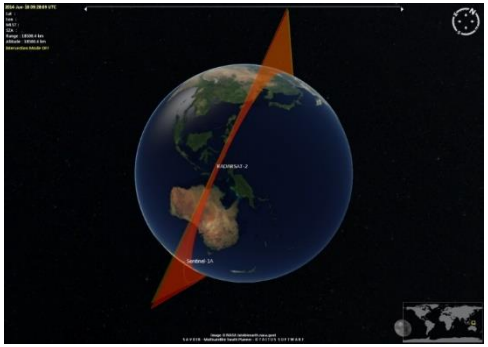
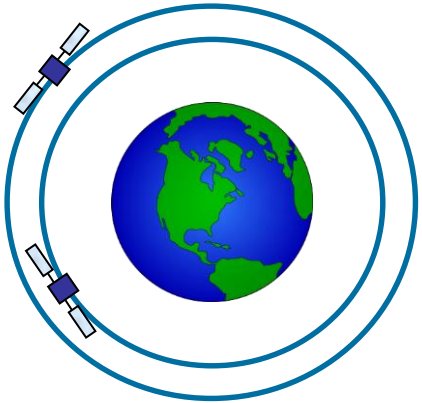
# Radar Interference between C-band SAR Missions

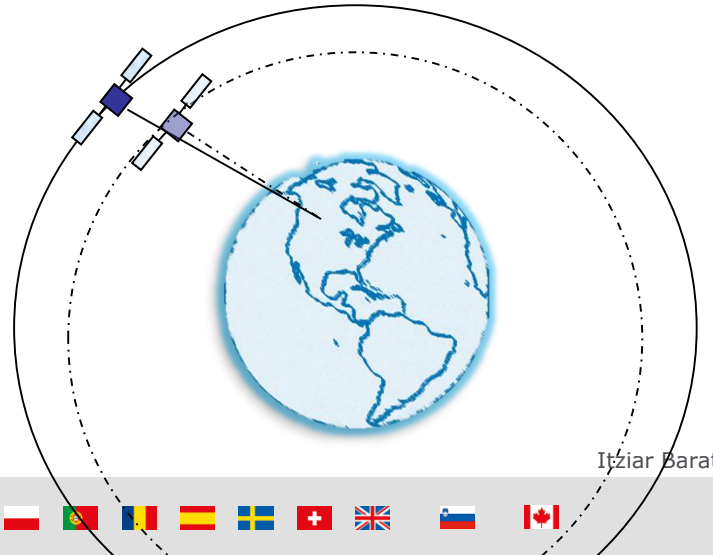
Itziar Barat, Berthyl Duesmann, Dirk Geudtner, Bjorn Rommen
Mélanie Lapointe, Stéphane Côté
Marielle Chabot, Casey Lambert, Dan Williams

# Why there are SAR interferences



Most SAR missions fly in a dawn-dusk orbital plane, but at a different altitude. As a result, there are regular intersections of the SAR footprint. When these SAR missions operate within the same radar signal frequency band, then radar interference may occur during the SAR data acquisition resulting from the signal backscattered from the surface.

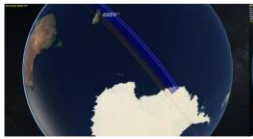
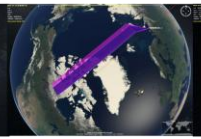
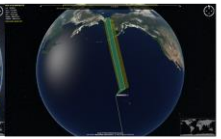




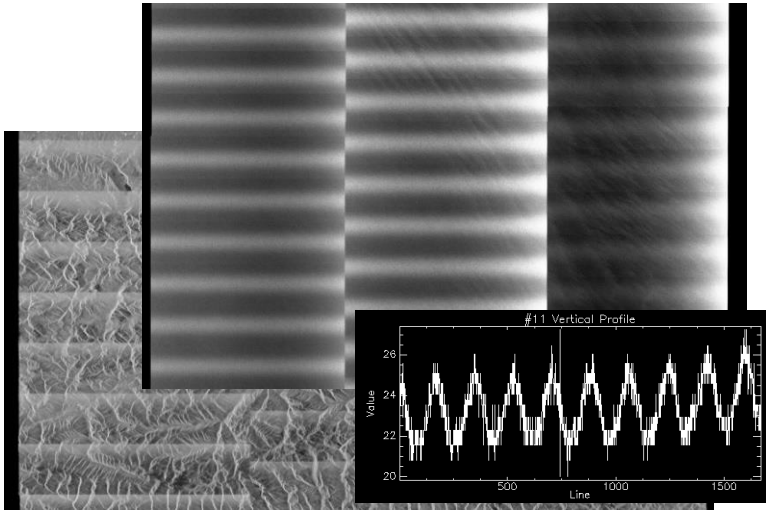
# Sentinel-1A / Radarsat-2 interference campaign

Sentinel-1 and Canada's RADARSAT-2 and RADARSAT Constellation Mission (RCM) operate in C-band at the same centre frequency of 5.405 GHz.

During the commissioning of Sentinel-1A, a campaign of coordinated acquisitions with Radarsat-2 took place with the conclusion that Radio Frequency Interference exited, and although it does not pose a threat to either space segment because the source of interference is the backscatter signal of each other satellite and not a direct illumination, the image products are affected.

| 12th June 2014 | 15th June 2014 | 5th July 2014 |
|---|---|---|
|  |  |  |
| **Sentinel-1A**<br>07:07:00Z to 07:14:00 UTC<br>S5 mode<br>HH+HV<br>**Radarsat-2**<br>07:07:00 to 07:14:30<br>(split in two acquisitions)<br>S4 mode in right looking<br>VV+VH | **Sentinel-1A**<br>13:00:00 to 13:11:00 UTC<br>EW mode<br>VV+VH<br>**Radarsat-2**<br>12:59:40 to 13:06:00<br>S1 beam in receive only mode, with 20 MHz pulse<br>HH+HV | **Sentinel-1A**<br>04:39:00 to 04:50:00<br>IW mode<br>VV+VH<br>**Radarsat-2**<br>04:40:00 to 04:48:40<br>S4 mode in right looking<br>HH+HV polarisation |

Many other interference have occurred between Sentinel-1 and Radarsat-2 and GAOFEN 3 since then.



# Pattern of the crossing points

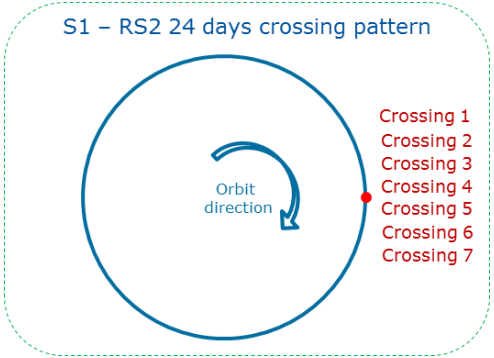
The interferences cannot be avoided, being both satellites (constellations) in the same orbital plane at different altitudes, it is inevitable that they will be on top of the same location regularly, however, there is a pattern on the locations where they cross.

The **pattern of the crossing points** between two satellites depend only on their orbits and it follows this two main rules:

- The location of the crossing points of a pair of satellites are evenly distributed, in time and space, therefore when one location is fixed the rest are automatically determined.

- The locations will be at different latitudes depending on the fraction part of the orbits between crossings. There will be as many latitudes as the inverse of fraction part of the orbits between crossings.

# Example of pattern: S1 - RS2




## Example: S1 – RS2 pattern:

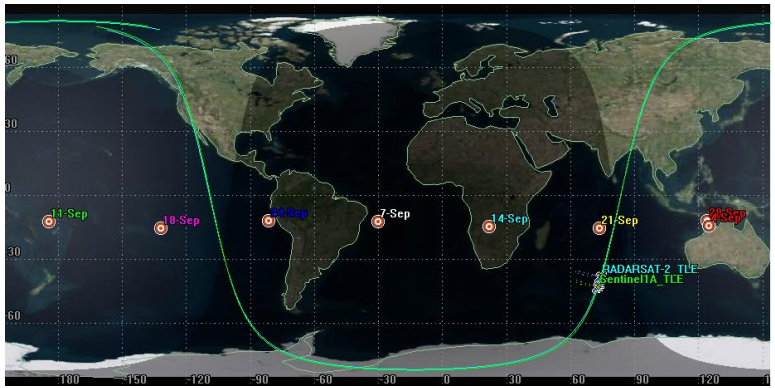
RS2 : 343 orbits in 24 days

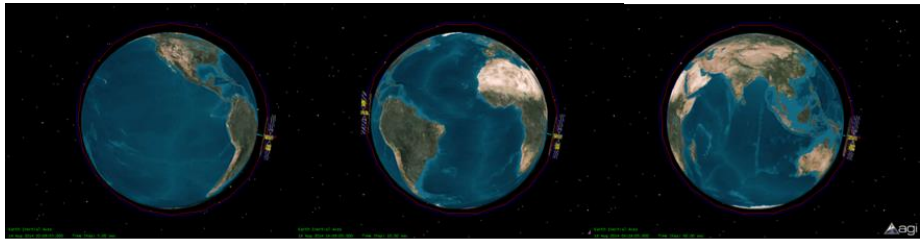
S1 : 175 orbits in 12 days

➡ Every 24 days, S1 completes 7 orbits more than RS2

They will cross **7 times every 24 days** i.e. once every 3.42857 days.

In these 3.42857 days the S1 satellite completes 50 revolutions while RS2 satellite 49, Consequently these 7 crossings happen at 1 point in the orbit at the same in argument of latitude ➔ at the same latitudes on Earth



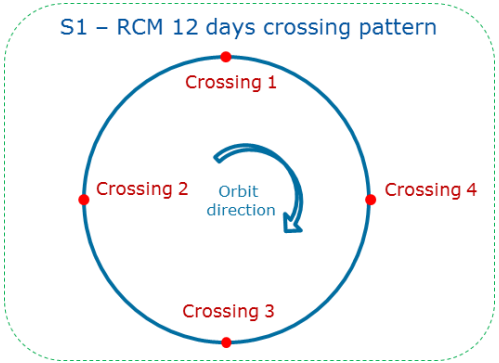



Initail position

After 25 S-1 orbits
24.5 RS2 orbits

After 50 S-1 orbits
49 RCM orbits

# Example of pattern: S1 - RCM



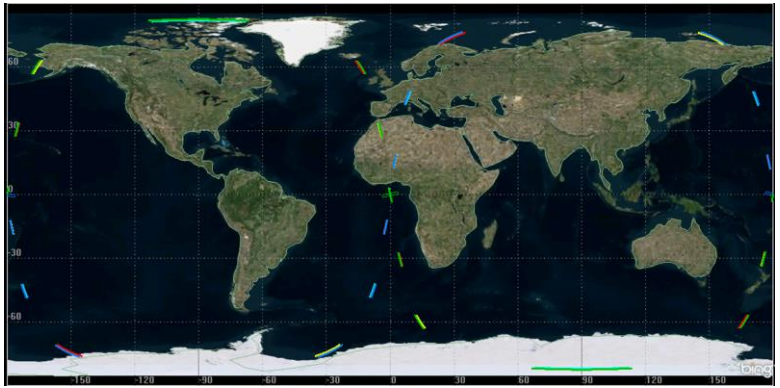

RCM : 179 orbits in 12 days

S1 : 175 orbits in 12 days

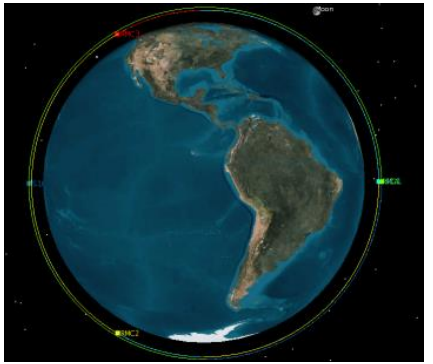
➡ Every 12 days, RCM completes 4 orbits more than S1

They will cross **4 times every 12** days i.e. once every 3 days.

In these 3 days the S1 satellite completes 43+3/4 revolutions while RCM satellite 44+3/4, Consequently these 4 crossings happen at 4 different points in the orbit separated -90 degrees in argument of latitude ➔ at 4 different latitudes on Earth



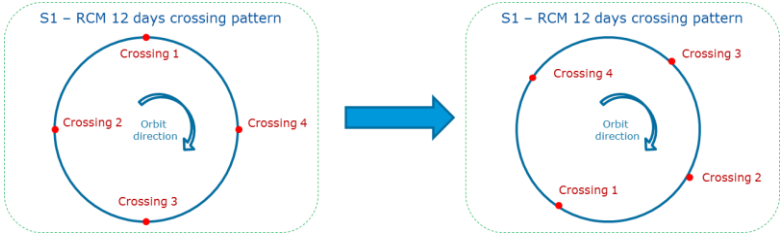
But there **are two S-1 and three RCM's**, therefore there will be **24 crossings in 12 days, once every 12 hours**

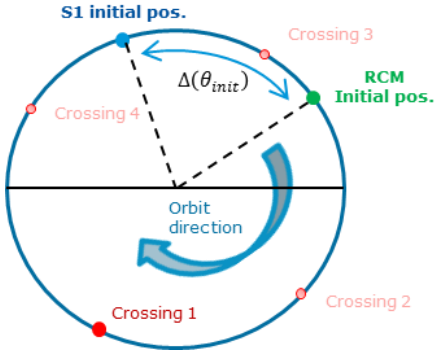


# Location of the pattern intersection points

The **pattern of the crossing** between two satellites is **fixed by their orbits**

Can this pattern be shifted? i.e. can we chose **the position of the crossing points within the pattern**?




The crossing points position will depend on the initial position and phase between both satellites.

$$\theta_{crossing} = \theta^{S}_{init} + \omega^{S} t_{crossing}$$

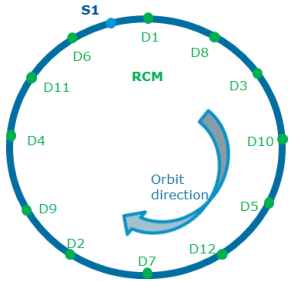
$$\theta_{crossing} = \theta^{RCM}_{init} + \omega^{RCM} t_{crossing}$$

$$\theta_{crossing} = \theta^{S}_{init} + \omega^{S} \frac{\left(\theta^{S}_{init} - \theta^{RCM}_{init}\right)}{\left(\omega^{RCM} - \omega^{S}\right)}$$

# How to rotate the pattern

The position of the crossing points depend on the initial phase between satellites. What drives the initial phase between satellites?

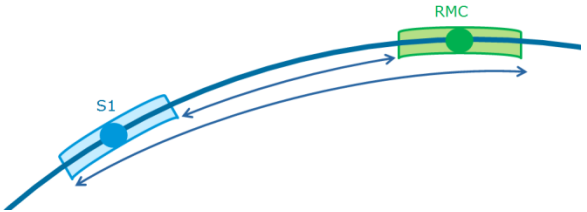
- The difference in **ground track** at a certain **day of the cycle**




A small shift in the ground-track will **move** the crossing points **significantly**

**All the satellites of a constellation are moved together**

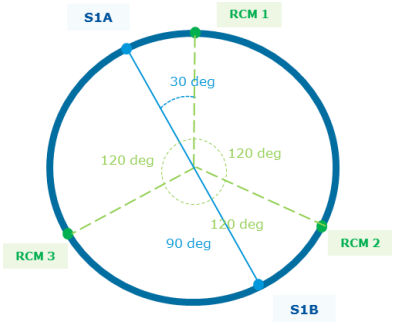
- The difference in **Mean Local Solar Time**

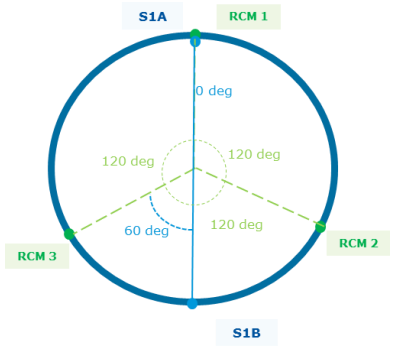


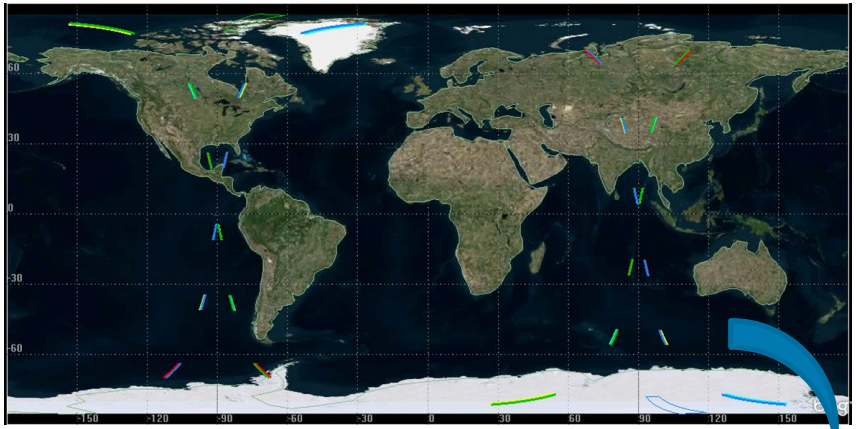

A small shift in the MLST will **move** the crossing points **only a few degrees**

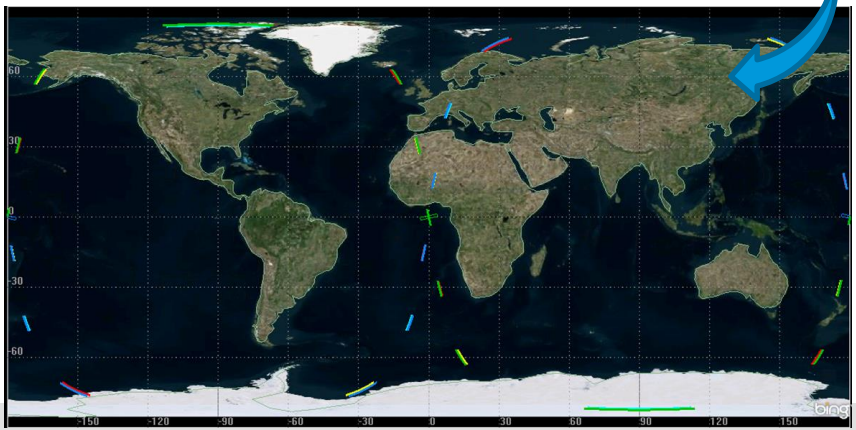
**Each of the satellites of a constellation can be moved independently**

# Example: Change on the day of the Cycle





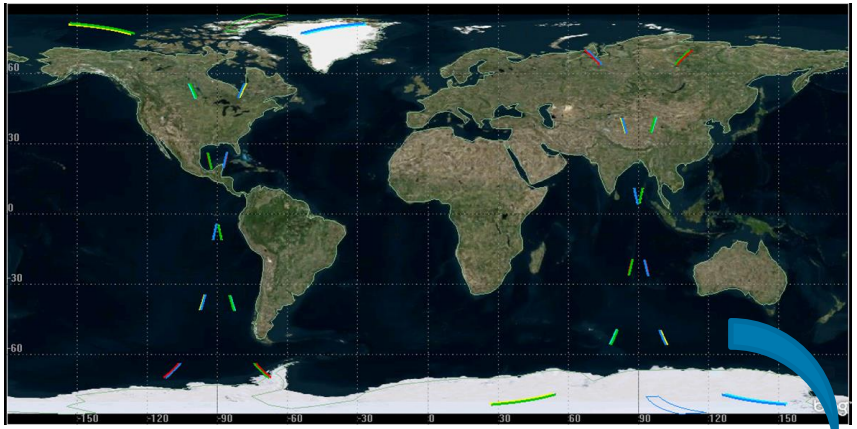
Same Ground-track

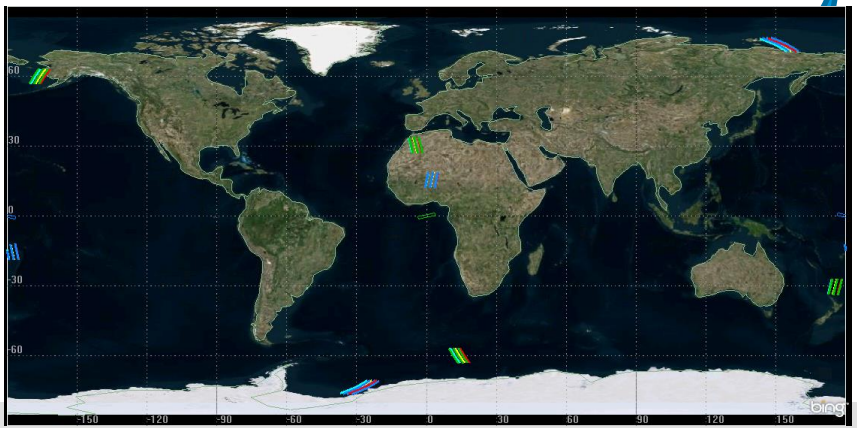
Same MLST

**Different day on the cycle**

# Example: Change the MLST

| Satellite | MLST |
|---|---|
| RCM1 | 18:00:00 |
| RCM2 | 18:00:00 |
| RCM3 | 18:00:00 |





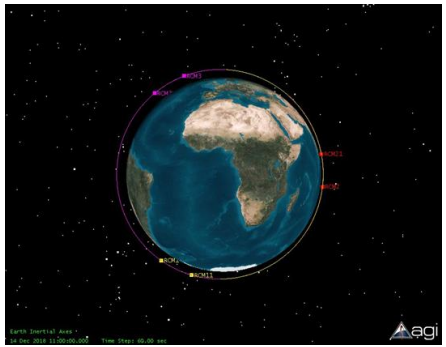
| Satellite | MLST |
|---|---|
| RCM1 | 18:00:11 |
| RCM2 | 18:00:00 |
| RCM3 | 17:59:49 |

Same Ground-track

**Different MLST**

Same day on the cycle

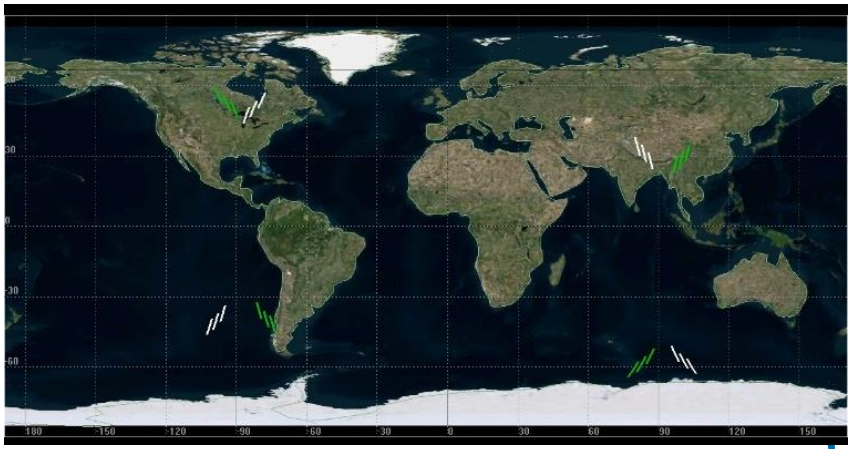
# Example: Change the Ground Track

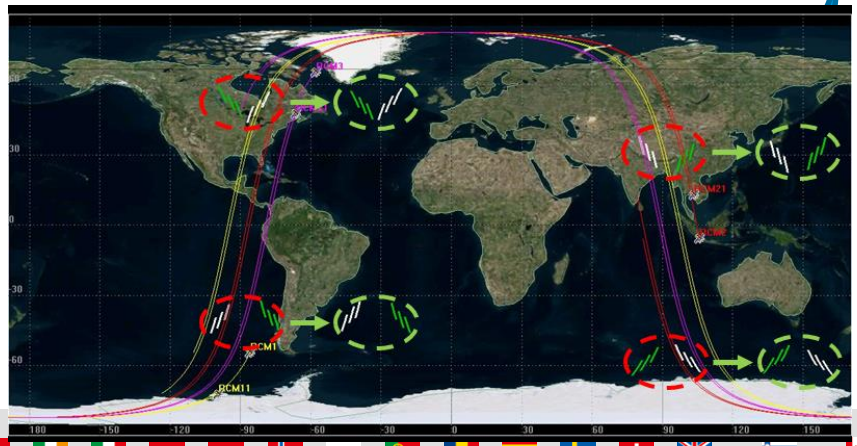


Ground-track shift of 1.27 deg

➔

Orbit phase shift of 18.6 deg





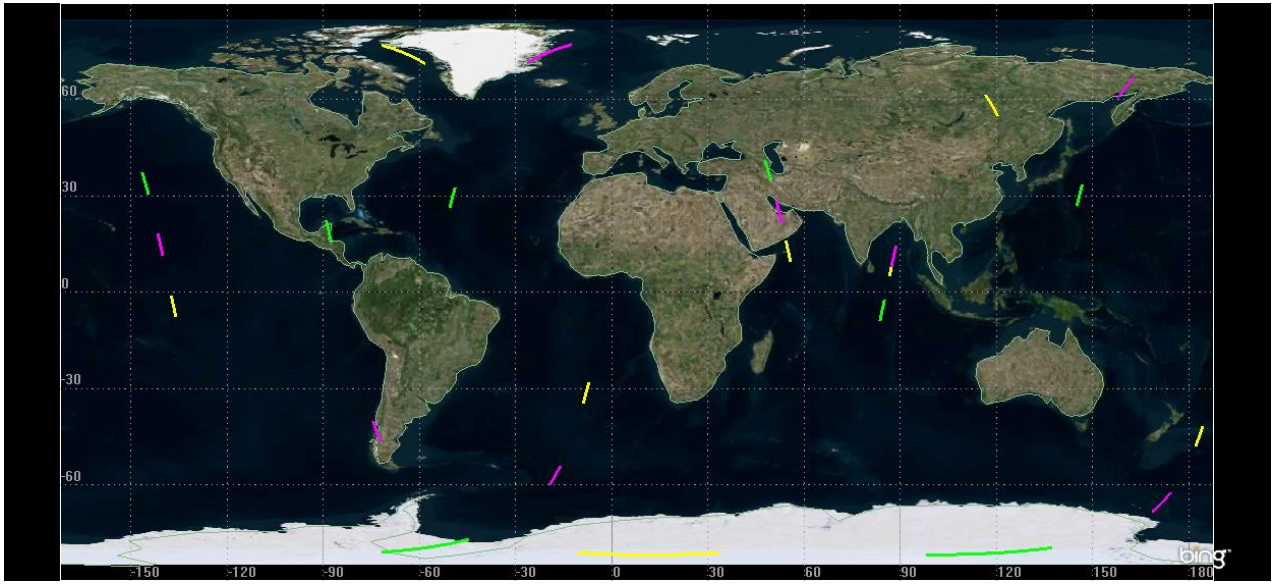
**Different** Ground-track

Same MLST

Same day on the cycle

# CURRENT CROSSING POINTS S1 / R2 /RCM

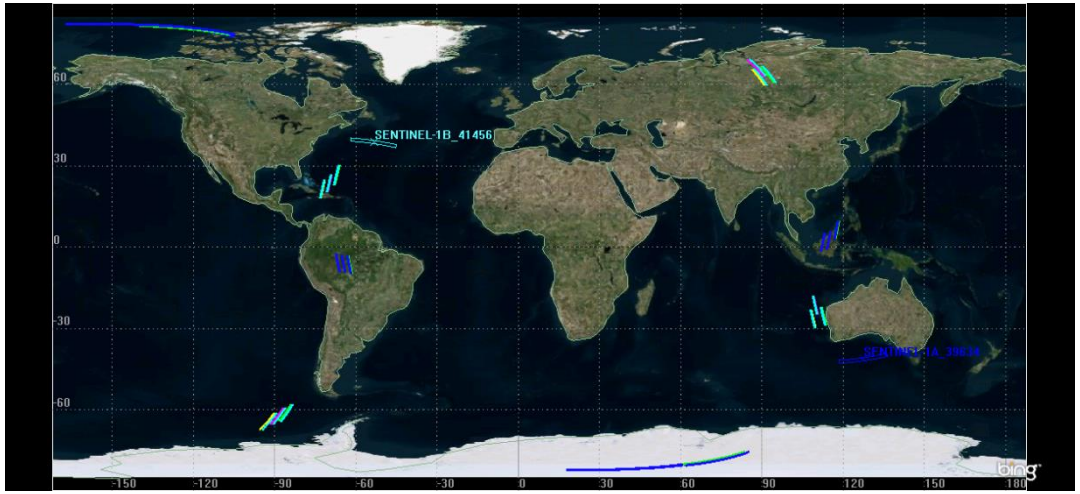
# RCM - S1: Status at launch

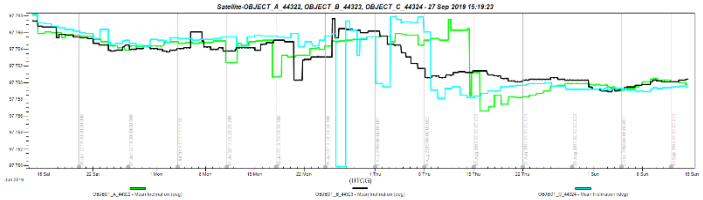


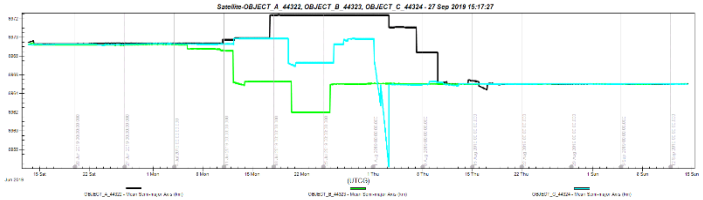

The picture shows the first crossing points between RCM and S1 constellation right after RCM launch (13 Jun to 26 Jun)

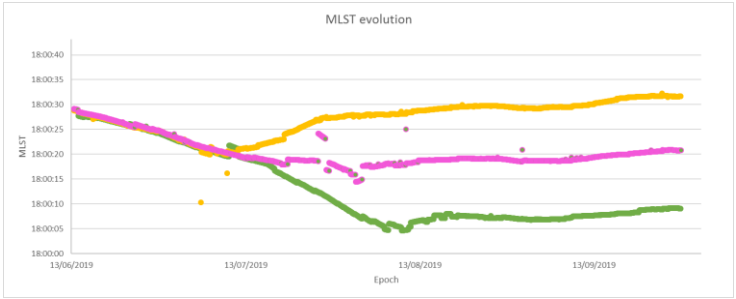
The drift of RCM orbit with respect to its nominal one causes an “irregular” pattern

# RCM – S1 Current situation



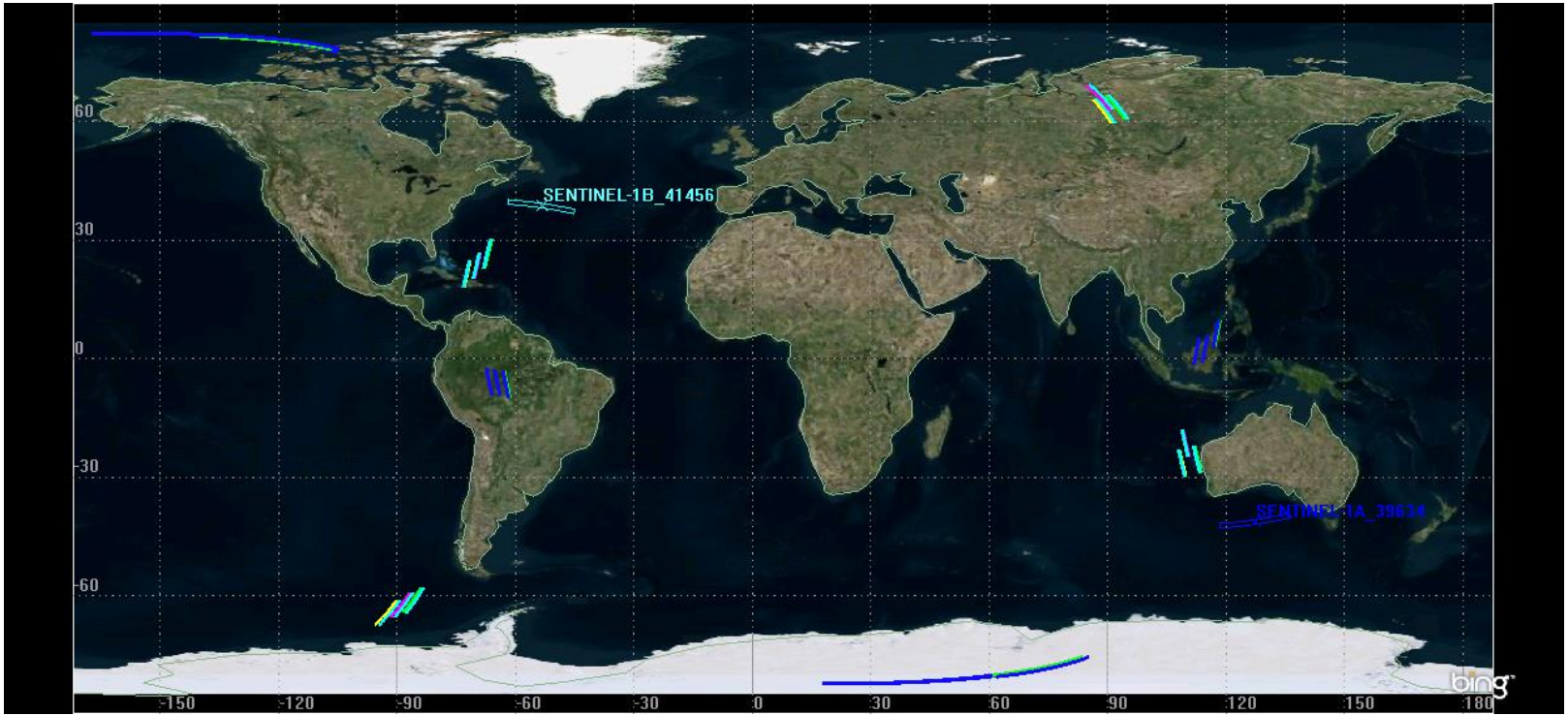




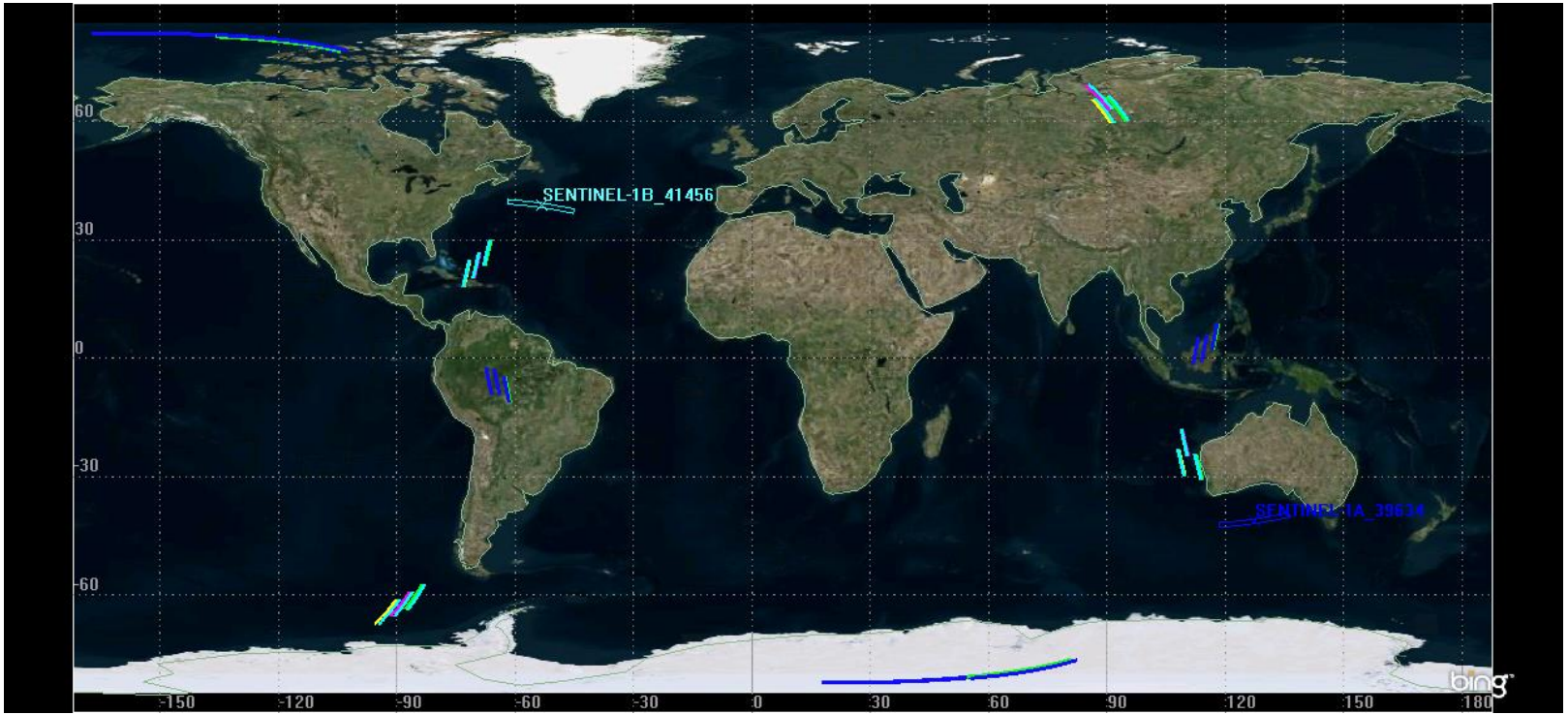

The picture shows the first crossing points between RCM and S1 constellation right after RCM orbit acquisition (20 Aug to 2 Sep)

The fact that the MLST difference between RCM's is in the order of 11 seconds results in the grouping all the crossing points in 8 different areas.

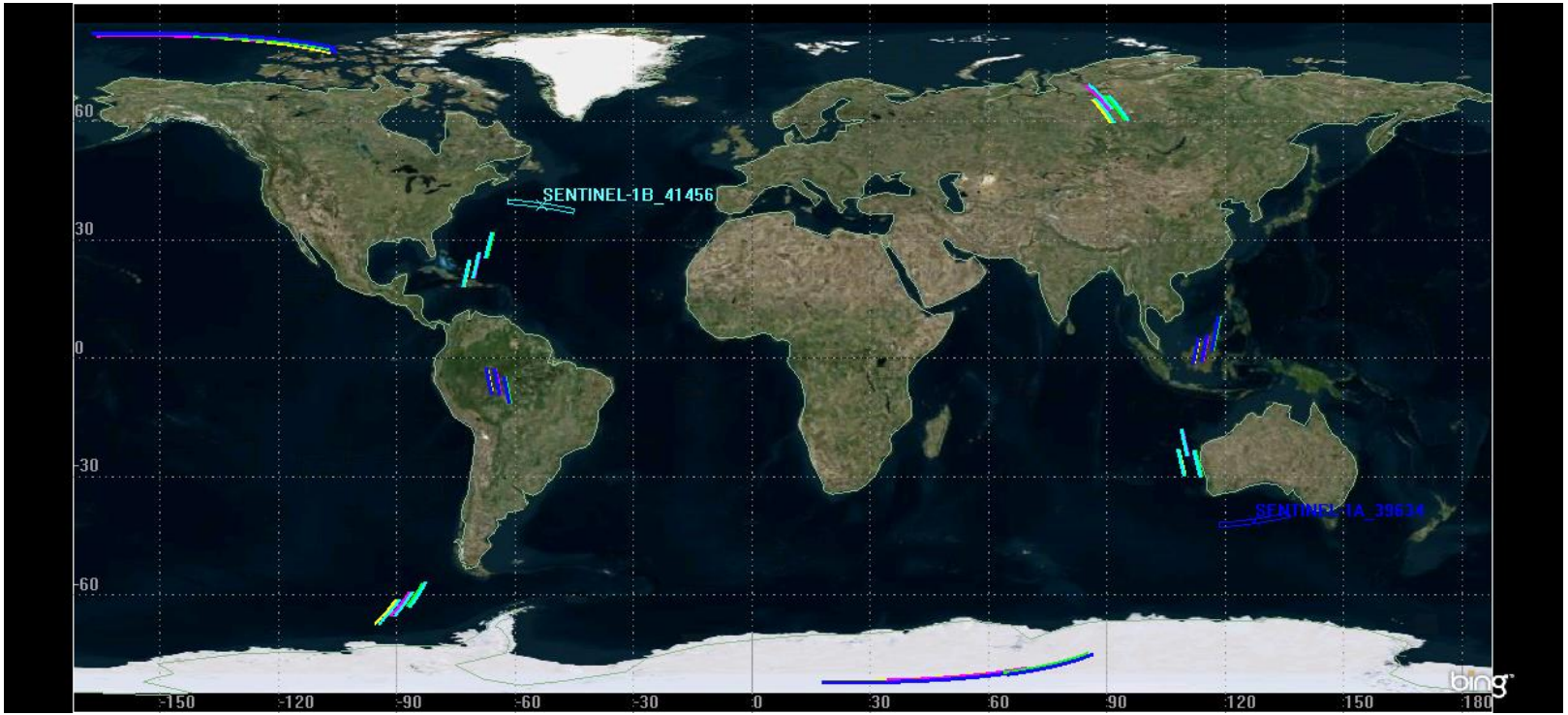
# RCM – S1: Evolution 20 Aug to 2 Sep



# RCM – S1: Evolution 2 Sep to 14 Sep



# RCM – S1: Evolution 14 Sep to 28 Sep



# RCM – S1: Long term evolution

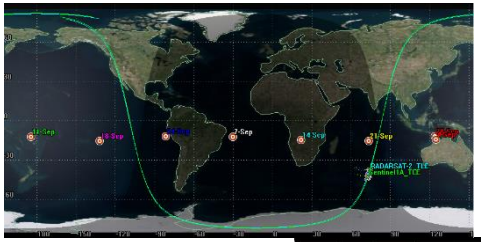
The **pattern of the crossing** between two satellites is **fixed by their repeat cycle**, as the orbits of both constellations have a fixed repeat cycle the **crossing pattern between each pair of satellites will remain the same**

The **position of the crossing points** depend on the initial phase between satellites, i.e. **day of the cycle, ground-track difference and MLST difference**

The ground track of both missions is maintained, so it has been stablished and fixed the day of the day of the cycle, therefore **the evolution of the crossing pattern for each pair of satellites will depend on the evolution of the difference between their MLST**

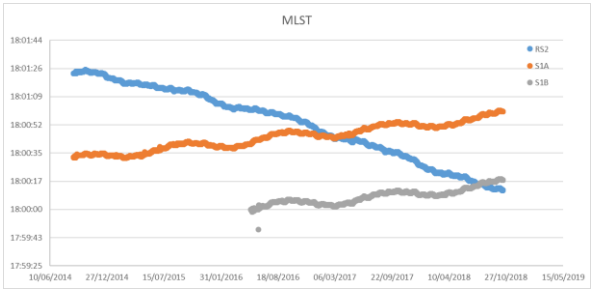
A perfect initial inclination helps in the MLST control and can keep the MLST synchronized with no (or nearly no) need of maneuvers.

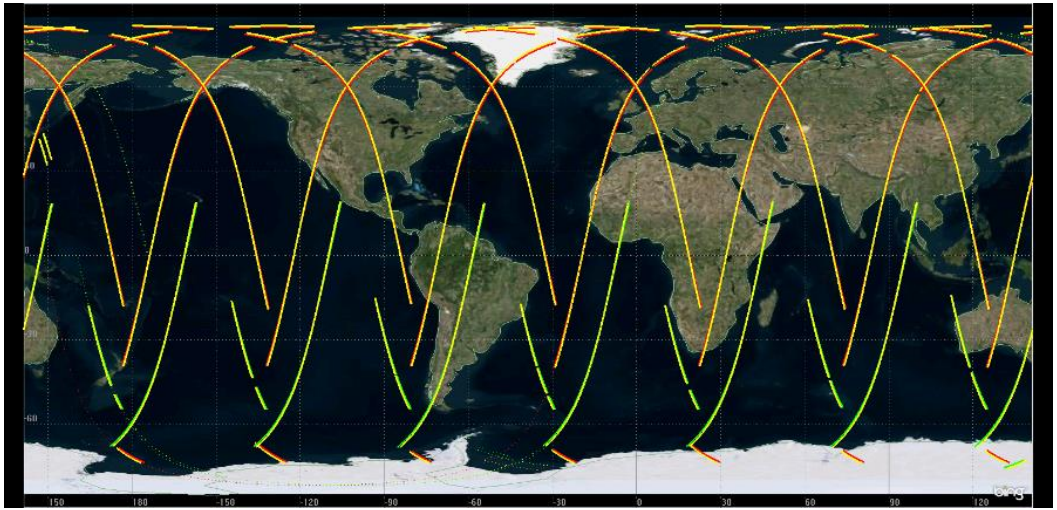
# R2 – S1: Evolution September 2014 to Oct 2018



S-1A RS2
September 2014

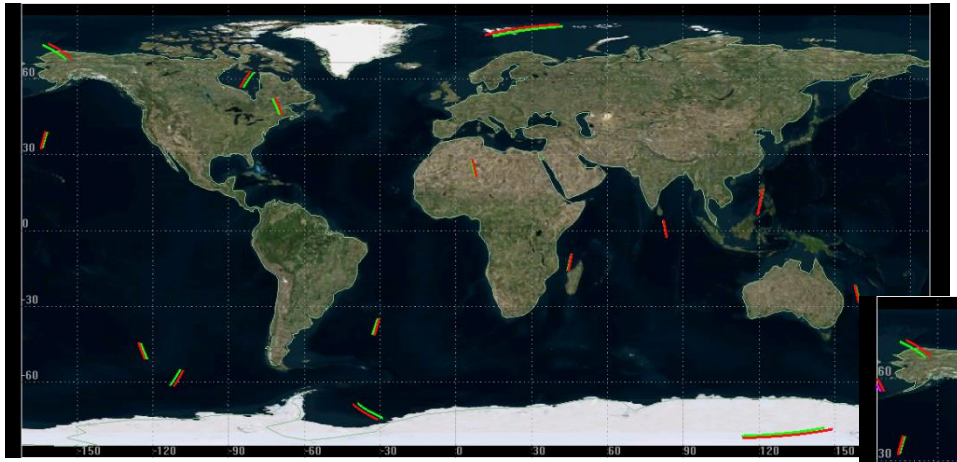
S-1A RS2
September 2015



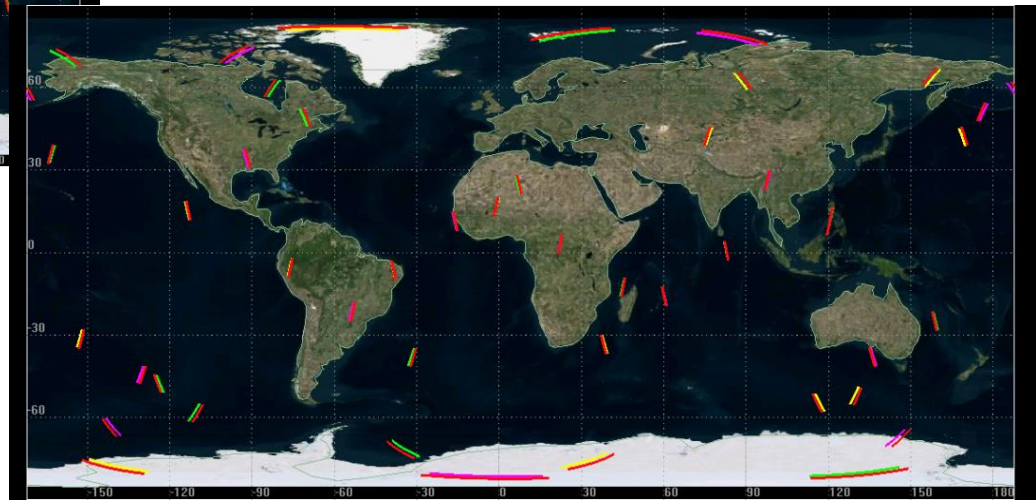
S-1A RS2 evolution of the crossing points

# R2 – RCM crossing points (20 Aug – 14 Sep)



Crossing of one RCM with RS2
20 Aug – 14 Sep

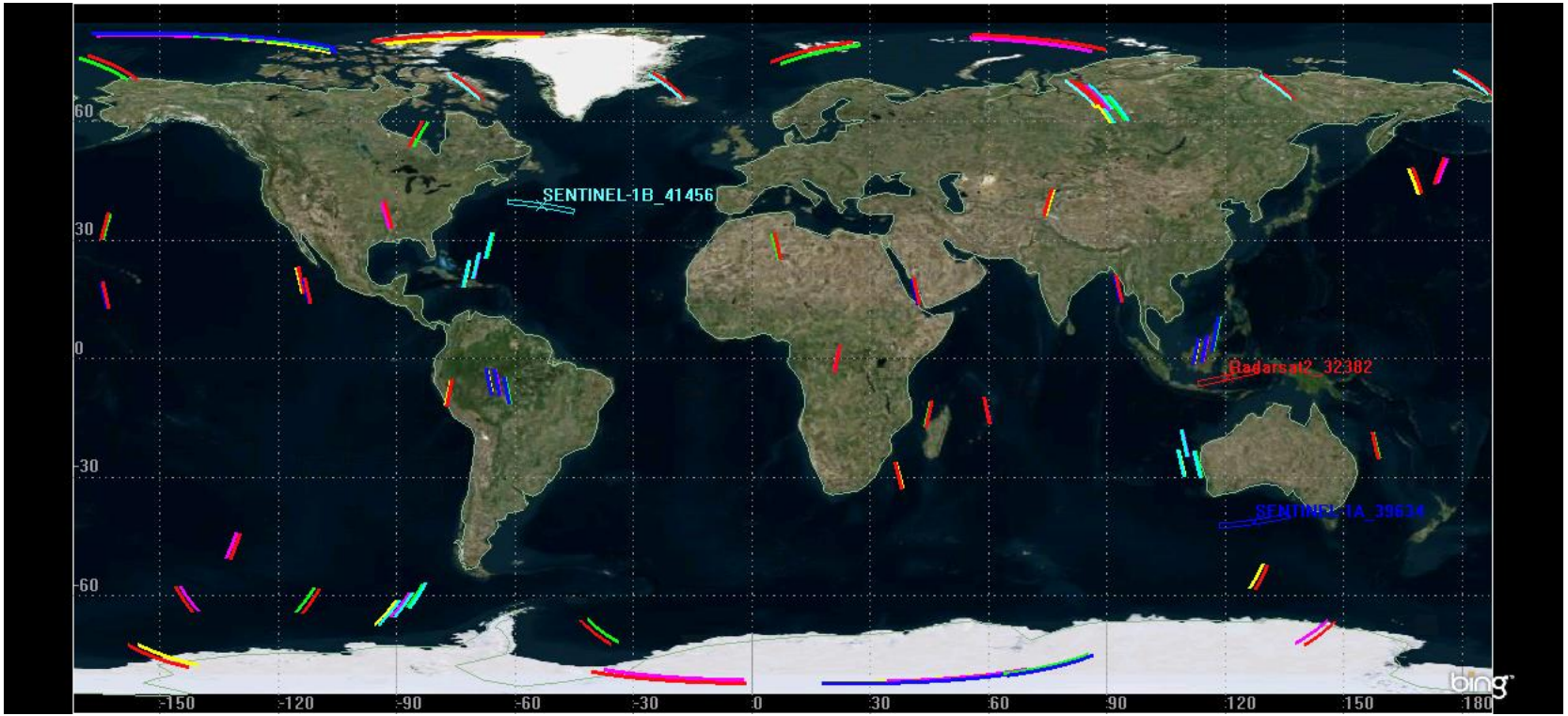
Three RCM's with RS2
20 Aug – 14 Sep



RS2 : 343 orbits in 24 days
RCM : 179 orbits in 12 days

Every 24 days, each RCM completes 15 orbits more than RS2

# R2 / S1 / RCM crossing points (20 Aug – 14 Sep)



# Crossing to Potential Interference

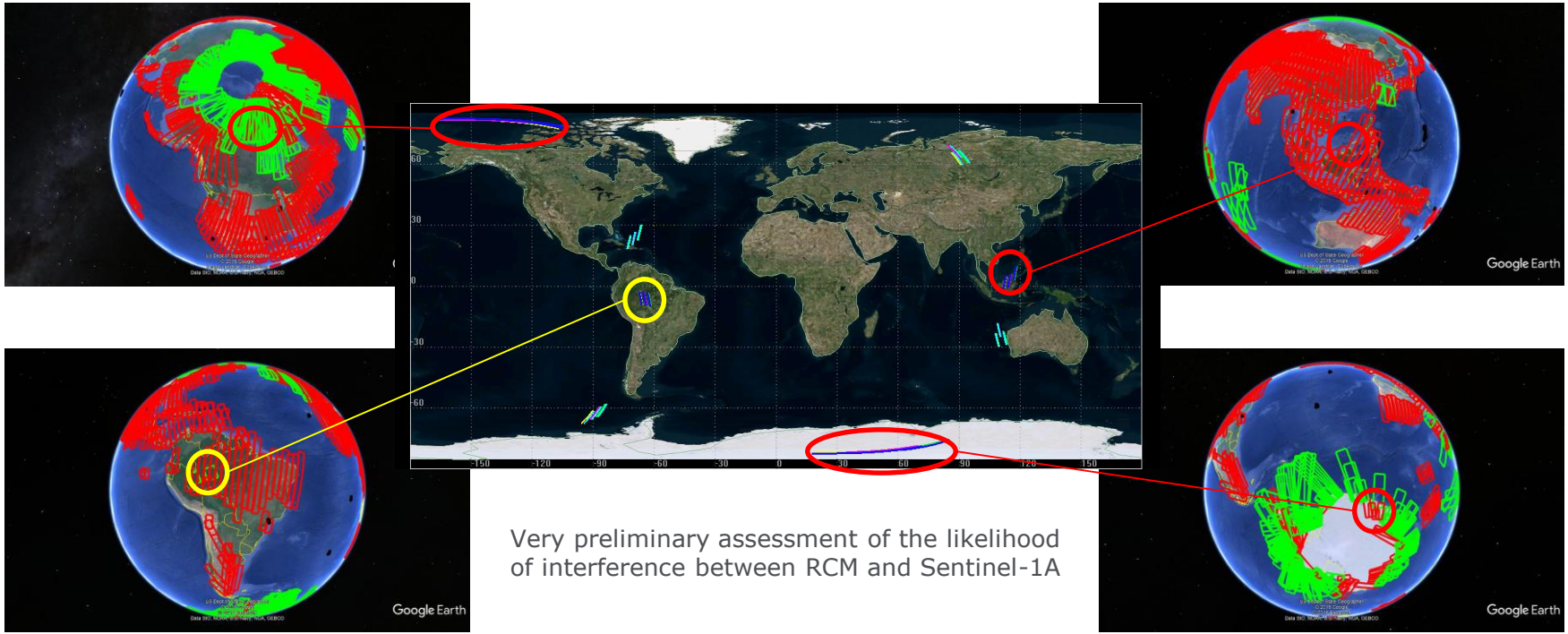
When two SAR satellites cross each other, both need to be acquiring data in order to result in radar interference, therefore **calculating only the crossing points does not provide all the information**.

**Some missions**, like Sentinel-1, **have a predefined acquisition plan** that repeat every repeat cycle. This doesn't prevent that acquisitions outside of the predefined plan may happen, but they will be less likely.

**Comparing the crossing points with the acquisition plans provides a better understanding on the likelihood of potential interferences from the backscatter signal of each other satellite.**

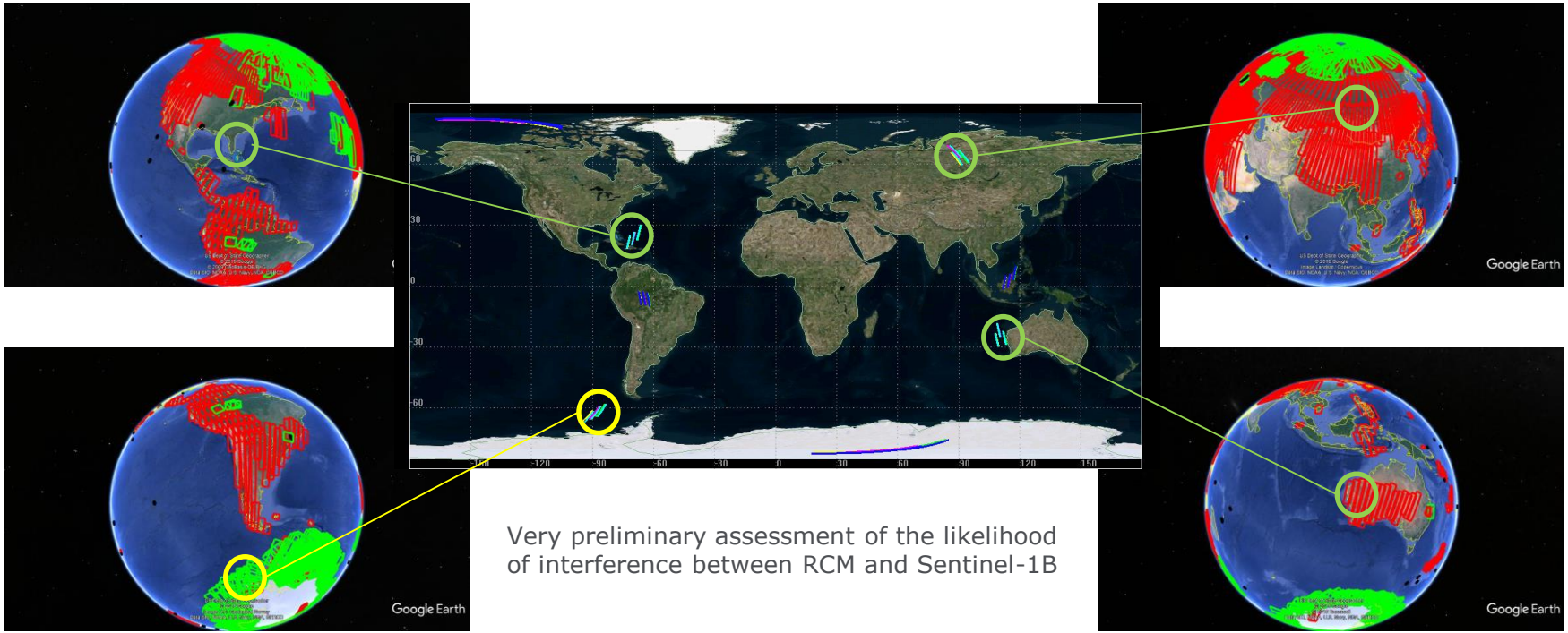
**As an exercise**, the crossing points of RCM with Sentinel-1 have been compared with the acquisition plans of Sentinel-1A and Sentinel-1B in order to have an very preliminary assessment. Note RCM plan (if any) is not considered, and a **more detailed analysis is necessary to reach any firm conclusion.**

# S1A 2017-2018 acquisition plan




Very preliminary assessment of the likelihood of interference between RCM and Sentinel-1A

# S1B 2017-2018 acquisition plan




Very preliminary assessment of the likelihood of interference between RCM and Sentinel-1B

# ASAR 2019: Lessons learnt for future work

1. Multi-Source Data Integration is not only possible but it opens a full range of new applications
2. It is not a conflict, it is an opportunity


ndicates the number of
measurements taken in a
short time interval every 12 days.

# Conclusions

- **Repeat cycle of satellites ➔ Defines the pattern**

The pattern of interferences depends on the repeat cycle and cycle length of both orbits, being the location of the interferences of a pair of satellites evenly distributed, in time and space

- **Differences in Ground-track, MLST and day on the cycle ➔ Shift the pattern**
  - **Day of the cycle** no impact on the missions, but limited configurations
  - **Ground Track** allows a big shift, but all the satellites in the constellation move together
  - **MLST** generally only small changes are possible, but allows each satellite to move independently

- **MLST difference evolution ➔ Drives the shift in the initial crossing points.**

A minimum maintenance is needed in order to contain the crossing points within certain areas. For perfect Sun-synchronous down-dusk orbits the implications in orbit maneuvering are minimal

- **Acquisition plans need to be considered** to have a clear evaluation of the likelihood of interference happening over a crossing point.

# References


- "Dynamic and control of the interference locations between 2 SAR constellations". I. Barat, B. Duesmann, M. Lapointe, S. Côté. IAC 2018, October 2018, Bremen, Germany.

- "Dynamic and control of the crossing locations between 2 SAR constellations". Itziar Barat, Berthyl Duesmann, Montserrat Piñol, Mélanie Lapointe, Stephane Côté. Living Planet Symposium 2019, Milano, Italy.

- Joint Investigations on Radarsat-2/Sentinel-1A Mutual RFI', B. Rommen, I. Barat, M. Chabot, C. Lambert, D. Williams. CEOS SAR 2015.

# First S1-A RCM-1 Interference

Itziar Barat, Francisco Ceba, Berthyl Duesmann, Björn Rommen

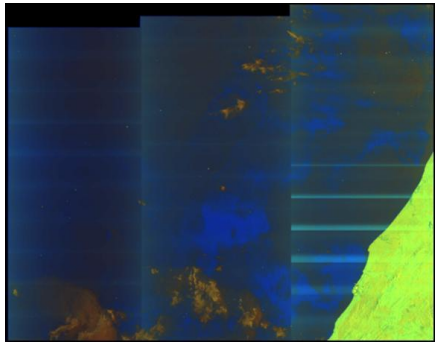
02/Nov/2019

# Crossing Points

- Each S-1 S/C has 4 crossing points with each RCM S/C. There are in total 24 time windows per cycle, grouped in 8 areas, to acquire a mutual interference.
- According to the S-1 nominal mission planning, only in 1 over the 8 possible crossing areas there is an acquisition planned. That's with S1-A over Indonesia.
- The crossing points were calculated using TLEs and therefore a certain error was expected.
- One of the crossing points was expected on 1st/Nov/2019 22:12:00-22:14:00 approx.
- CSA placed an RCM-1 acquisition in Low Resolution 100m mode HH-HV for 2019-11-01T22:14:00 (UTC) for a 238 seconds duration.
- For more info see the presentation from I. Barat on ASAR 2019.

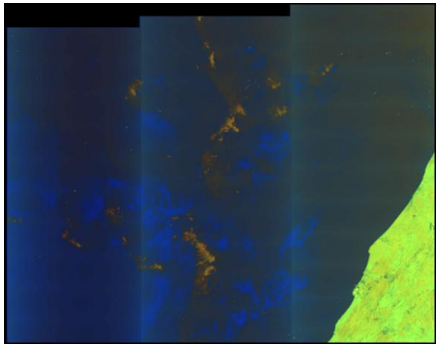
# QuickLooks

2019-11-01 22:14:21



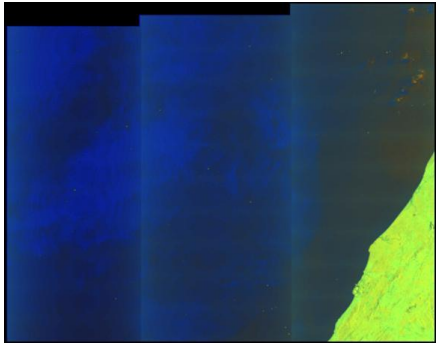
T0

2019-10-20 22:14:21



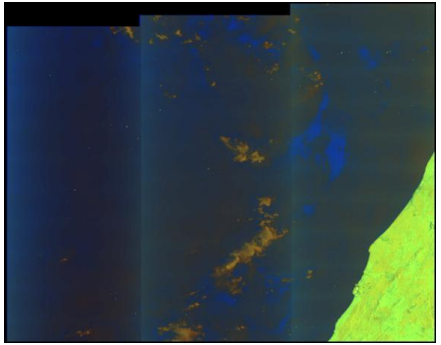
T0-12 days

2019-10-08 22:14:21



T0-24 days

2019-09-26 22:14:21



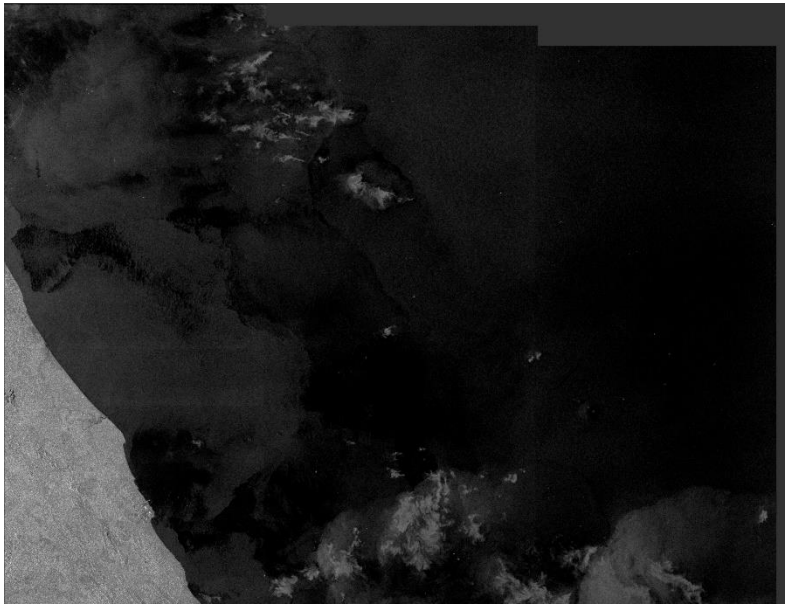
T0-36 days

**No RFIs spotted on previous passes.**

# Acquisition on 2019-11-01 22:14:21-22:14:50

- RFI expected. RCM-1 was in dual pol HH+HV while S1-A was in VV+VH.

Therefore higher interference level is expected in the S1-A X-pol channel.



VV

VH

# Conclusions

- An interference has been observed. The RFI is clearly visible on IW-1.
- It can't be confirmed whether the interference is coming from RCM-1 or on-ground radars.
- In order to discard on-ground radars past images have been displayed to see if this area has a frequent presence of RFIs.
- All the available images on the area of interest are S1-A acquisitions. All have the same rel. orbit, thus there is only one image every 12 days.
- Three past overpasses with 12 days difference each (S1-A) have been presented and no RFI has been found.
- All the quicklooks available from 9th/Jan/2016 untill 20th/Oct/2019 (100 images in total) have been checked. No RFI has been found in any of them.
- **It can be concluded that the acquired RFI is very likely an interference coming from RCM-1.**
- **It is suggested to repeat the coordinated acquisitions, but starting one minute earlier in order to acquire the peak of the interference, that happens a few seconds earlier than the planned S1A acquisition.**