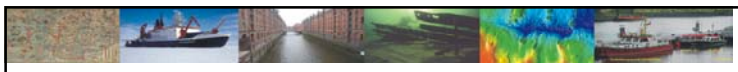

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T5I – Hydrographic Surveying in Practise (2966)

Investigation of Attitude Sensors for Hydrographic Applications

– GNSS, Motion Sensor and Low Cost Sensors
-First results-

Volker Böder

Integrating the Generations

FIG Working Week 2008

Stockholm, Sweden 14-19 June 2008

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Motivation

- Especially multibeam however also singlebeam applications need high reliable attitude determination
  - Direct referencing with RTK: heading, roll, pitch
  - Indirect referencing with tides: heave, roll, pitch
- Challenge: dm-accuracy in shallow waters
  - Wreck search, feature detection
  - Archaeology
  - Exploration
- Different sensor technology is available
  - GNSS, IMU (AHRS, INS)
- Missing: control of attitude determination
  - System calibration in MBES before measurement
  - SBES?

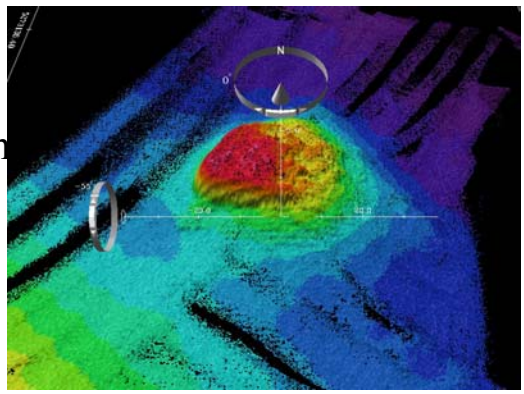
Equipment

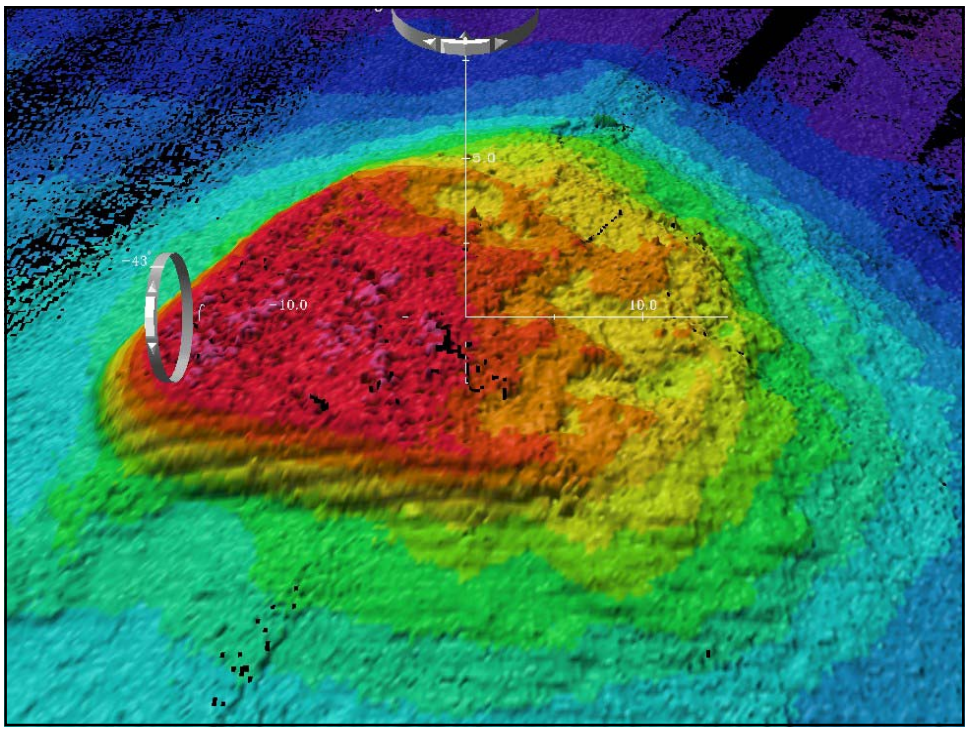
- ***Positioning and Attitude Determination***
  - Leica: System 500 (RTK)
  - Javad: JAVAD 4 Gyro (GNSS Positioning and Attitude)
  - Geo++ GNSS-Software GNATTI
  - IXSEA: OCTANS III (fiberoptic IMU)
- ***Echosounder Reson SeaBat 8101***

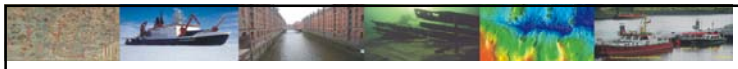
Photo from P. Andree

Archaeology under water

- „Mäuseturm“ in Güttingen, CH
- Cooperation with Archaeologists from Kanton Thurgau
- Manmade structure (completly?), probably Middle Ages







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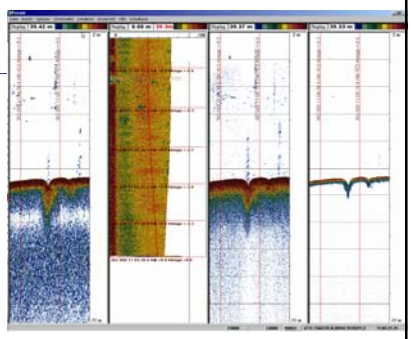
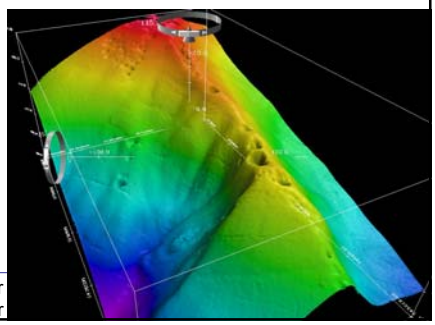
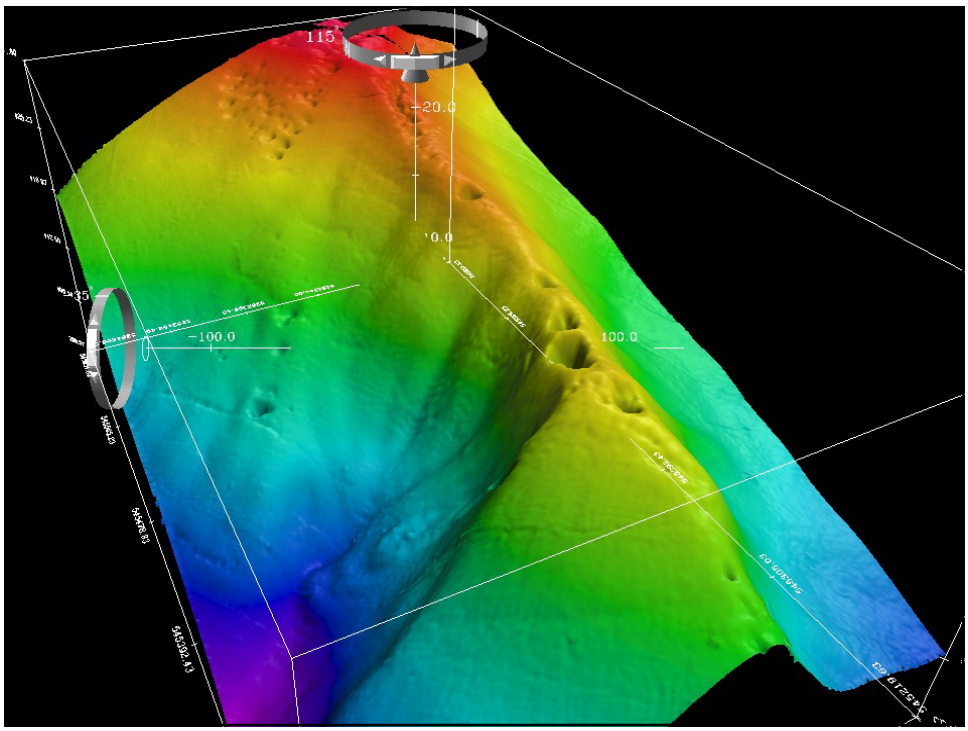
Research/Exploration

- Cooperation with „Institut für Seenforschung“, Lake Constance
  - With Dr. Martin Wessels
  - Methane gas?

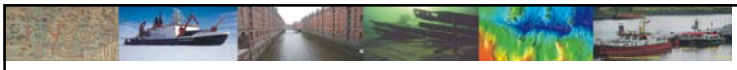






Advantages/Disadvantages GNSS/IMU

GNSS	Inertial Measurement Units
+ no drift + long baseline: high accuracy + price ?	+ high data rate + usually small unit
- Short baseline: low accuracy - Low data rate (usually 10 Hz, but increasing) - signal shading (installation on board, buildings, cranes, quay walls …)	- Drift - Influences by high dynamics - Location on board should be near gravitational center



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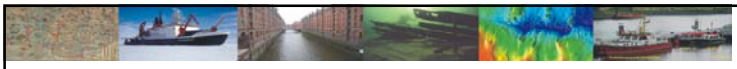
Investigations

- Project Norwegian Gem
  - GNSS
  - Motion sensor without GNSS support
  - Motion sensor with GNSS support
- Comparison GNSS – Motion Sensor
- Investigation of "just another sensor"
- Investigation Low Cost Sensor



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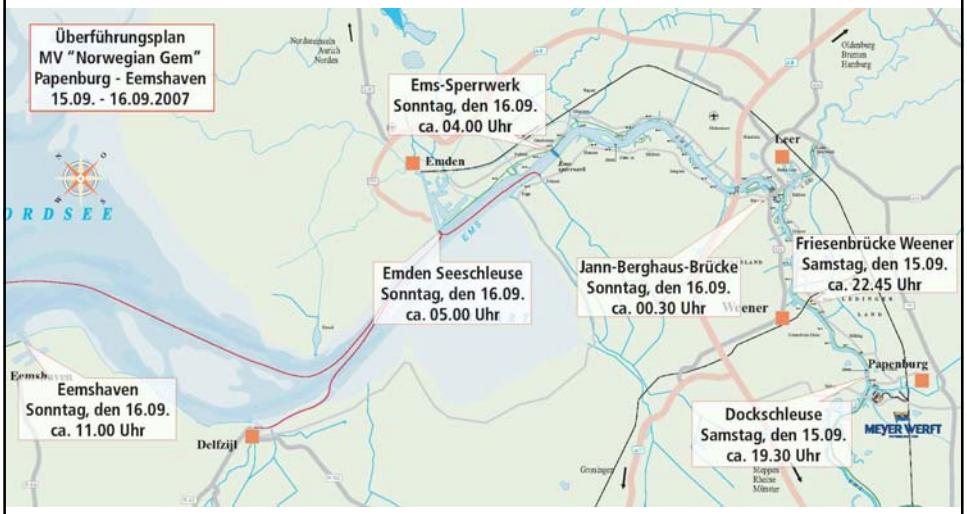
Project Norwegian Gem

- Goal of the Project
  - Shipping of luxury ship backwards along the river Ems
    - Length 300 m, width 32 m
  - High accuracy needed for precise navigation

- Project carried out by
  - HydroSupport: Bernd Koop
  - LGN: Cadastre and Land Surveying Authority of Lower Saxony
  - Investigation of attitude sensors within diploma thesis at HCU
    - Mario Röttger

Project Norwegian Gem

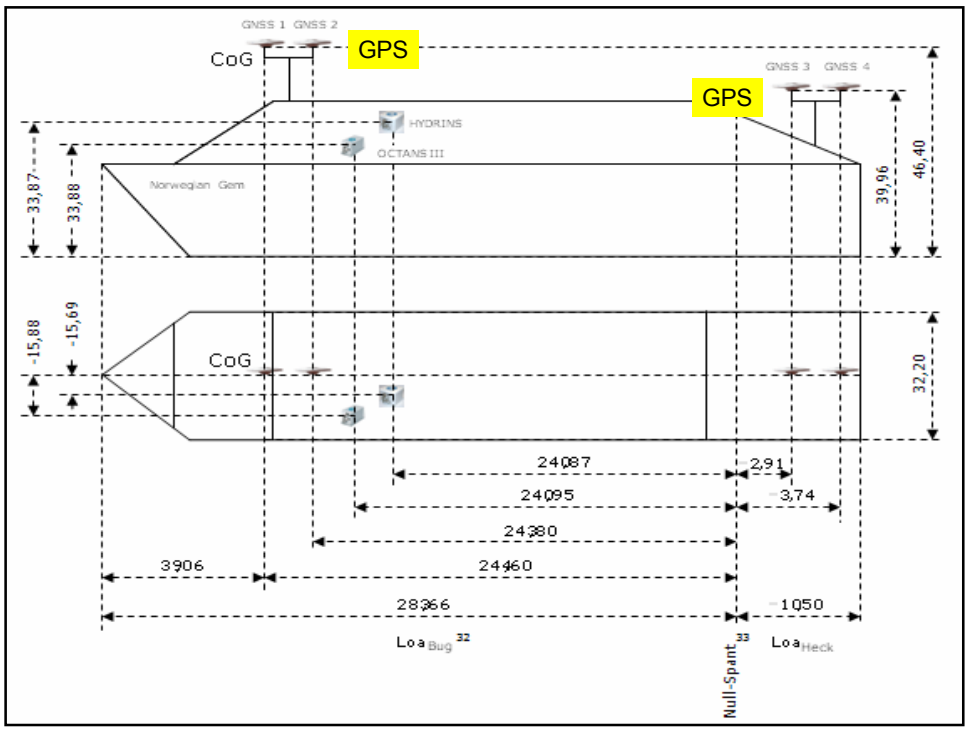


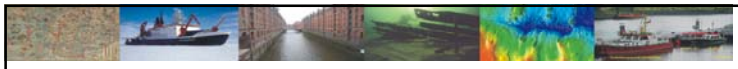
Accuracy of Attitude Sensors

- GNSS (geodetic equipment)
  - Depending on length of baseline between antenna
    - Approximation for accuracy
      - 0,3 [deg * m] / Length [m] for Heading (300 m : 0,001°)
      - 0,5 [deg * m] / Length [m] for Roll and Pitch
      - Higher accuracy with more sensors

- IXSEA OCTANS III
  - Heading
    - 0,1° secant latitude (HH: 0,17°)
    - Drift 0,05°/h
  - Roll/Pitch
    - 0,01°

- IXSEA HYDRINS
  - Heading
    - 0,02° secant latitude (HH: 0,034°)
    - Drift 0,01°/h
  - Roll / Pitch: see OCTANS III





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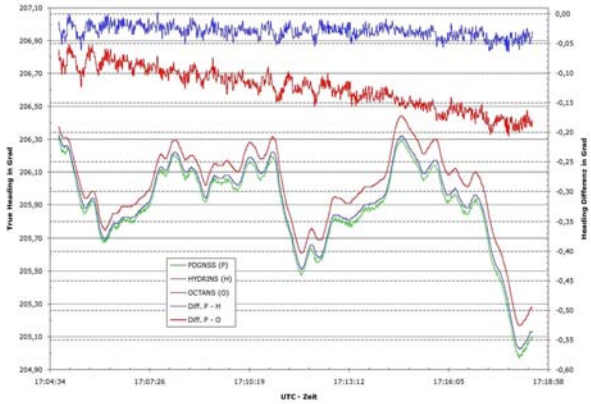
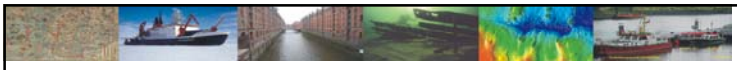
Project Norwegian Gem

Difference between GPS-ATTI, HYDRINS and OCTANS



- Motion Heading
  - 1,3° in 14 min
- Differences
  - GPS – OCTANS
    - Noise <0,1°
    - Drift 0,1° / 14 min !
  - GPS – HYDRINS
    - +/- 0,02°
    - Drift 0,01°/14min => 0,04°/h √



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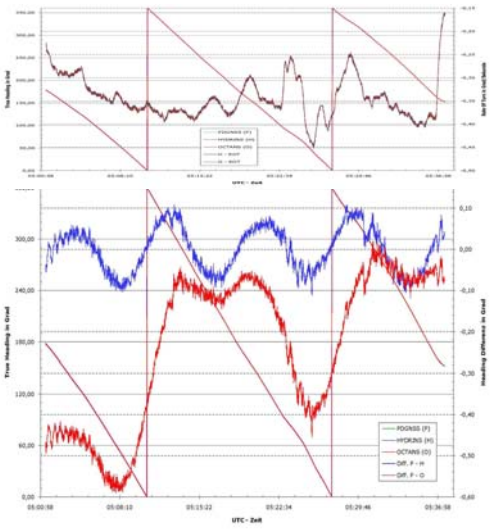
Project Norwegian Gem



- Motion in Heading
  - 2 circles in 36 min
- Rate of Turn
  - Varies between -0,25°/s to -0,45°/s
- Differences between
  - GPS-ATTI and OCTANS (unsupported IMU)
    - -0,6° to 0°
    - Drift 0,5°/5 min !
  - GPS-ATTI and HYDRINS (IMU supported by GNSS)
    - +/- 0,1°

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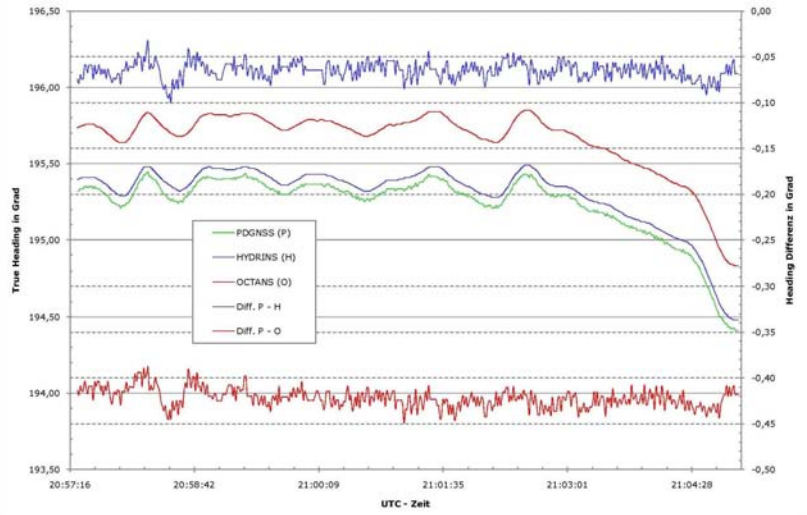
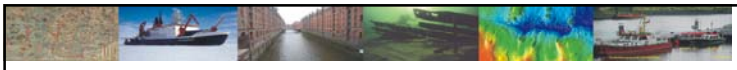
Project Norwegian Gem





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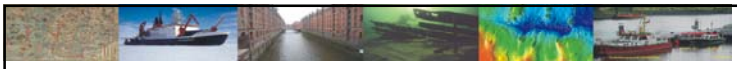
Conclusions Project Norwegian Gem

- HYDRINS operates within specifications
- OCTANS III didn't work within the specifications, as expected before
  - Replaced by another OCTANS III from IXSEA
- GPS supported IMU work properly and reliable
- GPS best method in this case, because of the long baseline (250 m)

- Shipping successful !!



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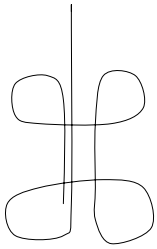
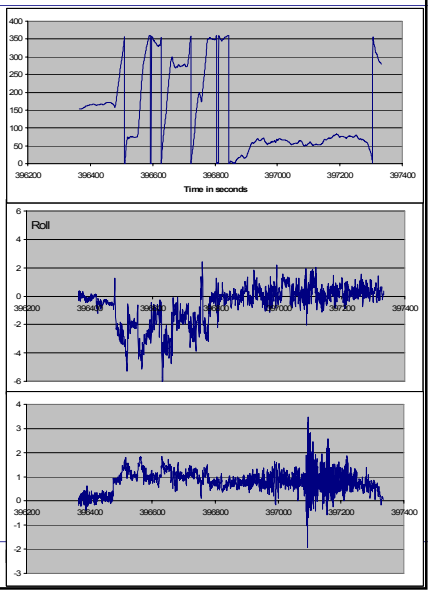
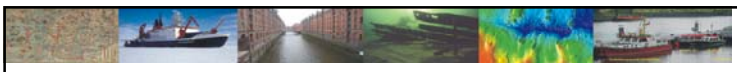
Investigation GNSS – OCTANS III (new)

"Cloverleaf" manoeuvre

Heading	0° to 360°
Roll	-6° to +2°
Pitch	-1° to +3°







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Investigation GNSS – OCTANS III (new)

"Cloverleaf" manoeuvre

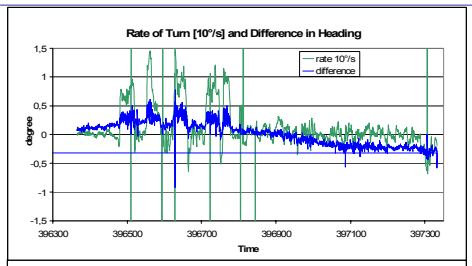
Heading

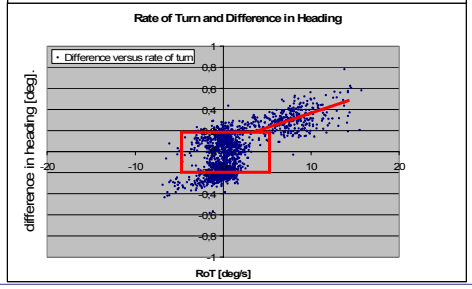
RoT < 5°/s
⇒ within specifications

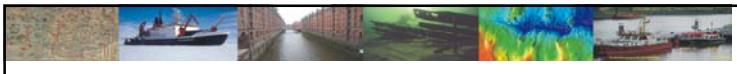
RoT > 5°/s
⇒ increasing errors ?

Drift after manoeuvre?

Additional investigation will follow







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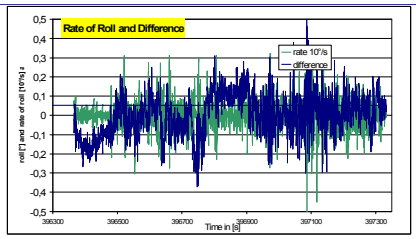
Investigation GNSS – OCTANS III (new)

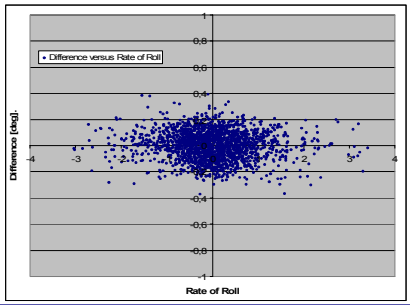
"Cloverleaf" manoeuvre

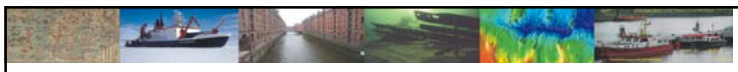
Roll

⇒ within specifications

(of GNSS-Attitude)







Conclusion GNSS – OCTANS III (new)

"Cloverleaf" manoeuvre

Roll and Pitch
within specifications of GNSS-Attitude

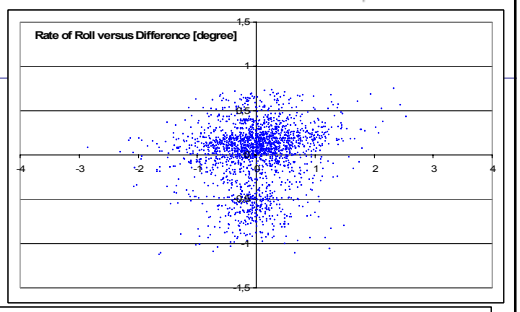
Heading
shows increasing errors starting from
rate of turn of ca. 5°/s

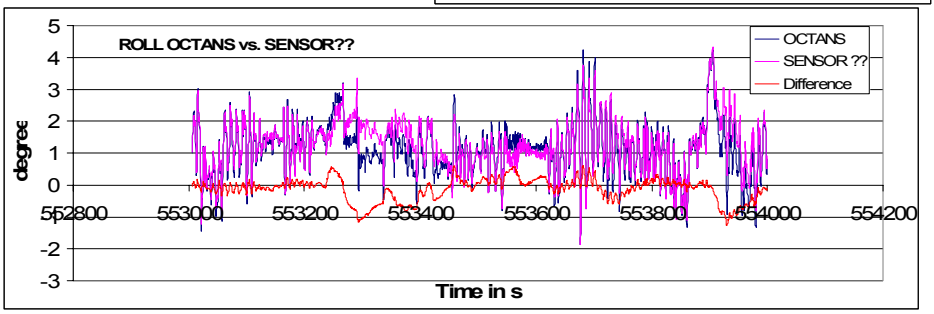
Just another sensor

- Project Lake Constance
- Investigation
  - Geo++ - GNATTI
  - IXSEA OCTANS
  - SENSOR ?? (anonymous)
    - Sensor sold with new echosounder (not HCU!)
    - Installed as good as possible, but not in gravitation center
    - Installation was not optimal !!
    - Announced accuracy 0,3° in roll and pitch
  - First result: be aware of + and – declaration!
    - Offsets and
    - Angle definition

Results OCTANS - ??

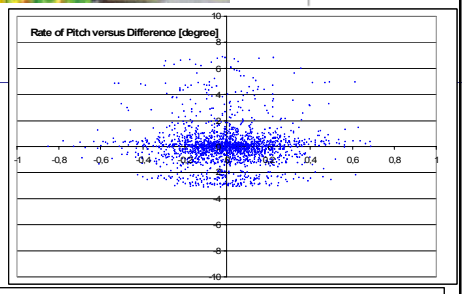
- Roll
  - -1° to +4°
  - Rate of Roll: ca. +/- 2°/s
  - Std.dev. dROLL: 0,35° √

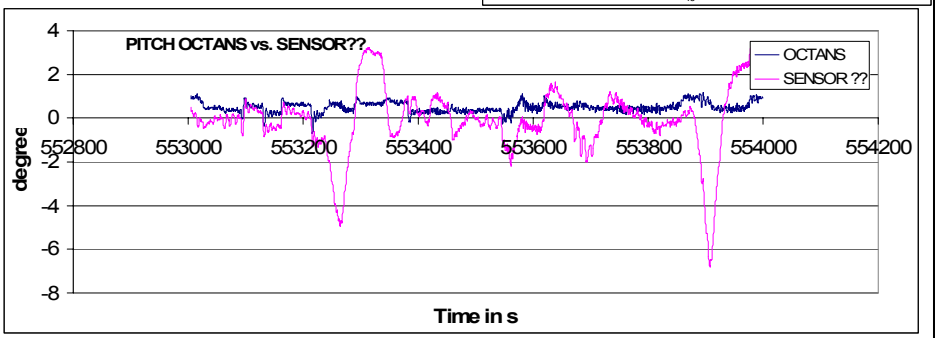




Results OCTANS - ??

- Pitch
  - -0,5° to +1°
  - Rate of Pitch: ca. +/- 0,8°/s
  - Std.dev. dROLL: 1,5°





Low-Cost Sensor XSENS MTi

- Diploma Thesis Michael Barth
- Xsens MTi consists of
  - 3 fiber optical gyro, 3 accelerometer and 3 magnetometer
  - MEMS-components (micro electronic measuring system)
  - output in quaternions and/or Euler

Heading	
Static Accuracy	<1 deg
Resolution	0.05 deg
Roll / Pitch	
Static Accuracy	<0.05 deg (for ±90 deg amplitude)
Range No limitation	(-180 deg to 180 deg)
Resolution	0.05 deg
Dynamic Accuracy	2 deg RMS

Tests on Survey Launch Level-A

Xsens MTi

IxSea Octans III

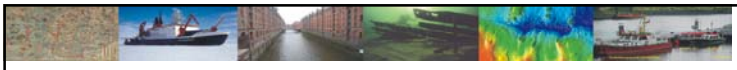
JAVAD 4 Gyro
Geo++ GNATTI

Performance

Heading	
Static Accuracy	<1 deg
Resolution	0.05 deg
Roll / Pitch	
Static Accuracy	<0.05 deg (for ±90 deg amplitude)
Range No limitation	(-180 deg to 180 deg)
Resolution	0.05 deg
Dynamic Accuracy	2 deg RMS

Heading	
Accuracy	0.1 deg secant latitude
Resolution	0.01 deg
Settling time (static conditions)	< 1 min
Full accuracy settling time (all conditions)	< 5 min
Heave / Surge / Sway	
Accuracy	5 cm or 5% (whichever is highest) Set-up free (SAFE-HEAVE ™)
Roll / Pitch	
Dynamic accuracy	0.01 deg (for ±90 deg amplitude)
Range	No limitation (-180 deg to 180 deg)
Resolution	0.001 deg

Modus	Navigation	Positionierung
Kurs (Heading)	0.06 deg ' 0.12 deg ''	0.10 deg '''
Stampfen (Pitch)	0.15 deg ' 0.29 deg ''	0.10 deg '''
Rollen (roll)	0.25 deg ' 0.20 deg ''	0.25 deg '''
Genauigkeit 2D	0.5 ... 1 m	1 ... 5 cm
Genauigkeit Höhe	0.5 ... 1 m	2 ... 5 cm



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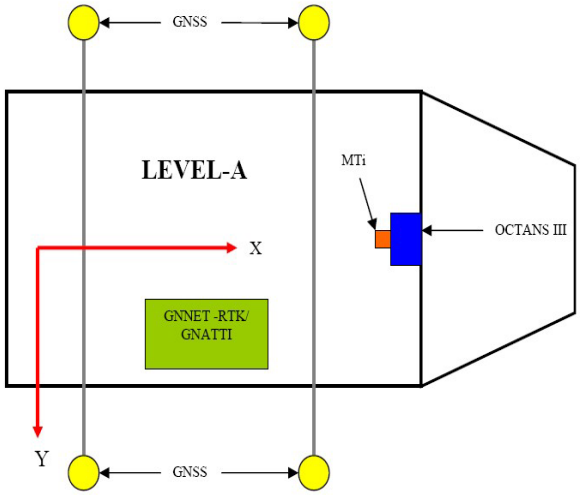
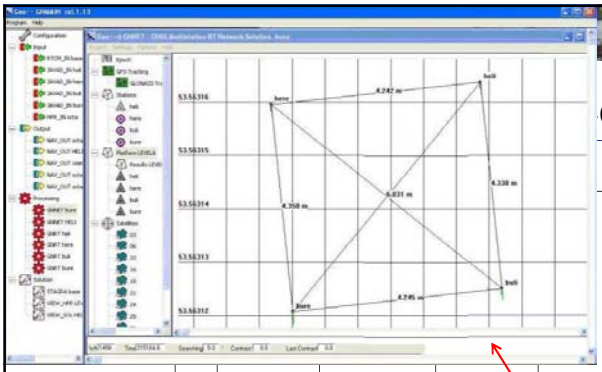
Survey Launch Level-A





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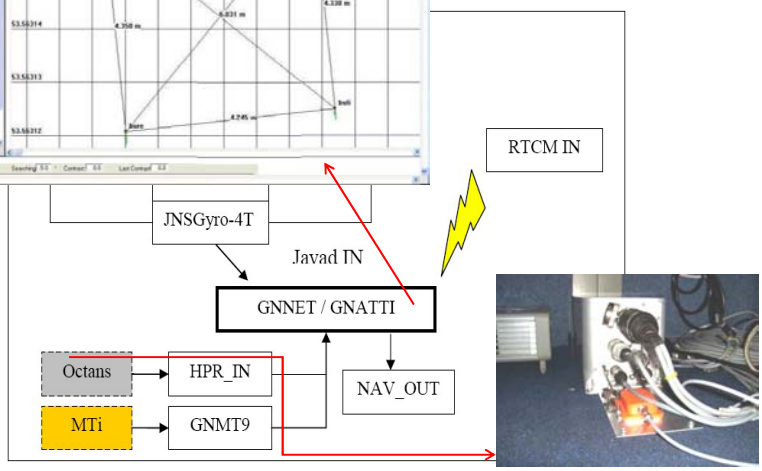
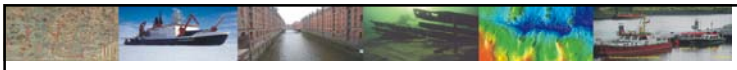
evel-A





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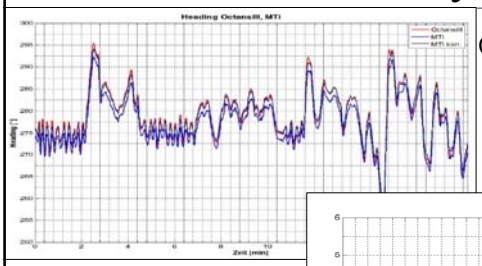
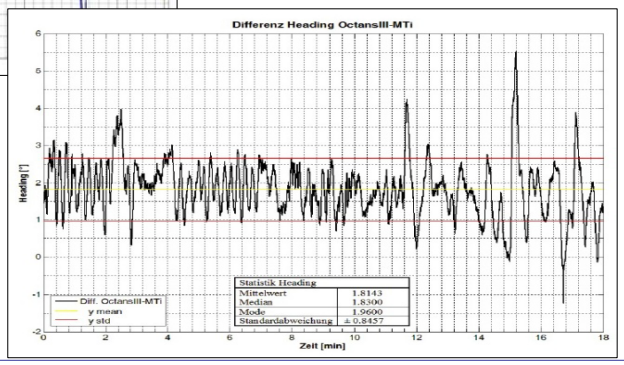
Tests on Survey Launch Level-A



Comparison between Octans III and MTi



Mean difference:
1.8° +/- 0.8°

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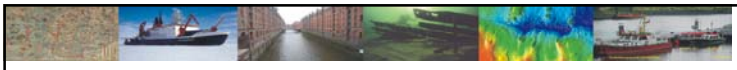
Conclusions XSENS MTi

Messung	Heading			Pitch			Roll		
	Mean	Std.	Range	Mean	Std.	Range	Mean	Std.	Range
C2	2,4°	±0,9°	13,5°	0,6°	±0,8°	3,3°	1,7°	±0,3°	4,4°
C3	1,5°	±0,7°	6,8°	0,7°	±0,1°	1,9°	1,5°	±0,3°	2,6°
C4	1,8°	±0,8°	6,8°	0,4°	±0,6°	1,3°	1,8°	±0,2°	2,7°

- within specifications regarding std. dev., but several outliers
  - (see the range)

→ heading: homogeneous magnetic surrounding necessary
→ sometimes deviations >40° in heading, not shown here



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Conclusions

- Each motion sensor has own error characteristics, depending on
  - dynamics
    - of the ship
    - of the location on board the ship.
  - Vibrations on board
  - geographical latitude
  - Magnetic influences (In case of use of magnetometer inside the motion sensor)
- Reducing the error
  - GNSS support / use
  - System calibration before measurement (!),
  - calibration of motion sensors (?)
- Take care of all sensors !
- First results inside other projects
  - Goal: systematic investigation / calibration procedure

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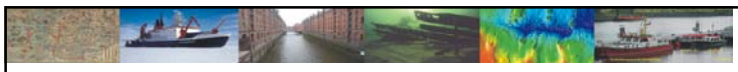
HafenCity University Hamburg
Department of Geomatics
volker.boeder@hcu-hamburg.de

IHSC2007

Thanks for your attention
and have a nice evening



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Add ons

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2nd IHSC 2008

- **Addressed to interested students**
- **18.08.-30.08.2008 at the Schlei**
- **Near ancient Viking Metropolis Hedeby (Haithabu)**
- **No participation fees**
  - **accomodation must be paid**
    - **bed for 6 Euros in a Danish Rowing Club with kitchen**
- **Contact to Producers, Companies and Archaeologists**
- **Searching for**
  - **Wrecks (ships and planes), underwater archaelogical sites, morphological structures**

Participants of IHSC 2007

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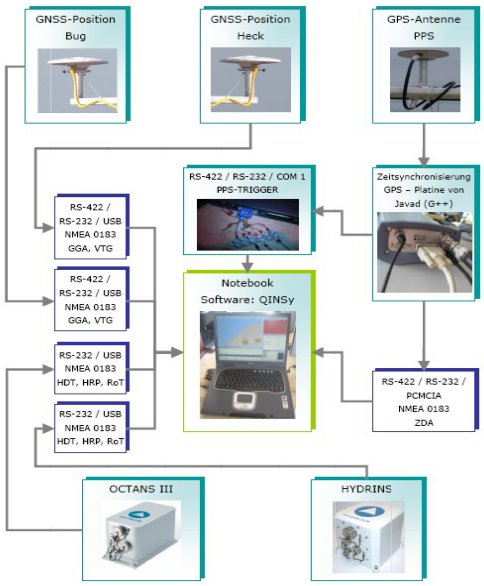
Welcome to the
- IHSC at the Schlei (18.08.-30.08.2008)
- in the course M.Sc. Hydrography (application until July, 15th, 2008)?

Platform Norwegian Gem



Project Norwegian Gem

- Investigation of Attitude Sensors
  - GPS-Attitude
    - 4 GPS-antennae
  - IMU with GPS-Support
    - IXSEA HYDRINS
  - IMU without GPS-Support
    - IXSEA OCTANS III
    - Known before the project:
      - Showing abnormal drifting in hydrographic measurement

      => Inestigation necessary