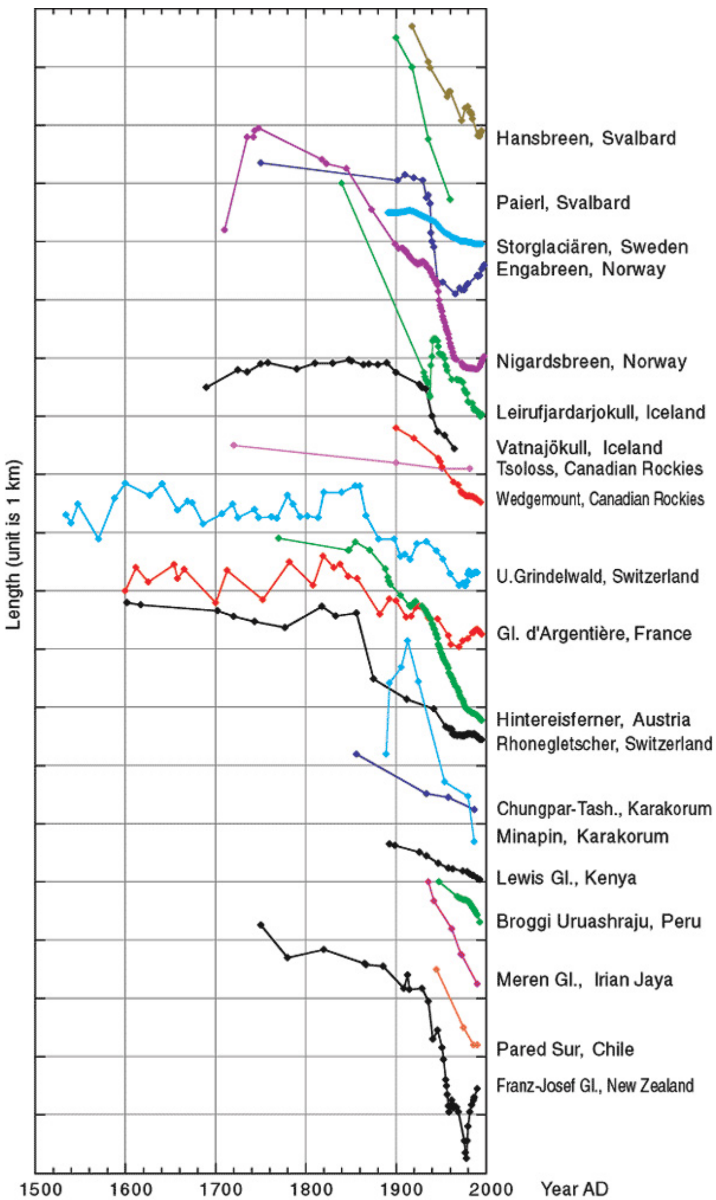
# Sea Ice Data: A Review

Jim Maslanik, University of Colorado
James.maslanik@colorado.edu

- Ice charting/mapping methods and data sets
- Error sources and characteristics
- Consistency and algorithm issues
- IST and SST within the ice pack



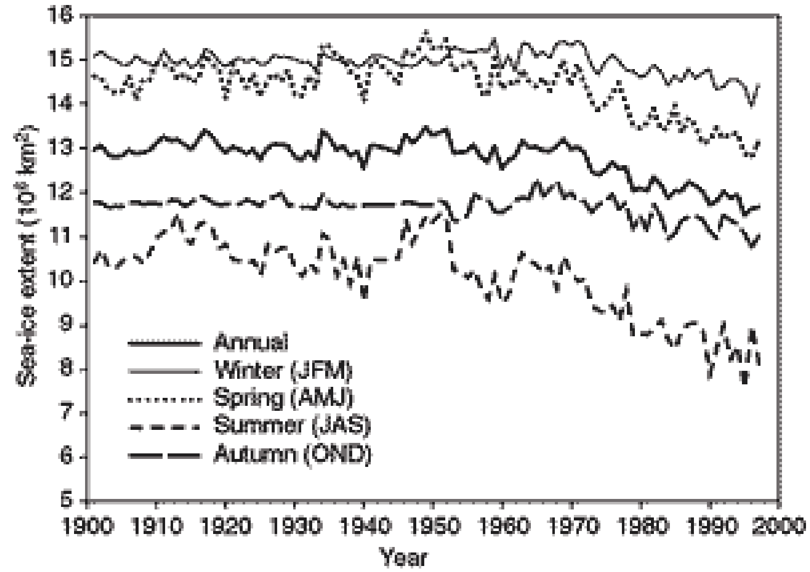
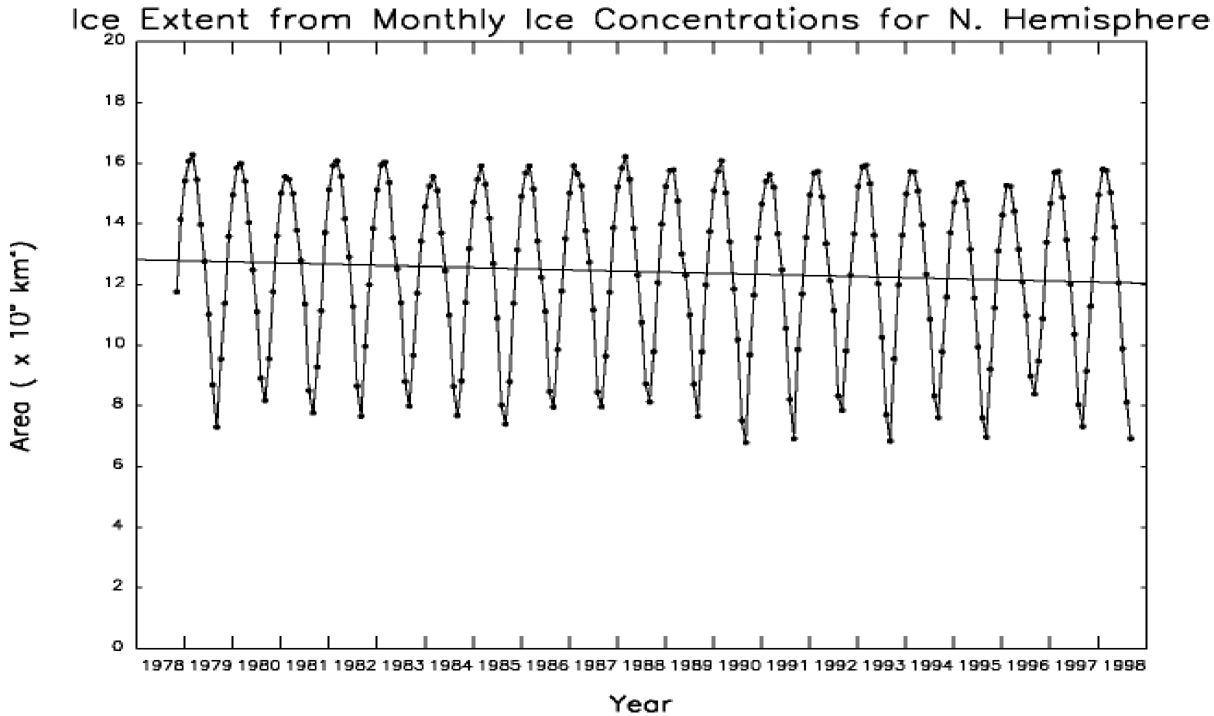
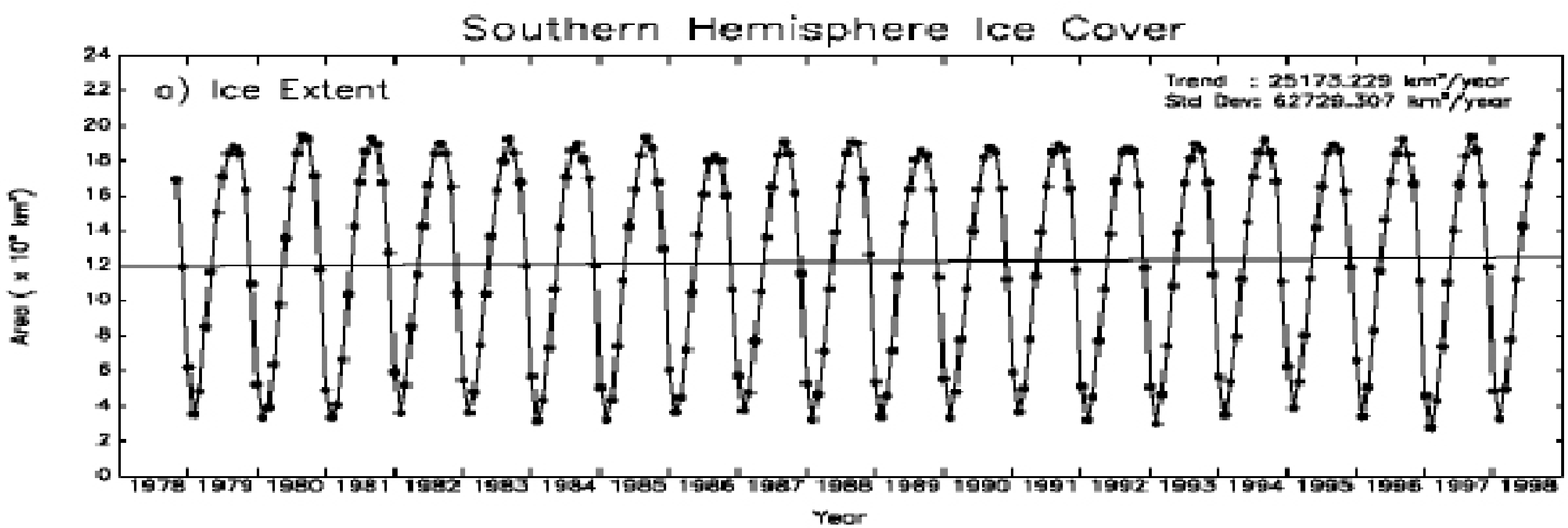




***Fig 2.15:*** *Time-series of annual and seasonal sea-ice extent in the Northern Hemisphere, 1901 to 1999, (Annual values from Vinnikov et al., 1999b; seasonal values updated from Chapman and Walsh, 1993.)*

**(IPCC, 2001)**


Ice Extent from Monthly Ice Concentrations for N. Hemisphere
Area ( x 10⁶ km²)
0
2
4
6
8
10
12
14
16
18
20
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
Year

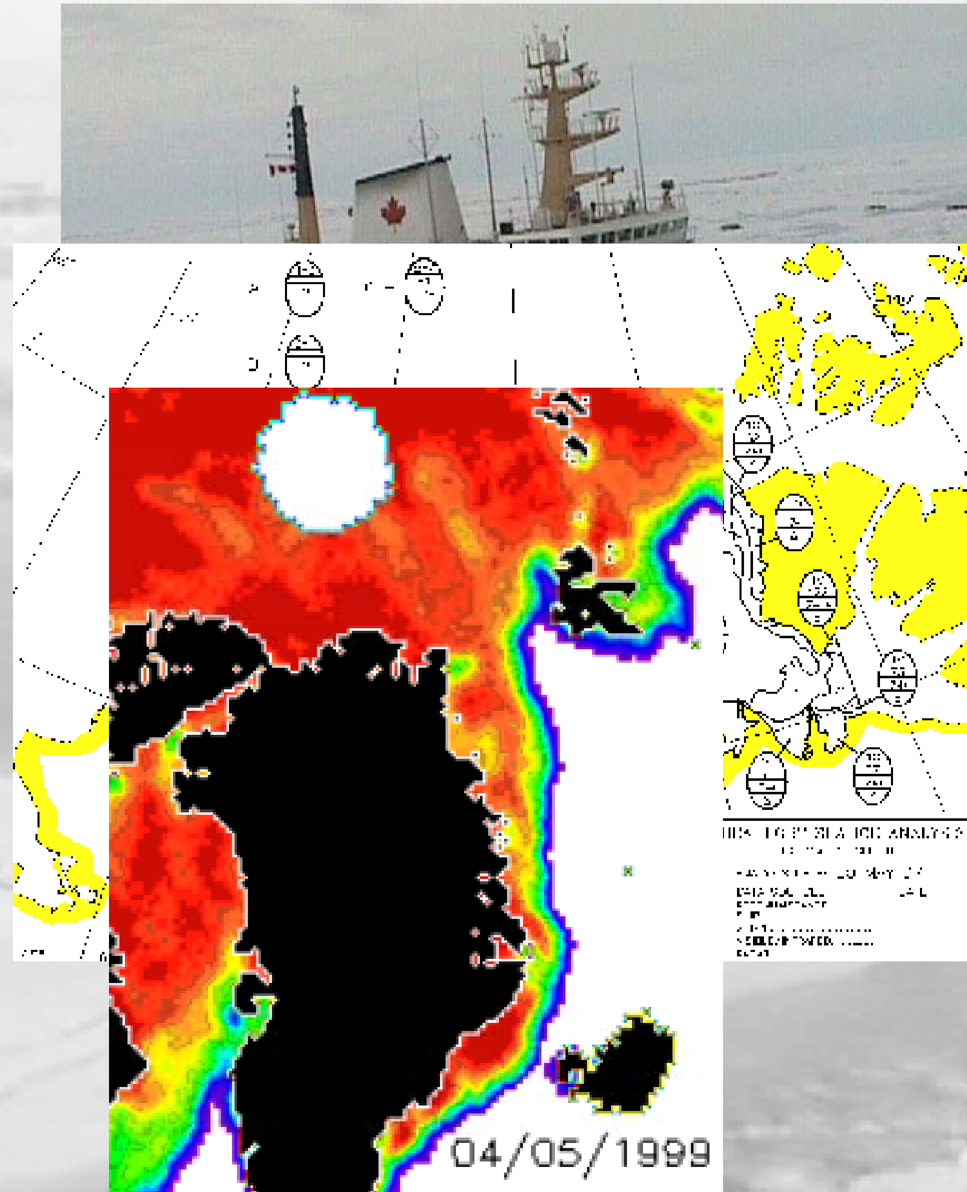

Southern Hemisphere Ice Cover
a) Ice Extent
Trend : 25173.229 km²/year
Std Dev: 62729.307 km²/year
Area ( x 10⁶ km²)
0
2
4
6
8
10
12
14
16
18
20
22
24
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998
Year

# Ice Charting and Mapping

•Ship-report compilations

•Ice charting with aircraft and satellite support

•Satellite-derived digital (algorithm) products



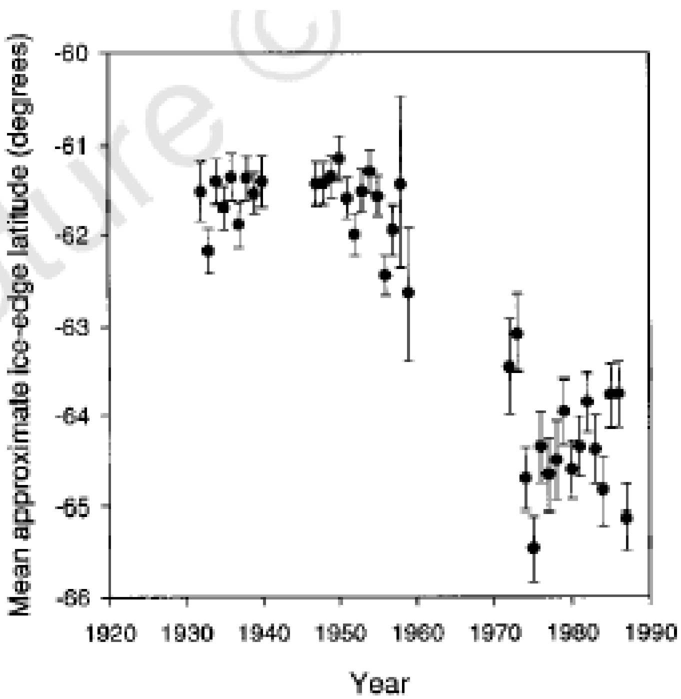
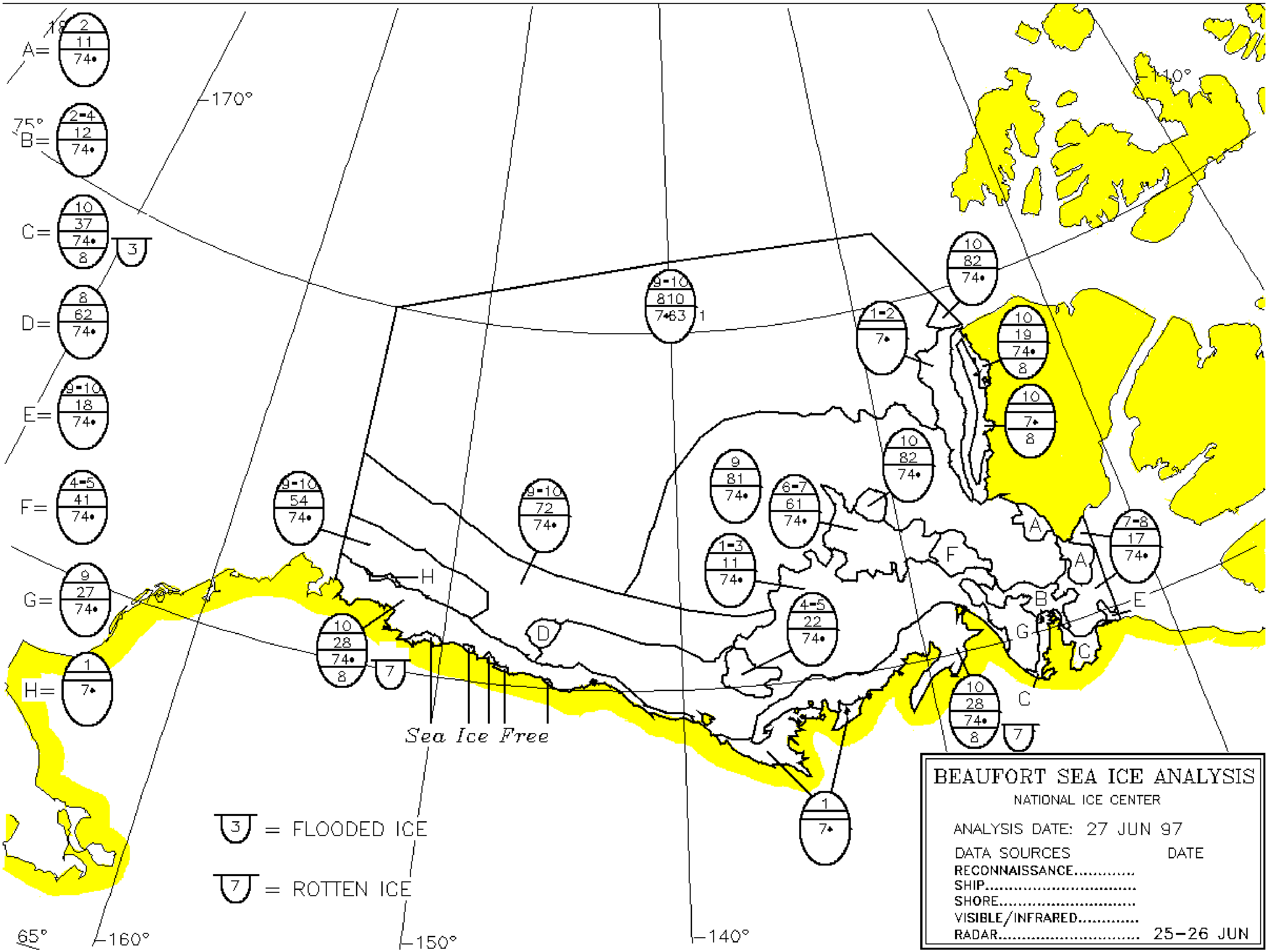



**Figure 1** Mean approximate ice-edge latitude in Antarctica from 1931 to 1987. The estimates are from a linear model fitted to whale-catch records, and are standardized to first 10-day period of January and the longitudinal sector 20°–30° E. The year is defined by the first decade (ten days) in January, and so, for example, 1932 is the mid-point of the 1931/32 season. The predictions are most precise at the centre-of-mass of the data, and so the selected decade and longitude are based on the mean value of each factor weighted by the number of observations at each of its levels. The year effects are corrected for decade and longitude, and so describe a generalized effect for the latitude of catches with time. The actual pattern over time for a given sector and decade would not necessarily correspond exactly to the pattern shown because there are likely to be interactions between the factors. However, these could not be estimated with the data available. The error bars represent ±1 standard error.

**(W. de la Mare, 1997, Nature, Vol. 389, 4)**

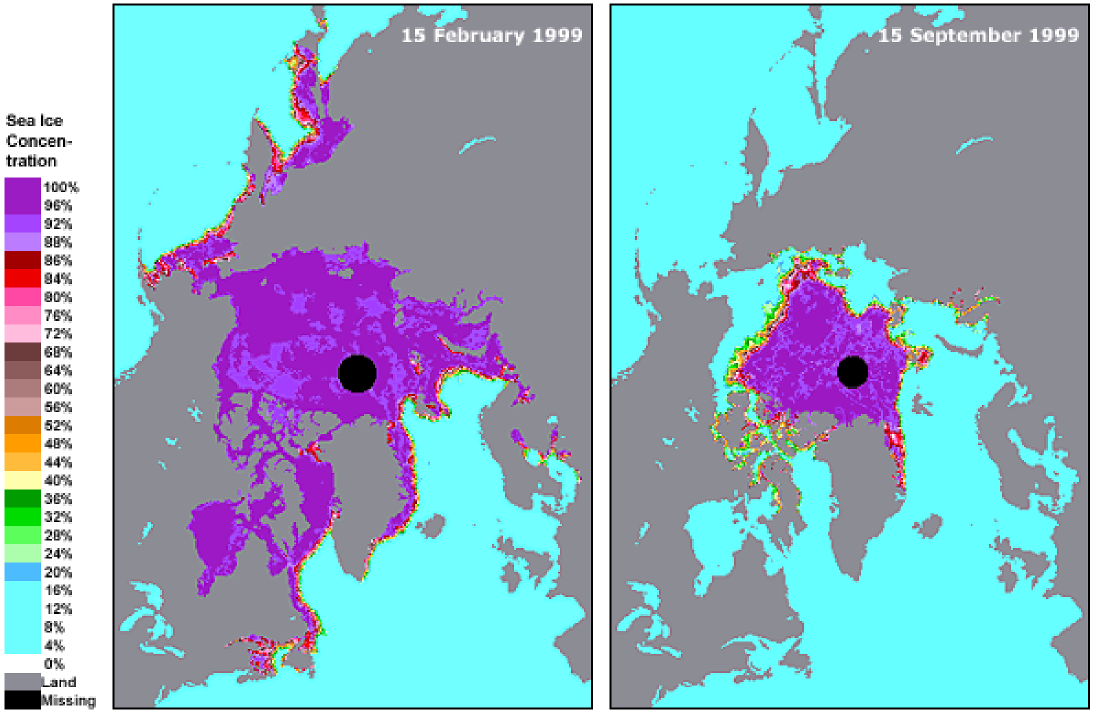

BEAUFORT SEA ICE ANALYSIS
NATIONAL ICE CENTER
ANALYSIS DATE: 27 JUN 97
DATA SOURCES DATE
RECONNAISSANCE............
SHIP..............................
SHORE............................
VISIBLE/INFRARED............
RADAR............................ 25-26 JUN
= FLOODED ICE
= ROTTEN ICE
Sea Ice Free
170°
160°
150°
140°
110°
75°
65°
A=
B=
C=
D=
E=
F=
G=
H=

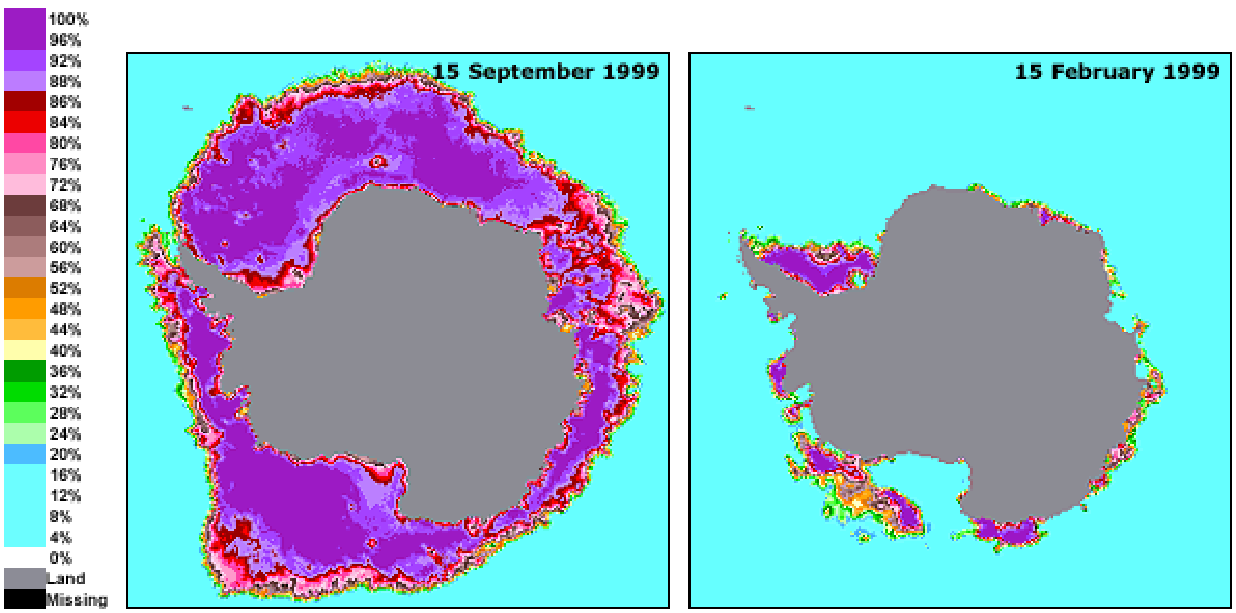
# Summary: Sources of Differences, Errors, Biases in Ice Reports and Charts

- Distribution of observations in time and space;
- Chart producers' areas of interest or emphasis;
- Changes in types of data available over time;
- Changes in personnel and skill level.

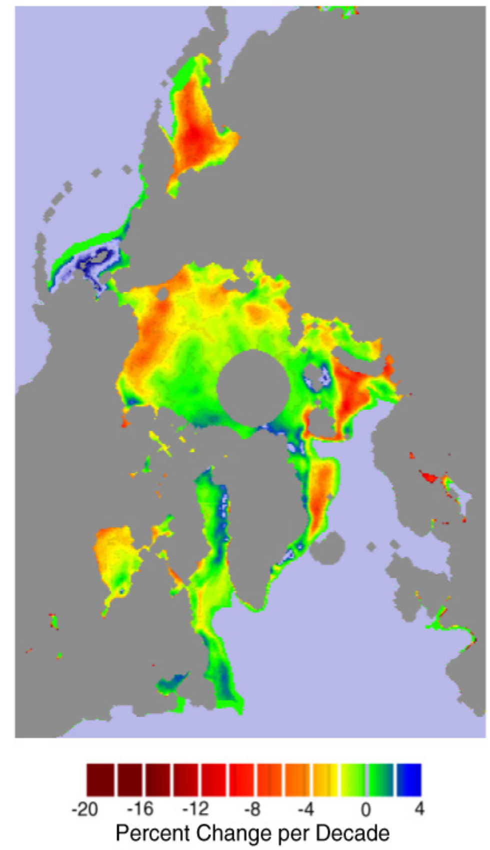
# Satellite-Derived Sea Ice Data Sets

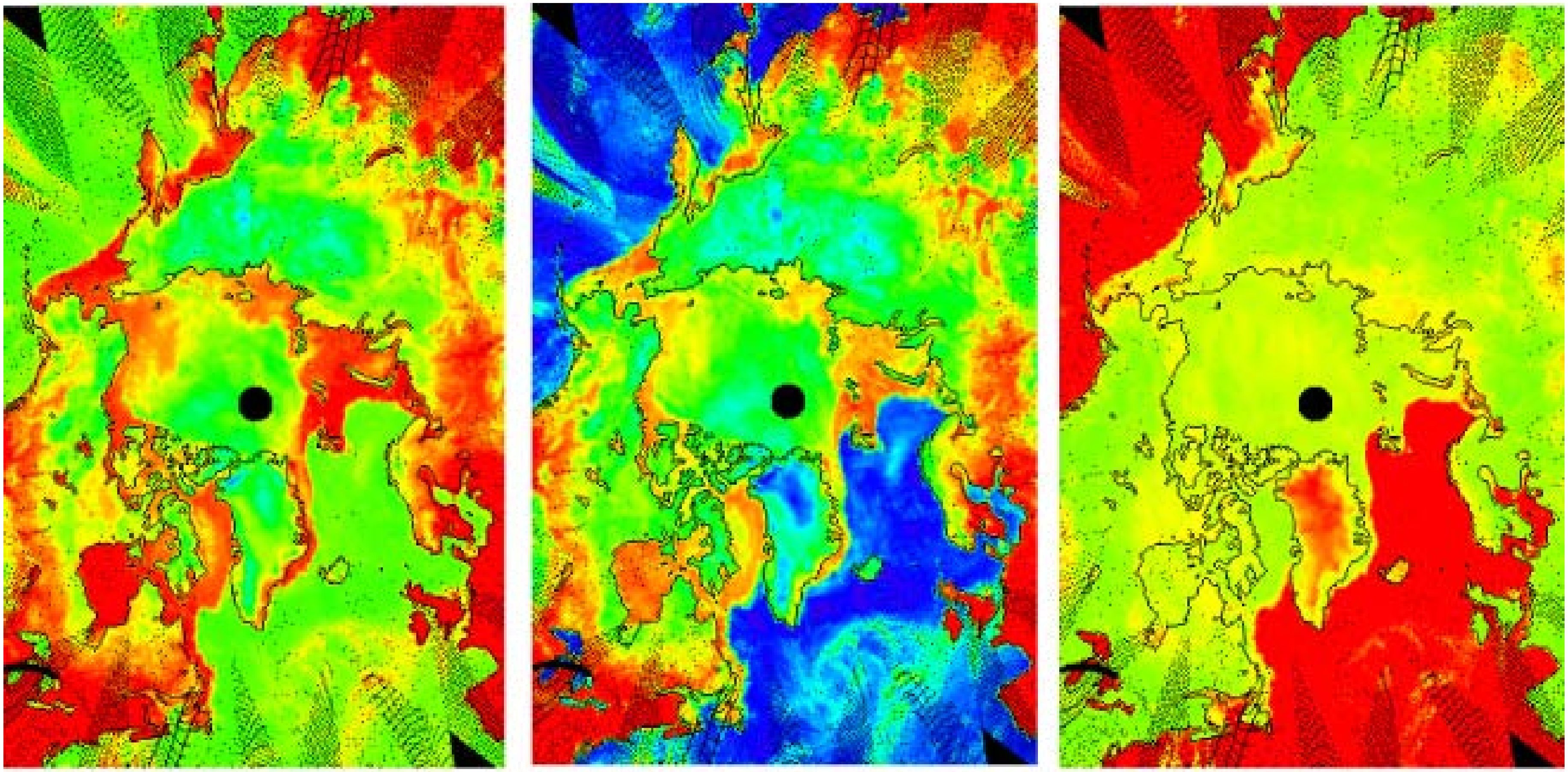
- Meteorological satellite products (visible/thermal band - e.g., AVHRR [1970's - present]);
- Synthetic aperture radar (ERS-1, ERS-2, RADARSAT [1991 - present]);
- Scatterometer (ERS, Quikscat);
- Passive microwave (ESMR, SMMR, SSM/I, *AMSR, CMIS* [1974 - present])



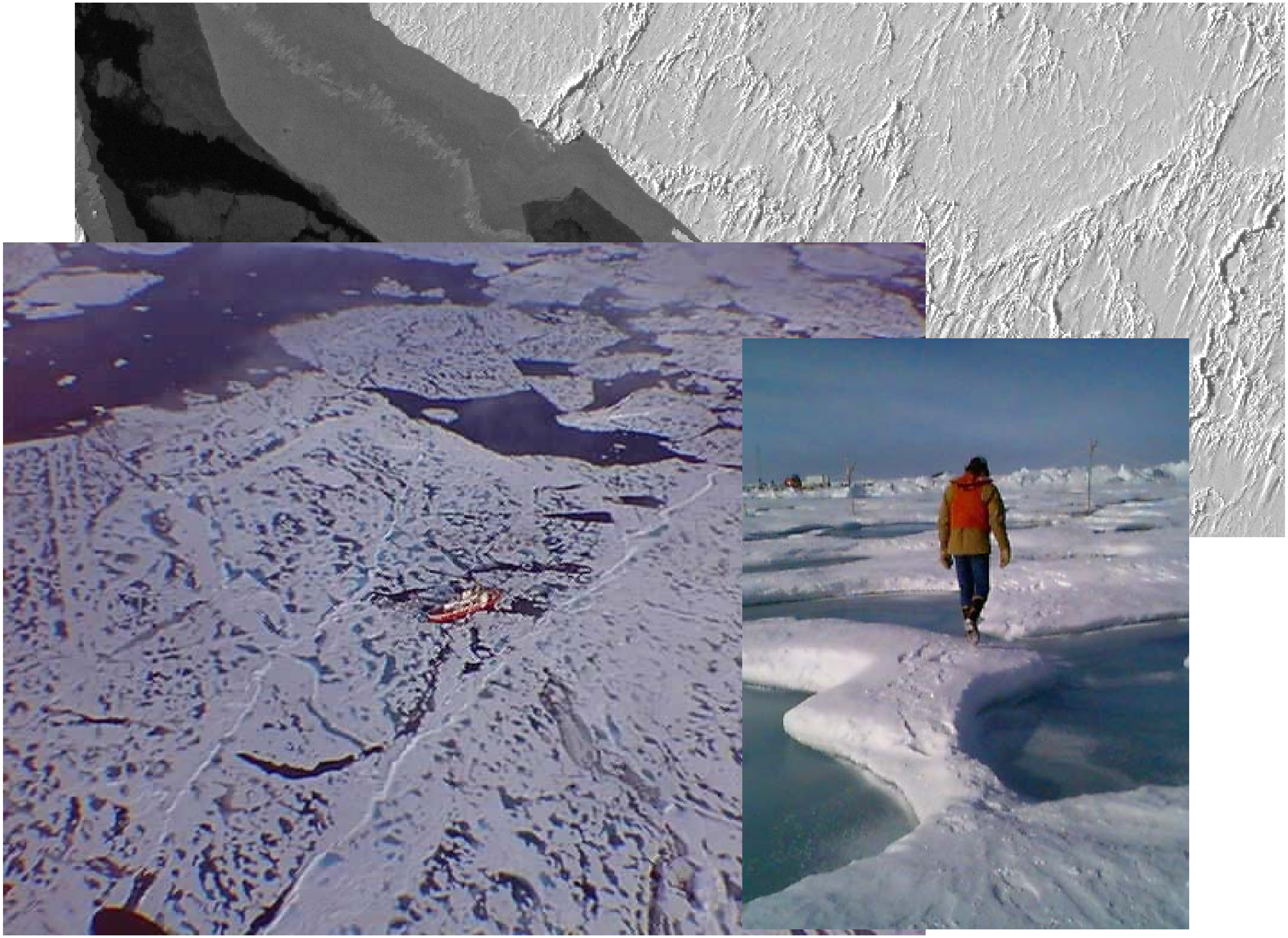



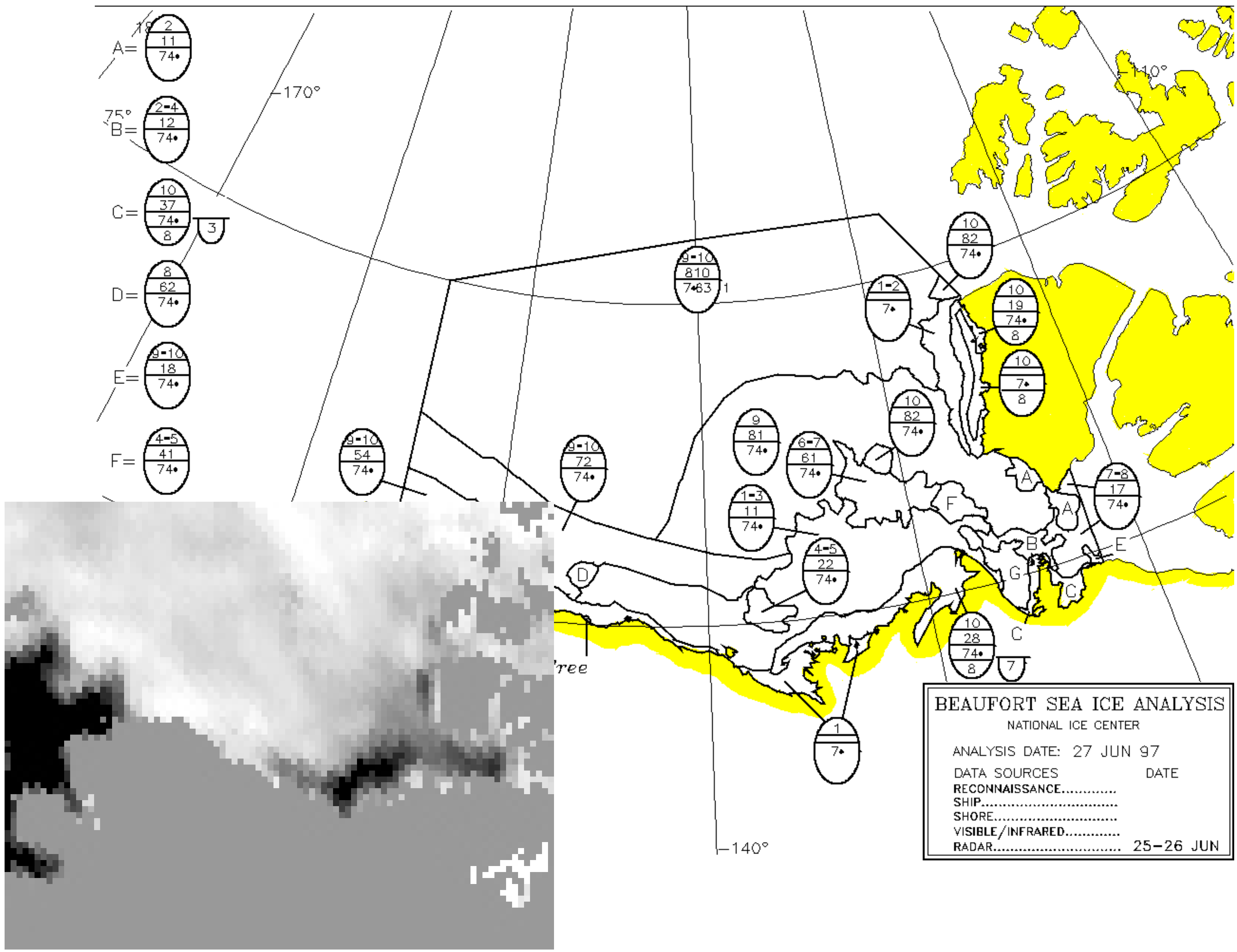

Mean Annual Trends in
Passive Microwave-Derived Ice Concentration
for 1979 to 1999





SSM/I 37 GHz Data for the Northern Hemisphere for 1 March 1999
(37 V. Polarization [left], 37 H. Polarization [center], normalized polarization ratio [right]



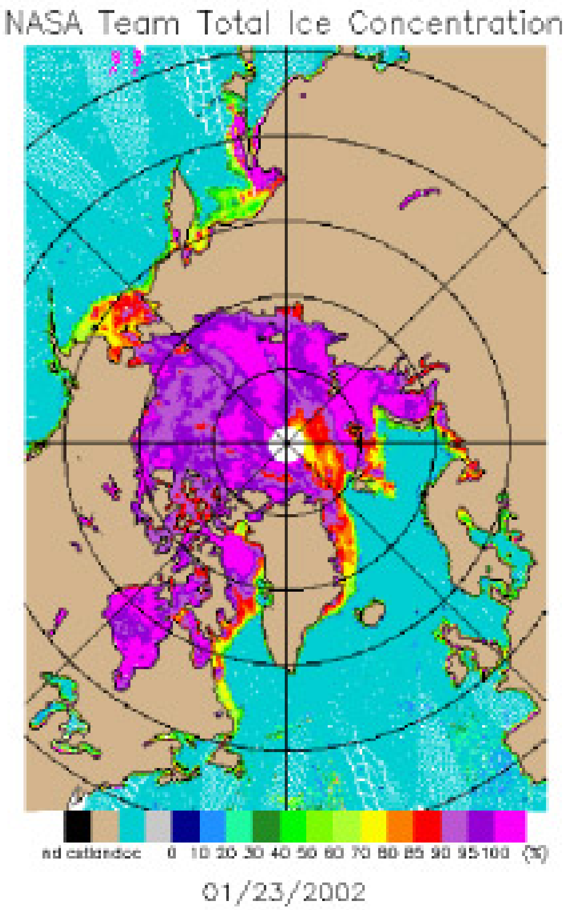


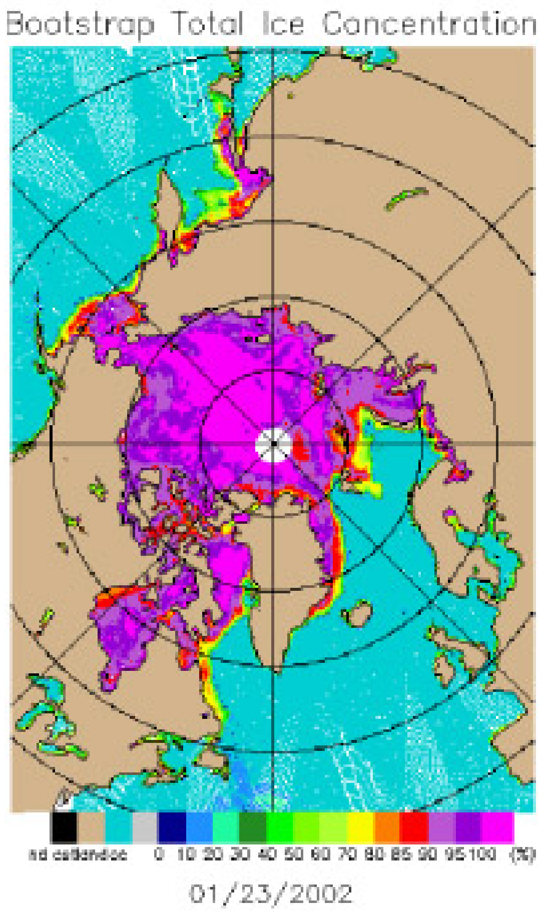
A=
B=
C=
D=
E=
F=
75°
170°
140°
140°
BEAUFORT SEA ICE ANALYSIS
NATIONAL ICE CENTER
ANALYSIS DATE: 27 JUN 97
DATA SOURCES DATE
RECONNAISSANCE............
SHIP...............................
SHORE............................
VISIBLE/INFRARED............
RADAR............................ 25-26 JUN

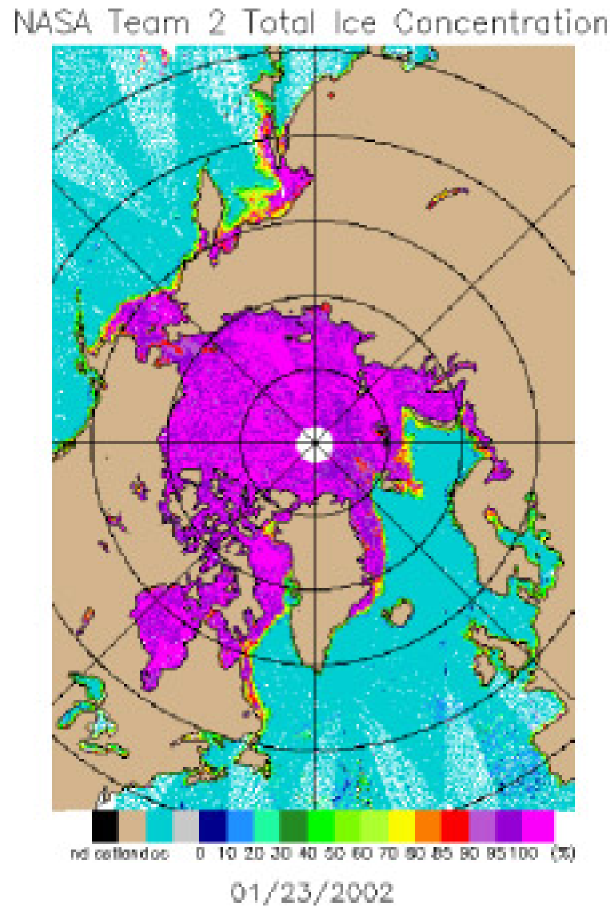
# Summary: Sources of Error and Biases in Passive Microwave-Derived Satellite Products

- Surface melt effects;
- Thin ice cover;
- Weather and ocean-surface contamination;
- Effects of variations in snow cover;
- Land contamination at coastlines;
- Gradual changes in atmospheric or surface conditions.

# Satellite Data / Algorithm Differences




Source: National Ice Center

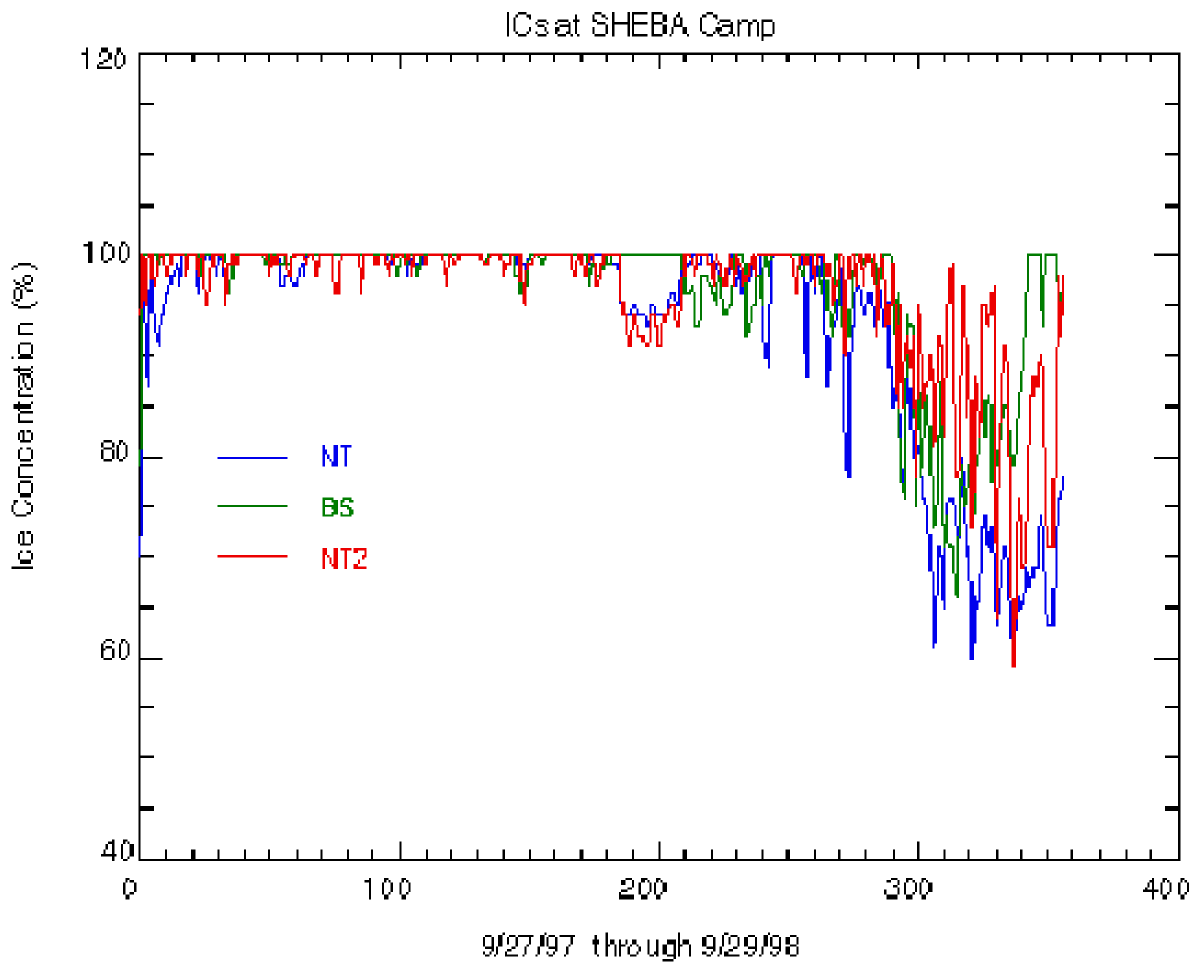
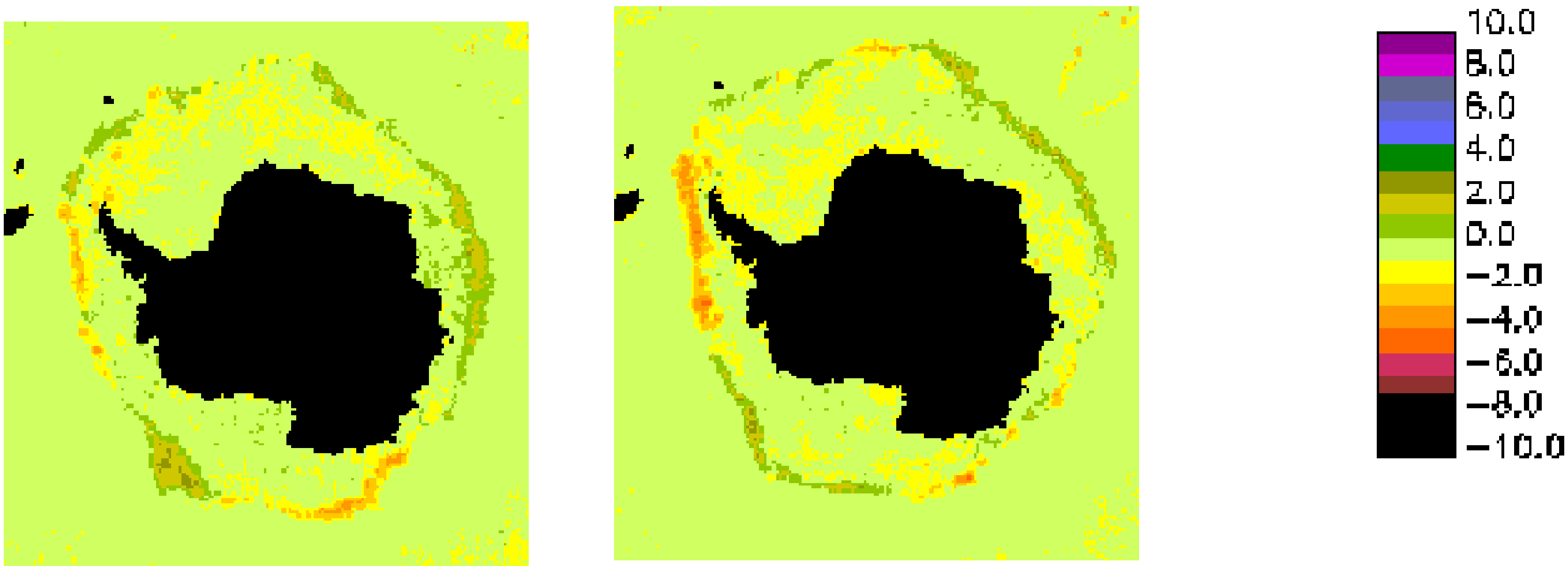



Figure 1. Comparison of SSM/I-derived sea ice concentrations from the NASA Team (NT), Bootstrap (BS) and the Enhanced NASA Team (NT2) sea ice algorithms at the SHEBA camp from 27 September 1997 through 29 September 1998.

Table 1. Comparison of orbital parameters for various passive microwave sensors.

| Parameter | Nimbus-7 | DMSP | DMSP | DMSP | AMSR |
|---|---|---|---|---|---|
| | SMMR | F8 | F11 | F13 | |
| | | | | | |
| Nominal Altitude | 955 km | 860 km | 830 km | 850 km | 705 km |
| Inclination Angle | 99.1 degrees | 98.8 degrees | 98.8 degrees | 98.8 degrees | 99.0 degrees |
| Orbital Period | 104 minutes | 102 minutes | 101 minutes | 102 minutes | 99 minutes |
| Ascending Node | approximately | approximately | approximately | approximately | approximately |
| Equatorial Crossing | 12:00 p.m. | 6:00 a.m. | 5:00 p.m. | 5:43 p.m. | 1:30 p.m. |
| (local time) | | | | | |
| Earth Incidence Angle | 50.2 degrees | 53.1 degrees | 52.8 degrees | 53.4 degrees | 55.0 degrees |
| Period of Operation | 10.25.1978- | 07.09.1987- | 12.03.1991- | 05.03.1995- | launch date: |
| | 08.20.1987 | 12.31.1991 | 09.30.1995 | present | December 2000 |
| Frequencies bands | 6.6 V/H | 19.3 V/H | 19.3 V/H | 19.3 V/H | 6.9 V/H |
| (GHz) | 10.7 V/H | 22.2 V | 22.2 V | 22.2 V | 10.7 V/H |
| | 18.0 V/H | 37.0 V/H | 37.0 V/H | 37.0 V/H | 18.7 V/H |
| | 21.0 V/H | 85.5 V/H | 85.5 V/H | 85.5 V/H | 23.8 V/H |
| | 37.0 V/H | | | | 36.5 V/H |
| | | | | | 50.3 V |
| | | | | | 52.8 V |
| | | | | | 89.0 V/H |

# Differences in ice concentration (SSM/I F11 vs. SSM/I F13)




August

September

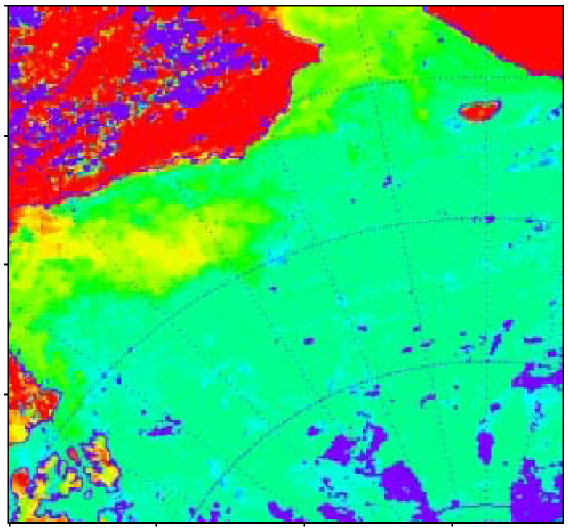
**Figure 5. Monthly spatial patterns of Southern Hemisphere total ice concentration differences.**

# Summary: Sources of Inconsistencies Between Passive Microwave Sensors, Platforms, and Algorithms

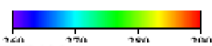
- Channel selection;
- Viewing angle;
- Overpass times;
- Algorithm nature and channel suite;
- Tie point (“calibration”) selection;
- Algorithm sensitivity to sensor drift;
- Algorithm sensitivity to second-order factors.

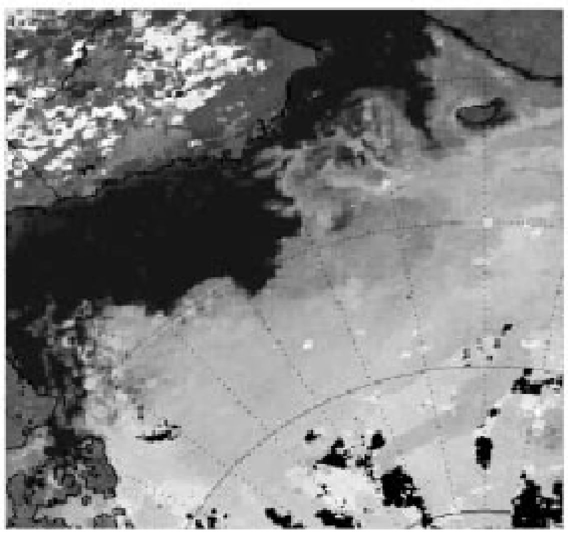
# SST and IST in the Marginal Ice Zone

AVHRR: July 1998

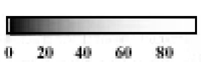


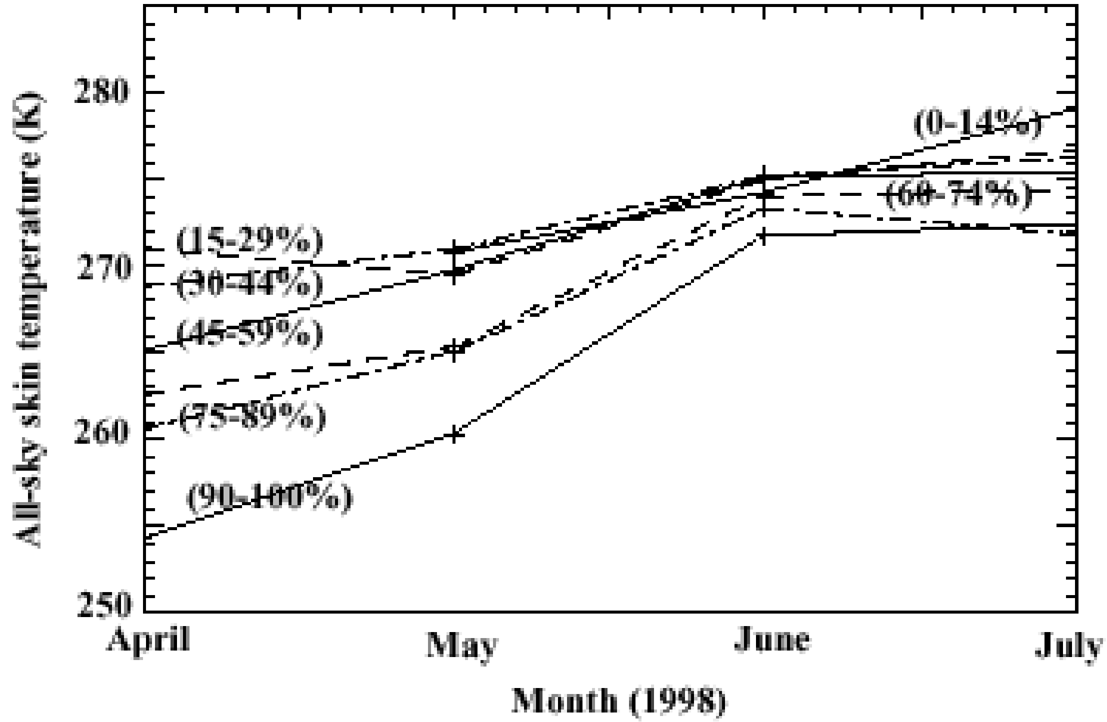
Skin temperature





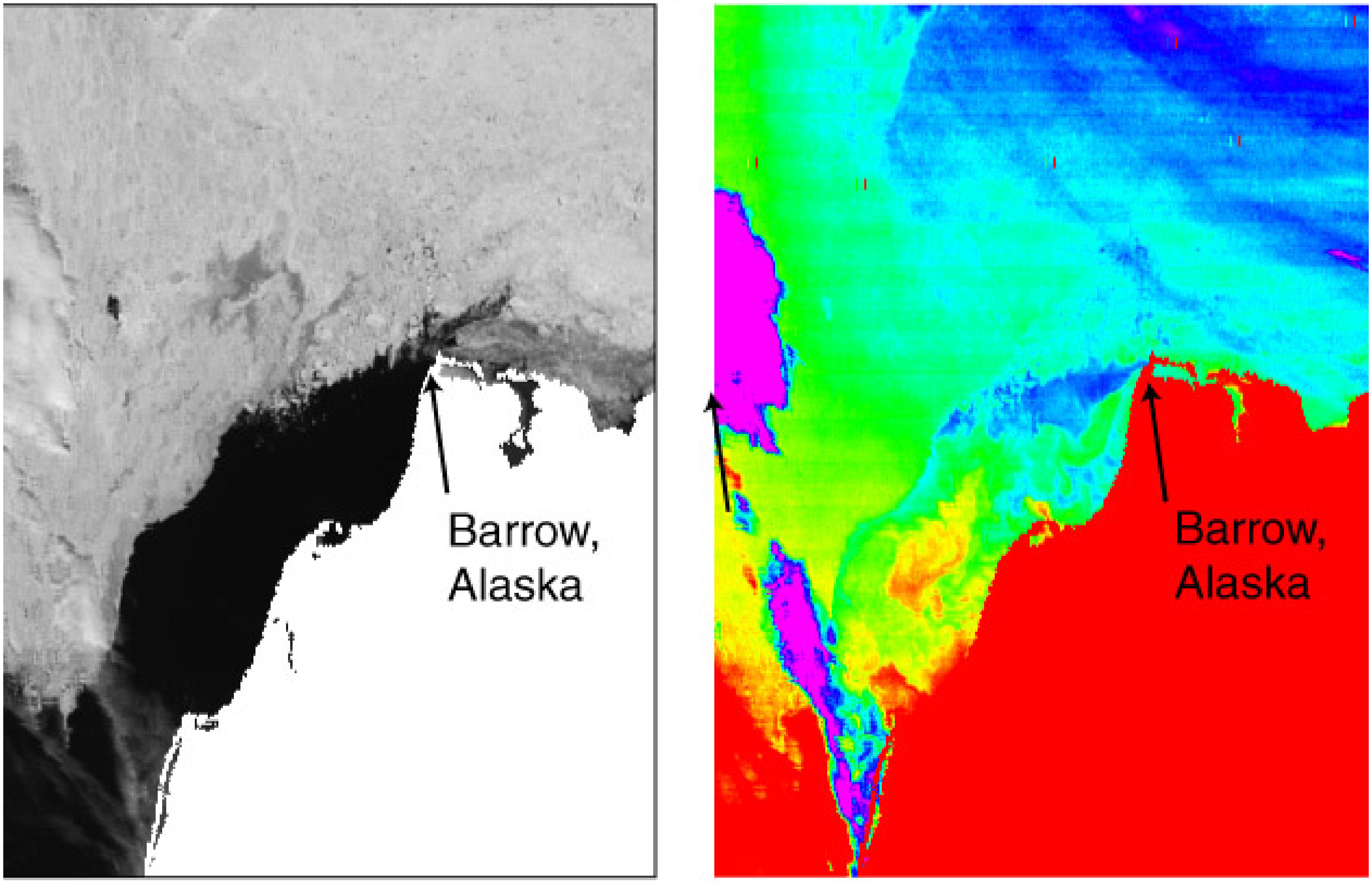
Albedo



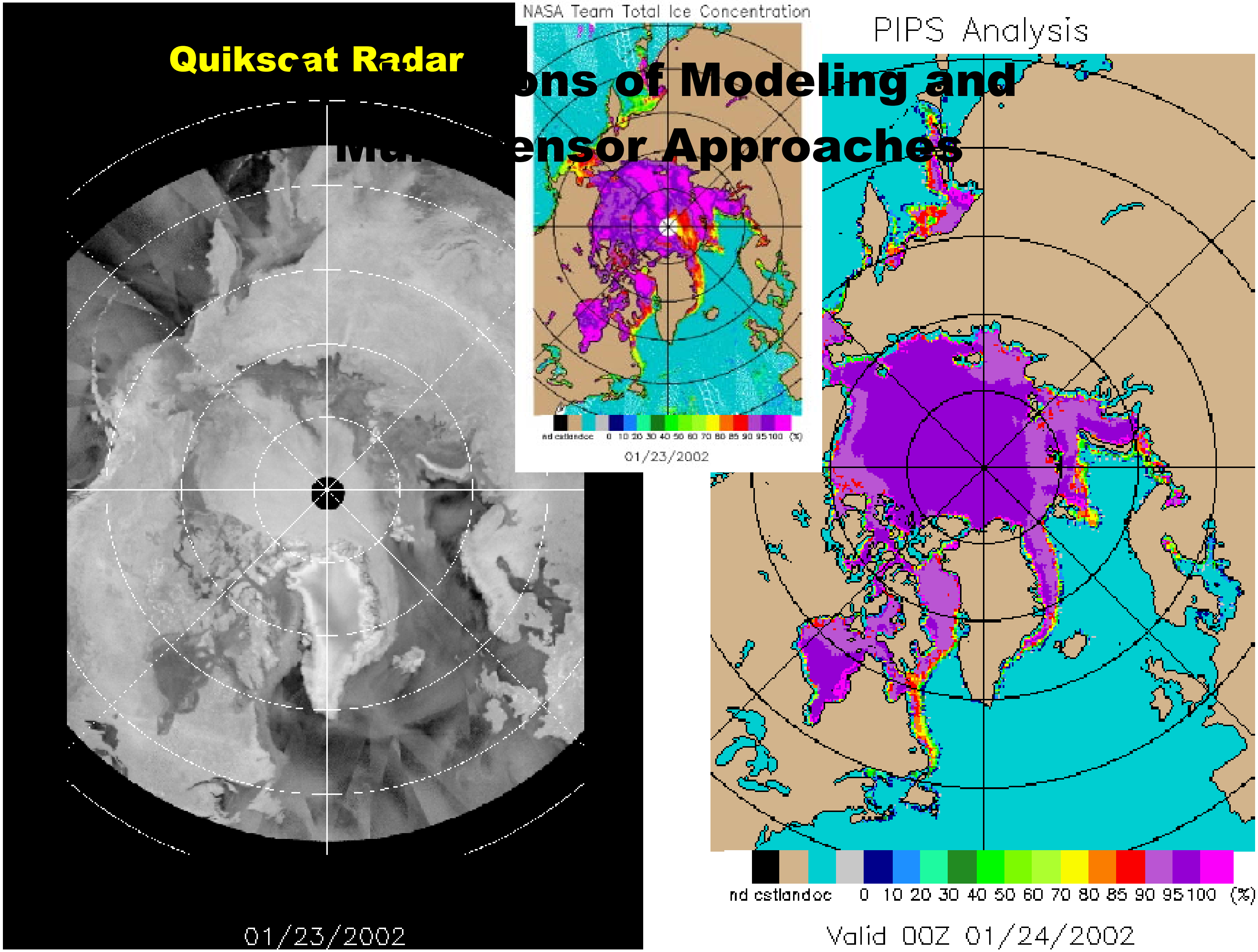

**Monthly mean AVHRR-derived all-sky skin temperatures for areas within ranges of sea ice concentration as estimated from SSM/I data. Concentration ranges in percent are listed next to the corresponding plot lines.**

## Summer Marginal Ice Zone Reflectance and Temperature
(EOS MODIS Imagery, 14 July 2001)




Ch. 1 (650 nm)    Ch. 32 (11.9 nm)

## …ons of Modeling and Mu… ensor Approaches



# Conclusions

•Three distinct types of records: point observations; manually-generated charts; satellite-based algorithms;

•Sources and biases vary with data type (thin ice, melt effects, etc.);

•Multisensor+modeling approaches likely to be effective for minimizing error and improving blending of products.

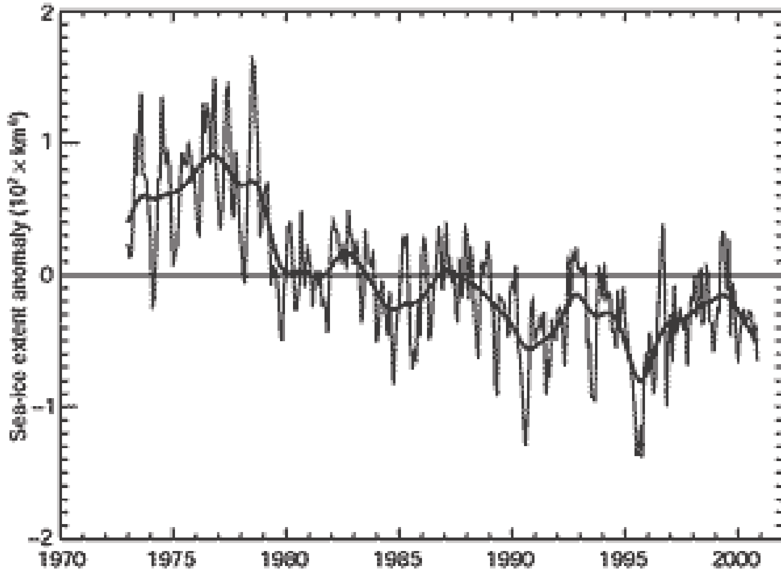



***Figure 2.14:*** *Monthly Arctic sea-ice extent anomalies, 1973 to 2000, relative to 1973 to 1996. The data are a blend of updated Walsh (Walsh, 1978), Goddard Space Flight Center satellite passive microwave (Scanning Multichannel Microwave Radiometer (SMMR) and Special Sensor Microwave/Imager (SSM/I)) derived data (Cavalieri et al., 1997) and National Centers for Environmental Prediction satellite passive microwave derived data (Grumbine, 1996). Updated digitised ice data for the Great Lakes are also included (Assel, 1983).*

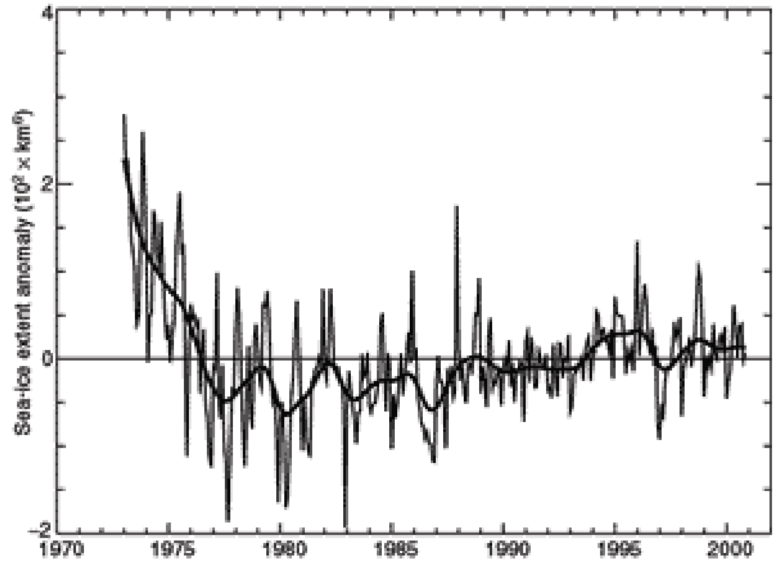
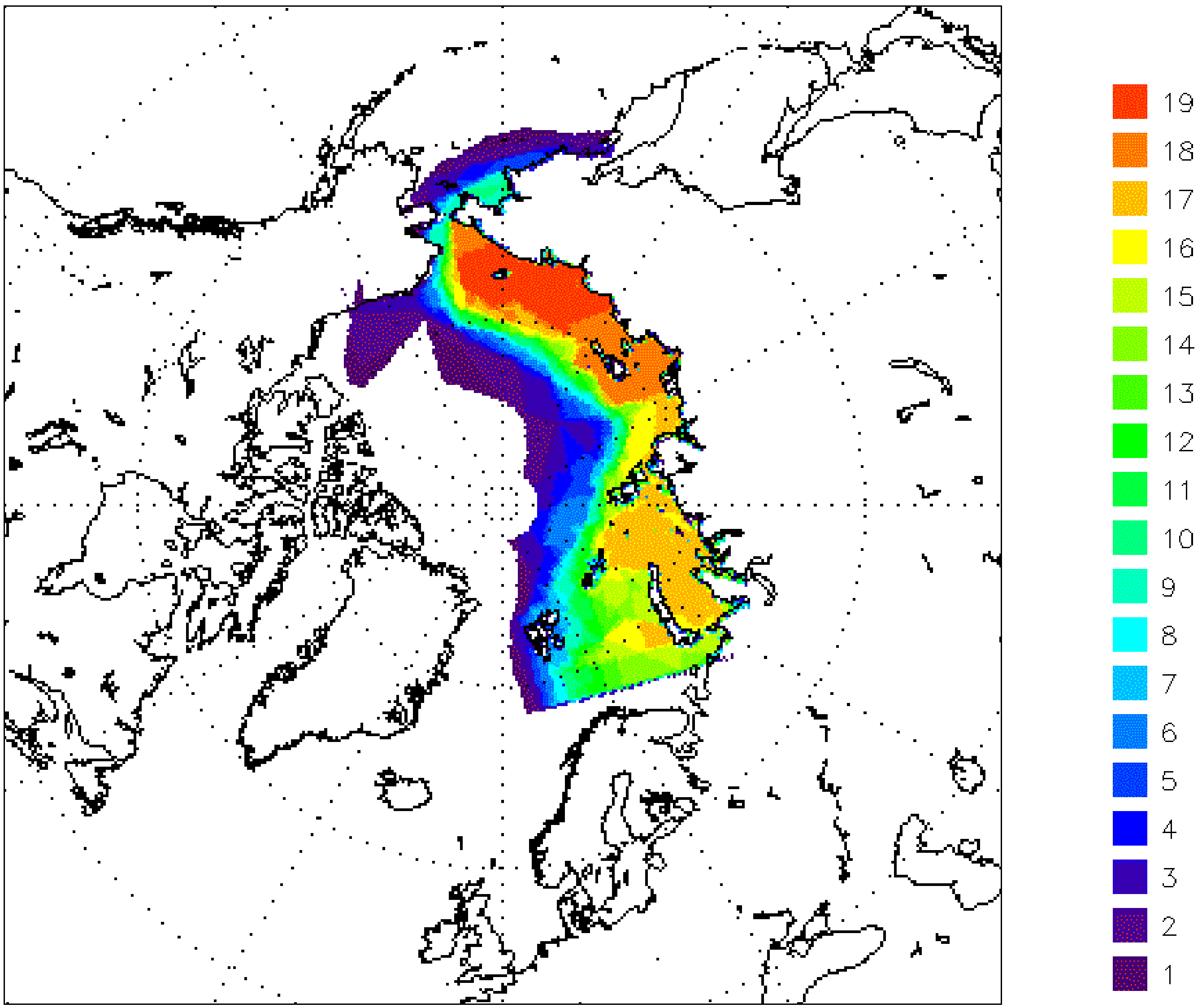



***Figure 2.16:*** *Monthly Antarctic sea-ice extent anomalies, 1973 to 2000, relative to 1973 to 1996. The data are a blend of National Ice Center (NIC) chart-derived data (Knight, 1984), Goddard Space Flight Center satellite passive-microwave (Scanning Multichannel Microwave Radiometer (SMMR) and Special Sensor Microwave/Imager (SSM/I)) derived data (Cavalieri et al., 1997) and National Centers for Environmental Prediction satellite passive-microwave derived data (Grumbine, 1996). It is uncertain as to whether the decrease in interannual variability of sea ice after about 1988 is real or an observing bias.*

**(IPCC, 2001)**

AARI 1972 files in EASE
Counts of Total Ice Concentration
Nearest Neighbor



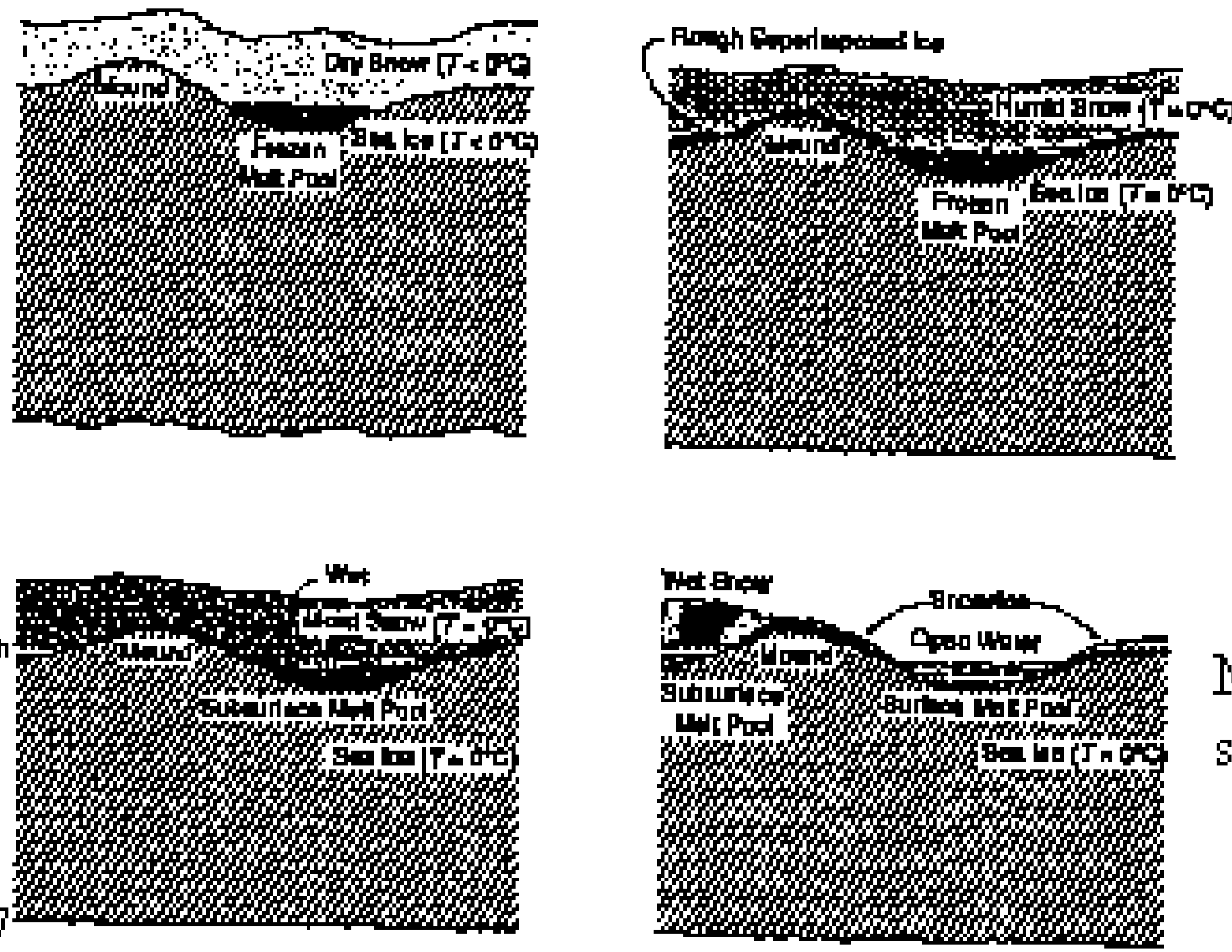
# Snow and ice conditions on multiyear ice

Winter, early spring

Late spring

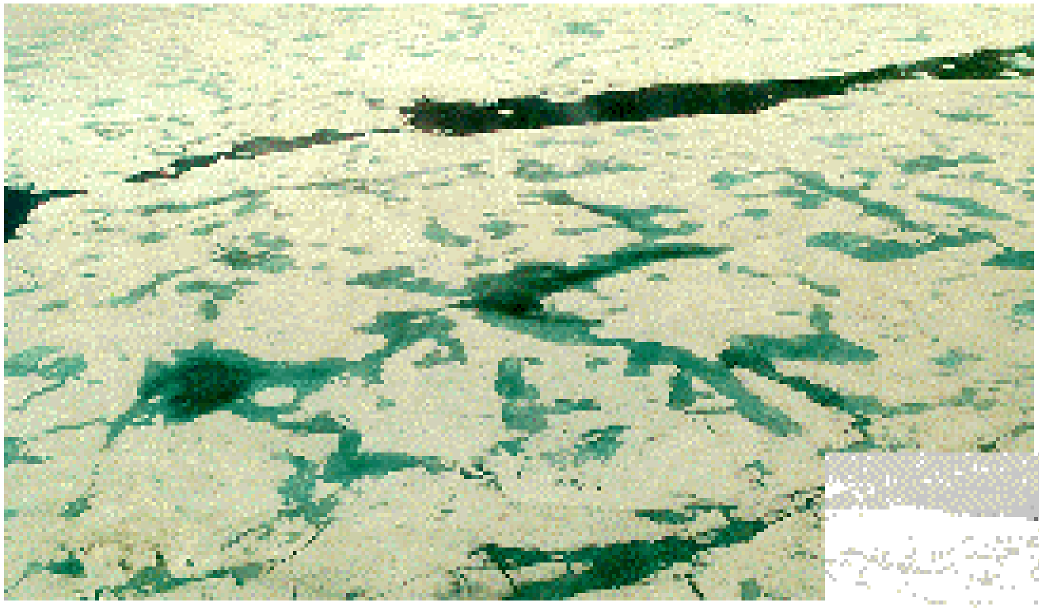
Early-mid summer

Mid-late summer

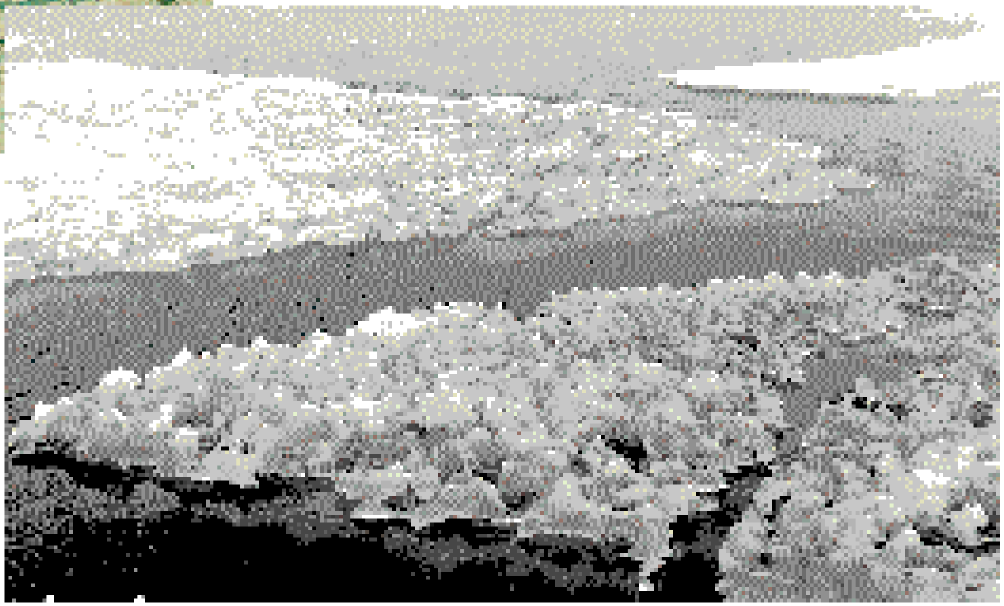



Onstott et al., 1987

# Ice melting

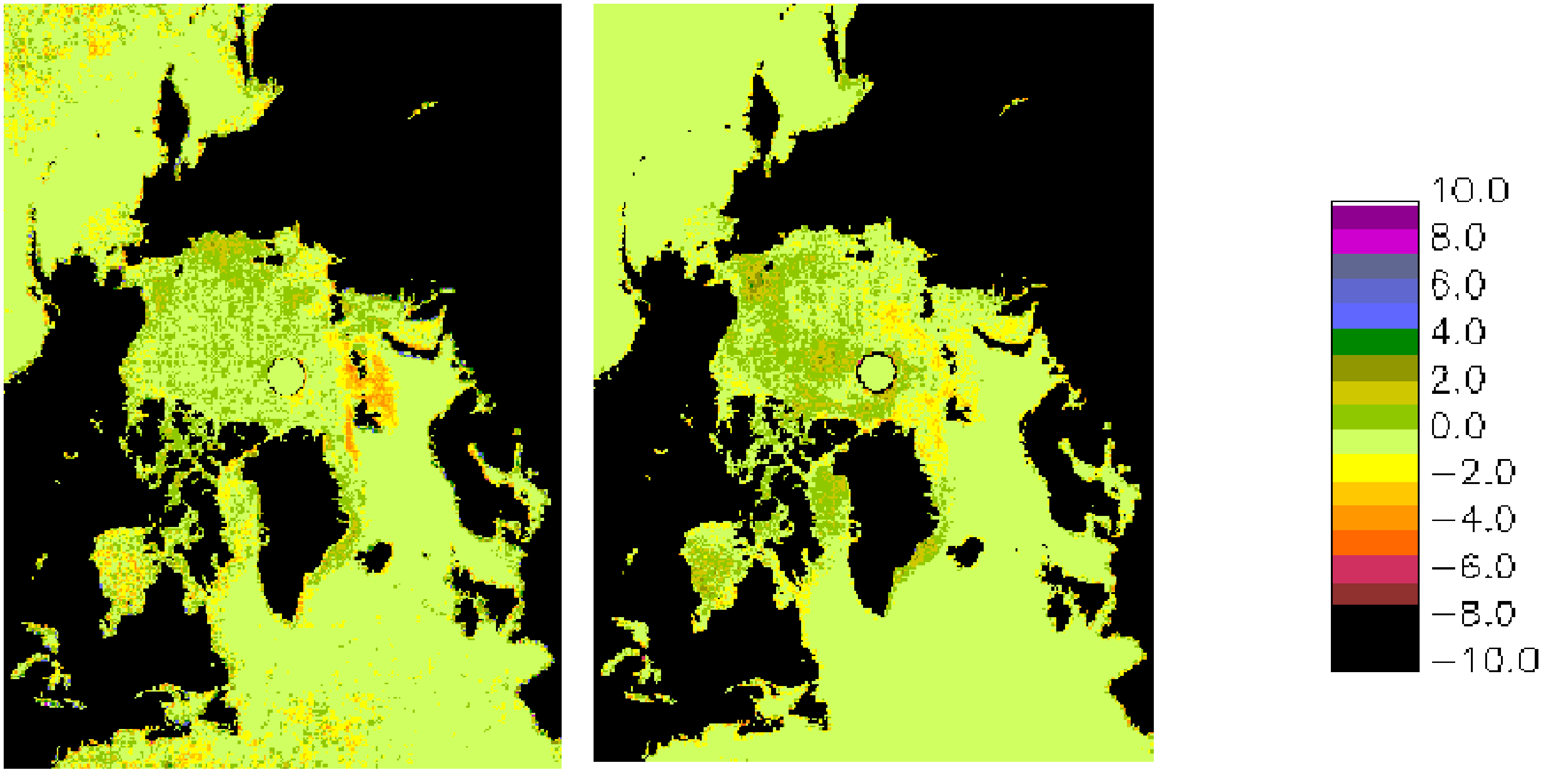


August 1991, north of Svalbard
Water ponds on top of ice.



Intense melting of ice surface.

# Differences in ice concentration (SSM/I F11 vs. SSM/I F13)

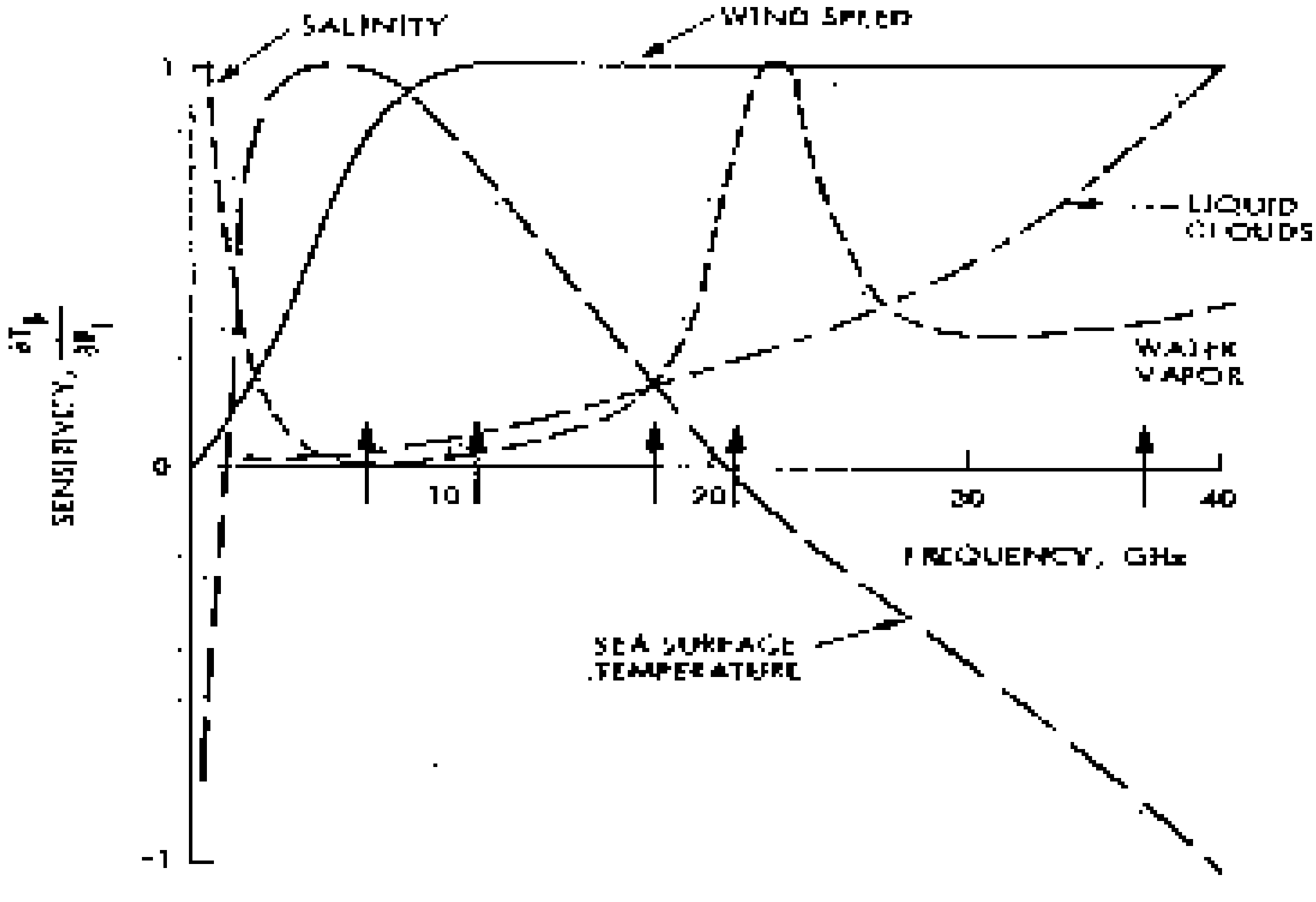



139-day Mean Total Ice Fractions

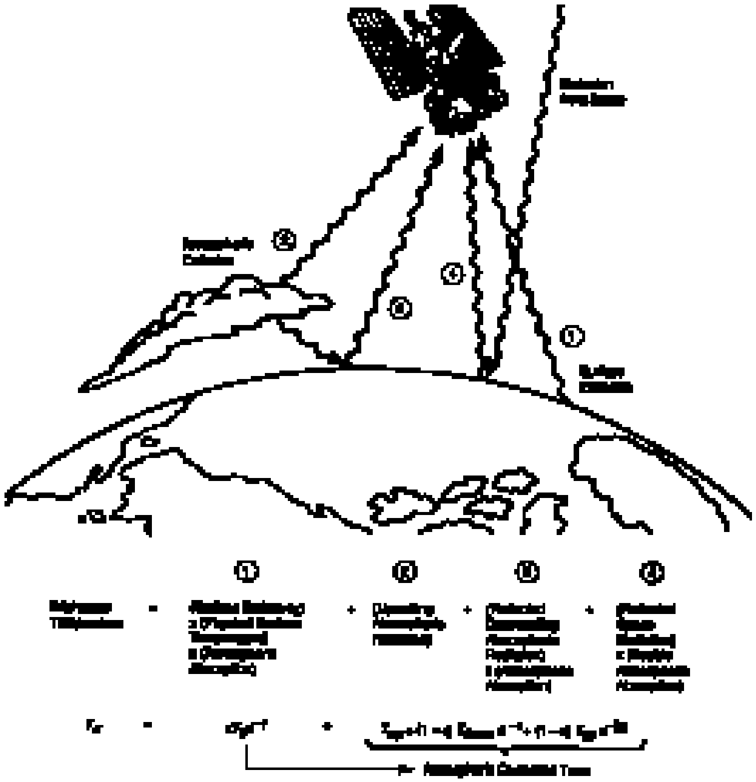
139-day Mean Multi Year Ice Fractions

**Figure 3 [a] and [b]. Overall mean (139-day) spatial patterns of Northern Hemisphere total and multiyear ice concentration differences.**

# Sensitivity of Tb to geophysical parameters

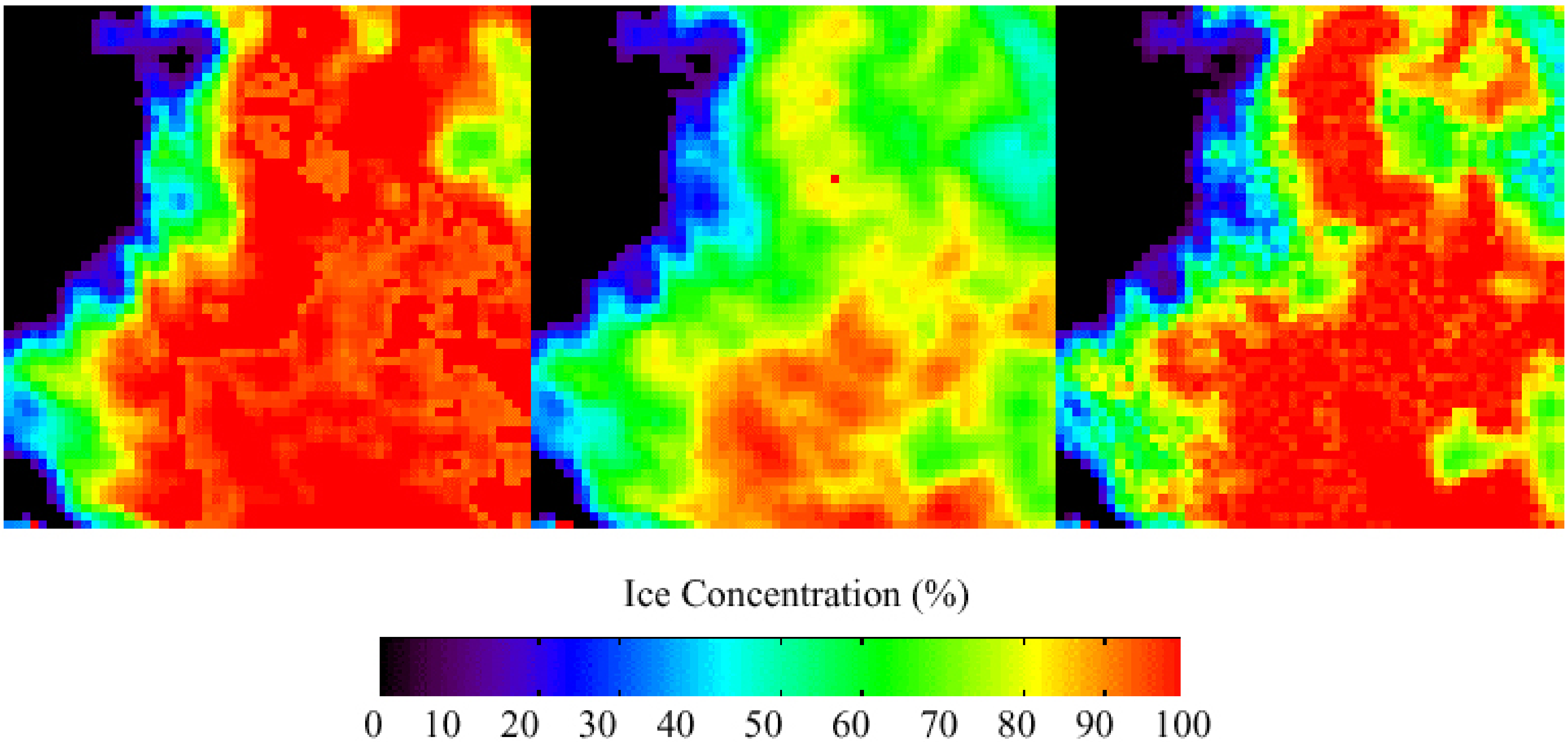


# Passive microwave radiometer



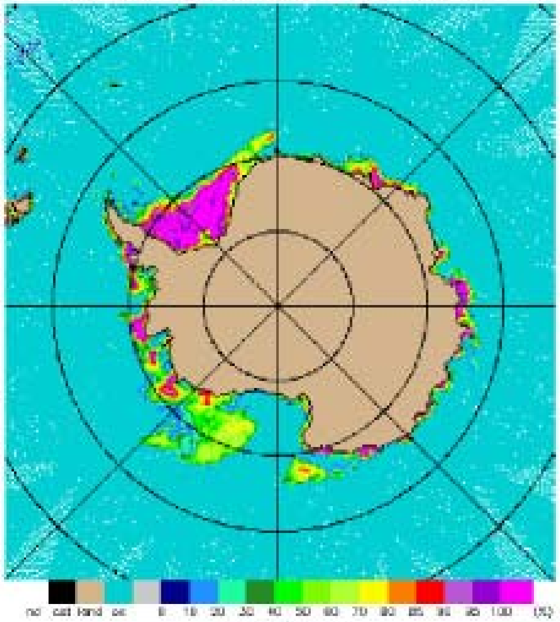
Four components of brightness temperature:

1: surface emission
2: upwelling atm. radiation
3: reflected downwelling rad.
4: reflected rad. from space



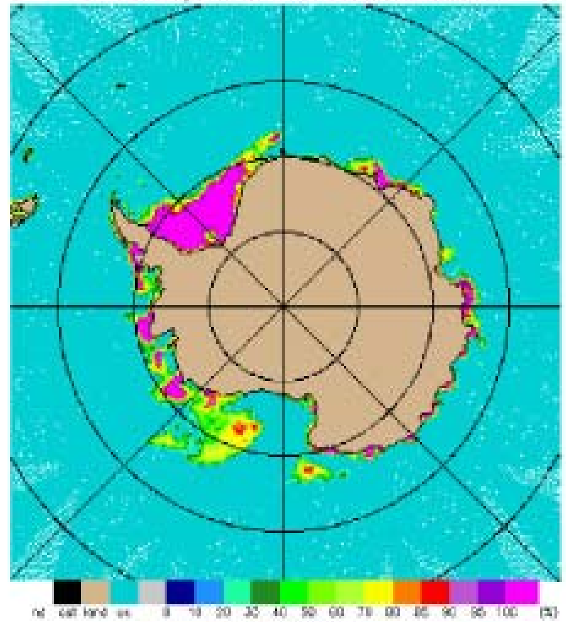

Sea ice concentrations from SSM/I as derived by the Bootstrap (left image), NASA Team (center image), and Enhanced NASA Team (right image) algorithms for 14 September 1998 near the SHEBA camp.

NASA Team Total Ice Concentration



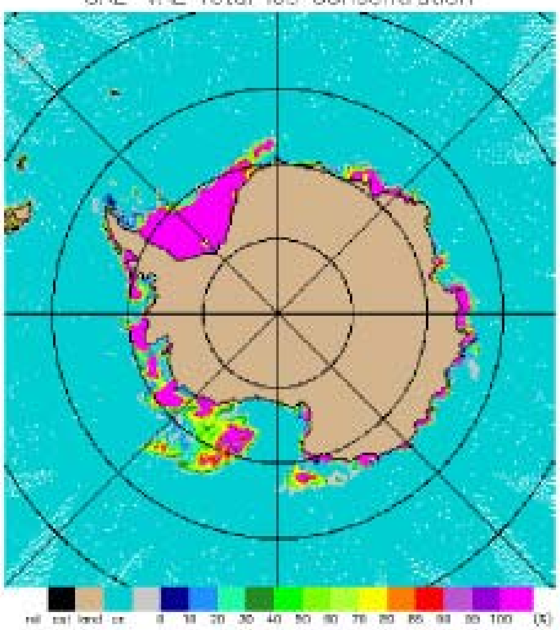

01/23/2002

Bootstrap Total Ice Concentration



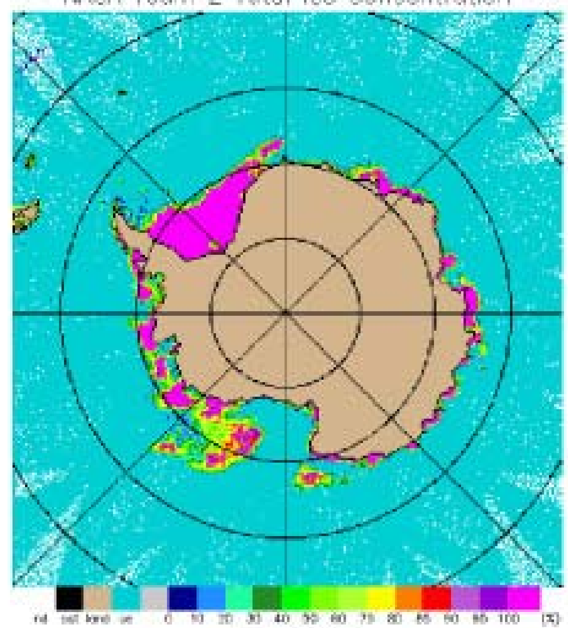

01/23/2002

CAL-VAL Total Ice Concentration




01/23/2002

NASA Team 2 Total Ice Concentration



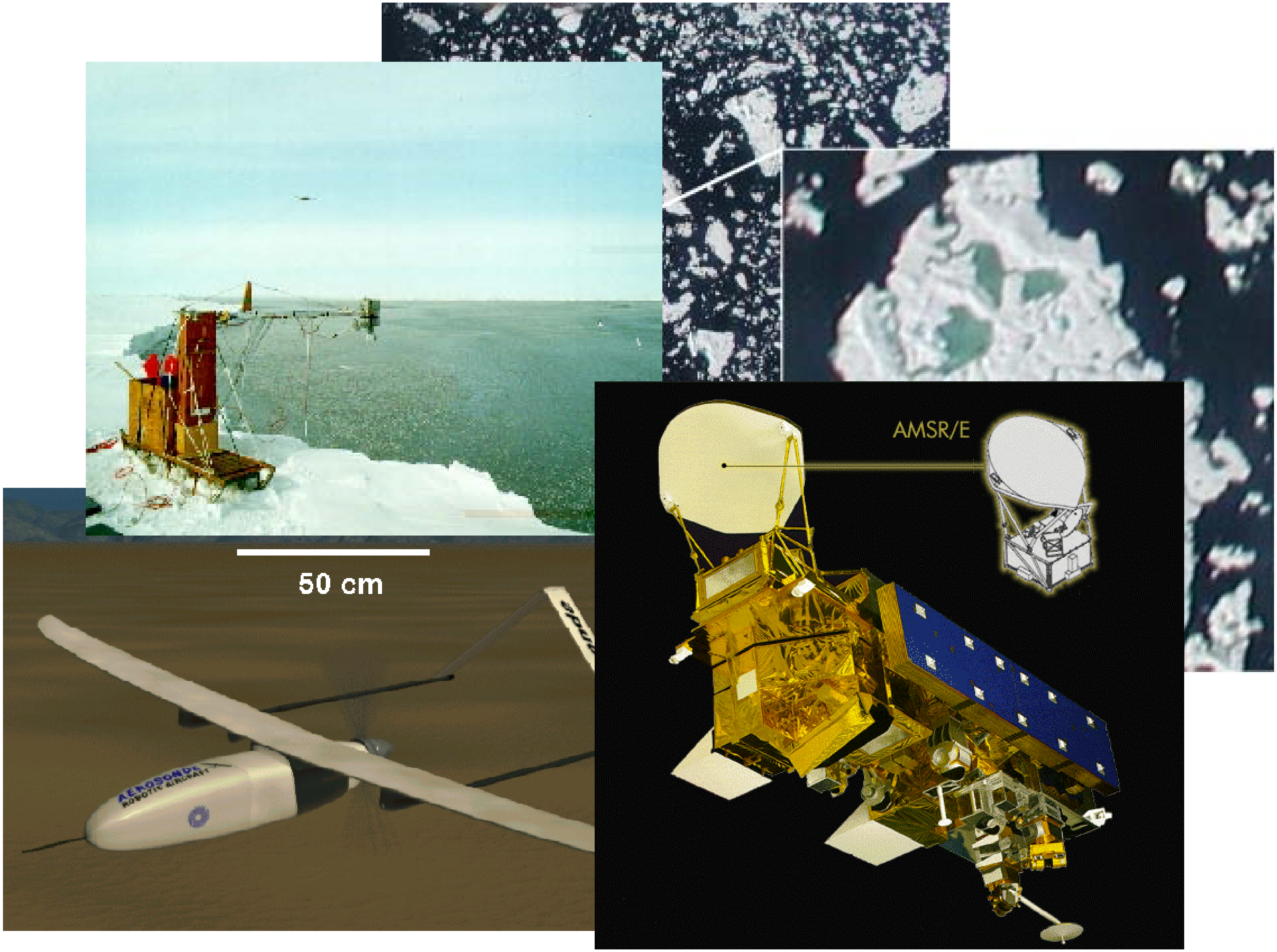

01/23/2002

Table 3. Surface and atmospheric parameters for the sensitivity tests.

| **Parameter** | **Range** | **interval** |
|---|---|---|
| *Surface* | | |
| Sea ice density | 700 - 930 $kg/m^3$ | 10 $kg/m^3$ |
| Salinity | 0 - 16 ‰ | 0.8 ‰ |
| Grain size | 0 - 10 mm | 0.5 mm |
| | | |
| Thickness (FY) | 0.2 – 2 m | 10 cm |
| Thickness (MY) | 1 – 6 m | 10 cm |
| Brine angle | 0 – 90° | 5° |
| Snow density | 220 – 550 kg/m3 | 15 kg/m3 |
| Snow grain size | 0 – 6 mm | 0.3 mm |
| Snow depth (FY) | 0 – 70 cm | 1 cm |
| Snow depth (MY) | 0 – 70 cm | 1 cm |
| Free water content (FY) | 0 – 40 ‰ | 2 ‰ |
| Free water content (MY) | 0 – 70 ‰ | 2 ‰ |
| | | |
| *Atmosphere* | | |
| Liquid water path (LWP) | 0 – 500 $g/m^2$ | |
| Precipitable water | 0 – 20 $kg/m^2$ | 2 $kg/m^2$ |

## Comparison of mean differences in sea ice extent between SSM/I F13 and F11 (F13 minus F11).

| Month | Mean Difference ($km^2$) | Standard Deviation ($km^2$) | Minimum Difference ($km^2$) | Maximum Difference ($km^2$) | t-value |
|---|---|---|---|---|---|
| **Northern Hemisphere** | | | | | |
| May | 3,080 ( 0.05%) | 38,442 | -106,250 | 95,000 | 0.42 |
| June | 14,208 ( 0.23%) | 72,359 | - 88,125 | 292,500 | 2.64 |
| July | 45,841 ( 0.91%) | 37,960 | -15,625 | 128,750 | 6.16 |
| August | 16,542 ( 0.42%) | 41,498 | -97,500 | 86,875 | 2.18 |
| September | 23,773 ( 0.60%) | 98,137 | -199,375 | 343,750 | 1.26 |
| **Central Arctic** | | | | | |
| May | - 1,473 (-0.03%) | 4,240 | -12,500 | 8,125 | -1.84 |
| June | 5,687 ( 0.11%) | 7,657 | - 6,250 | 28,750 | 4.07 |
| July | 23,125 ( 0.50%) | 6,803 | 11,250 | 39,375 | 17.34 |
| August | 16,499 ( 0.43%) | 12,353 | - 5,625 | 47,500 | 7.31 |
| September | - 5,069 (-0.14%) | 7,424 | -18,125 | 8,750 | -3.55 |
| **Southern Hemisphere** | | | | | |
| May | 46,340 ( 0.53%) | 72,359 | - 88,15 | 292,500 | 3.39 |
| June | 79,104 ( 0.64%) | 101,096 | - 75,625 | 523,750 | 4.29 |
| July | 6,436 ( 0.47%) | 84,691 | -125,000 | 284,375 | 3.87 |
| August | 59,166 ( 0.38%) | 61,851 | - 30,625 | 224,375 | 5.24 |
| September | 77,500 ( 0.44%)` | 49,839 | - 25,625 | 167,500 | 8.08 |


50 cm
AMSR/E
AEROSONDE