出國報告（出國類別：開會）

赴美國出席美國地球物理學會 2019 年秋季會議

服務機關：交通部中央氣象局
姓名職稱：連國淵副研究員
派赴國家/地區：美國
出國期間：108 年 12 月 8 日至 14 日
報告日期：109 年 2 月 10 日

摘要

美國地球物理學會秋季會議為地球科學界一年一度的重要國際會議，內容包括大氣科學、水文學、海洋科學等多項主題。本次參加會議除獲取國際新知外，主要目的是與美國的福衛 7 號衛星計畫（FORMOSAT-7／COSMIC-2）團隊交流互動。福衛 7 號衛星計畫是我國與美國合作的重要太空衛星計畫，該計畫的 6 顆衛星於 108 年 6 月 25 日發射升空，所收集的資料可運用於數值天氣預報中，提升天氣預報的準確度。本次會議有 1 個關於福衛 7 號衛星計畫的子會議，多位參與福衛 7 號衛星計畫的國際學者齊聚一堂，分享迄今各團隊的進度與成果。臺灣方面係國家太空中心人員代表包括國家太空中心、中央氣象局及學界的合作團隊，發表在此衛星計畫上的成果口頭報告。中央氣象局亦有多位人員出席發表張貼論文，呈現資料運用於數值天氣預報上的成果，使臺灣的貢獻能在此知名國際會議上被國際社群看見，有助於提升國際形象。未來如何將更多相關成果呈現至國際，進一步提升臺灣在這方面貢獻的能見度，仍然是需要持續努力的方向。

目次

一、目的

美國地球物理學會（American Geophysical Union；AGU）秋季會議（AGU Fall Meeting）為地球科學界一年一度的重要國際會議，會議主題包括大氣科學、水文學、海洋科學等多個領域。參與本次研討會，可了解世界各國在大氣與地球科學領域之技術發展與研究方向，掌握未來發展趨勢，對中央氣象局（以下簡稱氣象局）的研究與預報業務有所幫助，同時透過與國際專家學者交流，可提升氣象局氣象研究、觀測與預報在國際的能見度。

除了參與大會之外，本次出國的一個主要目的是與美國的福衛 7 號衛星計畫（FORMOSAT-7／COSMIC-2）團隊交流。福衛 7 號衛星計畫是我國與美國合作的重要太空衛星計畫，發射 6 顆衛星接收全球導航系統（Global Navigation Satellite System；GNSS）衛星訊號，進行掩星（radio occultation；RO）觀測。所收集的資料可透過資料同化（data assimilation）技術運用於數值天氣預報（numerical weather prediction；NWP）中，對於改善天氣預報有重要的幫助。本次大會中有 1 個關於福衛 7 號衛星計畫的子會議：「促進利用全球導航衛星系統做地球科學研究（Advancing Earth Science Research Using Global Navigation Satellite Systems）」，藉此機會，我國與美國參與福衛 7 號衛星計畫的專家學者齊聚一堂，分享福衛 7 號衛星自 108 年 6 月 25 日發射升空至今各團隊的進度與成果。

氣象局氣象科技研究中心連國淵副研究員為局推派參加本次會議的代表之一，此外林宗翰助理研究員與陳盈臻助理研究員 2 人一同前往參加。在會議中，連副研究員以張貼論文形式發表「早期福衛 7 號全球導航系統掩星資料於氣象局全球數值天氣預報系統的同化（Assimilation of early FORMOSAT-7/COSMIC-2 GNSS radio occultation data with the global NWP system at Central Weather Bureau (CWB)）」報告，並與林宗翰助理研究員共同發表「GSI 混成同化系統中全球導航系統掩星偏折角資料之觀測誤差的敏感度（The sensitivity of GNSS-RO bending angle observation errors in the GSI hybrid assimilation system）」報告（此 2 報告的摘要與張貼論文如附錄 1、2）。在 AGU 秋季會議的正式議程外，我國與美國的福衛 7 號校正／驗證（calibration/validation；Cal/Val）團隊亦在大會開始前，另行召開「暫定資料發表審查（Provisional Release Review）」的工作會議，討論即將公開釋出的暫定版本福衛 7 號掩星資料的品質是否達到可釋出標準，做為資料發表工作的參考，並一併討論未來雙方團隊的工作規劃。

由過去國內外的研究經驗指出，掩星觀測資料是一項重要的氣象資料，可補足廣大洋面上缺乏傳統現地觀測資料的問題，對於改善全球整體數值天氣預報的準確度有

明顯的效果，對於颱風生成與路徑預報也有一定程度的幫助與改善。同時，福衛 7 號衛星計畫亦是我國投注資源重點發展的太空計畫之一。報告人等透過參與國際相關團隊的交流與討論，習得世界各國在衛星掩星觀測資料用於數值模式資料同化的最新發展情況，對氣象局福衛 7 號相關工作的順利執行至關重要。

二、過程

本次 AGU 秋季會議於 108 年 12 月 9 日至 12 月 13 日在美國加州舊金山的 Moscone Center 會議中心舉行。報告人等於 12 月 8 日自臺北出發飛往美國舊金山機場，下飛機後立即參加當天下午我國與美國福衛 7 號工作團隊的「暫定資料發表審查」會議；12 月 9 日至 12 日參加 AGU 秋季會議並發表研究成果；12 月 13 日凌晨自舊金山搭機返回臺北。行程摘要如下表：

日期	停留地點	工作摘要
108/12/08 (日)	臺北— 美國舊金山	1. 自臺北至美國舊金山。 2. 參加與美國 COSMIC-2 Cal/Val 團隊合作的 Provisional Release Review 會議。
108/12/09 (一)	美國舊金山	參加第 1 天「美國出席美國地球物理學會 2019 年秋季會議」。
108/12/10 (二)	美國舊金山	1. 參加第 2 天「美國出席美國地球物理學會 2019 年秋季會議」。 2. 以張貼論文形式發表「Assimilation of early FORMOSAT-7/COSMIC-2 GNSS radio occultation data with the global NWP system at Central Weather Bureau (CWB)」，及共同發表「The sensitivity of GNSS-RO bending angle observation errors in the GSI hybrid assimilation system」論文。
108/12/11 (三)	美國舊金山	1. 參加第 3 天「美國出席美國地球物理學會 2019 年秋季會議」。 2. 參加科技部自然司地科研究推動中心舉辦之「第 12 屆臺灣及旅外地球科學學者座談會」晚會（AGU Fall Meeting 12th Taiwan Night）。
108/12/12 (四)	美國舊金山	參加第 4 天「美國出席美國地球物理學會 2019 年秋季會議」。
108/12/13 (五) 108/12/14 (六)	美國舊金山— 臺北	自美國舊金山返回臺北。

報告人於 12 月 8 日當地上午抵達美國舊金山國際機場，下午立即與美國福衛 7 號衛星計畫（FORMOSAT-7／COSMIC-2）的 Cal/Val 團隊進行「暫定資料發表審查」會議。本次會議臺灣方面出席人員有氣象局 3 人、國家太空中心 3 人與國立中央大學 1 人，其他未前往美國的相關工作人員亦透過視訊會議的方式參與。會中各方報告針對暫定版本福衛 7 號掩星資料之公開釋出的各項資料驗證工作，報告人代表氣象局全球與區域數值天氣預報團隊，報告氣象局在福衛 7 號初步資料同化的最新成果。會中決議當前暫定版本的福衛 7 號掩星資料的品質已達可公開釋出的標準，會後在同年 12 月 10 日開始於臺灣與美國的計畫網站上同步釋出，開放全世界下載。

12 月 9 日為 AGU 秋季會議的大會第 1 天。該會議由於與會者眾多，歷年都是以多個平行議程的形式舉辦，與會者自行在各時段選擇有興趣的子會議參與。本日上午與氣象局業務較相關的有「熱帶氣旋：觀測、模擬及可預報度（Tropical Cyclones: Observations, Modeling, and Predictability）」子會議，各國學者分別介紹包含行星邊界層、地表風觀測等對熱帶氣旋之影響，NOAA 與會學者介紹其颱風數值預報作業模式近期成果與未來規劃。下午報告人先參加「資料同化、可預報度及不確定性量化之進展（Advances in Data Assimilation, Predictability, and Uncertainty Quantification）」子會議，主要為資料同化領域的演講，有不少針對非常態分布誤差問題的嶄新先進資料同化方法被提出。接著就是前述之福衛 7 號衛星主題子會議，我國與美國參與計畫的專家學者報告福衛 7 號衛星自 108 年 6 月 25 日發射升空至今的進度與成果，臺灣方面由國家太空中心的人員代表合作團隊口頭報告。會中福衛 7 號跨國工作團隊也正式宣布暫定版福衛 7 號掩星資料即將公開釋出的消息。

12 月 10 日（大會第 2 天）上午為福衛 7 號主題子會議的張貼論文海報發表時間，因此上午就在張貼海報的會場為前來觀看海報的學者解說研究內容與成果（圖 1），並藉此機會和國際學者交流。我們的主要研究成果為氣象局已於 2019 年 7 月 16 日起接收福衛 7 號的早期資料，並立即啟動一組平行實驗評定同化福衛 7 號資料對數值天氣預報的影響，實驗結果顯示福衛 7 號資料對全球天氣預報的準確度有正面的影響，此項資訊對資料公開發表有相當大的幫助。我們也透過同化系統的診斷輸出，估計掩星偏折角資料的觀測誤差，並以實驗證實此估計的觀測誤差確實對改善同化結果有幫助。多位來自美國噴射推進實驗室（Jet Propulsion Laboratory）的學者對氣象局的福衛 7 號資料同化研究有高度興趣，與他們有詳細的討論。下午有「熱帶氣旋：觀測、模擬及可預報度」子會議的張貼論文海報發表，以及「資料同化、再分析及觀測系統模擬實驗：理論與應用（Data Assimilation, Reanalysis, and Observing System Simulation Experiments: Theory and Applications）」子會議的演講，也都是與氣象局業務密切相關

的主題。

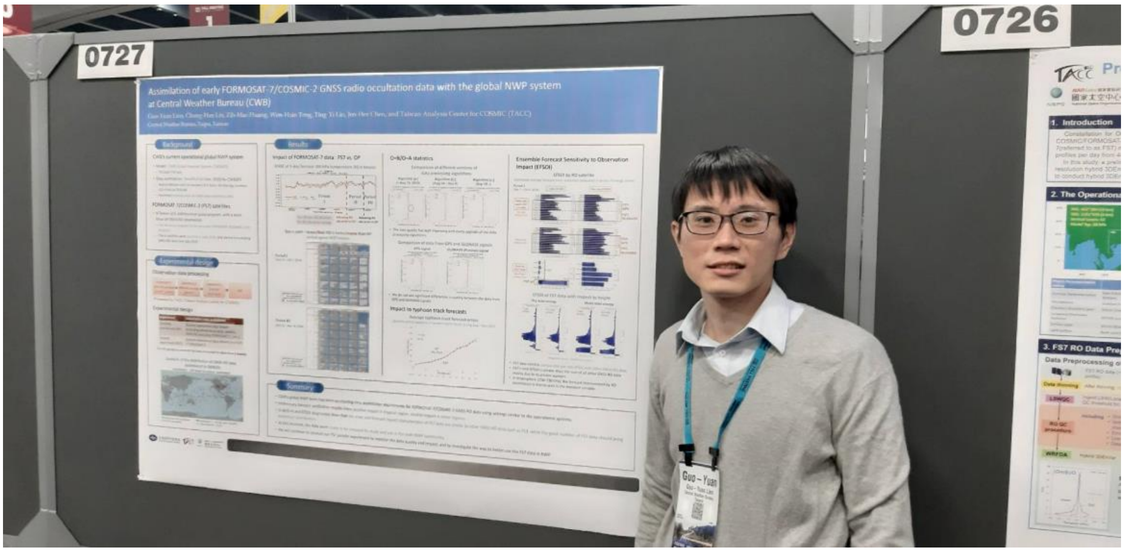


圖 1：報告人連國淵副研究員於張貼論文海報發表會場。

12 月 11 日（大會第 3 天）上午有「資料同化、再分析及觀測系統模擬實驗：理論與應用」子會議的張貼論文海報發表時間，下午則主要專注在聆聽「極端天氣事件：預報能力、不確定性量化及影響模擬(Extreme Weather Events: Forecast Skill, Uncertainty Quantification, and Impact Modeling)」子會議的演講，有來自美國 NCEP 的 Dr. Vijay Tallapragada 與來自歐洲 ECMWF 的 Dr. Florian Pappenberger，介紹這兩個先進數值天氣預報機構的最新發展概況，帶來許多令人興奮的議題。當天晚上則參加由科技部自然司地科研究推動中心與我國駐舊金山代表處共同舉辦的「第 12 屆臺灣及旅外地球科學學者座談會」晚會（AGU Fall Meeting 12th Taiwan Night），接待由世界各國前來參與 AGU 秋季會議的近 300 多位臺灣學者，是與臺灣的地球科學領域專家學者交流的好時機（圖 2）。

12 月 12 日（大會第 4 天）有「邊界層雲與紊流，以及其與下方陸表與海表的交互作用（Boundary Layer Clouds and Turbulence, and Their Interaction with the Underlying Land or Ocean Surface）」與「大氣對流：過程、動力與天氣及氣候的連結（Atmospheric Convection: Processes, Dynamics, and Links to Weather and Climate）」等子會議的張貼論文海報發表。

12 月 13 日大會最後 1 天由於沒有與氣象局業務相關的議程，遂按原計畫於當天凌晨搭機回國，於臺灣時間 12 月 14 日上午抵達桃園機場。

圖 2：多位臺灣學者於「第 12 屆臺灣及旅外地球科學學者座談會」晚會上的合照，左 1 為連國淵副研究員、左 2 與右 3 分別為氣象局的林宗翰助理研究員與陳盈臻助理研究員。

三、 心得及建議

本次為連員第 1 次參加 AGU 秋季會議，此會議為地球科學界規模最大的國際會議，初次參與果然遠勝於之前參加過的各個會議，主題包羅萬象，需要花費一些時間才能找到自己最有興趣聆聽的主題。

本次會議的主要目標為與國際相關學者分享氣象局在福衛 7 號衛星掩星資料的同化工作成果，提升氣象局在此工作上的能見度，並透過與國際學者的交流，促進氣象局福衛 7 號相關工作的順利執行。氣象局總計有 3 位研究人員一同前往，而國家太空中心與國立中央大學亦各有 3 位及 1 位學者與會，是相當不錯的代表團隊，使臺灣在福衛 7 號衛星計畫上所做的貢獻得以在此知名國際會議上呈現出來。在大會第 1 天下午的子會議「促進利用全球導航衛星系統做地球科學研究（Advancing Earth Science Research Using Global Navigation Satellite Systems）」上，由國家太空中心人員代表臺灣全體團隊統整報告臺灣迄今為止的貢獻與成果，臺下的聽眾人數約有兩百人，比預期的要多，顯示此衛星計畫在國際上的知名度與引發各界廣泛的興趣，對臺灣的國際形象應有很好的加分效果。

在福衛 7 號資料以資料同化技術運用於數值天氣預報的工作方面，經過和國際學者的交流，報告人等了解到臺灣在這項研究工作上所投注的心力其實是很大的，成果也完全不遜於美國合作方與其他國家。因此，如何將此成果適切地呈現至國際社群，提升臺灣在這方面的貢獻的能見度，確實是持續需要努力的方向之一。本次派員參與國際會議發表報告，是提升國際能見度不錯的方法，而諸如科學成果的整理等，也將是需要持續努力的方向。

附錄 1 – 連國淵等人張貼論文摘要與海報

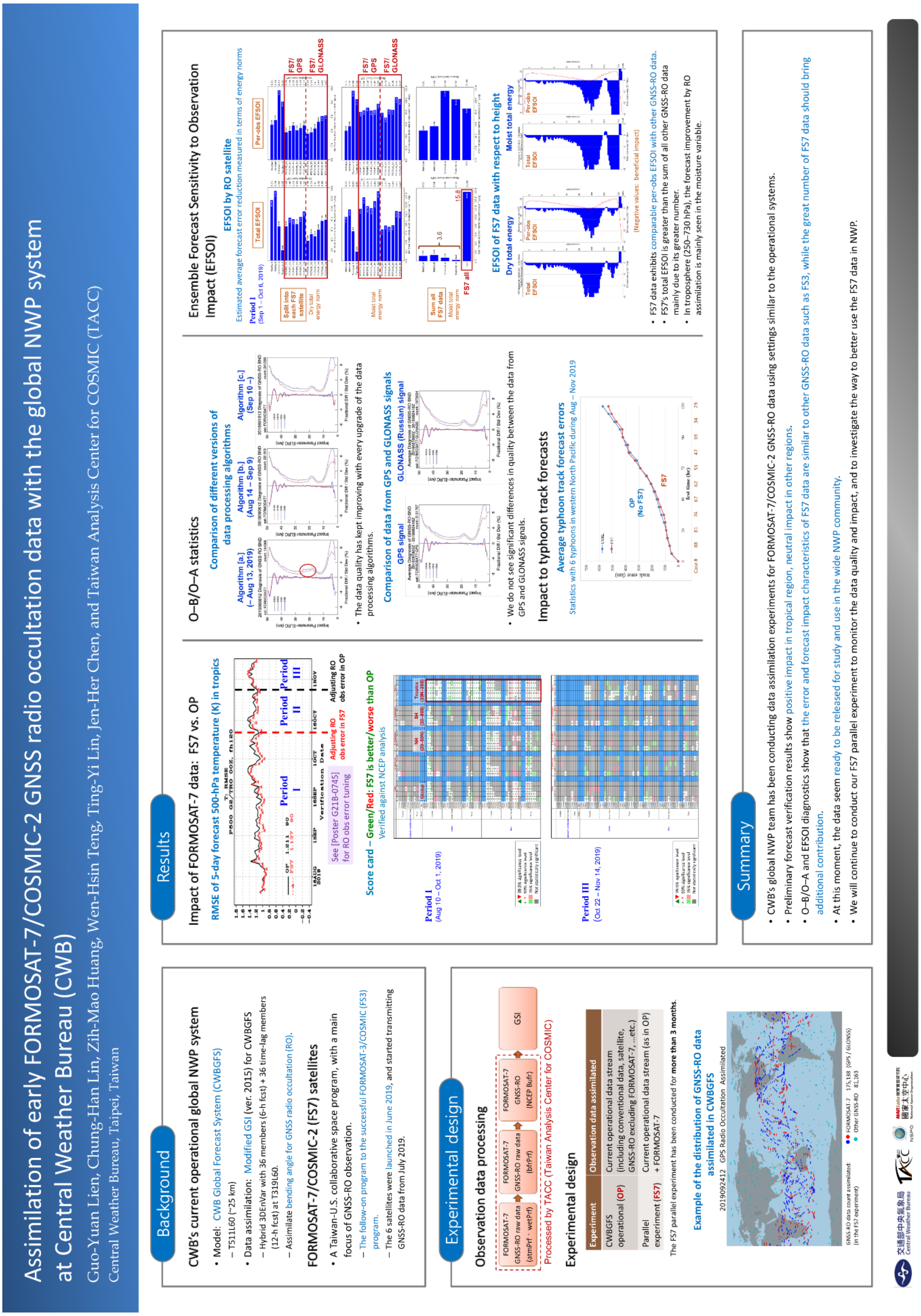
Assimilation of early FORMOSAT-7/COSMIC-2 GNSS radio occultation data with the global NWP system at Central Weather Bureau (CWB)

Guo-Yuan Lien[1]*, Chung-Han Lin*[1]*, Zih-Mao Huang*[1]*, Wen-Hsin Teng*[1]*, Ting-Yi Lin*[1]*, Jen-Her Chen*[1]*, and Taiwan Analysis Center for COSMIC (TACC)*

[1]*Central Weather Bureau, Taipei, Taiwan*

The FORMOSAT-7/COSMIC-2 satellites have been launched on June 25, 2019. It is a successor of the successful FORMOSAT-3/COSMIC mission and is expected to provide better deep tropical tropospheric moisture data compared to FORMOSAT-3/COSMIC. As a member of the project, Taiwan's Central Weather Bureau (CWB) has received early internal release of the FORMOSAT-7/COSMIC-2 GNSS radio occultation (GNSS-RO) data from Taiwan Analysis Center for COSMIC (TACC), starting from July 16, 2019. To evaluate the impact of the FORMOSAT-7/COSMIC-2 data for global numerical weather prediction (NWP), a parallel experiment assimilating the FORMOSAT-7/COSMIC-2 data in addition to the operational data stream is conducted with the global NWP system at CWB. We will show the results from this parallel experiment by the time of the presentation, including the impact to global forecast skills, observation minus background/analysis statistics, observation error diagnosis, and ensemble forecast sensitivity to observation (EFSO) diagnosis for the FORMOSAT-7/COSMIC-2 data. We expect that such information will be useful for the final public release of the FORMOSAT-7/COSMIC-2 data.

連國淵等人張貼論文海報全幅



連國淵等人張貼論文海報局部放大 **(1)**

Background

CWB's current operational global NWP system

- Model: CWB Global Forecast System (CWBGFS)
  - T511L60 (~25 km)
- Data assimilation: Modified GSI (ver. 2015) for CWBGFS
  - Hybrid 3DEnVar with 36 members (6-h fcst) + 36 time-lag members (12-h fcst) at T319L60.
  - Assimilate bending angle for GNSS radio occultation (RO).

FORMOSAT-7/COSMIC-2 (FS7) satellites

- A Taiwan-U.S. collaborative space program, with a main focus of GNSS-RO observation.
  - The follow-on program to the successful FORMOSAT-3/COSMIC (FS3) program.
  - The 6 satellites were launched in June 2019, and started transmitting GNSS-RO data from July 2019.

Experimental design

Observation data processing

FORMOSAT-7 GNSS-RO raw data (atmPrf、wetPrf) → FORMOSAT-7 GNSS-RO raw data (bfrPrf) → FORMOSAT-7 GNSS-RO (NCEP Bufr) → GSI

Processed by TACC (Taiwan Analysis Center for COSMIC)

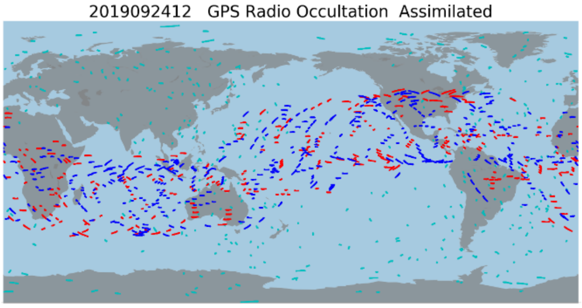
Experimental design

Experiment	Observation data assimilated
CWBGFS operational (**OP**)	Current operational data stream (including conventional data, satellite, GNSS-RO excluding FORMOSAT-7, ...etc.)
Parallel experiment (**FS7**)	Current operational data stream (as in OP) + FORMOSAT-7

The FS7 parallel experiment has been conducted for **more than 3 months**.

Example of the distribution of GNSS-RO data assimilated in CWBGFS

2019092412 GPS Radio Occultation Assimilated

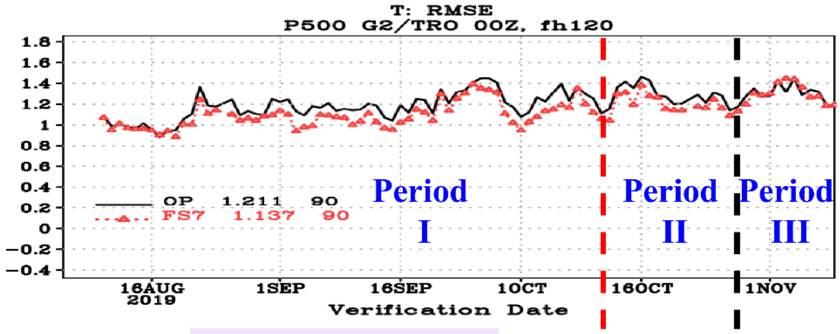


GNSS-RO data count assimilated: (in the FS7 experiment)
FORMOSAT-7 175,138 (GPS / GLONSS)
Other GNSS-RO 81,163

Results

Impact of FORMOSAT-7 data: FS7 vs. OP

RMSE of 5-day forecast 500-hPa temperature (K) in tropics



See [Poster G21B-0745] for RO obs error tuning

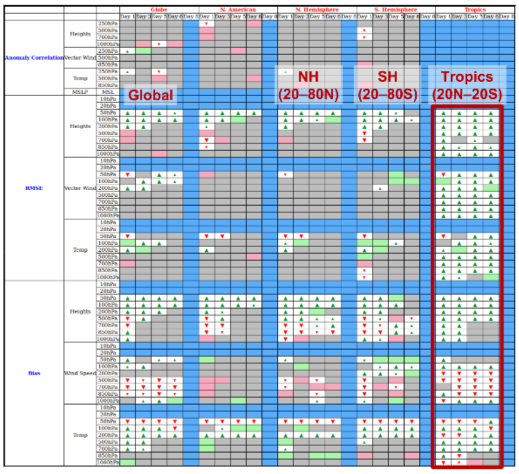
Adjusting RO obs error in FS7

Adjusting RO obs error in OP

Score card – Green/Red: FS7 is better/worse than OP

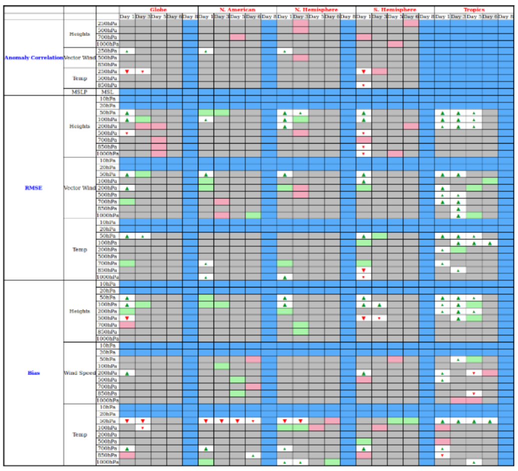
Verified against NCEP analysis

Period I
(Aug 10 – Oct 1, 2019)



▲▼ 99.9% significance level
▴▾ 99% significance level
95% significance level
Not statistically significant

Period III
(Oct 22 – Nov 14, 2019)

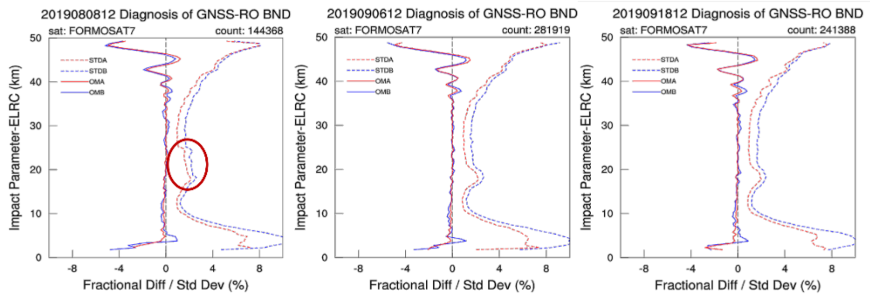


▲▼ 99.9% significance level
▴▾ 99% significance level
95% significance level
Not statistically significant

O–B/O–A statistics

Comparison of different versions of data processing algorithms

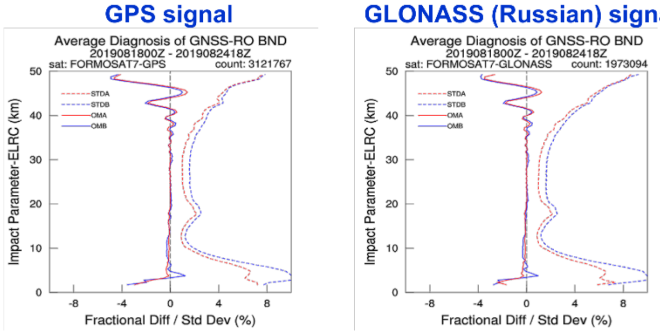
Algorithm [a.] (– Aug 13, 2019) | **Algorithm [b.] (Aug 14 – Sep 9)** | **Algorithm [c.] (Sep 10 –)**



- The data quality has kept improving with every upgrade of the data processing algorithms.

Comparison of data from GPS and GLONASS signals

GPS signal | **GLONASS (Russian) signal**

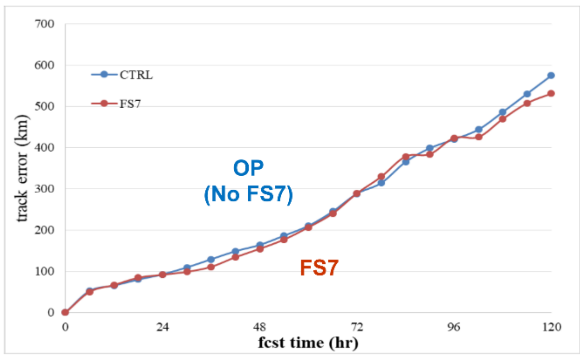


- We do not see significant differences in quality between the data from GPS and GLONASS signals.

Impact to typhoon track forecasts

Average typhoon track forecast errors

Statistics with 6 typhoons in western North Pacific during Aug – Nov 2019

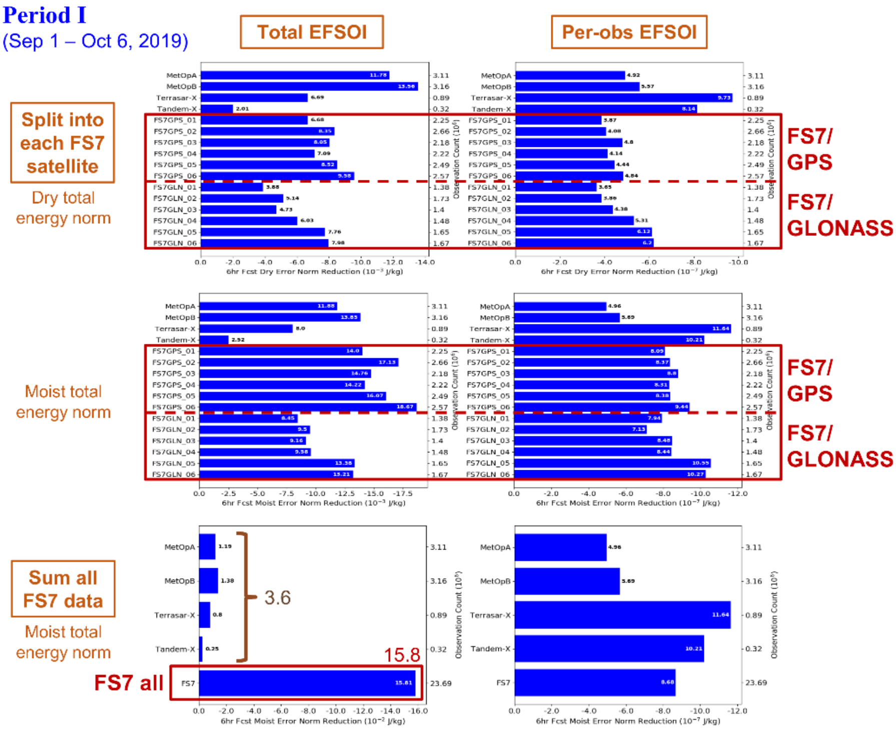


Case # 88 81 74 67 62 53 47 39 34 29

Ensemble Forecast Sensitivity to Observation Impact (EFSOI)

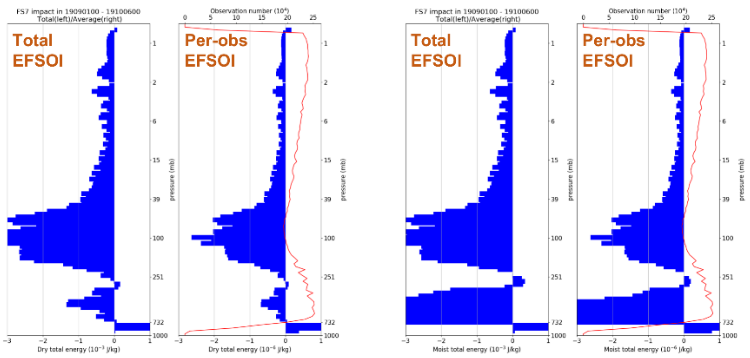
EFSOI by RO satellite

Estimated average forecast error reduction measured in terms of energy norms



EFSOI of FS7 data with respect to height

Dry total energy | Moist total energy



(Negative values: beneficial impact)

- FS7 data exhibits comparable per-obs EFSOI with other GNSS-RO data.
- FS7's total EFSOI is greater than the sum of all other GNSS-RO data mainly due to its greater number.
- In troposphere (250–730 hPa), the forecast improvement by RO assimilation is mainly seen in the moisture variable.

附錄 2 – 林宗翰等人張貼論文摘要與海報

The sensitivity of GNSS-RO bending angle observation errors in the GSI hybrid assimilation system

Chung-Han Lin[1]*, Zih-Mao Huang*[1]*,Guo-Yuan Lien*[1] *and Jen-Her Chen*[1]

[1]*Central Weather Bureau, Taipei, Taiwan*

In Taiwan's Central Weather Bureau (CWB), a version of NCEP Gridpoint Statistical Interpolation (GSI) hybrid data assimilation system, modified to be coupled with the CWB's Global Forecast System (CWBGFS), has been used for its operational numerical weather prediction. Regarding the use of GNSS radio occultation (GNSS-RO) data, the bending angle data have been assimilated using the default observation error settings in GSI, which is a family of empirical piecewise quadratic equations with respect to the observation height. To investigate whether these default observation errors in GSI are suitable for CWBGFS, we use the Desroziers (2005) method to estimate the optimal GNSS-RO bending angle observation errors in our system. The diagnosed observation errors are roughly two times as large as the default ones. Accordingly, a one-month assimilation experiment using the bending angle observation errors tuned based on the Desroziers statistics is conducted, and a significant positive impact on forecast skills is therefore obtained, indicating that the default observation error values in GSI are certainly too small. We note that this conclusion is valid when using GSI for CWBGFS, while for other models such as NCEP's GFS, we suspect that it would also be applicable, although it still requires experimental validation. In addition, the current results are obtained without the FORMOSAT-7/COSMIC-2 data, but further investigation on the same aspect for the upcoming FORMOSAT-7/COSMIC-2 data is anticipated.

林宗翰等人張貼論文海報全幅

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Introduction

- In Taiwan's Central Weather Bureau (CWB), a version of NCEP Gridpoint Statistical Interpolation (GSI) hybrid data assimilation system, modified to be coupled with the CWB's Global Forecast System (CWBGFS), has been used for its operational numerical weather prediction.
- For GNSS radio occultation (RO) data, the bending angle data have been assimilated using the default observation error settings in GSI, which is a family of empirical piecewise quadratic equations with respect to the observation height and latitude.

Methodology

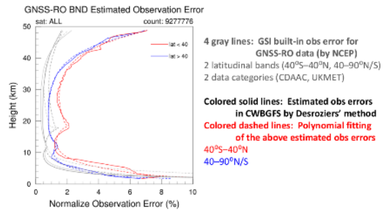
- To investigate whether these default observation errors in GSI are suitable for CWBGFS, we use the Desroziers (2005) method to estimate the optimal GNSS-RO bending angle observation errors in our system.
- The formulation to diagnose observation errors under the assumption of an optimal DA system:

$$E[\mathbf{d}_a^o(\mathbf{d}_b^o)^T] = \mathbf{R} \qquad \mathbf{d}_a^o = \mathbf{y}^o - H(\mathbf{x}^a) \qquad \mathbf{d}_b^o = \mathbf{y}^o - H(\mathbf{x}^b)$$

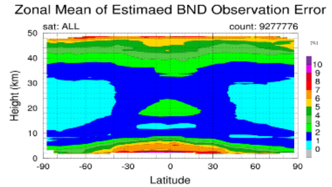
Observation error estimation

Default vs. estimated observation errors

Statistics computed based on one-month operational data



Latitude-height plot of zonal mean observation errors



- The estimated vertical observation error profiles of GNSS-RO bending angle data show similar characteristics as the default error profiles in GSI:
  – Largest at upper stratosphere and lower troposphere, and another peak at mid-levels.
- However, the estimated error profiles are about twice larger than the default observation errors in GSI !
- According to the results, new equations of vertical observation error profiles (the colored dashed lines in the above figure) are proposed by fitting to the estimated values:

$$obs\ err = 10^3 \times e^{-\alpha}$$

For latitude between 40°S and 40°N :

$$\alpha = \begin{cases} -0.8792362 + 0.3341449 \times (a - r_c) - 0.003730234 \times (a - r_c)^2, & a - r_c > 12 \text{ km} \\ -1.820805 + 0.7211169 \times (a - r_c) - 0.02935872 \times (a - r_c)^2, & a - r_c < 12 \text{ km} \end{cases}$$

For else:

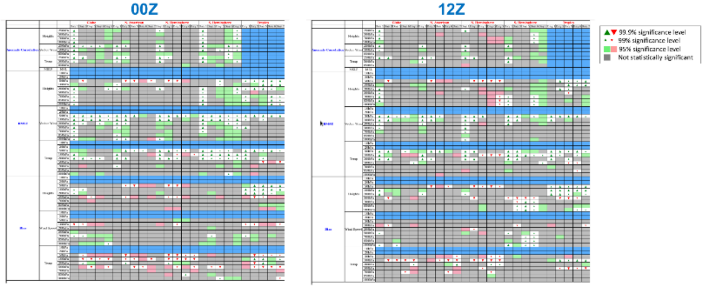
$$\alpha = \begin{cases} -2.752718 + 0.3965473 \times (a - r_c) - 0.004217492 \times (a - r_c)^2, & a - r_c > 18 \text{ km} \\ -2.015269 + 0.572622 \times (a - r_c) - 0.001600341 \times (a - r_c)^2, & a - r_c < 18 \text{ km} \end{cases}$$

a is impact parameter, r_c is Earth's local radius of curvature.

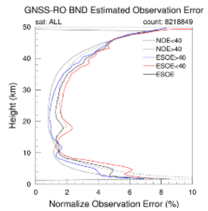
Assimilation experiment results

- We conduct two cycling assimilation experiments for one-month period:
  CTRL: with default observation errors in GSI ESOE: with estimated observation errors

Score card – Green/Red: ESOE is better/worse than CTRL



Re-estimated observation errors in ESOE



- The experimental results show that using the new observation errors of GNSS-RO data, tuned based on the Desroziers (2005) method, can actually lead to generally positive impacts on the forecast scores.
- Re-estimated observation errors based on the new ESOE experiment are close to the observation errors given (i.e., first estimation), confirming the convergence of the observation error estimation.

Summary

- We tune the observation errors of GNSS-RO bending angle in GSI based on the Desroziers method, and thus a significant positive impact is obtained in CWBGFS with cycling assimilation experiments.
- We note that this conclusion would only be valid when using GSI for the CWBGFS model.
- These results were obtained prior to the launch of the FORMOSAT-7/COSMIC-2 satellites. Further investigation on this aspect with the FORMOSAT-7/COSMIC-2 data is being conducted. See [Poster G21B-0727]

Reference:

Desroziers, G., L. Berre, B. Chapnik, and P. Poli, 2005: Diagnosis of observation, background and analysis-error statistics in observation space. *Q. J. R. Meteor. Soc.*, **131**, 3385–3396.

交通部中央氣象局 Central Weather Bureau

林宗翰等人張貼論文海報局部放大 **(1)**

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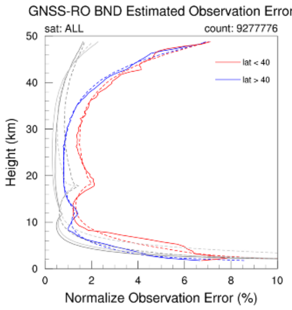
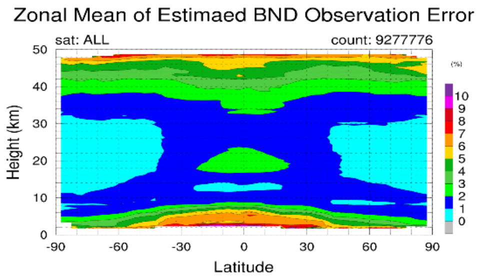


4 gray lines: GSI built-in obs error for GNSS-RO data (by NCEP)
2 latitudinal bands (40°S–40°N, 40–90°N/S) X 2 data categories (CDAAC, UKMET)

Colored solid lines: Estimated obs errors in CWBGFS by Desroziers' method
Colored dashed lines: Polynomial fitting of the above estimated obs errors
40°S–40°N
40–90°N/S

Latitude-height plot of zonal mean observation errors



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林宗翰等人張貼論文海報局部放大 **(2)**

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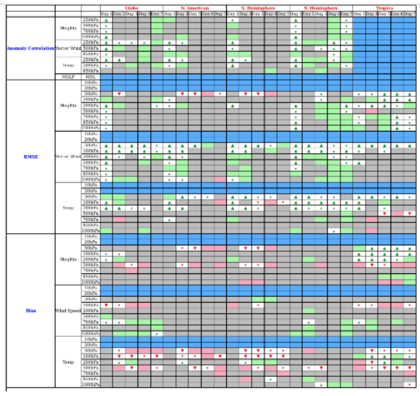
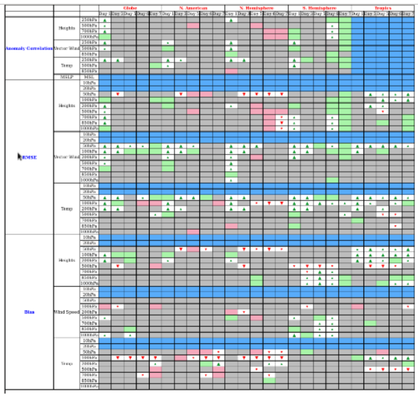
00Z



12Z



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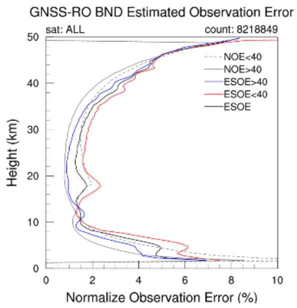

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