捕風捉雲 感受生息

探索雲霧帶裡的秘密

Fog-catching in Guanwu - Exploring the Secrets of Fog

特別感謝 Special thanks to / 台灣大學大氣科學系林博雄副教授 Asso Prof. Po-hsiung Lin of Dept. of Atmospheric Sciences, Nat'l Taiwan Univ.

採訪撰文 Interview & Text / 藍嘉俊 Jia-jun Lan
翻譯 Translator / 歐冠宇 Kuan-yu Ou

雲霧的「捕捉」研究，是生態科學研究上的重要進程。圖為雪見地區的司馬限山雲霧 / 陳家鴻攝

The research of "fog-catching" constitutes an important progress in ecological science. The picture shows the fogs in Simaxian Mountain, Syuejian area. /by Jia-hong Chen

顧名思義，觀霧，這個雪霸國家公園內的著名景點，是個終年雲霧繚繞的地方。但是，怎麼個「終年繚繞」，卻沒有明確的數據紀錄，因此也沒人說得明白。2006年，台大大氣科學系林博雄副教授首次造訪，當時的觀霧管理站主任，見機不可失，便提出了這個疑惑。對於這個問題，林教授不但有共鳴，而且也放在心上。直到2008年，他接受了國家公園委託，終於得以勾勒比較清楚的答案。

在觀霧捕霧

然而，霧的觀察研究並不是那麼想當然爾。一般來說，氣象專家研究的範圍，時、空尺度都非常的大，比如說探討北極半世紀以來的溫度變化，像這樣焦點集中在一小塊山區，並不多見。再加上林教授同時對生態議題感興趣，亦促成本計畫的推動。因為本區茂密豐富的森林植群，與這塊雲霧瀰漫的潮濕環境，有著密切關係。所以，這也是一項跨領域(氣象、生態)的合作。

好奇者可能會問，難道中央氣象局不能提供答案嗎？這是因為雖然觀測站遍佈全台，但霧水不屬於溫度、雨量、風場等常態儀器測量的項目，有的話，也僅限於局部地區，且是依賴人力目測記錄。因此總的來說，這次系統性在觀霧進行的「捕霧計畫」，堪稱是一項國內先驅型的研究。此外，調查結果亦能提供雪霸國家公園生態解說之用，並做為山區旅遊和生態調查的綜合指標。

根據氣象局的定義，能見度低於1公里、相對濕度接近100%稱之為「霧」。若以體積來辨識，霧：雲：水的比例是1：100：10000，也就是說霧的粒徑最小，要「抓住它」還真不容易。而研究經費有限是另一個挑戰。目前能針對霧進行科學觀測的，主要是一種稱為「能見度儀」的設備。但這種動輒超過50萬的昂貴儀器，不是一般學術研究能負擔的。

Just as its Chinese name implies, Guanwu in Chinese, a well-known attraction in Shei-Pa National Park (SPNP), is immersed in fogs all year round. But exactly how "foggy" this place was had never been proved or measured by anyone until 2006, when Asso. Prof. Po-hsiung Lin of Dept. of Atmospheric Sciences, Natl. Taiwan Univ., visited Guanwu Station. Driven by the inquiry posed by the station chief and his own curiosity, Lin embarked on a mission in 2008 to find a better answer under the commission of Taiwan's National Parks.

Catching the Fog in Guanwu

Observations on fogs are not as easy as one would think. While meteorological studies have usually been ambitious in terms of the range of time and space, such as the temperature change of the Arctic in the past half century, research focusing on only a small mountain area was rare. But urged by his interest in ecology-related issues, Lin decided to undertake this cross-discipline project between meteorology and ecology since the forest vegetation there is closely connected with the foggy, humid environment.

Some may question: why can't the Central Weather Bureau (CWB), with all its weather stations across Taiwan, provide the answers? It's because unlike temperatures, precipitation, and wind fields, fogs are not regularly monitored and measured, or only recorded within very small areas and by human eyes. So this systematic fog-catching project is truly a pioneering study in Taiwan, and its results may serve as materials for interpretation of the ecology in SPNP and as composite indicators for mountain tourism and ecological surveys.

According to the definition by the CWB, the visibility of fog must be less than 1 km, and the relative humidity of it close to 100%. In terms of volume, the ratio among fog, cloud and water is 1 to 100 to 10,000, with fog the smallest in particle size and most difficult to catch. Another challenge came from the limited budget as regular academic research cannot afford such equipment for scientific observation on fogs as a visibility meter, but costs more than half a million NT dollars.

雲霧瀰漫的潮濕環境與茂密豐富的森林植群有著直接的關係 / 陳家鴻攝
The foggy, humid environment is closely related to the dense forest vegetation. /by Jia-hong Chen

必先利其器

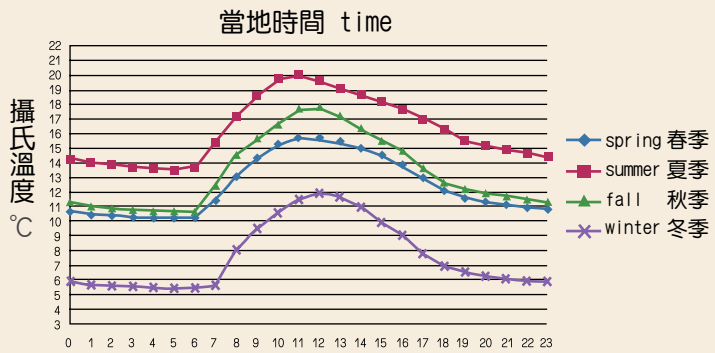
如此一來，尋找替代性的測量工具，就變成了關鍵。好在，如何把霧捕捉下來，國外有案例可循，而台大大氣科學系的大氣測計研究室，也累積了一些相關經驗。於是，林教授率領的團隊，便設計、製造出幾款「雲霧偵測器」、「雲霧攔截器」，同時搭配數位相機的定時拍攝，以紀錄霧出現的頻率與水量。國內的第一套完整的「捕霧陷阱」，就這麼被隱藏在觀霧的兩處樹林裡（也避免人與其他生物的干擾），其正式的名稱是「雲霧偵測攔截整合裝置」(Fog Detection and Interception Device，FDID)。由於事先已檢視過國外的儀器尺寸，也確保了團隊所得出的數據，能和國際文獻作對照。此外，並與研究生在台大大氣科學系打造一套3.6公尺長度的「霧風洞」，來驗證攔截網的捕霧效率。

這些戶外儀器的總造價不過一萬多元，成本是壓下來了，但其他的辛苦卻免不了。它們體積龐大且組件眾多，有些零件還要特別訂作，光是在台大先行組裝測試，就花了整整3天。測試無誤後才能拆解上車，浩浩蕩蕩的入山服役。基於長時間觀察的需求，儀器運轉的能源是另一項課題。原本寄望太陽能板，但架設不易、且穩定性不足，最後還是要拉條電線，而這在深山裡是相當麻煩的工作。此外，儀器架設的地點與朝向都是學問，方能確定該處取得的數據具代表性。這不但需要過去的氣象紀錄協助判斷，也得靠熟悉當地環境的解說志工提供意見。

Replacement Gadgets that Work Just Fine

It was pivotal, therefore, to find alternative equipment for catching and measuring fogs. Thanks to similar foreign cases as examples and some previous experiences by the Lab. of Instrumentation and Measurement at the Dept. of Atmospheric Sciences, NTU, Lin's team managed to design and develop several models of fog detectors and fog interceptors that, accompanied by digital cameras, recorded the frequency and volume of fogs. This complete set of "fog-catching trap," formally named Fog Detection and Interception Device (FDID), was installed deep in the woods at two spots (partly to avoid disturbance by people and other animals). By emulating the equipment used by other countries, this locally-made device was capable of producing internationally comparable data. Besides, Lin and his team also developed a 3.6-meter "fog wind tunnel" to test the efficiency of the device in catching the fog.

These NT$10,000-plus gadgets saved a great deal in cost, but took its toll on its large size and numerous parts. It'd take 3 days to assemble and test the device in NTU before it could be carried all the way into the mountains. Due to the need for longitudinal observations, the source of power to operate the device emerged as an issue. As solar cell panels would be hard to set up and unstable in power provision, Lin and his team opted for traditional power cords, which meant a demanding job in the mountains. They also had to consult previous weather records and some veteran interpreters in order to determine the sites and directions for installation to ensure that representative data and statistics could be obtained.



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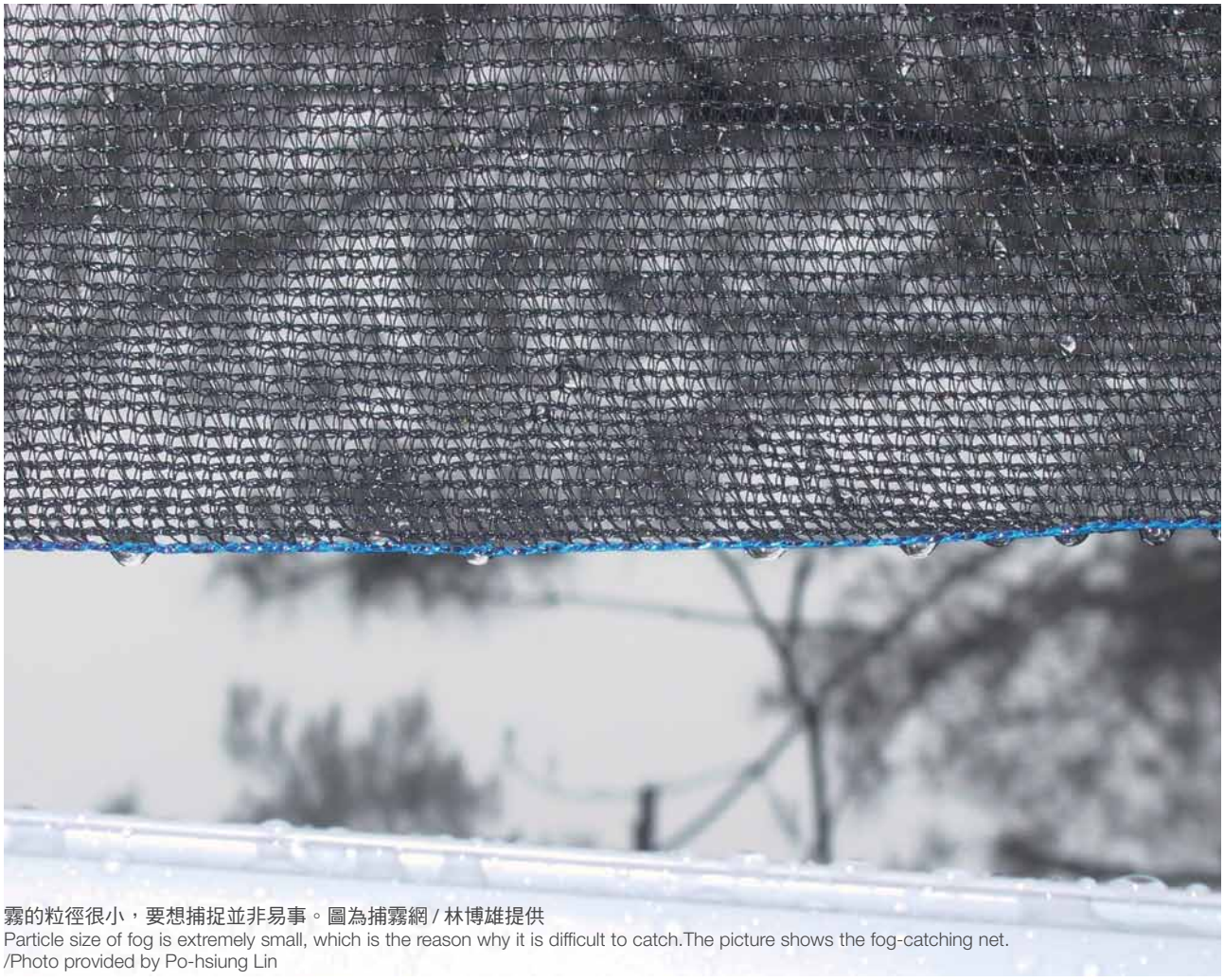
1. 自行設置的儀器體積龐大且組件多，光組裝與架設都是一門學問 / 林博雄提供
   The sizes of these self-designed gadgets are huge and because they have numerous parts, it takes lots of efforts to assemble them. /Photo provided by Po-hsiung Lin
2. 觀霧四季的氣溫逐時變化圖（縱軸為氣溫℃，橫軸為0~24小時）
   Hourly temperature map of the four seasons in Guanwu. (The vertical axis specifies the temperatures (in Celsius); the horizontal axis indicates time (0~24 hours)
3. 設備經費有限，故定時做儀器設備的檢修維護，是重要的執行項目之一。圖為研究人員進行雨量筒的清潔維護
   Due to limited budget, regular check and maintenance of equipments is a must-do. In the picture the researcher is cleaning the rain gauge.



霧的粒徑很小，要想捕捉並非易事。圖為捕霧網 / 林博雄提供
Particle size of fog is extremely small, which is the reason why it is difficult to catch.The picture shows the fog-catching net. /Photo provided by Po-hsiung Lin

從無到有，每一筆資料都是得來不易。在這裡先要認識一個陌生的名詞：「水平降水」。通常我們所熟知的降雨量，指的是某地區自天空落下的「垂直降水」。但是霧不一樣，它會水平飄移。因此，當地霧水量的多寡，要藉由水平降水的測量來判斷。

驚人的發現

根據研究團隊的調查顯示，觀霧地區因雲霧所帶來的水平降水相當可觀。以「有霧無雨」發生情境來計量，約是同季垂直降水量的9.3%；若將「有雨有霧」的狀況併入，則水平降水可達垂直降水量的37%。這說明了僅靠傳統的降雨量紀錄，不足以表示當地實際的潮濕環境，和飽滿的含水量。令林教授驚訝的是，這些數據，簡直已可媲美歐美團隊在低緯度雨林的觀測結果。此外，觀測期間有霧發生的天數，即所謂的「霧日」，更高達了98%。觀霧這塊金字招牌，可謂貨真價實。至於起霧的時間，調查顯示會因季節而有差別，夏季多發生於午後，秋冬則常集中於早上或上午。

當然，要觀霧，雪霸觀霧並不是唯一的選擇。以國家公園為例，北部的陽明山與中南部的玉山塔塔加，同樣能體驗雲霧的千變萬化，和蘊含其中的豐富森林帶。

Each piece of data was hard earned by Lin's and his team's effort to start from scratch.As fog moves horizontally, its volume is mostly measured by its "horizontal precipitation (HP)," a lesser-known term as opposed to "vertical precipitation (VP)" that scientists use in determining the volume of rainfall.

Stunning Findings

Surveys by Lin's team showed a considerable amount of horizontal precipitation in Guanwu area. The HP on "foggy days without rain" was about 9.3% of the VP in the same period, while the HP on "foggy days with rain" could hit as much as 37% of the VP. This evidence has indicated that traditional rainfall records are not enough to reflect how humid the place is and how high its water content is! The statistics have almost matched the results observed by European and American teams in low-latitude rain forests. And Guanwu truly lives up to its name because the percentage of the so-called "fog days" there is as high as 98%. Its fogs mostly emerge in the afternoons in summer and do so in the mornings in autumn and winter.

Guanwu, of course, is not the only site for people to watch fogs. Yangmingshan and Tataka (in Yushan) also boast capricious fogs and abundant fog forests.

通常，這些霧林帶多位於1,500～2,500公尺的高度，但地處熱帶、低海拔的墾丁國家公園的南仁山，也有分布。林教授推測，除了高度之外，水氣、風和濕度也是重要的因子，加上特殊的地形，就有條件形成。不過，關於霧林帶的空間分布，我們頂多像此刻的說明一樣，只能用手指點出大概的區位，其邊界還是不確定的。因此林教授也呼籲，一張清楚嚴謹的全國霧林帶範圍圖（等值線），應該要及早劃設出來，這是日後推動相關生態研究的基礎資料。

這次針對觀霧所作的雲霧調查，不但補足了地區的環境資料，其詳細的數據，更得以回饋給一些進行中的實驗計畫。林教授透露，中央氣象局目前正測試藉由地球同步衛星探測，判斷大範圍低雲/霧發生的可能。由於衛星距離遠、範圍廣，每一個觀測單元涵蓋的面積，就是一處5╳5公里的大方格，準確性如何令人好奇。比對結果顯示，觀霧當地的實地調查和衛星探測仍有相當的誤差，讓這個尚在實驗中的計畫，得以檢討、修正儀器與技術，使未來加入氣象預報行列時，有較高的精確度。

Generally fog forests are distributed at an altitude between 1,500 to 2,500 meters, but they are also seen in some tropical and low-altitude areas such as Mt. Nanren in Kenting National Park. Lin speculates that this becomes possible when conditions like water vapor, wind, humidity and special landforms cooperate. But so far, the exact boundary of Taiwan's fog forests is still vaguely known, and Lin urged that nationwide distribution isograms of fog forests be drawn as early as possible in order to facilitate related ecological research in the future.

The statistics on fog collected by Lin in Guanwu are not only complementary to previous data of the local area but also helpful to some ongoing research projects. For example, the CWB is attempting to predict the possibility of large-scale low clouds and fogs through detecting them with a geosynchronous satellite, but the accuracy of such long-distance and broad-range detection is questionable. It turned out that Lin's field investigation on fogs could well serve to correct and modify the data, equipment and techniques of the CWB project, and help to increase the accuracy of future weather forecasts.

基本資料的累積與建立

此外，全球暖化是當今最受關注的環境議題。有學者懷疑，氣候暖化可能造成台灣霧林帶的高度往上提升。但如同先前所言，國內對雲霧的嚴謹紀錄還在起步，林教授認為，未來累積夠長的觀測資料，我們必定能清楚回應這個推測。

不過相對於山區，霧的觀測在平地是比較完整的。資料顯示，平地的霧日有逐漸減少的趨勢。有學者認為，這與人類污染環境有關。因為都市和工廠排放大量的氣體，這些細小微粒吸收了周圍的水氣，讓它無法形成霧，所以平地的霧就越來越少了。那麼反過來說，霧是否被污染了呢？林教授接下來的計畫，這是要回答的問題之一。2011年他將與德國專家合作，一起在溪頭調查當地霧的化學成分。類似的霧化學研究也已在棲蘭山區由東華大學完成。

More Basic Data Needed

As global warming has become one of the hottest environmental issues, some scholars have cast doubt on whether it would move or has moved Taiwan's fog forests to higher altitudes. This speculation can only be clearly verified or responded when more and longer-term records on fogs across Taiwan are accumulated, says Lin.

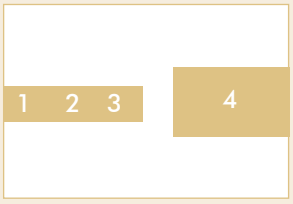
But compared to observation data on mountain fogs, that on urban fogs is much richer. And the data shows that the number of fog days in urban areas is dwindling. Some researchers think this has to do with pollutions caused by humans as gases emitted from cities and factories would absorb much of the vapor to forbid the formation of fogs. As for whether urban fogs have been polluted, this is among what Lin is about to answer by collaborating with German experts in 2011 to study the chemical composition of fogs in Sitou.

雲霧研討國際年會去年(2010)已邁入第5屆，交流持續進行中。對某些國家而言，把飄在空中的霧抓下來，不只是為了研究，更有實際的用途。如南美洲的智利、中美洲的波多黎各和夏威夷茂宜島等地，將攔截下來的霧水，補充做為地區旱季時民生或灌溉用水。為求一網打盡，這些捕霧網的面積還真不小，有的寬度和網球場寬度相當。這樣的經驗可供我們參考，說不定未來能應用在小區域中。

然而無論如何，台灣基礎資料的建立與完備，仍是首要工作。如同前述，沒有全國霧林帶的範圍圖、沒有化學成分的鑑定，如何知道哪裡的霧水可以應用？這條路沒有捷徑，而且需要跨單位的合作。林教授由衷期待，握有資源的氣象局、林務局和國家公園，在雲霧的議題上，今後能夠有更多更積極的跨界合作。

Exchanges of studies on fogs have been making progress in the International Annual Conference on Fogs, which marked its fifth year in 2010. Scientists in some countries catch fogs not just for the sake of academic research but for more practical purposes. For example, in Chile, Puerto Rico, and Maui, (in Hawaii) fogs have been intercepted as supplements for domestic daily use and irrigation in dry seasons. Some of the fog-catching nets are as wide as a tennis court, and may serve as a great reference for applications in smaller ranges.

Whatever potentials the studies on fogs may have ahead, the current priority still is to establish and accumulate basic data on fogs in Taiwan. Without mapping out the national isograms of fog forests and figuring out the chemical composition of fogs, applications on practical use can never be possible. This is a task without any shortcut, and Lin truly hopes the more resourceful agencies such as the CWB, the Forestry Bureau, and the national parks may work together on issues of fogs in Taiwan.



1-3. 觀霧地區因雲霧所帶來的水平降水相當可觀，圖左至右為2008年8月3日所做的觀測紀錄照，可清楚看到約至下午時分，起霧狀況已相當濃厚 / 林博雄提供
Horizontal precipitation in Guanwu area is considerable. Pictures from left to right are the obsevation records, from which one can see clearly that the fog is quite heavy in the afternoon. /Photo provided by Po-hsiung Lin

4. 平地與保育地帶的霧是否會因空氣污染的影響而有所不同，是林教授的調查計畫之一。圖為在巨木林道山椒魚保育地的移動型氣象站與曠時照像機 / 林博雄提供
Whether air pollution is the reason that the urban fogs and mountain fogs are different is one of the focuses in Lin's project. The picture shows the moveable weather station and time-lapse camera in the conservation area of Formosan Salamander *(Hynobius formosanus)* in Big Trees Forest Road. /Photo provided by Po-hsiung Lin

簡介 *Profile*

林博雄 Po-hsiung Lin

台灣大學大氣科學博士，現為台灣大學大氣科學系專任副教授，同時為該系「大氣測計實驗室」負責人，專長為大氣測計、航空氣象與計算機輔助學習。

With a Ph.D. degree in atmospheric sciences, National Taiwan University, Lin is currently a full-time associate professor in the Dept. of Atmospheric Sciences, NTU, and the director of the Laboratory of Instrumentation and Measurement at the Dept. He specializes in instrumentation and measurement of the atmosphere, aeronautical meteorology, and computer-aided learning.