Radio Propagation

Terminology, Measurement, Prediction

FRRL Program

September 2007

AH6EZ

You have a choice…

- You can turn on your radio and see who you can work
  - This is OK for simple random contacts

Or

- You can do some simple research and know the band conditions
  - This is best for contesting and specific DX

Radio Propagation is Variable…

- HF propagation varies a lot
  - It also varies around the planet
  - It varies year by year, month by month, day by day, minute by minute
- This means that many measurements and trends are important for accuracy

So where do you learn of band conditions?

- WWV at 18 minutes after each hour
- Subscribe to the ARRL Propagation Bulletin
- Look at the ARRL band charts
- Built-in to many web based logging programs
- Listen to HF Beacons
- Listen to locally vacant TV channels for VHF enhancements

What do you learn from these sources?

- Recent and averaged solar activity
- Solar weather disturbances
- History and predictions

Solar Electromagnetic Radiation

- Normal solar process
- Solar radiation wavelength has HF effect
  - Ultraviolet ionizes F region
  - Soft X-Rays ionize E region
  - Hard X-Rays ionize D region
  - Daytime vs nighttime effects
- Solar matter (charged electrons/protons)
  - Solar wind, quiet day is 400km/sec
  - Mostly impacts high latitude absorption

Measuring Earth's Magnetic Field

- Measured by magnetometers
  - Invented by CF Gauss in 1832
- Creates daily A index (0=quiet, 400=storm)
  - Average of eight 3 hour K indices
  - A index below 15 is good for HF propagation
- K index (0-quiet, 9=severe storm)
  - K index below 3 is good for HF propagation

Measurement Variations

Geomagnetic and Solar Indices - updated: Sep 03 2303 UTC

Geomagnetic K-indices and Running A-indices

Station and Index	3-hour Synoptic Periods							
Sep 03	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
Boulder K-indices	3	3	3	3	4	2	1	*
Boulder 24-hour running A-index	23	19	19	15	17	16	13	*
USAF Estimated Planetary K-index	3-	3	2+	3-	3	2	2	*
Est. Planetary 24-hour running A-index	22	18	17	15	14	14	11	*
Sep 02	00-03	03-06	06-09	09-12	12-15	15-18	18-21	21-24
Boulder	3	5	3	5	3	3	4	2
Boulder 24-hour running A-index	15	19	19	22	22	22	24	23
USAF Estimated Planetary K-index	4-	5	3	4+	4-	2+	4	3-
Est. Planetary 24-hour running A-index	13	18	18	20	22	22	24	23
Fredericksburg	3	5	3	2	3	2	3	2
College	4	5	5	6	5	4	3	2

Local Noon Solar Radio Flux

Sep 03 Station / Local Noon	245 MHz	410 MHz	610 MHz	1415 MHz	2695 MHz	4995 MHz	8800 MHz	15400 MHz
Learmonth / 0500 UTC	12	22	37	62	73	124	227	526
San Vito / 1200 UTC	11	23	*	56	71	120	211	487
Sag Hill / 1700 UTC	14	21	27	41	64	126	*	464
Palehua / 2300 UTC	12	22	33	56	66	118	216	499

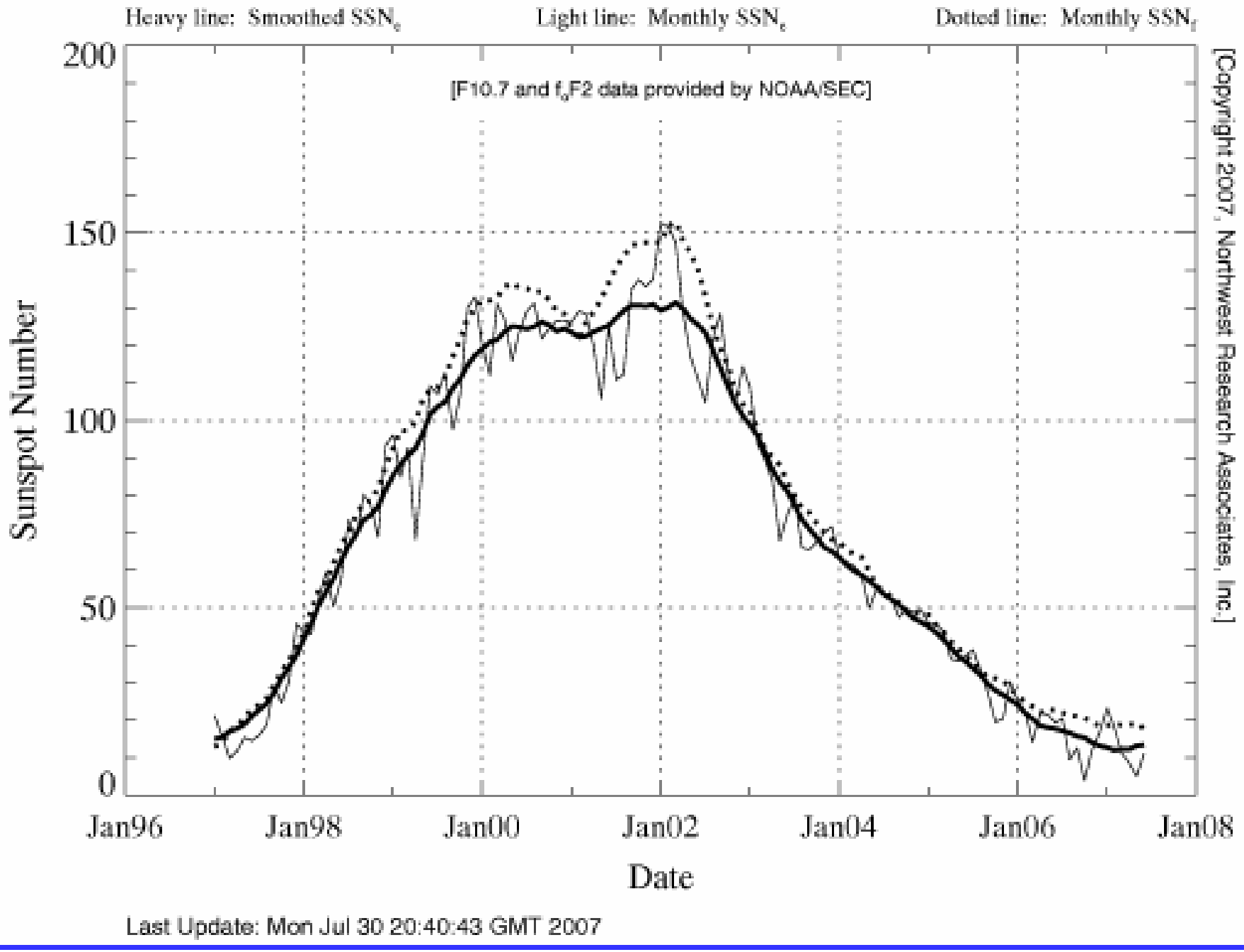
Sun Spots

- Associated with Ultraviolet Radiation
  - Related to F region ionization
- Daily or even monthly average number is rough
- Smoothed sunspot number used for predictions
  - 6 months of past/future + present month of data
  - SSN is always 6 months behind present month
  - Smoothing can mask short term effects
- High SSN better for higher HF frequencies
- Lower SSN better for lower HF frequencies

Sunspots and Solar flux

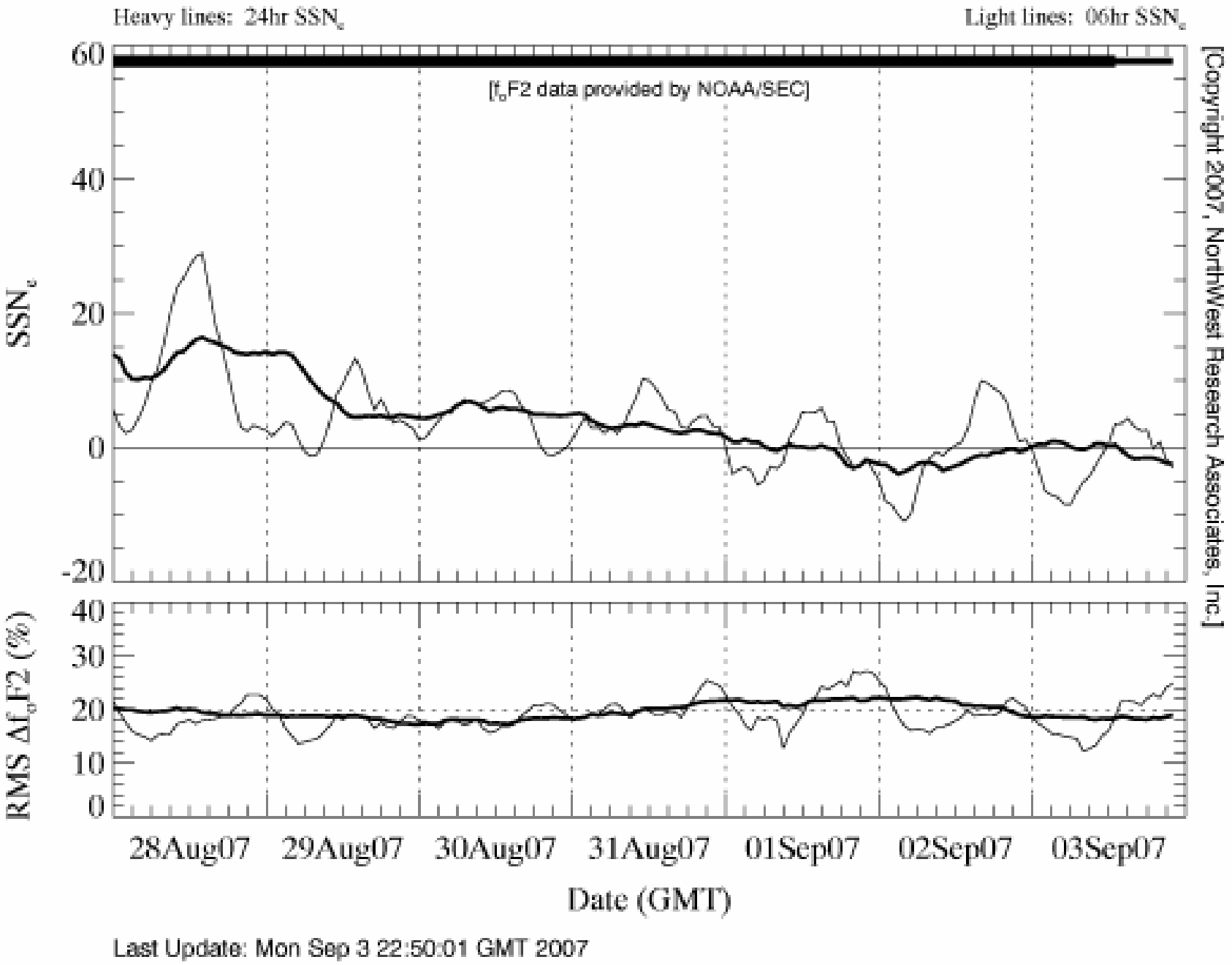
- Sunspots counted visually
- Radiation level from sunspots is needed
- 10.7cm (2.8GHz) baseline magnetic flux
- It has nothing to do with HF propagation
- Predictions are based on SSN and smoothed flux
- Use effective SSN (SSNe) for short term predictions

Cycle 23 Effective Sunspot Number



Last Update: Mon Jul 30 20:40:43 GMT 2007

Effective Sunspot Number (SSN_e)



Last Update: Mon Sep 3 22:50:01 GMT 2007

Propagation Disturbances

- Solar Flares (X-Ray flares)
  - Classified as small-C medium-M or large-X
  - X flares can cause loss of all HF on sun side of Earth with increased D region absorption within 10 minutes of solar eruption, no warning
  - X flares can cause polar cap absorption
- Coronal Mass Ejections (CME)
  - Sudden jumps in solar wind, hours/days to reach Earth so event is predictable
  - If Sun's magnetic polarity different from Earth, large variation in Earth's magnetic field, increases in A and K indices
  - Reduction in Maximum Usable Frequency (MUF)

Daily Government Solar Reports

- Part 1A: Analysis of solar activity (flares/CME)
- Part 1B: Forecast of solar activity
- Part 2A: Geophysical activity summary
- Part 2B: Geophysical activity forecast
- Part 3: Flare/CME probability
- Part 4: Observed, predicted 10.7cm solar flux
- Part 5: Observed, predicted A indices
- Part 6: Geomagnetic activity probabilities

- US Govt, USAF, other governments and institutes

NOAA Space Weather Terminology

NOAA Space Weather Scales			
Geomagnetic Storms	**Solar Radiation Storms**	**Radio Blackouts**	**Descriptor**
G5	S5	R5	Extreme
G4	S4	R4	Severe
G3	S3	R3	Strong
G2	S2	R2	Moderate
G1	S1	R1	Minor

Table 3.1 - Geomagnetic Storm levels	
Planetary K indices	**Geomagnetic storm level**
K = 5	G1
K = 6	G2
K = 7	G3
K = 8	G4
K= 9	G5

Table 3.2 - Solar Radiation Storm levels – GOES	
Flux level of > 10 MeV particles	**Solar Radiation Storm level**
10	S1
10^2	S2
10^3	S3
10^4	S4
10^5	S5

Table 3.3 - Radio Blackouts	
Peak x-ray level and flux	**Radio Blackout level**
M1 and (10^{-5})	R1
M5 and (5×10^{-5})	R2
X1 and (10^{-4})	R3
X10 and (10^{-3})	R4
X20 and (2×10^{-3})	R5

Worst Solar Radiation Storm

Category		Effect	Physical measure
Scale	**Descriptor**	**Duration of event will influence severity of effects**	
Solar Radiation Storms			**Flux level of >= 10 MeV particles (ions)***
S 5	**Extreme**	**Biological:** unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** **Satellite operations:** satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. **Other systems:** complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5

Expected less than 1 day every 11 years

Worst Radio Blackout

Category		Effect	Physical measure
Scale	**Descriptor**	**Duration of event will influence severity of effects**	
Radio Blackouts			**GOES X-ray peak brightness by class and by flux***
R 5	**Extreme**	**HF Radio:**Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. **Navigation:** Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2×10^{-3})

Expected less than 1 day every 11 years

Effects of Worst Geomagnetic Storms

Category		Effect	Physical measure
Scale	**Descriptor**	**Duration of event will influence severity of effects**	
Geomagnetic Storms			**Kp values* determined every 3 hours**
G 5	**Extreme**	**Power systems:** : widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. **Spacecraft operations:** may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. **Other systems:** pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.)**.	Kp = 9

Expected 4 days every 11 years

W W V information

- Broadcast on 2.5, 5, 10, 15, and 20 MHz
  - Sometimes listening to 10KW from CO is enough
  - Call 303-497-3235
  - WWVB 60 KHz 50KW
- Previous days 10.7cm solar flux
- Previous days mid-latitude A index
- Current mid-latitude 3 hour K index
- General indication of +/- 24 hr space weather
  - Geomagnetic storms (gusts in solar wind speed)
  - Solar radiation storms (particle energy increase)
  - Radio blackouts (X-Ray emissions)

Typical W W V Broadcast

- Geophysical Alert Message wwv.txt
- Issued: 2007 Sep 03 2106 UTC
- Prepared by the US Dept. of Commerce, NOAA, Space Environment Center
- Geophysical Alert Message
- Solar-terrestrial indices for 03 September follow
- Solar flux 68 and estimated mid-latitude A-Index 13
- Mid-latitude K-index at 2100 UTC 03 Sept was 1 (09 nT)
- No space weather storms observed for the past 24 hours
- No space weather storms expected for the next 24 hours.

So what does this mean?

W W V transmits local K and A Index

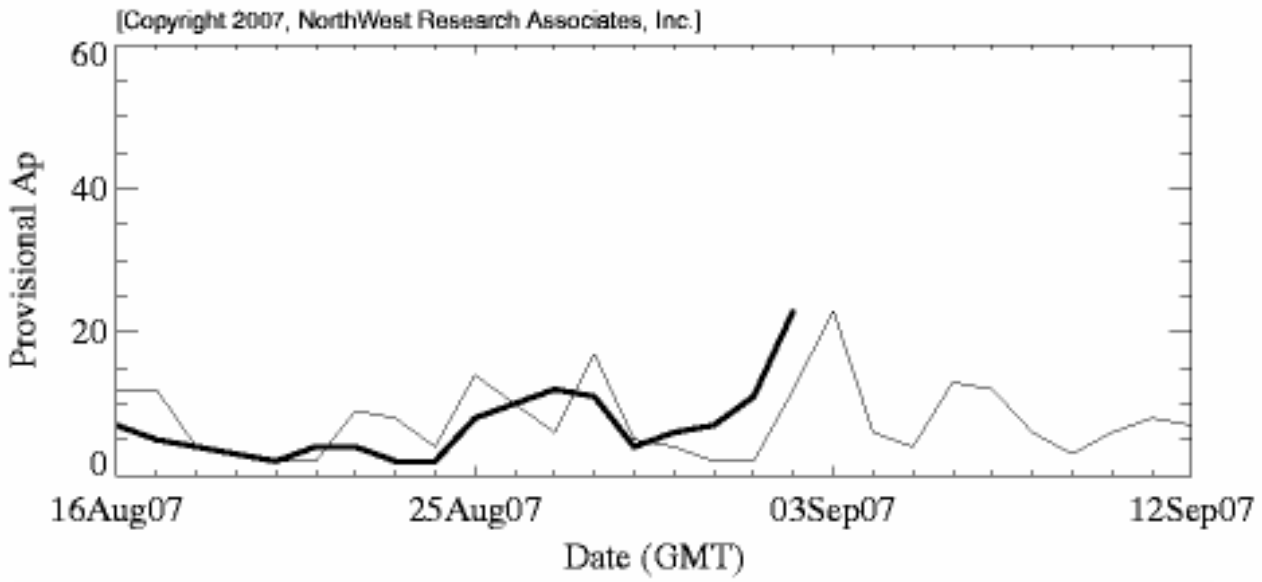
- W W V gives a picture of the Colorado conditions, not planetary
- K index refreshed every 3 hours

K	nT
0	0-5
1	5-10
2	10-20
3	20-40
4	40-70
5	70-120
6	120-200
7	200-330
8	330-500
9	>500

K	a
0	0
1	3
2	7
3	15
4	27
5	48
6	80
7	140
8	240
9	400

K Index

- Disturbances in H field in 2 planes
- K_p for Planetary (introduced in 1949)
- Planetarische Kennziffer (Planetary Index)
- Measured at 11 global sites
- K < 3 good stable conditions
- K > high absorption, poor F reflections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Universal Time
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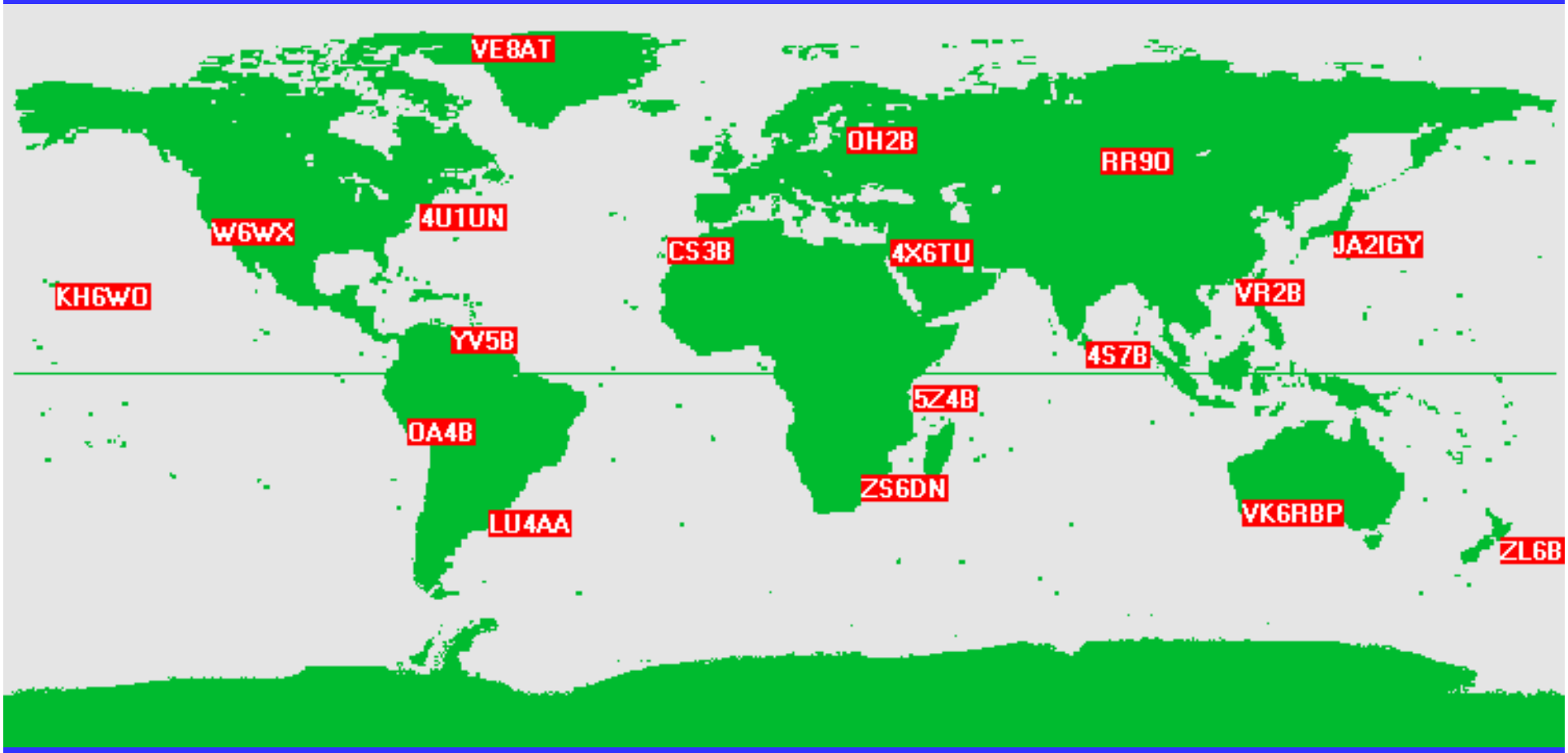
HF Beacons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CS3B
4X6TU
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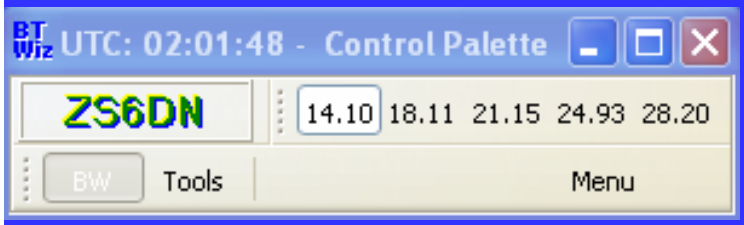
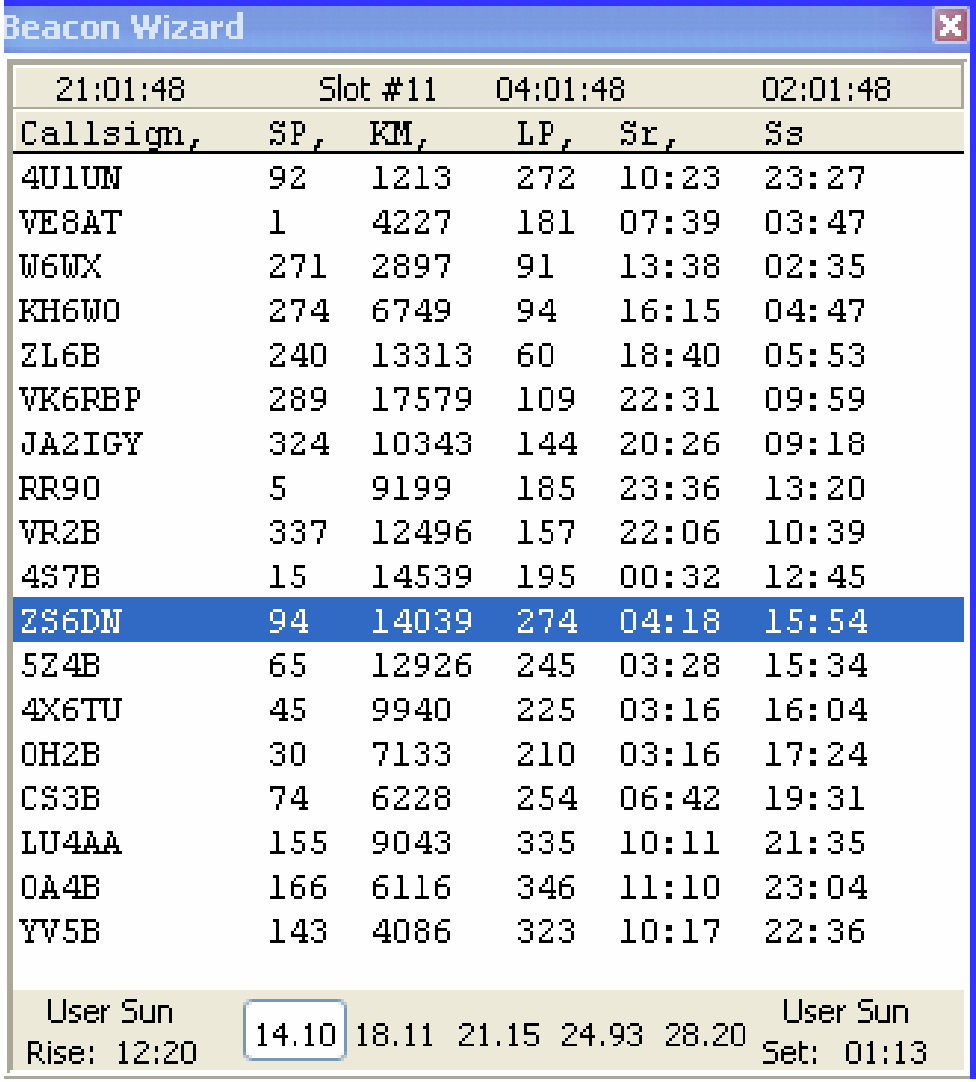
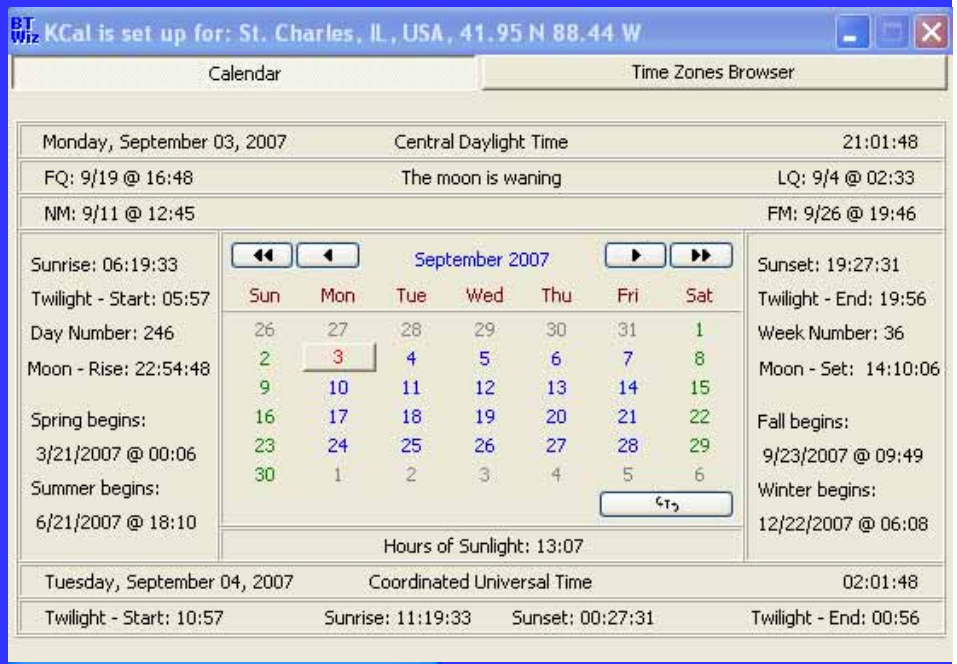
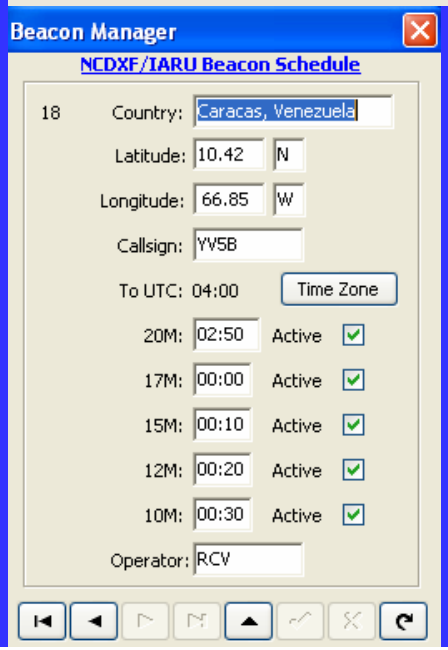
VK6RBP
LU4AA
ZL6B

Beacon Wizard $25









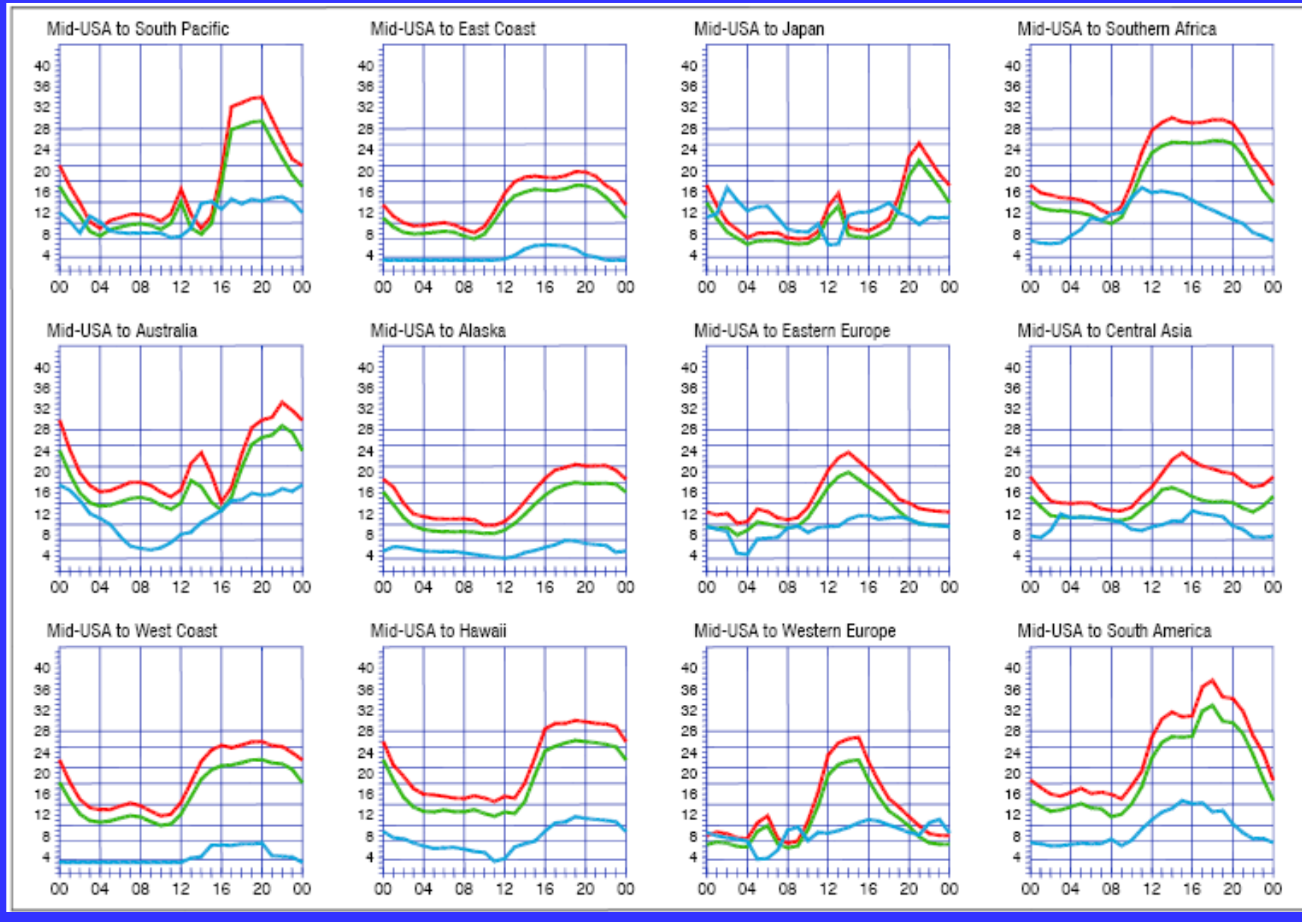
HF Beacon Tracer FREE

www.w6nek.com

ARRL Propagation Bulletin

- Sunspot numbers pulled up from 0 this week, but barely. Average daily sunspot numbers rose over nine points to 12.9. Geomagnetic conditions were quiet.
- This morning the Australian Ionospheric Prediction Service sent out a warning of increased geomagnetic activity centered on September 1 due to a wind stream from a solar coronal hole. They predict today, August 31, will be quiet with increasing activity late in the day, unsettled to active conditions with possible minor storm on Saturday, September 1, and mostly unsettled conditions September 2.
- Geophysical Institute Prague predicted earlier that August 31 would be quiet to unsettled, September 1 unsettled to active, unsettled conditions September 2-3, quiet September 4-5, and unsettled to active again on September 6.
- Over the same period the US Air Force predicts a Planetary A index of 15, 25, 12, 12, 8, 5 and 15 for August 31 through September 6. From the same prediction, it looks like September 8-17 may see a return of 0 sunspot days.
- For more information concerning radio propagation, see the ARRL Technical Information Service at, http://www.arrl.org/tis/info/propagation.html. Monthly propagation charts between four USA regions and twelve overseas locations are at, http://www.arrl.org/qst/propcharts/.
- Sunspot numbers for August 23 through 29 were 12, 12, 14, 13, 12, 14 and 13 with a mean of 12.9. 10.7 cm flux was 70.8, 71.6, 71.5, 70.1, 69.2, 70.1, and 69.6 with a mean of 70.4. Estimated planetary A indices were 2, 2, 8, 10, 12, 11 and 4 with a mean of 7. Estimated mid-latitude A indices were 1, 1, 6, 10, 10, 9 and 4, with a mean of 5.9.

Band Charts - Another ARRL Service



Radio Propagation is Fundamental to our Hobby

Learning about it helps:

Public Service – getting the message through

DX – knowing when/where to get on the air

Contests – Maximizing your scores