SWOT Ocean CalVal

17. Bonnefond (FR) – FOAMS: calibration/validation
18. Melville/Lenain (US) - Airborne ocean topography measurements
19. Mertikas (Greece) – CalVal at the Gavdos Site of Crete
20. Watson (Australia) – Studies around Australia
21. Matsui (Japan) – SWOT-JAXA: Japanese oceanographic research in SWOT.

See also CalVal part in:

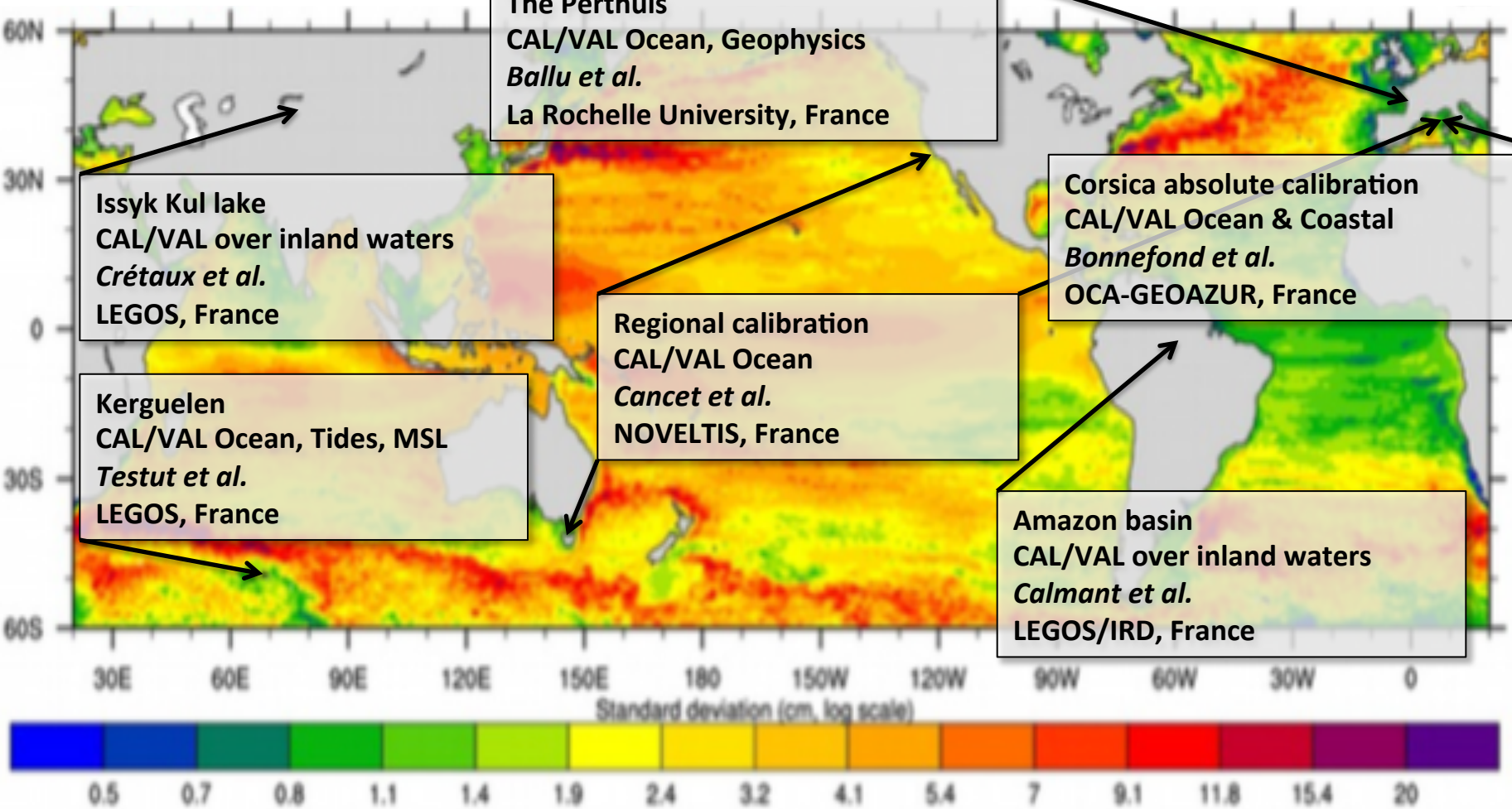
6. Gourdeau/Marin/Ganachaud (FR) – Tropics: A case study in the South West Pacific

Using FOAM project facilities for SWOT CAL/VAL (FOAMS)

FOAM: From Ocean to inland waters Altimetry Monitoring

Goal: aggregate the past and current effort of several groups, in order to notably establish a **homogeneous network of calibration sites** geographically distributed for more robust characterization of the existing and future radar altimeter system instrument biases and their drifts **over ocean and inland waters**. The group is also involved in the **development of high resolution models** (tides and Dynamic Atmospheric Correction).

~40 peer review publications from 2008 to 2016



The Perthuis
CAL/VAL Ocean, Geophysics
Ballu et al.
La Rochelle University, France

Issyk Kul lake
CAL/VAL over inland waters
Crétaux et al.
LEGOS, France

Corsica absolute calibration
CAL/VAL Ocean & Coastal
Bonnefond et al.
OCA-GEOAZUR, France

Regional calibration
CAL/VAL Ocean
Cancet et al.
NOVELTIS, France

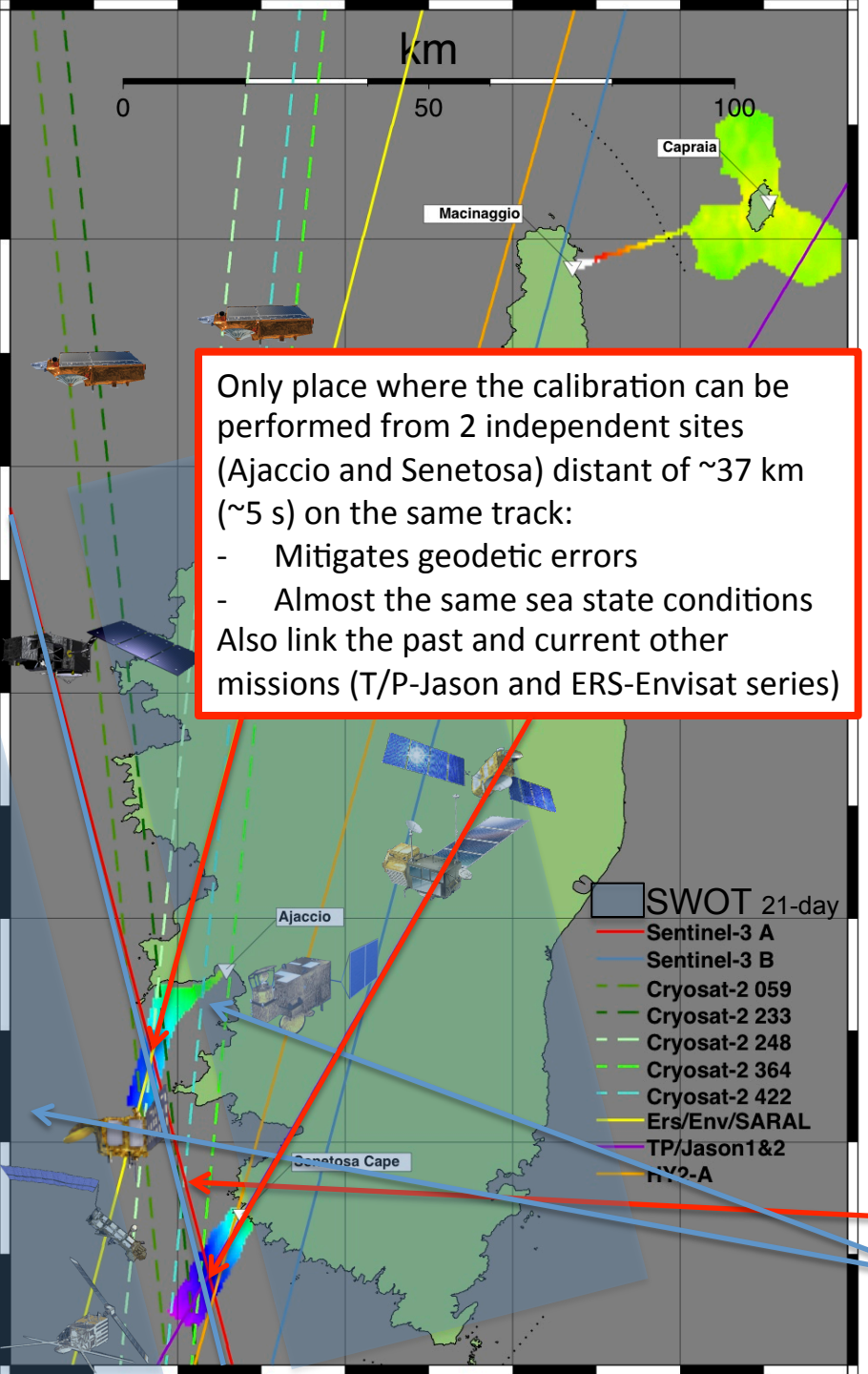
Kerguelen
CAL/VAL Ocean, Tides, MSL
Testut et al.
LEGOS, France

Amazon basin
CAL/VAL over inland waters
Calmant et al.
LEGOS/IRD, France

SWOT Science Definition Team meeting, 13-16 June 2013, Pasadena, USA

Corsica Multi-mission Calibration Site

***P. BONNEFOND*[1]**, *O. LAURAIN*[2], *P. EXERTIER*[2], *T. GUINLE*[3], *P. FEMENIAS*[4]
[1]OP/SYRTE, Paris, France; [2]OCA/GEOAZUR, Sophia-Antipolis, France; [3]CNES, Toulouse, France; [4]ESA/ESRIN, Frascati, Italy



Only place where the calibration can be performed from 2 independent sites (Ajaccio and Senetosa) distant of ~37 km (~5 s) on the same track:

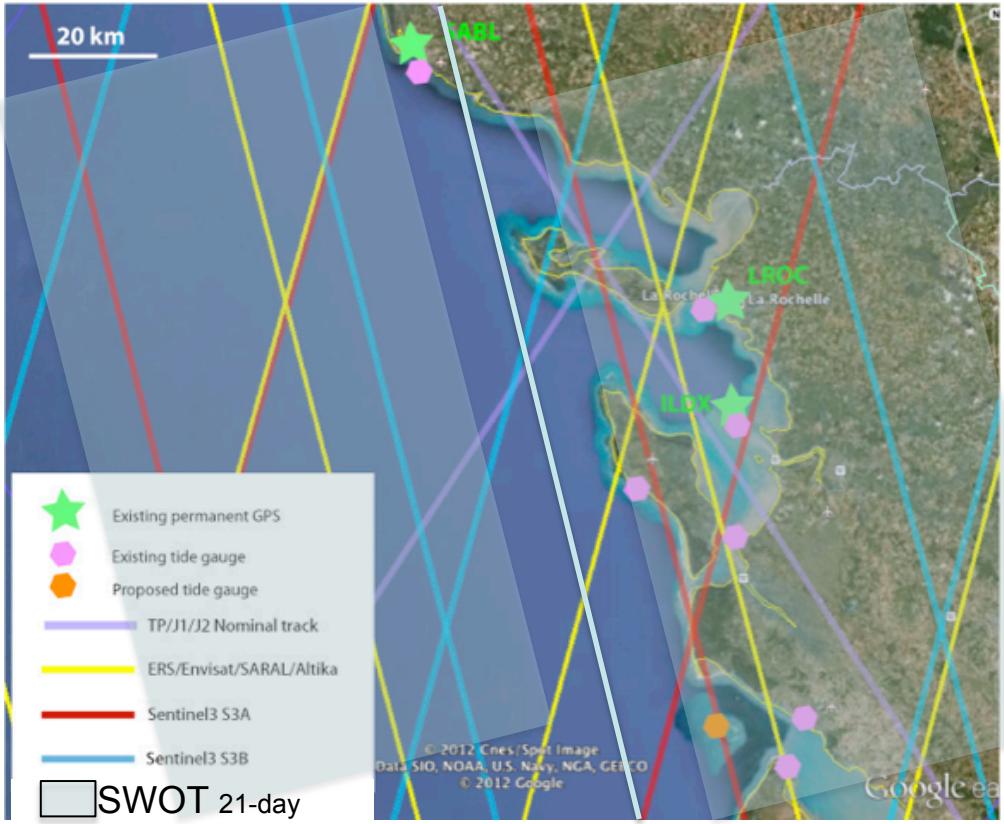
- Mitigates geodetic errors
- Almost the same sea state conditions

Also link the past and current other missions (T/P-Jason and ERS-Envisat series)

- **Senetosa CNES calibration site** established in 1998
  - Supports continuous monitoring of Jason-2&3 (and formerly T/P and Jason-1)
  - Equipped with 4 pressure tide gauges leveled to the permanent GPS receiver
- **Ajaccio configuration** established in 2000
  - Supports continuous monitoring of SARAL/ALtiKa (and formerly ERS, Envisat)
  - Fiducial point near Ajaccio equipped with GPS/ SLR(FTLRS)/DORIS.
  - Equipped with a radar tide gauge (SHOM) leveled to the permanent GPS receiver
- **Corsica multi-mission calibration site: existing facilities also used for CryoSat-2, HY-2A and Sentinel-3A**
- **Open-ocean altimeter readings** connected to tide gauges via detailed **local geoid model**
  - Derived from intensive GPS buoy and catamaran surveys along ground track (in 1999 for Senetosa. Extension to Ajaccio (2005) and Capraia (2004)
  - Open-ocean verification locations for GPS-based SSH measurement systems deployments.
  - **Planned connection of the Ajaccio and Senetosa local geoids along the Sentinel-3A track**
  - **Planned extension under SWOT swath in the Gulf of Ajaccio and offshore**

The Perthuis on the French Atlantic coast:

V. BALLU[1], L. TESTUT[1,2], X. BERTIN[1], M. GRAVELLE[1], P. TIPHANEAU[1], G. WOPPELMANN[1], F. FRAPPART[3], F. PEROSANZ[3]
[1]La Rochelle university, France ; [2]LEGOS, Toulouse, France; [3]GET, Toulouse, France



- **Redundant, quality and reliable data both on the atmosphere through GPS and meteorological data and on the sea level.**
- **Regular GPS buoy sessions beneath satellite tracks for absolute calibration purpose**
- **Investigate the coastal contamination effects on the range retracking and on the wet tropospheric correction**
- **The Cordouan lighthouse will also host the GNSS-R system (reflectometry)**
- **Existing high resolution models in the area including estuaries**

Satellite tracks in the area of the Perthuis, with existing tide gauges and GPS stations. The **proposed offshore tide gauge** is also shown in orange on the map (Cordouan lighthouse). In addition to the **three tide gauges collocated with on-land GPS** which are part of the SONEL program (La Rochelle, Ile d'Aix and Les Sables d'Olonne), four other tide gauges, belonging to the RONIM network are also available in the area and could benefit CAL/VAL activities in the area.

Regional CALVAL method: Validation at non-dedicated sites

M. CANCET[1], *E. JEANSOU*[1], *F. LYARD*[2]
[1]*NOVELTIS, Toulouse, France;* [2]*OMP/CNRS/LEGOS, Toulouse, France*

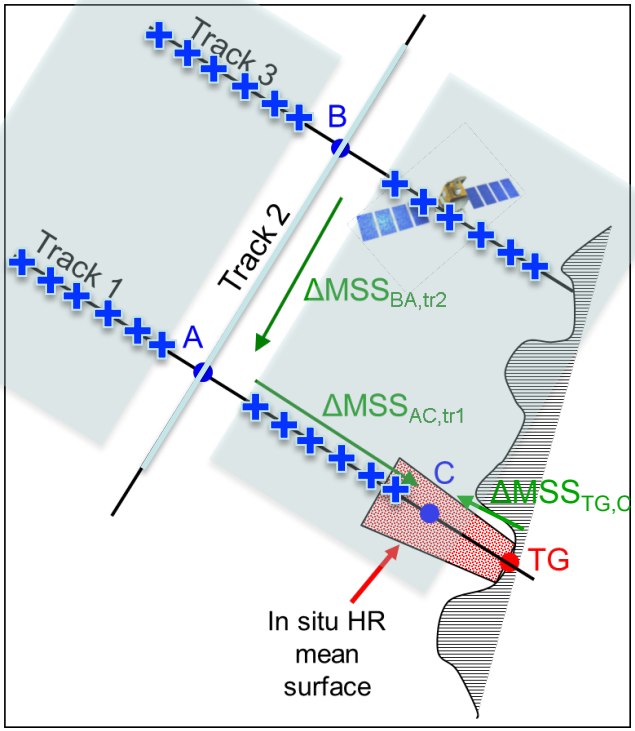
Combination of:

Absolute CALVAL: Direct comparison between altimeter and tide gauge SSH (point C).

✓Only for satellite passes flying over the calibration sites: directly comparable to the absolute bias estimates computed by the local in situ calval groups (Corsica, Harvest, Bass Strait, Gavdos…)

Offshore CALVAL: Computation of the bias on offshore passes (points A & B)

✓Following a succession of accurate mean sea surface profiles, combining several missions



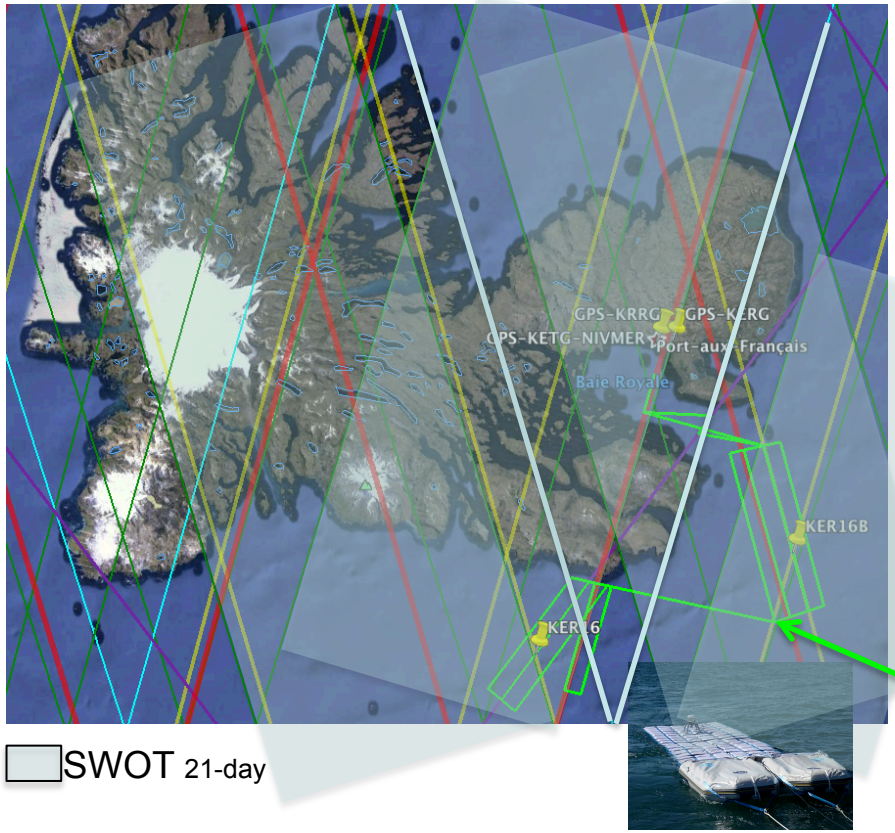
=> Regional CALVAL = Link between the local and global cal/val methods

→ Successfully applied for Jason-2, Envisat and SARAL/AltiKa at Bass Strait, Corsica and Harvest locations

→ Can be applied on a grid covering the SWOT swath in vicinity of the calibration sites

Kerguelen Islands CAL/VAL activities

***L. TESTUT*[1], *M. CALZAS*[2], *A. GUILLOT*[2], *C. DREZEN*[2], *P. BONNEFOND*[3]**
[1]LEGOS, Toulouse, France; [2]DT/INSU, Brest, France; [3]OP/SYRTE, Paris, France;



- **Permanent TG since 1993 at 20 Km from cal/val site**
- **Deployment of 3 moorings since 2009 under track #179**
- **GPS buoy session at cal/val site**
- **Instrumental development of a GPS buoy with DT/INSU**
- **Development of HR barotropic model for dealiasing**
- **"Geoid" mapping in January 2016**

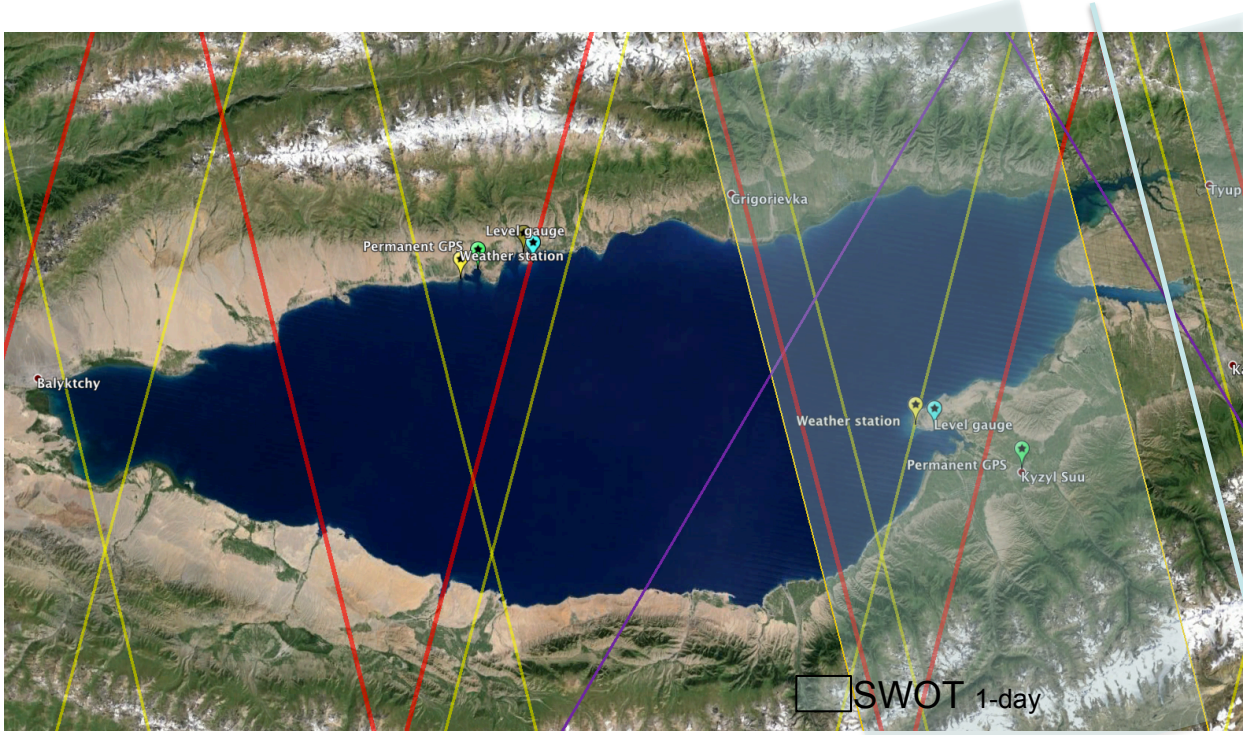
Main satellite tracks around Kerguelen Island. Satellite tracks are: red and blue respectively for Sentinel-3A and Sentinel-3B, purple for T/P and Jason, Yellow for ERS–1&2, Envisat and SARAL/AltiKa. The pins indicate the location of the tides gauges as well as the position of the moorings deployed under the Jason and SARAL/AltiKa). The reference tide gauge (actually made of two), part of the observatory including a permanent GPS station and a weather station.

Absolute calibration over the Lake Issykkul

J.-F. CRETAUX[1], M. BERGÉ-NGUYEN[1], S. CALMANT[1], F. FRAPPART[2], F. PEROSANZ[2], S. TASHBAEVA[3], V. ROMANOVSKI[3]
[1]LEGOS, Toulouse, France; [2]GET, Toulouse, France; [3]IWPH, Kyrgyz Republic

- **Permanent facility since 2004: weather stations, two permanent GPS stations and gauges**

- **Size of the Lake, ~6000 km²: all the past and current missions have over flown the lake: T/P, Jason-1/2/3, ERS-1&2 and Envisat, Geosat and GFO, Icesat, CryoSat-2, SARAL/AltiKa, Sentinel-3A**



- **Calibration experiments through cruise campaigns at overflight time over the lake Issyk-kul**

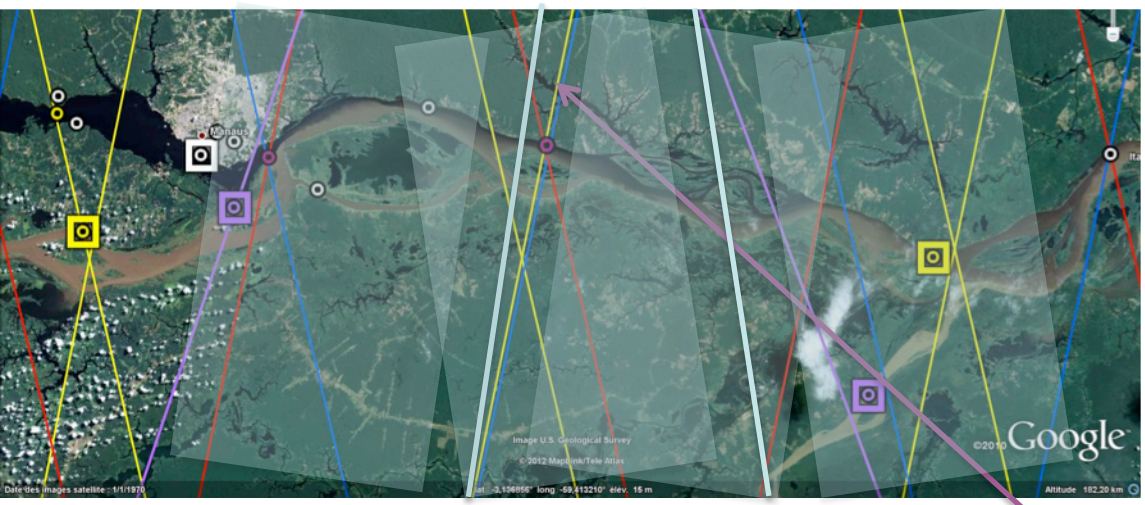
- **GNSS reflectometer near Cholpon Ata**

- **1 swath of SWOT will overfly the lake during the 1-day phase**

- **4 ground tracks (~6 swaths) during the 21-day phase**

Altimetry Biases over Amazon basin

***S. CALMANT*[1]**, *J.-F. CRETAUX[1], M. BERGÉ-NGUYEN[1], F. FRAPPART[2], F. PEROSANZ[2], F. SEYLER[3], J. SANTOS DA SILVA[4]*
[1]LEGOS, Toulouse, France; [2]GET, Toulouse, France; [3]IRD/ESPACE, Montpellier, France; [4]UEA, Manaus, Brazil

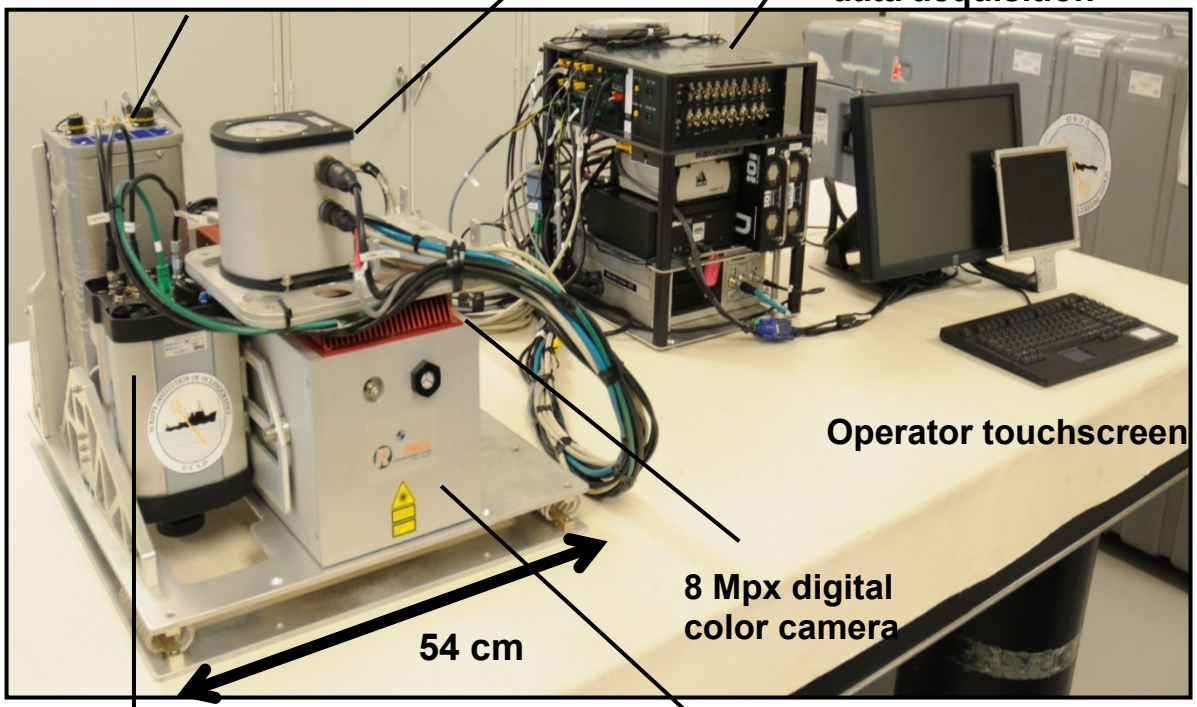


- **Large number of leveled gauges maintained and used for T/P, Jason and ERS/Envisat**
- **Three sites will be dedicated to the Sentinel-3 satellites, one already exists (the eastern most one), the two others has been installed in 2013, with first priority to the central one which also serve for SARAL/AltiKa**

Location of the in-situ equipments dedicated to the CAL/VAL activity along the Amazon River. **Dots stands for gauges, with the same color code as for the missions**, namely red for Sentinel-3A, blue for Sentinel-3B, yellow for ERS-Envisat-SARAL/AltiKa and purple for TOPEX/Poseidon and Jason-1&2. **Squares stand for the places with permanent GPS and weather stations**. Other places are just leveled with GPS.

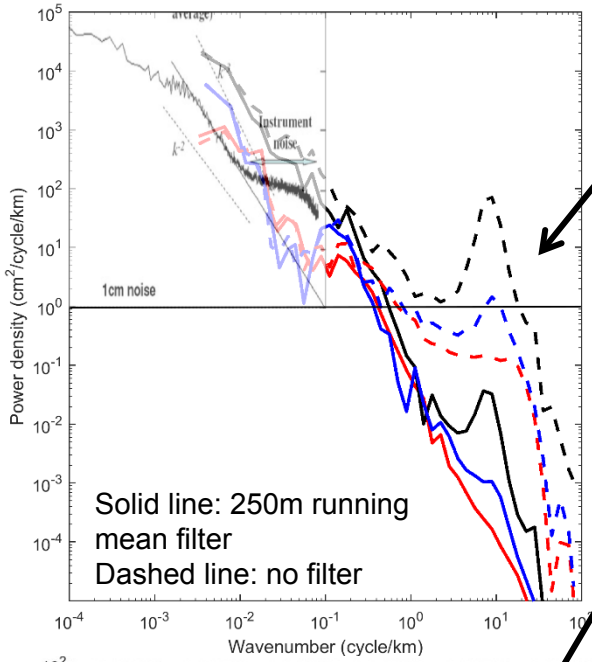
Lidar Altimetry, Surface Temperature, Waves and Currents from the SIO Modular Aerial Sensing System (MASS)

Ken Melville & Luc Lenain
Scripps Institution of Oceanography

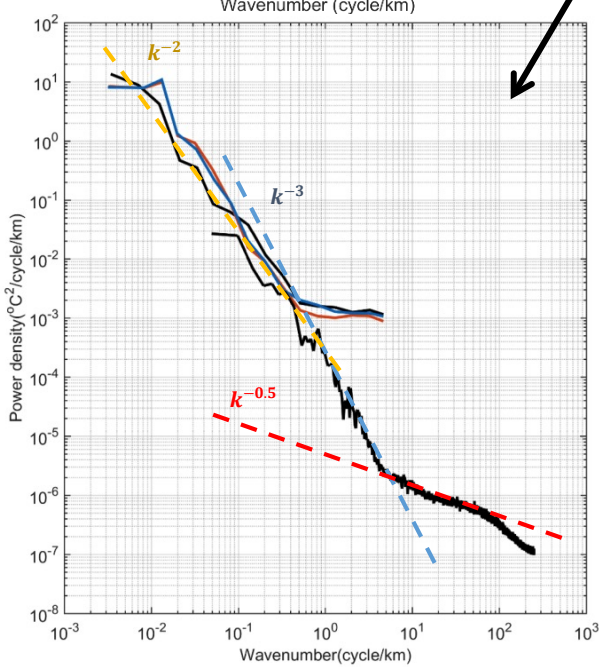


High-Resolution SSHA and SST from Airborne Altimetry and IR

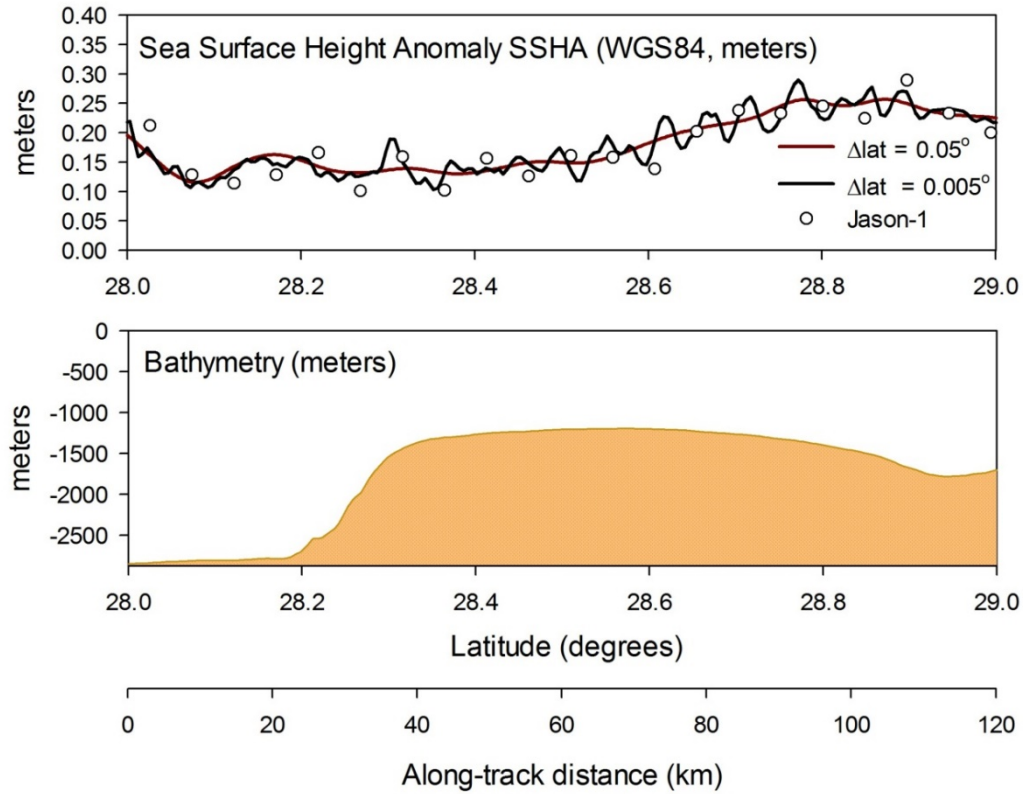
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego



SSH and SST wavenumber spectra in the Gulf of Mexico

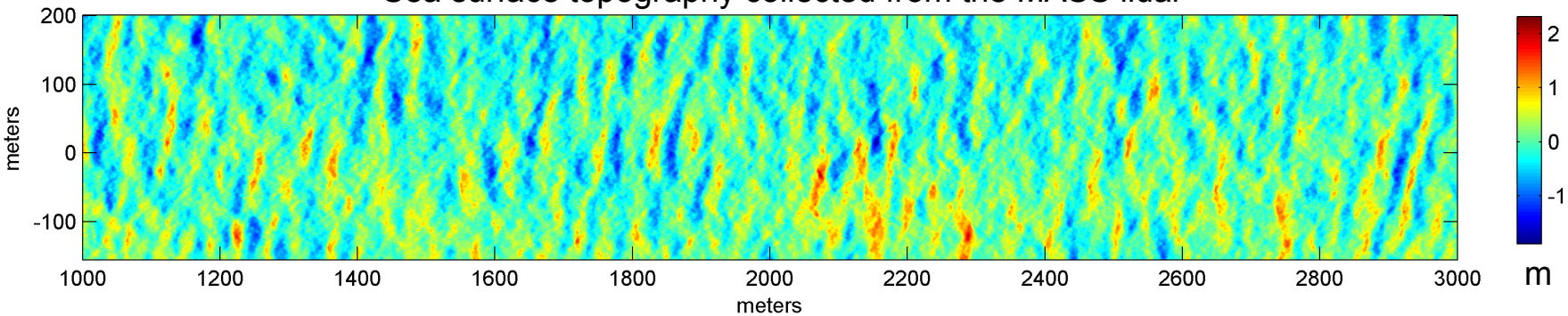


Comparison of SSHA from Jason-1 and the lidar altimeter along a satellite track in the Gulf of Mexico, October 2011.

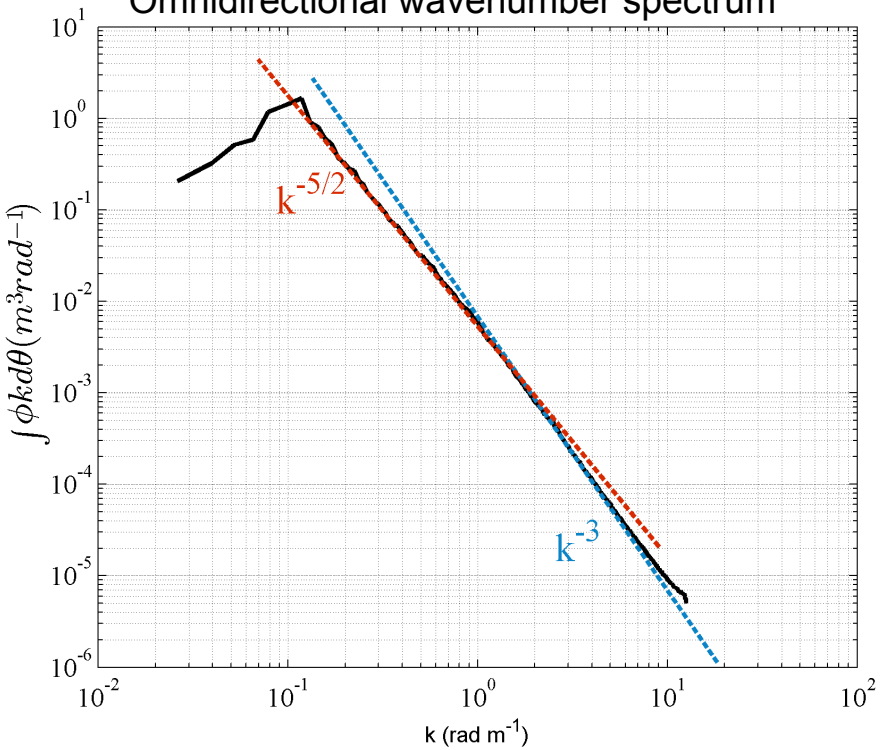


Surface Waves Measured by the MASS Lidar

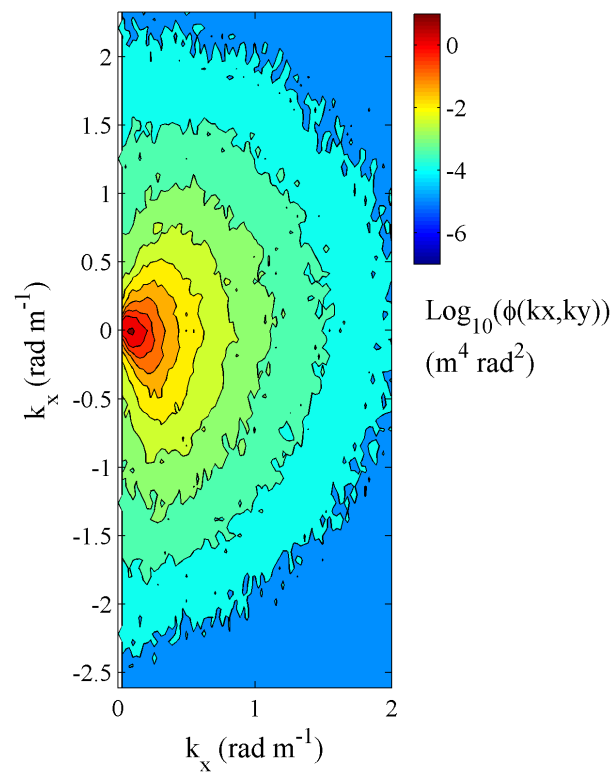
Sea surface topography collected from the MASS lidar

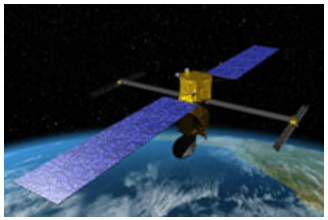


Omnidirectional wavenumber spectrum



directional wavenumber spectrum

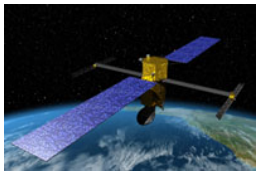




Calibration and Validation of SWOT oceanographic products using Gavdos & Crete Permanent Infrastructure

S. P. Mertikas[1], C. DonLon[4] , C. Mavrocordatos[4], I. N. Tziavos[3], D. Galanakis[2], Ach. Tripolitsiotis[2], X. Frantzis[1], O. Andersen[5]

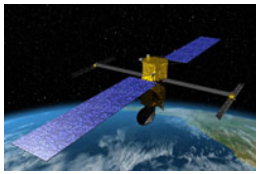
[1] Technical University of Crete, , Greece;
[2] Space Geomatica Ltd. , Greece;
[3] Aristotle University of Thessaloniki, Greece;
[4]ESA/ESTEC, The Netherlands
[5] Danish Space Center, Denmark,

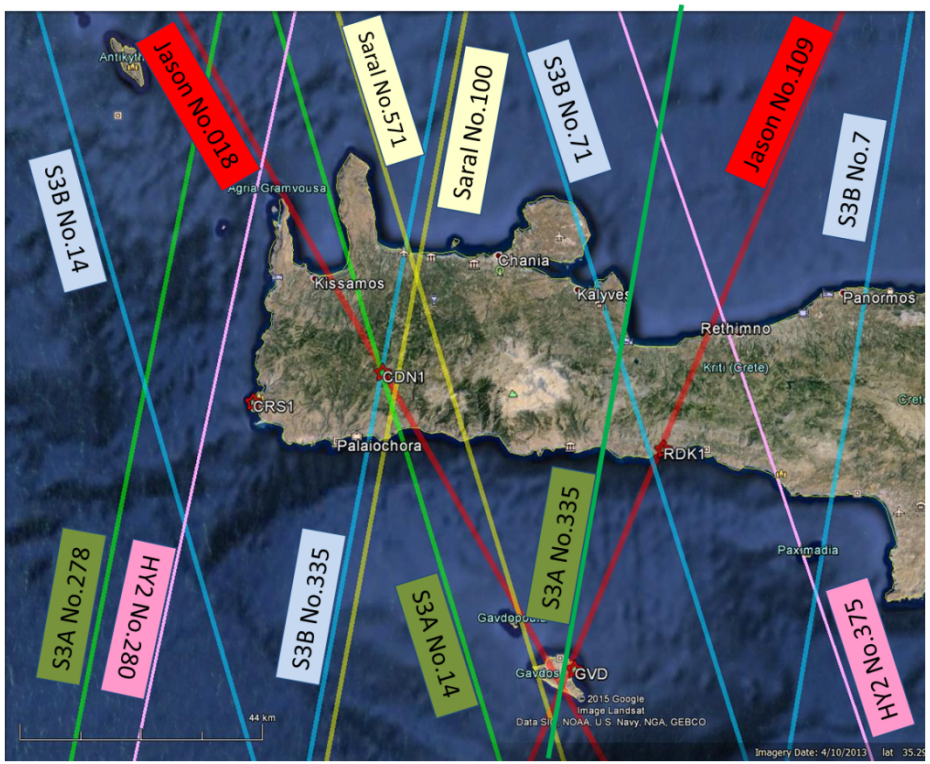


Plans for SWOT Cal/Val at sea

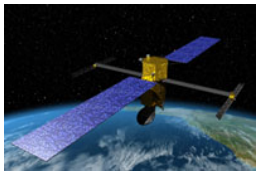
- **Absolute Cal/Val** for the SWOT mission using existing facilities Crete/Gavdos.
  - Sea-surface height;
  - wet troposphere & Ionosphere delays,
  - sea state, wave heights, etc.
- Fiducial Reference Measurements at SI traceability standards;
- Permanent basis, continuously, on a common and reliable reference system;
- Absolute Multi-mission **Cross-Calibration** (i.e., Jason series, Sentinel-3, HY-2, SARAL/AltiKa, etc.);
- Historic Cal/Val records at the same location, setting, and conditions,
- Real-time airborne and/or ship-borne Cal/Val over 30km×100km, south of Crete (tentative).

Gavdos/Crete Cal/Val

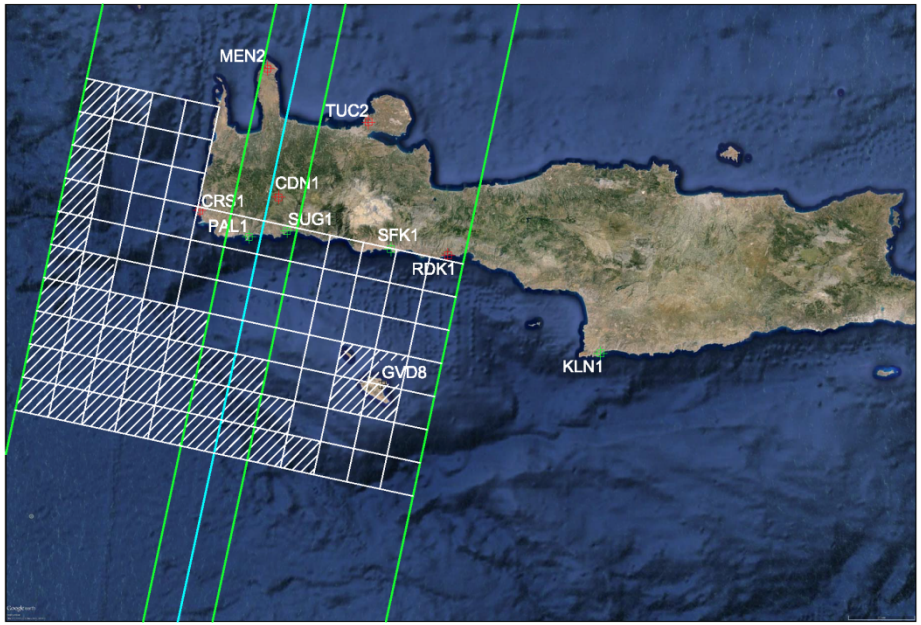




GeoMatLab



SWOT Pass No. 58 (Asc), No. 349 (Desc.)



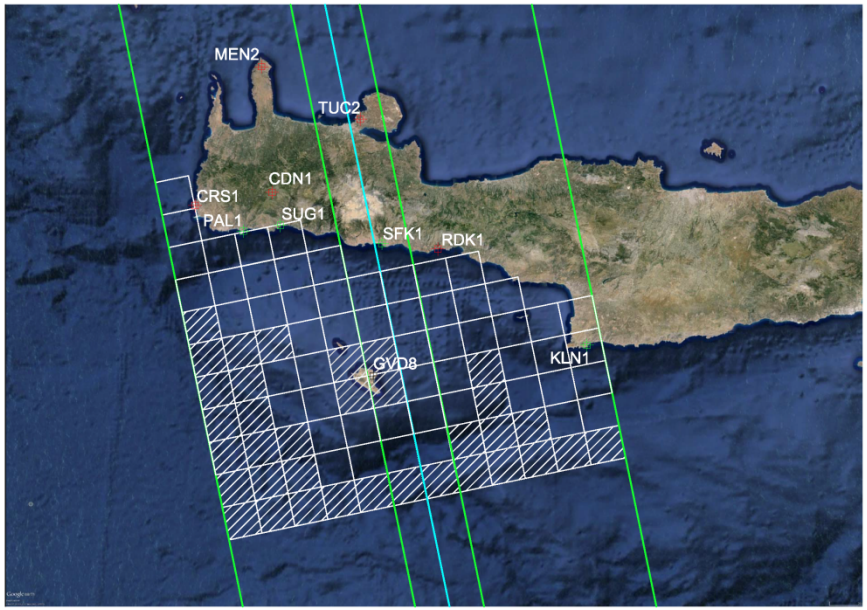
SWOT Descending Pass No. 349

Existing Cal/Val sites:

-CRS1, GVD7, GVD8, RDK1, MEN2, TUC2

Planned Cal/Val Sites:

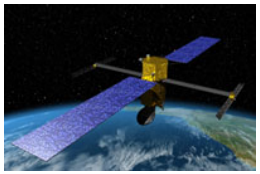
-SFK1, SUG1, KLN1



SWOT Ascending Pass No. 58

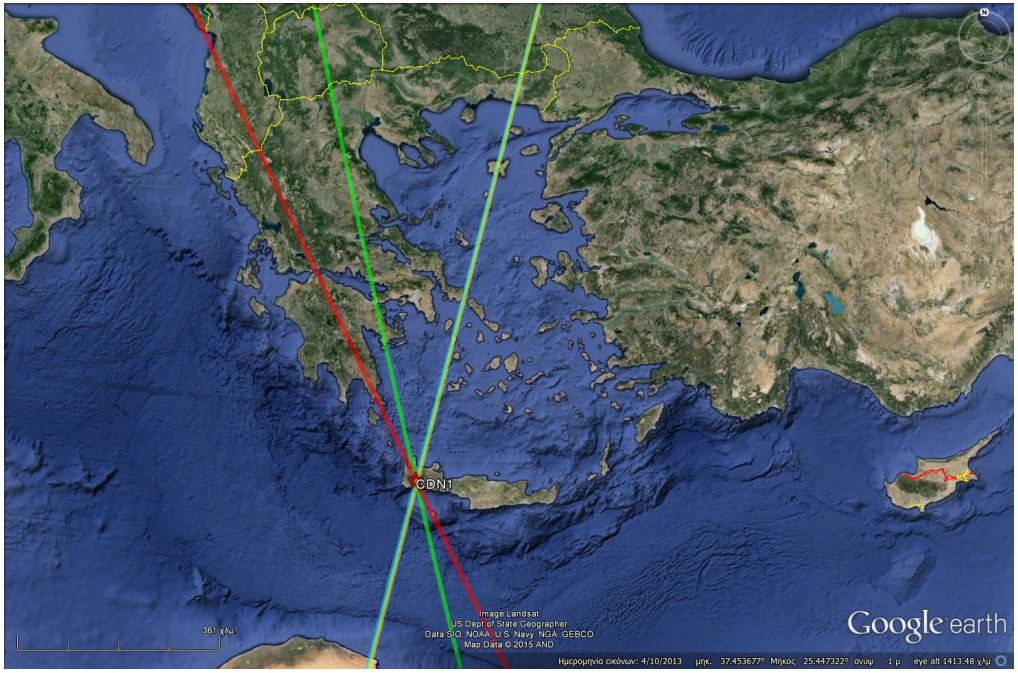
- Each square is 10km×10km,
- Shaded areas more than 30km from Cal/Val sites (Less accurate on sea-surface),
- Around Gavdos "may" be land contaminated.

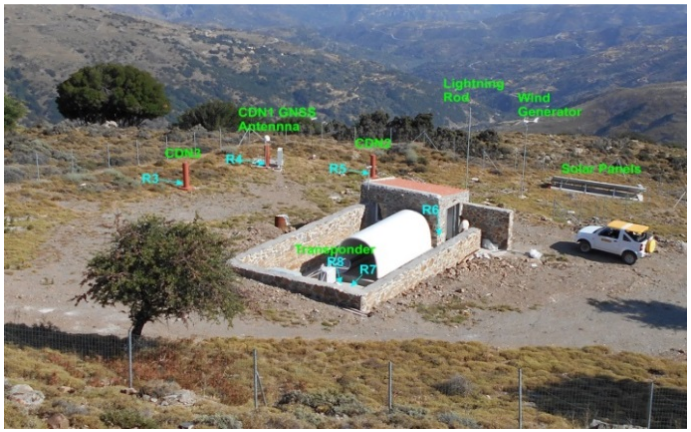
GeoMatLab



Plans for SWOT on Land

- interferometric <u>antennas baseline length and orientation</u> in space;





GeoMatLab

SWOT Cal/Val around Australia

Christopher Watson (University of Tasmania) cwatson@utas.edu.au
Benoit Legresy (CSIRO)

With support from the Australian Integrated Marine Observing System (IMOS)

Potential Australian Cal/Val Sites of Interest

Three sites of interest emerge within the proposed 1-day SWOT cal/val orbit:

1) Bass Strait (40°39'S 145°36')

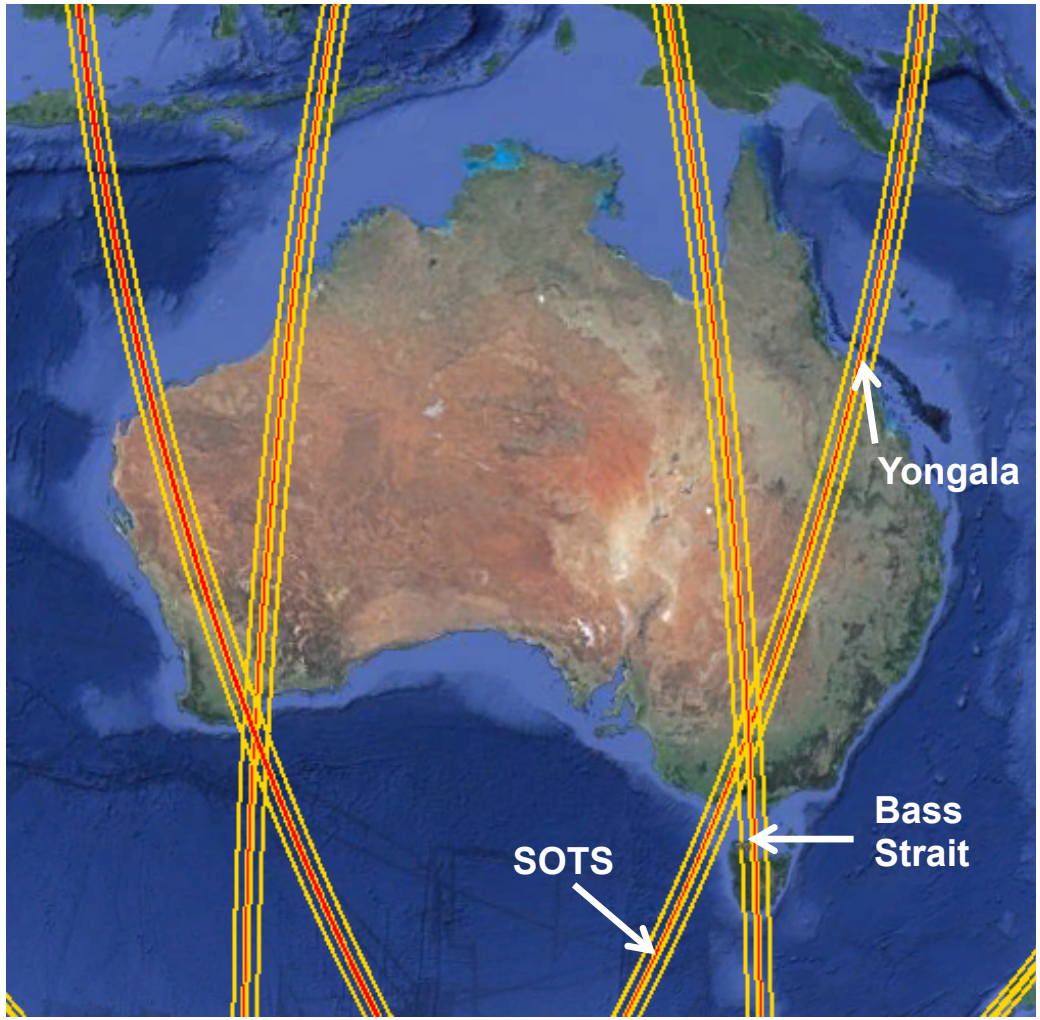
- Historic cal/val site for Jason-series missions
- ~ 50 m water depth. Instrumented with ocean moorings (T, S, P), 3D ADCP, and GPS buoys.
- This site remains the least logistically difficult to instrument of the three sites mentioned here.

2) SOTS (47°S, 141°)

- IMOS mooring site in the sub-Antarctic zone
- Offers large SWH, strong currents, severe storms
- 4.5km water depth – numerous sensors deployed through the column.
- Investigating potential for adding carrier phase GPS to the surface expression.
- Additional observations possible, but synchronising vessel times the biggest challenge.

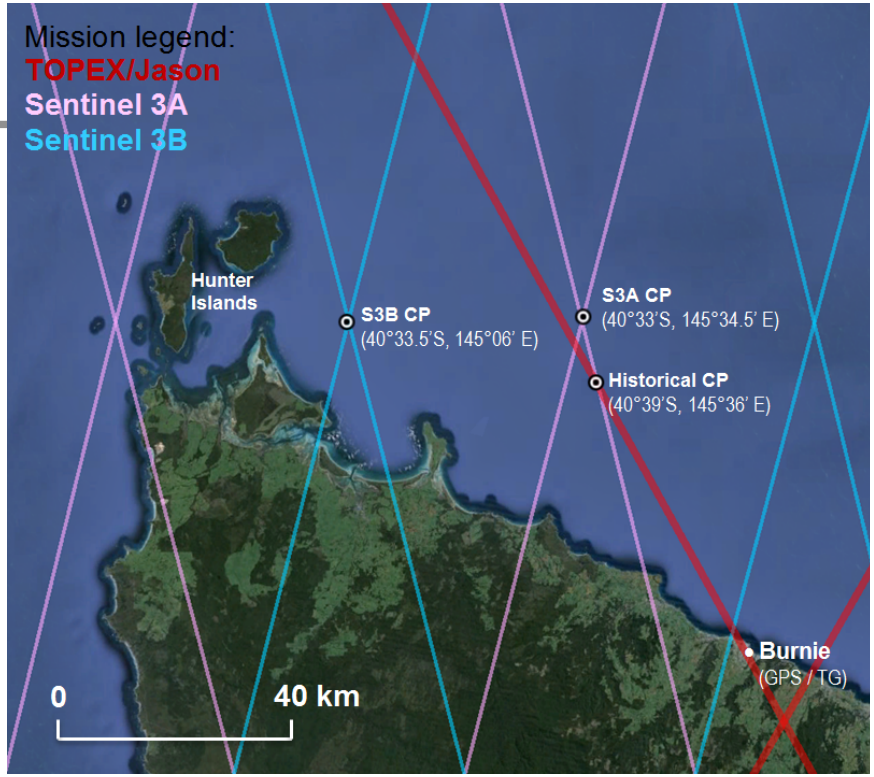
3) Yongala (19°18'S, 147°37')

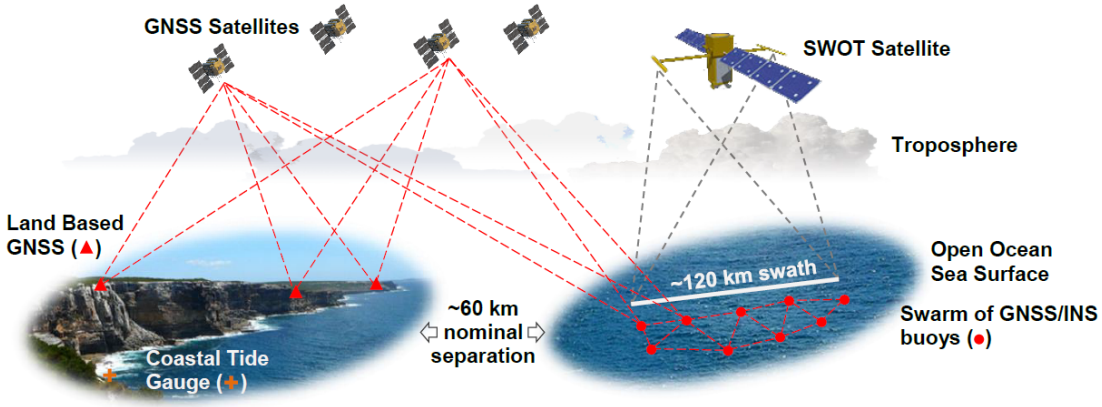
- IMOS national reference station site.
- ~20 km offshore in Great Barrier Reef
- ~30 m water depth. Instrumented with numerous sensors throughout the column.

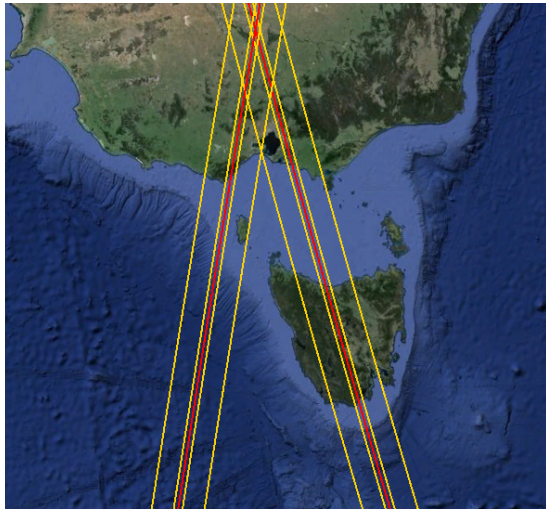


Bass Strait

- We have enhanced the instrumentation and model development in Bass Strait to enable validation of Jason-series missions, as well as Sentinel-3A and 3B.
- The historic comparison point (CP) is located within the KaRIN component of the 1-day repeat swath.
- We have a proposal pending with the Australian Research Council to deploy ~10-15 GPS equipped buoys in the region to aid cal/val of the phase screen during the SWOT cal/val phase.







UNIVERSITY of TASMANIA AUSTRALIA CSIRO IMOS

SOTS and Yongala

- The SOTS (47°S, 141°) and Yongala (19°18'S, 147°37') sites offer potential as secondary Australian targets for single point based SSH/SWH validation.
- Will require instrumentation of the mooring surface expression with carrier phase GPS, inertial and pressure sensors.
- If service visits to SOTS coincide with the 1-day orbit phase, additional towed sampling may be possible to profile the region around the mooring …

- Please come and discuss at the poster session!

SWOT Science Team Meeting

Title: Development of calibration/validation and assimilation methods of wide-swath sea surface height measurements in the western North Pacific and surrounding marginal seas

PI: Kai MATSUI (JAXA)

CI Members

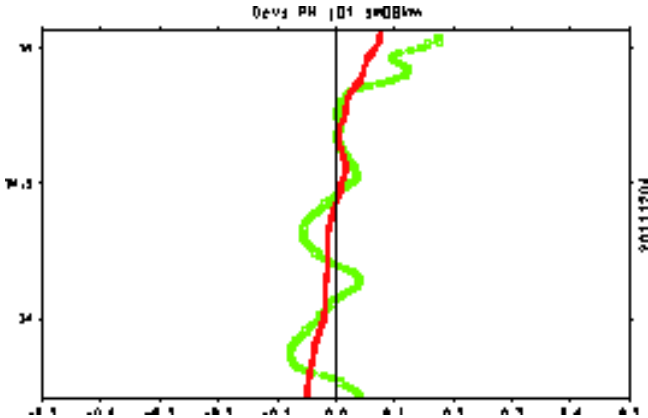
Name	Institute
Naoto EBUCHI	Hokkaido University
Yosuke FUJII	Meteorological Research Institute(MRI)
Kaoru ICHIKAWA	Kyushu University
Yoichi ISHIKAWA	JAMSTEC
Osamu ISOGUCHI	RESTEC
Shinichi ITO	Tokyo University
Yukio MASUMOTO	Tokyo University

Name	Institute
Yasumasa MIYAZAWA	JAMSTEC
Akihiko MORIMOTO	Ehime University
Hideharu SASAKI	JAMSTEC
Kosei SASAOKA	JAMSTEC
Toshio SUGA	Tohoku University
Hiroshi UCHIDA	JAMSTEC
Norihisa USUI	Meteorological Research Institute(MRI)

1. New cal/val methods for SWOT snapshot SSH field

✓SSH measured by a real-time kinematic (RTK) GNSS receiver mounted on a ferry revealed significant small-scale undulations with wavelengths of the order of 10 km, which are possibly related with ageostrophic processes.

✓Since scales of ageostrophic process are generally small both in time and space, cal/val of the SWOT data requires to obtain the two-dimensional reference SSH field with a reasonable spatial resolution and acceptable temporal lags.

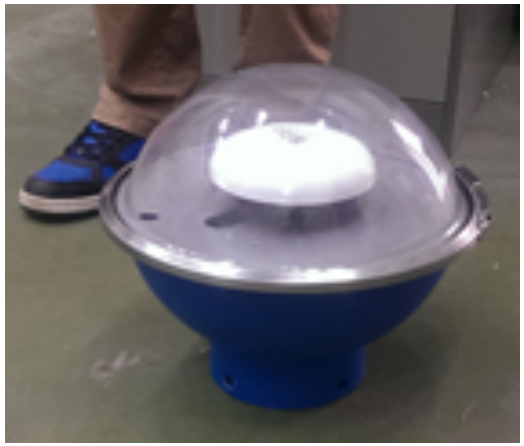


The temporal anomaly SSDH components on 04 Dec 2011 determined by RTK GNSS (green) and ADCP (red)

New cal/val methods

✓Multiple quasi-stationary platforms: a similar RTK GNSS system is newly installed to a surface drifter, which can be deployed to any place for a short period.

✓Moving platforms: SSH measuring methods using stereo cameras, LiDAR and GNSS-R are planned to be mounted on multi-copter drones.



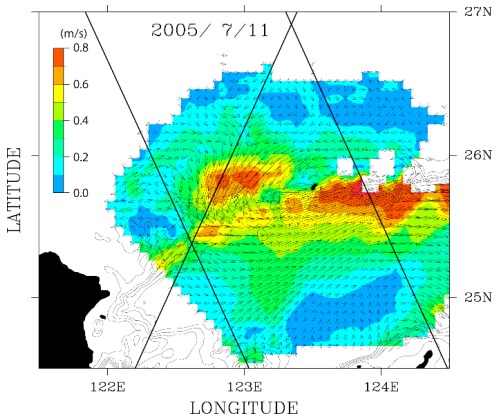
RTK GNSS drifter

2. Meso/submeso-scale features seen in various observations

HF radars

✓Comparisons with conventional altimeters revealed that coastal alt data include small-scale noises that does not contributes to the geostrophic velocity and HF radar may include significant ageostrophic components that would not be represented in SSHA

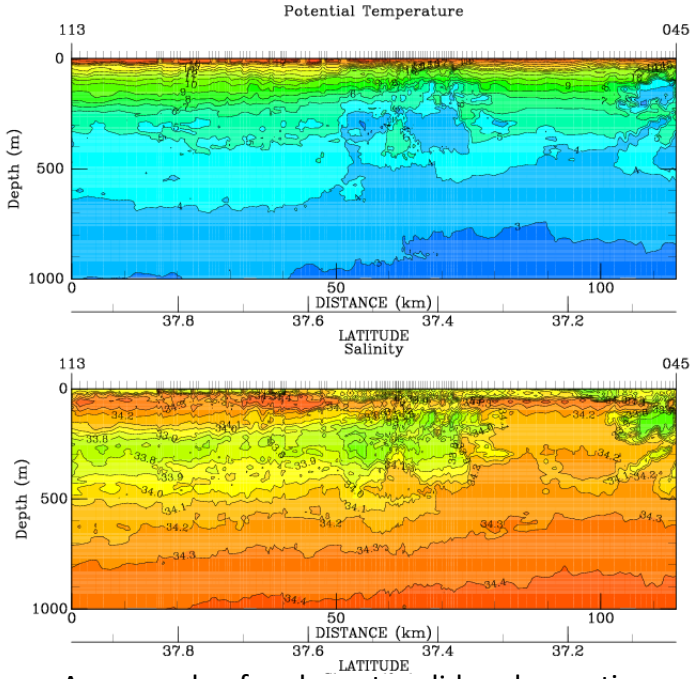
✓Utilized to investigate how the coastal SSHA corresponds to geostrophic velocity components and how the ageostrophic velocity contaminates the coastal SSHA.



Daily mean of sea surface current anomaly by HF radar and Jason-2 tracks

High-resolution obs. and possible connection to biological activities

✓By comparing SSH with high-spatial-resolution maps of satellite images, in-situ ship and underwater glider observations, we are going to investigate the small-scale ocean physics such as submesoscale eddies, fine-scale fronts, filaments and so on, and their effects on ecosystem/biogeochemical processes in detail, to enhance understanding of mesoscale processes and the links between biological and physical processes.



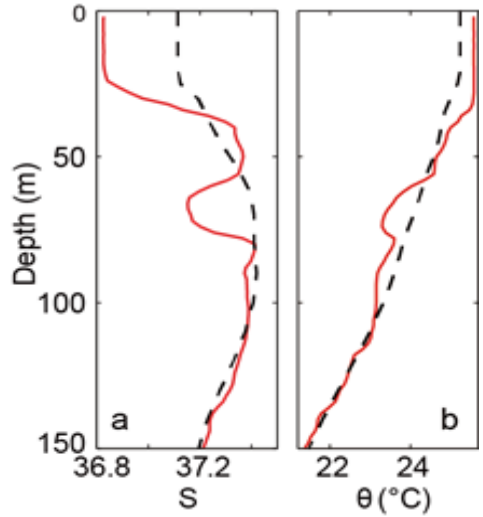
An example of underwater glider observations

3. Small-scale features seen in numerical models

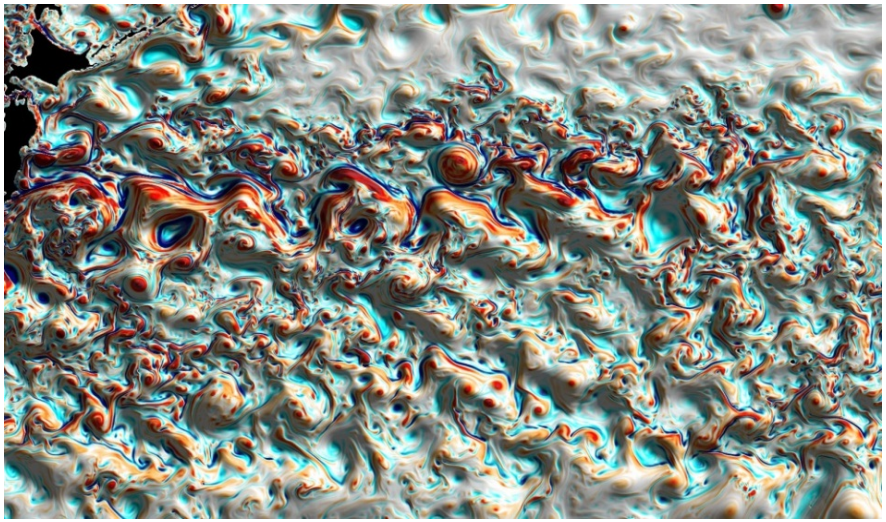
✓Structure and distribution of interleaving, or lateral intrusion of different water masses properties, in the northwestern Pacific Ocean near Kuroshio and Kuroshio Extension region and their relation with submesoscale phenomena are investigated, by analyzing in-situ data of Argo floats and gliders and results from high-resolution ocean models.

✓Combining the observations and simulations, parameters and a method to diagnose 3D structure of the interleaving and their relationship to SSH variability will be investigated.

✓This study will provide a way through which SWOT SSH data contribute to advance our understanding of interleaving and submesoscale variability in the upper ocean.



An example of interleaving structure in the tropical North Atlantic. (a) Salinity and (b) potential temperature observed by an Argo float (red lines) and climatology profiles (black dashed lines). (After Shcherbina et al., 2015)



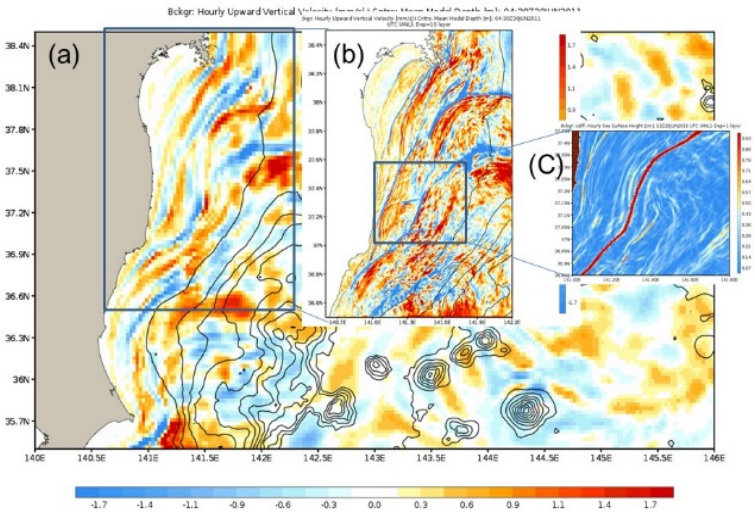
Surface relative vorticity (color) and SSH (relief with shade) in Kuroshio Extension region in winter (March 15, 2002) simulated by a high-resolution North Pacific model.

4. Data Assimilation for SWOT data

Evaluation of error covariance structure generated by internal waves using EnKF

✓Based on the SWOT simulator and JCOPE-T, pseudo-SSH anomaly representing the internal tide and motion will be sampled.

✓The error covariance matrix will be designed from the pseudo-SSH and implemented in an ensemble Kalman Filter to examine the reproducibility of the meso/sunmesoscale signals form the SWOT.

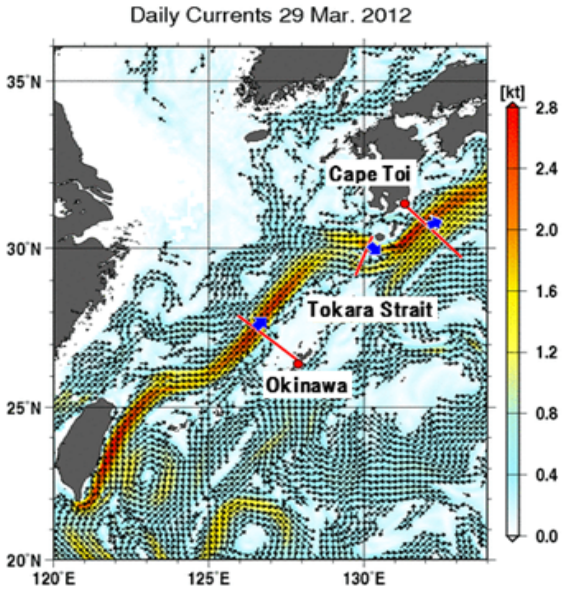


A snapshot of JCOPE-T (1/36 deg. grid) vertical velocity (in mm/s) at a sub-surface level mainly representing internal waves

Variational Assimilation method for high-resolution data

✓Procedures for assimilating the SWOT data in data assimilation systems is developed and OSSEs are performed, paying attention on the difference in the measurement error characteristics between conventional altimetry data and the SWOT data.

✓An effective method of assimilating the SWOT data with their complicated error statistics will be explored.



Daily current field around the East China Sea from MOVE/MRI.COM