Ber. d. Reinh.-Tüxen-Ges. 28, 93-104. Hannover 2016

The Vegetation of Unusual Climates

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Abstract

Vegetation is generally constrained by climate, but insight can be gained by examining the vegetation of more unusual climatic situations as well as norms. After consideration of what seems normal, though, the focus is not on unusual vegetation *per se*, but rather on unusual climatic situations and how they can be identified. What is "unusual" (climatically)? What is the vegetation of these unusual situations – and why? And what, if anything, do these unusual situations have in common? This inquiry may also be useful because climates in a globally warmed world may seem unusual as compared with today.

Keywords: climatic zonation, criteria for unusualness, edge locations, exceptional climates, extreme conditions, genetic climates, unusual vegetation, Walter climates

Introduction

This paper is more speculative than strictly substantive. We know that vegetation structure, function and geographic patterns are related to climatic conditions, but more insight might be gained by examining the vegetation of more unusual climatic situations. Vegetation has many aspects and can probably be classified in many more ways than can climate. So the pragmatic question is not what kinds of vegetation are unusual, but rather what kind vegetation occurs under the unusual climatic conditions. This inquiry can perhaps be organized around four main questions:

- What is usual?
- What is "unusual" (climatically)?
- What is the vegetation of unusual climates – and why?
- Why are unusual climates important, and what can we learn from such situations?

We do not consider unusual microclimates, or past or future climates, but rather climatic situations that appear unusual today. The approach is geographic, global, and a bit encyclopedic, attempting to catalog the world's main unusual climates. The climate data used include absolute minimum temperatures, which not everyone considers, and are from many sources, as collected over 40 years by the author.

What is Usual?

"Usual" in this sense means occurring in regular geographic patterns that can be understood and predicted, at least to some degree, over large areas, including globally. For this one needs an adequate global classification system. As a first cut we take those basic divisions used since Classical Antiquity, namely tropical, temperate and polar. Climatology in the 19th century added the idea of "almost" – i.e. subtropical and subpolar – plus mid-latitude division into warm-temperate (with milder winters) and cool-temperate (with cooler summers). Finally we recognize the basic asymmetry of the Northern versus Southern Hemispheres (cf TROLL 1948, BOX 2002) and add the fundamentally continental boreal climate of the large high-northern land masses. Limiting and threshold climatic values for these basic divisions go back to original suggestions by SUPAN (1879), KÖPPEN (1884) and ANDERSSON (1902), among others.

Further climatic subdivision of the world has followed three main approaches:

- a quantitative approach, as by Köppen, which permits drawing boundaries and making maps but provides not so much real climatic insight;
- a so-called genetic approach, which is based on causal mechanisms (mainly global atmospheric circulation) rather than concrete, empirical values; and
- a more recent approach, by LAUER (and RAFIQPOOR 2002), based on the duration of periods of particular significance, such as warm and wet seasons.

Of these, the last reflects vegetation requirements the best and may be the best overall – but it is less well known, less developed, and harder to use directly.

The genetic approach by Walter is perhaps the best known, is easy to use, provides a global geographic framework, and offers an adequate criterion for deciding what is "usual", i.e. regular and predictable. The Walter system did, however, have one major flaw: its type V ("warm-temperate") occurs on continental west and east sides for totally different reasons, and in latitudes that barely even overlap. Also, Walter had only 9 basic types, with no subtypes and no subdivision of altitudinal belts. The first problem was overcome by dividing type V into:

- a Marine West-Coast (Vm) climate on continental west sides, and
- a more appropriately named, truly Warm-Temperate (Ve) climate on continental east sides

(see BOX & FUJIWARA 2013, 2015; cf BOX & FUJIWARA 1988; BOX 1995a, 2015; WALTER & BRECKLE 1991). The resulting 10 climate zones occur in a regular geographic pattern that has been shown on an Ideal Continent (BOX 2002). Lack of subdivisions was treated by introducing a system for denoting subtypes: 'a' for arid, 'c' for [more] continental, and 'm' for maritime. Following WALTER (1954, 1968, 1973, 1977), the potential vegetation of the main zones and altitudinal belts has also been postulated (see BOX 2016, 2014) and mapped (predicted from climate, see BOX 1995b). An abbreviated summary of this expanded-Walter system is shown as Table 1 and can be used as a basis for deciding what is climatically normal, at least at present.

What is "Unusual"?

Unusual vegetation may suggest unusual climatic conditions, but this must be decided on an individual basis. For example, the Brazilian *cerrado* is unusual in having evergreen woody vegetation despite a pronounced dry season. Explanations for this have included extreme soil poverty, good soil water-holding capacity, and small rainfall events that can occur even in the dry season (e.g. HUECK 1966). As a result, one cannot see the climate as unusual. For most climate types in the global system one can recognize subtypes. Some have quite different vegetation, such as the *Larix* woodlands of ultra-continental boreal (VIIIc) eastern Siberia; the birchwoods of maritime boreal (VIIIm) Beringia and Iceland; the *Artemisia* and other semi-deserts and deserts of temperate arid (VIIa) western North America and interior Eurasia; and the "warm-temperate deciduous" forests of marginally warm-temperate (Ve-VI) areas (cf BOX & FUJIWARA 2015). All of these represent recurring subtypes and thus cannot be seen

Table 1: Zonal Climates, Soils and Vegetation Types

Climate Type		**Seasons**	**Zonal Soils**	**Natural Vegetation**	**Altitudinal Belts**
Equatorial	I	warm, no frost, no dry season	deep yellow-brown latosols	Tropical rainforests	Paramo rosette scrub Cloud forest, Montane rainforest
Tropical Wet/Dry	II	warm, no frost, wet/dry seasons	latosols, often crusty	Raingreen forests/ woodlands	Moist puna grassland Evergreen montane forest
	II-III			Thorn-scrub/savanna	Semi-EG woods/forest
Subtropical Arid	III	hot/mild, little rainfall	coarse, alkaline sand/rubble	Deserts & semi-deserts	Dry puna steppe Xeric montane scrub
Mediterranean	IV	warm/mild, dry summer	rocky red clay and other	Sclerophyll woods/ scrub (maquis), dwarf scrub (garrigue)	Dry cushion scrub Montane conifer woods [sclerophyll scrub]
Marine West-Coast	Vm	mild/cool, much rainfall	shallow, acidic brown soils	Temperate rainforests	Wet alpine tundra Mixed rainforests
Warm-Temperate (east sides)	Ve	hot/mild, no dry season	red-yellow clay, often deep	Evergreen broad-leaved and mixed forests	Alpine tundra Mixed evergreen forests
Typical Temperate	VI	warm/cold, no dry season	brown forest soils	Summergreen broad-leaved forest	Alpine tundra Conifer forest Mixed forest (BL + NL)
Temperate Continental	VII	warm/cold, low rainfall	deep black to drier brown/tan	Prairie (+ forest-steppe), bunch-grass steppe	Dry alpine tundra Drier conifer forests
a. Temperate Arid	VIIa	warm/cold little precip.	coarse, alkaline sandy/rubbly	Cold-winter desert/ semi-desert	Alpine steppe Dry conifer woods
Boreal	VIII	mild/severe, humid summer	podzol	Boreal conifer forest, larch woods	Alpine tundra
Polar	IX	cold/severe	rubbly histosol	Polar tundra	[nival ice]

Altitudinal belts (last column) are listed from alpine downward and are not aligned horizontally with other lines within their climate type.

Abbreviations: BL = broad-leaved NL = needle-leaved EG = evergreen as climatically unusual. Similar logic precludes seeing transitional areas or zonal altitudinal belts as unusual, even when these have different vegetation.

These observations suggest that definite criteria are needed for deciding what may or may not be "unusual". Some such criteria are listed in Table 2. Neither subtypes nor transitions involving recognized climatic zones should be seen as unusual. Three-way transitions, however, may be unusual, as for example around Winnipeg (Manitoba), where conditions to the west are rapidly drier (VII), to the north rapidly colder (VIII), and to the southeast milder (VI), with a longer summer.

Table 2: Concepts and Criteria for Climatic Unusualness

Criteria	**Examples**
Climatic Subtypes	Tropical/subtropical areas beside cold ocean current, maritime boreal, maritime dry temperate (VIIx)
Transitions	
-temperate to tropical	S Texas, Florida, N-central Argentina, Iran
-unusual transitions	Rapid summer to winter rainfall maximum
-three-way transitions	Winnipeg area
Zonation Exceptions	Equatorial E Africa, Venezuelan *llanos*, maritime deserts
Extreme conditions	Extreme low temperatures, extreme seasonality, very short cold summer, daily freeze-thaw cycle
Unique conditions/situations	T minima only slightly below means (e.g. monsoon China) Sudden T minima far below means (e.g. SE USA)
-unique uplands	Tibet, Yunnan, Iran, Mexico
Strange vegetation	Madagascar, Australia, southern Africa
-plant forms	*spekboom*, phyllodes, needle grasses, restios, leafless trees, mini-succulents, mallees, leptophyll treelets, big tussocks
Hard to classify	Ushuaia, Lhasa, Sichuan basin, upland Iran, austral
-marginal areas of larger regions	Galicia, SW Ireland; veld; pampa
Where models often fail	Tropical alpine/subalpine, Sichuan basin, ultra-maritime
Areas with inadequate climate data	Tropical high mountains
Areas with azonal soil	Southeastern US coastal plain; wetlands; volcanic soils
What people think is unusual	Cold at low elevation in tropics

Abbreviation: T = temperature

Major exceptions to the global zonation pattern occur in four locations: northern South America, where a dry season (II) comes almost to the equator; coastal Peru, where the cold Humboldt current stabilizes the atmosphere, prevents rainfall, and extends the [maritime] subtropical arid climate (IIIm) almost to the equator; the Patagonian rain shadow, which replaces the normally occurring east-side typical temperate climate (VI) with a maritime-temperate subhumid (VIIm) climate that extends out into the Atlantic; and equatorial East Africa, where normal precipitation lows near the solstices actually become dry seasons (Ia). These and some other regions have long been recognized as having "problem climates" (TREWARTHA 1961, 1981), but they can all be understood and placed within the global system. Neither these climates nor their vegetation types are really unusual – they're just in the wrong locations.

Extreme climatic conditions may also seem unusual, and some may produce unusual vegetation, such as the equatorial alpine paramo with its wide daily fluctuations between daytime warmth and nighttime freezing. Other climatic extremes might include places with the very lowest temperatures, such as around Oymyakon (-71ºC) in eastern Siberia; or with extreme rainfall totals (8-10m or more), as in the lowland Chocó of NW Colombia, in island montane belts on Yakushima and Kauai, or at Cherrapunji in montane eastern India (which also has a two-month dry season). None of these situations, though, has vegetation that does not occur in somewhat similar form under similar conditions elsewhere, and each can be placed somewhere within the global classification. Perhaps more truly unusual are unique regions, such as the Tibetan Plateau (VII-Vc), the Yunnan Plateau (Ve), and the Mexican highlands (Vc-II), each of which is the only large highland region in its particular climatic zone (or transition). Also unique and perhaps "unusual" is the Sichuan Basin (28-32ºN), just north of Yunnan, where absolute minimum temperatures are not far below winter means and may not be below about -12ºC (but beware the short measurement periods!). Such minima are rather high for an upland mid-latitude basin (400-600m) and permit some subtropical taxa to occur.

Unusual vegetation may involve unusual plant forms, such as the restios and miniature succulents (*Lithops*, *Fenestrina*) of South Africa, the needle grasses (*Triodia*) of Australia, the leafless arborescents (e.g. *Haloxylon*) of the sand deserts of Middle Asia, the *Sasa* understoreys of Japan, the tall forbs of snowmelt areas in the Russian Far East, or the "strange" tree and tall-succulent forms of Madagascar. Or the structure or seasonality of the vegetation may be unusual, such as evergreenness in wet-dry northern and arid central Australia. Unusual vegetation may suggest an unusual climate, but it may also result from other unusual conditions, such as rocky, deep-sand, seepage-prone, or nutrient-poor substrates.

Geographic models should be validated geographically, i.e. by bioclimatic or vegetation types or regions, not just by cumulative statistics (BOX & MEENTEMEYER 1991). Places where model results do not match reality might also suggest unusual climatic situations. For example the climate-driven world model of equilibrium plant biomass accumulation (see map in MIYAWAKI & BOX 2007) fails in tropical alpine belts, predicting much greater accumulations than probably ever occurred there. The world climatic model of soil CO_2 evolution (BOX & MEENTEMEYER 1993) failed in the wettest tropical areas until a special exception was made for areas where the soil is always saturated. And global models for the occurrence of plant types (e.g. BOX 1981, 1995c, 1996) fail in some ultra-oceanic temperate locations by predicting laurophyll forest.

Finally, some situations should perhaps be considered unusual because they are hard to classify or simply because people see them as unusual. Regions that are routinely difficult to classify include edge locations, such as ultra-oceanic European areas with milder winters (e.g. Galicia, western Ireland); geographically isolated regions, such as Tierra del Fuego; and some very isolated islands that are not quite truly polar or subpolar. In addition, a computer program WALTRIZR designed to identify the expanded-Walter climate types of sites had special problems in drier mountain regions, as in western North America.

An initial "long list" of unusual situations (climatic, vegetational or both) is shown in Table 3, with sample locations. Some of these have already been mentioned, and some are not as unusual climatically as their vegetation suggests. Even so, the list does reflect some of the observations above. In particular, these "unusual" situations do seem to have some things in common, namely that they often occur:

- in edge locations, such as on the edge of a large land mass;
- in the more oceanic Southern Hemisphere;
- in oceanic situations; or/and
- in highland situations.

These situations often involve climatic conditions favorable for certain plant or vegetation types that do not occur nearby. Evolution, however, did not always produce those types, per-

Table 3: Initial Subjective List of Unusual Climatic and Some Vegetation Situations

	Situation	Climate Type	Example Locations
I	wet-dry equatorial	Ia incl. belts	E Africa, incl. mountains
	dry inner-tropical islands	Ia	Curaçao; Kanton, Malden, Johnston
	inner-tropical deserts	Ia-III	Somalia, Suqutra
	dry-tropical subalpine (above clouds)	I-II subalpine	Venezuela, E Africa
II	tropical winter-rain	IIw	Madras area
	island rainshadows	II-III	Caribbean and other islands
	humid-subtropical	II-Ve	S China, S Asia
III	deserts with very erratic rainfall	III	central Australia
	maritime subtropical arid	IIIm	Canarias, Cabo Verde
	cold-current subtropical deserts	IIIm	coastal Peru, Namibia; Cabo Frio
	cold-current subtropical foothills	IIIm-colline	Peruvian loma
IV	tropical transitions	IV-II	upland Iran
	interior mediterranean (drier)	IVc	western USA, Mid-East
	summer- to winter-rain transitions	IV-Ve	South Africa, SE Australia
Ve	continental warm-temperate	Vc	central Texas, interior Australia
	subhumid warm-temperate	Ve-VIIm	Rio Grande do Sul (campos)
	marginal with cold extremes	Ve-VI	SE USA
V	cool-oceanic islands	Vo	mid-lat. oceans (Tristan Cunha, Gough)
	oceanic warm-temperate	V	NZ North Island
	ultra-cool austral	V-VIIIm	upland Tasmania, New Zealand
VI	monsoon temperate	VIc	E and N China
	ultra-continental typical temperate	VIc-VIII	inland Manchuria
	windward oceanic temperate	VIm-Vm	Galicia, SW Ireland
	oceanic cool-temperate	VIm-VIIIm	Chile; Scotland-Ireland
VII	continental tropical transitions	VII-II	S Texas, N-central Argentina
	maritime subhumid	VIIm	pampa, central Argentina
	maritime rain shadows	VIIm, VIIx	Patagonia, NZ South Island
VIII	maritime boreal	VIIIm	N Scandinavia; W Alaska
	ultra-continental boreal	VIIIc	NE Siberia
	dry boreal	VIIIa	Ft Yukon
subpolar:	maritime subpolar	VIIIm-IXm	Iceland; Beringia
	ultra-oceanic subpolar	VIm-IXm	Ushuaia
	cool-stenothermal islands	IXm-Vm	Macquarie, Kerguelen
IX	maritime polar	IXm	Falklands, S Georgia; Aleutians.
	dry polar	IXa	N Siberia; interior N Canada

haps due to the small sizes of the regions involved. Many of these regions are relatively less accessible, thus less studied, and hard to classify. One might also note that, arguably, the status of these situations as “unusual” does not depend on the classification system used – they would probably be “unusual” in any classification because they occur in geographically unusual locations.

Vegetation of Unusual Climates

What climatic situations, then, are truly unusual? Table 4 shows a short list of the top 10 subjectively chosen “unusual” locations, most of which are indeed geographically isolated. They are also difficult to place in the global zonation, but a suggestion is given for each one.

At the top of the list is the southern tip of South America, around Ushuaia (55ºS), where the occurrence of evergreen broad-leaved forest at a warm-month mean not reaching 10ºC breaks all the rules. Monthly mean temperatures range between about 9.5º and 1.5º; the mean minimum in the coldest month is about -4ºC, and the lowest temperature ever measured (only 16 years) is about -21ºC. Both the low summer mean and absolute minimum below -15ºC violate normally expected temperature limits for evergreen broad-leaved trees, and the former for mer for tree occurrence at all. Actually, the small-leaved evergreen *Nothofagus betuloides* stands may be succeeded by summergreen *N. pumilio*, which contradicts another normal pattern, namely that more shade-tolerant evergreen (e.g. laurophyll) trees usually replace more light-demanding deciduous trees, as in East Asia and eastern North America. The low temperature minima suggest that Ushuaia should be classified as transitional VIm-IXm (rather than Vm-IXm). All of this is unique in the world, unusual, and global models would not work well here.

Table 4: Short List of Ten Putative "Most Unusual" Situations

Situation/Condition	**Locations**	**Climate Type and Belt**	**Vegetation**
Southern tip of South America	Ushuaia	VIm-IXm	Evergreen and summergreen forest at Tmax < 10°C (*Nothofagus*)
Stenothermal, almost subpolar islands (T > 0°C but < 10°C)	Kerguelen, Macquarie, Marion Island	IXm-Vm	Largely evergreen, often megaphyll herbfields
Subhumid tropical highland to temperate lowland continuum	Puna to Patagonia	III alpine to VIIx	Xeric bunch-grass and shrub steppe, with cushion shrubs
Tropical dry subalpine belts (above cloud level)	Venezuela, East Africa	I-II subalpine	Scrub, partly with rosette forms from the alpine belt
Foothill fog belt above coastal desert	Peruvian foothills	IIIm colline	Loma fog vegetation
Dry-Subtropical Highland	Tibetan Plateau	II-VIIa mont-subnival	Sparse semi-desert/desert steppe (*Kobresia*) with patchy summergreen scrub/woods
Dry-Subtropical Upland	Iranian Plateau	IV-II coll-montane	Summergreen + evergreen microphyll scrub
Subalpine warm-temperate of Southern Hemisphere	Eastern Australia	Ve subalpine	*Eucalyptus*, gradually decreasing in height but without physiognomic change
Grassland and mosaic in humid warm-temperate	S Brazil-Uruguay-E Argentina	Ve-VIIm	Campos and pampa (tussock) grassland
Ultra-oceanic temperate	Galicia, SW Ireland	VIm-Vm	Windswept summergreen forest, in winter mild enough for evergreens

Abbreviations: coll = colline (foothill) belt, mont = montane belt; T = temperature, Tmax = mean temperature of warmest month

Next on the list are three small, quite isolated, almost subantarctic islands that have even cooler summers than Ushuaia but winter means farther above freezing. These islands are Marion and Kerguelen, at 47-49°S in the Indian Ocean, and Macquarie at 55°S, south of Aus-tralia. All three have warm-month mean temperature of 7-8°C and cold-month means between 2° and 3.5°C. Absolute minima are given as between about -8° and -12°C, but measurement periods are short. By contrast, Campbell Island (53°S) is closer to a land mass (just south of New Zealand), has higher mean temperatures (9.4° to 4.9°C) and a higher absolute minimum of -6.7°C (over 40 years). All have quite sufficient precipitation, and except for Campbell have treeless landscapes and might be classified as IXm-Vm. More typical maritime subpolar (IXm) islands, such as the Aleutians or South Georgia, are at slightly higher latitudes, closer to large land masses, and are colder, in summer and winter. The vegetation of these almost subantarctic islands is almost entirely herbaceous and includes such large-leaved plants as the famous Kerguelen cabbage (*Pringlea antiscorbutica*) and compact, cushion-like *Azorella selago*. Macquarie has herbfields of *Pleurophyllum* and other macrophylls, plus graminoid vegetation (cf JENKIN & ASHTON 1979). An early estimate of productivity rivaling that of tropical rainforest was erroneous, but later estimates 600-1140 g/m^2/year (dry matter, JENKIN & ASHTON 1970) are still higher than in other subpolar or polar situations, due to the long growing season.

Next on the list is a cool-subhumid situation that is unusual for its long north-south extent, from the tropical (II-III) alpine belt of Peru to the lowland maritime-subhumid (VIIm) climate of southern Argentina. The cool, windy conditions remain remarkably consistent over this long gradient, with higher southward latitude offsetting the potentially higher temperatures of lower elevation. Over this entire extent the vegetation physiognomy changes very little. The dry puna consists of bunch-grass and tussock steppe, with cushion forms (including hemispheric cacti, e.g. *Tephrocereus*), while the low-elevation Patagonian steppe is also dominated by bunch grasses, with cushion forms, including hemispheric and flat cushions of *Azorella* species (HUECK 1966, WALTER 1968).

Another high-mountain situation that may be unique involves tropical subalpine areas that lie above the cloud level – and are thus drier but are not yet high and cold enough to be alpine. Such 'subparamo' situations occur in the northern Andes of Venezuela and in equatorial East Africa (cf the "ericaceous belt" of HEDBERG 1951). In Venezuela, annual precipitation decreases from 1700mm at Mérida (1500m, at the base of the higher mountains) to 690mm at Mucuchies (3000m, near the top of the cloud belt) (cf 682mm at Páramo de Mucuchies, 4221m). Precipitation data from HEDBERG (1964) also show a clear precipitation decrease at around 3000m on Mt. Kilimanjaro, above the cloud belt. In both areas the alpine belt has large cauli-rosette forms that descend somewhat into the subalpine belts, which otherwise, though, seem to be different, with scrub in Venezuela but tussock grasses and *Philippia* in East Africa. At lower elevation, persistently foggy conditions in the 'loma' belt of Peru, above the dry but cool strip of coastal desert, create a fairly unique maritime foothill (IIIm-colline) climate and vegetation that develops much more during El Niño events.

At least two areas in the world have continental grassland climates that grade, in subtropical latitudes (about 25-30°), from temperate continental (VII) into tropical wet-dry (II). These two areas, both at low elevation, are in south Texas and central Argentina. At high elevation, though, such a continental subtropical transition occurs only in Tibet. The Tibetan Plateau is high and dry (VIIa montane to subnival) but with a distinct summer rainfall peak that is due partly to the monsoon system and partly to a location that would be tropical wet-dry (II) at low elevation. Climatic data from Tibet are quite insufficient to describe its bioclimatic variation in detail, and Tibet is hard to place in the global zonation. It is not, however, a place where global models should fail. Its landscapes include large areas of open *Kobresia* steppes, with woody vegetation only in protected areas.

Another fairly unique upland area is the Iranian Plateau, which represents a transition (IVc-II) from winter rainfall in the Middle East to summer rainfall as one gets into monsoon effects in Pakistan. Although the climate is largely still continental-mediterranean, sclerophyllous woody species are largely replaced by summergreen species, in what BLUMLER (2015) has called the "Zagros Gap". This is another area where the climatic data are inadequate, both in their geographic coverage and in length of measurement.

In Australia, *Eucalyptus* species have expanded to occupy most climates except the most arid – and some occur even there on special substrate situations. It comes as a surprise, though, to see stunted eucalypts extending upward in the mountains all the way to treeline, as in the warm-temperate (Ve) mountains from New South Wales to Victoria. The characteristic eucalypt physiognomy does not really change, the trees just get shorter and more contorted. Climatic data from the higher montane and subalpine belts are not common, but here are some examples, including mean temperatures of the warmest (Tmax) and coldest (Tmin) months, and the absolute minimum (Tabmin, periods of measurement not given and probably short):

	Lat.	Elev.	Tmax	Tmin	Tabmin
Kiandra (NSW)	35.5°	1400m	13.5°	-0.4°	-20.6°
Kosciusko (NSW)	36.5°	1530m	12.6°	0°	-14.4°
Mt. Hotham (Vic.)	36.6°	1860m	11.2°	-2.8°	-12.8°

The actual absolute minima that might occur over a century can be estimated and are probably a bit lower than shown here, but these data do suggest why the evergreen eucalypts still dominate well up into the high mountains. This situation may or may not be a truly "unusual" climate, but it is difficult to place in the global system, since warm-temperate climates normally have lower temperatures in their higher mountains.

A long well known problem in vegetation-climate relations involves the pampa grasslands of Uruguay and Argentina, which occur in a maritime-subhumid temperate (VIIm) climate that appears to have enough precipitation to support woodlands (WALTER 1966). The occurrence of slightly salinized depressions in more southern parts of this region, however, combined with the often windy conditions, have suggested that potential evapotranspiration was underestimated and that the climatic water balance is in fact negative over much of the area (WALTER 1968, pp 686-697; BOX 1986). The area also has many small lakes and seasonal ponds, which are tied to groundwater flows, both in and out (cf BOCANEGRA et al. 2013). The pampa involves large tussock grasses, usually separated by bare ground, which suggests further that water is limiting in at least some parts of the warm season. As one goes further south into the Andes rain shadow, conditions become drier, even though the temperature regime remains rather maritime (denoted VIIx, see BOX 2016).

The final entry in Table 4 is from ultra-oceanic areas of Atlantic Europe, such as Galicia and southwestern Ireland, where the lack of low absolute minimum temperatures suggests that evergreen broad-leaved forest could occur. Some absolute minima in the western British Isles include: -11.3ºC at Shannon airport (38 years); only -14.4° at Prestwick airport (67 years; but -19.9° over 38 years in nearby Glasgow city); -15.1° at Armagh (115 years, perhaps lower recently); only -9.4° at Cork (30 years); and only -18.3° over 83 years at Lerwick (60ºN) in the Shetland Islands. On the east side of Great Britain, absolute minima include -19° (82 years) at Aberdeen, -18° (38 years) at Edinburgh, and -19° (60 years) at Fairford in the English midlands. In western France, some relevant absolute minima (all measured over only 40 years) include: -14° at Brest (Bretagne), -15° at Nantes (lower Loire valley), and -13.4° at La Rochelle; over 66 years, though, Bordeaux has an absolute minimum of -16.4ºC, and Limoges, directly inland, shows -25.8° (measured over 40 years). Finally, in Galicia, measured absolute minima are much higher, for example: -7ºC at A Coruña (37 years), -10° at Lugo (24 years), -9° at the Coruña-Santiago airport (55 years), -5° at the Pontevedra-Vigo airport (53 years), and -8.6° at Ourense (58 years); further east, Oviedo (Asturias) shows -10.4ºC over 107 years, and San Sebastian shows -12.1° over 98 years. All of these values cause global models to predict evergreen broad-leaved forest for these locations.

In addition to these "most unusual" situations, there are certainly other places with unusual climatic conditions, unusual vegetation or both. Some that come to mind readily include: the birchwoods of maritime-boreal (VIIIm) northern Scandinavia; the campos of humid warm-temperate (Ve) southernmost Brazil and into Uruguay; some lower-rainfall but not yet extreme rain-shadow areas on the northeastern part of New Zealand's South Island (e.g. Blenheim, with only 642mm); the areas of rapid transition from summer rain to winter rain that occur along the south coasts of South Africa and Victoria; the succulents of Suqutra and of the Canary Islands; and the many unusual tree and succulent forms on Madagascar. A perhaps related question is posed by subalpine Ecuador, where introduced *Eucalyptus* and northern conifers grow quite tall at mean temperatures that remain around 10-12ºC all year and perhaps up toward Cotopaxi (3560m), with monthly mean temperatures between 7.8º and 8.3ºC all year.

It might be useful to ask what characteristics, if any, these unusual situations have in common? For one thing, most "unusual" climates occur over relatively small areas. As a result, their vegetation usually did not evolve locally but is rather a mixture of elements and influences from larger neighboring regions. This suggests, among other things, that the vegetation is not particularly well adapted to the unusual conditions but only that it is able to survive them. Further, the vegetation of such unusual climatic regions consists largely of generalist species, i.e. species with wide ecological amplitudes (including weedy species). In some cases, stabilizing dominant species are missing and the vegetation remains "disturbed". In some cases, the vegetation represents the penultimate vegetation stage of succession in nearby, less "unusual" areas. For example, although the lack of extreme low temperatures in some parts of Atlantic Europe would appear to permit evergreen broad-leaved forests, the actual vegetation is low, windswept summergreen forest or woods.

Why are Unusual Situations Important?

Unusual climatic and vegetation situations may be interesting and provide insight into vegetation-climate relationships. In the future, though, with pervasive global climate change, there may be more such unusual situations. In general, it appears that global climates in the future may be not only warmer but also more maritime, with reduced temperature extremes and continentality gradients; and more humid, due to higher evaporation rates (e.g. IPCC 2013). Despite regional exceptions, what appear to be anomalous, unusual climates may become more common, their individual types more numerous, and they may cover larger areas.

Some climatic regions may become larger, perhaps especially maritime subpolar areas such as Vm-IXm and VIm-IXm areas, even maritime boreal (VIIIm) and cool-temperate (VIm) areas. Some regions may become smaller, such as the true, inherently continental boreal zone (VIII) and its ultra-continental subzone in eastern Siberia (VIIIc). Some regions, however, may not become more humid, in particular perhaps the Mediterranean area and some warm-temperate (Ve) and even typical-temperate (VI) areas, as in the southeastern USA (e.g. KARL et al. 2009, MELILLO et al. 2014) and parts of China.

If "unusual" climates are likely to become more common in the warmer future, then it is perhaps useful to study the vegetation-environment relationships of currently "unusual" climatic situations, especially those that are "marginal", perhaps oceanic, and include some of the expected future characteristics. One especially good starting point for such study is the recent book on *Plants at the Margins*, by CRAWFORD (2008).

Acknowledgement

The author would like to thank again not only Prof. Richard Pott and other meeting organizers but also all the participants of the annual Tüxen meeting for honoring me on my 70th birthday. I will always remember it gratefully.

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