專訪颱風獵人吳俊傑教授

滿身風雨終無悔

No Regrets Despite All the Wind and Rain

An Interview with Typhoon Hunter Chun-chieh Wu

夏天，風生水起的季節，也是颱風獵人最忙碌的時刻。

陽光熾熱，照得海水暖洋洋的。風從海洋獲得能量，加強對流，又進一步增強風速，從海上汲取更多能量，再加強對流……慢慢地，對流越來越強，越來越強，終致推動形成逆時針旋轉的強烈氣旋——颱風。所有航空器紛紛走避，唯有一架噴射機，從台中清泉崗機場起飛，迎面直衝而去。

科技斥候，深入險境刺探敵情

迎面追風而來的噴射機，要不在凌晨五點起飛，要不就半夜十一點回航；飛行中有時遇上雷擊，有時被冰雹砸，緊急時還得在暴風圈籠罩的機場降落。機艙裡載著颱風獵人，一批冒險深入前線刺探敵情的科技斥候。面對飛行過程顛簸不安，這群人內心做何感想？如何面對內心恐懼，與家人擔憂生死的壓力？

「說實在早就沒有感覺，畢竟我從學生時代就開始飛了。真要說壓力，現在最大的壓力是責任，是民眾對氣象預報高度期待帶來的壓力。」台灣最資深的颱風獵人吳俊傑回答。

早在1991年吳俊傑就在墨西哥外海穿越颱風眼。他是現任台灣大學大氣科學系系主任，也是國科會和中央氣象局共同支持的「追風計畫」主持人，從2003年起開始帶領團隊飛到可能侵台颱風上方約13公里高空，觀測颱風周遭大氣環境。今年8月，莫拉克颱風釀成巨災，輿論撻伐氣象局預報不準的聲浪不斷；

Summer, a season of wind and rain, is the busiest time in a year for typhoon hunters.

Scorching sun bakes the sea water, from which wind gets energy and increases its convection, which in turn brings up the wind speed again and then the cycle of stronger and stronger momentum and convection. Finally, an intense counterclockwise cyclone – typhoon – takes shape, and is shunned by all aircraft except one jet plane flying from Ching-Chuang-Kang Airport in Taichung right into it.

Deep into the Red Zone

This typhoon-chasing jet always takes off at 5 a.m. or returns at 11 p.m. in the danger of thunderstokes, hailstones, or emergency landings at nearby airports in storm. Inside the plane are a group of typhoon hunters probing the cyclone deep into the red zone. How do they handle every jolty flight and their fear and their family's worries?

"Frankly, I got used to all this long time ago. I started doing it since I was still in school. If there is any stress, it's from the responsibility to meet the public expectation of accurate weather forecasts," answered Chun-chieh Wu, the most senior chaser of typhoons in Taiwan.

Having flown through the eye of a typhoon near Mexican coast back in 1991, Wu now chairs NTU's Department of Atmospheric Sciences and directs the DOTSTAR project co-developed by National Science Council and Central Weather Bureau (CWB). Since 2003, he has started flying with his team over to about 13 km above any typhoon potentially affecting Taiwan to conduct a close watch. This August CWB was under public attack with its misjudgment on the

採訪撰文 Interview & Text / 張碧慧 Joyce Chang　翻譯 Translator / 歐冠宇 Kuan-yu Oui　圖片提供 Photo provided by / 吳俊傑 Chun-chieh Wu

飛上天，追的不僅是難以捉摸的風，也為人們預測安全之道 / 部落客 jack8 攝
They took a plane flied to the sky, figured out the best way to forecast typhoon news for people / by jack8

期間「追風計畫人員表示莫拉克是虛胖颱風」的不實報導，也讓團隊遭受波及。

「虛胖颱風」其實是傳媒自行創造的名詞，再套用追風計畫名義做出的聳動新聞標題。承受了巨大壓力，吳俊傑除了簡短發文澄清，只輕描淡寫表示「做對的事，小誤解還好。」但中央氣象局預報中心主任吳德榮選擇提前退休一事，他難掩不捨，認為氣象局屢次在天災過後變成「代罪羔羊」。

calamitous Typhoon Morakot while Wu's team was also falsely criticized by misleading news stories.

Some media arbitrarily created the term "seemingly strong typhoon" and quoted it under the name of the DOTSTAR to make a lurid title. Under huge pressure, Wu set straight the record with a brief notice and just shrugged it off as a minor misunderstanding. But he felt sorry for the ensuing early retirement of De-rong Wu, director of the Weather Forecast Center, and the scapegoat role forced upon CWB when Nature hit hard.

氣象預報準不準？

吳俊傑解釋，氣象預報不準乃因「科學有其侷限。」氣象預報是將觀測到的大氣、海洋資料，放進電腦的動力方程式進行運算。經費考量，絕不可能鋪天蓋地蒐集所有的資料，尤其海洋上的資料更是不易取得。再者，以電腦進行模擬，首先必須將大氣空間切成許多小格，也就是所謂的網格點；但觀測資料不論在水平或垂直的分布都不均勻，不盡然能與電腦中的網格對應，因此需要藉由適當的數學方法才能將觀測資料放到網格點進行運算。此外，為求預報時效，使用的數學方法不能太過繁雜，網格點的大小也必然受到限制，更須適當簡化模擬所需的動力方程式，以縮短運算時間。另方面，這些預報的動力方程式對初始資料十分敏感，些微的初始誤差會隨著反覆的運算而成長，再加上大氣是一個極度複雜的系統，科學家對某些物理過程的了解仍不足。如此，氣象預報當然存在科學誤差。

以颱風路徑預報為例，目前所有國家在颱風來襲24小時前的預測，平均誤差約100公里。換句話說，預報和實際登陸地點差距好幾個縣市，在科學上誠屬合理；有些縣市依照預報白放了一天颱風假，有些照常上班上課卻遇上強風豪雨，在科學上亦不得不然。「而100公里還只是平均值」，吳俊傑指出，如果某次運氣好，預報誤差只有50公里，合理推論另一次預報或許就「運氣不好」，誤差可能達150公里。

颱風走哪裡　雨就降哪裡

降雨更是氣象預報的終極挑戰。莫拉克颱風帶來的暴雨重創南台灣，颱風期間氣象局7次上修累積雨量遭受抨擊。事實上，降雨預報本來就必須根據最新數據隨時修正，台灣更是極少數敢於提供降雨預測的國家，目前全球的降雨預報平均命中率也只有0.2～0.3 。（當預報 A 區域降雨，實際降在 B 區域，而 AB 兩區的重疊範圍是 C，則降雨預報準確率是 C/(A+B − C)。）

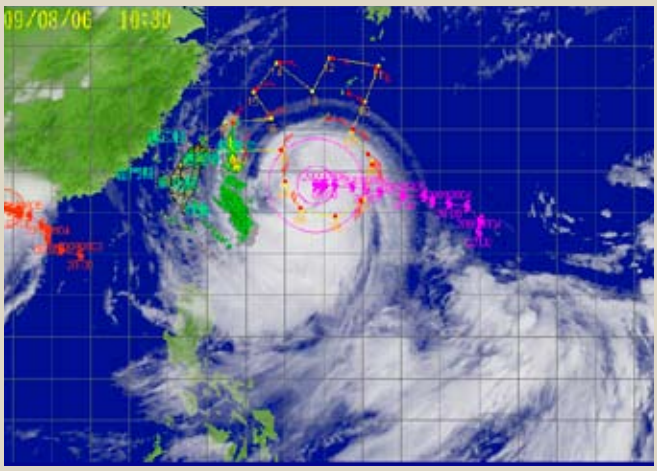
Reasons for Inaccurate Forecasts

Wu explained that lack of accuracy in forecasts results from the limit of science. A forecast is calculated by dynamics formulas with data observed from the atmosphere and the sea. A limited budget forbids boundless comprehensive data gathering, especially that at sea. Besides, computers simulate the typhoon by making numerous grids for the atmosphere, which may not perfectly represent real scenarios. And to provide timely forecasts, the mathematical tools and formulas must not be too complicated and the size of each grid is also restrained. While the dynamics formulas are highly sensitive to the initial data, minor errors will grow large after repeated calculation. Given the extreme complexity of atmosphere and lack of knowledge in certain physical processes of it, scientific errors in weather forecasts are inevitable.

In predicting the track of typhoon, for example, the worldwide average error of forecast 24 hours ahead the landfall is about 100 km, which equals to a difference of several cities/counties but is still considered scientifically tolerable. That's also why some cities would have a placid typhoon break while others would have a stormy workday. And 100 km is just the average; as a 50-km error means “lucky,” an “unlucky” forecast could misjudge the track by 150 km.

Rain Falls Where Typhoon Goes?

Even tougher is to predict precipitation, the ultimate challenge in weather forecasting. The way CWB revised its forecasts seven times on potential rainfall brought by Morakot was gravely criticized. In fact, precipitation forecasts are subject to change based on the latest data, and Taiwan has been one of the few countries that dare to offer predictions on rainfall, whose worldwide average accuracy is only 0.2 to 0.3. (Calculated by the formula C/(A+B − C). A means rainfall in predicted area A; B means rainfall in actual area B; C means rainfall in the overlap of areas A & B.)



影響降雨的因素極其複雜，即便颱風路徑相同，搭配不同地形或外圍大氣環境，降雨區域也未必相同。賀伯颱風、桃芝颱風，颱風走哪裡，雨就降哪裡。卡玫基颱風和莫拉克颱風則不然，颱風走北部，雨降中南部；且卡玫基豪雨主要降在中部都會區，莫拉克豪雨集中降在中南部山區。

大氣是難以套用公式的混沌系統，故而天有不測風雲，人有旦夕禍福。在台灣，每年因風災造成的損失平均超過170億元。就像生命無常需要購買人身保險一樣，吳俊傑認為面對颱風也應該有風險管理的觀念。寧可過度準備，事前投資精進氣象預報實力，天災來襲才能減少萬一。

投資氣象預報的回收不容小覷。在台灣，多放一天颱風假的經濟影響將近百億台幣。而美國，颶風路徑預報誤差只要減少1英里（約1.6公里），警報區域的撤離成本就能降低100萬美金。

那麼，降低1.6公里預報誤差，困難嗎？過去30多年來，氣象預報利用雷達、衛星、飛機觀測等，將蒐集來的大氣資料同化到電腦模式做運算；將颱風來襲前24小時的路徑預測，從1970年代平均誤差300公里，

Elements affecting rainfall are so complex that even the same tracks of typhoons may come with different types and locations of rainfall as landforms and peripheral atmospheric conditions may play a role. Typhoons Herb and Toraji were the type that rain fell where they went, while for Kalmaegi and Morakot the rain fell in southern Taiwan as they headed north, with downpour mainly on central Taiwan metropolises and central/southern mountain areas respectively.

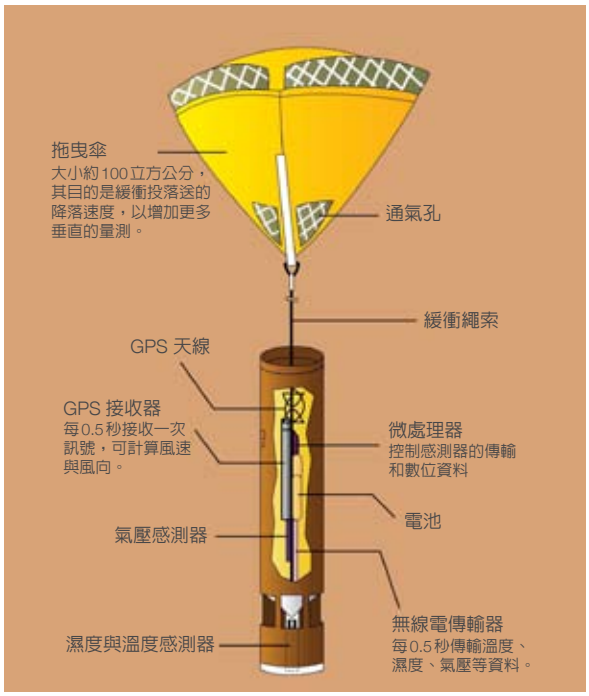
The atmosphere is a chaotic system hard to predict through formulas. That's why natural disasters happen. In Taiwan, the annual average loss caused by typhoons is over NT$17 billion. Just as buying insurance relieves the loss brought by accidents, Wu believed, investing in the perfection of forecasting would reduce the damage of natural disasters and gain remarkable payback.

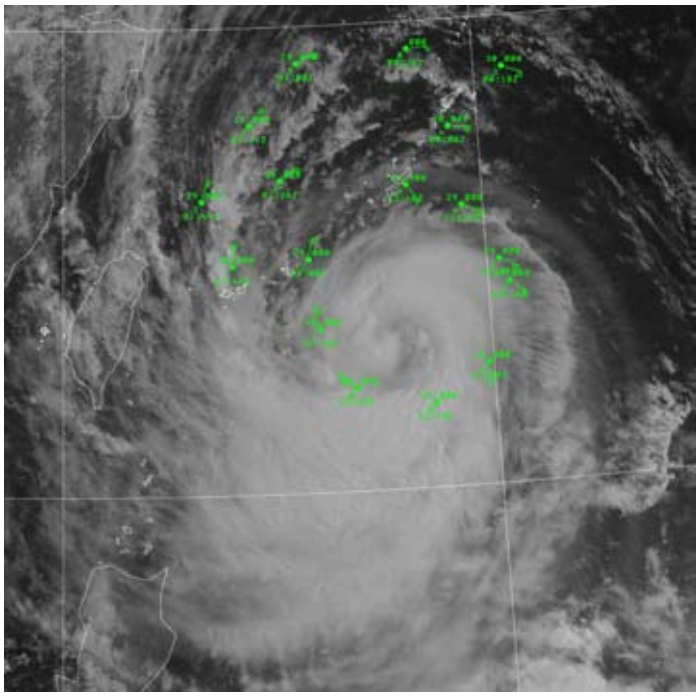
In Taiwan, the economic output affected by a one-day typhoon break is near NT$10 billion while in the U.S., every one mile (about 1.6 km) by which a forecast reduces its error in predicting hurricane tracks would lower the cost in evacuating the red-alert areas by US$1 million.

How difficult is it to reduce the error by 1.6 km? Over the past 30-plus years, weather forecasters have used radars, satellites, airborne observations, etc. to

1 2 3 4 5

1. 追風計畫租用漢翔公司的噴射機，此為改裝後的機艙內部。
The jet plane rented by the DOTSTAR from Aerospace Industrial Development Corporation (AIDC). The picture shows the inside of the remodeled cabin.
2. 針對莫拉克颱風，追風計畫實際飛行觀測路徑。
The DOTSTAR team took a flight to observe the track of Typhoon Morakot.
3. 追風計畫研究團隊（著橘衣）與漢翔機組人員合照。
The DOTSTAR team (dressed in orange) posed for a photograph with AIDC aircraft staff.
4. 追風團隊繞行颱風外圍追風，遇上飛行顛簸、雷擊、冰雹，在所難免。
The DOTSTAR team circles the rim of the typhoon in chase of it. Encounters with turbulence, thunderstrokes and hailstones are common.
5. 追風計畫英文代號 DOTSTAR（Dropwindsonde Observation for Typhoon Surveillance near the TAiwan Region）。
DOTSTAR stands for Dropwindsonde Observation for Typhoon Surveillance near the TAiwan Region.





大幅降低到今天的100公里。換言之，30多年來誤差值降低達66%，平均每年約改進2%。然而，吳俊傑提醒，即便未來維持每年2%的改進速率，真正能縮減的誤差公里數換算後「也越來越有限了。」

這與民眾的期待顯然背道而馳。隨著突破歷史紀錄的異常氣候不斷發生，面對一次又一次無法保住身家財產的威脅，民眾對氣象預報的要求越來越簡單，就是零誤差。在這種高度期待壓力下，吳俊傑表示追風計畫未來會持續著重「策略觀測」進行研究。

找出敏感位置，集中火力標靶觀測

策略觀測又叫「標靶觀測」。醫療上的標靶治療，直接對準癌細胞攻擊，而不像傳統化療散彈打鳥連正常細胞一併殺死。「標靶觀測」道理相同。

侵襲台灣的颱風，主要發生在觀測資料稀少的海洋，追風計畫利用飛機飛到海面繞行颱風，投擲「投落送」(dropwindsonde，大氣偵測探空儀)蒐集大氣資料，再傳送到氣象局電腦進行運算。而投落送的投擲位置如果無關緊要，投再多都沒用，找出真正影響颱風路徑的「敏感位置」進行標靶觀測，才是省錢又能發揮效果的關鍵。追風團隊可以計算得知，颱風會沿著太平洋高壓帶的邊緣移動，因此，颱風暴風圈靠近高壓帶邊緣的位置，就是一種敏感位置。

compute atmospheric data collected and assimilated into the computerized model to reduce the error of 24-hour-ahead track forecasts from 300 km in the 1970s to 100 km nowadays, which means a 2% improvement every year in a period of more than 30 years. Even with this rate, space for future error reduction is becoming limited.

This limitation, however, is evidently contradictory to the public expectation. With record-setting climatic abnormalities continuing to threaten people's lives and properties, the public request on weather forecasts becomes ever simpler: zero error, a goal that, Wu said, the DOTSTAR project would keep striving for by focusing on "strategic observations."

Targeted Observations on Sensitive Areas

Strategic observations are also called targeted observations, which act like targeted therapy in medical treatment against cancer that do not kill whatever kinds of cells as traditional chemotherapy does. Targeted observations work in the same way.

Typhoons affecting Taiwan are formed mostly on the ocean, where data observed is rare. The DOTSTAR would send its plane to sea surface, circling a typhoon and dropping the dropwindsonde, a weather reconnaissance device, into it to collect data, which would be transmitted back to CWB for computing. What matters is not the number of dropwindsondes but the location at which they are thrown into a typhoon. Finding "sensitive areas" becomes the key to an economical and effective targeted observation. Wu's team has found that typhoons move along the edge of a Pacific high, which indicates a sensitive area.

1 2

1. 投落送結構示意圖。
The structure of a dropwindsonde.
2. 追風計畫測得莫拉克颱風各氣壓面的風向、風速資料。
The DOTSTAR team had obtained the data of wind directions and wind speeds in various pressure levels of Typhoon Morakot.

敏感位置的氣流變化相對較大。每當可能侵台颱風生成，颱風獵人就要登上噴射機，到一個凡民航機都避之唯恐不及的敏感位置實地進行觀測。吳俊傑表示，在美國，這種工作有政府全職專業研究與技術人員負責；在台灣，要求具氣象專長的公務員冒這種險有實質困難，目前只能仰賴學術界。

學術界何以甘冒大不險？除追求科學突破外，不為其它，研究成果只要能降低數十公里的路徑預報誤差，不知能節省多少防災救災成本，保全多少幸福家庭。

Sensitive areas feature greater air current changes, but they are right where the typhoon hunters head into aboard a jet whenever a threatening typhoon takes shape. Wu said that in the U.S. this task is taken by full-time professional researchers and technicians, while in Taiwan it is hard to ask meteorologist civil servants to brave such danger, so the duty has fallen upon the academia.

Why is the academic community willing to take such great risk? In addition to pursuing scientific advancement, it's because if their studies may reduce the error in track forecasts by just dozens of kilometers, considerable amounts of money and numerous families will be well saved.

吳俊傑完成任務走出機艙。受限飛航管制，追風噴射機要不在清晨起飛，要不就半夜回航，加上往返台中車程，追風團隊總是摸黑出動或返家。
Chun-chieh Wu was walking out of the cabin after a flight mission. Due to the air traffic control, the DOTSTAR jet always takes off at dawn or returns at midnight. The trips to and from Taichung considered, the DOTSTAR team always leaves home and returns in the dark.

追風計畫 The DOTSTAR project

追風計畫全名為侵台颱風之飛機偵察及投落送觀測實驗。此計畫利用噴射機搭載投落送（大氣偵測探空儀），以每架次5～6小時時間飛到颱風周圍約13公里高度投擲，以取得颱風周圍關鍵區域的大氣資料，包括溫度、溼度、氣壓以及風速等。即時傳入中央氣象局及世界各國氣象單位的電腦系統後，可協助預測颱風路徑及周圍結構。

從2003年的杜鵑到今年的莫拉克、芭瑪颱風，追風計畫已針對34個颱風完成42航次的飛機偵察及投落送觀測任務。至2004年底為止，投落送資料平均可以改進美國氣象局、美國海軍及日本氣象廳全球電腦模式24～72小時前颱風路徑預測準確度達20%。

The project of Dropwindsonde Observation for Typhoon Surveillance near the TAiwan Region (DOTSTAR) employs jet plane rides to the skirts of typhoons and releases dropwindsondes at an altitude of 13 km while conducting observations for 5 to 6 hours each flight to collect atmospheric data , including temperature, humidity, air pressure, wind speed, etc., in key areas at the rims of typhoons. The data will be transmitted in real time to the computers of CWB in Taiwan and of weather agencies around the world to facilitate the prediction of the tracks and peripheral structures of typhoons.

From Typhoon Dujuan in 2003 to Morakot and Parma in 2009, the DOTSTAR has completed 42 surveillance flight missions for 34 typhoons. As of the end of 2004, the data collected by dropwindsondes may help the U.S. Weather Bureau, U.S. Navy and Japan Meteorological Agency improve the accuracy of typhoon track forecasts 24 to 72 hours ahead of landfall by up to 20%.

吳俊傑教授簡介 Profile of Prof. Chun-chieh Wu

台灣大學大氣科學系特聘教授兼系主任，國科會和中央氣象局共同執行之「追風計畫」主持人。主要研究領域涵蓋颱風動力(路徑、強度、降雨、位渦診斷、颱風與海洋、地形的交互作用等)、策略性觀測及數值模擬與同化。有關追風計畫詳細內容，請參考追風計畫專屬網站：http://typhoon.as.ntu.edu.tw/DOTSTAR/tw/intro/intro.php

Distinguished Professor and Chairman of the Department of Atmospheric Sciences, National Taiwan University, and Director of the DOTSTAR project (Dropwindsonde Observation for Typhoon Surveillance near the TAiwan Region). Major research areas include typhoon dynamics, targeted observations, and numerical modeling and data assimilation of typhoons. More details about DOTSTAR are posted on the project's website at: http://typhoon.as.ntu.edu.tw/DOTSTAR/tw/intro/intro.php