Meteorological and Hydrological Service of Croatia

www.meteo.hr

DROUGHT FORECASTING IN CROATIA USING STANDARDIZED PRECIPITATION INDEX (SPI)

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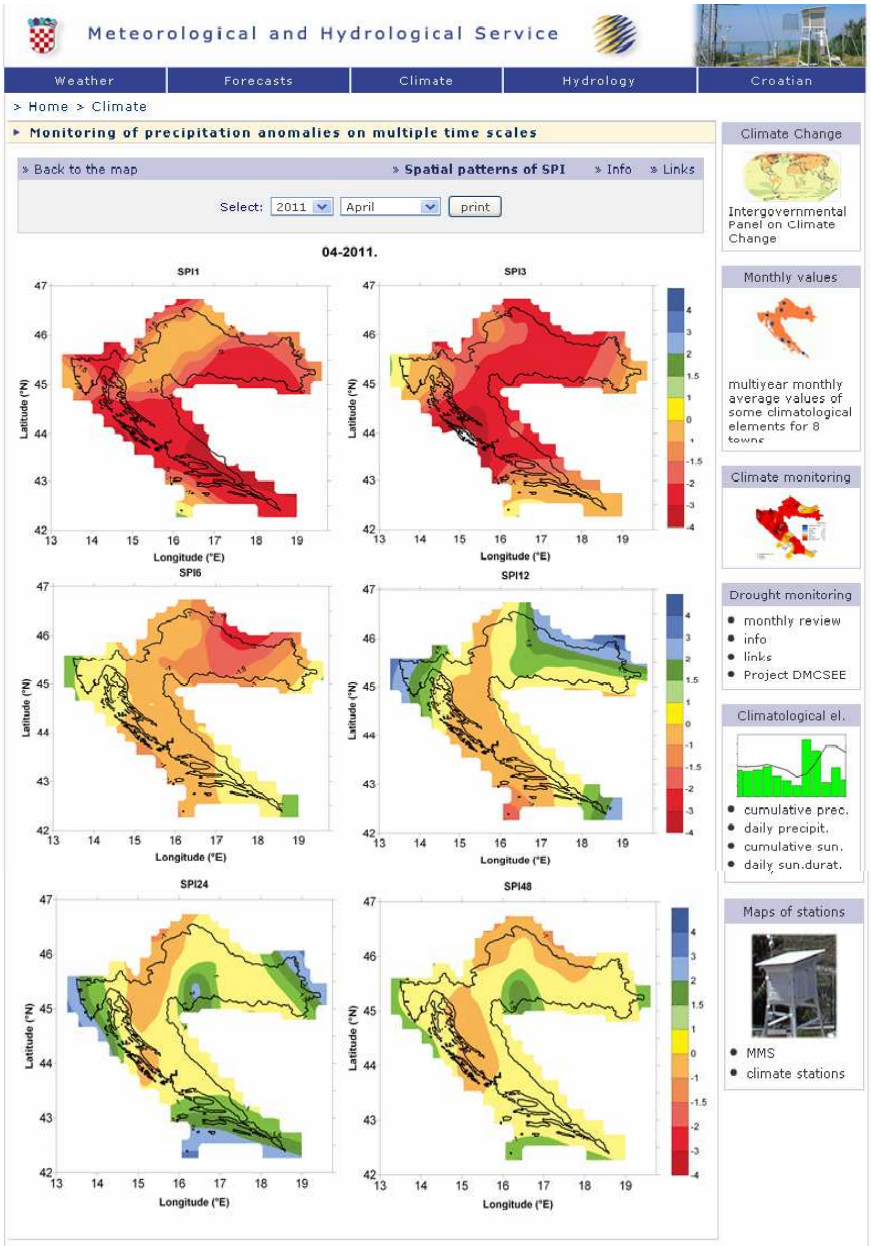
Outline

1. Motivation
2. Data and methods
3. Results
4. Conclusions and future work

1. Motivation

- in Croatia drought causes highest economic losses (39%) among all hydro-met. events; most frequent hazard
- in last two decades the highest damages due to drought impacts were in 2000 (84%), 2003 (90%) and 2007 (80%)
- e.g. Eastern Cro: 2007 the highest monthly precipitation deficit in the last 110yrs
- current drought monitoring system in Croatian HM Service (www.meteo.hr) is based on SPI on different time scales

(1, 3, 6, 12, 24, 48 months)



=> an increasing interest in developing methods for drought warning system in Croatia

Drought early warning system should:

- drought monitor
- provide an early warning of drought onset and it's intensity in timely manner
- have drought prediction compoment

(to protect crops, fire risk, water supply etc.)

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Standardized Precipitation Index (SPI)

- universal measure of meteorological drought accepted by WMO
- developed by McKee et al (1993)
- suitable tool for assesing drougth intensity and duration
- uses only the precipitation data at given location
- can be calculated for different time scales -separates different types of drought (meteorological, hydrological, agricultural)

Standardized Precipitation Index (SPI)

- fit the precipitation sums for a certain time scales to the gamma probability distribution
- a long base period precipitation data are needed for calculating parameters (calibration)
- cumulative prob. distribution is transformed to a standardized normal distribution
- SPI > 0 : precipitation > median

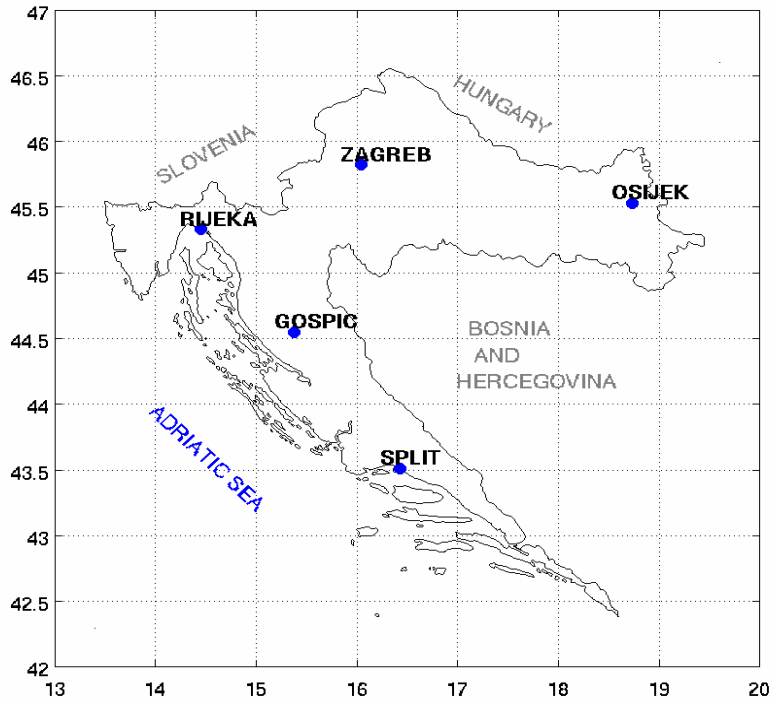
  SPI < 0 : precipitation < median
- utilizes incomplete gamma pdf due to comparisons around the world

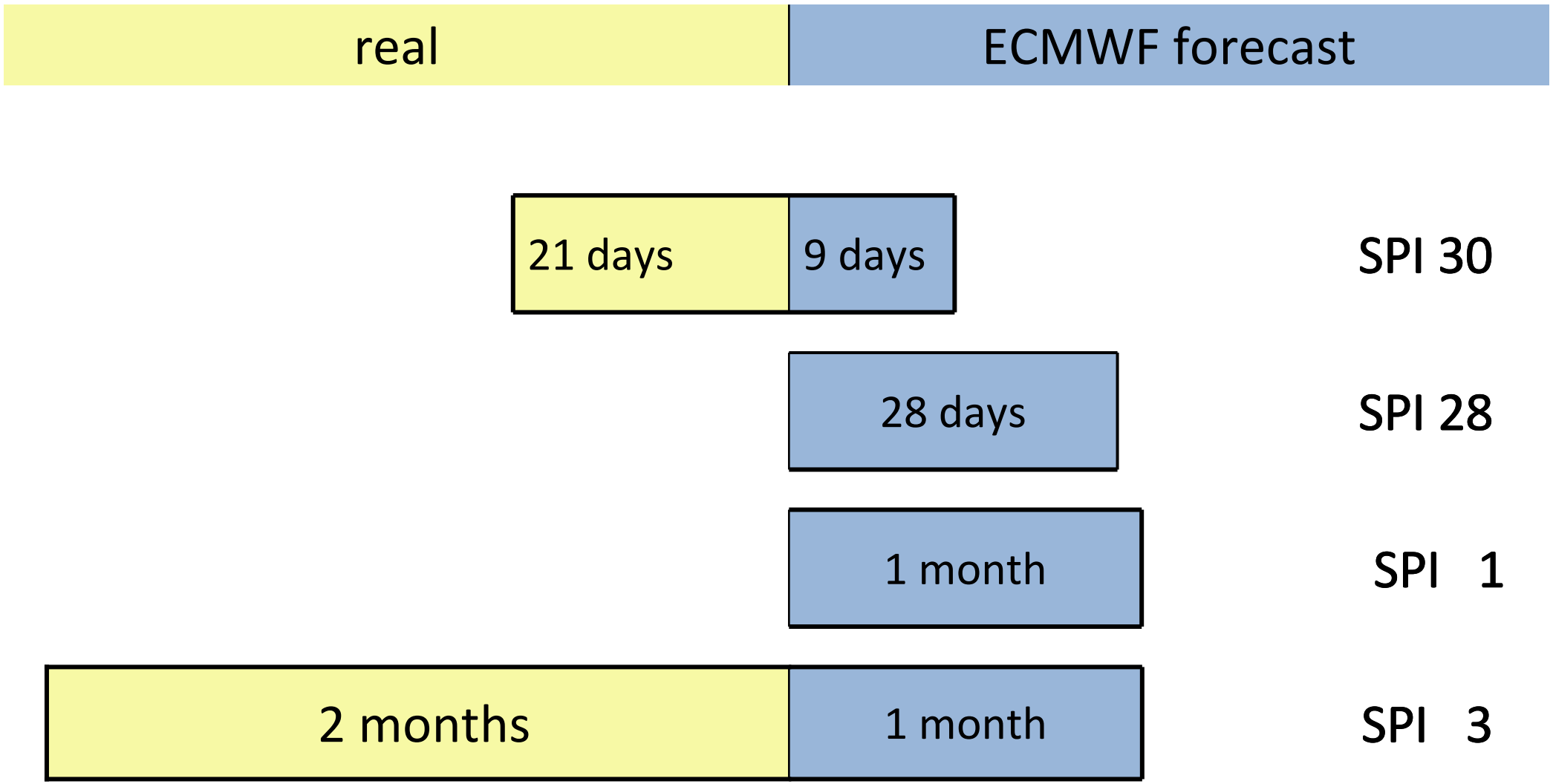
- daily and monthly precipitation records for 5 met. stations representing different climate regions in Croatia

- ECMWF precipitation forecast:
  - medium range (9 days)
  - monthly (28 days)
  - seasonal (1 month)

- 2007-2011

- calibration period 1981-2005




real
ECMWF forecast
21 days
9 days
SPI 30
28 days
SPI 28
1 month
SPI 1
2 months
1 month
SPI 3

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Verification methods

- 1) as for continuous variable
  - Mean error - me
  - Mean absolute error - mae
  - Root mean square error - rmse

Verification methods (2)

- 2) as for categorical values
  - define forecasted event based on SPI threshold

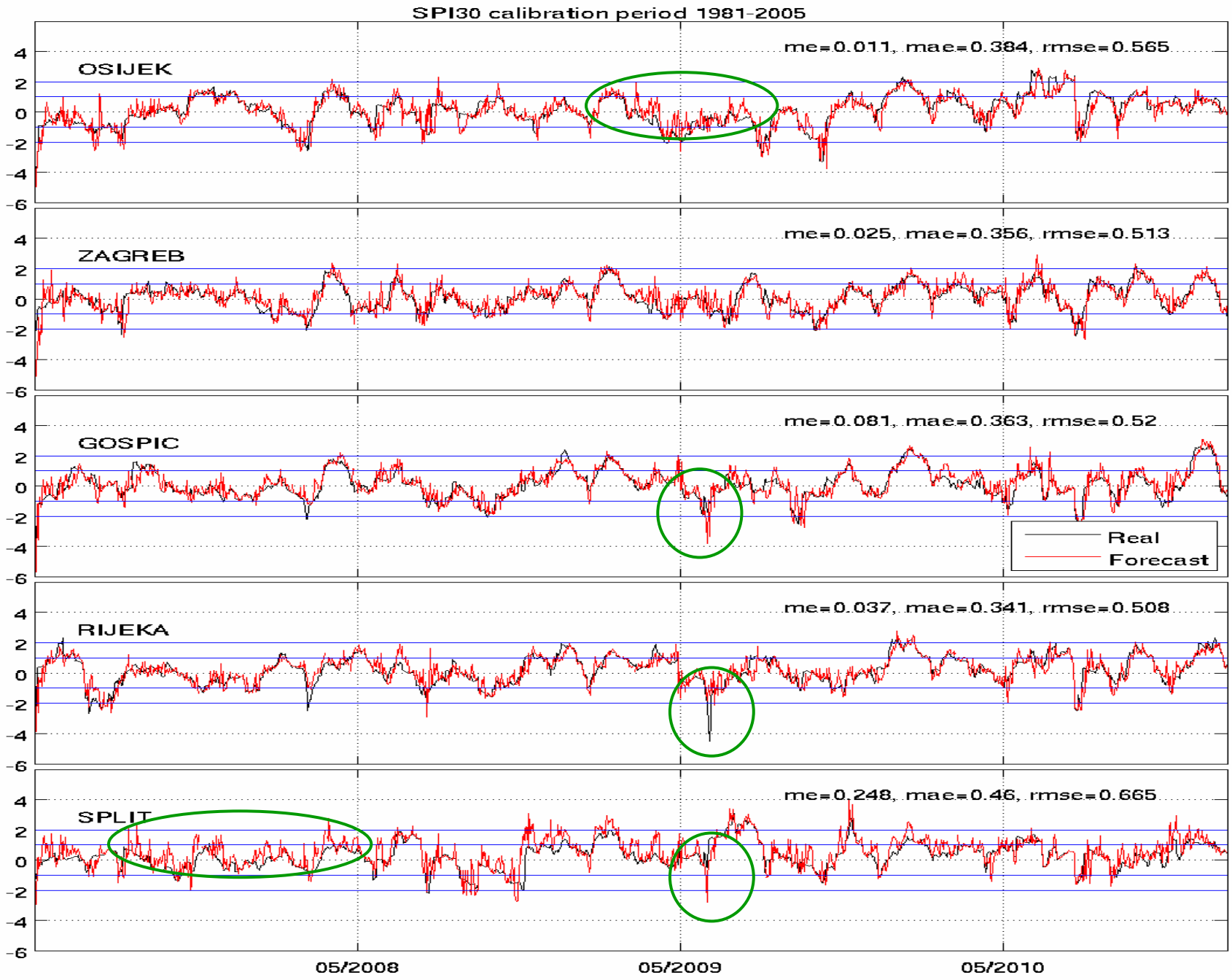
SPI Values	Category
>= 2.0	Extremely Wet
1.5 to 1.99	Severely Wet
1.0 to 1.49	Moderately Wet
-0.99 to 0.99	Near Normal
-1.0 to -1.49	Moderately Dry
-1.5 to -1.99	Severely Dry
<= -2.0	Extremely Dry

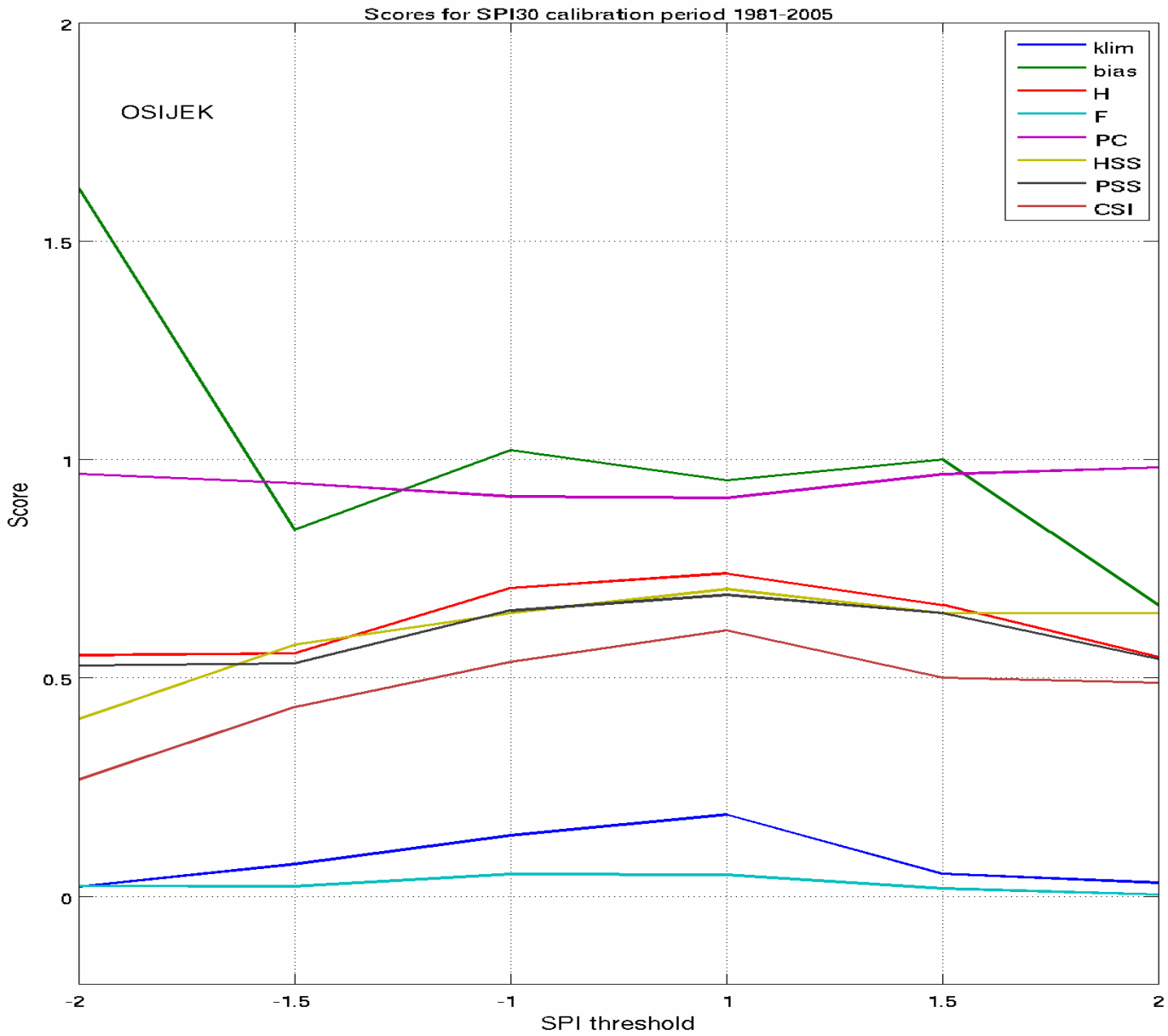
– based on forecasted/observed events a contingency table is calculated

2 × 2 contingency table

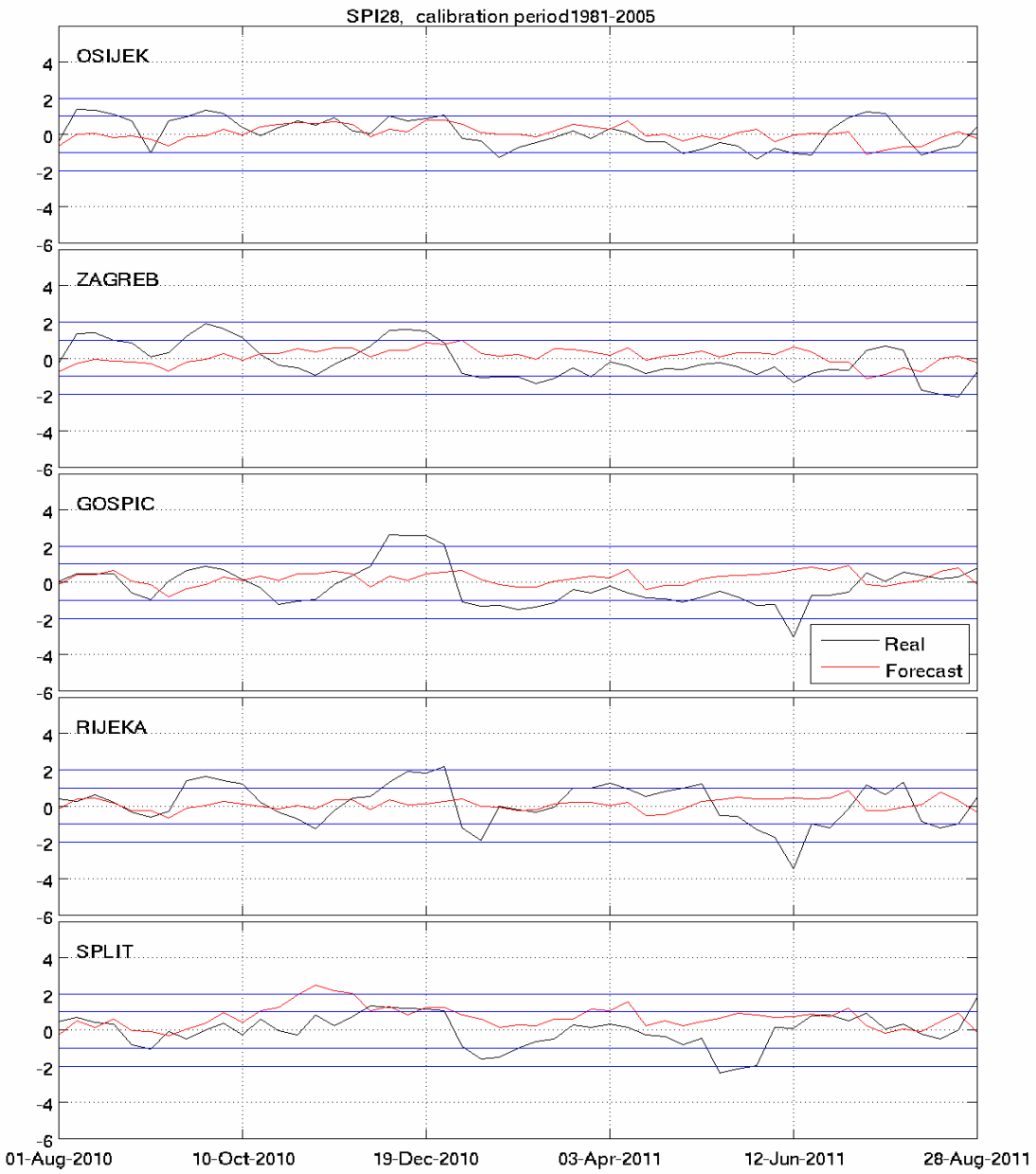
		observed	
		Yes	No
forecast	Yes	a HITS	b FALSE ALARM
	No	c MISS	d CORR. REJECT.

Bias=(a+b)/(a+c)	
H= a/(a+c)	hit rate
F = b/(b+d)	false alarm rate
PC = (a+d)/n	proportion correct
HSS =2*(ad-bc)...	Heidke skill score
PSS=(ad−bc)/(a+c)*(b+d)	Pierce skill score
CSI=a/(a+b+c)	Critical success index

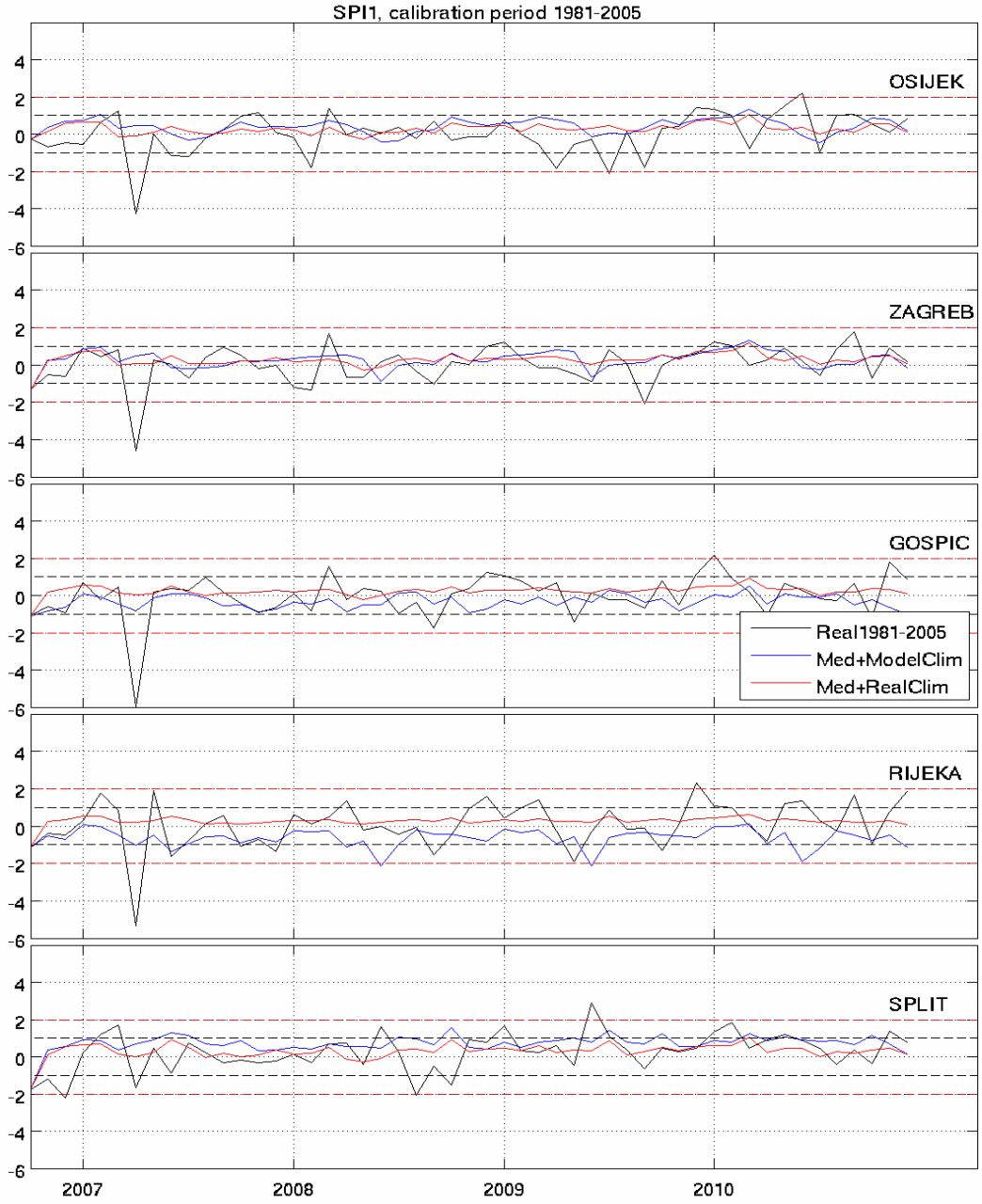

SPI30 calibration period 1981-2005
OSIJEK
me=0.011, mae=0.384, rmse=0.565
ZAGREB
me=0.025, mae=0.356, rmse=0.513
GOSPIC
me=0.081, mae=0.363, rmse=0.52
Real
Forecast
RIJEKA
me=0.037, mae=0.341, rmse=0.508
SPLIT
me=0.248, mae=0.46, rmse=0.665
4
2
0
-2
-4
-6
05/2008
05/2009
05/2010


Scores for SPI30 calibration period 1981-2005
OSIJEK
klim
bias
H
F
PC
HSS
PSS
CSI
Score
SPI threshold
2
1.5
1
0.5
0
-2
-1.5
-1
1
1.5
2

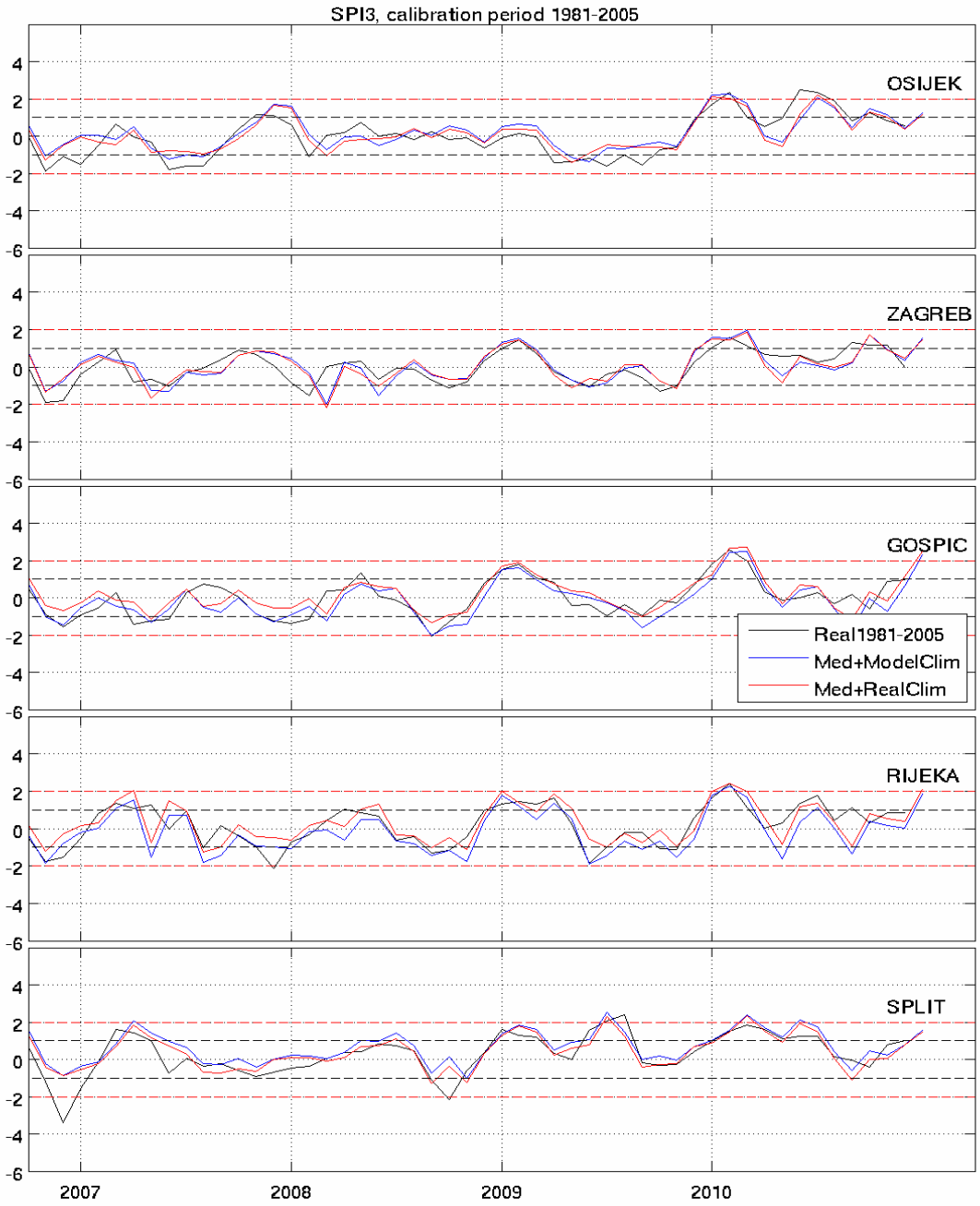
thresh.	a	b	c	d	n	clim	bias	H	F	PC	HSS	PSS	CSI
ZGM													
-2.0	5	12	6	1311	1334	.008	1.545	.455	.009	.987	.351	.445	.217
-1.5	12	34	19	1269	1334	.023	1.484	.387	.026	.960	.292	.361	.185
-1.0	72	81	40	1141	1334	.084	1.366	.643	.066	.909	.494	.577	.373
1.0	155	52	50	1077	1334	.154	1.010	.756	.046	.924	.707	.710	.603
1.5	43	41	17	1233	1334	.045	1.400	.717	.032	.957	.575	.684	.426
2.0	1	13	3	1317	1334	.003	3.500	.250	.010	.988	.107	.240	.059
OSI													
-2.0	16	31	13	1274	1334	.022	1.621	.552	.024	.967	.405	.528	.267
-1.5	55	28	44	1207	1334	.074	.838	.556	.023	.946	.576	.533	.433
-1.0	132	59	55	1088	1334	.140	1.021	.706	.051	.915	.649	.654	.537
1.0	184	53	65	1032	1334	.187	.952	.739	.049	.912	.703	.690	.609
1.5	46	23	23	1242	1334	.052	1.000	.667	.018	.966	.648	.648	.500
2.0	23	5	19	1287	1334	.031	.667	.548	.004	.982	.648	.544	.489
GOS													
-2.0	10	13	8	1303	1334	.013	1.278	.556	.010	.984	.480	.546	.323
-1.5	35	14	18	1267	1334	.040	.925	.660	.011	.976	.674	.649	.522
-1.0	68	40	46	1180	1334	.085	.947	.596	.033	.936	.577	.564	.442
1.0	174	80	36	1044	1334	.157	1.210	.829	.071	.913	.698	.757	.600
1.5	91	30	22	1191	1334	.085	1.071	.805	.025	.961	.756	.781	.636
2.0	39	8	14	1273	1334	.040	.887	.736	.006	.984	.771	.730	.639
RIJ													
-2.0	14	10	14	1295	1333	.021	.857	.500	.008	.982	.529	.492	.368
-1.5	28	16	28	1261	1333	.042	.786	.500	.013	.967	.543	.487	.389
-1.0	90	41	42	1160	1333	.099	.992	.682	.034	.938	.650	.648	.520
1.0	223	66	60	984	1333	.212	1.021	.788	.063	.905	.720	.725	.639
1.5	60	28	43	1202	1333	.077	.854	.583	.023	.947	.600	.560	.458
2.0	9	5	12	1307	1333	.016	.667	.429	.004	.987	.508	.425	.346
SPL													
-2.0	1	15	5	1312	1333	.005	2.667	.167	.011	.985	.085	.155	.048
-1.5	18	14	18	1283	1333	.027	.889	.500	.011	.976	.517	.489	.360
-1.0	46	31	38	1218	1333	.063	.917	.548	.025	.948	.544	.523	.400
1.0	226	206	24	877	1333	.188	1.728	.904	.190	.827	.558	.714	.496
1.5	90	111	13	1119	1333	.077	1.951	.874	.090	.907	.546	.784	.421
2.0	28	59	8	1238	1333	.027	2.417	.778	.045	.950	.434	.732	.295


SPI28, calibration period1981-2005
OSIJEK
ZAGREB
GOSPIC
RIJEKA
SPLIT
Real
Forecast
4
2
0
-2
-4
-6
01-Aug-2010
10-Oct-2010
19-Dec-2010
03-Apr-2011
12-Jun-2011
28-Aug-2011

threshold	a	b	c	d	n	klim	bias	H	F	PC	HSS	PSS	CSI
ZGM													
-2.0	0	0	1	25	26	0.038	0.000	0.000	0.000	0.962	0.000	0.000	0.000
-1.5	0	0	3	23	26	0.115	0.000	0.000	0.000	0.885	0.000	0.000	0.000
-1.0	0	0	3	23	26	0.115	0.000	0.000	0.000	0.885	0.000	0.000	0.000
1.0	0	0	10	16	26	0.385	0.000	0.000	0.000	0.615	0.000	0.000	0.000
1.5	0	0	4	22	26	0.154	0.000	0.000	0.000	0.846	0.000	0.000	0.000
2.0	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
me=-.256	mae=1.042	rmse=1.185											
OSI													
-2.0	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.5	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.0	0	0	1	25	26	0.038	0.000	0.000	0.000	0.962	0.000	0.000	0.000
1.0	0	0	6	20	26	0.231	0.000	0.000	0.000	0.769	0.000	0.000	0.000
1.5	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
2.0	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
me=-.363	mae=0.653	rmse=0.788											
GOS													
-2.0	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.5	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.0	0	0	2	24	26	0.077	0.000	0.000	0.000	0.923	0.000	0.000	0.000
1.0	0	0	4	22	26	0.154	0.000	0.000	0.000	0.846	0.000	0.000	0.000
1.5	0	0	4	22	26	0.154	0.000	0.000	0.000	0.846	0.000	0.000	0.000
2.0	0	0	4	22	26	0.154	0.000	0.000	0.000	0.846	0.000	0.000	0.000
me=-.219	mae=0.882	rmse=1.119											
RIJ													
-2.0	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.5	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.0	0	0	2	24	26	0.077	0.000	0.000	0.000	0.923	0.000	0.000	0.000
1.0	0	0	8	18	26	0.308	0.000	0.000	0.000	0.692	0.000	0.000	0.000
1.5	0	0	4	22	26	0.154	0.000	0.000	0.000	0.846	0.000	0.000	0.000
2.0	0	0	1	25	26	0.038	0.000	0.000	0.000	0.962	0.000	0.000	0.000
me=-.265	mae=0.854	rmse=1.049											
SPL													
-2.0	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.5	0	0	0	26	26	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.0	0	0	1	25	26	0.038	0.000	0.000	0.000	0.962	0.000	0.000	0.000
1.0	4	6	2	14	26	0.231	1.667	0.667	0.300	0.692	0.297	0.367	0.333
1.5	0	4	1	21	26	0.038	4.000	0.000	0.160	0.808	-0.066	-0.160	0.000
2.0	0	3	0	23	26	0.000	Infinity	NaN	0.115	0.885	NaN	NaN	0.000
me=0.438	mae=0.736	rmse=0.940											


SPI1, calibration period 1981-2005
OSIJEK
ZAGREB
GOSPIC
RIJEKA
SPLIT
Real1981-2005
Med+ModelClim
Med+RealClim
4
2
0
-2
-4
-6
2007
2008
2009
2010

threshold	a	b	c	d	n	clim	bias	H	F	PC	HSS	PSS	CSI
ZGM													
-2.0	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
-1.5	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
-1.0	1	0	5	45	51	0.118	0.167	0.167	0.000	0.902	0.261	0.167	0.167
1.0	0	1	5	45	51	0.098	0.200	0.000	0.022	0.882	-0.034	-0.022	0.000
1.5	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
2.0	0	0	0	51	51	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
me=0.263	mae=0.705	rmse=1.012											
OSI													
-2.0	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
-1.5	0	0	5	46	51	0.098	0.000	0.000	0.000	0.902	0.000	0.000	0.000
-1.0	0	0	7	44	51	0.137	0.000	0.000	0.000	0.863	0.000	0.000	0.000
1.0	0	1	10	40	51	0.196	0.100	0.000	0.024	0.784	-0.037	-0.024	0.000
1.5	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
me=0.283	mae=0.830	rmse=1.133											
GOS													
-2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
-1.5	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
-1.0	1	0	5	45	51	0.118	0.167	0.167	0.000	0.902	0.261	0.167	0.167
1.0	0	0	6	45	51	0.118	0.000	0.000	0.000	0.882	0.000	0.000	0.000
1.5	0	0	3	48	51	0.059	0.000	0.000	0.000	0.941	0.000	0.000	0.000
2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
me=0.259	mae=0.763	rmse=1.175											
RIJ													
-2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
-1.5	0	0	4	47	51	0.078	0.000	0.000	0.000	0.922	0.000	0.000	0.000
-1.0	1	0	7	43	51	0.157	0.125	0.125	0.000	0.863	0.194	0.125	0.125
1.0	0	0	12	39	51	0.235	0.000	0.000	0.000	0.765	0.000	0.000	0.000
1.5	0	0	6	45	51	0.118	0.000	0.000	0.000	0.882	0.000	0.000	0.000
2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
me=0.187	mae=0.911	rmse=1.258											
SPL													
-2.0	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
-1.5	1	0	4	46	51	0.098	0.200	0.200	0.000	0.922	0.311	0.200	0.200
-1.0	1	0	5	45	51	0.118	0.167	0.167	0.000	0.902	0.261	0.167	0.167
1.0	0	1	10	40	51	0.196	0.100	0.000	0.024	0.784	-0.037	-0.024	0.000
1.5	0	0	5	46	51	0.098	0.000	0.000	0.000	0.902	0.000	0.000	0.000
2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
me=0.060	mae=0.740	rmse=1.014											


SPI3, calibration period 1981-2005
OSIJEK
ZAGREB
GOSPIC
RIJEKA
SPLIT
Real1981-2005
Med+ModelClim
Med+RealClim
4
2
0
-2
-4
-6
2007
2008
2009
2010

threshold	a	b	c	d	n	clim	bias	H	F	PC	HSS	PSS	CSI
ZGM													
-2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
-1.5	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
-1.0	5	0	11	35	51	0.314	0.313	0.313	0.000	0.784	0.384	0.313	0.313
1.0	0	7	0	44	51	0.000	Infinity	NaN	0.137	0.863	NaN	NaN	0.000
1.5	0	1	0	50	51	0.000	Infinity	NaN	0.020	0.980	NaN	NaN	0.000
2.0	0	0	0	51	51	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
me=0.049	mae=0.435	rmse=0.537											
OSI													
-2.0	0	0	4	47	51	0.078	0.000	0.000	0.000	0.922	0.000	0.000	0.000
-1.5	2	1	2	46	51	0.078	0.750	0.500	0.021	0.941	0.541	0.479	0.400
-1.0	10	0	11	30	51	0.412	0.476	0.476	0.000	0.784	0.517	0.476	0.476
1.0	7	4	1	39	51	0.157	1.375	0.875	0.093	0.902	0.678	0.782	0.583
1.5	4	1	4	42	51	0.157	0.625	0.500	0.023	0.902	0.563	0.477	0.444
2.0	0	1	0	50	51	0.000	Infinity	NaN	0.020	0.980	NaN	NaN	0.000
me=0.021	mae=0.391	rmse=0.484											
GOS													
-2.0	0	0	2	49	51	0.039	0.000	0.000	0.000	0.961	0.000	0.000	0.000
-1.5	0	2	2	47	51	0.039	1.000	0.000	0.041	0.922	-0.041	-0.041	0.000
-1.0	4	1	13	33	51	0.333	0.294	0.235	0.029	0.725	0.250	0.206	0.222
1.0	6	2	0	43	51	0.118	1.333	1.000	0.044	0.961	0.835	0.956	0.750
1.5	6	2	0	43	51	0.118	1.333	1.000	0.044	0.961	0.835	0.956	0.750
2.0	0	5	0	46	51	0.000	Infinity	NaN	0.098	0.902	NaN	NaN	0.000
me=0.065	mae=0.492	rmse=0.620											
RIJ													
-2.0	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
-1.5	0	0	1	50	51	0.020	0.000	0.000	0.000	0.980	0.000	0.000	0.000
-1.0	7	0	9	35	51	0.314	0.438	0.438	0.000	0.824	0.516	0.438	0.438
1.0	4	9	0	38	51	0.078	3.250	1.000	0.191	0.824	0.398	0.809	0.308
1.5	4	4	0	43	51	0.078	2.000	1.000	0.085	0.922	0.628	0.915	0.500
2.0	0	5	0	46	51	0.000	Infinity	NaN	0.098	0.902	NaN	NaN	0.000
me=0.095	mae=0.418	rmse=0.527											
SPL													
-2.0	0	0	0	51	51	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.5	0	0	0	51	51	0.000	NaN	NaN	0.000	1.000	NaN	NaN	NaN
-1.0	2	1	9	39	51	0.216	0.273	0.182	0.025	0.804	0.213	0.157	0.167
1.0	6	10	0	35	51	0.118	2.667	1.000	0.222	0.804	0.452	0.778	0.375
1.5	5	4	1	41	51	0.118	1.500	0.833	0.089	0.902	0.612	0.744	0.500
2.0	0	1	0	50	51	0.000	Infinity	NaN	0.020	0.980	NaN	NaN	0.000
me=0.038	mae=0.448	rmse=0.570											

Outline

1. Motivation
2. Data and methods
3. Results
4. Conclusions and future work

4.1. Conclusions

- SPI30 (21 real + 9 forecasted) skillful
  - slight overestimating of SPI (too wet)
  - often still not catching extreme events

- Monthly and seasonal forecasts (SPI28, SPI1 and SPI3) significantly less skill
  - signal too weak (no extreme forecasts)
  - monthly fc. skill comparable to seasonal?

4.2. Future work

- establish operational SPI forecast (SPI30) combining real and forecasted data
- apply probabilistic approach (use ensemble members instead of ensemble median/mean)
- find best fitting PDF to calculate station SPI
- SPI6, SPI12...


It's fantastic!
I can find out the exact weather outside this exact house at this exact moment - all on the INTERNET!