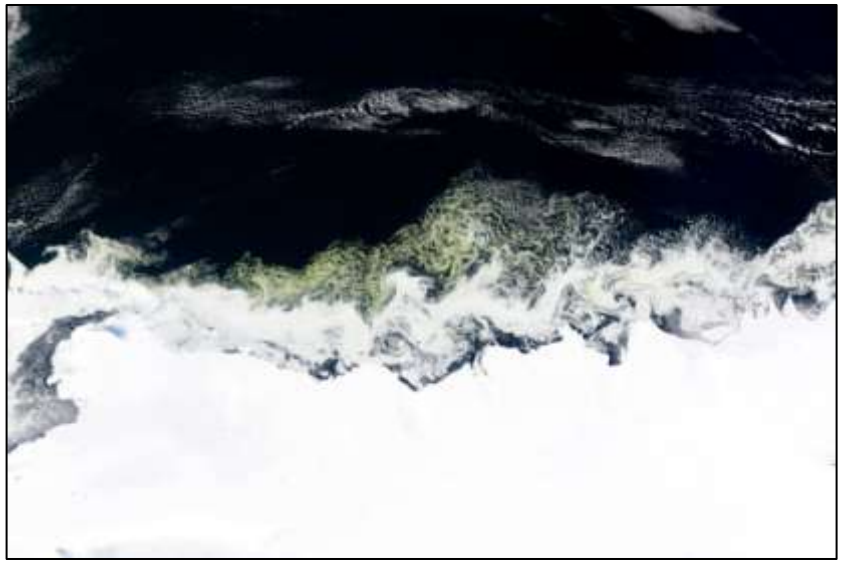
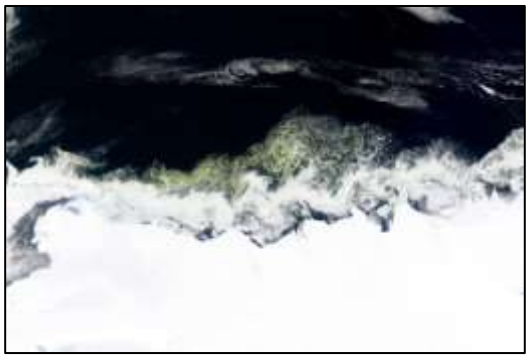
Remote Sensing in the Southern Ocean: Overview of existing techniques and future directions



Patrick N. Halpin
Jason Roberts
Marine Geospatial Ecology Lab
Duke University Marine Lab

Outline:



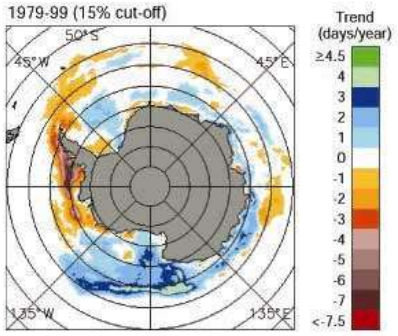
- Problem
- Scales of Remote Sensing
- Southern Ocean Scale Remote Sensing
  - SST
  - Ocean Color / Productivity
  - Ice
  - SSH
  - Oceanographic Features
  - Assimilating Oceanographic Models: HYCOM
- In-situ Scale Remote Sensing
  - Active sonar prey mapping
  - Ship-born ice image analysis
- Conclusions / Discussion

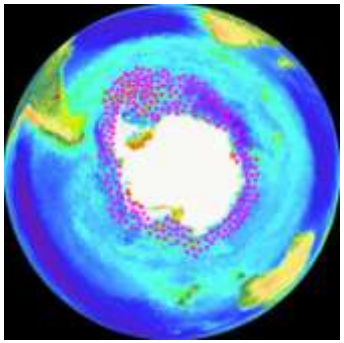
Problem:

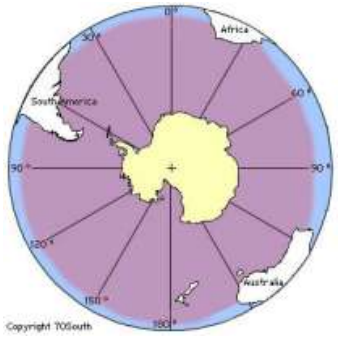
In order to better understand whales in the Southern Ocean we need to be able to actively observe their physical and biological environment at multiple spatial and temporal scales.

Remote sensing provides:

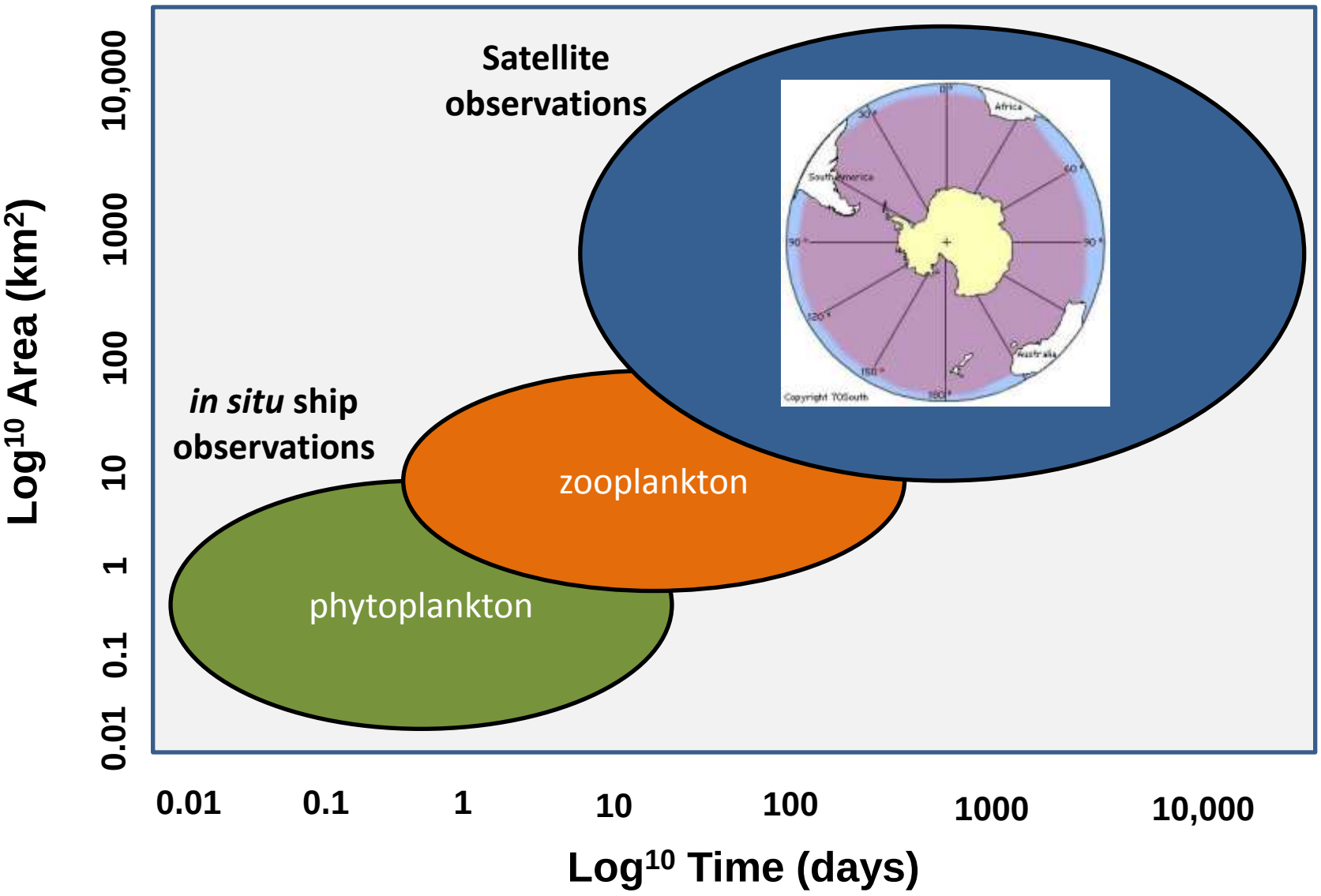
- **Covariates for habitat and density models**
- **Observations of productivity and prey distributions**
- **Monitoring & validation data**





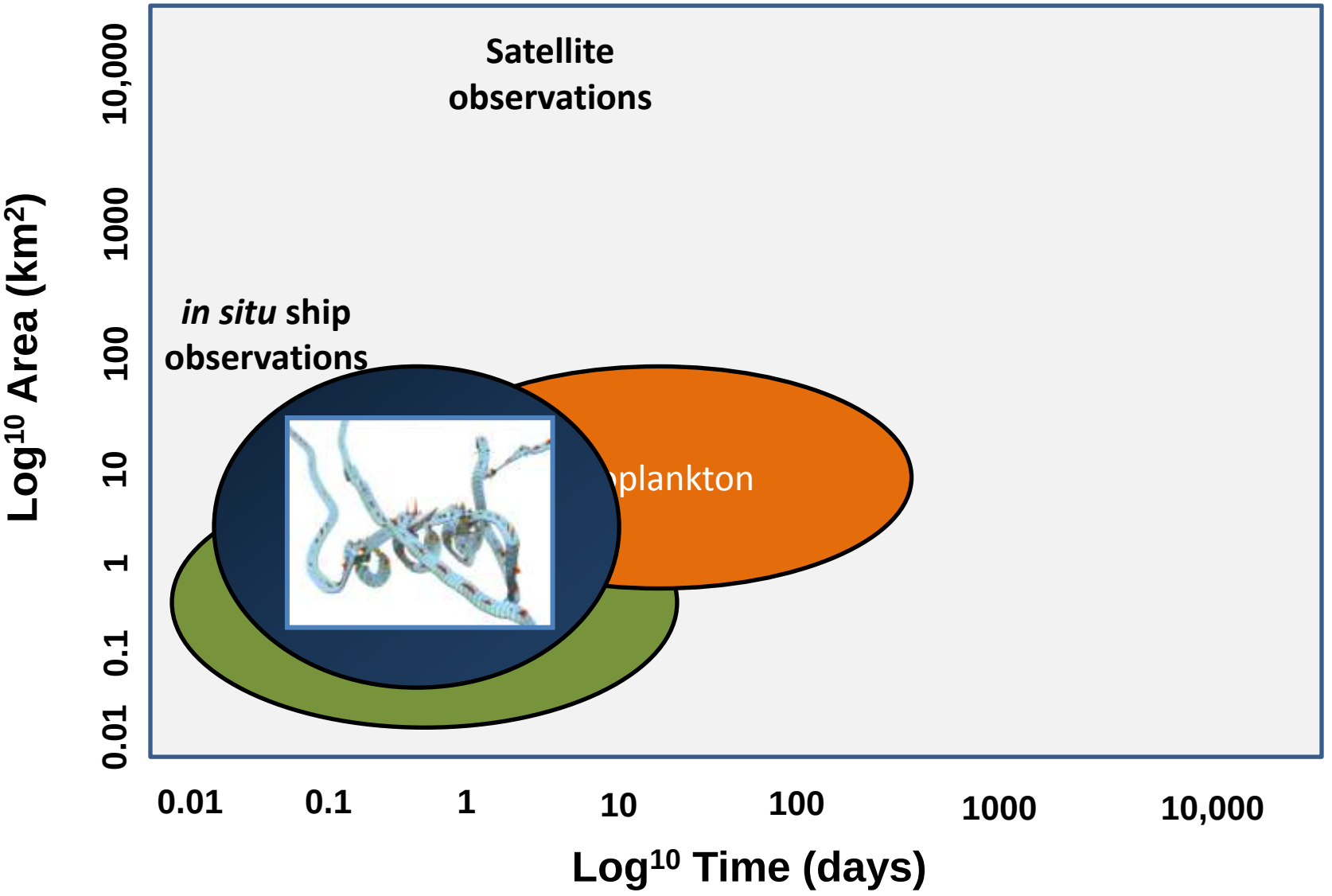


Southern Ocean: Scales of Remote Sensing



Modified after: Esaias, Wayne E., 1981: Remote Sensing in Biological Oceanography. Oceanus, Vol. 24, Number 3, 32-38.

Southern Ocean: Scales of Remote Sensing



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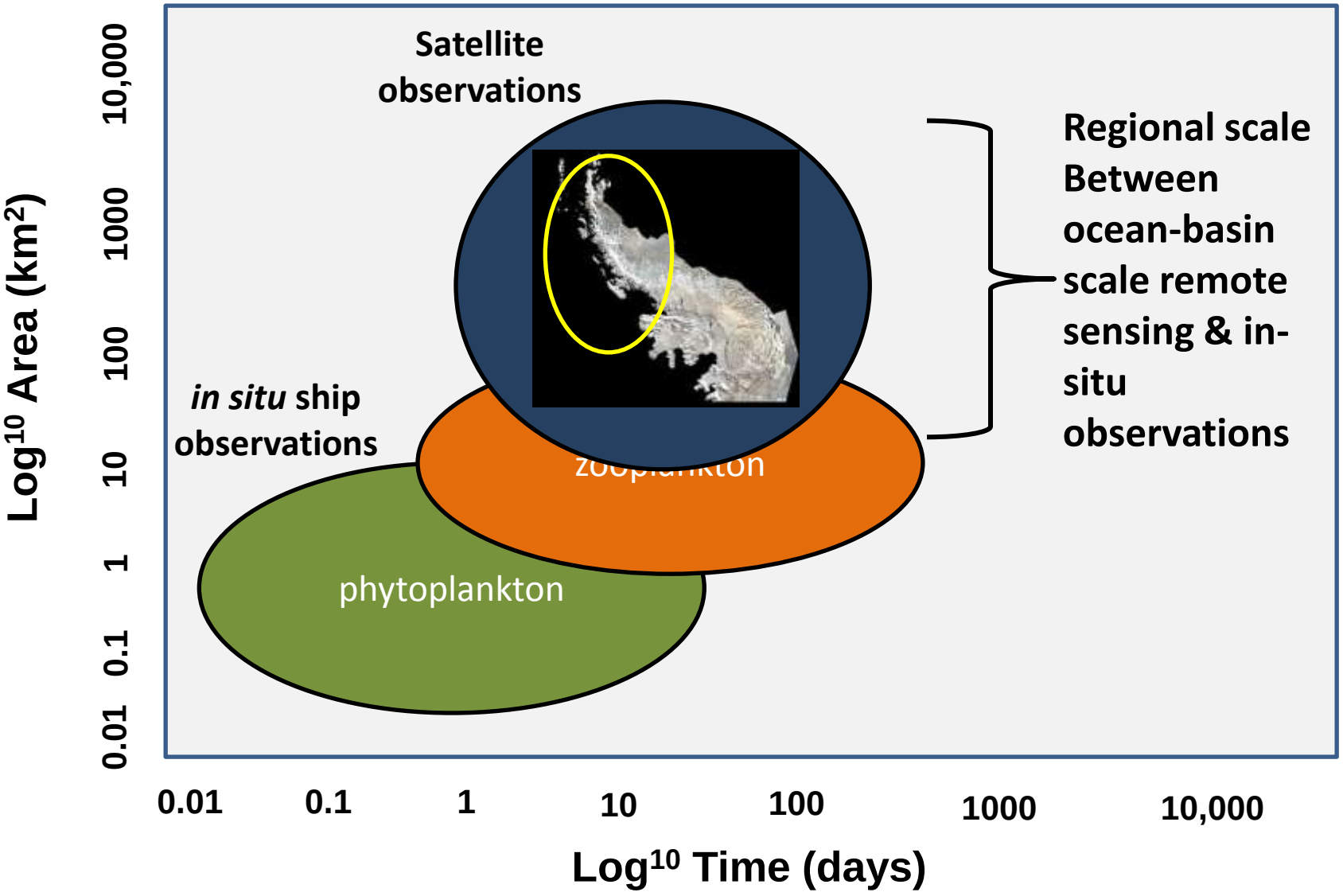
Southern Ocean: Scales of Remote Sensing



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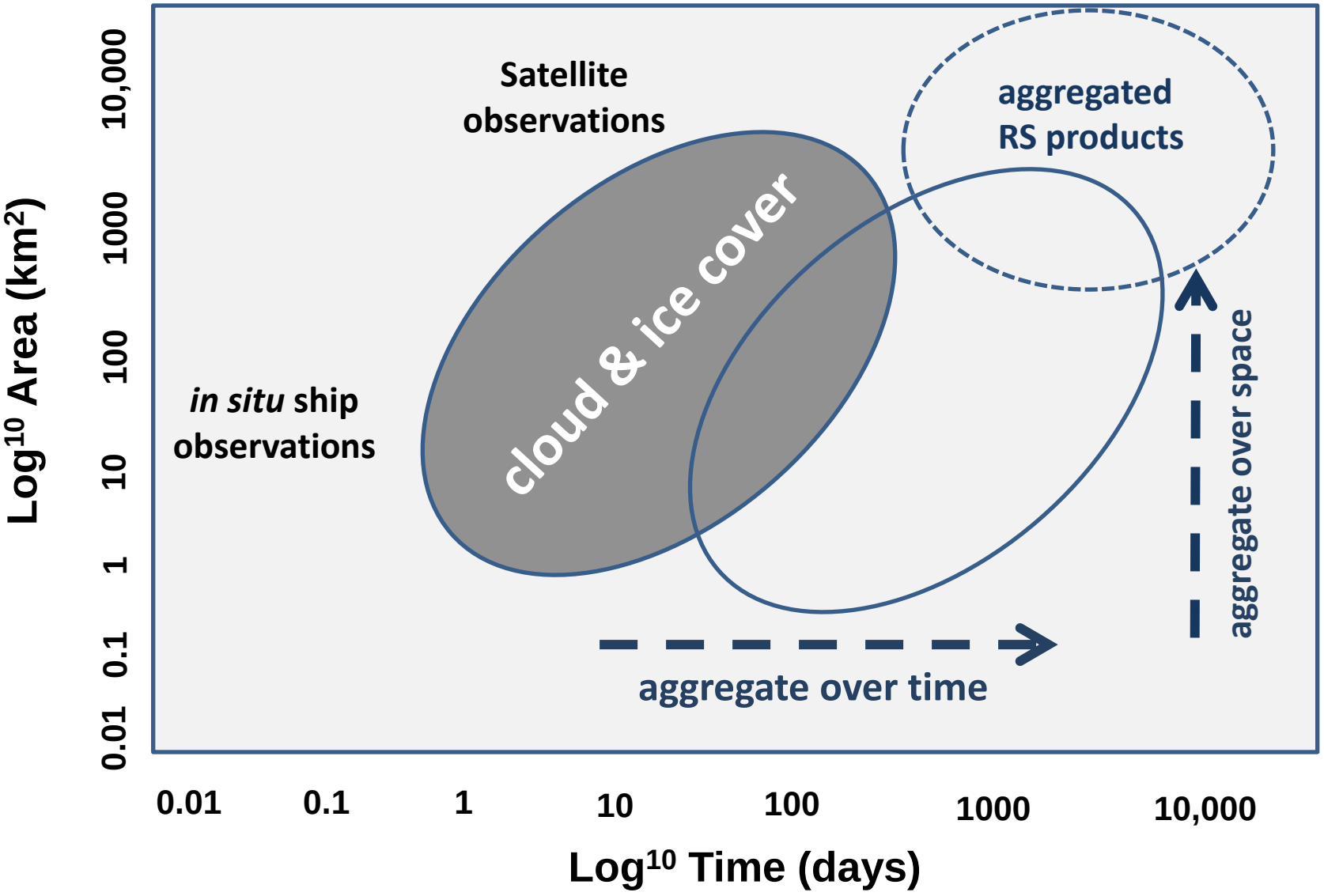
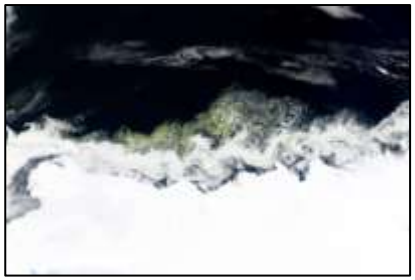
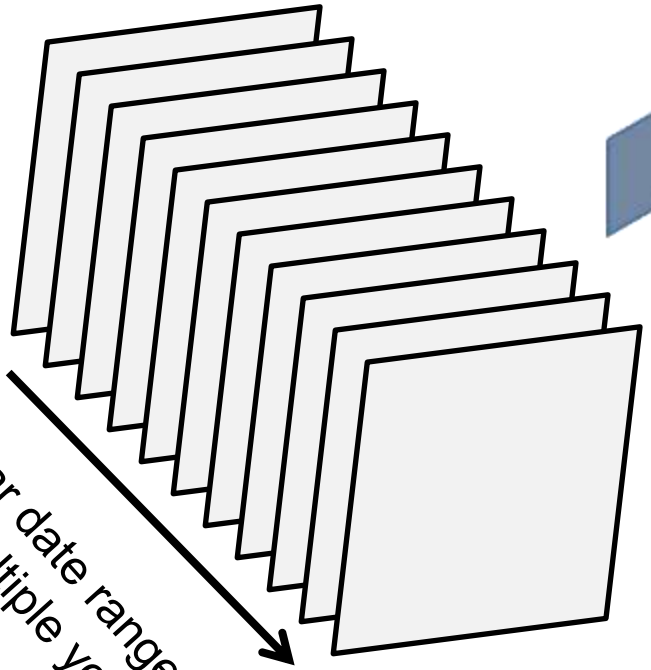
Southern Ocean: Scales of Remote Sensing

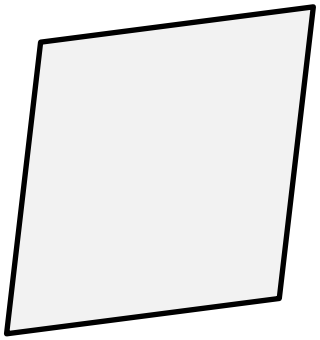


Aggregation of Remote Sensing images

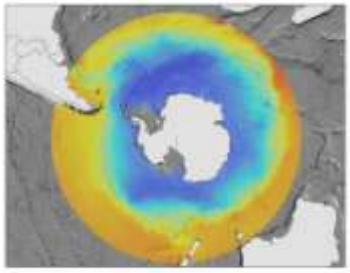
Development of annual or monthly climatologies





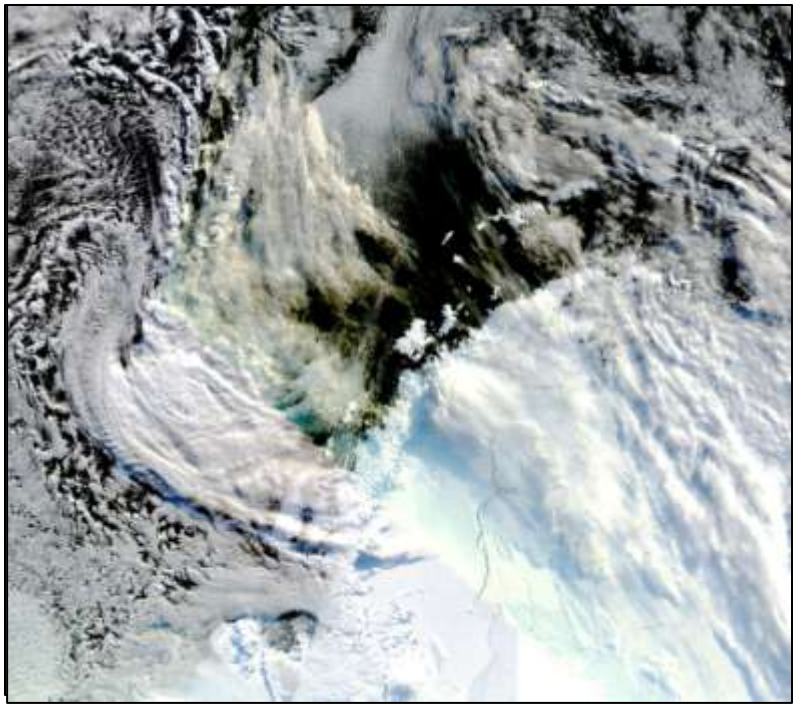


weekly, monthly, seasonal or annual climatologies

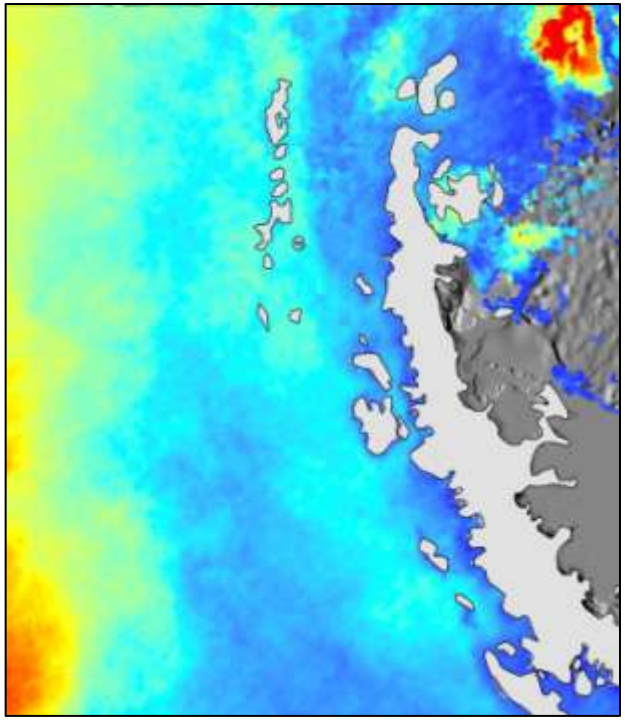


A decadal climatology may require >10^5 images

Raw daily MODIS – TERRA image vs. Monthly SST composite

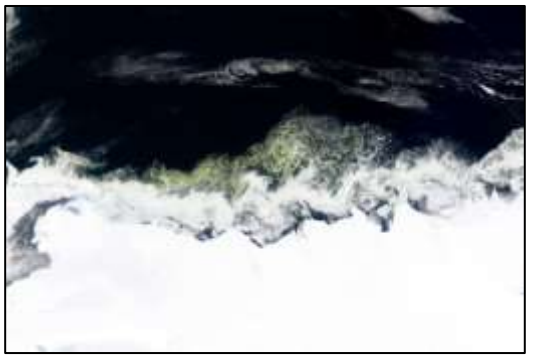


The “real” Southern Ocean



A composite view of surface conditions

Outline:



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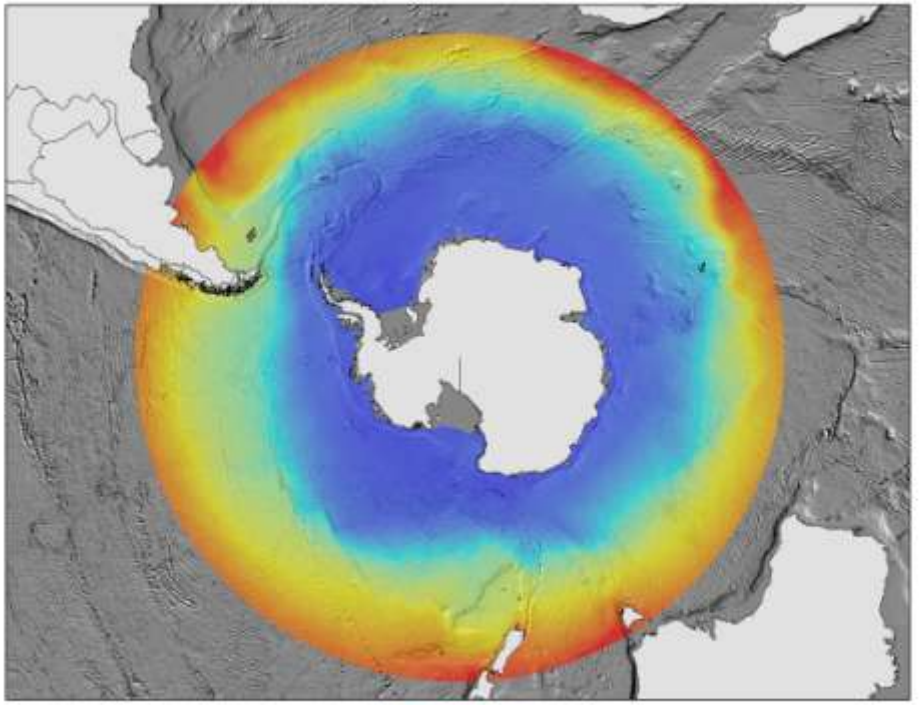
Cumulative Sea Surface Temperature (SST)

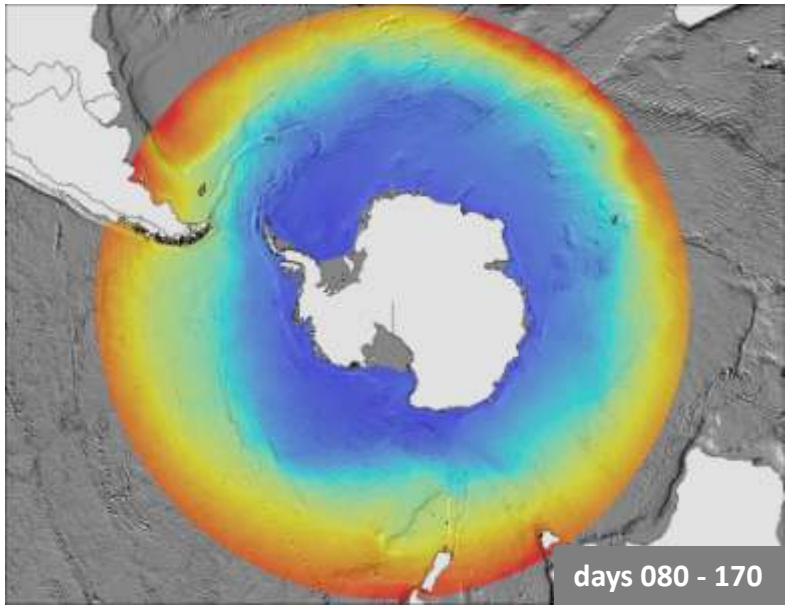
Terra MODIS L3 SST
cumulative climatology
from daily data
1999 to present

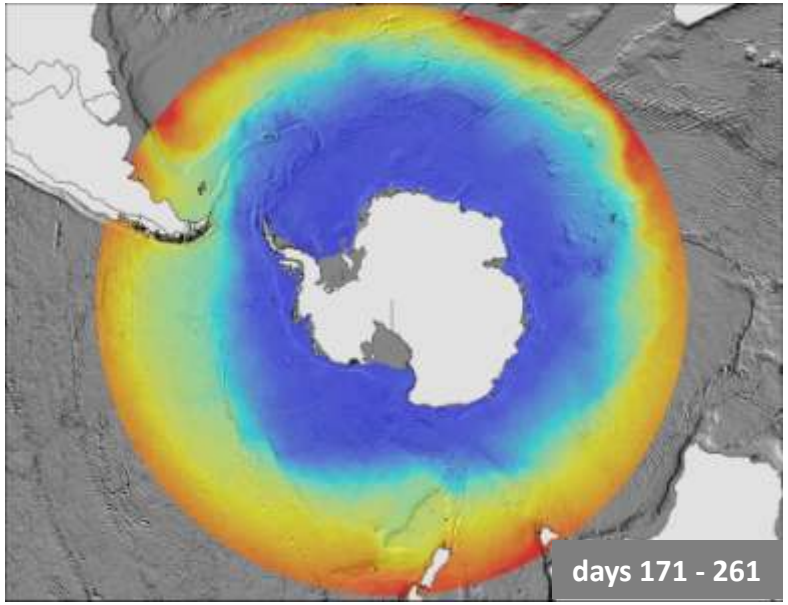


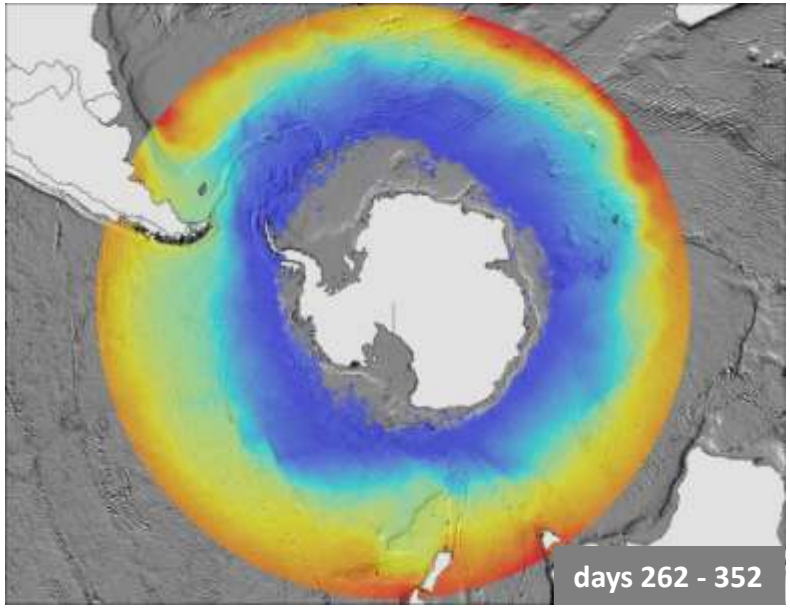
south pole stereographic using a cell size of 2.325 km, which is the effective resolution of the original MODIS L3 data at latitude 60 S

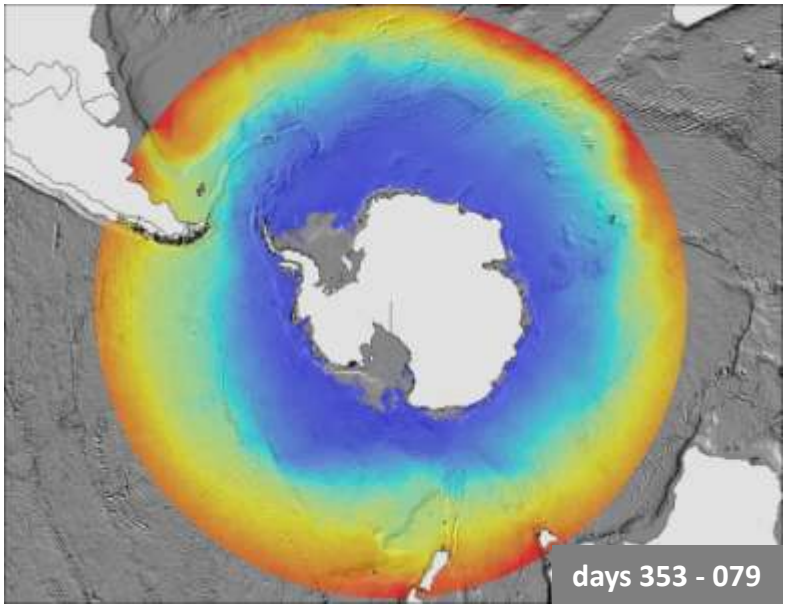
NASA GSFC OceanColor Group http://oceancolor.gsfc.nasa.gov/

Seasonal (91 day) Sea Surface Temperature (SST)



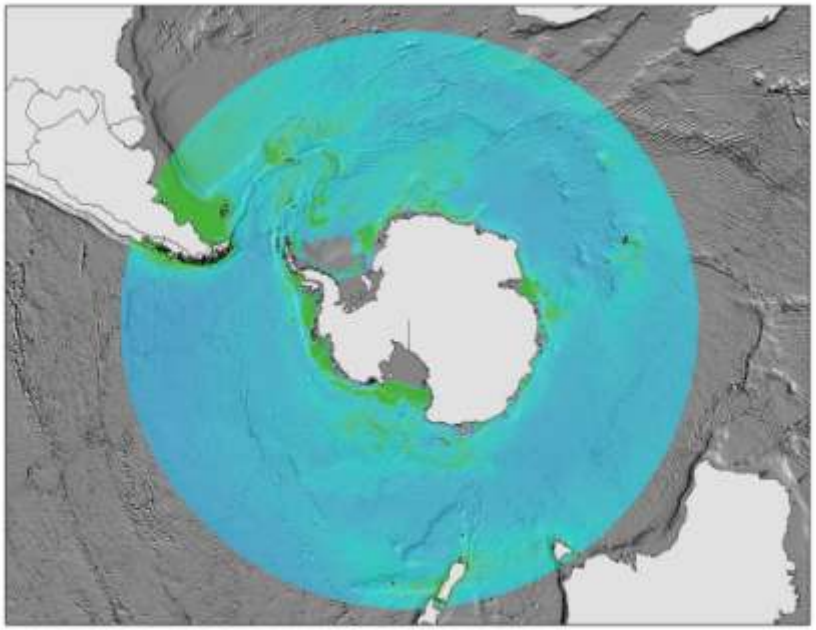


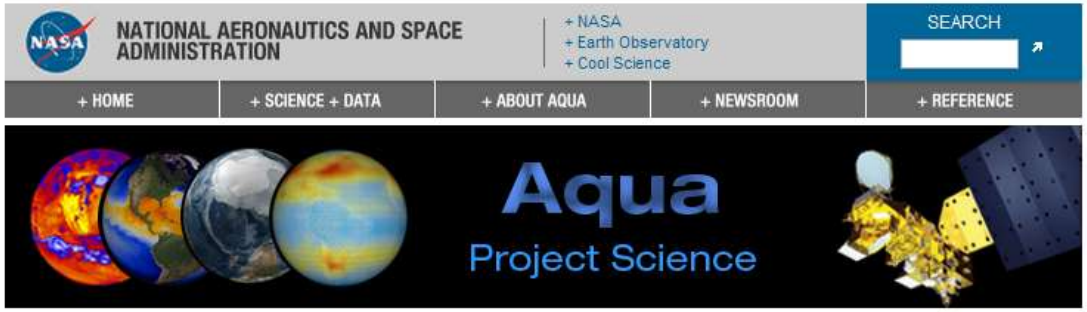




Chl_a Cumulative Average

MODIS Aqua L3 chlorophyll
cumulative climatology
from daily data
June 2002 to present

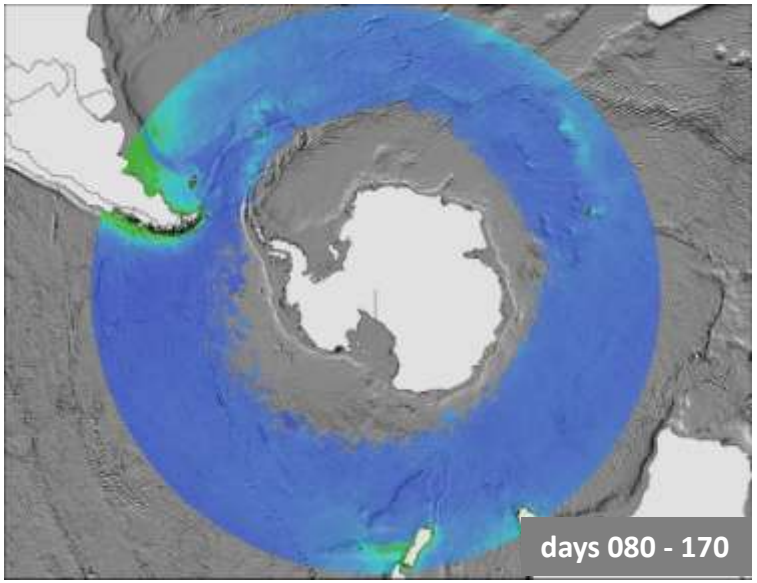


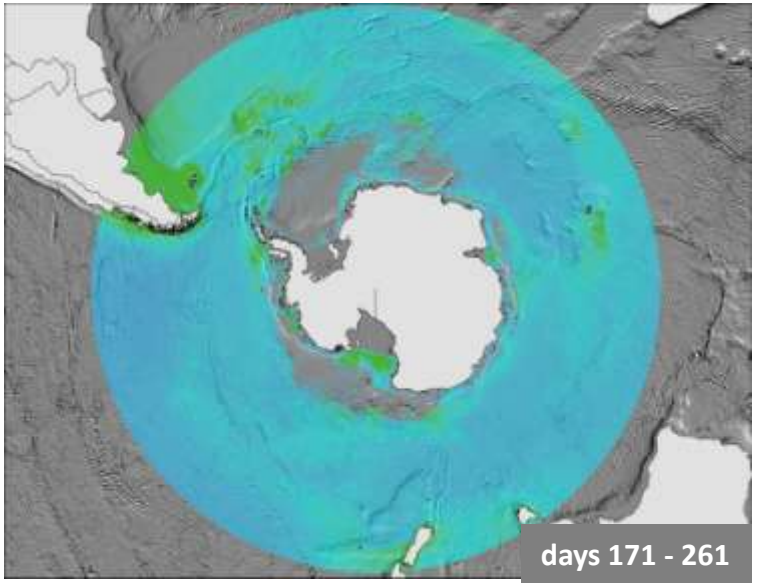


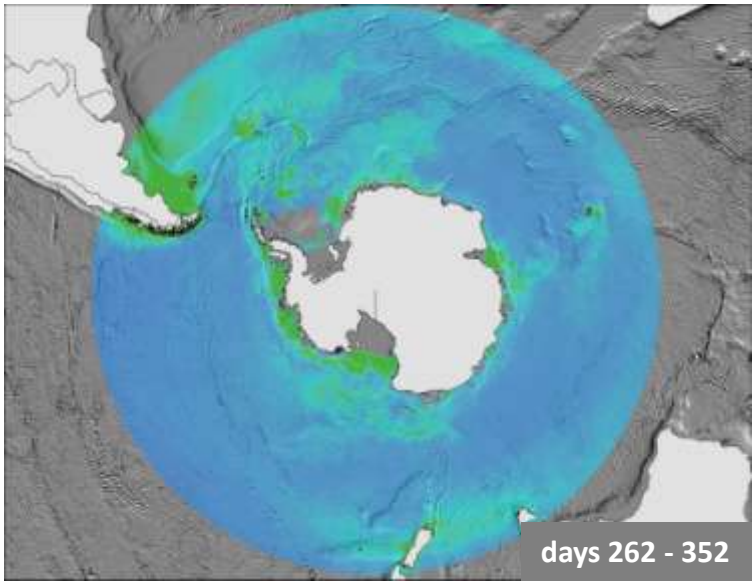
south pole stereographic using a cell size of 2.325 km, which is the effective resolution of the original MODIS L3 data at latitude 60 S

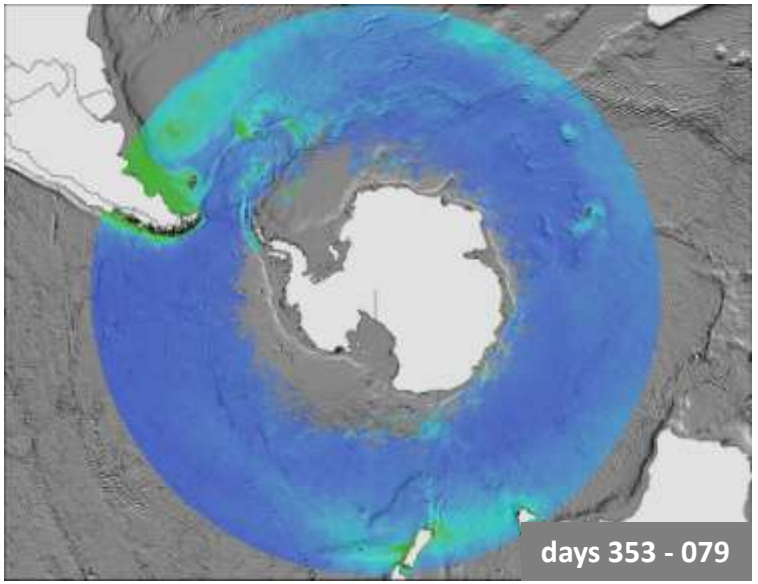
NASA GSFC OceanColor Group (http://oceancolor.gsfc.nasa.gov/

Seasonal (91 day) Chl_a Average



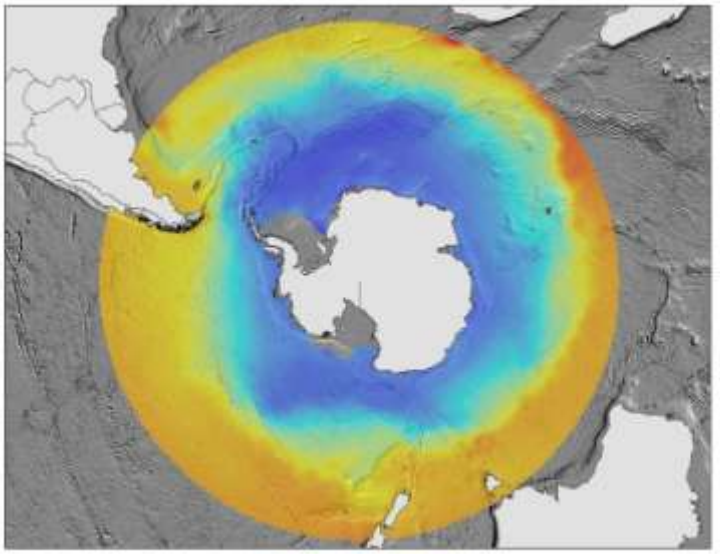






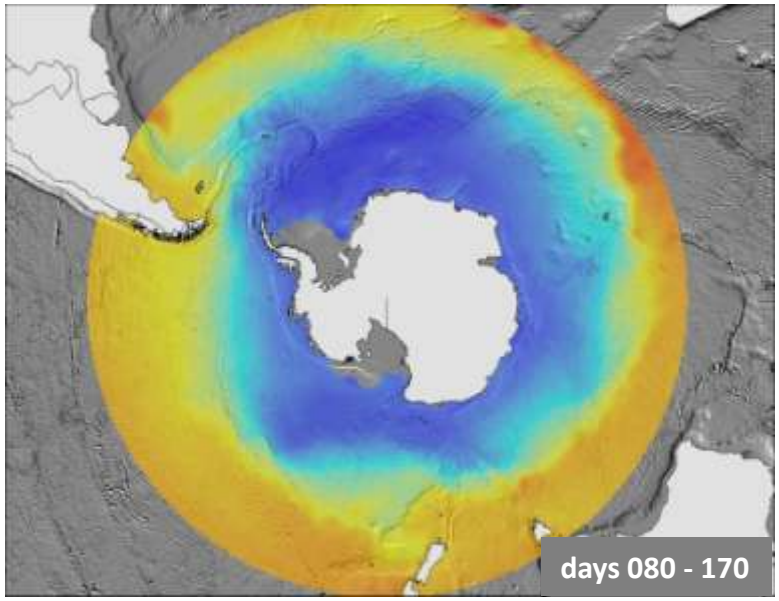
Cumulative Mean Sea Surface Height (SSH)

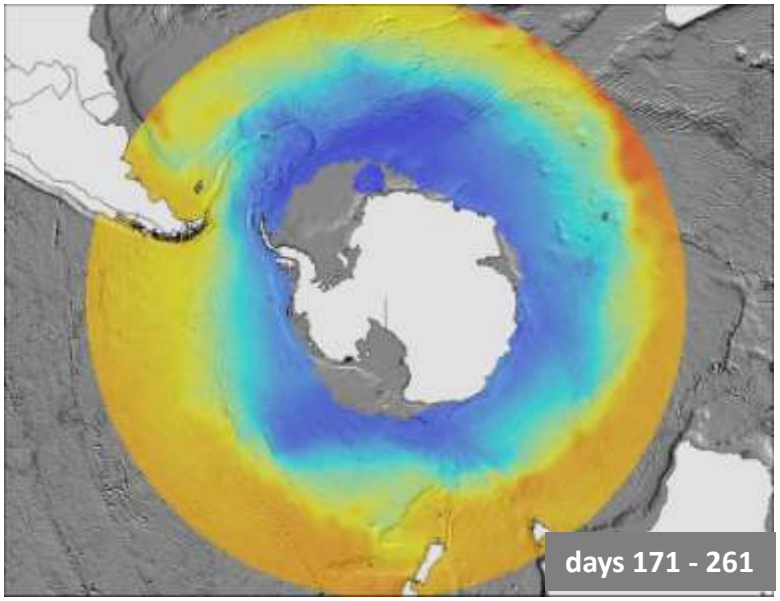
Aviso DT-MADT SSH
7-day 1/3 degree global
1993-2010

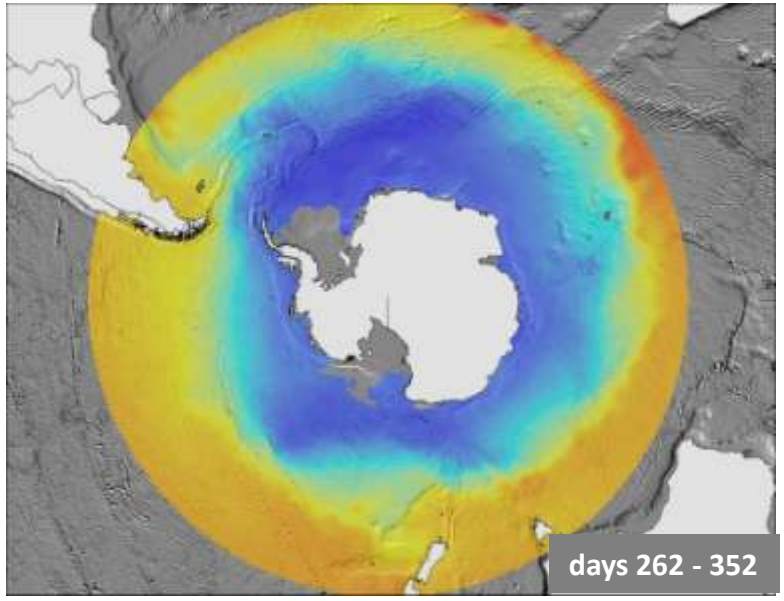


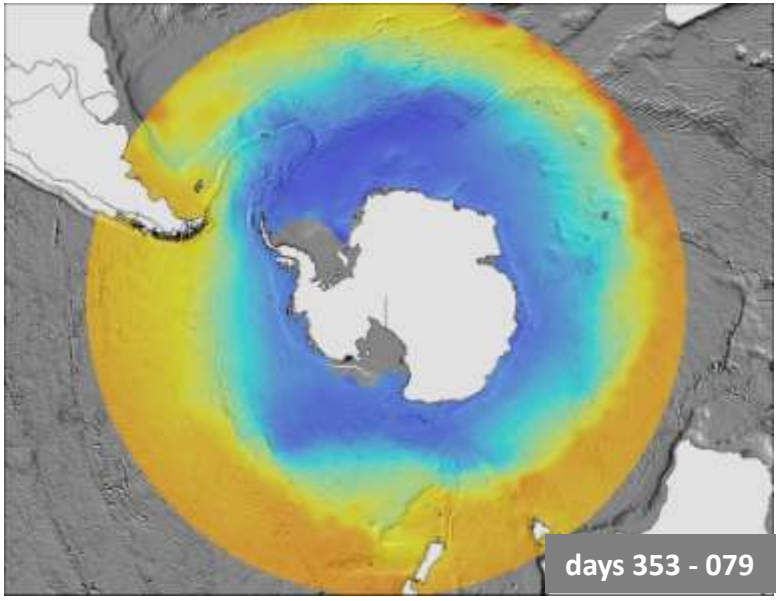
http://www.aviso.oceanobs.com/en/index.html

Seasonal (91 day) Mean Sea Surface Height (SSH)









Cumulative Mean Sea Ice

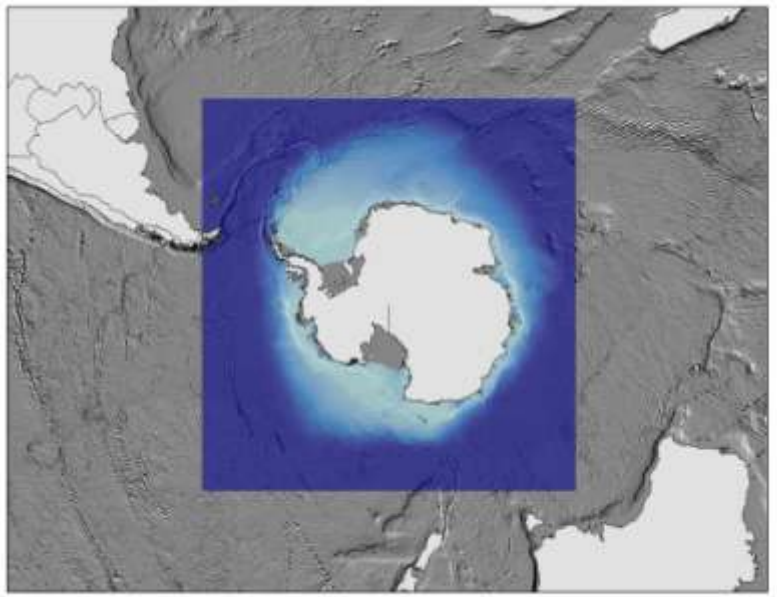
AMSR-E

Antarctic ice concentration

6.25 km

Polar View

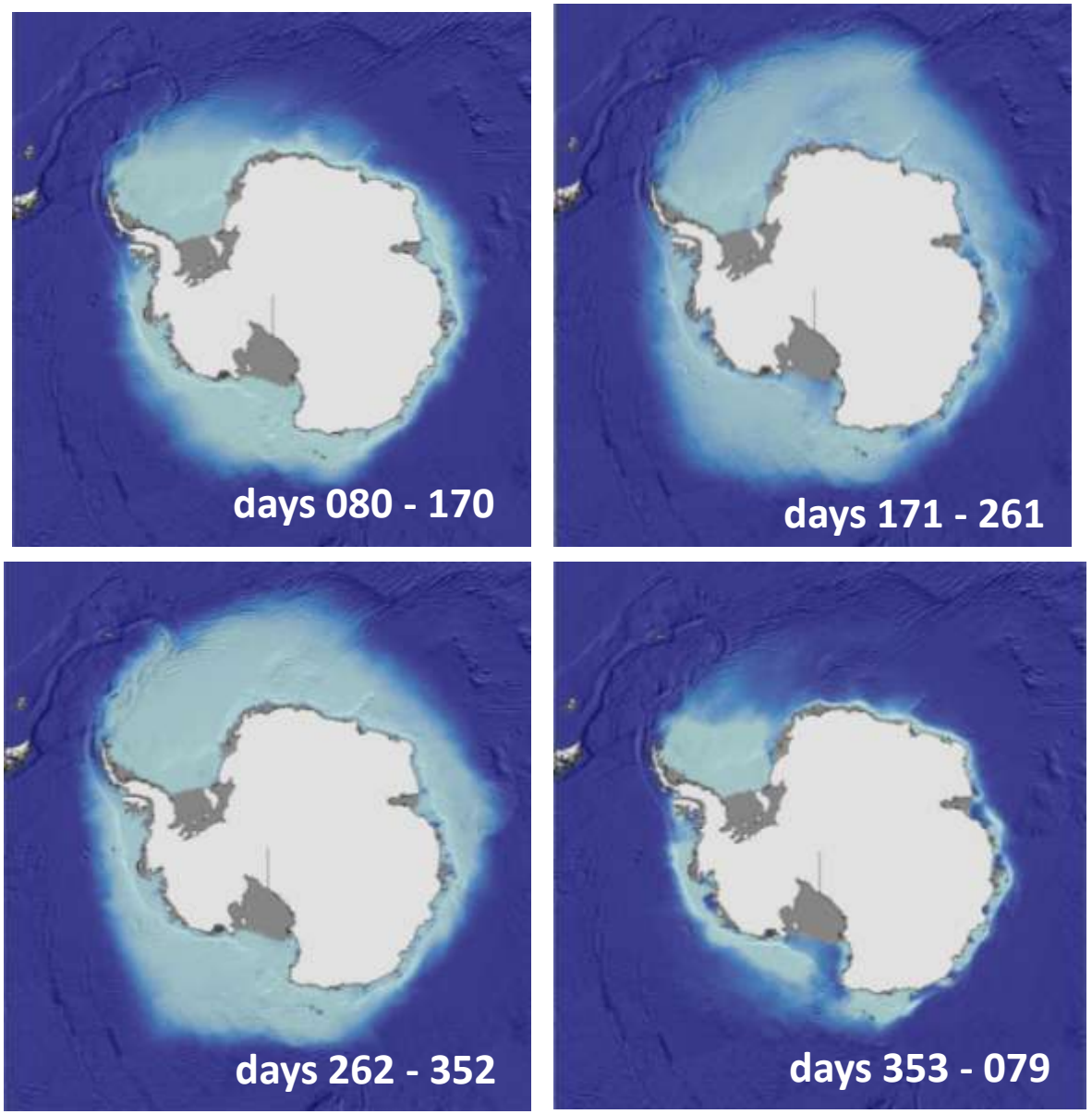
Universität Bremen



The AMSR-E Sensor stopped responding in October 2011

Spreen et al. (2008) documentation on the sea ice data, see:
ftp://ftp-projects.zmaw.de/seaice/AMSR-E_ASI_IceConc/AMSRE-ASI-Info.txt

Seasonal (91 day) Mean Sea Ice



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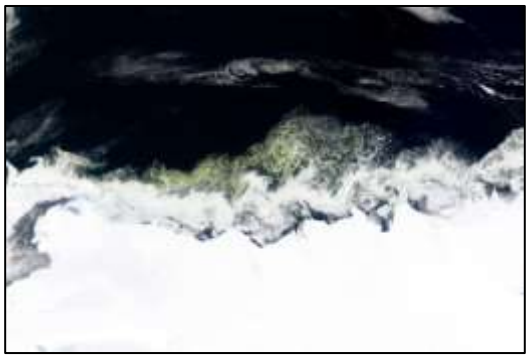

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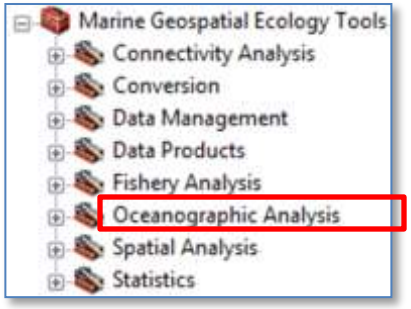
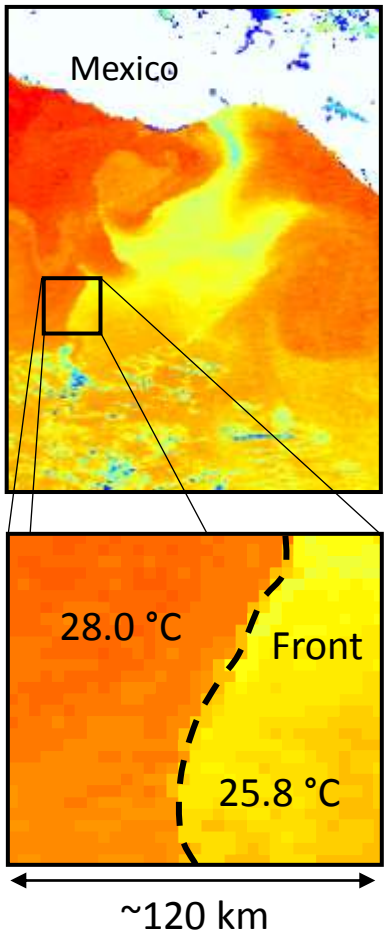
Identify fronts in SST images

MGET: Marine Geospatial Ecology Tools

Roberts *et al.* 2010

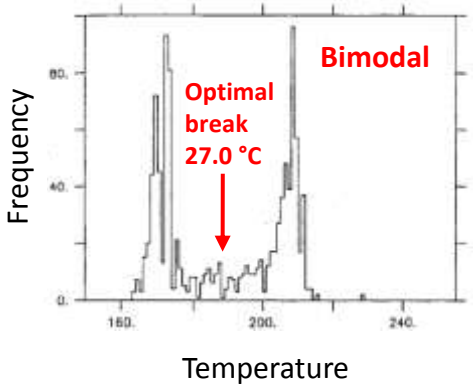


AVHRR Daytime SST
03-Jan-2005

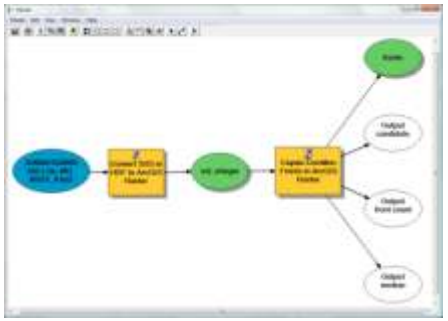


Cayula and Cornillion (1992) edge detection algorithm

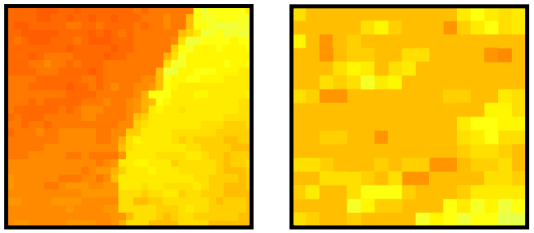
Step 1: Histogram analysis



ArcGIS model



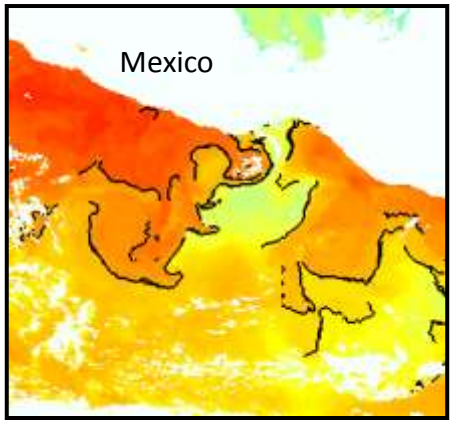
Step 2: Spatial cohesion test



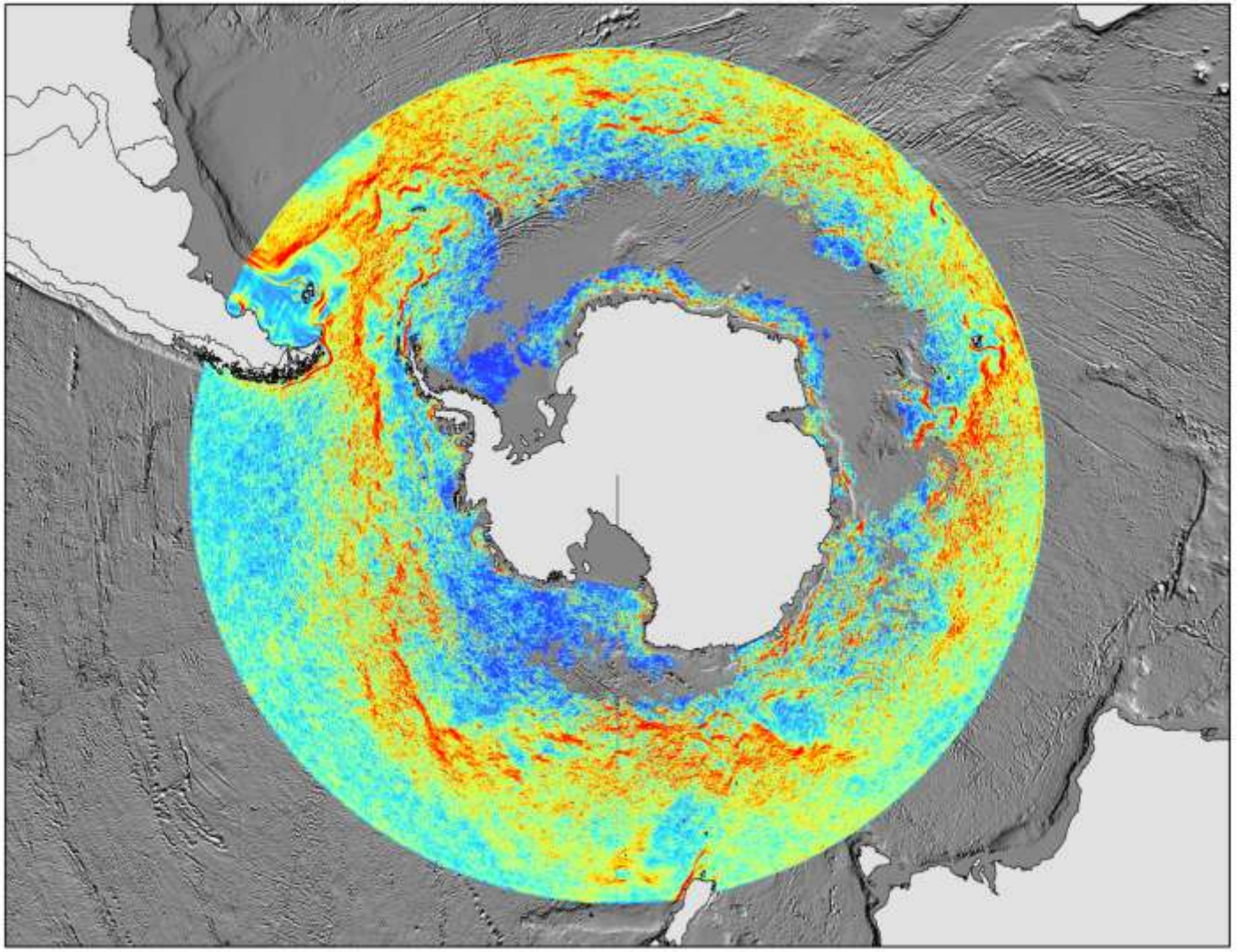
Strong cohesion → front present

Weak cohesion → no front

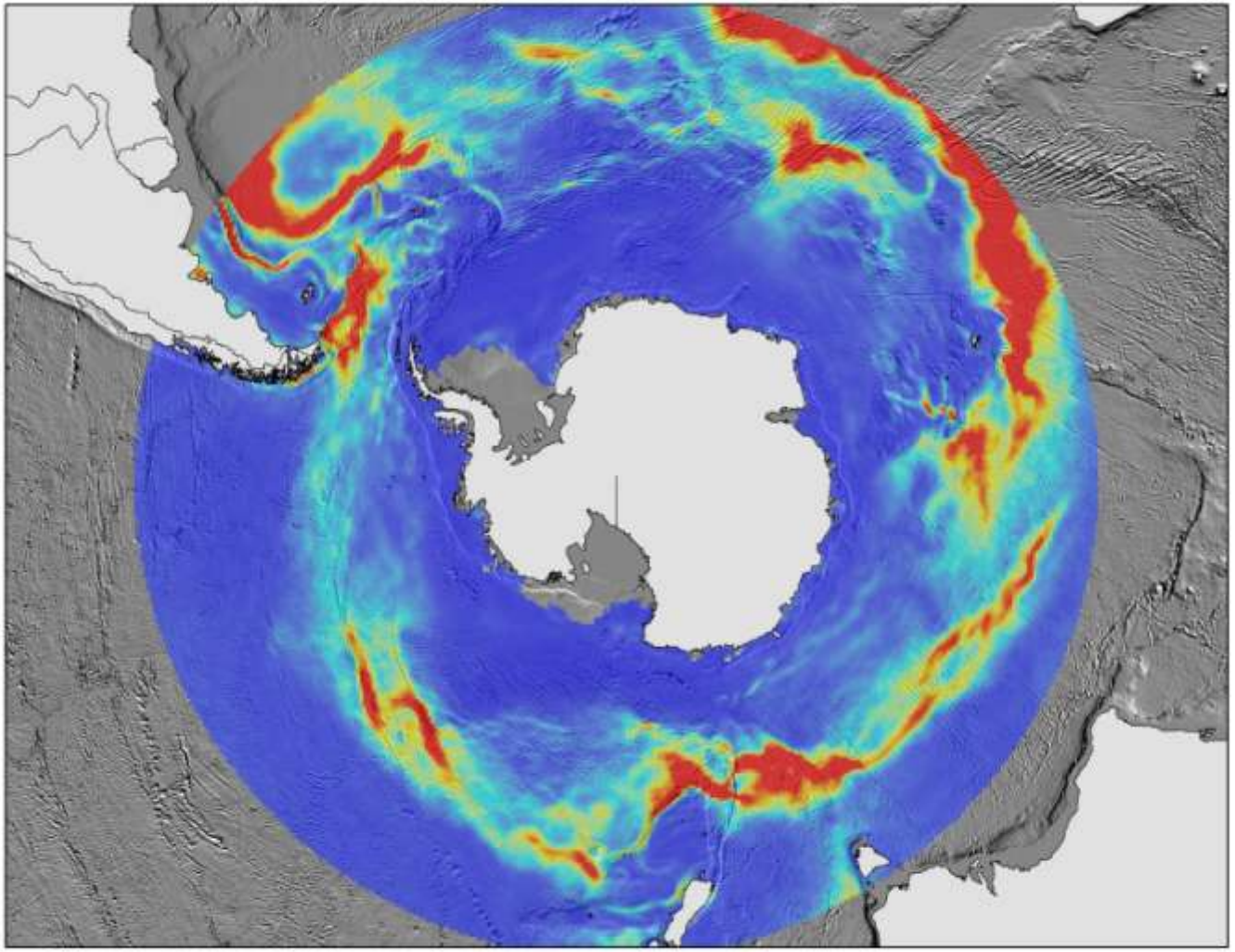
Example output



Night-time SST Front Probability

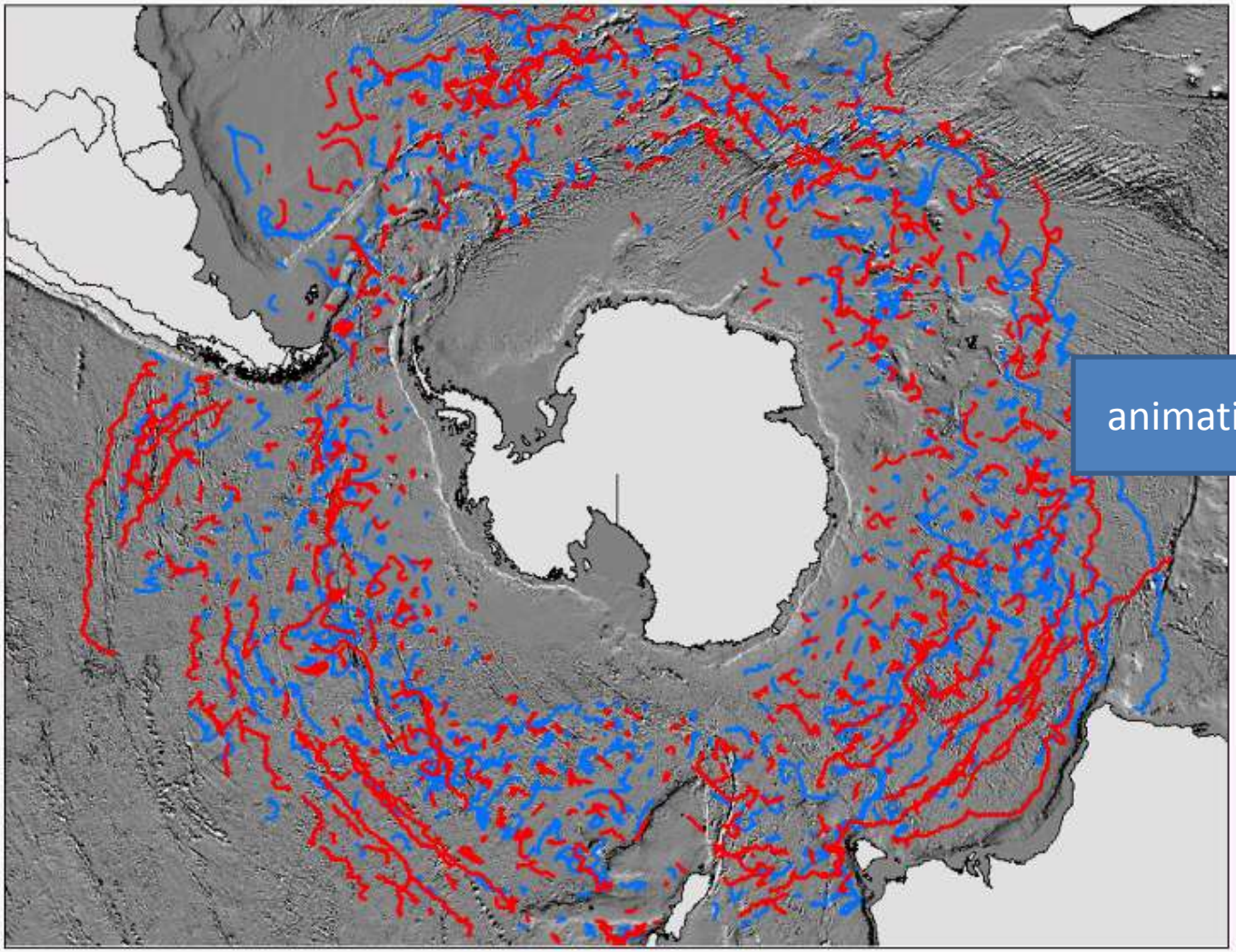


Cumulative Mean Eddy Kinetic Energy



computed from Aviso 7-day 1/3 degree global DT-MADT Ref geostrophic currents, 1993-2010

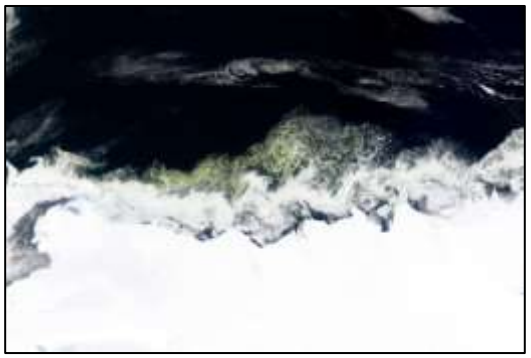
Eddy centroids & tracks



Red = cyclonic

Blue = anticyclonic

Outline:



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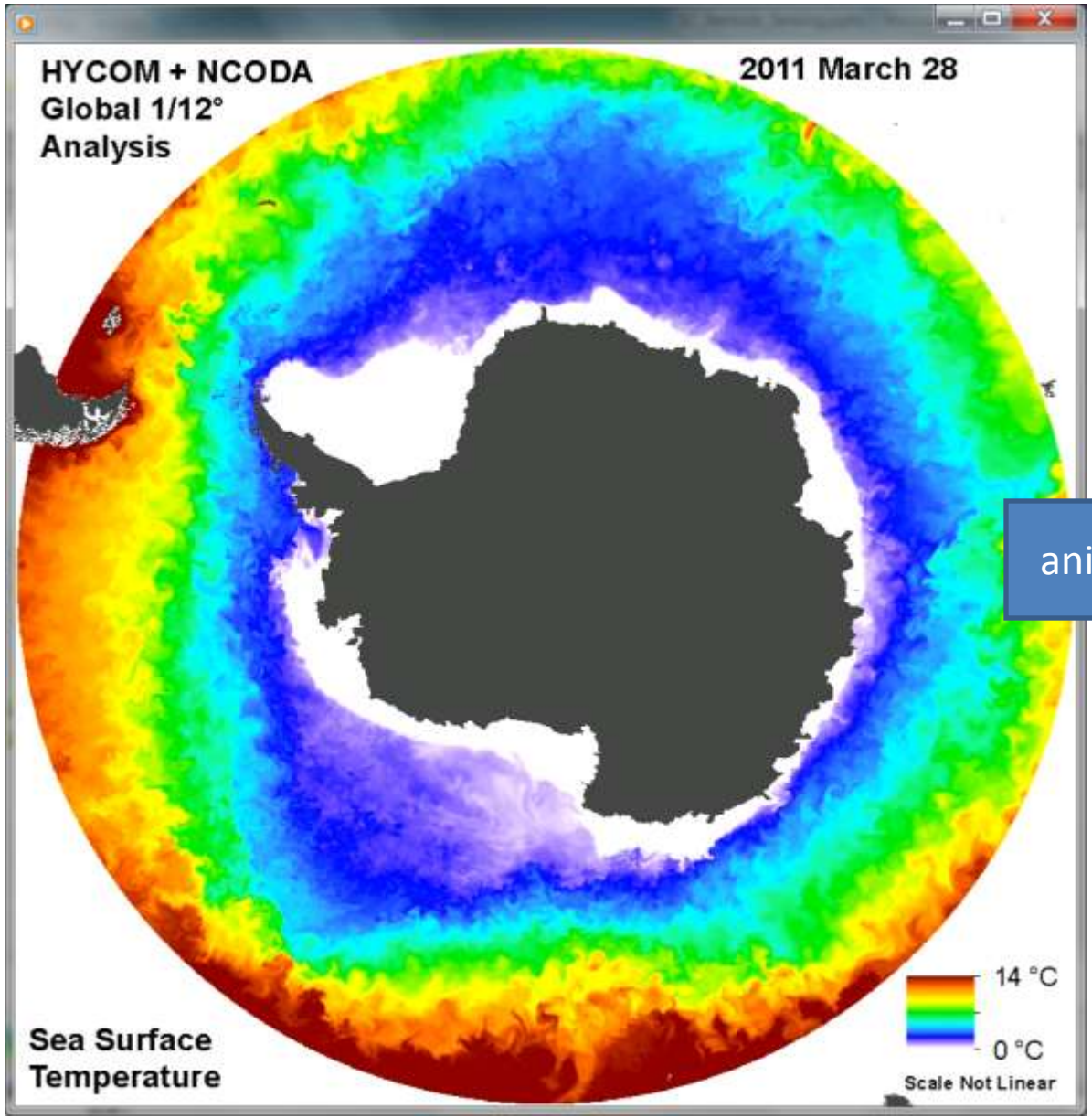
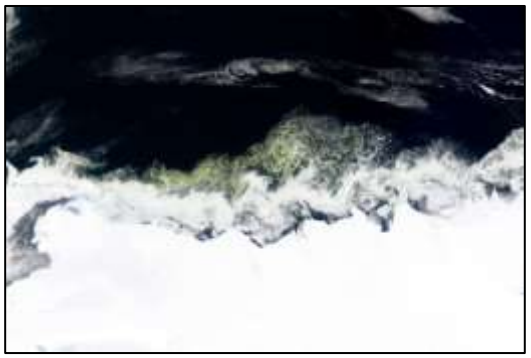


animation

HYCOM SST data (2011-03-21 to 2012-03-21) from the HYCOM +NCODA Global 1/12 Degree Analysis (http://hycom.org/dataserver/glb-analysis/expt-90pt9)

Outline:



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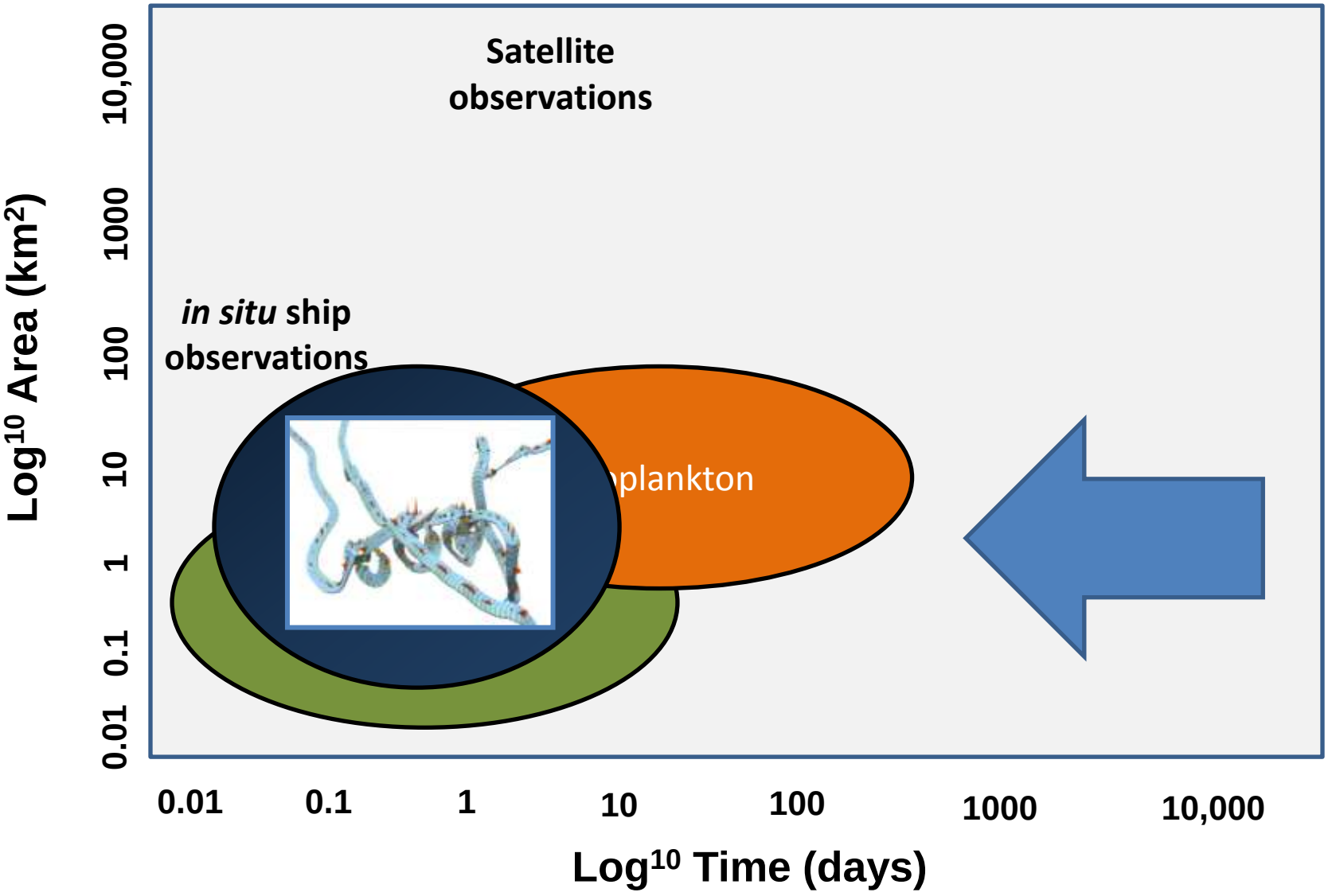
Southern Ocean: Scales of Remote Sensing



Modified after: Esaias, Wayne E., 1981: Remote Sensing in Biological Oceanography. Oceanus, Vol. 24, Number 3, 32-38.

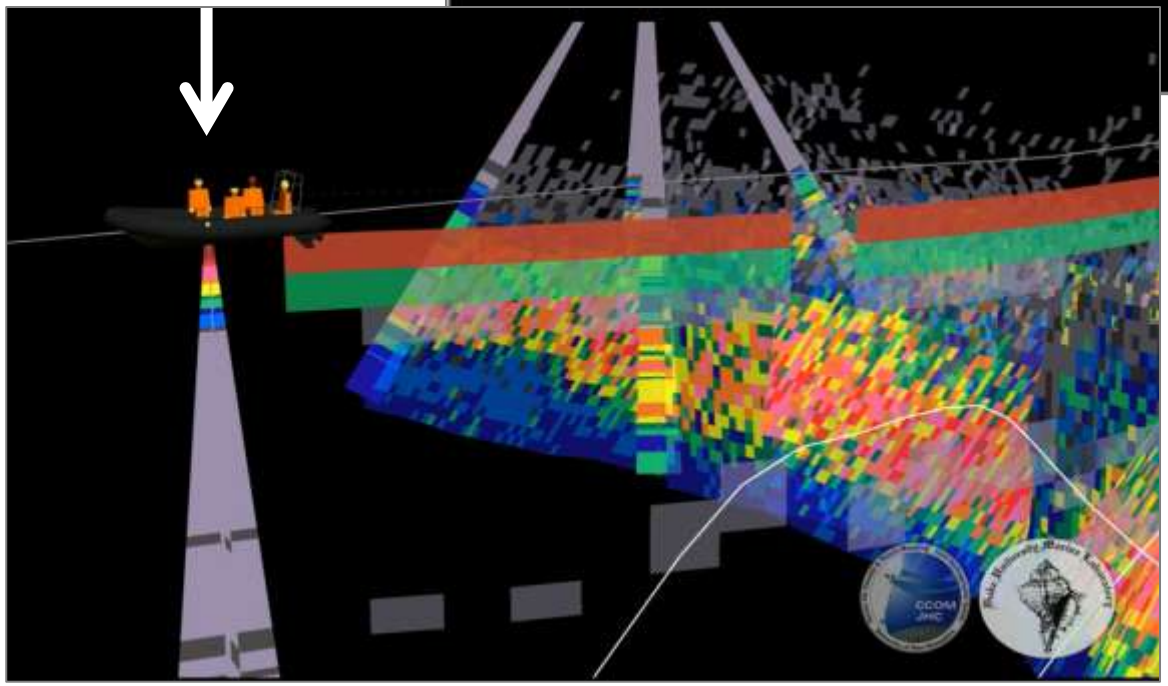
Duke University lead 2 recent expeditions to Antarctica

Duke Scientists
Nowacek
Friedlaender
Halpin
Read
Johnston

2009 April – June Field Season (RV L.M. Gould)
2010 May – June Field Season (RV NB Palmer)

ship active acoustics
ADCP / EK60

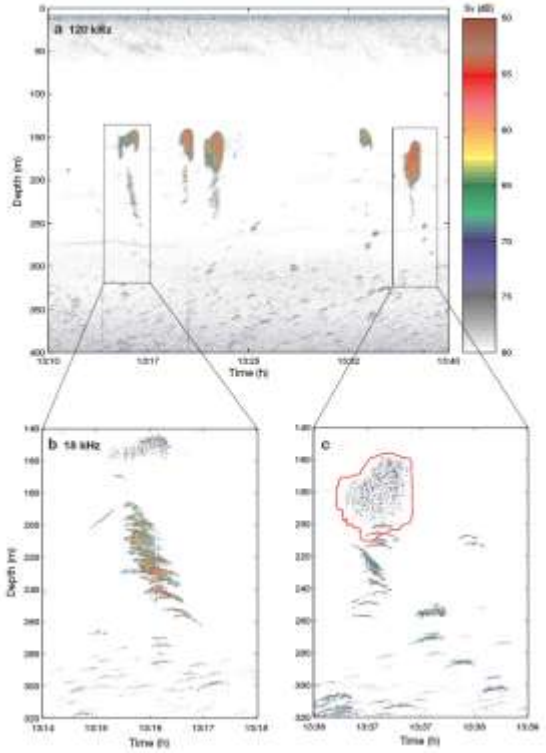
RHIB boat
active acoustics
EK60



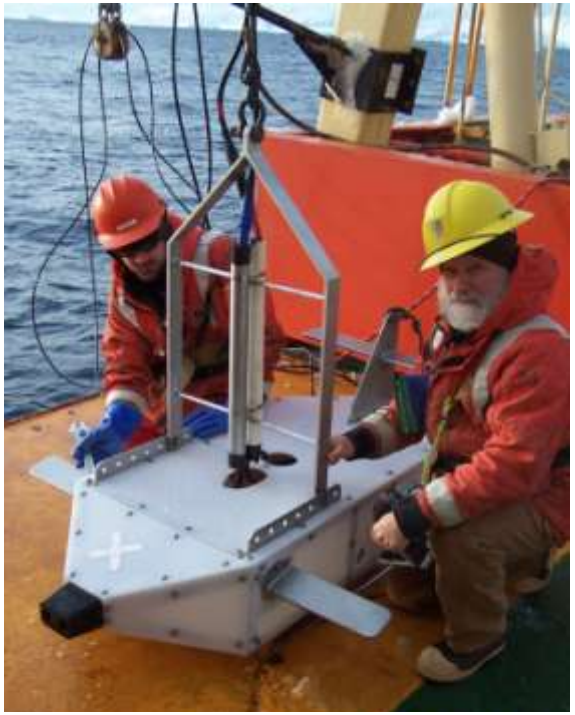
Active acoustics: to measure the krill

(1) ship

(2) RHIB boat

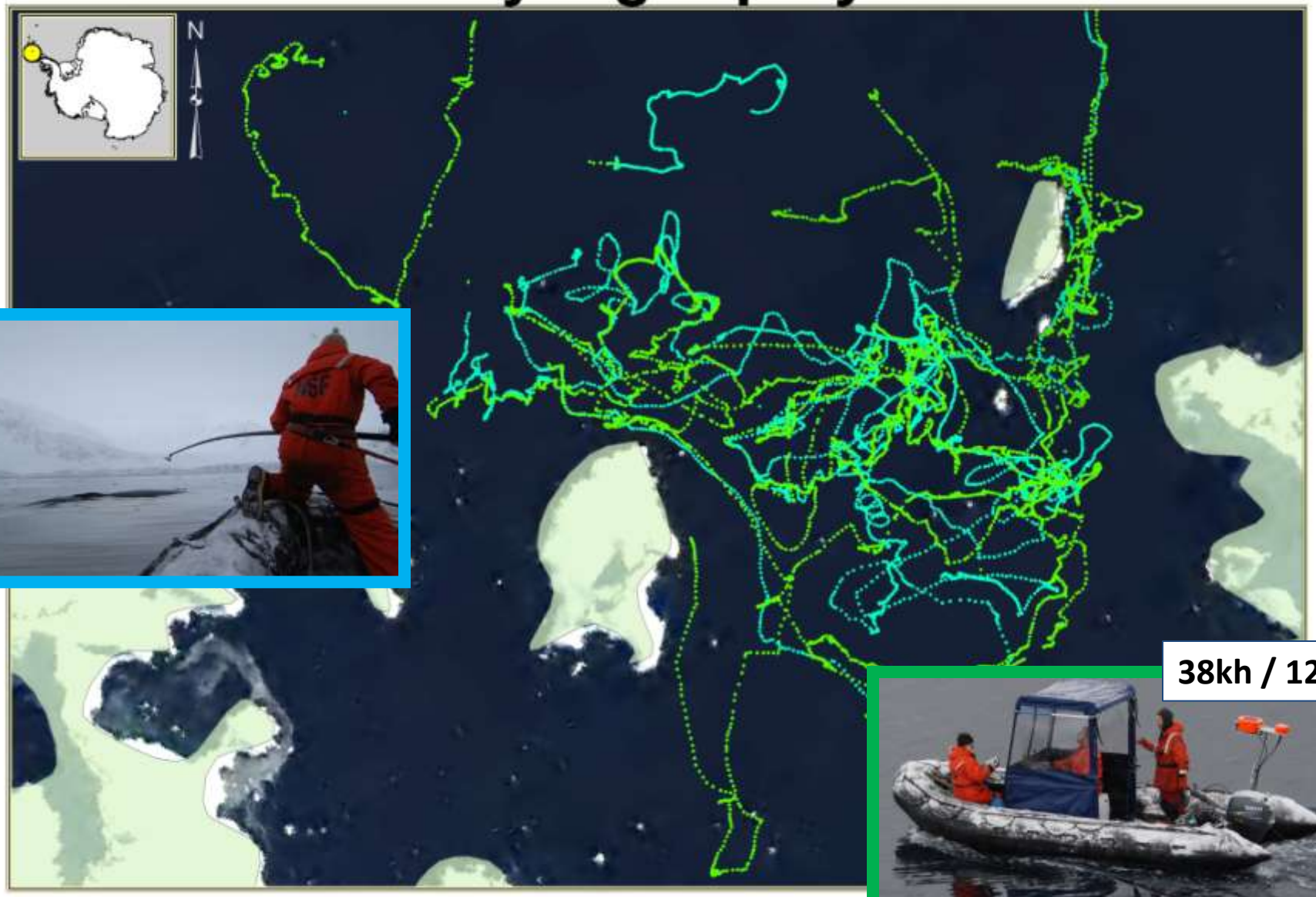


(3) towed “fish”



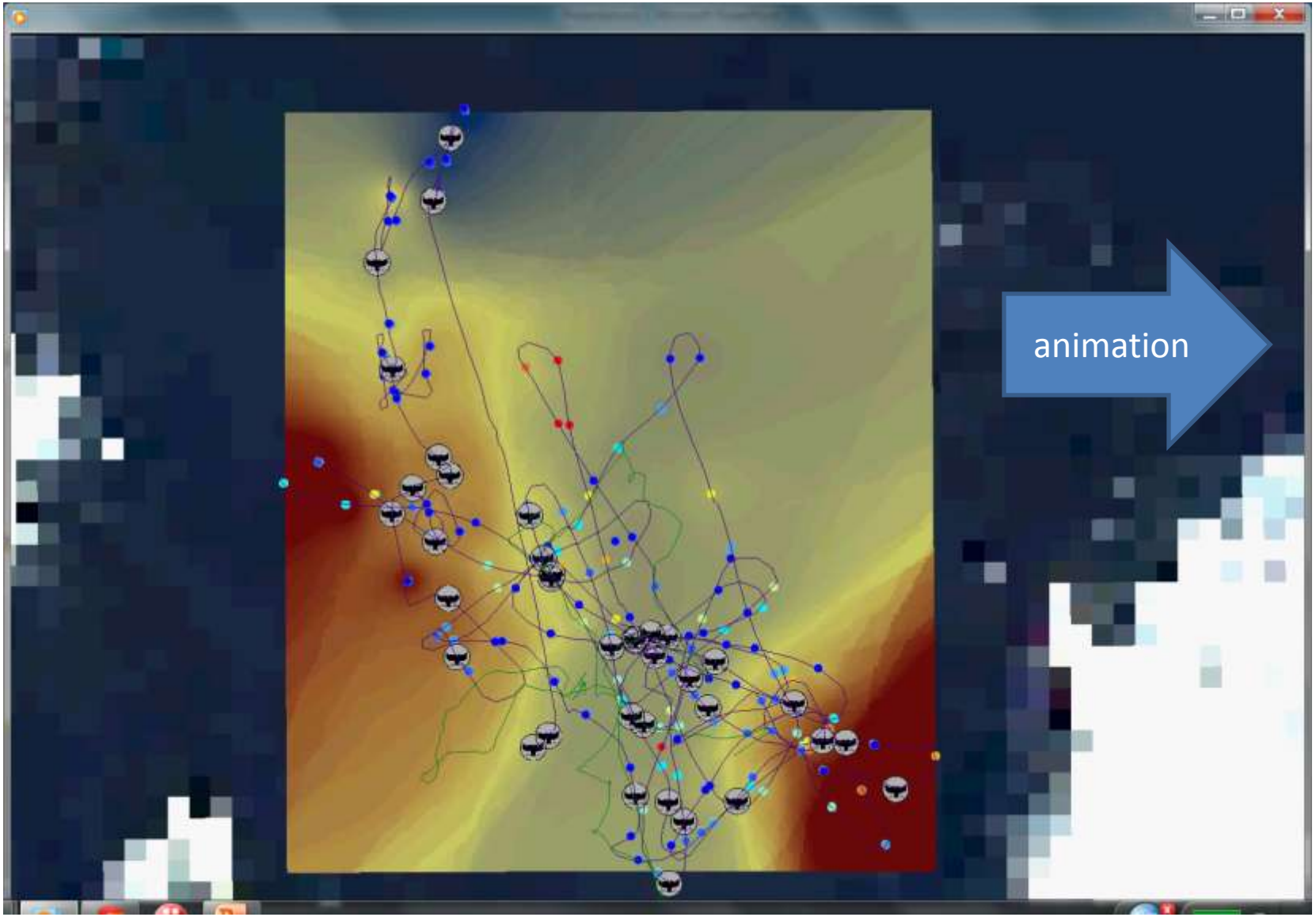
EK60 active acoustics prey mapping RHIB Boat…

Wilhelmina Bay tag & prey boat tracks

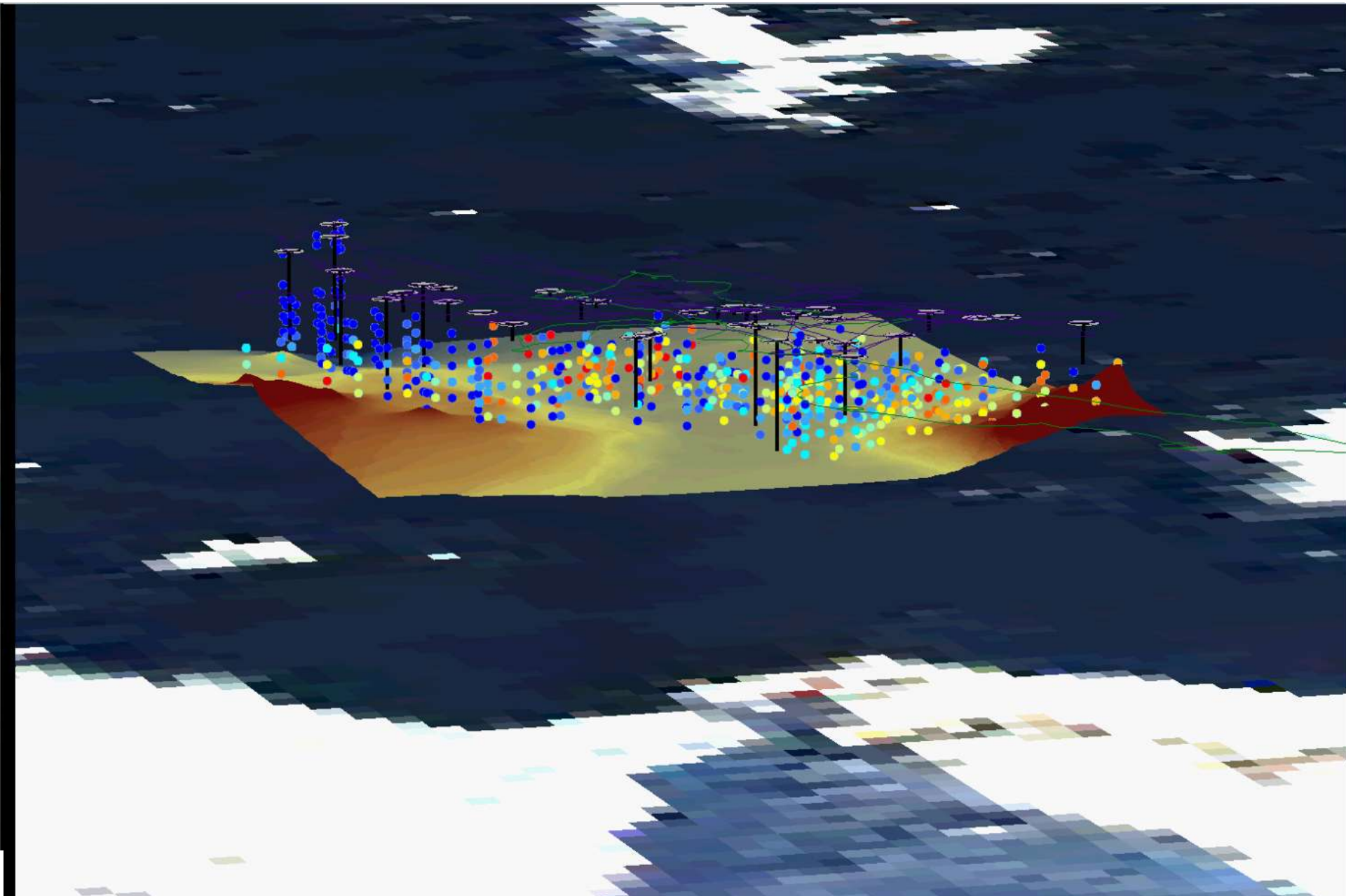


38kh / 120kh

Fine-scale prey mapping in 3D



Fine-scale prey mapping in 3D



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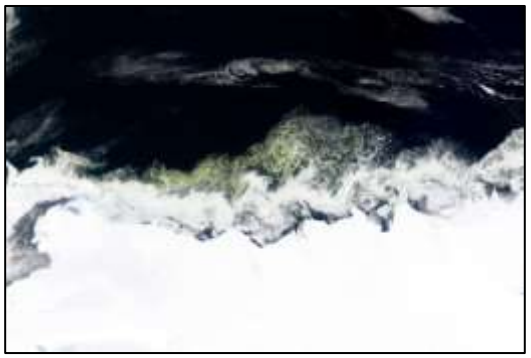
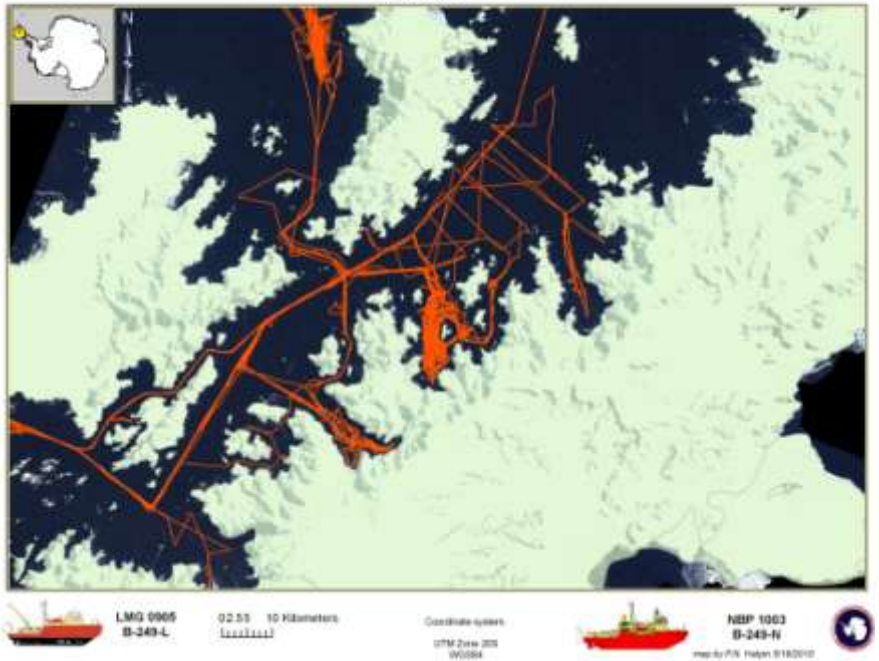


- Problem
- Scales of Remote Sensing
- Space / Time context
- Southern Ocean Scale Remote Sensing
  - SST
  - Ocean Color / Productivity
  - Ice
  - SSH
  - Oceanographic Features
  - Assimilating Oceanographic Models: HYCOM
- **In-situ Scale Remote Sensing**
  - **Active sonar prey mapping**
  - **Ship-born ice image analysis**
- Review / Discussion

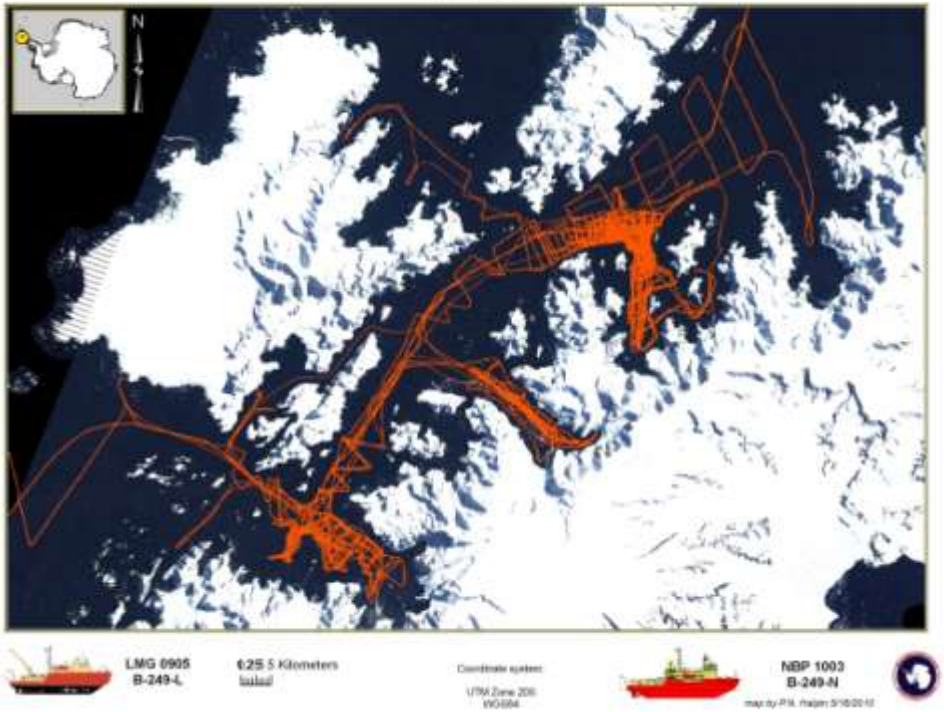
2009



Two late-season survey years:

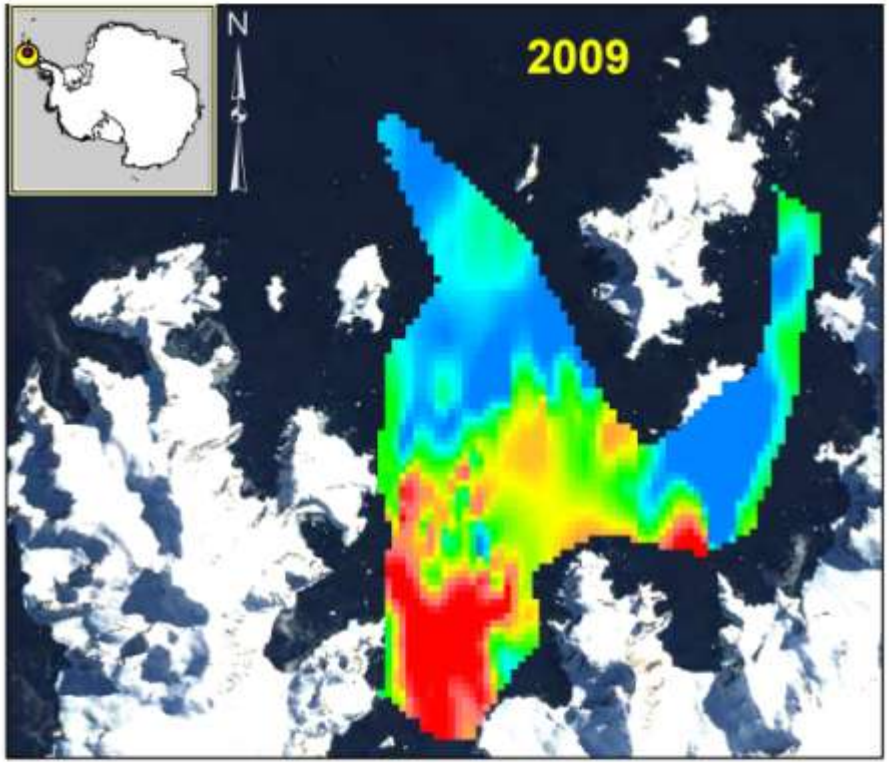
Significant differences in surface ice cover

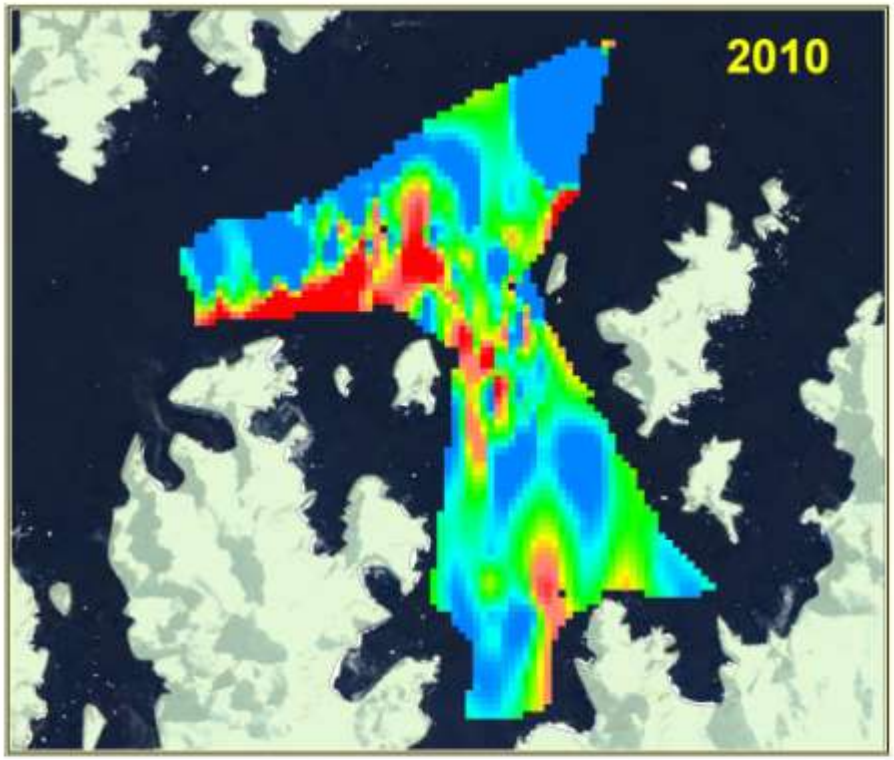
2010



Humpback whale sitings Wihelmina Bay
May 1-2, 2009 vs. May 12-14, 2010

Biomass density estimates from ADCP Backscatter





Coordinate system:

UTM Zone 20S
WGS84

LMG 0905
B-249-L

0 3.75 7.5 15 Kilometers

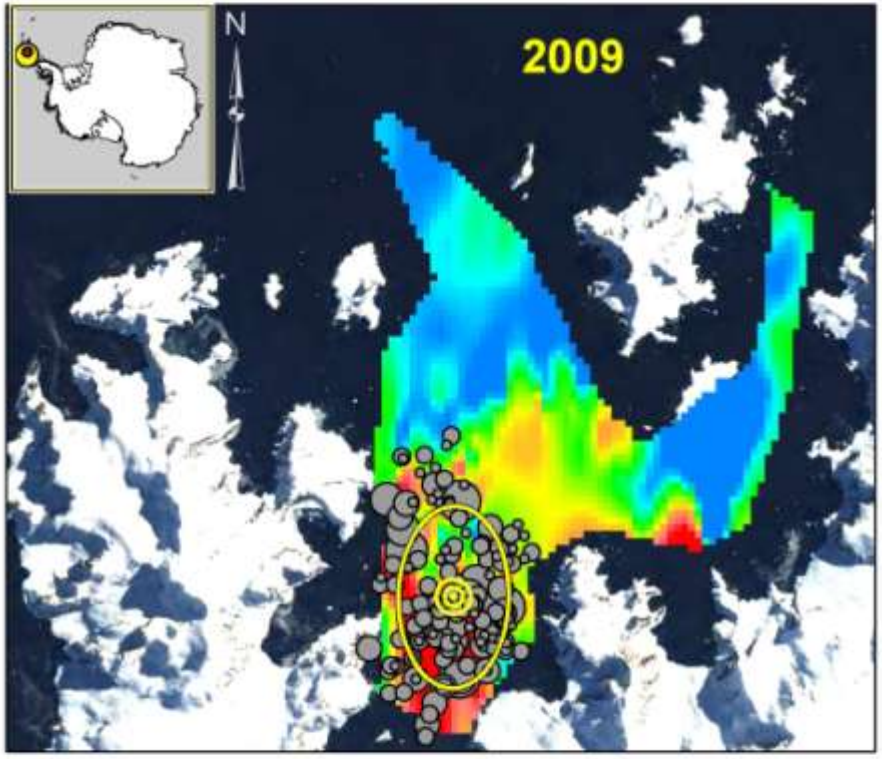
NBP 1003
B-249-N

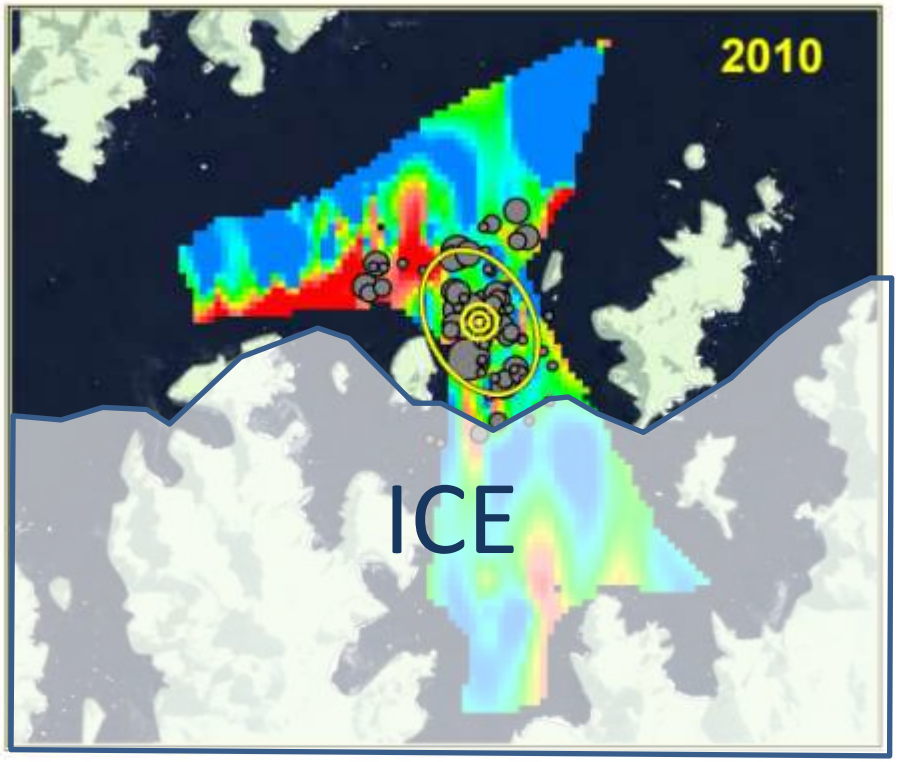
map by P.N. Halpin 5/16/2010

Humpback whale sitings Wihelmina Bay
May 1-2, 2009 vs. May 12-14, 2010

Humpback group size

Biomass density estimates from ADCP Backscatter





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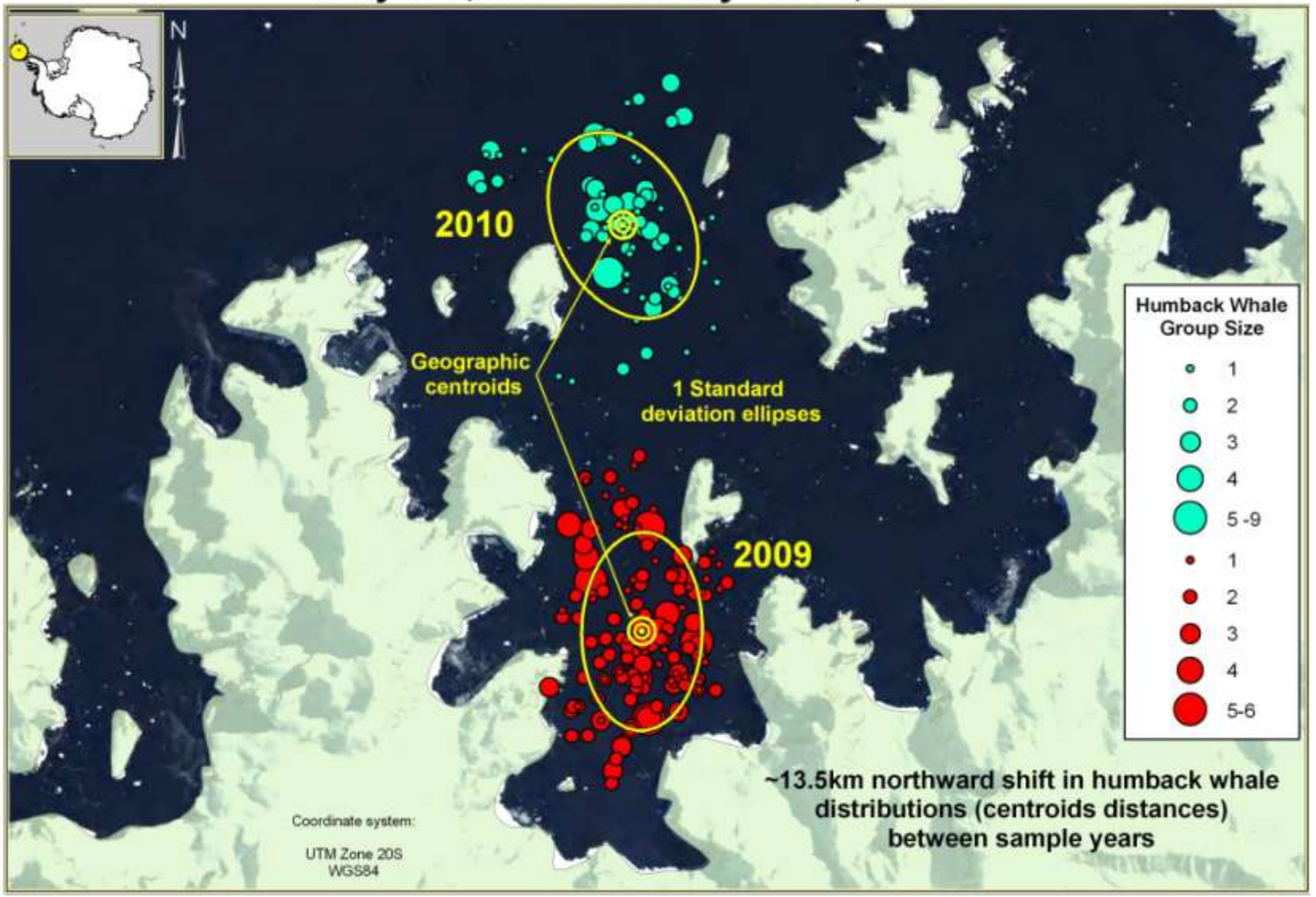


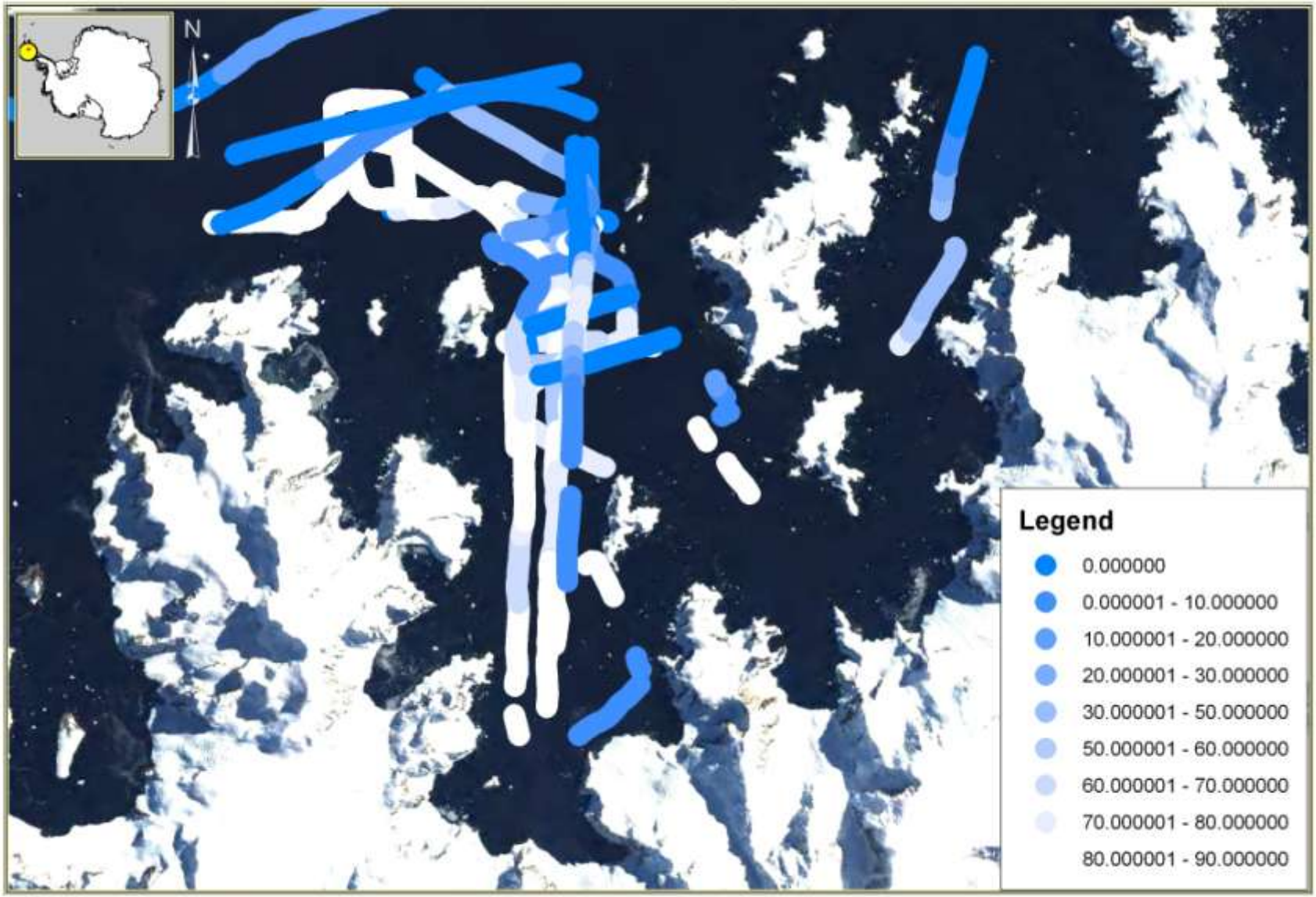
LMG 0905
B-249-L

0 3.5 7 14 Kilometers

NBP 1003
B-249-N

map by P.N. Halpin 5/16/2010

2010 Visual Surveys: Percent Ice



LMG 0905
B-249-L

0 187.5 375 750 Kilometers

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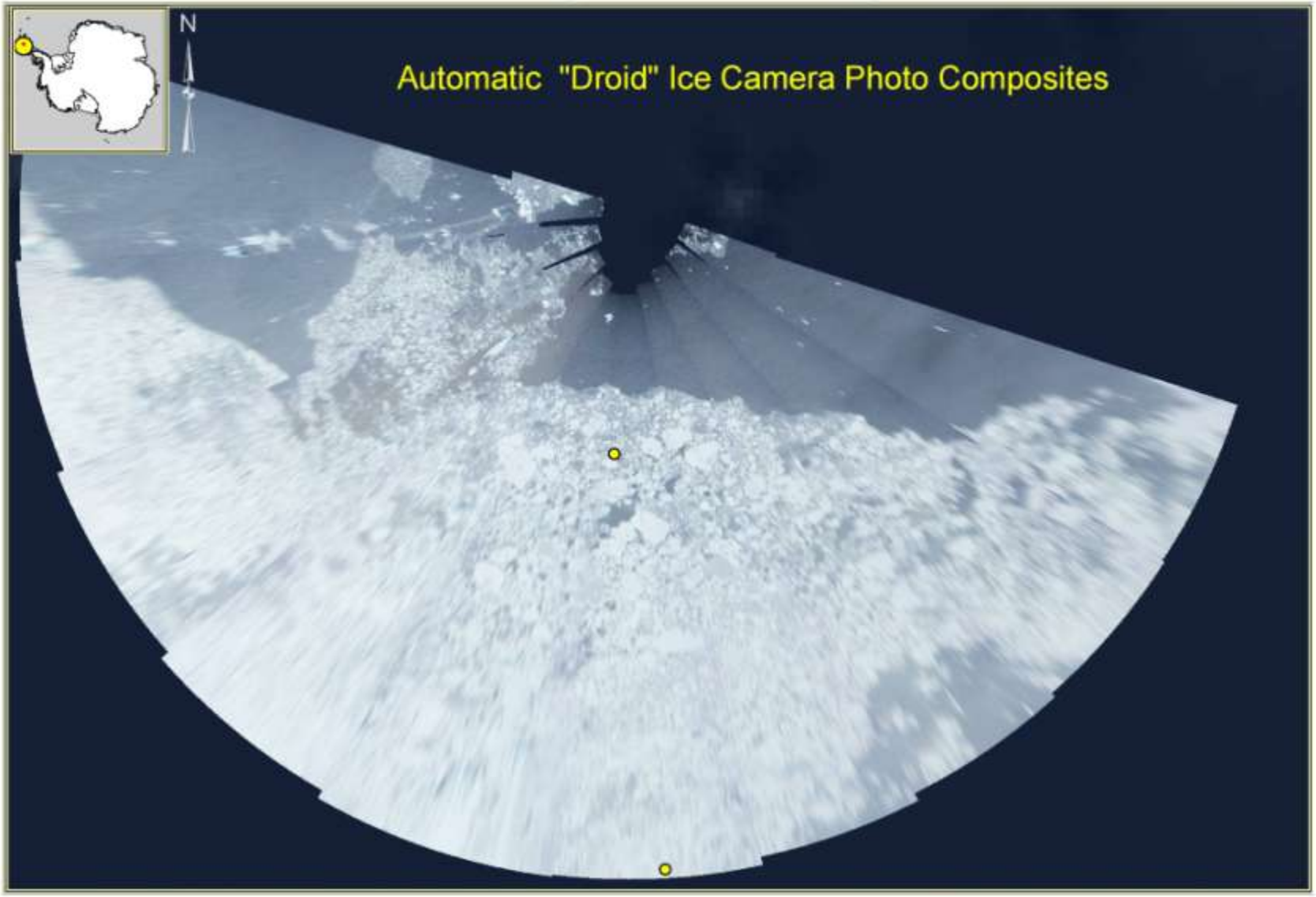
NBP 1003
B-249-N

map by P.N. Halpin 2010

2010 Ice Analysis

Roland Arsenault
University of New Hampshire

Wilhelmina Bay Ice Analysis 2010



LMG 0905
B-249-L

0 0.03 0.06 0.12 Kilometers

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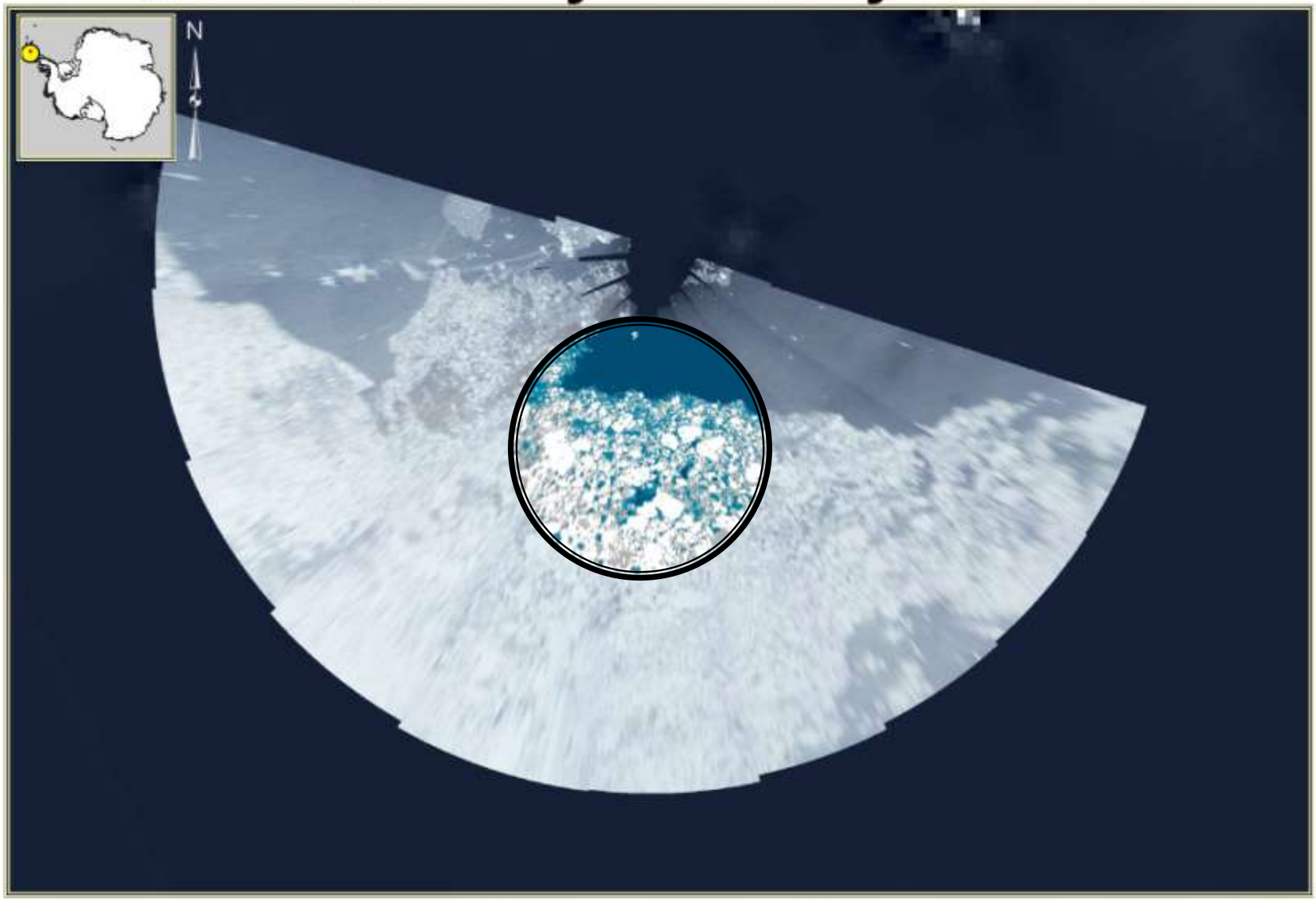
UTM Zone 20S
WGS84

NBP 1003
B-249-N

map by P.N. Halpin 5/16/2010

Wilhelmina Bay Ice Analysis 2010



LMG 0905
B-249-L

0 0.2 0.4 0.8 Kilometers

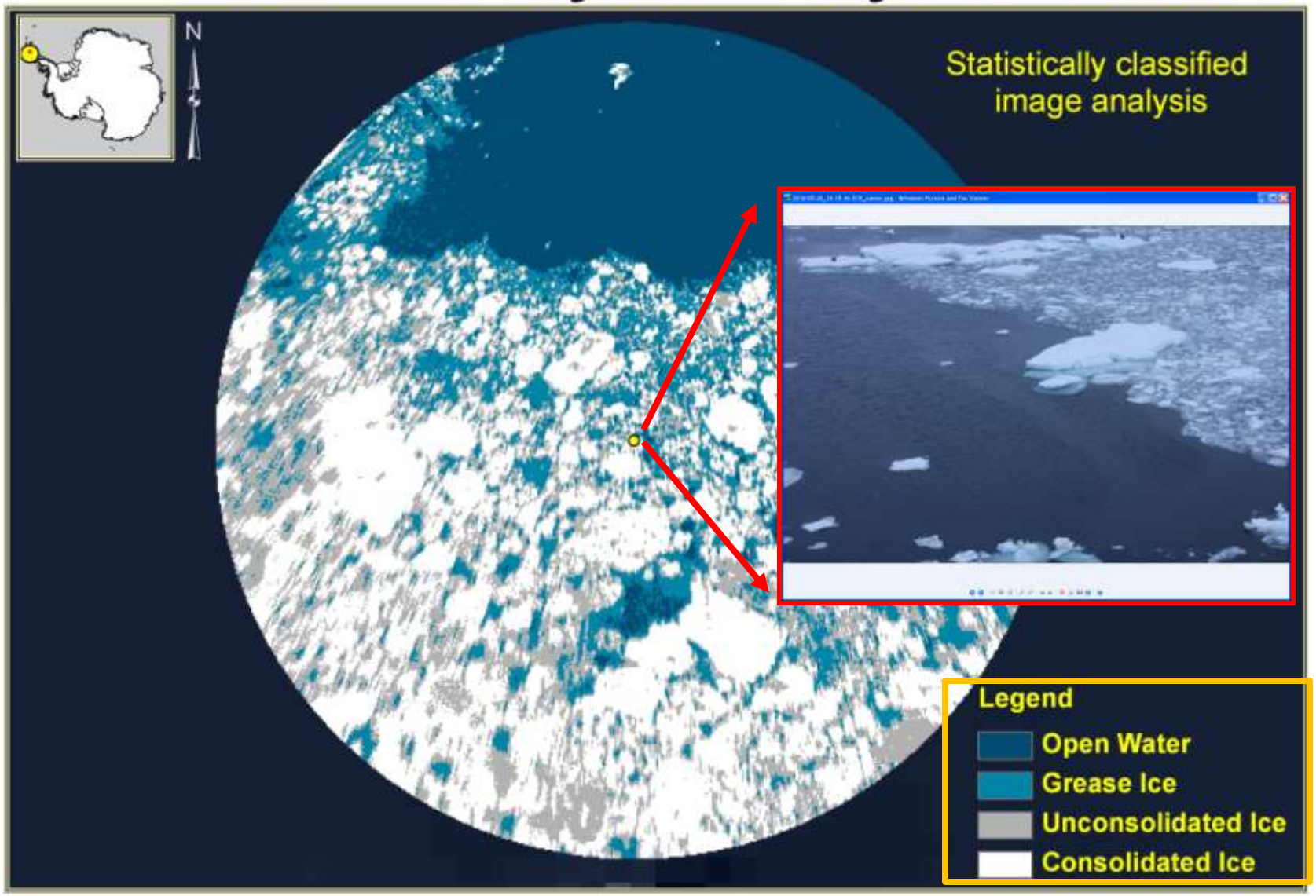
Coordinate system:

UTM Zone 20S
WGS84

NBP 1003
B-249-N

map by P.N. Halpin 5/16/2010

Wilhelmina Bay Ice Analysis 2010



LMG 0905
B-249-L

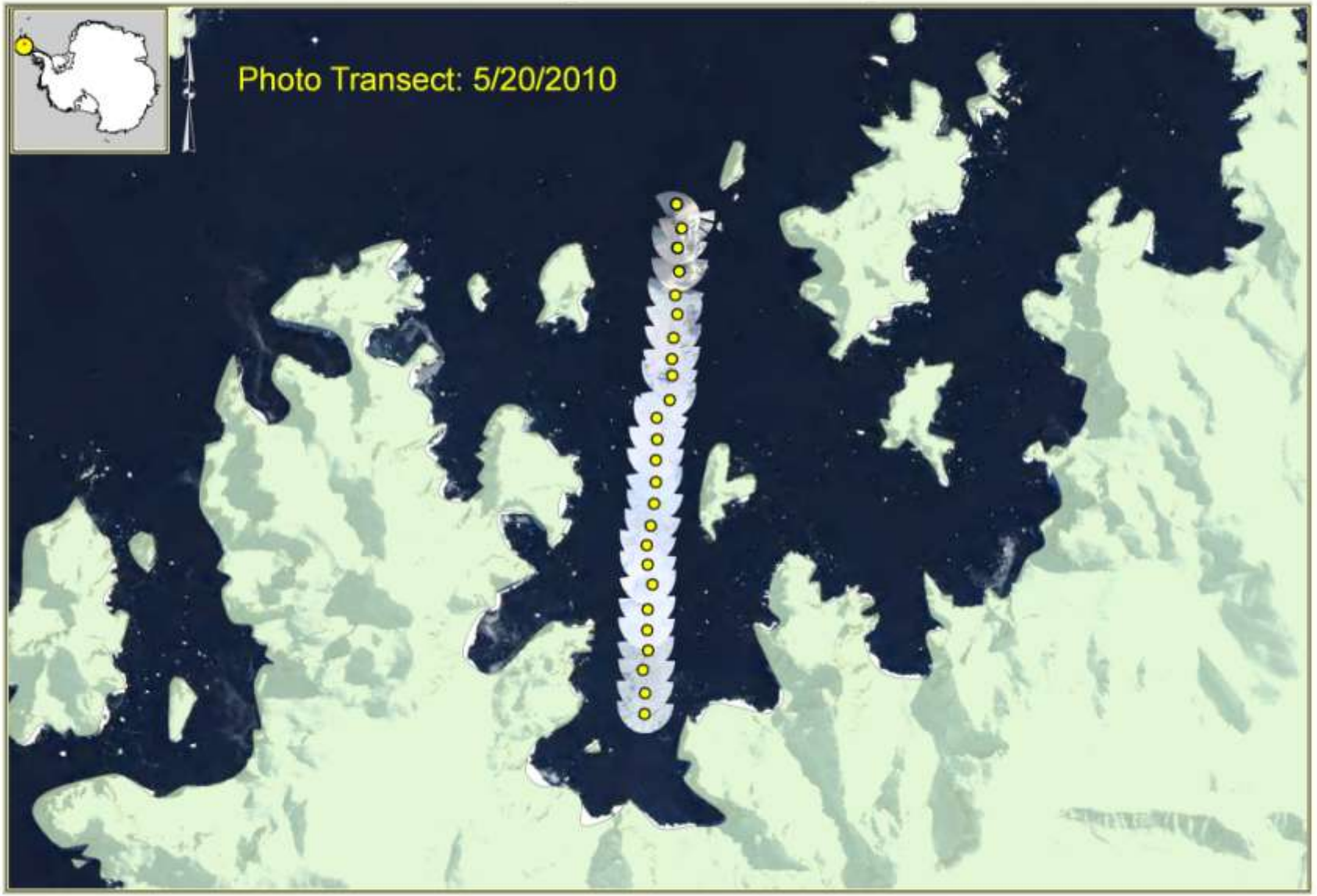
0 0.01 0.02 0.04 Kilometers

Coordinate system:
UTM Zone 20S
WGS84

NBP 1003
B-249-N

map by P.N. Halpin 5/16/2010

Wilhelmina Bay Ice Analysis 2010



LMG 0905
B-249-L

0 0.5 1 2 Kilometers

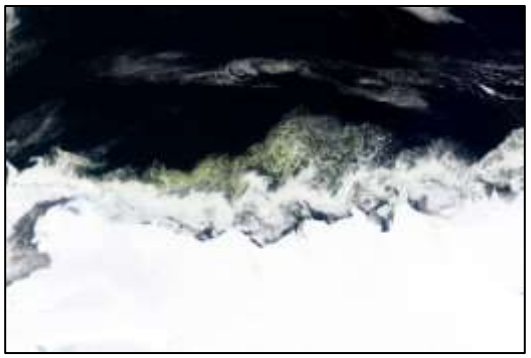
Coordinate system:

UTM Zone 20S
WGS84

NBP 1003
B-249-N

map by P.N. Halpin 5/16/2010

Outline:



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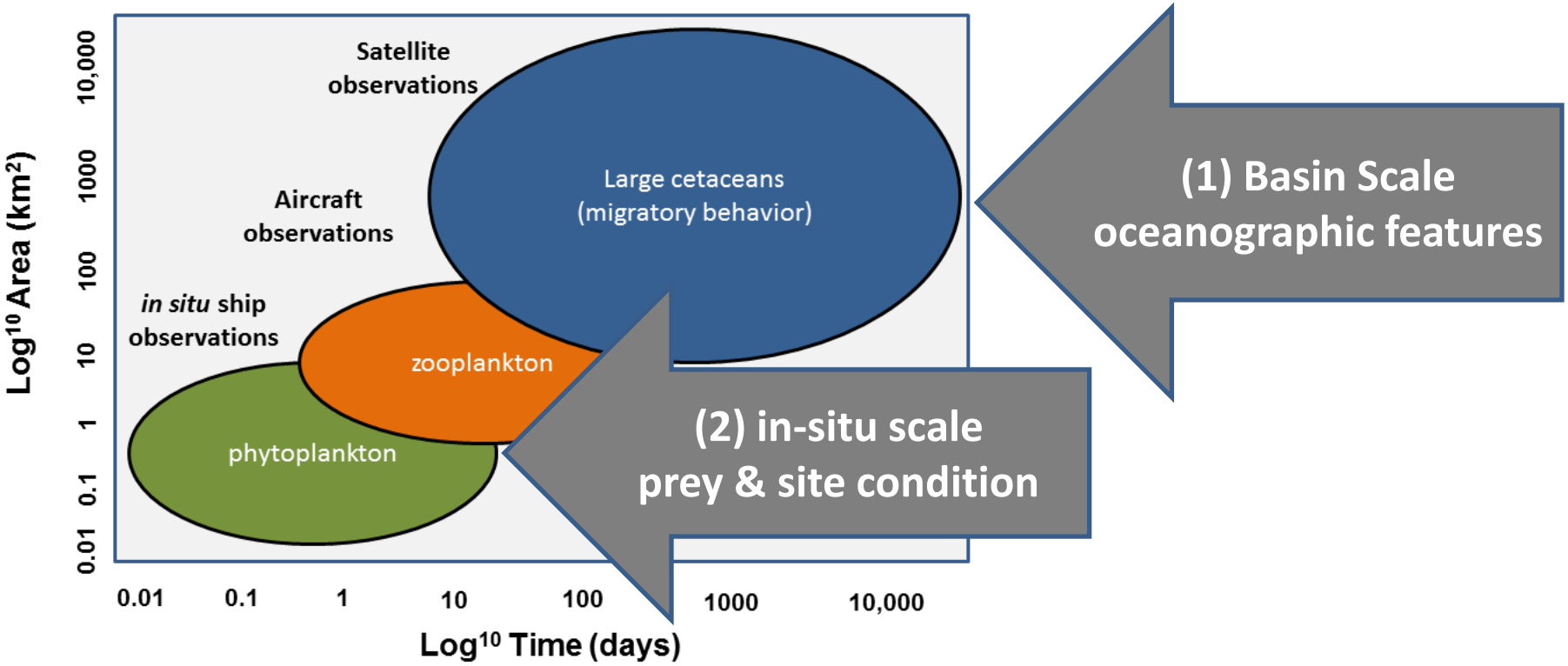
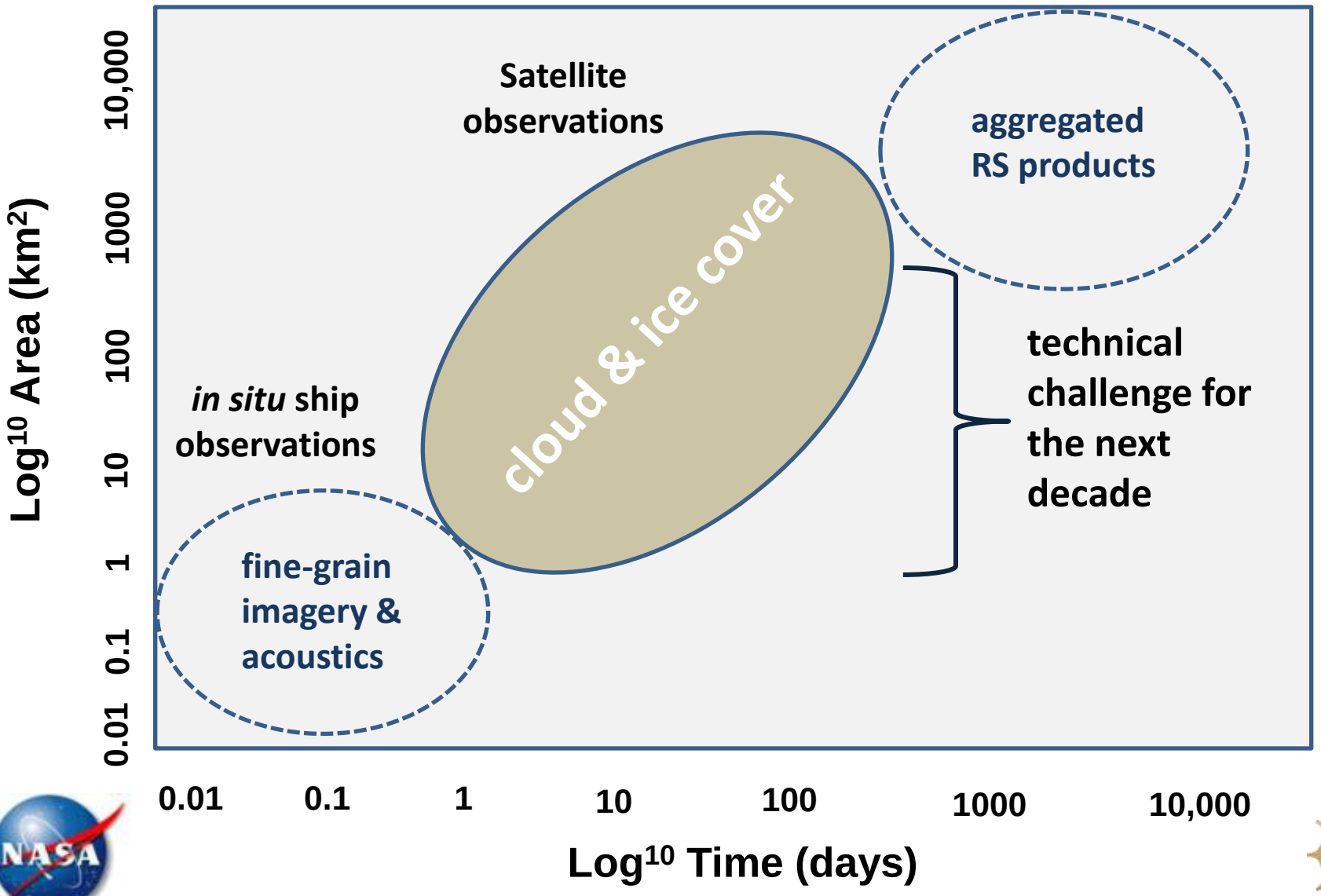
Conclusions

New innovations in remote sensing are being developed at two distinct scales:



Conclusions



Duke UNIVERSITY

Antarctica