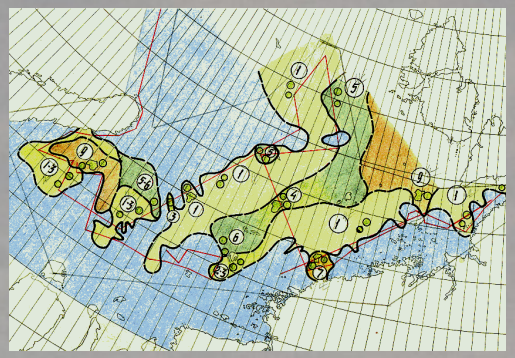
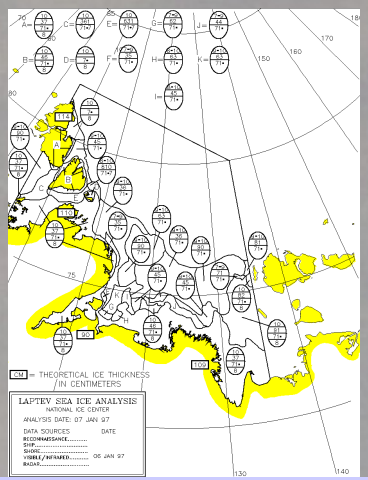
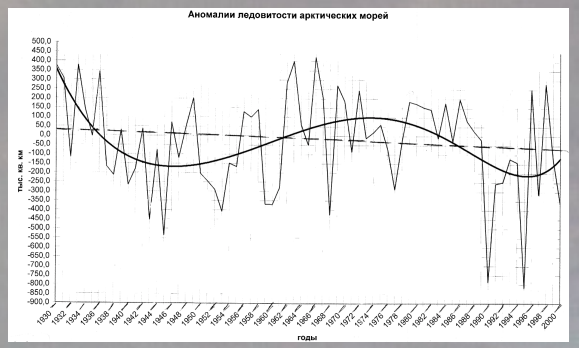






Investigation of Arctic ice cover variance using XX century historical ice charts information and last decades' microwave data

Vasily Smolyanitsky,

Arctic and Antarctic Research Institute &

JCOMM Expert Team on Sea Ice

We'll try to cover following topics in presentation:

- Info on WMO project "Global Digital Sea Ice Bank" including its content and samples of ice charts from national services
- Recent advances in constructing blending dataset, including brief descriptions of developed blending technique and output dataset
- Assessment of sea ice variability in different forms – 1D linear trend, 2D linear trend and 2D oscillations

  and
- on different datasets – a) ice charts and b) passive microwave

WMO Global Digital Sea Ice Data Bank project during 1989-2003:

- At its second session in August 1992 NSIDC, NIC and AARI were only contributors
- In May, 2000 the last 8th session was held there representatives from the main ice services are data centers were present, including AARI, Argentina, BSIM, China, CIS, DMI, Iceland, JMA, NIC, NSIDC
- During 1980s-90s project was supervised by the former CMM sub-group on sea ice and its own Steering Group,
- Now it has two archiving centers at NSIDC and AARI
- It is supported by JCOMM-I resolutions and now supervised by JCOMM PA Services Expert Team on Sea Ice
- In October 2002 last 9th session was held in Buenos Aires

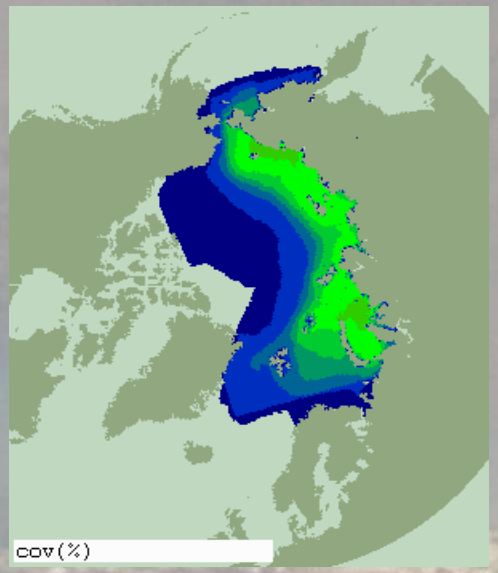
Summary of GDSIDB content

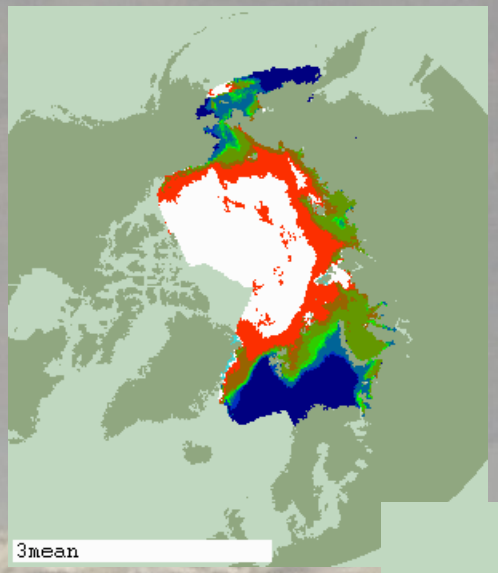
The main five GDSIDB datasets are described in the table. Included are also the period, covered by dataset, existence of gaps, sea ice parameters in dataset and number of charts in SIGRID format (WMO, 1989). Samples are shown on next slides…

№	Title of data set	Period / periodicity	Gaps ?	Sea ice parameters	Number of charts
1a	Arctic and Antarctic Research Institute (AARI) revised ice charts for the Eurasian Arctic	1950-1992 / 10 days	Yes	CT, SD, FI	1988
1b	Arctic and Antarctic Research Institute (AARI) ice charts for the Antarctic	1971-1990 / 10 days	Yes	CT, SD, FI	475
2a	National Ice Center (NIC) ice charts for the Northern Hemisphere (northward 39° N)	1972-1994 / 7 days	No	CT, SD, FI	1200
2b	National Ice Center (NIC) ice charts for the Southern Hemisphere (southward 50° S)	1973-1994 / 7 days	No	CT	1150
3	Canadian Ice Service (CIS) ice charts for Canadian Arctic	1968-1998 / 7 days	Yes	CT, SD, FI	3437
4	Baltic Sea Ice Meeting ice charts (Finland - FIMR and Sweden - SMHI)	1960-1979 / 3-4 days	No	CT, SV, FI	1042
5	Ice charts for the Sea of Okhotsk from the Japan Meteorological Agency (JMA)	1970-2002 / 7 days	No	CT	1000

CT – total concentration, SD – stage of development and partial concentration,
SV – ice thickness, FI – fast ice information.

1st dataset: AARI, Arctic, summary for 1950-1992





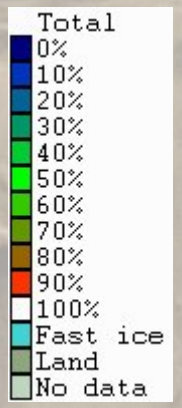
Sea Ice parameters included:

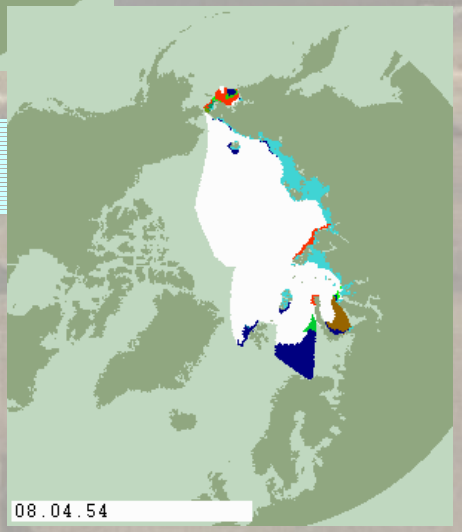
- total concentration
- stages of ice development (up to 11 acc. to WMO Nomenclature, including NY, FY, MY etc.)
- indicator for drifting/fast ice
- estimate of mean-weighted thickness of level ice

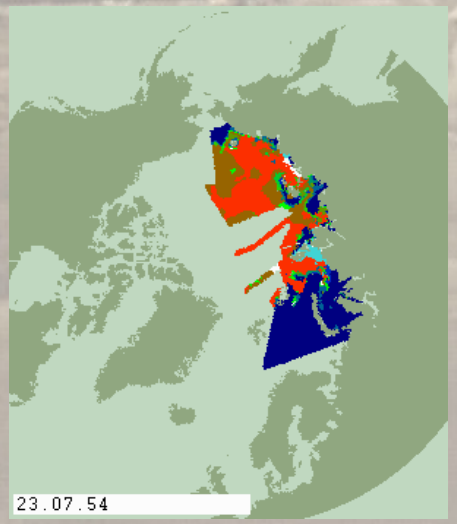
Coverage (n/N), %

Robust mean

- 10-days periodicity with gaps in time and space
- in SIGRID-1, EASE-GRID ArcInfo compatible formats



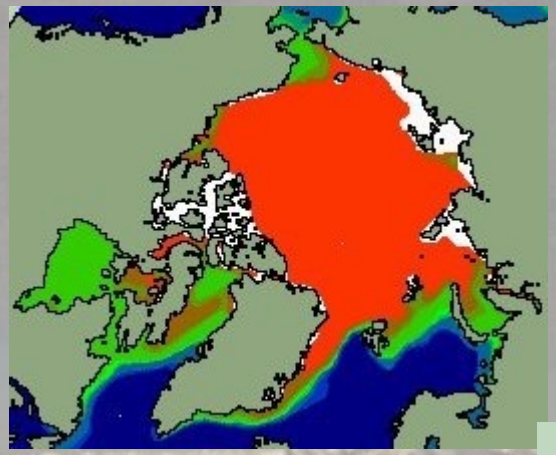




Sample winter chart (April, 1954)

Sample summer chart (July, 1954)

2nd dataset: NIC, Arctic region, summary for 1972-1994



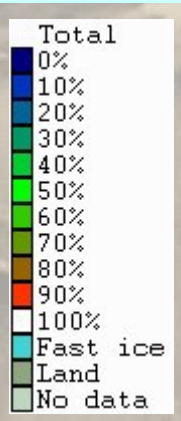
Sea Ice parameters included:

- total concentration
- stages of ice development (up to 11 acc. to WMO Nomenclature, including NY, FY, MY etc.)
- indicator for drifting/fast ice
- estimate of mean-weighted thickness of level ice

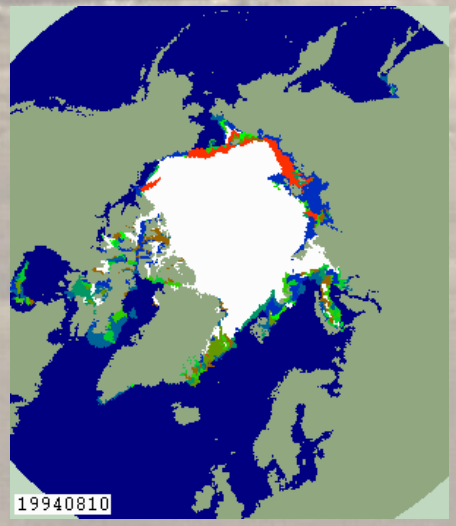
Coverage (n/N) = 100 %

Robust mean

- 7-days periodicity without gaps in time and space
- in SIGRID-1, EASE-GRID ArcInfo .e00 and other compatible formats



First chart (03.01.1972)



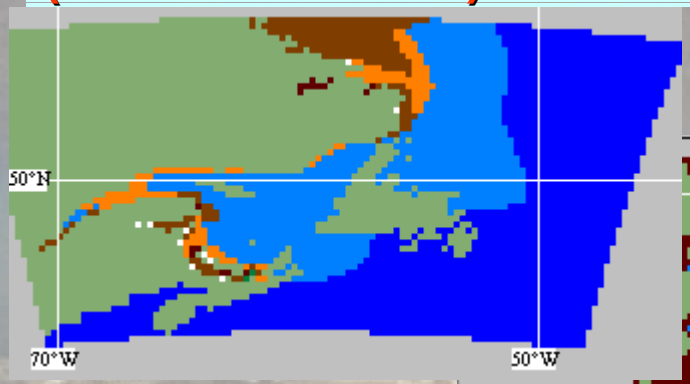
One of the last charts (10.08.1994)

3rd dataset: CIS, Canadian Arctic, summary for 1968-1998

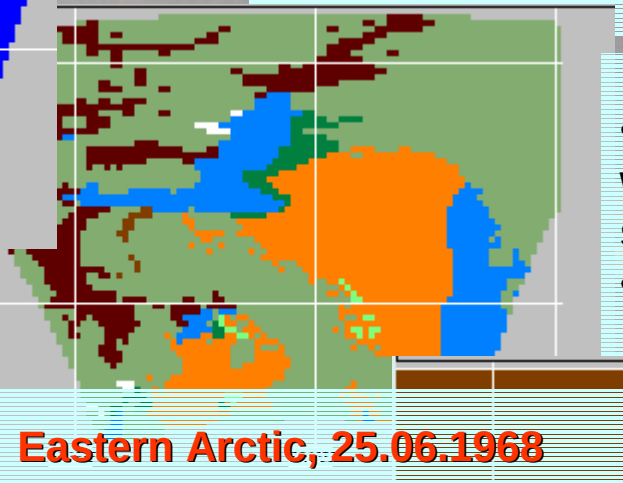
Coverage (n/N)
= 100 % for ice season
(~November - ~ June)

Sea Ice parameters included:

- total concentration
- stages of ice development (up to 11 acc. to WMO Nomenclature, including NY, FY, MY etc.), mean-weighted thickness…..
- indicator for drifting/fast ice

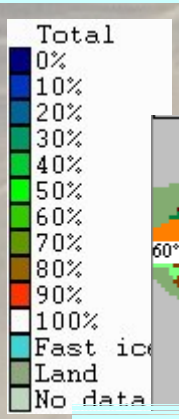


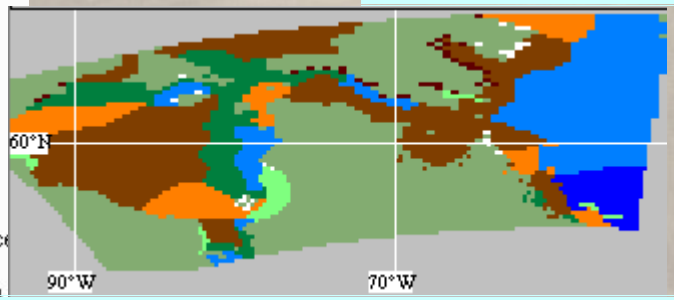
Eastern Coast, 14.02.1969



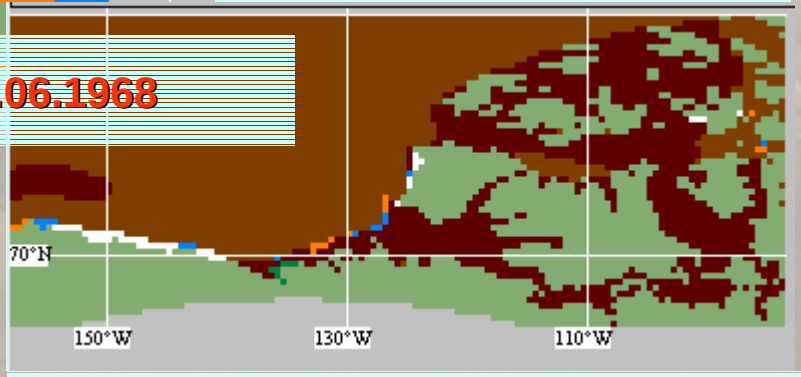
Eastern Arctic, 25.06.1968

- 7-days periodicity without gaps in time and space
- in SIGRID-1, ArcInfo .e00





Hudson Bay, 21.06.1971



Western Arctic, 21.06.1974

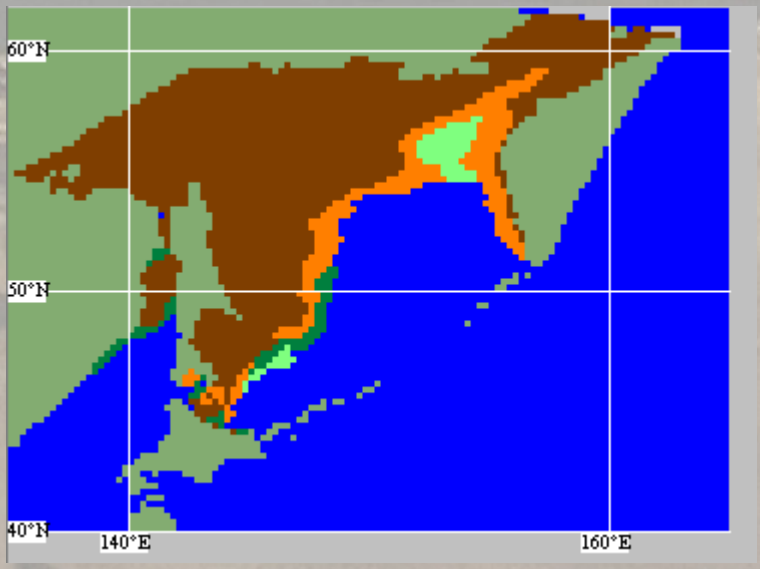
4th dataset: JMA, Sea of Okhotsk, summary for 1971-2002

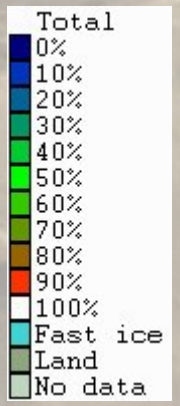
Sea Ice parameters included:

- total concentration

Coverage (n/N)
= 100 % for ice season
(~December - ~ May)

- 5-days periodicity without gaps in time and space
- in SIGRID-2, EASE-GRID





Sea Ice chart for 03.02.1994

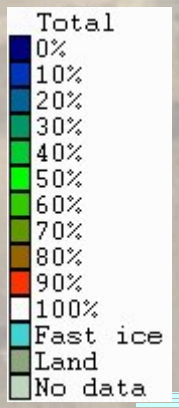
5th dataset: BSIM (FIMR and SMHI), Baltic Sea, summary for 1960-1979

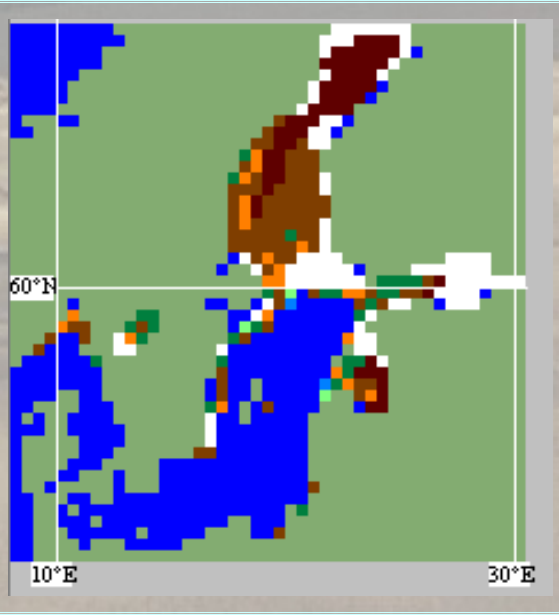
Sea Ice parameters included:

- total concentration
- sea ice thickness / 9 stages of ice development acc.
- fast ice indicator

Coverage (n/N)
= 100 % for ice season
(~November - ~ June)

- 3-4-days periodicity without gaps in time and space
- in SIGRID-1, Baltic code, EASE-GRID

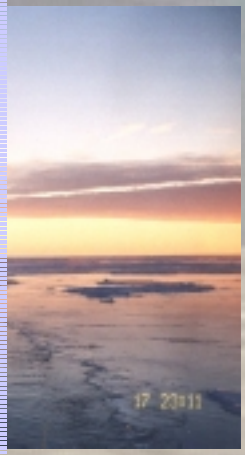




Sea Ice chart for 14.02.1967

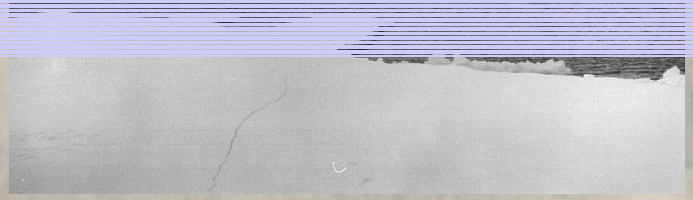
We define following total summary for the whole GDSIDB:

1) Ice charting now has more than 100 years practice, i.e. we may assess long-term trends



2) WMO Nomenclature firstly introduced in 1950s, incorporates experience from a number of national services, i.e. we may blend ice charts

3) Ice charts are still more harmonized product than remotely sensed data, using ice charting technique we can test how different Sea Ice Terms, e.g. ice edge and openings are described by remotely sensed means, i.e. validate them



Next section will describe Arctic total concentration blended data set for 1950-1998 based on GDSIDB ice charts

....thanks to Hadley Center support the first draft was at last completed in December 2002....

Blending technique includes following ~6 steps:

1. Extraction of total concentration layer from all mentioned five GDSIDB datasets in SIGRID format on a 15'x15' grid
2. Transformation of all datasets to monthly spacing
3. Adding 6th dataset – monthly Northern Hemisphere 1 degree ice extent dataset (also known as J.Walsh dataset) and its reprojection to 15'x15' grid
4. Blending data by substituting by the most significant according to area of responsibility of national ice service
5. Calculation of climatic monthly values
6. Populating gaps by new climatic monthly values

Output is very friendly to users and easily programmable. It includes 2 files: 1) **factual data** and 2) **flags of origin** for each cell.

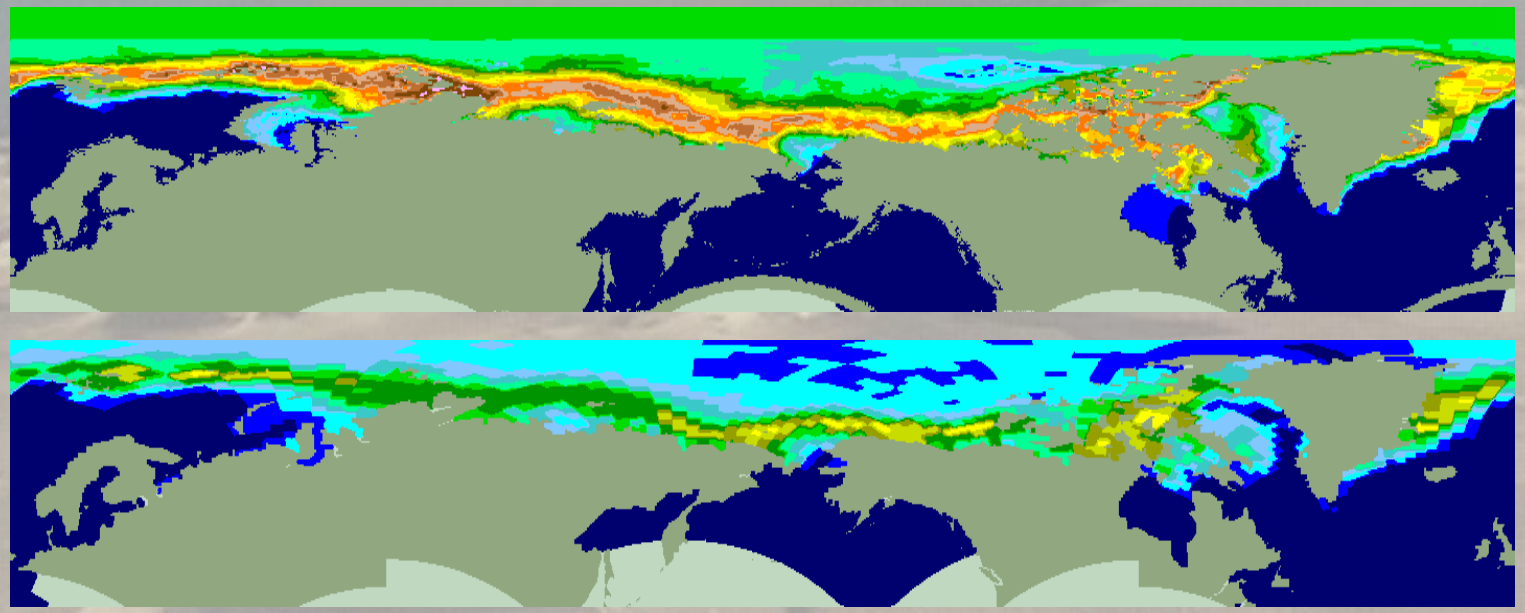
Following is a summary for flags of origin of the blended data set for 1950-1998

№	Source (national ice service, center, author)	%
1	Danish Meteorological Institute	.02
2	Japan Meteorological Agency	.02
3	Navoceano (USA)	.61
4	Kelly data set	11.68
5	Joint Ice Center (USA)	10.70
6	**Climate (still too much !!!!)**	**48.18**
7	Temporal extrapolation of Kelly data set	.73
8	National Ice Center	20.00
9	Baltic Sea Ice Meeting (Finland and Sweden)	.12
10	Canadian Ice Service	1.29
11	Arctic and Antarctic Research Institute (Russia)	3.48
	No data	3.20

We may try to estimate the quality of a new dataset in the terms of 'amount of information' inside it.

Normalized entropy used for that purpose shows that the blended dataset contains much more information in comparison with J.Walsh data set during the whole seasonal cycle….

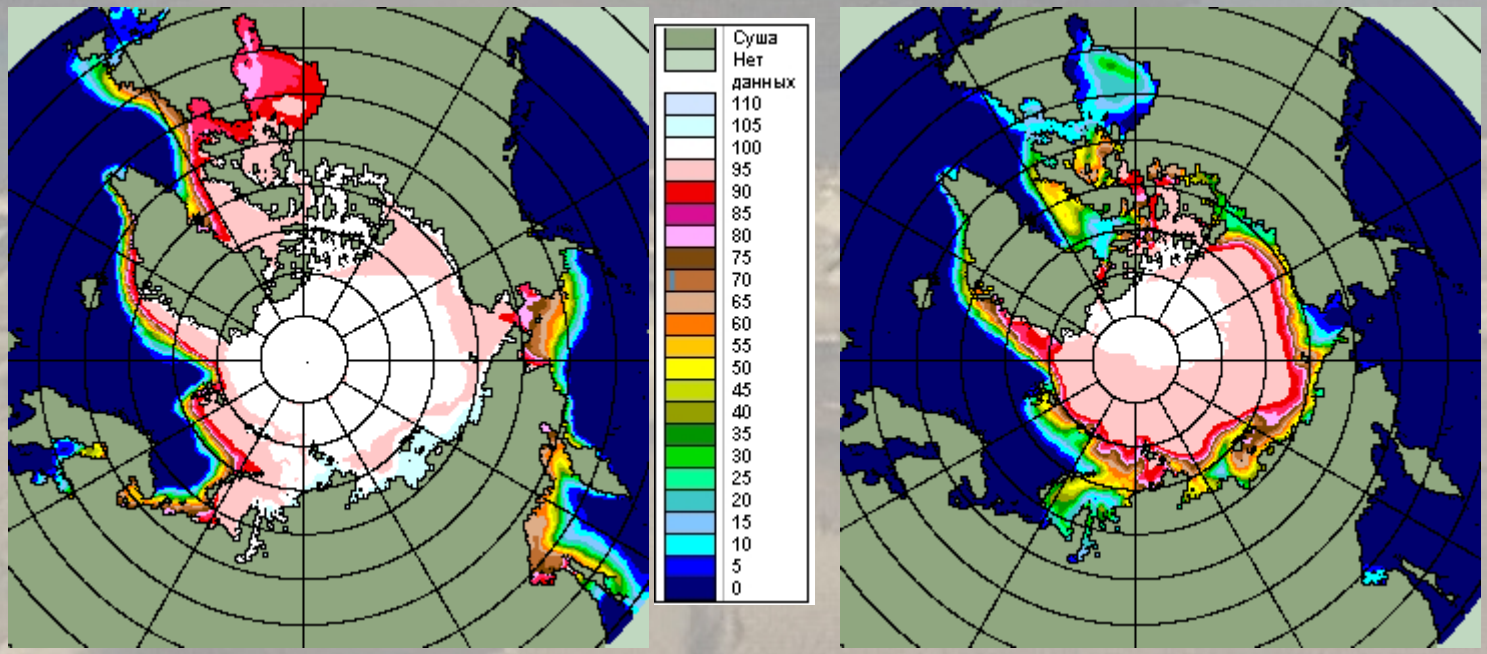
New blended dataset



J.Walsh data

September

On a basis of blended dataset we may draw a proposal for WMO norms on sea ice or sea ice mean state for second part of XX century



Winter robust mean

Summer robust mean

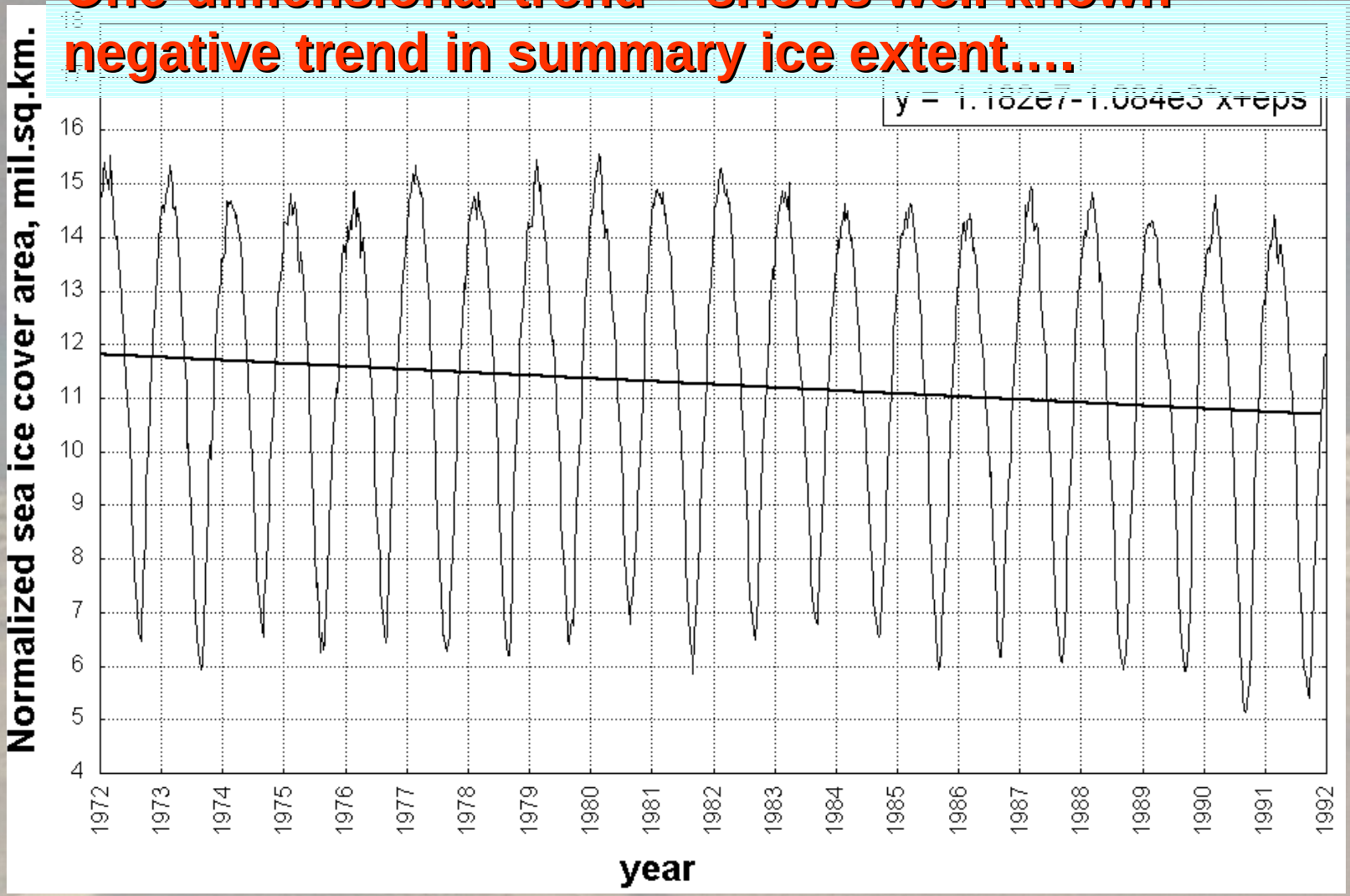
Next section will deal with assessment of sea ice variability on the basis of:

1) **GDSIDB data, i.e. based on ice charts**
2) **SSMR-SSMI imagery**

And we'll try to answer the question: is there evidence for trends or/and oscillations in sea ice variability ?

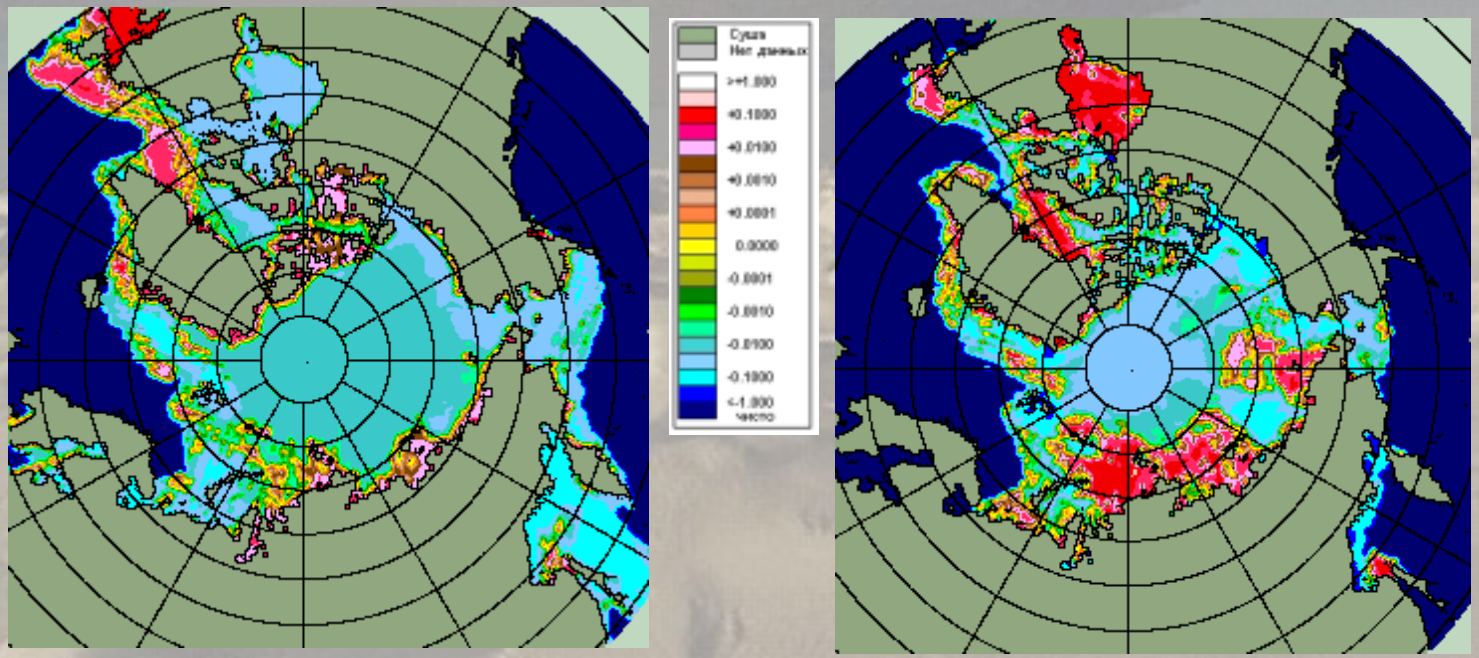
Presently analysis is made only for the Arctic and for sea ice total concentration. In the nearest future we plan to extend it for Antarctic and other sea ice parameters

One-dimensional trend – shows well known negative trend in summary ice extent….



Weekly values and linear multi-annual trend of the normalized (by total concentration) sea ice cover area for Northern Polar Region for 1972-1991 period, 7-days NIC sea ice charts

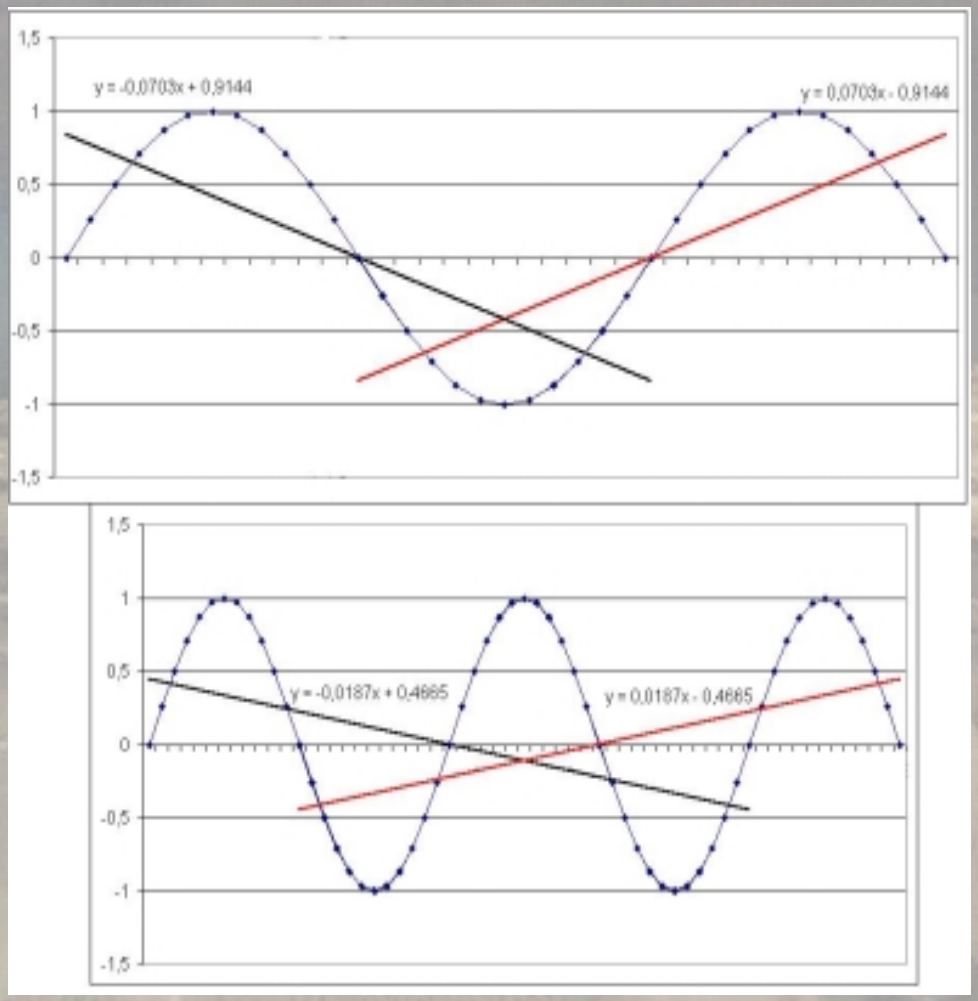
2D trend for 1950-1992 based on blended GDSIDB data shows both “+” and “-” trends in space and changes in its distribution in seasonal cycle



Winter

Summer

At the same time we should not forget that linear trend depends greatly on chosen interval and its longevity….

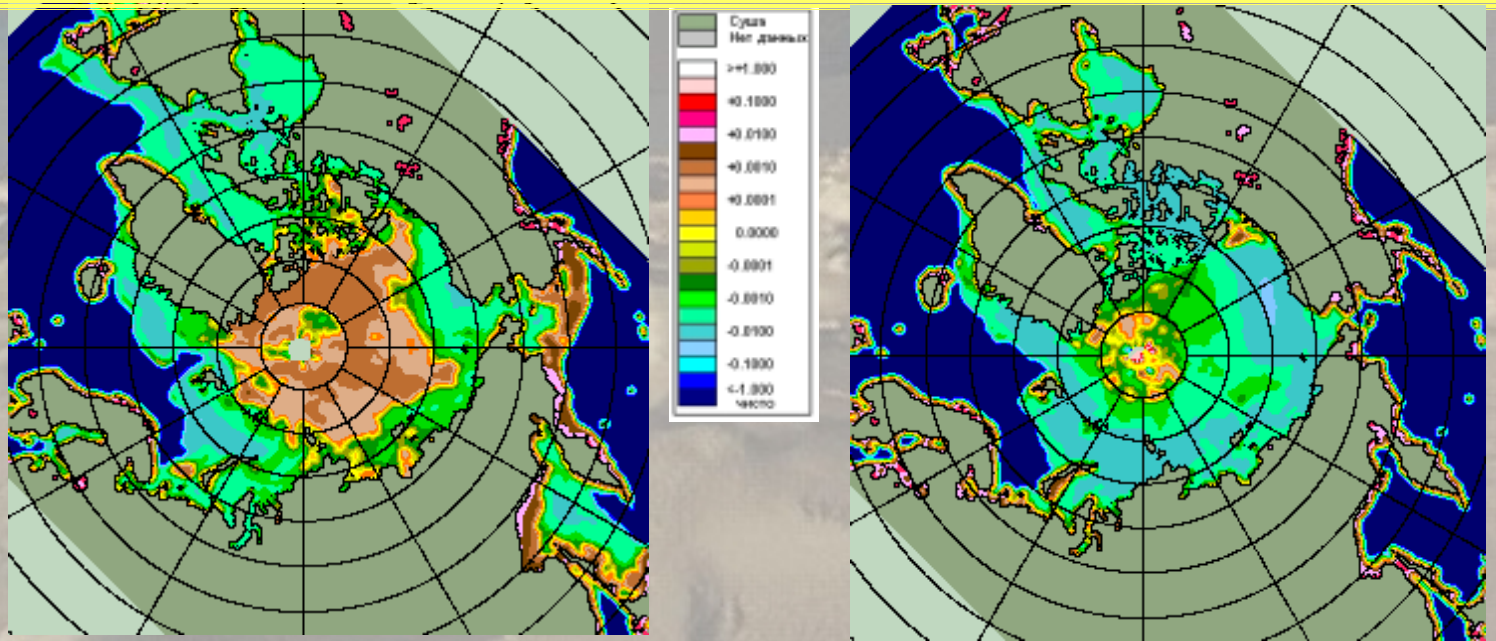


Note how the values of “fiction” trends are the function of chosen interval and its longevity

(taken from Gudkovich&Kovalev, March, 2002)

2D trend for 1) other period - 1978-2002 and 2) other data – daily SSMR-SSM/I shows different spatial and seasonal distribution of “+” and “-” so far proving dependences of linear trend from starting point and dataset longevity…

Linear trend (total concentration) for 1978-2002 (daily SSMR-SSM/I data)

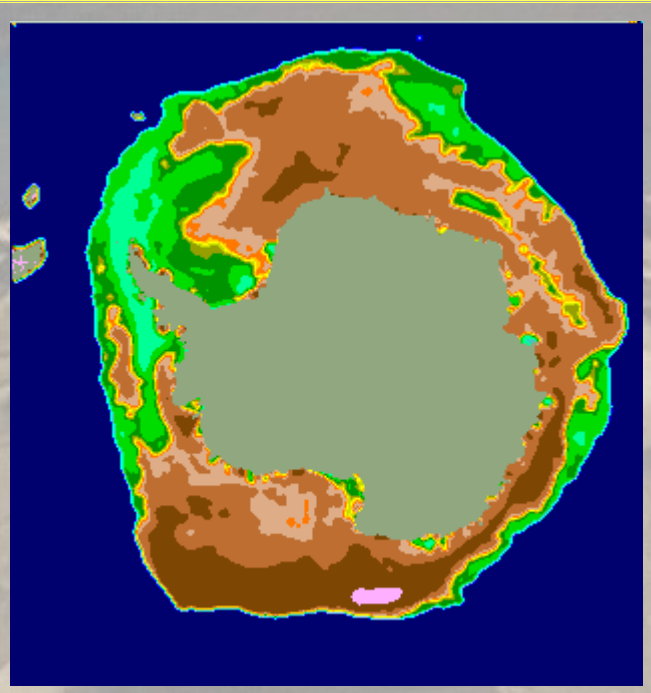


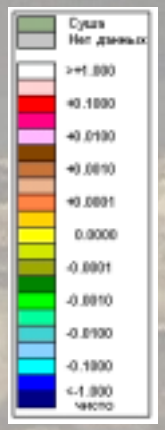
Winter

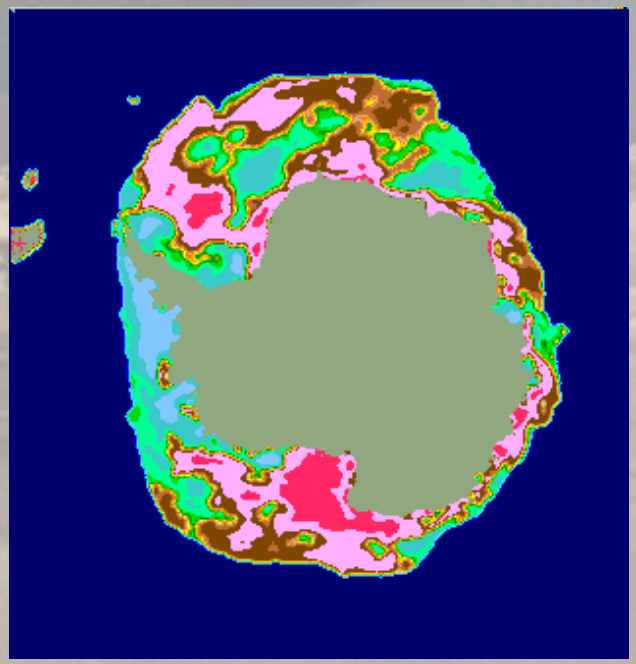
Summer

Shown for comparison are samples of 2D trends for Antarctic, again 1) period is 1978-2002 and 2) data is SSMR-SSM/I

Linear trend (total concentration) for 1978-2002 (daily SSMR-SSM/I data)







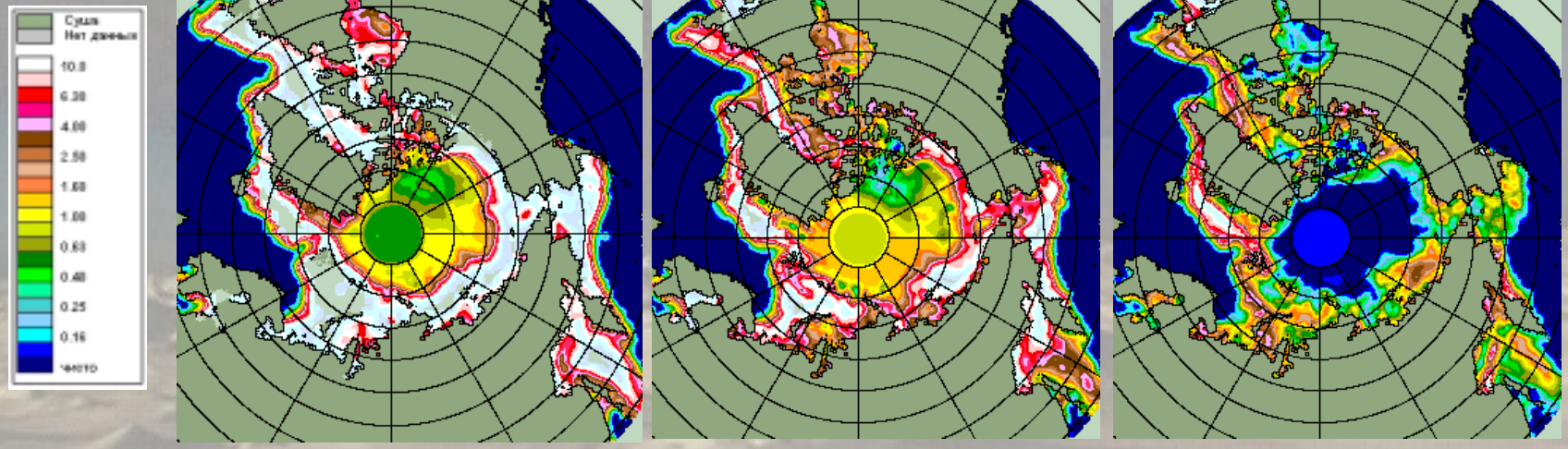
Winter

Summer

And how can we find evidence for long-term periodicity ? We may use spectral analysis of datasets.

- Presently we have chosen wavelet transform for analysis
- Taken into processing is a subset of blended data for 1950-1994
- Averaging of output is made for 3 sub-periods: 5-15, 15-25 and 30-40 years (correspond to several natural forcing factors, including auto-oscillations in ice cover, long-term moon-solar tide, NAO)

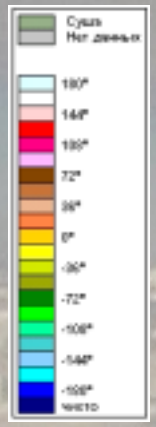
Amplitude of oscillations for total concentration

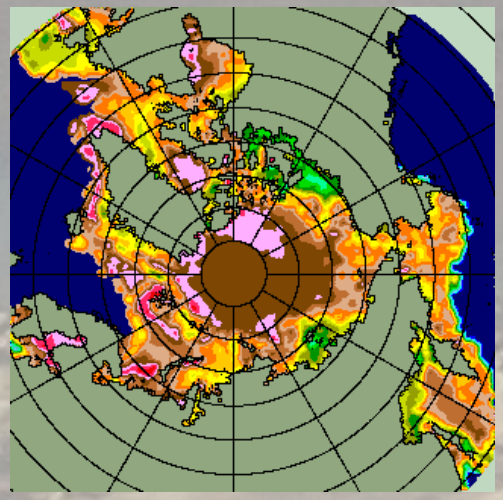


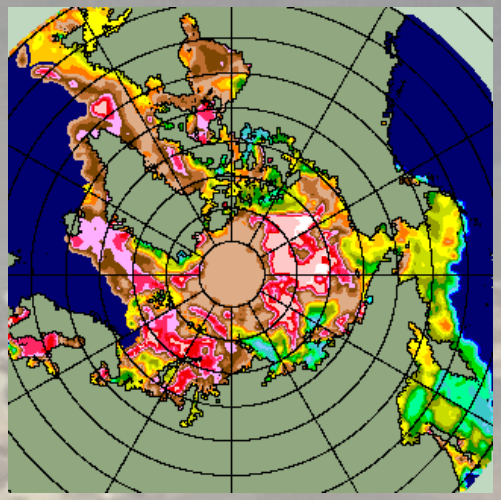
5-15 years 15-25 years 30-40 years

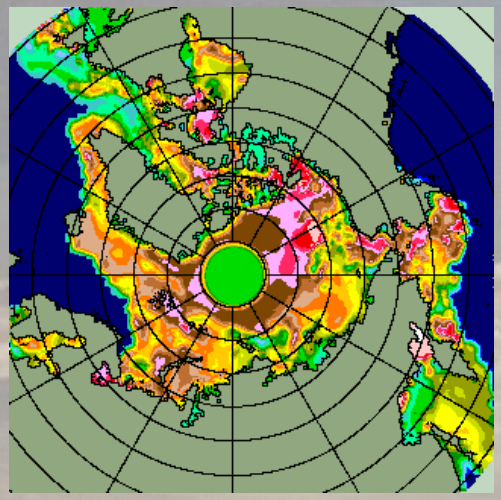
- We may see that the greatest amplitude is for the shortest period and for the boundary shelf seas

Phase of oscillations for total concentration





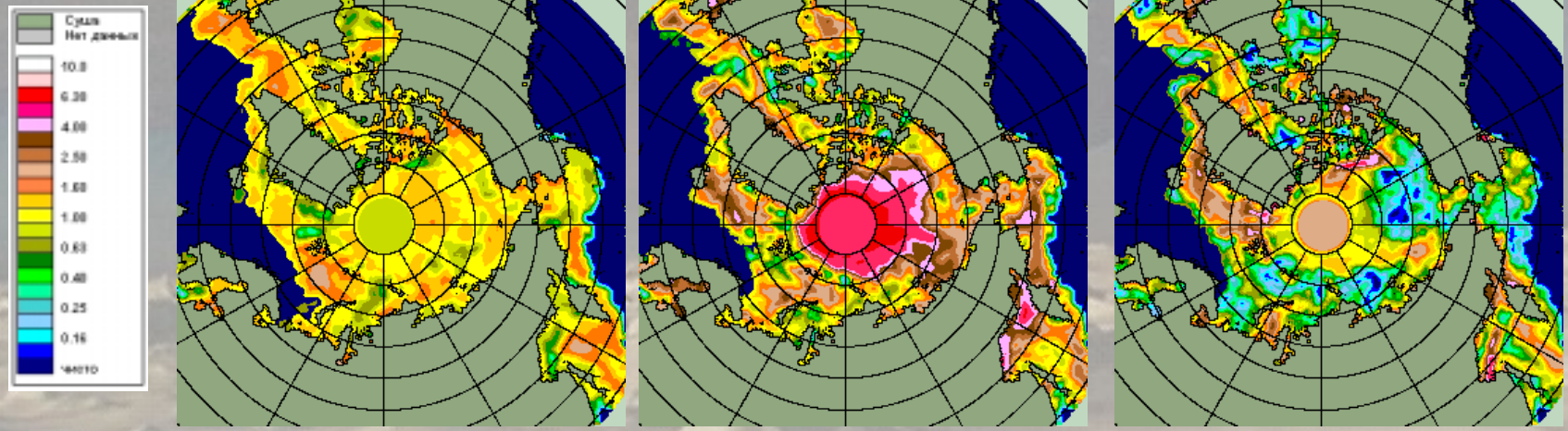




5-15 years **15-25 years** **30-40 years**

- For the phase we may see that periods 15-25 and 30-40 show some kind of changing patterns with positive and negative phases – probably waves ?

Significance of oscillations (ratio to white/red noise) for total concentration



5-15 years 15-25 years 30-40 years

- And for significance values the most interesting fact is significant oscillations for SW Kara Sea, Eastern-Siberian Sea, also Greenland water…..

Following conclusions can be made:

- Application of wavelet transform averaged for 3 characteristic time intervals, corresponding to known external long-term factors like NAO and moon and solar tides (5-15, 15-25 and 30-40 years) allows showing existence of significant set of fluctuations in ice total concentration throughout the whole Arctic Ocean
- the greatest in amplitude are for boundary seas and for the shorter period of fluctuations
- such phenomena as ice opposition and possibility of existence of “convergence waves” moving from the Kara and Chukcha Seas to Laptevs and Eastern-Siberian Seas are also revealed

What are further perspectives ?

- Further steps should be done in cooperation with all national ice services and data centers
- We need interrelation/response from WCRP/CLiC
- We'll extend ice charts series: for AARI – pre 1950, for Canada – pre 1968 and for all services – extend up to present
- We'll use new formats to archive data – SIGRID3 – friendly with GIS, so make archive more accurate
- We'll Include other ice parameters – stages of sea ice development (MY, FY) from AAR, CIS, NIC and derived parameters – thickness of level ice

Further perspectives (continued):

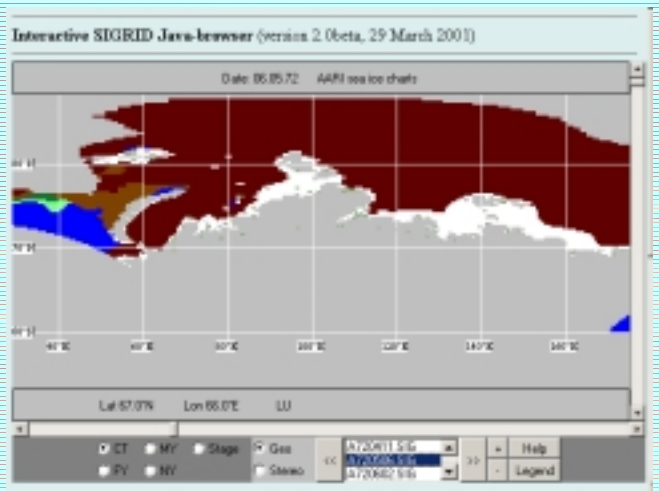
- We also plan to improve blending technique for Arctic by using not general climatic values by typical for definite years
- We'll also improve data base for Antarctic:
  - Complete QC for AARI data
  - Complete QC for NIC data
  - Blend data
- Timetable will be drawn at the next ETSI/GDSIDB sessions in autumn 2004

Present access to the GDSIDB data:

1. At NSIDC (http://nsidc.org) use http- or ftp- links to copy data in SIGRID or EASE-GRID formats or contact User services

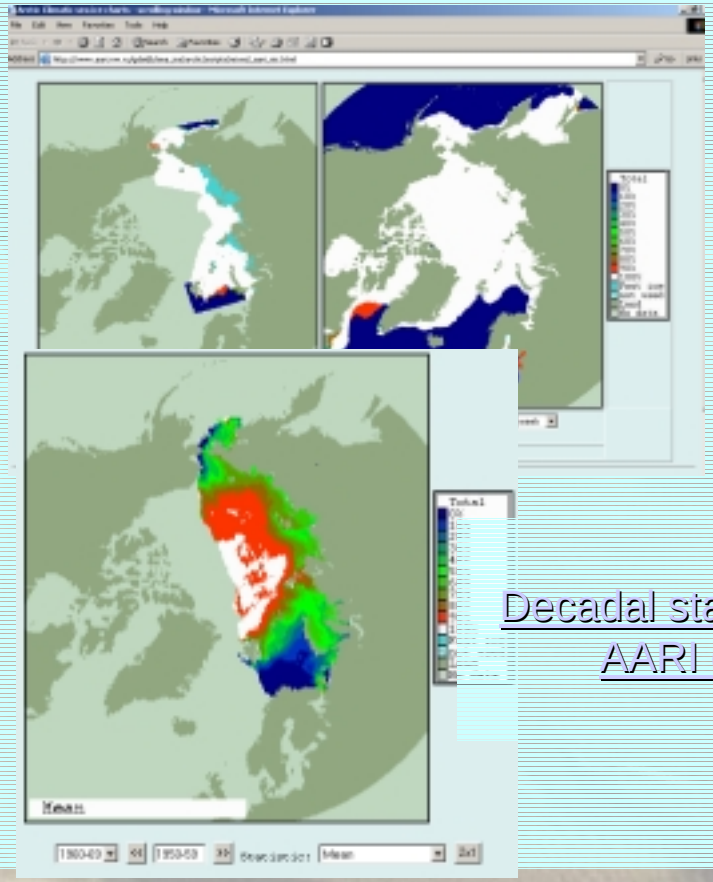
Access to the GDSIDB data *(continued)*

2. **At AARI web-site (http://www.aari.nw.ru) go to GDSIDB page (http://www.aari.nw.ru/gdsidb/) to get graphical replica of SIGRID data, various climate statistics or e-mail to wdc@aari.nw.ru to get d**



Java-browser for SIGRID data

Mixed AARI and NIC charts



Decadal statistics for AARI data