CLIMATIC HAZARDS IN CHILE

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Abstract: Climatic hazards in Chile are assessed in terms of the influence of extra-tropical cyclones and either excess precipitation leading to floods or much reduced precipitation causing droughts. Some simple qualitative concepts have been developed for precipitation forecasting on an annual basis, in terms of above normal, normal or below normal categories. ENSO events are not explicitly treated as climatic hazards, except in so far as their contribution to precipitation with the understanding that an El-Nino situation will enhance precipitation and a La Nina event will reduce precipitation generally in south-east Pacific. Finally, these hazards are assessed in view of possible sea level rise due to greenhouse warming and coastal land uplift or subsidence due to tectonic processes.

1.0 INTRODUCTION

Climatic hazards in Chile fall generally in two classes. The first type is associated with cyclones in the forms of waves, either short period wind waves and swell or long gravity waves such as storm surges. The second type of hazard is due to precipitation or lack of it, i.e. in the form of floods and droughts. The second type of hazard is not totally independent of the first one because excess precipitation from cyclones can contribute to flooding.

ENSO (El-Nino Southern Oscillation) events will not be treated as a natural hazard, except their contribution to precipitation increase or decrease for floods and droughts, only the meteorological aspects alone will be considered here. For example, for flooding, the important roles played by orograhical, hydrological and geomorphological factors will not be treated here.

Finally a somewhat new technique of weather analysis using the so-called Mobile Polar Highs (MPH's) approach (Le Roux, 1998) could supplement the traditional analysis of emphasizing the low pressure systems.

2.0 CYCLONES AFFECTING CHILE

The ocean basins in which tropical cyclones (TC's) are generated is shown in Figure 1. It can be seen that no TC's are generated close to Chile. Sometimes it is possible that, even though tropical cyclogenesis may not occur near by, their tracks could still impact a given area, but as can be seen from Figure 2, even this does not happen for Chile.

However, there are extra-tropical cyclones (ETC's) that traverse the southern part of Chile from west to east as can be seen from Figure 3.

In principle, the wind fields and the pressure gradients associated with the ETC's could give rise to storm surges on the southern part of the Chilean coast. However, according to Anon (1993) storm surges are not significant on the coast of Chile. The amplitude in meters of storm surges on the Chilean coast for return periods of 1, 10, 100 and 1000 years, respectively are 0.3, 0.4, 0.4, 0.5.

3.0 PERCIPITATION OVER CHILE

Earlier it was mentioned that ENSO events by themselves will not be treated as hazards. However, Figure 4 schematically depicts the types of hazards globally that could be associated with ENSO events.

As for precipitation forecasting for floods and droughts in Chile, some of the meteorological and oceanographical factors that are relevant are shown schematically in Figure 5.

Aceituno et al (1993) state that the key atmospheric factors determining the climate characteristics along the extra tropical west coast of South America are the subtropical anticyclone in the southeastern Pacific and the circumpolar belt of migratory low pressure systems. In Figure 3 the tracks of these low pressure systems (ETC's) have been shown. The sub-tropical anticyclones in the south-east Pacific and south-west Atlantic (Figure 5) have been designated for convenience as the Chile high and the Argentina high. The general oceanic conditions around Chile can be seen from Figure 6.

It is well know (Beran and Rodier (1985)) that there is a connection between high pressure centers and droughts. Here an attempt was made for very simple qualitative precipitation forecasting over Chile with possible application to floods as well as to droughts, making use of only three categories at any given location: is the annual value above normal, normal or below normal.

Long duration precipitation data records for 43 stations listed in Table 1 and shown in Figure 7 (for Station 20 no data record was available) were used to determine if the precipitation was above or below average for any given year as compared to a long term average value.

Table 1
Precipitation Stations in Chile

Station #	Station	Agreement	Station#	Station	Agreement
1	Punta Tortuga	75%	23	Punta Tumbes	54%
2	La Serena	74%	24	Concepcion	69%
3	Vicuna	71%	25	Nonquen	66%
4	Ovalle	73%	26	Isla Santa Maria	68%
5	Combarbala	80%	27	San Cristoba	66%
6	Puerto Oscuro	79%	28	Los Angeles	67%
7	Petorca	80%	29	Nacimiento	63%
8	Catapilco	84%	30	Angol	70%
9	Punta Angeles	73%	31	Los Suaces	69%
10	Limache	83%	32	Victoria	72%
11	Quilpue	74%	33	El Aromo	70%
12	Santiago	90%	34	Padre Las Casas	59%
13	San Bernardo	75%	35	Puerto Saavendra	57%
14	Isla Mas Afuera	58%	36	Purulon	69%
15	Acuelo	75%	37	Panguipulli	62%
16	La Obra	77%	38	Valdivia	66%
17	Talcahuano	68%	39	Puerto Montt	64%
18	Constitucion	73%	40	Ancud	62%
19	Punta Carranza	69%	41	Isla Guafo	60%
20	Cauquenes		42	Islote Evangelista	48%
21	Parral	66%	43	Bahia Felix	48%
22	San Carlos	65%	44	Punta Arenas	57%

Average of 43 stations: 68%
Average of 40 stations: 70%

As a zero order precipitation forecast, to determine whether a given year would have above or below average rainfall, a very simple criterion was used. It is assumed that El-Nino years will produce above average and La Nina and normal years produce below average value, the average successes rate of hindcast is 68%.

For 43 stations, the best value was for Santiago at 90% and the worst value for Bahia Felix at 48%. Stations 42, 43 and 44 are so far south, one would not expect the ENSO signal to be strong there. If these three stations are excluded, then the average rate of success is 70%. It is expected that when all the other climatic factors shown in Figure 5 are included as well as local orographic factors at each station, then the average success rate might climb to about 85%.

4.0 Mobile Polar Highs (MPH's)

In traditional weather analysis, the emphasis is always on migratory low pressure systems (MLP's). This can be supplemented with an additional analysis using the concept of Mobile Polar Highs (MPH's) advanced by Le Roux (1998) in which it is the high pressure systems that are routinely kept track of. It is believed that this MPH approach is particularly relevant for understanding climate change and climatic shifts.

Figure 8 shows the tracks of the MPH's in the southern hemisphere (SH) that will impact on the weather and climate of Chile. Figure 9 shows the dynamics of winter weather in South America. MPH's shown in Figure 8 move out in all directions from the Antarctic, and the three southern aerological spaces intercommunicate easily before coming under the influence of the Andes, which have a marked effect north of 30°S (Le Roux, 1998).

5.0 SEA LEVEL RISE (SLR)

According to Figure 10, the northern part of the Chilean coast is experiencing submergence while the southern part is subjected to uplift.

Table 2 lists the relative sea level change at some Chilean stations

Table 2

Variation of the Relative Sea Level (RSL) in millimeters per year (adapted from Emery and Aubrey (1991).

Station	**Number of Years of Data Record**	**Rate of Change of RSL**
Arica	21	3.5
Antofagasta	25	-3.4
Caldera	21	1.7
Valparaiso	13	1.7

Figure 11 shows that the rivers in northern Chile contribute about 120 km^3 per year of fluvial water annually into the ocean. Compared to the largest value on the globe (3,900) in Southeast Asia, this is not significant, but nevertheless could still be important for the local coastal processes.

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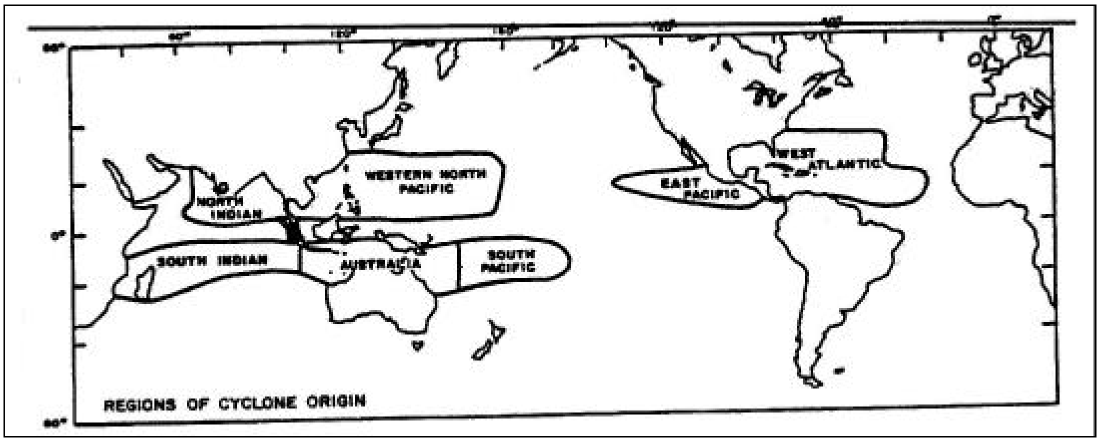

Figure 1

Ocean Basins in Which Tropical Cyclones are Generated
(From Gray, 1978)

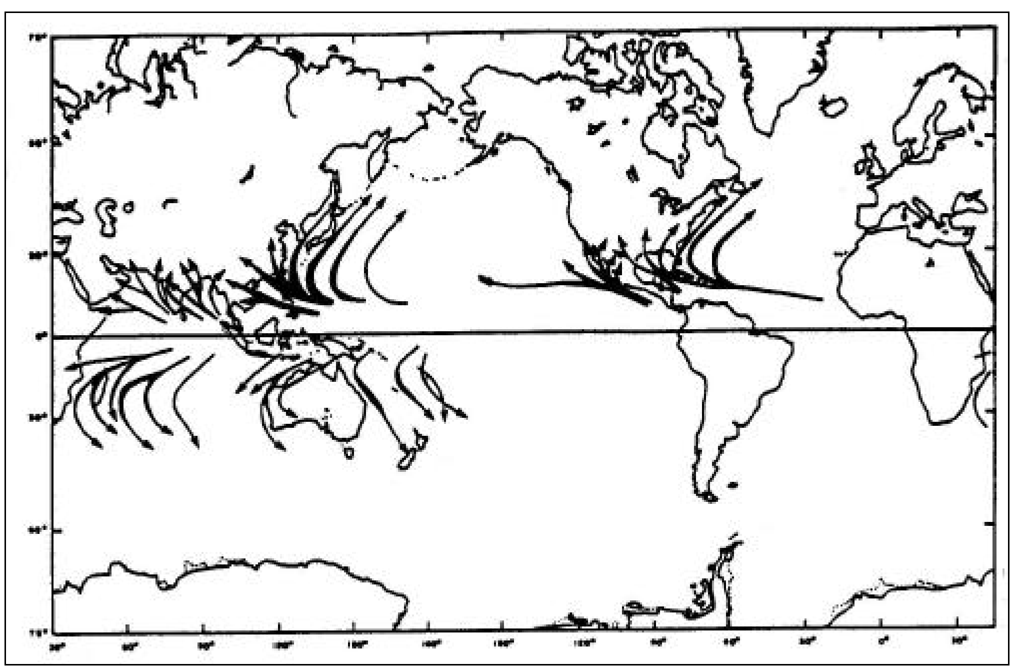

Figure 2
Preferred annual tropical cyclone paths. Arrow widths are proportional to storm frequencies along indicated paths. (Crutcher and Quayle 1974)

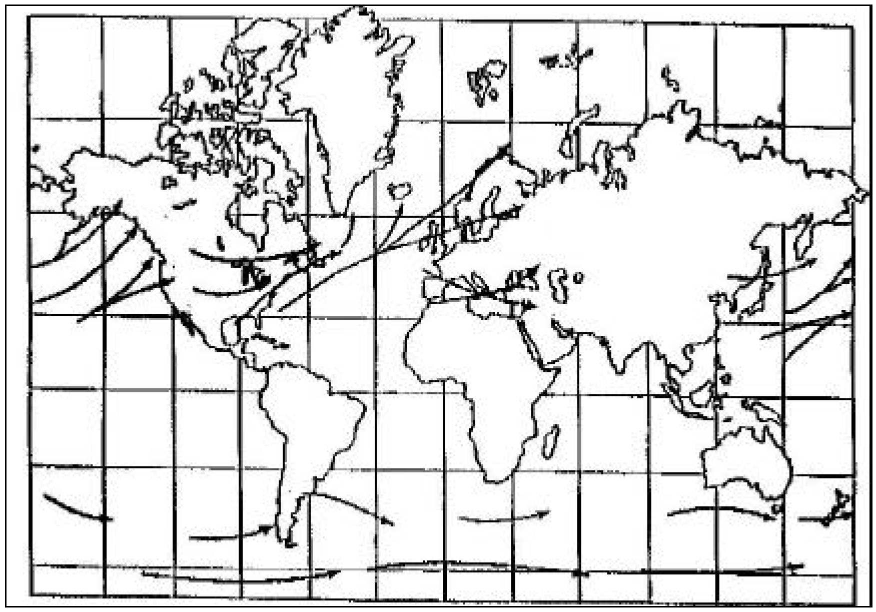

Figure 3
Generalized world-cyclone paths
(From Donn,   )

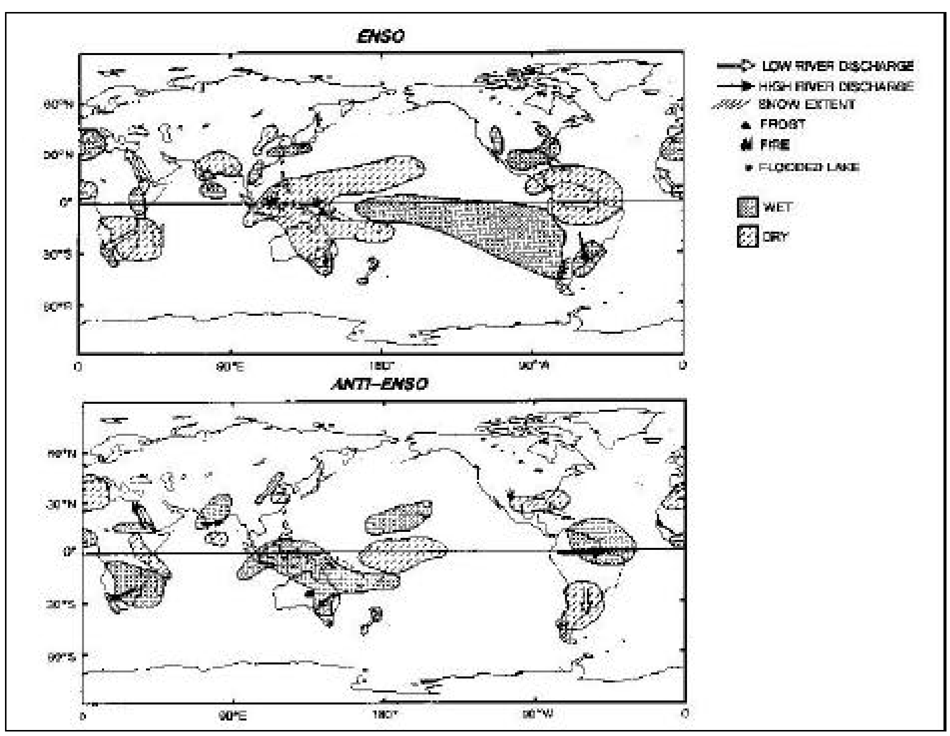

Figure 4
Climatic impacts associated with (a) El Nino and (b) La Nina phases derived
from historical record (Allan 1994)

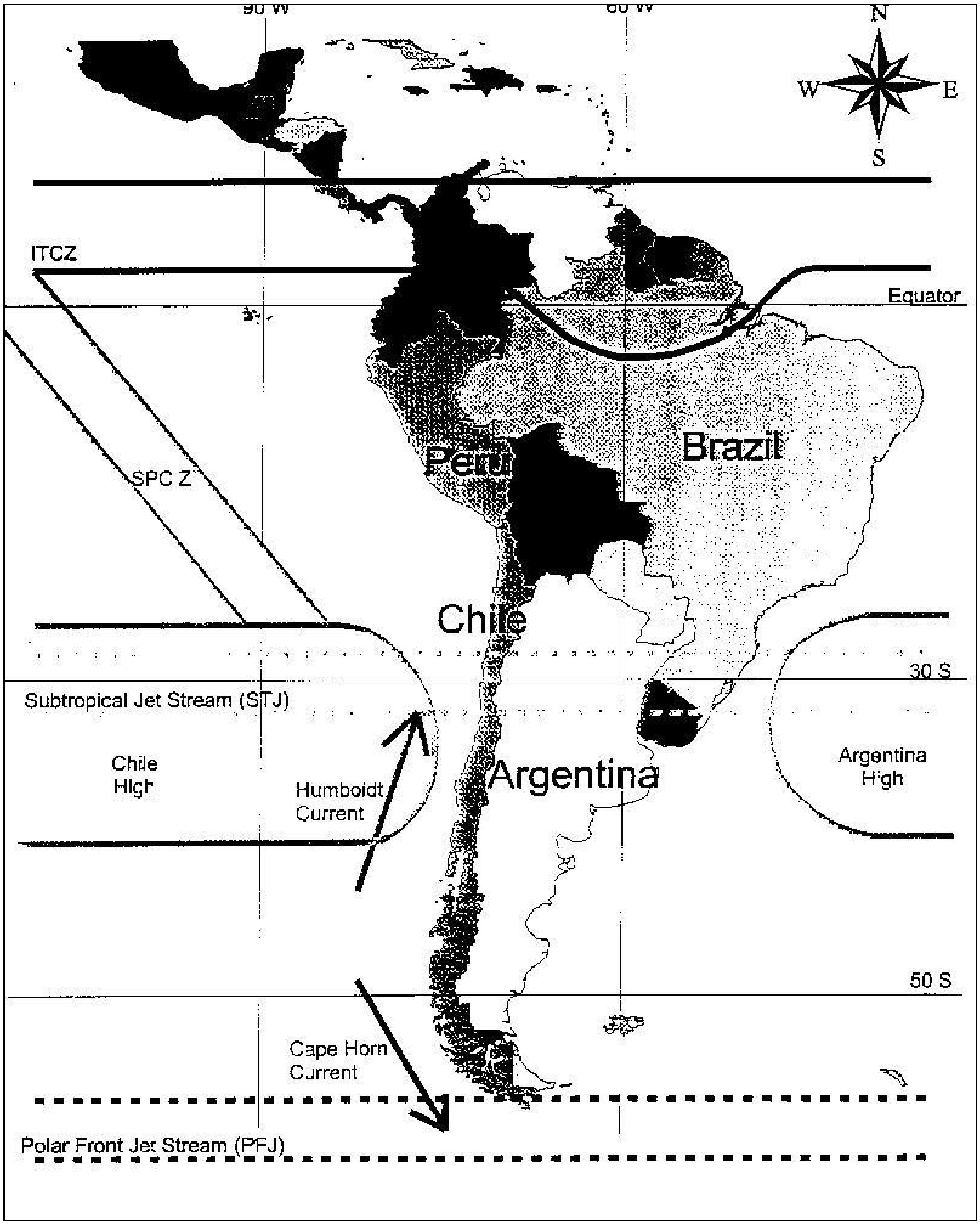

Figure 5

Meteorological and Oceanographic Parameters Relevant for the Climate of Chile

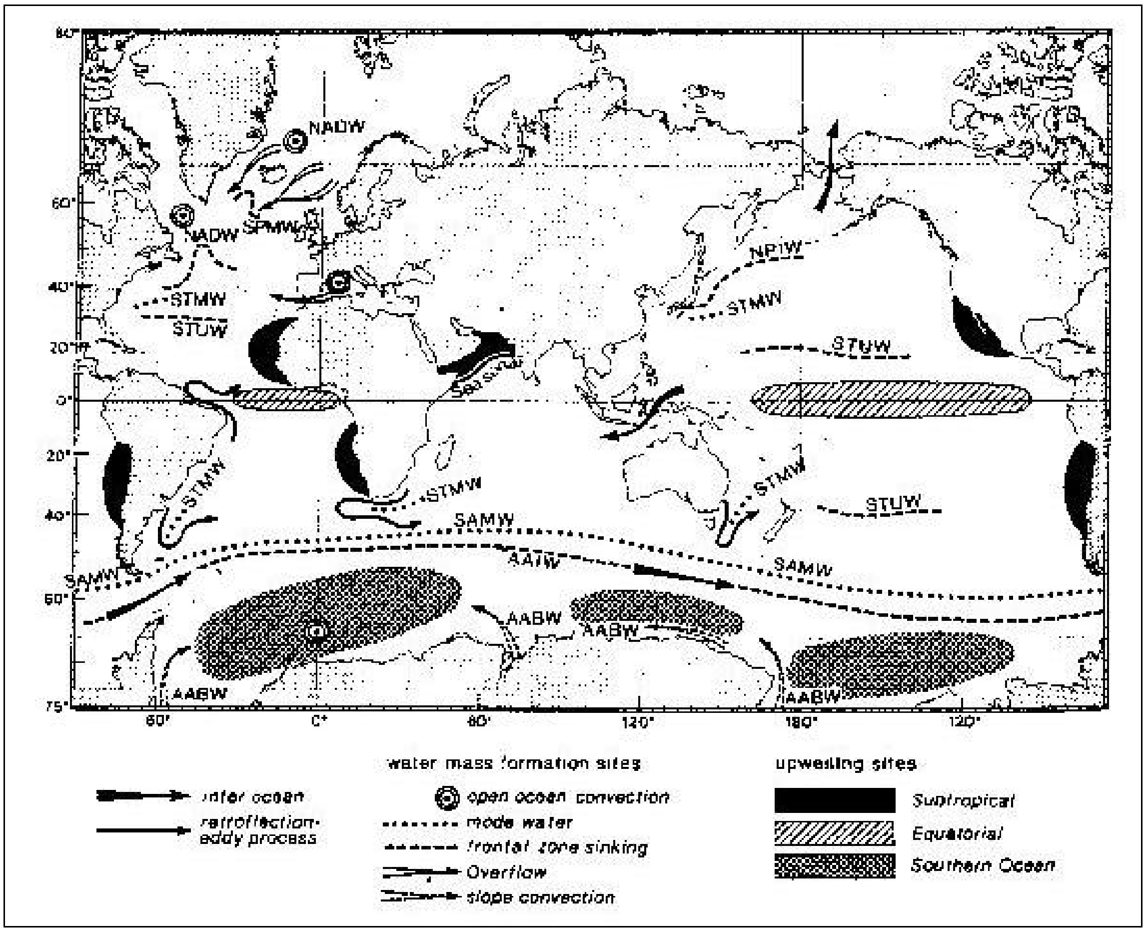

Figure 6

Location of generation and transformation areas of the major water masses: North Atlantic Deep Water (NADW), Antarctic Bottom Water (AABW), Subtropical Model Water (SAMW), Subtropical Underwater (STUW), Subpolar Mode Water (SPMW) and North Pacific Intermediate Water (NPIW): also indicated are interocean and intergyre exchange/retroflection regimes. The dashed line in the southern ocean circumpolar belt marks the polar front and the formation region for Antarctic Intermediate water (AAIW). In the regions where STUW forms, it produces the sub-surface salinity maximum. (From Clivar, 1995)

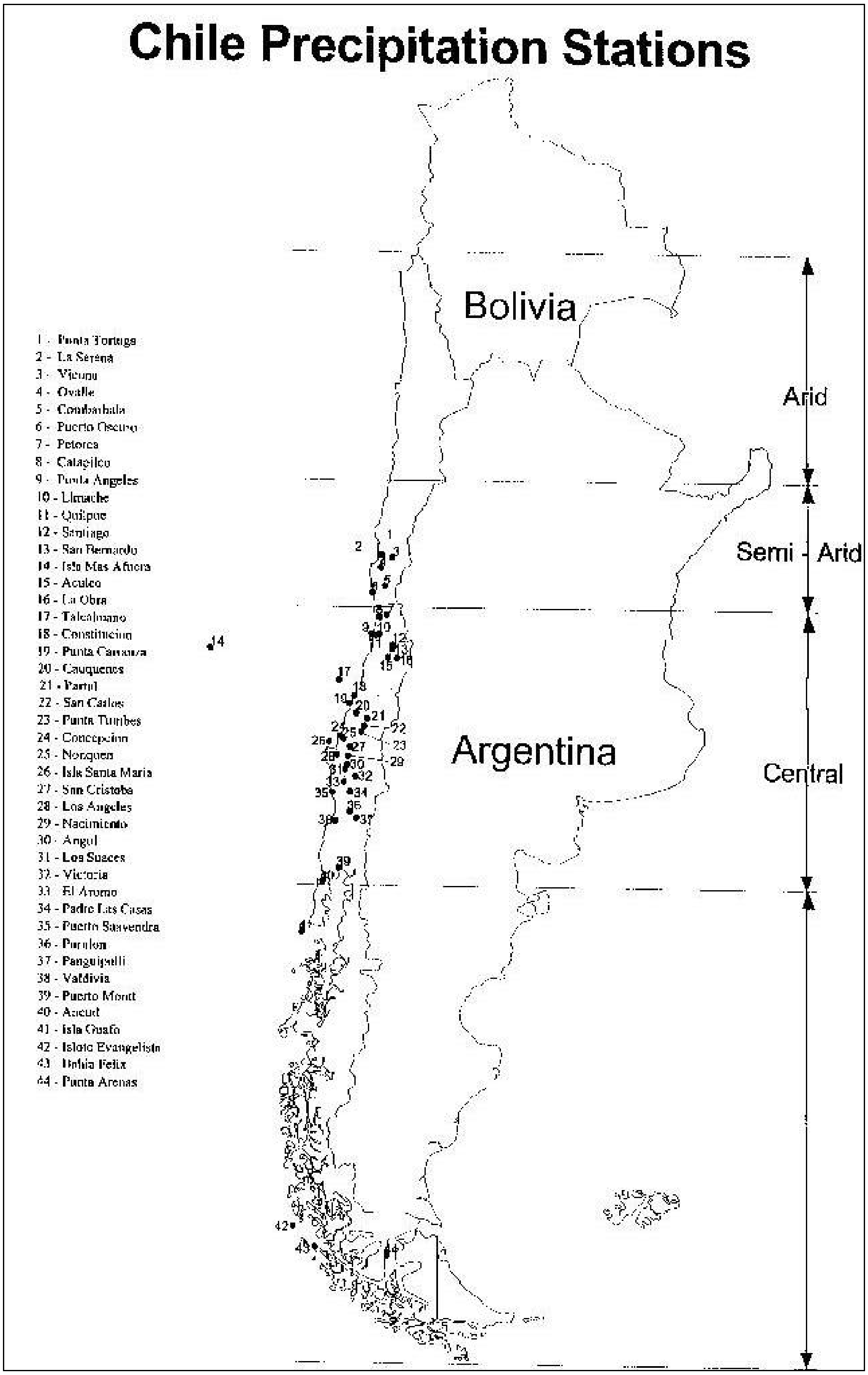
Chile Precipitation Stations
Bolivia
Argentina
Arid
Semi - Arid
Central
1 - Punta Tortuga
2 - La Serena
3 - Vicuna
4 - Ovalle
5 - Combarbala
6 - Puerto Oscuro
7 - Petorca
8 - Catapilco
9 - Punta Angeles
10 - Limache
11 - Quilpue
12 - Santiago
13 - San Bernardo
14 - Isla Mas Afuera
15 - Aculeo
16 - La Obra
17 - Talcahuano
18 - Constitucion
19 - Punta Carranza
20 - Cauquenes
21 - Parral
22 - San Carlos
23 - Punta Tumbes
24 - Concepcion
25 - Nonguen
26 - Isla Santa Maria
27 - San Cristoba
28 - Los Angeles
29 - Nacimiento
30 - Angol
31 - Los Sauces
32 - Victoria
33 - El Aromo
34 - Padre Las Casas
35 - Puerto Saavedra
36 - Purulon
37 - Panguipulli
38 - Valdivia
39 - Puerto Montt
40 - Ancud
41 - Isla Guafo
42 - Isloto Evangelista
43 - Bahia Felix
44 - Punta Arenas

Figure 7

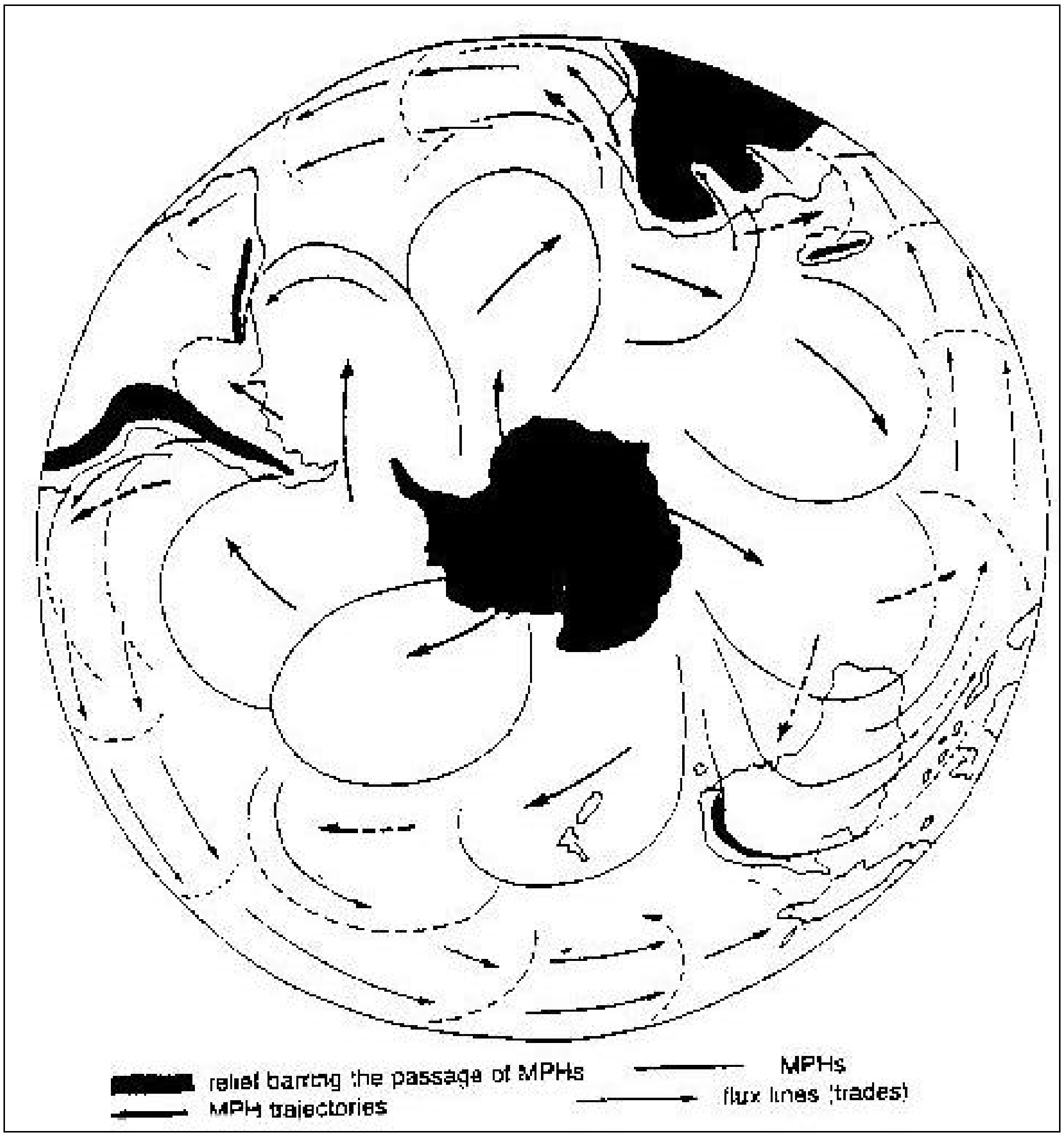

Figure 8

Trajectories of Mobile Polar Highs and resultant circulation in the lower levels of the troposphere: southern hemisphere. (From Leroux, 1998)

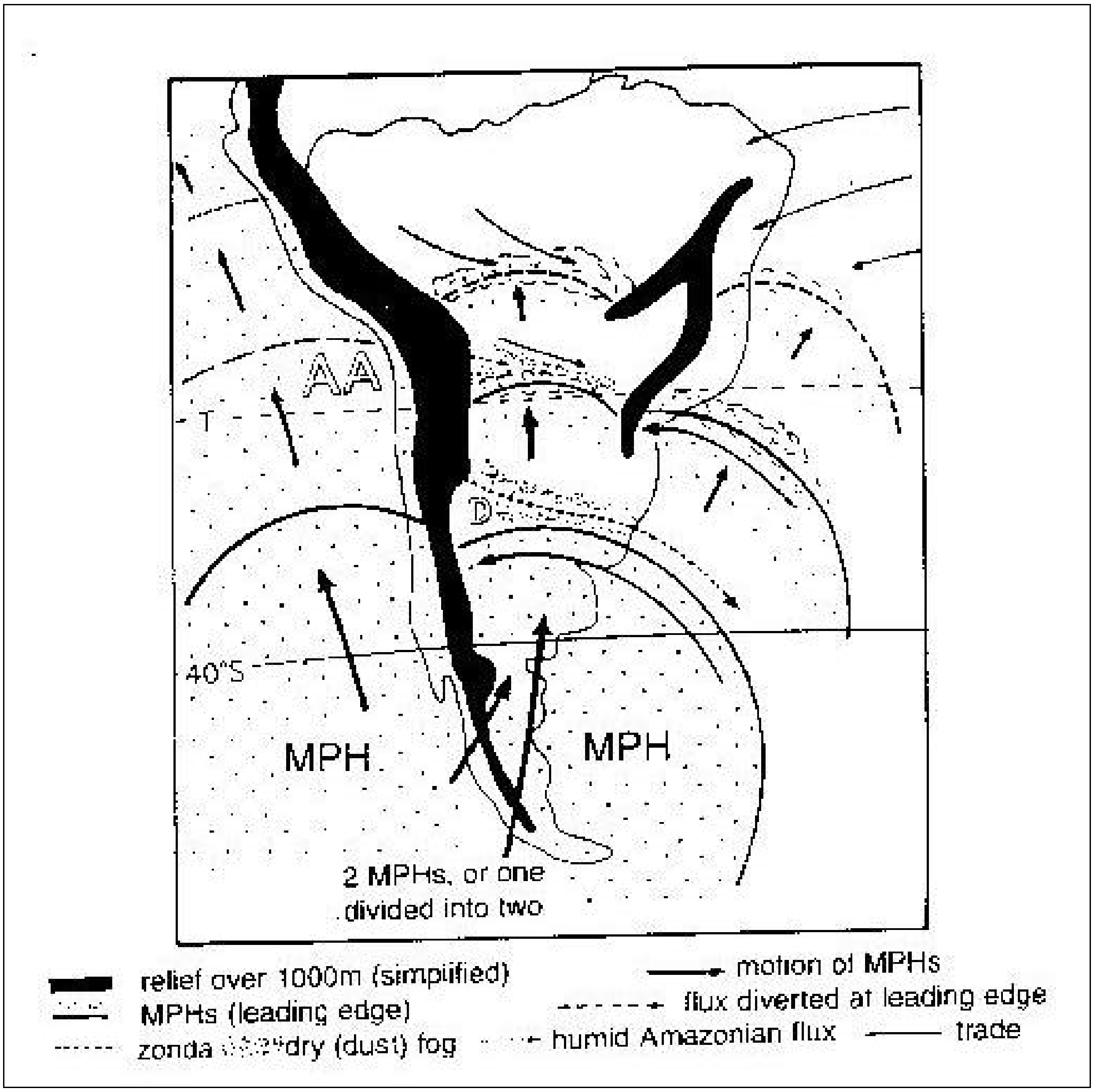

Figure 9

Dynamics of winter weather in South America (Surface diagram). (From Le Roux, 1998)

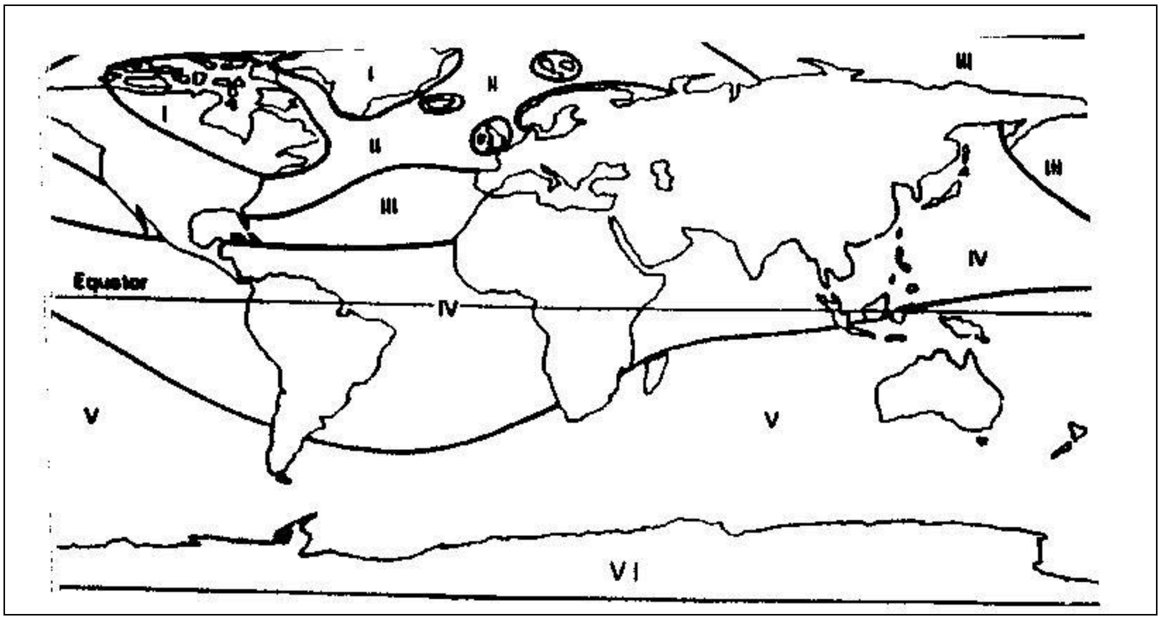

Figure 10

Six predicted zones of relative sea level change: Emerged beaches are dictated for zones I, III, V and VI. From Jelgersma and Tooley (1993)

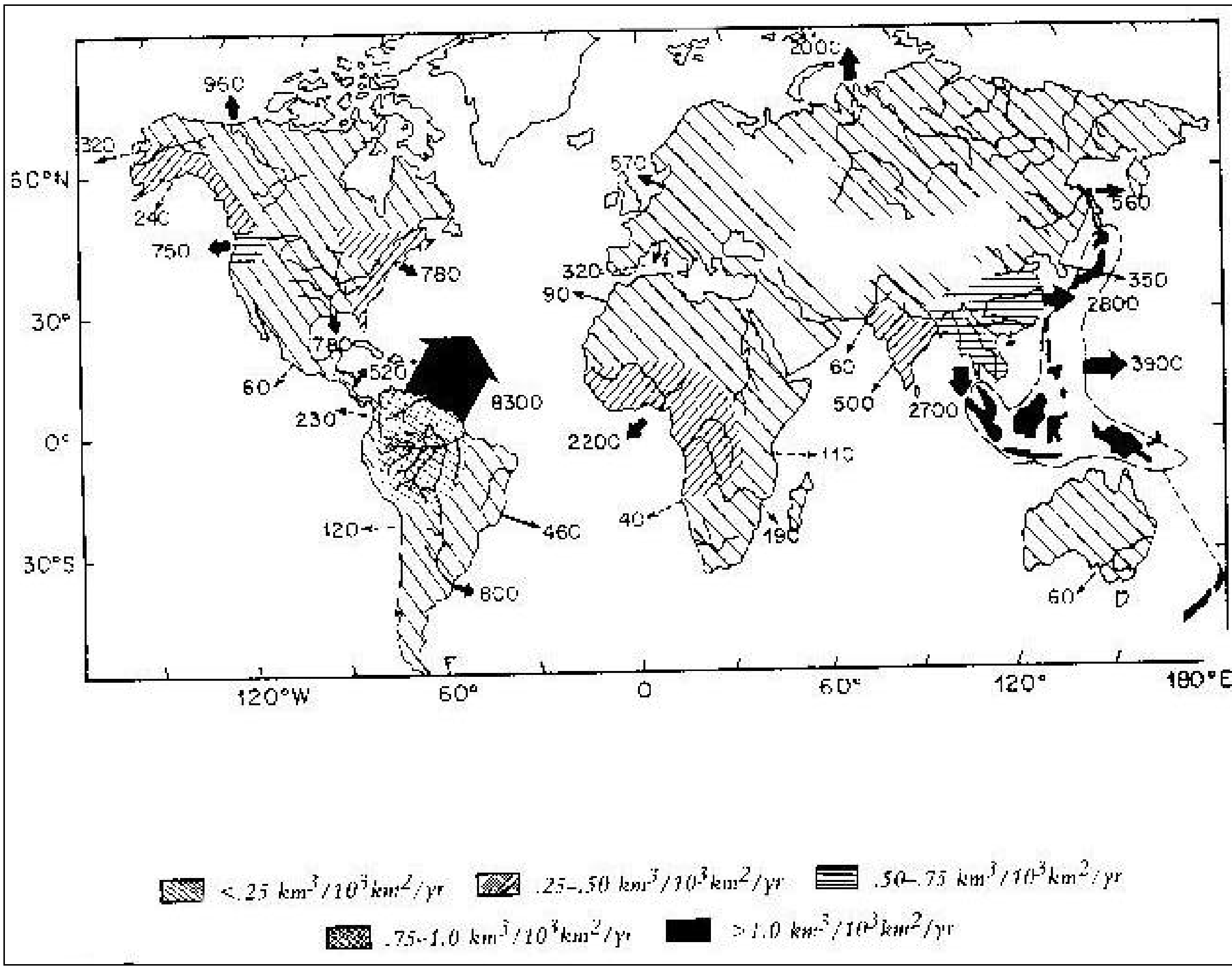

Figure 11

Annual discharge of fluvial water to the oceans. Numbers in km3/yr; arrows proportional to the numbers. Average rates of annual discharge of water (in $km^3/10^2/yr$) indicated by shaded areas.