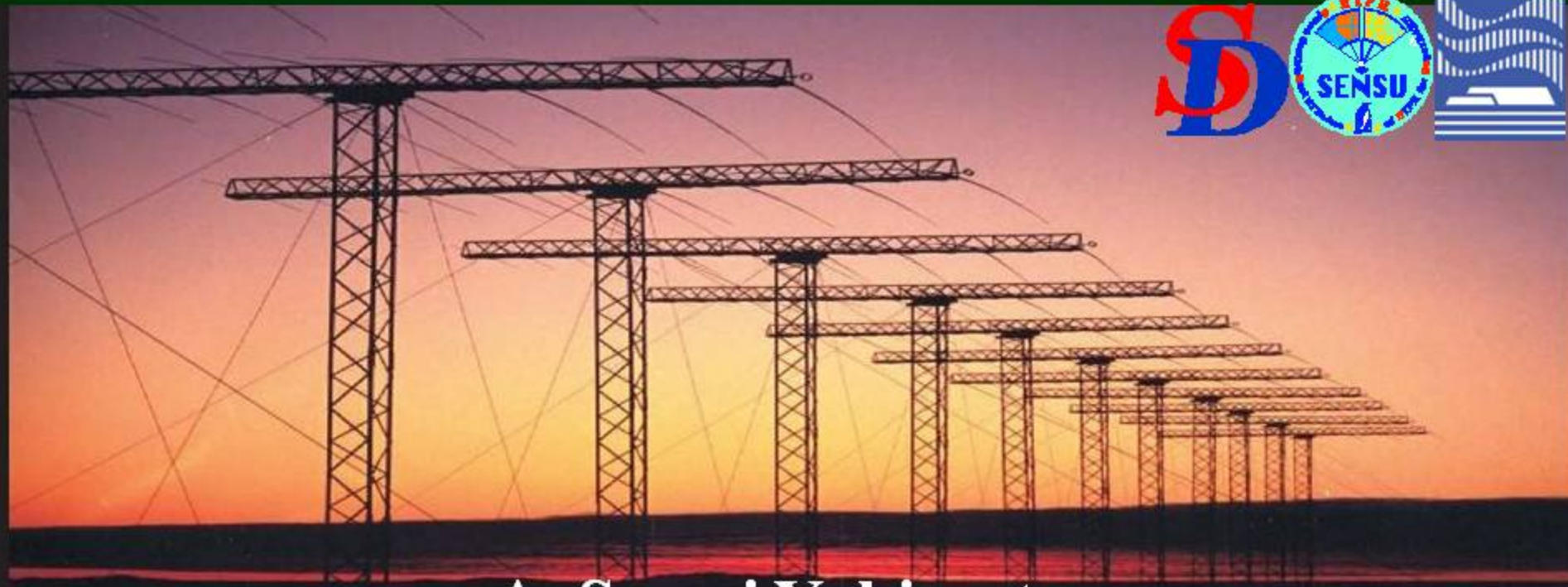
# SENSUレーダー第IX期南極研究観測計画 (2016-2023)

# Antarctic Syowa station SENSU SuperDARN radars in the 9th phase of JARE Antarctic project (2016-2023)

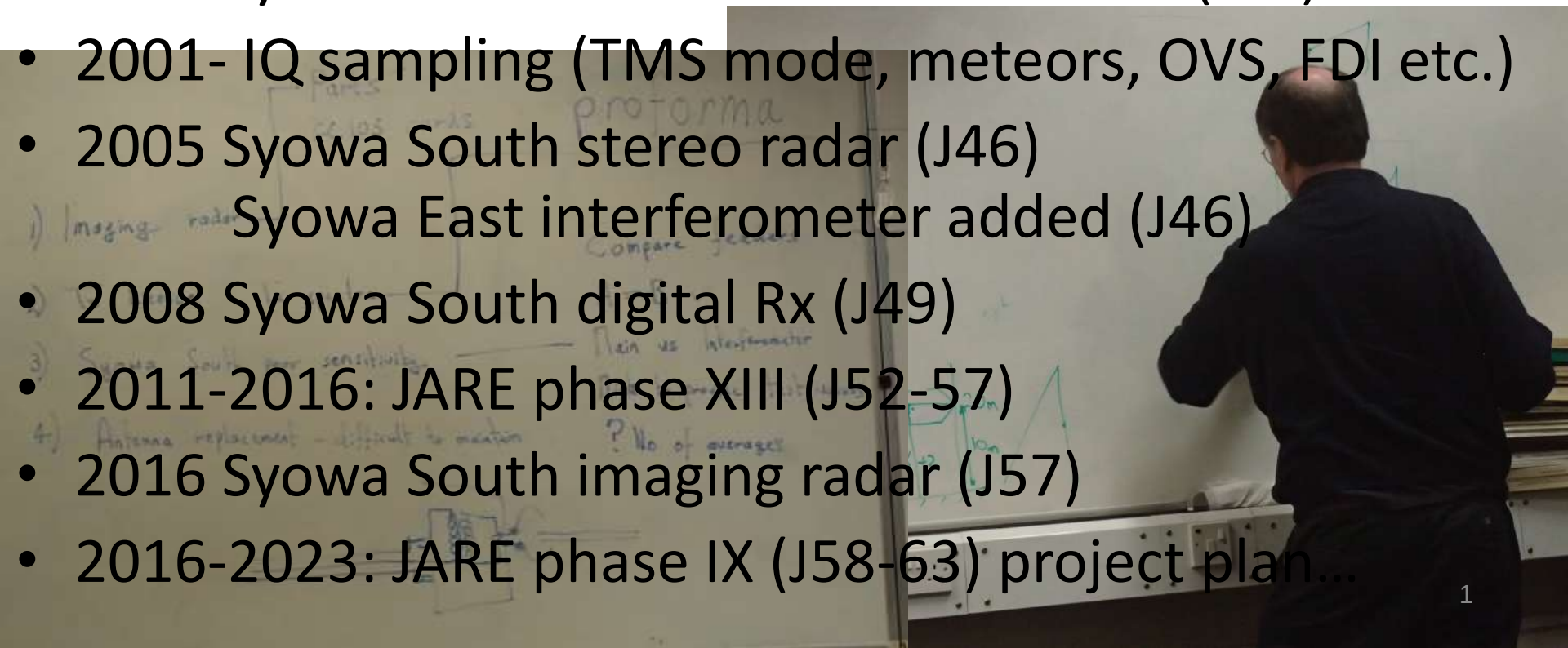


A. Sessai Yukimatu
NIPR/SOKENDAI

*SENSU Syowa South radar taken by Mr. Yasuo Kato, a UAP member of JARE36 in 1995*

# SENSU Syowa brief history

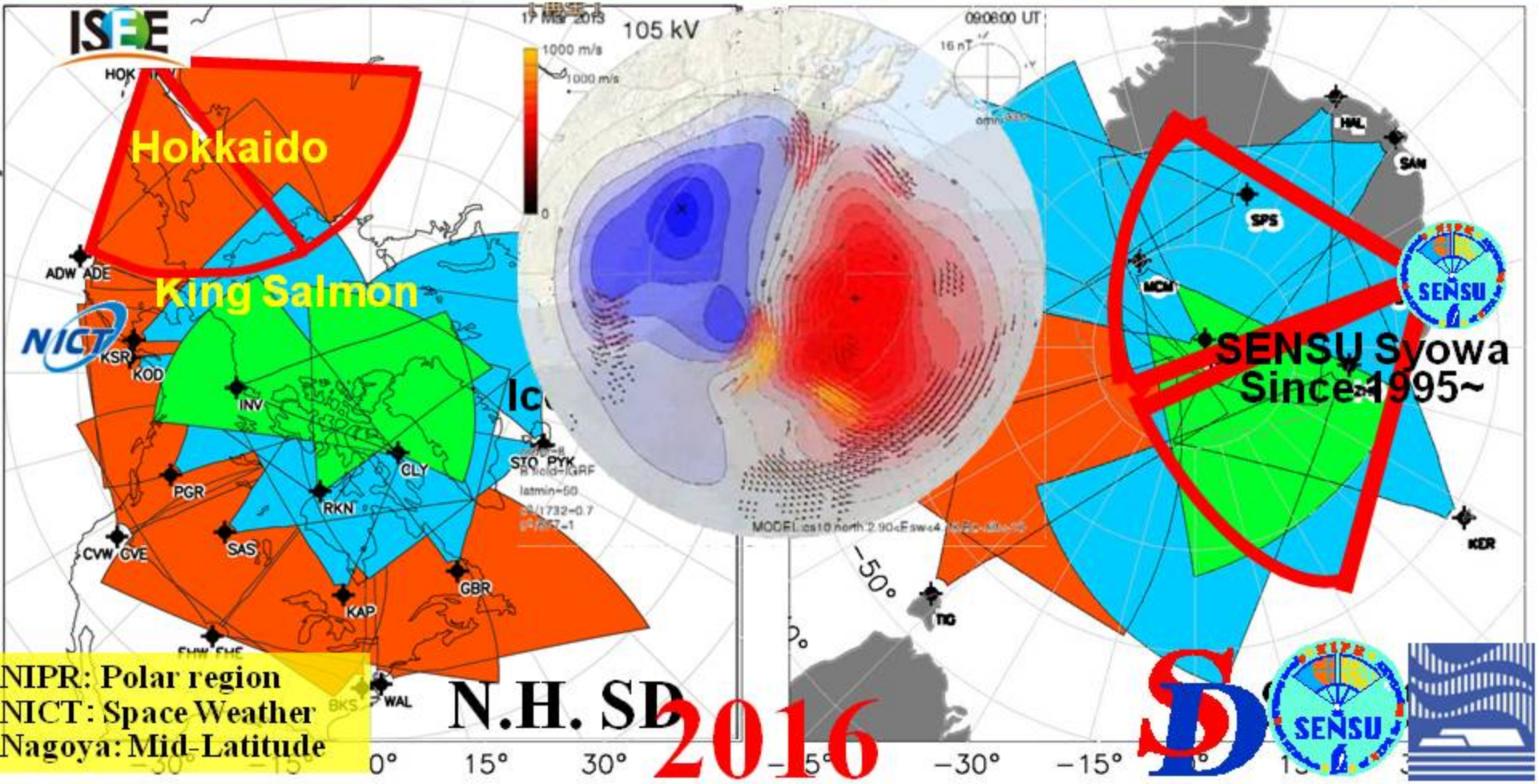
- 1989 Prof. Ogawa proposed to join HFR network
- 1995 SuperDARN started and NIPR joined
  Syowa South installed & started (JARE36)
- 1997 Syowa East installed & started (J37)
- 1999 Syowa South antenna reconstructed (J40)
- 2001- IQ sampling (TMS mode, meteors, OVS, FDI etc.)
- 2005 Syowa South stereo radar (J46)
  Syowa East interferometer added (J46)
- 2008 Syowa South digital Rx (J49)
- 2011-2016: JARE phase XIII (J52-57)
- 2016 Syowa South imaging radar (J57)
- 2016-2023: JARE phase IX (J58-63) project plan...



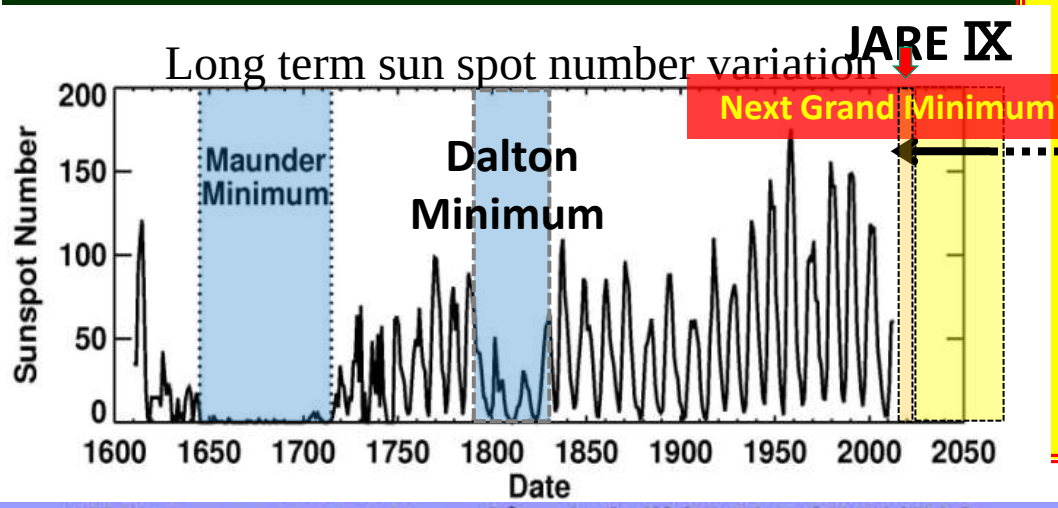
# AP0904 SuperDARNレーダーを中心としたグランドミニマム期における極域超高層大気と内部磁気圏のダイナミクスの研究

## Studies On Polar Upper Atmosphere during Possible Solar Grand Minimum Period and Inner Magnetosphere Dynamics with SuperDARN Radars

A. S. Yukimatu(PI), H. Miyaoka, T. Nagatsuma, N. Nishitani, K. Hosokawa, T. Hori, M. Watanabe, H. Kawano, Y. Tanaka, Y. Ebihara, N. Sato and A. Kadokura



# Scientific targets and objectives

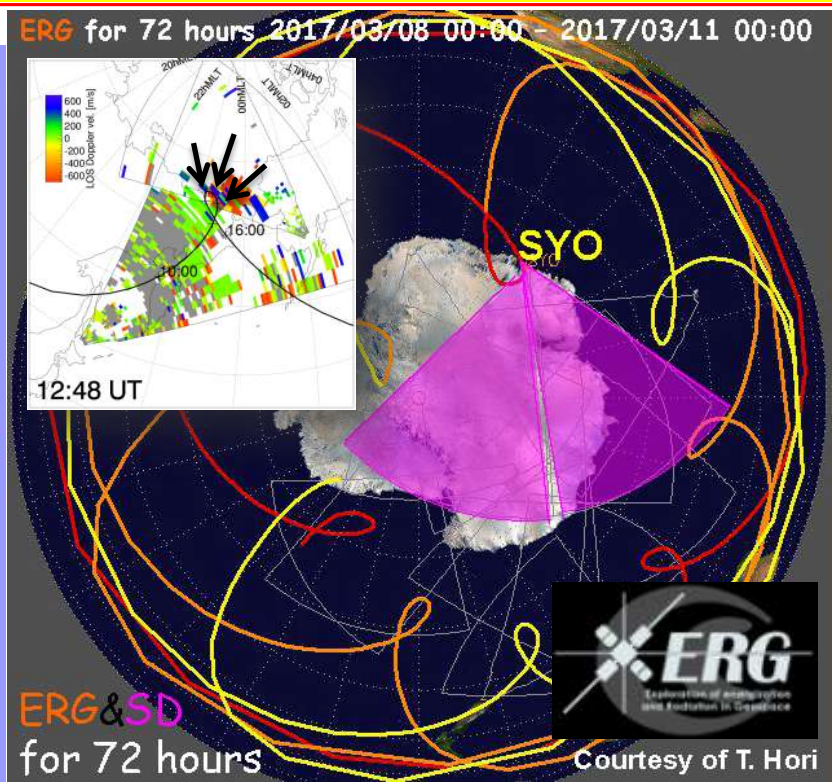



国際SuperDARN超高層大気観測と広域光学観測網による

**■Influences of Grand minimum (or low solar activities) to polar upper atmosphere**

**■Studies on dynamics of Inner magnetosphere**

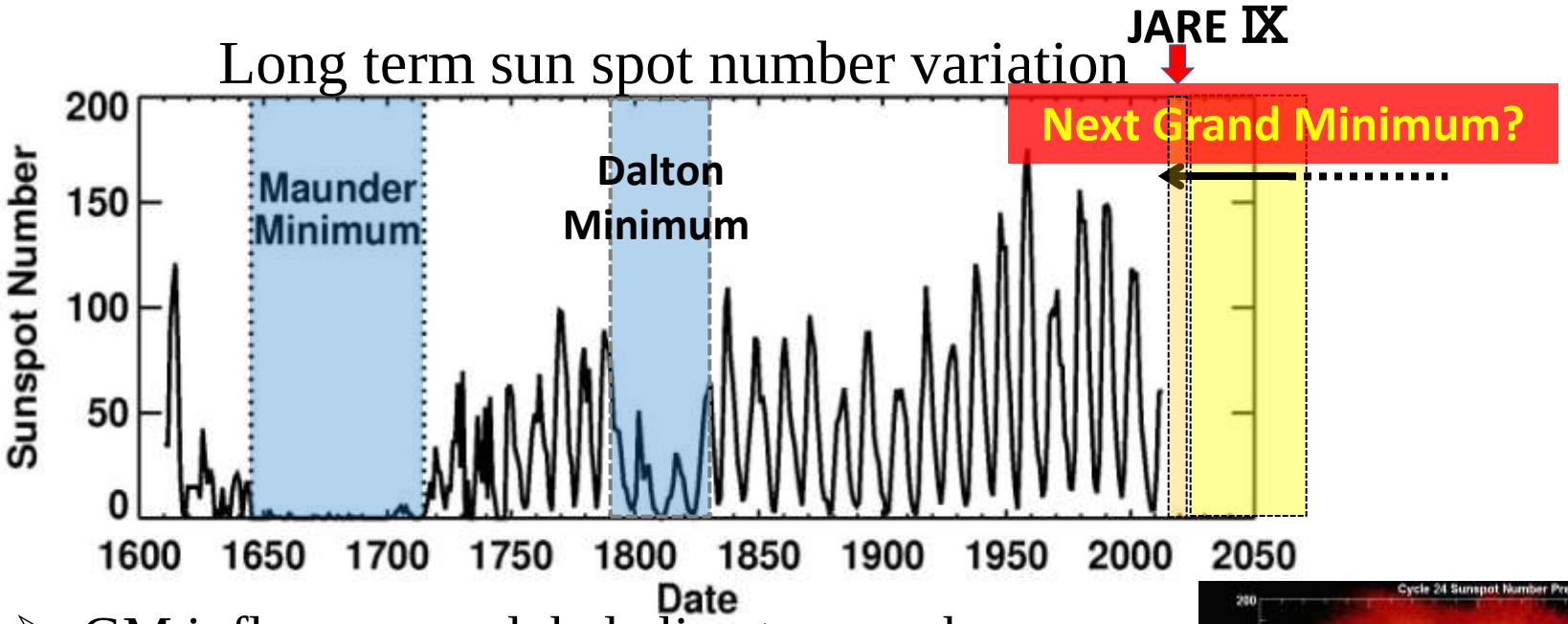
**★contribution to researches by ERG(FY2016)/VAP GB obs network, VarSITI(ISEST$_{(MinMax24)}$/SPeCIMEN/ROSMIC)**

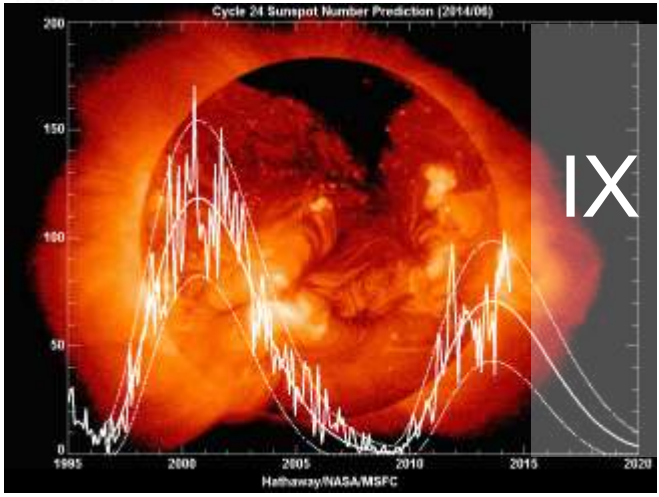
# **JARE IX** 6-year project period (FY2016-2023)

- Enter into solar minimum period (during normal 11-year cycle)
- Historical lowest solar activity since IGY expected

Long term sun spot number variation




- GM influence on global climate env. change : unknown incl. relation. w/global warming – quantitative evaluation is necessary.
- Polar upper atm. – most sensitive to external env. change including of solar activity, solar wind

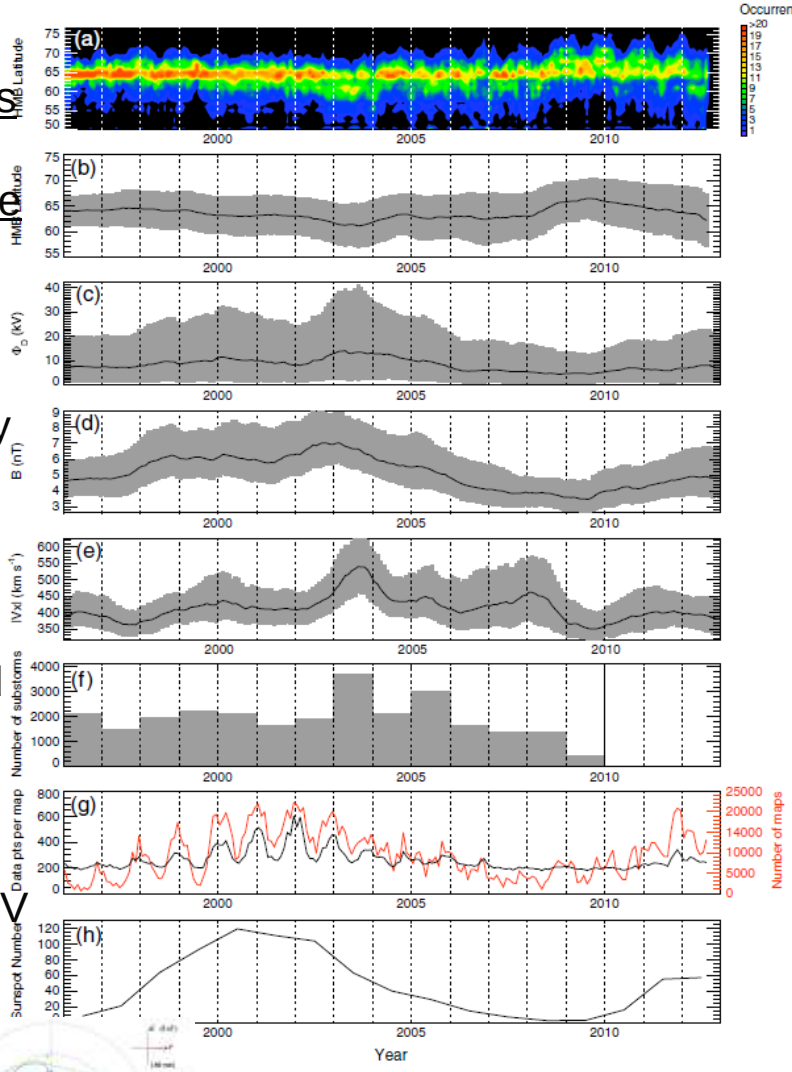


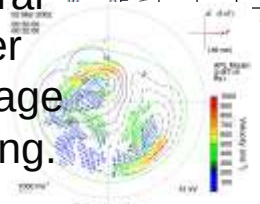

JARE: Japanese Antarctic Research Expedition

from Kadokura et al., NIPR Antarctic Observation Symposium 2014

# Importance on Grand Minimum studies

- Current unusual low solar activity suggests possible entrance into next historical Grand minimum. It is important to investigate and understand quantitatively its long term impacts on polar upper atmospheric environment and moreover global atmosphere or climate changes. It is just time for comprehensive researches, which also fits one of the main themes of SCOSTEP/VarSITI program.
- Changes of possible solar wind (and cosmic ray) energy inputs, influences on magnetospheric structure, e.g., cusp, polar cap, auroral oval, ionospheric convection, precipitating particles and distribution of high and low energy particles including radiation belts and those influences especially on polar upper atmosphere should be carefully investigated. E.g. Statistical study on relationship between solar activity/SW parameters and SD convection / cusp lat. has been started.
- Recent still growing SuperDARN network with wider FOV coverage in both hemispheres as well as higher spatial and temporal resolutions, also with capability of neutral wind detection, in conjunction with satellites and other ground based observation network has great advantage for the studies on SW-M-I-UA-LA cross region coupling.



**Imber, et al., JGR, 2013**

# Strategy

- Studies on **influences of Possible Grand minimum (less active solar activities in a longer term) on Coupling processes of Solar Wind, M-I coupling, storms/substorm activities, neutral-ionized atmos. coupling (cross-region couplings) and interaction btw high and mid lat. ionosphere**
- **Less storms? Also less substorms activities??**
- Less auroral activities? smaller auroral oval? less bright?
- Shrunk polar cap? – higher latitude for OCFLB? – how about cusp lat.??

  SD, optical auroral measurement network
- how subauroral region phenomena will change and how it will influence on high and mid latitude ionosphere and interaction inbtw?
- Radiation belt at higher latitude? Ring current & plasmapause?
- Less sources of high energy particles due to less active acceleration mechanisms?
- Or **increasing GCR** causes higher population and more active energetic particles?

  Ne increase at lower upper atmos.? How about altitude of ionosphere?

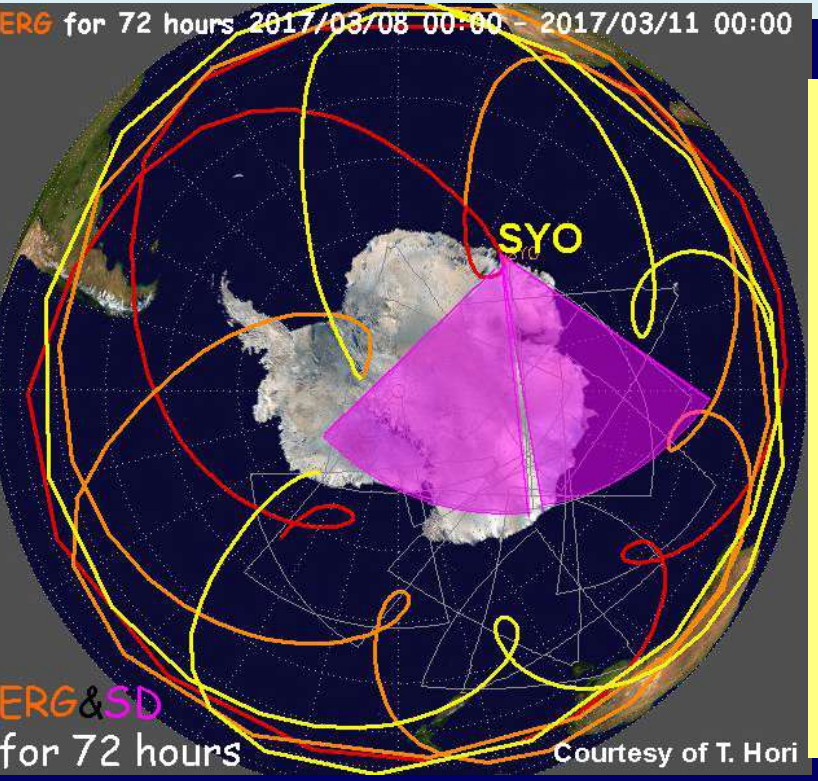
  -VAP, ERG, SD, … all closely related to…

  - **SCOSTEP/VarSITI/ISEST/MinMax24 and SPeCIMEN**
- How less active ionospheric phenomena could cause lower atmosphere climate?

  SD and PANSY with optical inst. over and around Syowa

  -**SCOSTEP/VarSITI/ROSMIC**

# ERG & VAP footprints under SD FOVs and PC5 monitoring, SC events

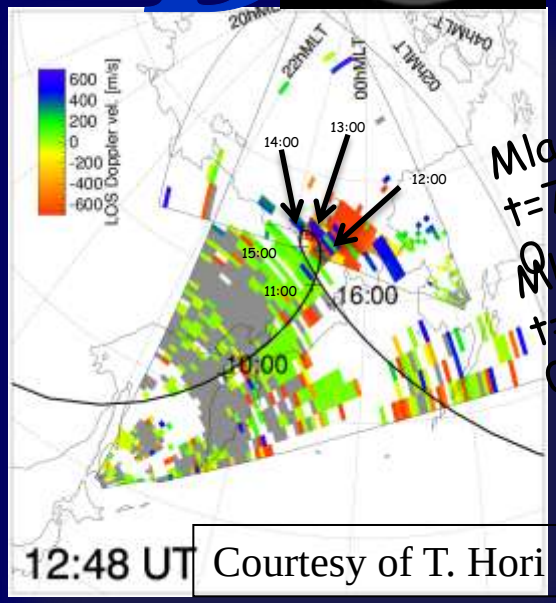



## SD-ERG collaboration

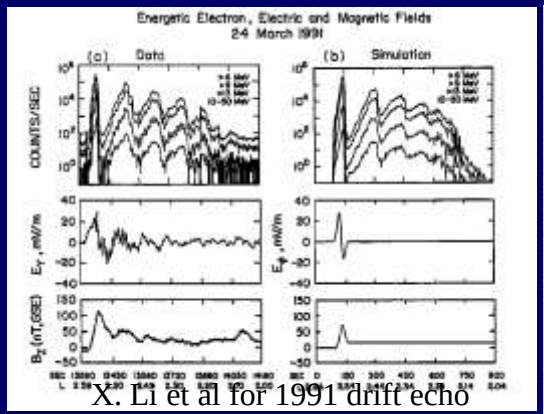
Global E & Pc5 monitoring – particle accelaration mechanisms

Special mode for conjugate obs.

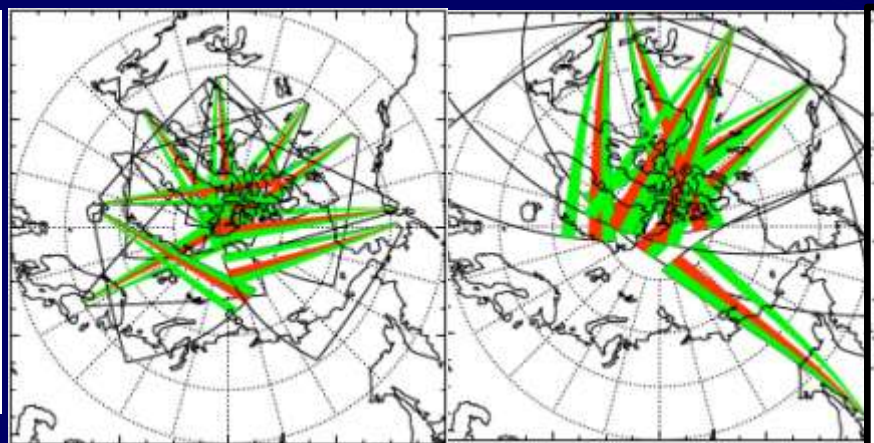
Global E at SCs …

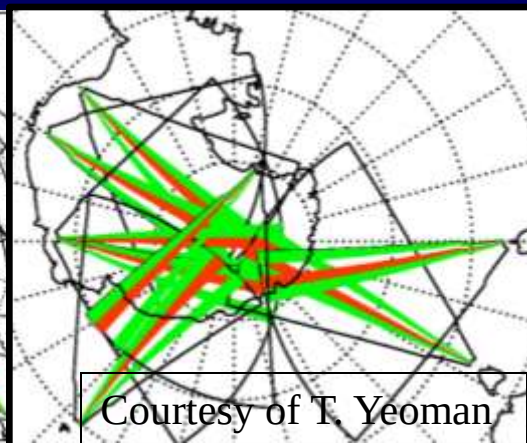



Courtesy of T. Hori



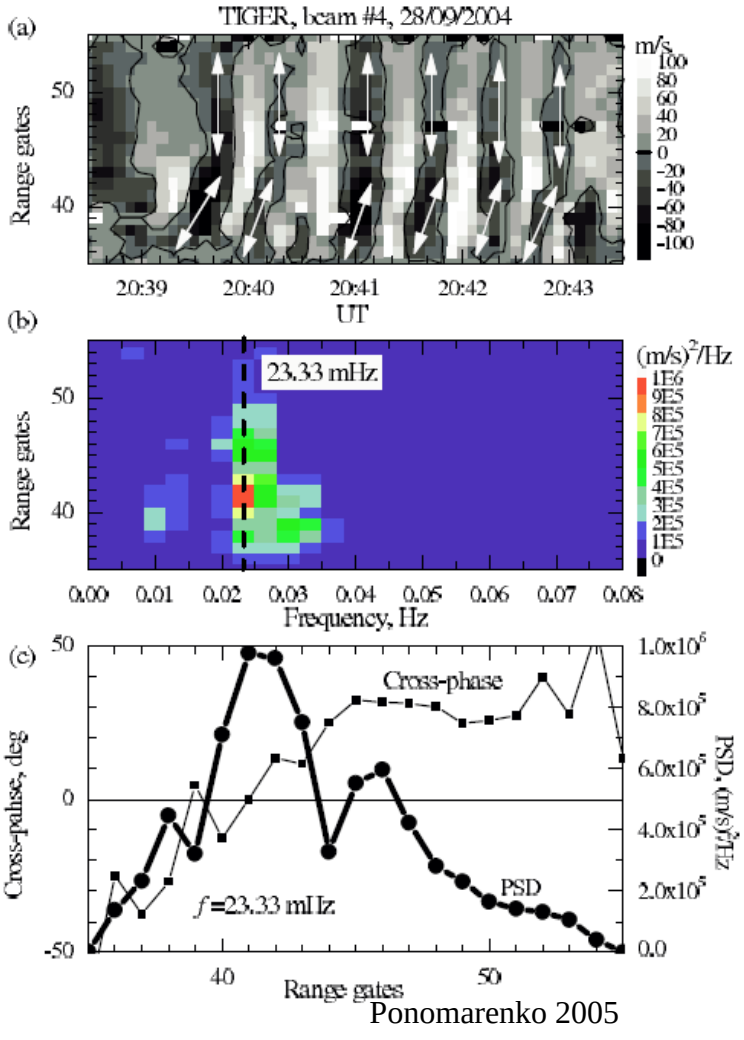

X. Li et al for 1991 drift echo events triggered by an large SC





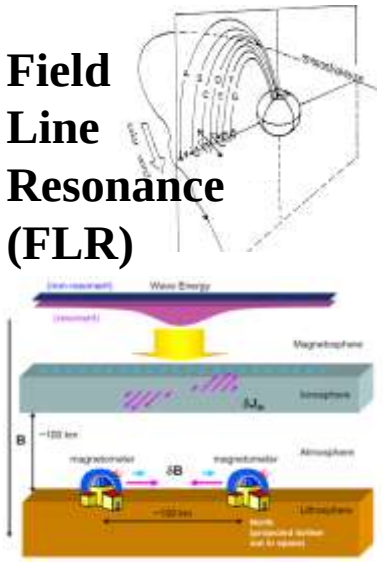
Courtesy of T. Yeoman

# SD P.P. Detection by monitoring Pc5 FLR (collaborative work w/Kawano@Kyushu)



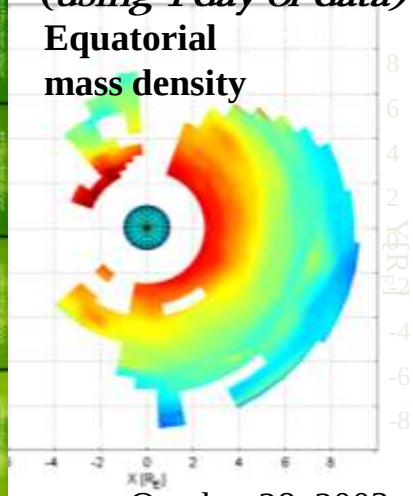

Ponomarenko 2005

**Field Line Resonance (FLR)**

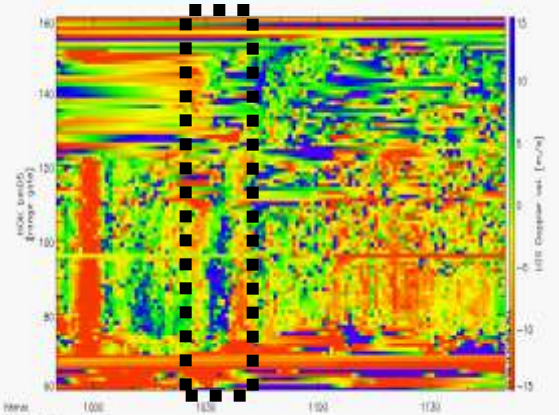


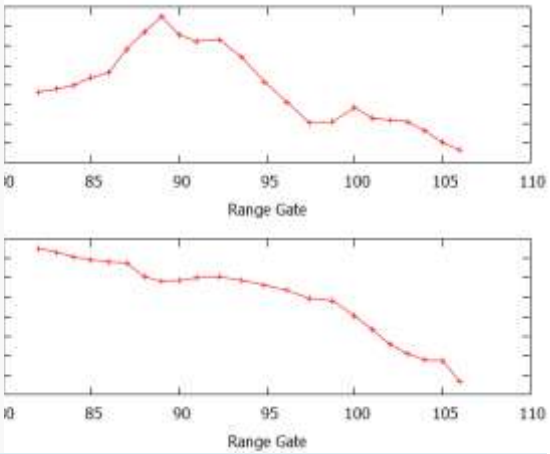

*From ground FLR (using 1 day of data)*

**Equatorial mass density**



October 28, 2003






Kawano 2015 (submitted)

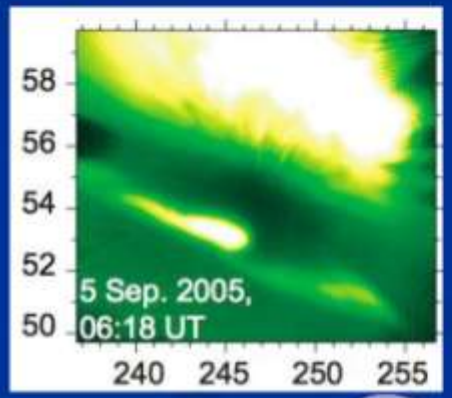
→SDdePPdet-Collaboration w/ H. Kawano

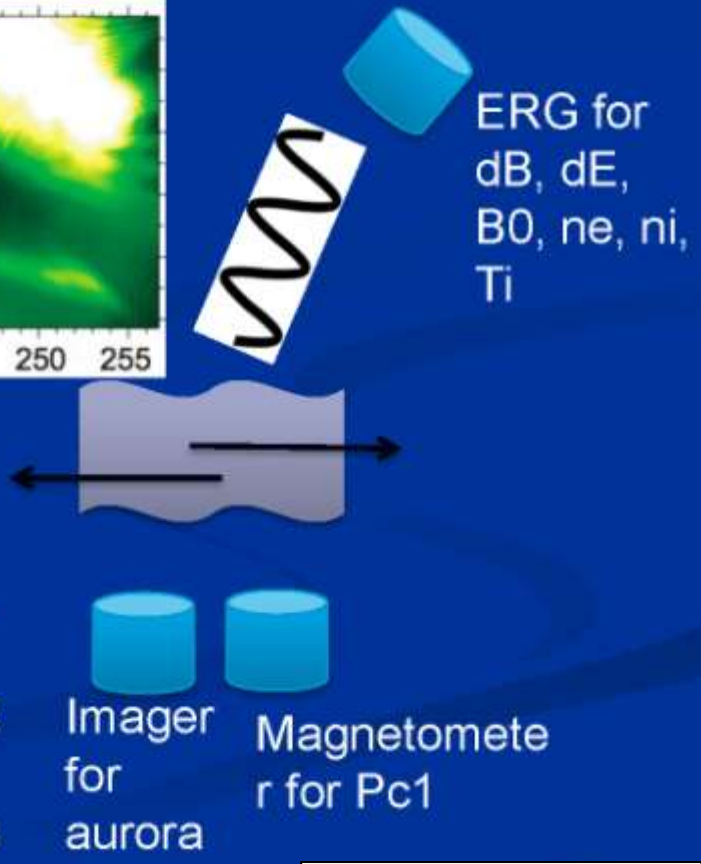
Courtesy of H. Kawano

# Study on the motion of Pc1/EMIC proton auroras

The proton aurora which related to Pc1/EMIC shows swinging and drift motions in longitude and latitude, respectively. Is there relation with ambient convection?

- Proton aurora
  - ground-based imagers (OMTI, THEMIS, NORSTAR)
- Pc1/EMIC
  - induction magnetometers (STEL, CARISMA, and ERG)
- Convection
  - mid-latitude SuperDARN radars
  - ~1 min. resolution required
- Plasma parameters for the EMIC generation: $B_0$, $f_{pe}/f_{ce}$, ion ratio, ion temperature
  - ERG



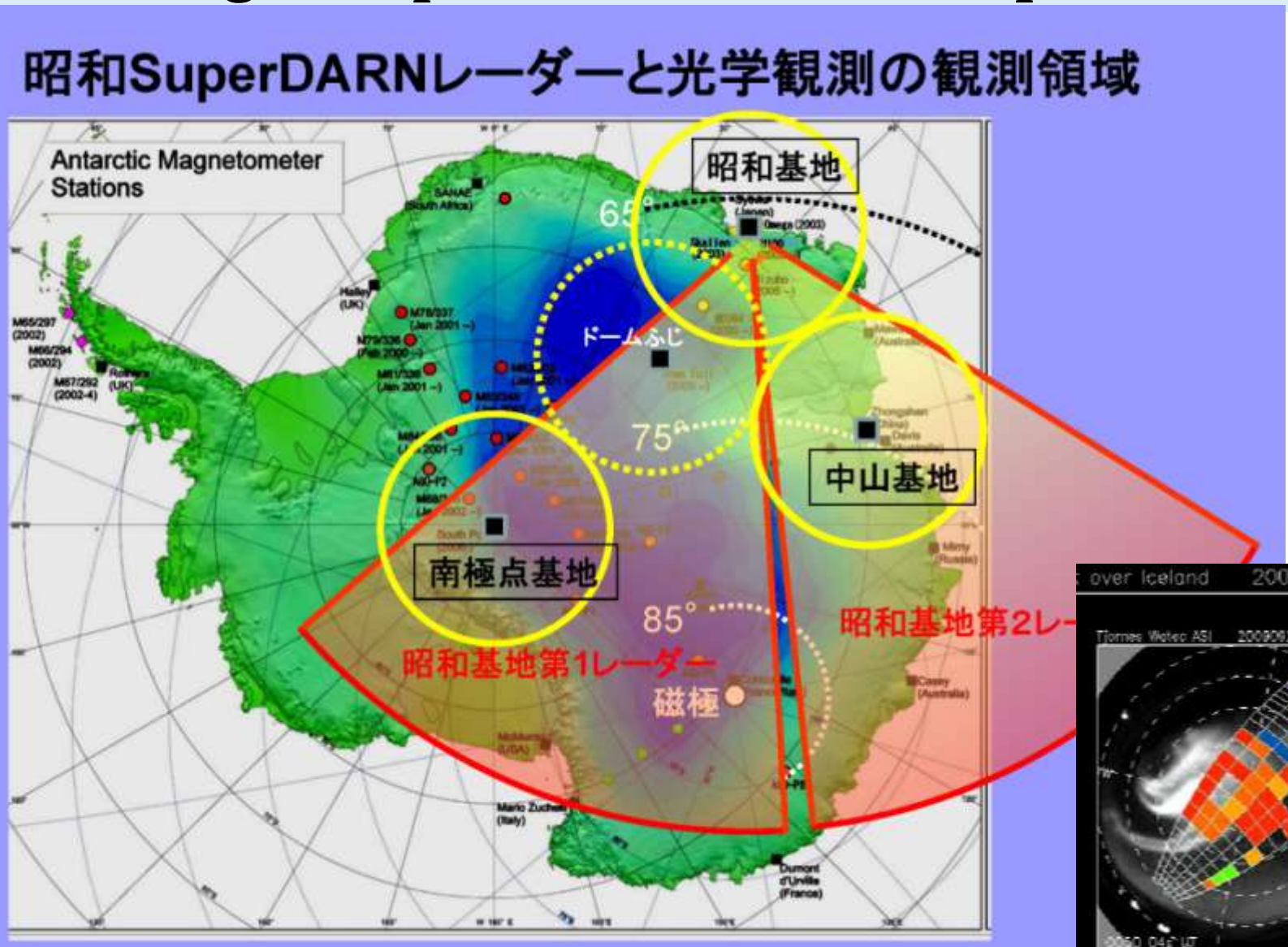




→SDdeEMIC-Collaboration w/ T. Hori

, SD-j-core meeting @NIPR

Courtesy of T. Hori

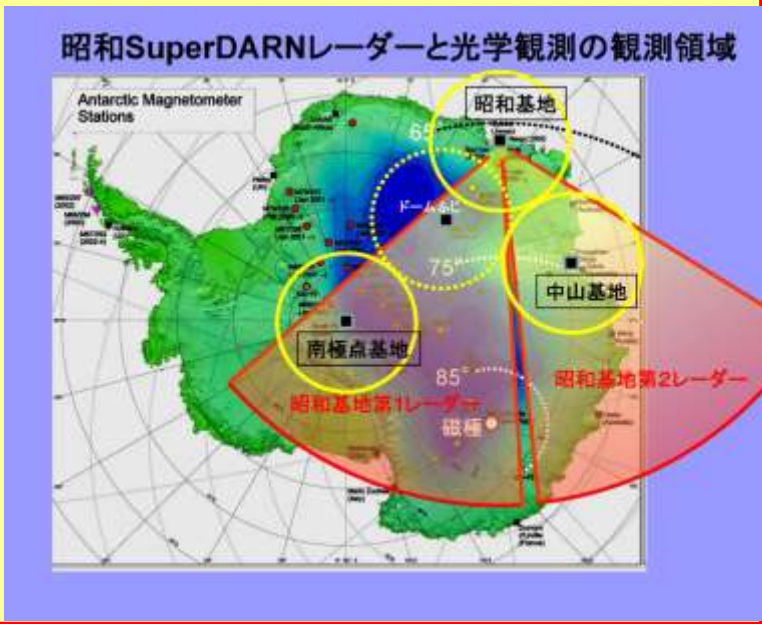
# FOVs of all sky camera network under SENSU FOVs & 2-D high temp. resol. Aurora SD/Opt. observation



# MOON (Multi-point Optical Observation Network)

## Multi-points All-sky imager obs. under SENSU FOVs

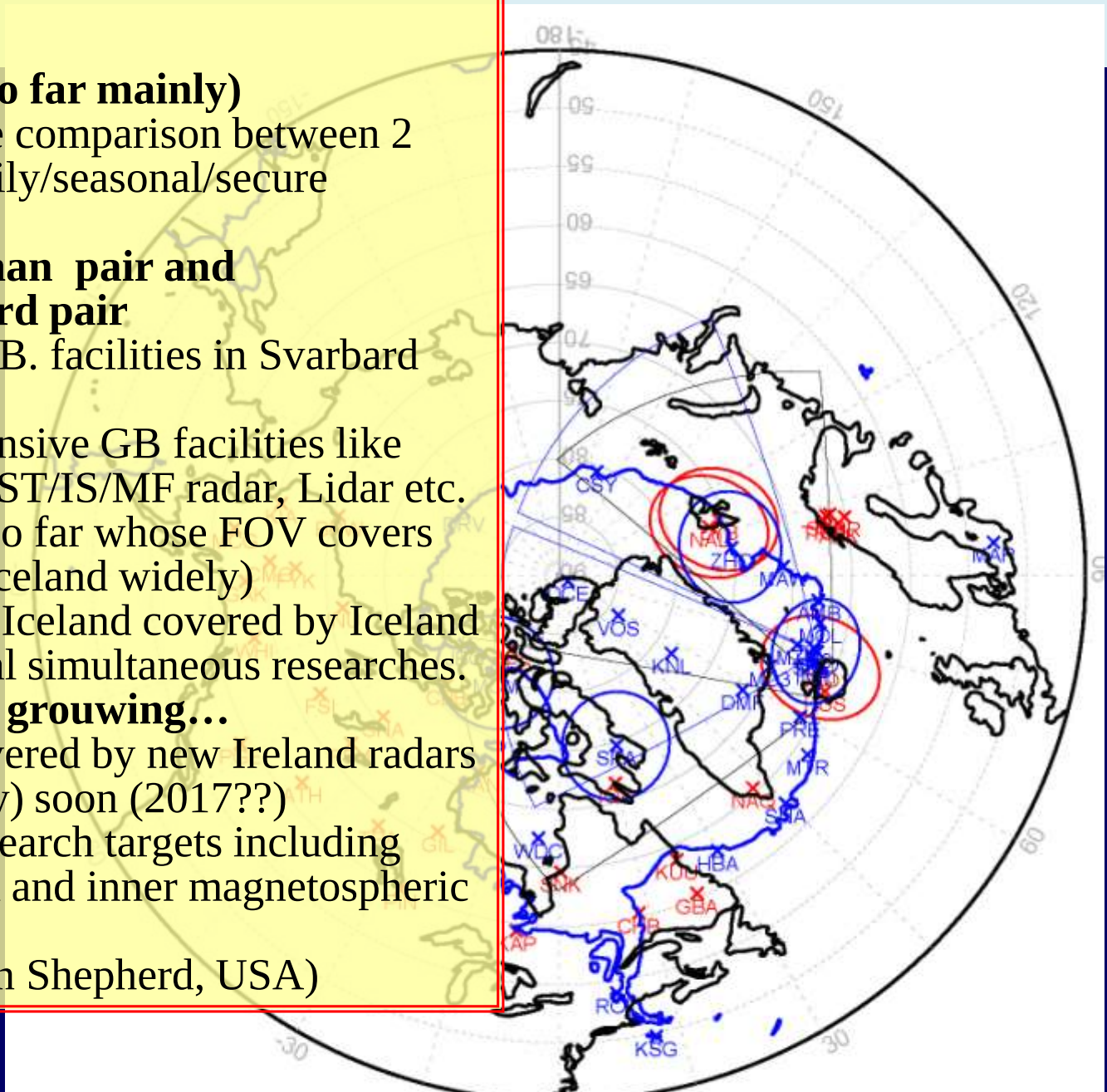
- **All-sky imager @ Chinese Zhongshan station in Antarctica**
  - All sky color imager since 2012 (delegated to PRIC/CHINARE)
  - Plan to upgrade to monochromatic all-sky camera
- **All-sky imager at Dome-Fuji station in Antarctica**
  - Installed in 2013 – self-automatic camera using PLATO-F unmanned power supply system.
    No Dome-F operation due to icebreaker difficulties to access Antarctica several years, currently the observation stops.
  - Plan to resume its operation after Dome-F ope. Resumes in later JARE 9th phase.
- **All sky imager at South-pole station**
  - It will continue to operate with other JARE project, AP1003 by Y. Ebihara.



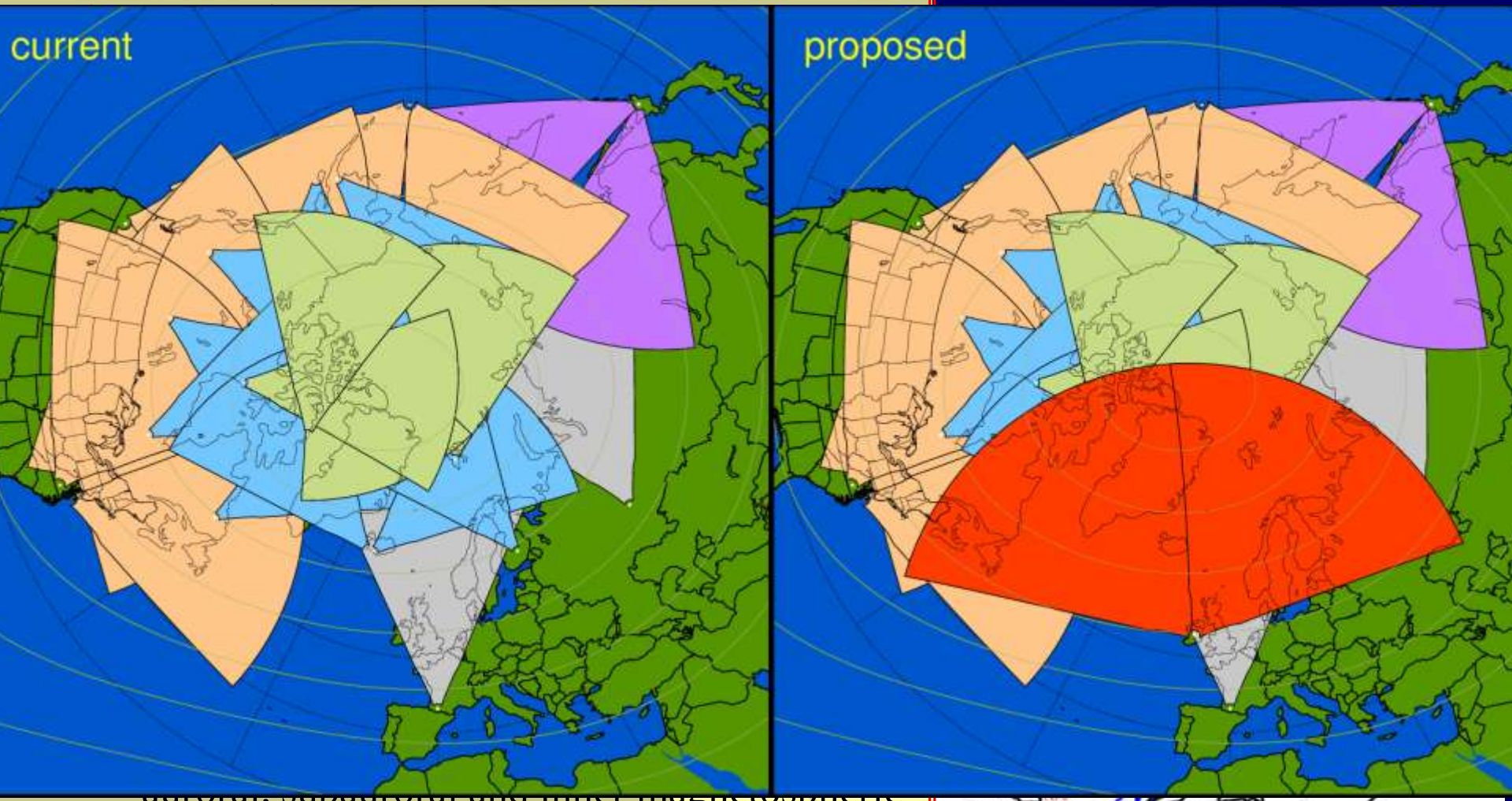
# Future conjugate observation

## 広域共役点観測

- **Syowa-Iceland pair (so far mainly)**
  - Limited area – fine comparison between 2 points but large daily/seasonal/secure variation.
- **Syowa East +Zhongshan pair and Iceland East – Svalbard pair**
  - Comprehensive G.B. facilities in Svarbard and Zhongshan
  - Syowa : comprehensive GB facilities like Many opt. inst., MST/IS/MF radar, Lidar etc. But no SD radars so far whose FOV covers over Syowa (and Iceland widely) though Tjornes on Iceland covered by Iceland East – many optical simultaneous researches.
- **However,… SD is still grouwing…**
  - Iceland will be covered by new Ireland radars possibly (hopefully) soon (2017??)
  - Many potential research targets including auroral, subauroral and inner magnetospheric studies… (proposal by Simon Shepherd, USA)



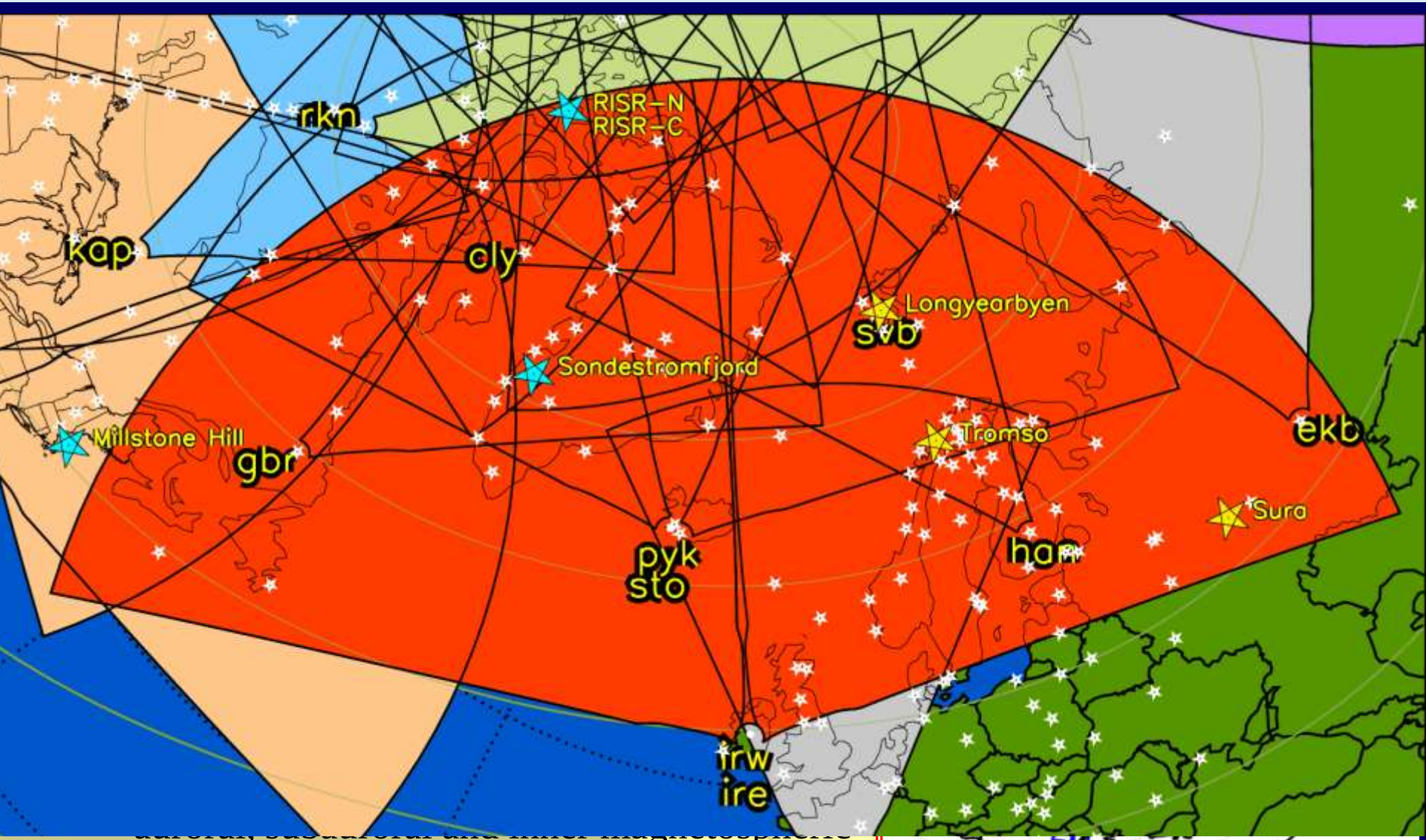
# Future conjugate observation




auroral, subauroral and inner magnetosphere studies…

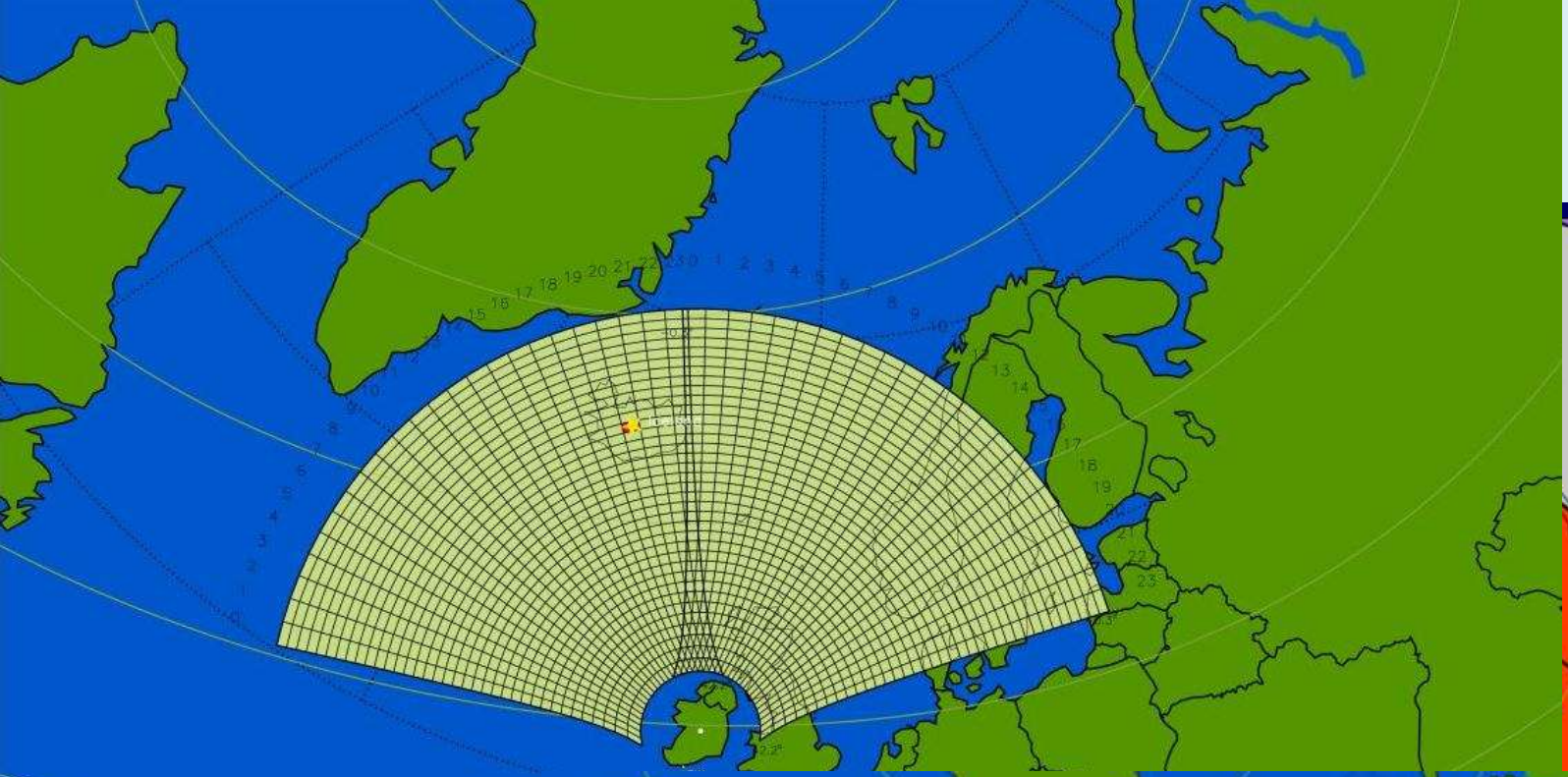
Courtesy of S. Shepherd

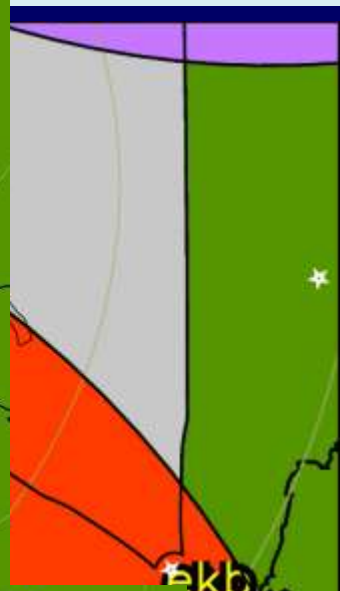
# Future conjugate observation

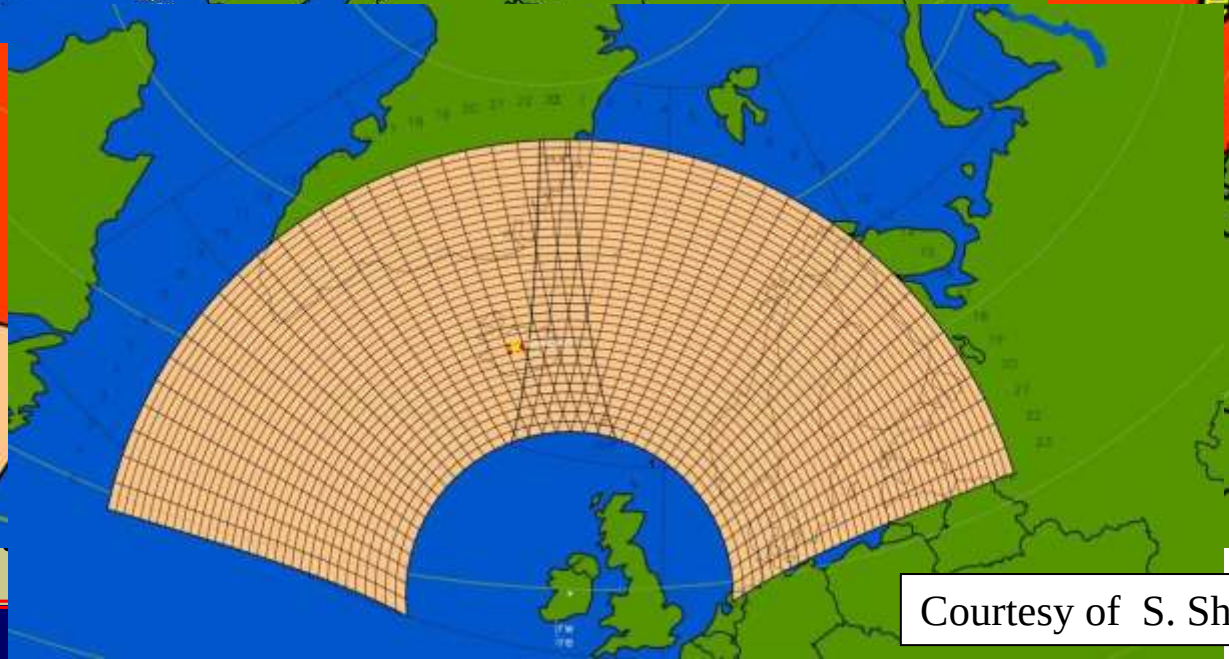



studies…

Courtesy of S. Shepherd







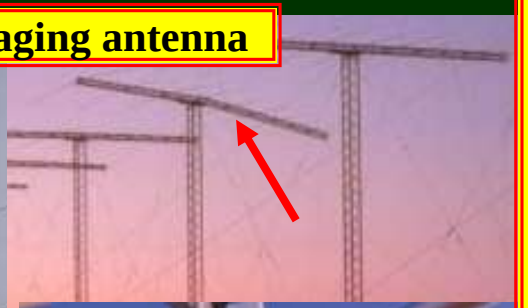
studies…

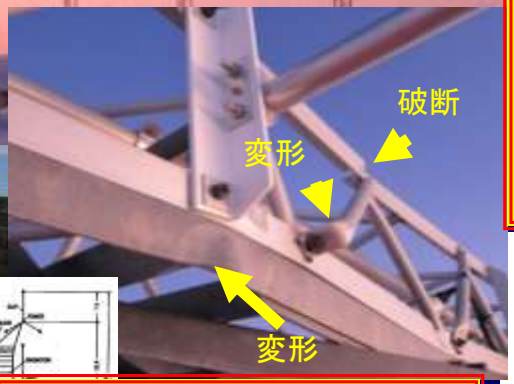
Courtesy of S. Shepherd

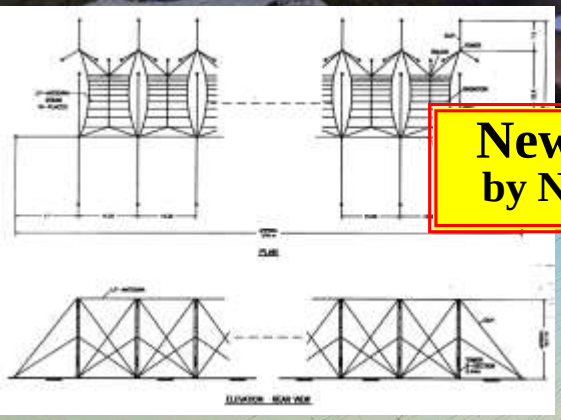
# Antenna upgrade


**More than 20 yrs have passed since first light in 1995, maintenance of aging antenna get harder and issue due to metallic fatigue started to appear these years – replacement by a new type wire log-periodic antenna (used in SD Alaska radar) is being planned and been prepared.**

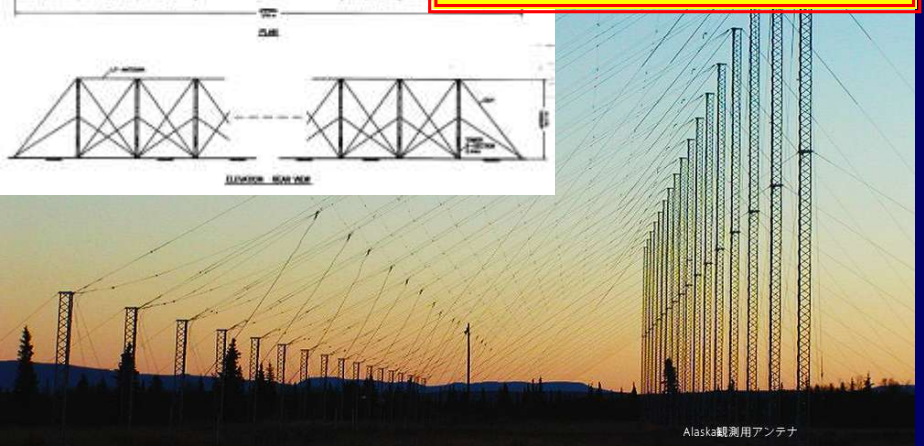
## Hard maintenance of aging antenna

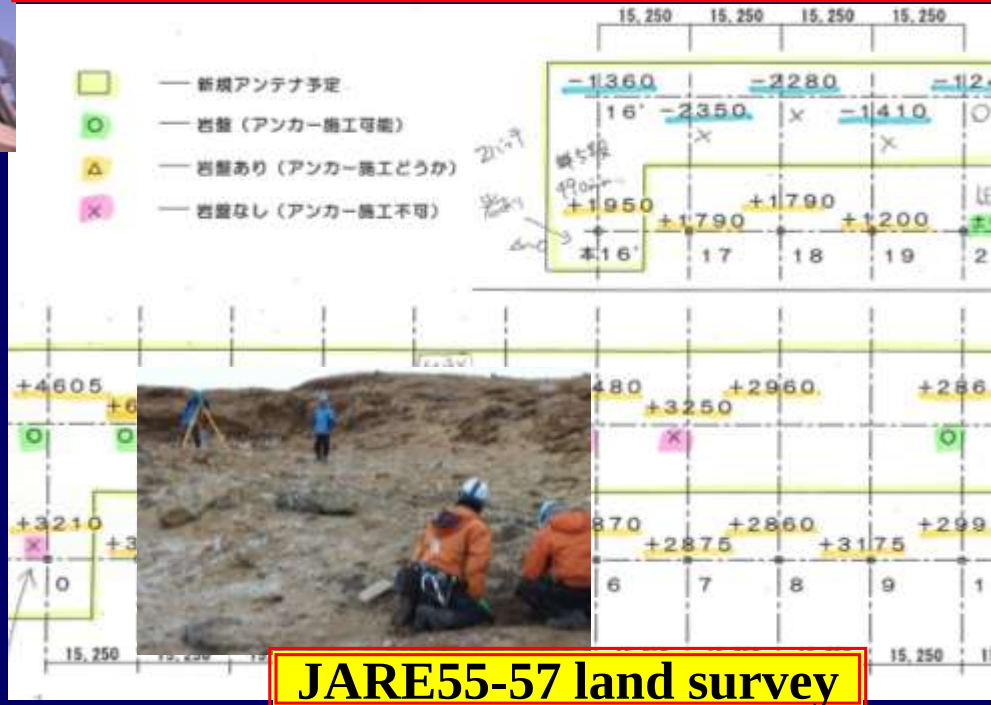




## New wire LP ant.
**by NICT(wje)@Alaska**



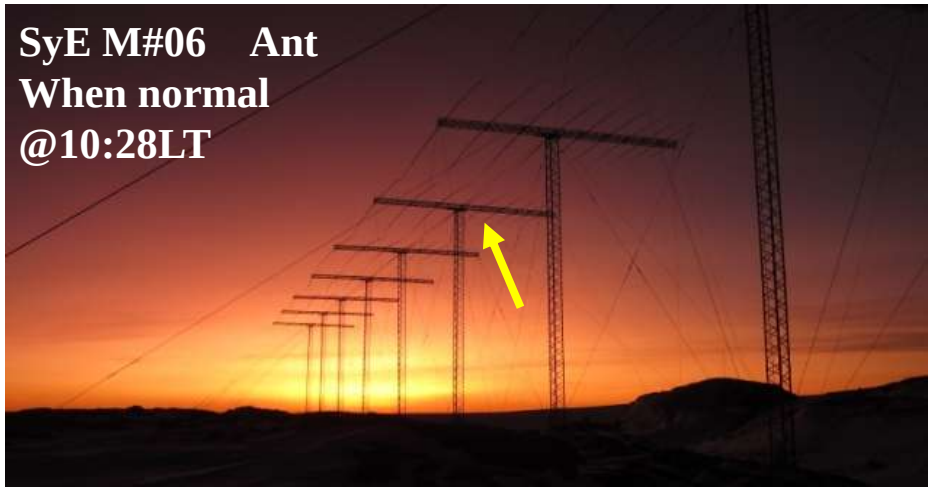




## JARE55-57 land survey

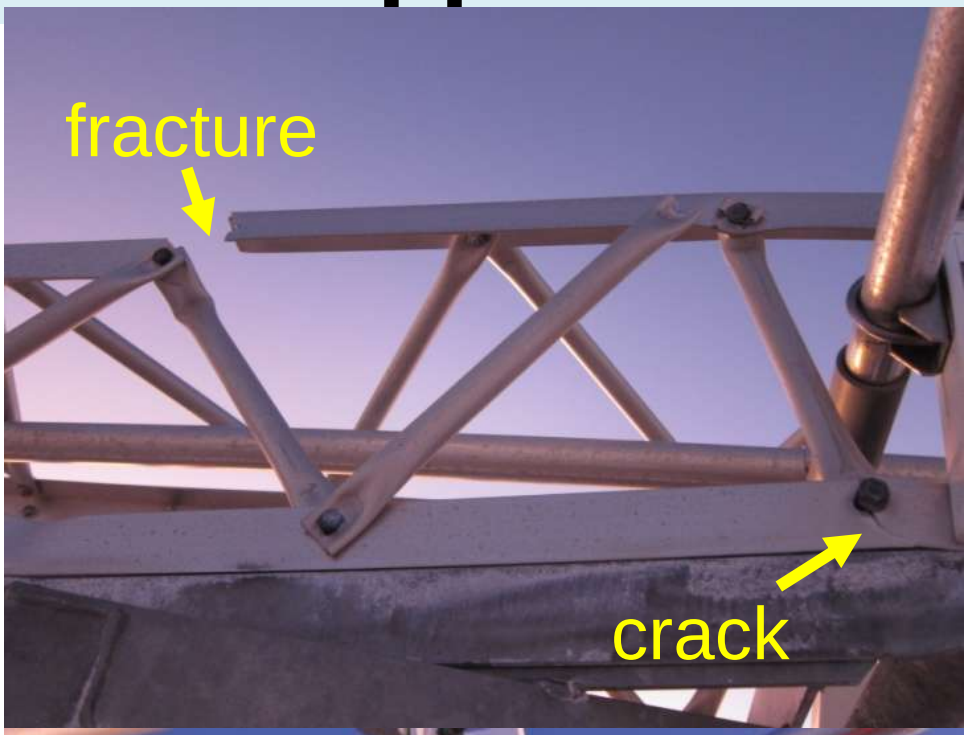
# New serious incidents appeared

## ●Boom/truss Broken(2013&2015)

These years, more serious structural construction parts started to be broken
→aging? Metallic fatigue started?! Dangerous!







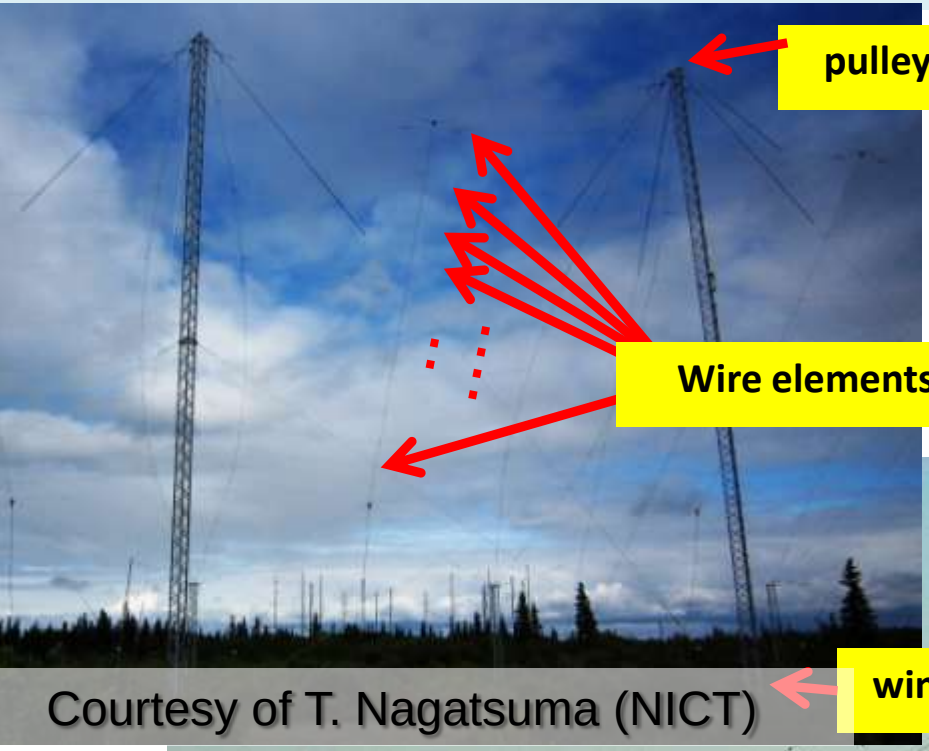

# Upgrade required and candidates

**King Salmon @ Alaska**
**Wire L.P. antenna**
**Easy maintenance if required**
**Little maintenance required**


Rankin Intel **TTFD (Twin Terminated Folded Dipole) antenna**
Good F.B. ratio
Maintenance not bad?
But once destructive event happens,
Maintenance may possibly be very hard…

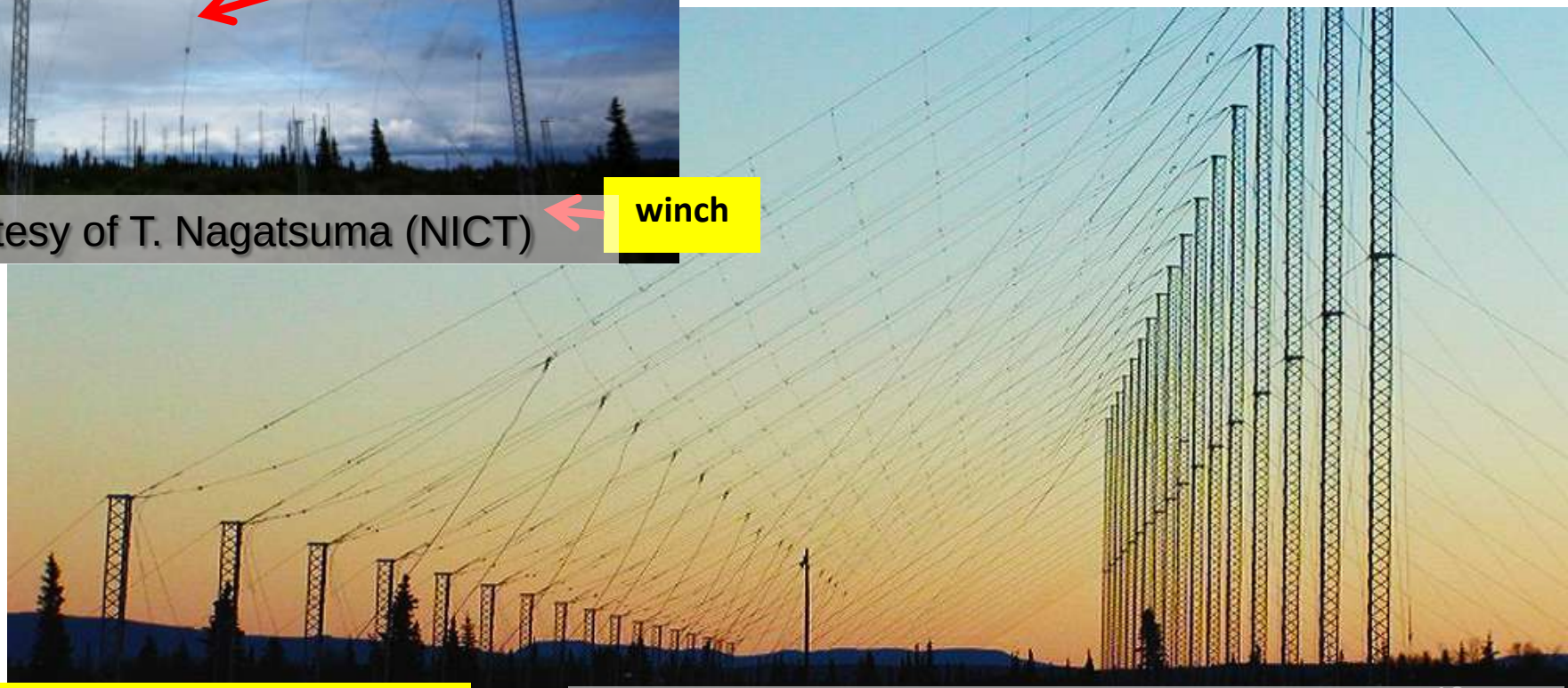
- Metallic fatigue due to aging started?!
- Antenna upgrade is necessary to continue our essential scientific operation and to ensure safety
- Maintenance cost (labor and budget) has been large and non-negligible – which should be considerably reduced.
- Current Sabre-type requires much maintenance.
- TTFD in fashion – good FB ratio but needs much work process when wire needs to be replaced.
- Wire Log-Periodic : little (almost no?) maintenance, easy maintenance (w/ pulley) even if required – proven at King Salmon and Zhongshan radars!!

# Wire Log-Periodic antenna design for Syowa




Courtesy of T. Nagatsuma (NICT)

- Reuse tower (+1 new added)
- 5m pillars – new basement and anchors -how to install?
- **Non-flat ground – beams ok? & adequate height?**

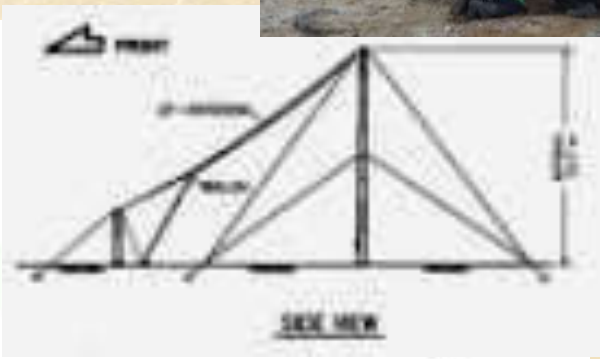


**King Salmon antenna**

Courtesy of West Japan Electronics co.(wje.jp)

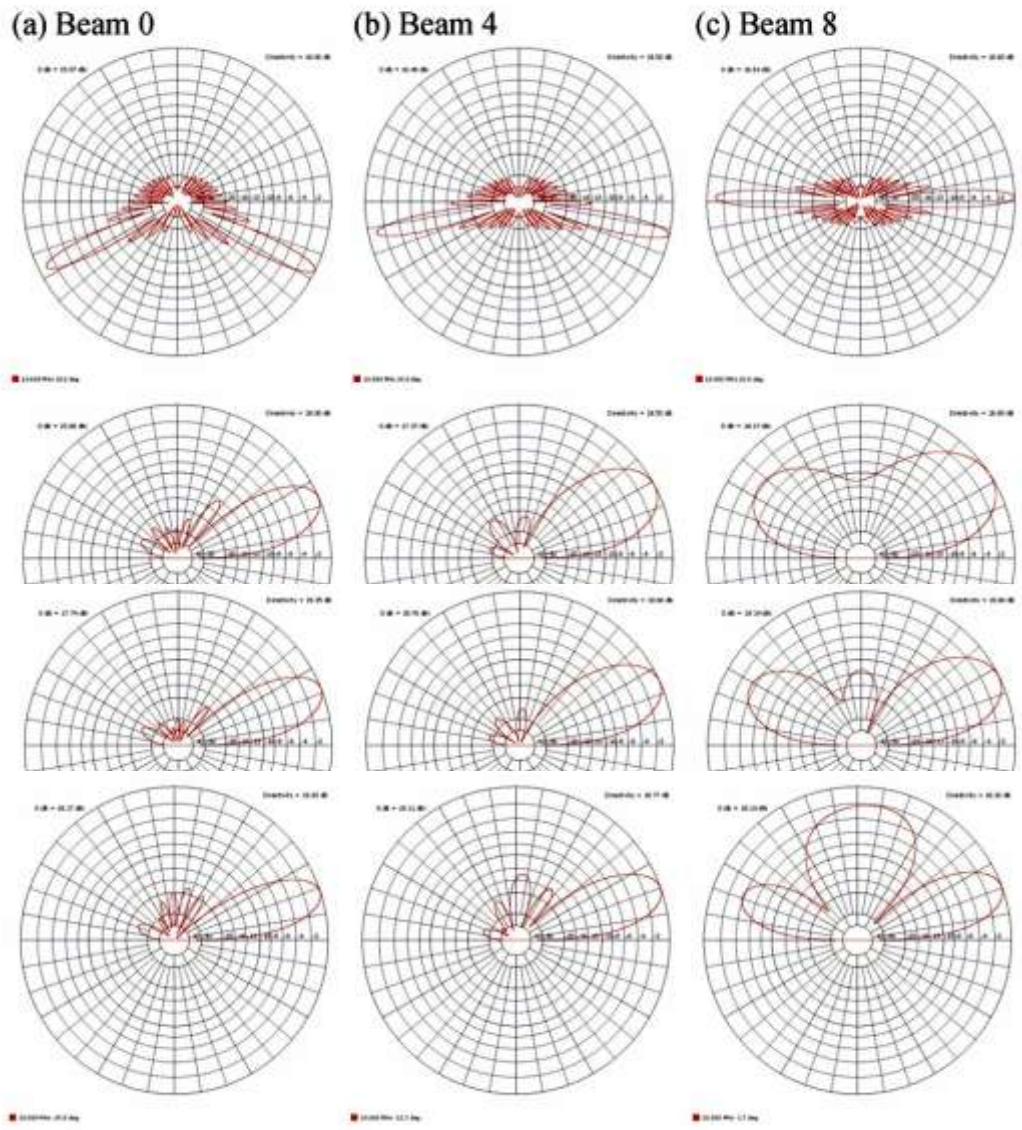
# Land Survey for Non-flat ground at Syowa sites


- boresite direction – land slope < 10 degree
- array direction – land slope < 20 degree
- No problem on beam forming especially by using new wire antenna directed obliquely downward?!
- Simulation w/ NEC2



# Effect of antenna height on vertical pattern

Azimuthal and elevation patterns for $h$=12m, $f$=10MHz
Array of 16 log-periodic dipole array antennas
— good ground condition —




**H=12 m** — **EleMax=34deg**

**H=15 m** — **EleMax=28deg**

**H=20 m** — **EleMax=23deg**

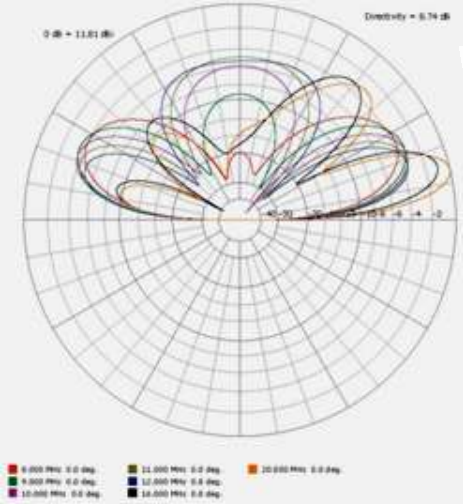
# Effect of ground inclined to boresite direction on v. pattern

Variation of elevation pattern w.r.t. the inclined ground

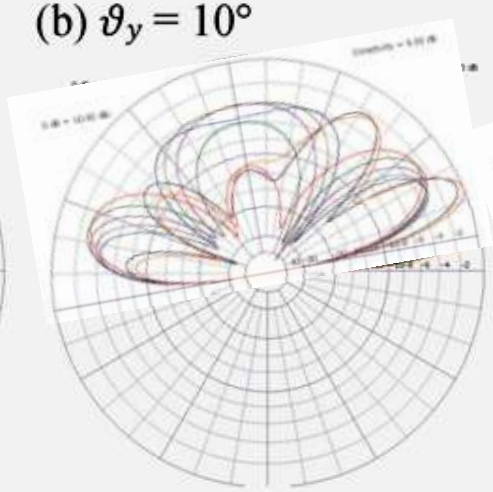
A single log-periodic dipole array antenna

— good ground condition —

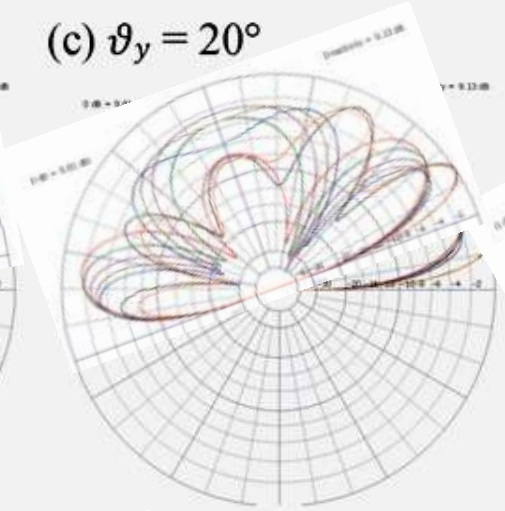
(a) Inclination: $\vartheta_y = 0°$.



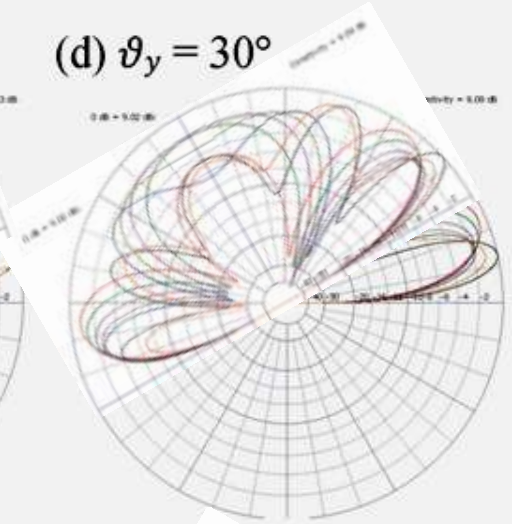
(b) $\vartheta_y = 10°$



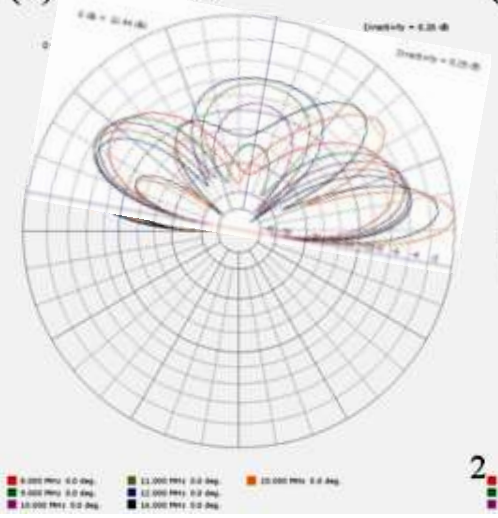
(c) $\vartheta_y = 20°$



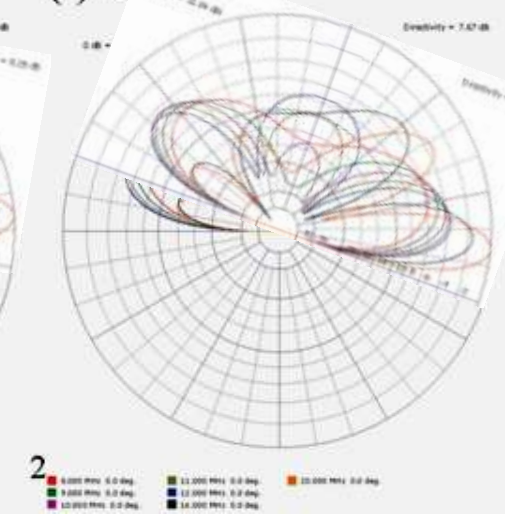
(d) $\vartheta_y = 30°$



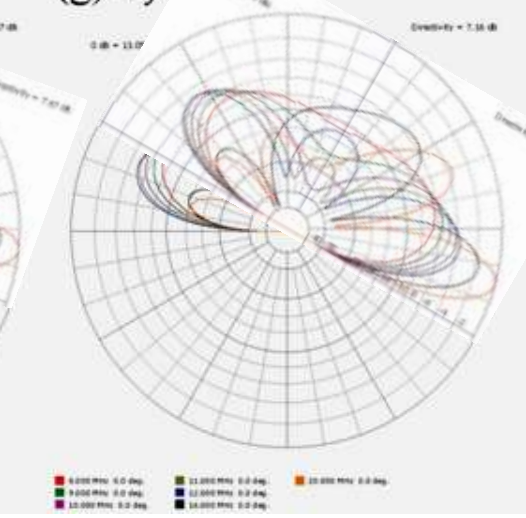
(e) $\vartheta_y = -10°$



(f) $\vartheta_y$ = -20°



(g) $\vartheta_y$ = -30°

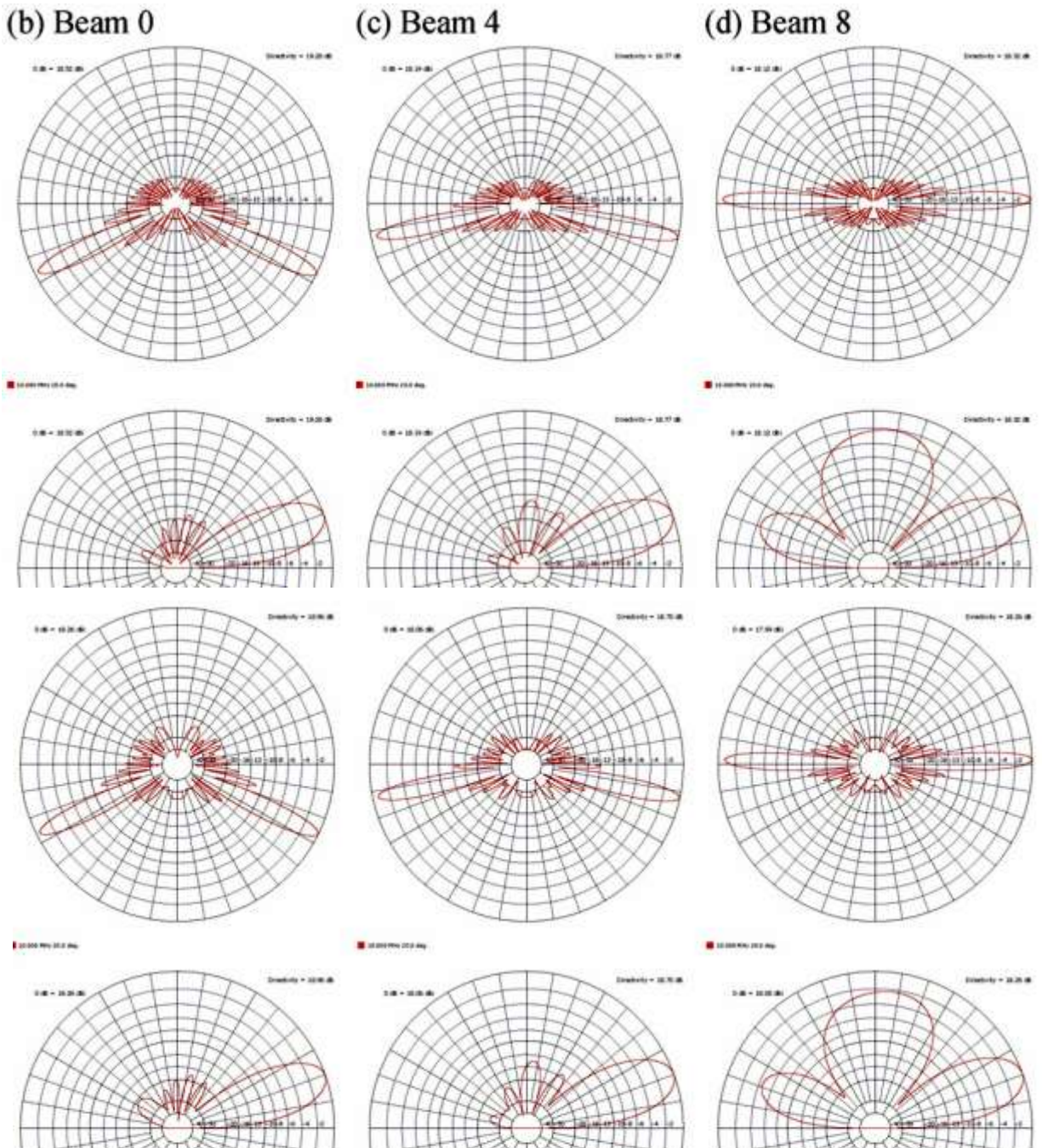


# Effect of generally inclined ground on beam pattern

**H=20 m, Freq 10MHz**
**good gnd cond.**

## Flat Ground

**Randomly inclined gnd**
**boresite dir Δθ < 10deg**
**array dir Δθ < 20deg**

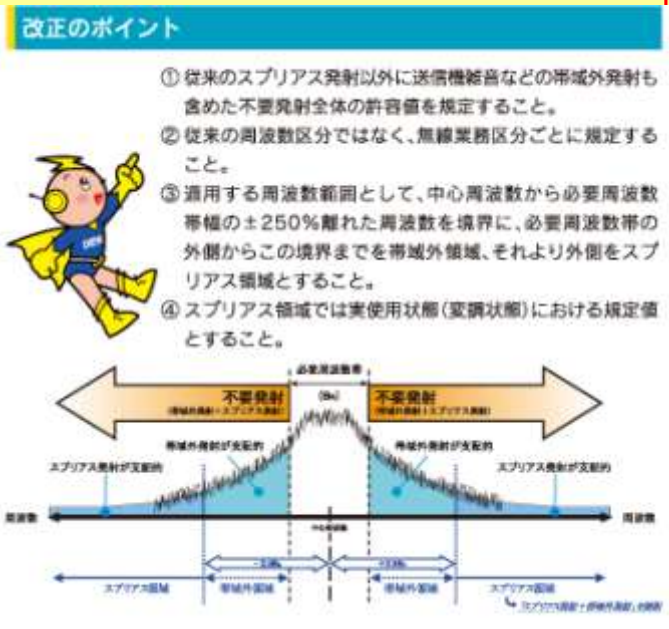


# SD radio authority licenses issue

## 短波レーダー電波法改正対応

- SENSU Syowa South (since 1995) and Syowa East (since 1997): Japanese radio wave authority license obtained in 1994, 1996 & 2004.

- 2005(H17).12.1 Radio regulation law changed (more strict for spurious specification)
- Licenses obtained before 2007(H19).11.30 can be used as were until 2017 (H29).12.1 but they need to be updated to meet new regulation until 2022(H34).11.30 (mid JARE 63 (in 9th)) (if not, Important SD operation will not be able to be continued).
- started to discuss with radar manufacturers (NJRC and U. of Leicester, UK) as well as radio authority on how we can manage to upgrade our transmitters etc.



# Summary and Future

Next JARE 6-year project phase IX

- Wider global coverage by SD FOVs will provide more accurate global potential maps and other physical parameters for SW-M-I-C studies.
- Esp. deep contributions to Inner Magnetospheric physics w/ VAP/ERG and other G-B. obs. network and theoretical works. Also started to try, e.g., to enable I-M mapping and EMIC detection with SD.
- Current unusual low solar activity suggests possible entrance into next historical Grand minimum which is important to understand quantitatively its long term impacts on polar upper atmospheric environment and global atmosphere or climate changes. SD with global coverage of FOVs are ready to contribute to the issue, that is one of the main themes of SCOSTEP/VarSITI program.
- Higher spatial and temporal resolution capability will enable us to study smaller scale E field structure and related transient phenomena like substorms, aurora, patches, FAIs etc by collaborating with satellites, rockets and other g.b. radars and optical inst. network to understand MIC.
- Make SD be higher resolution global meteor radar network to contribute to MTI region dynamics and cross-region coupling studies in collaboration with other MLT related instruments.
- SD FOVs still growing covering Iceland soon : possible wider/global conjugate studies
- To achieve most or all above, close collaboration with other observational techniques and theoretical works are essentially important. Collaboration with EISCAT-3D and PANSY radars etc are particularly of great importance for comprehensive cross region coupling studies.
- Collaborative research proposals are always welcome.