ESTIMATION OF THIN ICE THICKNESS FROM AMSR-E FOR A COASTAL POLYNYA IN THE ARCTIC

R.K. Kamaljit Singh,
Sandip R. Oza, N.K. Vyas, Abhijit Sarkar
OSD/MOG/RESA, SAC ISRO

kamaljit.rajkumar@gmail.com

Presentation for 2nd Workshop on Remote Sensing and Modeling of Surface Properties, 9-11 June, 2009 , Toulouse, France

ESTIMATION OF THIN ICE THICKNESS

- INTRODUCTION
- OBJECTIVE
- DATA
- METHODOLOGY
    - ASSUMPTIONS
    - HEAT FLUX CALCULATIONS
    - THICKNESS ESTIMATION FROM AMSR-E
- RESULTS AND ERROR ANALYSIS
- CONCLUSION

INTRODUCTION

Polynyas are mesoscale non-linearly shaped regions of sea ice and open water

They occur in regions where climatologically sea ice is present

Polynyas play a critical role in maintaining the atmospheric heat and oceanic salt fluxes

Production of sea ice can be monitored effectively through the calculation of surface heat fluxes at the polynya

Coastal polynyas are sites of large amount of sea ice production and dense water formation

Combination of IR and microwave remote sensing techniques can be utilised for an accurate determination of thickness of thin ice

OBJECTIVE

To estimate thin ice thickness using AMSR-E brightness temperature data from the calculation of conductive heat flux through the ice surface using MODIS IST data

DATA

89 GHz AMSR-E L3 Brightness Temperature data for 7th March, 2008, which is at 6 KM resolution. The 89 GHz channel with its higher spatial resolution is found to be practically useful in the study of coastal polynyas

MODIS L3 Ice Surface Temperature Night-mode (MOD29P1N) for 7th March, 2008, which is at 1 KM spatial resolution

NCEP/NCAR RA 1 for atmospheric parameters used in flux calculations

METHODOLOGY

First, the projections of both the data, viz., the AMSR-E B.T. data (in EASE grid PS projection) and the MODIS IST data (in Lambert Azimuthal Equal Area projection) are brought to the same i.e., Geographic Lat/Lon projection, without changing their resolutions

Heat flux is calculated using the MODIS IST data and the corresponding *thermal thickness* is calculated from the conductive heat flux measurement derived from surface temperature retrieval assuming the thickness of ice to be uniform.

Several assumptions are made during the estimation.

METHODOLOGY

A) ASSUMPTIONS

1. Linear temperature profile through the ice
2. **Uniform ice thickness for a given grid cell**
3. Thermal equilibrium with a constant sea water temperature of 271.2K
4. **Conductive heat flux through the ice equals the heat flux coming from the atmosphere at the ice-atmosphere interface**

METHODOLOGY

B) HEAT FLUX CALCULATIONS

Following Martin et al. (2003):

Net flux (from the atm)=outgoing longwave(OLR)+incoming longwave(ILR)+latent heat(LH)+sensible heat(SH) …(1)

Following Yu and Rothrock (1996) and Ohshima et al.(2003) & Nihashi and Ohshima (2001):

$OLR=\varepsilon\sigma(Ts)^4$ …(2)

$ILR=\varepsilon^*\sigma(Ta)^4$ …(3)

$LH=\rho\ L\ Ce\ U\ (qa - qs)$ …(4)

$SH=\rho\ cp\ Cs\ U\ (Ta - Ts)$ …(5)

Surface temp comes from MODIS

METHODOLOGY

B) HEAT FLUX CALCULATIONS…

qa = (e f es(Ta))/p …(6), e=0.622, f=90%

qs = (e es(Ts))/p …(7)

} Sp. humidity

es = $10^{(9.4051 - 2353.0/T)}$ …(8) (Fleagle-Businger Eqn.)

} Vap press

No incoming short-wave radiation.

Fi=ki * (Ts – Tf)/ht …(9) ki=2.034 W/m-K

Net heat flux = Fi (Energy balance at the interface) …(10)

Thermal thickness (1 km) ht is obtained from eqn. (10)

Net flux & IST at 1km are averaged to 6km to derive thickness at 6km resolution

METHODOLOGY

C) THICKNESS ESTIMATION FROM AMSR-E

Polarization Ratio is defined as

PR = (TBv-TBh)/(TBv+TBh) ...(11)

PR values for pixels located within the defined region of the polynya are selected for analysis

Corresponding to these pixels MODIS ***thermal thickness**** values are also noted

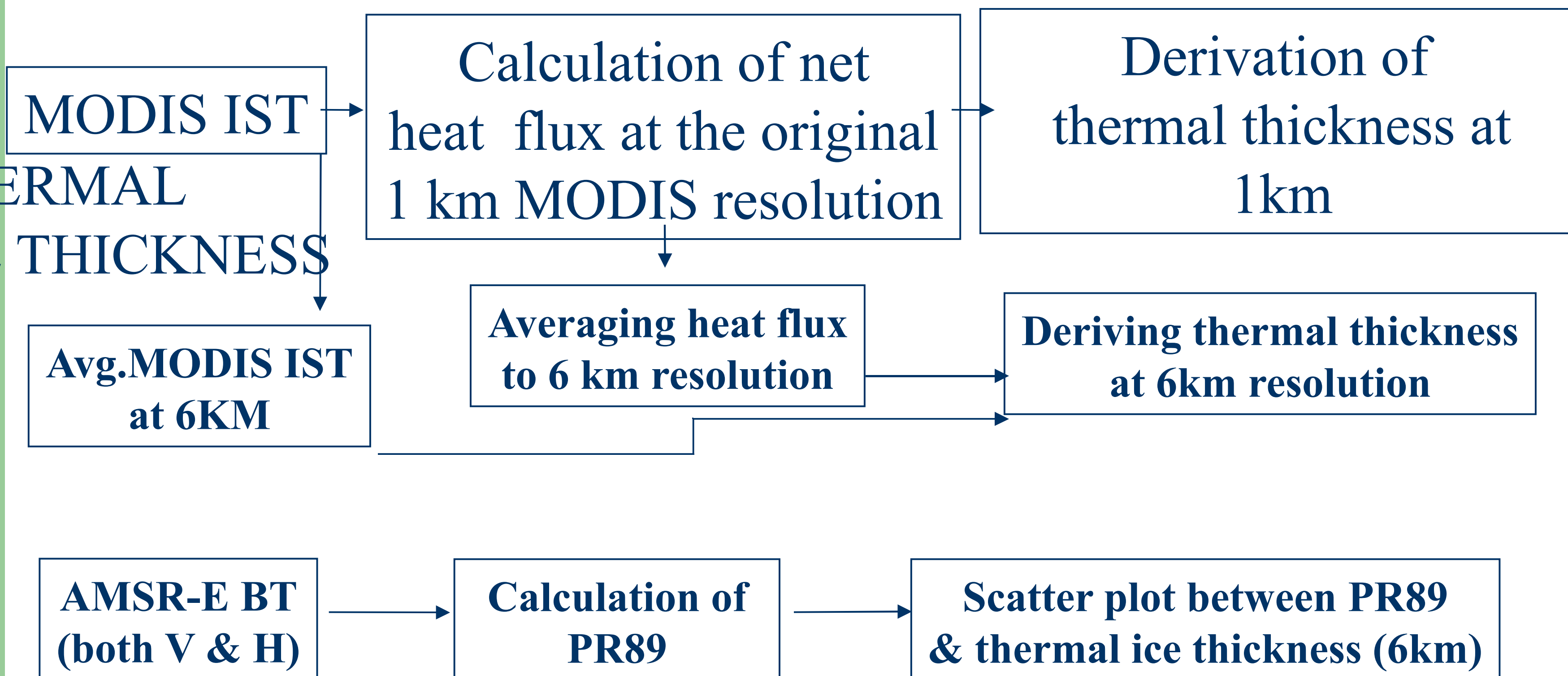
Scatter plot is plotted between the corresponding PR values and the ***thermal thickness****

**Thickness at 6km resolution*

METHODOLOGY

ALGORITHM FLOWCHART

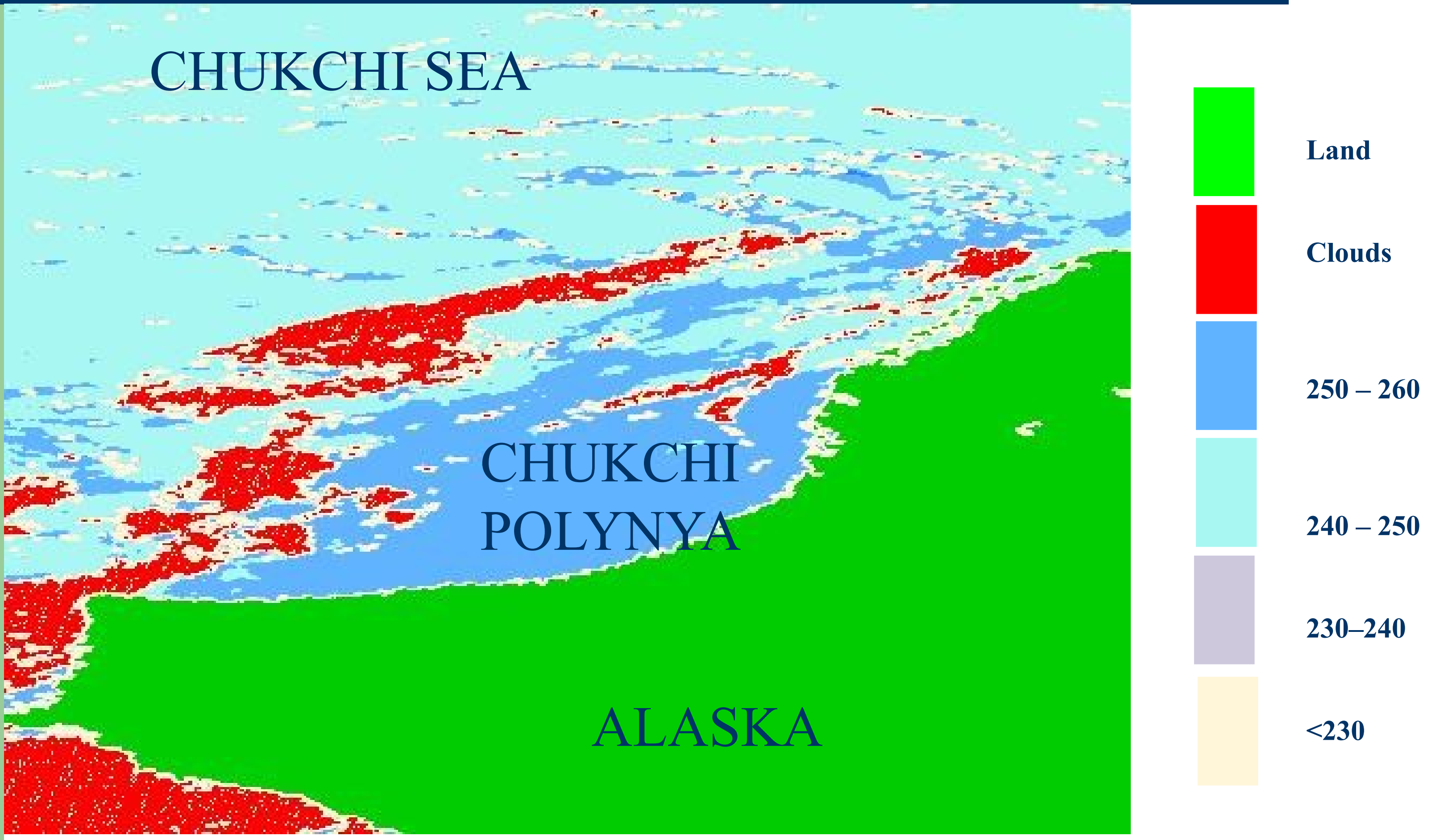
THERMAL ICE THICKNESS



AMSR-E THICKNESS

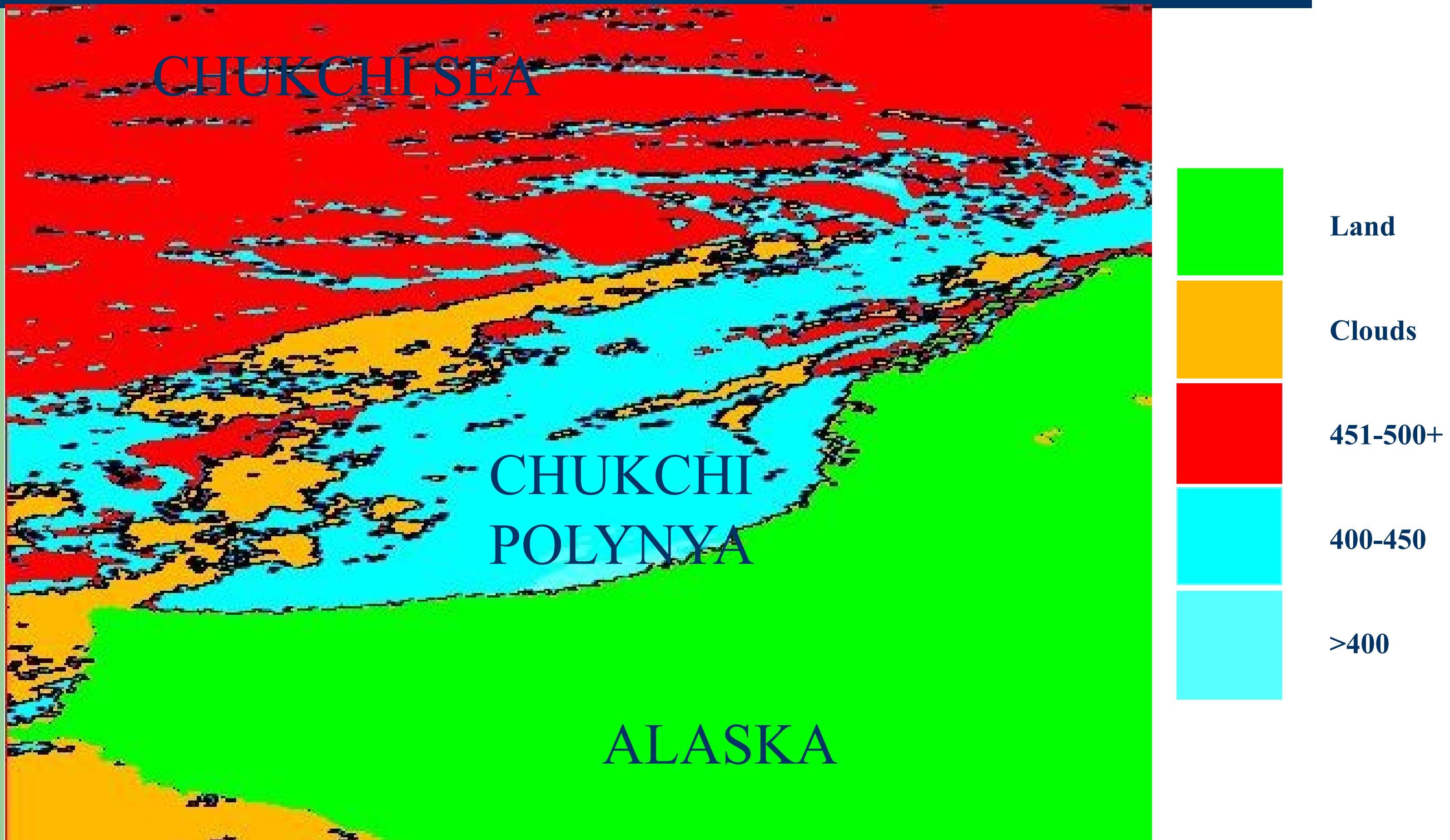
RESULTS AND ERROR ANALYSIS

MODIS IST (kelvins)



RESULTS AND ERROR ANALYSIS

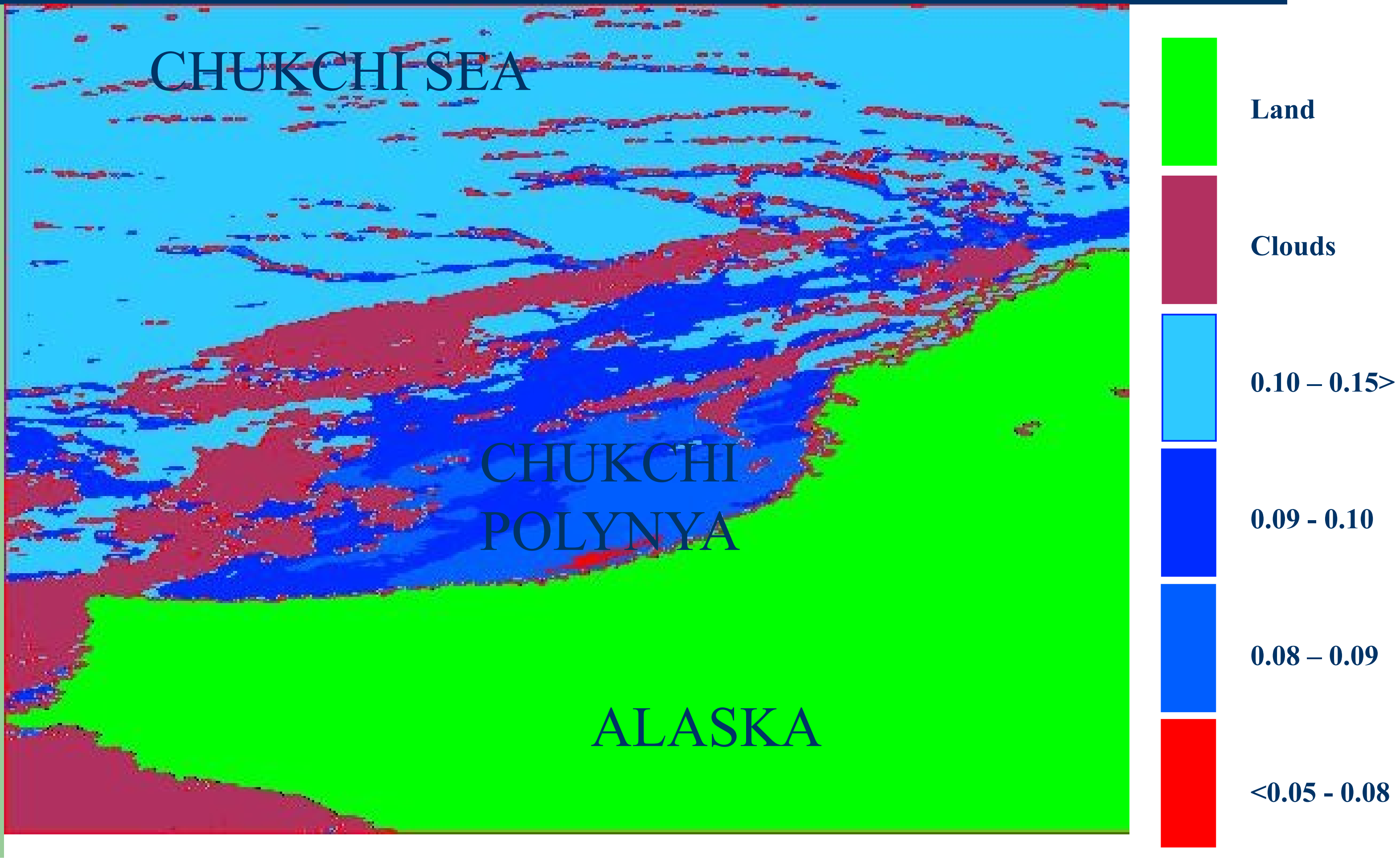
NET HEAT FLUX (W/sq.m.)



Thin ice thickness estimation: Kamaljit

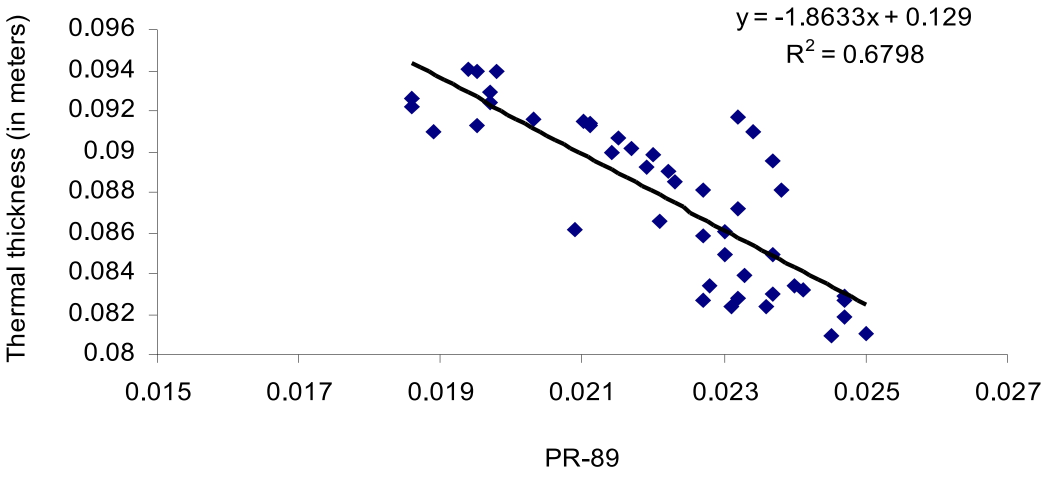
RESULTS AND ERROR ANALYSIS

THERMAL THICKNESS (m)



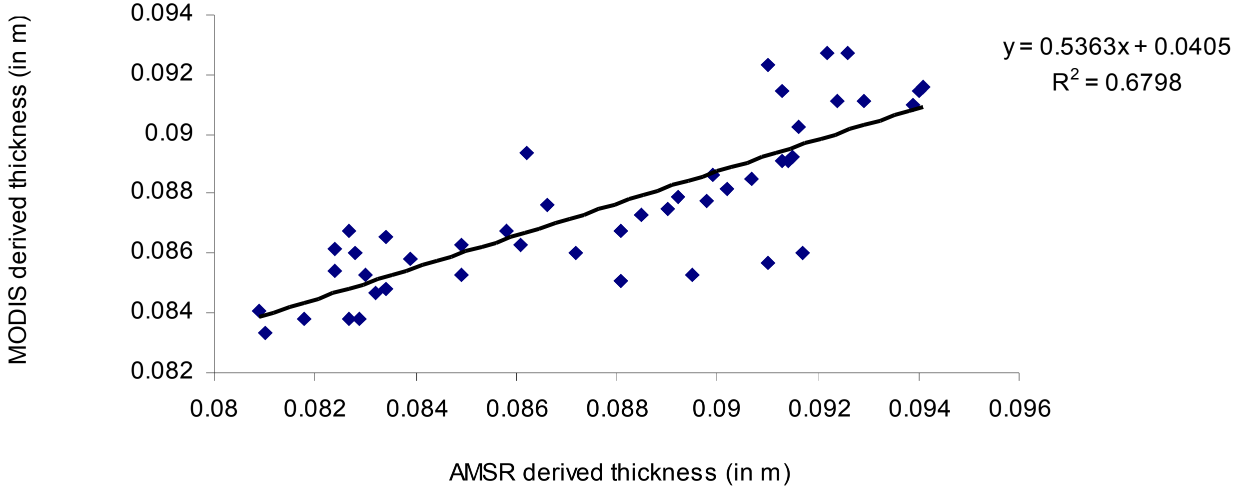
RESULTS AND ERROR ANALYSIS

MODIS THICKNESS VS PR-89



RESULTS AND ERROR ANALYSIS

MODIS THICKNESS VS AMSR-E THICKNESS



RESULTS AND ERROR ANALYSIS

ERROR ANALYSIS

PR	Obs_thickness(m)	Predicted_Thickness (m)	Error (%)	bias(b-c)
0.0186	0.0972	0.0928	4.571872	0.004444
0.0196	0.0908	0.0913	-0.53529	-0.00049
0.0207	0.0933	0.0897	3.891822	0.003631
0.0213	0.091	0.0888	2.432011	0.002213
0.0219	0.0915	0.0879	3.929169	0.003595
0.0224	0.0916	0.0872	4.836507	0.00443
0.0228	0.0921	0.0866	5.991618	0.005518
0.0232	0.0839	0.0860	-2.49545	-0.00209
0.0235	0.083	0.0856	-3.07548	-0.00255
0.0238	0.0831	0.0851	-2.42072	-0.00201
0.0245	0.0853	0.0841	1.427257	0.001217
0.025	0.0817	0.0833	-2.01652	-0.00165

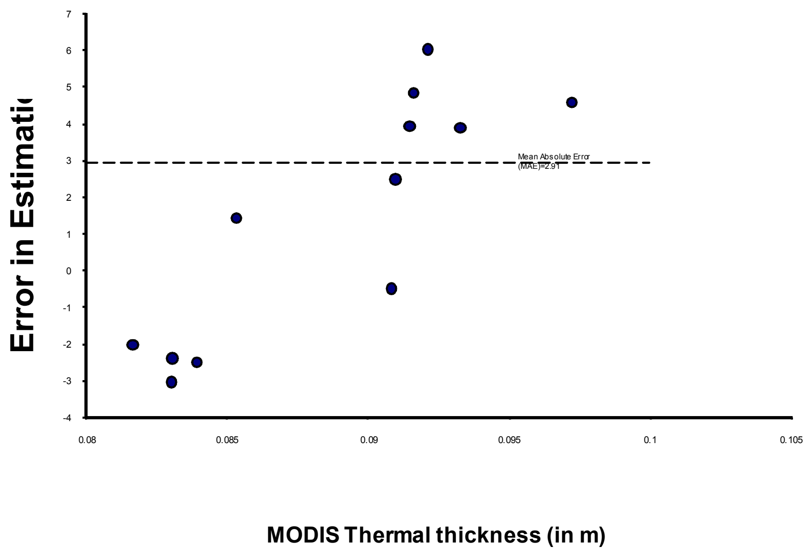
RESULTS AND ERROR ANALYSIS

ERROR ANALYSIS contd.

Error in the estimation of thickness is calculated and a mean absolute error of around 2.9% is obtained. An average difference (bias) of around 0.001m exists between the MODIS thickness and the AMSR-E thickness.

RESULTS AND ERROR ANALYSIS

ERROR ANALYSIS contd.



- Error in estimation of thickness increases with increasing thickness

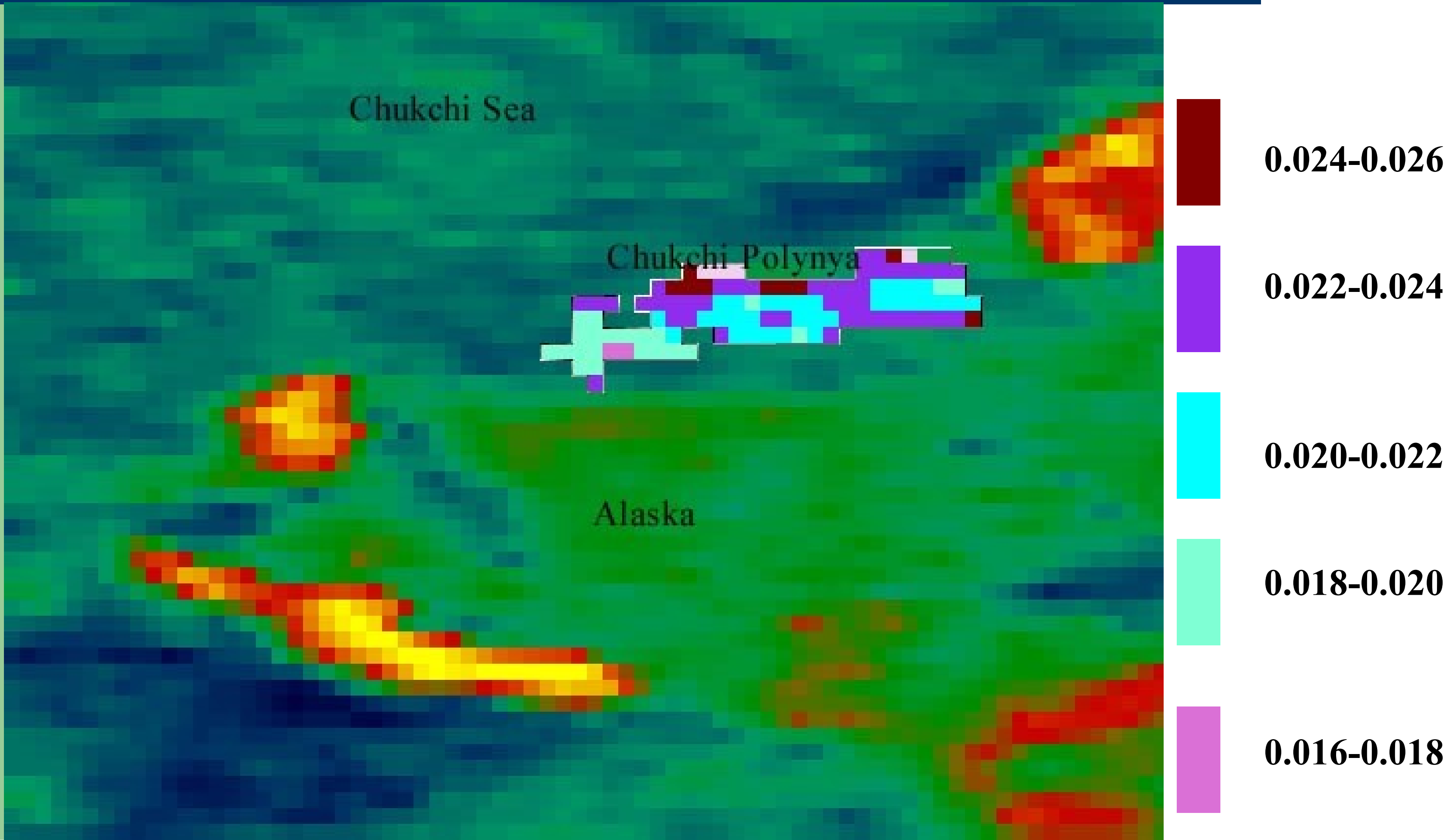
CONLCUSION

- **This study reflects the usefulness of the combination of two different types of sensors (MODIS & AMSR) for the estimation of thin ice thickness**
- **This study can be effectively used in the estimation of thin ice thickness in polynyas where the *in situ* observations are sparse**
- **From the results it is found that thickness is closely related to the polarization ratio at a specific frequency**
- **Even though there exist differences in the thickness derived from the two techniques, the average error is ~3%**
- **This study can be further extended for use in the estimation of ice productions in the Polar regions**

Thank You Very Much

Questions and Suggestions !

POLARIZATION RATIO at 89 GHz

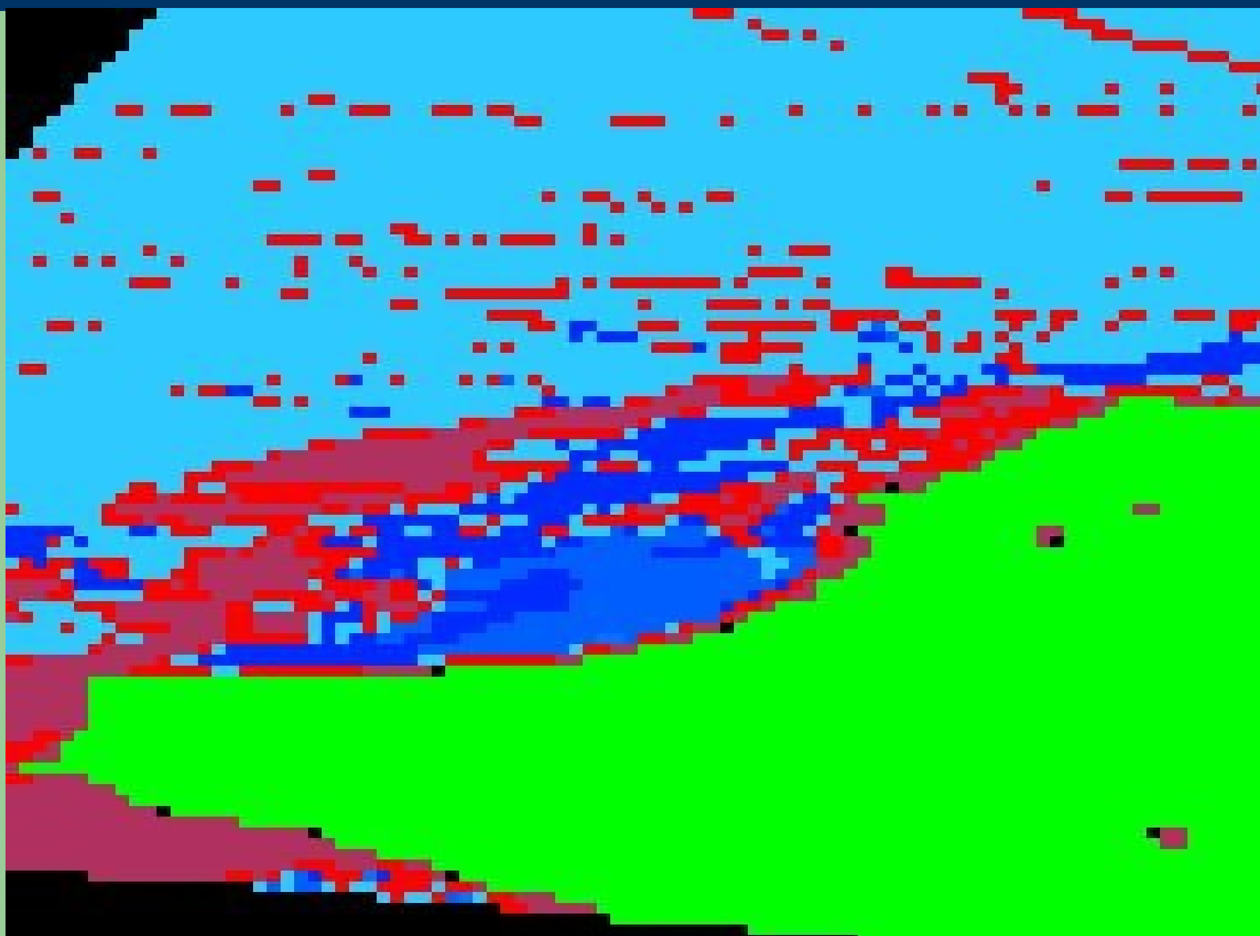


ACKNOWLEDGEMENTS

Sincere thanks to:
Mr. Takeshi Tamura of the Institute of Low Temperature Science, Hokkaido University for his constant help and scientific advices whenever requested for.
Prof. Seelye Martin of the School of Oceanography, University of Washington for his help on the location and identification of the polynya under study and his scientific comments.
Last but not the least to the Director, SAC and Dy. Director, RESA for permitting me to present this paper at the Workshop.

MODIS THERMAL THICKNESS

AT 6KM RESOLUTION



THERMAL THICKNESS (in meters)

- Land
- Clouds
- 0.15-0.20
- 0.10 – 0.15>
- 0.09 - 0.10
- 0.08 – 0.09