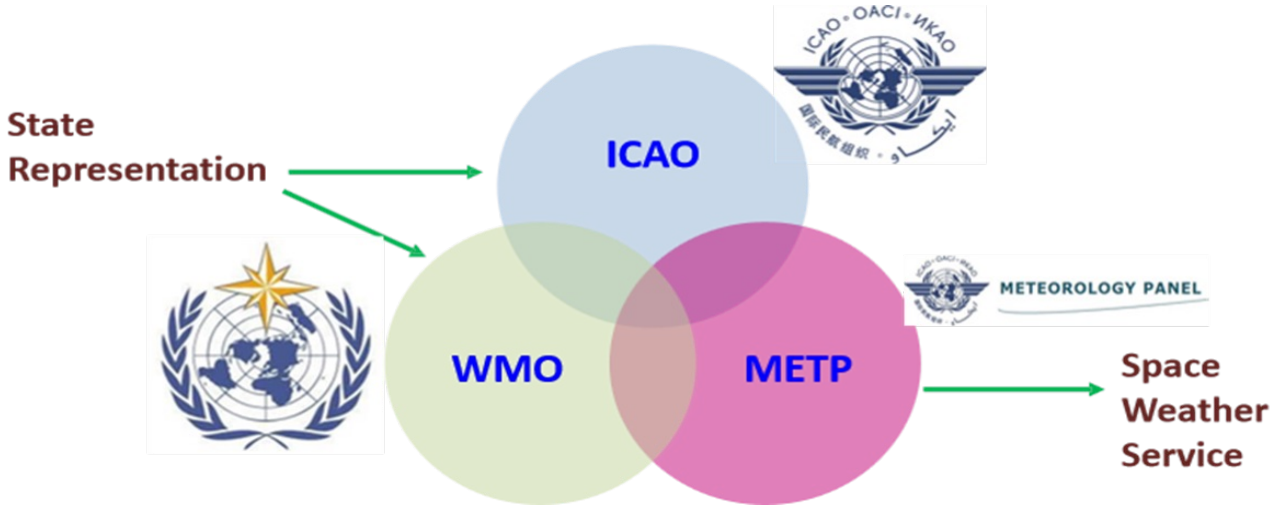
Operating experience of the Russian segment CRC of the Global Space Weather Center in Support of International Air Navigation

One of the tasks of the working group on space weather is to coordinate efforts to provide international procedures for monitoring, forecasting and transmitting information on extreme space weather events.
An example of such activities is the International Space Weather Service for air navigation organized under the auspices of the ICAO (International Civil Aviation Organization) with the participation of WMO (World Meteorological Organization). The Russian Federation takes the most active part in the implementation of this project. In 2018, the Russian-Chinese Space Weather Consortium (CRC) was established, which included

- National Space Weather Center of China Meteorological Administration (NCSW),
- Aviation Meteorological Center of the Civil Aviation Authority (AMC/CAAC)
- Institute of Applied Geophysics of Roshydromet (IAG).



Management of the space weather service within ICAO

Space weather centers for air navigation are regulated by the Convention on International Civil Aviation. It's the service in which the space weather centers provide the information on the space weather phenomena which may affect the communications, navigation and surveillance systems and/or pose a radiation risk to aircraft occupants.

Following international audit by the ICAO Council, four Global Centers have been designated:

1.PECASUS
(Finland, UK, Germany, Austria, Poland, Italy , Netherlands, Belgium, Cyprus, South Africa)

2. Space Weather Prediction Center
USA

3. ACFJ
(Australia, Canada, Japan, France)

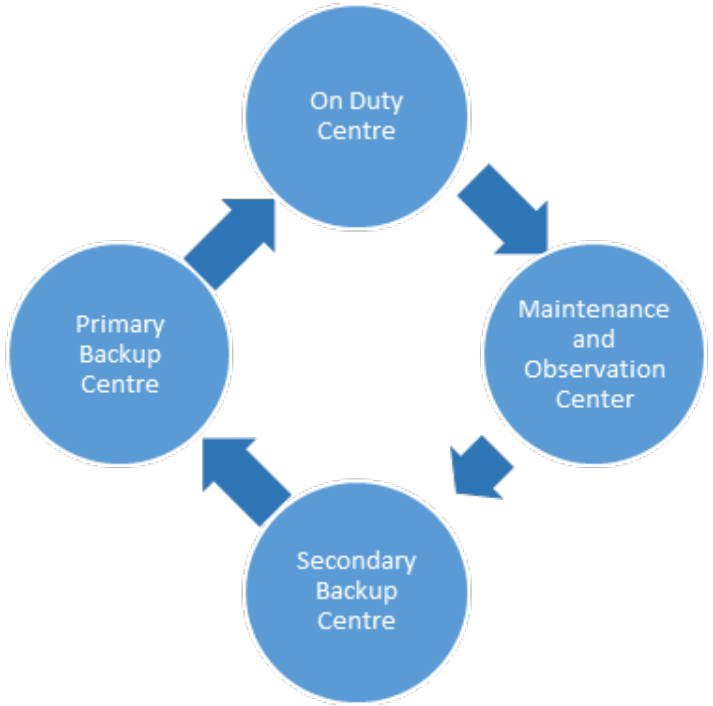
4. CRC
(China, Russia)

Duty Schedule and Transfer of Responsibility Scheme

On November 16, 2021, in accordance with the decision of the ICAO Meteorological Commission, the CRC started the service as one of the four Global Space Weather Centers for Air Navigation (before that day, three centers had been in service).

Each center will only hold one of the following roles at a time: ODC, PBC, or SBC, or MOC.

The responsibility revolves in the following manner:



Month	Date	On Duty Centre	Primary Backup Centre	Secondary Backup Centre	Maintenance and Observation Centre
Nov 2021	02	SWPC	ACFJ	PECASUS	
	16	ACFJ	PECASUS	SWPC	CRC
	30	PECASUS	SWPC	CRC	ACFJ
Dec	14	SWPC	CRC	ACFJ	PECASUS
	28	CRC	ACFJ	PECASUS	SWPC
Jan 2022	11	ACFJ	PECASUS	SWPC	CRC
	25	PECASUS	SWPC	CRC	ACFJ
Feb	08	SWPC	CRC	ACFJ	PECASUS
	22	CRC	ACFJ	PECASUS	SWPC
Mar	08	ACFJ	PECASUS**	SWPC**	CRC
	22	PECASUS	SWPC**	CRC**	ACFJ
Apr	05	SWPC	CRC**	ACFJ**	PECASUS
	19	CRC	ACFJ**	PECASUS**	SWPC
May	03	ACFJ	PECASUS	SWPC	CRC
	17	PECASUS	SWPC	CRC	ACFJ
	31	SWPC	CRC	ACFJ	PECASUS
June	14	CRC	ACFJ	PECASUS	SWPC
	28	ACFJ	PECASUS	SWPC	CRC
July	12	PECASUS	SWPC	CRC	ACFJ
	26	SWPC	CRC	ACFJ	PECASUS
Aug	09	CRC	ACFJ	PECASUS	SWPC
	23	ACFJ	PECASUS	SWPC	CRC
Sep	06	PECASUS	SWPC	CRC	ACFJ
	20	SWPC	CRC	ACFJ	PECASUS
Oct	04	CRC	ACFJ**	PECASUS**	SWPC
	18	ACFJ	PECASUS**	SWPC**	CRC
Nov	01	PECASUS	SWPC**	CRC**	ACFJ
	15	SWPC	CRC**	ACFJ**	PECASUS
	29	CRC	ACFJ	PECASUS	SWPC
Dec	13	ACFJ	PECASUS	SWPC	CRC
	27	PECASUS	SWPC	CRC	ACFJ
Jan 2023	10	SWPC	CRC	ACFJ	PECASUS
	24	CRC	ACFJ	PECASUS	SWPC
Feb	07	ACFJ	PECASUS	SWPC	CRC
	21	PECASUS	SWPC	CRC	ACFJ
Mar	07	SWPC	CRC**	ACFJ**	PECASUS
	21	CRC	ACFJ**	PECASUS**	SWPC

Timetable of global space weather centers

The threshold values for moderate and severe intensities for advisory generation

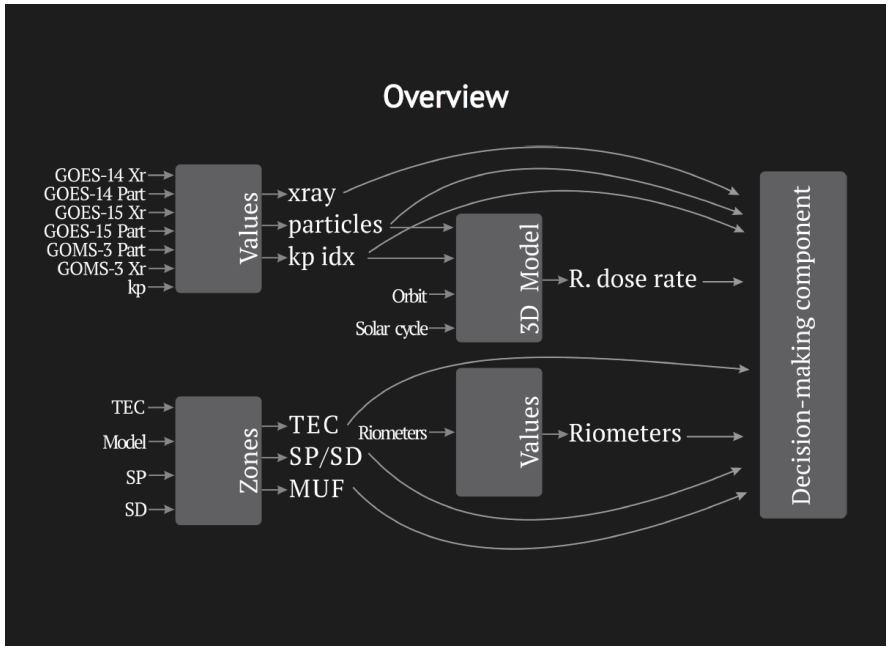
Effect	Sub-effect	Parameter used	Moderate	Severe
GNSS	Amplitude Scintillation	S4 (dimensionless)	0.5	0.8
GNSS	Phase Scintillation	Sigma-phi (radians)	0.4	0.7
GNSS	Vertical Total Electron Content (TEC)	TEC units	125	175
RADIATION		Effective dose rate (micro-Sieverts/hour)	30	80
HF COM	Auroral Absorption (AA)	Kp	8	9
HF COM	Polar Cap Absorption (PCA)	dB from 30MHz riometer data	2	5
HF COM	Shortwave Fadeout (SWF)	Solar X-rays (0.1-0.8 nm) ($W\text{-}m^{-2}$)	$1x10^{-4}$ (X1)	**$1x10^{-3}$ (X10)**
HF COM	Post-Storm Depression	MUF**	30%	50%

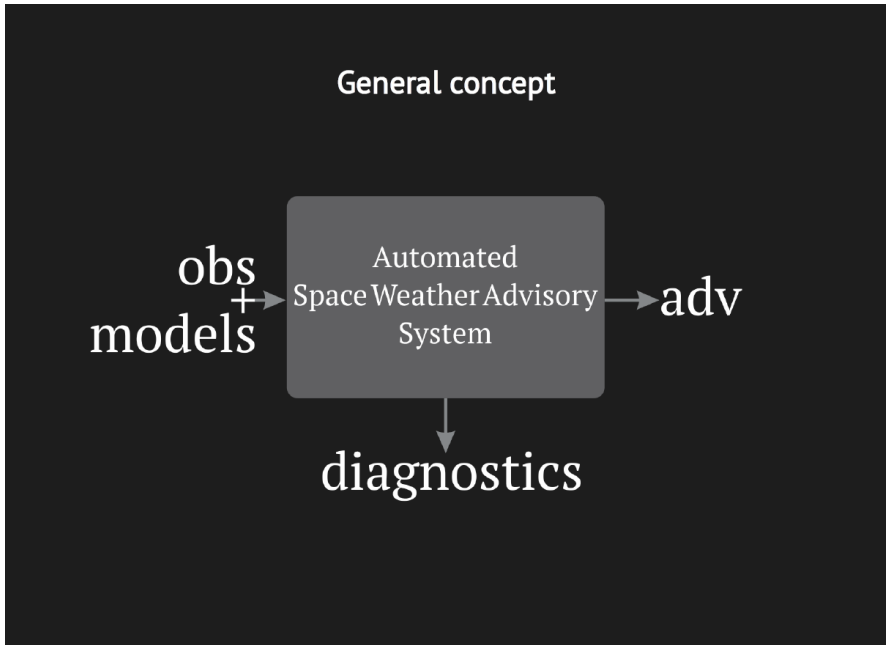
Our space weather monitoring instruments

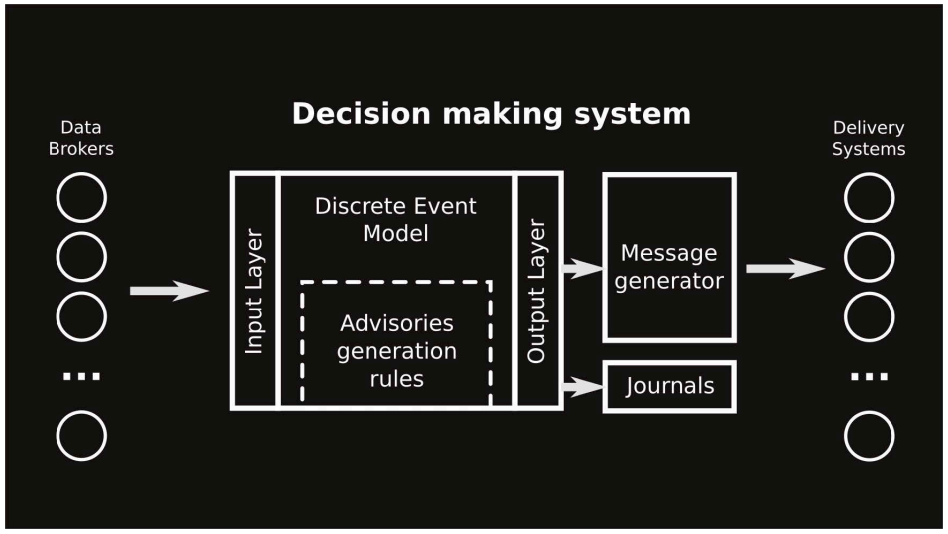
To meet the ICAO criteria we have carried out extensive scientific and methodological work to modernize the existing methods, algorithms and programs and created the new ones. In particular, the calculation of the radiation situation on air routes during strong solar flares at various altitudes from 5 to 18 kilometers, with a step of about a thousand of meters for all regions, seasons and the local time with the calculation of the background values for each height. We have developed new methods and programs for the operational calculation of ionospheric parameters and identification of inhomogeneities..

We especially note that the monitoring of space weather disturbances primarily relies on satellite observation data: low-orbits, geostationary and extra magnetospheric spacecrafts.

Our Center Structure







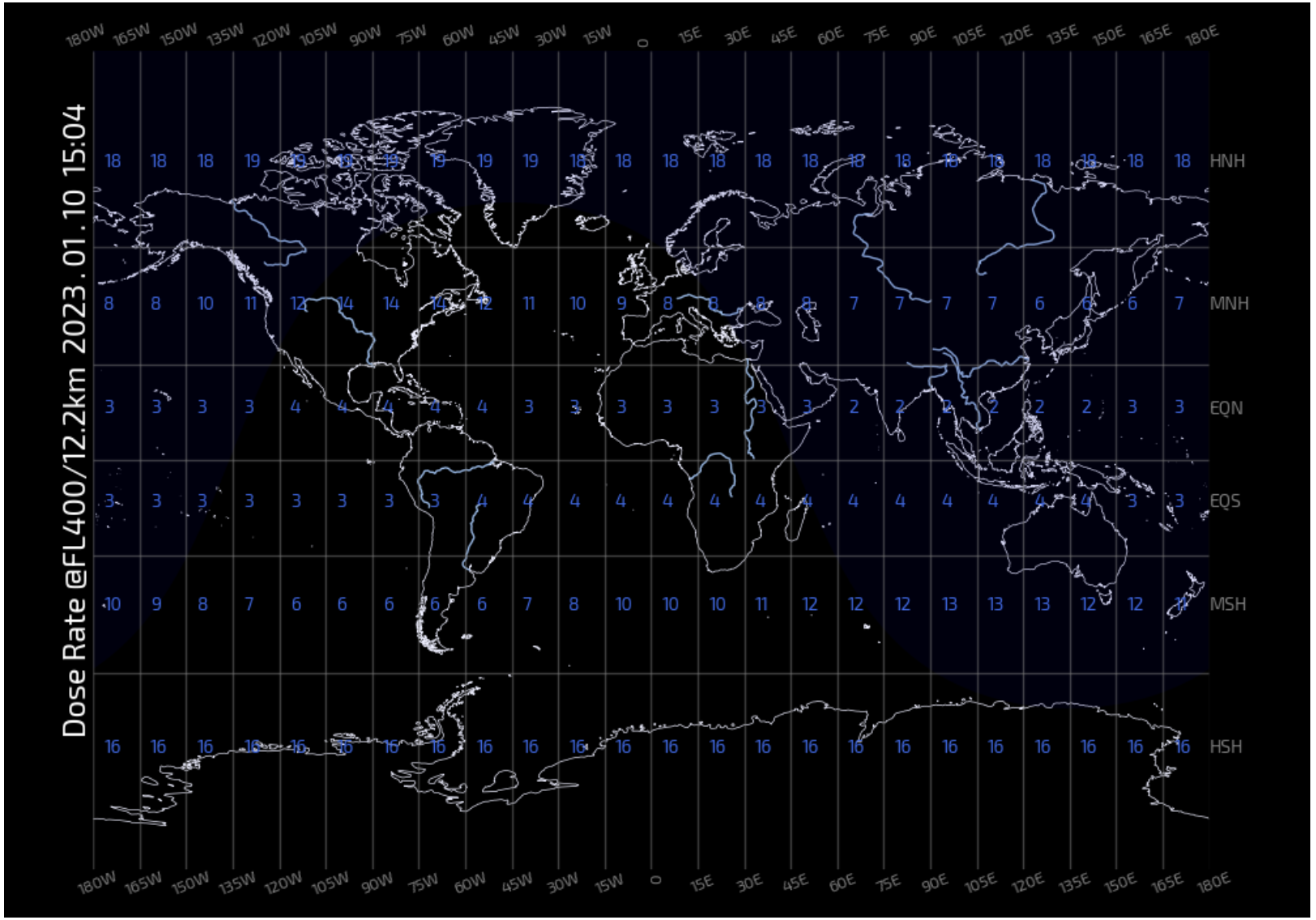
Details on decision making component:

it processes four independent event chains simultaneously:

1. Flight radiation effective dose
2. HF communication impairment
3. GNSS availability issues
4. Energetic particle events nowcast

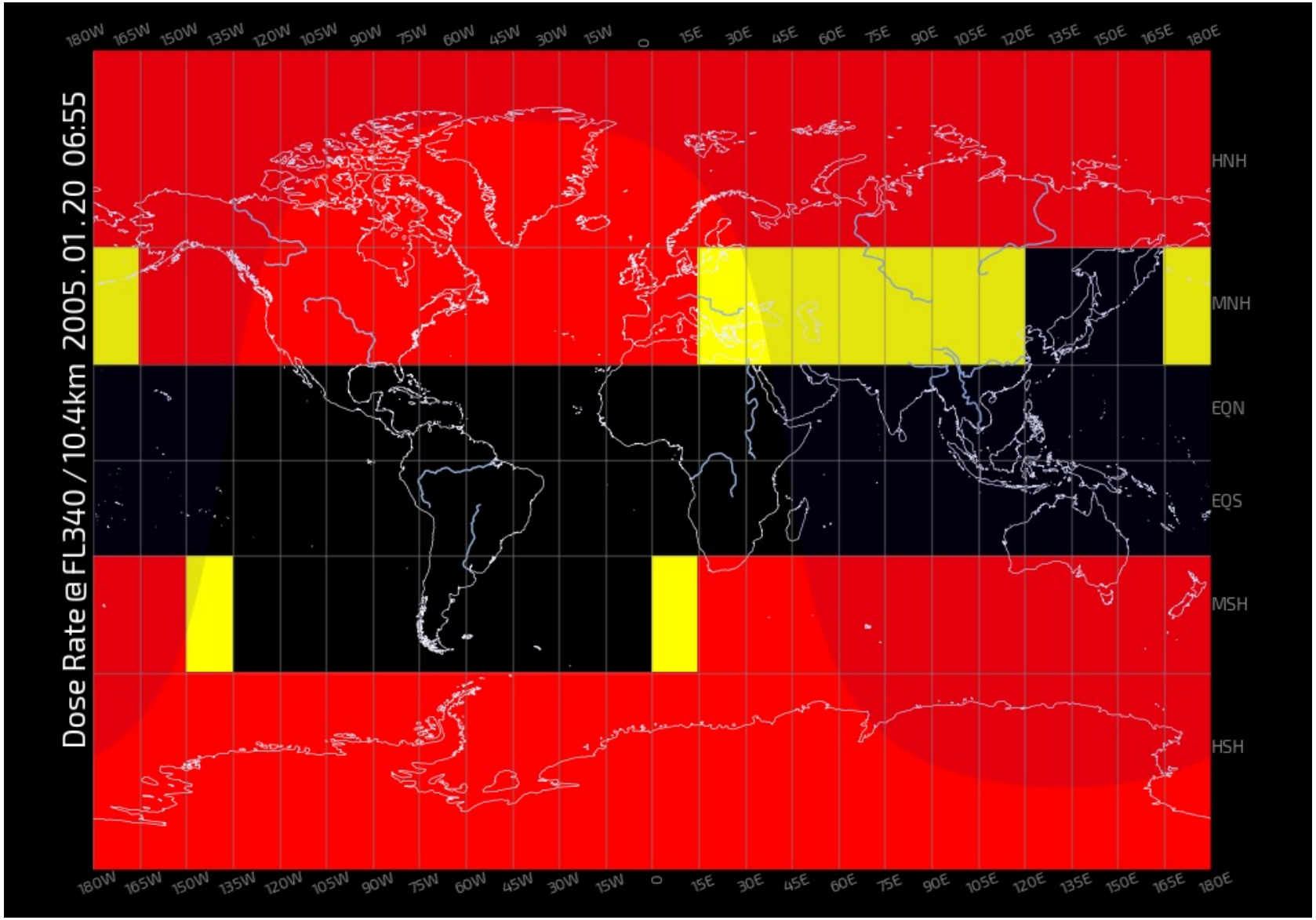
Warning our robot about reaching critical values by some parameter

Quiet time radiation exposure map



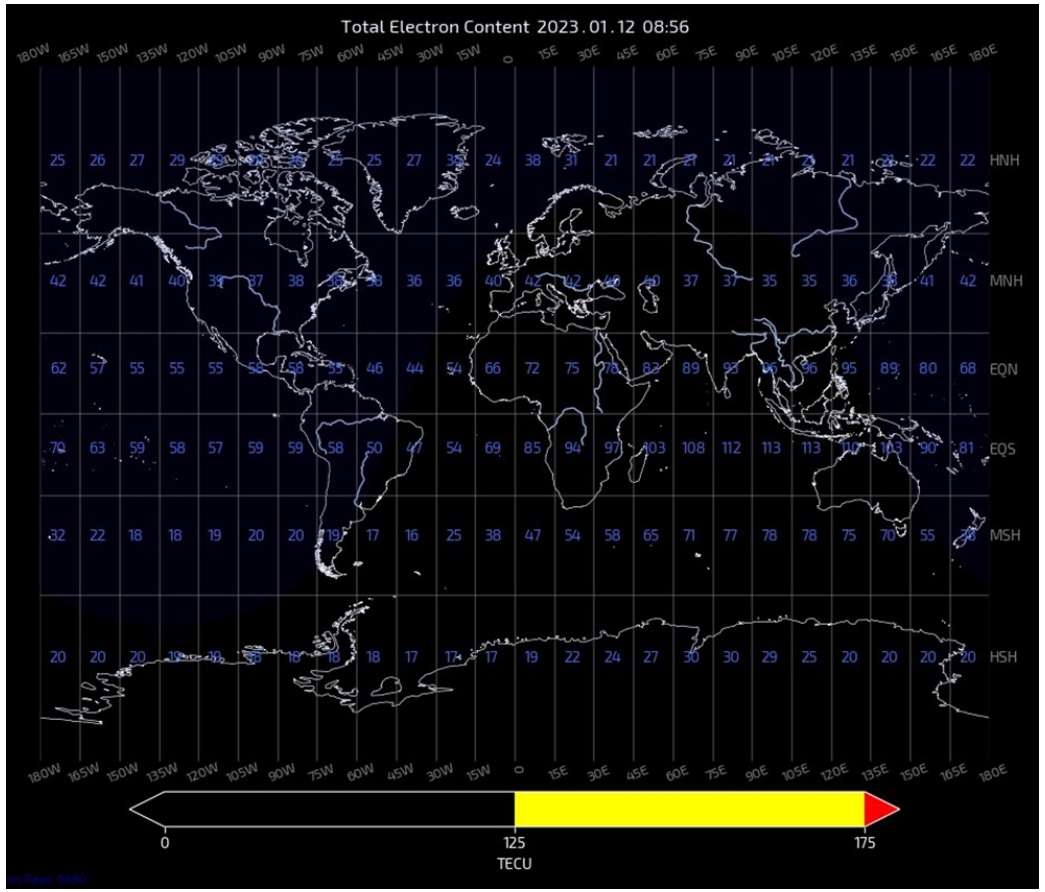
Radiation at aircraft flight (FL400/12,2 km) is on background level

Radiation exposure intensity map during strong disturbances

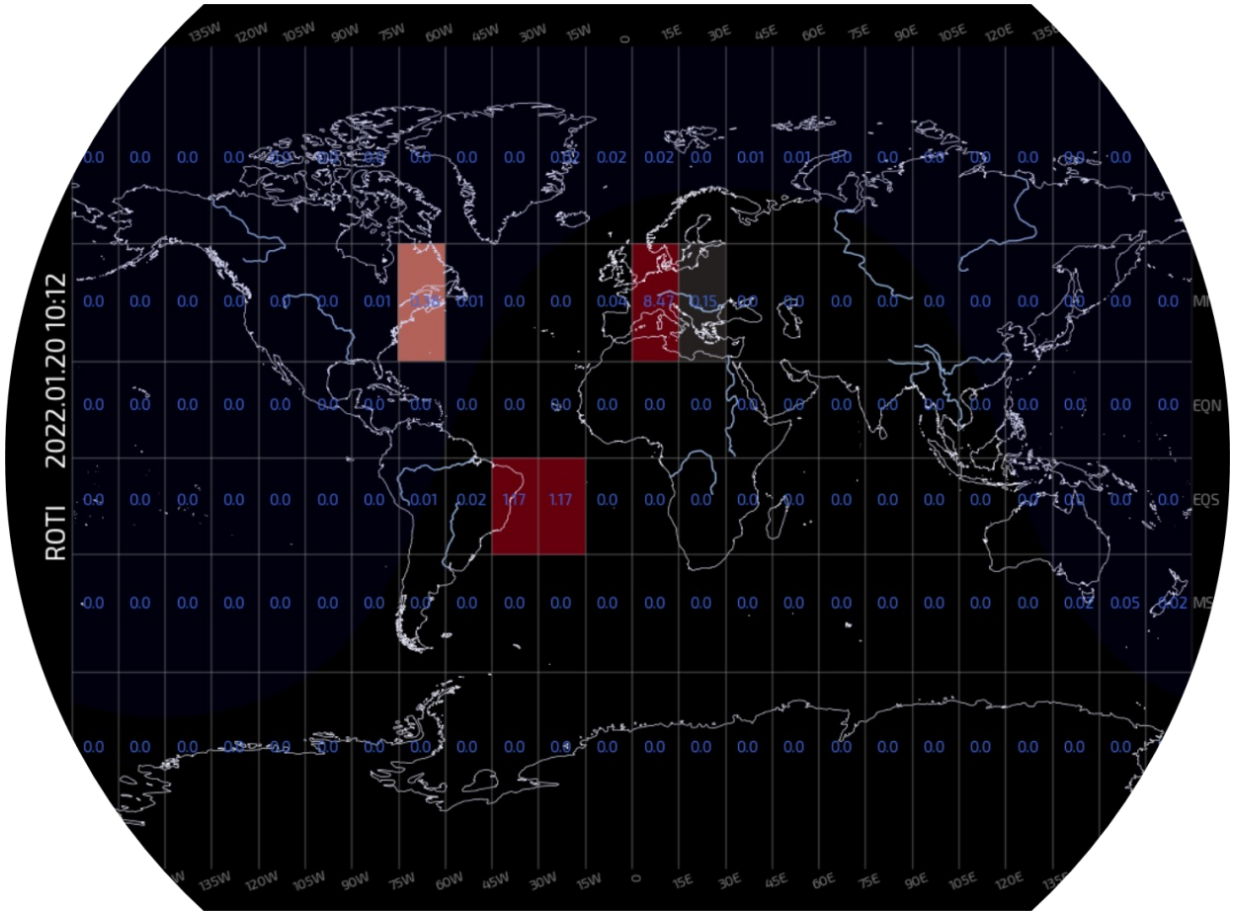


Maps of inhomogeneities of the Earth's ionosphere

Our maps of irregularities in the Earth's ionosphere on January 20, 2022 (TEC and ROTI), which can degrade the quality of radio communications and navigation accuracy



Total Electron Content (TEC) global map



Ionospheric scintillation (ROTI) map

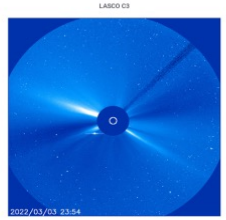
Composition of information summary at Handover

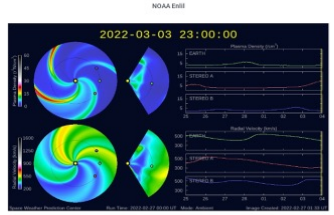
ICAO SPACE WEATHER HANDOVER BRIEF
CRC

2022-03-08 05:59 UTC

Current Conditions

Coronal mass ejection

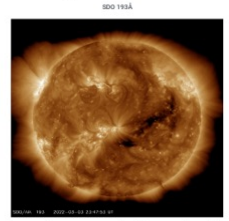


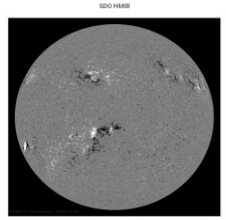


No Earth-directed CMEs were observed

Current Conditions

Active regions





Active regions currently observed on the solar disk: 2957 (Eai,S17W48), 2958 (Axx, N17W43), 2960 (Dhi, S21E17), 2961 (Axx, S14W57), 2962 (Cro, N28E30), 2963 (Cro, S18W15)

The five low-activity groups observed on the visible disk.

Current Conditions

Solar wind

Over the past 24 hours, the solar wind speed has varied from 500 km/s to 470 km/s, the current value being about 470 km/s.

Three Day Forecast

Three day Forecast (summary)

Date (UTC)	Solar flares > M5	Solar flares > X1	F10.7	Highest Kp	Proton (>10 MeV) (peak flux, pfu)
2022-03-08	10%	1%	116	3	1%
2022-03-09	10%	1%	114	2	1%
2022-03-10	10%	1%	112	2	1%

No significant solar related effects expected

Formal Handover

ODC handing over responsibility (clear verbal request)

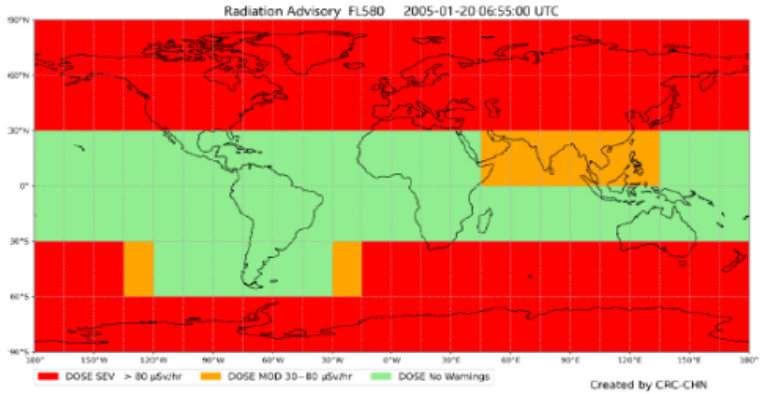
Center	Date	Time	Name
CRC	2022-03-08	08:00	Dr. Vyacheslav Burov

PBC receiving responsibility (clear verbal acceptance)

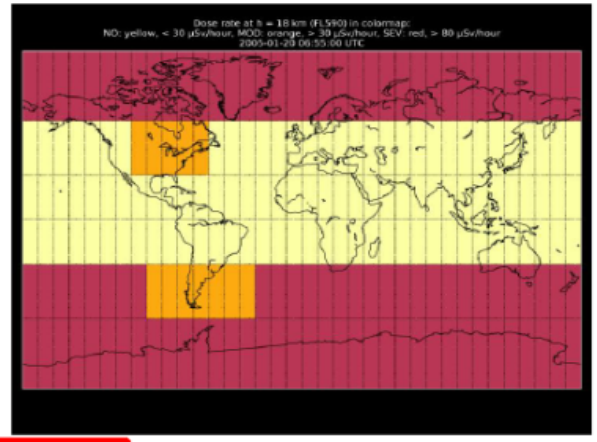
Center	Date	Time	Name
ACFJ	2022-03-08	08:00	

Comparison of the results of calculating the dose rate of the Russian and Chinese CRC segments

- **20/01/2005-06:55UTC-FL580**

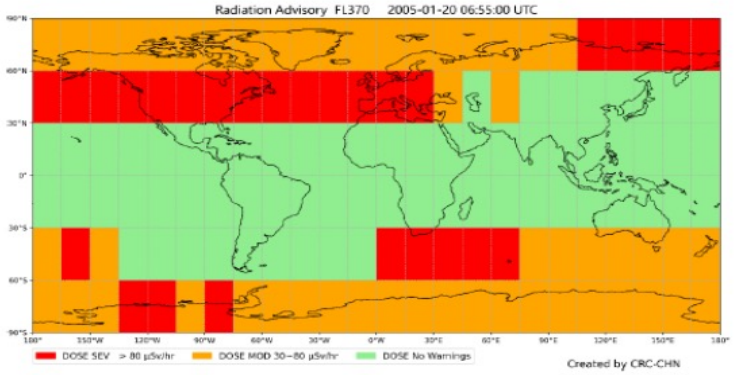


CRC-CN

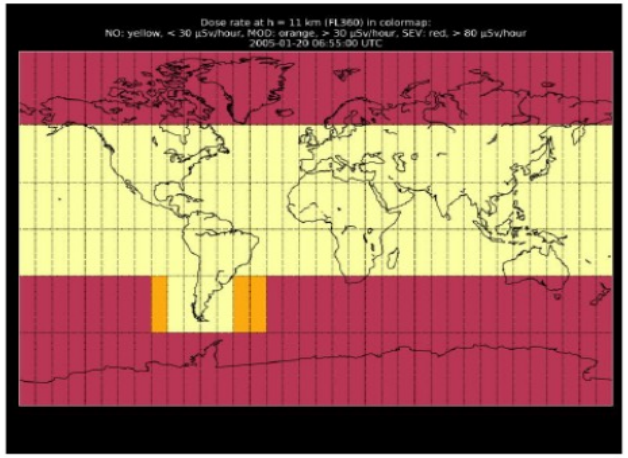


CRC-RU (FL=590)

- **20/01/2005-06:55UTC-FL370**

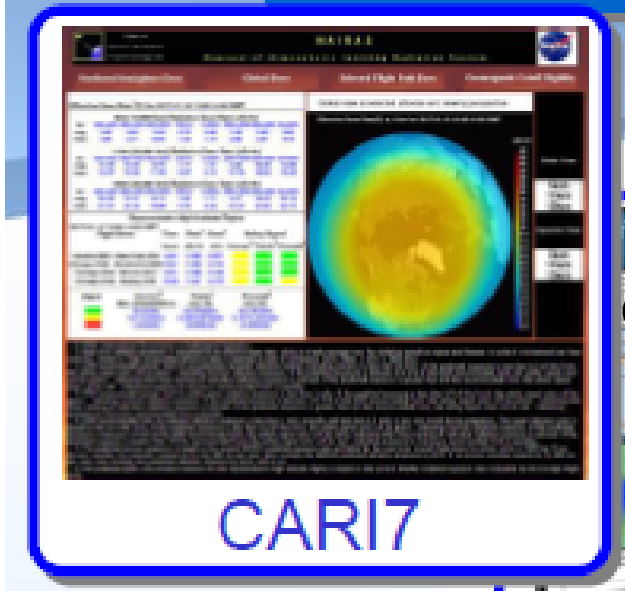


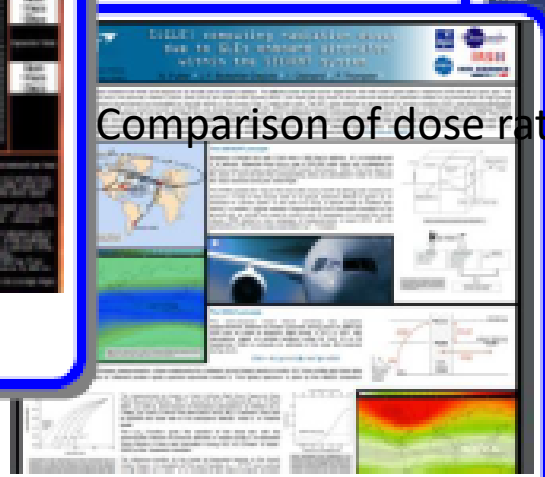
CRC-CN

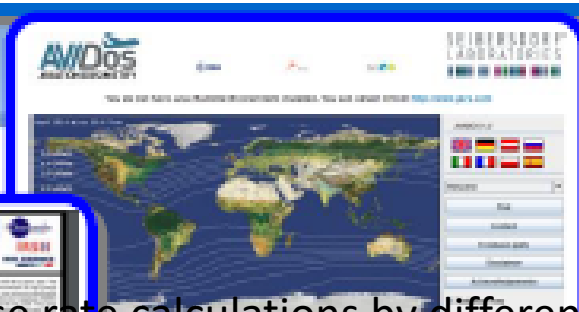


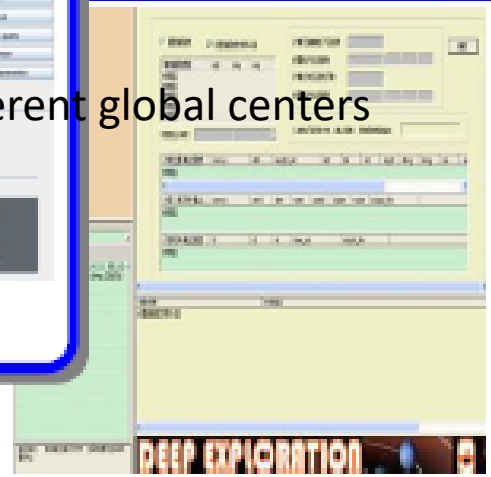
CRC-RU (FL=360)

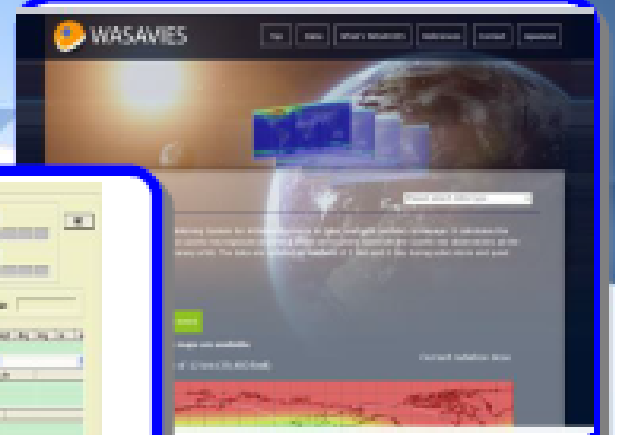
Comparison of model spec


CARI7


SIGLE


AVIDOS


CRC


WASAVIES

Comparison of dose rate calculations by different global centers

	CARI7	AVIDOS	WASAVIES	SIGLE	CRC-CN	CRC-RU

Thank you for attention!