CNES MAG

SPACE • INNOVATION • SOCIETY

EN FR

#81
August 2019

WIND AND WAVES

AN ENIGMATIC DUO

CNES
CENTRE NATIONAL D'ÉTUDES SPATIALES

INSIDE

PARTNERS

Mentioned in this issue: p. 6/9/20/22/29/35 National Aeronautics and Space Administration (NASA); p. 21/22/25/26/30 China National Space Administration (CNSA); p. 8/9/26 European Space Agency (ESA); p. 29 Canadian Space Agency (CSA); p. 29 United Kingdom Space Agency (UKSA); p. 6/21/25 Thales Alenia Space; p. 9/10/15/36 Mercator Ocean International; p. 8/35 National Oceanic and Atmospheric Administration (NOAA); p. 9/11/25/35 Eumetsat; p. 11/15/25 Ifremer, the French institute of marine research and exploration; p. 16/18 CLS; p. 17 IGE environmental geosciences institute; p. 20 GRGS space geodesy research group.

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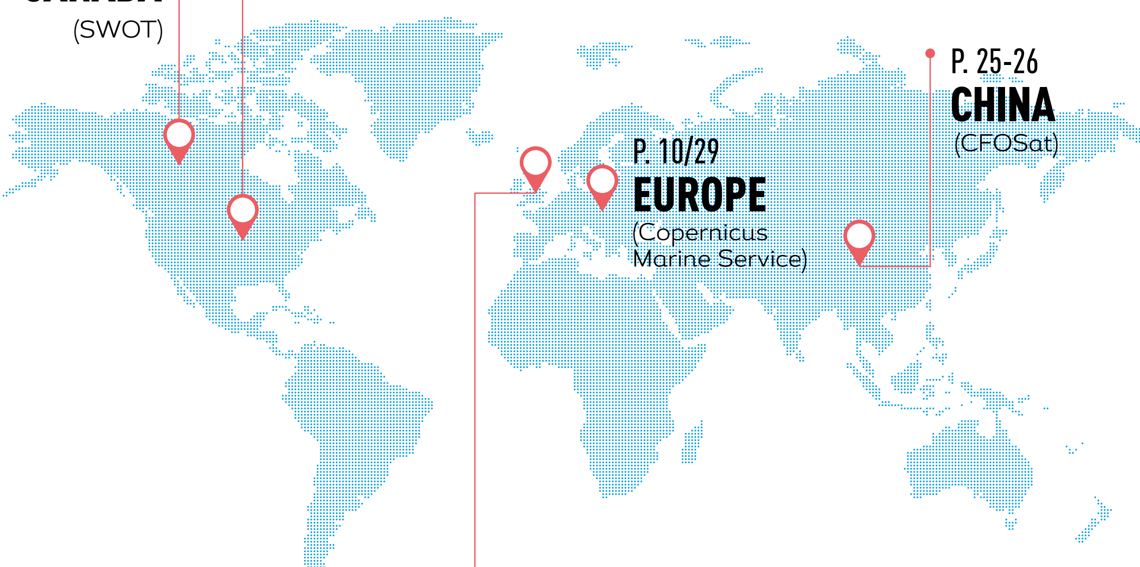
NATIONS STUDYING THE OCEANS AT FINE SCALE



CONTRIBUTORS

PHILIPPE ESCUDIER

Philippe Escudier has made his passion for the oceans his specialist subject. From TOPEX/Poseidon to Vagsat–the future CFOSat–he has worked on every programme. During his time as business director with CLS, he marketed services for marine resource management. Now in charge of developing space applications at CNES, he helped us to recount the incredible saga of space oceanography.

SOPHIE COUTIN-FAYE

As CNES's 'high priestess' of altimetry, Sophie Coutin-Faye has been instrumental in conceiving this space domain of excellence that has revealed the continuing rise in sea level. In charge of the agency's Altimetry and Argos programmes (the latter another key contributor to climate research), she is guided by her commitment to communicating knowledge to both users of satellite data and the wider public. She was our 'final authority' on the subject for this issue.

THIERRY LAFON

After working for more than 10 years on the Jason-1 and Jason-2 programmes, Thierry Lafon took over the reins of the SWOT project in 2008, focusing in particular on development of the mission's French components. He is the 'face' of this project, handling its technical complexity and relations with our U.S. partners with equal ease. He found time in his very busy schedule to explain the great expectations surrounding this new satellite.

BOYD VINCENT

Boyd Vincent has been part of the CNESmag adventure from its early days. A free-lance translator working for the space industry, he seeks to write fluid prose that's easy to read, always looking for linguistic and cultural pathways between French and English to make the text of the magazine sing. This wordsmith, as he likes to define himself, is our 'English voice'.

CNESMAG

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IMPRIM'VERT®

Wind and waves—an enigmatic duo that immediately conjures up days spent at the beach. Yet behind the holiday images hide the keys to our planet's climate. Because it is the constant interaction between atmosphere and ocean that dictates our weather. Its understanding is vital to meteorology, and its evolution tells us about climate change and its impact on the environment. Contributors to this issue of CNESMAG have focused on such phenomena, emphasising the vital role that satellites play in their observation. That's because only satellites can provide global data on land masses and oceans over very long periods of time. The Earth today is being constantly monitored, so that we can take its pulse and predict its evolution. Thanks to our satellites, we are leading the way in this field. With the US, TOPEX/Poseidon and Jason have revealed that ocean levels are rising by an average of 3.4 millimetres every year. With India, SARAL-AltiKa is providing outstanding refined altimetry data. With China, CFOSat is the first satellite to observe winds and waves simultaneously. While with Europe, the Copernicus programme's Sentinel satellites are measuring certain ocean parameters for the very first time. All of which allows us to gain an ever better understanding of wind and wave changes and of their impact on our planet's climate.

JEAN-YVES LE GALL
CNES PRESIDENT

KARIN

French to the core

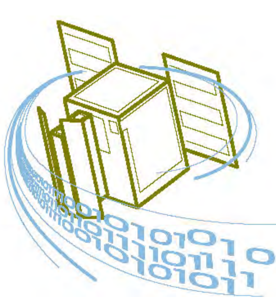
In the footsteps of the TOPEX/Poseidon and Jason series of satellites, SWOT[1] is set to make the already close partnership ties between France and the United States in the field of oceanography closer still. For this mission, NASA asked CNES to supply the radiofrequency unit (RFU) that is the analogue 'core' of the satellite's KaRin wide-swath interferometric altimeter (see p. 27). The aim is to boost the main instrument's performance (see p. 18) thanks to the observing geometry afforded by the two radar antennas perched at either end of a boom. Developed by Thales Alenia Space, the RFU will be delivered this summer to the Jet Propulsion Laboratory in California for integration in KaRin.

1. Surface Water and Ocean Topography.

SWOT is an Earth-observation satellite designed to measure ocean topography and the level of surface waters, lakes and rivers.

SCO
POOLING GLOBAL DATA

The Space Climate Observatory (SCO) is the culmination of one of the 12 commitments made at the One Planet Summit in Paris in 2017. Initiated by CNES and officially launched by President Emmanuel Macron at this year's Paris Air Show, the observatory is seeking to leverage international cooperation and satellite data. Sixty space agencies have got behind the concept, 25 of them having already signed a Joint Declaration of Interest, since joined by various NGOs and public bodies. These founding partners are committed to pooling multi-source global data, especially data from satellites. As the guardian of this 'heritage', the SCO will be making such data widely available—a precious aid to inform local planning decisions, for example. A first pilot site confirmed the viability in June last year of this global observatory that will be making extensive use of big data and artificial intelligence.

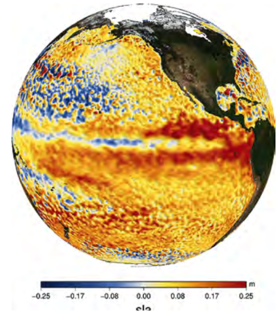


8 TERABITS

The amount of data KaRin will be beaming back every day. That's eight million million bits! The data will be shared between France and the United States and handled automatically on the ground by thousands of core processors.

CFOSAT
ALL SYSTEMS GO

Following its launch by a Chinese Long March 2C vehicle, CFOSat wasted no time beating all records for precociousness. From the end of the in-orbit checkout phase, the French and Chinese teams in Toulouse and Xi'an, the capital of Shaanxi province, received confirmation that everything was on track, from the satellite's position to power-up of its instruments and data processing systems. All systems are go and CFOSat is bang on schedule. The two radars—the French SWIM instrument and the Chinese SCAT instrument—began delivering wave spectra and wind maps of exceptional quality from the outset, fully matching theoretical models. Early in July, the satellite entered its operational phase and will now be helping scientists to gain new insights into ocean phenomena and how they interact with the atmosphere (see CNES in Action p. 25-26).



In May 2015, the early signs of an El Niño are visible in the Pacific Ocean.

TOSCA
MAKING THE RIGHT CHOICES

CNES takes its disruptive role very seriously, soliciting proposals from the French scientific community every year. The TOSCA[1] expert committee then assesses submitted proposals in the fields of oceans, land surfaces and atmospheric science, giving an informed opinion on innovative work requiring support. Last year, for example, the oceans working group looked at in-situ profiles collected from elephant seals. More than 20 females were tagged with high-frequency transmitters that continuously logged temperature, salinity and light data, and in certain cases phytoplankton fluorescence. Combined with altimetry data prefiguring the forthcoming SWOT mission, this wealth of information has helped to unveil phenomena like deep ocean fronts.

1. Terre, Océan, Surfaces Continentales, Atmosphère - Earth, oceanography, land surfaces and atmosphere.

86

Projects backed by CNES's TOSCA oceans programme in 2018. Some 400 research scientists contributed to this work, which yielded around 300 scientific publications of the highest quality.

EL NIÑO
THE TEARAWAY TODDLER

El Niño is a seasonal warm current off the coast of Peru, and one of the potentially most destructive ocean phenomena there is, bringing devastating floods, torrential rain and even typhoons in its wake, with dramatic consequences for the populations and economies of affected nations. The last big El Niño episode—in 1997-1998—claimed 23,000 victims around the globe and left a trail of damage costing between 34 and 46 billion dollars. TOPEX/Poseidon was the first to detect the early warning signs of its onset, and the science of satellite altimetry has been tracking it closely ever since. In 2015, for example, it detected an oncoming El Niño which, fortunately, failed to develop. While it can do nothing against nature's whims, satellite altimetry does help to take timely safety measures. Observations are made every three months and look out to six months ahead. NOAA[1] manages a website with weekly bulletins and analyses.

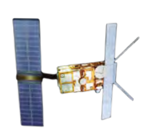
1. National Oceanic and Atmospheric Administration.

OCEANOGRAPHY SATELLITES

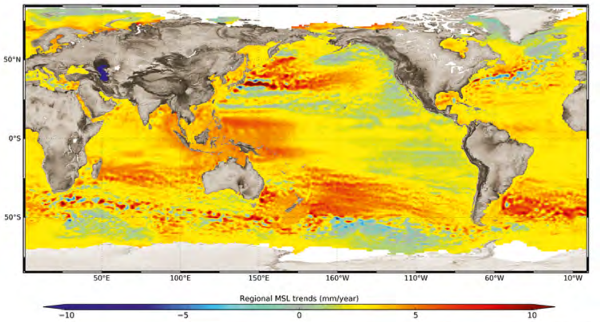
TOPEX-POSEIDON (CNES-NASA)

Launched in 1992, the Poseidon altimeter combined with the DORIS instrument measured sea surface height with a precision of a few centimetres.

ERS (ESA)



Europe's first remote-sensing satellites, ERS-1 (launched in 1991) and ERS-2 (launched in 1995) measured ocean colour and surface temperature up to 2000.



Change in mean sea level from January 1993 to September 2018 derived from cumulative high-precision satellite altimetry data (TOPEX/Poseidon and Jason-1, 2 and 3).

3.4 MM

Over the course of the 20th century, sea level rose by less than 2 mm a year. Between 1993 and 2003, altimetry data from TOPEX/Poseidon estimate the rise at 2.9 mm a year. Today, the rise in mean sea level is 3.4 mm/year.

JASON-3
THE GOLD STANDARD

Through successive generations of altimeters on the Jason series of satellites, CNES has tirelessly pursued its aim of pinpoint precision. Drawing on the heritage of its pioneering predecessor TOPEX/Poseidon, Jason-3, launched in 2016, has now reached the landmark of centimetre accuracy, an achievement it owes to the dedication and perseverance of the agency's teams. Jason-3 is also a key element of the European Copernicus programme and Eumetsat, and fuels the prediction models of the Copernicus Marine Environment and Monitoring Service (CMEMS) operated by Mercator Ocean International. This standing assures its visibility on the global stage and guarantees the series' long-term future. Jason-3 altimetry measurements also form part of the wealth of data on which the IPCC relies to keep track of our evolving climate and reach its conclusions to inform public policies.

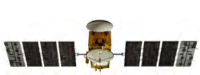
30%

The world's oceans absorb nearly 30% of carbon dioxide emissions generated by humans; they contain 50 times more of this gas than the atmosphere. This CO_2 then descends to the ocean depths with the currents. The cold regions of the oceans absorb more CO_2 than warm regions.

17.5°

The mean ocean temperature down to 200 metres, roughly the same as at the surface. But it isn't uniform all over the globe, reaching a maximum of 27-28°C in the tropical oceans and a minimum of −1.8°C in polar waters.

JASON (CNES-NASA)



Smaller versions of TOPEX/Poseidon, three Jason satellites (2001-2008-2016) succeeded each other and will be followed by Sentinel 6.

ENVISAT (ESA)

Launched in 2002, the successor to ERS-1 and ERS-2 brought the capability to deliver data in near-real time.

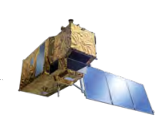
SMOS (ESA)

SMOS is a minisatellite launched in 2009 that measures ocean surface salinity. The first salinity map using SMOS data was generated in 2010.

SARAL (CNES-ISRO)

SARAL is a French-Indian satellite studying sea, ice and river surface levels with its AltiKa payload. Launched in 2013, it took over from Envisat, offering greater precision and resolution.

SENTINEL (ESA)



The Sentinel satellites began launching in 2016 for the European Copernicus programme and are supporting the Copernicus Marine Environment and Monitoring Service (CMEMS).

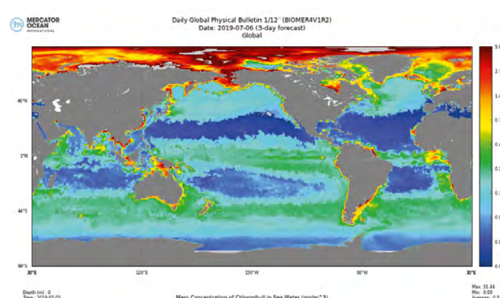
IPCC
EXTREME EMERGENCY ON PLANET EARTH

We left the IPCC[1] raising the climate alarm with its sixth report in 2018. Its two latest reports, set to be released in August and September, are no more reassuring. Benoît Meyssignac, an oceanographer at the LEGOS space geophysics and oceanography research laboratory, confirms: "*Recent research indicates that sea level rise is gathering pace.*" Since 2005, melting of land ice has accelerated and is now the main contributor to rising sea level, and it's expected to gain momentum in the coming decades. In the medium term, this rise will have a big impact on the frequency of extreme weather events. Such events—a recent example being windstorm Xynthia, which triggered a 1.15-metre rise in sea level—are still considered rare today, but they will be commonplace by the end of this century unless greenhouse gas emissions are curbed. With sea level in danger of rising as much as one metre by 2100, coasts and overseas territories are under threat and steps need to be taken now to prepare them to cope.

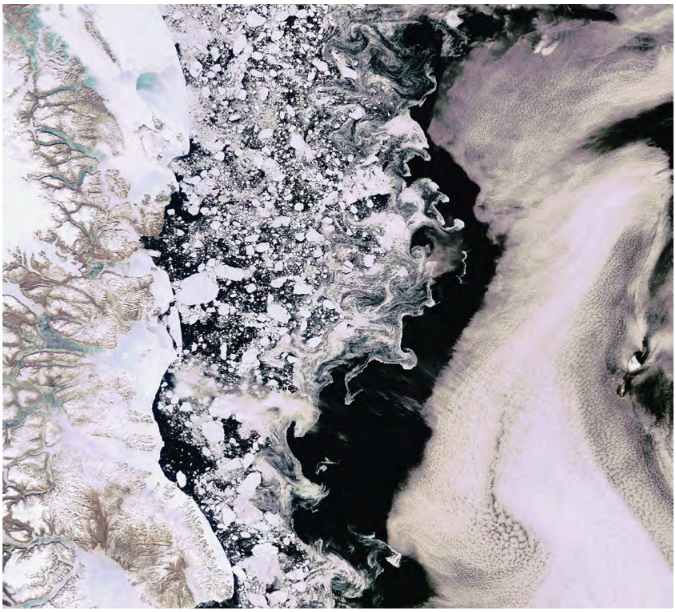
1. International Panel on Climate Change.

MERCATOR OCEAN INTERNATIONAL
OCEANS UNDER CLOSE WATCH

Whether you're a research scientist, a developer of maritime safety applications, a fish farming business or simply a concerned citizen, Mercator Ocean International offers free access to observations and forecasts covering the world's blue (currents, temperature, salinity, sea surface height), white (sea ice) and green (micro-plankton and chlorophyll) oceans. Operational oceanography—analysing, modelling and monitoring physical, dynamic and biogeochemical ocean parameters, at the surface and at depth—is the relatively young field of research that is central to Mercator Ocean International's activities. Such information relies on a solid value chain that starts with satellite observations and ends with ocean data products needed by global environment and biodiversity programmes like the United Nations' Sustainable Development Goals (SDGs).



Chlorophyll concentration at the ocean surface derived by the 1/4° biogeochemical analysis and prediction system operated by Mercator Ocean International.



Eddies in the Arctic Ocean viewed by Envisat: the ice is being broken up by waves in the Greenland Sea at the start of the spring thaw.

EUMETSAT

BETTER WEATHER FORECASTS

So, what's the weather forecast like for tomorrow? Be they regional or global, today's forecasts are looking further ahead than that. To improve forecasting, we need to understand what's going on in the oceans and how they interact with the atmosphere. Eumetsat[1] delivers a broad array of bulletins, warnings and other vital services for sailors, ocean yacht racing, ship routing and protection of offshore platforms, based on data from satellites such as Jason, Sentinel and Metop. Spaceborne altimeters supply measurements of sea surface heights, the main indicators of climate change, while imaging radiometers track rising surface temperatures thought to be driving increased cyclonic activity. Eumetsat is also keeping an eye on sea ice, especially in the Arctic Ocean. Information on ice extent, thickness, temperature and drift is critically important to the economy, climate and meteorological models.

1. European Organisation for the Exploitation of Meteorological Satellites, an intergovernmental body federating 30 European nations.

ODATIS

A UNIQUE RESEARCH PORTAL

Through a single portal, a common catalogue and harmonized search engine optimization, CNES and its partners—the French national scientific research centre CNRS, the French institute of marine research and exploration Ifremer, the IRD development research institute, the SHOM naval hydrographic and oceanographic office and maritime universities—are facilitating scientific research by pooling climate data. The DataTerra research infrastructure combines four data centres[1] under the same roof. ODATIS is the Oceans centre centralizing multi-source data and products. CNES's AVISO[2] data centre supplies it with highly precise altimetry measurements. Other satellite data products are also generated with Ifremer, like SMOS salinity maps and CFOSat products. Once validated, enhanced, merged, catalogued and distributed, all of these data are coordinated by national research bodies. While aimed primarily at the scientific community, businesses, government departments, the tourism sector and citizens can also access ODATIS to track ocean conditions.

1. Solid Earth, Oceans, Atmosphere and Land Surfaces.
2. Archiving, Validation and Interpretation of Satellite Oceanographic data.

#COMMUNITY

Every day, CNES engages with you on social networks and you share your thoughts and questions with us. Join the conversation!

@JULNOUR
Ta-ra-ra boom-de-ay. With text, too.

Well I never! It appears I'm a marine weather expert for CNES! Fame at last! ❤️

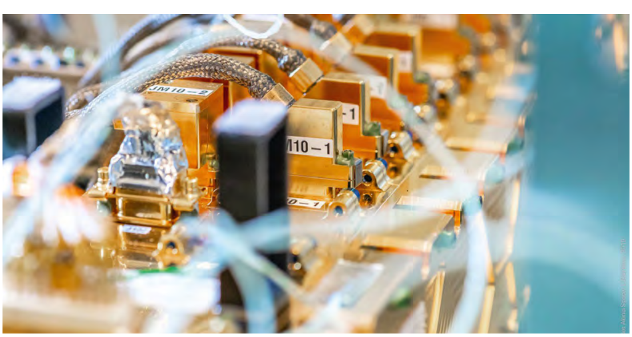
@SENGENES MATHIEU
@m51sen

Might that be the duplexer for SWOT's RFU? 🤔

IN REPLY TO @CNES

@CNES
L'actu du CNES, le Centre National d'Études Spatiales

A mystery picture #ImageMystère caught! What satellite do you think this… 'thing' belongs to? 🧐



@SPACE_THOMALICE
Science journalism/communication team 📝 Videographer with a passion for space 🚀 Member of @cafe_sciences ☕ #BananaForScale and #SpreadThePipouness

For those of you who missed the start of the story, #CFOSAT is a satellite studying waves on Earth. #CNESTweetup #CNESDrawup

@PINTOFSCIENCEFR
Bringing research to the wider public in a relaxed and informal atmosphere at the #pint19 bar from 20 to 22 May 2019. All countries @pintsWorld Account managed by @MarineArnd

Sea level rise is accelerating according to satellite data, and melting ice in Greenland is one of the causes. If the entire Greenland ice sheet were to melt, sea level would rise by 7.2 metres. buff.ly/2EW9OEI

Q & A

JEAN-LOUIS ÉTIENNE

A SEASONED EXPLORER OF EXTREME ENVIRONMENTS, Jean-Louis Étienne knows the world's oceans inside out. As he gets ready to go to sea in the Southern Ocean in a specially designed research vessel, he tells us about his current exploration projects and plans to acquire in-situ data to validate calibration of oceanography satellites.

WHERE DOES THIS CALL OF THE OCEANS AND COLD CLIMES COME FROM?

Jean-Louis Étienne: When I was a lad, I loved being outdoors and dreaming of adventures in the mountains. Later on, after completing my training as a surgical intern, I joined Éric Tabarly's crew on the round-the-world yacht race and met Father Jaouen, a Jesuit priest who offered young people the chance to turn their lives around through sailing. After that, driven by my constant attraction to the Polar Regions, I organized my own expedition to the North Pole, which is kind of my personal Cape Horn. I failed on my first attempt in 1985 but succeeded in 1986, which gave me a great sense of achievement and release. I said to myself: "*this is the life for me!*" As I explored lands like Greenland, where sea and mountains meet, the oceans gradually became my playground for which I built *Antarctica* and today *Tara*, a boat that's robust enough to withstand the polar ice.

IN YOUR 30 YEARS EXPLORING THE GLOBE'S EXTREME LATITUDES, HAVE YOU SEEN THE EFFECTS OF GLOBAL WARMING FIRST HAND?

J.-L. E.: I've seen two very concrete examples with my own eyes. At the North Pole in 2010, I flew in a balloon over the pack ice I'd crossed on foot at the same time of the year in 1986. And in place of the really compact ice I remembered, I saw large areas of open water: on average, the ice there has thinned from 1.8 metres in 1986 to 1.2 metres today. At the South Pole, the crossing of the Antarctic Peninsula I undertook in 1989 is now quite simply impossible: the first 600 kilometres vanished between 2000 and 2002, as documented by satellite images.

WHAT ROLE HAVE SPACE TOOLS PLAYED IN YOUR ADVENTURES?

J.-L. E.: An absolutely vital one! At the poles, I was all alone and my only means of contact with base camp was a small radio. CNES supplied me with an Argos transmitter equipped with the Sarsat distress system. As the signal had to be sent to Toulouse for processing, every evening I transmitted for an hour so I could receive my position the morning after! Space has also revolutionized ocean racing: when I went round the world with Tabarly in 1979, all we had was a sextant. Today, skippers are able to stay ahead of storms and play with the elements to use the winds to their advantage.

YOU'RE NOW WORKING ON A NEW RESEARCH VESSEL TO EXPLORE THE SOUTHERN OCEAN. TELL US MORE ABOUT THIS POLAR POD PROJECT.

J.-L. E.: With its circumference of 22,000 kilometres, the Southern Ocean circling Antarctica acts as a giant conveyor belt between the Atlantic, Indian and Pacific oceans. It's kind of like Earth's central heating system, but all scientific publications on the subject have concluded that we need to acquire long time series of in-situ measurements and observations. To remain stable in this stormy ocean that sailors call the Furious Fifties, we've designed Polar Pod, an upright vessel standing 100 metres tall, 80 metres of it under the water. It's a manned station that will acquire data and disseminate them whenever possible in real time. Crews of three sailors and four scientists will relay one another every two months for a period of at least two years. Like the International Space Station, Polar Pod will be the international oceanographic station. In all, 43 institutions from 12 nations are involved in the science part of the expedition, coordinated by the French national scientific research centre CNRS.

WHAT KIND OF DATA ARE YOU GOING TO COLLECT?

J.-L. E.: We'll be sailing in the midst of a vast and still unknown reserve of marine biodiversity, with different types of floating ice. Polar Pod has no engine, generates its own energy and is silent, so we'll be able to distinguish the sound signature of species to establish an inventory of marine wildlife. We're

"WHETHER THROUGH TREES OR PHYTOPLANKTON, GREENING THE LAND AND OCEANS IS THE ONLY WAY TO CAPTURE CO_2, SO WE NEED TO BE DOING THAT WHEREVER WE CAN."

JEAN-LOUIS ÉTIENNE

SEASONED EXPLORER OF EXTREME ENVIRONMENTS

"LIKE THE INTERNATIONAL SPACE STATION, POLAR POD WILL BE THE INTERNATIONAL OCEANOGRAPHIC STATION."

going to collect samples, notably of plankton to gauge the impact of ocean acidification, as well as that of human activities like production of plastics and heavy metals. The vessel is equipped with a suite of sensors and instruments to study a range of phenomena, like for example air/ocean exchanges, sea state and wave dynamics, and ocean colour. CNES will be using some of these in-situ data to verify measurements by satellites like Jason, Sentinel and CFOSat. We're also working with Mercator Ocean International to compare their forecasts with what we see. Ifremer, the French institute of marine research and exploration, will be distributing all of these data.

WHY IS GAINING NEW INSIGHTS INTO THE SOUTHERN OCEAN SO IMPORTANT?

J.-L. E.: Today, the key thing at stake is the environmental impact of global warming. Now, the Southern Ocean is the main regulator of our climate: How much CO_2 can it absorb and exchange with the atmosphere? Not only does it absorb excess heat and transport it around the globe, but it also draws down CO_2, which dissolves and turns all the more quickly into carbonic acid where the water is cold. All of these processes are clearly causing the oceans to acidify. We're in increasing danger from massive disruptions in the water cycle, which we're already seeing for example in the growing intensity of extreme weather events in the Cévennes region of France near the Mediterranean and tropical storms caused by excess heat in the ocean and atmosphere.

HOW CAN SPACE HELP TO MEET THESE CHALLENGES?

J.-L. E.: Satellites freely circle the globe with no need for visas or passports! They enable us to track the key problem of CO_2 emissions and identify geographic areas and focus our efforts to curb them. Their increasingly precise sensors are aiding research in many fields: we can now detect species and plankton density, and from there determine biological activity. That's why validating calibration of satellite measurements with in-situ data is so vital.

WHAT MESSAGE DO YOU HAVE FOR FUTURE GENERATIONS?

J.-L. E.: Populations without energy are condemned to poverty, and without water they are condemned to war. There are so many things we can do to avoid this. We all affect climate through how we travel and what we consume. Everyone must act at their level. Find out if your parents' bank is investing in coal mines; if it is, ask them to let their manager know they're going to change bank. Whether through trees or phytoplankton, greening the land and oceans is the only way to capture CO_2, so we need to be doing that wherever we can.

Profile

1986
First man to reach the North Pole alone on foot after 63 days.

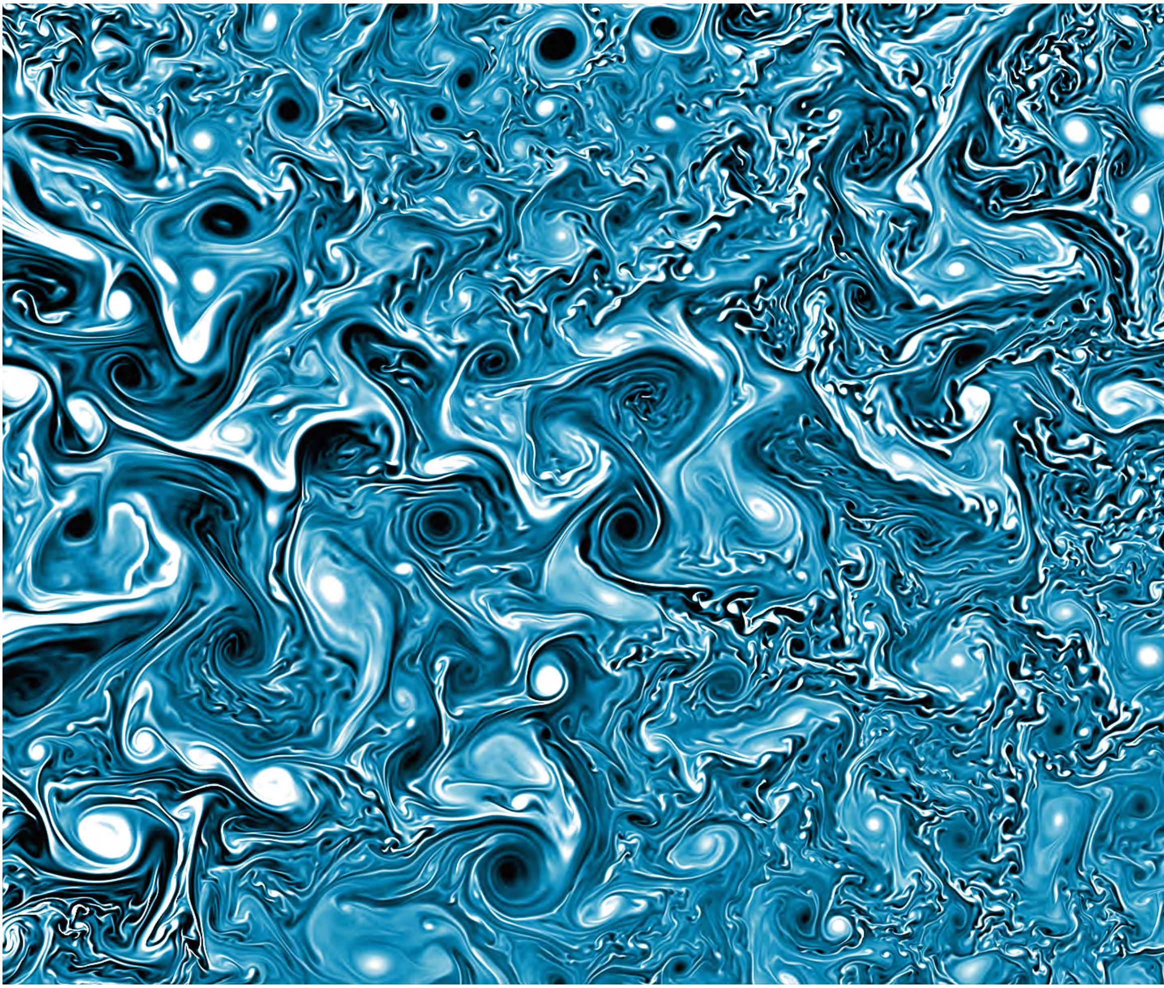
1990
Longest crossing of the Antarctic with a dog sled (6,300 km in 7 months).

1990 to 1996
Educational expeditions on the polar yacht *Antarctica*.

2010
First balloon crossing of the Arctic Ocean.

MARINE MOVEMENTS

High-resolution imagery and great white sharks are helping biologists to understand just how fragile deep-sea ecosystems are. Satellite altimetry data generated by CNES, the University of Oregon and CLS are compared with ocean eddies and meanders distributed through a data platform called AVISO. By matching these data with the predators' movements tracked by the Argos system, the biologists are able to locate their feeding zones and thus prioritize research on regions of the ocean that are vital to preserve them. The combined data also inform efforts to conceive sustainable fishing policies and identify effective protection measures for marine areas.



EDDIES UP CLOSE

Do the oceans hold the key to climate change? To find out, the high-resolution SWOT[1] mission will survey the 'signature' of currents at increasingly small scales, from 50-kilometre eddies to filaments spanning just 10 kilometres. Probing the ocean depths, it will simulate the role of vertical exchanges in marine biology. Some of the chaotic effects of the oceans are still poorly understood, but the IGE environmental geosciences institute is using very-high-resolution data to conceive numerical models that will facilitate data assimilation in operational prediction models.

1. Surface Water Ocean Topography

44,000

The number of pulses the radiofrequency unit (RFU) inside KaRin, the altimeter on the SWOT satellite, will have to handle per second, without dropping a single one! This electronic unit is the most complex ever to operate in K_a band.

50

THE NUMBER OF ESSENTIAL CLIMATE VARIABLES (ECVs) likely to aid our understanding of climate change, 26 of which can be observed from space. Satellite-based observation of the oceans is helping to measure an increasing range of variables such as topography, temperature, ice (thickness, extent and concentration), iceberg drift, ocean colour (chlorophyll concentration), surface roughness/sea state (wind and waves) and more recently salinity.

TEAM

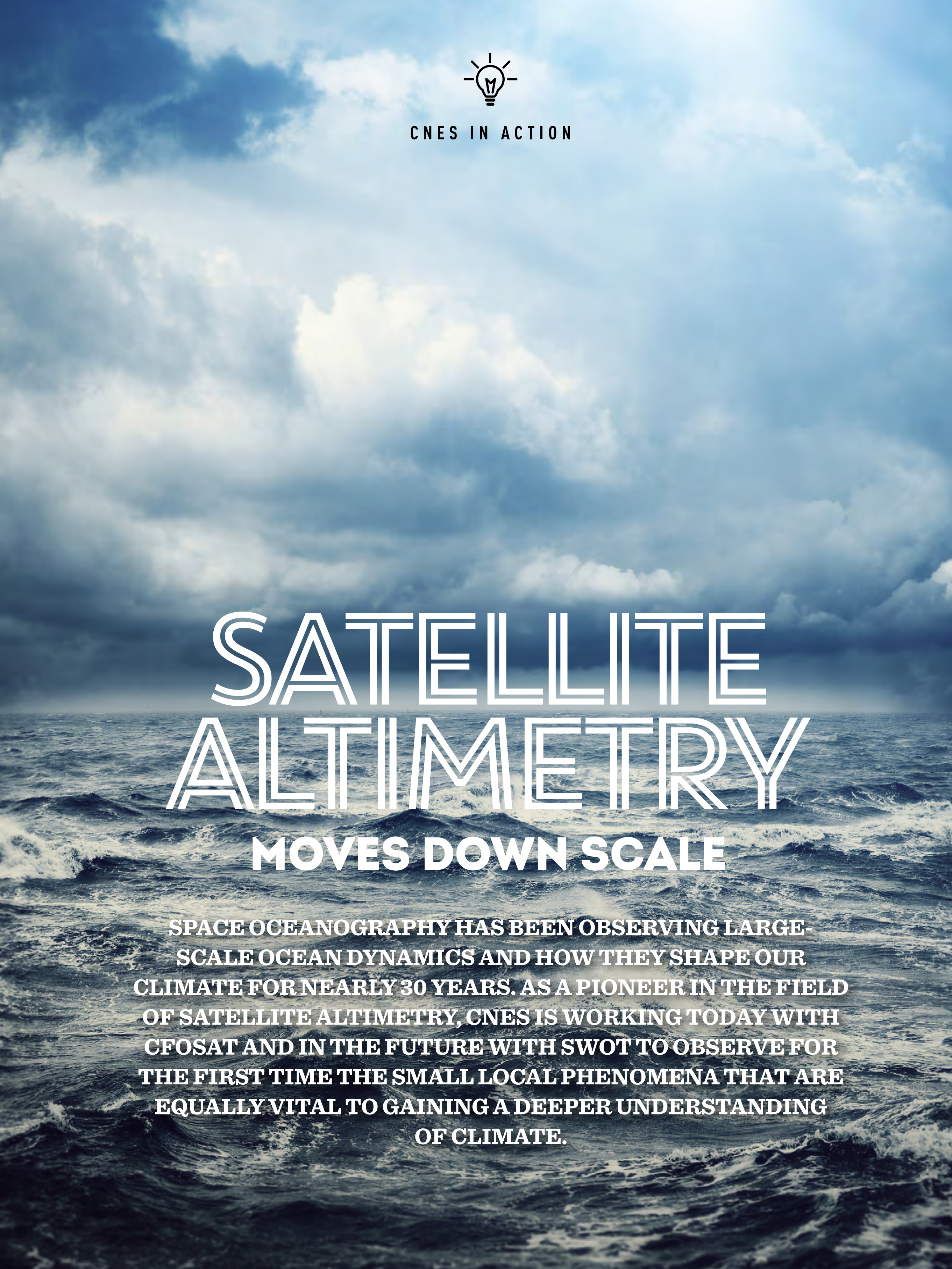
As a general rule, a science mission is led by a principal investigator (PI) and a science team working with the scientific community. From the outset, the field of satellite altimetry set up its own Ocean Surface Topography Science Team (OST-ST), comprising 300 international and interdisciplinary scientists studying the oceans and altimetry data users.

CLS

CNES subsidiary CLS was eagerly awaiting CFOSat to give new insights to meteorologists, oceanographers and climatologists, and to give fishermen and yachtsmen warning of dangerous sea conditions. During the satellite's six-month in-orbit commissioning phase, the company's teams worked to quickly calibrate and then validate the data from its SWIM instrument. Scientists were the first to set eyes on the results before the data were widely released starting this July.

Variability

Ocean currents are responsible for 80% of surface variability in the open ocean. Near coastlines, such variations can be as high as 10 metres. With measurements accurate to one centimetre, satellite altimetry has uncovered a link between tides and climate.



SATELLITE ALTIMETRY

MOVES DOWN SCALE

SPACE OCEANOGRAPHY HAS BEEN OBSERVING LARGE-SCALE OCEAN DYNAMICS AND HOW THEY SHAPE OUR CLIMATE FOR NEARLY 30 YEARS. AS A PIONEER IN THE FIELD OF SATELLITE ALTIMETRY, CNES IS WORKING TODAY WITH CFOSAT AND IN THE FUTURE WITH SWOT TO OBSERVE FOR THE FIRST TIME THE SMALL LOCAL PHENOMENA THAT ARE EQUALLY VITAL TO GAINING A DEEPER UNDERSTANDING OF CLIMATE.

Satellite altimetry started on dry land before reaching the sea. GRGS, the French space geodesy research centre federating teams from ten national research institutes, was the first to demonstrate the new discipline's value. By extending it to oceanography, CNES applied it to *"a turbulent environment driven by complex dynamics consisting of currents, eddies and tides,"* in the words of Philippe Escudier, the agency's former head of Oceans and Cryosphere programmes. The oceans are well suited to this type of measuring technique, as they generate both horizontal and vertical movements of large water masses. They also store 93% of the excess heat from global warming, which combined with the influxes of freshwater from melting glaciers is causing the oceans to expand and sea level to rise. But that's not all: oceans are also a 'sink' for carbon gas absorbed from the atmosphere. These well-known global interactions conceal a multitude of phenomena at varying scales that are difficult to investigate. It was to this huge research task that CNES committed itself in 1987, signing a memorandum of understanding with NASA to develop a high-precision altimetry mission—a world first. TOPEX/Poseidon was born.

13 CM

Initial performance
targeted by TOPEX/Poseidon for the accuracy of its sea surface height measurements. Today, performance has improved more than fivefold, enabling scientists to track global sea level rise with a precision of 0.5 mm a year.

METEORIC RISE

Launched in 1992, this first-ever oceanography satellite achieved exceptional results for 13 years, enabling CNES to acquire world-class expertise in satellite altimetry. *"Everything was driven by the goal of millimetre accuracy and performance gains, in the measuring of geometry, precise orbit determination, radar and processing, and geophysical corrections,"* recalls Philippe Escudier. CNES, the national mapping, survey and forestry agency IGN and GRGS achieved such accuracy thanks to the DORIS[1] precise

Malé, the capital of the Maldives, is facing the dual threat of submersion and coastal erosion.

positioning system, able to determine the satellite's orbit to within one or two centimetres. DORIS determines satellite trajectories and the position of ground stations through a dense and uniform network of ground beacons. This and subsequent missions helped scientists to unveil and quantify variations in ocean topography (seasons, climate anomalies, mean sea level, etc.). They also revealed the role of oceanic and coastal tides, tracked currents and eddies, and detected the first signs of an onset of the El Niño phenomenon (see Roundup p. 8). Each millimetre gained in precision brought new improvements on both satellites and on the ground, as this type of composite measurement combines data from several instruments and from numerical models. Processing of data on the ground is therefore of prime importance.

SUSTAINED RESEARCH AND LEAP-AHEAD TECHNOLOGIES

From 2001 onwards, the Jason series of satellites took over TOPEX/Poseidon's mantle. Built around ground-breaking technologies, they proved just as fruitful. CNES developed a generic spacecraft bus called Proteus[2], greatly reducing instrument mass without diminishing performance and thus paving the way for minisatellites operating in low Earth orbit. Jason also signalled the shift of satellite altimetry to operational services for sectors closely dependent on ocean conditions, such as maritime safety, conservation of fish stocks and weather forecasting. Combining this reference mission and other complementary missions, scientists were able to acquire a denser and richer corpus of observations. For example, TOPEX/Poseidon measurements were combined with those from ERS and the U.S. Navy's GFO mission, and Jason data were combined with those from Envisat and later SARAL (India) and HY2 (China). The European Copernicus programme is a perfect illustration of this approach. Ultimately, Jason-CS-Sentinel 6 will succeed Jason-3 and follow in the footsteps of the benchmark missions developed since 1992.

The CFOSat satellite's SWIM instrument undergoes testing in the anechoic chamber at Thales Alenia Space.

Despite all of these advances, much still remains to be learned about our oceans and CNES continues to play a leading role in monitoring them. With the China National Space Administration (CNSA), it is operating the CFOSat mission (see Roundup p. 7), whose first results have already confirmed the good performance of the satellite's radar instruments. The initial collaboration with NASA has since blossomed into a longstanding partnership on the Jason series and is now set to continue with SWOT[3], which starting in 2021 will cast its beady eye on surface waters, shorelines and estuaries that until now have been little investigated (see p. 25-26).

1. Doppler Orbitography and Radiopositioning Integrated by Satellite
2. Reconfigurable Platform for Observation, Telecommunications and Scientific Uses
3. Surface Water and Ocean Topography

60,000

TOPEX/Poseidon

bowed out in 2006 after circling the planet 60,000 times. Its data laid the foundation for the new field of operational oceanography, and are still used today.

INDUSTRY

A DOMAIN OF EXCELLENCE

The Jason satellite's altimeter antenna being tested in the BCMA antenna test chamber at the Toulouse Space Centre.

Although only a niche market at first sight, space oceanography has in fact spawned a whole new industry. It was Thales Alenia Space (TAS) that CNES called on to build the first Poseidon altimeter; 20 years later, it has produced the best 12 altimeters ever seen and is today the world leader in the field. This first successful collaboration led to the design of the Proteus reconfigurable spacecraft bus, around which the Jason-1 satellite and a whole series of minisatellites in low Earth orbit—Jason-1, 2 and 3, Calipso, CoRot and SMOS—were built. CNES also designed the DORIS precise positioning system to support satellite altimetry missions. Thomson-CSF Detexis (formerly Dassault Electronique) built the instruments, 17 of which are still flying today. Nicknamed the 'space surveyor', it played a role in other real-time precise image location missions. Last but not least, synergies were also developed with Argos instruments, as both systems are rooted in a still-fertile industrial line of Doppler receivers.

OCEAN VARIABILITY CLOSER INSIGHTS NEEDED

There's only so much the big ocean currents can tell us. With global warming threatening coastal regions, we need more than ever to gain greater insight into small-scale ocean dynamics—a challenge that satellite altimetry is equipped to meet.

At large scales, we've already learned a great deal from conventional altimetry (see box p. 24), which has helped scientists to decipher the processes driving large-scale ocean circulation, sea level variations and horizontal redistribution of heat in the oceans. This information is vital to determine the state of the oceans and gauge its effect on global climate change; but it's not sufficient to understand local phenomena. These are what cause ocean variability, but they don't all work the same way or at the same time all around the globe. For example, a moderate global rise in sea level can have much greater consequences than expected on coastal regions and their populations. Many factors—small-scale local winds, swell, waves and ocean dynamics—come into play.

71%

The 'global ocean' is the term encompassing the Atlantic, Arctic, Indian, Pacific and Southern oceans. Together, they cover almost 71% of Earth's surface, an area of some 361 million sq.km.

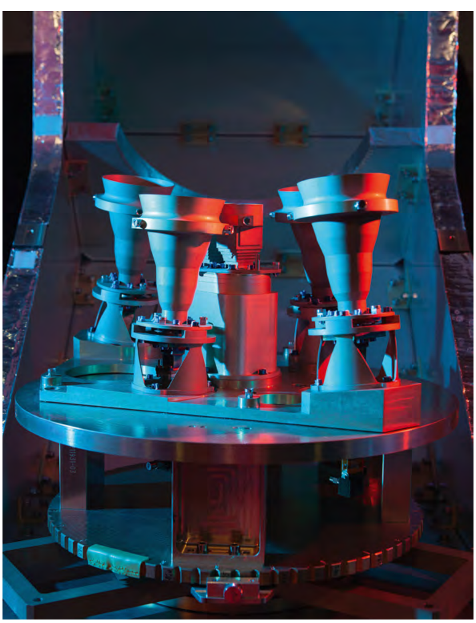
Seen from space, eddies and filaments seem small, but the disruptions they cause have a profound impact on ocean/atmosphere exchanges, affecting currents well outside their initial zone. That's why we need to investigate such small-scale phenomena to enter the correct parameters in ocean models and better predict regional ocean variability. But this is precisely where good data are lacking.

PROBING WINDS, SCANNING COASTS

"We need to be able to measure sea state very precisely in a way that factors in the role of waves in all wind conditions, because the wind has a very big impact on heat and carbon exchanges between the oceans and atmosphere. Given the way climate is evolving, we urgently need to gauge this impact to refine our projections out to 2100 and

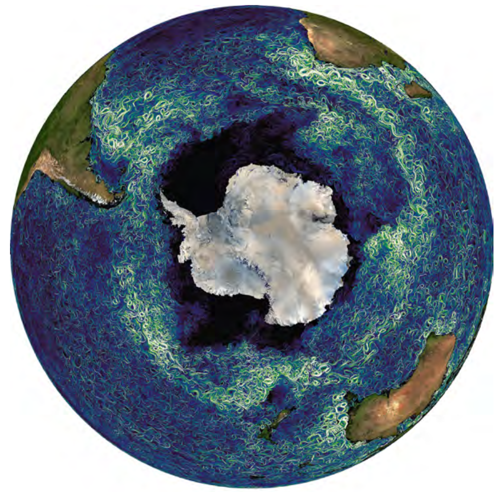
beyond," explains Benoît Meyssignac from the LEGOS space geophysics and oceanography research laboratory. This is what the CFOSat satellite has been designed to do. It will deliver data on how waves respond to surface winds for simulations. The effect of wind on ocean dynamics is also felt at intermediate scales, where zones of friction are generated between eddies and filaments, and vertical movements appear. These 'turbulences' disturb medium-scale ocean currents and also significantly impact coastal regions, for which vital data are lacking. High hopes are being pinned on new high-resolution altimetry technologies in space, which are the only way to observe these phenomena. With SWOT[1], altimetric resolution will be increased tenfold, yielding the first significant elements to complement existing products for operational organizations.

1. Surface Water and Ocean Topography



These six horns are the centrepiece of the French SWIM radar. As well as measuring sea surface height, this innovative instrument provides information about the direction and frequency of ocean surface waves.

REVIEW



GETTING THE BIG PICTURE

Conventional altimetry revealed the circulation of ocean gyres—large systems of circular currents—and major currents. Before the advent of satellite altimetry missions, the Kuroshio Current ('black stream' in Japanese)—the most powerful Antarctic circumpolar current in the world—and the Gulf Stream had almost never been observed. Investigating these currents that persist for several weeks to several months a year is vital. Satellite altimetry has also precisely estimated the rise in sea level at 3.4 millimetres a year. Now, long time-series of observations are needed over decades to understand variations in the large-scale circulation and how they are related to anthropogenic greenhouse gas emissions and the current acceleration in sea level rise. Only a concerted and consistent long-term analysis of sea level variations and the 50 other identified essential climate variables (see p. 18) will enable us to fully understand the mechanisms of climate change.

TECHNOLOGY NEW CONCEPTS

Today, CNES and its partners are offering new and more precise modes of observation. With the CFOSat and SWOT satellites, oceanography is riding on a wind of technological innovation.

The Brahmaputra estuary, Bangladesh, seen by Sentinel-2B.

Wind and wave data currently available to oceanographers are sketchy at best. The CFOSat programme—a collaboration between CNES and its Chinese counterpart CNSA, with support from partners with an interest in ocean state data like the national scientific research centre CNRS, the French institute of marine research and exploration Ifremer and the national weather service Meteo-France—intends to fill this gap.

WIND AND WAVES LEAD A DANCE

It took 12 years for this mission approved in 2007 to advance to the operational stage. CFOSat is carrying two unique radar instruments. One of them, SWIM[1], was conceived by CNES to analyse surface waves. Developed by Thales Alenia Space, SWIM builds on the heritage of previous missions (CryoSat, SARAL and Jason) but employs an innovative concept based on rotating radar beams scanning the ocean surface to cover a wide swath of 180 kilometres. SWIM is capable of delivering very precise data on wave height, wavelength and direction—a first for a spaceborne instrument. The satellite's other instrument is the Chinese SCAT[2], which measures the direction, intensity and velocity of surface winds.

CFOSat's other unique feature is that both instruments sit on the same platform and will cover the same area of interest. As a result, wind maps and wave spectra will be generated at the same time, over the same place and from the same position. Acquiring measurements simultaneously in this way is required to understand how winds and waves interact. Besides their science value, the data will also be used by marine forecasters for operational services like those developed by Eumetsat. And the mission's performance will also be gauged by its quick turnaround times, as data are expected to be delivered within three hours of acquisition, thus greatly and rapidly improving weather forecasts.

WIDE SWATH FOR SMALL AREAS

SWOT has been designed as the logical successor to the Jason satellites, but with one important difference: it's built around a novel wide-swath altimeter (see Timeline p. 28-29). SWOT will have the dual mission of observing surface waters and ocean topography, covering zones rarely or never studied such as shorelines, rias, channels and estuaries. On a map, a shoreline is a clear, sharply defined line; in reality, coasts vary as a result of tides, waves and rising sea level. Estuaries are also critical zones with complex characteristics where salt water, brackish water and fresh water mix, creating exceptional conditions for biodiversity to thrive. While not as deep as the oceans, these zones nevertheless experience bottom turbulences that have never been investigated before. The scientific value of further probing ocean/atmosphere exchanges is significant, but the societal value of these buffer zones where more than 50% of the world's population lives is even greater. In recent decades, tourism has taken root in these regions where the ecological, economic and human risks are the greatest.

1. Surface Waves Investigation and Monitoring
2. wind SCATterometer

SKIM

PERFORMANCE GAIN

The SKIM[1] mission is all set to go after being pre-selected as a candidate for the ninth Earth Explorer mission of the European Space Agency (ESA). The final selection will be made this autumn. SKIM follows in the footsteps of SWIM and is designed to pursue close study of ocean surface phenomena, particularly the currents that transport heat, plankton and microplastics. It will combine a high-performance altimeter and a wave scatterometer like SWIM to map ocean topography, surface currents, waves and sea ice over most of the globe, operating in K_a band like SWOT to offer better resolution. All of these measurements are expected to bring new insights into the global exchanges going on at the ocean surface, which are still poorly understood. The mission could be launched in 2025.

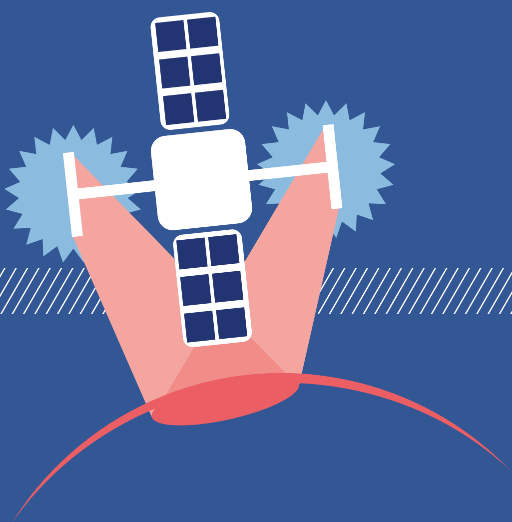
1. Surface KInematics Monitoring

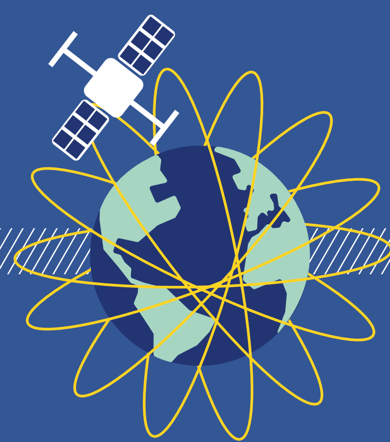
A SMALL REVOLUTION

WHERE CONVENTIONAL ALTIMETERS ACQUIRE A ONE-DIMENSIONAL PROFILE OF SEA SURFACE HEIGHT DIRECTLY UNDER THE SATELLITE TRACK, A WIDE-SWATH ALTIMETER PROVIDES A TWO-DIMENSIONAL PICTURE OF OCEAN TOPOGRAPHY. This 2D measurement breaks with the concept of a nadir radar altimeter, CNES's historic domain of expertise. The wide swath affords both better coverage and higher resolution. This new-generation altimeter is expected to refine ocean and climate prediction models, putting France in a good position for the development of future European missions carrying this type of instrument in the wake of SWOT. The technology could pave the way for observing phenomena at the scale of a few kilometres that conventional altimeters are unable to see.

The inside of SWOT's radiofrequency unit (RFU) before being covered with its multilayer insulation (MLI) at Thales Alenia Space in Toulouse.

SWOT





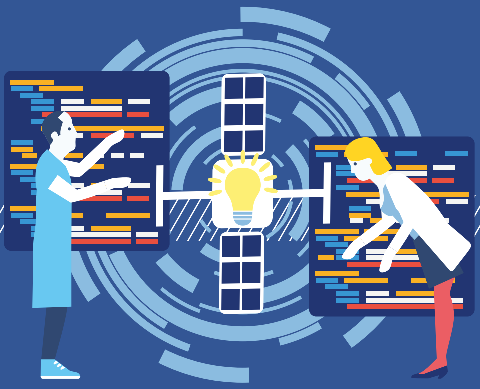
RESOLUTION
A NEW **ERA**

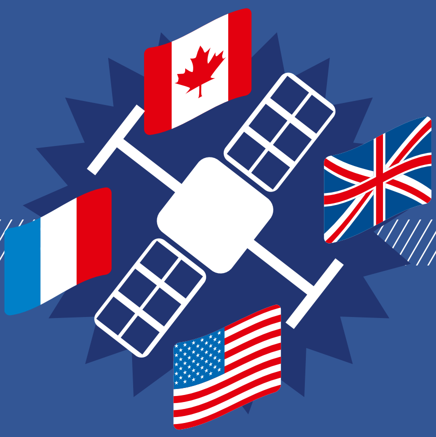
SWOT's main asset is its K_a-band radar interferometer or KaRin, set to usher in a new era in satellite altimetry with its improved accuracy and signal-to-noise ratio. Where conventional altimeters use a single antenna to measure the signal round-trip time, KaRin has two, perched at either end of a 10-metre boom and trained on the same point. This 'triangulation' technology enables a real gain in resolution. The minimum spatial resolution for SWOT has been set at 15 kilometres, good enough to decipher ocean circulation at meso- and sub-mesoscales.

REVISIT
A STABLE **RATE**

SWOT will revisit the same points on the globe every 10 days. Like previous missions, its revisit rate isn't yet frequent enough for crisis situations like natural disasters. To be able to refresh data more frequently, research is underway to conceive missions combining constellations of conventional altimeters and small wide-swath instruments. The WISA wide-swath altimeter project, currently in the early stages of design, prefigures the future of satellite altimetry.

THE JASON SERIES OF SATELLITES HAS SET THE BAR PRETTY HIGH, BUT NOW THEIR SUCCESSOR SWOT IS SET TO PUSH PERFORMANCE FURTHER STILL, COMBINING MISSIONS AND PARTNERSHIPS TO DELIVER EAGERLY AWAITED AND HIGHLY INNOVATIVE PRODUCTS. THE NEW SATELLITE WILL NOTABLY IMPROVE FORECAST BULLETINS FOR USERS OF SERVICES LIKE THE COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE (CMEMS).





INNOVATION

DISRUPTIVE TECHNOLOGIES **GALORE**

SWOT is a very costly mission. Because of its value for applications, CNES has received funding for its contribution to the mission under the government's PIA future investment programme. SMEs and mid-tier firms have also been involved in building major subsystems. From 2015, CNES set up a 'downstream' sector to plan how future data could be used, and its work has benefited SWOT. The conditions required to promote, exploit and ease access to data—and thus ensure an immediate return on investment—were put in place right from the start of the programme.

PARTNERSHIP

SWOT **IN GOOD HANDS**

Longstanding partners CNES and NASA are two of the four space agencies working together on the SWOT satellite. NASA is supplying the KaRin radiometer, a precise GPS receiver and the mission centre for the U.S. payload. CNES is supplying the satellite bus, the radiofrequency unit (RFU) for KaRin (see p. 6), the dual-frequency nadir altimeter (Ku-C), the DORIS precise-positioning system, the satellite command-control system and a data processing centre. The Canadian Space Agency (CSA) is providing the extended interaction klystrons (EIKs) that will generate and amplify microwave pulses for the main instrument's microwave transmitter, while the United Kingdom Space Agency (UKSA) is contributing to part of the RFU for KaRin.

PATRICK CASTILLAN

CFOSat project leader at CNES

“In China, time is simply a variable...”

Accents are always a giveaway: *“I’m a dyed-in-the-wool Toulouse lad,”* says Patrick Castillan with a smile. As an electronics engineer, he chose space *“for the technology and the adventure!”* Plain-speaking and with an infectious sense of humour, he loves collaborative projects. **After working on Jason-1 and Calipso with NASA, he took over CFOSat (China-France Oceanography Satellite) in 2006.** The project is the result of a political aspiration, since the French government wanted its agreements with China to include a space component. *“We’d never hosted Chinese colleagues at CNES, so the intercultural side of the project was all new territory!”* he comments. Combining the expertise of CNES and the China National Space Administration (CNSA), the satellite was orbited in 2018 and offers a new way to study the oceans. ***“Twelve years is a long time, but that’s how long it took to establish such an effective partnership. Culture, norms, communication, decision processes—everything’s different in China,”*** he says. He estimates that in 550 trips the team has covered a total of 4.5 million kilometres (2.8 million miles) between Paris and Beijing. *“We gradually forged working links, which have been a game changer. For the first tests in 2010, we plugged our mock-ups into their equipment and we all sat round the same screens. That’s when the cooperation became a real-world collaboration.”* Regularly nonplussed, baffled at times, French and Chinese colleagues gradually worked each other out. *“In China, time is simply a variable, whereas for us it’s the common thread tying together a whole way of life! We take a preventive approach, whereas they’re always about adaptability. We move forward through theories and modelling, while they rely on mock-ups and practical demonstration. And I think our meticulous administration raised a few eyebrows! **But through effort and compromise on both sides, CFOSat is a fantastic success, which makes us want to pursue other projects together,”*** he says. One of his key takeaways is the value of a spoken agreement—because *“if there’s trust, someone’s word is enough,”* making all those written memos somewhat superfluous.

MARINA LÉVY

Assistant director of the IRD development research institute's oceans, climate and resources department, and research director at CNRS, the French national scientific research centre

"Global warming is making the oceans less hospitable..."

The Deep Blue Sea is teeming with all kinds of life, which are a good indicator of its health. A graduate of France's prestigious École Polytechnique engineering school, Marina Lévy answered the ocean's call in order to "*understand what's really happening by bringing together all the various relevant disciplines*". With a postgraduate diploma in oceanography, meteorology and environment, followed by a PhD in phytoplankton production in the Mediterranean and a postdoc position at Columbia University, New York, focusing on biogeochemistry in the North Atlantic, she joined CNRS as a modeller. ***"To understand a problem, you need the big picture—which is possible by combining space technology to see the surface and in-situ studies to see what's beneath it,"*** she says. Over time, as models improved, the results became ever clearer: "*The ocean is subjected to dramatic human and climatic pressures, which we're only now detecting, mainly thanks to space and as the time series of data become long enough. Global warming is making the oceans less hospitable. Coral is struggling to adapt, fish species are migrating and phytoplankton at the base of the marine food chain are getting fewer nutrients.*" **A scientist who believes in dialogue, she's recently completed a five-year term as chair of the ocean group of CNES's TOSCA scientific committee (see p. 8) in order to "*forge closer links between French research and CNES*—**"*thanks to which our science community is at the forefront of ocean studies*". Biodiversity, climate, pollution, food security—faced with these challenges, the United Nations has proclaimed a Decade of Ocean Science, 2021–30. Hoping there'll be a mission dedicated to ocean colour for more-in-depth studies of coastal regions, heavily impacted by humans, she firmly believes in the role of satellites for the future: "*Altimetry, sea state, temperature salinity and more—* ***space missions are giving us new and ever more detailed information. To monitor changes and preserve the ocean, we need continuity in all these data".***

CHRISTOPHE GUINET

Marine ecologist at the French national scientific research centre's Chizé biology research centre

"We're making the connection between ocean conditions and how these creatures live."

Christophe Guinet first came across elephant seals as a graduate marine ecology researcher studying one of their predators, the killer whale. **"At Chizé, we build our knowledge about the behaviour of a species by observing colonies over the long term—some of them since 1950,"** he explains. "*In 2003, inspired by the experience of colleagues and nascent telemetry technologies, I saw elephant seals as an ideal species for collecting uniform measurements in the southern waters where they feed.*" Now a research director, **he's discovered a remarkable sentinel species: 98% of ocean temperature and salinity data in the Antarctic region is thanks to these deep divers,** which daily make up to 60 descents of 20 minutes or more, reaching depths of 500 to 2,000 metres (1,600 to 6,500 ft). The Argos transmitters they're fitted with don't do them any harm. Elephant seals can swim 4,000 kilometres (2,500 mi) in three months, so the transmitters had to be upgraded to archive the long time series of data, which are retrieved when the animals come ashore. "*By adapting the sensors to each species and its behaviour patterns, we're making the connection between ocean conditions and how these creatures live. When an individual comes up to breathe, it remains motionless, bobbing around on the swells, typically with its back to the waves. The sensors on its head tell us about the sea state: the accelerometer provides data about swell frequency and amplitude, the magnetometer about which way it's facing—so wind and wave direction.*" Temperature, salinity, dissolved oxygen, fluorescence, pressure and sea state—CNES uses all of these data to check and calibrate its satellite measurements in the Antarctic. Relying especially on the combination of CFOSat and SWOT data, Christophe also sees great value in the perspective afforded by 15 years of measurements: ***"Elephant seals are showing us how the Southern Ocean environment is changing.*** *The data they provide is helping us identify ecologically important areas and focus on applications for the sustainable management of marine resources.*"

Jacques Arnould,
science historian
and theologian,
CNES ethics officer.

ETHICS CORNER

JACQUES **ARNOULD**

ANCHORS AWEIGH!

Space hasn't just enabled us to observe this precious blue rock, Earth. It's also given us incredible capabilities for continuing to explore our planet's oceans. So let's not overlook the wisdom and experience of our seafaring fellows.

April 1610. After Galileo's night sky observations in Padua, Italy, the previous winter, the astronomical revolution had begun. In Prague, Johannes Kepler could write: "*Let us create vessels and sails adjusted to the heavenly ether, and there will be plenty of people unafraid of the empty wastes. In the meantime, we shall prepare, for the brave sky travellers, maps of the celestial bodies—I shall do it for the Moon; you Galileo, for Jupiter.*" Thus, when contemplating space travel, Kepler immediately likened it to navigating the world's oceans. John F. Kennedy picked up on this connection in his famous Moon speech in Houston, 12 September 1962: "*We set sail on this new sea…*" and "*whether this new ocean will be a sea of peace or a new terrifying theatre of war*".

ONE EXPANSIVE OCEAN

For over 60 years, we've been setting sail for space. But we've still much to learn from seafarers, because space is one incredibly expansive ocean, which we've barely begun to navigate. There's no other horizon, except that imposed by the limits of our knowledge and engineering. There's no far shore, except the partly explored planets and the patiently built ports—no doubt the trading counters of the future. And there are no bottomless depths, other than what the sharpness of our telescopes or the agility of our probes can fathom.

Are we ready to brave such an ocean? Are we prepared to push out from the relative safety of the coast and make for the high seas? What maps and charts do we have? What compasses and reference points, not just technical, but political and legal? Our experience of Earth's oceans is crucial as we seek to establish a common governance of space's mineral and other resources, and as we prepare our crews for the long voyages of the future.

Are we ready to weigh anchor?

MUST READ

SATELLITE ALTIMETRY OVER OCEANS AND LAND SURFACES

Edited by Prof. Dr. Detlef Stammer of the University of Hamburg and Dr. Anny Cazenave of the LEGOS space geophysics and oceanography research laboratory, this book offers an overview of satellite altimetry techniques and related missions. It covers the most recent applications, including studies of ocean dynamics and sea level. It also discusses space-based observations of the ocean surface and marine geoid, operational oceanography and applications of satellite altimetry for studies of the cryosphere and land surface waters.

Published by CRC Press in October 2017.

MUST SEE

Reference website

The AVISO website designed by CNES has become a global reference resource for altimetry. Dedicated to the use of satellite altimetry data measuring sea surface height, the website is open to everyone. The team interacts with users via a newsletter so they can keep pace with what people want and also improve services.

www.aviso.altimetry.fr

MUST READ

Advances in Space Research, Special Issue “25 years of satellite altimetry“

Late 2017 marked a quarter of a century of altimetry. Contributions from across the science community, progress made and discoveries in the last 25 years have been compiled for this special issue, currently going to press.

Published by Elsevier in the autumn.

9 MILLION

That's how many tonnes of plastic waste end up in the oceans every year. This waste is one of the factors driving climate change. Some experts even predict that by 2050, the weight of plastic in the oceans will exceed that of fish.

POSTERS

CFOSAT **IN RETRO STYLE**

In 2018, CNES designed a set of retrofuturistic posters on the year's key space events to raise public awareness about what we do as a space agency. Five posters were produced in Thomas Hayman's signature pointillist style, each taking its cue from the kind of graphics used in advertising in the 1960s. CFOSat was one of the chosen missions, and so has its own poster.
In June 2019, the poster series was singled out for an award by France's prestigious Art Directors' Club.

ARGONAUTICA

ALL SCHOOLS ON DECK!

From 22 to 24 May, the Mare Nostre Aquarium in Montpellier hosted a very attentive group of visitors: the classes involved in the Argonautica schools programme. CNES designed this programme with teachers to introduce young people to tools like Argos transmitters and show them how to use satellite data to investigate a whole range of topics. Underpinned by CNES missions, Argonautica is structured around the major environmental issues of our time, helping pupils understand how the oceans work and encouraging them to reflect on the future of the marine environment and the species living there. It's based on three pillars. The first is ArgoNimaux, which invites classes to track the movements of marine animals fitted with Argos transmitters and measure the impact of environmental variations on various species. Second, ArgOcéan immerses pupils in the major ocean currents, like the Gulf Stream. It also has a human component, where they track skippers in the Vendée Globe round-the-world yacht race. And third, ArgoHydro focuses on technological innovations and how to assess the impact of climate change on the water cycle, with schools encouraged to do field work at local lakes and rivers. For all these projects, classes involved in the Argonautica initiative have access to data from satellites and experimental buoys.

https://enseignants-mediateurs.cnes.fr/fr/web/CNES-fr/7161-argonautica.php

DIARY

21–25 OCTOBER 2019
Annual meeting of the Ocean Surface Topography Science Team (OST-ST), attended by 350 international scientists invited by CNES, NASA, NOAA and Eumetsat.
Chicago, IL

APRIL – MAY 2020
IASI meeting (Infrared Atmospheric Sounding Interferometer)
France

12–16 OCTOBER 2020
OST-ST meeting (Ocean Surface Topography-Science Team)
Darmstadt, Germany

TRIBUTE

Michel Lefebvre, the father of space altimetry, has died

Passionate about the ocean, Michel Lefebvre will be remembered for his infinite kindness. It is to this visionary that we owe France's first altimetry mission and the Doris system. Determined to build a true community around these issues, he also founded the series of "Jason" conferences which led, among other things, to the development of Mercator Ocean International.

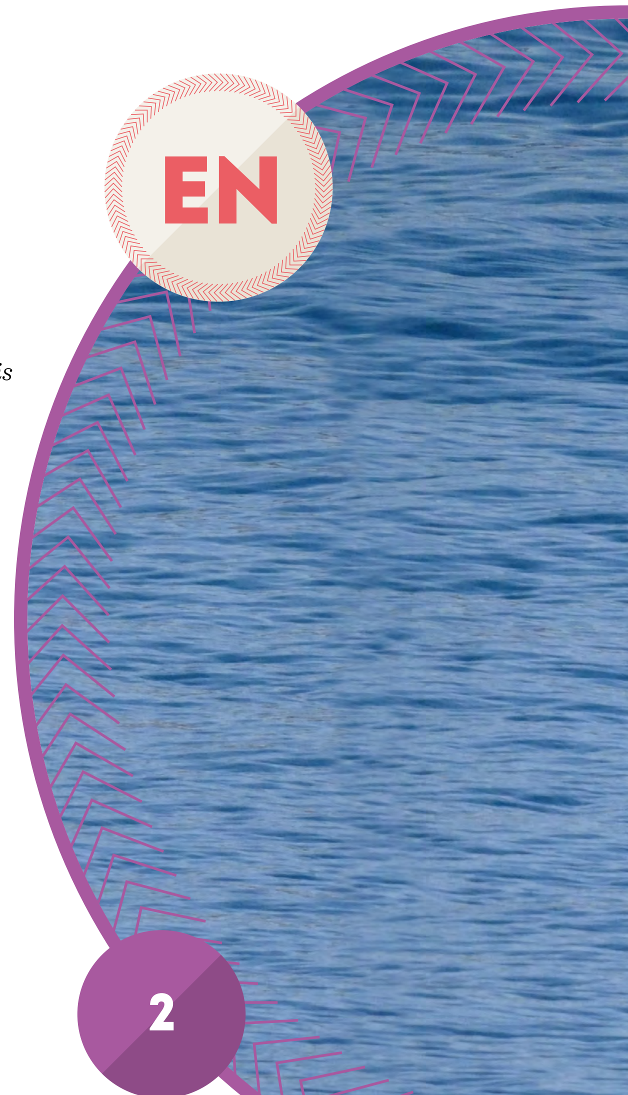
MAPPING THE OCEAN SYMPHONY

Under the ocean surface, it's hard to see that far. Only sound propagates any distance and is vital to marine life, creating a symphony sometimes seriously disrupted by humans. To fix this considerable problem, Brittany-based SME Quiet-Oceans is putting on line a system for monitoring and predicting natural and human-made noise—a tool built using satellite data.

All marine animals emit sounds to locate themselves, hunt for food or communicate. It's now proven that human noise impacts marine life in the short and long term. After working on NATO sonar exercises that had uncovered this issue as far back as 1995, Thomas Folegot and his two business partners decided to listen to the sea to protect it. Their idea: to compile an acoustic map.

To do that, they first had to characterize how sound is propagated in the ocean, which depends on the water's temperature and salinity, the depth and nature of the ocean floor, and sea state. *"Although we work underwater, we get our input data from space,"* explains Thomas Folegot. *"Combined with Mercator Ocean International to describe the oceanography of a zone, our Quonops systems retrieves all of the known raw data for that zone, notably shipping traffic, which is the main source of human noise."*

Since 2010 in Europe, the Marine Strategy Framework Directive requires any maritime project to provide an assessment of its sound footprint and impact on marine wildlife. Quonops lets users simulate various sources of noise for a region of interest on line. *"Users can thus define their work scenario and model what it adds to existing noise. The system then lets them match the acoustic map obtained to the potential presence of certain species to assess the risks and impacts of the project in question,"* concludes the acoustics expert.



2
million
acoustic maps already compiled by Quonops around the globe.