

太陽活動指数と電離層foF2の相関 (Correlation between Ionospheric foF2 Frequency and Solar Activity Indexes)

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Outline

- Radio Emission from the Sun
- Total flux measurements at Toyokawa and Nobeyama
- Total flux and Sunspot numbers
- Ionospheric measurements
- Correlation between solar activity indexes and foF2
- Summary

Quiet (non-flaring) Sun at Radio

- Emission mechanisms

- mainly thermal emission (thermal electrons)

- free-free emission
- gyro-resonance emission

$$T_b = \int T e^{-\tau} d\tau$$

- small contribution from non-thermal emission (small flares)

- Features

- solar disk

- limb / polar brightening

- active regions

- sunspot s(umbral or other oscillations)
- plages
- small scale active regions (XBP)

- dark filaments / prominences

- prominence eruptions / CME

- network and fine structures (high spatial resolution, ALMA?)

Total flux measurements

- Spatially integrated radio emission around 10 cm (3 GHz) is a good index of the solar activity
 - thermal f-f emission (upper chromosphere ~ corona)
+ gyro-resonance emission (sunspots)
 - Less influence from the terrestrial atmosphere (cloud, rain, ionosphere)
- Calibration method is well established
 - uniform data for a long time (good for solar cycle studies)
- Observations
 - Canada (Ottawa / Algonquin / Dominion, since 1947), Japan (Toyokawa / Nobeyama, since 1951), USA, etc.

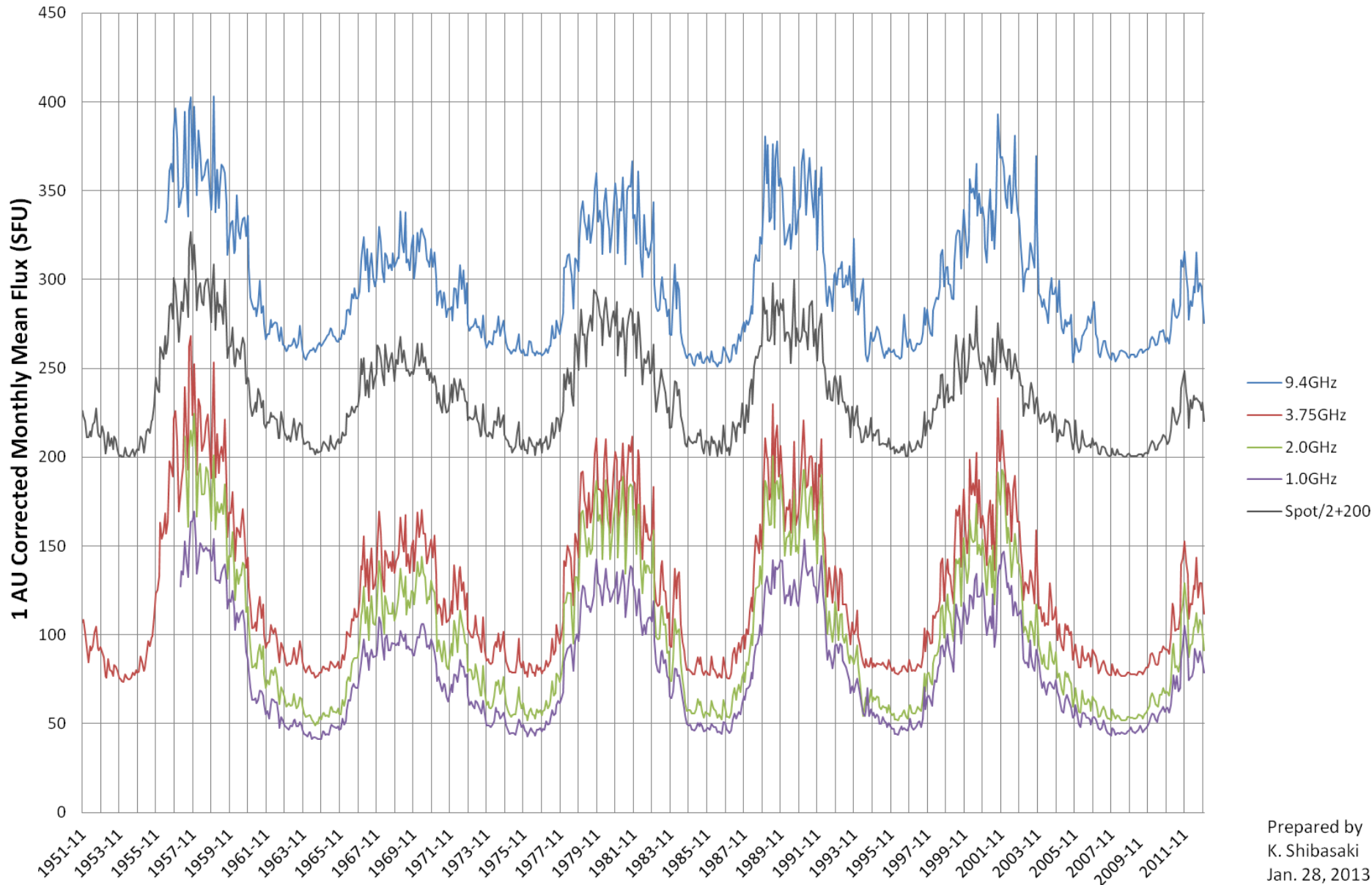
Nobeyama Radio Polarimeters



Polarimeters (Toyokawa / Nobeyama)

- Total flux and polarization measurements at:
 - 1.0, 2.0, 3.75, 9.4, 17, 35 and 80 GHz
 - longest observation is at 3.75 GHz since Nov. 1951
 - Robust absolute calibration method
- Data use
 - index of solar activity (> 5 solar cycles)
 - studies of particle accelerations in solar flares

Microwave Flux (1951 Nov. - 2012 December) & Sunspot Number

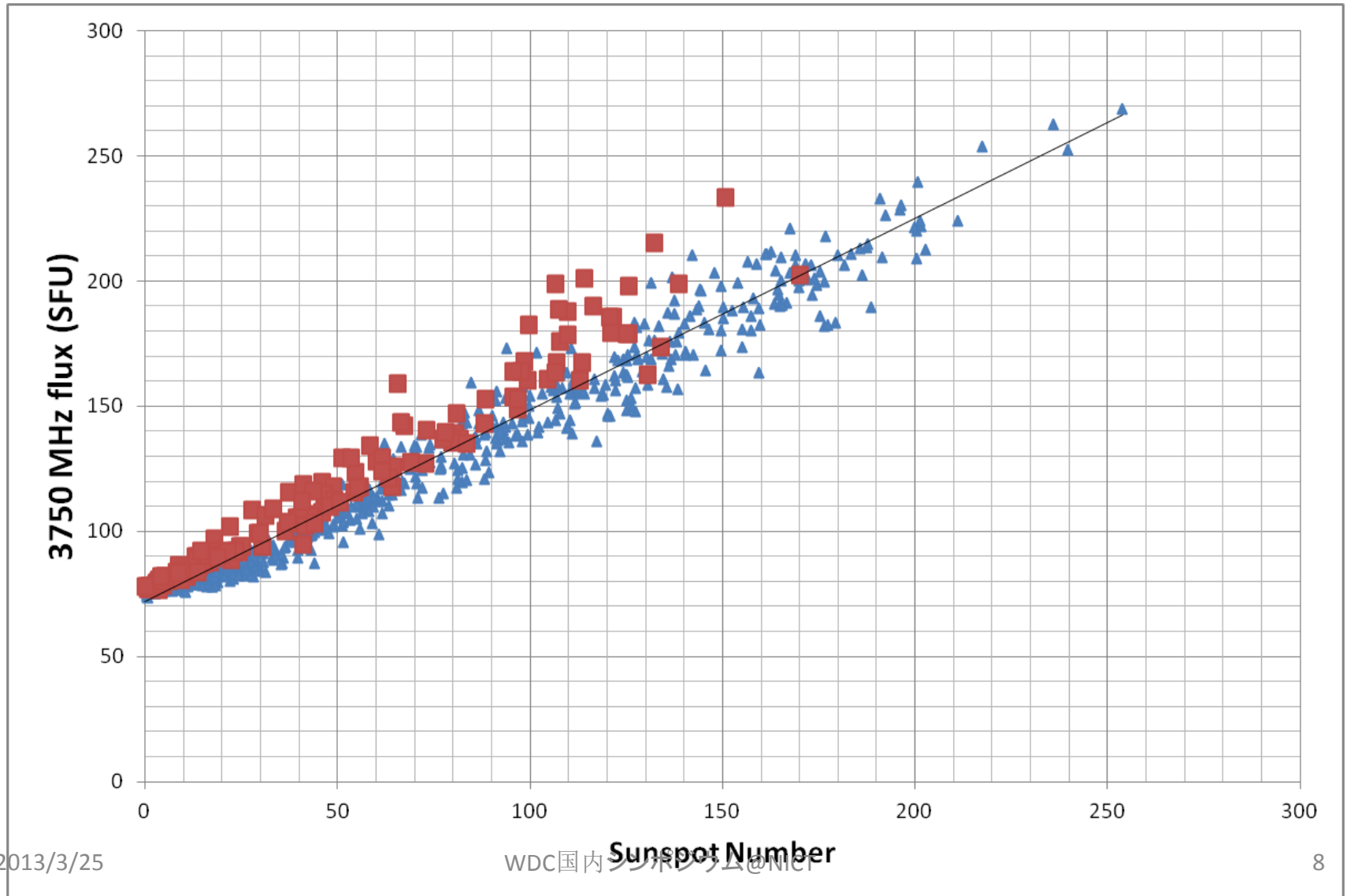


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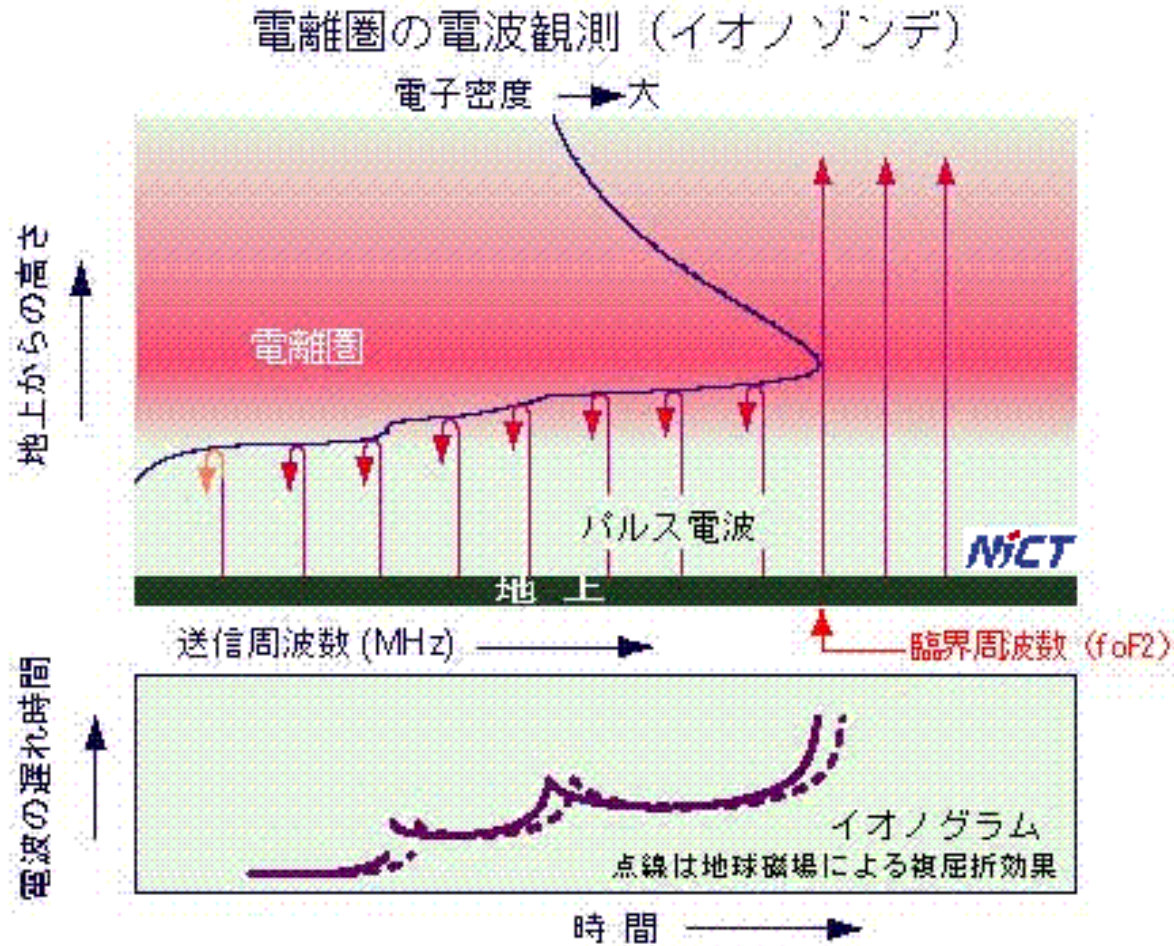
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Jan. 28, 2013

Sunspot Numbers and Total Radio Flux: Systematic deviation after 2000 (red)

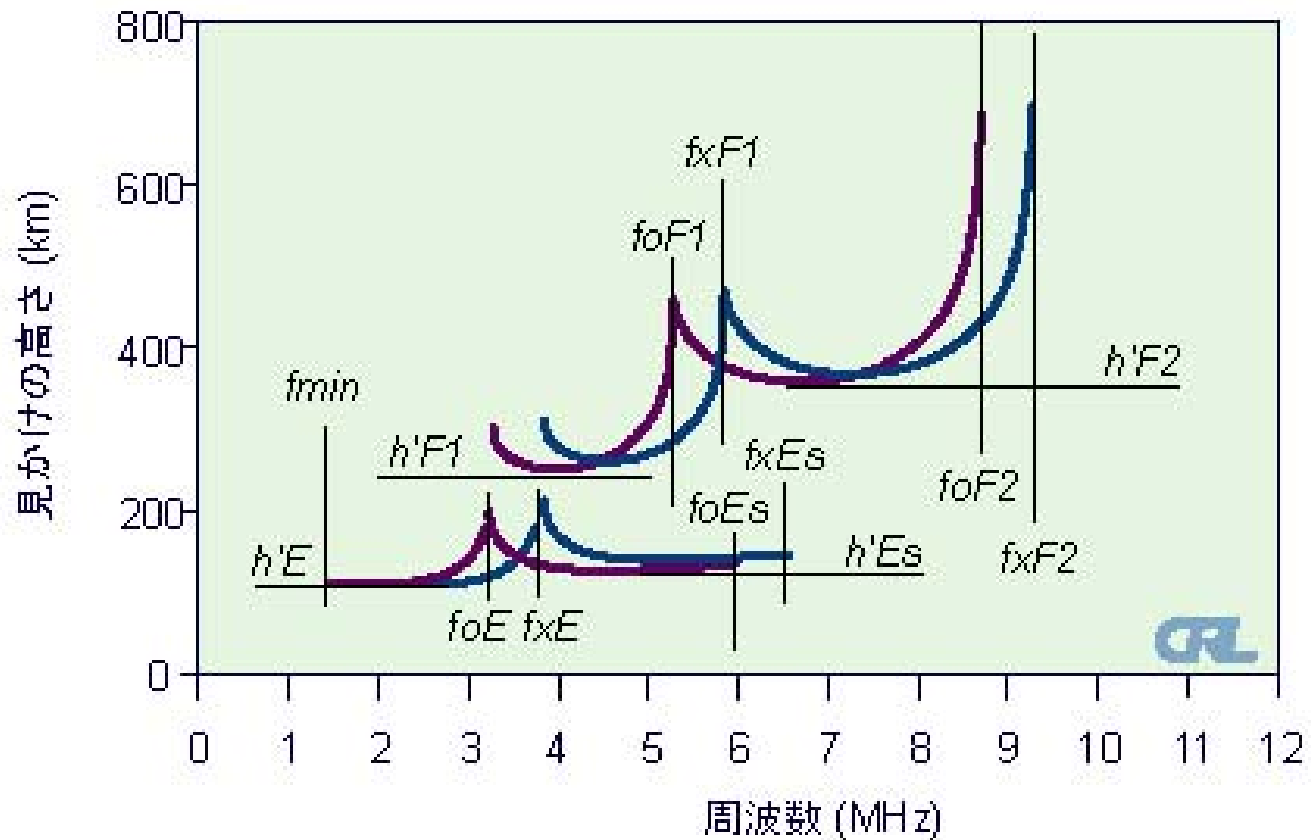


Measurement of Ionosphere

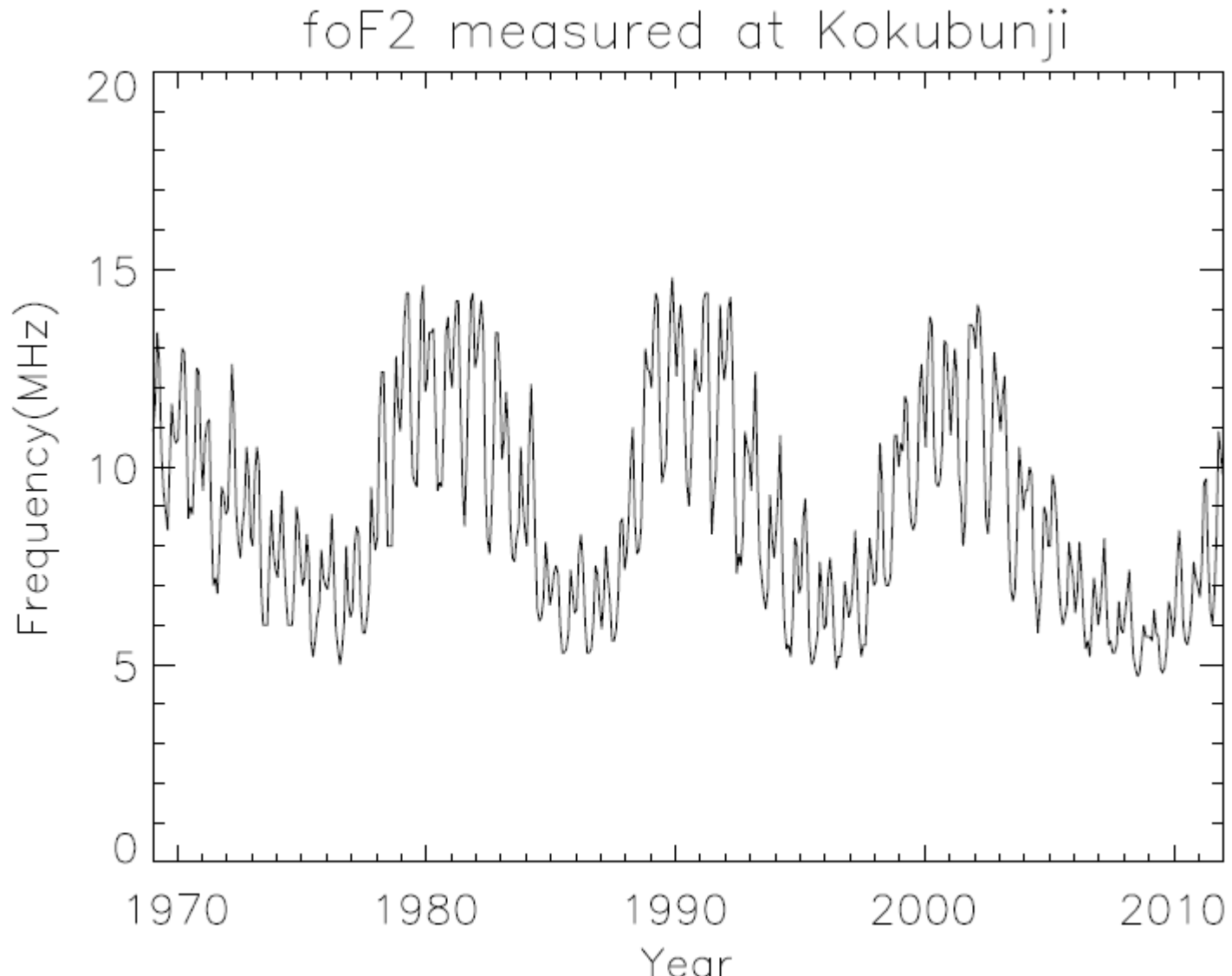


Ionogram

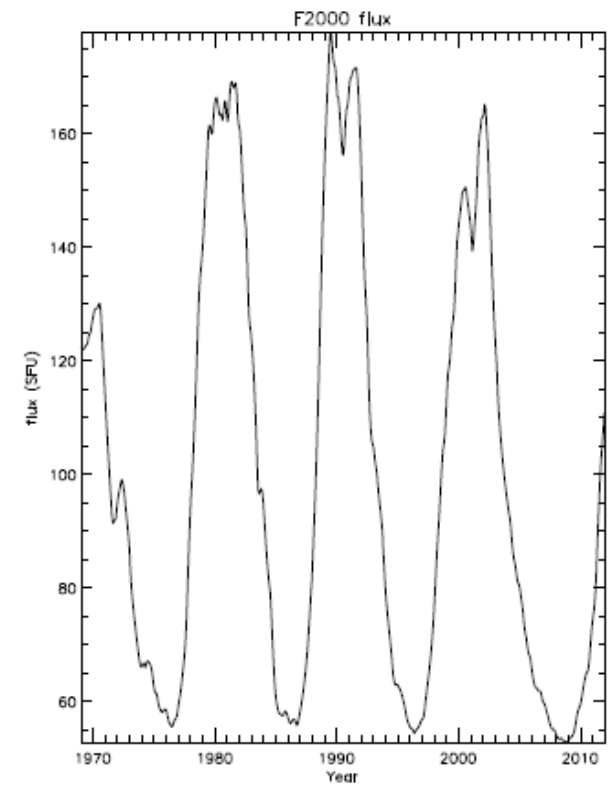
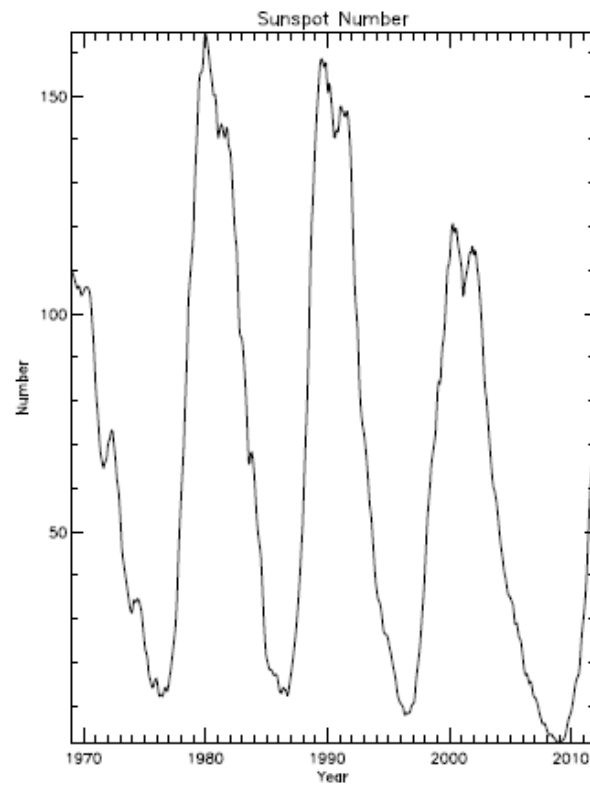
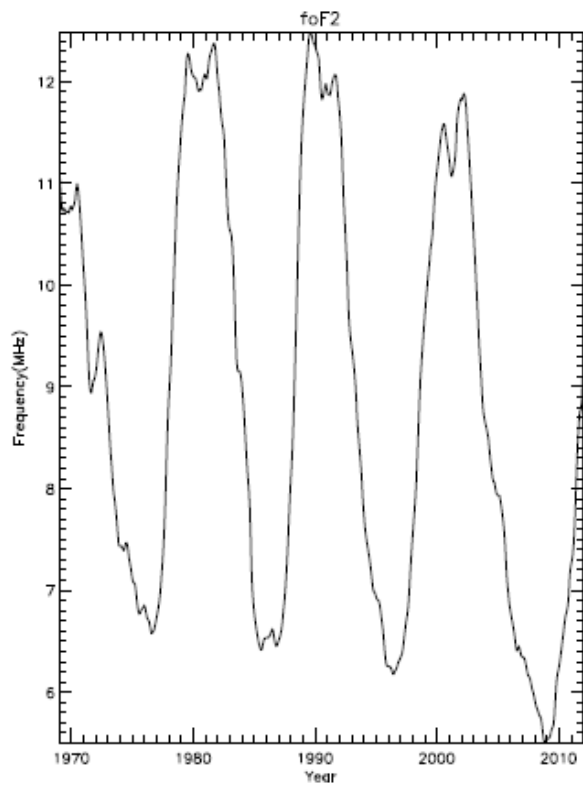
イオノグラムと読み取りパラメーター



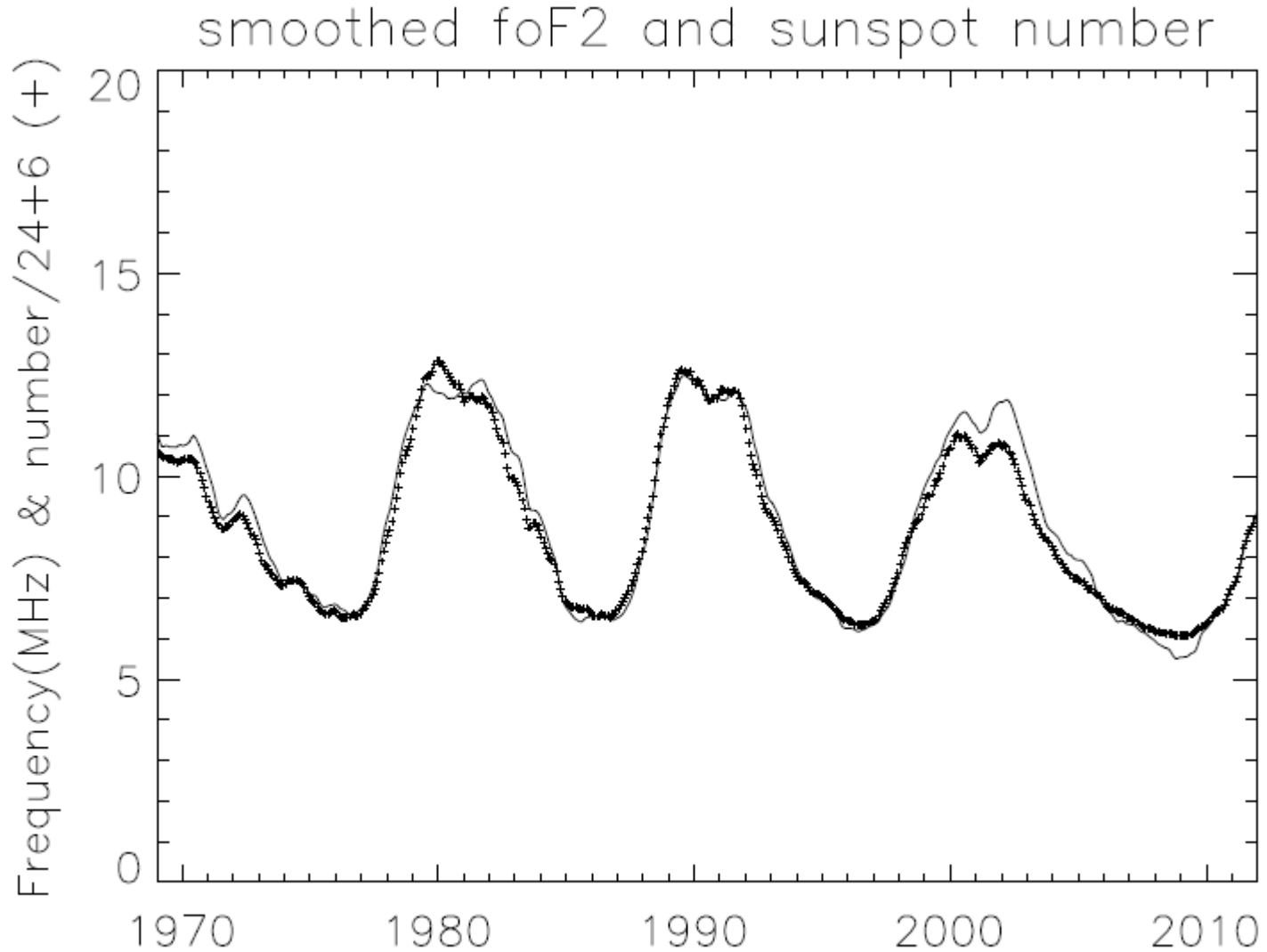
foF2 (1969-2011) measured at Kokubunji



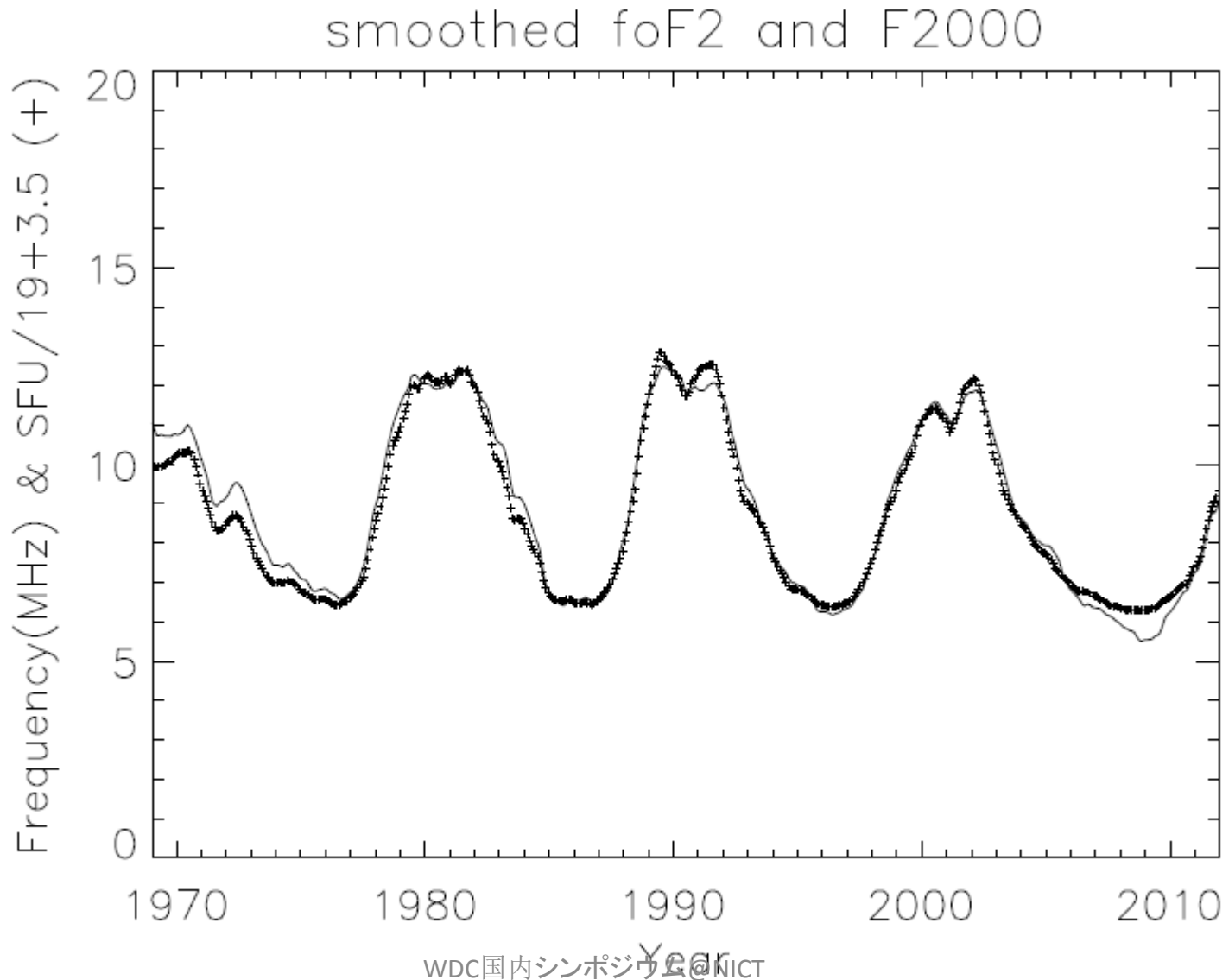
Smoothed foF2, Sunspot number, and Radio flux at 2000 MHz



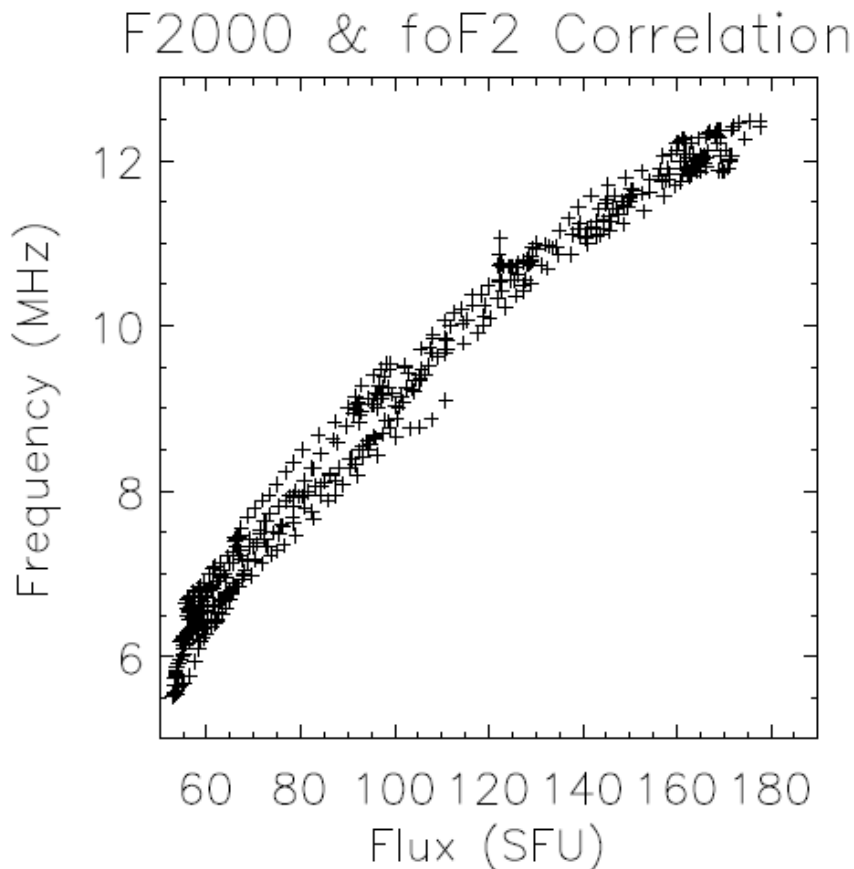
Smoothed foF2 and Sunspot Number(SIDC)



Smoothed foF2 and 2000MHz Flux



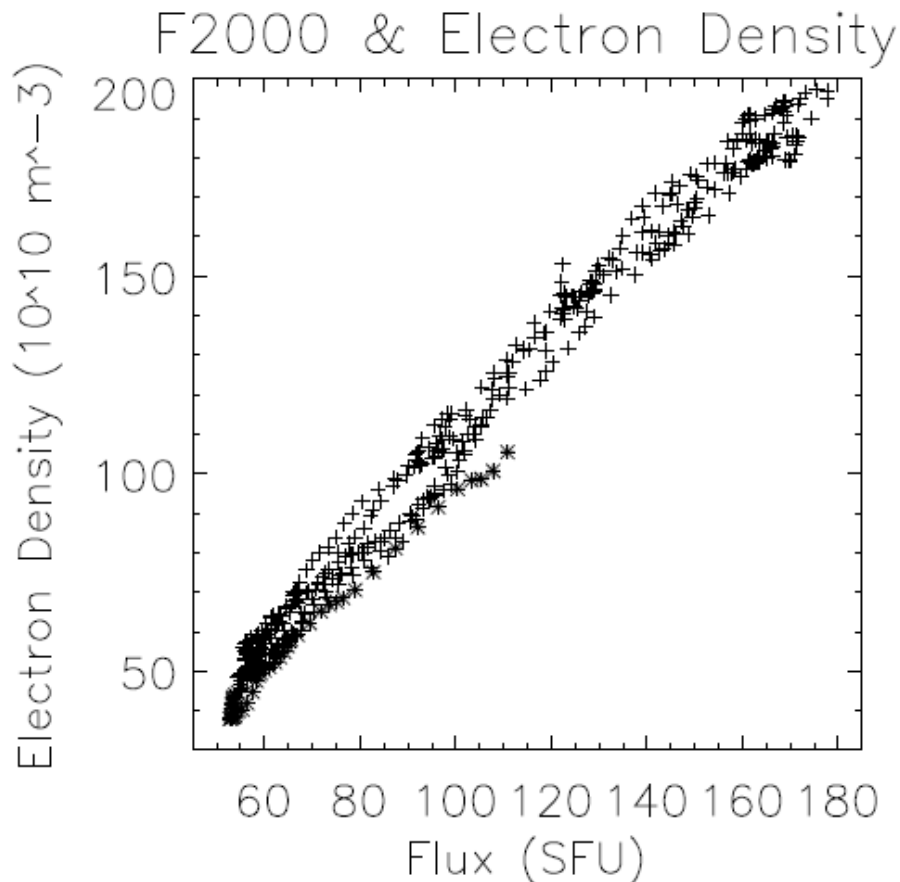
Correlation between Microwave Flux and foF2



Corr. Coeff.

- foF2:F1000 0.980
- foF2:F2000 0.986
- foF2:F3750 0.986
- foF2:F9400 0.968
- foF2:SSN 0.986

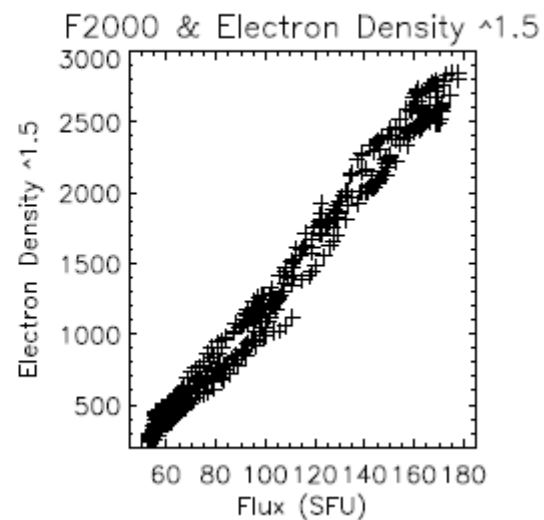
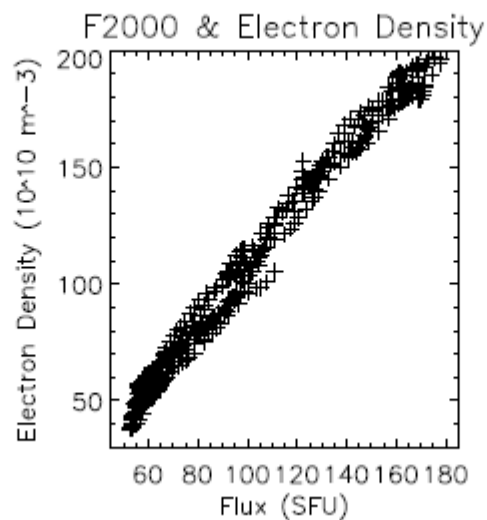
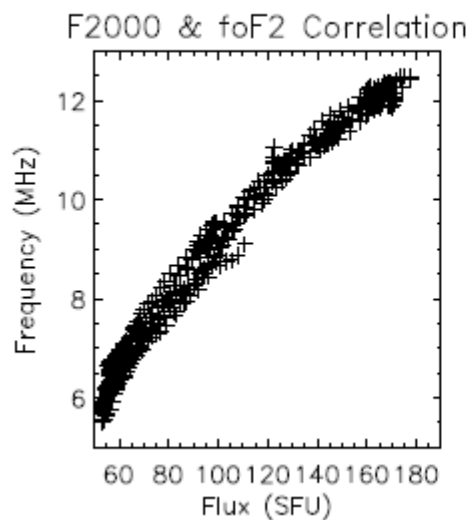
Correlation between Microwave Flux and Ionospheric Electron Density



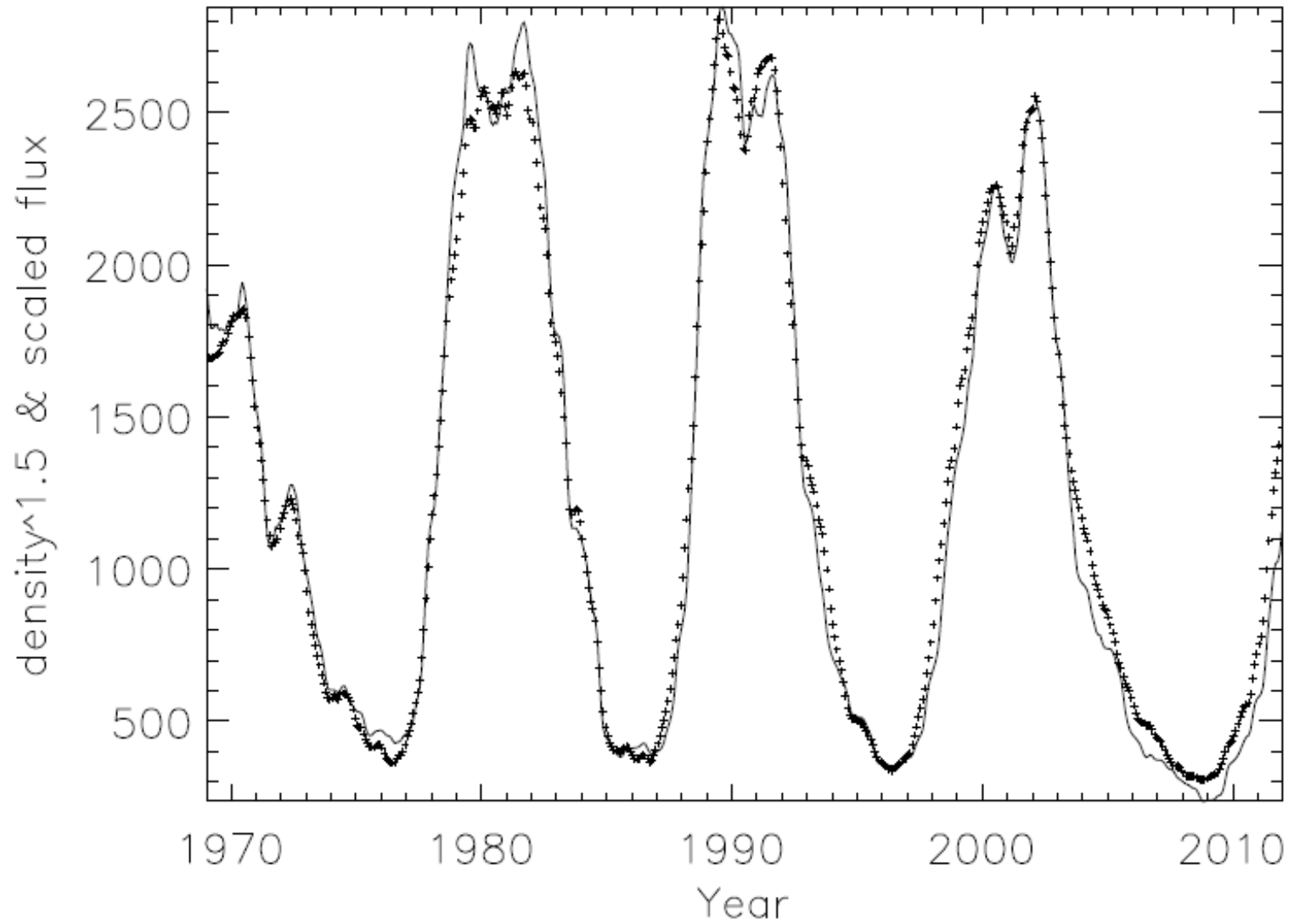
Corr. Coeff.

- Ne:F1000 0.986
- Ne:F2000 0.993
- Ne:F3750 0.992
- Ne:F9400 0.972
- Ne:SSN 0.989

F2000 vs foF2, foF2²(e density), foF2³



electron density $\wedge 1.5$ and scaled F2000



Current Solar Activity inferred from sunspot numbers and total radio flux

- The 24th solar activity indexes are low (about half of that of 23rd)
- Relation between sunspot numbers and radio flux have been changing after 2000
 - Less sunspots are formed ?
- Plasma frequency of the Ionosphere (F2 layer) has been decreasing
 - Better correlation with total radio emission rather than sunspot numbers
 - foF2 can be used as a solar activity index (UV emission)