Karlsruhe Institute of Technology

Comparison of different objective atmospheric circulation pattern analyses in the Jordan region

P. Laux[1], H. Kunstmann[1], K. Lutz[1], J. Jacobeit[2], Ch. Beck[2], A. Philipp[2], & A. Bárdossy[3]

Contact: patrick.laux@imk.fzk.de

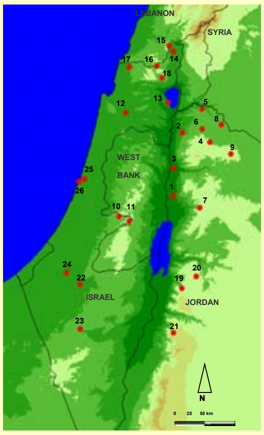
1 Karlsruhe Research Center, Institute of Meteorology and Climate Research IMK-IFU, 82467 Garmisch-Partenkirchen, Germany
2 University of Augsburg, Institute for Geography, 86135 Augsburg, Germany
3 University of Stuttgart, Institute of Hydraulic Engineering, 70550 Stuttgart, Germany

1. Objectives

- **Comparison** of different circulation pattern (CP) classification algorithms for the Jordan region.
  - Testing for **mutual dependency**
  - Assessing the **strength of the mutual dependency** for the whole-year-round and the seasonal consideration.
  - Analyzing the **persistence** of the mutual dependencies
- Analyzing the possibility of **making predictions** of a certain CP classification
- Testing the different methodologies for usability for **CP conditional rainfall modelling**

2. Research area

#	Station
1	Amman
2	Deirabisaid
3	Deirallaagr
4	Ennueiyime
5	Hartha
6	Irbidagr
7	Naur
8	Ramtha
9	Rihab
10	Qiryant -Anav
11	Jerusalem
12	Ramat -David
13	Kebutzat
14	Kefar Blum
15	Kefar Galad
16	Yiron
17	Eilon
18	Har Kenaan
19	Ainbisas
20	Hemud
21	Tafile
22	Beer -Sheva
23	Sed'e
24	Dorot
25	Qiryant -Shaut
26	Tel Aviv



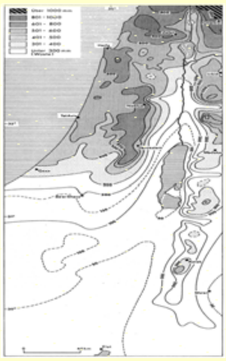


Figure 1: Location of the 26 rainfall observation stations in Israel and Jordan (left) and mean annual rainfall distribution (Karmon, 1983) (right).

3. Data

- **Daily time series** (1961-1990) of rainfall of 26 observation sites within the research area
- **Reanalysis data** (2) (1961-1990) from the National Center for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR)

4. Methodologies

4.1 CP classification methodologies

- **Bárdossy's objective classification (MOFRBC):** The classification was optimized to i) annual rainfall amount (labelled as Y), and ii) the seasonal rainfall amount (labelled as S) of the 26 stations in Israel and Jordan. SLP and GPH500 were used as predictor variables, which led eventually to 4 different combinations of classification (Tab. 1).
- **Beck's objective classification:** A classification based on the subjective *Großwetterlagen* (Hess & Brezowsky, 1952) using SLP data for the region 40°N10°W-60°N30°E. First, the following three prototypes are defined: W-E, S-N and central low-pressure isobars. The spatial correlations of these prototypical patterns with the gridded SLP fields are calculated and expressed in terms of coefficients of zonality (Z), meridionality (M) and vorticity (V). The 10 *Großwettertypes* are represented by means of different combinations of these three correlation coefficients. Each daily SLP field is eventually assigned to that CP type according to the minimum Euclidian distance of its Z, M and V coefficient from those of the prototypes.
- **Alpert's semi-objective classification:** A CP classification using SLP data from the NCEP/NCAR reanalysis project, conducted for the region 27.5°N30°E – 37.5°N40°E. Discriminant analysis is used to classify the daily synoptic situation into the 19 predefined CPs. The definition of the CPs was done manually by experts prior to the classification. As the predefinition is a necessary step for this approach, and the actual classification is objective, the methodology is called semi-objective.

No	CP classification approach	Description	No. of CPs	Domain
1	MOFRBC (Bárdossy et al.,1995)	SLP, optimized for rainfall of the whole year	19 def. + 1 undef.	15°N10°E-45°N55°E
2	MOFRBC	SLP, optimized for rainfall of the four seasons	19 def. + 1 undef.	15°N10°E-45°N55°E
3	MOFRBC	GPH500, optimized for rainfall of the whole year	19 def. + 1 undef.	15°N10°E-45°N55°E
4	MOFRBC	GPH500, optimized for rainfall of the four seasons	19 def. + 1 undef.	15°N10°E-45°N55°E
5	Alpert (Alpert et al., 2004)	GPH1000, T1000, U1000, V1000	19	27.5°N30°E-37.5°N40°E
6	Beck (Beck et al., 2007)	SLP	18	22.5°N15°E-42.5°N50°E

Table 1: Description of the basic features of the different CP classification algorithms.

4.2 Measures of mutual dependency

1. **χ^2 – Test** is used to test whether there is an association between the CP classification approaches or not
2. The **standardized residuals** (difference between observed and expected frequencies) are indicating which CPs are mutually related
3. Calculation of the **adjusted contingency coefficient C** and the **Cramér coefficient V**
4. Calculation of **Guttmann's λ** to quantify the possibility of making predictions

4.3 Usability for CP conditional rainfall modelling

1. The difference between highest and lowest **wetness index I_{wet}** of the CPs belonging to a certain classification method (I_{wet} = ratio of the percentage of annual rainfall amount for a given CP and its appearance rate). The higher the difference, the higher is the discriminative power of dry and wet CPs and the better is the classification potentially suited for rainfall modelling.
2. The mean CP conditional rainfall amounts and the overall averages (unconditional) are calculated for each season. Both are used for rainfall modelling and the **skill score** is calculated using the mean square error of the estimations from the CP conditional and the unconditional classification:

$$S = 1 - (MSE_{class} / MSE_{ref})$$

S = 0 if $MSE_{class} = MSE_{ref}$ and S=1 for a perfect estimation!

5. Results

- For the whole-year-around classification (not shown), all the CP classification schemes are found to be non-independent (tested at α=0.01); for the seasonal approach (Tab. 2), two combinations are found to be independent.
- Clear seasonal variations of the strength of the associations are found. The highest contingency coefficients are found for the winter, the lowest for summer (Tab. 2).
- Just few classification combinations are found to be suited for making predictions (not shown here).
- The dependencies remain stable over the analyzed period (not shown here).
- Excepted for the whole-year-round consideration, CP conditional rainfall modelling reveals better results than unconditional modelling (Fig. 2).
- Best results are obtained for the northern and central parts of the research area (Fig. 2).
- Alpert's semi-objective approach shows the best performance (Fig. 2 & Tab. 3)

		MOFRBC SLP (Y)	MOFRBC SLP (S)	MOFRBC GPH500 (Y)	MOFRBC GPH500 (S)	ALPERT SLP	BECK SLP
Winter (DJF)							
MOFRBC	SLP(Y)	-					
	SLP(S)	0.78	-				
	GPH500(Y)	0.65	0.65	-			
	GPH500(S)	0.64	0.68	0.79	-		
ALPERT	SLP	0.65	0.69	0.59	0.62	-	
BECK	SLP	0.75	0.83	0.70	0.70	0.75	-
Spring (MAM)							
MOFRBC	SLP(Y)	-					
	SLP(S)	0.75	-				
	GPH500(Y)	0.55	0.56	-			
	GPH500(S)	0.55	0.61	0.78	-		
ALPERT	SLP	0.58	0.65	0.49	0.58	-	
BECK	SLP	0.69	0.77	0.57	0.61	0.72	-
Summer (JJA)							
MOFRBC	SLP(Y)	-					
	SLP(S)	0.70	-				
	GPH500(Y)	0.46	0.52	-			
	GPH500(S)	0.49	0.57	0.72	-		
ALPERT	SLP	0.37	0.40	0.31*	0.35*	-	
BECK	SLP	0.48	0.57	0.37	0.40	0.45	-
Autumn (SON)							
MOFRBC	SLP(Y)	-					
	SLP(S)	0.72	-				
	GPH500(Y)	0.55	0.55	-			
	GPH500(S)	0.55	0.62	0.73	-		
ALPERT	SLP	0.54	0.61	0.48	0.62	-	
BECK	SLP	0.65	0.71	0.58	0.59	0.72	-

* null hypothesis accepted at α=0.01

Table 2: Adjusted contingency coefficient between the different CP classifications (seasonal evaluation)

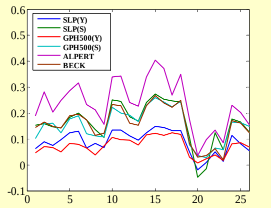


Figure 2: Skill score for rainfall modelling of the 26 observation stations in the Jordan region (see Fig. 1 for the location of the stations).

	Year	Winter (DJF)	Spring (MAM)	Summer (JJA)	Autumn (SON)
SLP(Y)	3.31	3.32	3.43	-	3.41
SLP(S)	7.25	4.36	6.22	-	8.46
GPH500(Y)	2.22	2.50	3.17	-	2.16
GPH500(S)	6.55	3.98	9.84	-	12.16
Alpert	15.52	5.90	23.18	-	23.23
Beck	6.03	3.72	4.21	-	6.17

Table 3: Difference between highest and lowest wetness index Iwet for the different CP classifications and seasons.