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DIE ERDE 140 2009 (2)	Contribution to Physical Geography	pp. 1-27
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- *Regional climatology – Hess-Brezowsky classification – Brittany, France*

**Olivier Planchon, Hervé Quénol and Samuel Corgne**

## **Assessing Precipitation and Large-Scale Weather Situations in Brittany: the Usefulness of the Hess-Brezowsky Classification**

*Die Untersuchung von Niederschlag und Großwetterlagen in der Bretagne: die Brauchbarkeit der Hess-Brezowsky-Klassifikation*

With 12 Figures and 6 Tables

An accurate knowledge of the rainy-air circulation types was developed. For this study, the Scorff watershed located in western Brittany was chosen because of its typical temperate oceanic precipitation regime. The identification of rainy-air circulation types was achieved using the Hess-Brezowsky classification of air circulation patterns for the period 2000-2004. Rainfall amounts and percentages were calculated for each group and individual air-circulation type for the studied time-period. The westerly and southerly circulation types generated the highest rainfall amounts during the cold season months. Southerly circulations prevailed during the remarkably wet winter of 2000-2001, including several longer periods with south-westerly circulations. The southern or south-western exposure of the watershed in the hilly inland area enhanced the heavy rainfall generated by the W, SW and S circulation types, and the difference between the rainfall amounts at coastal and inland stations was most remarkable during the wettest days. The comparison between the two wet winters of 2000-2001 and 2002-2003 showed a strong difference between the monthly precipitation amounts of Lorient and those of the two inland stations during the 2000-2001 winter. Because of the exposure of the catchment, the rainfall associated with the high occurrence of SW circulation types during the 2000-2001 winter was enhanced inland. On the other hand, during the 2002-2003 winter, with prevailing rainfall generated by westerly circulations, the exposure of the catchment was less favourable to a contrasted spatial distribution of precipitation.

### **1. Introduction**

In intensive agricultural regions like Brittany, short-term land-use and cover changes have an

impact on water transfer processes (*Cheverry* 1998) as crops need specific plant health products (pesticides, fertilizer etc.). These cultural practices have been pointed out by local manag-

ers (i.e. members of environmental organisations) as they contribute to a relative degradation of the water quality (in terms of nitrogen, pesticides, phosphor). Thus, a better knowledge of the pollutant transfer processes into water in the watersheds requires a fine monitoring of land-cover evolution at a field scale (with regard to products grown, e.g. corn, wheat, meadow). This monitoring allows to identify fields as “hot spots” for water transfer processes and then to help to plan environmental action.

In addition, the question of the effects of anthropogenic planning and activities is often raised after each hydrometeorological event which causes serious damage. North-western France has been subject to important land-use and land-cover changes during the second half of the twentieth century. These changes in farming practices and urban expansion (in the Scorff watershed, espe-

cially around the Lorient agglomeration) involved varied and heterogeneous surface condition changes in the catchments. The rise of the surface water level, especially in the catchments with an impermeable substratum, may be reinforced by these changes of surface condition (Moussa et al. 2001, Carlier and De Marsily 2004), but they are also connected to climatic features (Dupont et al. 2000, Dupont et al. 2008). Even if the countryside with many hedges, trees and small fields (*bocage*) has been preserved in western Brittany, the presence of fields with no or little vegetation during rainy winters increases pollutant fluxes (nitrogen, pesticides etc.) towards the rivers. The Scorff watershed is subject to a typical temperate oceanic precipitation regime with spatial variations that can highly influence land-use and land-cover management. In western Brittany, heavy precipitation in winter constrains farmers to leave their fields fallow, without any crops.

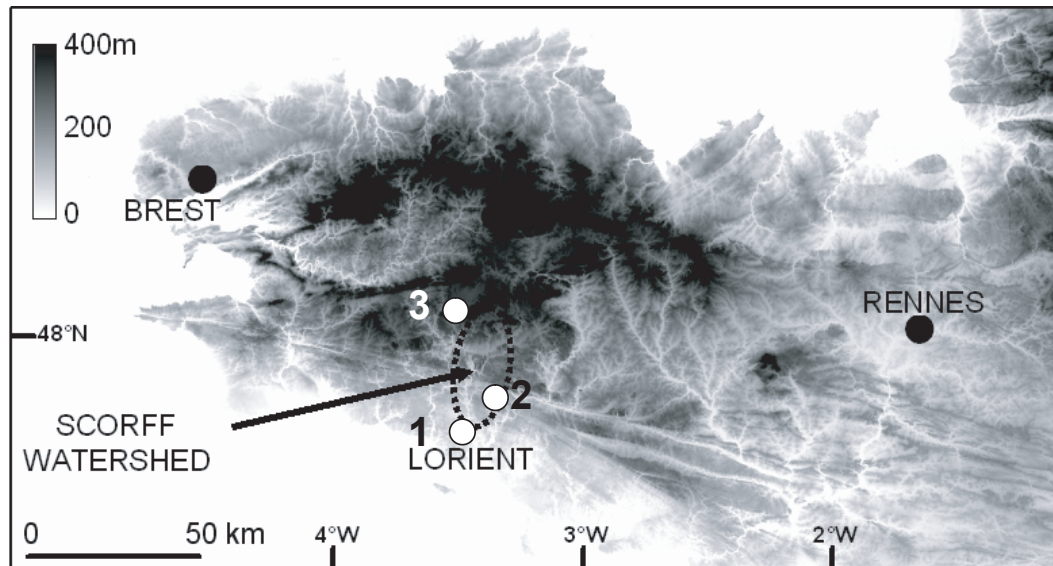


Fig. 1 Location of the studied area (Scorff watershed) in Brittany; with locations of the reference weather stations (1: Lorient, 2: Plouay, 3: Plouray). The digital elevation model of Brittany is extracted from ‘Global Land Cover Facility’, source: [www.landcover.org](http://www.landcover.org). / Lage des untersuchten Gebiets (Scorff-Einzugsgebiet) in der Bretagne; mit Lage der Referenz-Wetterstationen (1: Lorient, 2: Plouay, 3: Plouray). Das digitale Höhenmodell ist entnommen aus ‘Global Land Cover Facility’, Quelle: [www.landcover.org](http://www.landcover.org).

The high level of soil moisture prevents any efficient work of agricultural machinery in the fields. In the context of territorial planning, the land-use and land-cover monitoring focuses especially on the winter period because it represents an intermediary period for main crops in this region (wheat, corn, vegetables).

The impact of climate on the Scorff watershed was first analysed through the study of the space-time rainfall variability during four winters between 2000 and 2004 which were representative of different land-cover conditions (Corgne et al. 2002, Corgne et al. 2007). For an accurate knowledge of weather patterns causing rainfall, the Hess-Brezowsky classification of circulation patterns was applied to the 2000-2004 period. The Hess-Brezowsky classification allows research on long-term climatological data series because the daily *Großwetterlagen* catalogue has been available since 1881. This long period of observation will be essential for further studies on climate change. Precipitation amounts and percentages were calculated for each major type (GWT) over the studied period and for each year of this period, in order to identify the rainiest circulation types during the cold season. Analyses by subtypes (GWL) were carried out for remarkable cold seasons. This application of the Hess-Brezowsky classification is a first test of the validity of the method in western France, and the analysis of winters over a period of only 5 years is not the final goal but a first step to demonstrate the usefulness of the method for the area.

This study was carried out as part of the work of the RICLIM-CNRS 2663 multidisciplinary Research Group 'Climate Risks' ([http://www.uhb.fr/sc\\_sociales/riclim/](http://www.uhb.fr/sc_sociales/riclim/)) and was supported by the MAIF Foundation within the framework of a research programme entitled 'air-mass dynamics and climate risks'. This paper follows preliminary investigations including land-use and land-cover changes studies (Corgne et al. 2002, Corgne et al. 2007), held in collaboration with the Scorff Watershed Association and now developed further

within the framework of the CLIMASTER co-supported research programme (INRA and administrations of four regions in western France) about 'climatic change, agricultural systems, natural resources and territorial development'.

## 2. The Study Area and its Prevailing Climatic Features

### 2.1. Study area

The Scorff watershed represents an important environmental resource for territorial planning since it provides drinking water for eighty thousand people. The study area is a catchment of 482 km<sup>2</sup> located on the southwestern coastal area of Brittany (Fig. 1) and with a maximum altitude of 280 m on its northernmost edge. The Scorff watershed is characterised by relatively intensive mixed farming combined with wet and warm autumns and winters that produce significant amounts of nitrogen before the infiltration of water in winter (Cheverry 1998).

### 2.2. Large-scale rainy weather patterns and impacts on climatic features in Brittany

Heavier precipitation during the cold season is the distinctive feature of most of the seasonally contrasted regimes affecting the Atlantic coastal fringe of Europe (Wallén 1970). Brittany and all the west and north-west of France are usually subject to Atlantic weather disturbances throughout the year, but their frequency and intensity are subject to a seasonal variability. The precipitation regime in NW France is the result of the seasonal change in the circulation pattern in the mid- and high-latitudes over the North Atlantic Ocean and Europe (Pagney 1988). At the beginning of winter (December and January), the strong westerlies induce heavy precipitation on the European Atlantic fringe. December and January are the two rainiest months at Lorient in Brittany. From February onwards, the

*Tab.1* List of Hess-Brezowsky major types (GWT) and subtypes (GWL) of circulation patterns (Bárdossy and Caspary 1990; Fallot 2000; Gerstengarbe and Werner 2005) / *Übersicht über Großwettertypen (GWT) und Großwetterlagen (GWL) der Hess-Brezowsky-Klassifikation (Bárdossy und Caspary 1990; Fallot 2000; Gerstengarbe und Werner 2005)*

Hess-Brezowsky major types (GWT) and subtypes (GWL)	GWL
<b>Westerly circulations</b>	
West anticyclonic	WA
West cyclonic	WZ
West angular	WW
Southern West	WS
<b>Southerly circulations</b>	
Southwest anticyclonic	SWA
Southwest cyclonic	SWZ
South anticyclonic	SA
South cyclonic	SZ
British Isles low	TB
Western Europe trough	TRW
Southeast anticyclonic	SEA
Southeast cyclonic	SEZ
<b>Northwesterly and northerly circulations</b>	
Northwest anticyclonic	NWA
Northwest cyclonic	NWZ
North anticyclonic	NA
North cyclonic	NZ
North, Iceland high, anticyclonic	HNA
North, Iceland high, cyclonic	HNZ
British Isles high	HB
Central European trough	TRM
<b>Northeasterly and easterly circulations</b>	
Northeast anticyclonic	NEA
Northeast cyclonic	NEZ
Fennoscandian high anticyclonic	HFA
Norwegian Sea / Fennoscandian high anticyclonic	HNFA
Fennoscandian high cyclonic	HFZ
Norwegian Sea / Fennoscandian high cyclonic	HNFZ
<b>Main high / low pressure area over Central Europe</b>	
Central European high	HM
Central European ridge	BM
Central European low	TM
Transition / unclassified type	U

lower zonal index is connected to the weakening of the westerly circulation and the higher occurrence of meridional circulations (Lejenäs and Økland 1983, Shukla and Mo 1983, Barry and Chorley 1987). In summer, the area is subject to a higher occurrence of westerlies, but they are relatively weak and the weather disturbances occur at higher latitudes (northern Europe). Consequently, summer is the least rainy season in most of north-western France (at Lorient in Brittany, J-J-A: 15.6 % of the annual amount), but heavy precipitation can occur depending on circulation type and weather disturbances tracks. The westerly circulation strengthens in autumn, resulting in increasing precipitation amounts in western Europe. Topographical effects (the highest hills of Brittany reach about 380 metres) influence the effect of the circulation type on precipitation. Mean annual precipitation is less than 800 mm on the coast (south of Lorient), but is estimated at more than 1200 mm in the Black Mountains area (Kessler and Chambraud 1986, Lebourgeois et al. 2006). Unfortunately, there is no weather station on the highest hills (326 m).

### 3. Methodology

#### 3.1 The Hess-Brezowsky classification of circulation patterns

Analysis of space-time variability of precipitation and floods must take the variety of disturbance track patterns into account. Such an anal-

ysis is possible using the *Großwetterlagen* catalogue from the Hess-Brezowsky classification of circulation patterns. The Hess-Brezowsky subjective classification of large-scale circulation patterns is frequently used to characterise the atmospheric flow and weather patterns over the eastern North Atlantic and Europe (Hess and Brezowsky 1952, Gerstengarbe and Werner 2005, Kyseľý and Huth 2006). Based on mean air pressure distribution (sea level and 500 hPa level) over the North Atlantic Ocean and Europe, the classification initially identifies three groups of circulation types (zonal, mixed and meridional), which are divided into 5 major types (*Großwettertypen*, GWT: westerly circulation types, southerly circulation types, northwesterly and northerly circulation types, northeasterly and easterly circulation types, main high/low pressure area over Central Europe) and 29 subtypes (*Großwetterlagen*, GWL). A list of GWT and GWL is given in Table 1. The daily GWL catalogue has been available since 1881 and is constantly updated with a minimum allowed event duration of 3 days. The GWL catalogue has been checked and used in various studies assessing trends in frequencies, changes in event duration and transition probabilities between GWL types (Bárdossy and Caspary 1990, Klaus 1993), but has never been applied to climatological studies in western France. Despite its high relevance for Europe north of the Alpine range, the Hess-Brezowsky classification has rarely been used in France and there has never been an attempt to establish a similar alternative classification system for France. This classifica-

Tab. 2 Number and proportion of the unspecified anticyclonic patterns (number coding “0” in the Lamb Classification) in all anticyclonic patterns (number coding 0-8) / Anzahl und Anteil der unspezifizierten antizyklonalen Wetterlagen (Zahlencode „0“ in der Lamb-Klassifikation) an allen antizyklonalen Wetterlagen (Zahlencode 0-8)

	2000	2001	2002	2003	2004	2000-2004
<b>Total “0”</b>	63	80	80	97	78	398
<b>Total “0-8”</b>	98	131	114	156	127	626
<b>% “0”</b>	64.3	61.1	70.2	62.2	61.4	63.6

Tab. 3 Number and proportion of the unspecified cyclonic patterns (number coding “20” in the Lamb Classification) in all cyclonic patterns (number coding 20-28) / Anzahl und Anteil der unspezifizierten zyklonalen Wetterlagen (Zahlencode „20“ in der Lamb-Klassifikation) an allen zyklonalen Wetterlagen (Zahlencode 20-28)

	2000	2001	2002	2003	2004	2000-2004
<b>Total “20”</b>	72	53	68	26	38	257
<b>Total “20-28”</b>	123	95	114	72	88	492
<b>% “20”</b>	58.5	55.8	59.6	36.1	43.2	52.2

Tab. 4 Daily rainfall > 5 mm for the unspecified anticyclonic days identified using the Lamb classification and compared with the GWL for these days / Täglicher Niederschlag > 5 mm für die unspezifizierten antizyklonalen Tage, die mit Hilfe der Lamb-Klassifikation identifiziert und mit den GWL für diese Tage verglichen wurden

Date	Rainfall (mm)	GWL (Hess-Brezowsky)
<b>2000</b>		
30 March	5.4	TM – Central European low
1 October	6.2	TRW – Western Europe trough
17 December	12.8	WZ – West cyclonic
31 December	41.8	WS – Southern west
<b>2001</b>		
9 January	13.8	WS – Southern west
6 March	6.2	Unclassified
19 March	32.8	HNZ – North, Iceland high, cyclonic
12 May	6.2	HNFA – Norwegian Sea – Fennoscandian high anticyclonic
16 July	14.4	TRW – Western Europe trough
14 October	7.8	SA – South anticyclonic
2 December	5.8	WW – West angular
<b>2002</b>		
25 January	6.6	WZ – West cyclonic
7 April	11.6	HNFA – Norwegian Sea – Fennoscandian high anticyclonic
5 May	5.6	TRW – Western Europe trough
12 May	8.4	SWZ – Southwest cyclonic
5 August	14.4	TM – Central European low
20 October	5.0	SWZ – Southwest cyclonic
<b>2003</b>		
2 October	8.4	SWZ – Southwest cyclonic
31 December	8.6	TRM – Central European trough
<b>2004</b>		
25 May	6.2	NWA – Northwest anticyclonic
6 July	27.0	TRW – Western Europe trough



Tab. 5 Geographical coordinates of the three selected weather stations  
*Geographische Koordinaten der drei ausgewählten Wetterstationen*

Station	Latitude	Longitude	Elevation (m asl)	Distance to coast
Lorient	47°46'N	03°27'W	42	5 km
Plouay	47°56'N	03°19'W	138	22 km
Plouray	48°07'N	03°26'W	205	44 km

tion was mainly developed for the weather in Germany and neighbouring countries in Central Europe. Therefore, an essential aim of this paper is to assess if the Hess-Brezowsky classification can be applied to western Europe. The Hess-Brezowsky classification has occasionally been used to study the connection between climatic variability and stream flow (Stahl et al. 2002). Each GWL is defined by the average position of the main high or low pressure area, therefore all the anticyclonic and cyclonic circulation types are associated with a specific GWL.

In contrast, the Lamb classification, which could also be useful because of its geographical area of application (the British Isles), encloses a high proportion of unspecified anticyclonic or cyclonic circulation types (Lamb 1972, Jenkinson and Collison 1977). Using the Objective Jenkinson-Lamb daily catalogue updated by the Climatic Research Unit (<http://www.cru.uea.ac.uk/cru/ftpdata/lwtjenk.dat>) for the selected years between 2000 and 2004, more than 60 % of the anticyclonic circulation types (Tab. 2) and more than 50 % of the cyclonic circulation types (Tab. 3) were unspecified. For example, the position of the high pressure area involves very different and contrasting meteorological conditions in western France. Some of these weather patterns cause rainfall in western France. The unspecified anticyclonic circulation types of the Lamb classification included several days with heavy precipitation (up to 41.8 mm at Lorient between 2000 and 2004: Tab. 4). These days are associated with specific Hess-Brezowsky circulation types due to different

positions of the surface high pressure areas. Therefore, the Hess-Brezowsky classification seems more appropriate than the Lamb classification for a detailed study of the rainy circulation types.

Analysis was carried out here for each group and individual circulation type (GWL). Frequencies for the main categories were calculated for the 2000-2004 period. Precipitation amounts and percentages were calculated for each GWT on the basis of the data recorded at the weather station of Lorient over the 2000-2004 period and for each year of this period. More detailed observations and analysis using the Hess-Brezowsky classification were made in order to study the correlation between GWL and daily precipitation during specific seasons, e.g. the 2000-2001 extremely wet cold season at the three stations of Lorient, Plouay and Plouray. The weather maps, which allowed to analyse the weather patterns associated with some selected heavy rainfall events, were adapted from the NCEP Reanalysis retrieved from <http://www.wetter-zentrale.de>. The daily catalogue of the *Großwetterlagen Europas* (1881-2004) was obtained from the Potsdam Institute for Climate Impact Research (PIK: <http://www.pik-potsdam.de/research/publications/pikreports>).

### 3.2 Meteorological data

The climatic data used in this study are the daily precipitation recorded during the 2000-2004 period at three weather stations (Lorient, Plouay and Plouray; see Tab. 5) located in the Scorff watershed. The station of Lorient is the nearest to



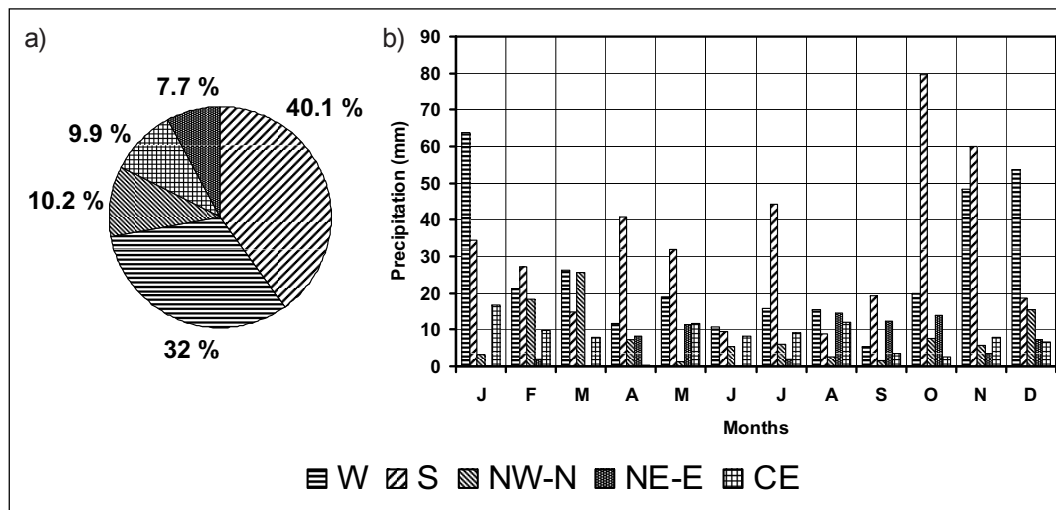


Fig. 2 Precipitation distribution (a) and amounts (b) at Lorient by Hess-Brezowsky GWT (2000-2004 period); W: westerly circulation types, S: southerly circulation types, NW-N: northwesterly and northerly circulation types, NE-E: northeasterly and easterly circulation types, CE: main high/low pressure area over Central Europe / Niederschlagsverteilung (a) und Niederschlagsmengen (b) in Lorient nach Hess-Brezowsky-GWT (Zeitraum 2000-2004); W: westliche Zirkulationstypen, S: südliche Zirkulationstypen, NW-N: nordwestliche und nördliche Zirkulationstypen, NE-E: nordöstliche und östliche Zirkulationstypen, CE: vorrangiges Hoch- bzw. Tiefdruckgebiet über Mitteleuropa

the Atlantic Ocean. The stations of Plouay and Plouray are situated in the northern part of the Scorff watershed, close to the Black Mountains. These stations belong to the French national weather agency Météo-France. In addition to the 2000-2004 rainfall time series, the data set of the 1971-2000 normals was used as a reference to define the precipitation anomalies.

## 4. Results

### 4.1 Connections between precipitation and GWT

#### 4.1.1 A monthly timescale study using Lorient as a reference station

About three quarters of the daily precipitation at the weather station of Lorient for the 2000-2004 period were associated with southerly (40%) and

westerly circulations (32%) (Fig. 2a), which include the more frequent major rainy circulation types throughout the year in western Europe (southwesterly and westerly circulation patterns: Moron 1990). Mean monthly precipitation for each GWT (Fig. 2b) clearly shows that the highest precipitation amounts were associated with southerly and westerly circulation types during the cold months. Adding the values expressed in both “W” and “S” bars, Figure 2 shows these two combined GWT generated precipitation amounts of about 100 mm at Lorient for the months of October (80.6% of the mean monthly precipitation amount), November (86.4%) and January (83.2%).

Monthly precipitation for each GWT (Fig. 3) shows more detail about particularities of some wet periods. The wet cold season is clearly shown in Figure 3, with a high variability of rainfall distribution among GWT. During the remarkably

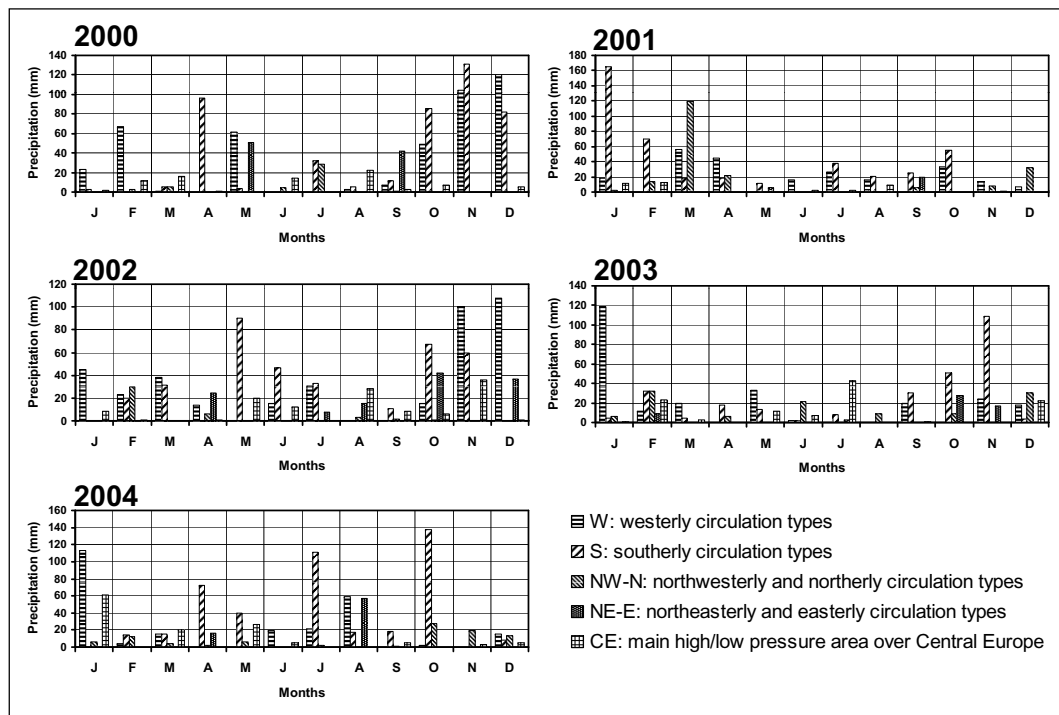


Fig. 3 Monthly rainfall amounts at Lorient by Hess-Brezowsky GWT (years 2000 to 2004)  
*Monatliche Niederschlagsmengen in Lorient nach Hess-Brezowsky GWT (Jahre 2000 bis 2004)*

wet cold season of 2000-2001, precipitation was essentially associated with southerly and westerly circulation types. The precipitation of the wet months of the 2002-2003 cold season (November, December and January) was largely associated with westerly circulation types. The year 2004 was characterised by remarkably wet months during other seasons (April, July and October). While the precipitation of the wet month of January was essentially due to westerly circulation types, the precipitation of the other wet months must be attributed to southerly circulation types. At the weather station of Lorient, the proportion of precipitation connected to both southerly and westerly circulation types between November and March was higher for the short 2000-2004 period (about three quarters: 75.3 %) than for the long time series of 1958-2005 (56.2 %). The proportion

of southerly (westerly) circulation types was 25.4 % (30.8 %) for the 1958-2005 period and 37.8 % (37.5 %) for the 2000-2004 period.

Figure 4 shows a high variability of the monthly precipitation anomalies at Lorient; it also shows the original aspect of the 2000-2001 cold season, with 7 successive months with positive anomalies (October 2000 to April 2001, including two maxima: March 2001, +178 % and November 2000, +149 %). The entire western France was subject to these anomalies which caused floods (Dupont et al. 2008). Other rainy winters occurred in the 1990s (1994-1995, 1999-2000). A winter rainfall increase has been recorded in western Europe since the middle of the 1970s, both in the British Isles (Mayes 1996, Kiely 1999) and in western France (Dubreuil et al. 1997, Dupont et al. 2000).

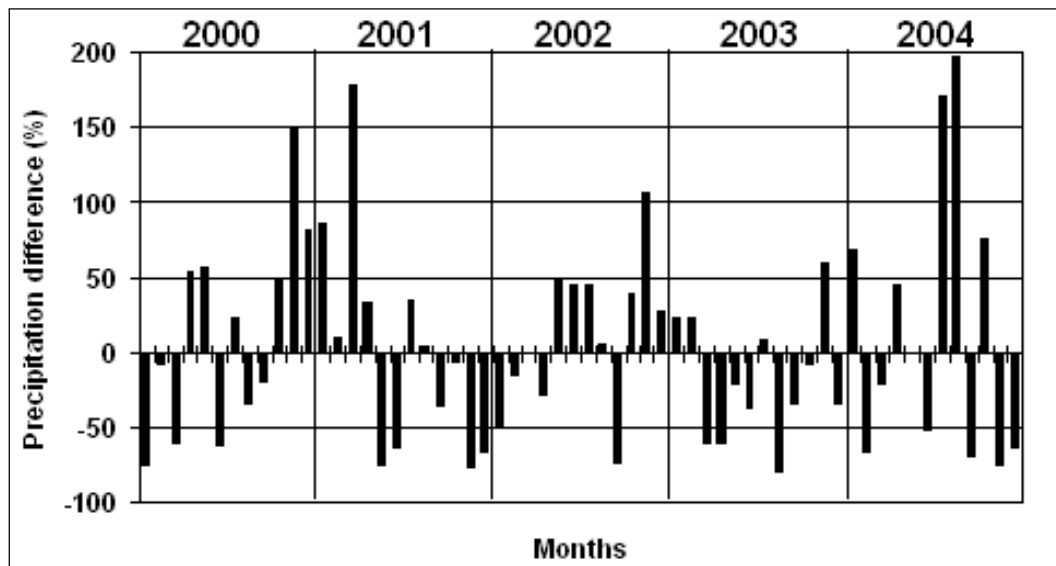


Fig. 4 Monthly precipitation anomalies at the station of Lorient: January 2000 to December 2004 vs the 1971-2000 period (%); monthly values in percentage of the 1971-2000 average / *Monatliche Niederschlagsanomalien an der Station Lorient: Januar 2000 bis Dezember 2004 gegenüber dem Zeitraum 1971-2000 (%)*; *monatliche Werte in Prozent vom Durchschnitt der Jahre 1971-2000*

According to *Bárdossy and Caspary* (1990), this winter rainfall increase was connected to a higher frequency of westerlies over Europe, but during the period between November 2000 and March 2001, the southerly circulation types were more frequent (39.7% of all circulation types) than the westerly circulation types (30.5%).

#### 4.1.2 Daily analysis for the 2000-2001 cold season

Wet winters in Western Europe are characterised by the occurrence of several periods with cyclonic weather patterns over the Atlantic Ocean and Europe. The prevailing winds in western-Atlantic Europe blow from the southwest quadrant (e.g. *Barrow and Hulme* 1997) and studies on the linkage between circulation patterns and precipitation amounts have shown that SW circulations produce the heaviest

precipitation in different regions even in eastern France (*Blanchet* 1981, *Claval* 1972, *Contat et al.* 1965). Results of the analysis using the Hess-Brezowsky classification showed that the proportion of the SW circulation types was 51.7% of the southerly circulation types and 20.5% of all circulation types between November 2000 and March 2001, including several longer periods of SW circulation during winter (between 1 and 9 December, between 1 and 6 January, between 22 and 28 January, and between 3 and 9 February). The 2000-2001 winter (December 2000, January and February 2001) recorded the highest occurrence of SWZ days since 1881 (20 days). Relative precipitation for each major circulation type showed important differences between the months of the 2000-2001 cold season (*Fig. 5*).

Relative precipitation for the westerly and southerly circulation types was 82.3% of all GWT (westerly: 32.1% and southerly: 50.2%) between

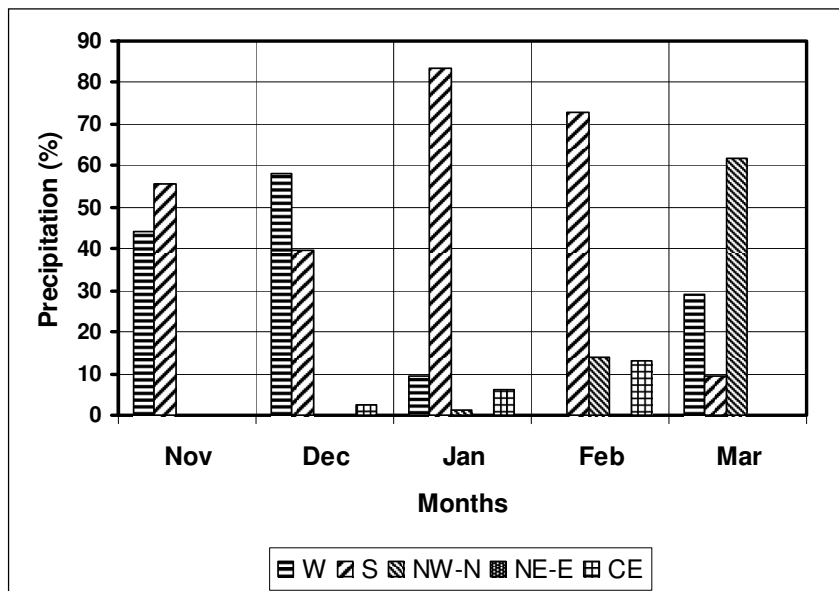


Fig. 5 Precipitation distribution at Lorient by Hess-Brezowsky GWT and by month during the 2000-2001 cold season; W: westerly circulation types, S: southerly circulation types, NW-N: northwesterly and northerly circulation types, NE-E: northeasterly and easterly circulation types, CE: main high/low pressure area over Central Europe / Niederschlagsverteilung in Lorient nach Hess-Brezowsky-GWT und Monat im Winter 2000-2001; W: westliche Zirkulationstypen, S: südliche Zirkulationstypen, NW-N: nordwestliche und nördliche Zirkulationstypen, NE-E: nordöstliche und östliche Zirkulationstypen, CE: vorrangiges Hoch- bzw. Tiefdruckgebiet über Mitteleuropa

November 2000 and March 2001. Precipitation during the early cold season (November-December) resulted from both westerly and southerly circulation types, and most of the precipitation during January and February was associated with southerly circulation types. March was characterised by high precipitation associated with northwesterly-north circulation types. *Figure 6* confirms and specifies these results. In NW France, the French national weather agency Météo-France sends flood alerts after a daily rainfall of more than 20 mm. Several daily rainfall events of more than 20 mm occurred during the remarkably wet 2000-2001 cold season. During the period of November 2000 – March 2001, most of the daily rainfall of more than 20 mm at Lorient was related to southerly (TB, TRW, SWZ, SWA) and westerly (WZ,

WS) circulation types. The long (16 days) and rainy period of southerly circulation during the month of November 2000 (total amount: 113.6 mm with two maxima: 11 November, 30.2 mm and 21 November, 24 mm) was a succession of rain-producing weather patterns over the Atlantic western Europe (TB, then TRW), characterised by a surface low over the British Isles. The weather pattern of the HNZ days of March 2001 was close to the previous weather patterns, because a S or SW surface flow over the west of France was associated with an Atlantic surface low. The longest succession of heavy rainfall events (between November 2000 and early January 2001) was characterised by a series of several days with alternating westerly and southerly circulation types. The heaviest rainfall event at Lorient was recorded at

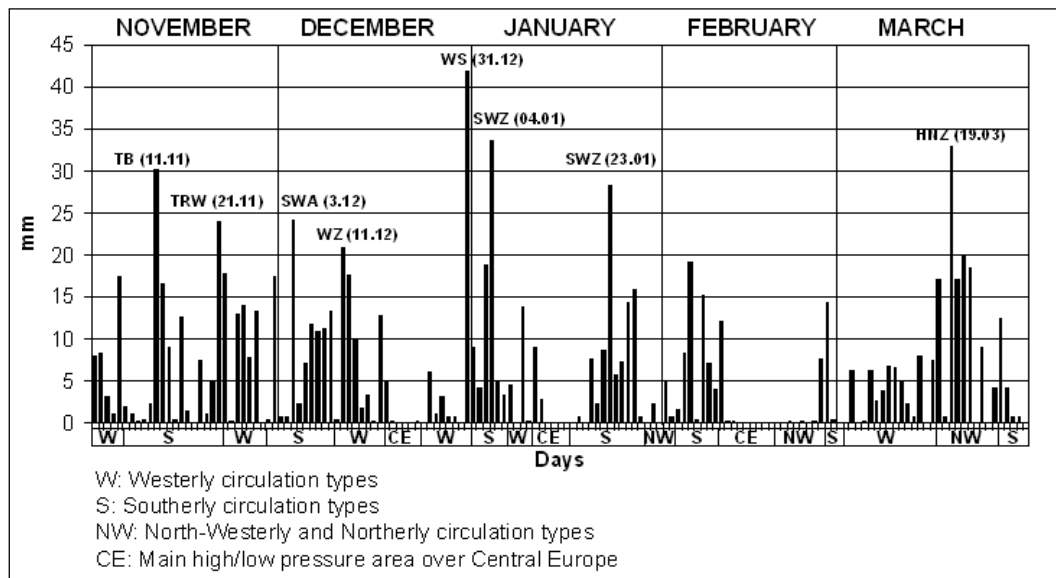


Fig. 6 Daily rainfall at Lorient (vertical bars) and Hess-Brezowsky GWT (bottom horizontal bar) during the 2000-2001 cold season; the corresponding GWT is mentioned for each rainfall event > 20 mm, with the date of the event. / *Täglicher Niederschlag in Lorient (vertikale Balken) und Hess-Brezowsky-GWT (unterer horizontaler Balken) im Winter 2000-2001; die entsprechende GWT ist für jedes Niederschlagsereignis > 20 mm erwähnt, mit dem Datum des Ereignisses.*

the end of this period (on 31 December 2000: 41.8 mm; the last day of a westerly period).

The heavy rainfall events affecting Brittany during the wettest days of the 2000-2001 cold season (31 December 2000: WS; 11 November 2000: TB; 4 January 2001: SWZ; 19 March 2001: HNZ) were generated by large-scale disturbed weather systems associated with an Atlantic low (Fig. 7). The low was located close to the British Isles (on 11 November 2000; 4 January 2001) or further westwards over the North Atlantic Ocean (on 31 December 2000; 19 March 2001), but the two highest daily rainfall amounts (on 31 December 2000: 41.8 mm; 4 January 2001: 33.6 mm) were associated with a westerly or southwesterly circulation type. As shown by Moron (1990), the meridional circulations with a low located near the British Isles (e.g. on 11 November 2000) can be similar to a SW circulation, with a prevailing

disturbance track over the northwestern part of Europe (including western France).

#### 4.2 Rainfall space-time variability analysis in the Scorff catchment using three reference stations

Figure 8 shows the comparison between the monthly rainfall amounts for the 2000-2004 period at the three reference stations located in the Scorff catchment. The coastal station (Lorient) was clearly less rainy than the other two (inland) stations. Topographical effects and especially the roughness of the hilly area cause higher rainfall amounts at the inland stations. The farthest inland station (Plouray) is the rainiest station: Plouray is located close to the southern slope of the Black Mountains, which reach about 300 m on the north-western edge of the Scorff catchment. For the month of December 2000,

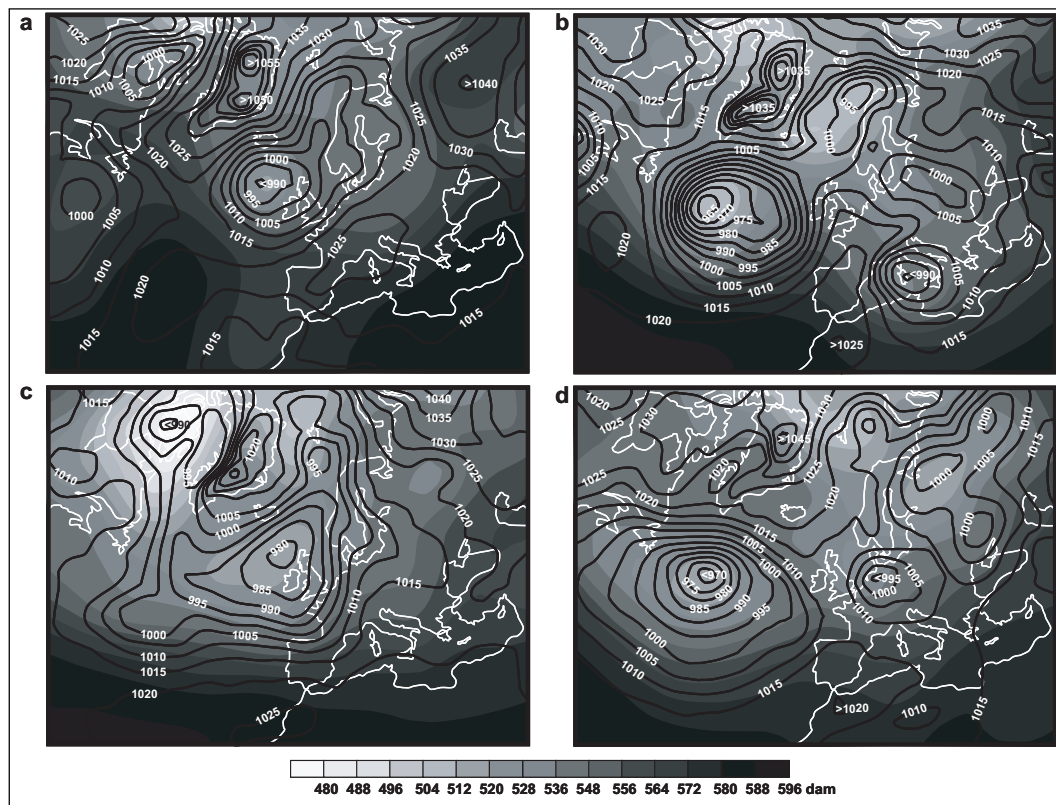


Fig. 7 Surface and high level maps (North Atlantic Ocean and Europe): sea level pressure (hPa) and geopotential at 500 hPa level (dam) of weather situations producing high daily rainfall amounts during the 2000-2001 cold season, adapted from NCEP Reanalysis, <http://www.wetterzentrale.de>; on a) 11 November 2000, b) 31 December 2000, c) 4 January 2001, d) 19 March 2001 / *Boden- und Höhenkarten (Nordatlantik und Europa): Luftdruck auf Meeresspiegelniveau (hPa) und Geopotential bei 500 hPa für Wetterlagen mit hohen täglichen Niederschlagsmengen im Winter 2000-2001, nach NCEP Reanalysis, <http://www.wetterzentrale.de>; am a) 11. November 2000, b) 31. Dezember 2000, c) 4. Januar 2001, d) 19. März 2001*

the rainfall amounts recorded at the stations of Lorient, Plouay and Plouray were 207.4 mm, 338.1 mm and 350 mm, respectively.

The difference between the rainfall amounts at coastal and inland stations was clearly shown during the wettest days, i.e. the event of 31 December 2000: the stations of Lorient, Plouay and Plouray recorded 41.8 mm, 74.1 mm and 69.6 mm respectively. The highest rainfall amounts were asso-

ciated with prevailing winds blowing from the southwest quadrant, therefore the southern or south-western exposure of the catchment enhanced heavy rainfall from S, SW and W circulation types in the hilly inland area. The ratio of days receiving a rainfall amount of > 10 mm and > 20 mm, for each GWL (Fig. 10), and the highest number of observations and the ratio of days with rainfall > 10 and > 20 mm for each GWL (Tab. 6) confirmed these observations.

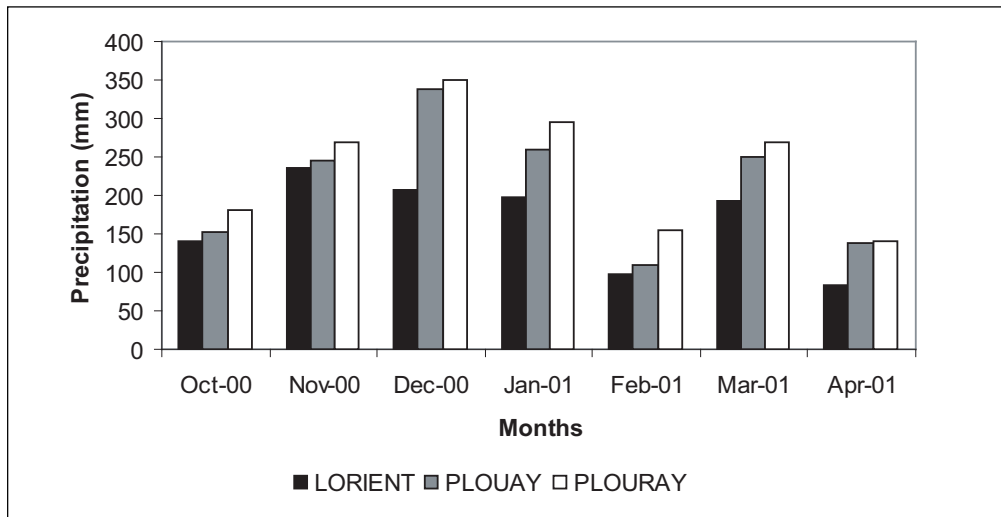


Fig. 8 Monthly rainfall at Lorient, Plouay and Plouray during the 2000-2001 cold season  
*Monatlicher Niederschlag in Lorient, Plouay und Plouray im Winter 2000-2001*

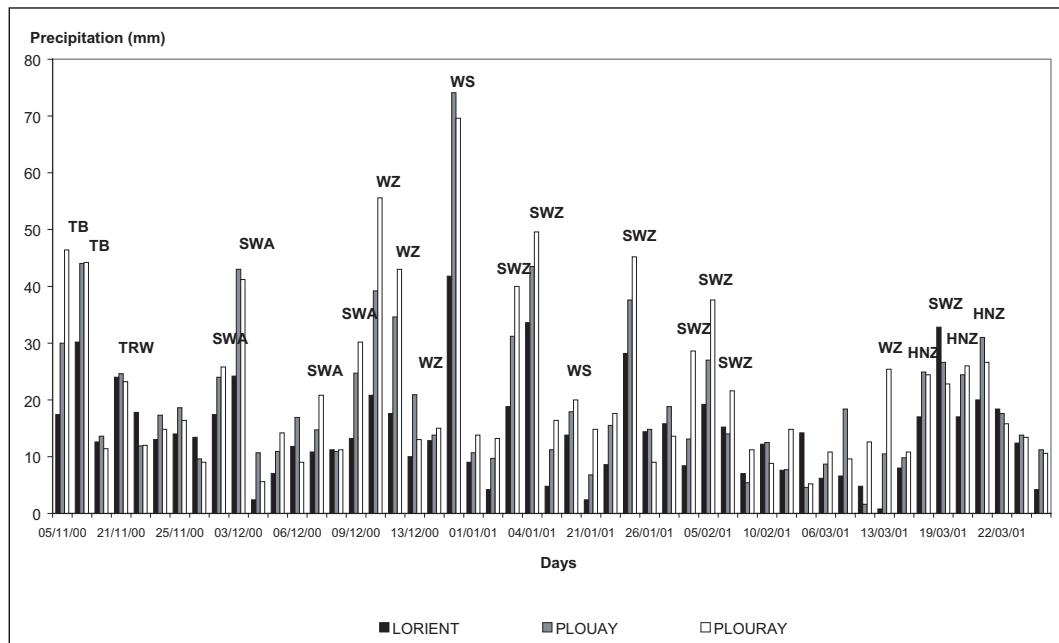


Fig. 9 Daily rainfall at Lorient, Plouay and Plouray (vertical bars) and Hess-Brezowsky circulation types corresponding to the highest daily rainfall amounts during the 2000-2001 cold season  
*Täglicher Niederschlag in Lorient, Plouay und Plouray (vertikale Balken) und Hess-Brezowsky-Zirkulationstypen für die höchsten täglichen Niederschlagsmengen im Winter 2000-2001*



The comparison between the ratio of days with rainfall  $> 10$  mm (Fig. 10a) and  $> 20$  mm (Fig. 10b) for the 2000–2004 period shows almost identical results: The rainy days were predominantly associated with the southerly circulation types (about 41 %), and secondly associated with the westerly circulation types ( $p > 10$  mm: about 37%;  $p > 20$  mm: about 36%). These results are similar to the precipitation ratio at Lorient (Fig. 2a). The rainy days associated with the southwesterly circulation types represented 56.1 % ( $p > 10$  mm) and 63.9% ( $p > 20$  mm) of the rainy days associated with southerly circulation types, followed by the rainy days associated with the individual TRW type ( $p > 10$  mm: 20.4 % and  $p > 20$  mm: 13.9 %). Results with reference to the individual GWL show that the days with precipitation  $> 10$  and  $> 20$  mm were most frequently associated with west cyclonic circulation types (WZ), followed by the southwest cyclonic circulation type (SWZ; Tab. 6).

The TRW circulation type and its associated south or south-westerly surface flow over western France caused heavy rainfall, especially during spring and summer but not necessarily inland (thunder showers), e.g. at Lorient on 7 July 2004 (73 mm). All the other events quoted in Table 6 were recorded during winter. Only two circulation types were classified as ‘anticyclonic’: SWA on 4 February 2002 and BM on 25 January 2004. Northwestern France was subject to the large-scale disturbed weather systems for these days, because of the disturbances track over the British Isles on 4 February 2002 (surface low located northwest of Scotland and Ireland) and over the Bay of Biscay on 25 January 2004 (surface low located west of Brittany). Except for the lower rainfall amount of 25 January 2004, highest winter daily amounts quoted in Table 6 were recorded at the inland stations (Plouay and Plouray), due to topographical and slope ef-

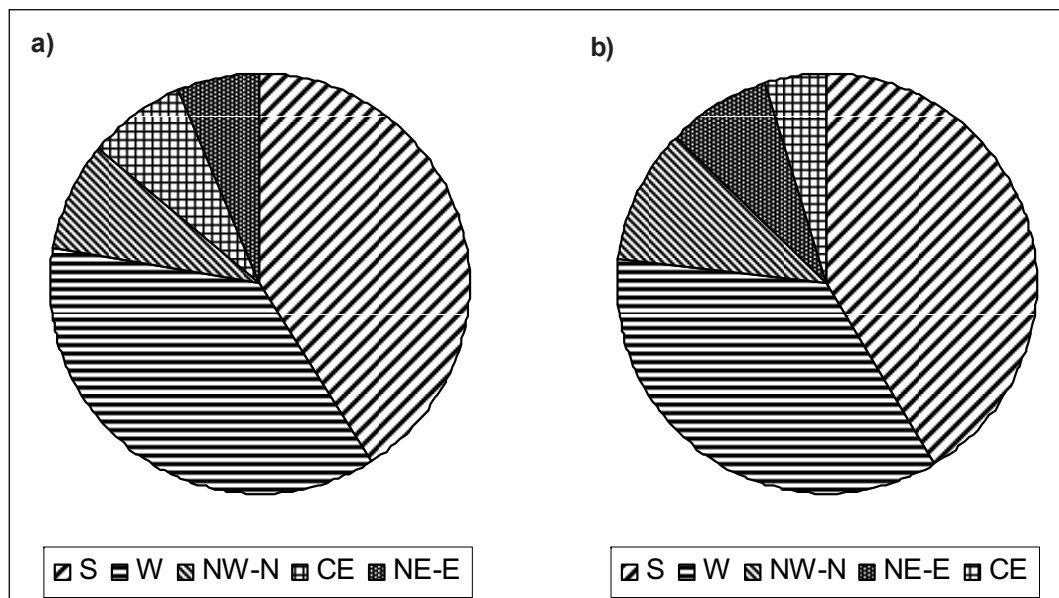


Fig. 10 Proportions of circulation types on days with rainfall  $> 10$  mm (a) and  $> 20$  mm (b) by Hess-Brezowsky GWT (years 2000 to 2004 at the stations of Lorient, Plouay and Plouray)  
 Anteile der Zirkulationstypen an Tagen mit Niederschlag  $> 10$  mm (a) bzw.  $> 20$  mm (b) nach Hess-Brezowsky-GWT (für die Jahre 2000 bis 2004 an den Stationen Lorient, Plouay und Plouray)

Tab. 6 Highest number of observations and ratio of days with precipitation (a) > 10 mm and (b) > 20 mm (observations in %, for each Hess-Brezowsky GWL, years 2000 to 2004 at the stations of Lorient, Plouay and Plouray) and maximum daily precipitation for each GWL ('Max. precipitation') at the stations of Lorient, Plouay and Plouray; 'Date': day on which the daily maximum precipitation amount was recorded / *Höchste Anzahl von Beobachtungen und Anteil der Tage mit Niederschlag (a) > 10 mm und (b) > 20 mm (Beobachtungen in %, für jede Hess-Brezowsky-GWL in den Jahren 2000 bis 2004 an den Stationen Lorient, Plouay und Plouray) und maximaler täglicher Niederschlag für jede GWL ('Max. precipitation') an den Stationen Lorient, Plouay und Plouray; 'Date': Tag, an dem die maximale tägliche Niederschlagsmenge aufgezeichnet wurde*

a)	GWL	Observations (%)	Max. precipitation (mm)	Station	Date
	WZ	58 (24.4)	55.6	Plouray	11.12.2000
	SWZ	40 (16.8)	49.6	Plouray	04.01.2001
	TRW	20 (8.4)	73.0	Lorient	07.07.2004
	WW	17 (7.1)	42.2	Plouay	21.12.2002
	SWA	15 (6.3)	45.4	Plouray	04.02.2002
	BM	13 (5.5)	29.2	Lorient	25.01.2004

b)	GWL	Observations (%)	Max. precipitation (mm)	Station	Date
	WZ	20 (23.0)	55.6	Plouray	11.12.2000
	SWZ	16 (18.4)	49.6	Plouray	04.01.2001
	SWA	7 (8.0)	45.4	Plouray	04.02.2002
	WW	6 (6.9)	42.2	Plouay	21.12.2002
	TRW	5 (5.7)	73.0	Lorient	07.07.2004

facts. The comparison between the two wet cold seasons of 2000-2001 and 2002-2003 showed a more important difference during the 2000-2001 winter between the monthly precipitation amounts of Lorient and the two inland stations (Fig. 11).

Figure 11 suggests that the topographical effect, which causes a difference in precipitation between Lorient and the inland stations, could be enhanced or weakened depending on the prevailing rainfall circulation types. Figure 12a shows the high interannual variability of the GWT frequency in winter. The precipitation ratio at Lorient for each GWT (Fig. 12b) pointed out the two remarkable winters of 2000-2001 and 2002-2003.

Figure 12b shows that 63.2 % of the precipitation was due to the southerly circulation types (S: 40 % of all circulation types) during the 2000-2001 winter,

whereas 62.2 % of the precipitation of the 2002-2003 winter was due to the westerly circulation (W: 31.1 % of all circulation types). The coastal station (Lorient) was clearly less rainy than the other two (inland) stations. Because of the southern or south-western exposure of the catchment, the precipitation due to the high occurrence of SW circulation types during the 2000-2001 winter was enhanced at the inland stations. On the other hand, during the 2002-2003 winter, the exposure of the watershed was less favourable to a contrasted rainfall spatial distribution, because the zonal-westerly GWL were the prevailing rainy circulation types.

## 5. Conclusion

The results shown in this paper point out the relevance of the Hess-Brezowsky classification

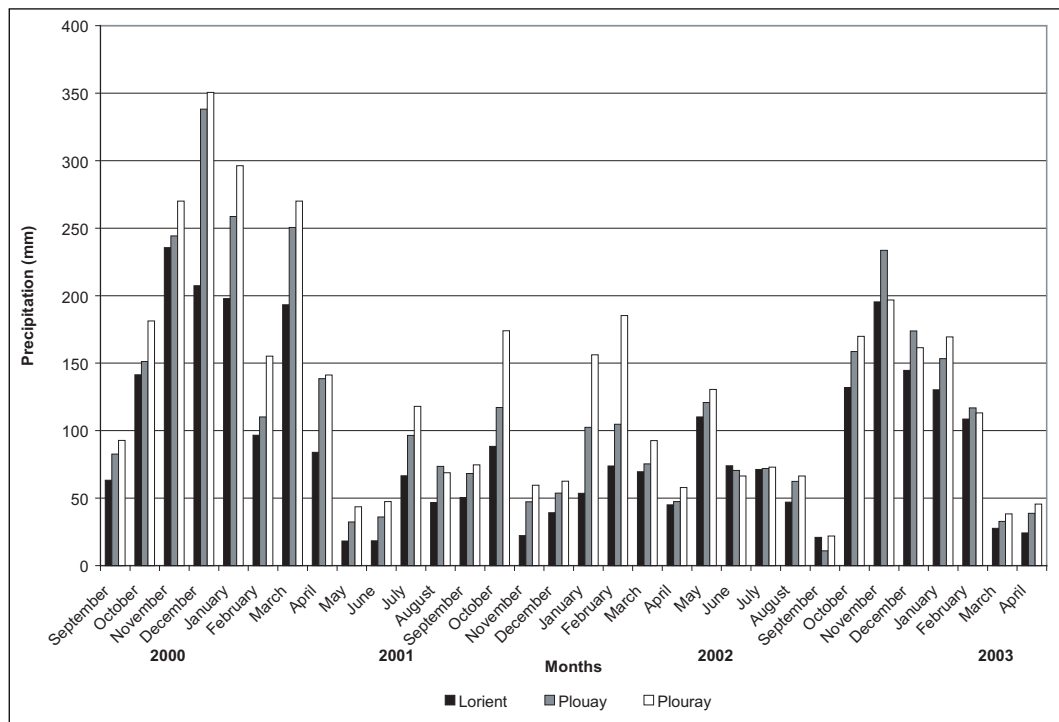


Fig. 11 Monthly precipitation at Lorient, Plouay and Plouray for the period 2000-2003  
*Monatlicher Niederschlag in Lorient, Plouay und Plouray für den Zeitraum 2000-2003*

of air circulation patterns in the identification of weather patterns producing significant winter precipitation in Brittany. The most frequent occurrence of rainy days associated with southerly and westerly GWLs confirm well-known observations in western Europe and justify the use of the Hess-Brezowsky classification in other areas outside Central Europe. The Hess-Brezowsky classification allows to identify precisely the rainy-air circulation patterns in western France and is therefore a useful tool to classify the rainfall events. A typology of rainy winters depending on the occurrence of circulation patterns and their effects on the spatial distribution of rainfall can be proposed and developed.

The remarkably wet 2000-2001 winter was characterised by a high spatial rainfall variability

between the three selected stations of the Scorff watershed and by generally high rainfall amounts. On the other hand, the spatial variability between the stations was relatively weak during the 2002-2003 winter. Observations and analysis using the Hess-Brezowsky classification of circulation patterns confirm that the rainfall circulation types in the Scorff watershed during winter are characterised by surface flows blowing from the southwest quadrant. Because of the exposure of the watershed, the precipitation due to the high occurrence of SW circulation types during the 2000-2001 winter was enhanced at the inland stations. During the 2002-2003 winter, the watershed exposure was less favourable to a contrasting spatial distribution of precipitation, essentially due to the prevailing zonal-westerly circulation types. Further analysis will be carried out using daily pre-

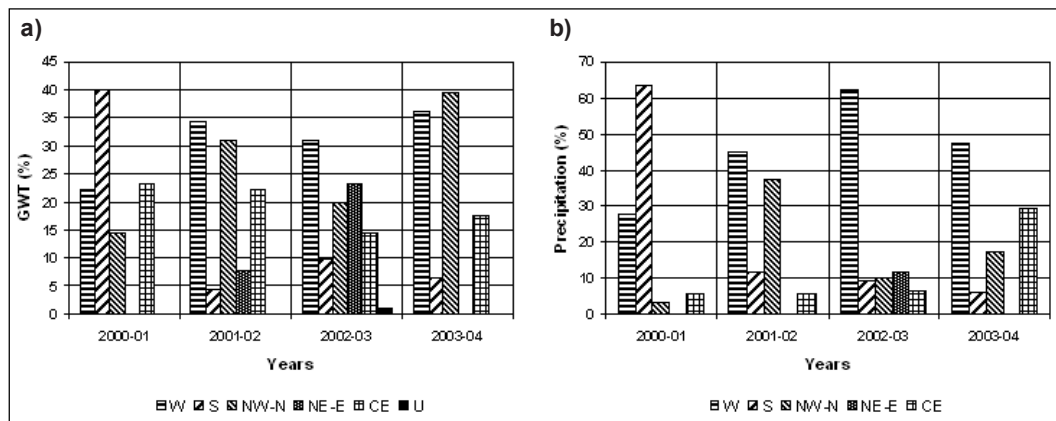


Fig. 12 Proportions of Hess-Brezowsky GWT (a) for winter (DJF) 2000-2001 to 2003-2004 and (b) precipitation ratio at Lorient for each Hess-Brezowsky GWT, winters 2000-2001 to 2003-2004; W: westerly circulation types, S: southerly circulation types, NW-N: northwesterly and northerly circulation types, NE-E: northeasterly and easterly circulation types, CE: main high/low pressure area over Central Europe, U: unclassified circulation types / Anteile der Hess-Brezowsky-GWT (a) in den Wintern 2000-2001 bis 2003-2004 und (b) Niederschlagsanteile in Lorient jedes Hess-Brezowsky-GWT für die Winter 2000-2001 bis 2003-2004; W: westliche Zirkulationstypen, S: südliche Zirkulationstypen, NW-N: nordwestliche und nördliche Zirkulationstypen, NE-E: nordöstliche und östliche Zirkulationstypen, CE: vorrangiges Hoch- bzw. Tiefdruckgebiet über Mitteleuropa

precipitation data and a larger sample of weather stations located in more varied sites during a longer time-period, in order to validate these results and to draw up more detailed maps. The weather pattern analysis will be carried on using the recent objective computational version of the Hess-Brezowsky classification (James 2007, <http://www.cost733.org/GWL/ObjGWL.html>). The interannual variability of the frequency of GWT and GWL and its impact on the proportion of heavy precipitation for the last century will be examined in further studies. Investigations of rainy-air circulation patterns since 1850 will allow to reveal trends and identify their possible connection with climate change. Furthermore, a typology of rainy winters depending on the occurrence of air circulation patterns and their effects on the spatial distribution of rainfall can be proposed and developed, also highlighting the connection with hydrological processes (floods).

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*Summary: Assessing Precipitation and Large-Scale Weather Situations in Brittany: the Usefulness of the Hess-Brezowsky Classification*

A differentiated knowledge of the rainy-air circulation types was developed as part of the RICLIM 2663 CNRS research group work on climate risks, within the framework of two research programmes about 'air-mass dynamics and climate risks', supported by MAIF Foundation, and about 'climatic change, agricultural systems, natural resources and territorial development (CLIMASTER)', supported by INRA and the administrations of four regions in western France. For this study, the Scorff watershed located in western Brittany was chosen because land-use and land-cover changes in this area raise questions about the environmental effects of the anthropogenic planning and activities. Environmental problems (pollutant fluxes, river risings) are increased by the presence of fields with no or little vegetation, during the rainiest period of autumn and winter. The climate impact on the Scorff watershed was first analysed through the study of the space-time variability of precipitation during four winters

between 2000 and 2004, which were representative of different land-cover conditions. The identification of rainy-air circulation types was achieved using the Hess-Brezowsky classification of air-circulation patterns for the 2000-2004 period. Precipitation amounts and percentages were calculated for each major type of circulation (*Großwettertypen*: GWT) at the weather station of Lorient for the 2000-2004 period and for each year of this period, in order to identify the rainiest circulation types during the cold season. More detailed observations and analysis using the Hess-Brezowsky classification allowed to point up linkages between the Hess-Brezowsky circulation subtypes (*Großwetterlagen*: GWL) and daily precipitation during remarkably wet cold seasons at the weather stations of Lorient, Plouay and Plouray. About three quarters of the daily precipitation at the weather station of Lorient were associated with southerly (40%) and westerly (32%) circulation types, which include the most frequent circulation types throughout the year in western Europe. The westerly and southerly circulation types caused the highest rainfall amounts during the cold season months. The prevailing southerly circulations, including several longer periods with south westerly circulations, caused the remarkably high precipitation amounts of the wet winter of 2000-2001. The southern or south-western exposure of the watershed in the hilly inland area enhanced the heavy rainfall generated by the W, SW and S circulation types, and the difference between the rainfall amounts of coastal and inland stations was the most remarkable during the wettest days. The daily rainfalls of more than 20 mm were predominantly associated with the southerly circulation types (especially the SW types: 63.9% of the southerly circulation types) and secondly with the westerly circulation types. The comparison between the two wet winters of 2000-2001 and 2002-2003 showed a stronger difference between the monthly precipitation amounts of Lorient and those of the two inland stations during the 2000-2001 winter. While 63.2% of the precipitation was associated with southerly circulations types during the 2000-2001 winter, 62.2% of the precipitation of the 2002-2003 winter was associated with westerly circulation types. Because of the exposure of the catchment, the rainfall associated with the high occurrence of SW circulation types during the 2000-



2001 winter was enhanced inland. On the other hand, during the 2002-2003 winter, with prevailing rainfall generated by westerly circulations, the exposure of the catchment was less favourable to a contrasted spatial distribution of precipitation. One might add here that in the Scorff watershed the relationship between rainfall and land-cover management during winter seemed to be significant when a high spatial variability of rainfall was noted. In western Brittany, heavy precipitation in winter constrains farmers to leave their fields fallow, without any crops. The high level of soil moisture prevents any efficient work of agricultural machinery in the fields. This combined approach to climate and land cover will be developed in further studies.

*Zusammenfassung: Die Untersuchung von Niederschlag und Großwetterlagen in der Bretagne: die Brauchbarkeit der Hess-Brezowsky-Klassifikation*

Als Teil der Arbeit der Forschungsgruppe RICLIM 2663 CNRS über Klimarisiken – im Rahmen zweier Forschungsprogramme zu „Luftmassendynamik und Klimarisiken“, gefördert von der MAIF-Stiftung, sowie zu „Klimawandel, Agrarsysteme, Naturressourcen und räumliche Entwicklung“ (CLIMAS-TER-Programm), gefördert von INRA und vier westfranzösischen Regionalverwaltungen – wurde eine differenzierte Analyse der niederschlagsreichen Großwetterlagen für das Einzugsgebiet des Scorff in der westlichen Bretagne entwickelt. Dieses Einzugsgebiet wurde ausgewählt, da sich hier aufgrund des Wandels von Landnutzung und Bodenbedeckung besondere Fragen stellen hinsichtlich der Auswirkungen anthropogener Aktivitäten auf die Umwelt. Umweltprobleme, wie z.B. Schadstoffflüsse oder Überschwemmungen, treten vor allem dann auf, wenn während der regenreichsten Zeit im Winter und Herbst die Pflanzendecke fehlt oder nur gering vorhanden ist. Das Klima des Scorff-Einzugsgebietes wurde zunächst analysiert hinsichtlich der räumlichen und zeitlichen Variabilität des Niederschlags in den vier Wintern der Jahre 2000-2004, in denen unterschiedliche Bedingungen bei der Bodenbedeckung herrschten. Mit Hilfe der Hess-Brezowsky-Klassifikation für (Groß-)Wetterlagen gelang es, die niederschlagsreichen Luftmassenzirkulationstypen für die Jahre 2000-2004 zu identifizieren.

Für jeden Hauptzirkulationstyp (Großwettertyp, GWT) wurde die Niederschlagsmenge der Jahre 2000-2004 insgesamt sowie für jedes einzelne Jahr an der Wetterstation von Lorient gemessen und hinsichtlich ihrer prozentualen Verteilung dargestellt, um die niederschlagsreichsten Zirkulationstypen während der kalten Jahreszeit zu bestimmen. Ausführlichere Beobachtungen und Analysen unter Verwendung der Hess-Brezowsky-Klassifikation erlauben es, einen Zusammenhang zwischen den Hess-Brezowsky-Großwetterlagen (GWL) und den täglichen Niederschlägen während der besonders feuchten Wintermonate an den Wetterstationen von Lorient, Plouay und Plouray aufzuzeigen. Ungefähr drei Viertel des täglichen Niederschlags an der Wetterstation von Lorient hängen mit südlichen (40 %) und westlichen (32 %) Zirkulationstypen zusammen, die ganzjährig die häufigsten Wetterlagen in Westeuropa bilden. Diese westlichen und südlichen Wetterlagen verursachen die höchsten Regenmengen während der Wintermonate. Die vorherrschenden südlichen Wetterlagen, einschließlich einiger längerer Perioden mit südwestlichen Wetterlagen, verursachen die bemerkenswert hohen Niederschläge des feuchten Winters 2000/2001. Die Süd- oder Südwestexposition des hügeligen Binnenlandes des Einzugsgebietes erhöhte noch den ohnehin starken Niederschlag, der durch West-, Südwest- und Südwestwetterlagen entstand; und der Unterschied zwischen den Niederschlagsmengen von Küsten- und Inlandsstationen war an den feuchtesten Tagen am größten. Eine Tagesniederschlagsmenge von mehr als 20 mm kann in erster Linie auf südliche Wetterlagen zurückgeführt werden (besonders auf südwestliche Lagen, die 63,9 % der südlichen Wetterlagen ausmachen) und in zweiter Linie auf westliche Wetterlagen. Der Vergleich zwischen den beiden feuchten Wintern 2000/2001 und 2002/2003 zeigt, dass der Unterschied in der monatlichen Niederschlagsmenge zwischen Lorient und den beiden Binnenlandstationen 2000/2001 größer war als 2002/2003. Während im Winter 2000/2001 63,2% des Niederschlags an südliche Wetterlagen gebunden waren, konnten im Winter 2002/2003 62,2 % des Niederschlags auf westliche Wetterlagen zurückgeführt werden. Im Binnenland traten aufgrund der Exposition des Einzugsgebietes während des Winters 2000/2001, der sich durch einen hohen Anteil an südwestlichen Wetter-



lagen ausgezeichnete, stärkere Niederschläge auf. Da im Winter 2002/2003 der Niederschlag vor allem westlichen Wetterlagen entstammte, führte die Exposition des Einzugsgebiets in dieser Zeit nicht zu größeren Unterschieden der Niederschlagsmengen zwischen Küste und Binnenland. An dieser Stelle ist anzufügen, dass die Beziehung zwischen den Niederschlägen und der Bodenbewirtschaftung im Winter vor allem dann signifikant erscheint, wenn eine hohe räumliche Variabilität der Niederschläge vorliegt. In der westlichen Bretagne zwingen die starken Niederschläge im Winter die Bauern dazu, in dieser Zeit ihre Felder brach liegen zu lassen. Die hohe Bodenfeuchte verhindert eine effiziente Arbeit der landwirtschaftlichen Maschinen auf den Feldern. Dieser Forschungsansatz, der Klima und Bodenbedeckung miteinander verknüpft, soll in zukünftigen Untersuchungen weiterentwickelt werden.

*Résumé: L'évaluation des précipitations et des situations météorologiques à grande échelle en Bretagne: l'utilité de la classification Hess-Brezowsky*

Une méthode d'analyse des types de circulations atmosphériques pluvieuses a été développée sur le bassin versant du Scorff dans le cadre du groupe de recherche RICLIM 2663 CNRS sur les risques climatiques, d'un programme soutenu par la Fondation MAIF (« Dynamique des masses d'air et risques climatiques ») et du programme CLIMASTER (« Changement climatique, systèmes agricoles, ressources naturelles et développement territorial ») soutenu par l'INRA et 4 régions de l'ouest de la France. Le bassin du Scorff, situé en Bretagne occidentale, a été choisi en raison des problèmes environnementaux causés dans ce secteur par les changements d'utilisation et d'occupation du sol, et plus généralement les aménagements et activités anthropiques. Ces problèmes environnementaux (transferts de polluants, crues) sont accrus par la présence de sols nus ou peu végétalisés durant la période pluvieuse d'automne-hiver. Dans cette étude préliminaire, l'impact du climat sur le bassin versant du Scorff a été étudié à travers la variabilité pluviométrique durant quatre hivers, de 2000 à 2004, qui sont représentatifs des différentes conditions d'occupation du sol observées dans la région. L'identification

des types de circulation atmosphérique a été réalisée au moyen de la classification de Hess-Brezowsky pour la période 2000-2004. Pour chaque « grand type » de circulation atmosphérique, ou GWT, les quantités et pourcentages de précipitations ont été calculés avec les données de la station de Lorient, pour la période 2000-2004 et pour chaque année, afin d'identifier les types de circulations les plus pluvieuses durant la saison froide. Des observations et analyses détaillées, utilisant la méthode Hess-Brezowsky, ont permis aussi de mettre en évidence des liens entre les types de circulations (GWL) et les précipitations quotidiennes durant les saisons froides remarquablement arrosées, pour les stations de Lorient, Plouay et Plouray. Environ les trois quarts des précipitations enregistrées à la station de Lorient étaient associées à des circulations de sud (40 %) et d'ouest (32 %), qui incluent les types de circulations les plus fréquemment observés toute l'année sur l'Europe occidentale. Les circulations d'ouest et de sud ont généré les précipitations les plus abondantes durant les saisons froides de la période étudiée. Des circulations de sud prédominantes, notamment des circulations de sud-ouest qui se sont produites durant de longues périodes, expliquent les précipitations exceptionnellement abondantes de l'hiver 2000-2001. L'exposition au sud ou au sud-ouest du bassin versant et le relief de collines de l'intérieur exacerbent les fortes précipitations liées aux circulations d'ouest, de sud-ouest et de sud, accentuant ainsi la différence de quantités de précipitations entre le secteur côtier et l'intérieur du bassin versant, très importante durant les journées les plus arrosées. Les précipitations quotidiennes de plus de 20 mm étaient associées en priorité à des circulations de sud (notamment de SW : 63.9 % des circulations de sud), et secondairement aux circulations d'ouest. La comparaison entre les hivers pluvieux de 2000-2001 et de 2002-2003 a montré une différence plus importante des quantités mensuelles de précipitation entre Lorient et les deux stations intérieures durant l'hiver 2000-2001. Alors que 63.2 % des précipitations de l'hiver 2000-2001 étaient associées à des circulations de sud, 62.2 % des précipitations de l'hiver 2002-2003 étaient associées à des circulations d'ouest. En raison de l'exposition du bassin versant, les précipitations associées aux circulations de sud-ouest ont été intensifiées sur les stations de l'intérieur durant l'hiver

2000-2001. En revanche, pendant l'hiver 2002-2003, dont une grande partie des précipitations était associée à des circulations d'ouest, l'exposition du bassin versant était moins favorable à une distribution spatiale contrastée des précipitations. Il convient d'ajouter que, dans le bassin versant du Scorff, la relation entre les précipitations et la gestion de l'occupation des sols durant l'hiver a semblé plus significative lorsque la variabilité spatiale des précipitations était importante. La gestion des cultures durant l'hiver en Bretagne est en effet fortement tributaire du volume des précipitations, qui si elles sont importantes, contraignent les agriculteurs à laisser leurs parcelles en sols nus sans aucune culture; les machines agricoles ne pouvant travailler le sol lorsqu'il est trop

humide. Cette approche croisée du climat et de l'occupation du sol sera développée ultérieurement.

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