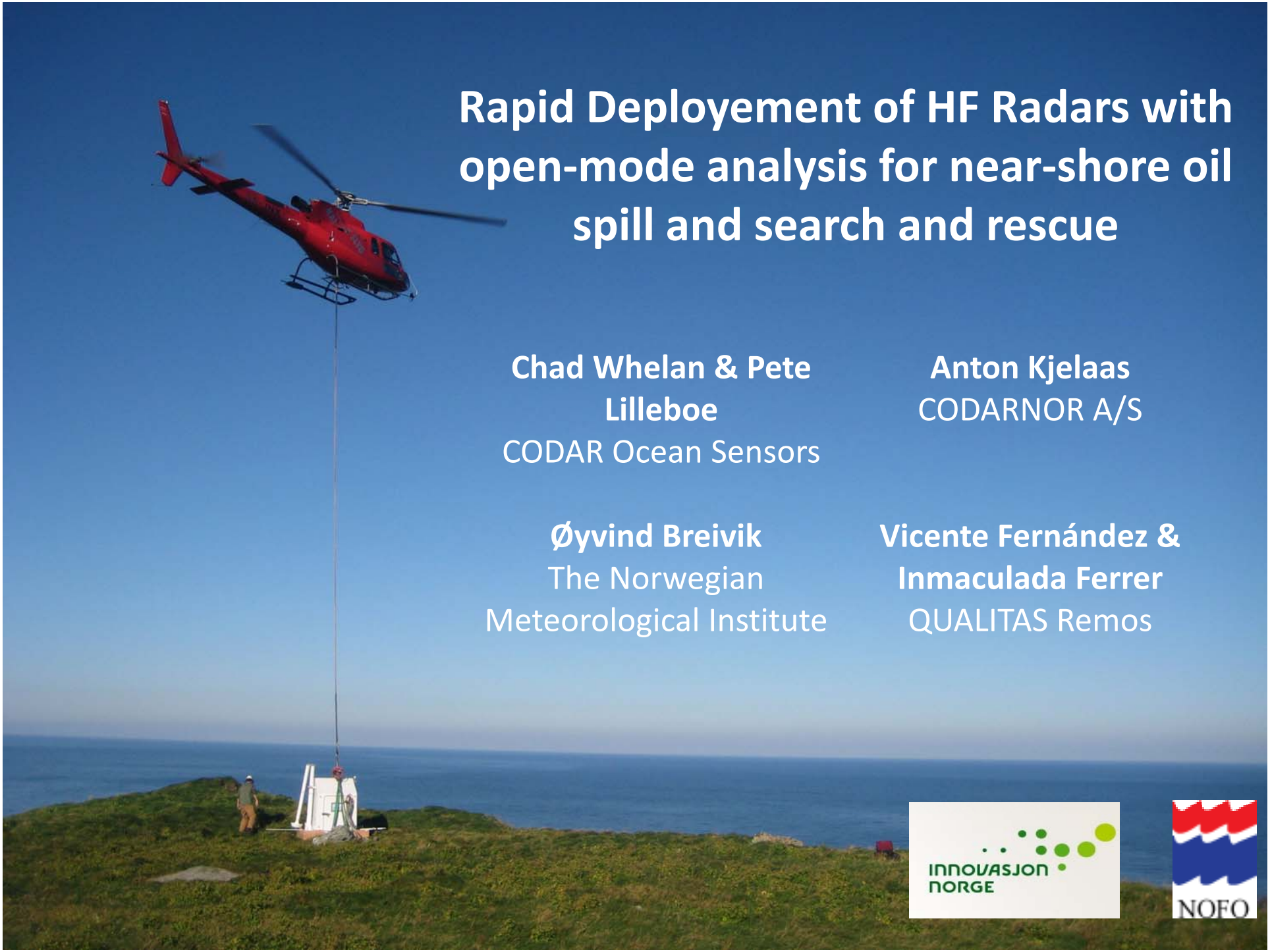


Rapid Deployement of HF Radars with open-mode analysis for near-shore oil spill and search and rescue

Chad Whelan & Pete Lilleboe
CODAR Ocean Sensors

Anton Kjelaas
CODARNOR A/S

Øyvind Breivik
The Norwegian Meteorological Institute

Vicente Fernández & Inmaculada Ferrer
QUALITAS Remos

INNOVASJON NORGE

NOFO

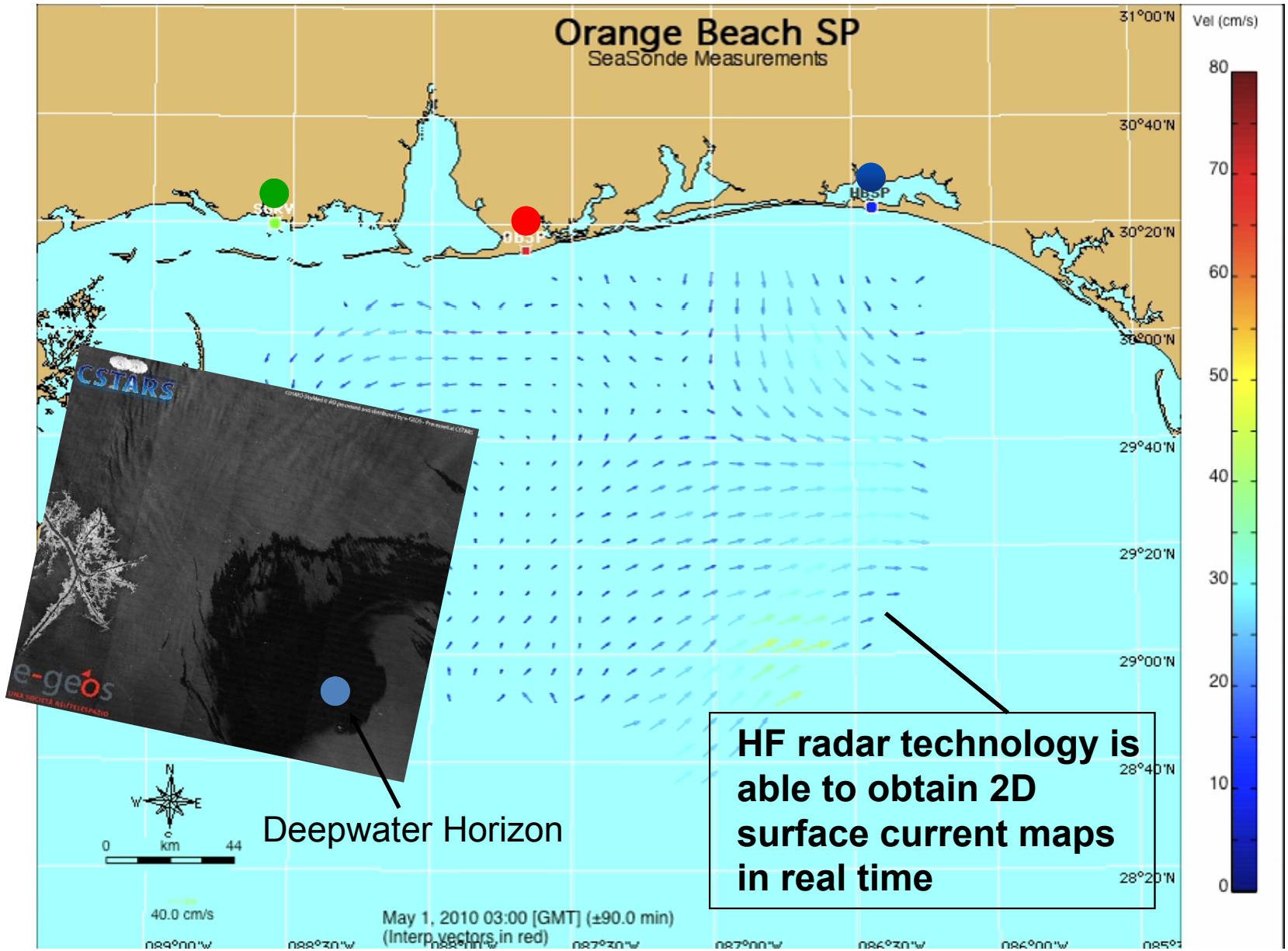
Outline

1. Why develope a rapid response HF Radar for oil spill operations?
2. NOFO (Norwegian Clean Sea Association) project
3. Operational 2D surface current maps from HF Radar and OMA technique
4. Deployment and field trials in the northern coast of Norway
5. Conclusions and on-going work

Deepwater Horizon
April, 2010

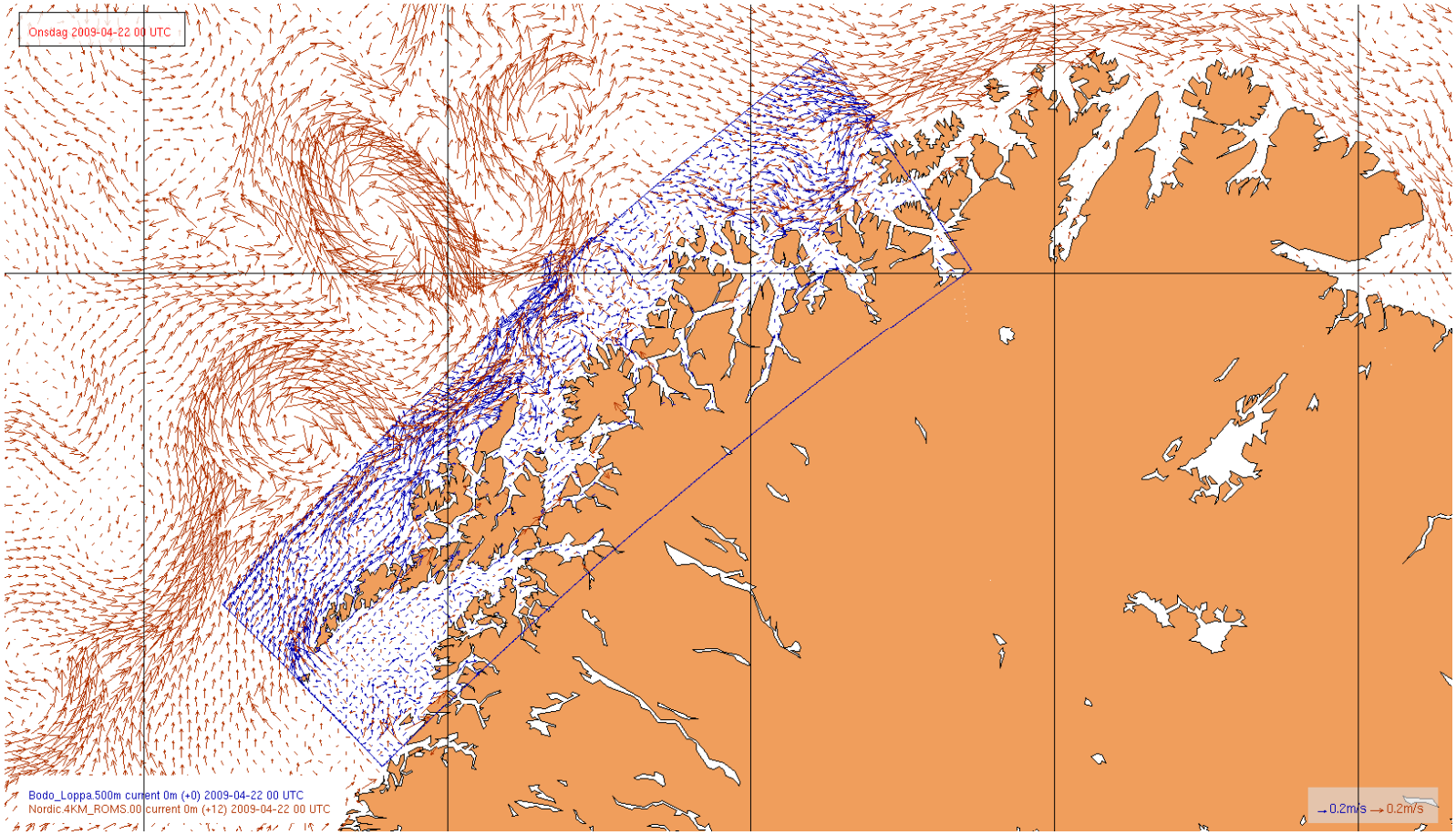
Knowing the current fields will help the oil spill operation

HF radar currents expample: University of So. Mississippi Long Range SeaSondes, May 1, 2010



Place of focus: Northern Norway

You can’t drive to most places!



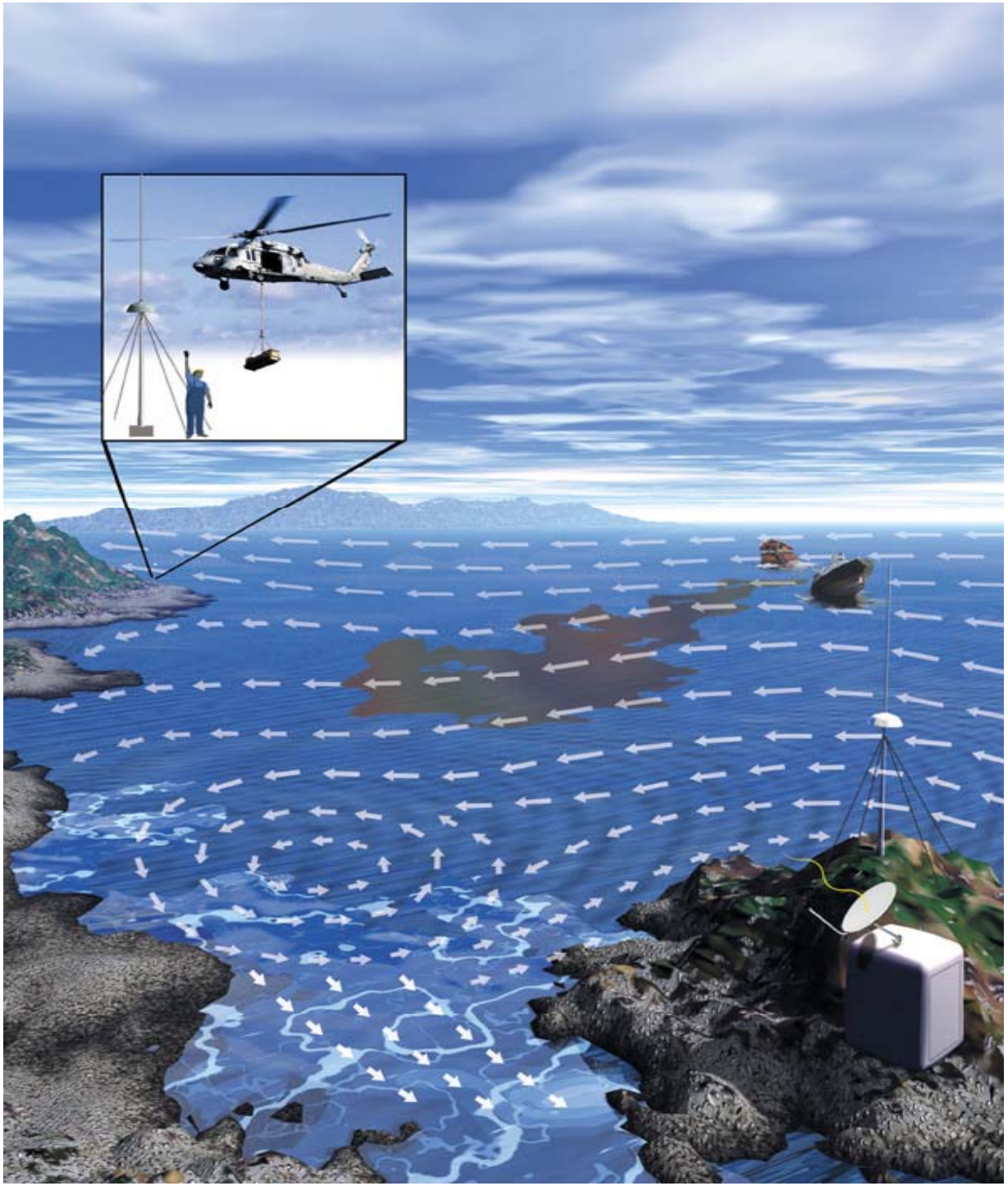
Nordic 4km + Bodo-Loppa 500m. operational models covering the Lofoten area.
The outer model is an implementation of the regional ocean model system (ROMS) on 4km resolution.
The innermost model is a 500m resolution model.

What is a rapid deployable HF radar?

Deploy HF Radar SeaSondes by Helicopter to Remote Locations when necessary in **1 or 2 days**

Provide Value-added information, not just currents

Build in enough redundancy to make products robust and reliable



Innovation Norway

Norsk Oljevernforening For Operatørselskap

Norwegian Clean Seas Association for Operating Companies

NOFO

Project objectives

1 Develop a **mobile SeaSonde HF radar** unit that can be rapidly deployed to the coast of Norway to aid in effective and efficient oil spill response (CODAR)

2 Develop a data service that provides high quality SeaSonde-derived 2-D current fields to The Norwegian Meteorological Institute in near real time for spill drift model input and operations planning (QUALITAS)

3 Demonstrate that SeaSonde-derived 2-D current fields can improve operational oil spill drift model results (Met.no)

Partners

CodarNor
Project Management
Field Trials & Demonstration

CODAR
Design and Fabrication of SeaSonde Rapid Deployment Unit

Qualitas Remos
Open Mode Analyses- OMA
Tailored Web Server Interface

Met.no
Data acquisition, archiving and web access
Data blending and extension of oil spill service to ingest blended HF current fields
Model-data evaluation

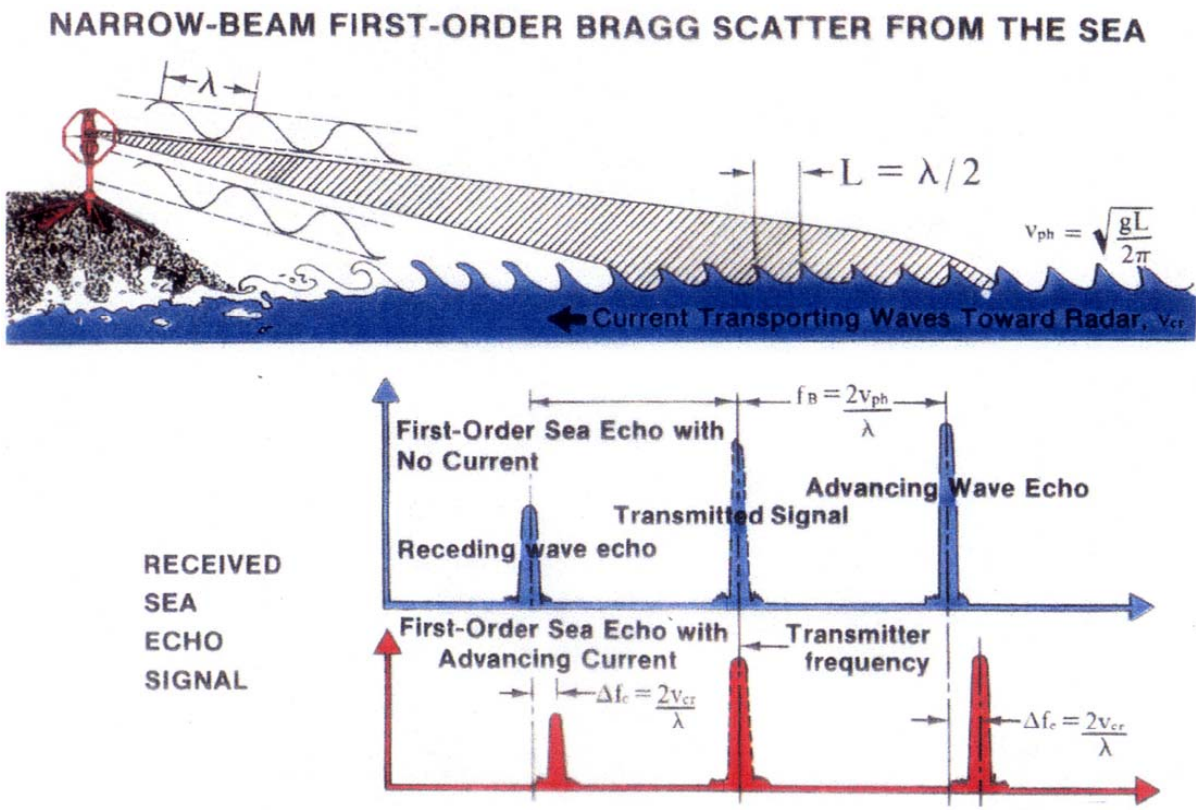
Improved oil advection forecasts are to be used to maximize efficiency and effectiveness of spill cleanup operations.

The mobile Rapid SeaSonde HF radar unit

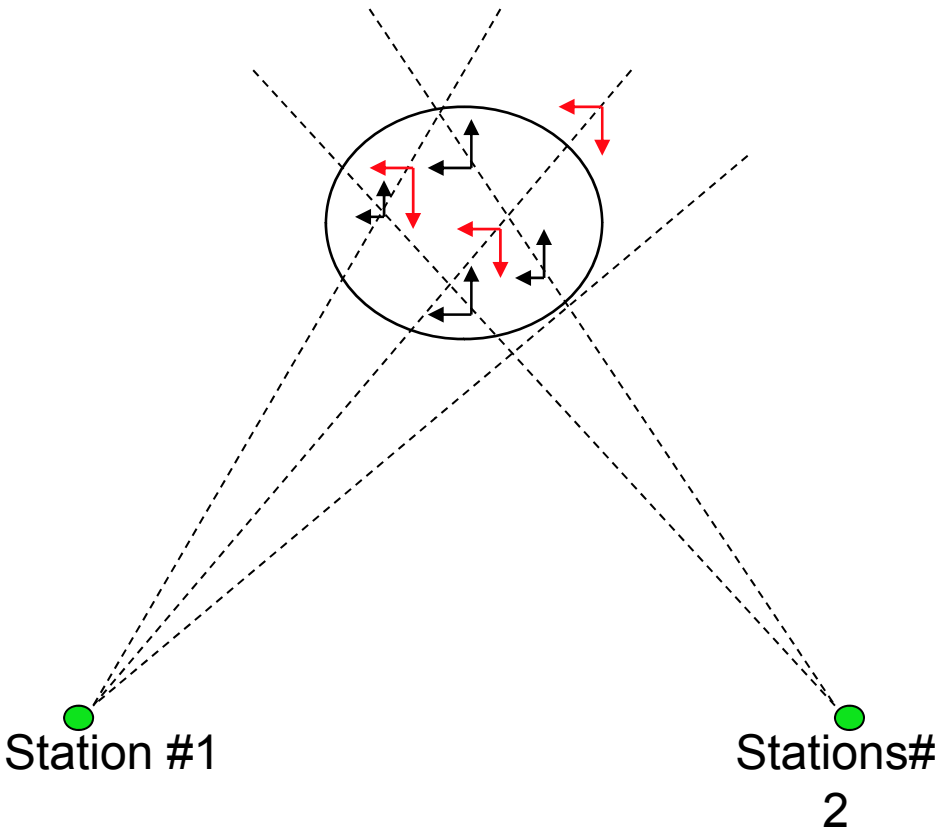
Radar HF Background

<u>At each antenna (station) we get the speed of water moving away or towards it (radials):</u>

- Sea waves generate backscatter echo which sums coherently and is identified at the radar receiver (**Bragg scatter**)
- The received signal is shifted versus the emitted signal due to the **Doppler effect** (obtaining surface speed)
- Sea currents are calculated by subtracting the wave speed obtained based on the (theoretical) deep water dispersion relation



Local method to obtain 2D Surface Currents



•Grid spacing and averaging circle are defined such that several radials from each site contribute to each total vector

•All vectors falling in averaging circle are resolved into orthogonal components (U, V)

•Linear least squares performed on U, V components separately

•Goal is to balance maximizing resolution while minimizing neighboring grid dependence **and data gaps**

Gaps!

•RF Interference
•Baseline instabilities
•Local coastline and topographic shadowing
•Poor antenna isolation

Avoid gaps :
2D Surface Currents field from HF radar and Open-boundary Modal Analysis (OMA)

Robust mechanism for interpolating and gap-filling two dimensional velocity HF radar measurements (*Kaplan and Lekien, JGR 2007*)

Advantages:

•Smooth, two-dimensional current fields with **no gaps**

•Produce **currents closer to the coast**

•Use radial current vectors directly in OMA to produce total current vectors – no need for intermediate 'local' vector combining

•**Gap-filling acceptabl**e if gaps occur infrequently or for integrative applications **(e.g, Lagrangian Trajectories)**

Open Mode Analysis (OMA)

•Modal analysis is based on a vorticity-free (u_φ) and a divergency-free (u_ψ) decomposition:

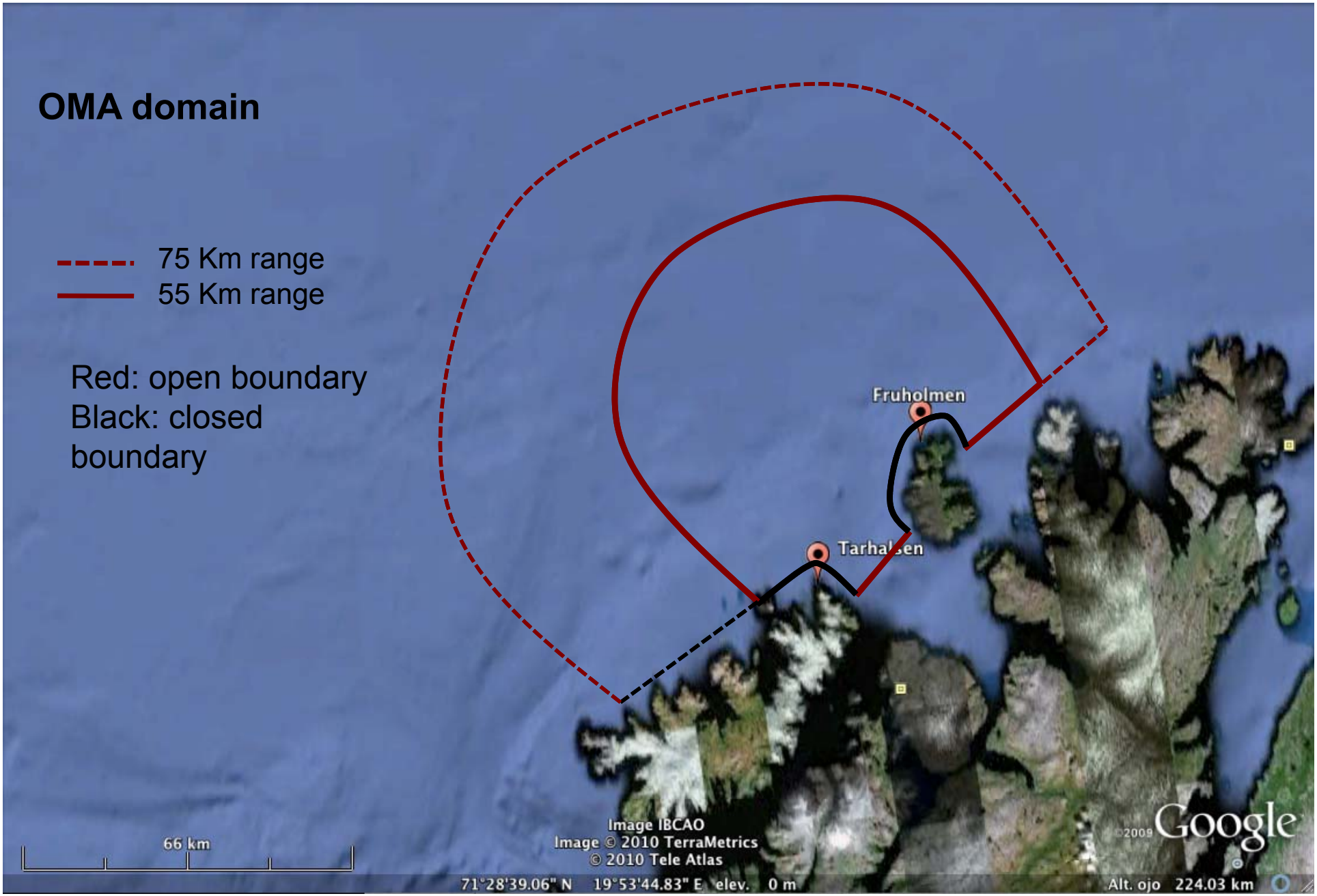
$$\mathbf{u=u_\varphi+u_\psi}$$

The modes (φ, ψ) are computed solving two laplacian eigenvalues problems on the domain with Dirichlet and Neumann condition on the coast and adding boundary modes to account for flow in the open boundary

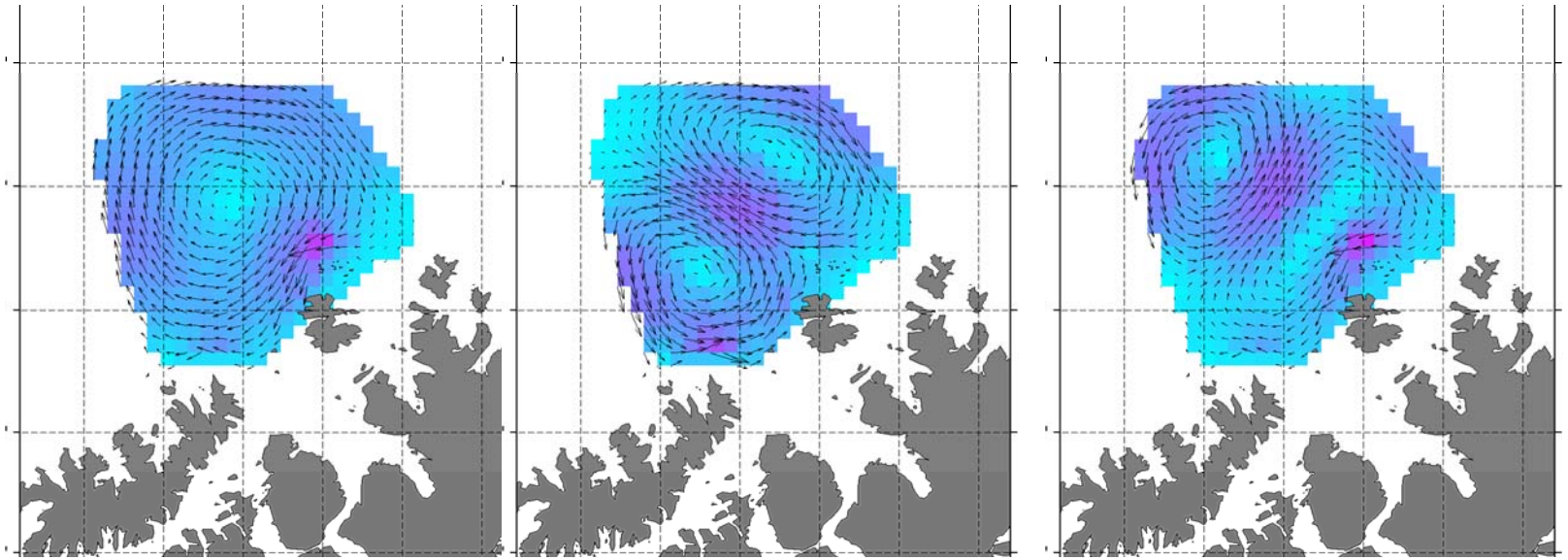
•The modes depend only on the shape of the **(pre-defined)** domain and on the definition of the closed and open domaian

•The modes are computed **only once** at the beginning and used each hour to obtain 2 D fields

OMA domain

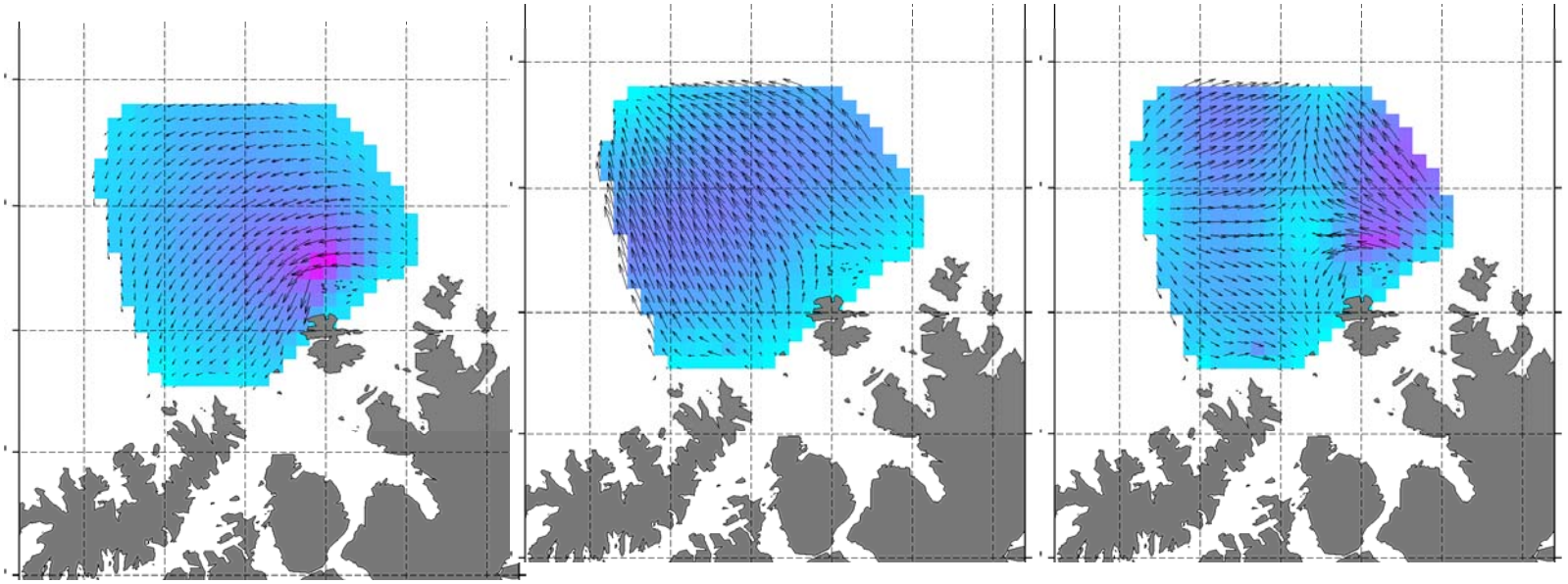

75 Km range
55 Km range
Red: open boundary
Black: closed boundary
Fruholmen
Tarhalsen
66 km
Image IBCAO
Image © 2010 TerraMetrics
© 2010 Tele Atlas
©2009 Google
71°28'39.06" N 19°53'44.83" E elev. 0 m
Alt. ojo 224.03 km

Non-divergent Modes ψ_i (Dirichlet)



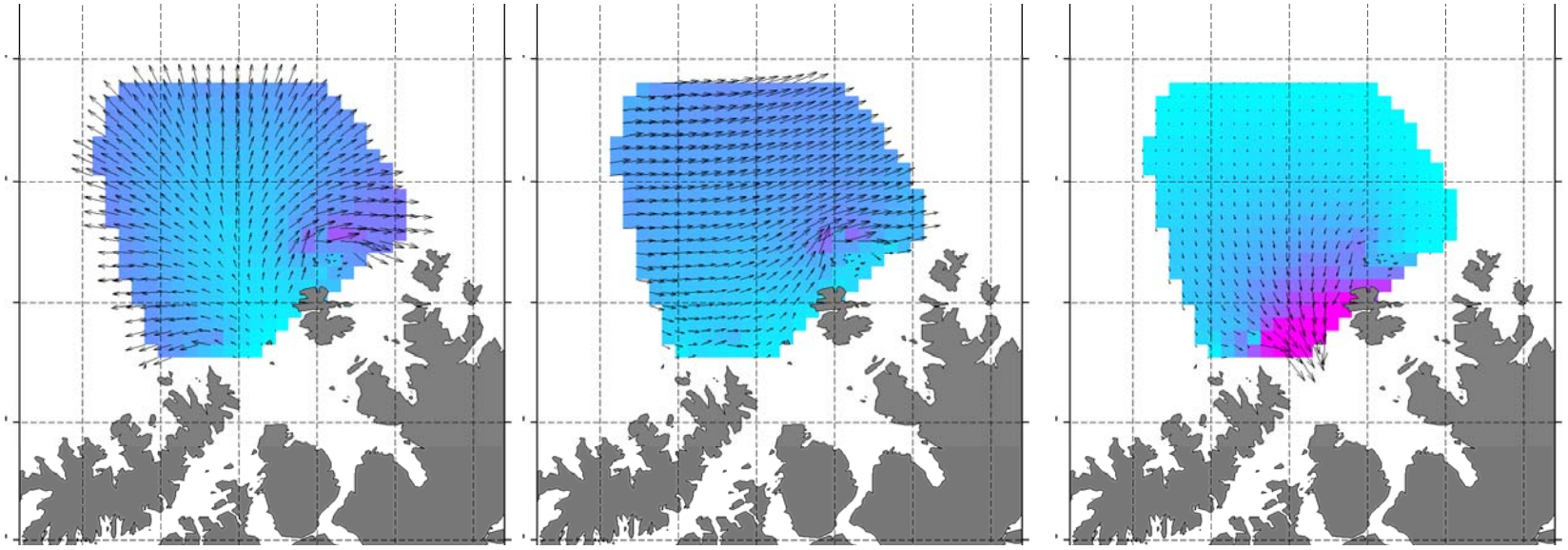
+ ....

Non-rotational φ_i (Neumann)



+ ....

Boundary Modes φ_i^b (Flow in and out the domain)



+ ....

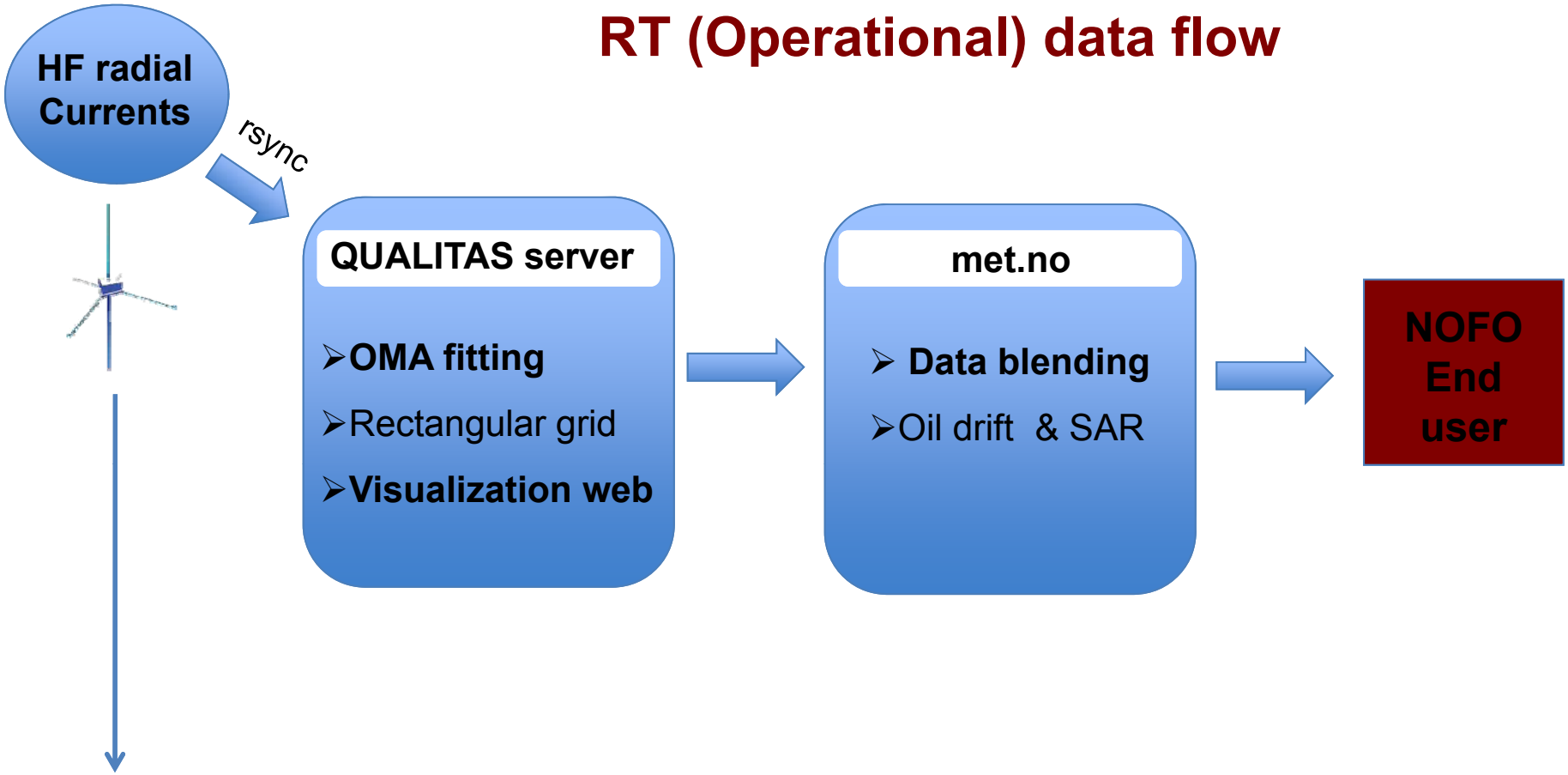
Any current field can be expanded in the interior and boundary modes:

$$\vec{u} = \sum_{i=1}^{\infty} \alpha_i^{\Psi} \hat{k} \times \nabla \Psi_i + \sum_{i=1}^{\infty} \alpha_i^{\varphi} \nabla \varphi_i + \sum_{i=0}^{\infty} \alpha_i^{b} \nabla \varphi_i^{b}$$

<u>OMA Current field construction:</u>

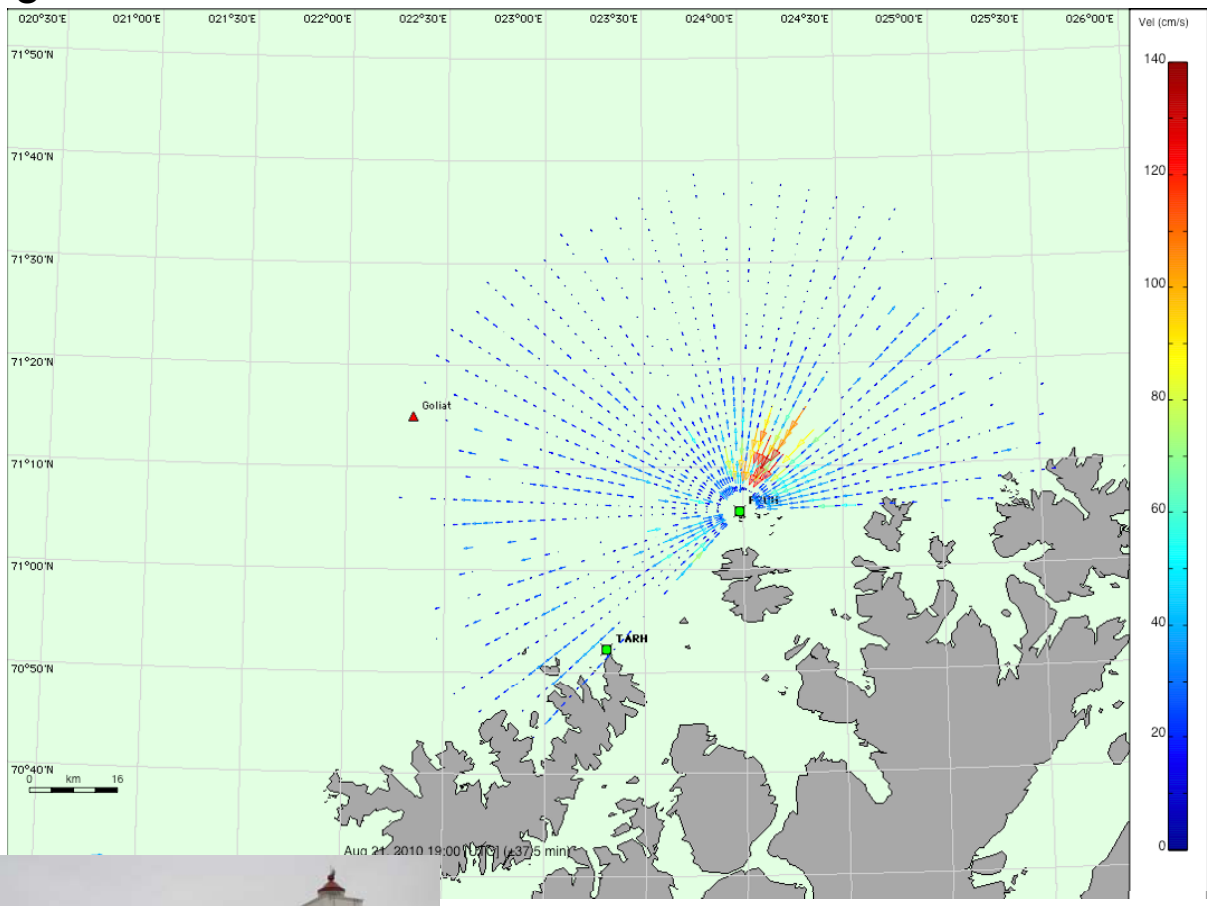
Minimizing a cost function to determine the ideal combination of modes which gives the **best fit to available measurement data (i.e radials from radar Antenna)**

RT (Operational) data flow



- **2 Radial Seasonde radial stations**. Fruholmen (fixed) and Tarhalsen (Mobile)
- **Frequency of operation:** 12 Mhz. BW: 75 Khz. Radial resolution: 2 Km
- **Communications**: Ice.net modem 450 MHz band

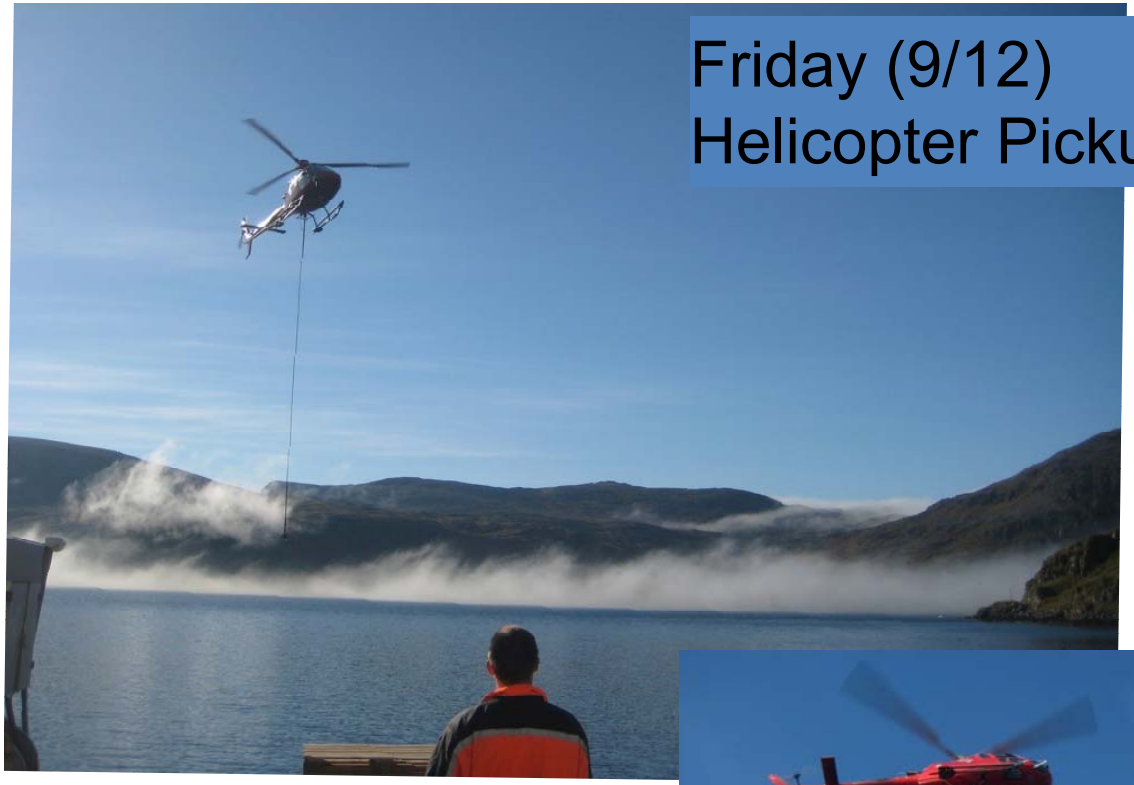
Fruholmen Site: The northernmost lighthouse in the world.
Fixed location. Deployment, August 2010

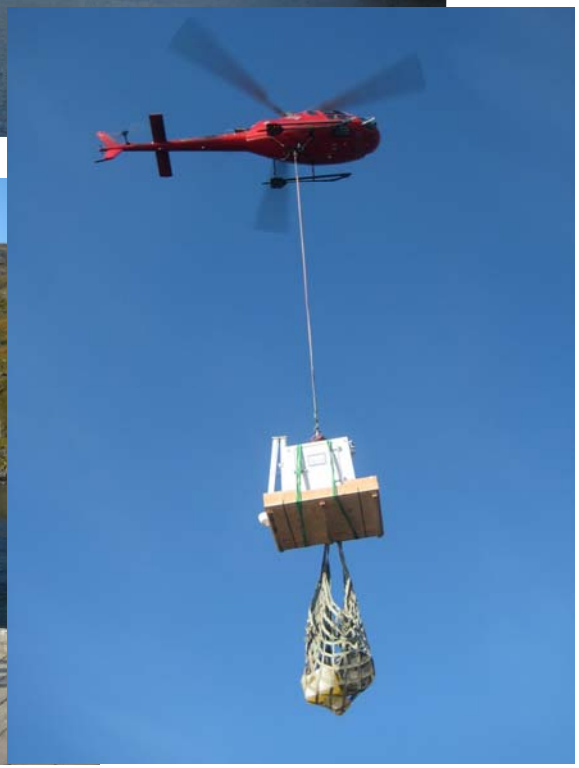


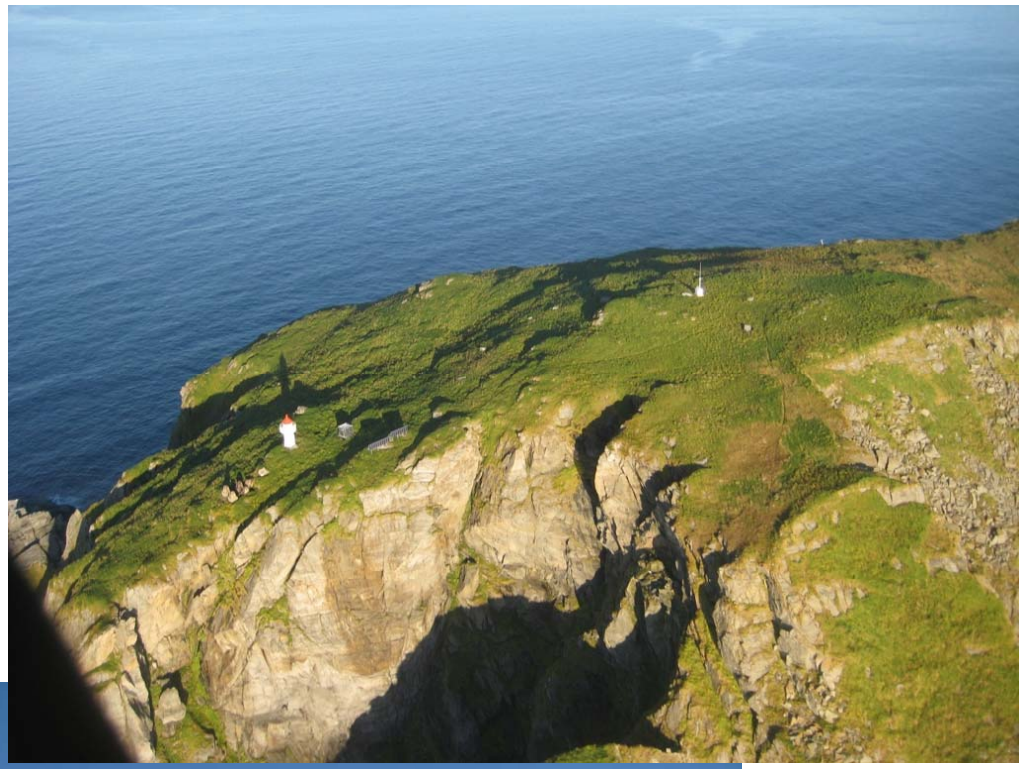
Tarhalsen Site: Hard-to-reach, no infrastructure: SeaSonde Mobile

Test Deployment
September, 2010

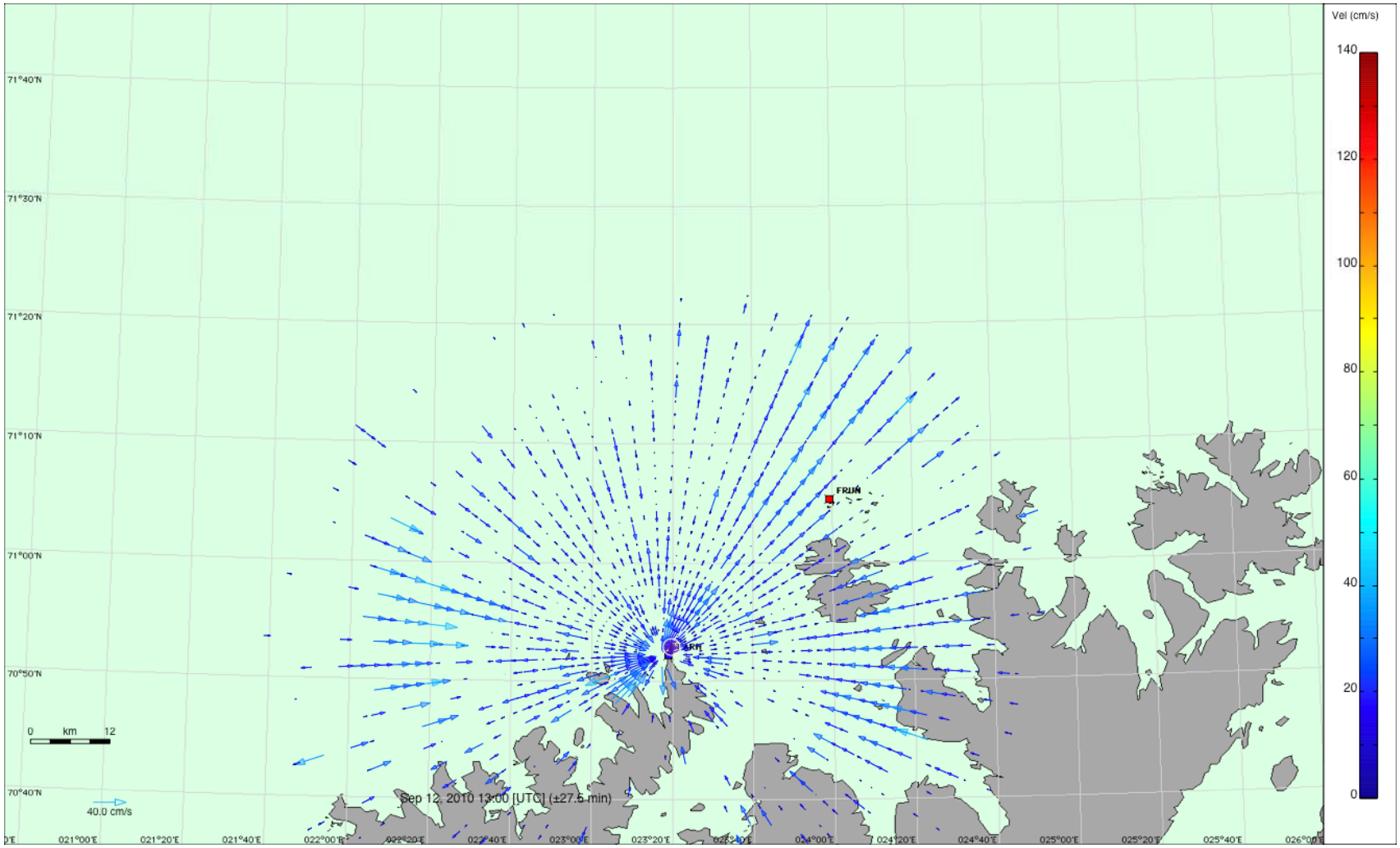
Friday (9/12)
Helicopter Pickup





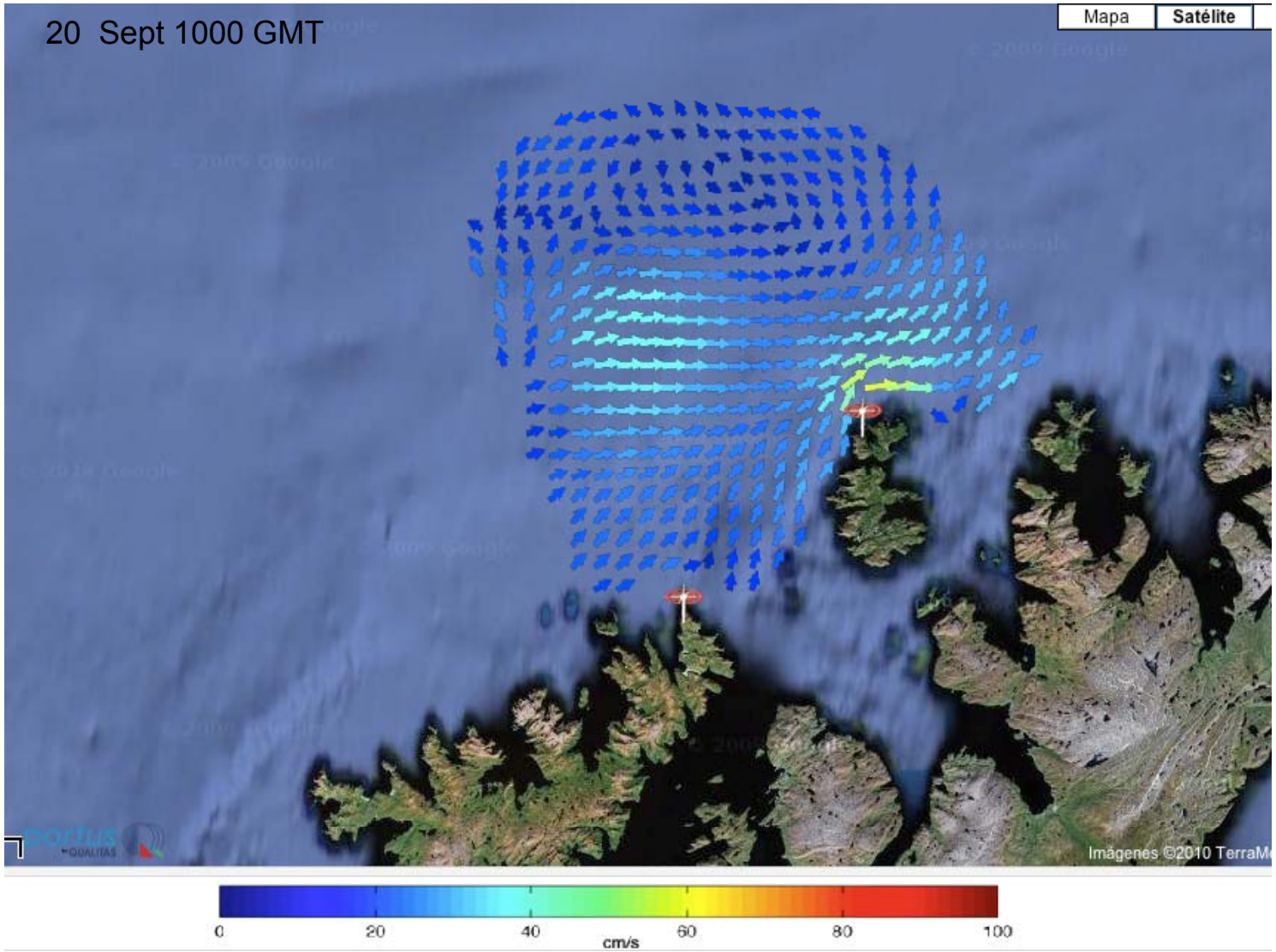


A **couple of hours** after the deployment (september 12) we get radials for the Mobile unit. Range 60 Km



OMA reconstructed fields from radials in a rectangular grid of 2.5x2.5 Km.

- No gaps
- Tangent to the coast



What about Antenna Pattern Measurements (APMs)?

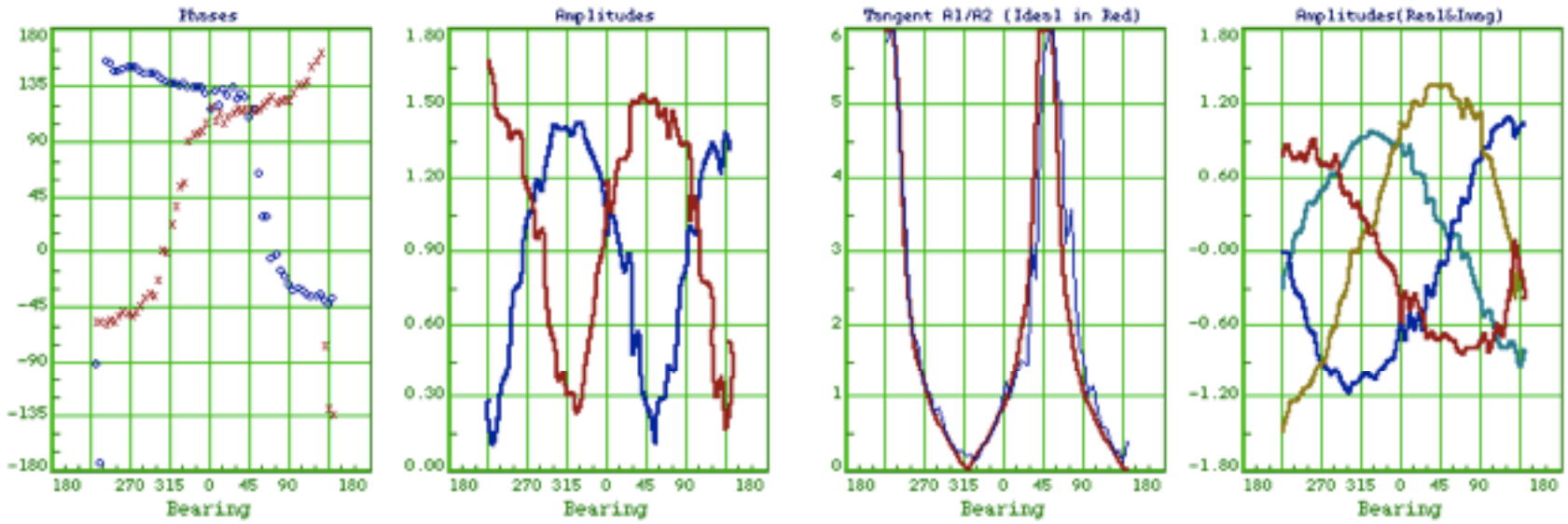
- During Rapid Response, site permissions not as critical - you should have your choice of ideal sites for temp deployment then measuring pattern not critical.

- Define sites along coast that you would deploy to ahead of time & measure the pattern before a rapid deployment situation

- Measure pattern by walking transponder around antenna, if room is available

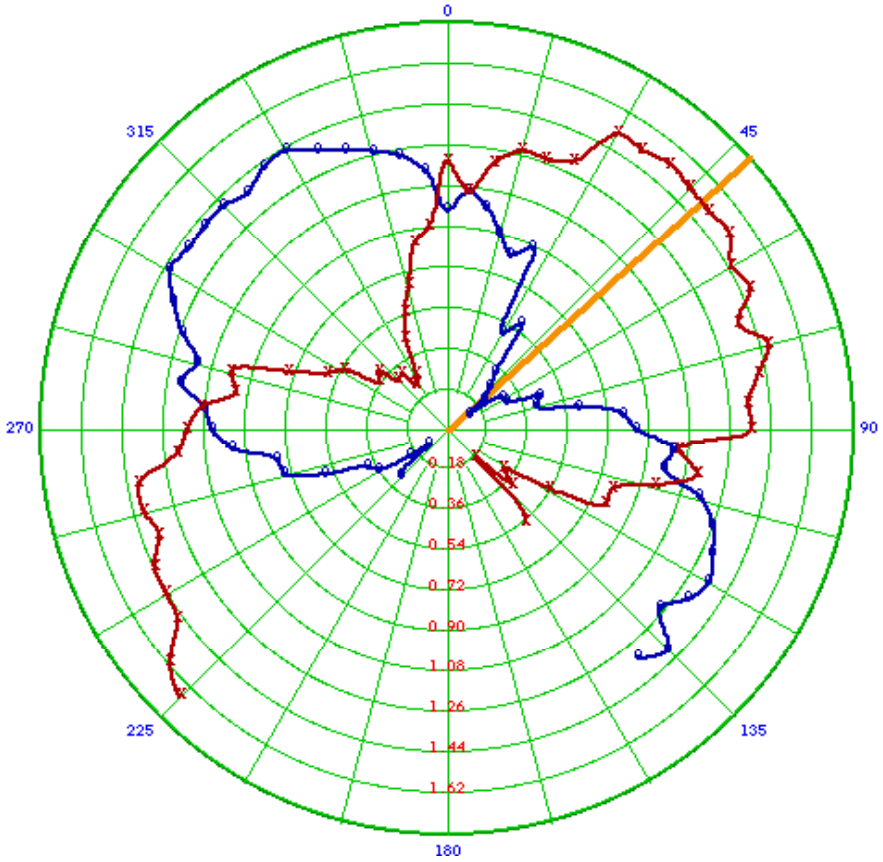
- Or...

Use the
helicopter!



It works!

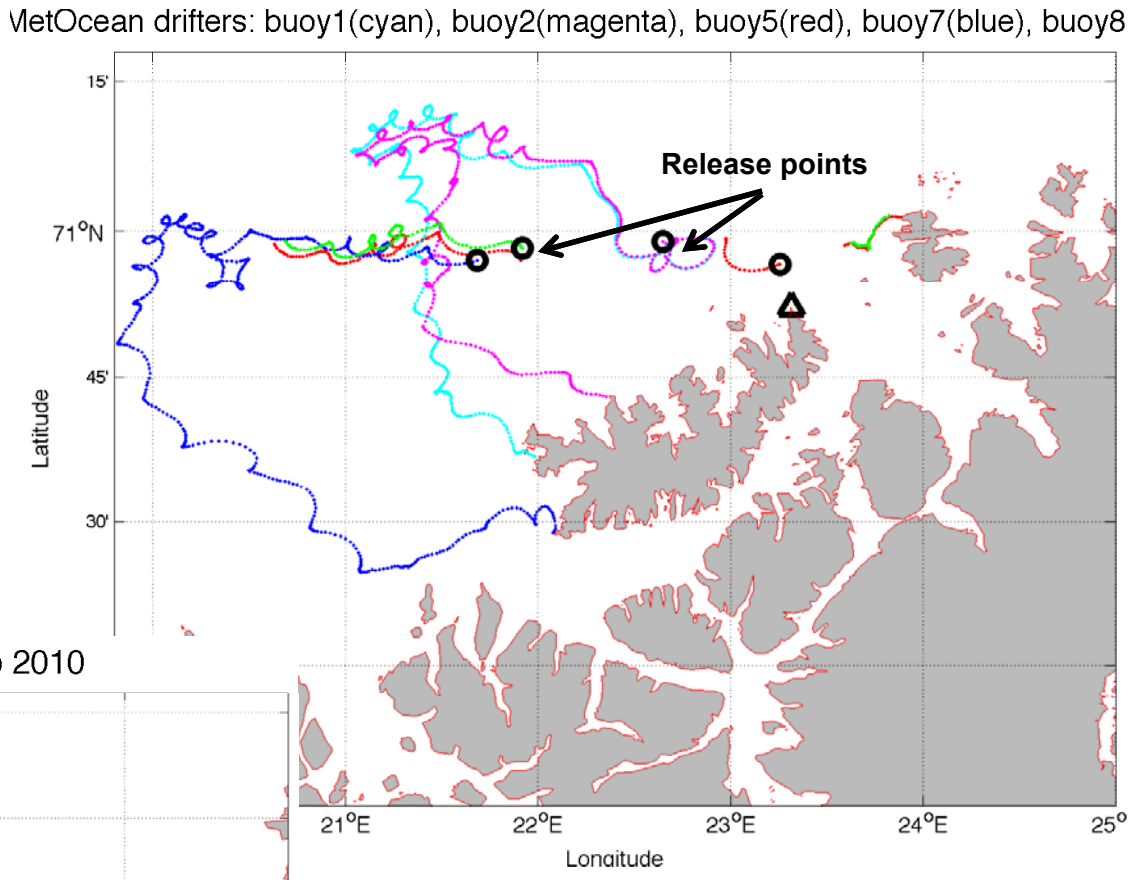
Pattern was confirmed by measuring with transponder aboard a boat

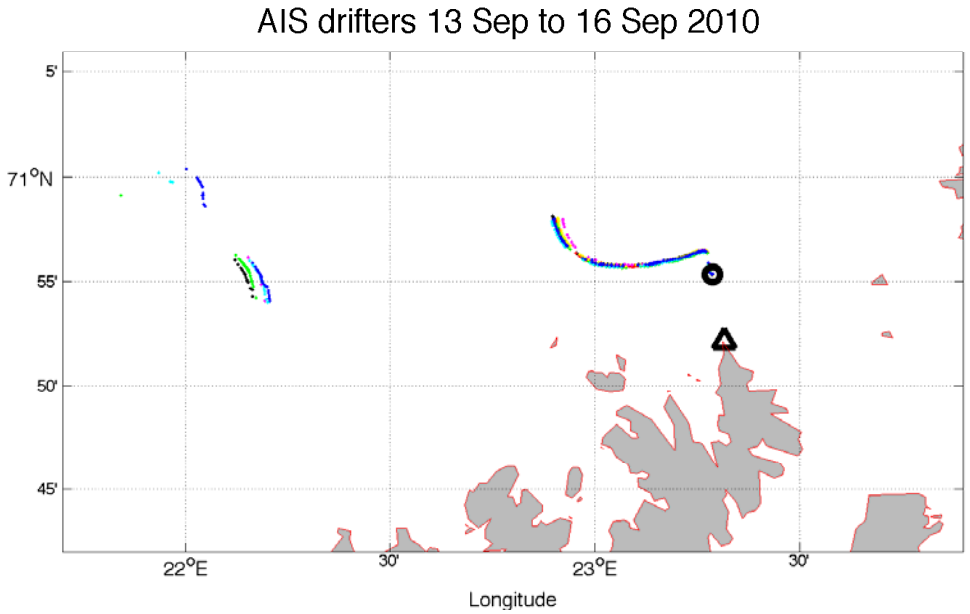


Oil Drifters Deployed for Comparison and HF validation

8x Aanderaa Oil Drifters using AIS

6x MetOcean Argosphere Oil Drifters using Iridium





Very strong winds in the release ≈ **20knots (10m/s) !!** ➔ drifters out of the total vector OMA domain

Conclusions:

- The rapid deployment (some hours) mobile Radar HF have been succesfully tested in northern Norway
- The (real time) “rapid” OMA 2d vectors are succesfully created
- A first radial validation of the mobile radar unit has been performed

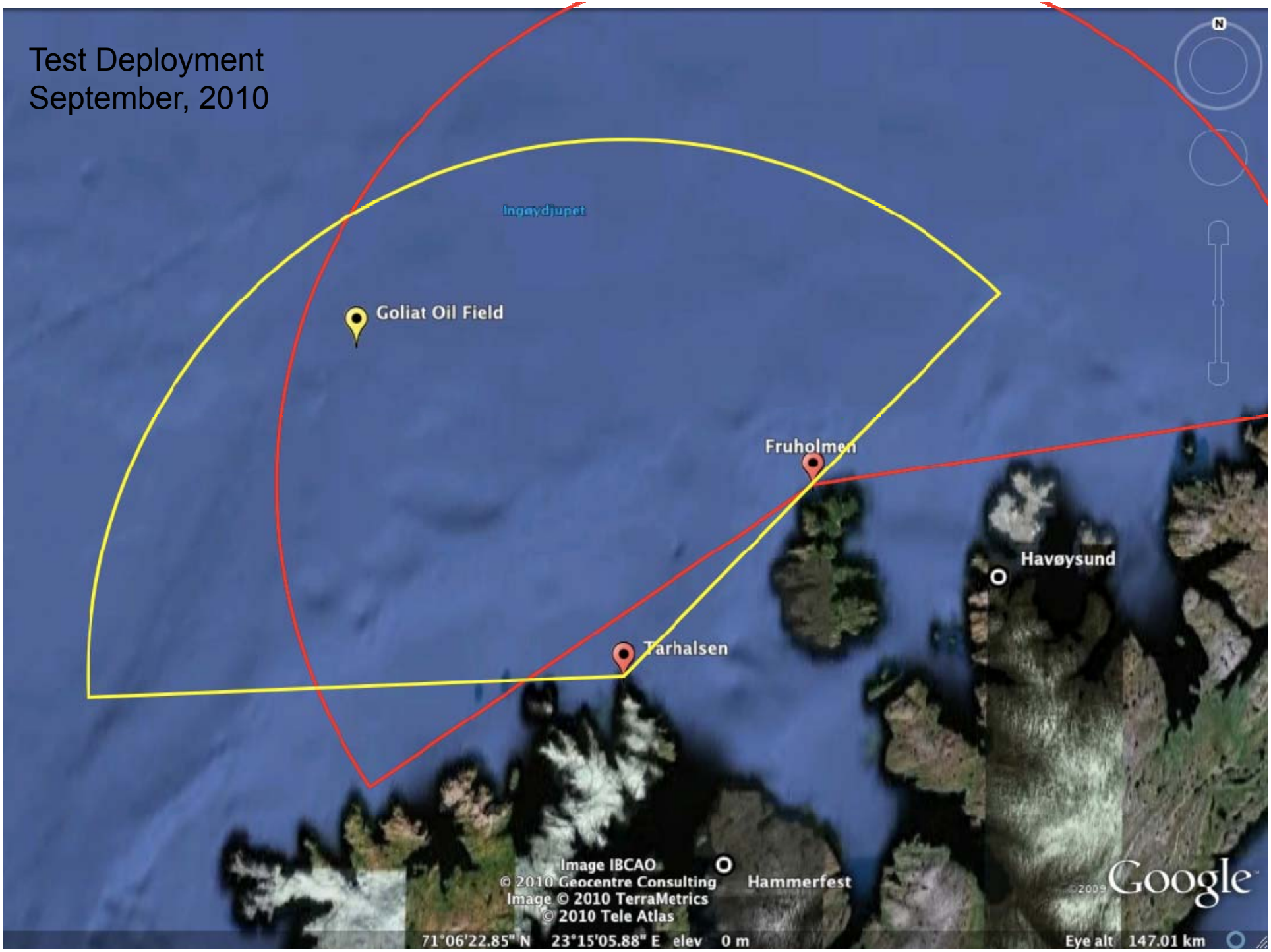
Next Steps:

- Evaluate and Revise Shelter & Antenna Design
- Compare **qualitatively** HF Current Fields with and without OMA applied to drifters deployed during experiment
- Apply and evaluate data “blending” technique to spill trajectory forecasts

Thank you!

Data Blending
The Norwegian Meteorological Institute

- Attempts to assimilate HF current data have been tried, but the results thus far are that the improvement to ocean forecasts is generally short-lived and very localized in space
- Coastal current quickly advects any assimilation effects out of domain
- **Blend HF current fields** with ocean model fields ,where available, for use directly in the operational oil drift system.
- Blending will provide smooth fields with a gradual transition from pure model to almost pure HF- derived currents where coverage is good
- Use error estimates included with SeaSonde outputs


Test Deployment
September, 2010
Ingøydjupet
Goliat Oil Field
Fruholmen
Havøysund
Tarhalsen
Hammerfest
Image IBCAO
© 2010 Geocentre Consulting
Image © 2010 TerraMetrics
© 2010 Tele Atlas
71°06'22.85" N 23°15'05.88" E elev 0 m
Eye alt 147.01 km
Google