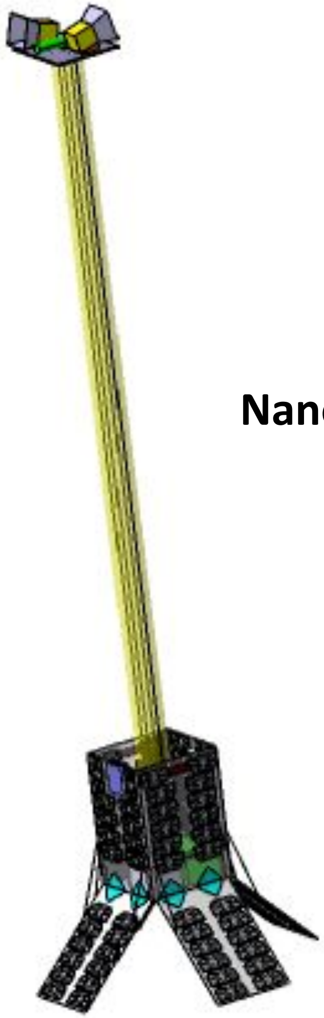
Cubesat projects within IPGP



12U
NanoMagSat

3U-6U
IONOGLOW

1er Workshop Cubesat Étudiants National, 09-10/06/2016, Paris, France

NanoMagSat
a forerunner nanosatellite
for geomagnetic and ionospheric observations

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CEA-Léti, MINATEC, Grenoble

1er Workshop Cubesat Étudiants National, 09-10/06/2016, Paris, France

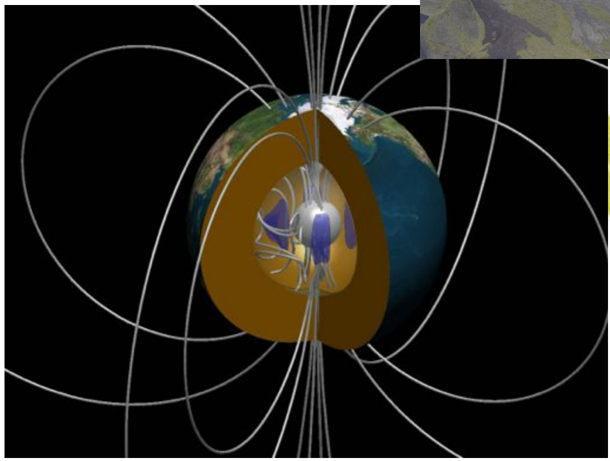
Goals of the NanoMagSat project

- To design and build a forerunner nanosatellite for geomagnetic and ionospheric observations, by taking advantage of lessons learned from the ongoing ESA Swarm mission
- Short/medium-term : to enhance the science return of the Swarm mission
- Long-term : to open the way to collaborative space geomagnetic and ionospheric observations, by extending the International Network of Geomagnetic Observatories "Intermagnet" to space

The Earth's magnetic Field has a great variety of sources

- The main source is the geodynamo within the core
- This main source is responsible for the magnetization of rocks with the Earth's crust, itself a source of secondary magnetic fields
- But electrical currents also flow within the ionosphere, the magnetosphere and even the oceans

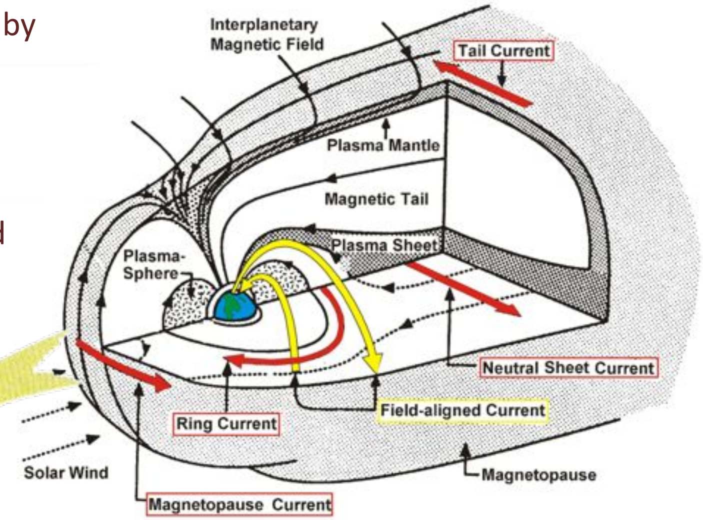
Rocks in the crust are magnetized by the core field



J. Aubert, IPGP

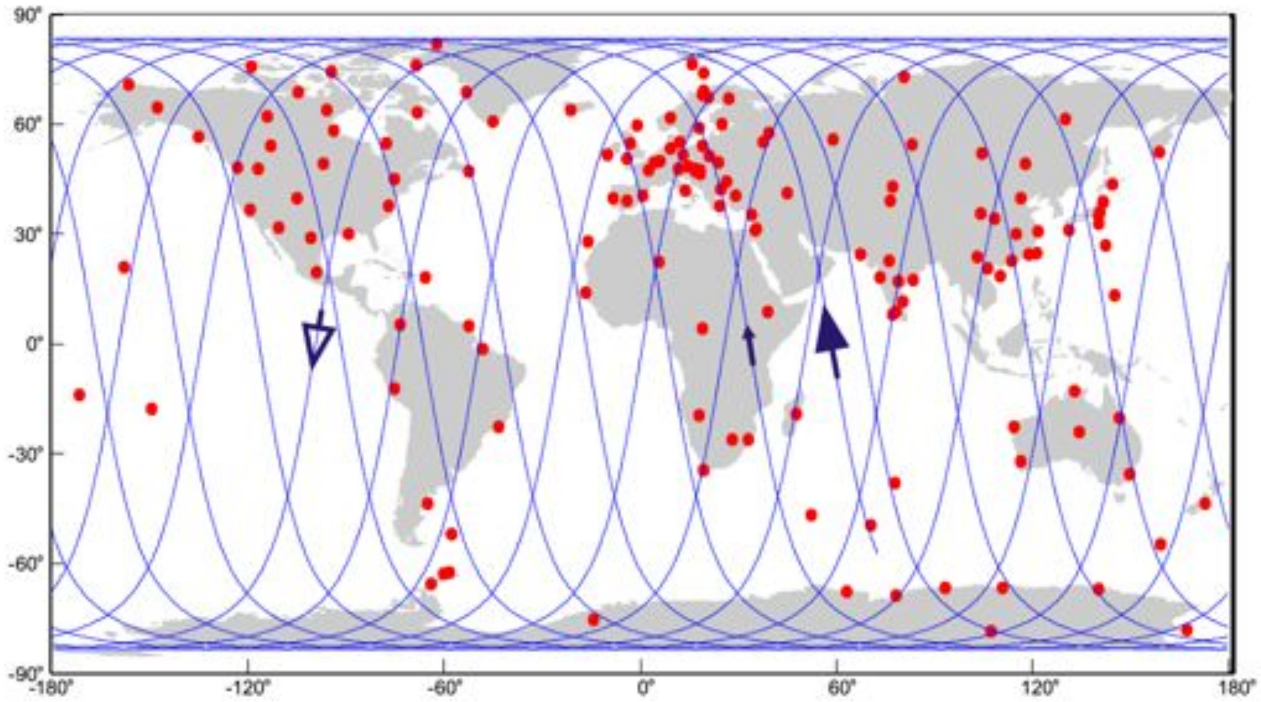
In the liquid and conducting core lies the geodynamo

In the ionosphere, ionized by the Sun and excited by thermal tides, electrical currents arise



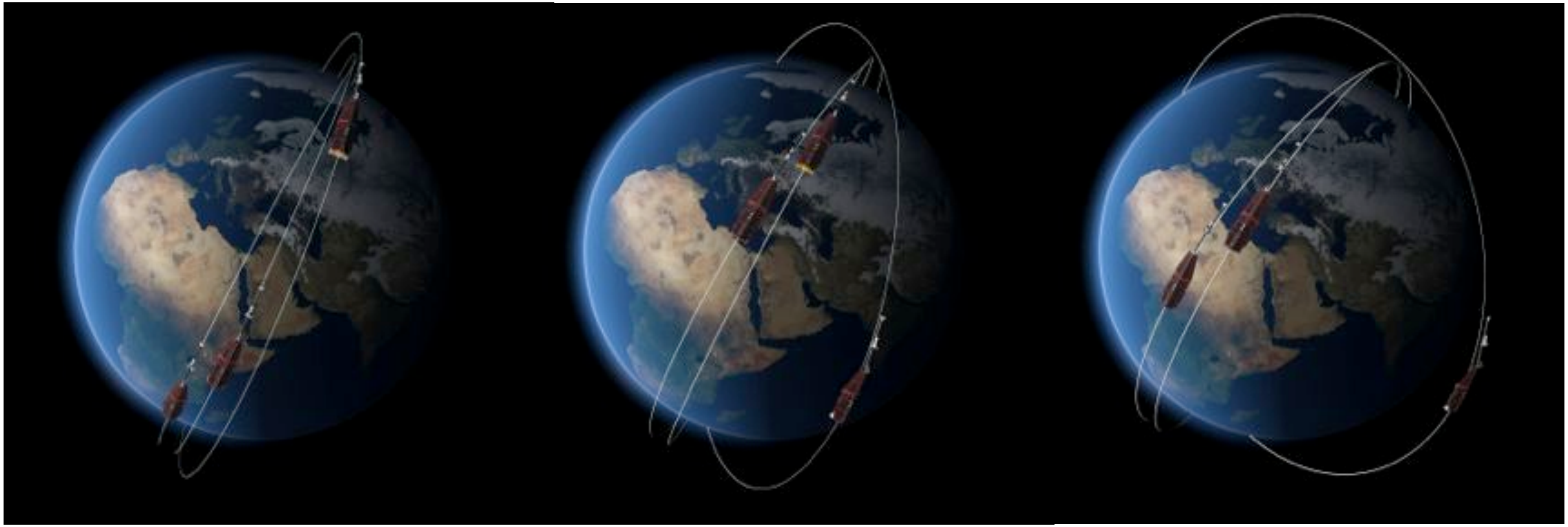
In the magnetosphere, motion of charged particles form large-scale electrical currents

Challenges of magnetic observations



Deciphering the signal from each source requires very accurate magnetic observations at different local times

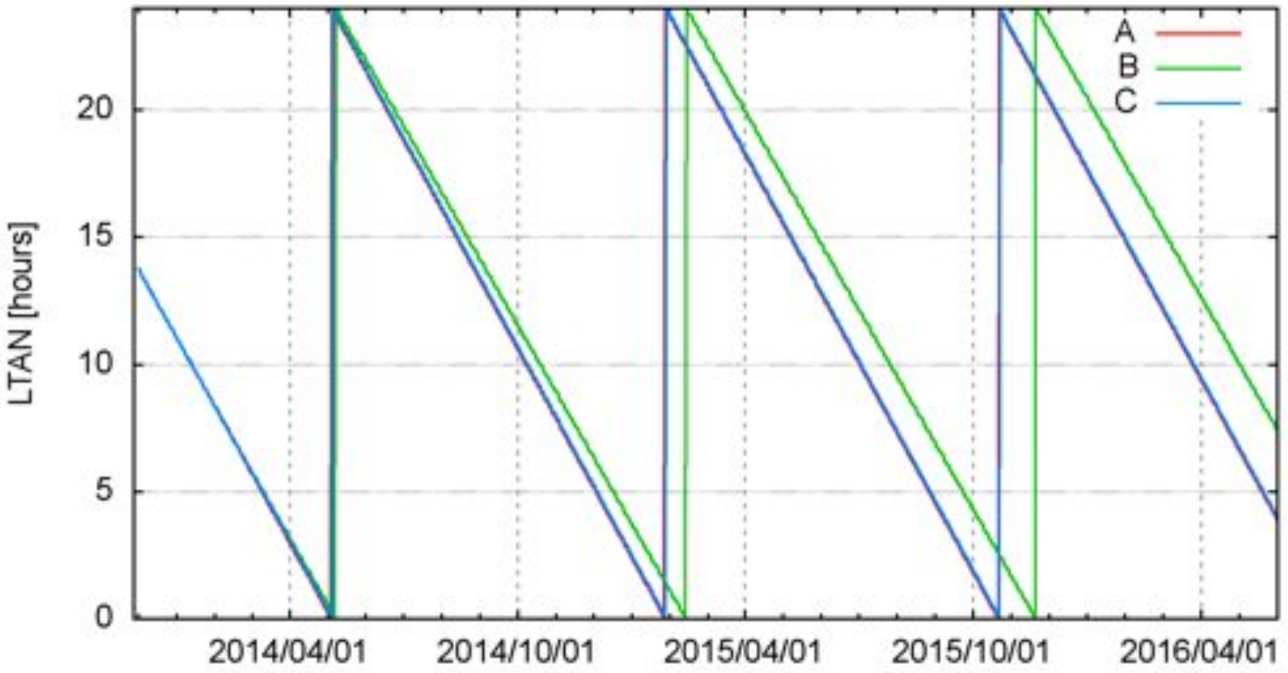
Local time separation of Swarm satellites



End of April 2014 | 3 hrs: April 2016 | 6 hrs: April 2018

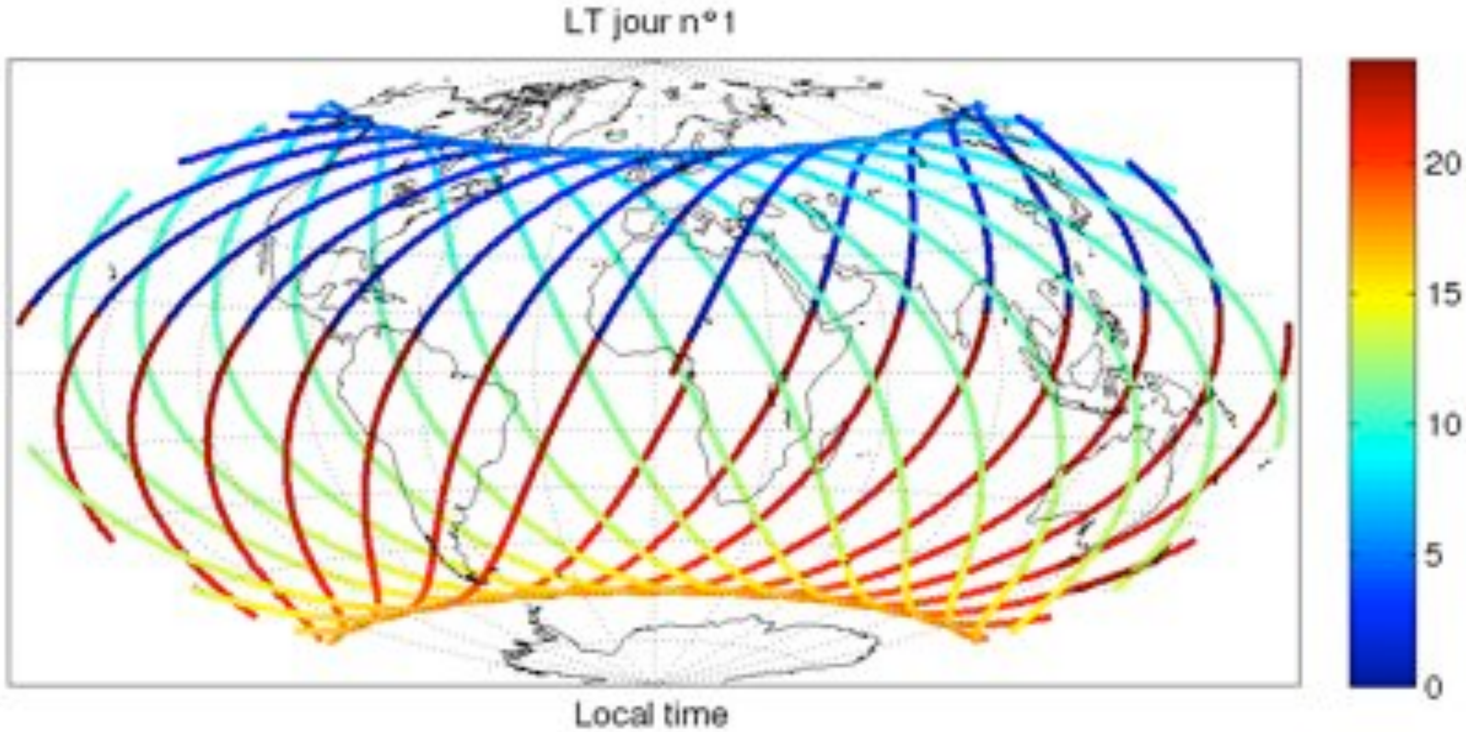
- It will take almost another three years to reach 6 hrs local time separation, and only four different local times would then be sampled.

Time needed to cover all local times



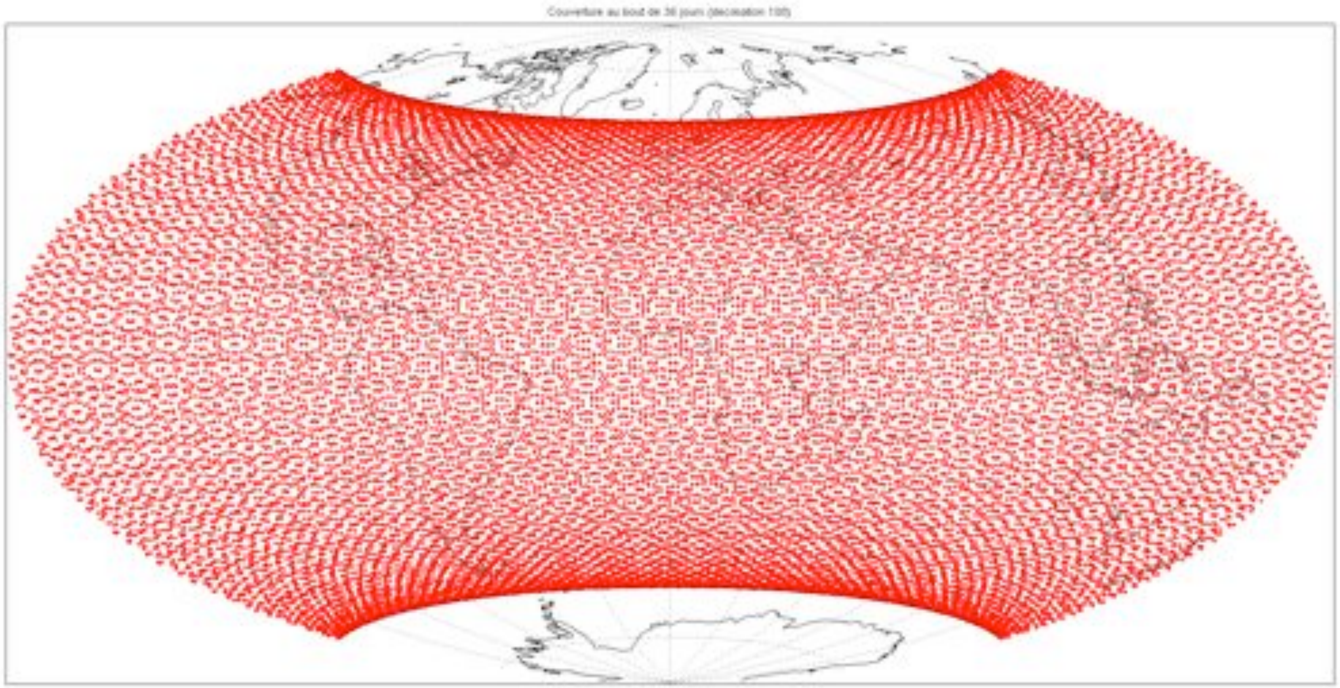
- It currently takes roughly four months for the Swarm constellation to cover all local times.
- This will decrease to two months when full separation of Alpha/Charlie with respect to Bravo will be reached (April 2018)
- This is very nice, but could still be improved

A satellite on an orbit at (say) 60° inclination would provide the missing local times fast



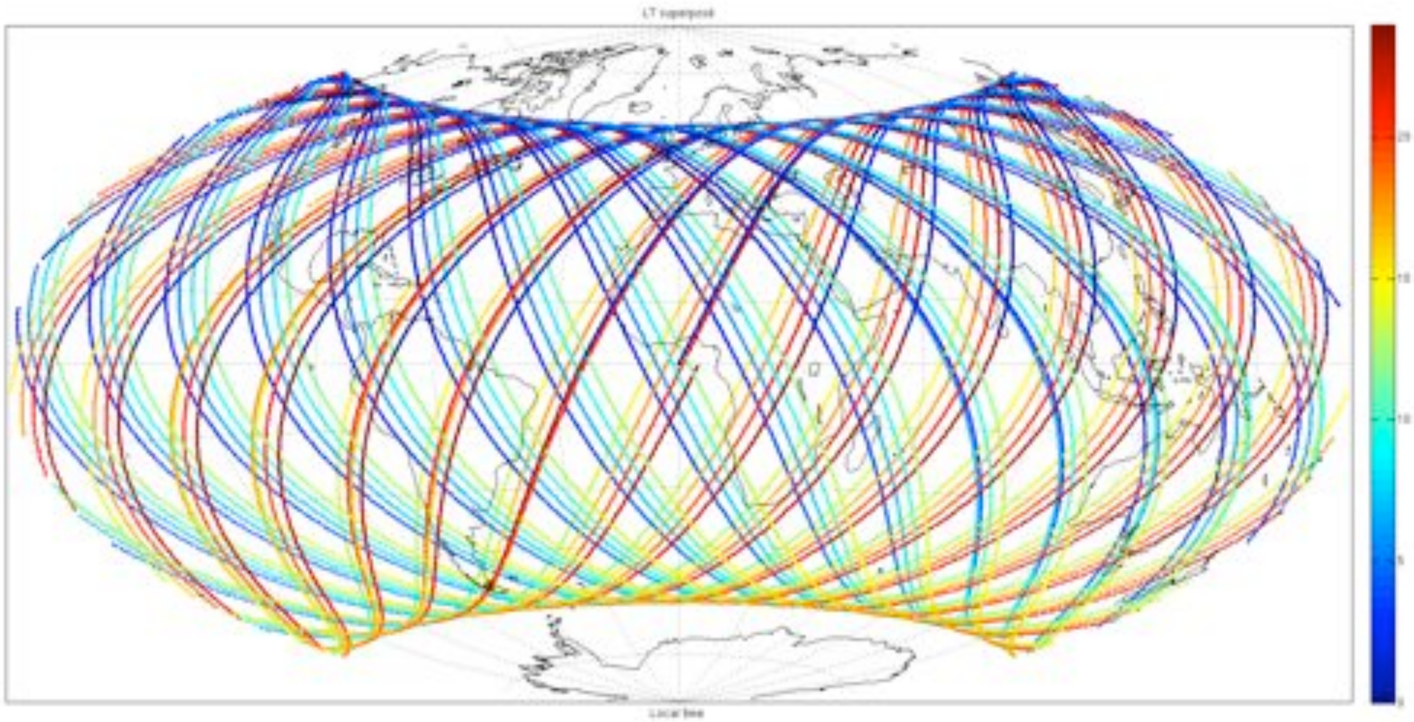
One day of local time and geographic coverage

A satellite on an orbit at (say) 60° inclination would provide the missing local times fast



Geographic coverage after 36 days (1 point every 100 s)

A satellite on an orbit at (say) 60° inclination would provide the missing local times fast as well as crossing orbits (tie points)



Combined Days 1, 9, 18 and 27 of local time and geographic coverage

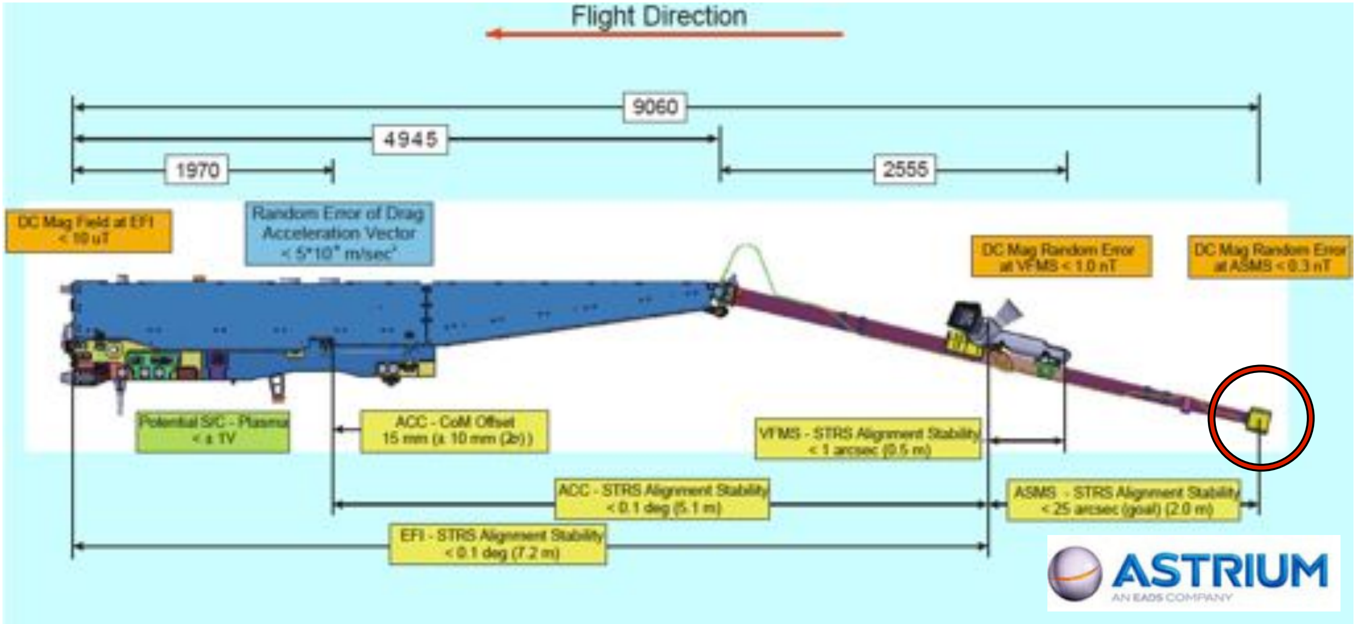
Benefits such a satellite would bring for investigation of the magnetic field sources

- Higher temporal resolution for ionospheric Sq field models (down to one month)
- Improved reconstruction of fast changes (sub-annual) of the core field
- The lithospheric field could also be improved, also thanks to the 60° crossing of the orbits (providing tie points)

But also:

- Improved understanding of local ionospheric currents
- Improved spatial description of the magnetospheric field
- Improved input for investigations of the electrical conductivity of the Deep Earth, and tidal signals

Current payload on the Swarm satellites



Absolute Scalar Magnetometer (CEA/LETI, CNES), 1Hz (scalar + vector) OR 250 Hz scalar

Vector Field Magnetometer and Star Tracker (DTU Space), 50Hz, 1Hz

Accelerometer (VZLU, CZ), 1Hz

Electric Field Inst. (Charge particle imager, UC; Langmuir Probe, Uppsala), 2Hz

GPSR (Ruag), 1 Hz

The Swarm ASM instrument can be used as a stand-alone dual purpose magnetometer

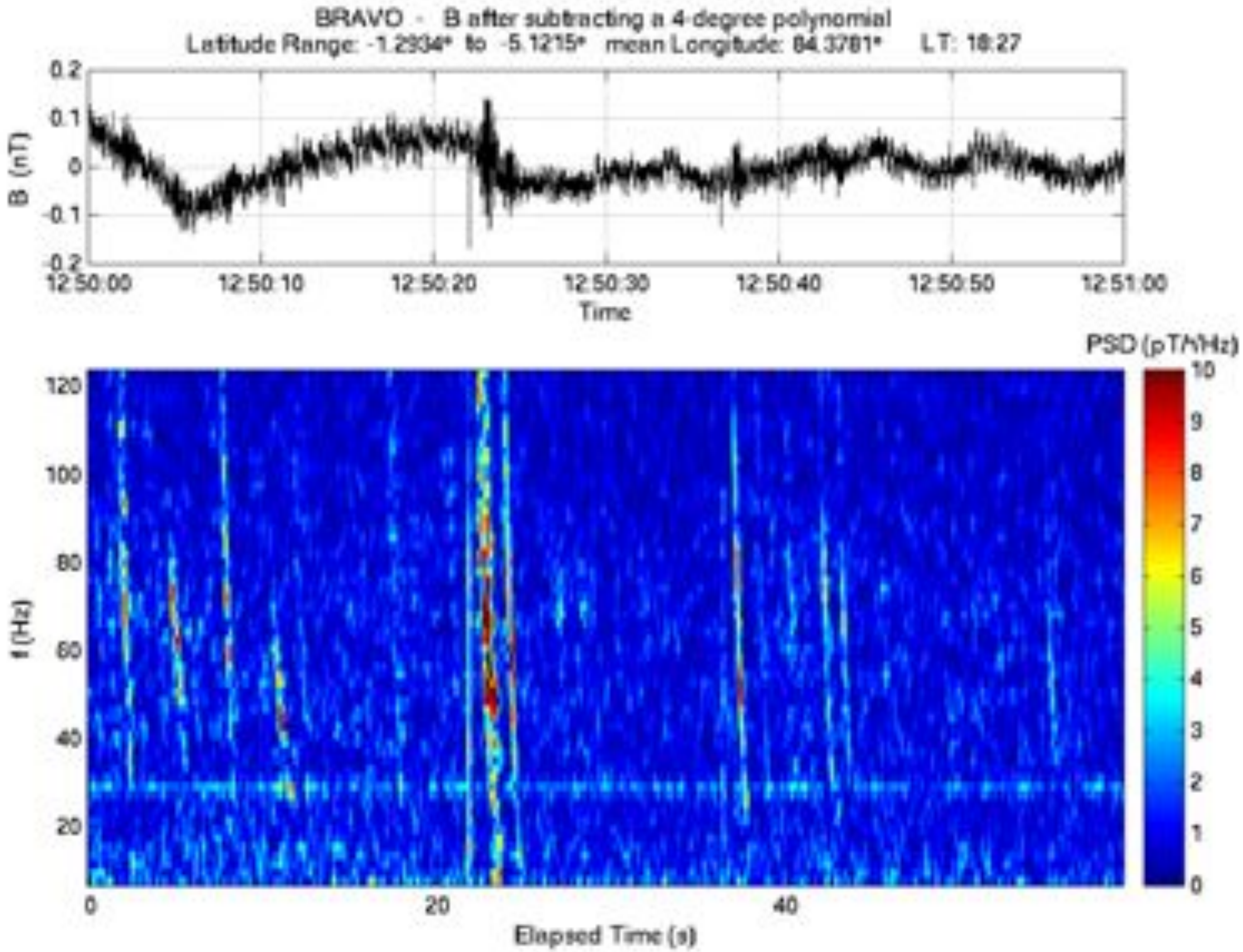
- It can provide independent absolute scalar (σ = 65 pT) and vector data (with self-calibration procedure, σ = 1.6 - 1.9 nT) at 1 Hz

  -> these “vector mode” data have been used to compute very valuable global field models, despite the remoteness of the star cameras away on the boom (Hulot et al., GRL, 2015; Vigneron et al., 2015)

- It can also provide high frequency absolute scalar data (resolution close to 1pT/√Hz) at 250 Hz

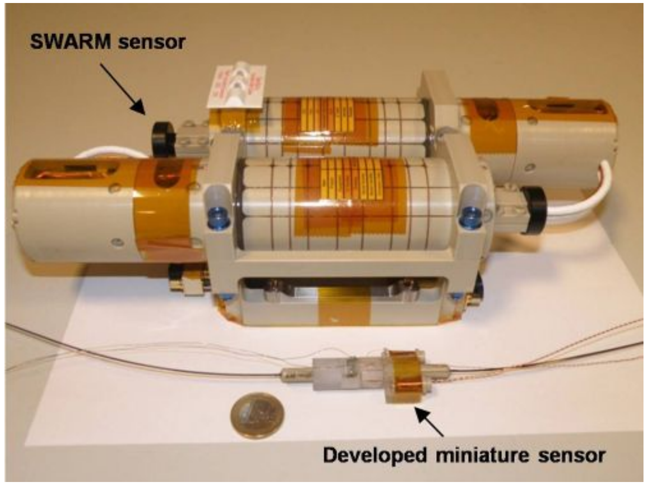
  -> these “Burst mode” data testify for interesting small scale features in plasma bubbles, and can detect “whistler” types of signals

Example of low frequency “whistler” type of signals detected with the ASM burst mode



Progress on the ASM instrument

- The instrument is currently being miniaturized (Rutkowski et al., Sensors Actuators, 2014)

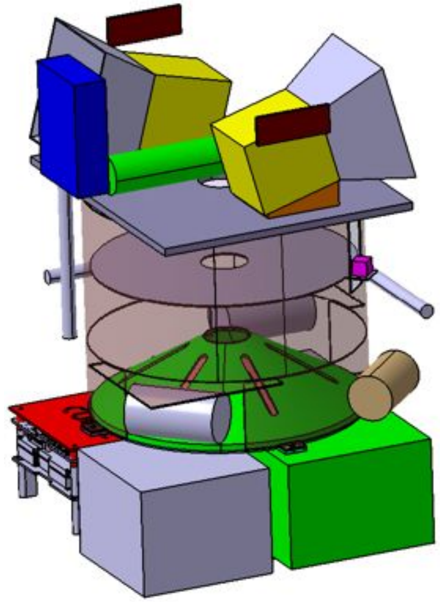


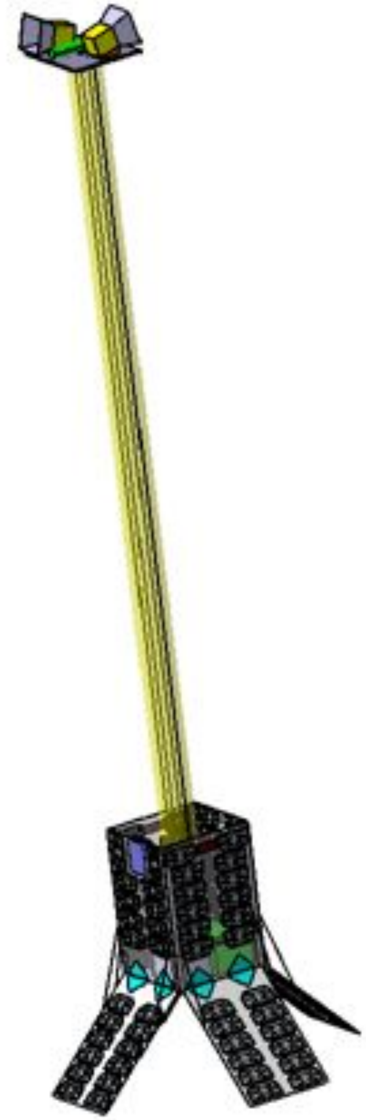
- Issues identified on Swarm (see Léger et al., EPS, 2015; Fratter et al. AA, 2016) are currently being solved

- The instrument could be run in a permanent dual mode so as to simultaneously provide 1Hz scalar + vector data AND 250 Hz scalar data.

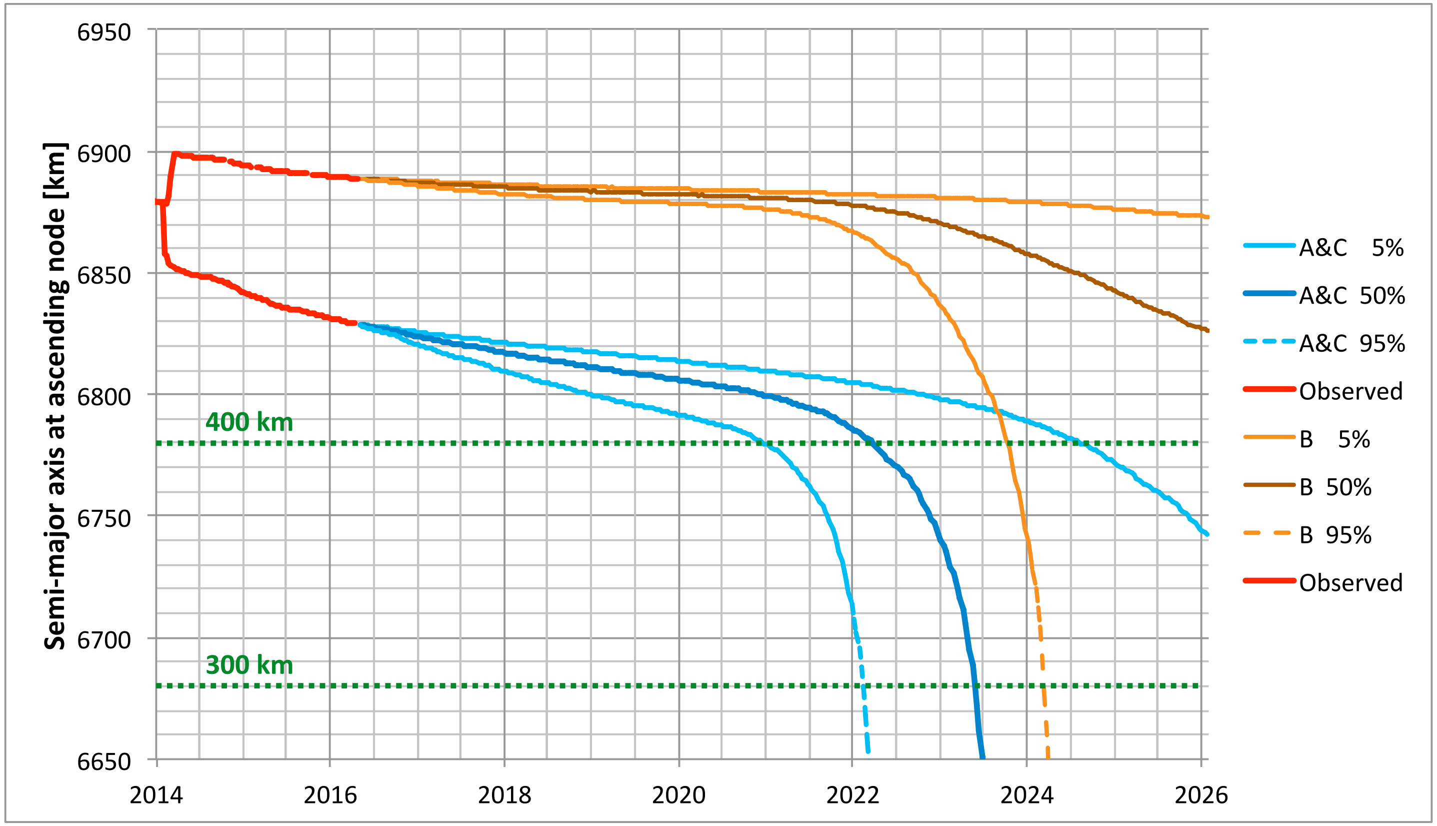
The NanoMagSat project

- **12U Cubesat** (20cmx20cmx30cm) with a 2m boom for the magnetometry payload
- **Miniaturised ASM** magnetometer in **dual vector/burst mode, with two star cameras**.
- Possibility of **miniaturized VFM or search coils** to also measure high frequency vector field fluctuations (up to 500 Hz ?)
- **Langmuir Probes** (Te, Ne)
- **Dual frequency GPS** (TEC)
- **Little attitude control**: gravitationally stabilized (requirement: spin < 40°/mn swing < 30°/mn to keep bias below 0.2nT)
- **No propulsion**





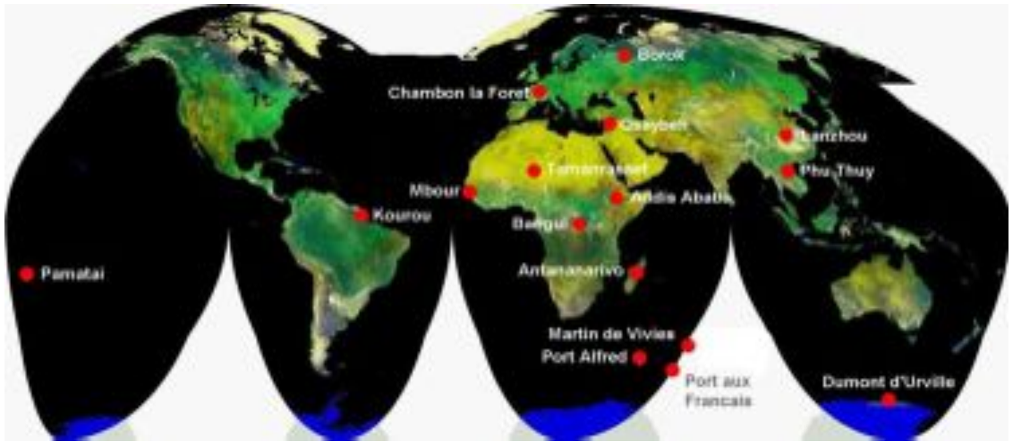
Aiming at a launch before 2021



- Swarm's constellation is complete up to 2022, at least
- Higher Bravo satellite could stay even longer in orbit, likely well beyond 2024

Next steps

- Complete the NanoMagSat Phase 0 study within CNES (June 2016)
- Run a set of complete end-to-end simulations with the help of the Swarm science community
- Present the mission to the next level within CNES (Fall 2016 ?)
- Improve Swarm by taking advantage of a low-cost nanosatellite
- Move towards an “InterMagSat” network of orbiting magnetic observatories (space extension of the “Intermagnet” network of ground magnetic observatories)



Ecole et Observatoire des Sciences de la Terre

Institut de recherche pour le développement

BUREAU CENTRAL DE MAGNÉTISME TERRESTRE France

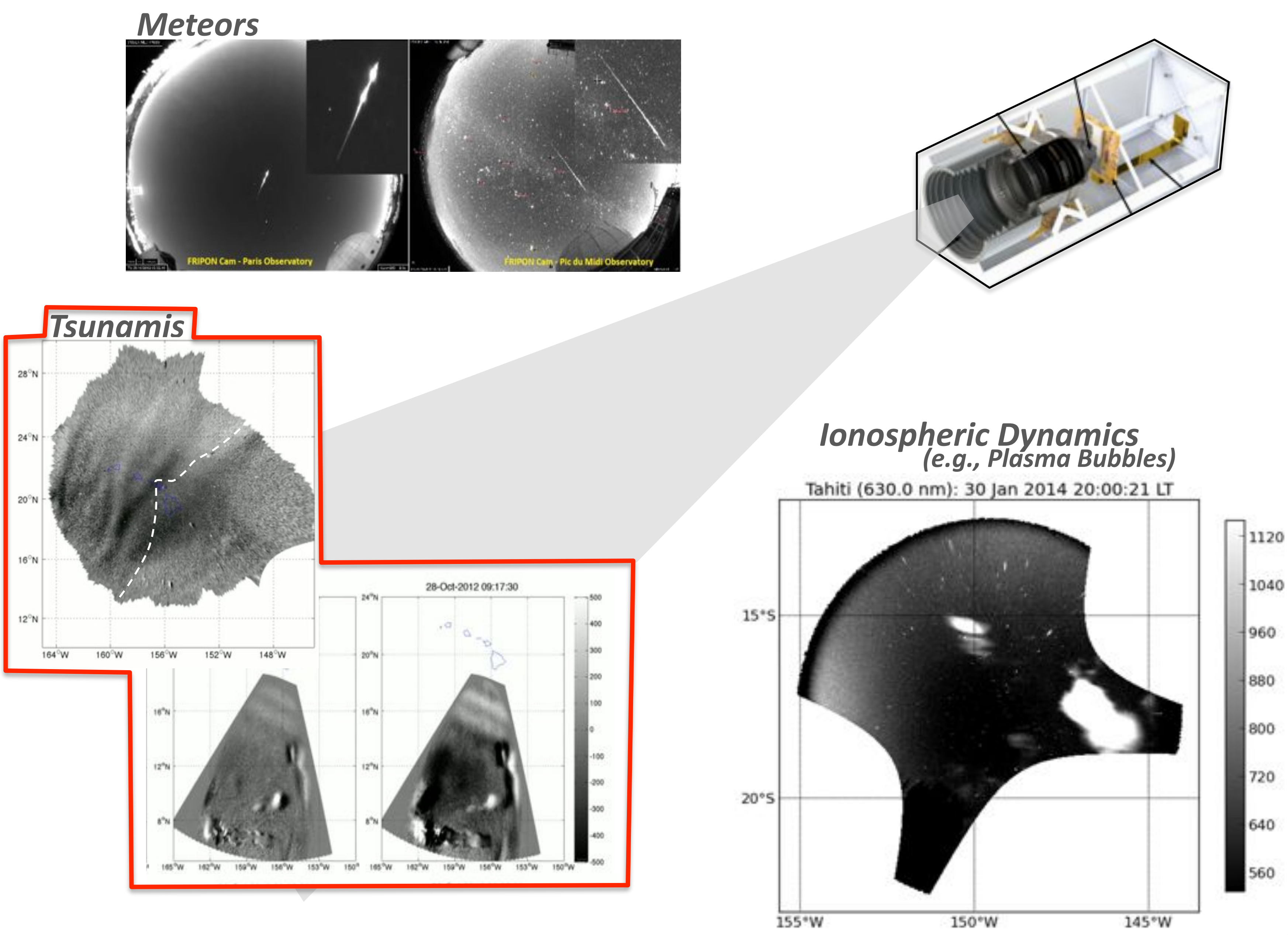
IONOGLOW: *Ionosperic Dynamic & Tsunami Airglow Detector*

Giovanni Occhipinti, Elvira Astafyeva, Philippe Lognonné, *et al.*

IPGP
INSTITUT DE PHYSIQUE DU GLOBE DE PARIS

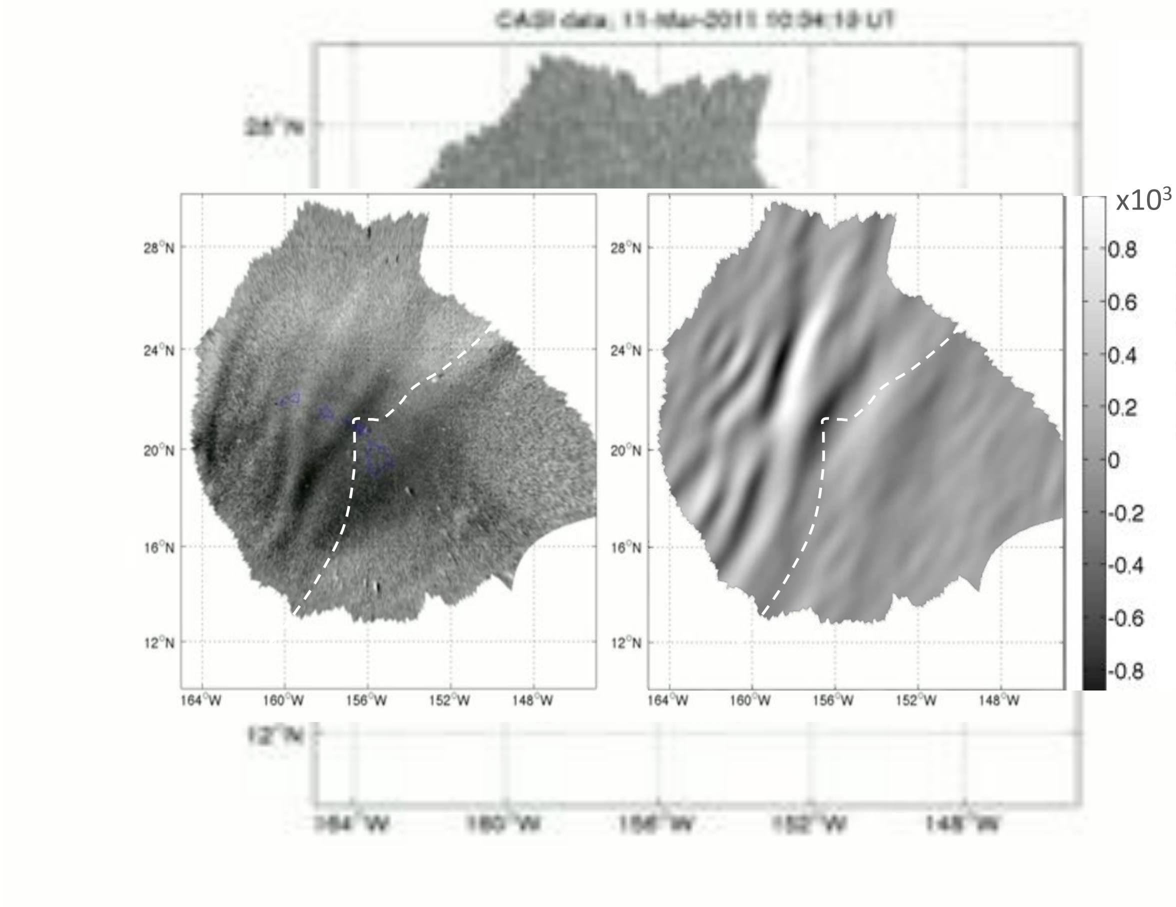
cnes

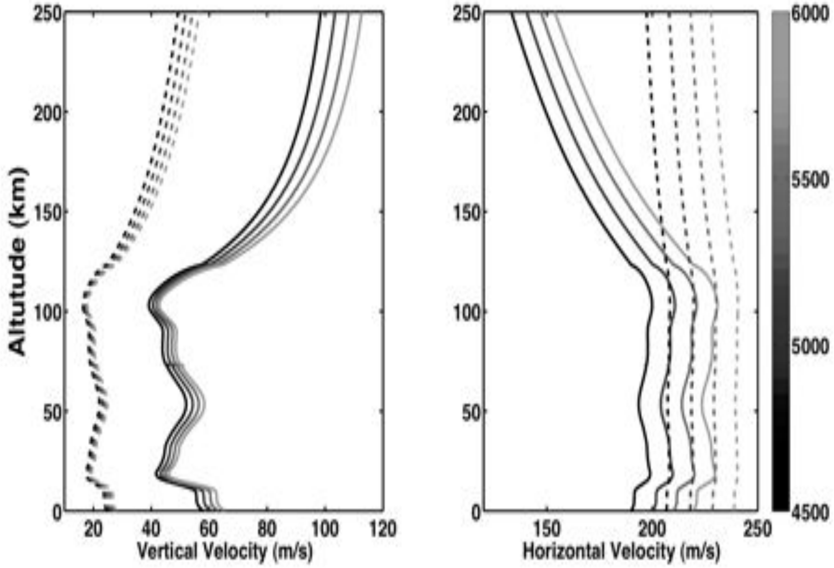
IONOGLOW: *Ionosperic Dynamic & Tsunami Airglow Detector*

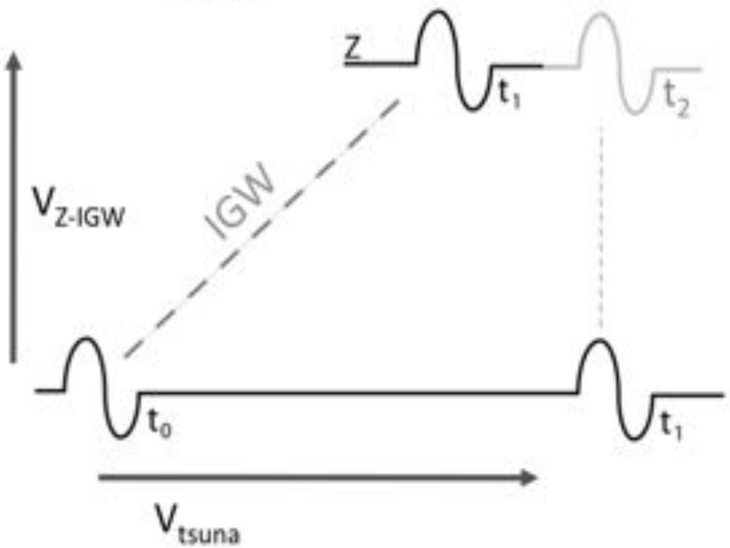


IONOGLOW: *Ionosperic Dynamic & Tsunami Airglow Detector*

Tsunamigenic Tohoku Earthquake M_w=9.3
11 March 2011





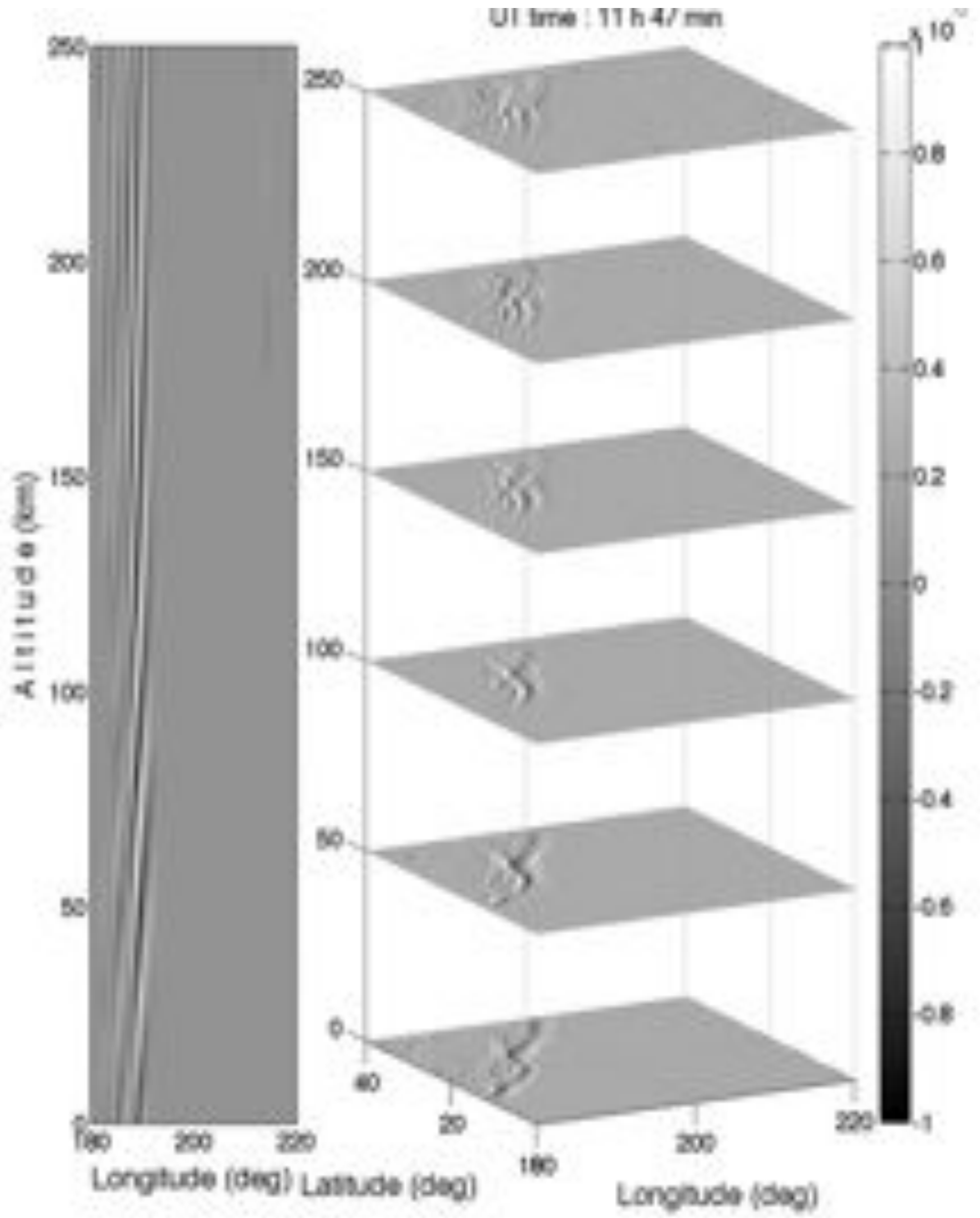


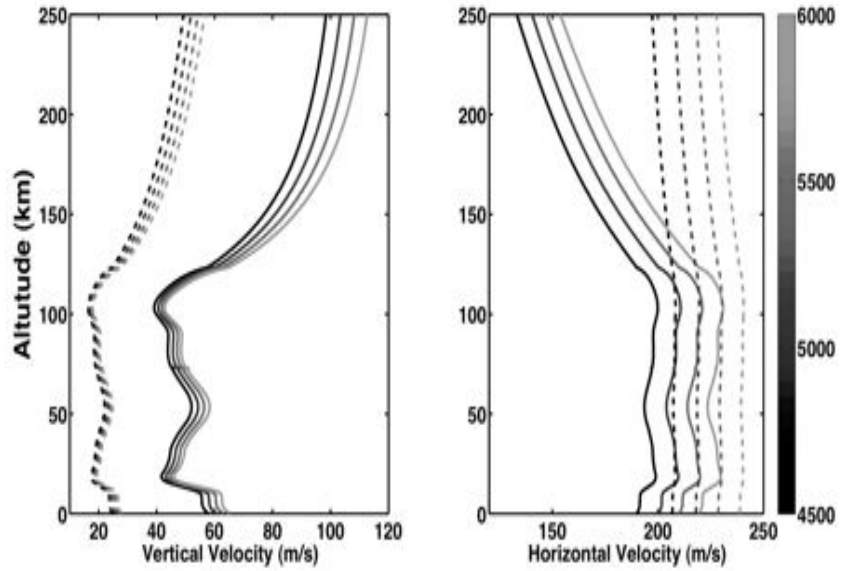
Charge exchange	$O_2 + O^+ \rightarrow O_2^+ + O$
Dissociative Recombination	$O_2^+ + e^- \rightarrow O + O(^1D)$
Airglow emission	$O\left(^1D\right) \rightarrow O\left(^3P\right) + h\nu$

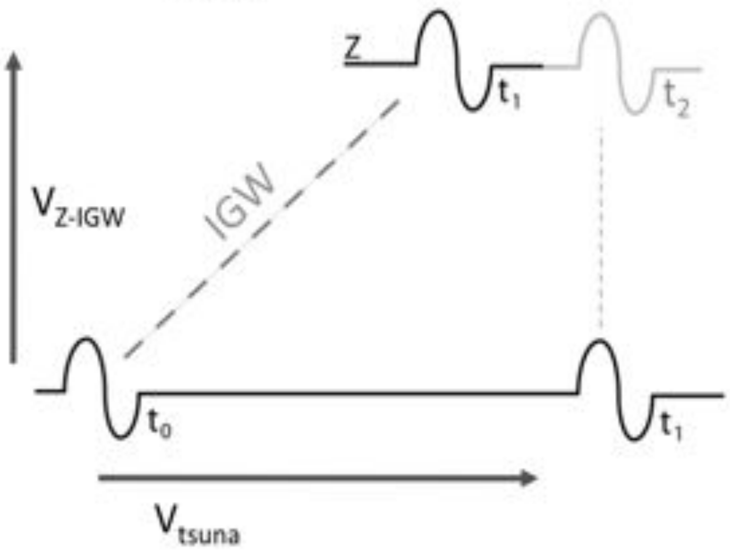
[Occhipinti et al., EPS, 2011; Makela et al., GRL 2011]
]

IONOGLOW: *Ionosperic Dynamic & Tsunami Airglow Detector*

Tsunamigenic Tohoku Earthquake, 11th Mars, 2011 (Mw=9.3)







[Occhipinti et al., EPS, 2011]

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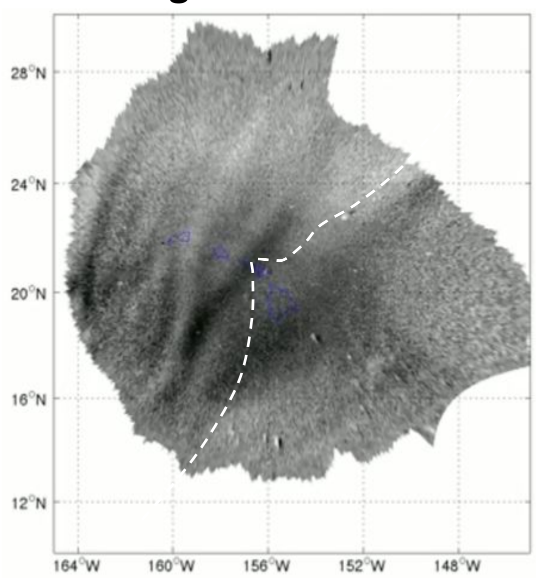
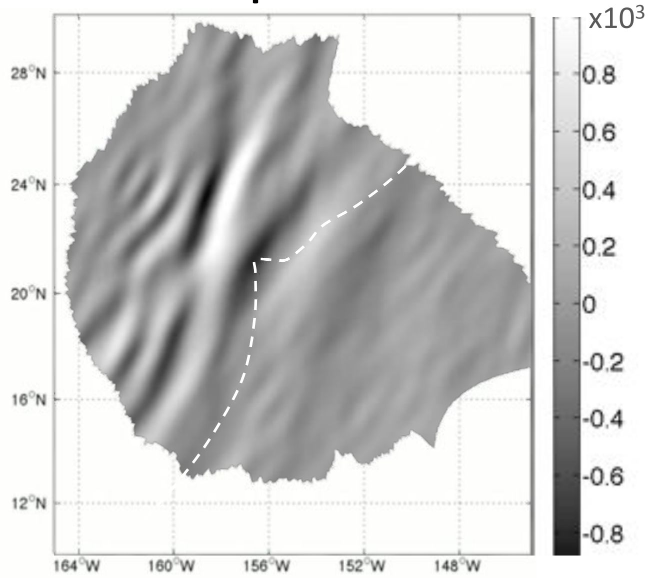
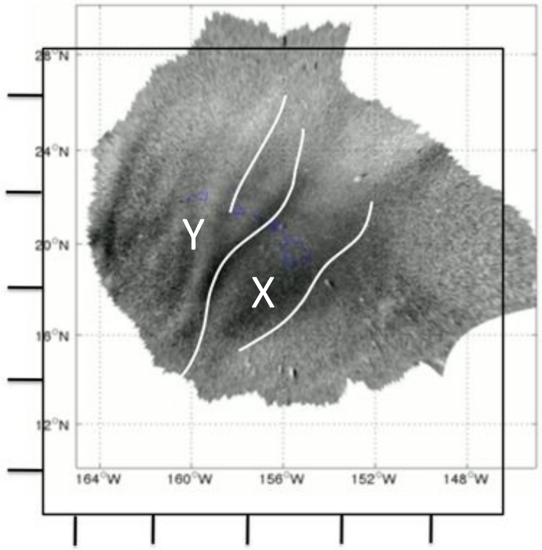
Tsunamigenic Tohoku Earthquake, 11th Mars, 2011 (Mw=9.3)

Airglow observation



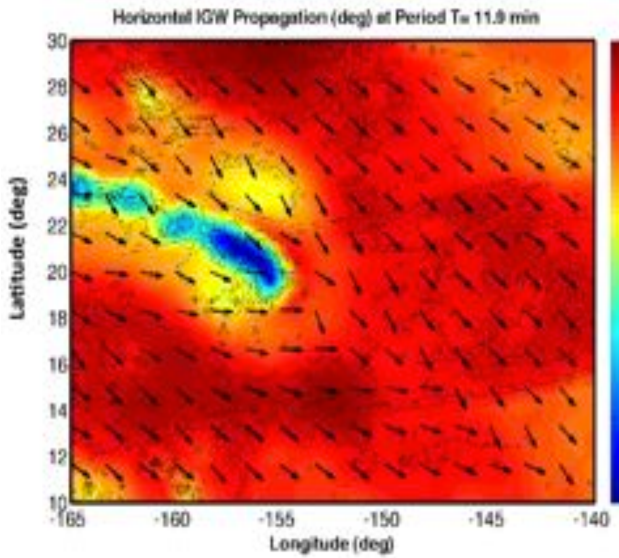
Vertical disp. of IGW model

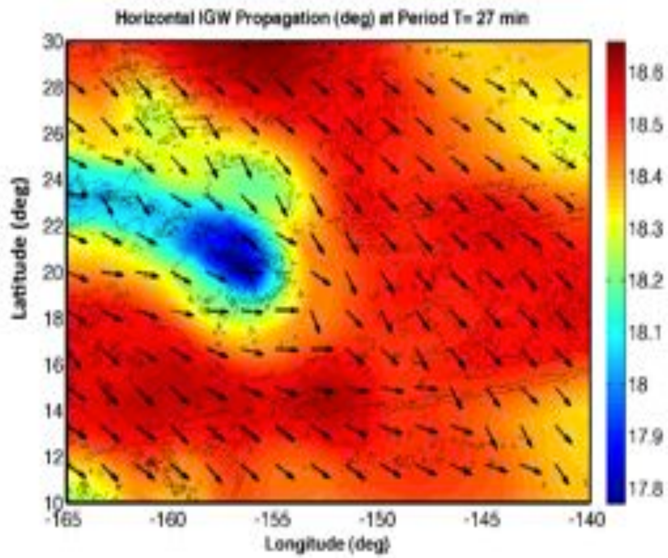


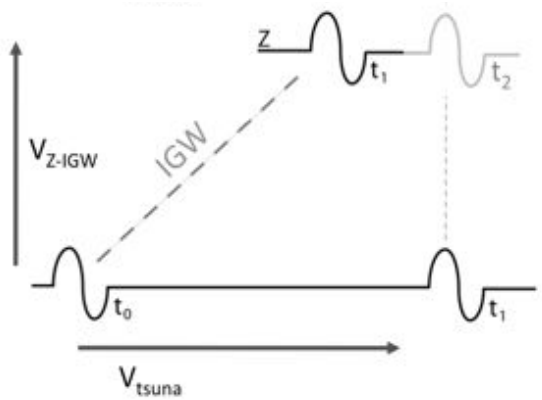


shift

latitude ~ 2°
longitude ~ 2°





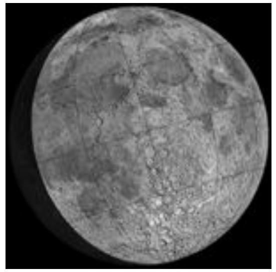


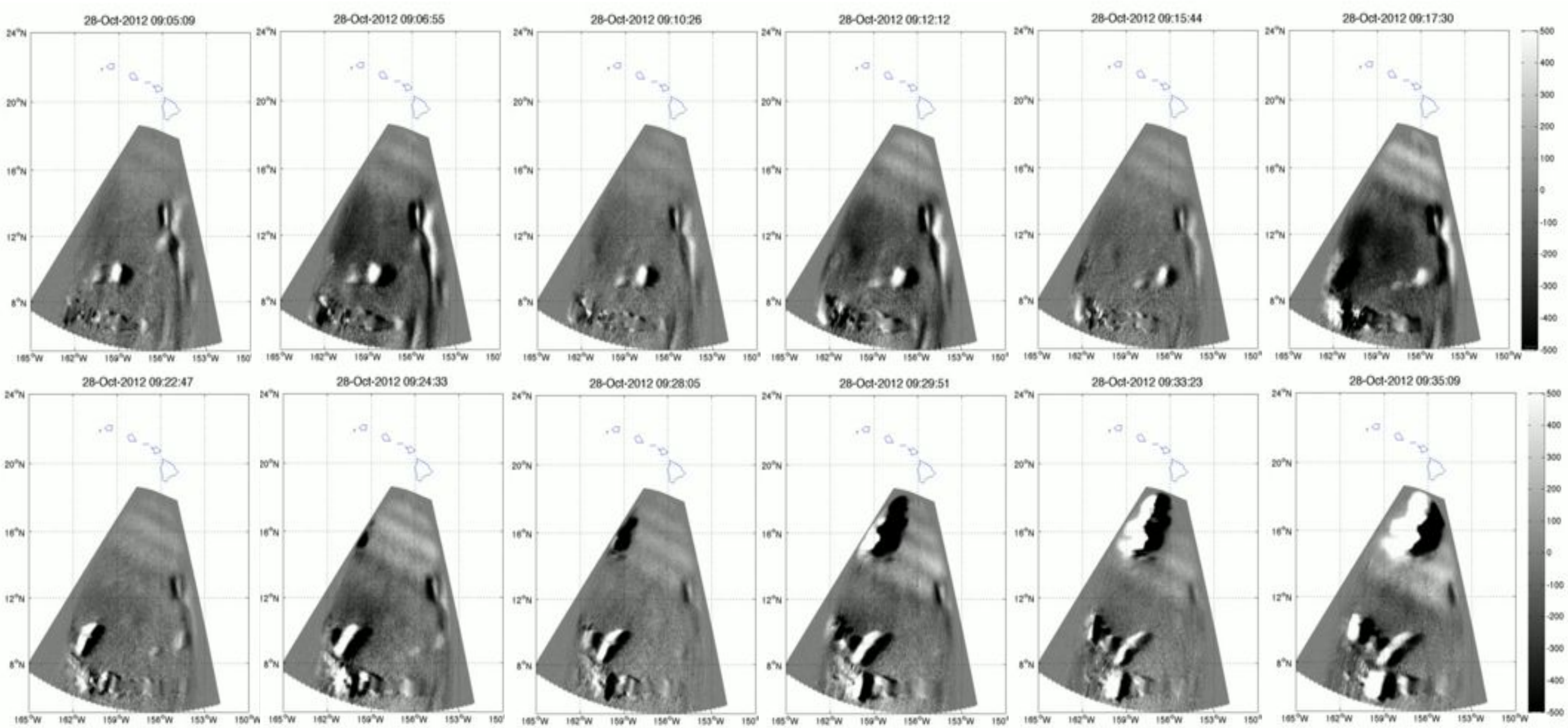
[Occhipinti et al., EPS, 2011]

IONOGLOW: *Ionosperic Dynamic & Tsunami Airglow Detector*

Queen Charlotte tsunami M_w 7.7

27 October 2013

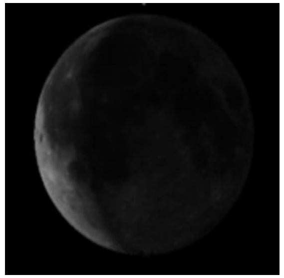


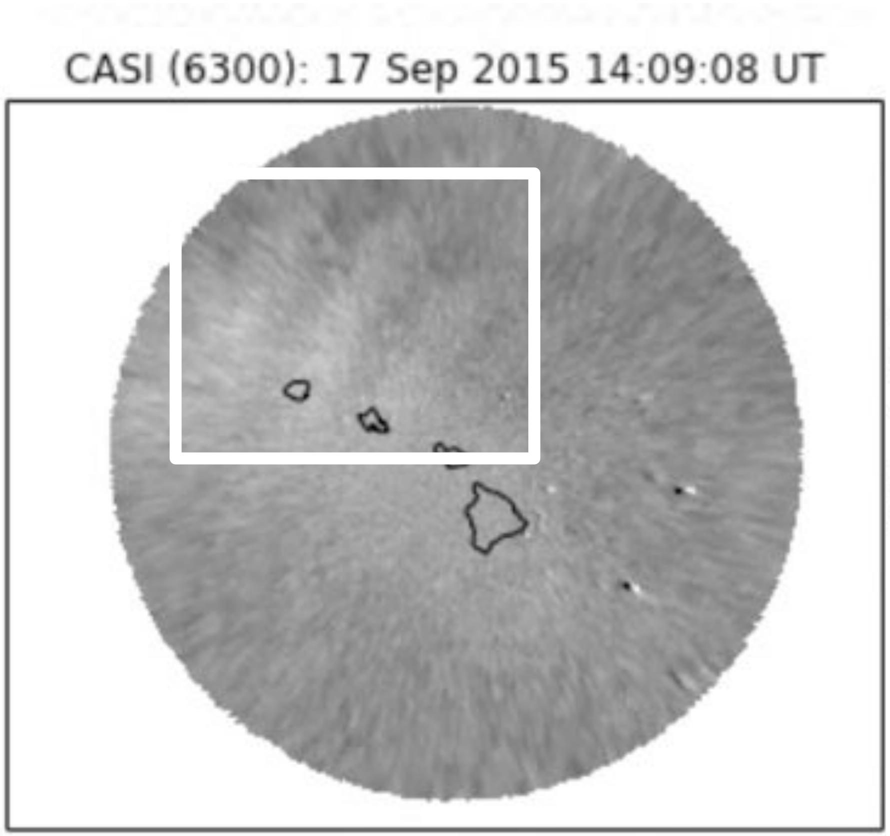


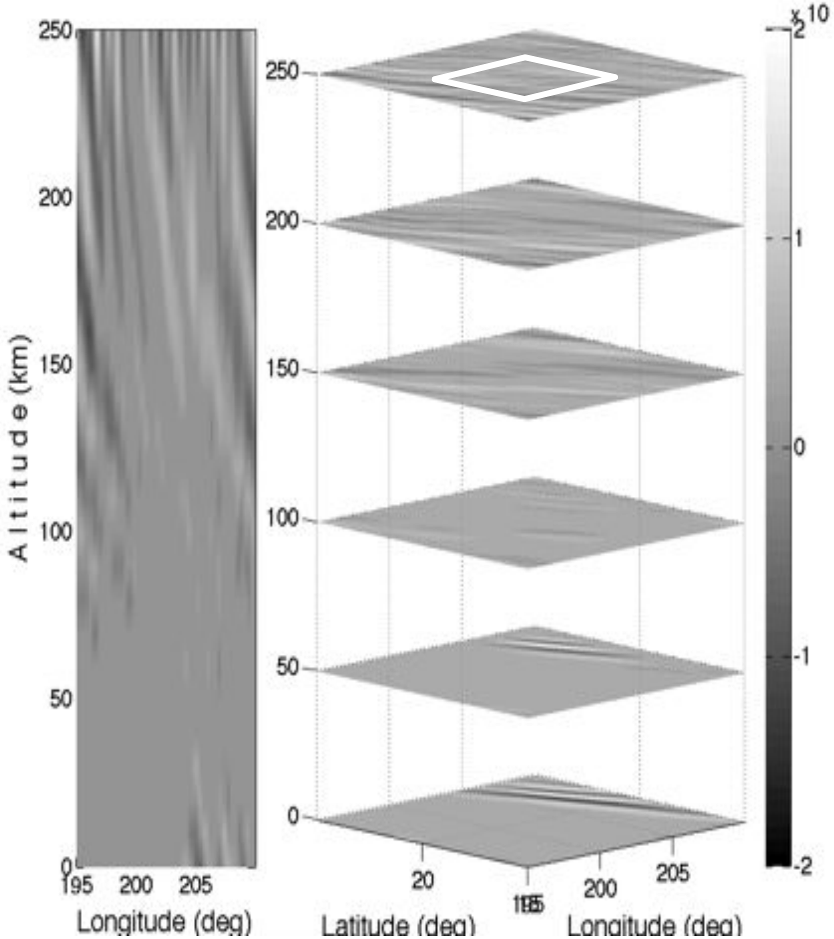
IONOGLOW: *Ionosperic Dynamic & Tsunami Airglow Detector*

Chile tsunami M_w 8.2

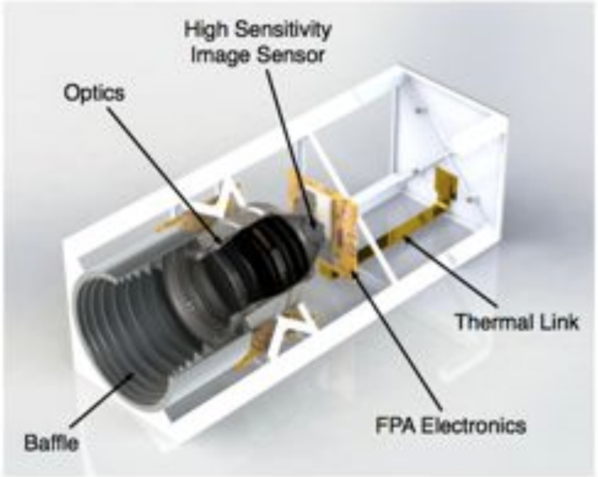
16 September 2015

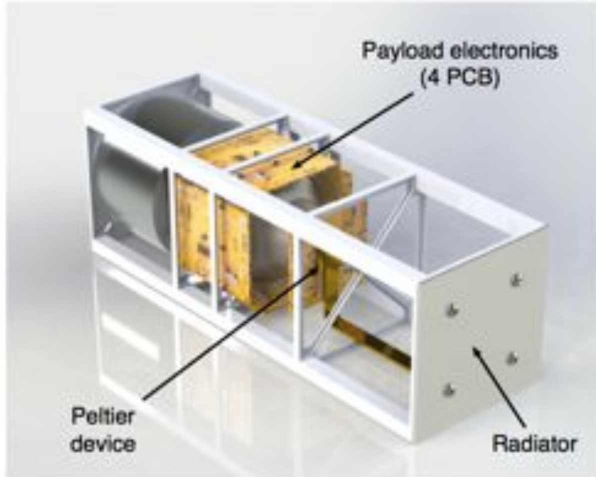


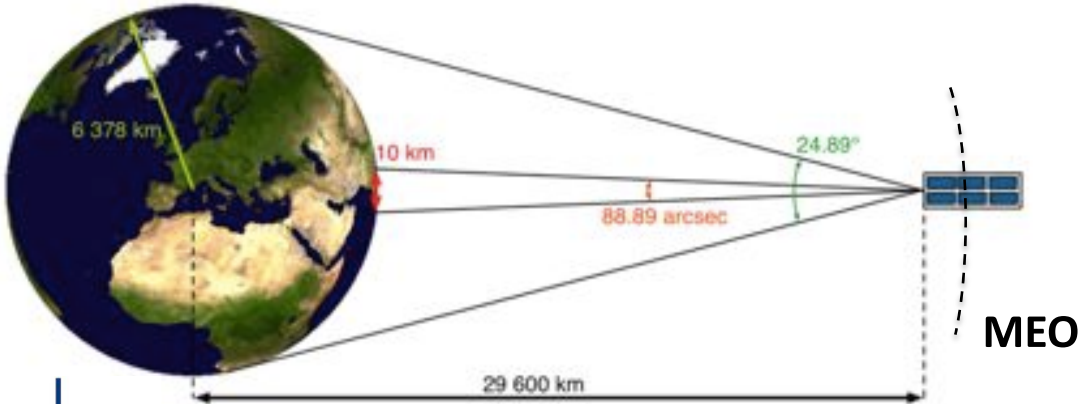




Phase 0







Concept Validation

3U >> 5-10 Rayleigh
(limit of feasibility)
or
6U >> 3-5 Rayleigh
(comfortable feasibility)
or
Sat >> 1 Rayleigh
(high cost)

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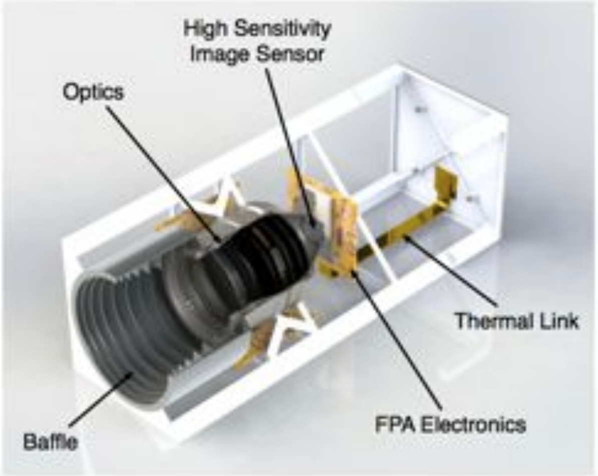
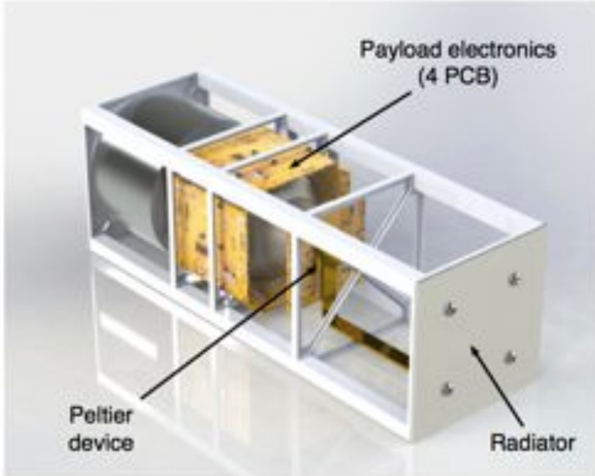
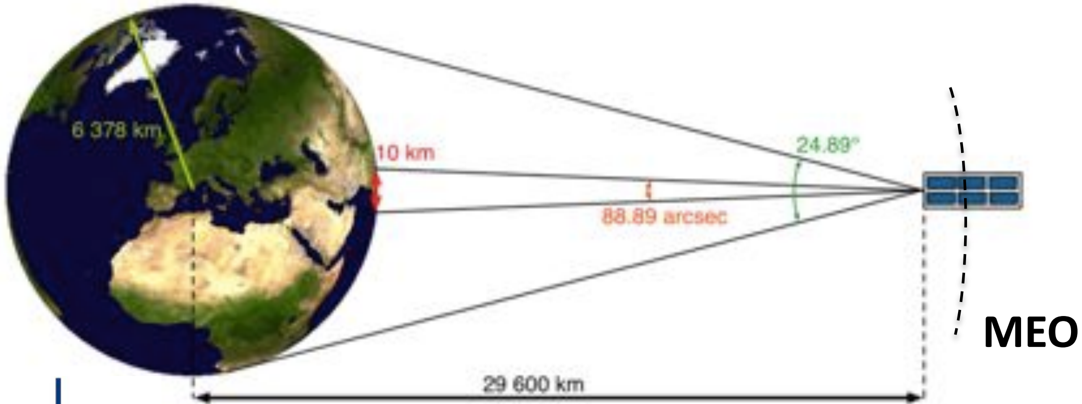
>> Tohoku signal was ± 15 Rayleigh <<

2011 / 2012 / 2013 / 2014 / 2015 / 2016 / 2017 … 2020

Phase 0







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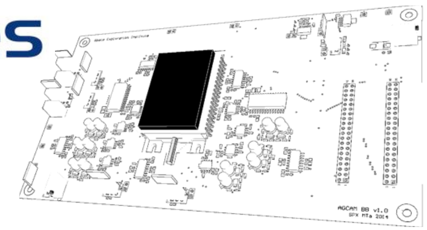

Phase A

Development
of the CCD electronic
for sensor prototype

>> Tohoku signal was ± 15 Rayleigh <<

2011 / 2012 / 2013 / 2014 / 2015 / 2016 / 2017 … 2020