→ 2nd SMOS SCIENCE CONFERENCE

Major achievements using SMOS over Cryosphere

Lars Kaleschke
Institute of Oceanography
University of Hamburg

Acknowledgements

IRO2 and SMOSIce

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Terrestrial Cryosphere

Kimmo Rautiainen, Juha Lemmetyinen, Jouni Pulliainen **Finnish Meteorological Institute**

Mike Schwank **Gamma Remote Sensing and Swiss Federal Institute WSL**

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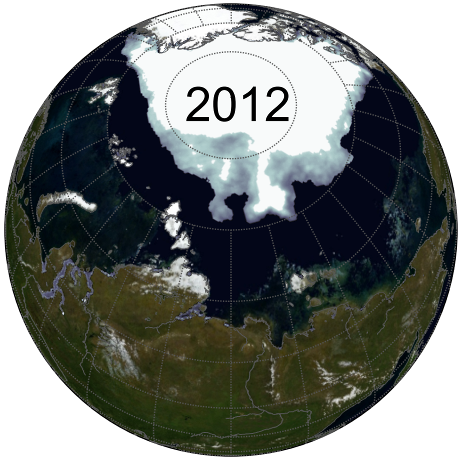
smosice
support to science element

Grand Challenge

Improved understanding of the cryosphere in a changing climate clearly is a “Grand Challenge" [Word Climate Research Programme, WCRP]

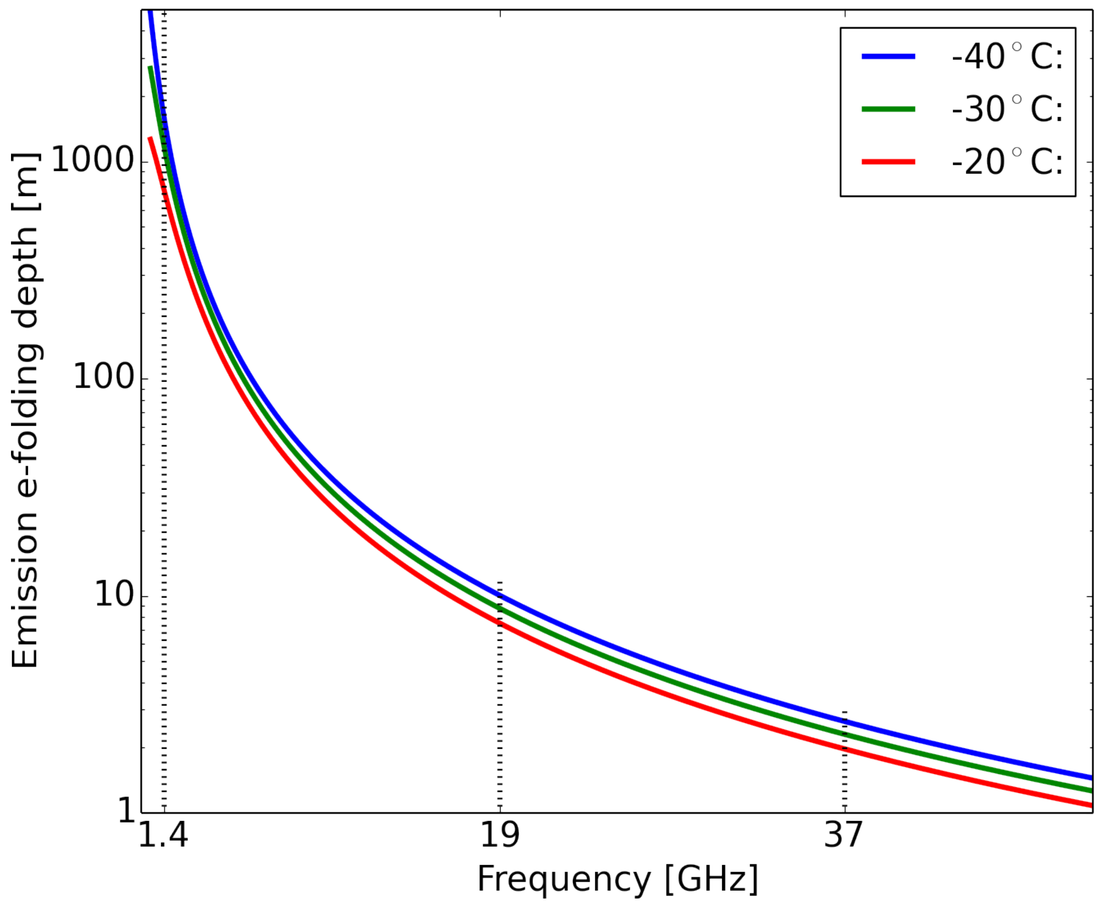


- Prospect of an ice-free Arctic Ocean
- Impact of thawing permafrost on the global carbon cycle
- The role of ice sheet dynamics in sea level rise

SMOS potential for an improved understanding of the cryosphere

Ice is a very low-loss medium with a minimum of absorption at 1 GHz

- Absorption increases with increasing temperatures and concentration of impurities (e.g. salt ions)
- SMOS measures the emission from very deep ice sheet layers
- Distinct advantages for retrieval of cryospheric parameters



Penetration depth for pure ice after Mätzler et al. (2006)

Retrieval of geophysical parameters

Field	Parameter	Status / references
Sea ice	thickness (<1.5m) snow thickness	Operational / U.Hamburg Kaleschke et al. (2010,2012); Tian-Kunze et al. (2014); Maaß et al. (2013, 2015ab)
Terrestrial cryosphere	freeze / thaw state	Finnish Meteorological Institute Rautiainen, Lemmetyinen, Pulliainen et al.
	snow density and ground permittivity	GAMMA Schwank et al.
	temperature gradient	Mironov et al. (2013)
Land ice	internal ice temperature	CRYOSMOS PI G. Macelloni, IFAC
	bedrock topography	DTU
	surface characteristics	LGGE
Ice shelve	ice temperature, marine ice	U.Hamburg

See CRYOSMOS Presentations & Poster

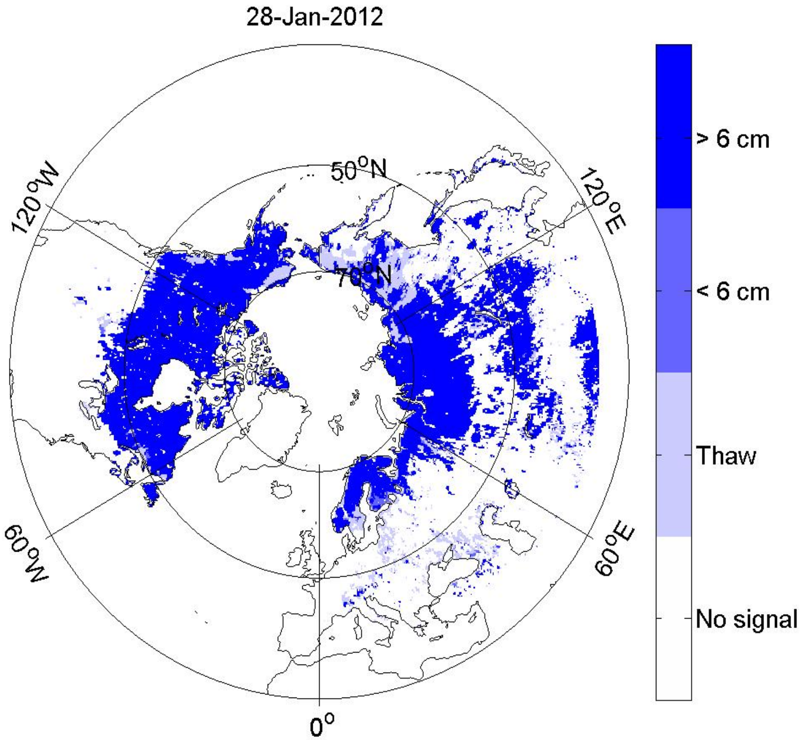
Soil freeze / thaw state

Prototype retrieval algorithm for space-borne L-band observations

Discrimination into thawed, frozen and partially frozen states

CATDS data (Level 3 L-band brightness temperature data, H and V pol, multiple incidence angles)

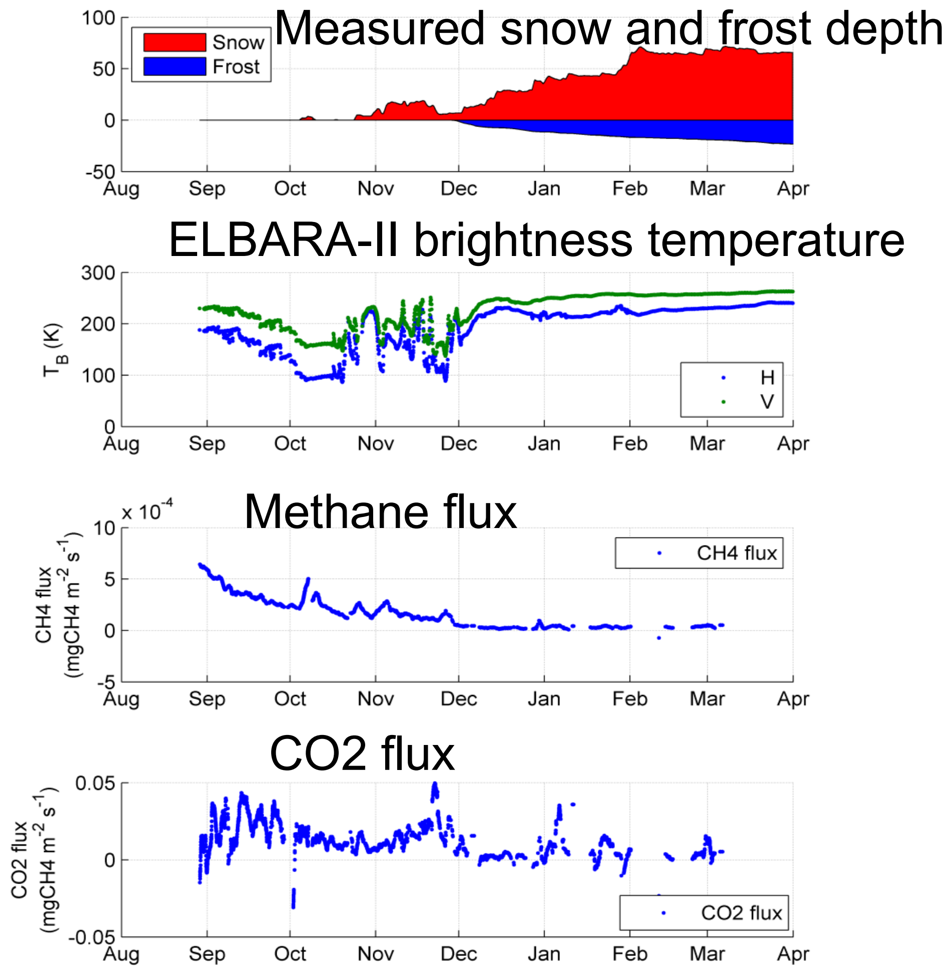
Coverage of complete Northern Hemisphere



Courtesy of Kimmo Rautiainen, Juha Lemmetyinen, Jouni Pulliainen (Finnish Meteorological Institute)

Link to carbon exchange

Since 2013 ELBARA-II installed at wetland (peatbog) site, Sodankylä, Finnland.



- Very wet autumn → brightness temperature and CH_4 flux drops
- Soil freezing further dropped CH_4 flux

Courtesy of Kimmo Rautiainen, Juha Lemmetyinen, Jouni Pulliainen (Finnish Meteorological Institute)

Snow Density and ground permittivity

Schwank, M., C. Mätzler, A. Wiesmann, U. Wegmüller, J. Pulliainen, J. Lemmetyinen, K. Rautiainen, C. Derksen, P. Toose, M. Drusch, Snow Density and Ground Permittivity Retrieved from L-Band Radiometry: A Synthetic Analysis, IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING (2015, in press)

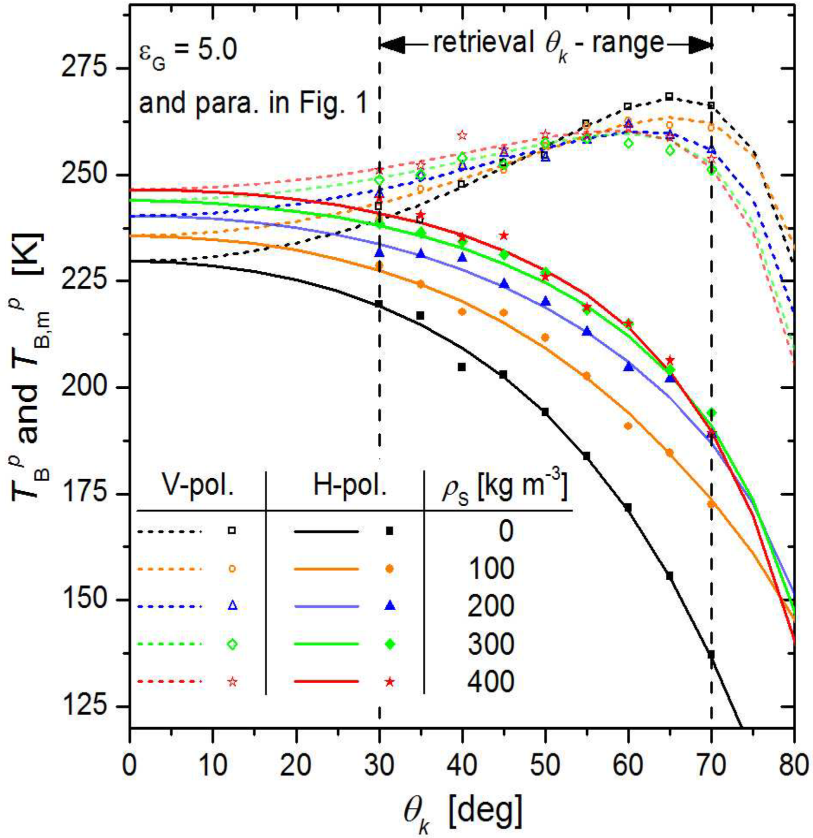
Simulated L-band $T_B^p(\theta)$ are sensitive to soil permittivity ε_G and density ρ_S of the lowest layer of even dry snow (which is almost fully transparent).

a) A transparent layer is **not** necessarily **'invisible'**.

b) The parameters $\boldsymbol{P} = (\varepsilon_G, \rho_S)$ could be estimated from L-band $T_B^p(\theta)$

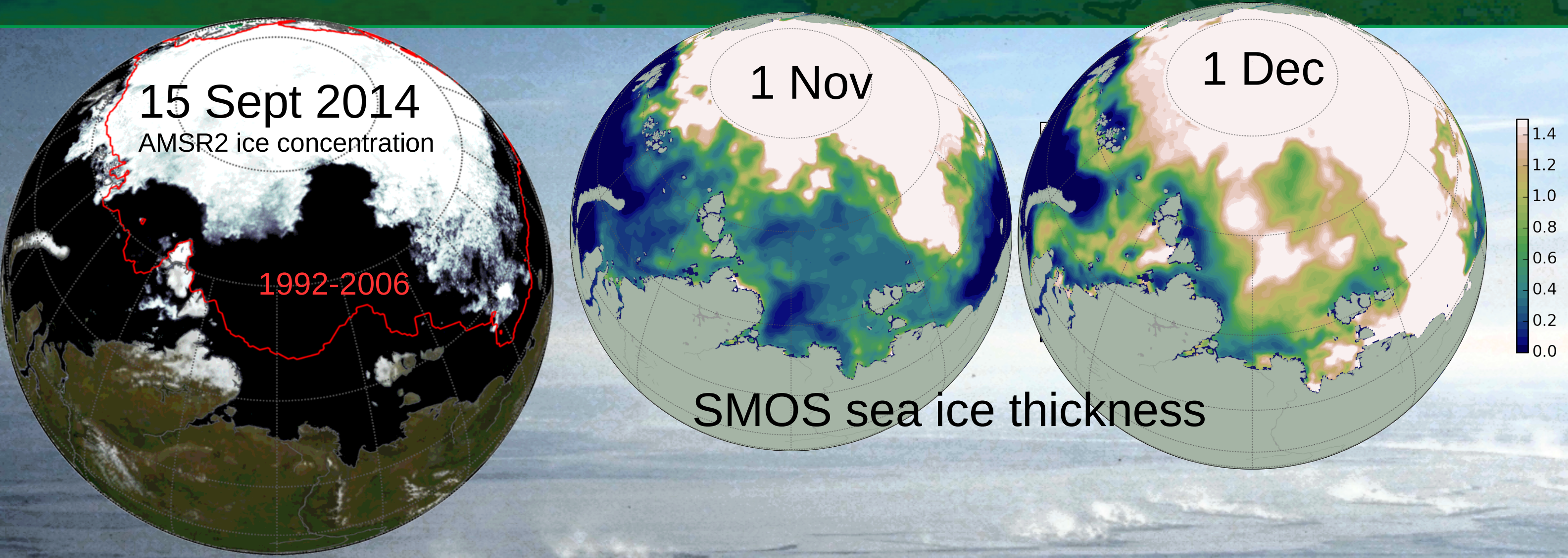
c) ρ_S-retrievals would be a **novel SMOS product**, that can improve the reliability of current remote sensing-based SWE estimates.

d) ε_G-retrievals will be approx 30% higher than corresponding current SMOS retrievals assuming 'invisible' dry snow.



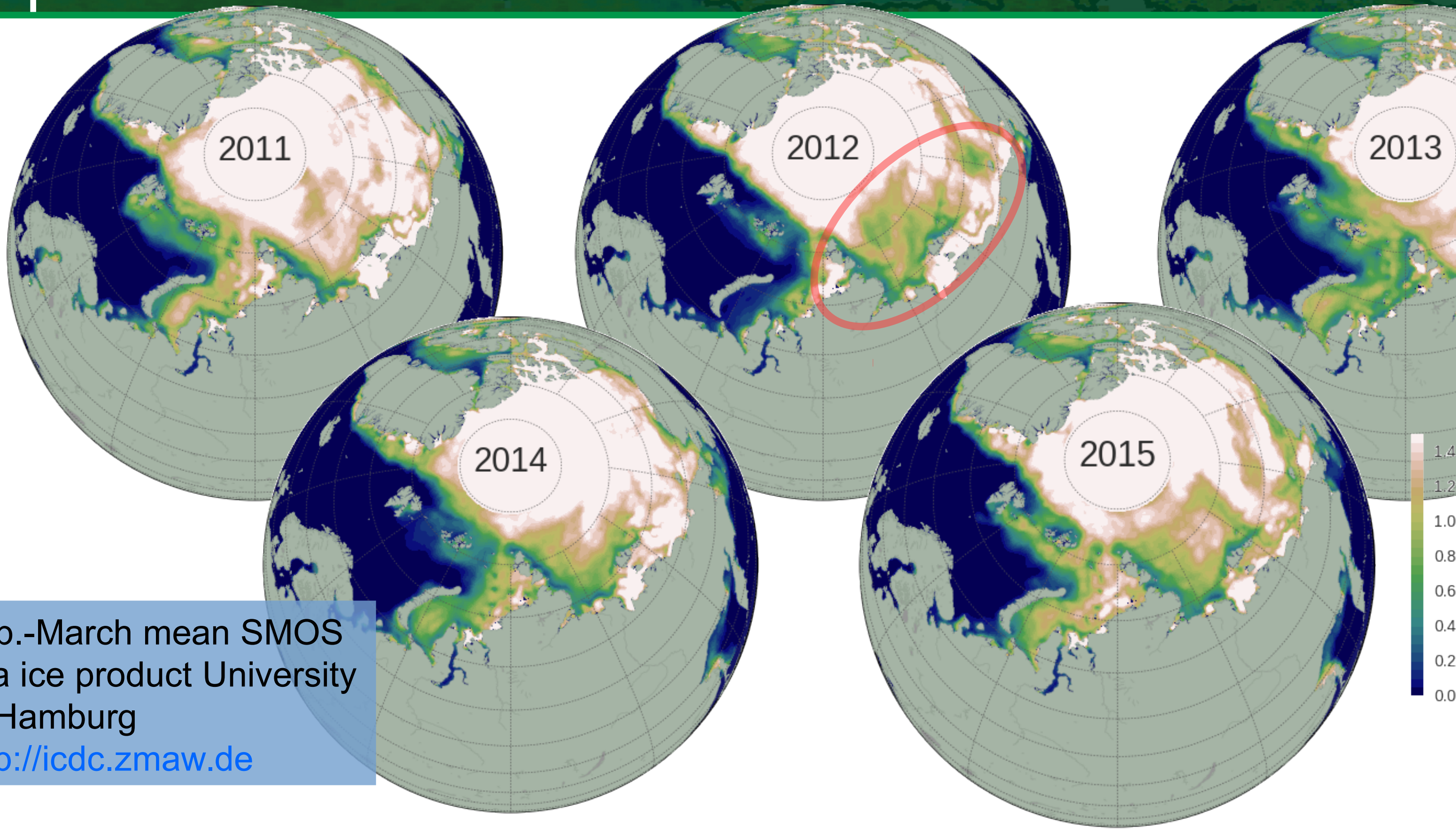
Courtesy of Mike Schwank (Gamma Remote Sensing and Swiss Federal Institute WSL)

Observing Arctic freeze-up



Kaleschke et al., Sea ice thickness retrieval from SMOS brightness temperatures during the Arctic freeze-up period, Geophys. Res. Lett., 2012

SMOS sea ice thickness:
potential for seasonal forecast

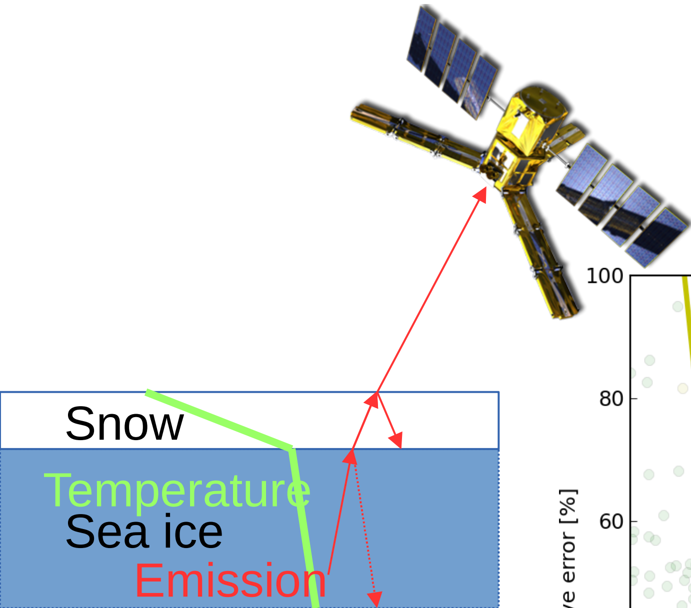


Feb.-March mean SMOS sea ice product University of Hamburg
http://icdc.zmaw.de

- Knowledge of the sea ice thickness field is important for sea ice extent forecasts up to 8 months ahead and has a significant impact on the forecast error in Arctic 2 m temperature a few months ahead — Day et al., GRL 2014
- SMOS ice thickness assimilation leads to improved thickness forecasts — Yang et al., JGR, 2014

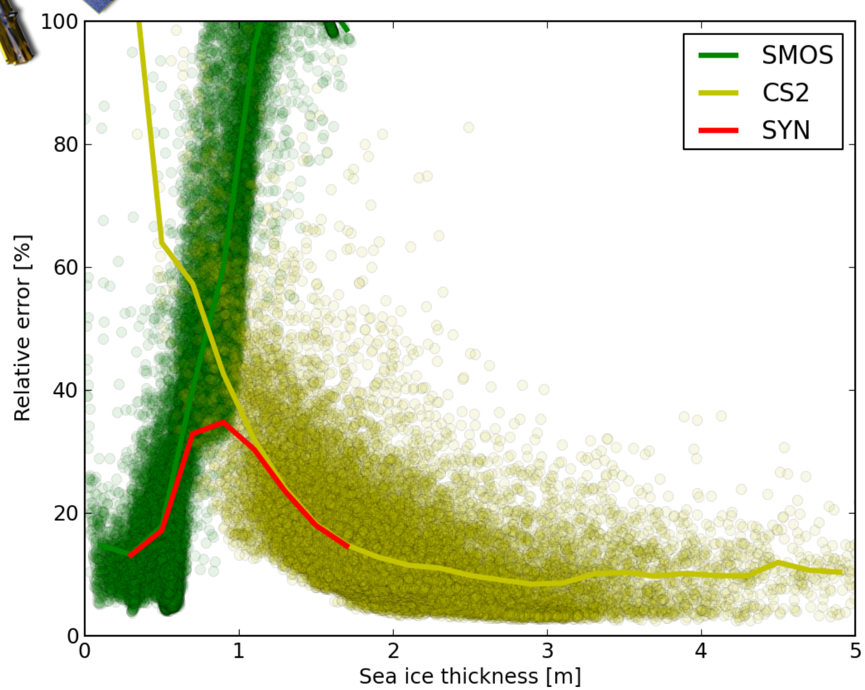
Synergy of SMOS and CryoSat2

The perfect couple for sea ice thickness

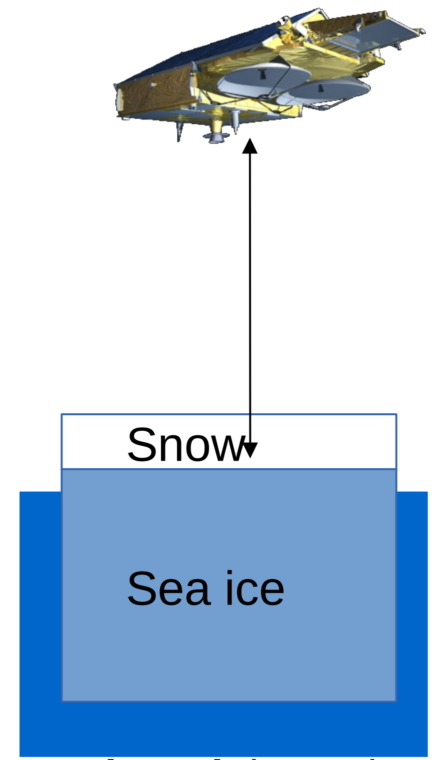


Brightness temperature depends on

- ice thickness
- snow thickness
- ice concentration, temperature, salinity, roughness,..



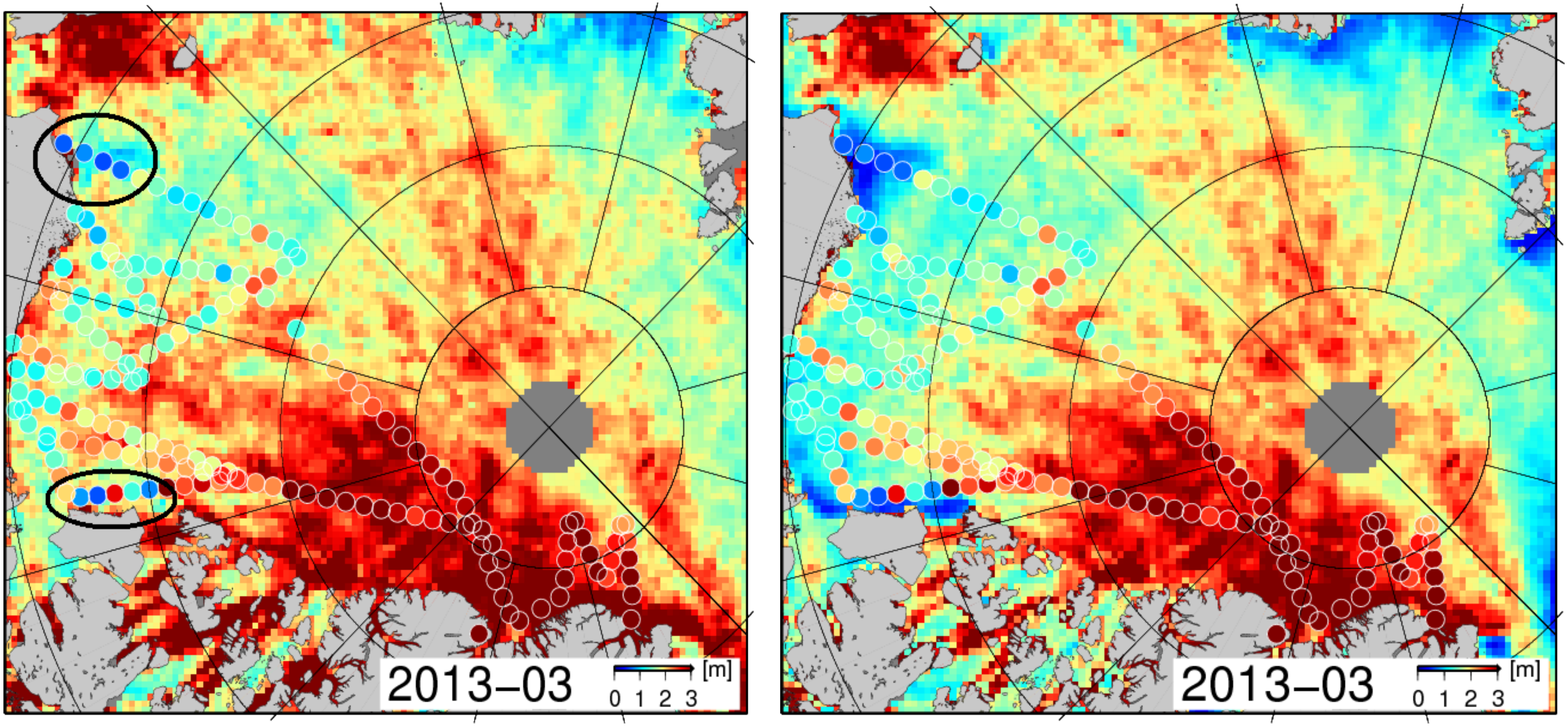
Combination is more accurate than single SMOS & CS2 products



Freeboard depends on

- ice thickness
- snow thickness
- density of snow and ice

Synergy of SMOS and CryoSat2



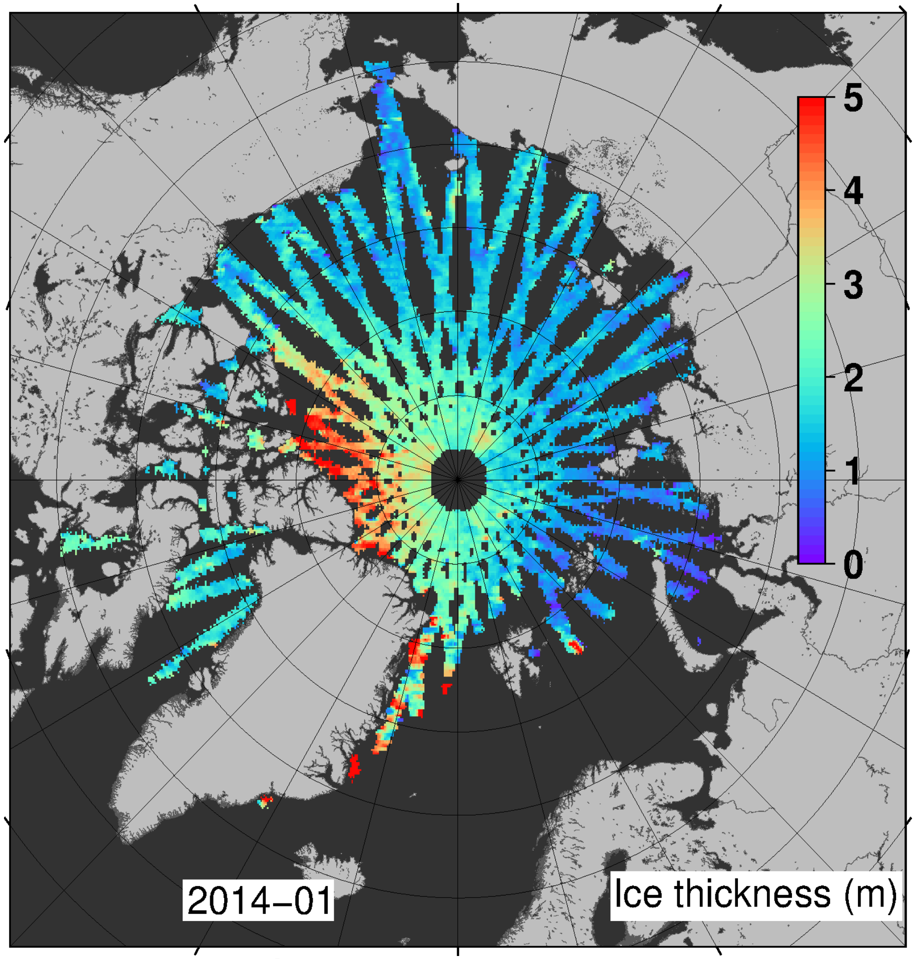
CryoSat2 SMOS+CryoSat

Combined product agrees better with NASA Operation Ice Bridge data (airborne campaign)

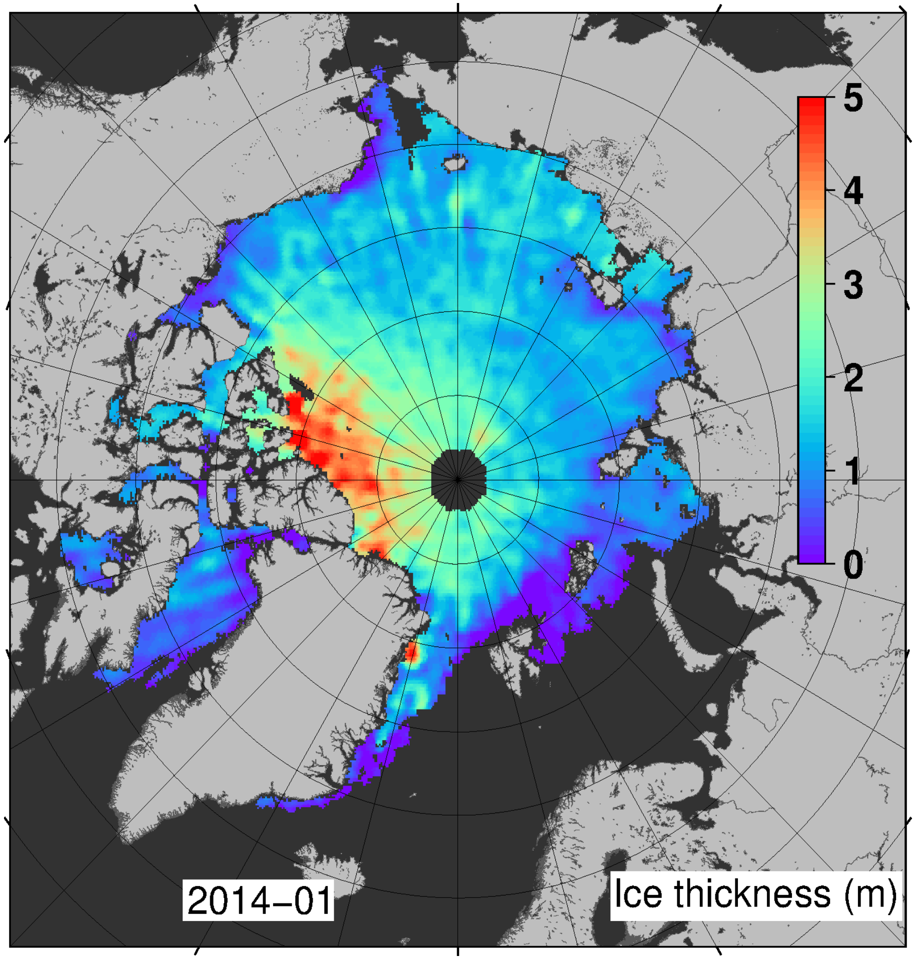
Kaleschke & Ricker, 2012

Synergy of SMOS and CryoSat2

Towards new combined products using Optimal Interpolation Data Fusion



Weekly CryoSat-2



Weekly CryoSat-2 + SMOS OI

Courtesy of R. Ricker (AWI), SMOS+ Sea Ice ongoing work

Arctic Shipping

Hamburg Ship Model Basin HSVA
ship dependent parameters for route optimization module

arcticportal.org

Foto: Marius Bratrein, NPI

SMOS Sea Ice Validation

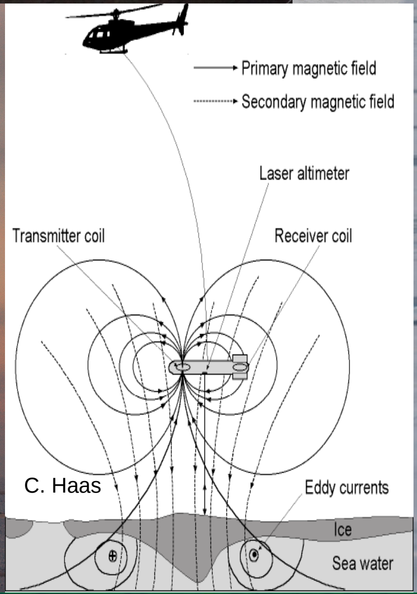
SMOSIce / IRO2 Barents Sea Campaign March 2014


Michael Offermann, U. Hamburg


DTU Space

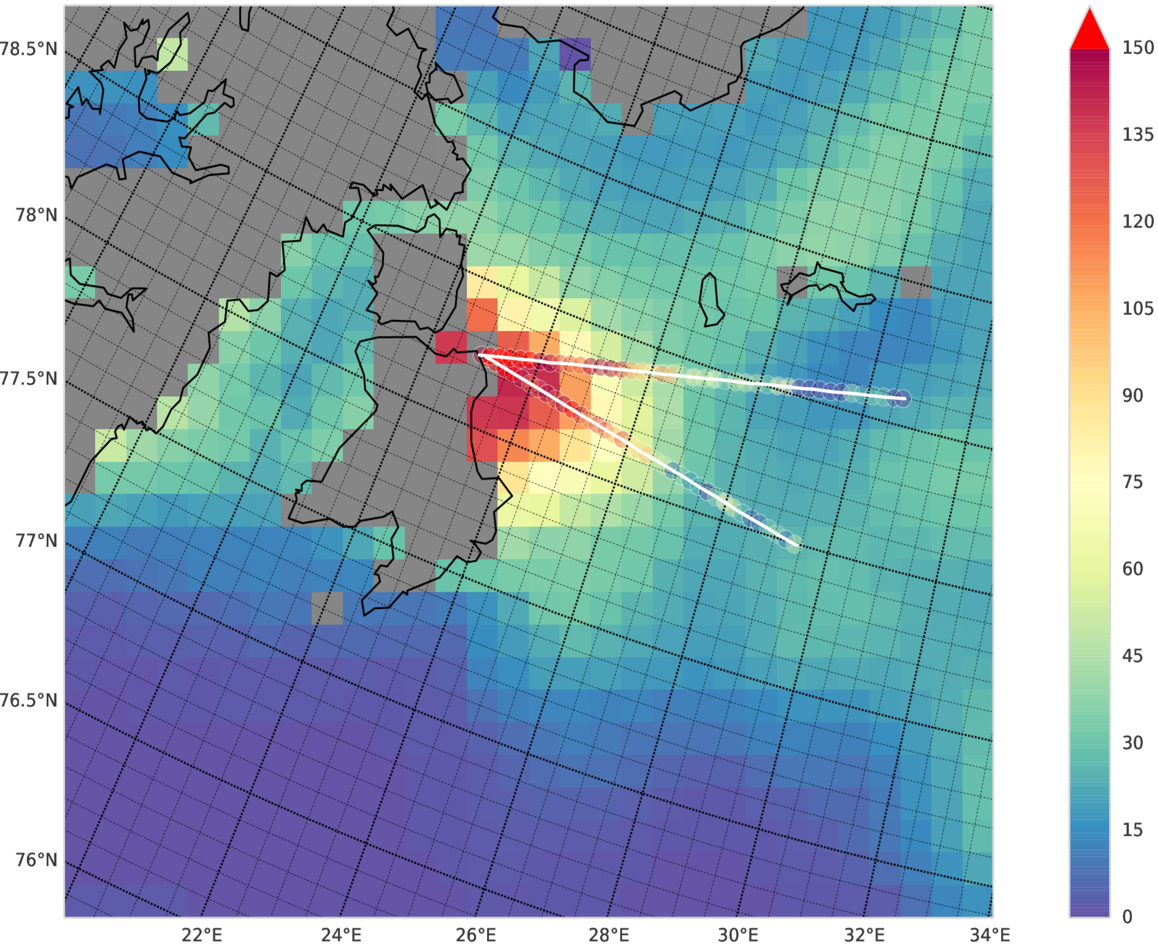

Foto: Stefan Hendricks, AWI


Niels Fuchs, U. Hamburg

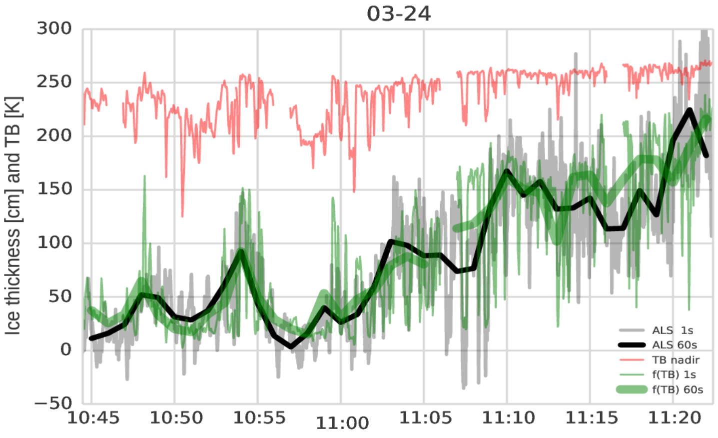


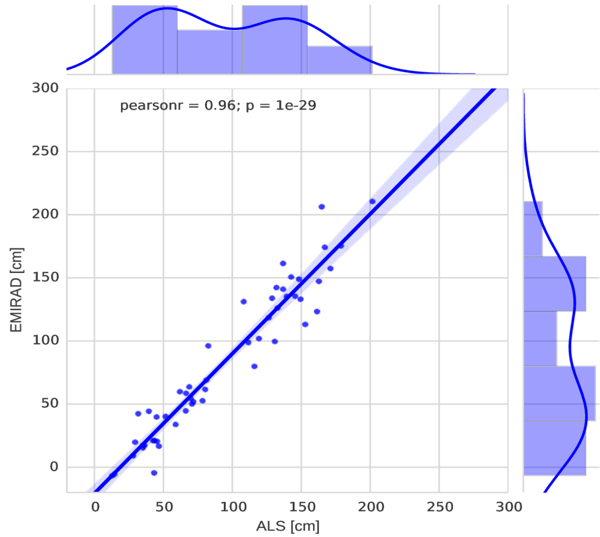
C. Haas

Validation: Thickness from airborne laser scanner (freeboard) and EMIRAD2 L-band TB

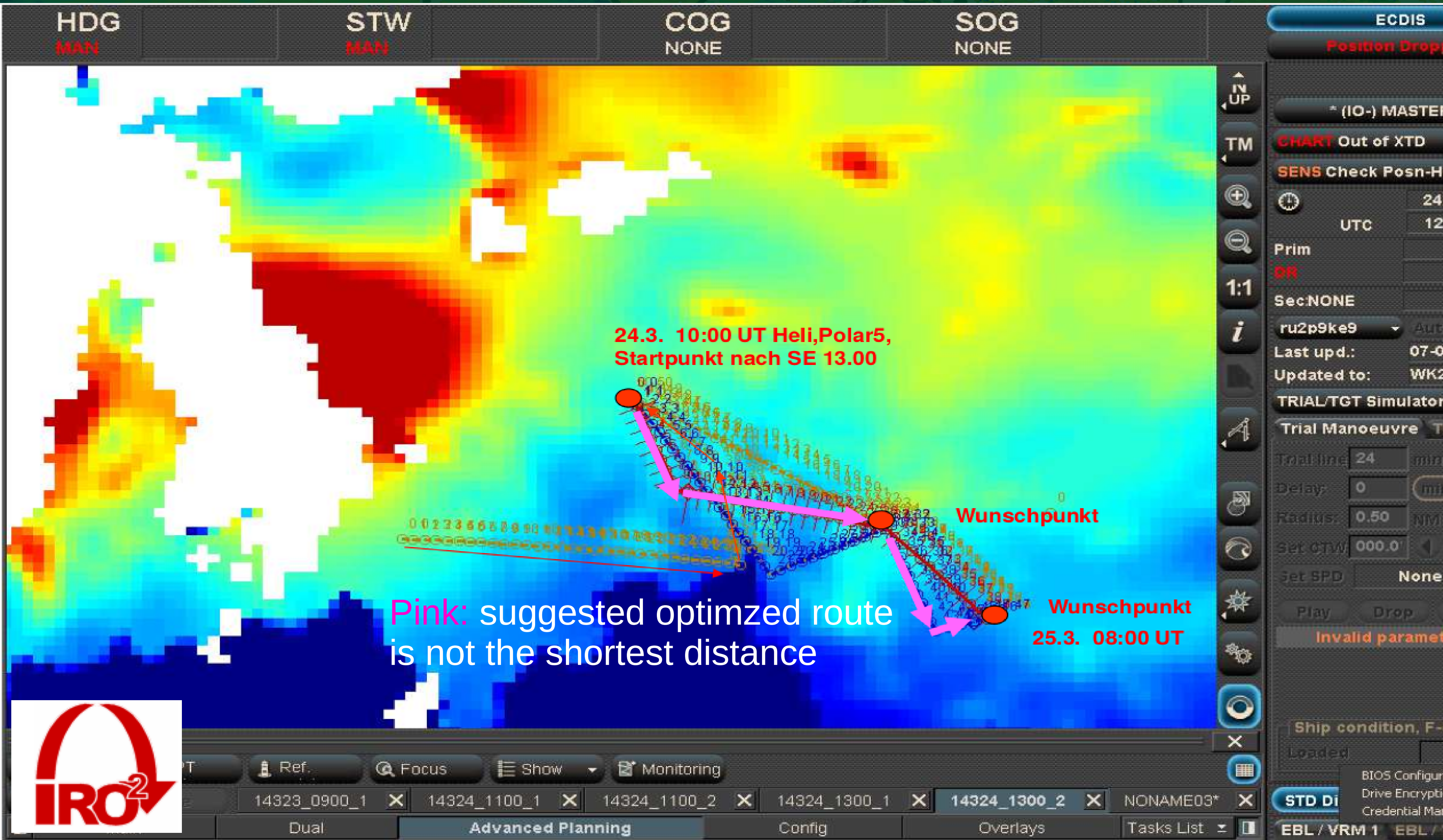


Polar 5 ALS and SMOS ice thickness





Ship route optimization: ice forecast model initialization with SMOS ice thickness



Summary

- Understanding of the cryosphere in a changing climate is a Grand Challenge
- SMOS has unique capabilties for observation of the cryosphere:
  - terrestrial soils and permafrost (free/thaw, temperature), snow density
  - land and shelve ice
  - sea ice and snow thickness
- Decline of Arctic sea ice raises increasing interest in Arctic shipping and the need for operational sea ice forecast systems for safe and economic navigation
- Sea ice thickness as one of the key parameters needed for the initialisation of forecast models for short-term and seasonal prediction can be obtained from SMOS
- Successful test and demonstration of operational short-term forecast and ship route optimization system in Barents Sea, March 2014; Successful coordinated flights with Polar 5 and helicopter for SMOS and CryoSat-2 validation; Unique dataset covering thin ice and deformed ice in the marginal ice zone; Preliminary analysis confirms validity of 1.4 GHz sea ice thickness retrieval
- Combination of SMOS and CryoSat2 for new interpolated products and improved sea ice thickness/volume estimates