財團法人國家實驗研究院國家太空中心

全球定位科學應用研究委託案(3/3)

101年度「全球定位科學應用研究中心」

期末報告

工作項目(3.1)：全球大氣垂直結構分析報告(I I I)

計畫名稱：進行掩星資料應用於全球大氣與氣候模擬、分析前置技術發展：以掩星資料進行全球大氣分析與探討大氣垂直結構分布

執行期間： 2012/2/18~2013/2/17

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一、摘要

工作項目 3A 研發除針對 GPS 掩星觀測反演之一般性全球溫度進行誤差評估，亦針對特殊事件(如火山灰效應、日蝕現象等)，用以彰顯掩星觀測在大氣分析上的獨特貢獻，此研發成果在實用性作業的價值在於新機制的發現以及重要機制的瞭解. 當作業模式欠缺核心的重要機制. 模式的過程將很難與大氣的過程接近, 因此透過預測模式對大氣機制掌握的增進以提升預測結果.

例如, 日蝕現象所發現的對流層降溫低平流層增溫的現象是測試預測模式對平流層和對流層偶和機制預測能力的好機會; 火山灰效應對於飛航天氣預測的重要性已經在 2010 年冰島火山灰造成歐洲飛機的停飛事件上再次顯現特殊事件的全球性影響; 沙漠沙塵對大氣的影響是全球性的, 瞭解沙塵影響大氣的方式有助於提升預測模式在大西洋和太平洋區域的預測能力. 。

由於新機制的發現以及重要機制的瞭解需要更多更好且更為密集的掩星觀測資料,在後續規劃上,特殊事件的研究分析建議應進一步加強並列入為主要工作任務, 以分析比較預測模式對上述特殊事件的預測能力.

二、前言

In this work, we focus on using FORMOSAT-3/COSMIC (F3C) data to analyze vertical thermal structures of the atmosphere below 40 km altitudes; and to study the coupling mechanisms between the stratosphere and the troposphere.

三、成果報告

3.1. Stratosphere-Troposphere Coupling Studies Using F3C

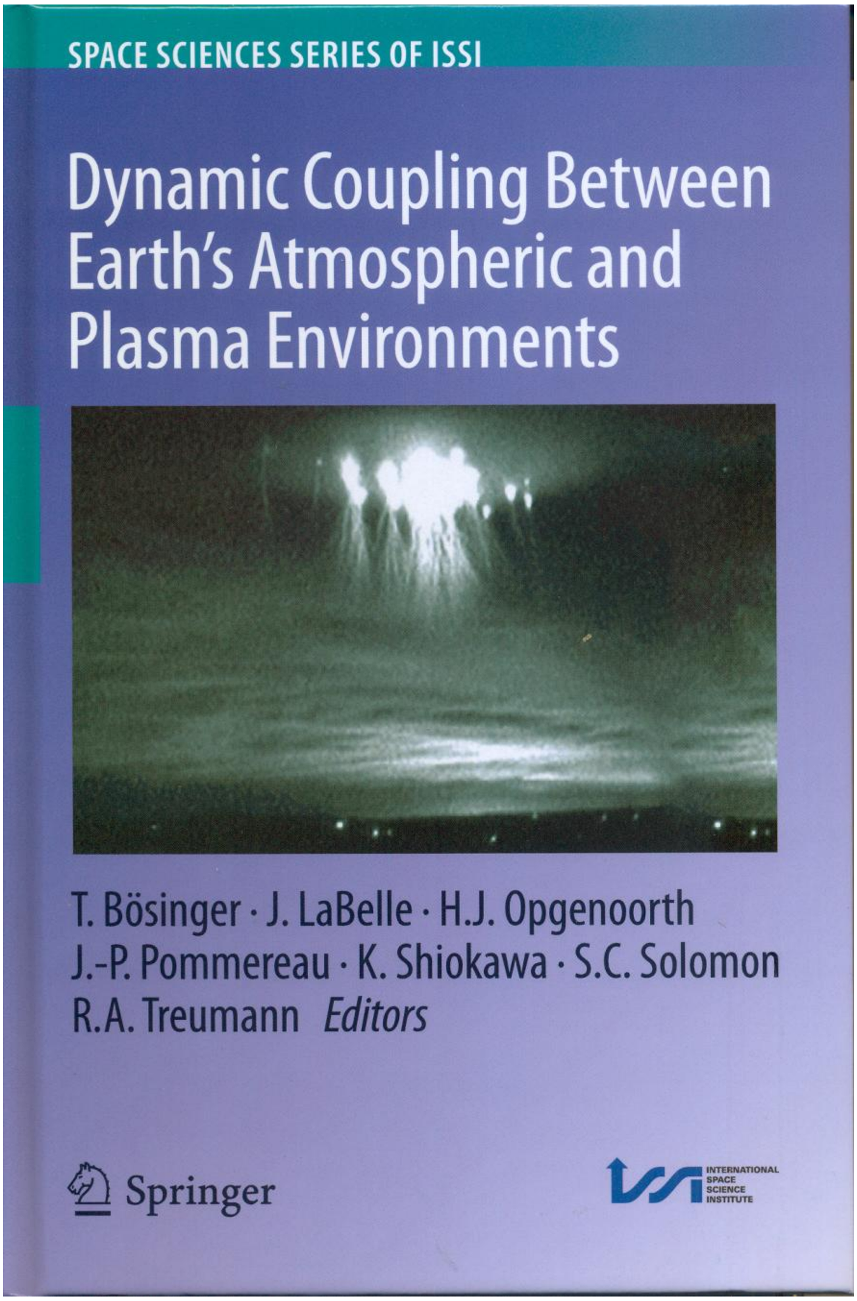
Sudden tropospheric cooling and induced stratospheric warming were found during the 22 July 2009 total solar eclipse. Can the 22 July 2009 hallmark also be seen in other major solar eclipses? Here we hypothesize that the tropospheric cooling and the stratospheric warming can be predicted to occur during a major solar eclipse event. In this work we use the FORMOSAT-3/COSMIC (F3C) Global Positioning System (GPS) radio occultation (RO) data to construct eclipse-time temperature profiles before, during, and after the passages of major solar eclipses for the years 2006-2010. We use four times a day of meteorological analysis from the European Centre for Medium Range Weather Forecast (ECMWF) global meteorological analysis to construct non-eclipse effect temperature profiles for the same eclipse passages. The eclipse effects were calculated based on the difference between F3C and ECMWF profiles. A total of five eclipse cases and thirteen non-eclipse cases were analyzed and compared. We found that eclipses cause direct thermal cooling in the troposphere and indirect dynamic warming in the stratosphere. These results are statistically significant. Our results show -0.6 to -1.2 °C cooling in the troposphere and 0.4 to 1.3 °C warming in the middle to lower stratosphere during the eclipses. This characteristic stratosphere-troposphere coupling in temperature profiles represent a distinctive atmospheric responses to the solar eclipses.

Major solar eclipses such as total solar eclipse and annular solar eclipse arise from direct block out of incoming solar radiation by the moon to the atmosphere [Zirker, 1980; Lindsey et al., 1992; Pasachoff, 2009]. This sudden drop in the incoming solar radiation causes the cooling of the surface and higher up, resulting in the changes of atmospheric temperatures. These temperature variations drive changes in pressures and winds [Ballard et al., 1969; Anderson et al., 1972, Founda et al., 2007; Gerasopoulos et al., 2007; Kameda et al., 2009; Wang and Liu, 2010], and induces vertically propagating gravity waves [e.g., Chimonas, 1970; Chimonas and Hines, 1971; Seykora et al., 1985; Zerefos et al., 2007]. Solar eclipse also changes the ionosphere total electron density [Le et al., 2009]. Treumann et al. [2008] described the physics of electric discharges in the atmospheric gases, and average altitude profiles of temperature and mass density from the surface to 150-km altitude.

Though the troposphere and the stratosphere are regarded as a coupled system [Holton et al., 1995], the effects of the eclipse on this coupled system is not well known, due to the lack of observational data from the troposphere to the stratosphere when the lunar shadows move through the atmosphere.

Wang and Liu [2010] used F3C data to study the atmospheric effect of the 22 July 2010 total solar eclipse. They found a significant cooling through the troposphere and a distinctive warming in the lower stratosphere. This sudden tropospheric cooling and stratospheric warming appeared as a hallmark in the coupled stratosphere-troposphere system during the 22 July 2009 total solar eclipse. Can the 22 July 2009 hallmark also be seen in other major solar eclipses? Here we hypothesize that the tropospheric cooling and the stratospheric warming can be predicted to occur during a major solar eclipse event. The motivation for this study is to use F3C GPS RO data, together with the daily ECMWF global meteorological analysis, to demonstrate that the tropospheric cooling and stratospheric warming feature is indeed a hallmark during a major solar eclipse.

The results of this work has been published as a chapter in a book entitled “Dynamic Coupling Between Earth’s Atmosphere and Plasma Environments”, Springer, 2013. Following is a photo figure of this book.



3.2. Vertical Temperature Profiles Variability in the Lower Troposphere

Long-range transport of the Saharan dust plumes is a pronounced feature occurring during May-September of each year over the tropical North Atlantic atmosphere [Dunion and Veldon, 2004]. Hence, the impacts of these transporting Saharan dust plumes and

its associated Saharan air are of great importance for weather predictions [Pratt and

Evans, 2009] and climate assessments [Mahowald and Luo, 2003].

Previous studies have shown that Saharan dust plumes exert influences over the tropical North Atlantic atmosphere by changing vertical wind shear [Dunion and Veldon, 2004], vertical thermodynamic stability [Dunion and Veldon, 2004; Wong and Dessler, 2005; Dunion and Marron, 2008; Jury and Santiago, 2010], water vapor content [Dunion and Marron, 2008], and sea surface temperatures [Evan et al., 2009]. These results were mostly derived based on limited radiosondes launched from fixed islands [Dunion and Marron, 2008] and ships [Nalli et al., 2005], and aircraft sampling [Calson and Prospero, 1972; McConnell et al., 2008]. Most of the observations were made around the western boundary (80°W — 60°W) and the eastern boundary (~ 20°W) of the tropical North Atlantic atmosphere [Sun et al., 2009].

As such, detailed observations for the long-range transport Saharan dust plumes in the longitudes between 20°W, where dust plumes leave the Sahara Desert and enter the North Atlantic atmosphere, and 60°W, where dust plumes have traveled over the 40 degrees in longitudes and are about to enter the North Western Atlantic regions, remain elusive. Currently, only satellite observations are able to provide high density measurements over the vast open ocean regions.

The benefits of using satellite data over the tropical North Atlantic atmosphere, that were not available in previous works, have been shown recently. Wu et al. [2006] and Sun et al. [2009] showed that the assimilation of the Aqua AIRS satellite data during the Saharan dust outbreaks enables the models to make more realistic predictions of hurricane tracks than the predictions without the usage of the Aqua AIRS data.

3.3. Comparison of F3C Data With Radiosondes

1) Following is a table (Table 1) showing the warm years (red colored) and

cold years (blue colored) since 2006 until present. This table is an extract from a report by US Climate Prediction Center. In this work, we use F3C data to understand the atmospheric responses in the vertical during these very different years.

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2006	-0.9	-0.7	-0.5	03 16	3 13	3 14	3 15	3 16	0.5	0.8	1.0	1.0
2007	0.7	3 16	03 14	03 15	03 16	03 16	03 16	-0.6	-0.9	-1.1	-1.2	-1.4
2008	-1.5	-1.5	-1.2	-0.9	-0.7	-0.5	03 16	03 15	03 14	03 15	03 17	03 1:
2009	03 1<	03 1;	03 19	03 15	3 14	3 17	0.5	0.6	0.7	1.0	1.4	1.6
2010	1.6	1.4	1.1	0.7	3 15	03 16	-0.8	-1.2	-1.4	-1.5	-1.5	-1.5
2011	-1.4	-1.3	-1.0	-0.7	03 17	03 15	03 15	03 16	-0.6	-0.8	-1.0	-1.0
2012	-0.9	-0.7	-0.5	03 16								

Table 1.

Most of the previous works on the analysis of the past ENSO events generally employed the use of the meteorological reanalysis data. For example, data taken from NCEP, UKMO, ECMWF, etc, are frequently used to derive understanding of ENSO events.

However, as Figure 1 shows that direct measurements of vertical temperature profiles from radiosondes in the stratosphere is rare. In a sharp contrast, direct profile temperature measurements in the upper troposphere contain more data than those shown in the stratosphere (Figure 2).

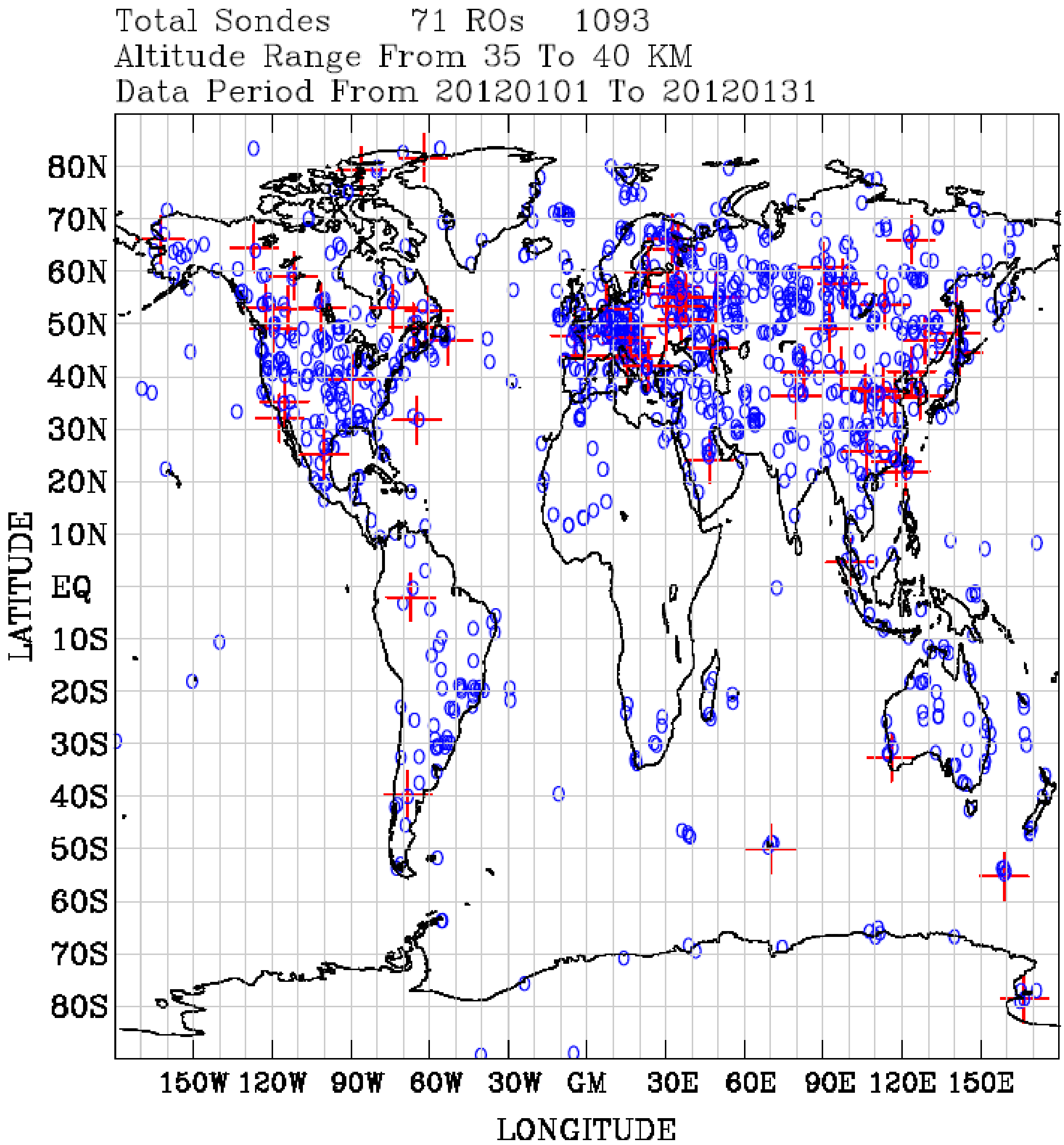


Figure 1. Availability of direct profile of temperature measurements in the altitude range between 35 and 40 km from radiosondes (red crosses) and F3C profiles (blue circles) for January 2012.

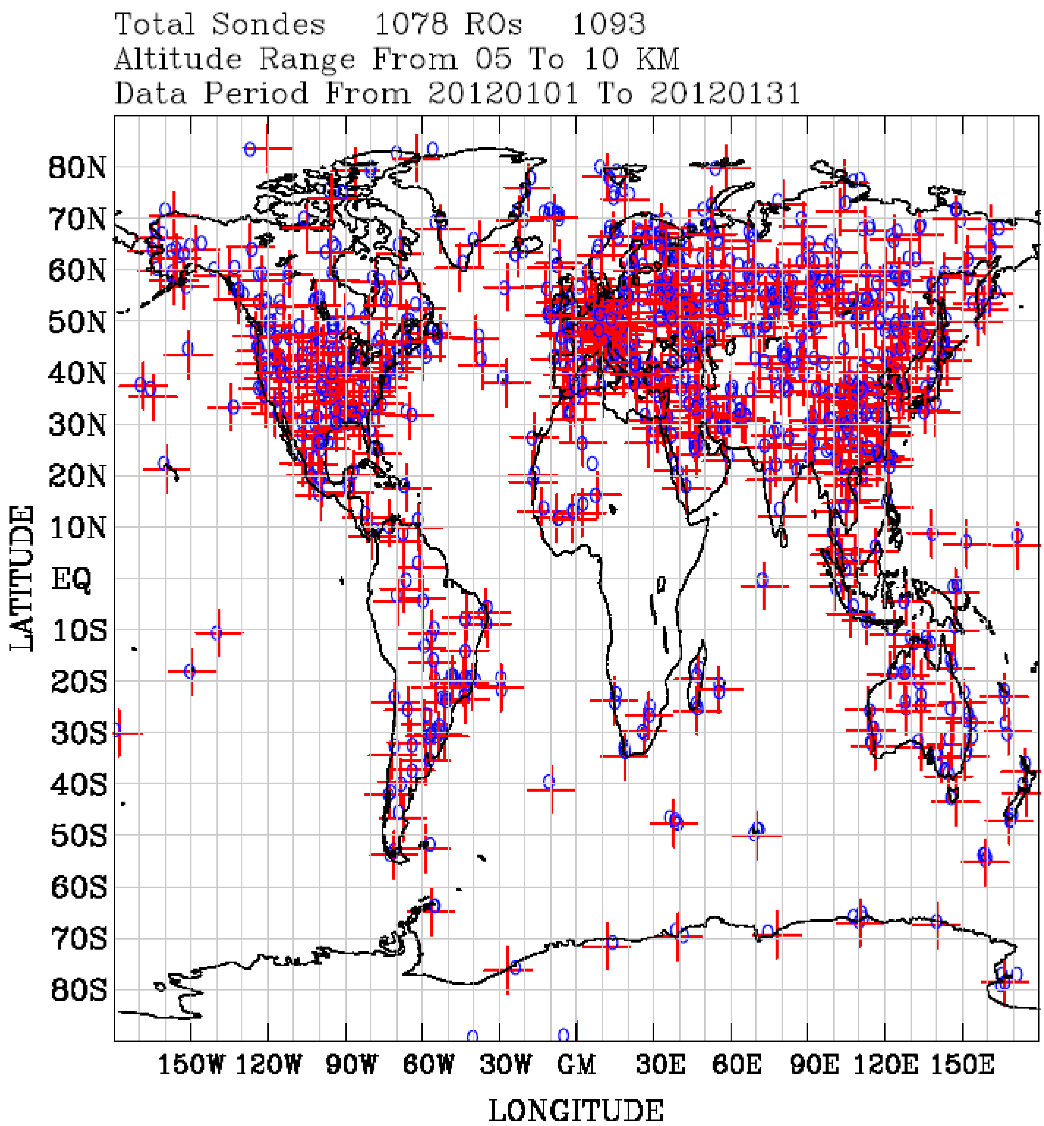


Figure 2. Availability of direct profile of temperature measurements in the altitude range between 5 and 10 km from radiosondes (red crosses) and F3C profiles (blue circles) for January 2012.

We have continued working on this line of analysis, to understand the accuracy of the F3C data when compared with the radiosondes in the different layers of the atmosphere and different regions of the world.

Currently, we have obtained detailed radiosonde data for the period from Apr 2006, when the F3C was launched, to July 2012. We have also created gridded RO data based on F3C data and all F3C post-processed profiles. Based on this rich data set, we expect to work out spatial and temporal accuracy analysis for

the F3C data since Apr 2006.

2) Other works are ongoing (please refer to the table shown in section 5.

四、結語

We have continuously worked on the use of F3C data to elucidate the working of the atmosphere from surface ocean/land, through troposphere and to the stratosphere. We intend to produce good results following these works, which can be useful for understanding the coupling processes in the atmosphere.

eale et al. [2009] reported positive impact of assimilating AIRS in forecasting tropical cyclones. Wang [2010] combined profiles of temperature measurements from F3C with aerosol index (AI) data from OMI to show that profiles of temperature response to the Saharan dust outbreaks exhibit pronounced warming of the atmosphere at altitudes below 5 km, with the maximum warming of 3-5 K occuring around 2-3 km altitudes.

It is very encouraging to see that the enhanced spatial coverage of the Aqua AIRS and the F3C Global Positioning System (GPS) radio occultation (RO) data over the tropical North Atlantic atmosphere provide more detailed observations of the transporting dust plumes than were previously available from the conventional data [Wong et al., 2009; Huang et al., 2010]. These additional data were able to improve predictions of hurricane tracks. In this work we use the F3C GPS RO data to reveal temperature variations of the transporting dust plumes. We compare F3C with Aqua AIRS observations. We also compare and contrast these satellite observations with meteorological analyses from the National Centers for Environmental Predictions (NCEP), the United Kingdom Met Office (UKMO), and the European Centre for Medium Range Weather Forecast (ECMWF), in the days with and without Saharan dust outbreaks. These comparisons highlight the importance of the changing temperature structures associated with the long-range transport Sahara dust plumes which are not often seen by the meteorological analyses (as shown here) but prominently feature from the F3C and the AIRS observations.