2011年1月31日STE研中緯度レーダー研究会

国際SuperDARNレーダーの発展

～日本のSuperDARNプロジェクトの発展史

～

佐藤夏雄（国立極地研究所）
小川忠彦（通信総合研究所）

SuperDARN

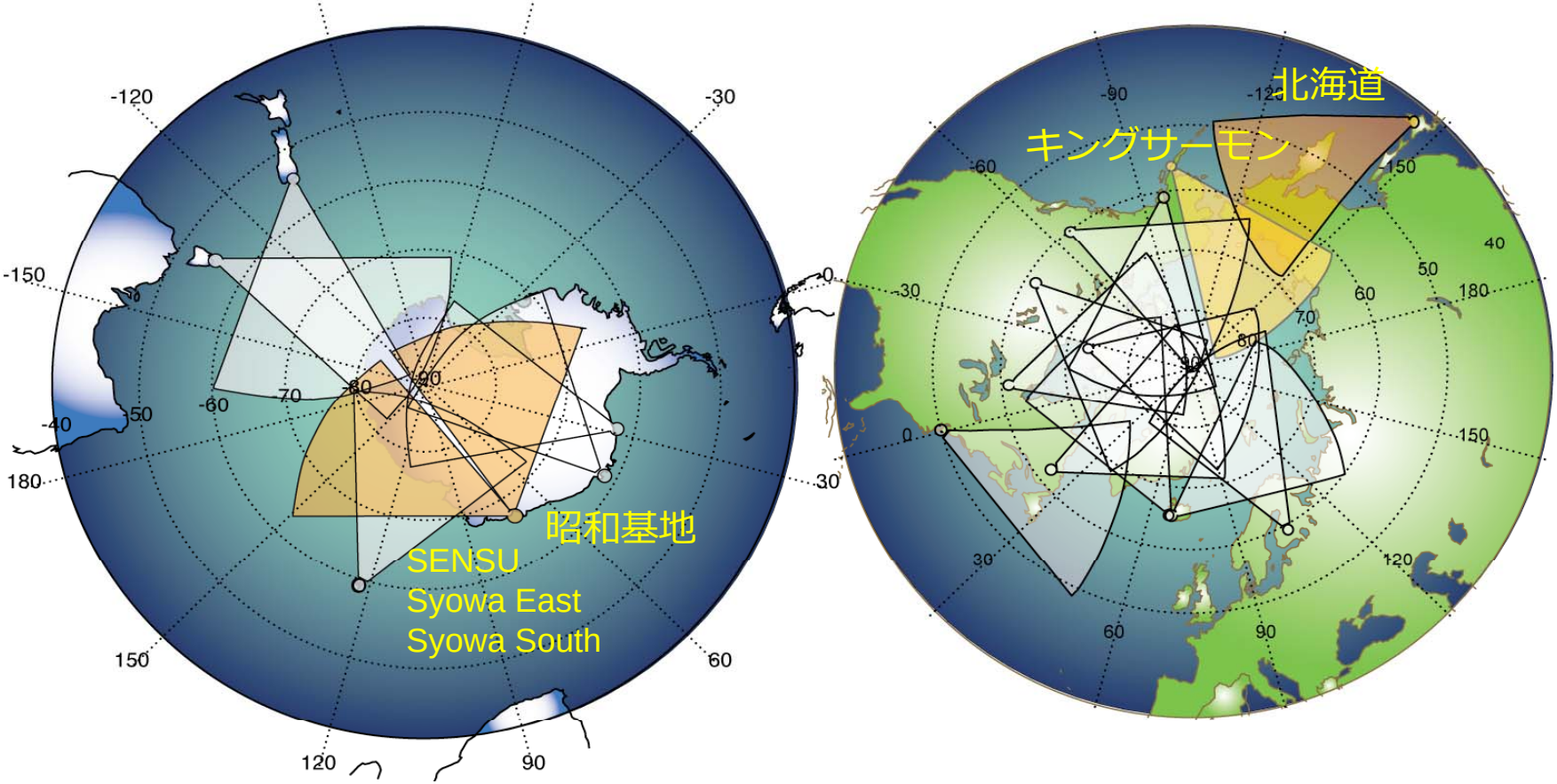
国際大型短波レーダー網

＊国際SuperDARNは両極域の大部分をカバーした大型短波レーダーネットワーク
＊8～20MHzの電波を発射し、電離層からの反射波を「通年・連続的」に受信
＊エコー強度、ドプラー速度、スペクトル幅の情報が得られる
＊全て共通の仕様で製造され、共通の観測制御プログラムで稼働している為、各レーダーのデータは完全に互換性がとれ、データの相互利用が極めて容易

日本のSuperDARNレーダー

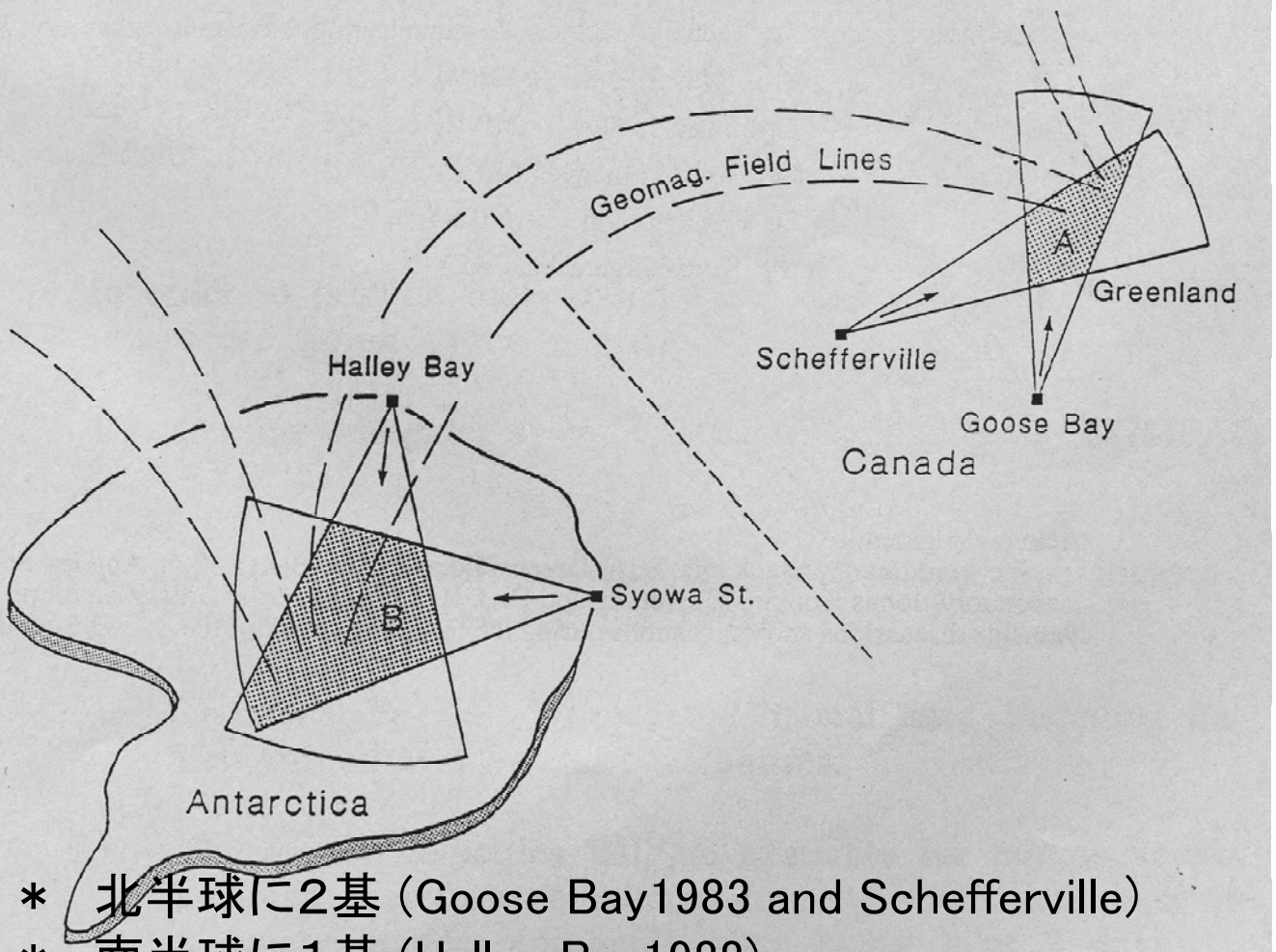
SuperDARN

Super Dual Auroral Radar Network



日本のSuperDARNレーダー

１９８９年代のレーダー配置図



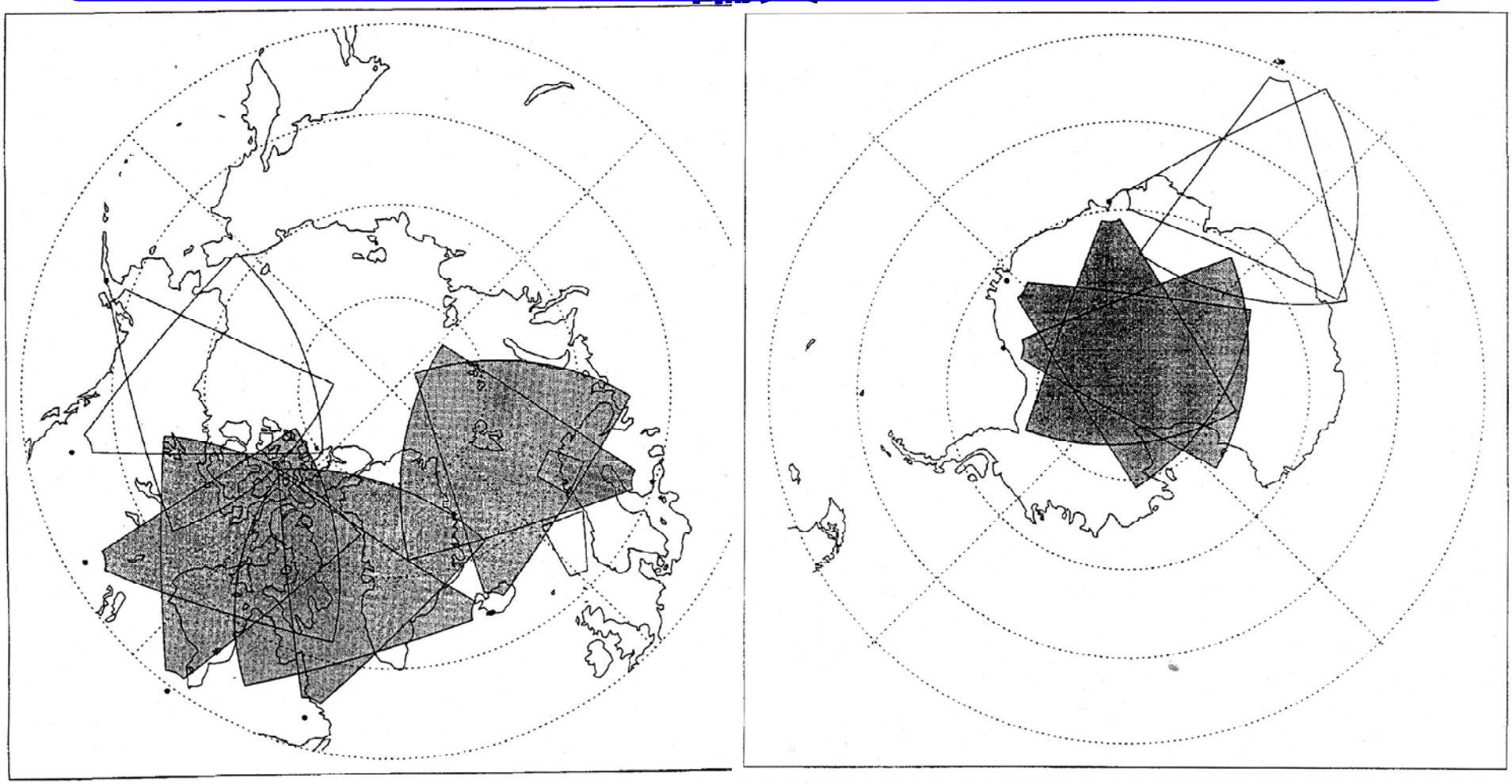
＊　北半球に2基 (Goose Bay1983 and Schefferville)

＊　南半球に1基 (Halley Bay1988)

(Ogawa et al., 1989)

Fig. 2. Schematic illustration of viewing areas by Antarctic twin HF radars (B) and Canadian twin HF radars (A). A and B make a geomagnetically conjugate pair.

１９９５年代のレーダー配置図：Greenwald論文



Greenwald et al., Space Science Review (1995)

白抜きは計画中のレーダー

＊この時点では、キングサーモン、北海道レーダーは記載が無い

２００４年代のレーダー配置図

SuperDARN

Super Dual Auroral Radar Network

An International Radar Network for Studying the
Earth's Upper Atmosphere, Ionosphere, and Connection into Space

２００７年：Chisham論文レーダー

Chisham et al., Surv. Geophysics(2007)

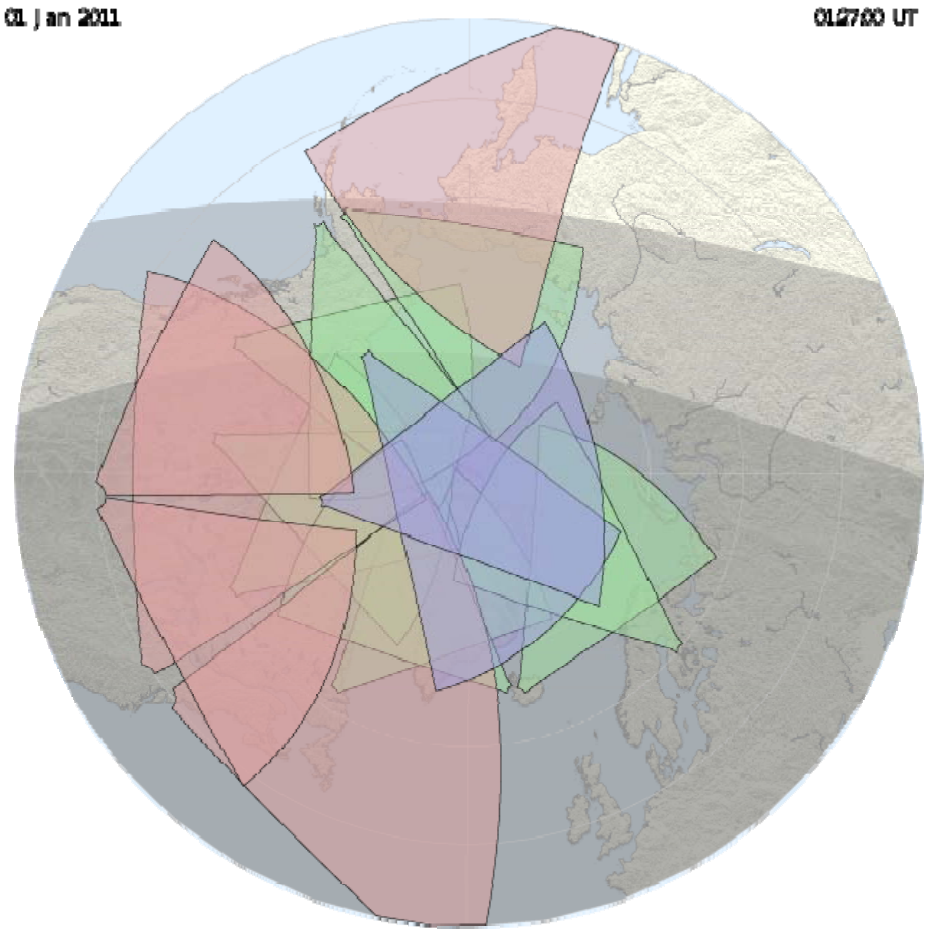
Table 1 Details of all the current SuperDARN radars

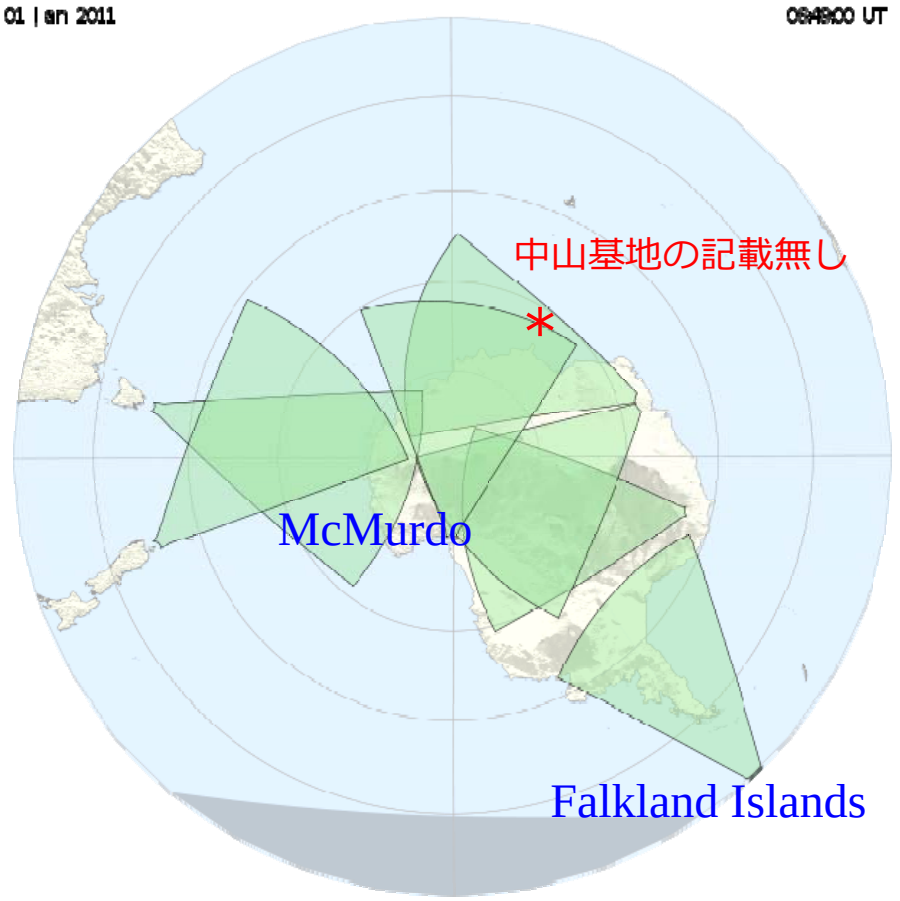
Current SuperDARN Radars

Radar name	Code		Commenced operation	Geographic co-ordinates	
	Old	New		Latitude	Longitude
Northern hemisphere					
Goose Bay	g	gbr	Oct 1983	53.32° N	60.46° W
Kapuskasing	k	kap	Sep 1993	49.39° N	82.32° W
Saskatoon	t	sas	Sep 1993	52.16° N	106.53° W
Iceland West (Stokkseyri)	w	sto	Aug 1994	63.86° N	22.02° W
CUTLASS Finland (Hankasalmi)	f	han	Jun 1995	62.32° N	26.61° E
CUTLASS Iceland East (Pykkvibaer)	e	pyk	Nov 1995	63.86° N	19.20° W
Kodiak	a	kod	Jan 2000	57.60° N	152.20° W
Prince George	b	pgr	Mar 2000	53.98° N	122.59° W
King Salmon	c	ksr	Oct 2001	58.68° N	156.65° W
Wallops Island	i	wal	Jun 2005	37.93° N	75.47° W
Rankin Inlet	–	rkn	May 2006	62.82° N	93.11° W
Southern hemisphere					
Halley (SHARE)	h	hal	Jan 1988	72.52° S	26.63° W
Syowa South	j	sys	Feb 1995	69.00° S	39.58° E
Sanae (SHARE)	d	san	Feb 1997	71.68° S	2.85° W
Syowa East	n	sye	Feb 1997	69.01° S	39.61° E
Kerguelen	p	ker	Jun 2000	49.35° S	70.26° E
TIGER Tasmania	r	tig	Jan 2001	43.38° S	147.23° E
TIGER Unwin	u	unw	Nov 2004	46.51° S	168.38° E

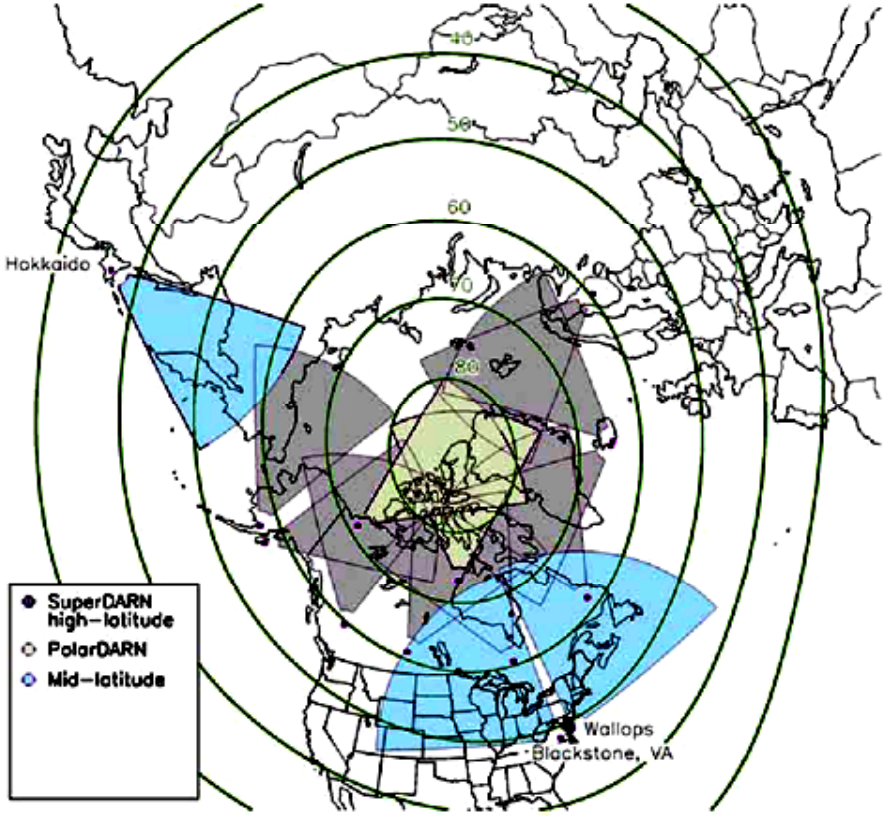
２０１１年現在のレーダー配置図

北半球　　南半球

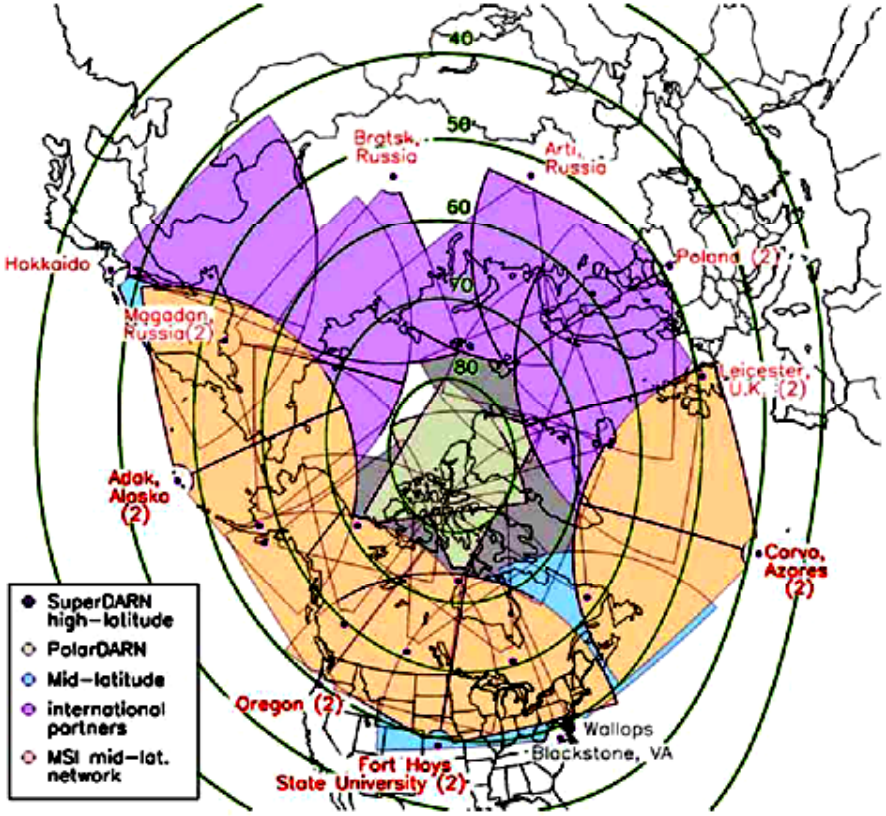




現在と将来計画（北半球）

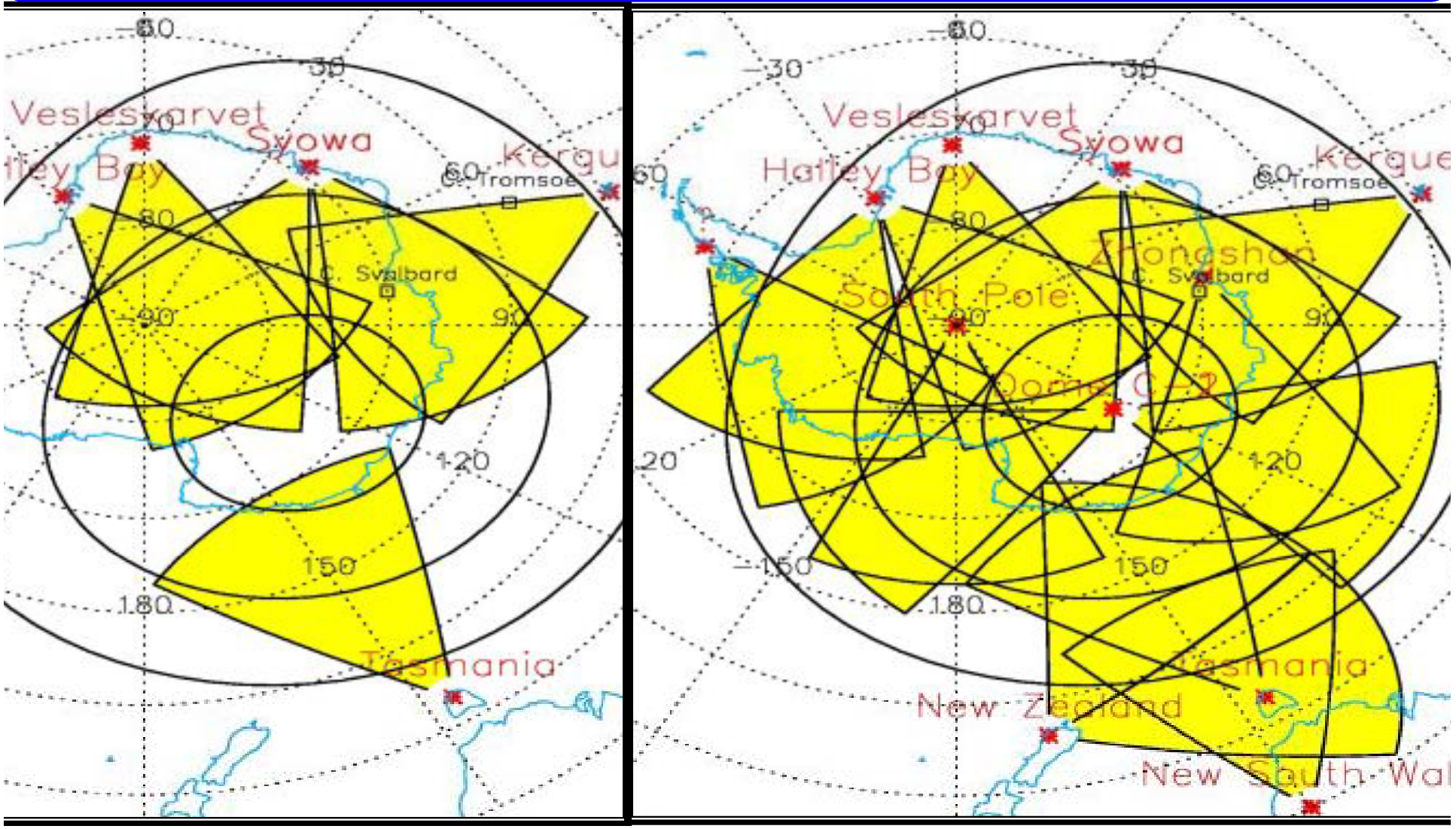


Current



Proposed

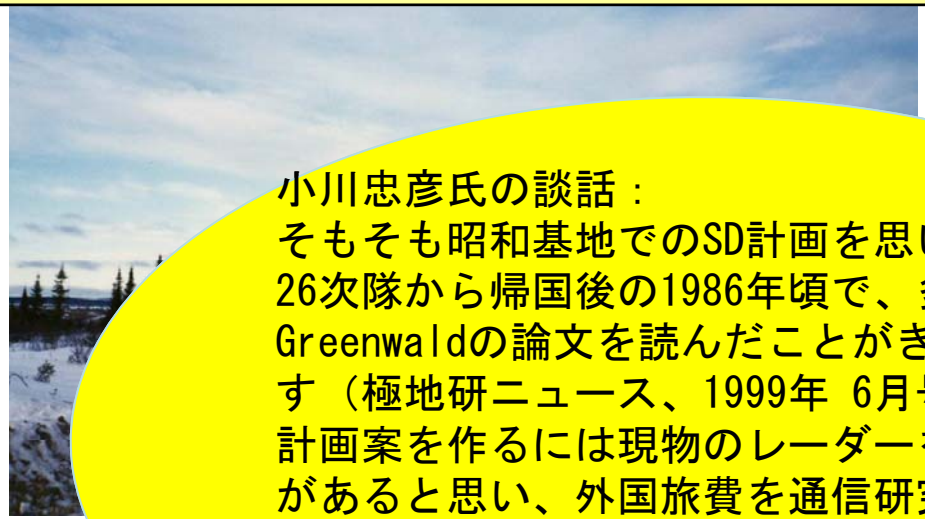
現在と将来計画（南半球）



2000　　S.H. SD　　20??

昭和基地レーダーの始まり:1988年

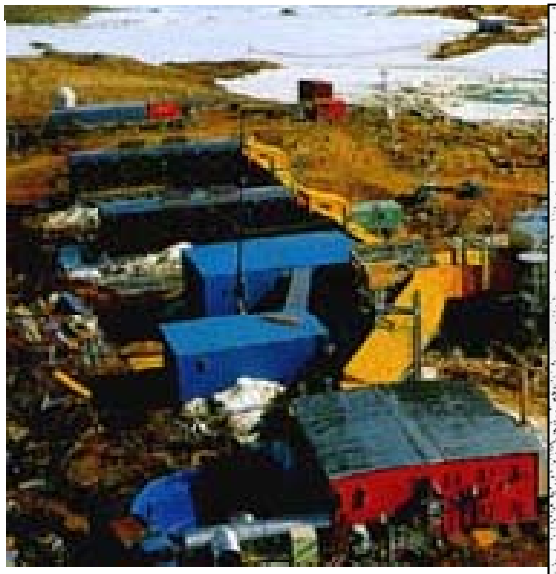
Dr. Ogawa visited APL and Goose Bay Radar Site in November 1988



小川忠彦氏の談話：
そもそも昭和基地でのSD計画を思い立ったの26次隊から帰国後の1986年頃で、多分Greenwaldの論文を読んだことがきっかけです（極地研ニュース、1999年 6月号）。
計画案を作るには現物のレーダーを見る必要があると思い、外国旅費を通信研究所に要求したところ、運良く予算がつき、
APLに一ヶ月ほど滞在し、その間にGoose Bayレーダーを見学できました。

昭和基地レーダーの始まり：1988/1989年

February 1989
Proposal of HF radar experiment to NIPR
as one of the projects at Syowa Station
during the STEP period (1990 -1995)



日経新聞
1989年
2月11日

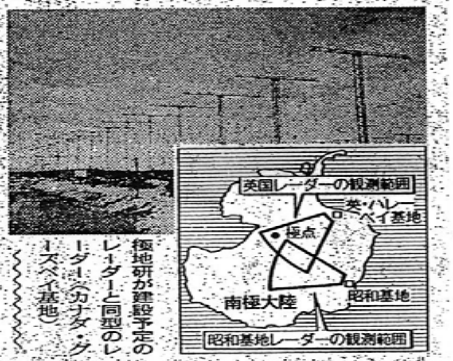
南極昭和基地に
大型短波レーダー

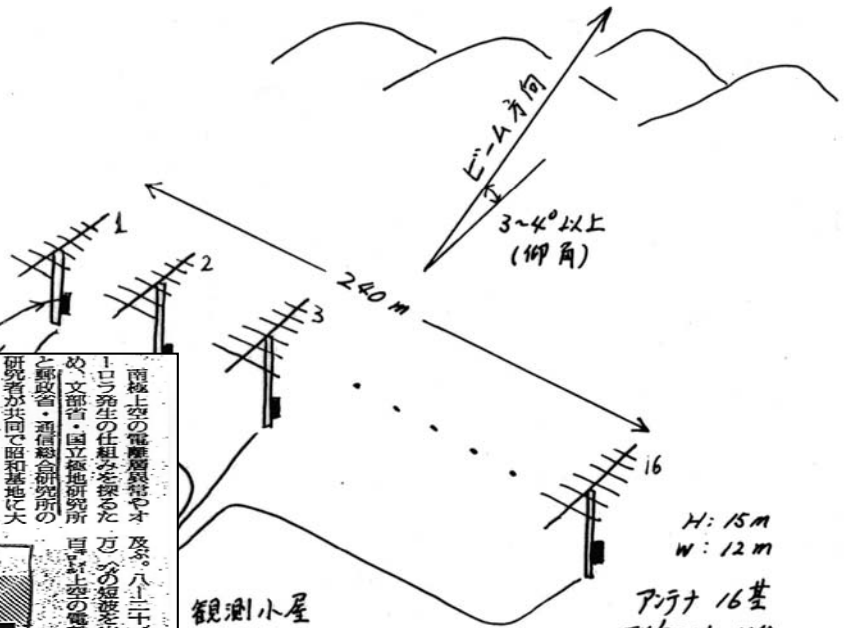
電離層異常など探る

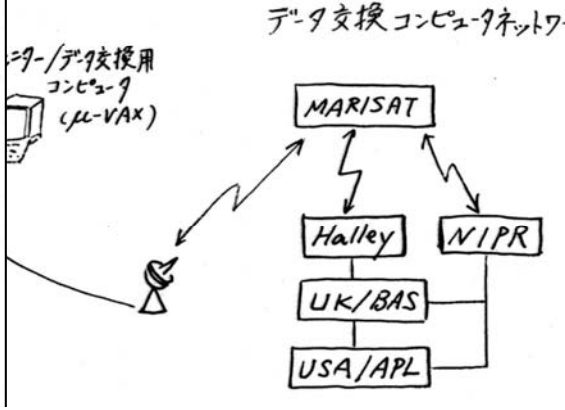
南極上空の電離層異常やオーロラ発生の仕組みを探るため、文部省・国立極地研究所と郵政省・通信総合研究所の研究者が共同で昭和基地に大型短波レーダーを建設する計画をまとめた。九〇年からスタートする科学衛星などを使った国際共同研究「ステップ計画」に参加する欧米研究者からの強い要請にこたえたもので、九二年初めの完成を目指している。このレーダーはテレビ受信用アンテナに似た巨大アンテナ（高さ十五㍍、最大幅十二㍍）を一直線に十六基並べた「フェーズド・アレイ型レーダー」。全長は二百四十㍍に及ぶ。八一二十㌔㌹の短波を出し、百一四百㌔㍍上空の電離層の状態を観測する。

地球のまわりは地球自身がつくる強い磁場（磁気圏）でおおわれており、南極や北極は磁力線（磁場を形づくる力）が磁気あらしの発生の仕組みの出入り口にあたる。このため南極上空の電離層を調べれば地球周囲の磁気圏の様子もわかり、電波障害の原因となる太陽が吹き出す高エネルギー粒子が磁力線にとらえられて発光するオーロラのメカニズムも解明も期待できるという。

北極圏にはカナダ・グースベイとの型のレーダー施設があり、南極では八八年一月に英国南極調査所（BAS）がハレー・ベイ基地と同タイプのレーダーを設置、昭和基地にレーダーを設置すれば二点から同じ電離層を観測して精度を向上できるため、BASなどの研究者が日本に対し早期建設を要望していた。九〇年から日米欧が協力し打ち上げる「GEOTAIL」など磁気圏観測衛星を利用した、地上基地同士でデータ交換のネットワークをつくれる計画もあり「磁気圏の解明が進む」と関係者は話している。







主な経過:1988年

Ogawa　提案 *(1988*年極地研関係者への説明用*)*

昭和基地大型短波レーダ計画について

1988.12.14
通信総合研究所
小川　忠彦

－

１．はじめに

南極STEP計画(1990-1995）の一環として、昭和基地に大型短波レーダ(8-20 MHz ）を設置し、既存のVHF レーダ(50/120 MHz)では観測できない極冠帯やカスプ領域の電離層プラズマ運動の観測計画を提案している（第11回[1988], 12回[1989]極域における電離圏磁気圏総合観測シンポジウム）。このような短波レーダは1983年からカナダのGoose Bay で、また、1988年初頭からは米国／ＮＳＦの援助を受けて南極のHalley Bayで稼働中で、着々と成果が出つつあり、その有効性は証明済みである。更に、目下フランスがカナダのSch-effervilleに建設中であるが、今の所、稼働の見通しはない、とのことである。

筆者は、科学技術庁の援助で、1988年11月に米国（Johns Hopkins Univ./Applied Physics Laboratory ：ＡＰＬ）とカナダ（Labrador/Goose Bay）に出張し、昭和基地短波レーダ計画について、ＡＰＬのDr.Greenwald(Goose BayレーダのＰＩ）とDr.Baker、および英国／British Antarctic Survey（ＢＡＳ）のDr. Dudeney (Halley Bay レーダのＰＩ）と議論し、また種々の技術情報を入手したので、その概要を以下にまとめる。ＡＰＬとＢＡＳは、STEP期間中の衛星群による国際共同観測（ISTP）に呼応する観点から、できれば１９９２年初頭からの昭和レーダの観測開始を希望している。

主な経過：1988年

Ogawa　提案メモ(1988)

ＤＡＲＮ会議：

ＳＴＥＰでは多数の衛星が配置される予定であるが、これに呼応した地上観測として、極域の短波レーダ観測ネットワークが重要視されている。ＮＡＳＡは、ＳＴＥＰでＧＧＳ (Global Geospace Study) という地上観測プログラムを実施するが、その中に、短波レーダによる観測研究を目的とするＤＡＲＮ（Dual Auroral Radar Network ; Principal Investigatorは米国 Johns Hopkins大学のDr.Greenwald）という計画がある。Greenwald から、昭和基地短波レーダもこれに参加して欲しい、という申入れが口頭で来ている。さらに、1989年４月に英国ケンブリッジ市においてＤＡＲＮ会議を開くので、極地研の関係者and/or筆者が是非参加して日本の計画を発表するとともに、日本－米国－英国間の研究協力について話し合いを持ちたい、という依頼も受けた。極地研の関係者は是非派遣すべきであると思う。

主な経過：1989年

THE JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
Johns Hopkins Road, Laurel, Maryland 20707-6099
Telephone: (301) 953-5000 and 792-5000

February 24, 1989

Dr. T. Hirasawa
National Institute of Polar Research
9-10 Kaga 1-chrome
Itabasi-ku
Tokyo 173
Japan

Dear Dr. Hirasawa,

After a long period of waiting and much effort on the part of many scientists, the satellite mission known as ISTP/GGS has become a funded program. The satellites are being built, and in the early to mid-nineties they will be launched. Our goal is to use the data from these satellites and the ground-based coherent radar network, known to NASA as DARN, to provide new understanding of fundamental magnetospheric and ionospheric processes.

The original DARN proposal was based upon a global network of pairs of coherent VHF radars. Advances in technology and understanding over the past decade have resulted in new types of HF coherent rada
probing the ionosphere to very high magnet
altitudes. These HF radar systems ar
Labrador, Schefferville, Quebec, and
come to my attention that a four
development by the National Inst
is to be situated at Syowa S
important complement to the othe
the DARN experiment. Not only w
of the Halley radar, but it will
doppler measurements in the latter's f
will provide reliable plasma convection meas

It is important to consider how the new HF radar
incorporated into the original DARN concept. For this reason, and also to reacquaint ourselves with the proposal that was written so many years ago, we are planning a two day meeting of the DARN team (co-investigators and/or designated interested parties) to be held in Cambridge, England on 24-25 April. Since a Japanese HF radar at Syowa would add significantly to the contributions of the DARN experiment to ISTP/GGS, I would like to invite you and Dr. T. Ogawa of the Japanese Radio Research Laboratory to attend this meeting and participate in the discussion. I also hope that you might be able to give the DARN investigators an update on your development plans at that time. If you are agreeable with this suggestion, I would plan to include your contribution on the first day of the meeting.

I believe that attendance at this meeting will be beneficial to you as well as to members of the DARN team. Not only will we see old faces, but we may be able to develop a global strategy of coherent radar observations that could be put into effect even before the launch of the first GGS spacecraft.

Local arrangements for the meeting are being handled by Dr. John R. Dudeney of the British Antarctic Survey. The meeting will be held at BAS. John is endeavoring to arrange modest, moderately-priced hotel or guest house accommodations for between 20 to 30 pounds sterling per night including bed and breakfast. If you prefer more luxurious lodging at a higher price, John can arrange this too. John is also making arrangements for a special dinner on Monday evening. Please notify John by February 28 of your preference in accommodations, the specific nights that you will require accommodations, the number in your party and your interest in the Monday dinner. Write to John at this address:

British Antarctic Survey
National Environment Research Council
Madingly Road
Cambridge, CB3 OET, England.

Alternatively, you can reach John in the following ways:

Telephone: 01144-223-61188.

le: 223-62616

CAM G)

for Dudeney]

Dudeney of the time that you will
se, you can write to me at APL, call
11303 (APL JHU LAUR).

I am looking forward
in Cambridge.

With best regards,

Ray Greenwald

Raymond A. Greenwald

RAG:me

Greenwaldから平澤先生へ１９８９年４月開催のDARN会議参加の招待状

主な経過：1989年

Summary of the DARN Workshop

FUTURE DIRECTIONS

- Transmitter upgrade will begin this summer. The new transmitters will provide greater reliability and increased transmitting power at the higher operating frequencies.

- PACE will be part of the ground based system for the ISTP/GGS project. The coherent scatter radar observations for ISTP are known as DARN (Dual Auroral Radar Network). The PACE radars will be complemented by the STARE radars (Germany and Finland), the SABRE radar (UK), the SHERPA radar (Schefferville, Quebec), and the BARS radar (Canada) and probably a new HF radar which will be built at Syowa, Antarctica (Japan).

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.....6
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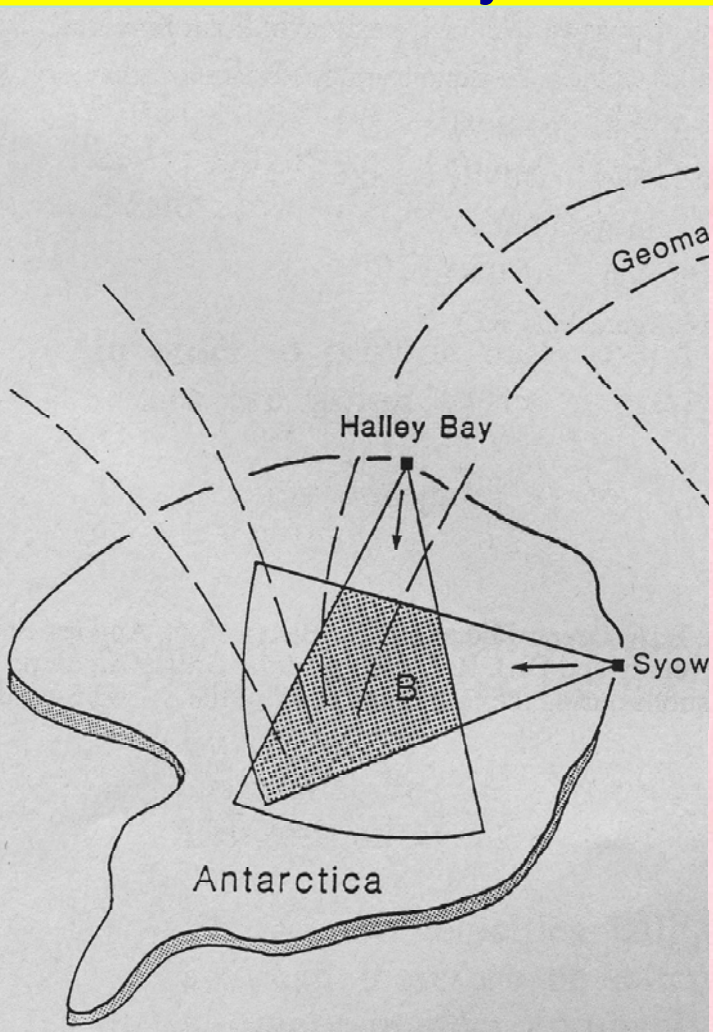
A. NASA plans (R. Whitman)
B. DARN key parameters
C. Event data
D. Reference frames
E. Using the ISTP database
F. Conclusions

VI. Future Meetings.....11

VII. Meeting of the Ground Based observers and Theory group of GGS (May 10, 1989, Baltimore, MD).....11

主な経過：1989年
SyowaレーダーのOgawa提案



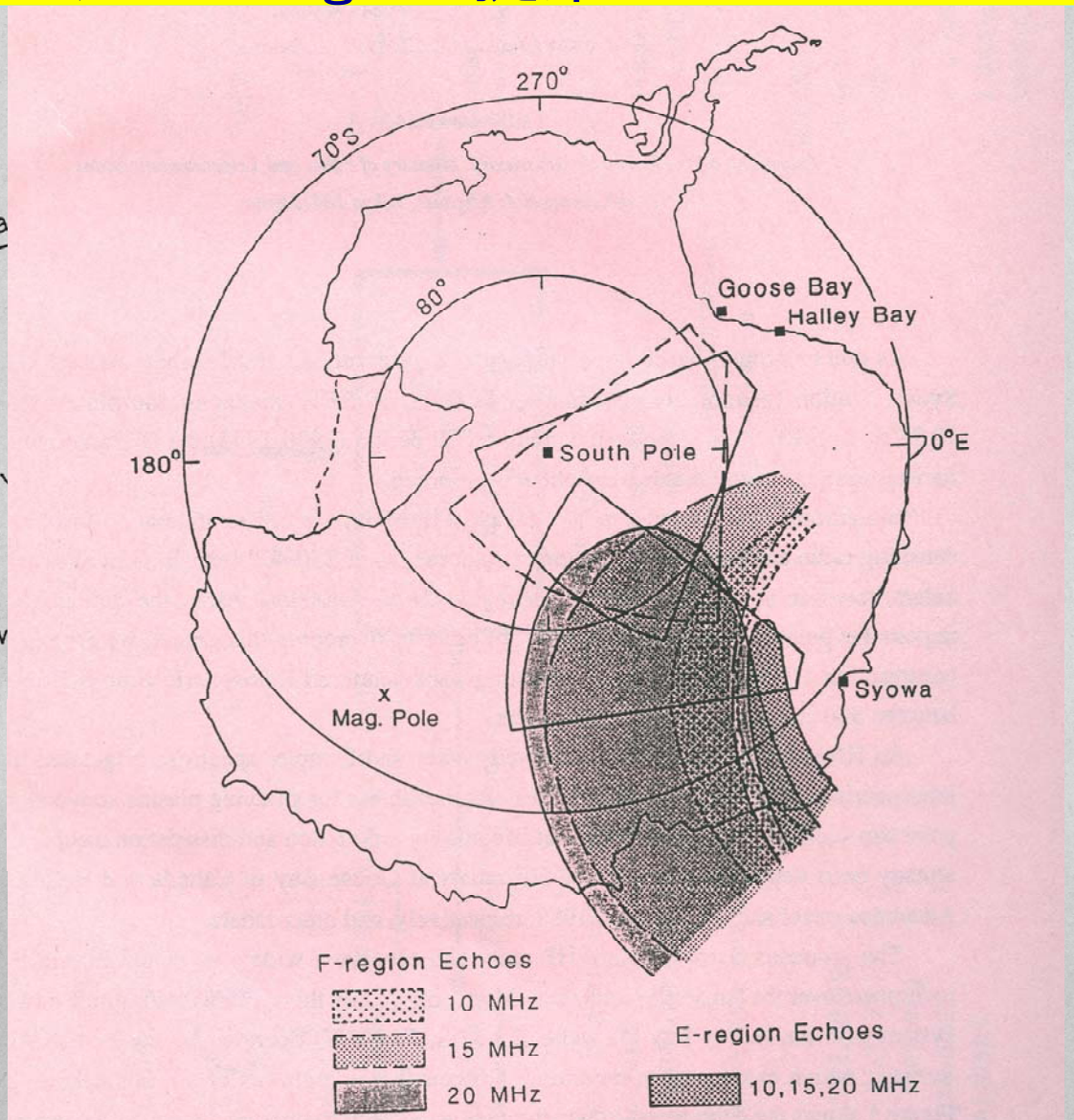


Fig. 2. Schematic illustration of viewing areas by Antarctic twin HF radars (B) and Canadian twin HF radars (A). A and B make a geomagnetically conjugate pair.

…duction and dissipation mechanisms has
…ose Bay in Canada and Halley Bay in

主な経過：1989年

Syowaレーダーのプロジェクトチームメンバー

Organization of the Syowa Station HF Radar Experiment

Principal Investigator: Prof. Takeo Hirasawa (National Institute of Polar Research, Japan)

Co-Investigators: Dr. Tadahiko Ogawa (Communications Research Laboratory, Japan)

Prof. Masaki Ejiri (NIPR)

Prof. Natsuo Sato (NIPR)

Dr. Hisao Yamagishi(NIPR)

Dr. Ryoichi Fujii (NIPR)

Mr. Kiyoshi Igarashi (CRL)

主な経過：1989年

Working Agreement

PI間の合意書(案)

7. Term of Agreement

All three parties agree to operate this agreement in a spirit of goodwill and conciliation, bearing in mind the harsh and unpredictable environments in which the three radars will be operated. This agreement will remain in force for so long as the three radars are funded by the sponsoring organisations.

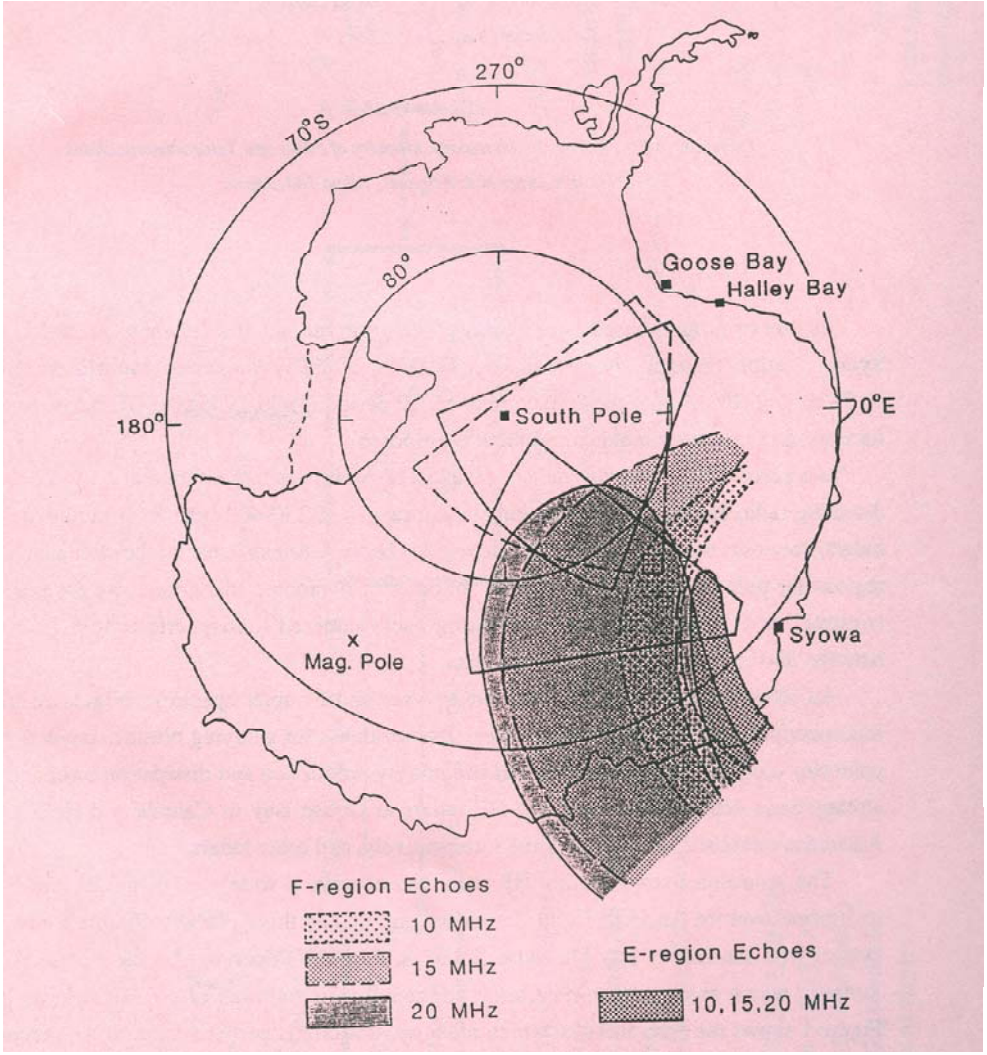
Alterations to this working agreement can only be made by mutual consent of the three PI's.

Signed:	Signed:	Signed:
Prof T Hirasawa	Dr J R Dudeney	Dr R A Greenwald
Date:	Date:	Date:

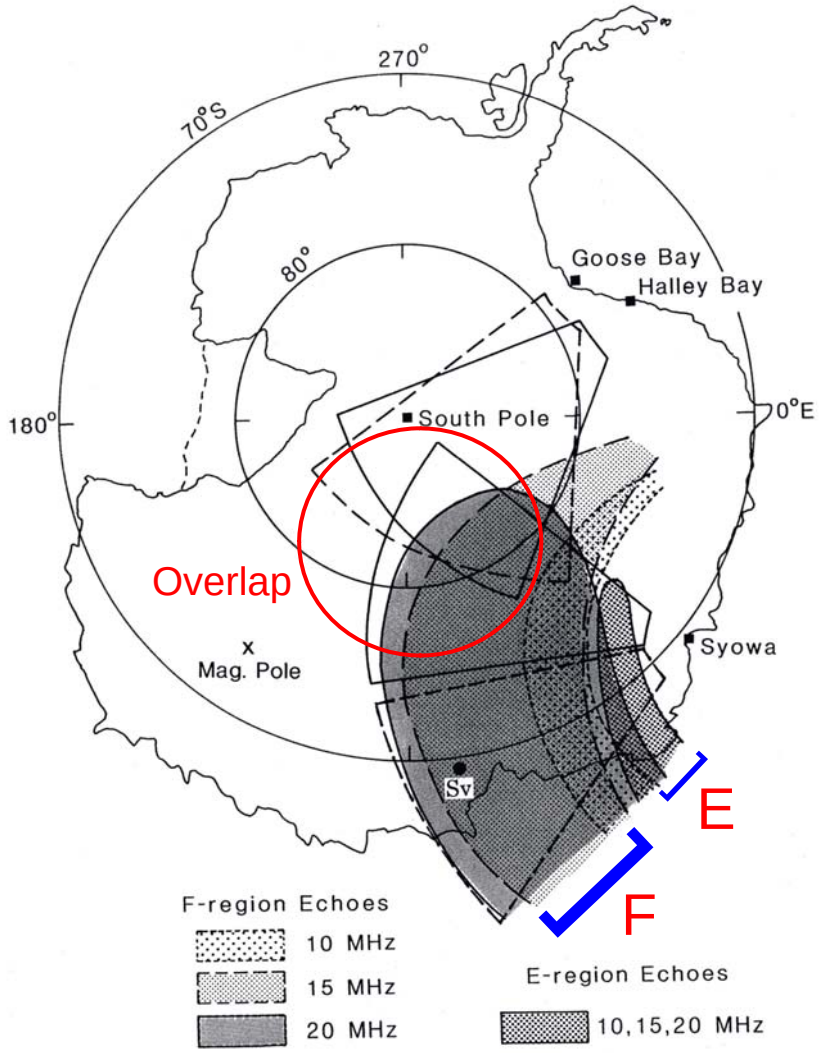
provision of the Syowa radar system.

主な経過：1989/1990年
SyowaレーダーのOgawa提案

(Ogawa et al., 1989)



(Ogawa et al., 1990)



Sv: EISCAT Svalbard Radar

主な経過：１９８９年１２月？

佐藤夏雄と藤井良一がAPL訪問：１９８９年１２月？
目的：レーダーの具体的導入（購入）交渉

Greenwald, Dudeny, Pinockが同席

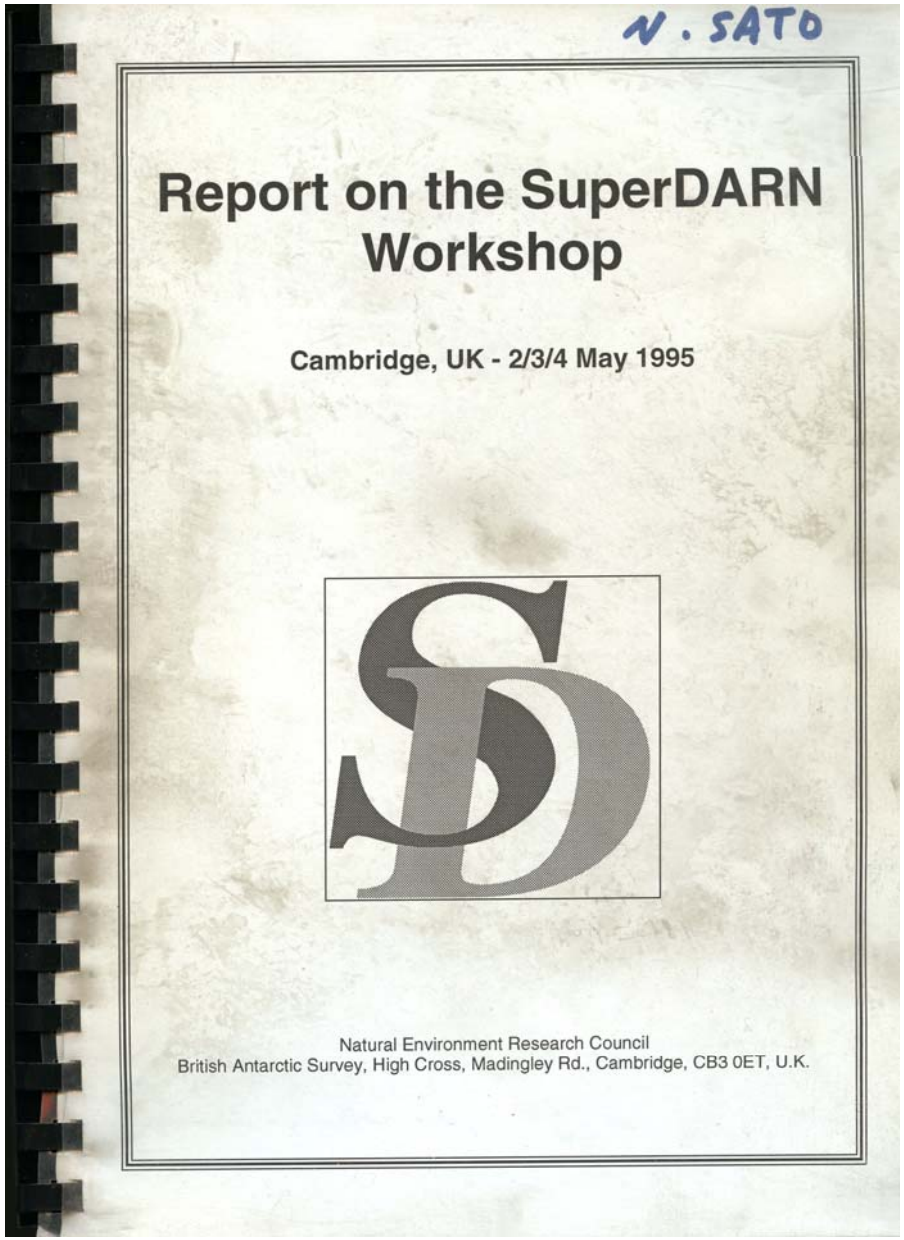
交渉決裂

APL:軍の研究所＝＞　民間商社との取引はダメ
NIPR:国の機関＝＞APLとの直接取引はダメ

解決策

APLが回路図等の詳細情報を提供する
＝＞　国内メーカで製作

１９９５年：国際SuperDARNの創設

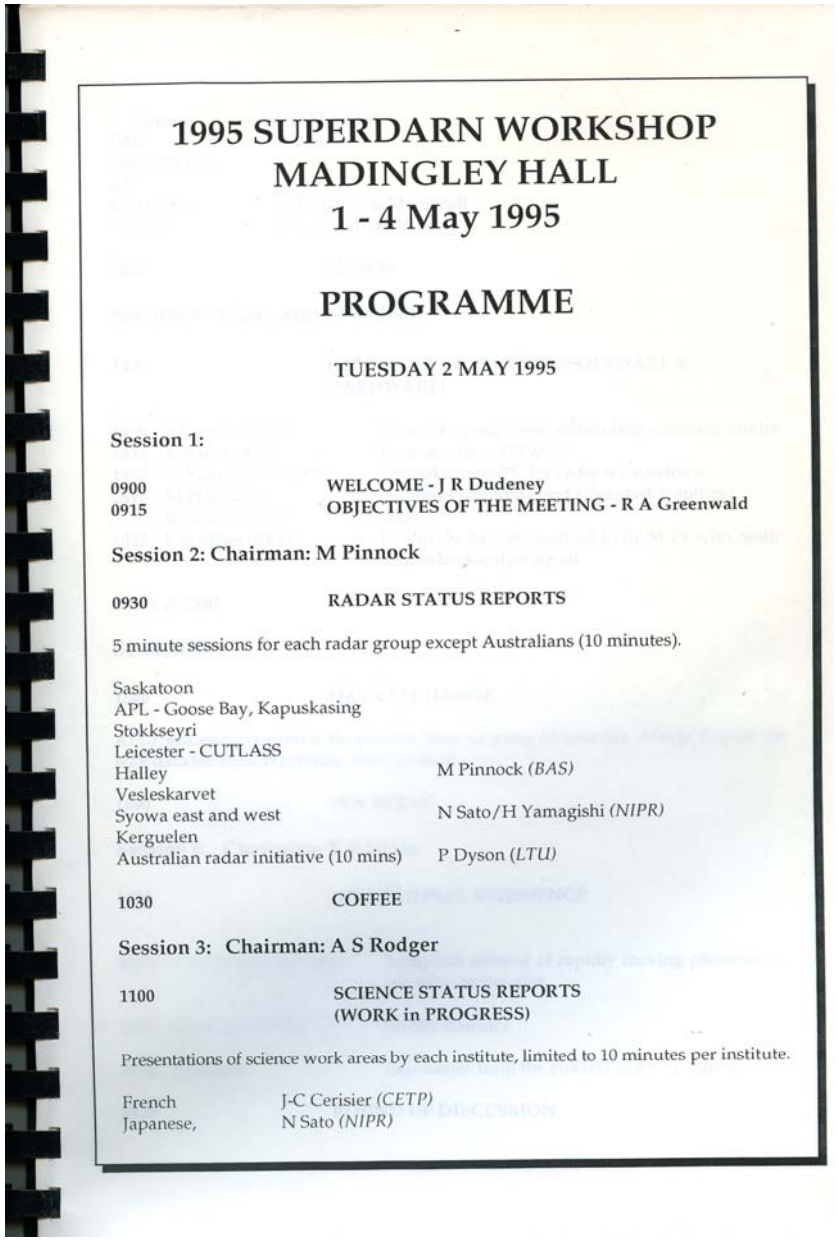


N. SATO

Report on the SuperDARN Workshop

Cambridge, UK - 2/3/4 May 1995

Natural Environment Research Council
British Antarctic Survey, High Cross, Madingley Rd., Cambridge, CB3 0ET, U.K.



1995 SUPERDARN WORKSHOP
MADINGLEY HALL
1 - 4 May 1995

PROGRAMME

TUESDAY 2 MAY 1995

Session 1:

0900 WELCOME - J R Dudeney
0915 OBJECTIVES OF THE MEETING - R A Greenwald

Session 2: Chairman: M Pinnock

0930 RADAR STATUS REPORTS

5 minute sessions for each radar group except Australians (10 minutes).

Saskatoon APL - Goose Bay, Kapuskasing Stokkseyri Leicester - CUTLASS Halley	M Pinnock *(BAS)*
Vesleskarvet Syowa east and west	N Sato/H Yamagishi *(NIPR)*
Kerguelen Australian radar initiative (10 mins)	P Dyson *(LTU)*

1030 COFFEE

Session 3: Chairman: A S Rodger

1100 SCIENCE STATUS REPORTS
(WORK in PROGRESS)

Presentations of science work areas by each institute, limited to 10 minutes per institute.

French	J-C Cerisier *(CETP)*
Japanese,	N Sato *(NIPR)*

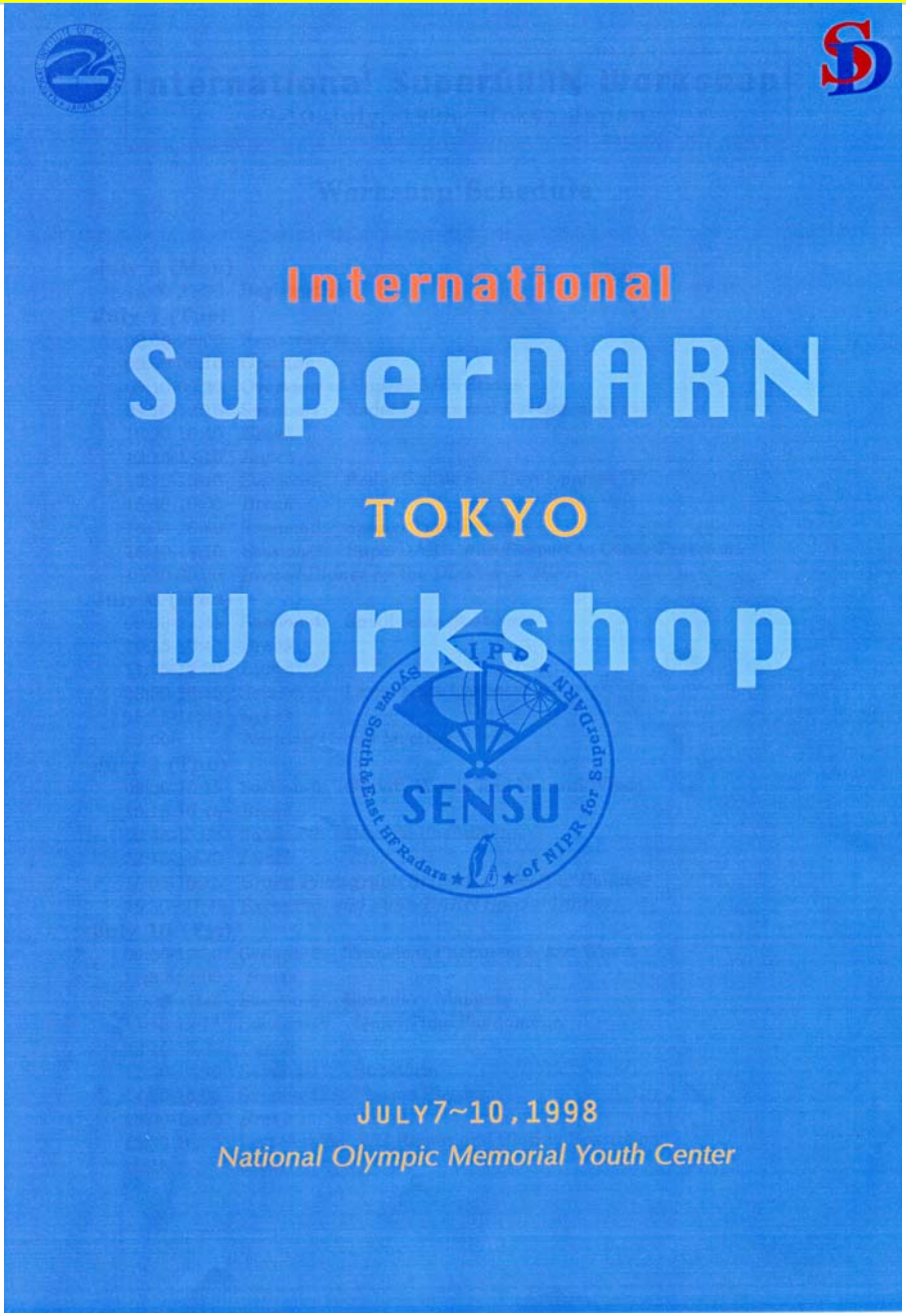
1995年：SuperDARN発足ワークショップ

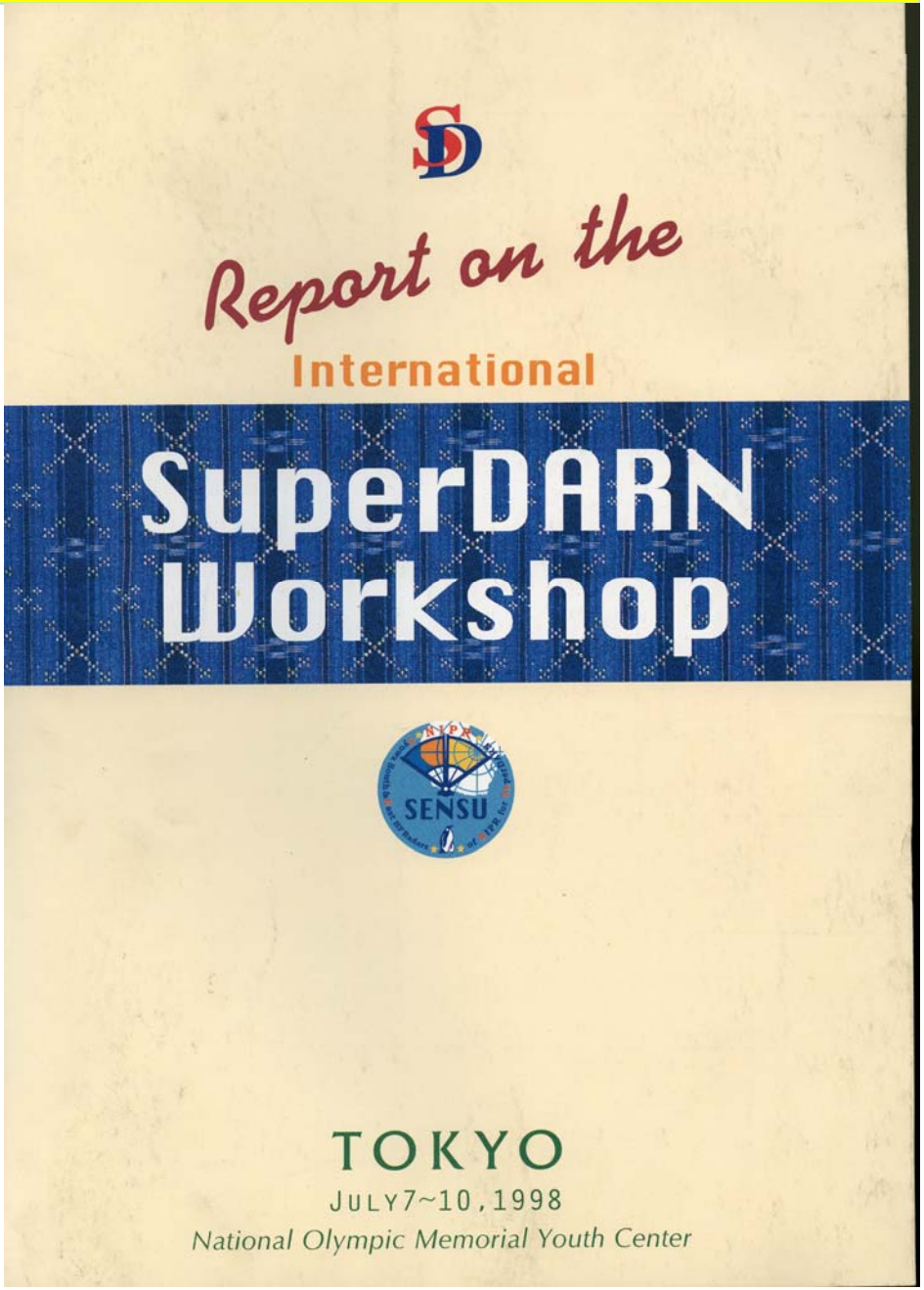
1997年：南ア_ SuperDARNワークショップ

SuperDARN 97

12–15 May 1997
Itala Game Reserve
South Africa

1998年：東京SuperDARNワークショップ

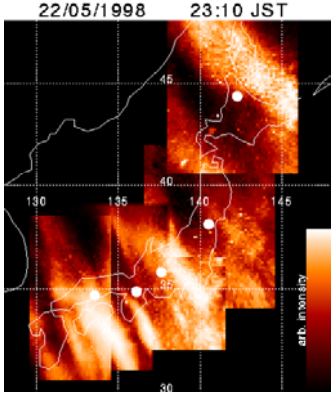


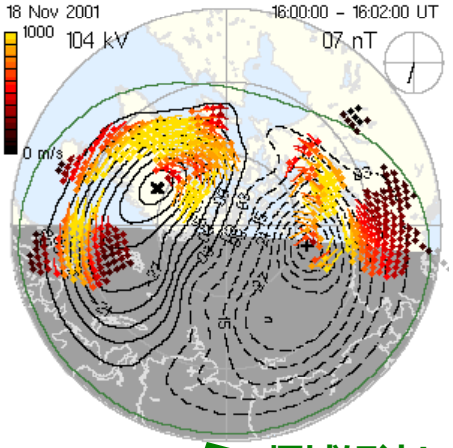


1998年：東京SuperDARNワークショップ

北海道-陸別SuperDARNレーダー（2006年11月稼働）

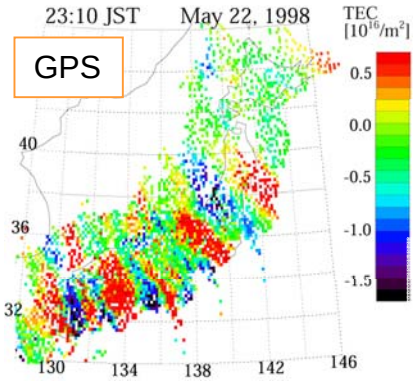
大気光イメージング

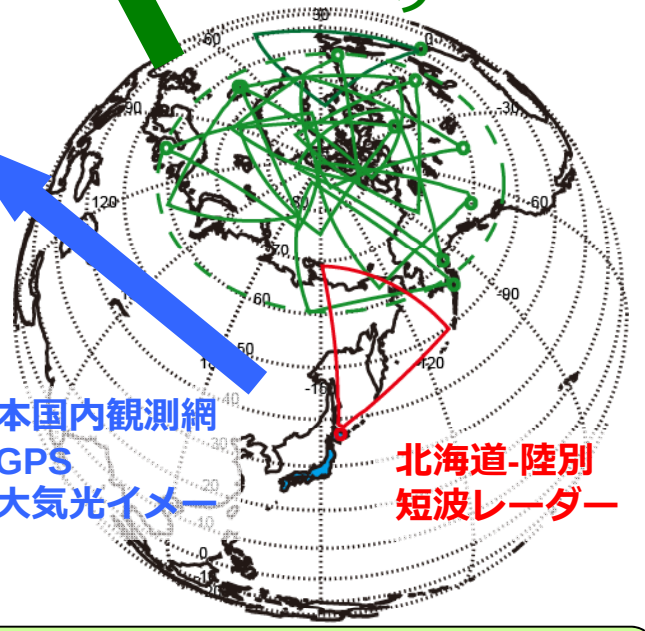




極域短波レーダーネットワーク

GPS

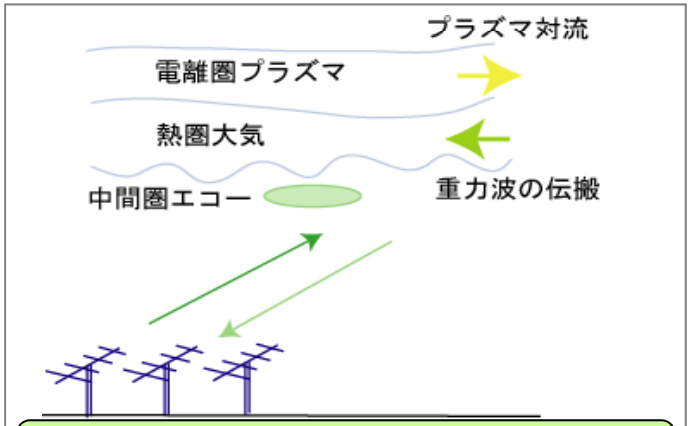




日本国内観測網
・GPS
・大気光イメージ

北海道-陸別
短波レーダー

従来の観測空白域をカバー
高緯度と中緯度を結ぶ領域のダイナミクスの統一的な解明



電離圏・熱圏・中間圏にわたる観測

2007年 : 北海道SuperDARNワークショップ

昭和基地SuperDARNレーダー導入経過：まとめ

１９８８年：昭和基地レーダーの小川提案

１９８９年：英国BASで開催されたDARN会議で昭和レーダー計画発表

１９８９年：昭和基地レーダーの予算獲得

１９９０年：２基のレーダーを配備する方針

１９９３年：第３４次隊で設置予定場所の整地開始

１９９５年：第３７次隊で第一レーダーを設置

１９９５年：ケンブリッジでSuperDARN発足のPI署名

１９９７年：第３９次隊で第二レーダーを設置

１９９８年：東京SuperDARNワークショップ開催

２００１年：アラスカ・キングサーモンレーダー稼働

２００６年：北海道レーダー稼働

２００７年：北海道SuperDARNワークショップ開催

主な経過：1995年　Greenwald et al 論文

DARN/SUPERDARN

A Global View of the Dynamics of High-Latitude Convection

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(Received 6 July, 1993)

Abstract. The Dual Auroral Radar Network (DARN) is a global-scale network of HF and VHF radars capable of sensing backscatter from ionospheric irregularities in the E and F-regions of the high-latitude ionosphere. Currently, the network consists of the STARE VHF radar system in northern Scandinavia, a northern-hemisphere, longitudinal chain of HF radars that is funded to extend from Saskatoon, Canada to central Finland, and a southern-hemisphere chain that is funded to include Halley Station, SANAE and Syowa Station in Antarctica. When all of the HF radars have been completed they will operate in pairs with common viewing areas so that the Doppler information contained in the backscattered signals may be combined to yield maps of high-latitude plasma convection and the convection electric field. In this paper, the evolution of DARN and particularly the development of its SuperDARN HF radar element is discussed. The DARN/SuperDARN network is particularly suited to studies of large-scale dynamical processes in the magnetosphere-ionosphere system, such as the evolution of the global configuration of the convection electric field under changing IMF conditions and the development and global extent of large-scale MHD waves in the magnetosphere-ionosphere cavity. A description of the HF radars within SuperDARN is given along with an overview of their existing and intended locations, intended start of operations, Principal Investigators, and sponsoring agencies. Finally, the operation of the DARN experiment within ISTP/GGS, the availability of data, and the form and availability of the Key Parameter files is discussed.

1. Introduction

One of the primary goals of the ISTP/GGS mission is to study the transport of mass and energy through the Geospace environment. The solar wind plasma imping-

Space Science Reviews **71:** 761–796, 1995.

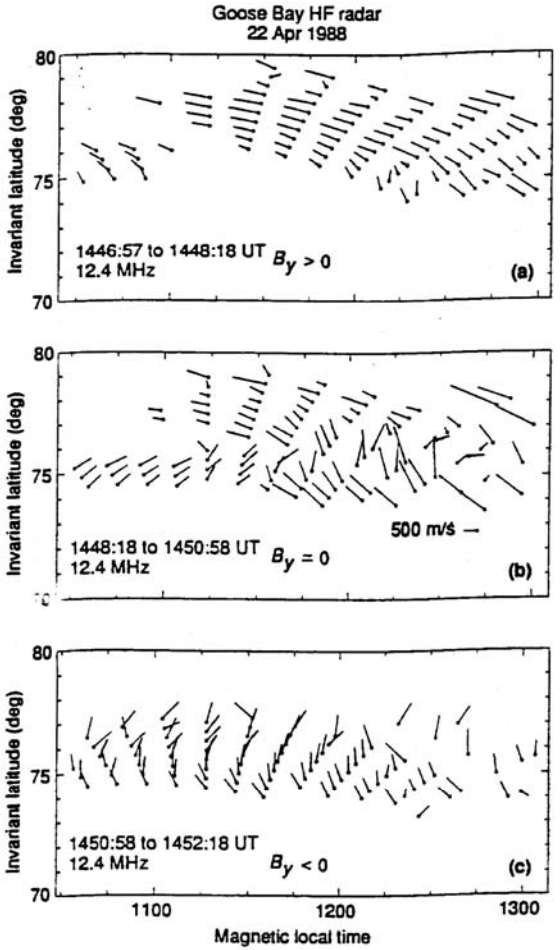
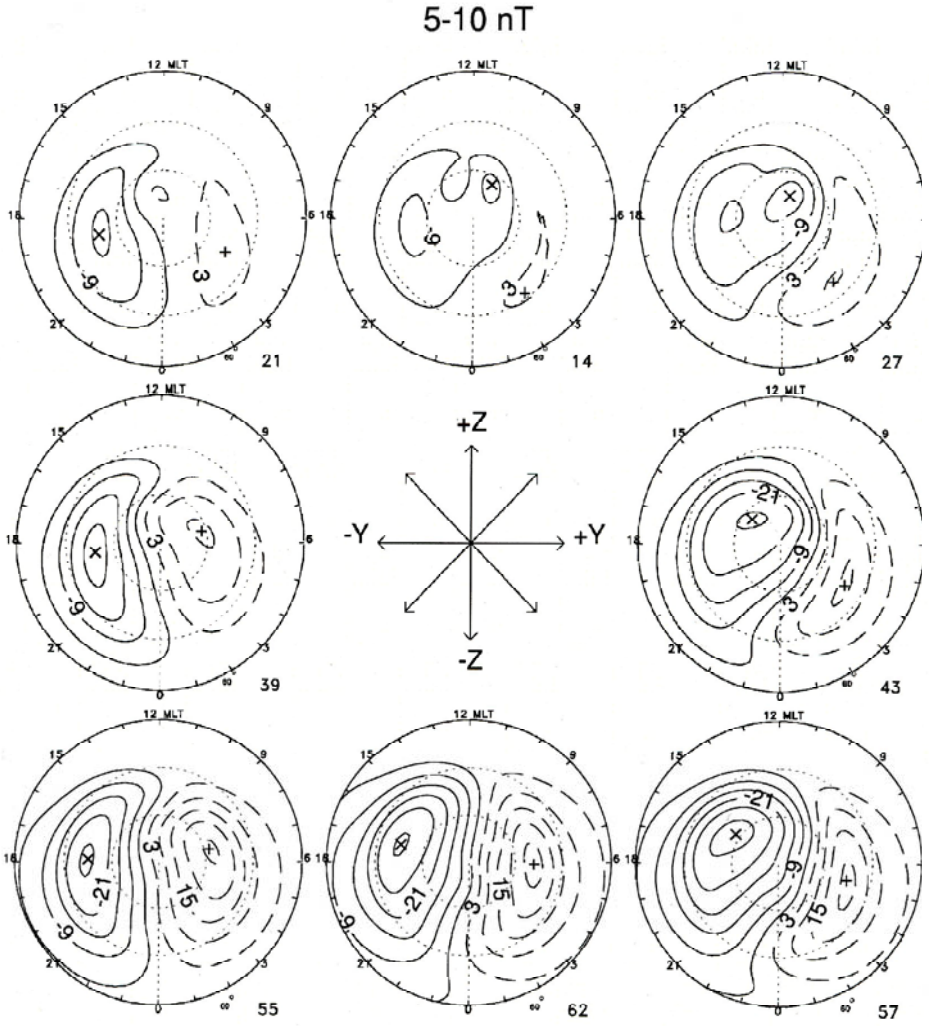
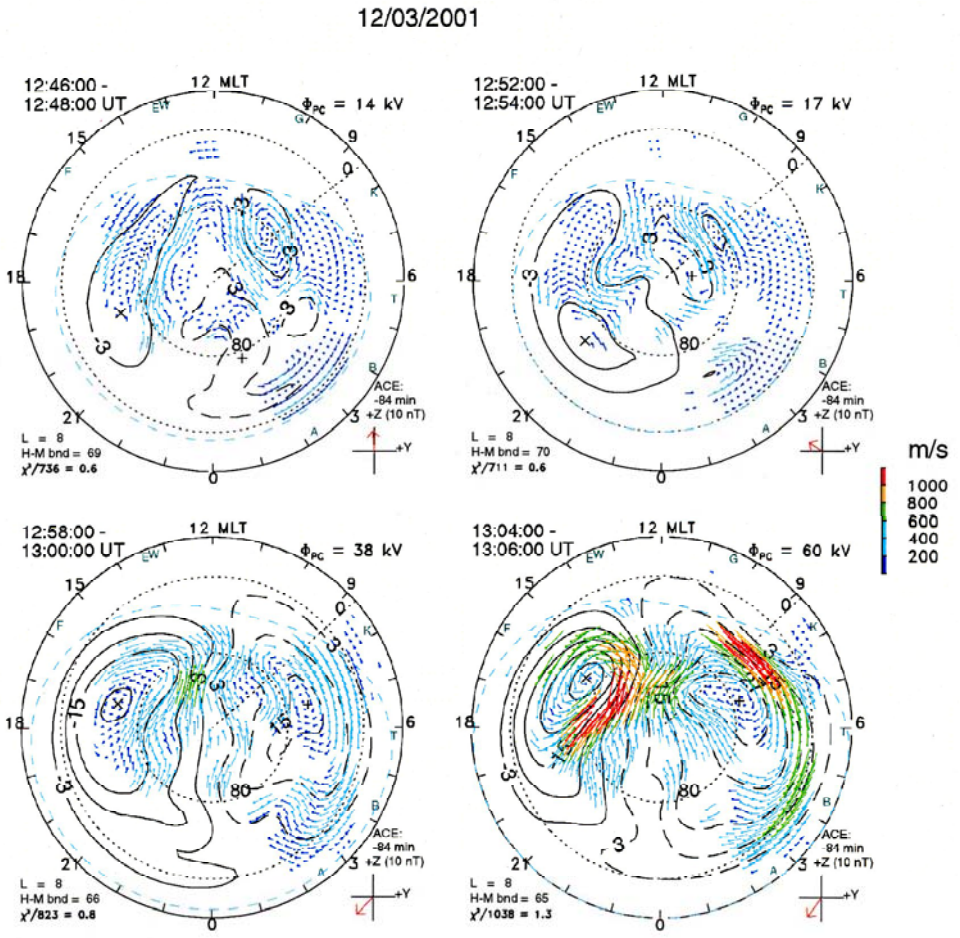


Fig. 7. Goose Bay radar observations of the temporal variation of F-region plasma drift patterns in the vicinity of the cusp and cleft as IMF B_y changes from positive to negative and B_z remains negative (From Greenwald *et al.*, 1990).

主な経過：2007年　Chisham et al 論文





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Greenwald et al., 2005

今後の計画

日本の研究成果も含め、

冊子にまとめたい