Sea ice concentration and extent for climate research: status, issues and opportunities

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Outline

- **Requirements**
- **Currently available data sets and how these meet requirements**
- **Issues requiring further research**
- **Suggestions for a strategy to address these issues**

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Requirements

- **GCOS climate monitoring principles generally require the following of climate monitoring systems:**
  - **Stability**
  - **Homogeneity**
  - **Continuity**
  - **High priority for data-sparse or sensitive regions**
  - **Integration of IPCC-type requirements into plans**
  - **Easy user access to data**
  - **Quantification of uncertainties and biases**

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Currently available data sets of sea ice concentration and extent (not exhaustive) (1)

- **NSIDC lists the following sea ice concentration data sets in its catalogue (see http://nsidc.org/data/sea_ice.html):**
- **Passive microwave retrievals:**
  - **AMSR-E/Aqua Daily L3 12.5 & 25 km Tb, Sea Ice Conc.**
  - **Bootstrap Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I**
  - **DMSP SSM/I Daily and Monthly Polar Gridded Sea Ice Concentrations**
  - **DMSP-F8 SSM/I Pathfinder Global Level 2 Sea Ice Concentrations**
  - **Near Real-Time DMSP SSM/I Daily Polar Gridded Sea Ice Concentrations**
  - **Near Real-Time SSM/I EASE-Grid Daily Global Ice Concentration and Snow Extent**
  - **Nimbus-5 ESMR Polar Gridded Sea Ice Concentrations**
  - **Nimbus-7 SMMR Polar Gridded Radiances and Sea Ice Concentrations**
  - **Sea Ice Concentrations from Nimbus-7 SMMR and DMSP SSM/I Passive Microwave Data**
- **Digitised chart analyses:**
  - **AARI 10-Day Arctic Ocean EASE-Grid Sea Ice Observations**
  - **Arctic and Southern Ocean Sea Ice Concentrations**
  - **Arctic Sea Ice Charts, 1953-1986: W. Dehn Collection**
  - **Environmental Working Group Joint U.S.-Russian Arctic Sea Ice Atlas**
  - **NOAA/NMC/CAC Arctic and Antarctic Monthly Sea Ice Extent**
- **In situ campaign measurements:**
  - **Coordinated Eastern Arctic Experiment (CEAREX) Data**

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Currently available data sets of sea ice concentration and extent (not exhaustive) (2)

- **In addition the following are also available:**
  - **HadISST1 sea ice concentration (Rayner et al (2003) see http://hadobs.metoffice.com/hadisst/)**
  - **Global Digital Sea Ice Data Bank (GDSIDB) collection and blended analysis of this with Walsh data set and climatology, created by Vasily Smolyanitsky (see http://www.aari.nw.ru/gdsidb/gdsidb_2.html)**
  - **other non-collected operational charts**
  - **ACSYS Historical Ice Chart Archive**
  - **Historical data from the Canadian Ice Service**
  - **EUMETSAT Ocean and Sea Ice Satellite Application Facility (SAF) product**
  - **Synthetic Aperture Radar (SAR) sea ice conc.**
  - **Scatterometer, MODIS (ice edge)**
  - **etc**

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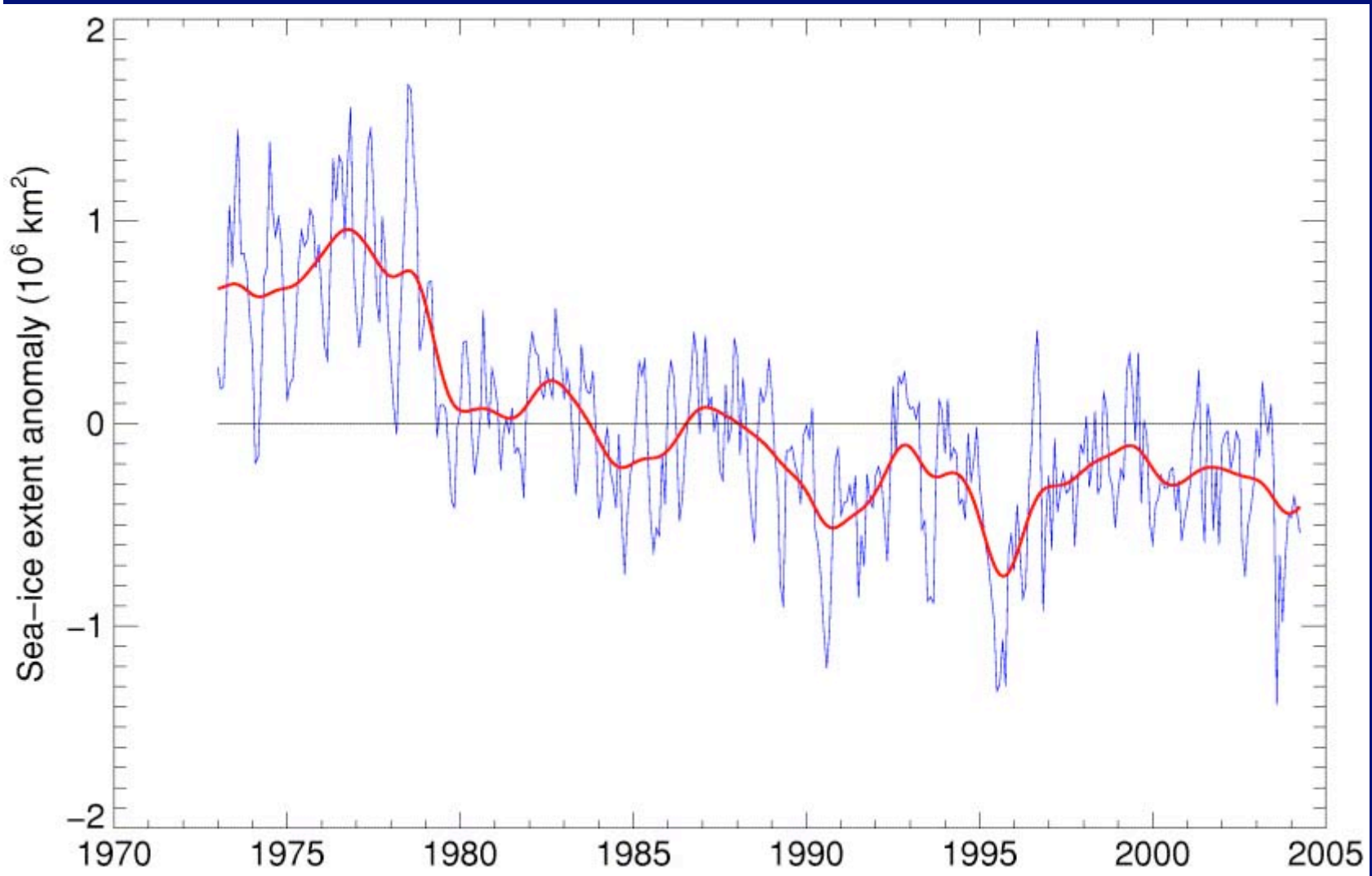
Northern Hemisphere sea ice extent anomaly (10^6 km^2), 1973 - April 2004

Data are from a version of HadISST1, as used in IPCC TAR and WMO Annual Statements on Climate



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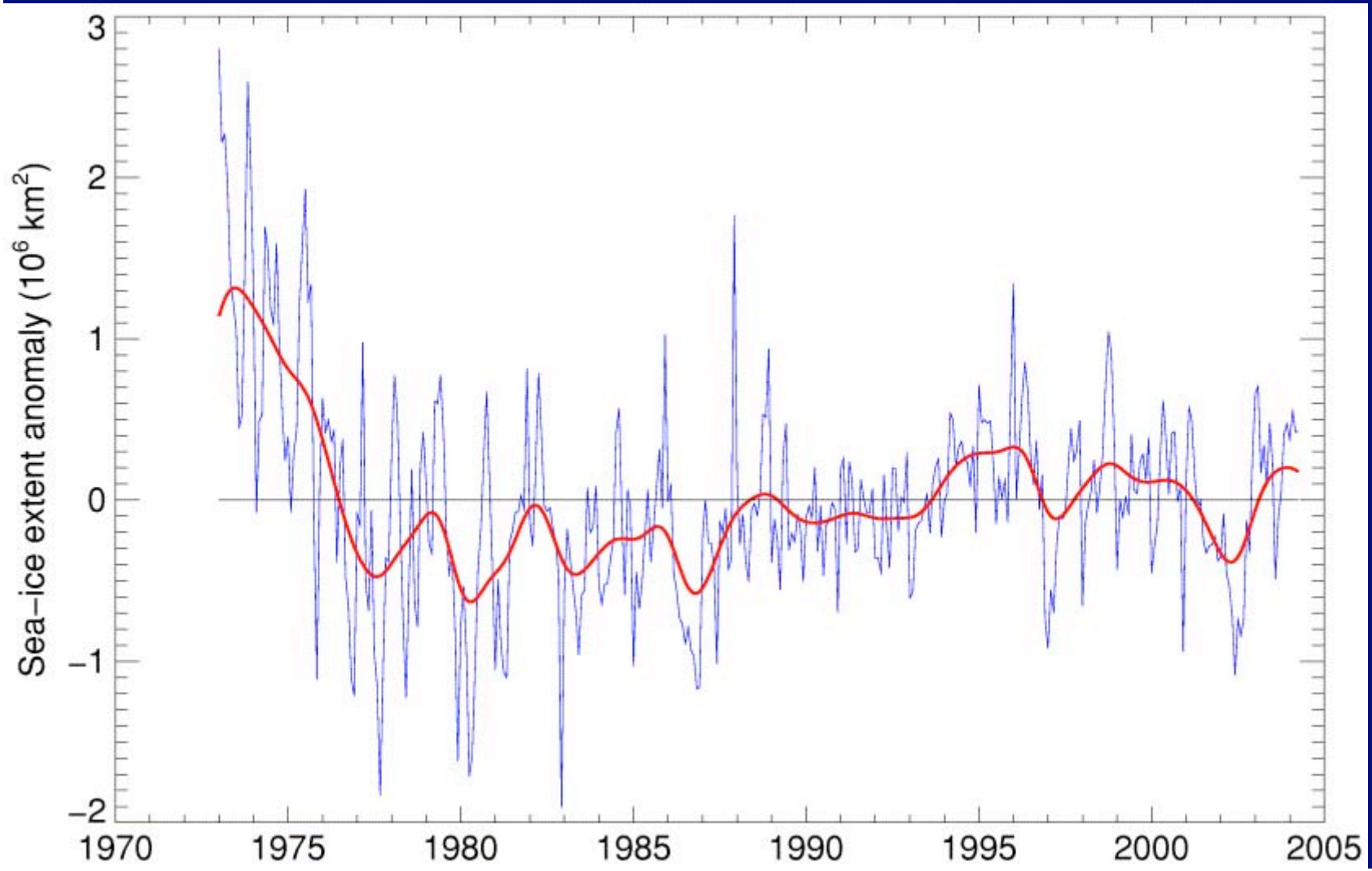

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Algorithms for retrieval of sea ice concentration from passive microwave observations

- **List of passive microwave algorithms:**
  - **NASA Team**
  - **NASA Team2**
  - **Cavalieri (1994)**
  - **Bootstrap**
  - **Revised Bootstrap**
  - **Bristol**
  - **Artist**
  - **SEALION**
  - **Cal/Val**
  - **AES York**
  - **Svendsen/Norsex**
  - **Svendsen (1997)**
  - **Technical Univ. Denmark improved res. Bootstrap**
  - **Markus and Dokken**

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Satisfaction of requirements?

- **Stability: un-tested for passive microwave?**
- **Homogeneity: very difficult problem, needs understanding of the way charts are/were created and how this relates to a p.m. sea ice concentration field**
- **Continuity: p.m. instruments successively launched operationally, operational charts are routinely produced.**
- **High priority for data-sparse or sensitive regions: there is little ground truth validation data**
- **Integration of IPCC-type requirements into plans: ?**
- **Easy user access to data: charts are becoming more accessible, point observations still stuck in archives, hard to access metadata for p.m.?**
- **Quantification of uncertainties and biases:**

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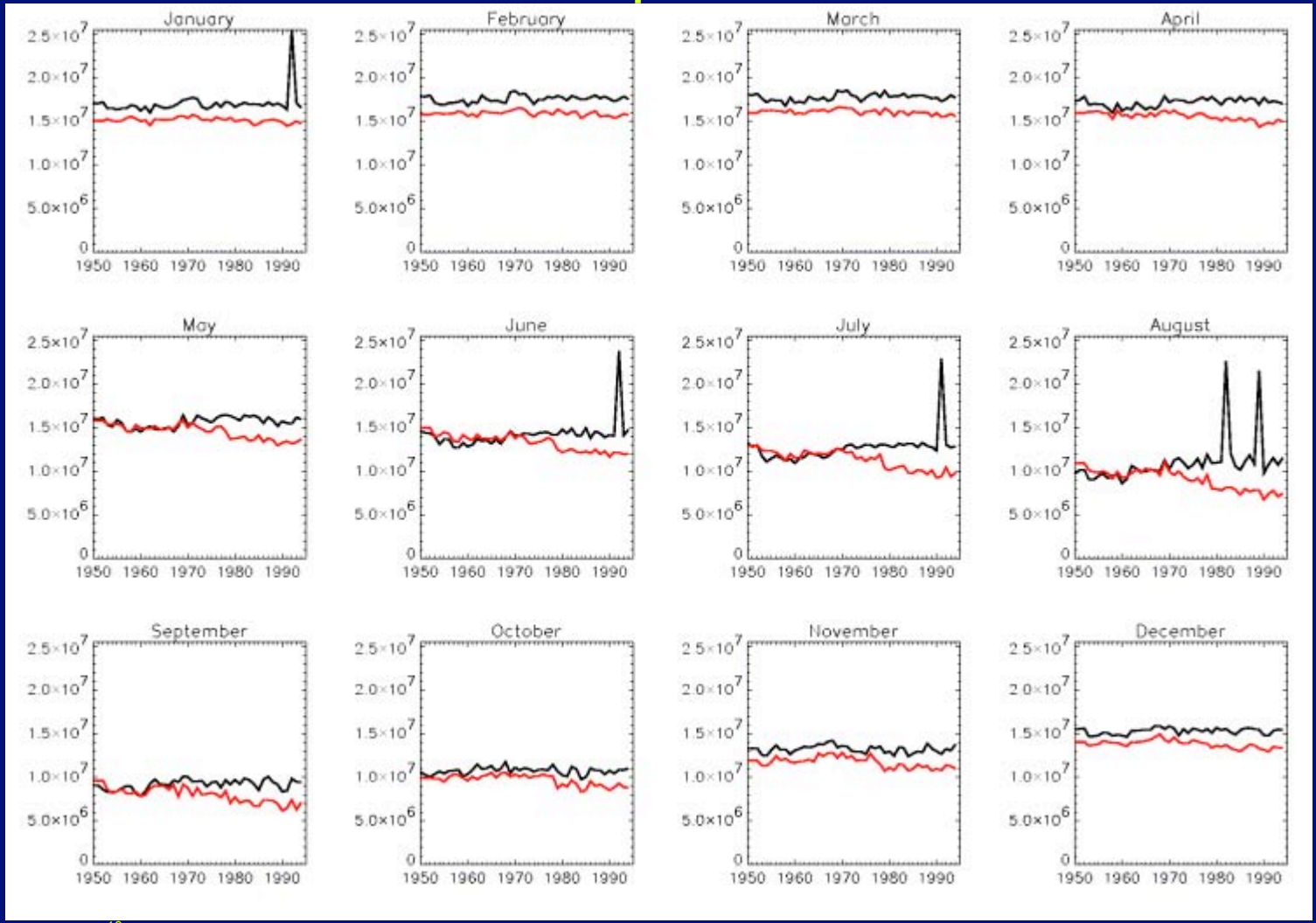
Comparing HadISST1 (red) and blended GDSIDB data set (black)

Northern Hemisphere sea ice extent



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Published error estimates for various passive microwave data sets

- Passive microwave underestimates sea ice concentration by an average of 25% in summer (but the underestimate can be more or less than this) and 5-10% in winter. This variability is surely reduced by averaging, but it's mostly all in one direction.
- Thin ice is the big problem as the algorithms don't take this into account in their formulation (except Cavalieri (1994)). Ice with thickness less than 50cm is a problem.
- Passive microwave smears out a compact edge and compresses a diffuse edge. Spot checks of the ice edge position using a 15% concentration cutoff against NIC ice charts show that when there is a broad, diffuse ice edge, the passive microwave products studied sometimes did not detect ice where the concentration can be as high as 60%. When the ice edge is more compact, the 15% concentration cutoff reflects its location fairly well.
- The winter coverage of open water is only about 0.3% (in some areas). New openings in the ice, that appear as linear leads, freeze over almost immediately.
- All areas should be considered to be equally susceptible to summer melt effects.

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Initial assessment of uncertainties in HadISST1

- **The summer bias in the passive microwave is always in one direction, but HadISST1 has been "corrected" for this, so the error will be more two sided. It's also possible that the winter bias has also been corrected out.**
- **The ice edge was preserved from the input data sets, so the edge effects are still in HadISST1**
- **In the passive microwave period, suggest +/- 15% in summer and +/- 5% in winter, due to the bias corrections in HadISST1 (where thickness greater than 50cm)**
- **Could still be a bias of up to 40% in HadISST1 near the edge (where thickness less than 50cm)**
- **use melt/freeze data to identify likely changeover dates from winter-summer values**

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Outstanding issues: progress

- **Reconciling chart-based and passive microwave derived concentration data sets**
  - **report was prepared for CLIMAR-II on inter-comparison of statistical parameters of sea ice long-term variability based on passive microwave and ice charts (Smolyanitsky)**
  - **Need to explore differences in detail. In particular summertime trends appear rather different (due to use of climatology in blend?)**
- **Sourcing data for the Antarctic**
  - **ETSI-I agreed to prepare historical sea ice data information for the Southern Ocean. Status report will be available by ETSI-II, autumn 2004**

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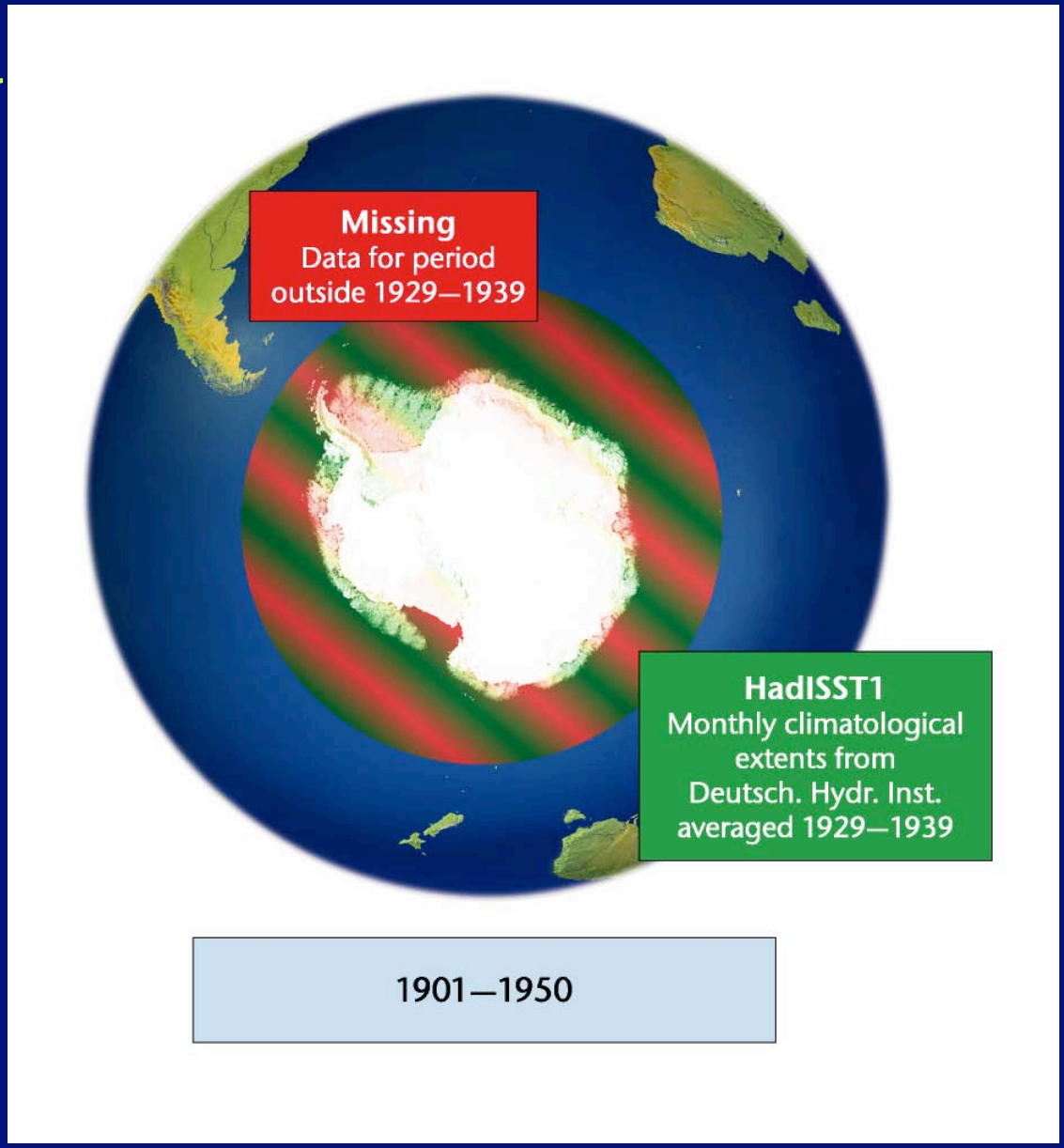
Sea ice data availability: in HadISST1 and in the future



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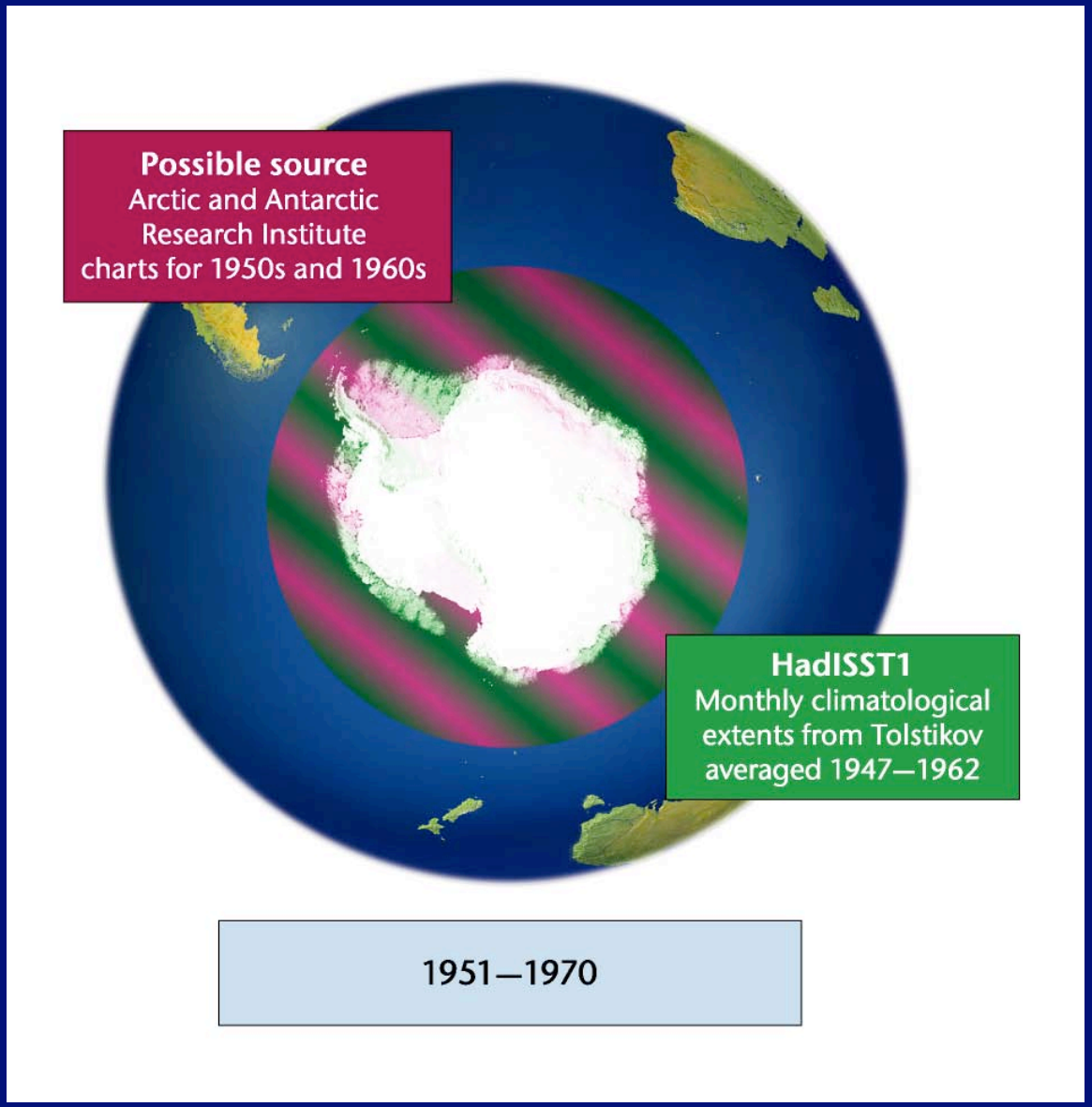
Sea ice data availability: in HadISST1 and in the future



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Outstanding issues: no progress

- **Identifying the "best" passive microwave algorithm (or combination of algorithms) for retrieval of sea ice concentration**
- **Critical reassessment of passive microwave record in context of extended GCOS climate monitoring principles**
- **Retrieving more-accurate concentrations at times of melt**
- **Deriving fields of uncertainty**
  - **Analysis of sensor drift/overlap issues required**

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My personal strategy for short term progress (1)

- **Encourage production of error estimates for blended chart data set.**
- **Select preferred passive microwave data set, assign initial error estimates and perform detailed inter-comparison with blended chart data (so as to inform IPCC 4AR). If selected algorithm is not available in truly homogeneous data set, encourage producer to do this. If required metadata not easily accessible encourage access to this.**

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My personal strategy for short term progress (2)

- **Depending on result of ETSI survey try to find funds for digitization of historical Southern Ocean sea ice *[start with NSIDC]***
- **Encourage research into development of methods for retrieval of sea ice during times of melt**
- **Liaise with lead author team on Observed Cryosphere chapter of IPCC 4AR when announced (contact Susan Solomon in mean time). Use combined influence to try and encourage focused work from data set providers.**
- **Include very focused session on sea ice in next scheduled marine meeting. Invite contributions aimed at answering some selected remaining questions, rather than general presentations about sea ice.**

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Suggestions in draft AR2 implementation plan

- **Strongly support the following recommendations:**
  - **O24/OF7 re improving access to in situ observations of sea ice**
  - **O25/OF7 re setting up of international analysis centre(s), if this is only way work is likely to be funded – establishes importance and would be focused on climate requirement from the start**
  - **C11 (CF5) re provision of historical data sets including metadata to archives**
  - **Point 71 re data archaeology (particularly Antarctic), but needs careful investigation of the availability of such information**

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Opportunities for future development of sea ice parameters

As contributed by Chad Dick, Director CliC Project Office

- **CryoSat is due for launch later this year which hopes to measure sea ice thickness. Calibration and validation activities will bring together a range of ice thickness measuring techniques for an intensive measuring period (next spring?) north of Greenland.**
- **Some data archaeology continues in Russia - mainly based at AARI and the Fram Arctic Laboratory there. This includes a project to collect all available data from the Fram drift track over the last century.**
- **A couple of projects are working on use of EOFs of ice edge position from the satellite era to reconstruct past records - that is fill in the gaps that are so common in older observations, based on statistical analysis of variations from the modern era. This is being attempted for the Nordic Seas (at Norsk Polarinstitutt) and the Chukchi Sea (IARC in Alaska).**
- **IPY presents opportunities. Chad would like to see an attempt to bring all older sea ice records into electronic existence, and then to use reconstruction to provide a useful record that could be tied in with longer re-analyses that are now being considered. At the moment the records are still a bit fragmented.**

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Opportunities for future development of sea ice parameters

As contributed by Chad Dick, Director CliC Project Office

- **Additionally, IPY may be an opportunity for year round obs in Antarctica, following growth and decay of sea ice for one season, and watching its effect on ocean and atmospheric circulation. This should be a combination of in situ and remote sensing. The International Programme for Antarctic Buoys (IPAB) have also suggested a one year, one-off, intense deployment of buoys in the sea ice zone round Antarctic to try to get a critical mass of obs that help in future modelling.**
- **Envisat is up there now, and there is some work going on to reproduce Ron Kwok's Radarsat Geophysical Processing System (which gives ice motion, and estimates of thickness and age over the Western Arctic) for the entire Arctic.**
- **North Pole drifting stations are back on the go, and the Japanese have been deploying ice tethered buoys that gives upper ocean measurements.**
- **An 'IceCam' has been designed and is seeking additional deployments. It takes photos of ice at regular intervals from ships of opportunity (i.e., ships are being sought that would be willing to carry these), and an analysis system can be used to give estimates of ice concentration, sometimes thickness. A central database is being set up for these.**

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