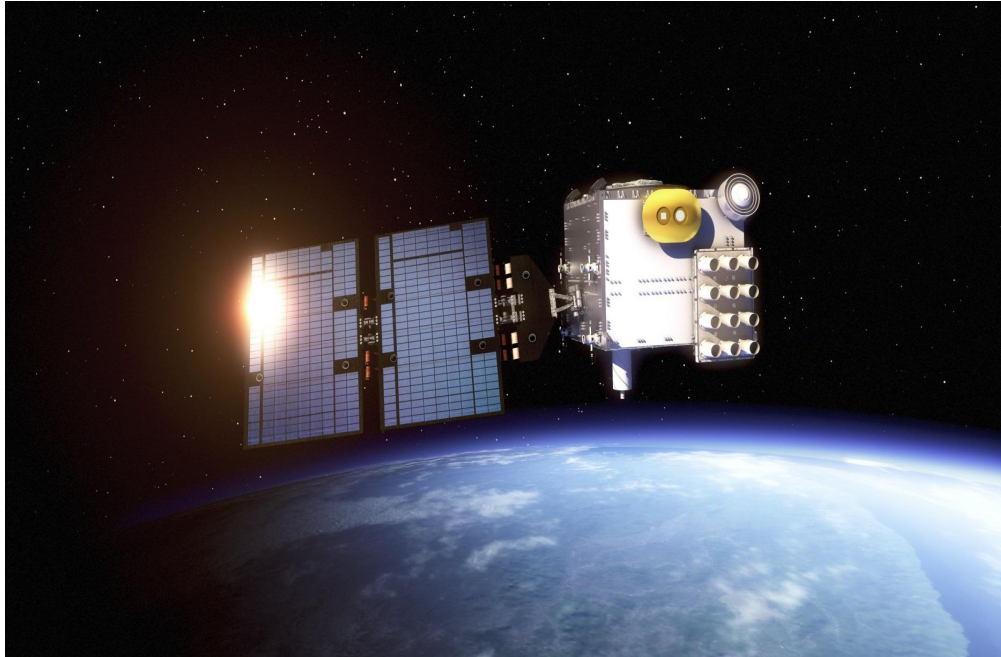# FORMOSAT-7/COSMIC-2 Mission Update

US: Wei Xia-Serafino (NOAA), Jan-Peter Weiss (UCAR)

Taiwan: Vicky Chu, Cheng-Yung Huang(NSPO) , Su-Ya Chen (NCU), Charles Lin (NCKU), Jing-Shan Hong (CWB)
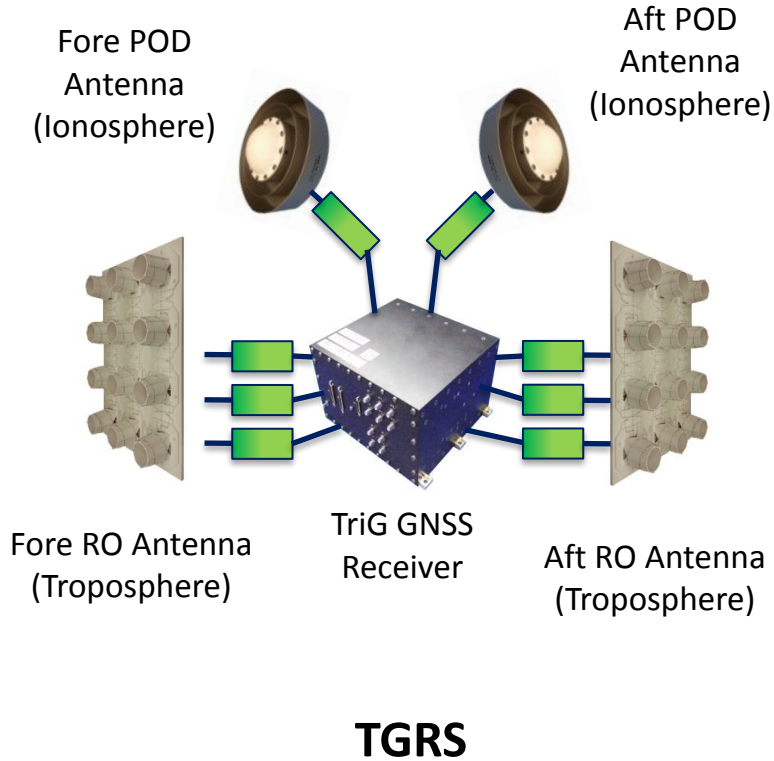
And FS7C2 Team

April 7, 2021

IROWG

Outline

- Payload and Satellite Overview
- Constellation Deployment
- Data Coverage
- Data Review and Data Performance
- Data Application
- TROPS
- Data Release Schedules
- Summary
- Acknowledgement
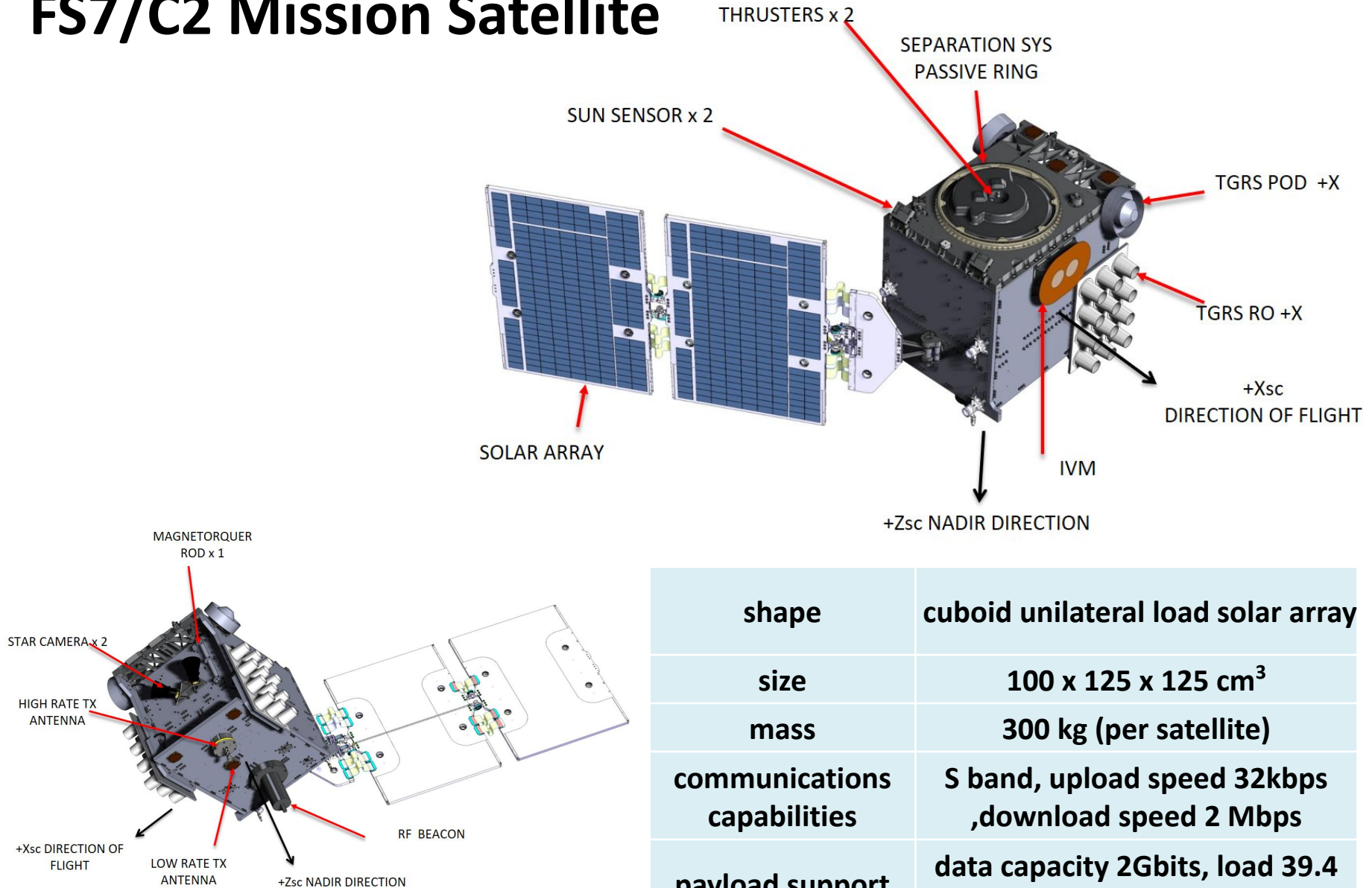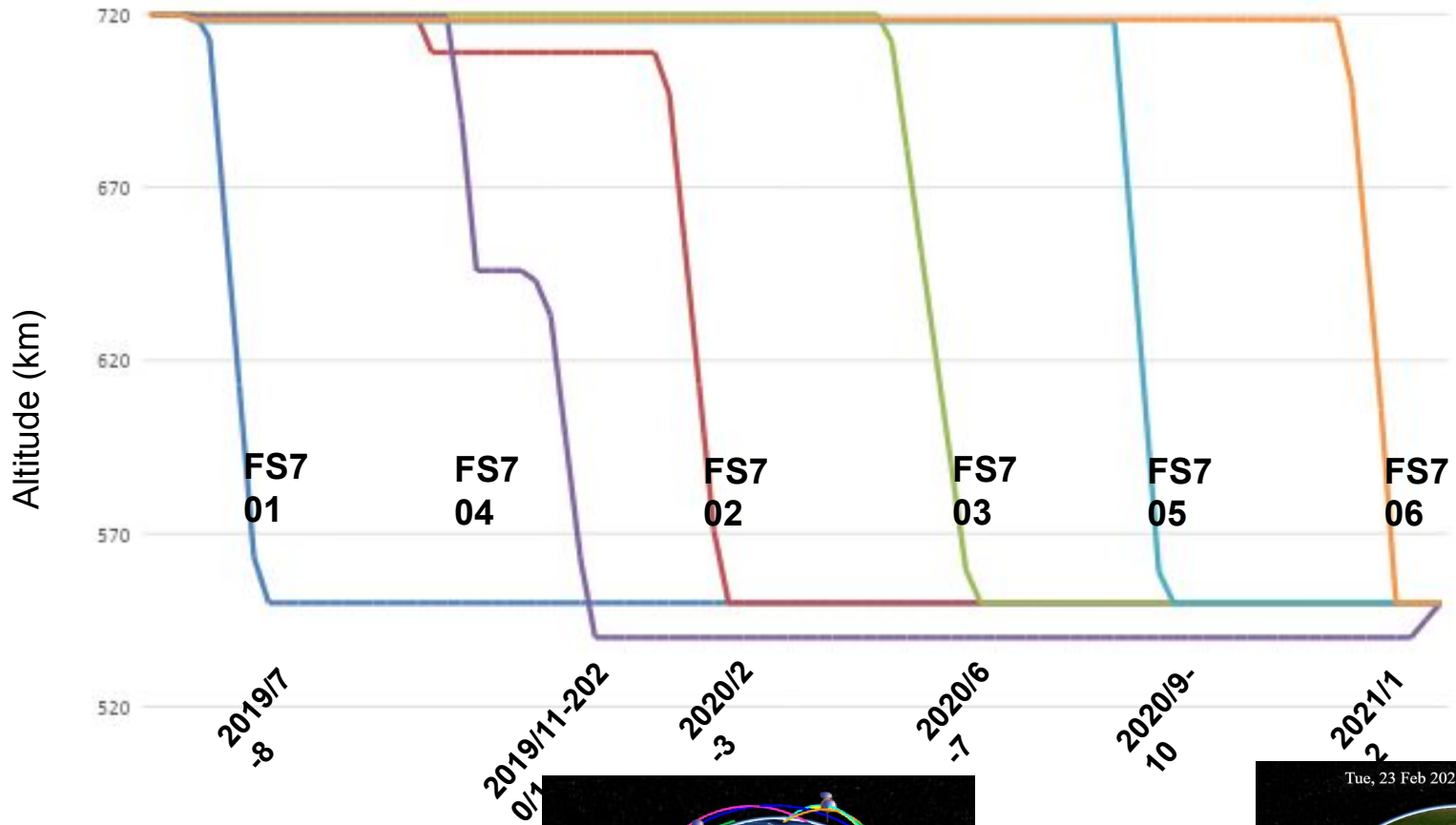
FS7/C2 Payload Instruments

Fore POD Antenna (Ionosphere)

Aft POD Antenna (Ionosphere)

Fore RO Antenna (Troposphere)

TriG GNSS Receiver

Aft RO Antenna (Troposphere)

TGRS

IVM

RFB

| Mission Payload	TGRS (Tri-GNSS Radio occultation System)	To measure the amplitude and phase/group delay of GNSS signals
Science Payload	IVM (Ion Velocity Meter)	To measure in-situ ion density, drifts (Electric fields), temperature & composition
	RFB (Radio Frequency Beacon)	To measure total electron content and ionospheric scintillation.

FS7/C2 Mission Satellite

THRUSTERS x 2

SEPARATION SYS
PASSIVE RING

SUN SENSOR x 2

TGRS POD +X

TGRS RO +X

+Xsc
DIRECTION OF FLIGHT

SOLAR ARRAY

IVM

+Zsc NADIR DIRECTION

MAGNETORQUER
ROD x 1

STAR CAMERA x 2

HIGH RATE TX
ANTENNA

+Xsc DIRECTION OF
FLIGHT

LOW RATE TX
ANTENNA

+Zsc NADIR DIRECTION

RF BEACON

|	
shape	**cuboid unilateral load solar array**
size	**100 x 125 x 125 cm^3**
mass	**300 kg (per satellite)**
communications capabilities	**S band, upload speed 32kbps ,download speed 2 Mbps**
payload support	**data capacity 2Gbits, load 39.4 kg, power supply 95W**

Constellation Deployment

Altitude (km) vs. time chart showing deployment of FS7 satellites from 720 km to mission orbit:

- FS7 01 — 2019/7-8
- FS7 04 — 2019/11-2020/1
- FS7 02 — 2020/2-3
- FS7 03 — 2020/6-7
- FS7 05 — 2020/9-10
- FS7 06 — 2021/1-2

Mission Orbit
Altitude 520 km ~ 550 km
Inclination 24 deg
Orbital Plane Separation Angle
60 deg

Tue, 23 Feb 2021 03:45:00 GMT
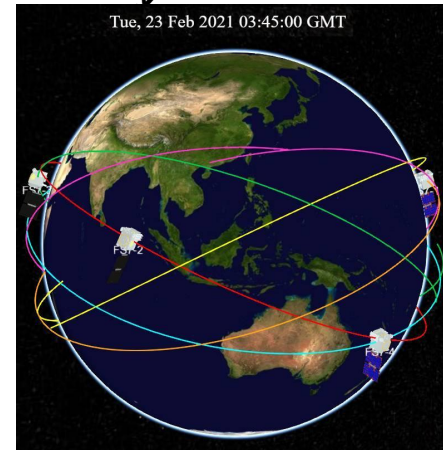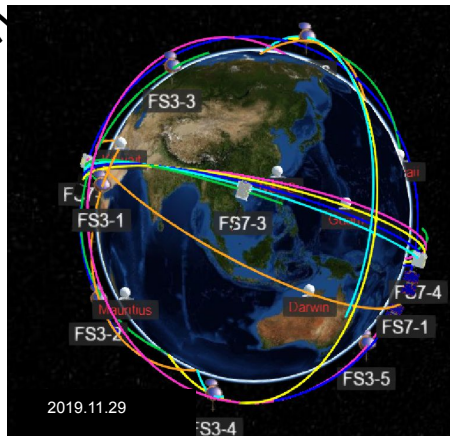
Data Coverage

- **Data distribution in 100 minutes**
- **+/- 50 deg latitude**
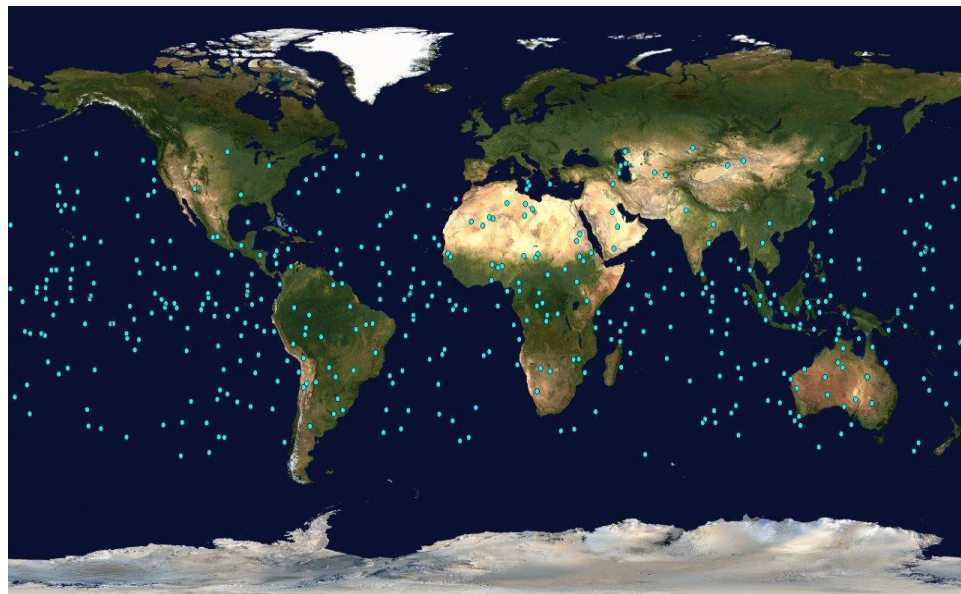
2019/10/14 in early orbit — FORMOSAT-7 2019.287 #5152

2021/03/17 FM1-FM6 in final orbit — FORMOSAT-7 2021.76 #5168

Spatial and temporal distribution
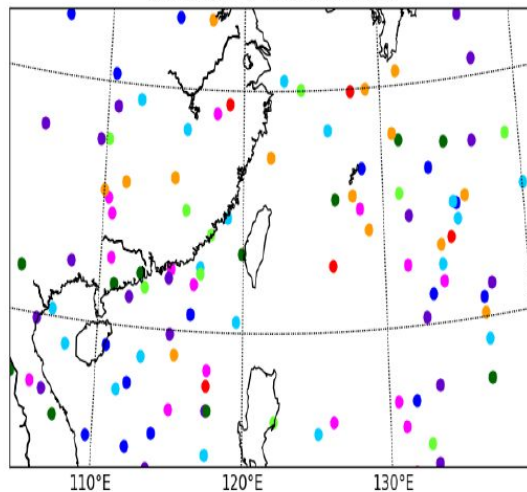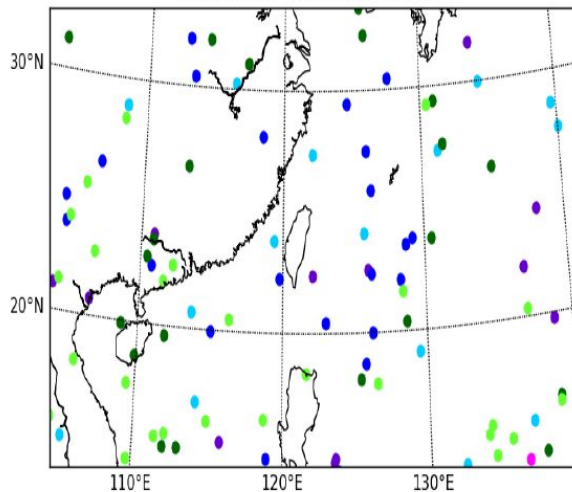
00 ~ 03   03 ~ 06   06 ~ 09   09 ~ 12   12 ~ 15   15 ~ 18   18 ~ 21   21 ~ 24

Initial/Final Operation Capability
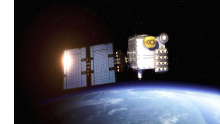
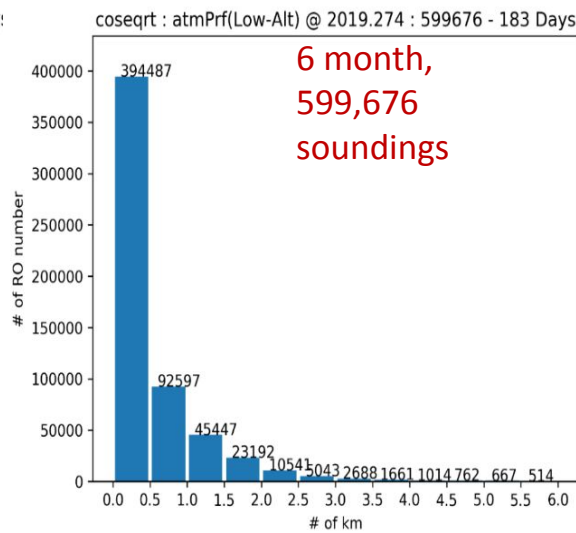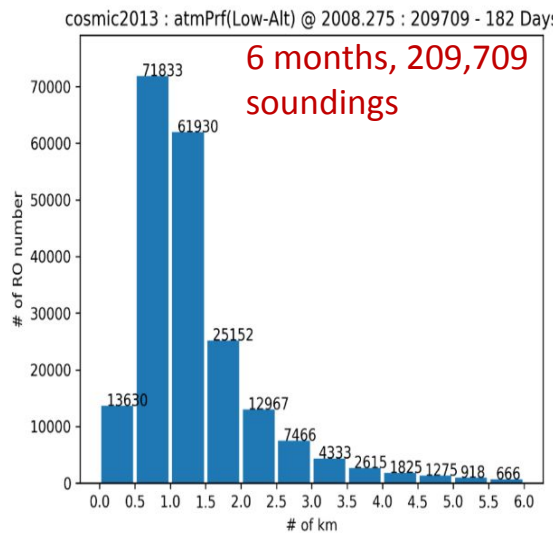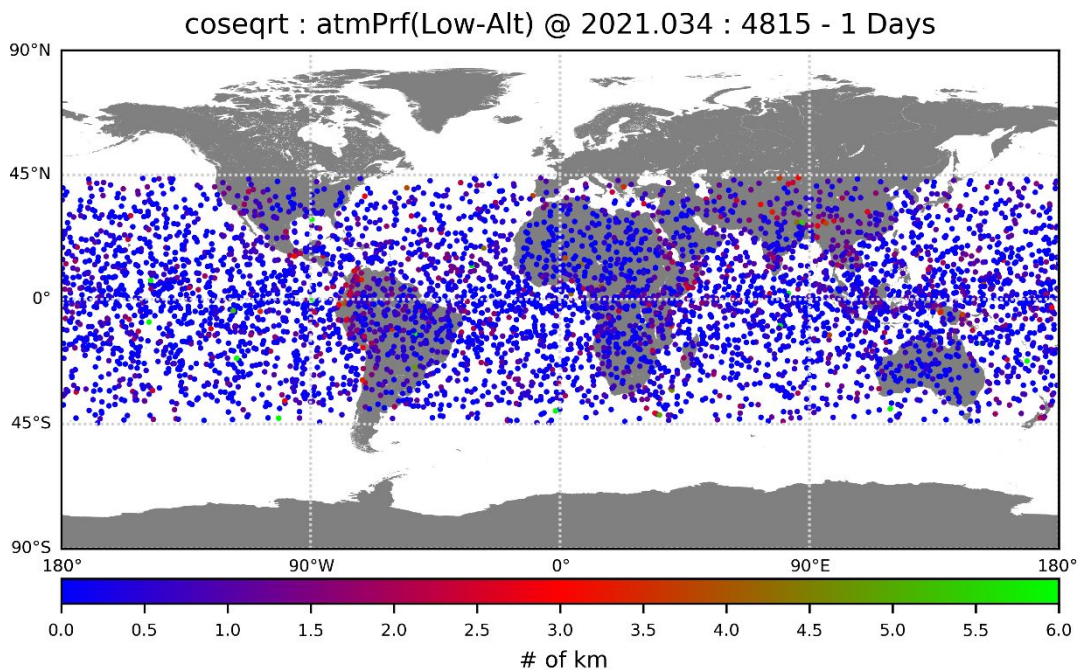| IOC	Milestone	Accomplished
Satellite IOC	✔ Complete satellite's health check ✔ Satellite in normal operations	*October, 2019*
Neutral Atmosphere IOC	✔ Provisional TGRS neutral atmospheric data was released in December, 2019. ✔ TGRS products available for operational use in March, 2020.	*February, 2020*
Ionosphere IOC	✔ Initial Space Weather TGRS products available for operational use	*November, 2020*
Neutral Atmosphere FOC	✔ Satellites in deployed constellation ✔ Complete neutral atmosphere data validation	*April, 2021*
FOC	✔ 6 satellites are launched and deployed with proper constellation separation allowing more than 75 data dumps per day. ✔ Sufficient ground stations are deployed to meet latency and operational availability requirements for those 6 satellites. ✔ Taiwan Data Processing Center is operational. ✔ US Data Processing Center is operational. ✔ Backup emergency command load capability is available. ✔ Archive capability is available.	*June, 2021 (Estimated)*

Calibration/Validation Results

L1 CA SNR ~ 2,800 V/V
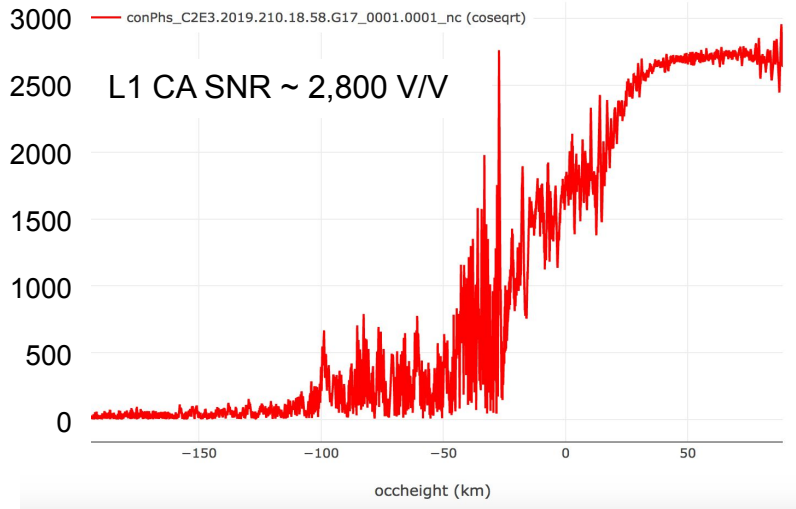
F7/C2 on Feb 5, 2020 – 5,546 profiles

C2 RO: YES duct
ECMWF: YES duct
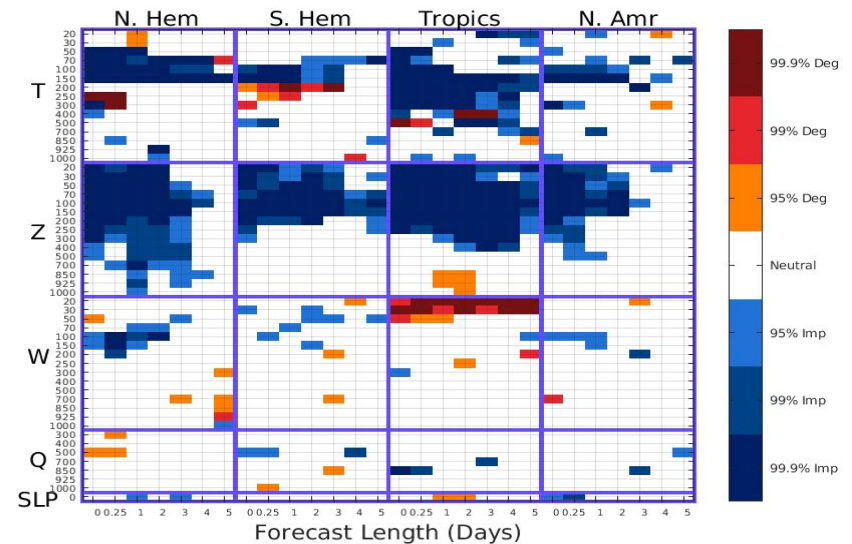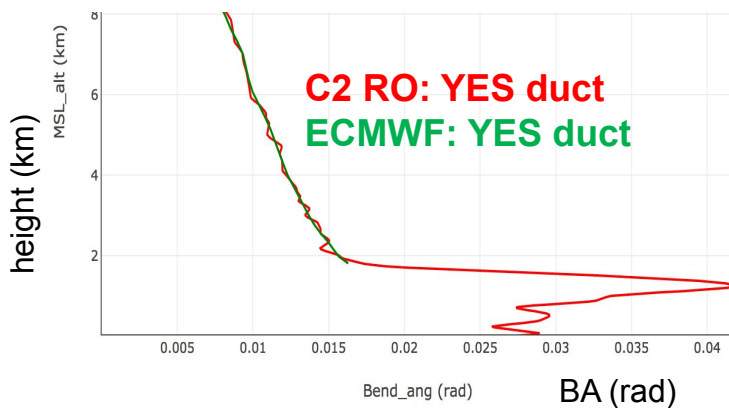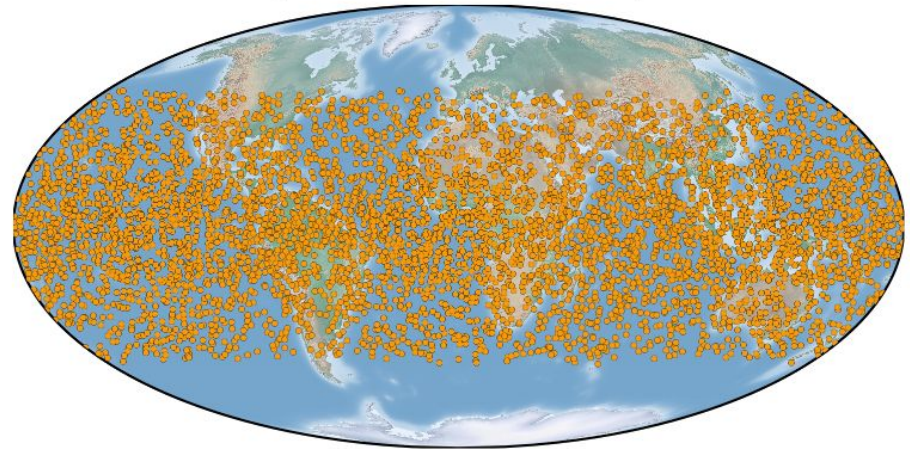
Radio Occultation Penetration Depth

cosmic2013 : atmPrf(Low-Alt) @ 2008.275 : 209709 - 182 Days

6 months, 209,709 soundings

71833
61930
25152
13630
12967
7466
4333
2615 1825 1275 918 666

# of RO number

# of km

coseqrt : atmPrf(Low-Alt) @ 2019.274 : 599676 - 183 Days

6 month, 599,676 soundings

394487
92597
45447
23192
10541 5043 2688 1661 1014 762 667 514

# of RO number

# of km

Courtesy from Shu-Ya Chen

coseqrt : atmPrf(Low-Alt) @ 2021.034 : 4815 - 1 Days

# of km
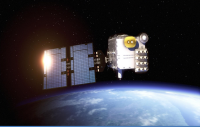
Statistically significant positive impact in tropics; Neutral-to-positive impact in other areas

(22 Oct. 2019 – 1 Mar. 2020)

With/without RO data assimilation

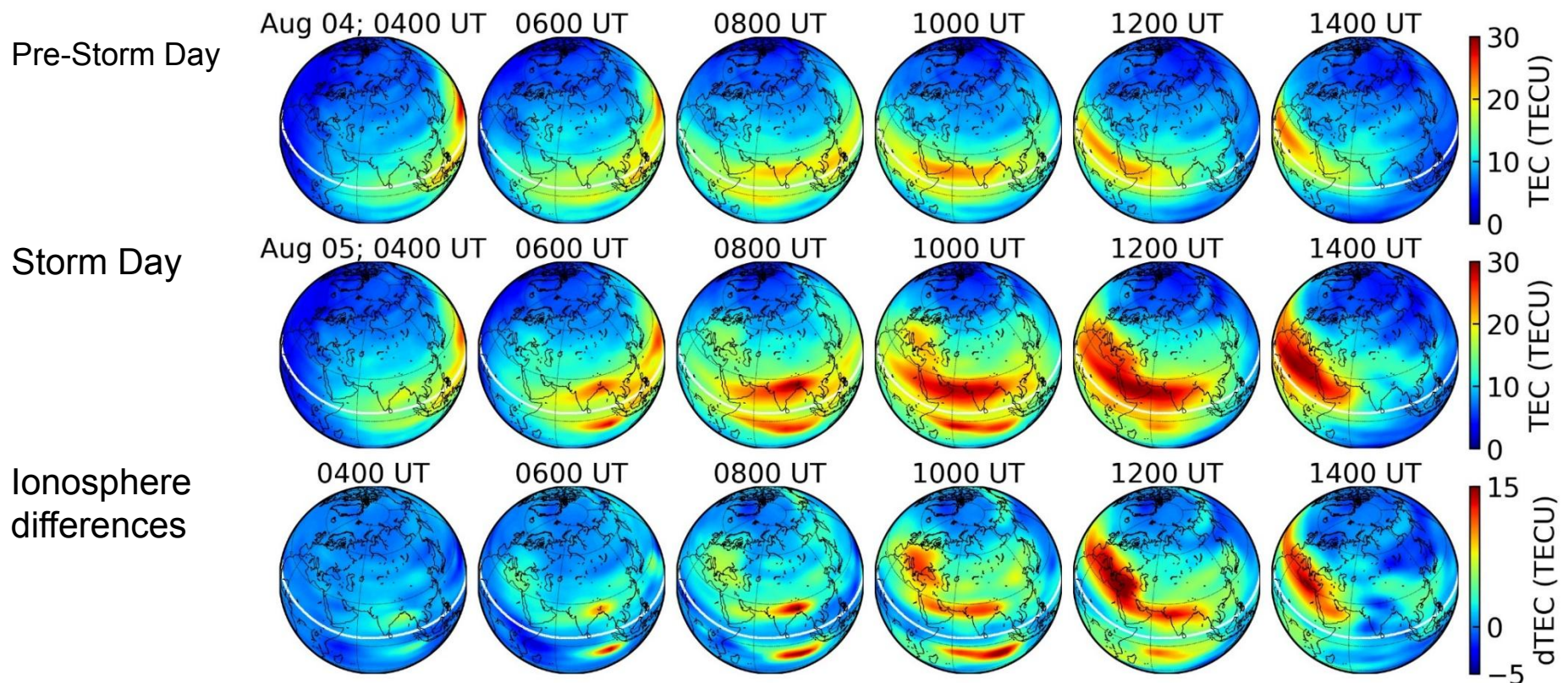Use of the RO observation BELOW 4-km further improve the model forecast

ALL/4-km above RO data assimilation

Green: positive impact

Courtesy from CWB NWP team

A minor magnetic storm creates very noticeable ionosphere response, which is unexpected

August 2019   **Dst (Real-Time)**   WDC for Geomagnetism, Kyoto

GIS TEC maps

Pre-Storm Day

Aug 04; 0400 UT   0600 UT   0800 UT   1000 UT   1200 UT   1400 UT

Storm Day

Aug 05; 0400 UT   0600 UT   0800 UT   1000 UT   1200 UT   1400 UT

Ionosphere differences

0400 UT   0600 UT   0800 UT   1000 UT   1200 UT   1400 UT
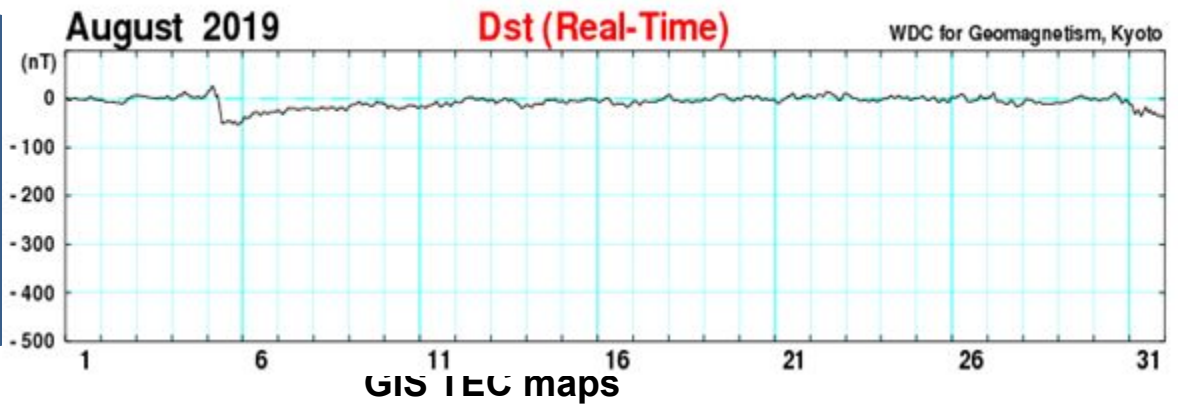
Courtesy from NCKU and NCU

Data Release Schedule

Product	Status	Released

• Near Real Time TGRS atmospheric products
     ▫ Atmospheric excess phase
     ▫ Atmospheric profiles (atmPrf, wetPf2)
• Satellite Orbit
     ▫ Precise orbit determination
	Operational	March 2020

TGRS GPS Absolute Total Electron Content	Operational	September 2020
TGRS GLONASS Total Electron Content	Operational	January 2021
IVM in-situ ion density	Operational	April 2021 (Estimated)
Post Process TGRS atmospheric products	Operational	April 2021 (Estimated)
TGRS Electron Density Profiles TGRS Scintillation Amplitude Index	Provisional	March 2020

TROPS

https://tacc.cwb.gov.tw/v2/en/trops_download.html

About   FS7-TDPC   FS7-TROPS   FS3   Links

FS-7 TROPS realtime

By Level:

Daily Tar | Level0 | Level1a | Level1b | Level2 | Level3

By Category:

Ionosphere

ionPhs: Link | File Description
Ionospheric excess phases and auxiliary data used for generating ionospheric profiles. Note: No differencing is applied - expect receiver clock errors on L1 and L2.

ionPrf: Link | File Description
Ionospheric profiles of electron density. The accuracy is genereally about 10^4-10^5 cm^{-3}. Caveats: Some profiles may be affected by cycle-slips.

igaPrf: Link | File Description
Ionospheric profiles of electron density (Ne) derived from the aided-Abel inversion.

GIS: Link | File Description
Global Ionospheric Specification (GIS) of 3D electron density maps. Providing hourly 3D global electron density distribution by assimilating radio occultation (RO) and Global Navigation Satellite System (GNSS) total electron content (TEC) by implementing a Gauss-Markov Kalman filter algorithm.

Raw GPS Data

trgLv0: Link | File Description
This file contains level 0 (raw binary) data from the FORMOSAT-7 TRIG GNSS Receiver Payload.

opnGns: Link | File Description
Atmospheric occultation data in a simple custom binary format. This data file contains all high rate atmospheric data sent us by the GNSS receiver on the LEO.

podCrx: Link | File Description
Raw L1 and L2 pseudo-range and carrier phase tracking data in compressed RINEX 2.20 format

leoAtt: Link | File Description
Attitude and rough position data from the FORMOSAT-7 spacecraft andthe GOX navigation solutions.

leoOrb: Link | File Description
Precise FORMOSAT-7 spacecraft orbits. The orbit precision based on internal orbit overlap comparisons is on average less than 15 cm 3D RMS (0.15 mm/sec 3D velocity).

scn1c2: Link | File Description
On-board S4 amplitude scintillation index and auxiliary data

Summary

✔ Constellation deployment completed in February 2021.

✔ All six satellite are well operated at mission constellation.

✔ Near real time atmospheric data was released.

✔ Major ionospheric data was released.

✔ FS7/C2 data made positive Impacts on terrestrial weather and space weather.

Acknowledgements

Thanks to the FS7/C2 Program partners!