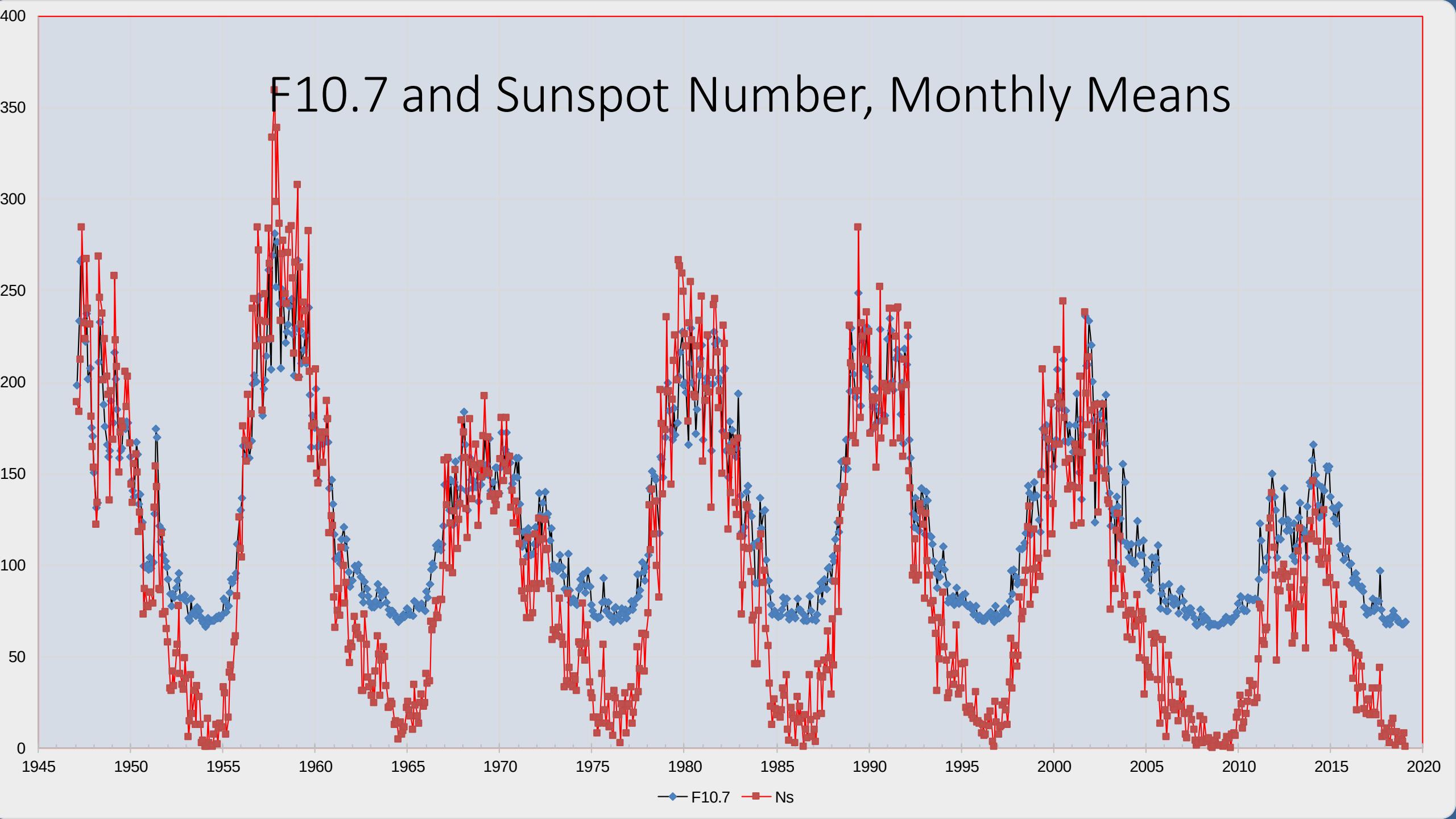
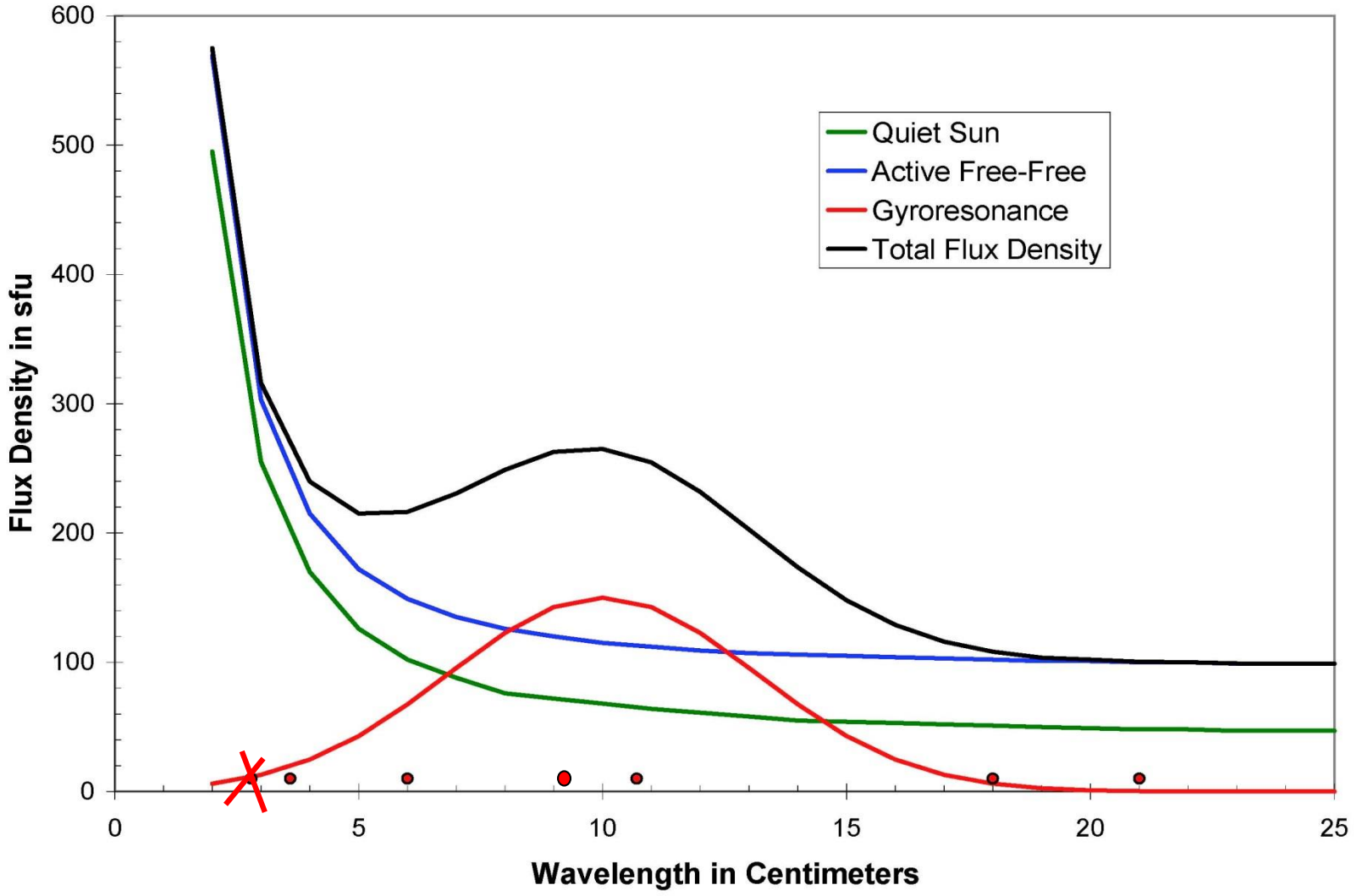
Solar Radio Monitoring in Canada – F10.7: Past, Present and Future

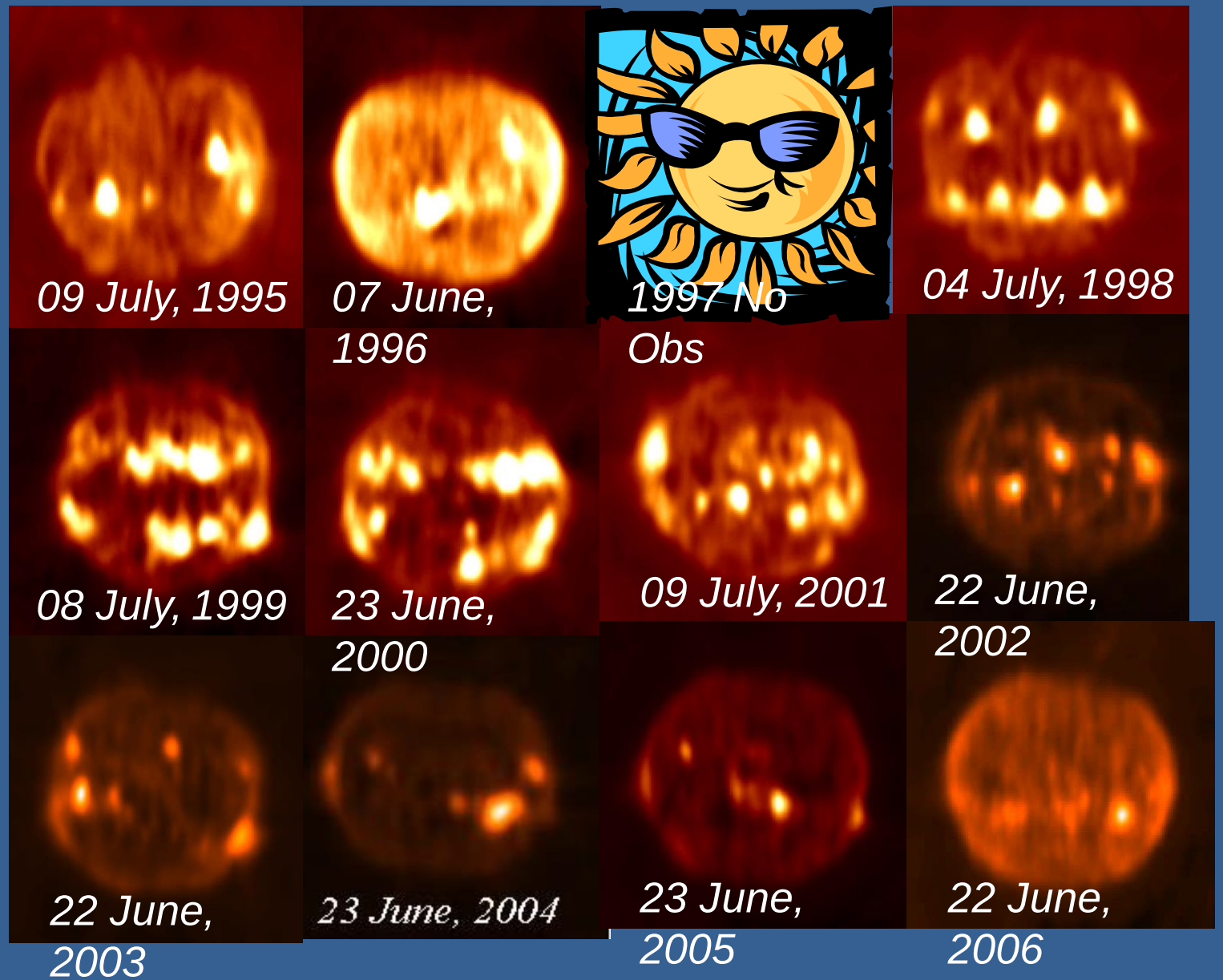
Ken.Tapping@nrc-cnrc.gc.ca

NRC · CNRC

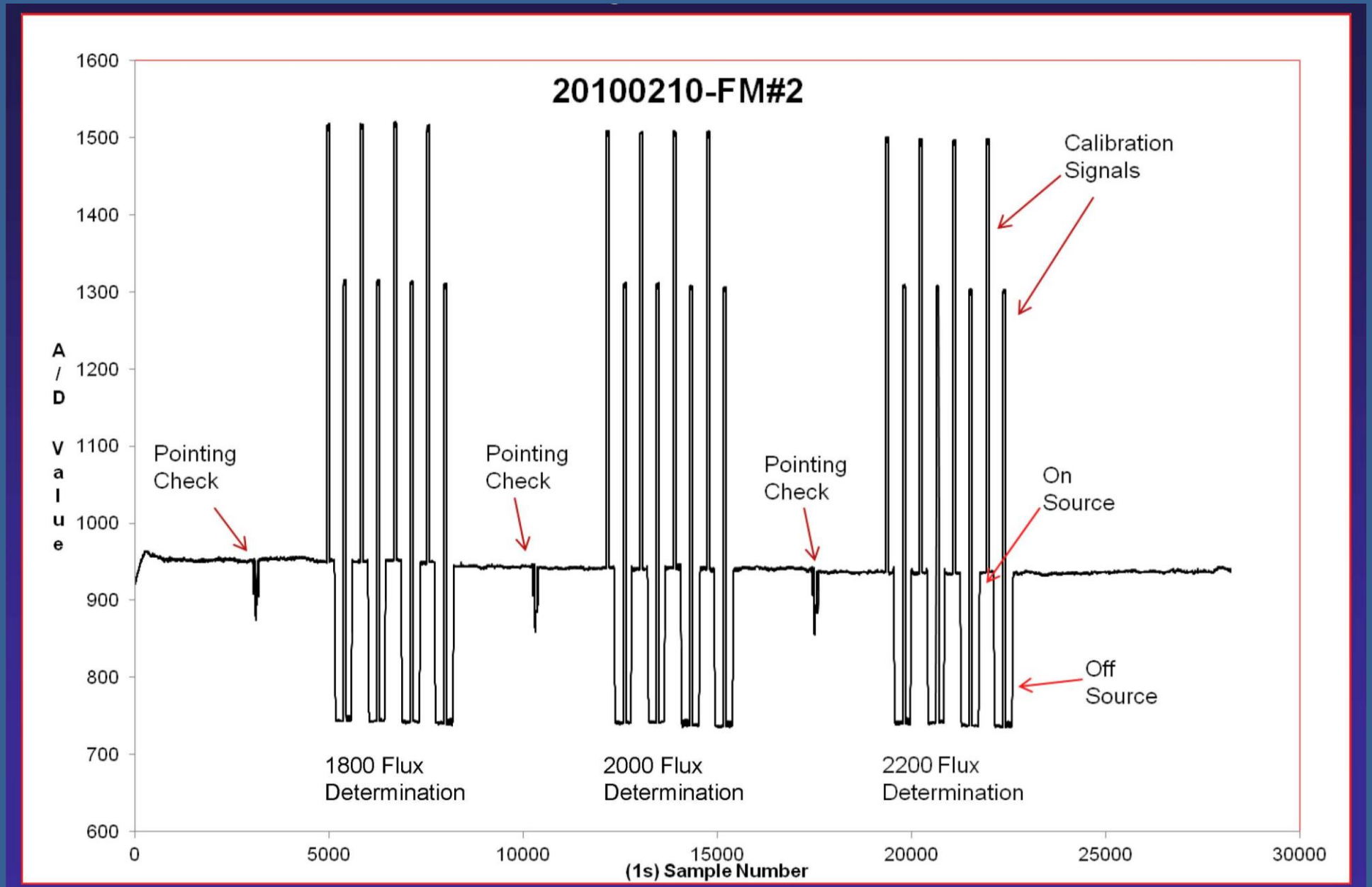

F10.7 and Sunspot Number, Monthly Means
400
350
300
250
200
150
100
50
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
F10.7
Ns


Quiet Sun
Active Free-Free
Gyroresonance
Total Flux Density
Flux Density in sfu
600
500
400
300
200
100
0
0
5
10
15
20
25
Wavelength in Centimeters

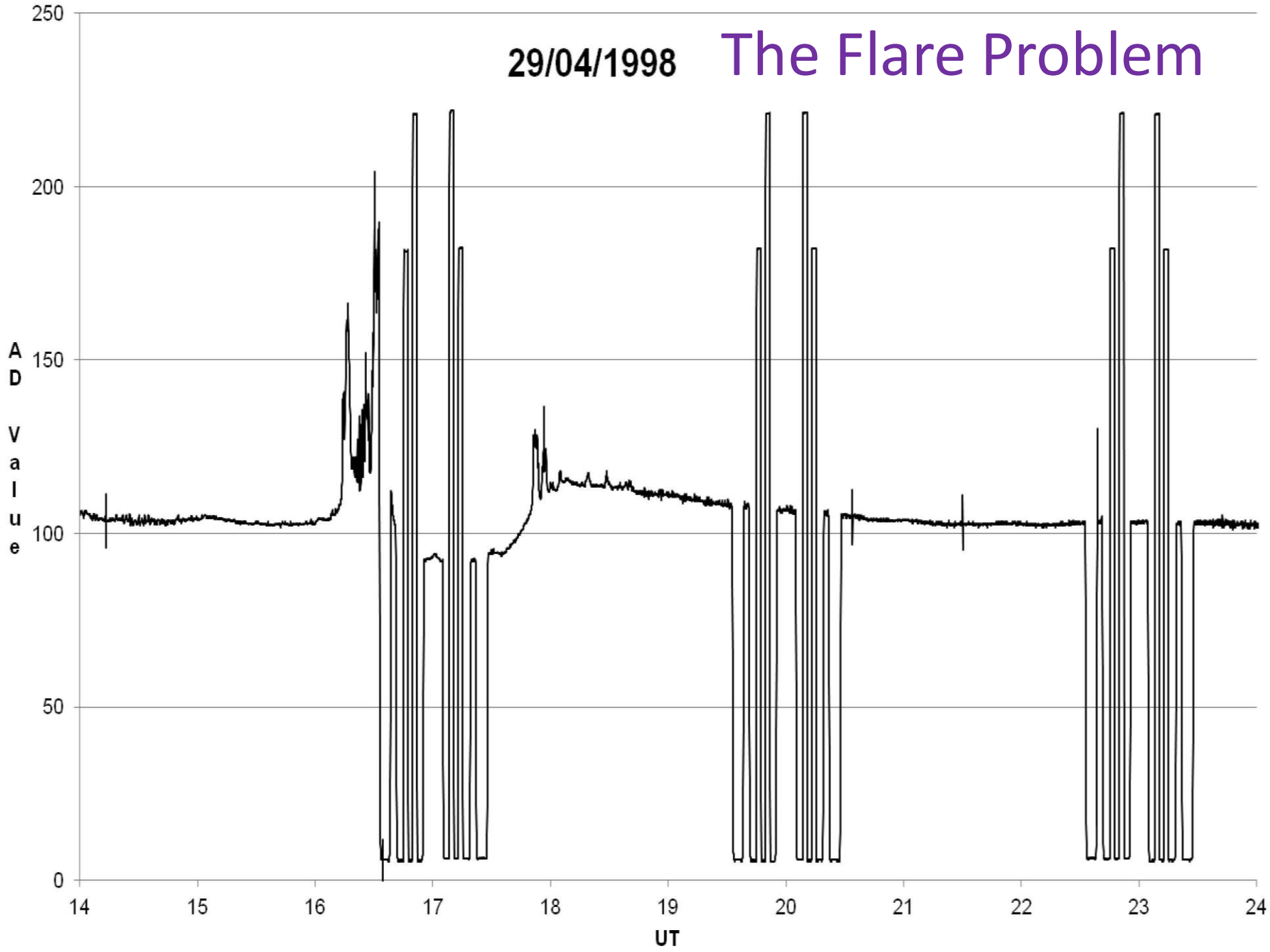
Radio Images of Sun at 21cm Wavelength



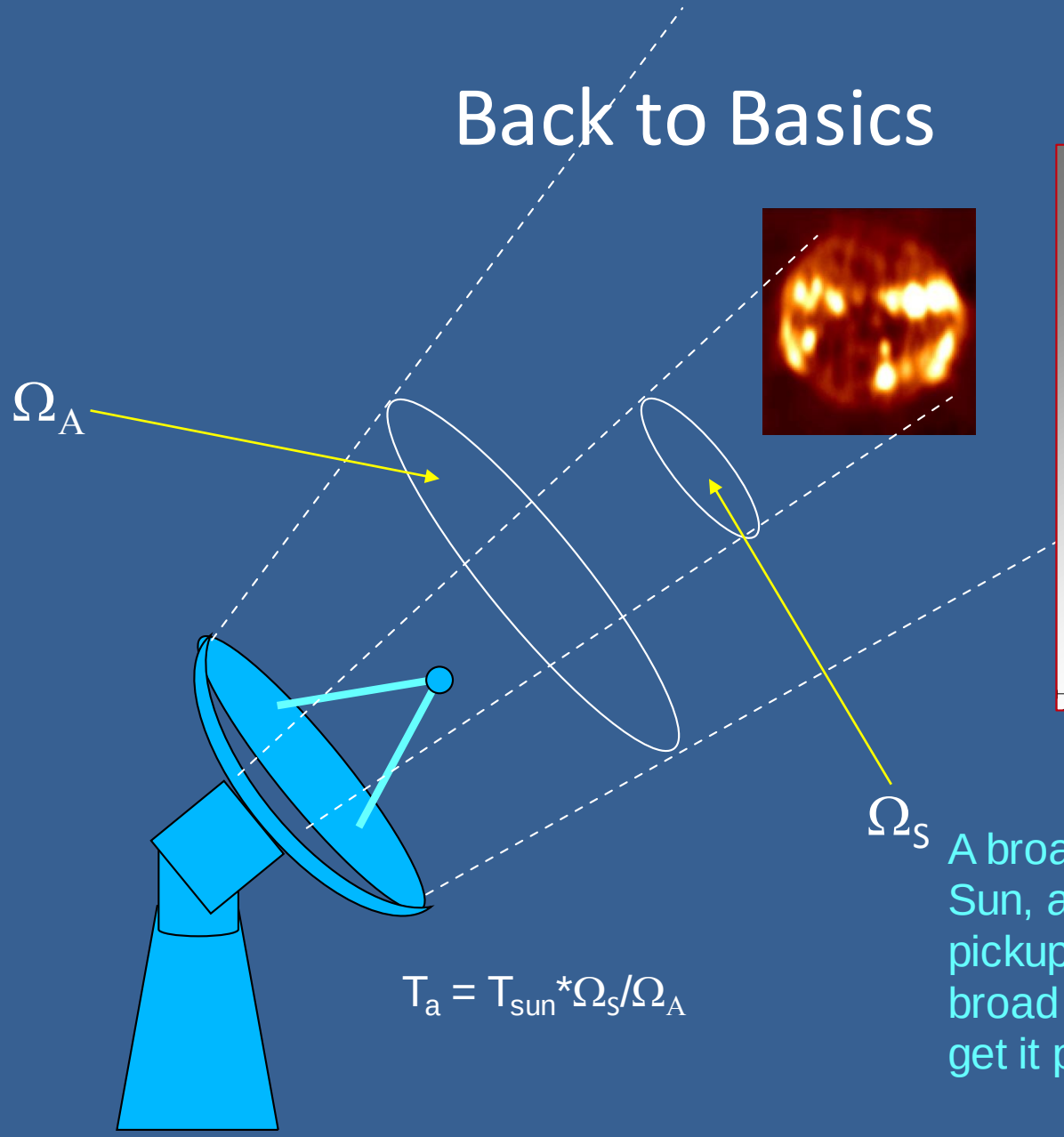
CR File + Flux Determinations

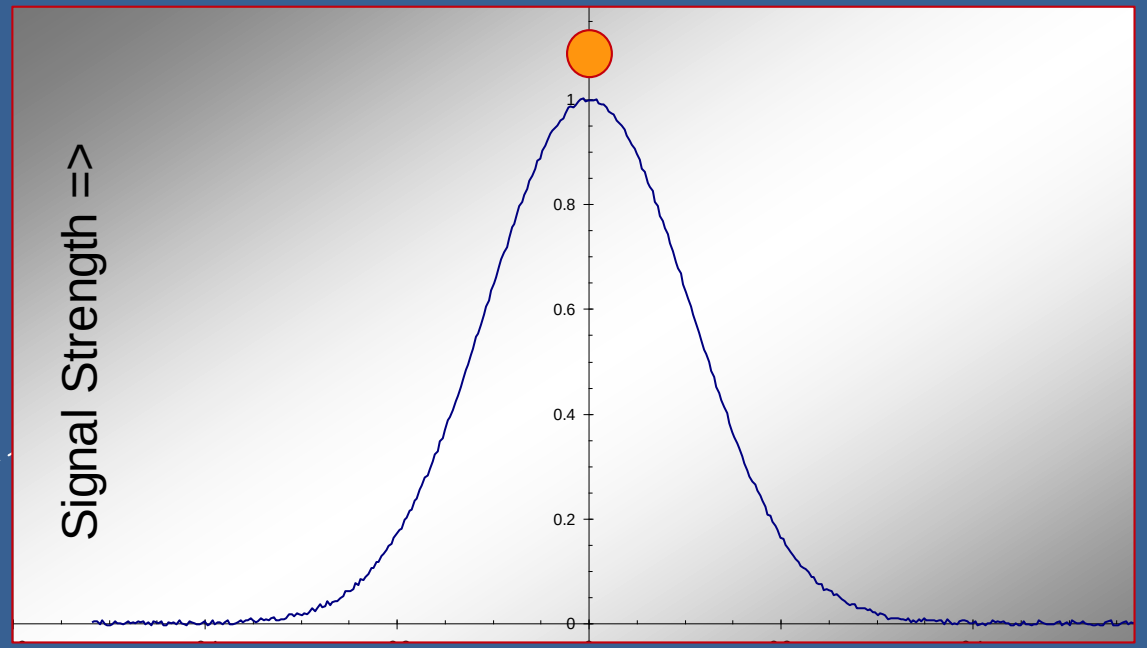


The Flare Problem



Back to Basics

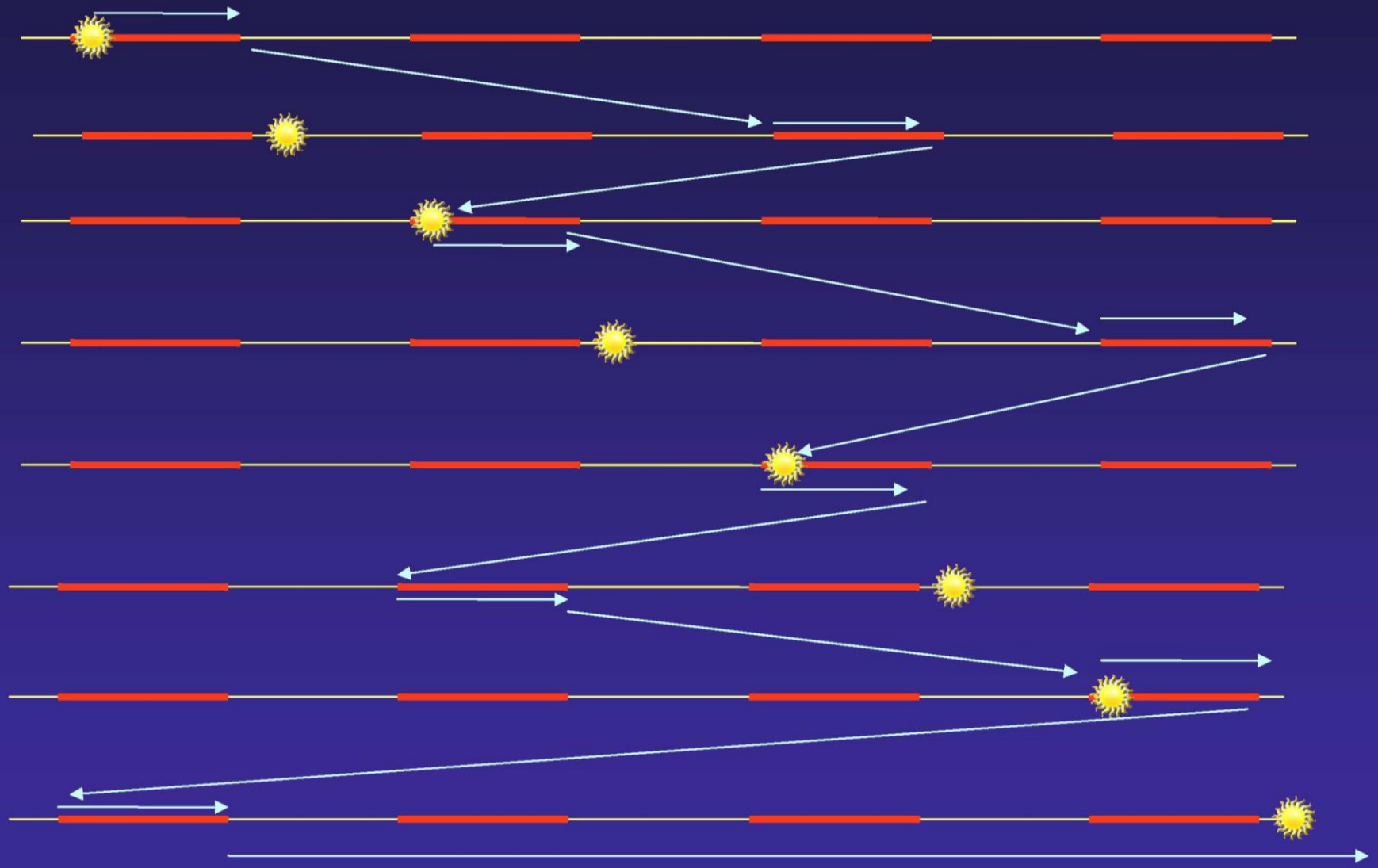




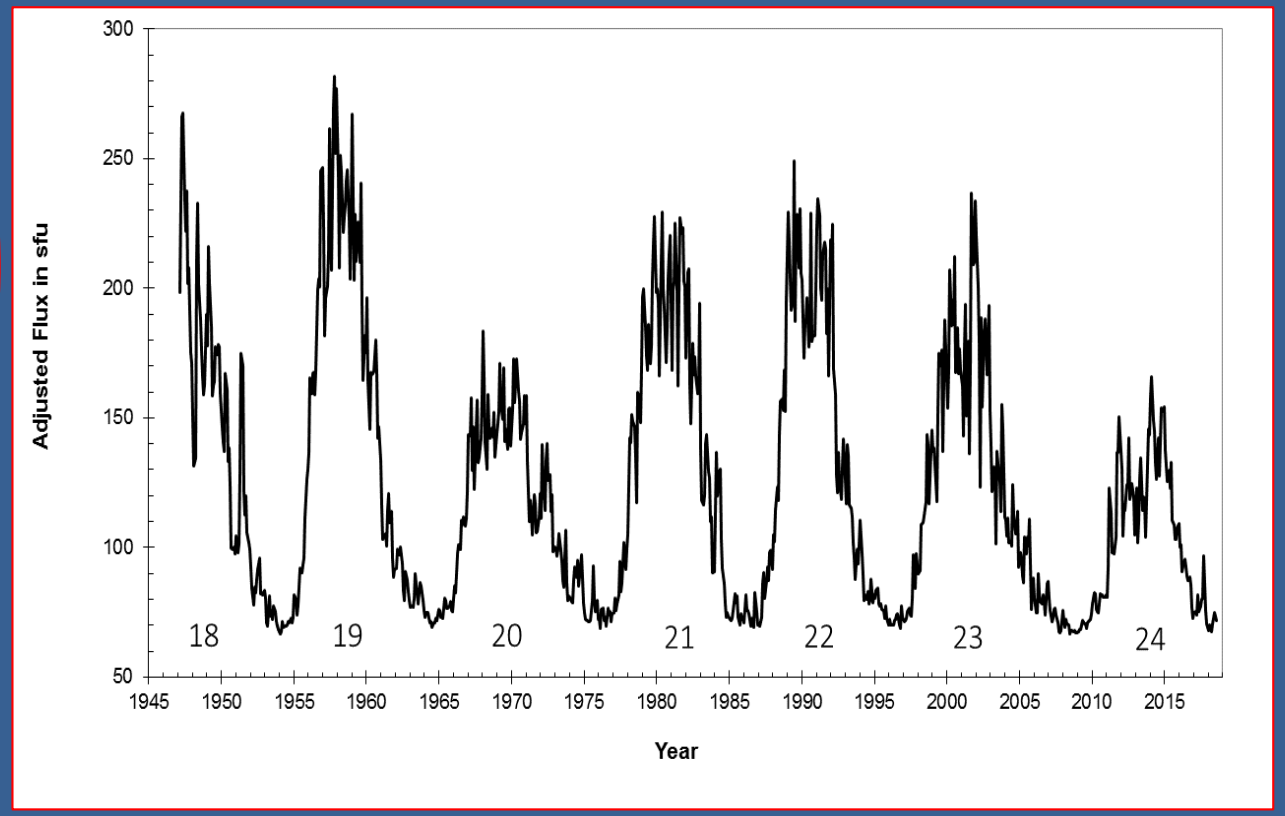
$T_a = T_{sun} * \Omega_S / \Omega_A$

A broad beam gives a more constant sensitivity over the Sun, at the expense of reduced sensitivity and increased pickup of surious noise from the ground. In addition, a broad beam means having to move the antenna further to get it pointed far enough off-source. Need to compromise

Flux Determination Procedure



F10.7: A Measure of Solar Activity



Some of the Uses of F10.7

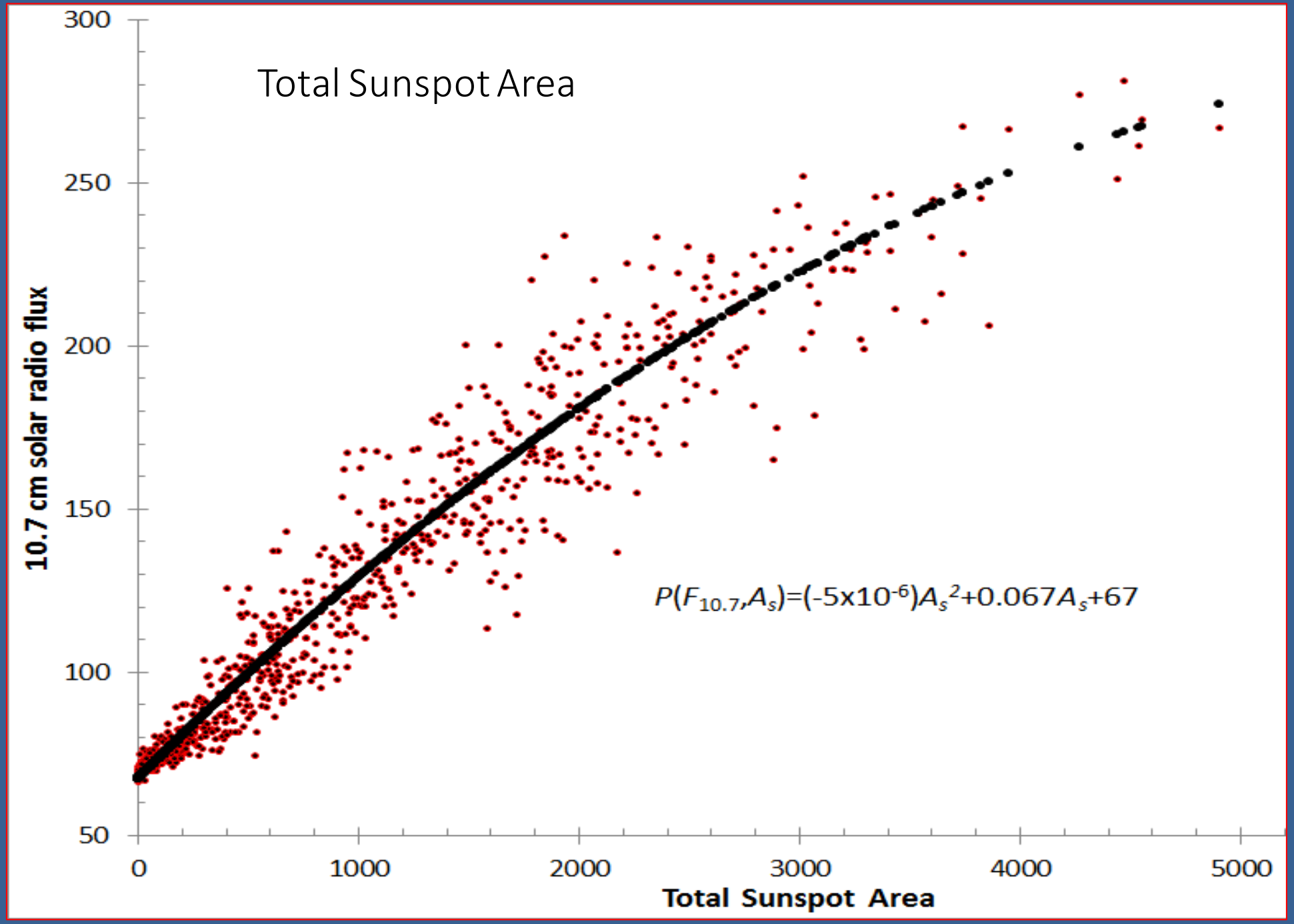
- As a simple, empirical indicator of the current level of solar magnetic activity.
- As a common standard for radar network calibration.
- As a proxy for UV/EUV fluxes heating the upper atmosphere (for satellite orbit management).
- As a proxy for the UV/EUV fluxes driving ionospheric processes and radio propagation.
- As proxies for solar emissions hard to obtain with usable data continuity.
- As a proxy calibration bridge joining data series with gaps.
- As a proxy for extending solar data into the past (back to 1947).
- For studies into trends/changes in solar behaviour.

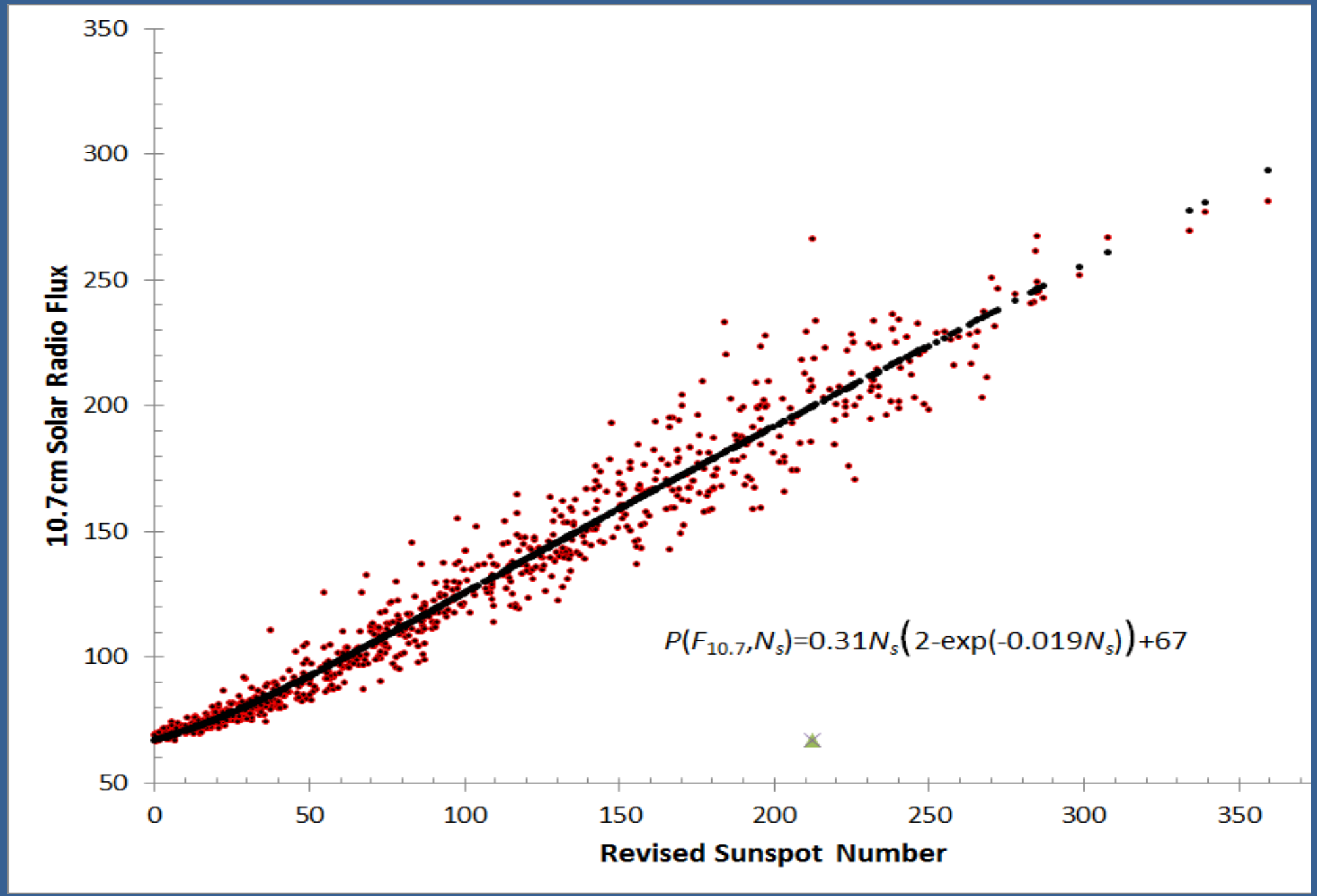
Undersampling Etc.

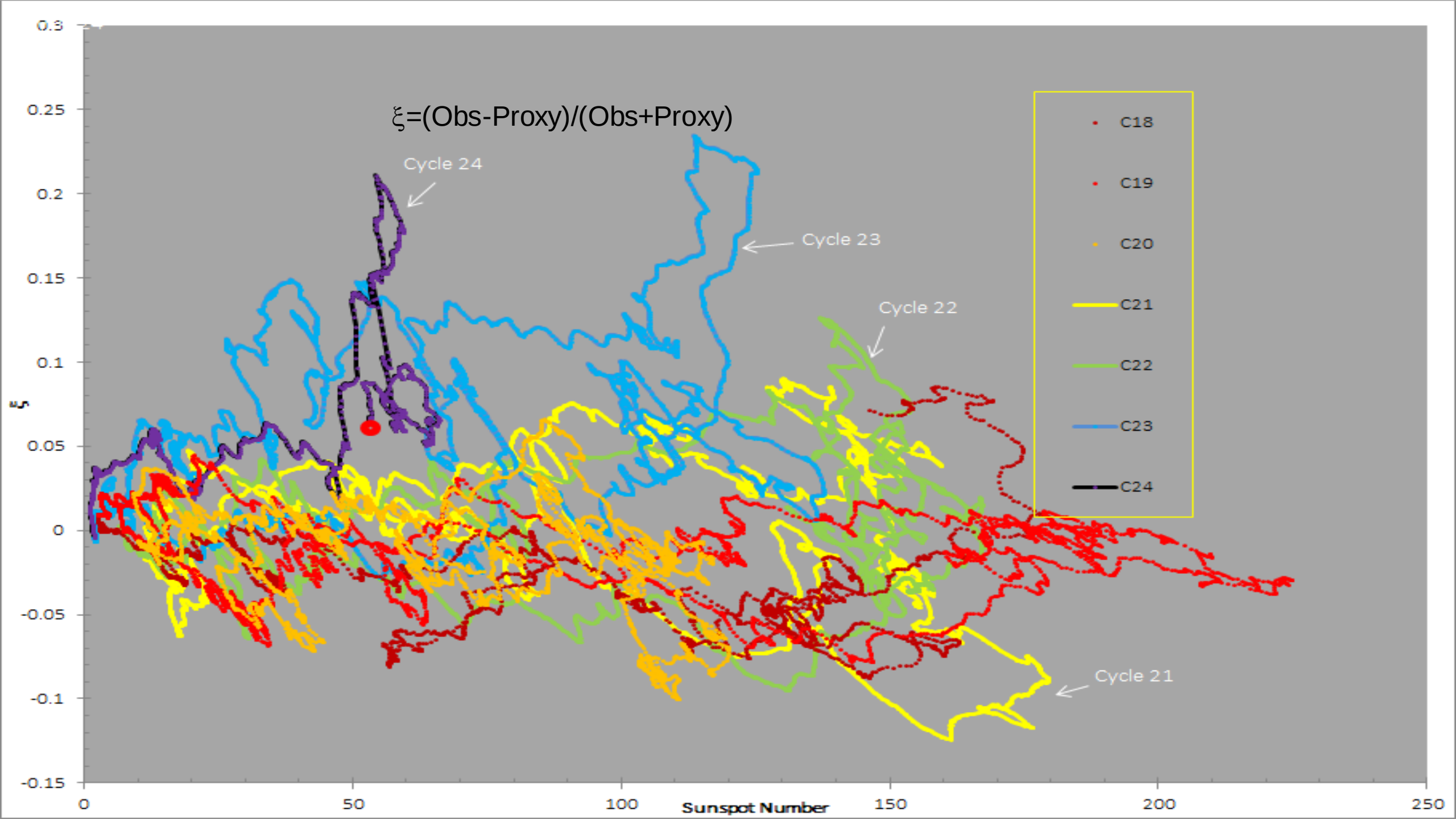
- Three measurements are made each day, each taking one hour, centred around local noon. No other measurements are available.
- When activity is low, even one measurement a day is adequately representative of what the Sun is up to. When activity is high this might not be true.
- A flare or burst during a flux determination may render it meaningless as an index of general solar magnetic activity.
- In a summer-long study when solar activity was moderate, we found that 95% of the time, a single noon measurement was within 2% of the mean value of the emission averaged from sunrise to sunset (16 hours at that time of year).
- The only reliable solution is a multi-instrument, 24-hour, every day monitoring programme with flux determination times staggered so that data gaps can be filled in.

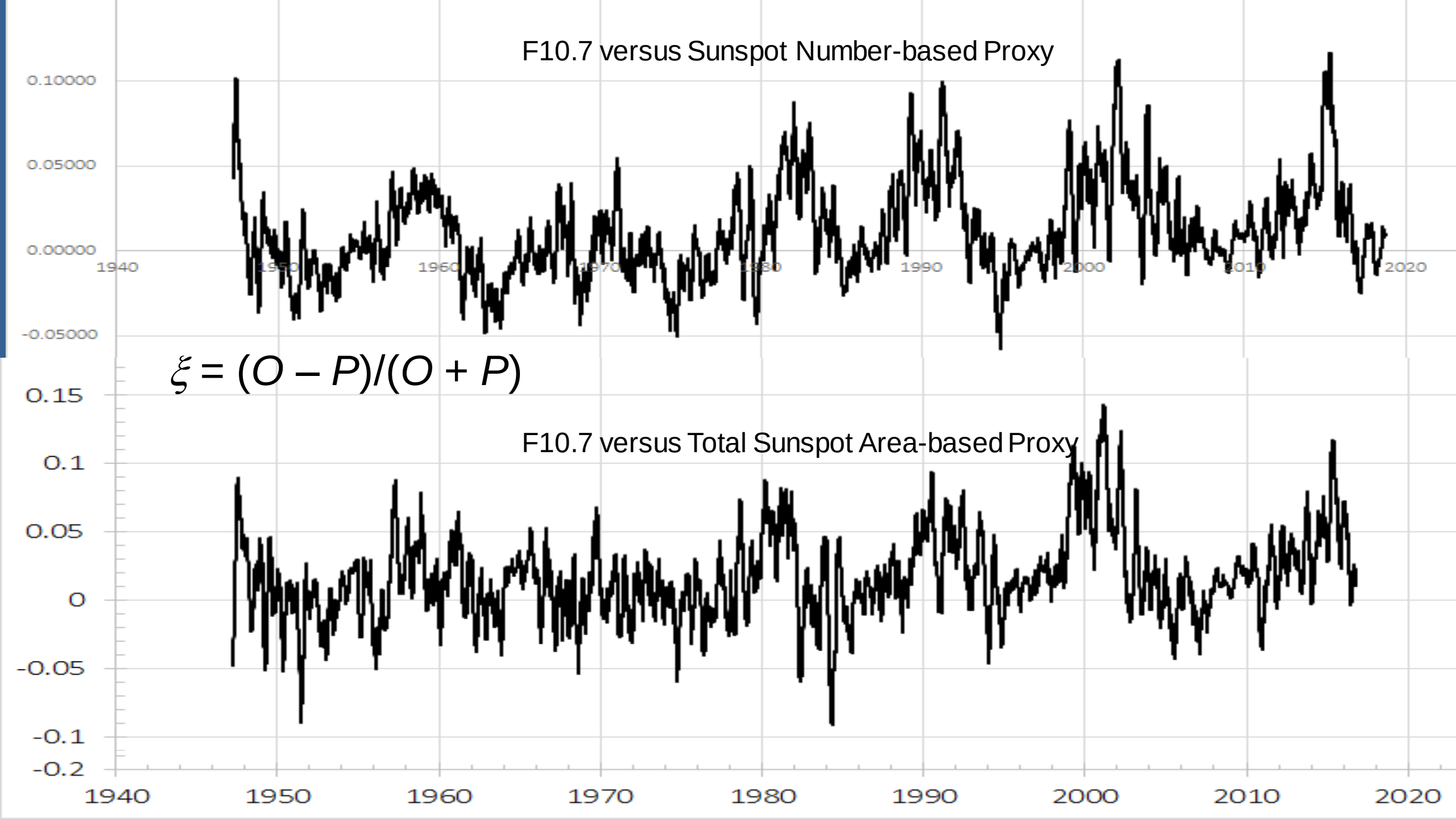
Undersampling

- How closely do the measurements truly reflect what we assume them to be?
- How does this impact the application of the data?
- What to do about it, if anything?
- In comparing with other data or making proxies, it is recommended to increase the statistical similarity of the data by imposing a filter function on it which becomes a dominant factor in their statistical properties. At least match their characteristic timescales.

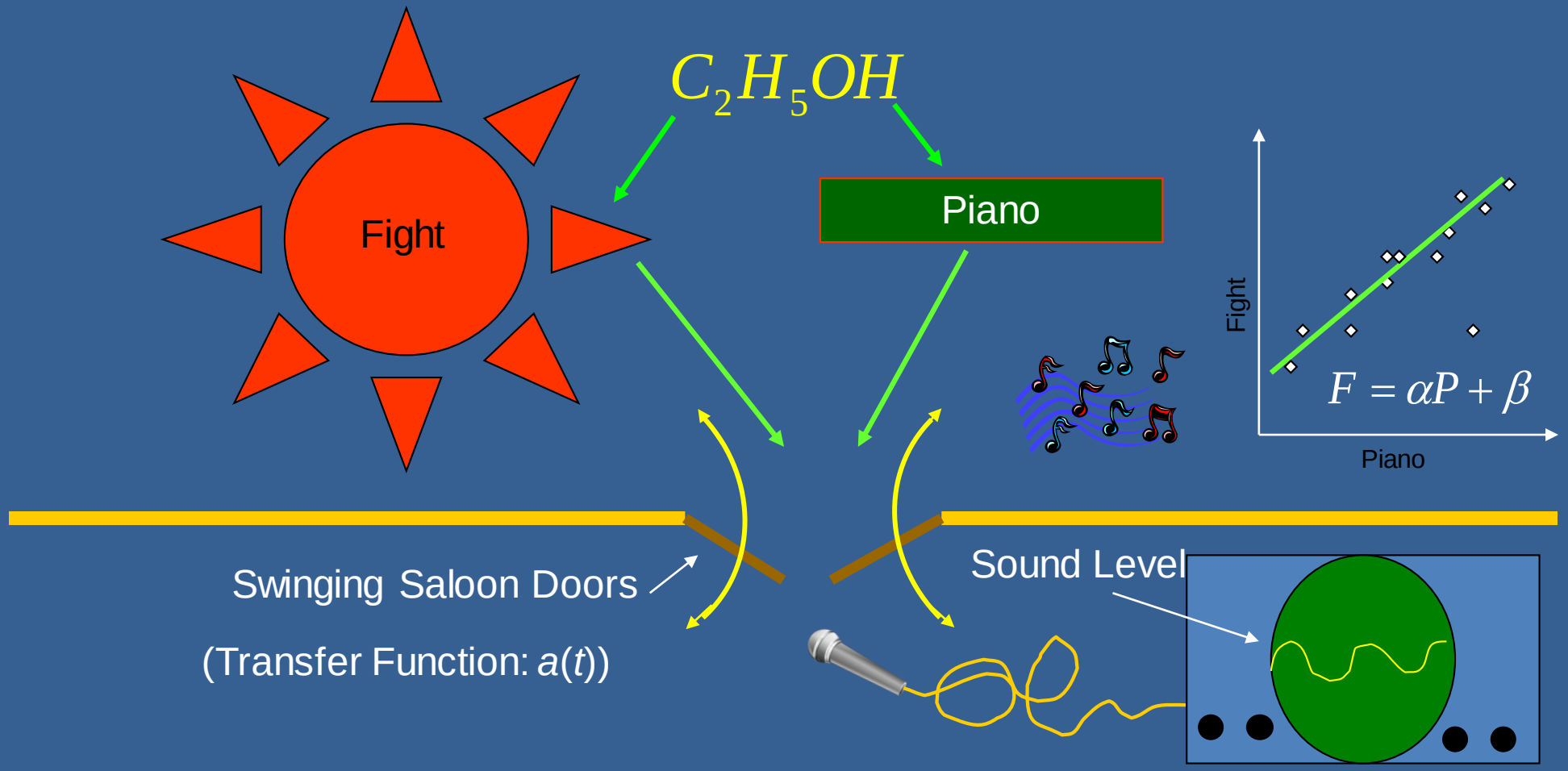

Total Sunspot Area
10.7 cm solar radio flux
Total Sunspot Area
300
250
200
150
100
50
0
1000
2000
3000
4000
5000
$P(F_{10.7},A_s)=(-5x10^{-6})A_s^2+0.067A_s+67$


10.7cm Solar Radio Flux
Revised Sunspot Number
$P(F_{10.7},N_s)=0.31N_s\left(2\text{-}\exp(\text{-}0.019N_s)\right)+67$
350
300
250
200
150
100
50
0
50
100
150
200
250
300
350


ξ=(Obs-Proxy)/(Obs+Proxy)
Cycle 24
Cycle 23
Cycle 22
Cycle 21
C18
C19
C20
C21
C22
C23
C24
ξ
Sunspot Number
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
50
100
150
200
250


F10.7 versus Sunspot Number-based Proxy
0.10000
0.05000
0.00000
-0.05000
1940
1950
1960
1970
1980
1990
2000
2010
2020
$\xi = (O - P)/(O + P)$
F10.7 versus Total Sunspot Area-based Proxy
0.15
0.1
0.05
0
-0.05
-0.1
-0.2
1940
1950
1960
1970
1980
1990
2000
2010
2020

Proxies: Rosa's Cantina, El Paso, Texas



$$Volume = a(t)\Big(Fight(C_2H_5OH(t),t) + Piano(C_2H_5OH(t),t) + \Psi(Fight, Piano, t)\Big)$$

The Next Generation Solar Flux Monitor:1 Why?

- F10.7 is produced by at least two emission processes: thermal free-free and thermal gyroresonance. We might getter proxies if we could separate the contributions from these emission processes.
- Radio emission at centimetre wavelengths comprises a mix of contributions from the chromosphere, transition region and the corona. If we can separate the contributions….. Current changes in solar behaviour suggest a change in the relationship between activity in the photosphere, chromosphere and corona.
- Usable for antenna network calibration. needs, flux measurements will not be distributed freely until 2017 or so.

CSA
NRCan
NRC
Joint Project

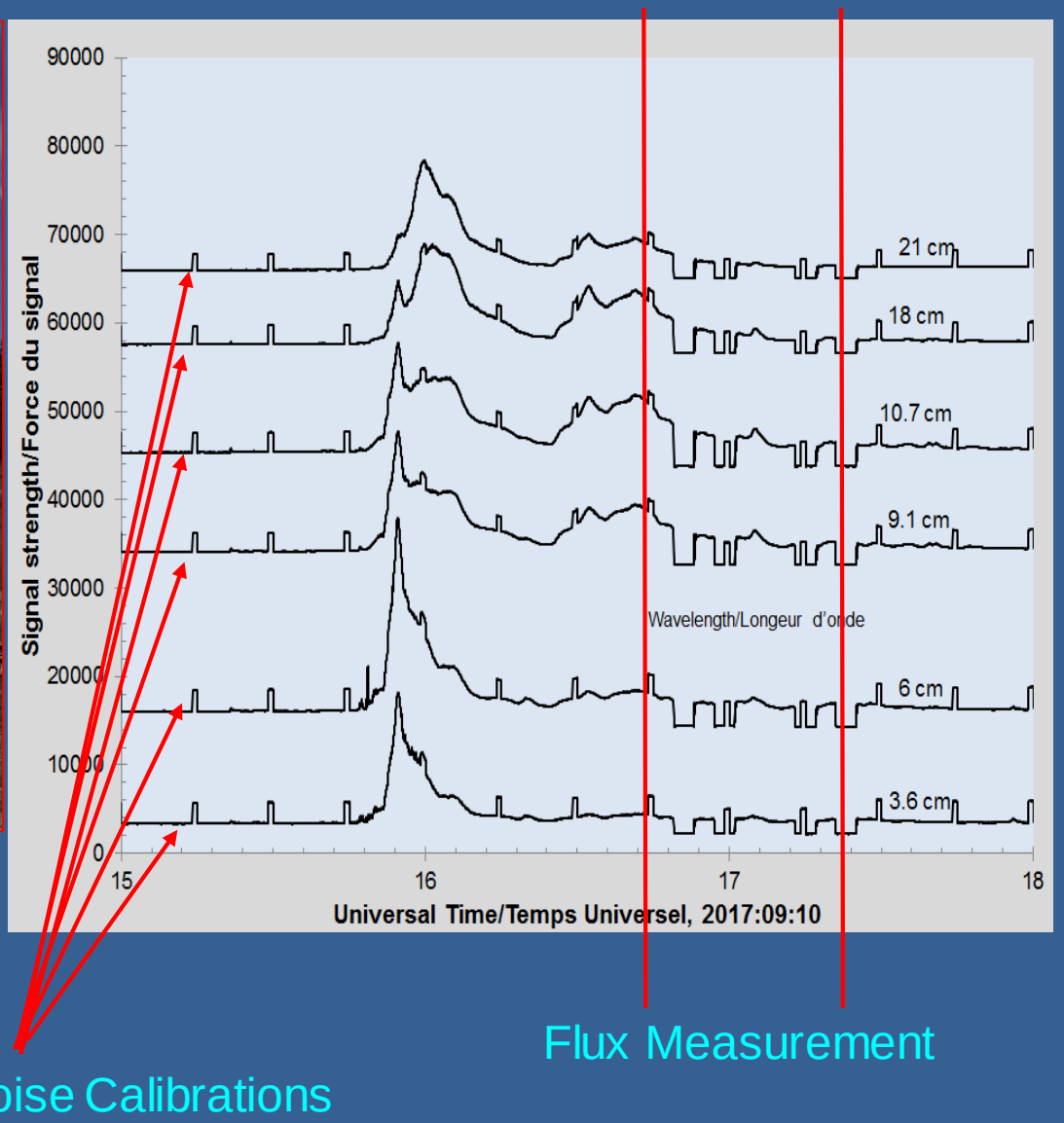
The Next Generation Solar Flux Monitor:2 Why?

CSA
NRCan
NRC
Joint Project

- Although observations at multiple wavelengths are already available, they are made in different ways, using different instruments, not consistently calibrated, and not necessarily at the same time. This restricts the possibility of combining them into a useful whole for other than crude intercomparison.
- We would rather have the same instrument make all the measurements, at the same time, using identical hardware, in the same manner, and calibrated on the same basis.
- The challenge is how one can observe the Sun with uniform sensitivity over a wide range of wavelengths.

The Next Generation Solar Flux Monitor:3

CSA
NRCan
NRC
Joint Project



Noise Calibrations

Flux Measurement

- Fluxes on at least six wavelengths: 21, 18, 10.7, 9.1, 6.1, 3.6 cm
- Sampling rate 1000 samples/sec for each wavelength.
- Uses progressive under-illumination of the antenna to make the beamwidth largely independent of wavelength so the same antenna can be used for all the flux monitoring.
- Currently optimizing software and doing observational testing (implementation was interrupted for 2 years by funding issues).
- Not calibrated yet.
- Unique in having gone through three upgrades without any continuous observations. A good thing really in that it better integrates the instrument into the DRAO operating environment.

Where Now?

- Having moved one flux monitor to Linux/C we are replacing the receiver backend with an Ettus X310 SDR device. Once tested the other flux monitor will be identically upgraded.
- The Next Generation Solar Flux Monitor, with its new software will have another calibration run, after which the data will be put on the web.
- The existing flux monitors will remain the primary sources of F10.7, with the NGSFM measurements providing a tertiary backup. This instrument is markedly different from the other machines and those differences will inevitably appear in the data statistics.
- In addition to the existing data source: spaceweather.gc.ca, we are setting up another publically accessible data website at the Canadian Space Astronomy Data Centre.
- I retired on 2nd May. I am still employed by NRC for two days a week plus whatever other days I feel like going in. Nobody is trying to steal my office. My responsibilities remain the same, but we are in the process of putting things together for taking on a replacement, who will work with me and DRAO Operations Staff.