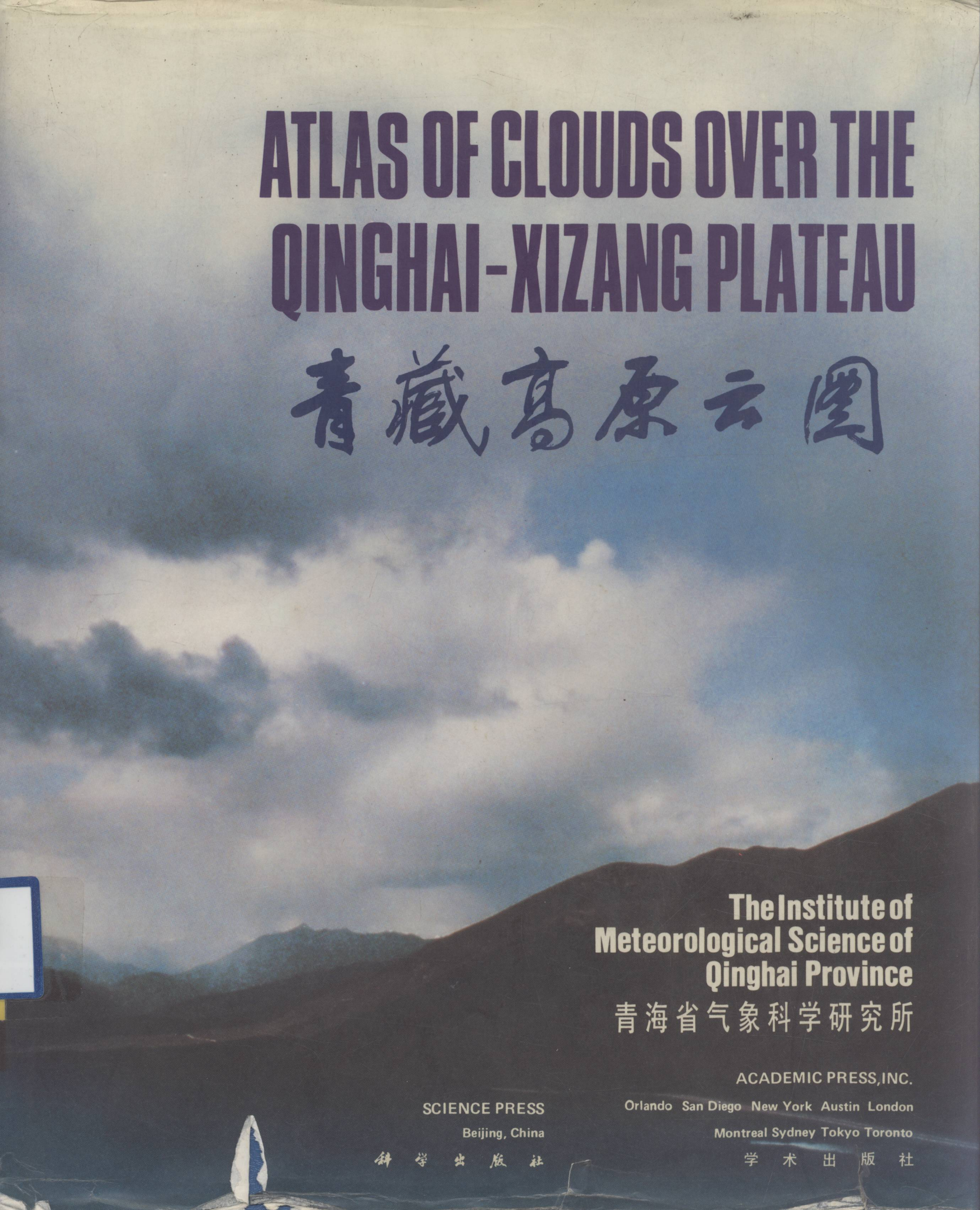
ATLAS OF CLOUDS OVER THE QINGHAI-XIZANG PLATEAU

青藏高原云图



The Institute of Meteorological Science of Qinghai Province

青海省气象科学研究所

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Satellite image for the main part of the Qinghai-Xizang Plateau and principal sites of cloud photographing.

(By kind permission of Messrs. Zhang Qingshan and Liu Cheng of the Satellite Center of the State Meteorological Administration)

青藏高原主体地区地形图及主要拍摄点　　（国家气象局卫星中心张青山、刘诚提供图片）

●	Photographing spot	拍摄点	G	Nagarze	浪卡子	N	Xigaze	日喀则
A	Wudaoliang	五道梁	H	Lhunze	隆　子	P	Tingri	定　日
B	Tuotuohe	托托河	I	Nangxian	朗　县	R	Pagri	帕　里
C	Amdo	安　多	J	Mainling	米　林	S	Yadong	亚　东
D	Nagqu	那　曲	K	Zhongba	仲　巴	▲	Mount Qomolangma	珠穆朗玛峰
E	Lhasa	拉　萨	L	Saga (Gy' gya)	萨　嘎（加加）	△	Gêladaindong	各拉丹冬
F	Nyingchi	林　芝	M	Lhaze	拉　孜			

FOREWORD

The unique Qinghai-Xizang Plateau is an entity more than four kilometres above sea level on the average and more than two million square kilometres in area. This gigantic plateau can aptly be compared to a mainstay in the westerly jet streams. It not only confronts them, but also forces them to cross over it, or to branch off and flow past it. The difference in atmospheric thermodynamics between the Plateau and the surrounding air at same level frequently results in the discrepancy of temperature between them, thus the spatial distribution of air pressure is affected, and a seasonal thermo-circulation of atmosphere is formed. Therefore, the various synoptic systems in the general atmospheric circulation are complicated by the presence of the Qinghai-Xizang Plateau. As the Plateau covers a huge area, where the elevation, topograph and character of ground surface differ from place to place, there exists a great distinction in weather and climate in its various parts.

The above factors have created many weather and climate features unique to the Qinghai-Xizang Plateau; these features have aroused much interest of meteorologists in China and abroad. As a result, many field studies have been conducted, monographs written, and valuable contributions made. However, so far little has been done on the clouds over the Plateau.

Under the auspices of the Commission of Sciences and Technology of Qinghai Province and the Meteorological Bureau of Qinghai Province, and under the guidance of the Institute of Meteorological Science of Qinghai Province, a special research group working on *Atlas of Clouds over the Qinghai-Xizang Plateau* was formed in 1981. The members of the group studied for three years clouds across the Plateau except the district of Ngari (northwestern part of the Plateau), traveling a distance of 40,000 kilometres. A great number of cloud photos, data of cloud heights measured by laser radar, panoramic photos of cloud and films on the motions of clouds were made available; some of the material of certain principal cloudsource areas was examined more than twice.

In addition to general surveys, in order to take pictures of the evolutions of different cloud patterns at the same spot and orographic clouds, many places with typical topography, or near the cloud-source mountainous areas were chosen for the photographing. Among them were the Ngoring Lake (having a wide water surface), Darlag and Warima (in the Huanghe River valley), Maji Snowberg (one of the cloud-forming sources), Dawu pastureland (of a broad terrain), Tanggula Range (the source region of the Changjiang River), Nagqu (in the northern part of the Plateau), Lhasa and Nyingchi (in the valley of the Yarlung Zangbo River), Pagri of Yadong and Chuangmuda of Tingri District (on the northern slope of the Himalayas) and Mt. Jiazela (in the west of the Plateau). The authors spent about one month at each spot to take these photos. That was why numerous photos and films of various weather systems showing remarkable peculiarities of the Qinghai-Xizang Plateau were obtained. From over 3000 photos, more than 500 were chosen and presented to a meeting held at Xining of Qinghai Province in August of 1984

for assessment by specialists.

For a better understanding of the clouds over the Qinghai-Xizang Plateau by meteorologists and researchers of related disciplines at home and abroad, we have compiled this book – *Atlas of Clouds over the Qinghai-Xizang Plateau*. The aim of this Atlas is to furnish reference materials for weather observation and forecast, and to provide general and special examples and statistical results of clouds over the Plateau for academicians engaged in meteorological education, aeronautical navigation, cloud physics, dynamics of cumulus; micro-scale synoptic meteorology, aeroclimatology and meteorology of the Qinghai-Xizang Plateau.

Contained in this Atlas are 277 photos (152 groups), which focus on clouds peculiar to the Qinghai-Xizang Plateau, or reflect the characteristics of its weather and climate. As many examples showing geneses and evolution processes of special clouds and orographic clouds as possible are included. Some of the clouds which are frequently seen over plains but are rare over the Qinghai-Xizang Plateau, such as Altostratus opacus and Cirrostratus nebulosus, are also included as patterns which just occasionally occur over the Plateau. From photos of clouds belonging to the same genera, those taken at different places and in different seasons and presenting certain features, are chosen. Efforts have been made to illustrate or to establish a fact or a phenomenon about a cloud with a series or a group of photos. Furthermore, a group of panoramic photos of the evolutions of cloud systems reflecting the whole sky conditions and clouds accompanied by optical phenomena such as halo, corona and morning or evening glow are given.

Owing to the limitations of field surveys, it was impossible to collect necessary data for some of the peculiar clouds, and to get a better idea of their genesis mechanisms. However, photos of such clouds are also included in the Atlas as they may suggest new facts or phenomena.

The height of a cloud layer is directly correlated with the weather system and atmospheric stratification. The authors measured the cloud heights with China-made laser nephoscopes Model GGU3–1. The data thus obtained are contained in the comments on cloud plates and the tables of cloud heights. The laser nephoscope was calibrated by the manufacturer before and after the operation; it was also co-calibrated with radar to ensure normal performance during investigations.

In order to explore the background of the geneses or evolutions of some clouds, the authors widely analysed the synoptic charts, surface synoptic maps T-lg P diagrams, data of upper winds, etc., which comprised some more than 300 examples, and calculated the physical variables of some examples. For comparison, as many as 20 items of statistics, covering a period of 10 years and obtained from 123 representative stations of various physical regions throughout the country were analysed. It is on the basis of all these studies that A General Survey of Cloud over the Qinghai-Xizang Plateau was written.

The members of the research group of *Atlas of Clouds over the Qinghai-Xizang Plateau* worked under very difficult circumstances such as lack of oxygen, hardly endurable climate, sparsely populated wildernesses and bad communication facilities. There were altogether 14 people who did the field work. The chief of the group was Wu Hexuan; the members were Wan Zhengyi (female), Tang Lanquan, Li Xuanyou and Chen Jian. Taking part in the work at one time or another were Shan Jingwu, Wu Shoutian, Lin Zihao, Ge

Yuehua, Wu Zhenhuai, Hu Qingyun, He Yong, Ren Weidong and Su Liang.

Data analysers were Wu Hexuan and Wan Zhengyi; data calculators were Wu Zhen and Yu Lingdi.

The authors acknowledge their indebtedness to the heads and staff members of the Meteorological Bureau of Xizang Autonomous Region, Xigaze Meteorological Observatory, Pagri Meteorological Station. The 3rd company of P.L.A. at Tingri and other observatories and stations in Qinghai and Xizang for their warm-hearted help.

The authors also express their deep thanks to Professors Tao Shiyan, Gao Youxi, Shu Jiaxin, Yi Shiming, Yao Zhensheng, Tian Mingyuan, Associate Professors Hou Hongsen, Guo Enming, Engineers Lu Dongwen, Tong Letian, Yang Changxin, Xu Huanbin and Li Shutan for their encouragements and suggestions given in the course of work. We give our sincere appreciation to Professor Wang Pengfei for his distinguished guidance in the whole work and his kind help with the writing of the commentaries of the Atlas and to Associate Professors Sheng Chengyu for his valuable suggestions and translation, and Gao Guopei who did the translation.

Finally, the authors express their gratitude to all those who have cared for and supported this work.

Wu Hexuan
February, 1986

前　言

举世无双的青藏高原，是平均海拔超过四公里、面积超过二百万平方公里的高大实体，它象西风急流里的一个“中流砥柱”，既承受着急流的冲击，也迫使急流翻越或分支绕流。青藏高原与周围同高度大气热力性质的差异，往往造成温度的不一致，从而影响气压的空间分布并形成季节性热力环流。因此，大气环流中的各种天气系统由于青藏高原的存在，就变得十分复杂。青藏高原面积广大，其海拔高度、地形、地表面的性质，各有不同，所以在高原上各地的天气并不一致，各地气候也有明显差异。

由于上述原因，青藏高原具有独特的天气气候特征，为国内、外气象学家注目，已有不少现场考察报告、专题研究论著，对此作出了显著的贡献。但是，有关青藏高原云的研究，至今仍然做得很少。

在青海省科学技术委员会、青海省气象局大力支持下，青海省气象科学研究所领导下，1981年组成了“青藏高原云图”专题科研组，对青藏高原的云进行考察。历时三年，行程逾四万公里，除阿里地区未能实地考察外，对重点云区曾作了两次以上的复验性考察，取得了一批云态照片、激光云高数据、全天摄影云图和云的一些动态电影资料。

为了拍摄不同云状在同一地点的连续变化和地形云，除普查性考察外，在重点考察云区中，选取了代表各类地形和生云山区附近为定点拍摄点，如较大水面的鄂陵湖；黄河流域的达日、哇日玛；局地造云源地之一的玛积雪山；地形开阔的大武牧场；长江源头的唐古拉山；藏北高平原的那曲；雅鲁藏布江流域的拉萨、林芝；喜马拉雅山脉北侧的亚东帕里、定日区仓木达；高原西部山区的加泽拉山。我们在每个拍摄点各工作一个月左右，摄得了一批各类天气系统下出现的具有青藏高原显著特点的云状照片。从3000多张照片中初选500余幅，于1984年8月在青海省西宁市，经国内同行和专家审议，通过技术鉴定。

为了使国内、外的气象界以及有关学科的研究者了解青藏高原的云，因此我们编纂了《青藏高原云图》。本图集的出版，首先在于为天气观测和天气预报提供参考资料；其次在于为气象教学、航空事业、云物理学、积云动力学、小尺度系统天气学、高空气候学、青藏高原气象学等研究领域，提供青藏高原云的普遍与特殊实例和某些资料性的统计结果。

本图集选定了277幅（152组）云状照片，着重选入具有青藏高原特点或反映青藏高原天气气候特征的各类云状。对特殊云、地形云尽可能编入其形成或演变过程的实例。有些在平原地区常见，但在青藏

高原上却极少出现的标准云状，如蔽光高层云、薄幕卷层云等，仅作为曾出现的云状编入。同一云属则选取不同地点，不同季节，具有特色的照片编入。力求用一系列或一组云状照片阐述或佐证一个有关云的现象或事实。另外还选用了一组全天照相的反映视野天空状况的云系演变图和伴有晕、华、霞等光象的云状。

限于现场探测条件，对有些特殊云未能测得必要的数据，对其形成的物理机制还不够了解，仅作为新事实或新现象编入云图。

云层的高度，直接与天气系统、大气层结状况紧密相关。我们在考察现场用国产GGU3-1型激光测云仪测得了图片说明和云高统计中的云高数据。激光测云仪在使用前后均经厂方检验校准，考察期间曾与雷达互校，性能正常。

为了探讨部分云状的形成或演变的背景，普查分析了300多个实例的天气图、地面天气实况图、温度-对数压力图、高空风等资料，并计算了部分个例的物理量。以全国各类地形区域的123个代表站，10整年近20个统计项目的数据进行分析，作为与青藏高原对比的依据，归纳出了“青藏高原云的概况”。

“青藏高原云图”科研组，是在高原缺氧、气候恶劣、人烟稀少、交通不便和生活艰苦的条件下进行野外考察的。参加野外考察工作先后有14人。课题组长：吴鹤轩；组员：宛正颐（女）、唐兰泉、李宣友、陈建。参加过现场考察的还有单静武（托托河气象站）、伍受天（上海无线电二十三厂）、林自浩（青海省气象局）、葛跃华（青海省气象台）、吴振怀、胡庆云（青海省气象局）、何永（西藏气象局）、任卫东、孙亮（青海电视台）。

资料整理分析：吴鹤轩、宛正颐；资料统计：吴珍、于玲弟。

在考察期间曾得到西藏自治区气象局、日喀则气象台、帕里气象站、西藏定日区驻军三连，以及青藏地区部分气象台、站的领导和同志们的热情帮助，特此致谢。

向工作过程中给以鼓励并提出建议的陶诗言、高由禧研究员、束家鑫、易仕明高级工程师、么枕生、田明远教授、侯宏森、郭恩铭副研究员、陆同文、童乐天、杨长鑫、许焕斌、李树檀工程师表示衷心感谢。特别是向在选编云图和文字说明中给予热心指导和具体审定的王鹏飞教授表示由衷的感激。我们还向认真负责地将本图的中文译成英文并提出宝贵意见的盛承禹副教授及高国沛副教授表示衷心的感谢。

向所有关怀、支持本课题组工作的同志致谢。

吴鹤轩

1986年2月

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A General Survey of Cloud over the Qinghai-Xizang Plateau

I. Characteristics of Principal Cloud Shapes Found over the Qinghai-Xizang Plateau

Cloud observations are generally made in accordance with the classification set out in *the International Cloud Atlas* (1956) published by the World Meteorological Organization, a morphological classification which is based on the shapes and colours of clouds seen from the earth. This classification, though lacking in accuracy in distinguishing certain types of clouds, is hardly replaceable, as is shown by international practices over the years. The reason is simple: so far, the naked-eye observation is still the chief means for the identification of clouds.

The classification above is based on naked-eye observations of clouds over areas of moderately high altitudes. However, the Qinghai-Xizang Plateau is a region where the altitude is 4000 m above sea level, the freezing level is relatively low and the water content of clouds is less. Consequently, in spite of the fact that some of the clouds seen there are similar to those found in areas of low altitudes, many of them assume shapes peculiar to this region. Besides, the processes of evolution of these clouds can hardly be adequately covered by definitions and descriptions contained in *the International Cloud Atlas.* As it turns out, discrepancies can often be found between the clouds over the Plateau and the definitions and descriptions of *the International Cloud Atlas.* It is these discrepancies that reveal the special laws governing the weather and climate of the Qinghai-Xizang Plateau. So it follows that these special cloud shapes of the Plateau should be treated as varieties of certain frequently seen cloud shapes, and be given names different from those listed in *the International Cloud Atlas.* However, since they are varieties, their new designations should not ignore their relationship with similar clouds covered in *the International Cloud Atlas.* This is the principle we follow in naming the special cloud shapes of the Plateau. The name "Cumulus capillatus" is a case in point (Plates 4—7).

This Atlas consists of photographs taken on the basis of eye-observation from the earth. This method, simple and easy to apply, proves particularly useful when micro-scale weather system clouds, special orographic clouds and indication clouds are studied for the purpose of providing reference material for weather forecasts. As is confirmed by practices, the eye-observation method, when used in conjunction with satellite cloud pictures, radar echoes, synoptic charts and sounding data in the study of clouds and weather, can produce very reliable results. The study of the characteristics, physical conditions, geographical distributions and temporal and spatial variations of the clouds over the Qinghai-Xizang Plateau is one of the important fields necessitated not only by the research of weather changes resulting from clouds, but also by the research in aeroclimatology and synoptic meteorology of plateaus, cloud physics and micro-scale synoptic meteorology.

Based on field surveys and examples contained in this Atlas, an attempt is made to list five features of clouds over the Qinghai-Xizang Plateau:

(1) The clouds have a large variety of shapes. Almost all the standard cloud shapes can be seen over the Plateau, the only difference being that some of them, such as Cirrostratus nebulosus, Altostratus opacus and Nimbostratus, are not so frequently found as in non-plateau areas. In addition, there are over the Plateau special clouds which are rarely seen in non-plateau areas; chief among them are large and long castellanus cloud belts, micro-scale stormy clouds, glacier clouds over snowberg, banner clouds and cumulus capillatus.

(2) Cloud heights are confused. Though clouds over the Plateau can be classified as high and low in terms of the distance between them and the ground, yet it often happens that high clouds are not really high, and low clouds are not really low over the Plateau; sometimes an inversion of the two types of clouds can be observed.

(3) Cloud transformation is rather complicated. This feature of the clouds over the Plateau is manifested in the direct transformation of cumuliform clouds into stratiform clouds, and from ice clouds into water clouds, as well as in the frequent emergences of a transitional state in which two species of clouds co-exist.

(4) Cloud evolution follows a special pattern. Stratiform clouds of the frontal system, which are often seen over areas of low altitudes, are rarely found over the Qinghai-Xizang Plateau, where in the processes of cloud evolution of various weather systems, high clouds will as a rule appear first, followed by low clouds, and clouds of medium height are rare here. Furthermore, precipitation mostly occurs when Cumulonimbus makes its appearance.

(5) Precipitation comes from all types of clouds. Apart from common precipitation bearing clouds, there are certain types of clouds such as virga which do not produce rain in low-altitude areas but can cause precipitation on the Plateau.

1. Cumulonimbus of the Qinghai-Xizang Plateau

This type of clouds may appear over the Plateau any day in the year in a large variety of shapes. Compared with its normal forms, Cumulonimbus over the Plateau is less dense and less dark in colour, and has a low glaciation level. Moreover, it has a small vertical thickness and covers a wide range horizontally, with virga hanging frequently from its bottom. There is no vigorous turbulence, and the cloud waist — the bee-waist-shaped part that connects the anvil and the main body of the cloud — is scarcely found.

The Cumulonimbus clouds of the summer-precipitation type are relatively massive, composed, in most cases, of several cloud cells, with their bases often taking the shape of a mamma or rotor, and accompanied by down-drag streaks of rain droplets. Most clouds of this type result from the low-pressure system of the Plateau, working in association with orographical dynamic and thermal convective effects.

A large quantity of energy can be released in certain localities by the orographical dynamic and thermal effects of the Plateau. This can lead to the formation of hail-stormy clouds and to the production of small-scale convective weather. The violently convective cloud usually has a very short life span, and is built up suddenly with its base getting very near to the ground or water surface — this is a form of Cumulonimbus peculiar to the Plateau (Plates 50–52).

Under the influence of mid- or lower-atmosphere strong winds or jet streams, the