

Polar Brightening and Solar Wind

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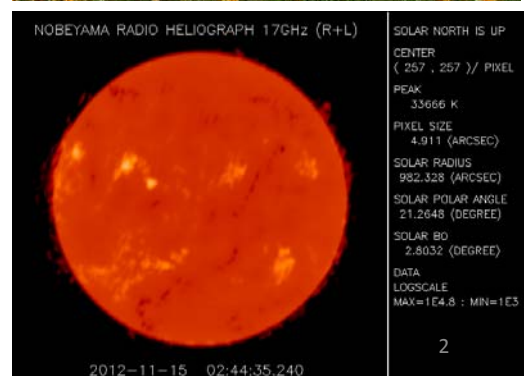
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Nobeyama Radioheliograph (NoRH) <http://solar.nro.nao.ac.jp/norh/>

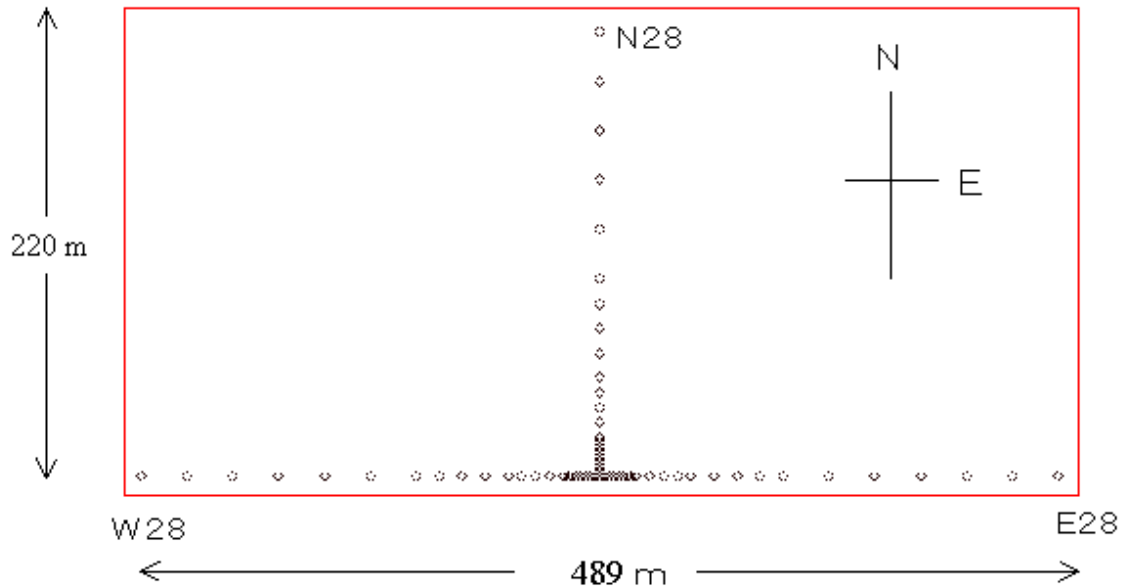
- Specification
 - 84 elements of 80 cm dishes
 - EW: 490 m, NS: 220 m
 - full disk
 - 17 GHz (I & V) and 34 GHz (I)
 - 10 /5 arcsec (17/34 GHz) res.
 - 1 second cadence
 - 0.1 cadence during flares
- Operation
 - 1992.6 ~
 - daily 8 hr (Local noon 03UT +/- 4h)
 - Full automatic operation
 - Images around local noon and every 10 min. are on the WEB



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NoRH Array Configuration



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Radio emission from the Quiet (non-flaring) Sun

- Emission mechanisms
 - mainly thermal emission (thermal electrons)
 - free-free emission
 - gyro-resonance emission
 - simple mechanism (classical EM), electrons are in LTE state, continuum emission: DEM measurements are not possible
 - small contribution from non-thermal emission (small flares)
- Features
 - solar disk
 - active regions
 - dark filaments / prominences
 - coronal holes
 - network and fine structures (high spatial resolution, ALMA?)

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

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Long-term Global Solar Activity Inferred from Microwave Observation

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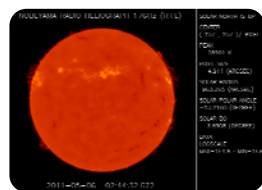
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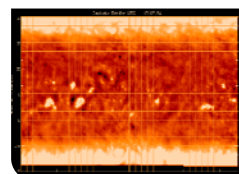
Synthesis of Radio Butterfly Diagram



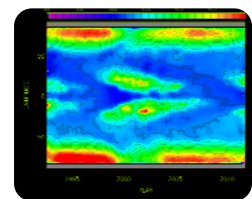
Nobeyama
Radioheliograph
Observation Since
1992



Daily Images
(7000)



Carrington
Rotation Maps
(260)



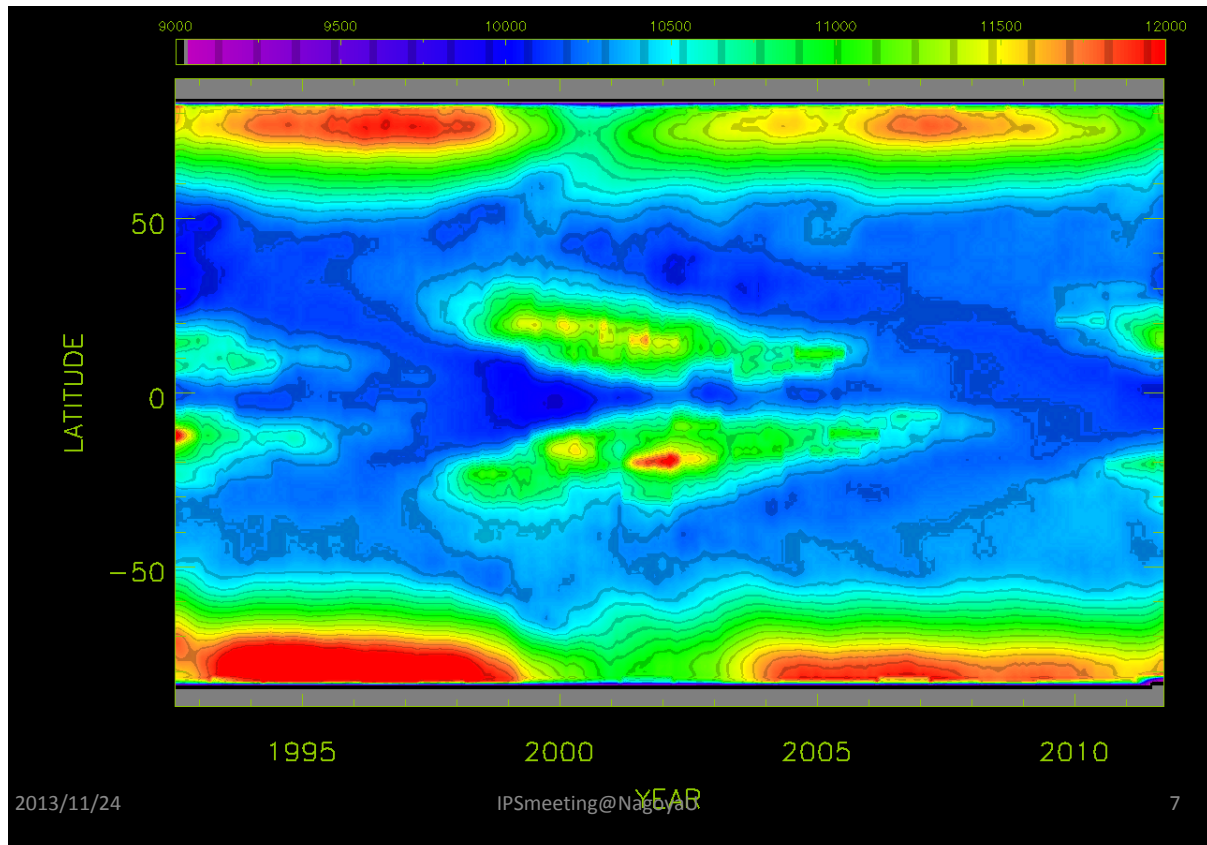
Radio Butterfly
Diagram

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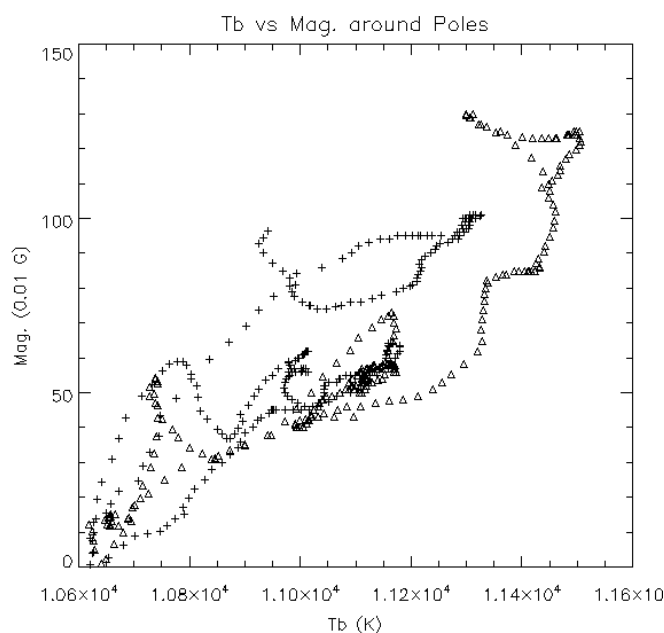
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Radio Butterfly Diagram (1992.7-2011.8)



Correlation between radio brightness and mag. field strength at polar region



- $+$: Np、 Δ : Sp
- Corr. Coeff. = 0.86
 - North : 0.84
 - South : 0.89
- Radio brightness at polar regions is a good indicator of polar magnetic field, even though physical mechanisms are quite different.

Why polar regions are bright in microwave

1. Limb brightening effect
 - Due to unknown heating mechanisms of upper atmosphere
2. Coronal hole effect
 - Polar regions are covered by CHs. > enhanced limb brightening
 - During solar max. period > no CHs, dark filaments absorb / suppress limb brightening
3. Magnetic activity effect
 - Good correlation between unipolar mag. field strength and polar brightening (even in low CHs) suggests hotter chromosphere associated with strong mag. field.
 - Enhanced chromospheric heating is needed in open magnetic field region (what mechanism? wave/flare?) proportional to B.

Long-term Global Interplanetary Activity Inferred from IPS Observation

Solar Wind Speed Measurement using Interplanetary Scintillation by STEL/Nagoya U.

Four stations at Fuji, Toyokawa Sugadaira and Kiso construct four-antenna system, which fully dedicated to ground-based solar wind observations. The routine-based solar v observations have been carried out using the interplanetary scintillation method.



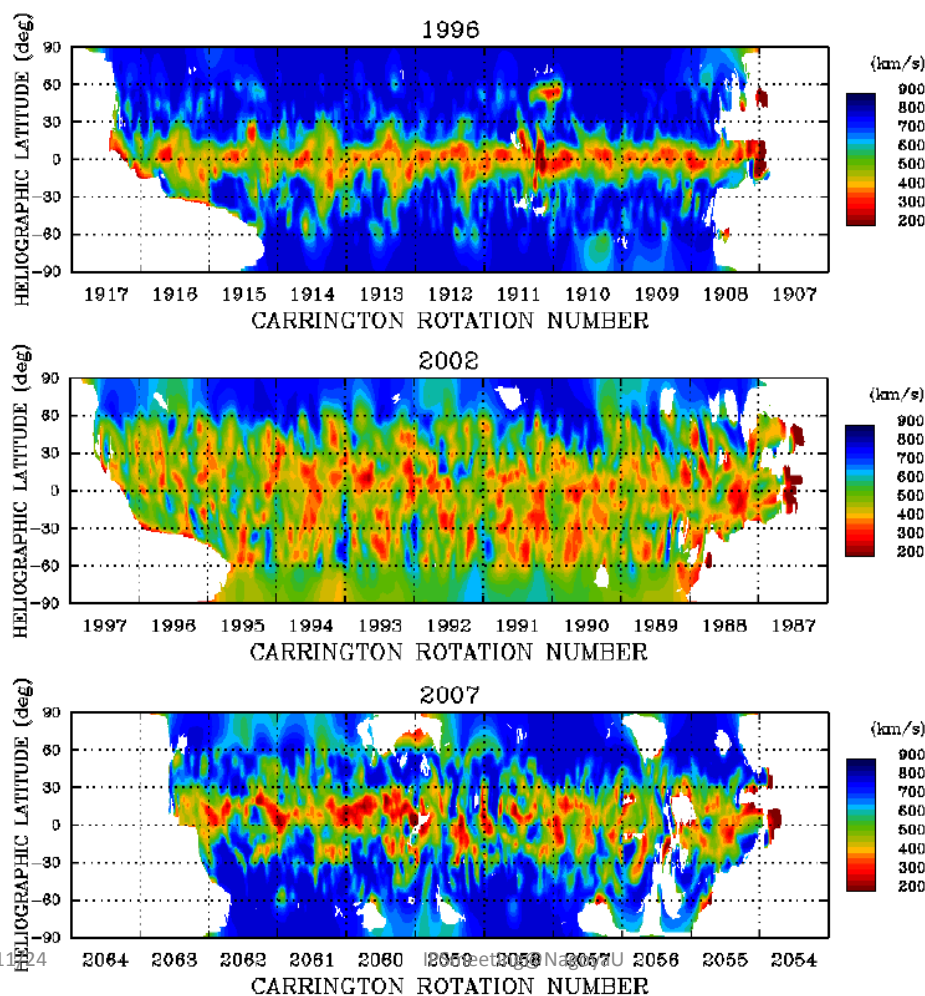
太陽風観測4点システムの観測点の配置。

Geographical arrangement of four-antenna system.

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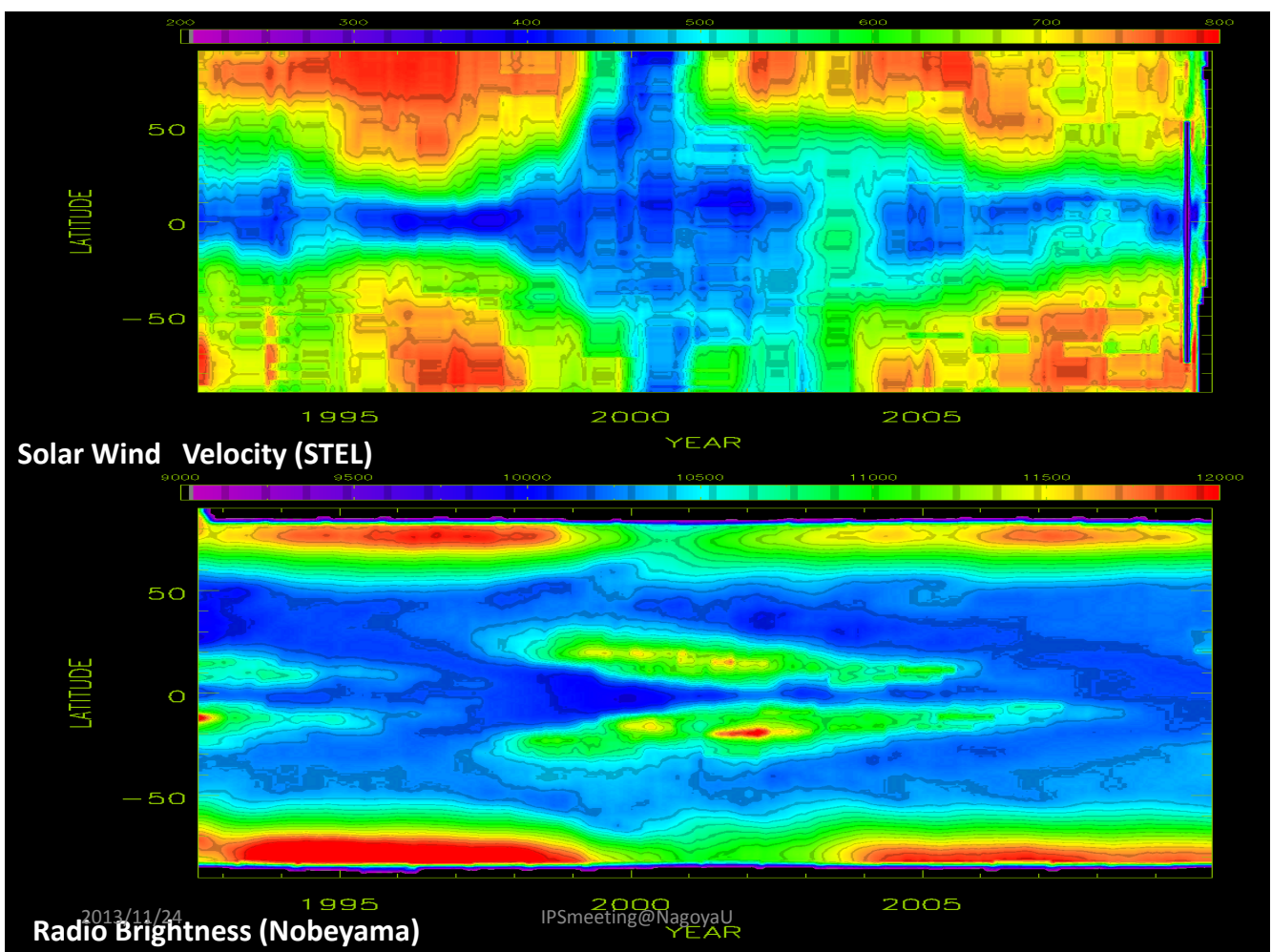
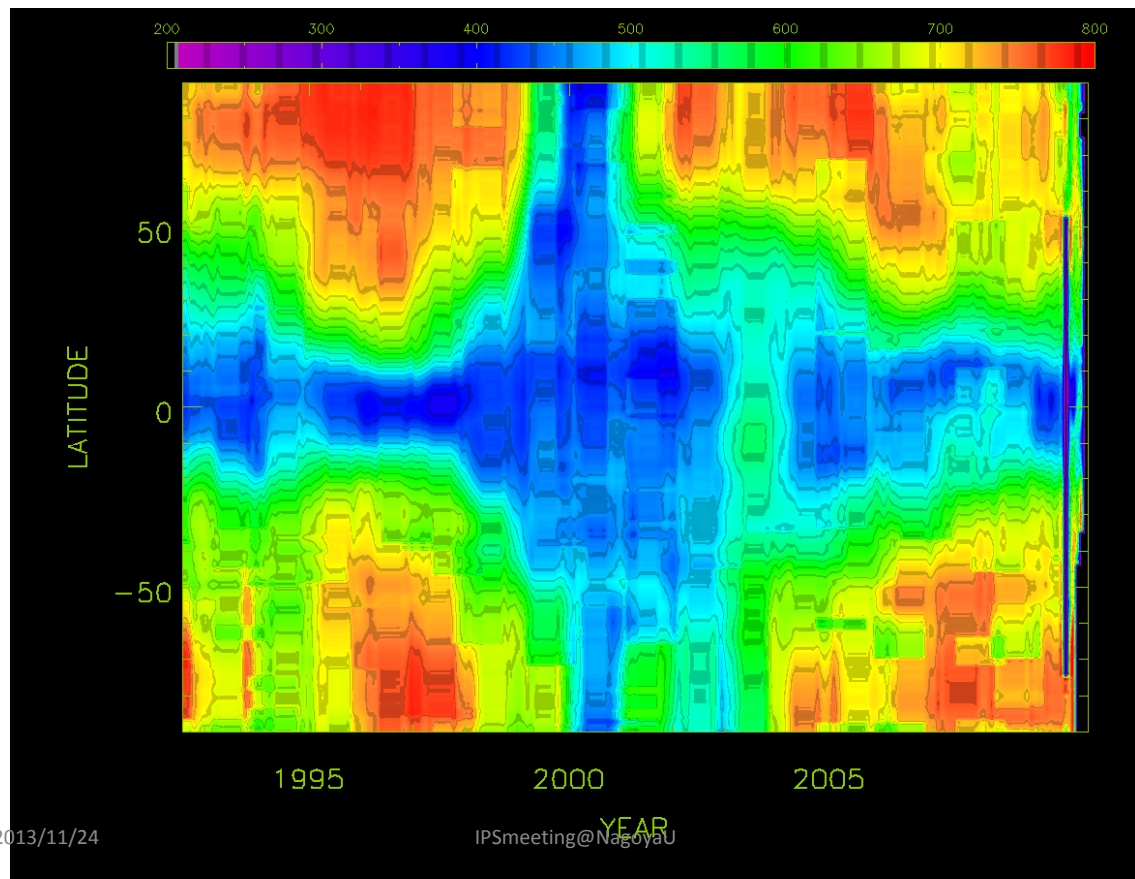


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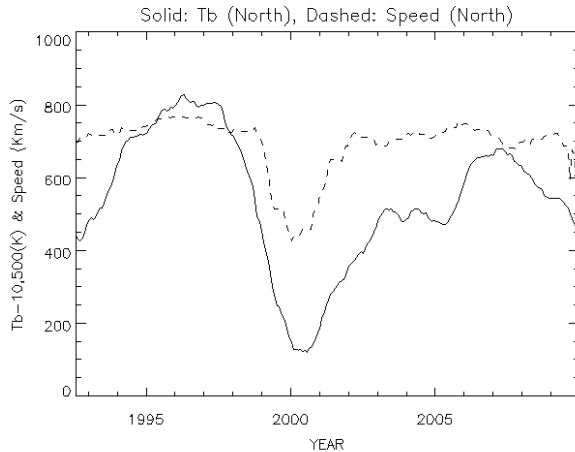
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Solar Wind Speed

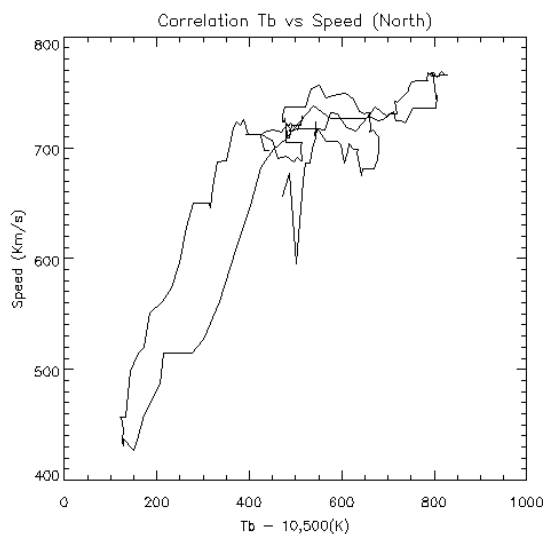


Northern High Latitude Brightness and Solar Wind Speed



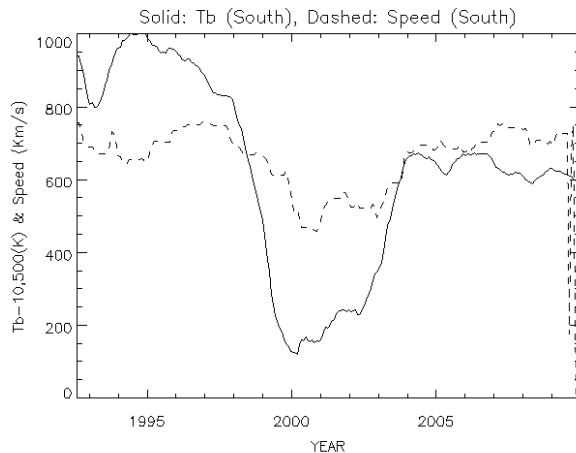
- N55~N80 averaged radio brightness (Tb – 10,500K, solid) and solar wind speed (km/s, dotted)

Correlation between radio brightness and solar wind speed at northern high latitude



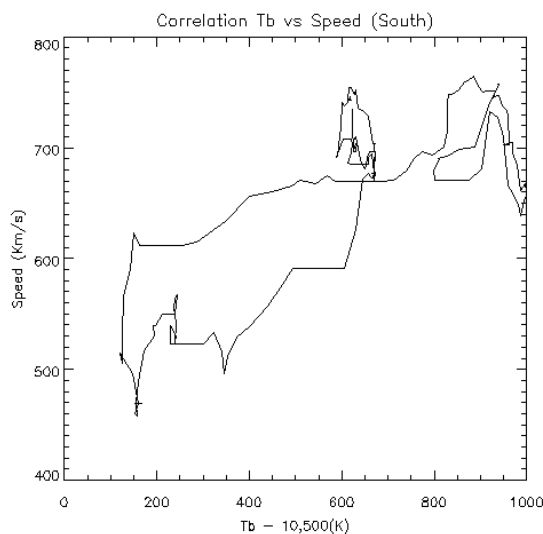
- Correlation Coeff. = 0.83
- Wind speed is nearly constant (750 km/s) at $Tb \geq 11,000$ K

Southern High Latitude Brightness and Solar Wind Speed



- S55~S80 averaged radio brightness (Tb – 10,500K, solid) and solar wind speed (km/s, dotted)

Correlation between radio brightness and solar wind speed at southern high latitude



- Correlation Coeff. = 0.79
- Less clear relation (Tb – speed) compared to the northern hemisphere

Why solar wind speed and radio brightness show so good correlation at high latitude

- Both radio brightness and solar wind speed depends on polar field
 - Radio brightness depends on lower atmosphere
 - Solar wind speed depends on higher atmosphere
- During solar maximum period:
 - polar field is weak > closed magnetic field
 - > suppress Tb and inefficient solar wind acceleration

Summary

- NoRH observed long-term, global activities of the Sun
 - NoRH characteristics
 - full disk observation
 - robust calibration method (redundant array, good uv coverage for extended quiet Sun disk (position, brightness))
 - proper frequency selection of 17 GHz for polar activity obs.
 - long and steady operation for 20 years
- We need further observations to study the current anomalous condition of global solar activity, not only to understand solar activity itself but also its influence to the interplanetary space and to the earth upper atmosphere.