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

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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

Southern Ocean: Scales of Remote Sensing

Southern Ocean: Scales of Remote Sensing

Log\(^{10}\) Time (days)

Log\(^{10}\) Area (km\(^2\))

Satellite observations

in situ ship observations

zoo plankton

phytoplankton

Regional scale Between ocean-basin scale remote sensing & in-situ observations

Southern Ocean: Scales of Remote Sensing

- **Satellite observations**
- **cloud & ice cover**
- **in situ ship observations**
- **aggregated RS products**

**Axes:**
- **Log\(^{10}\) Time (days)**
- **Log\(^{10}\) Area (km\(^2\))**

**Legend:**
- Aggregate over time
- Aggregate over space
Aggregation of Remote Sensing images

Development of annual or monthly 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
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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\textsubscript{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

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

AMSR-E
Antarctic ice concentration 6.25 km

The AMSR-E Sensor stopped responding in October 2011

Seasonal (91 day) Mean Sea Ice
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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

Step 2: Spatial cohesion test

Strong cohesion → front present
Weak cohesion → no front

~120 km

Mexico

Optimal break 27.0 °C
Bimodal

Frequency
Temperature

ArcGIS model

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
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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)
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Southern Ocean: Scales of Remote Sensing

Log$_{10}$ Time (days)

Log$_{10}$ Area (km$^2$)

Satellite observations

in situ ship observations

Phytoplankton

Zooplankton

Duke University lead 2 recent expeditions to Antarctica

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...
Fine-scale prey mapping in 3D
Fine-scale prey mapping in 3D
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Two late-season survey years:

Significant differences in surface ice cover
Humpback whale sightings 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 sightings Wihelmina Bay
May 1-2, 2009 vs. May 12-14, 2010

Humpback group size
Biomass density estimates from ADCP Backscatter

Coordinate system:
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map by P.N. Halpin 5/16/2010
Humpback whale sitings Wihelmina Bay
May 1-2, 2009 vs. May 12-14, 2010

~13.5km northward shift in humpback whale distributions (centroids distances) between sample years
2010 Visual Surveys: Percent Ice

Legend
- 0.000000
- 0.000001 - 10.000000
- 10.000001 - 20.000000
- 20.000001 - 30.000000
- 30.000001 - 50.000000
- 50.000001 - 60.000000
- 60.000001 - 70.000000
- 70.000001 - 80.000000
- 80.000001 - 90.000000

LMG 0905
B-249-L
008728
5 Kilometers

NBP 1003
B-249-N
map by P.N. Halpin 2010

Coordinate system:
UTM Zone 20S
WGS84
2010 Ice Analysis

Roland Arsenault
University of New Hampshire
Wilhelmina Bay Ice Analysis 2010

Automatic "Droid" Ice Camera Photo Composites
Wilhelmina Bay Ice Analysis 2010

Legend
- Open Water
- Grease Ice
- Unconsolidated Ice
- Consolidated Ice

Statistically classified image analysis

Coordinate system:
- UTM Zone 20S
- WGS84

map by P.N. Halpin 5/16/2010
Wilhelmina Bay Ice Analysis 2010

Photo Transect: 5/20/2010

LMG 0905
B-249-L
00.51 2 Kilometers

Coordinate system:
UTM Zone 20S
WGS84

NBP 1003
B-249-N
map by P.N. Halpin 5/16/2010
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Conclusions

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

1. Basin Scale Oceanographic features
2. In-situ scale prey & site condition
Conclusions

Satellite observations

aggregated RS products

technical challenge for the next decade

cloud & ice cover

in situ ship observations

fine-grain imagery & acoustics

Log^{10} Area (km^2)

Log^{10} Time (days)
Antarctica

Pat Halpin
Ari Friedlaender
Doug Nowacek
Reny Tyson
Dave Johnston
Lindsey Peavey
Elliot Hazen
Andy Read