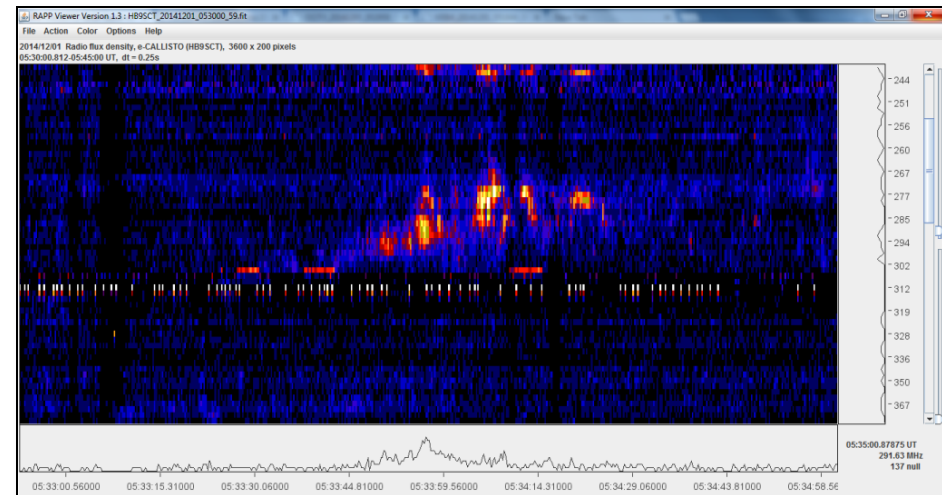
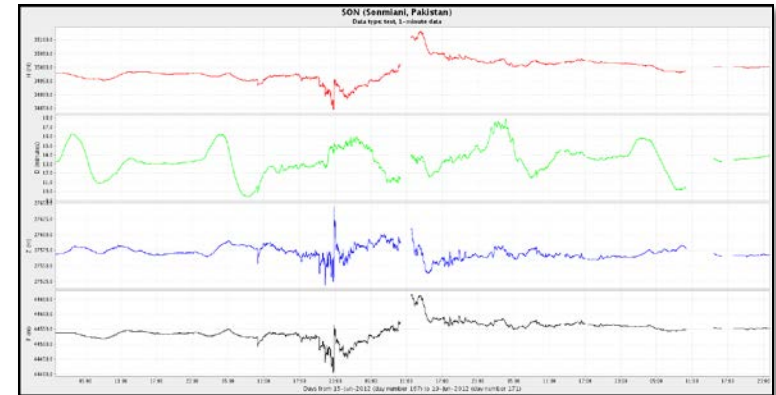
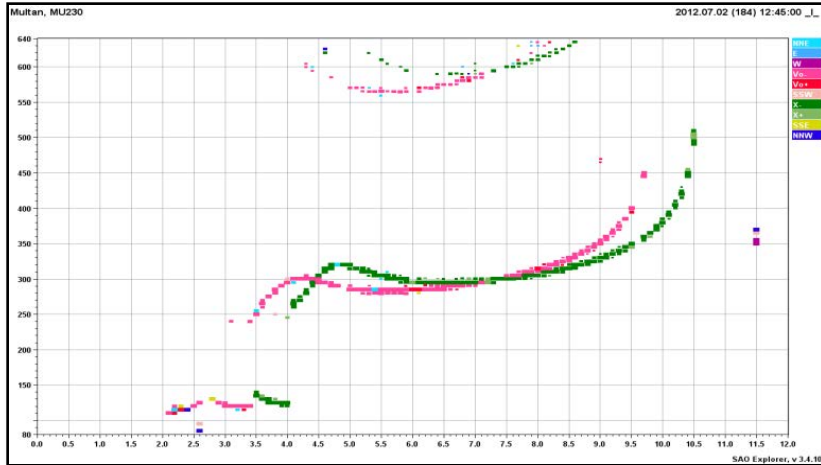


Space Weather Monitoring in Pakistan

**G. Murtaza
Space Science Dte
SUPARCO**

Activities in the context of SWx

- Monitoring and study of ionosphere
- Monitoring of geomagnetic field
- Monitoring of solar activity



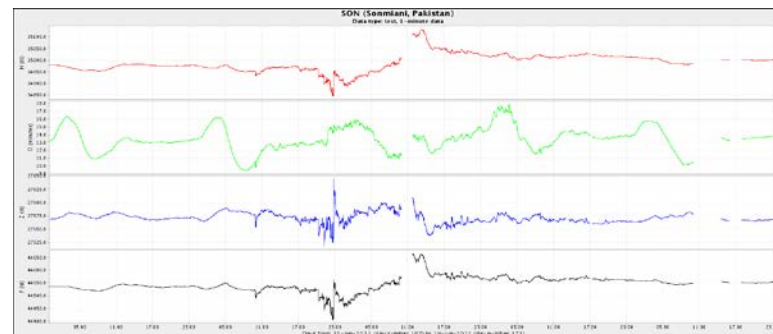
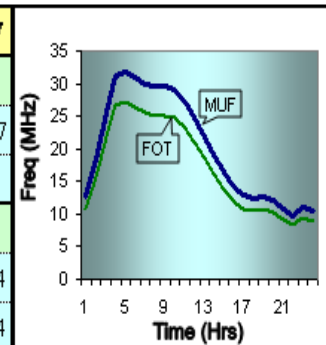
Purpose of SWx Operation/ Research

- Provision of SWx data and services to help mitigate risks to technological systems, operations and applications
- Provision of timely alerts and advisory regarding SWx to national agencies
- Sharing of data for carrying out scientific studies
- Collaboration with international SWx forecast centres for improvement of assimilative models and services

Services

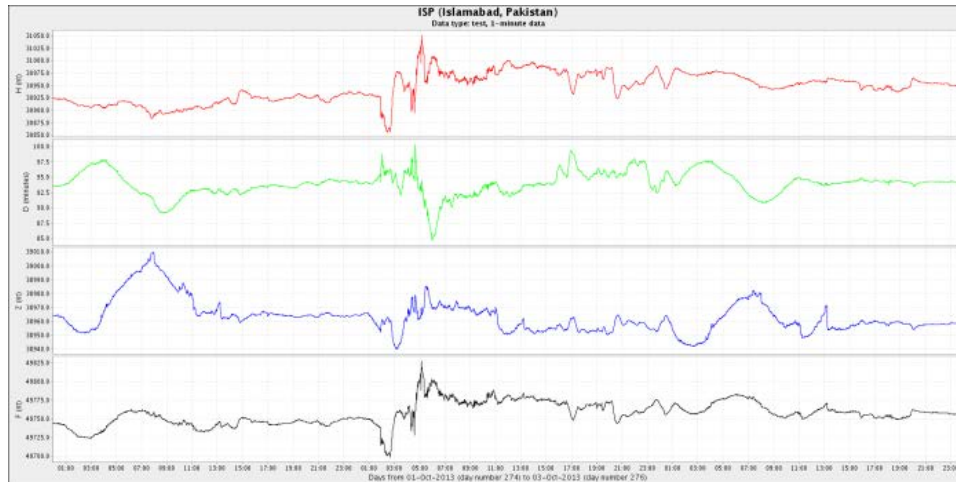
- MUF/ FOT Predictions
- Ionospheric data
- HF advisory
- Geomagnetic data
- Solar Flares/ Geomagnetic storm warning
- Training & Educational support

KARACHI-BEIJING												DISTANCE (Km) 4857	
HRS (UT)	0	1	2	3	4	5	6	7	8	9	10	11	
MUF (MHz)	12.6	18.3	25.7	31.2	31.9	39.9	30	29.6	29.6	29	27.2	24.7	
FOT (MHz)	10.7	15.6	21.8	26.5	27.1	33.9	25.5	25.2	25.2	24.7	23.1	21	
HRS (UT)	12	13	14	15	16	17	18	19	20	21	22	23	
MUF (MHz)	21.9	19.1	16.3	14	12.8	12.5	12.6	12	10.7	9.7	11.1	10.4	
FOT (MHz)	18.6	16.2	13.9	11.9	10.9	10.6	10.7	10.2	9.1	8.25	9.44	8.84	

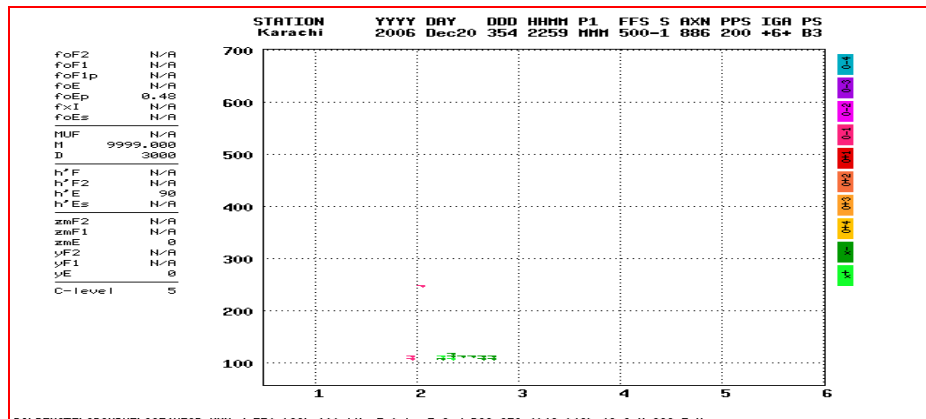


RAWALPINDI-MONROVIA												
Distance = 9049 KMs												
HRS (UT)	0	1	2	3	4	5	6	7	8	9	10	11
MUF (MHz)	10.1	8.5	10.0	8.7	10.4	17.1	25.8	32.2	31.1	29.5	28.5	28.3
FOT (MHz)	8.6	7.2	8.5	7.4	8.8	14.5	21.9	27.4	26.4	25.1	24.2	24.1
HRS (UT)	12	13	14	15	16	17	18	19	20	21	22	23
MUF (MHz)	27.6	25.2	21.6	18.2	15.6	12.9	10.9	10.3	10.6	11.4	12.3	12.0
FOT (MHz)	23.5	21.4	18.4	15.5	13.3	11.0	9.3	8.8	9.0	9.7	10.5	10.2

Services



Geomagnetic storm



Total blackout

Daily Space Weather Summary (SUPARCO)

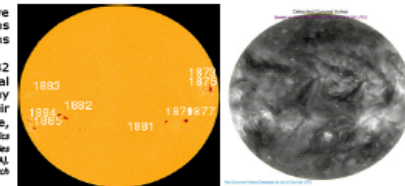
Tuesday, October 29, 2013, 12:25 PST



LOCAL CURRENT IONOSPHERIC CONDITIONS	
foF2	9.135 MHz
h'F2	295.6 km
MUF	26.60 MHz
Local ionospheric conditions are normal. HF radio comms expected to slightly disturbed with possibilities of shortwave fadeouts. In case of HF comms difficulty, try a higher frequency band.	
LOCAL GEOMAGNETIC CONDITIONS	
Kp	0 (max Kp in 24 hrs: 1, no effect)
Ap	4 (max Ap in 24 hrs: 10, no effect)
F	45046 nT (SON: 44800 nT)
	49509 nT (ISP: 49700 nT)
The local geomagnetic field is quiet now (as shown in green).	
LATEST SOLAR CONDITIONS	
SN-NOAA/KASI	155/155
Solar radio flux-NOAA/KASI	165/160 sfu
Solar wind speed	318.99 km/sec (varied in the past 12 hrs between 314 & 284 km/s)
Solar x-ray flares (11:30 PST)	C 1.8 (2057 UT/0157 PST: M1.5)
IMF	1.86 nT (varied in the past 12 hrs between 3.1 & 5.1 nT)
Bz	+0.233 nT (varied in the past 12 hrs between -0.1 & +3.7 nT)
Solar activity is active with background X-ray flux at C-class levels. Local geomagnetic conditions are at quiet levels. Local HF working frequencies are slightly elevated compared to monthly average predicted values. (The Kp and Ap indices and solar X-ray flares info are taken from the real-time software Proplab-Pro 3) (http://www.spaceweather.gov.pk , http://spaceweather.sasa.org.za/products-and-services/forecasts-and-predictions , www.us.gov.au , http://www.spaceweather.com , http://sds.cma.be/)	

Daily Sun: 29 October 2013

Normal geomagnetic and ionospheric conditions have been observed but episodes of disturbed conditions may prevail due to solar eruptions from active regions leading to radio blackouts and geomagnetic storms. The Active Regions AR 1875, AR 1877 and AR 1882 seem to be continuing to flare after releasing several M/C class flares and one X-class flare. This may continue as long as the sunspot regions maintain their complex magnetic configuration. There are no large, earthward CHs on the solar limb. (Images source: Solar Dynamics Observatory-SDO) Both images on right showing the Solar disk and Coronal Holes has been processed at SUPARCO using Automatic Solar Dynamic Analyzer (ASDA) developed jointly by the Korean Space Weather Centre of the Radio Research Agency (KRA) & Space Environment Laboratory (SELab))



DEFINITIONS	
foF2	Maximum frequency of F2-layer of the ionosphere
h'F2	Virtual height of the F2-layer
MUF	Maximum usable frequency for 3000km
Kp, Max Kp	Planetary index defining geomagnetic conditions, predicted value during geomagnetic unsettled conditions
Ap, Max Ap	Planetary A index defining geomagnetic conditions, predicted value during geomagnetic unsettled conditions
F	Magnitude of the total geomagnetic field vector
SON, difference	Sonmiani Geomagnetic Observatory mean value, difference limit from night time value from quiet conditions: 25-30 nT, max: 260 nT
ISP	Islamabad Geomagnetic Observatory mean value
SN	Relative sunspot numbers
NOAA	National Oceanic & Atmospheric Administration
KASI	Korean Astronomy & Space Science Institute
sfu	Solar flux unit (defines the solar radio 10.7 cm flux)
Solar Flare	Could be B, C, M and X depending upon the intensity of x-rays being emitted (each type has further 10 classes)
IMF	Interplanetary magnetic field (the source of which is Sun)
Bt	Total IMF
Bz	Vertical component of IMF (could be north/upward/positive or south/downward/negative)
AR	Active Regions on the sun currently in view
CME	Coronal Mass Ejection
CH	Coronal Hole

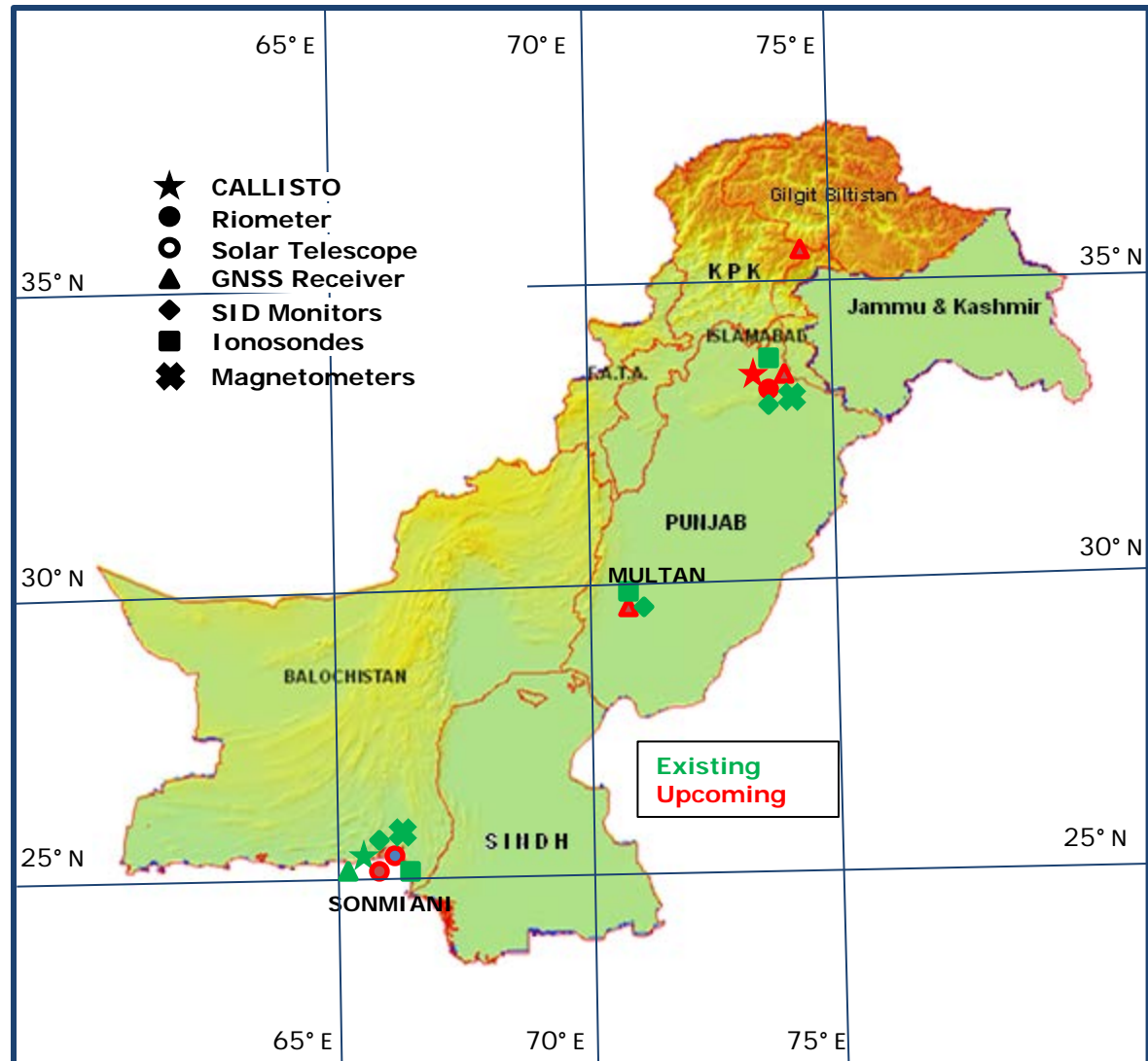
Daily space weather summary

History

Year	Event
1971	Establishment of ionospheric station at Karachi and installation of British Ionosonde Mark II
1975	Replacement of British Ionosonde Mark II by analogue Japanese Ionosonde PIR-9 (Panoramic Ionospheric Recorder-9) at Karachi
1978	Establishment of ionospheric station at Islamabad and installation of PIR-9B
1983	Establishment of geomagnetic observatory (AMOS-III) , EDA Canada at Karachi
1987	Replacement of PIR-9 by Digisonde DGS-256 at Karachi, establishment of ionospheric station at Multan and shifting of PIR 9 from Karachi to Multan
1992	Replacement of PIR-9 by Digisonde DGS-256 at Islamabad
2008	Installation of DPS-4 at Multan
2008	Establishment of Islamabad geomagnetic observatory and shifting of Karachi geomagnetic observatory to Sonmiani
2013	Installation of Sudden Ionospheric Disturbance (SID) Monitors
2014	Installation of GNSS TEC Scintillation Receiver and CALLISTO at Sonmiani
2015	Installation of GNSS TEC Scintillation Receiver and CALLISTO at Multan

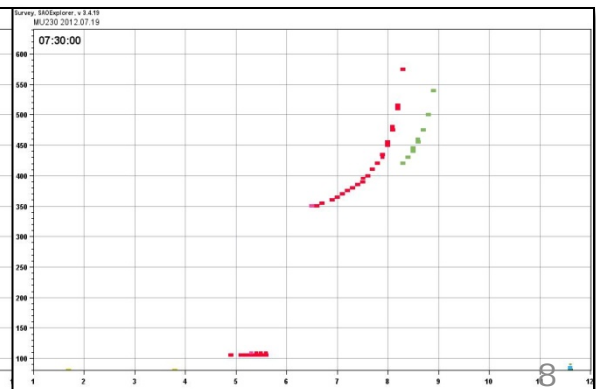
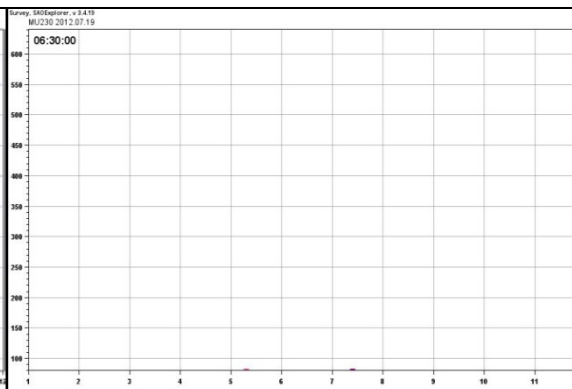
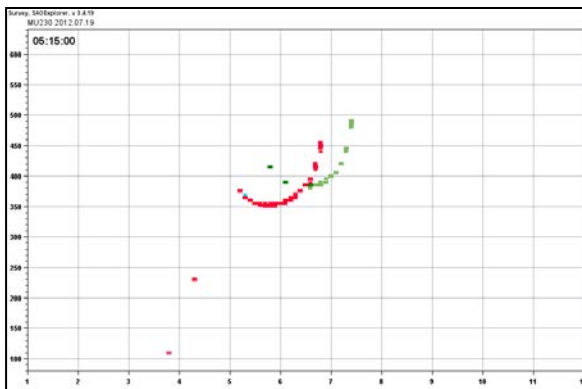
Infrastructure

- Ionosondes
- Magnetometers
- Variometers
- SID monitors
- CALLISTO
- Riometers
- Optical telescope
- GNSS TEC
Scintillation
receivers



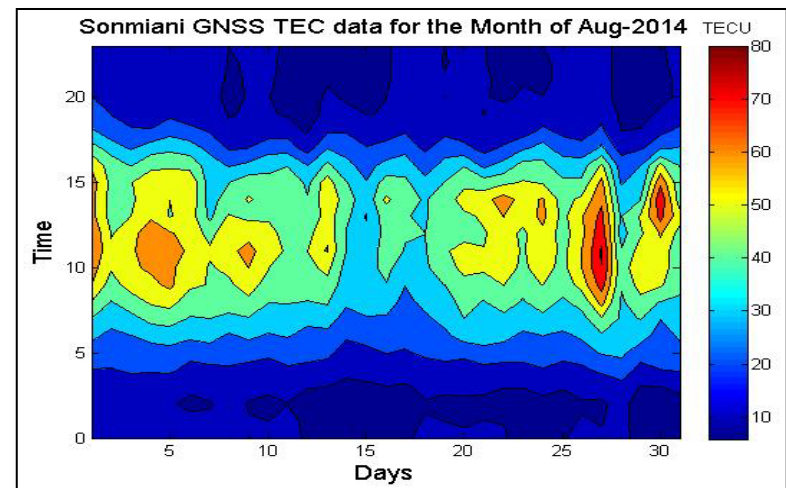
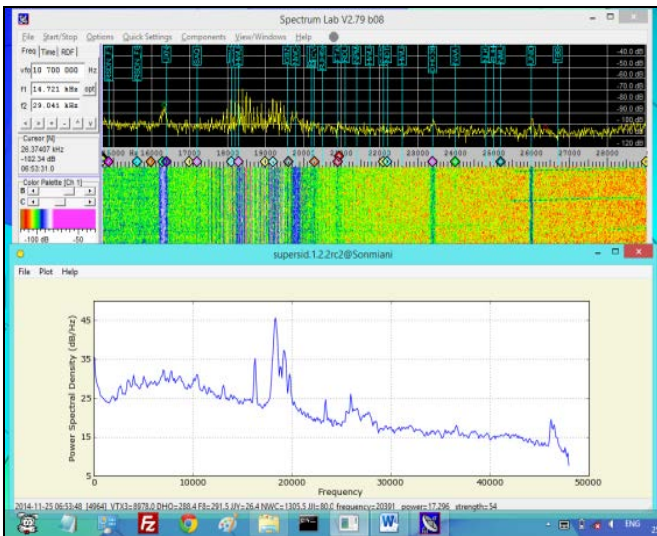
Ground Based Sensors (Ionosphere)

- DGS-256 at Sonmiani (geog: 24.95°N, 66.45°E) & Islamabad (geog: 33.75°N, 73.13°E)
- DPS-4 at Multan (geog: 30.18°N, 71.48°E)



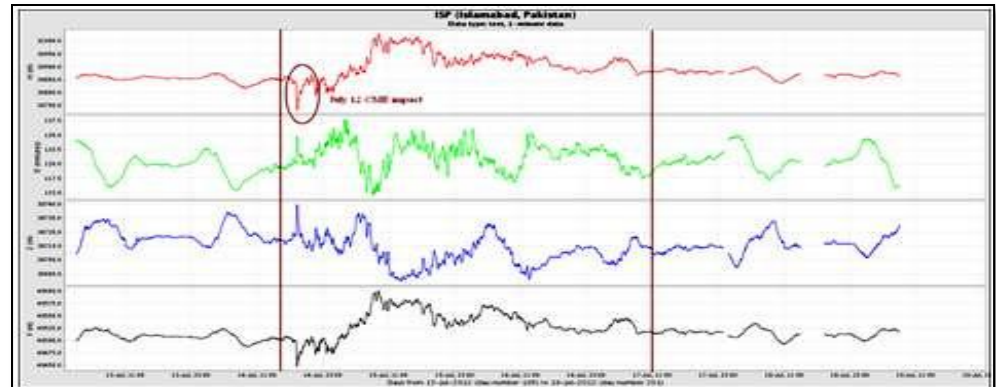
Ground Based Sensors (Ionosphere)

- GNSS TEC/ Scintillation receivers at Sonmiani & Multan
- SID monitors at Sonmiani, Multan & Islamabad



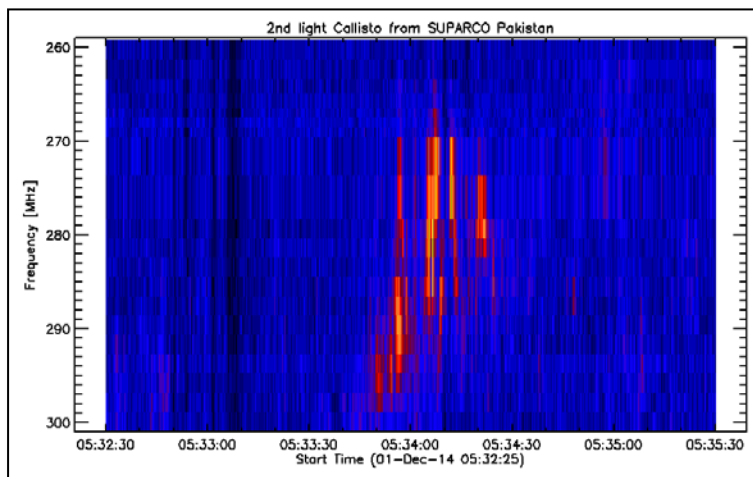
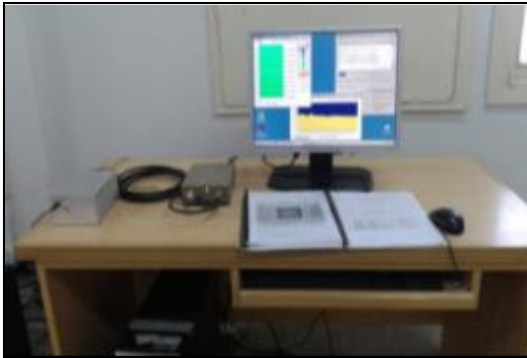
Ground Based Sensors (Geomag)

- Variometers/ magnetometers at Sonmiani (geom: 17.26°N, 141.33°E) & Islamabad (geom: 25.42°N, 148.73°E)



Ground Based Sensors (Solar)

- CALLISTO at Sonmiani & Multan
- Sunspot Observation Telescope at Karachi
- Solar activity monitoring softwares



Available Resources (contd)

Observation Data

- Ionosonde data at 15 min interval
- Geomagnetic data at 1 min and 2.5 sec interval
- Absolute geomagnetic field data 2-3 times in a week
- Solar radio burst data at 800 measurements/ sec
- SID data at 5 sec sampling rate
- Scintillation data at 1 sec interval & TEC data at 15 sec interval
- K – index

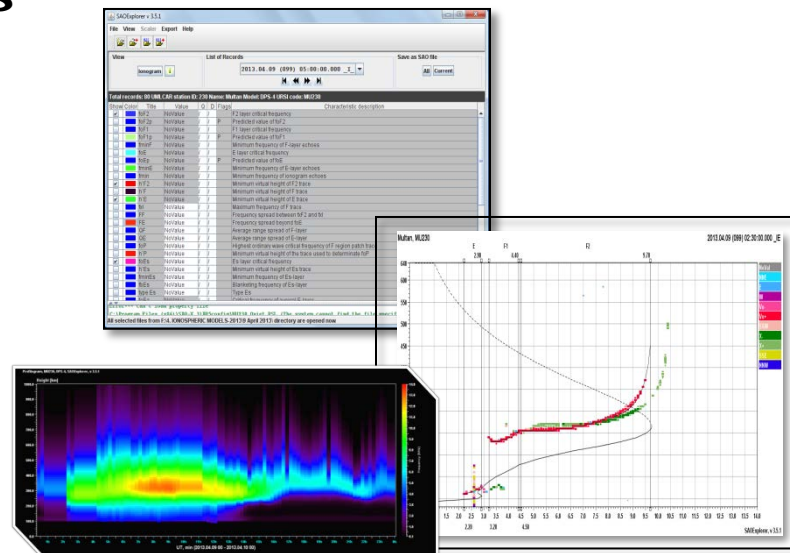
Model codes

- Near real time K-index codes
- Regional model codes using EOFs (Empirical Orthogonal Functions)

Available Resources

Measurement/Analysis Techniques

- *SAO Explorer – Ionospheric data*
- *Absolute/ Turbo basic routines – geomagnetic data*
- *KASM – k-index*
- *Spectrum Lab – VLF signals*
- *Python routines – Solar Radio Bursts*



Human Resources

Researchers	5
Technicians	9

International Cooperation (contd)

Membership:

- Asia-Oceania Space Weather Alliance (AOSWA)
- Inter program Coordination Team on Space Weather (ICTSW)
- International Real-time Magnetic Network (INTERMAGNET)

International Cooperation (contd)

APSCO studies:

- Atmospheric effects on ionospheric modeling through study of radio wave propagation and solar activity
- Research on determining precursors ionospheric signatures of Earthquake by ground based ionospheric



International Cooperation (contd)

SUPARCO shares its data with:

- WDC – Solar and Terrestrial Science
- INTERMAGNET
- APSCO

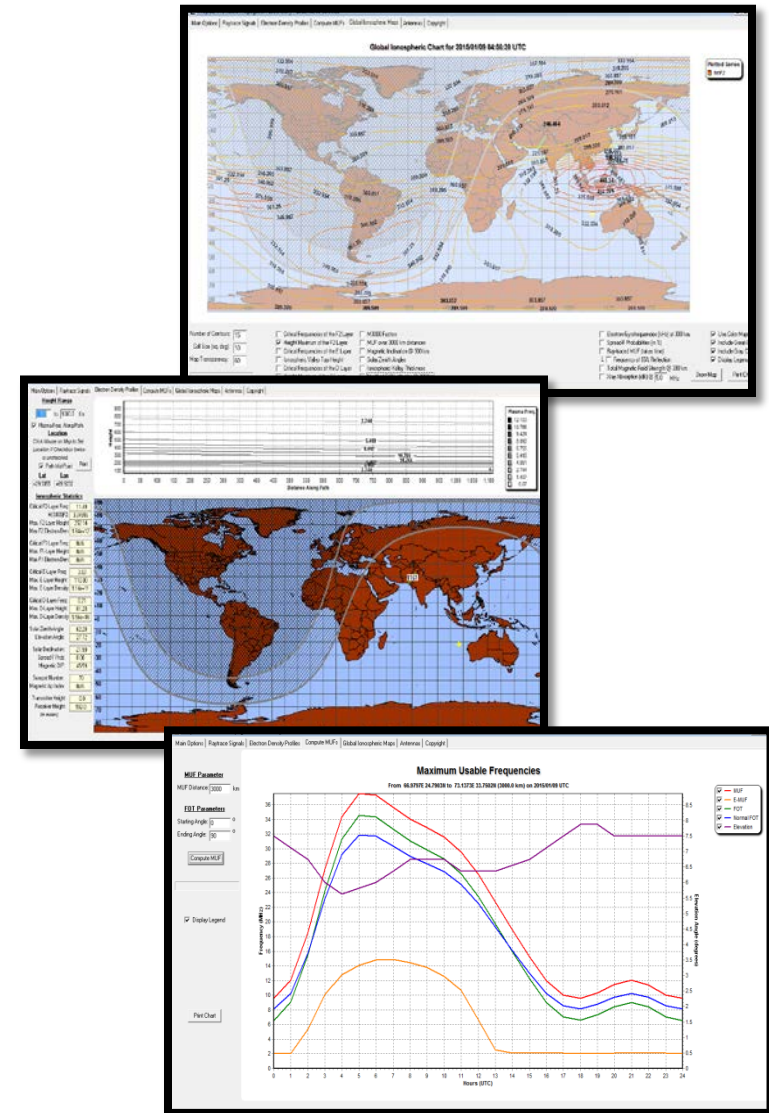
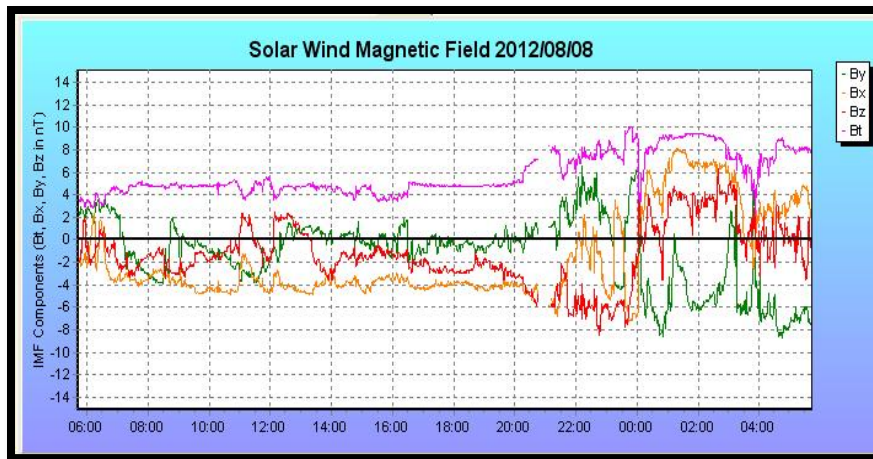
SUPARCO also contributed in:

- COSMIC Campaign – USA
- Oersted mission – Denmark

International Cooperation (contd)

SUPARCO benefits from:

- Space Weather Software/ Models
 - SWB
 - WSA-ENLIL
 - ASSA
 - PropLab, SWIM & SWARM
 - IGRF
 - IRI



International Cooperation (contd)

- Satellite Based Data/ Information
 - *GOES, ACE, SOHO, SDO*
- Web based data/ information
 - *Solar Indices (SSN, F10.7cm, T-index)*
 - *Geomagnetic Indices (Kp, Ap & Dst)*
 - *IQD & IDD*

International Cooperation (contd)

The 1st Workshop on "Geomagnetic Observatories and their Applications" was held for OIC member countries, 03-13 April, 2012 at the Geomagnetic Observatory, Islamabad with the collaboration of IRM, Belgium, ISNET & NCP. About 24 participants attended the Workshop among whom 09 were locals and 15 were foreigners.



Training and Short Courses

- Space Weather Challenges of Solar Cycle 24, Karachi
- Solar Radiation and modern technologies, Islamabad
- Space weather monitoring, Karachi
- Impact of Solar Radiation on Earth, Ionosphere and Geomagnetic Field, Karachi



Scientific Studies

- Validation of K-indices through comparative analysis for Sonmiani Geomagnetic Observatory, Pakistan, Journal of Atmospheric & Solar-Terrestrial Physics, 2013
- Geomagnetic activities in Pakistan since 2006-to date, Earth Science and Technology, 2012
- Study of maximum electron density NmF2 at Karachi and Islamabad during solar minimum (1996) and solar maximum (2000) and its comparison with IRI, Advances in Space Research, 2009
- Comparing IRI and a regional model with ionosonde measurements in Pakistan, Advances in Space Research, 2008

Future Plans

- Setup of collaborative Oblique Sounding hardware
- Development of professional skills necessitated for space weather predictions
- Joining as one of the regional centers of international network

Near Future Targets

Space Weather Monitoring Center

Pakistan is currently working towards the establishment of a Space Weather Monitoring Centre. The centre aims to integrate and upgrade the existing facilities at remote sites, and to install new ground based instrument for monitoring SWx.

Human Resource Development

- Higher studies
- Short trainings

Collaborative studies/ projects under:

- APSCO (in progress)
- AOSWA (planned)

Resources Required

- Flare Monitoring Telescope (FMT) in Pakistan
- Upgrading of ionosondes (DGS 256 & DPS-4)
- Collaborative studies in plasma and solar physics with any AOSWA members willing to undertake collaborative work. Requirement of data would depend on need basis.
- Accurate Models / codes for forecasting space weather

Resources Required (contd)

- Higher studies (MS, PhD) along with scholarships
- Short trainings on:
 - Scientific data analysis
 - Installation and calibration of instruments
- International cooperation to establish Space Weather Monitoring Centre

THANK YOU

Collaborative Future Studies (planned)

We are working on the following studies/titles and desire to publish these:

1. Variations in F2-layer parameters and comparison with IRI over Pakistan for deep solar minimum
2. Ionospheric variability of low and mid latitude for solar cycle 22 and 23 (under preparation)
3. Solar cycle effect on coupling of neutral and ionized species at F2 altitude
4. A study of the relationship between the critical frequency of the F2 layer of the ionosphere and the GPS total electron content in the equatorial anomaly region
5. Use of Pakistani and MAGDAS geomagnetic data to investigate EEJ
6. Effects of Coronal Hole High Speed Stream Effects on the Geomagnetic Field Variation at Sonmiani during 2007-2012

Collaborative Future Studies (planned)

We are working on the following studies/titles and desire to publish these:

- Development of Asia Oceania Reference Ionosphere model
- Ionospheric variability of low and mid latitude for solar cycle 22 and 23
- Use of Pakistani and MAGDAS geomagnetic data to investigate EEJ
- Development of Pakistani TEC map (EOF, SHA, Neural network)
- Study of effects of Solar Wind on the morphology of ionosphere