A quantile-quantile approach for the adjustment of climate potential for tourism at local and regional scales: Application to the Mediterranean coastal region

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Tourism and climate change: General remarks

- Tourism is a climate sensitive socioeconomic activity

- Key economic sector for most Mediterranean countries

- Climate determines tourism flows in Europe and seasonality in the industry

- Sun, sea and sand (3S) tourism is largely based on well defined perceptions of warm and sunny weather conditions

- 3S tourism is especially sensitive to temperature, rainfall, relative humidity, cloudiness (i.e. hours of sunshine) and wind speed (De Freitas el al., 2008)

- Climate change could affect tourism dynamics if weather perception altered
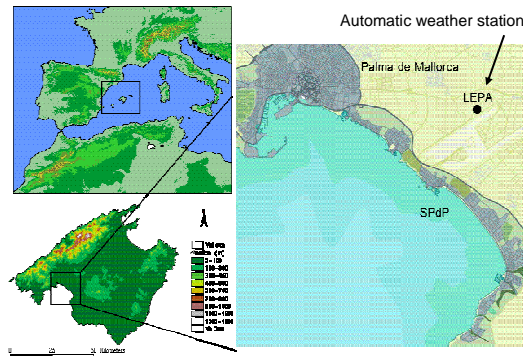
Socioeconomic features of tourism at local scales: the SPdP case

Balearic Islands

• 76,2% of the active population is directly employed within service sector

• Tertiary sector aggregates up to 72.8% of the whole inland companies (INE, 2009)

• Local employment pattern is strongly linked to the tourist demand in the county

System of Platja de Palma (SPdP)

• Main tourist resort in the Balearics

• 40000 tourist places and 34000 permanent inhabitants

• In average, 1.2 million of nights were spent per year during the 1999-2008 period

• The dominance of the 3S model over other tourist activities makes SPdP an excellent location for applying a climate index for tourism

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Database and methods

Observed CIT is derived from daily series recorded at the LEPA weather station for the 1973-2008 period: 2 m maximum temperature, accumulated precipitation, 2 m mean relative humidity, mean cloud cover and 10 m mean wind speed

Projected CIT is obtained from daily-averaged data provided by 13 Regional Climate Models (RCMs) run within the ENSEMBLES European project under A1B SRES (1973-2100; Hewitt and Griggs, 2004)

Multimodel approach: to cope with the uncertainties arising from model error formulations and boundary conditions

To account for local unresolved scales, a quantile-quantile correction for each individual RCM outputs is applied to the projected CIT (Amengual et al., 2011a)
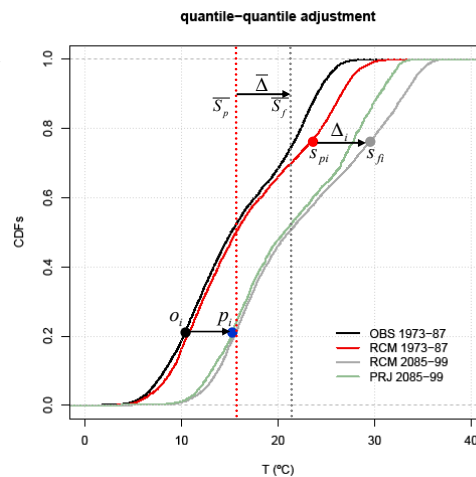
Quantile-quantile adjustment: Application to local scales

- Calibration task

1. compute changes in CDFs between a 15-year past (i.e. control; 1973-1987) and successive 15-year RCM time-slices (1994-2099)

2. shifts are corrected and transferred to the observed CDFs control period

- Validation task

1. evaluation between raw and calibrated data against observations for the 1994-2008 interval

2. calibrated daily RCM outputs for the 2010-2099 period convey climate signal

quantile−quantile adjustment

Climate index for tourism (CIT)

CIT estimates the satisfaction of 3S tourists as function of daily weather conditions (De Freitas et al., 2008)

It integrates the thermal (T), aesthetical (A) and physical (P) facets of the weather

CIT expresses the integrated body-atmospheric energy balance as a thermal sensation (TSN)
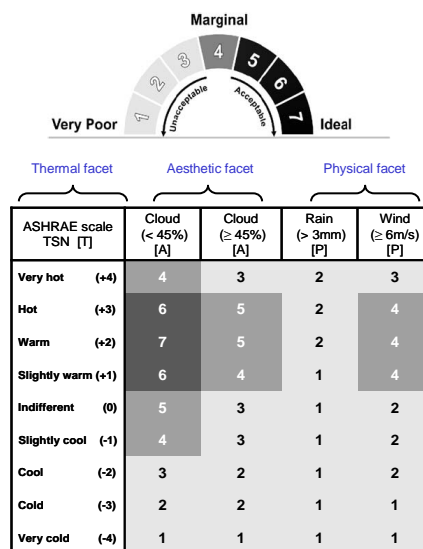
TSN is calculated with the RayMan model (Matzarakis and Rutz, 2007a; Matzarakis et al., 2007b)

RayMan yields the physiologically equivalent temperature (PET) as a thermal index

Thermal index is expressed as a thermal sensation by using the standard 9-point ASHRAE scale (ASHRAE, 2004)

Physical and aesthetic facets are combined with thermal facet accordingly to a weather typology matrix

It accounts for beneficial and detrimental effects on tourists' perception

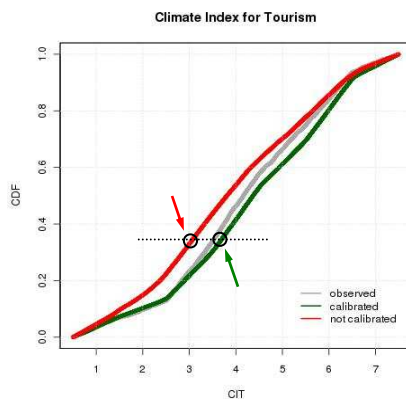| ASHRAE scale TSN [T]	Cloud (< 45%) [A]	Cloud (≥ 45%) [A]	Rain (> 3mm) [P]	Wind (≥ 6m/s) [P]
Very hot (+4)	4	3	2	3
Hot (+3)	6	5	2	4
Warm (+2)	7	5	2	4
Slightly warm (+1)	6	4	1	4
Indifferent (0)	5	3	1	2
Slightly cool (-1)	4	3	1	2
Cool (-2)	3	2	1	2
Cold (-3)	2	2	1	1
Very cold (-4)	1	1	1	1

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Quantile-quantile adjustment: Validation

Percentile-wise MAE and RMSE reveals an improvement of calibrated versus raw data for acceptable conditions (CIT=4,5)

Calibrated and observed data are fairly identical for unacceptable (CIT=1,2,3) and ideal (CIT=6,7) conditions

General improvement of the calibrated simulated perceived satisfaction of weather resource when compared against observations (Amengual et al., 2011b)

Climate Index for Tourism

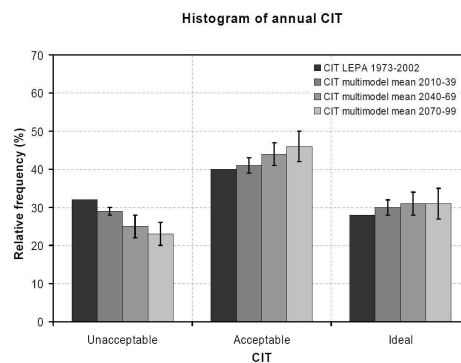| CIT CDFs	MAE cal	MAE raw	RMSE cal	RMSE raw
	0.17	0.29	0.19	0.34

Changes in annual mean regimes for SPdP

Present

• Acceptable conditions dominates in the annual mean regime

• Annual relative frequencies for acceptable and ideal conditions reaches up to 68 %

Future projections

• Redistribution of the annual mean CIT classes

• Shift of unacceptable towards acceptable and ideal conditions

• Slight improvement in the annual mean regimes

Histogram of annual CIT

Relative frequencies (%) for the annual distribution of the climate index for tourism of SPdP

Annual CIT	present (1973-2002)	early (2010-39)	mid (2040-69)	late (2070-99)
Unacceptable	32	29	25	23
Acceptable	40	41	44	46
Ideal	28	30	31	31
mean	4.28	4.37	4.47	4.52

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Tourism and seasonality: General remarks

1. In Spain, the tourist sector is marked by a strong seasonality:

• Large differences in occupancy rates between the cold and warm seasons

• Total tourism revenues are more than 50% higher in August than in December

• More than three times as many hotel nights were spent in August than in December (INE, 2009)

• Major source countries of tourists for the Palma municipality (2008): Germany (over 42%) and Great Britain (close to 27%)

2. Peak demand for 3S tourism is also strongly influenced by state holidays
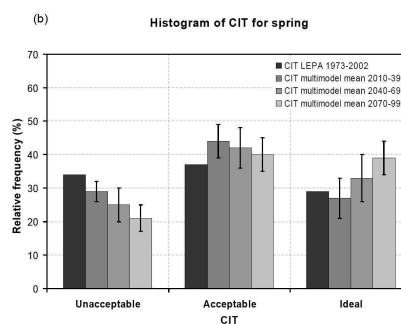
3. Future summery conditions could deteriorate in the Mediterranean and improve in western and northern Europe (Amelung and Viner, 2006)

Changes in seasonal mean regimes for SPdP

Spring

• An overall increase in the frequencies of acceptable and ideal conditions is projected

• Continuous decrease for the unacceptable conditions

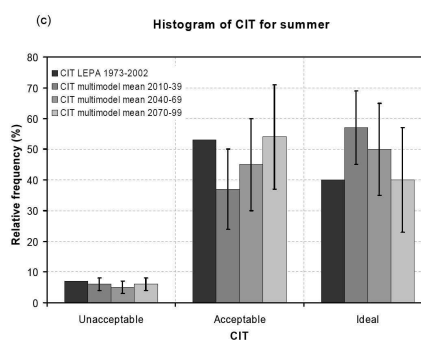| CIT	present	early	mid	late
Unacceptable	34	29	25	21
Acceptable	37	44	42	40
Ideal	29	27	33	39
mean	4.27	4.29	4.50	4.70

(b) Histogram of CIT for spring

Changes in seasonal mean regimes for SPdP

Summer

• Ideal conditions are expected to increase significantly until mid-century at the expense of the acceptable conditions and, then, the opposite occurs afterwards

• The frequency of unacceptable perceptions could remain nearly constant

Summer CIT	present	early	mid	late
Unacceptable	7	6	5	6
Acceptable	53	37	45	54
Ideal	40	57	50	40
mean	4.92	5.46	5.30	5.13

(c) **Histogram of CIT for summer**

Legend:
- CIT LEPA 1973-2002
- CIT multimodel mean 2010-39
- CIT multimodel mean 2040-69
- CIT multimodel mean 2070-99

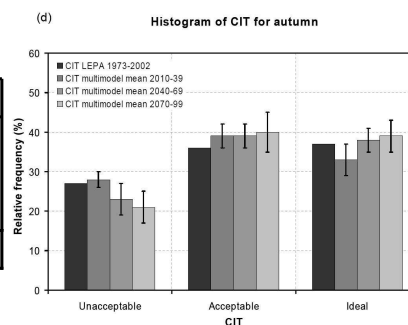Relative frequency (%) — CIT: Unacceptable, Acceptable, Ideal

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Changes in seasonal mean regimes for SPdP

Autumn

• Remarkable increase of acceptable conditions across the century

• Ideal conditions are expected to slightly decrease for the early period and, then, to lightly increase afterwards

• Moderate decrease in the unpleasant conditions

Autumn CIT	present	early	mid	late
Unacceptable	27	28	23	21
Acceptable	36	39	39	40
Ideal	37	33	38	39
mean	4.49	4.43	4.64	4.69

(d) **Histogram of CIT for autumn**

Legend:
- CIT LEPA 1973-2002
- CIT multimodel mean 2010-39
- CIT multimodel mean 2040-69
- CIT multimodel mean 2070-99

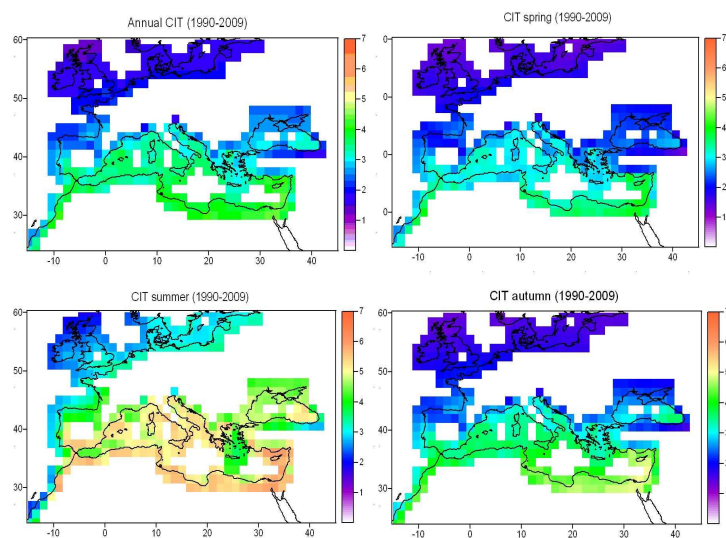Relative frequency (%) — CIT: Unacceptable, Acceptable, Ideal

Main results

• Current highest visitation levels coincide with acceptable or optimal perceptions of the weather resource (up to 93% of the relative frequency in summer)

• Expected increase of satisfactory weather perceptions for the shoulder seasons (spring: from 66% to 79%; autumn: from 73% to 79%)

• Optimal peak seasonal weather conditions would likely shift to the shoulder seasons at the end of the century (spring: from 29% to 39%; autumn: from 37% to 39%)

• Current seasonally adjusted of incoming tourism fluxes can be also ascribed to the temporal coincidence with the institutional seasonality

• Future imbalance between the natural and institutional seasonality

• Climate change impact on the tourist potential suggests a likely change on the seasonally adjusted sector for SPdP

Ongoing work: Application at regional scales

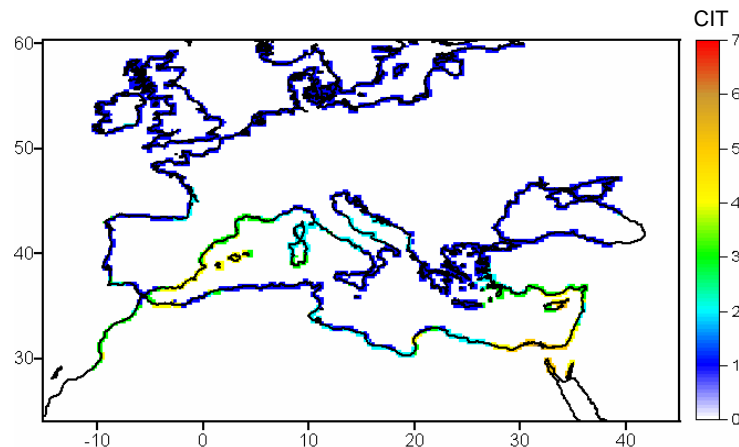Spatial distribution of mean observed CIT (1990-2009) for the Mediterranean and European coastal area

Observed data extracted from ERA reanalysis at 1.5 º

Ongoing work: Application at regional scales

Spatial distribution of the observed CIT (01-01-1990) for the Mediterranean and European coastal area

Observed data extracted from ERA Interim re-analysis at 0.7 °

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