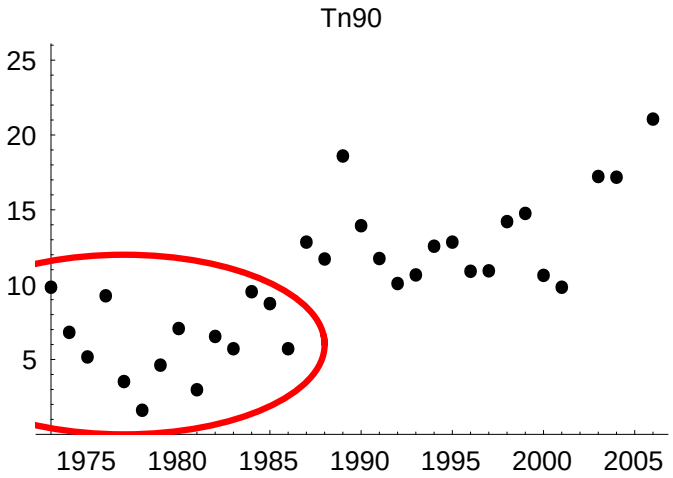
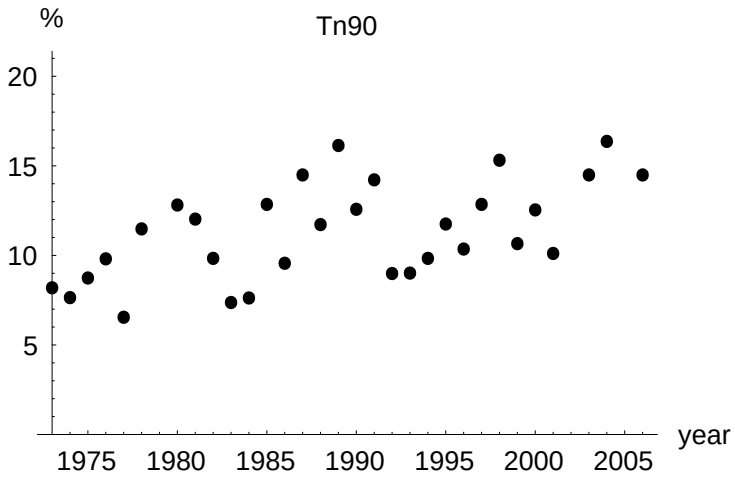
Morocco temperature data

NOUASSER



TANGER



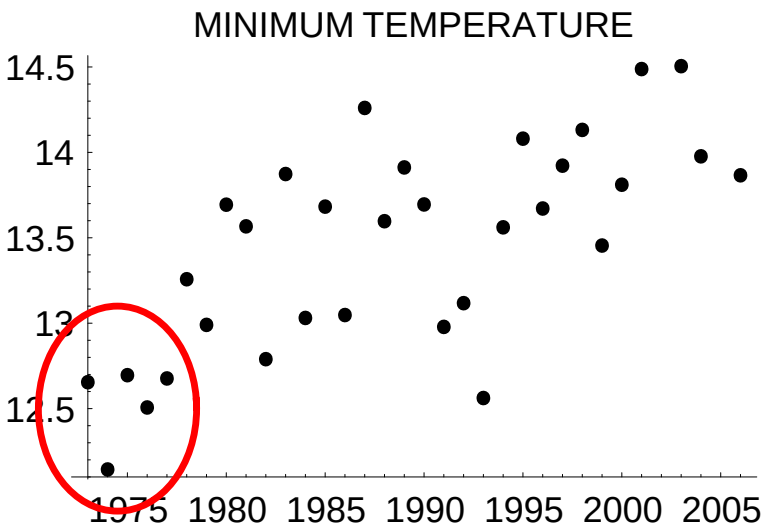
Tn90: Percent of time Tmin $>$ 90th percentile of daily min. temperature (warm nights)

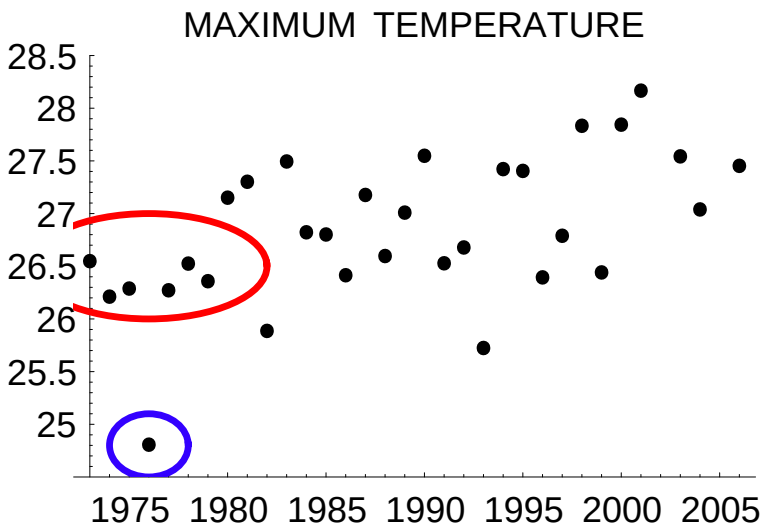
non climatic change?

(similar to the near station of Casablanca...)

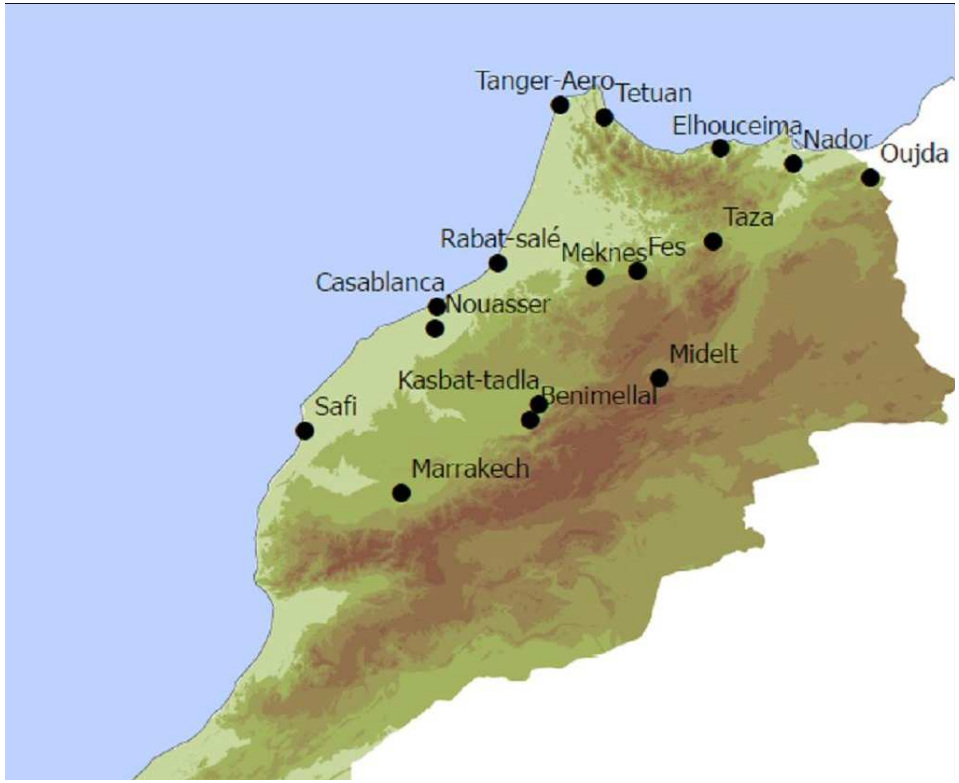
Morocco temperature data

MARRAKECH





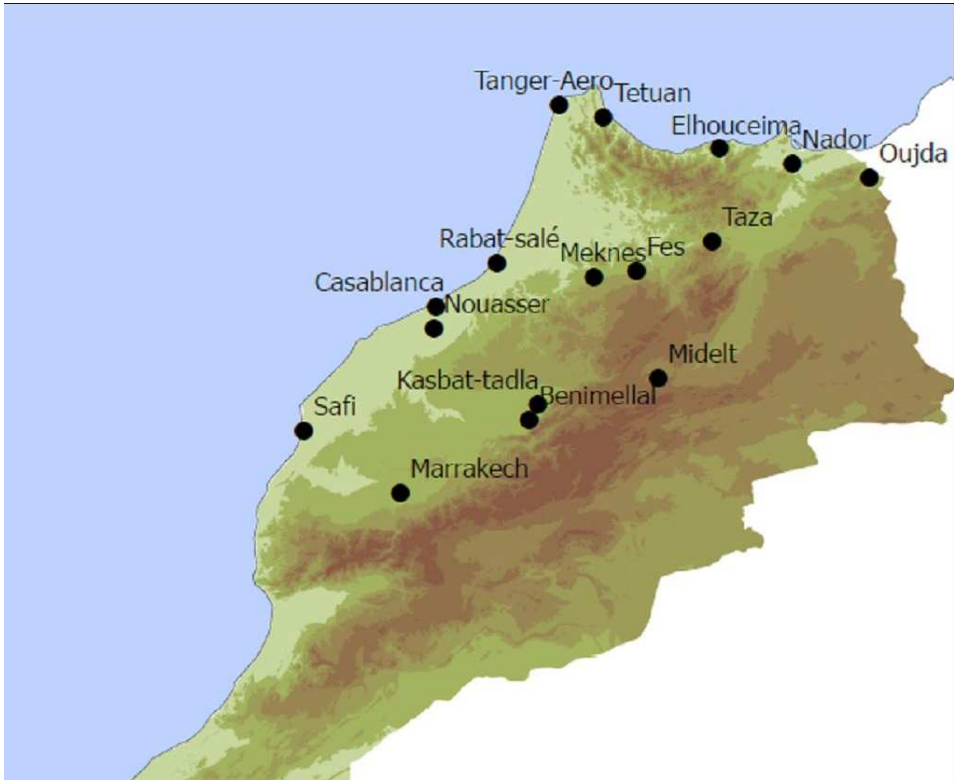
Morocco rainfall data



RAINFALL

Station	complete years
Nouasser	14
Marrakech	12
Rabat	10
Tanger	10
Fès	8
Meknes	8
Casablanca	7
Oujda	5
Safi	4
Taza	4
Midelt	3

Morocco rainfall data



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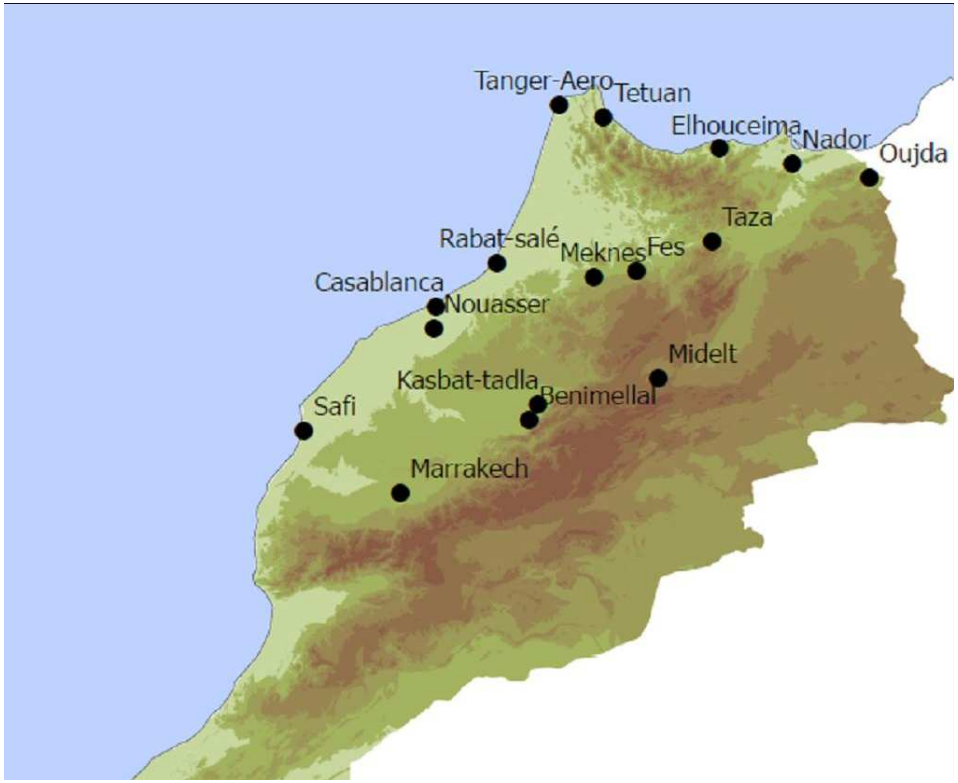
Béni Mellal, El Houceima, Kasbat, Nador and Tetouan have not been considered in the climatic analysis

Morocco rainfall data



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only a limited climate analysis is possible

Imputation of dekadal rainfall values

Proposal:

Aim of the work: weather yield function, Crop Specific Soil Water Balance + AgroMetShell $\hookleftarrow$ dekadal values (=10 days, r_d)

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New-LocClim (FAO, 2005) provides the estimates (*best*) of mean dekadal rainfall values, and σ (or confidence intervals): we compare these estimates to the observed data.

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r_d (mm)	missing days	$best$	$(best - \sigma,$ $best + \sigma)$	imputated value
–	10	18.77	(15.53, 22.01)	18.77
24.1	$<$10	20.67	(16.11, 25.24)	24.1
3.3	$<$10	14.87	(12.19, 17.54)	12.19
104.9	$<$10	19.42	(16.18, 22.66)	104.9

Imputation of dekadal rainfall values

- take into account as much as possible the observed values
- save autocorrelation of r_d s
- slightly more results on climate analysis
- inputs to AMS $\longmapsto$ Weather Yield Function

Weather yield function

WYF: crop yield = linear function of outputs of AMS

- Total Water Requirement (TWR)
- Water Satisfaction Index (WSI)

and

- water excess (WEX)
- water deficit (WDEF)
- actual evapotranspiration (ETA)

at several phenological phases (Initial, Vegetative, Flowering, Ripening) and Total

Crop yield data

1980–2006 (1982 missing)
(q/ha)

	durum wheat		soft wheat		barley	
Station	mean	std. dev	mean	std. dev	mean	std. dev
Béni Mellal	13.0	6.8	13.9	7.8	10.1	6.6
Casablanca	13.8	8.4	15.7	8.6	14.2	7.3
El Houceima	9.1	3.9	9.4	3.6	11.3	4.0
Fès	12.8	7.2	14.0	7.6	11.3	5.6
Marrakech	6.0	4.1	5.1	3.6	6.6	4.5
Meknes	15.3	7.0	16.9	7.5	13.6	5.8
Midelt	9.4	3.5	10.4	4.0	10.0	4.2
Nador	8.2	3.4	9.9	4.7	10.0	4.1
Nouasser	10.8	7.7	11.0	7.3	10.1	6.8
Oujda	5.9	3.7	6.1	3.8	6.3	3.8
Rabat	12.6	7.2	14.4	6.2	13.1	6.8
Safi	7.9	5.0	6.2	4.1	8.1	4.3
Tanger	11.8	3.3	11.9	5.5	13.2	3.9
Taza	11.0	5.5	9.5	5.4	9.8	4.4
Tetouan	12.9	3.4	13.6	3.8	12.9	3.5

Crop yield data

- strong correlation of the 3 cereals at each district:> 0.68
  apart Tanger
- strong correlation of similar cereals within districts:
- trend analysis: no trend. Please, note Rabat:

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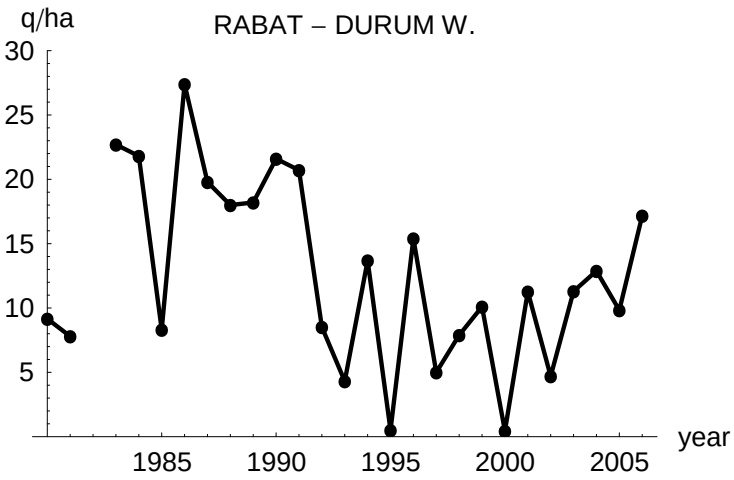

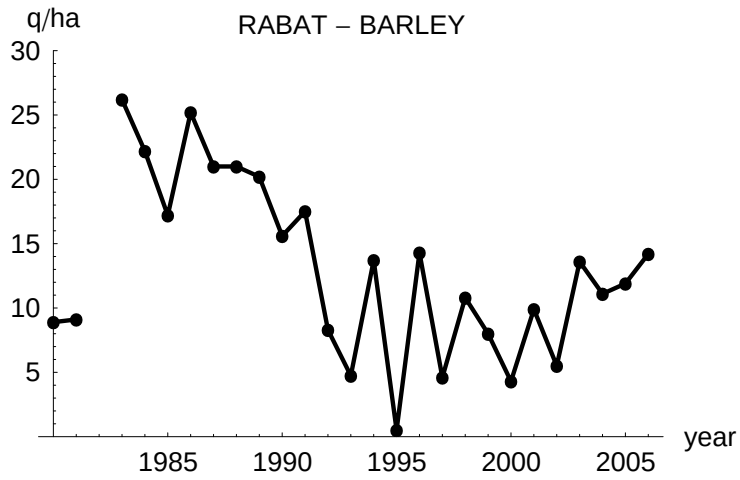

non climatic changes?

Variable selection

correlation

- between crop yield and outputs
- within outputs

Variable selection

correlation

- between crop yield and outputs
- within outputs

$\Rightarrow$ WSI, TWR

WDEFf , WDEFt,

ETAf, ETAr and ETAt.

Results: durum weat

District	Nr. of data	Variables	R^2	p-value	RMSE
Béni Mellal	15	WSI	0.88	$\ll 10^{-03}$	5.10
Casablanca	20	WSI, WEXt	0.83	$\ll 10^{-03}$	5.76
El Houceima	15	WSI	0.93	$\ll 10^{-03}$	2.49
Fès	20	WSI	0.58	$\ll 10^{-03}$	4.37
Marrakech	24	WSI, TWR	0.74	$\ll 10^{-03}$	2.13
Meknes	17	WSI, WEXt	0.89	$\ll 10^{-03}$	4.92
Midelt	17	WSI, TWR	0.89	$\ll 10^{-03}$	3.45
Nador	13	WSI	0.87	$\ll 10^{-03}$	3.10
Nouasser	24	WSI, TWR	0.86	$\ll 10^{-03}$	4.59
Oujda	18	WSI	0.84	$\ll 10^{-03}$	2.40
Rabat	24	WSI	0.81	$\ll 10^{-03}$	6.26
Safi	19	WSI	0.84	$\ll 10^{-03}$	3.36
Tanger	23	WSI, WEXt	0.94	$\ll 10^{-03}$	2.87
Taza	19	WSI, WEXt	0.89	$\ll 10^{-03}$	3.80
Tetouan	18	WSI	0.97	$\ll 10^{-03}$	2.35

Results: soft weat

District	Nr. of data	Variables	R^2	p-value	RMSE
Béni Mellal	15	WSI	0.88	$\ll 10^{-03}$	5.42
Casablanca	20	WSI	0.81	$\ll 10^{-03}$	6.93
El Houceima	15	WSI	0.92	$\ll 10^{-03}$	2.93
Fes	20	WSI, TWR	0.89	$\ll 10^{-03}$	4.71
Marrakech	24	WSI, TWR	0.66	$\ll 10^{-03}$	2.16
Meknes	17	WSI, WEXt	0.91	$\ll 10^{-03}$	4.95
Midelt	17	WSI, WDEFr	0.39	$\ll 10^{-03}$	3.13
Nador	13	WSI	0.88	$\ll 10^{-03}$	3.25
Nouasser	24	WSI, TWR	0.89	$\ll 10^{-03}$	4.18
Oujda	18	WSI, WDEFr	0.87	$\ll 10^{-03}$	2.15
Rabat	24	WSI, ETAi	0.92	$\ll 10^{-03}$	4.25
Safi	19	WSI, WEXt	0.86	$\ll 10^{-03}$	2.60
Tanger	23	WSI, WEXt	0.85	$\ll 10^{-03}$	4.99
Taza	19	WSI, WEXt	0.91	$\ll 10^{-03}$	3.32
Tetouan	18	WSI	0.96	$\ll 10^{-03}$	2.97

Results: barley

District	Nr. of data	Variables	R^2	p-value	RMSE
Béni Mellal	15	WSI, ETAi	0.89	$\ll 10^{-03}$	3.75
Casablanca	20	WSI	0.86	$\ll 10^{-03}$	5.03
El Houceima	15	WSI, TWR	0.63	$\ll 10^{-03}$	2.24
Fes	20	WSI, TWR	0.92	$\ll 10^{-03}$	3.25
Marrakech	24	WSI, TWR	0.52	$\ll 10^{-03}$	3.19
Meknes	17	WSI	0.88	$\ll 10^{-03}$	4.62
Midelt	17	WSI, TWR	0.89	$\ll 10^{-03}$	3.39
Nador	13	WSI	0.89	$\ll 10^{-03}$	3.51
Nouasser	24	WSI, TWR	0.87	$\ll 10^{-03}$	4.03
Oujda	18	WSI	0.81	$\ll 10^{-03}$	2.78
Rabat	24	WSI	0.83	$\ll 10^{-03}$	6.13
Safi	19	WSI, WEXt	0.86	$\ll 10^{-03}$	3.25
Tanger	23	WSI	0.93	$\ll 10^{-03}$	3.78
Taza	19	WSI	0.87	$\ll 10^{-03}$	3.88
Tetouan	18	WSI	0.96	$\ll 10^{-03}$	2.81

Weather Generator

A stochastic weather generator (WG) produces synthetic time series of weather data of unlimited length for a location based on the statistical characteristics of observed weather at that location. (IPCC)

Richardson-type WG:

- wet–dry days sequence by Markov procedure
- amount of precipitation falling on wet days using a functional estimate of the precipitation frequency distribution

Weather Generator

1. Data collection - observed daily climatological data for the variables and site(s) of interest should be collected, quality controlled and correctly formatted.
2. Parameterized - the parameters of the model are estimated using methods documented for the weather generator.
3. Model testing - time series of weather are generated and their statistics analysed and compared with the observed data on which they were based.
4. Climate scenarios - if the WG is to be used to create weather time series representing a changed climate, procedures will also be required for applying climate change information (e.g. on climate variability change from GCMs) as adjustments to the parameters of the WG. Some WG software also handles climate scenarios.

M&Rfi

M&Rfi is a new parametric generator. M&Rfi may be run with various numbers of variables (precipitation, solar radiation and daily extreme temperatures are typically involved) and at various time steps (1–day, 3–day, 5–day, 1–week, 10–day, half–month, 1-month).

Precipitations are modeled by **Gamma** distributions

Martin Dubrovsky, Institute of Atmospheric Physics, ASCR, Prague, Czechia

Checking simulations

1000 simulated years that should have the mean characteristics obtained from observed data.

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1000 simulated years that should have the mean characteristics obtained from observed data.

MEAN Site	data	T_{min} °C	T_{max} °C	T_{day} °C	Daily rainfall mm (> 0)
Marrakech	OBS	13.3	26.7	20.0	6.8
	SIM	13.7	27.1	20.4	6.3
Nouasser	OBS	11.4	23.5	17.5	6.0
	SIM	11.7	23.9	17.8	6.0
Rabat	OBS	12.7	22.2	17.4	7.9
	SIM	12.8	22.4	17.6	7.8
Tanger	OBS	13.4	22.1	17.7	9.0
	SIM	13.5	18.0	22.4	8.9

good mean (climatic) values

Checking simulations

1000 simulated years that should have the mean characteristics obtained from observed data.

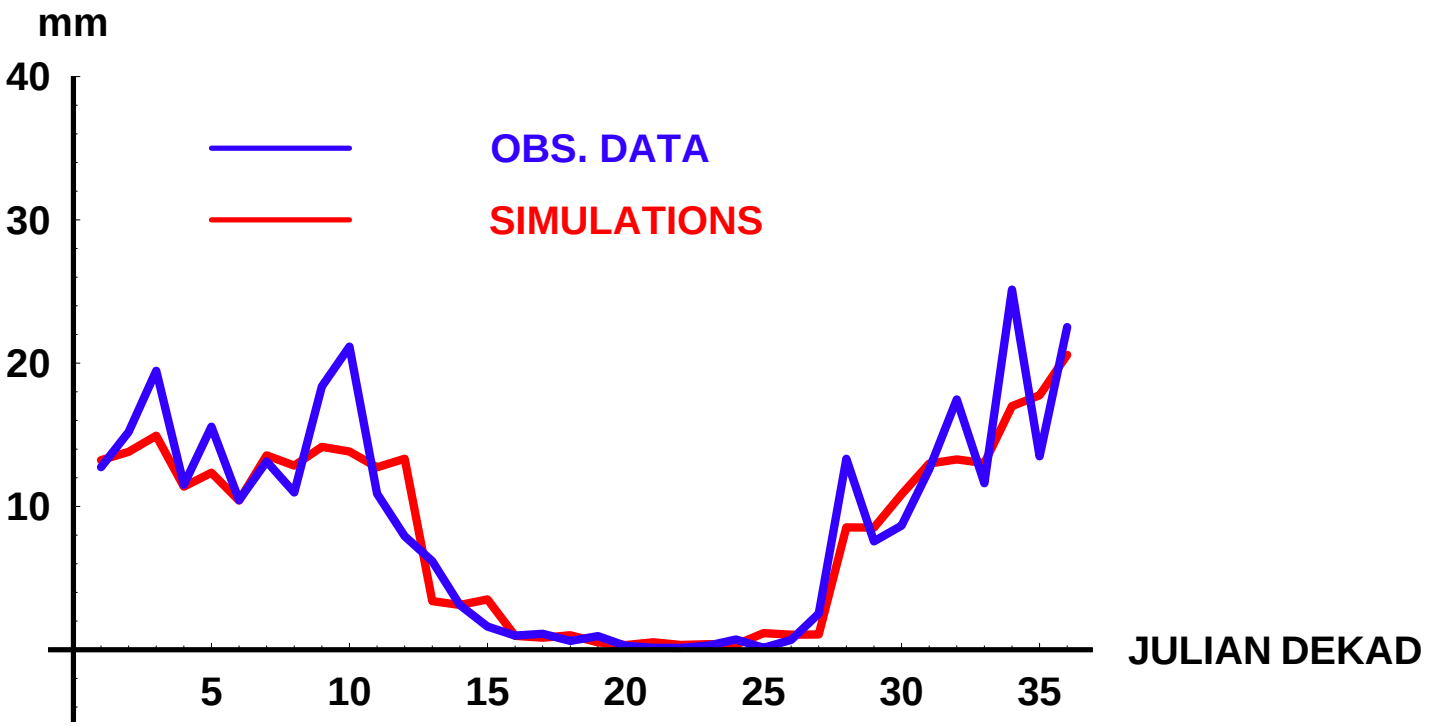
VARIANCE	T_{max} (°C)		T_{day} (°C)		D. rainfall (mm)	
Site	obs.	sim.	obs.	sim.	obs.	sim.
Marrakech	32.10	31.90	56.43	55.92	26.04	11.64
Nouasser	27.31	27.24	32.13	31.83	30.27	11.00
Rabat	21.06	20.97	21.52	21.38	36.42	21.84
Tanger	24.78	24.81	28.81	28.76	54.43	33.89

rainfall variability is underestimated

Checking simulations

1000 simulated years that should have the mean characteristics obtained from observed data.

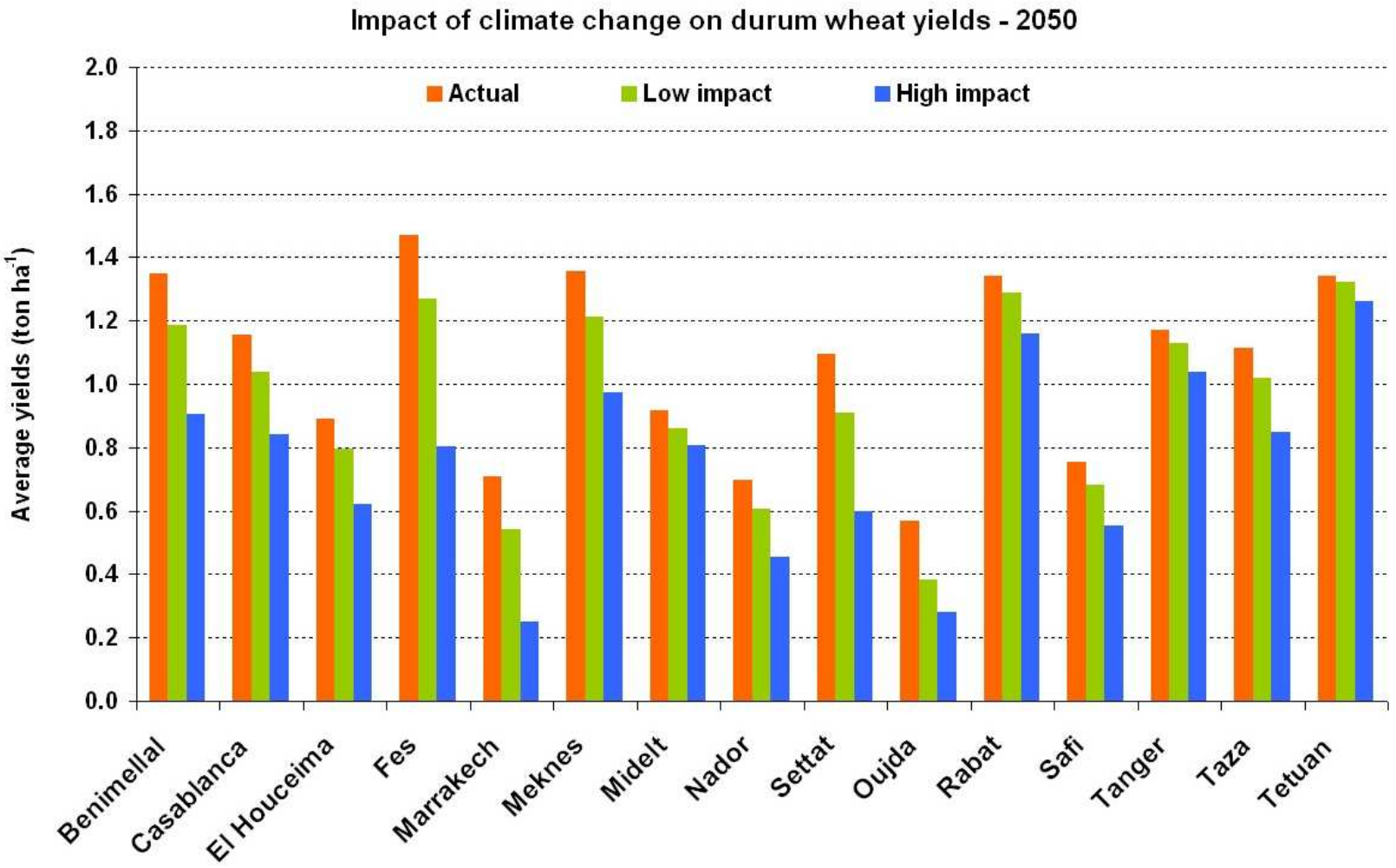
NOUASSER



Future work

- improvement of M&Rfi,
  Gamma $\longmapsto$ mixtures of Exponential distributions
- a different weather generator
  hidden Markov models (to be improved)
- better understanding of impact of WG errors on projected crop yields

Future work


Impact of climate change on durum wheat yields - 2050
Actual
Low impact
High impact
Average yields (ton ha-1)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Benimellal
Casablanca
El Houceima
Fes
Marrakech
Meknes
Midelt
Nador
Settat
Oujda
Rabat
Safi
Tanger
Taza
Tetuan


THANK YOU
FOR YOUR ATTENTION