Jet Propulsion Laboratory
California Institute of Technology

SDC Architecture Reference

Architecture Lead: Shadi Oveisgharan[1]

Study Coordinator: Paul Rosen[1], Phase II Lead: Stephen Horst[1], Batu Osmanoglu[2]

Value Frame Work Lead: Chris Jones[3], Performance Tool: Katia Tymofyeyeva[1], R&A: Ala Khazendar[1], Mission Plan: Adrien Maillard[1], Orbit Generation: Diana Illingsworth[3], SDC Team

1: Jet Propulsion Lab, 2: Goddard Space Flight Center, 3: Langley Research Center

Nov. 28th 2022

Table of Content

Selected Architectures

Architecture	Architecture Characteristic	Orbital Groups	Pol.	Per Satellite Swath (km)	Global Revisit Time (Days)	Local Revisit Time (Days)	Science Characteristic	Relative Cost
L1C	NISAR w/PWV inst.	1	Quad	240.0	12	12		2.9
L4A	2x NISAR w/Rose-L	4	Quad	240.0	3	3		3.6
L5A	NISAR via 5 Small Sats.	5	Dual	60.0	8	2		1.6
L6C	Rose-L Active Multi-Squint Co-fliers	2	Single	80.0*	6	6		1.0
L6E	Rose-L Passive Multi-Squint Co-fliers	2	Dual	80.0*	12	6		2.0
L8E	Sub-Daily Repeat for targeted area in 12 days	1	Dual	40.0	12	0.25		2.1
L9A	NISAR via Multi-Squint Co-fliers	3	Dual	80.0	12	4		2.4
L12B	Multi-Baseline Helical Orbit	2	Dual	40.0	6	6		2.3
L12C	Fast Revisit Low Cost per Sat.	12	Single	60.0	12	1 3		1.8
L18A	Multi-Squint Low Cost per Sat.	6	Single	60.0	12	3		2.2

*Reported swath is for the co-fliers, not Rose-L.

Urgent Response

Targeted Area

Regional

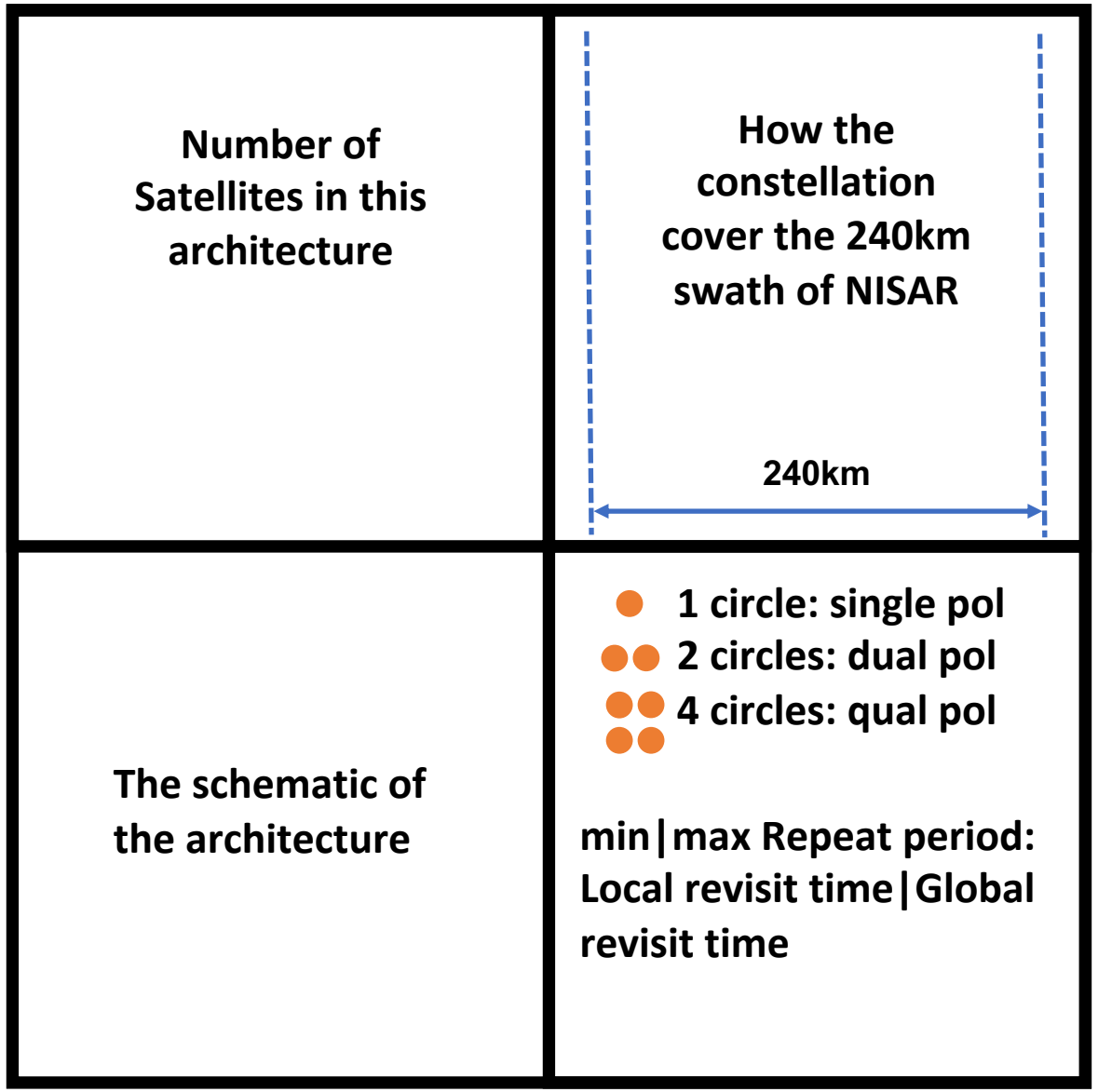
Improved single observation accuracy using phase

Reduced single observation accuracy using amplitude

3D Vector Deformation

Tomography for Veg. structure

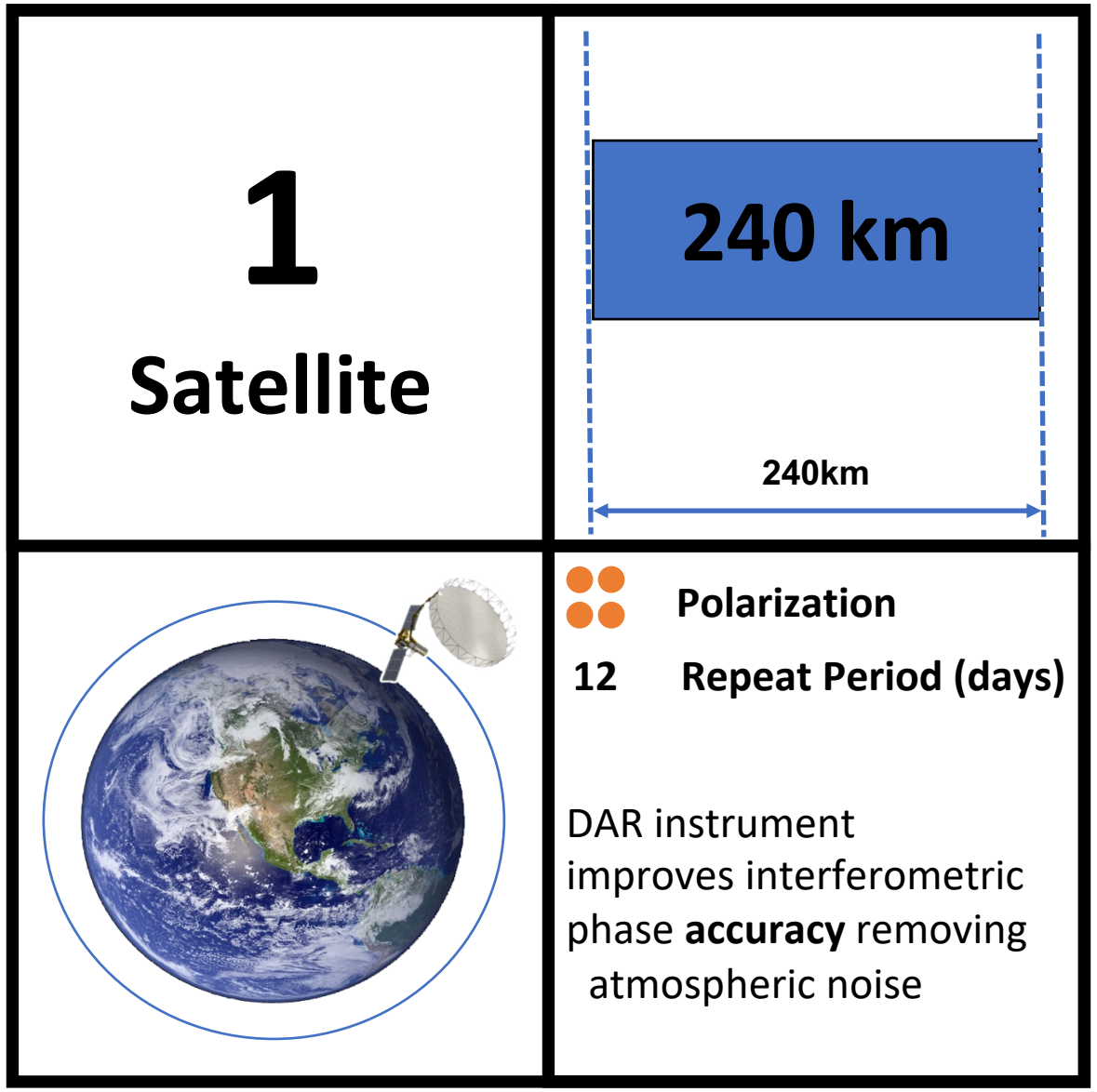
User Guideline



- L1A: is NISAR-Like architecture
- Focus mode: 2 or more satellites in the constellation have the same look angles for faster revisit time or removing atmospheric noise
- Extended mode: Satellites have different look angle through 240km swath to increase the coverage

L1C

Improved single observation accuracy using phase

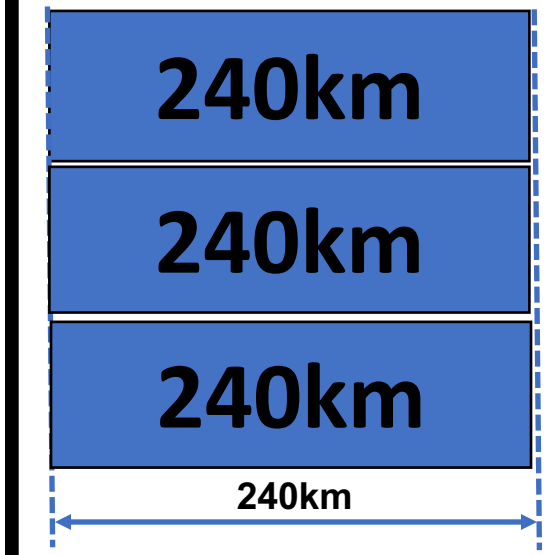


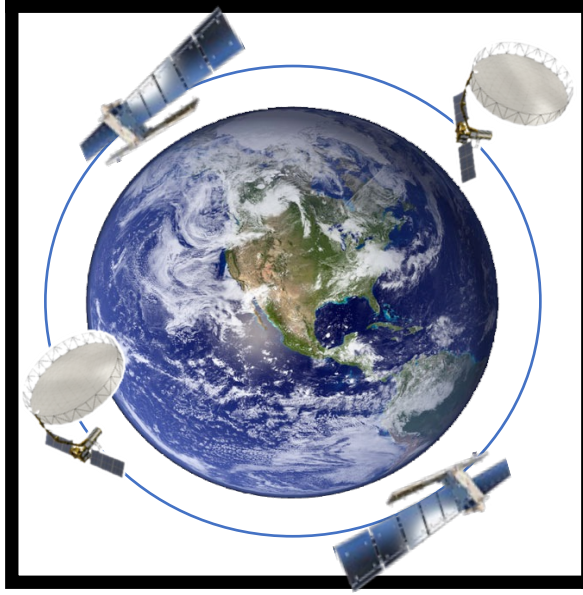
- Differential Absorption Radar (DAR) at millimeter wave frequency measures the phase delay through water vapor to remove it from InSAR phase

L4A

2+2

Satellites





Polarization

3 **Repeat Period (days)**

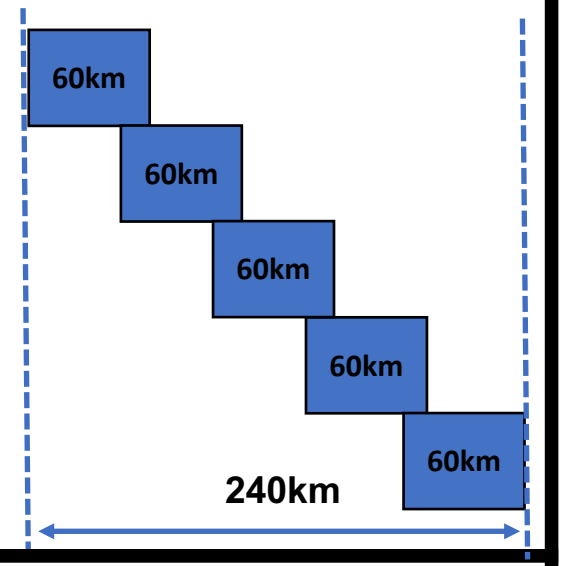
2 NISAR-like complement the 2 ESA ROSE-L
3 times faster global revisit time than NISAR
expensive

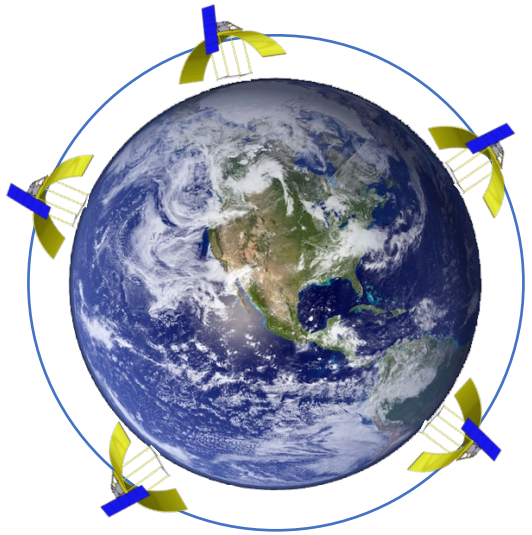
L5A

Urgent Response

5

Satellites



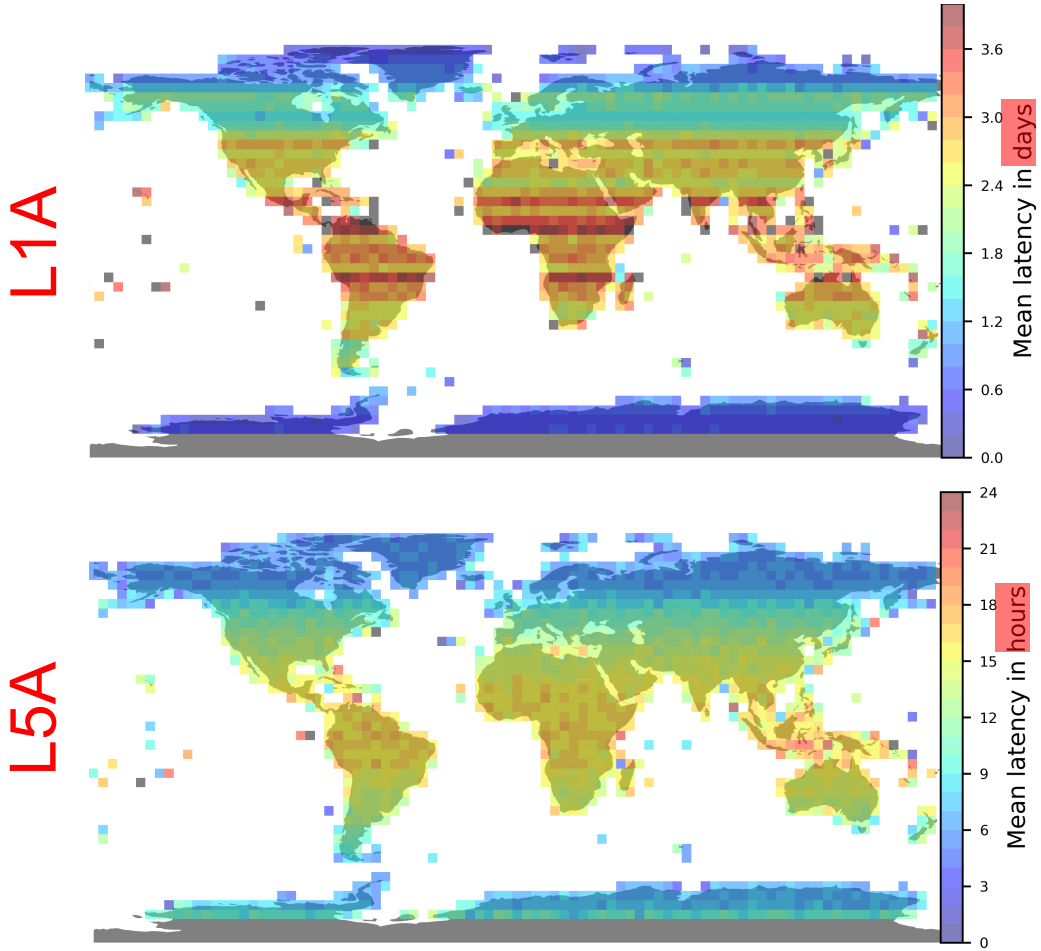


Polarization

2|8 Repeat Period (days)

10 days repeat orbit
Fast local revisit time for **urgent response**
(latency: hours instead of days)

Latency Map



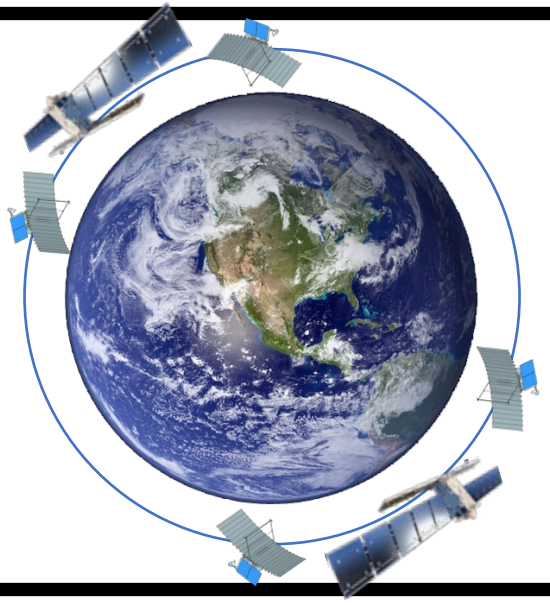
L5A (Continued)
Future Community Contribution

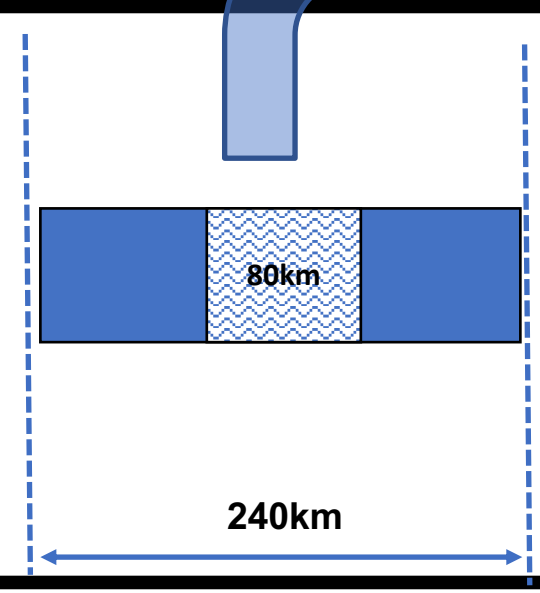
- Instead of overlaps between 5 satellites, we can plan to have
  - Four of them provide Global coverage
  - One of the satellites can be used to make 2 days interferometry for ¼ of NISAR Swath
- Your Input
  - Define campaigns for
    - 2 days interferometry in every 10 days
  - Otherwise we will plan global 2 days interferometry in every 40 days

L6C

4+2

Satellites

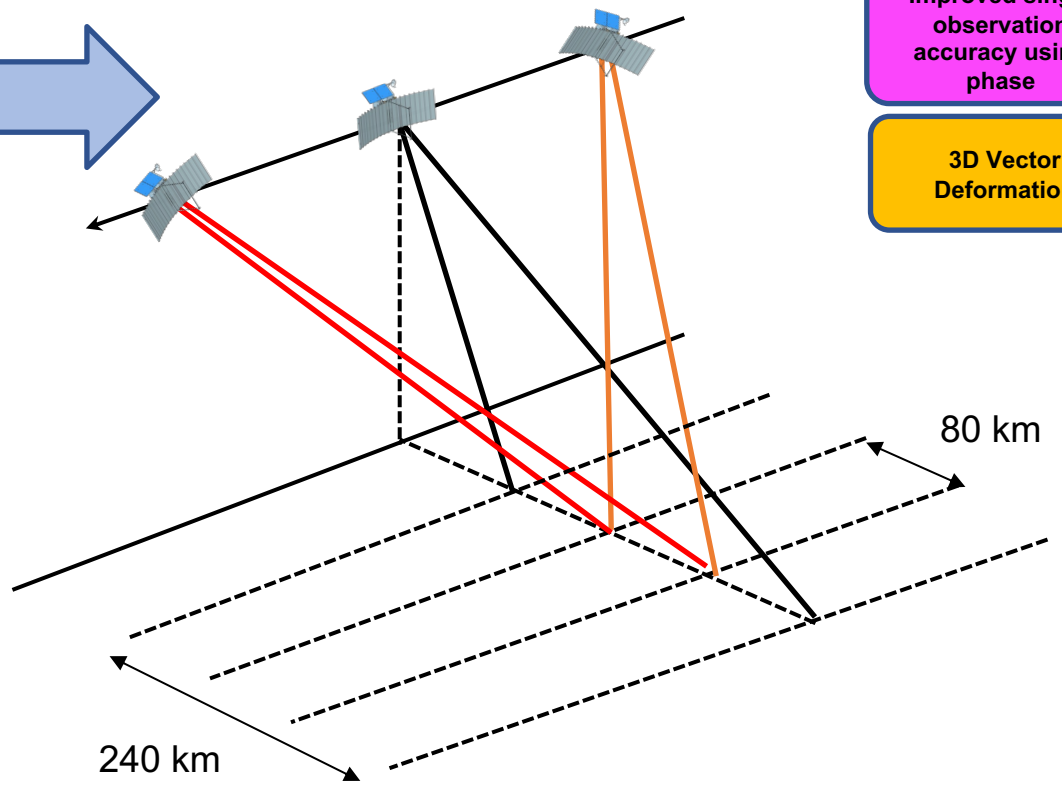




Polarization

6|12 Repeat Period (days)

Multi squint **active** co-flyers surrounding ROSE-L Atmospheric removal for 80km of ROSE-L Swath



Improved single observation accuracy using phase

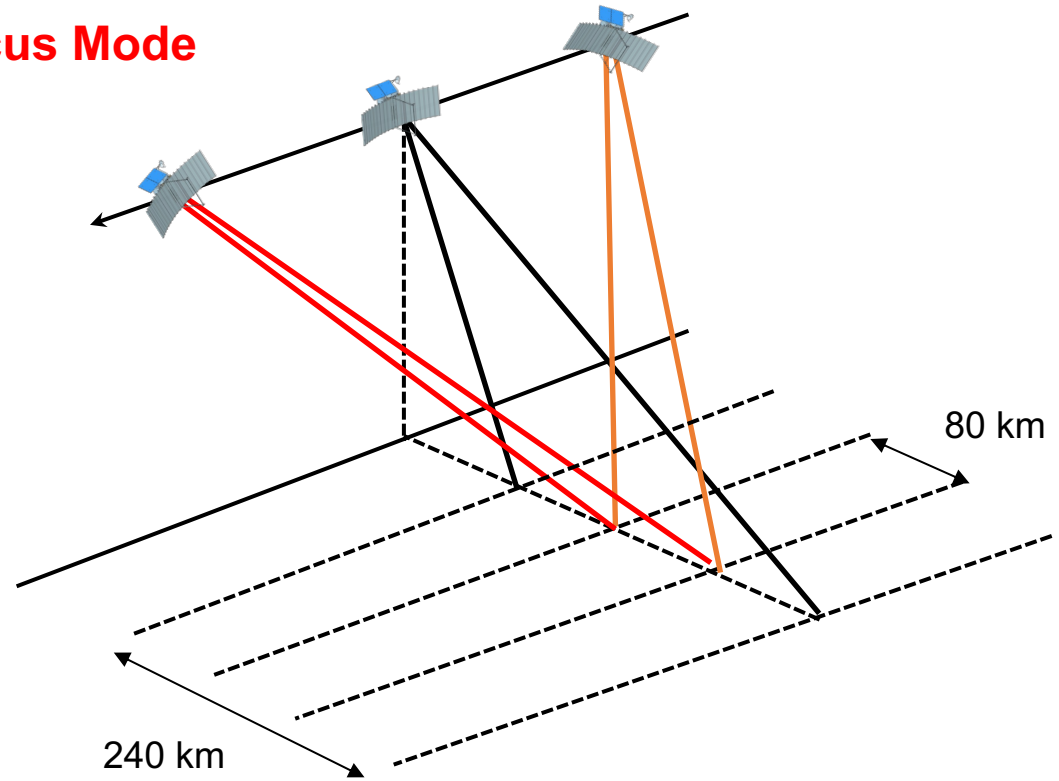
3D Vector Deformation

- Multiple real-time look angles enable:
  - accurate removal of atmospheric noise and better single observation accuracy
  - good estimation of all 3 spatial component (North, East, UP)

L6C (Continued)

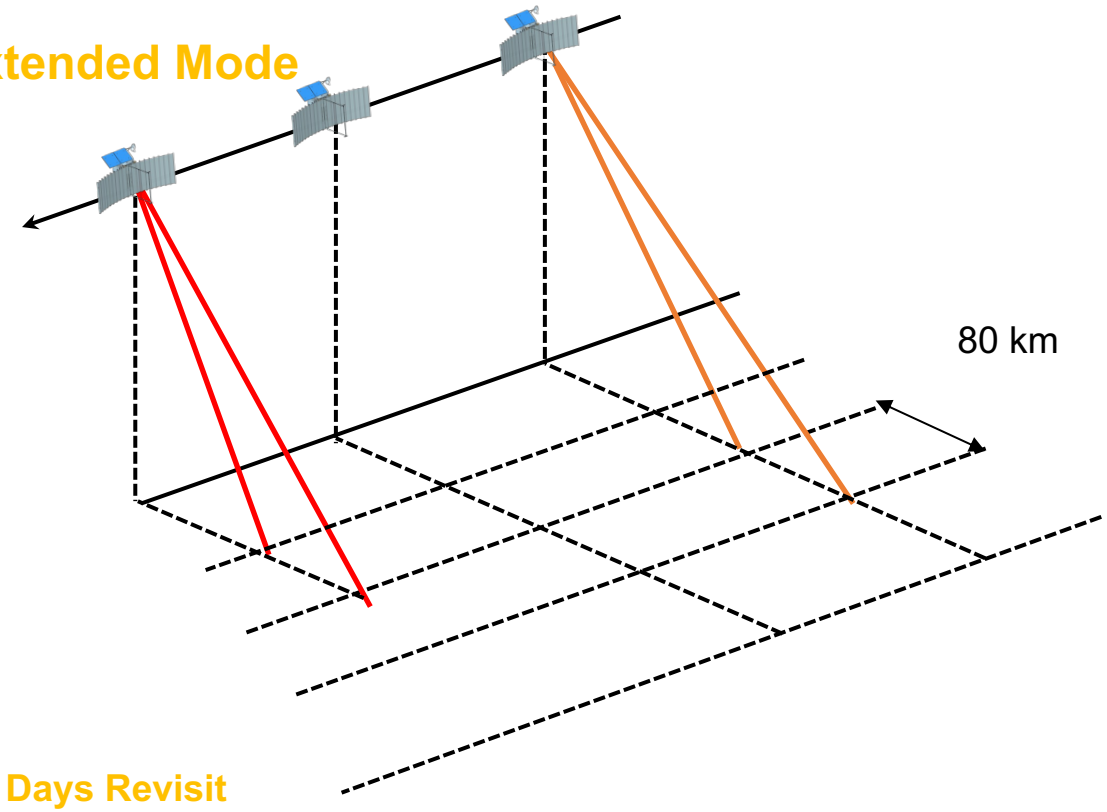
- Focus mode:
  - Mothership is on and co-flyers cover 80km of 240km swath for better LOS and 3D deformation accuracy
  - Global 12 days interferometric observations, and 6 days interferometric observation over Europe
- Extended Mode:
  - The mothership is off. The two co-flyers cover 160km
  - no atmospheric removal and 3D measurement
  - 6 days interferometric observation

Focus Mode



Atmospheric Removal

Extended Mode



6 Days Revisit

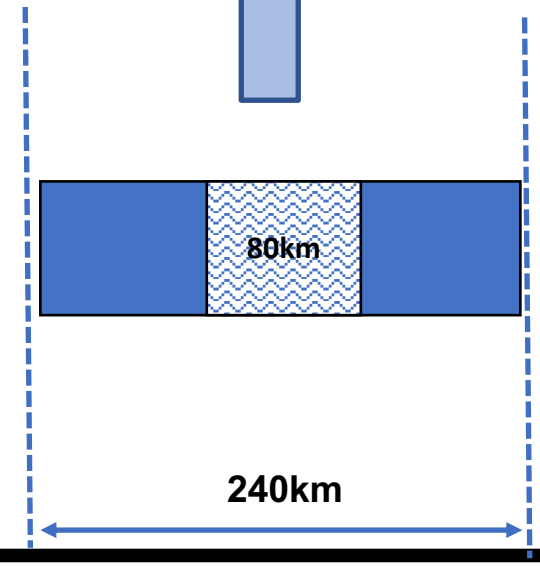
L6C (Continued)
Future Community Contribution

- Due to 80km swath gaps, we cannot do 6 days interferometry globally in extended mode
- Your Input
  - Define high priority campaigns for
    - extended mode with 6 days revisit (spatially and temporally)
    - For instance: mountainous regions in winter to beat down temporal decorrelation of snow

L6E

4+2

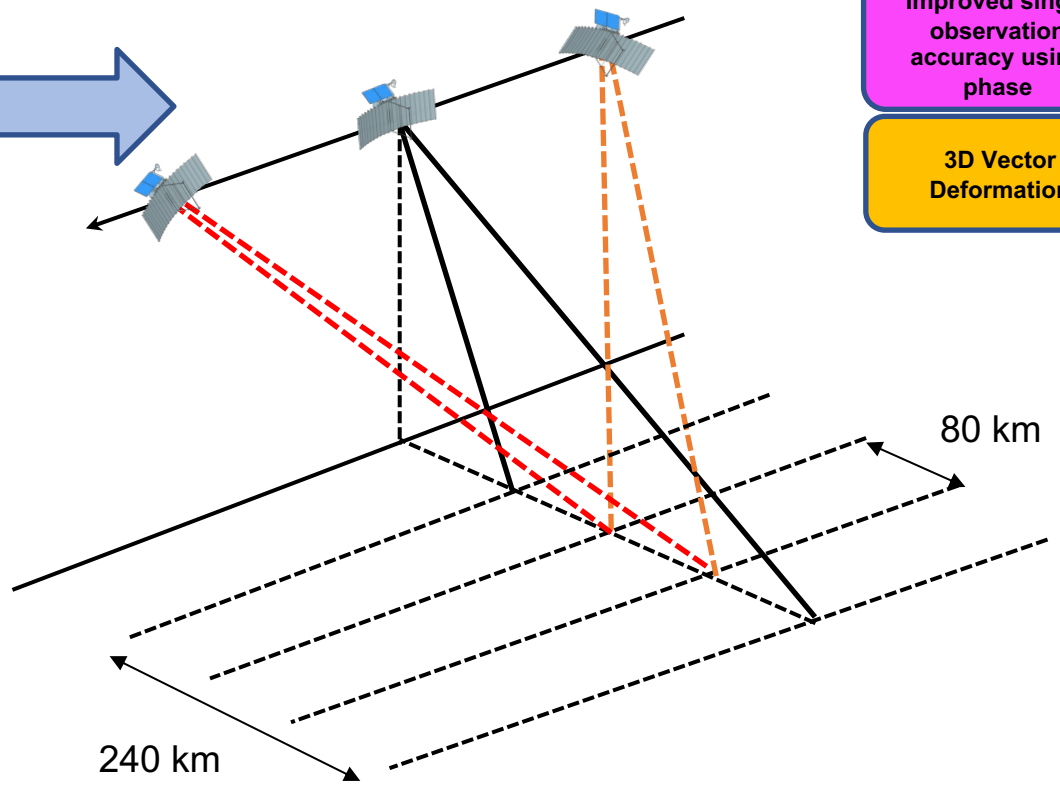
Satellites



Polarization

6|12 Repeat Period (days)

Multi squint **passive** co-flyers surrounding ROSE-L Atmospheric removal for 80km of ROSE-L Swath



Improved single observation accuracy using phase

3D Vector Deformation

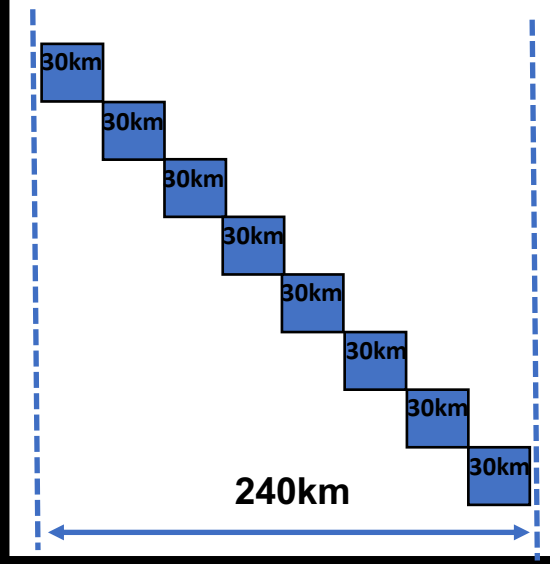
- Multiple real-time look angles enable:
  - accurate removal of atmospheric noise and better single observation accuracy
  - good estimation of all 3 spatial component (North, East, UP)
- Global 12 days interferometric observations, and 6 days interferometric observation over Europe

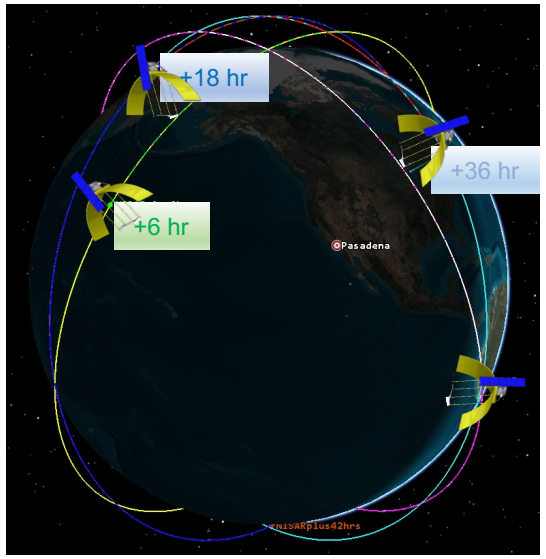
L8A

Targeted Area

8

Satellites





Polarization

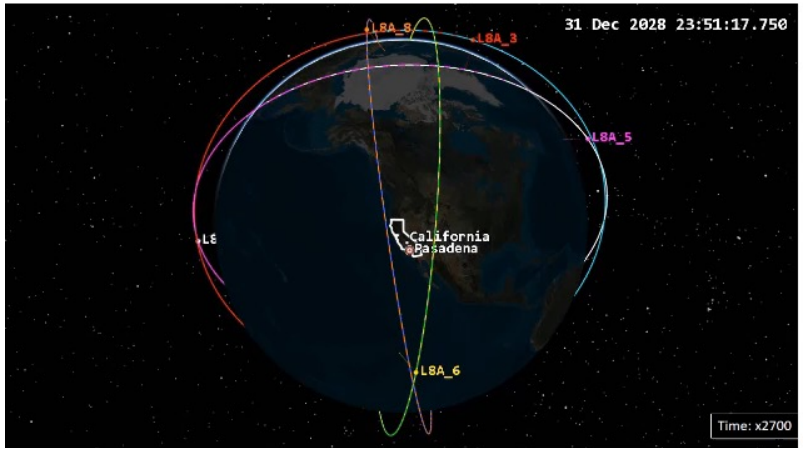
0.25 - 12 **Repeat Period (days)**

Mechanical steering can cover any 30km targeted area with 6 hours repeat in 2 days, every 12 days

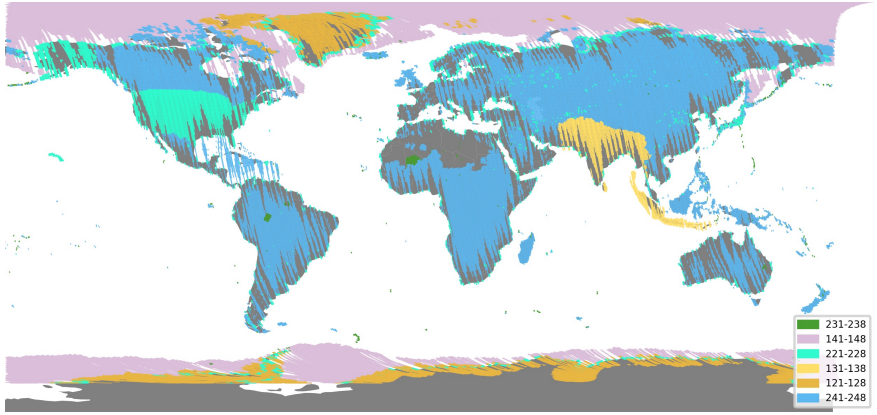
- Fast Temporal Sampling is needed for some processes to avoid aliasing of the deformation signal and better accuracy
  - Glacier flow subject to tidal forcing with 12 hour period
  - Soil moisture decays with days-long diffusion response
  - 8 SATM GOs requested 6 hours revisit time, mainly in coastal regions
- Eight satellites in 4 different orbital planes

L8A (Continued)
Modes

- Extended mode:
  - The eight satellites looks at different angles to cover 240km swath
- Focus Mode:
  - All eight satellites have the same look angle to make **6** hours interferometry for **2** days in 12 days repeat time over targeted areas (coastal regions is our target so far)
  - Mechanical steering causes big spatial gaps in the observation plan (as shown below)
  - Electronic steering is needed to avoid big gaps but it is expensive



Mechanical steering causes big holes in the observation plan



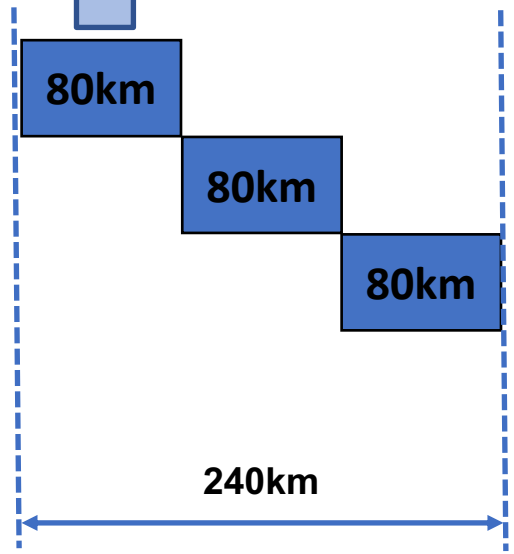
L8A (Continued)
Future Community Contribution

- Your Input
  - If going forward with mechanical steering (due to cost):
    - Identify the limited regions of interest for 6 hours repeat (the less regions the less gaps).
    - For instance: Do we need all the coastal regions?
  - If going forward with electronic steering:
    - Identify regions **other than coastal regions** for focused mode observation with concomitant regional gaps around that region
  - Can we choose 6(or 4) satellites instead of 8 (Still 6 hours revisit time but in 1.5(or 1) days instead of 2 days)?

L9A

9

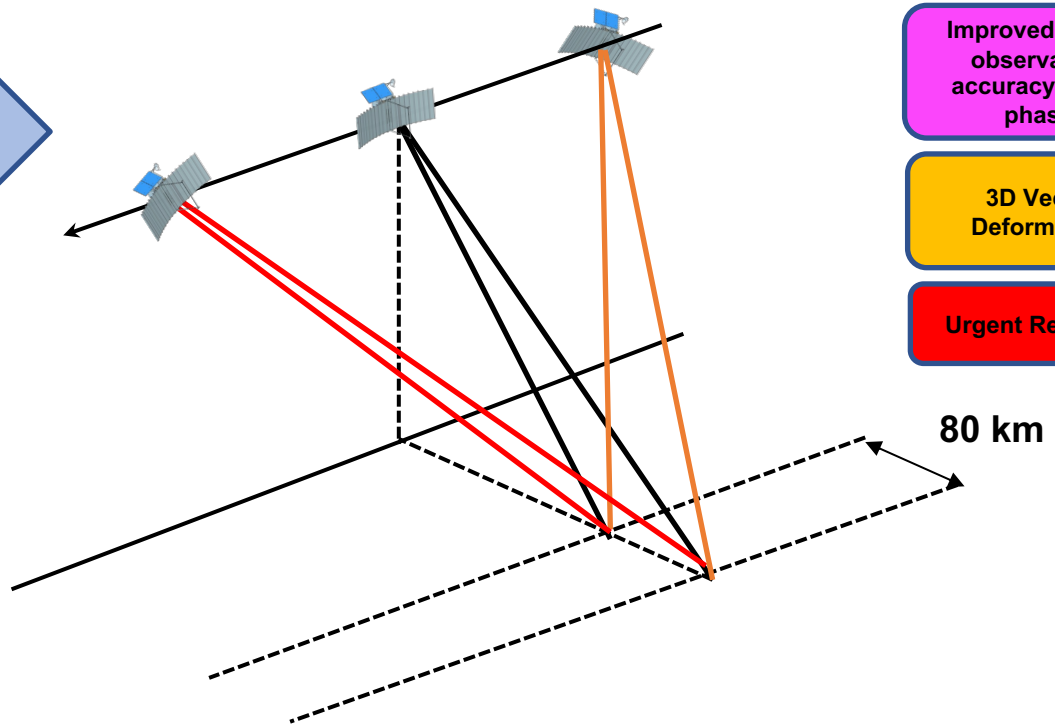
Satellites



Polarization

4-12 Repeat Period (days)

3 constellations of multi Squint geometry



Improved single observation accuracy using phase

3D Vector Deformation

Urgent Response

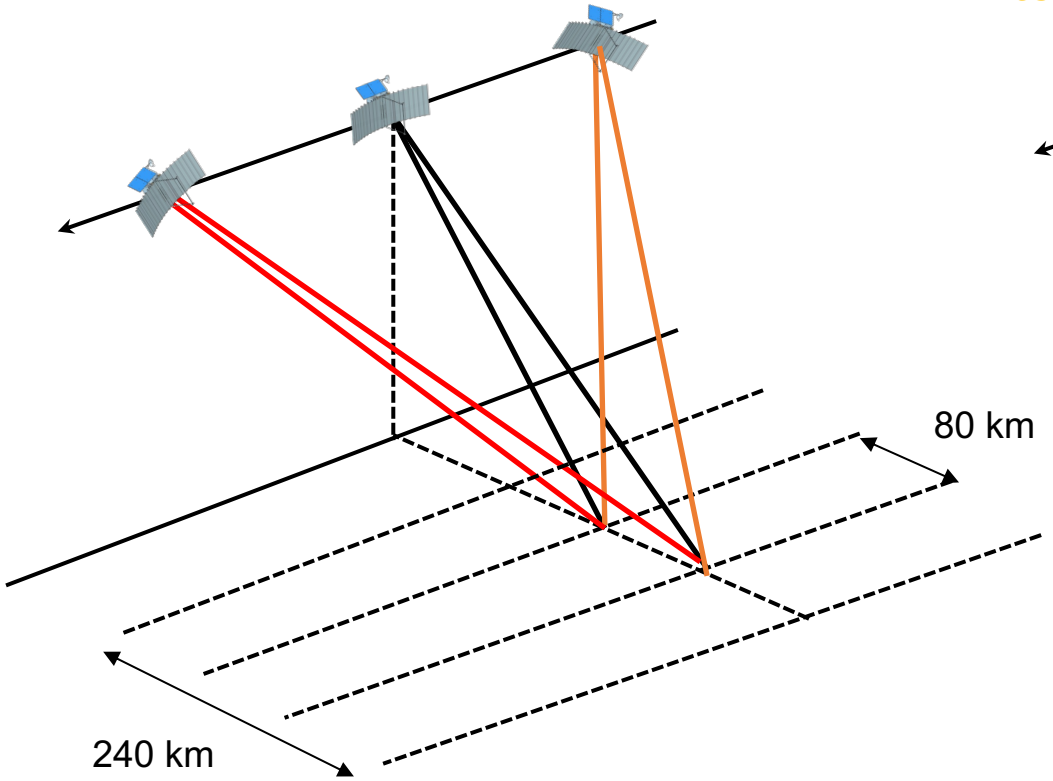
- Multiple real-time look angles enable:
  - accurate removal of atmospheric noise and better single observation accuracy
  - good estimation of all 3 spatial component (North, East, UP)
- Enables new science at the expense of coverage density

L9A (Continued)

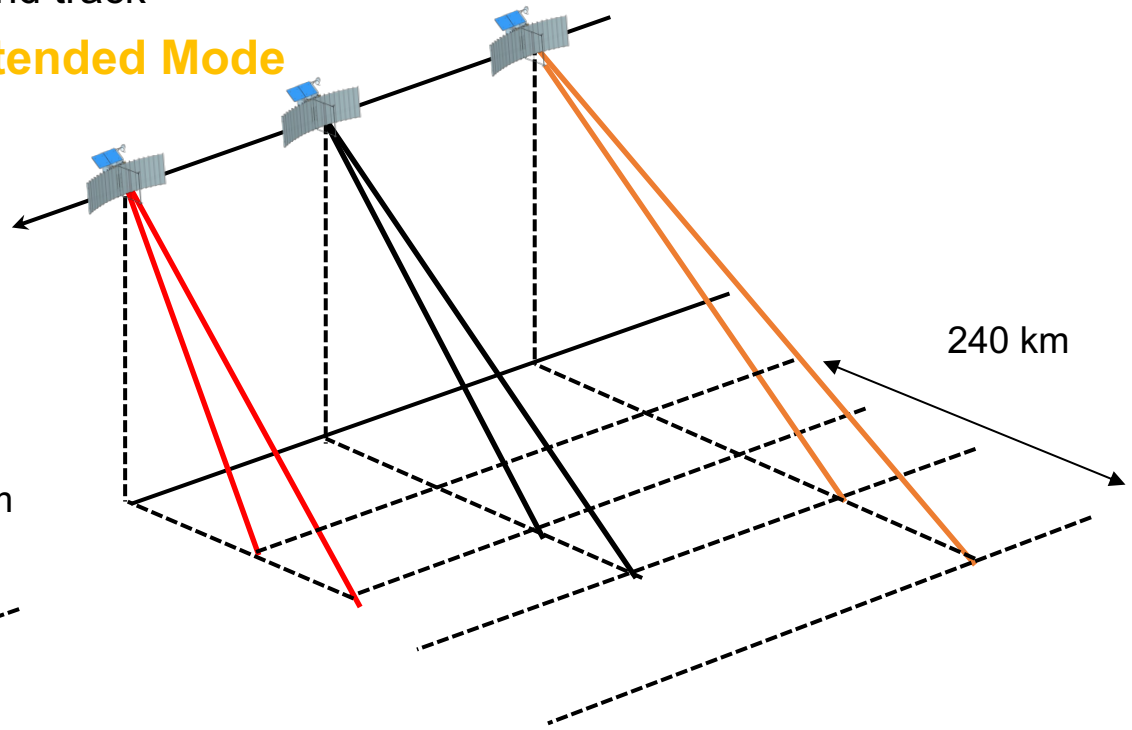
Modes

- Focus mode
  - Mothership and co-flyers cover the same ground track of 80km
- Extended Mode
  - The three satellites cover 240km ground track

Focus Mode



Extended Mode

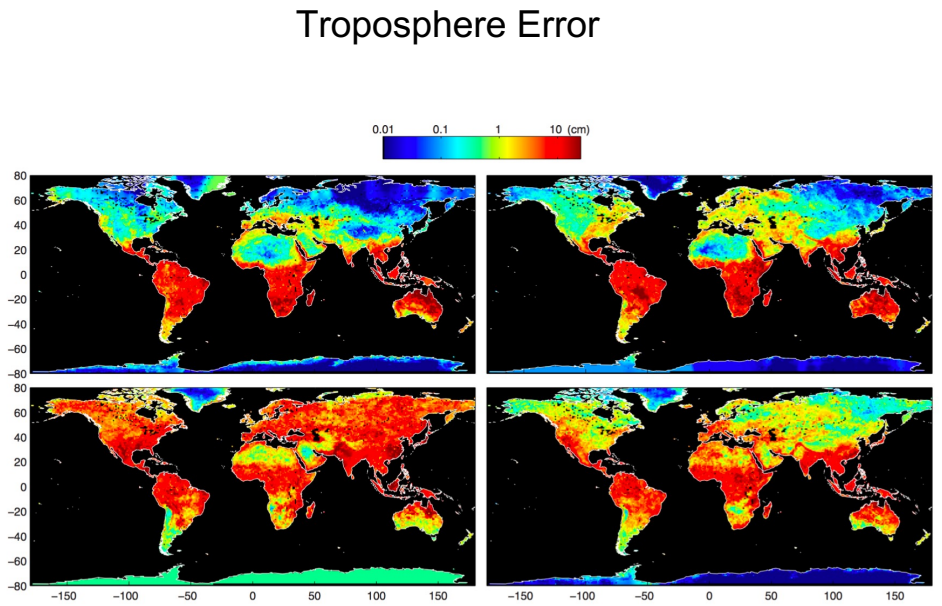


Atmospheric Removal

4 Days Revisit

L9A (Continued)
Future Community Contribution

- Instead of focus mode
  - all three clusters go to extended swath and make observations every 4 days
- Your Input
  - Define campaigns for
    - extended mode instead of focus mode
      - ➢ 4 days interferometry at the expense of non-atmospheric removal
    - For instance: Siberia in winter; troposphere error is small and fast revisit in forested regions helps with temporal coherence

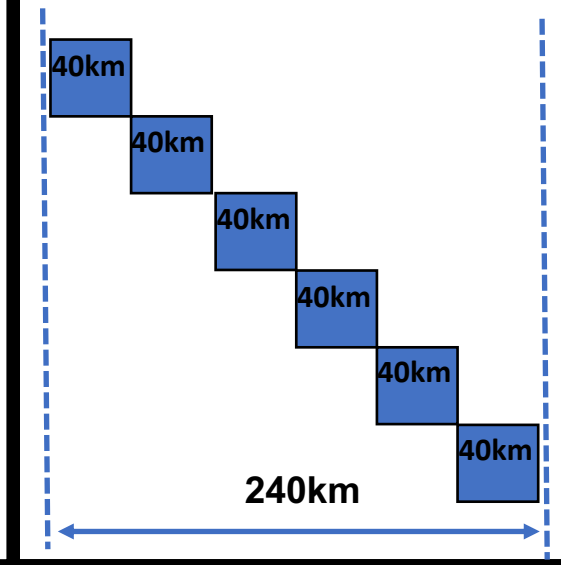


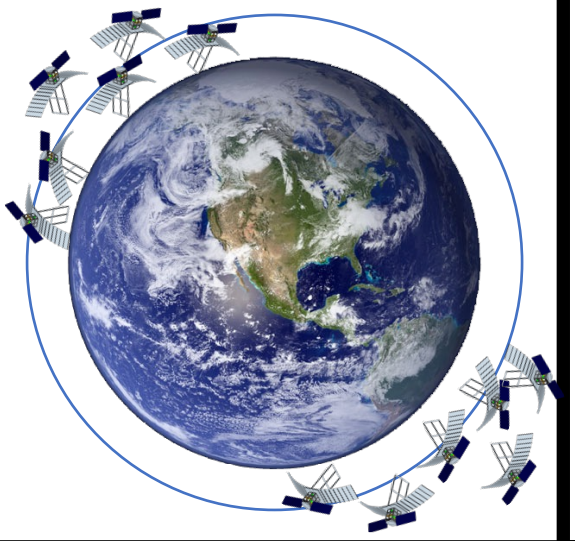
L12B

Tomography for Veg. structure

12

Satellites





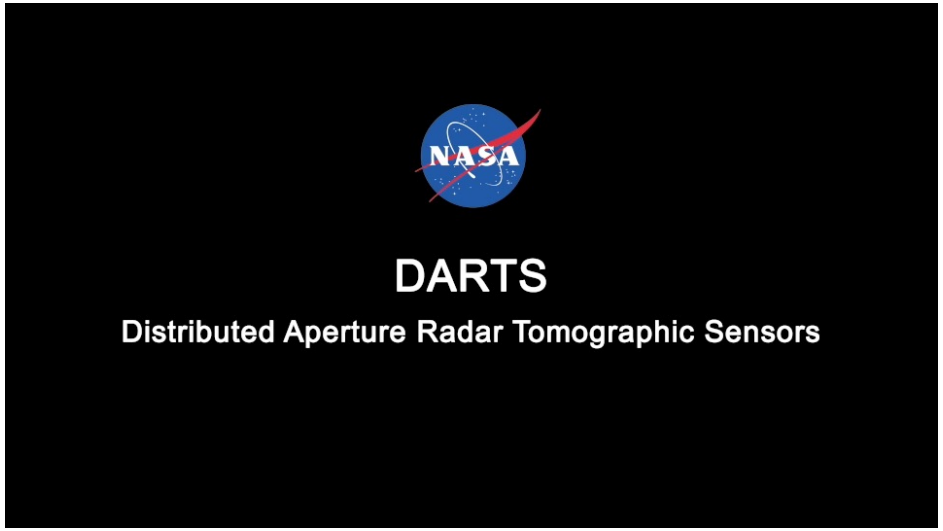
●● **Polarization**

6 **Repeat Period (days)**

Helical orbit to do tomography

- Two groups of six satellites operating in helical orbit.
- Non-zero baseline is used to make tomography for vegetation structure measurements

From DARTS project (ESTO IIP; PI: M. Lavalle)



L12B (Continued)

Modes

- Extended mode:
  - All 6 satellites in each constellation look at different look angles to cover 240km swath and do global 6 days interferometry
- Focus mode:
  - All 6 satellites look at the same look angle to do tomography
  - It takes 6*12/2 = 36 days to do global tomography
- Helical configuration does not support atmospheric removal/vector deformation of SDC
  - We cannot have simultaneous STV and SDC observation for atmospheric removal
    - STV requires along track baseline less than 10km [Lavalle et al, 2022]
    - SDC requires along track baseline of 250km
  - Reconfiguring the orbit positioning could support SDC atmospheric removal/vector deformation at the expense of STV

L12B (Continued)
Future Community Contribution

- Your Input
  - Identify, how often, spatially and temporally, you need to do tomography instead of repeat pass interferometry

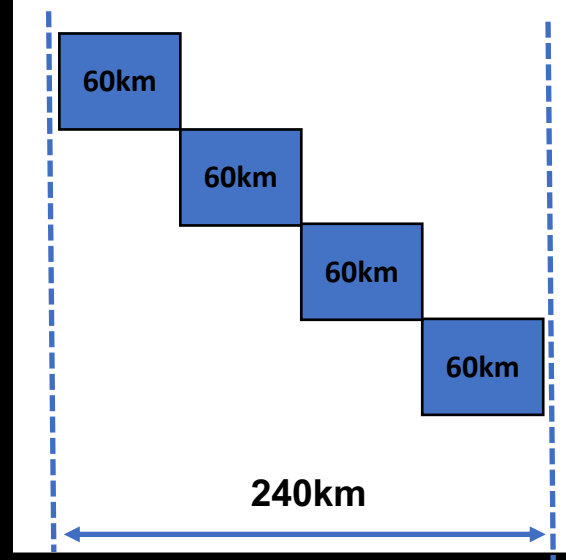
L12C

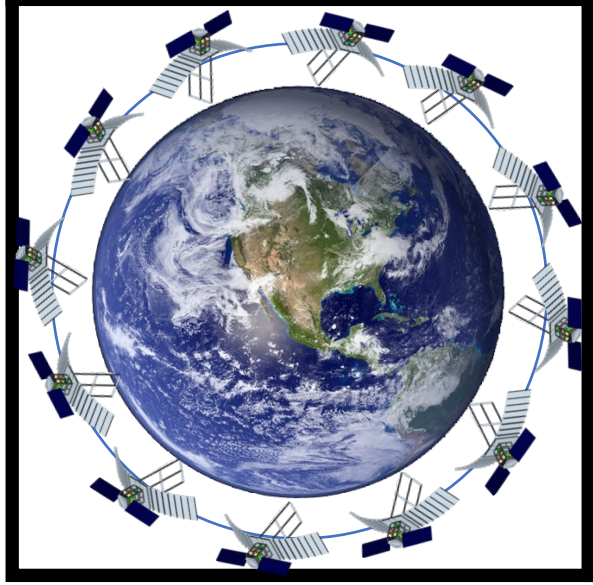
Urgent Response

Regional

12

Satellites



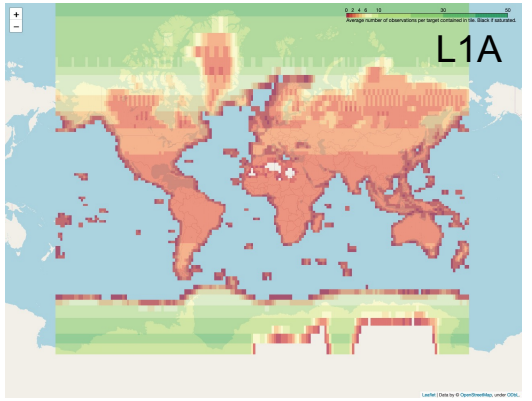


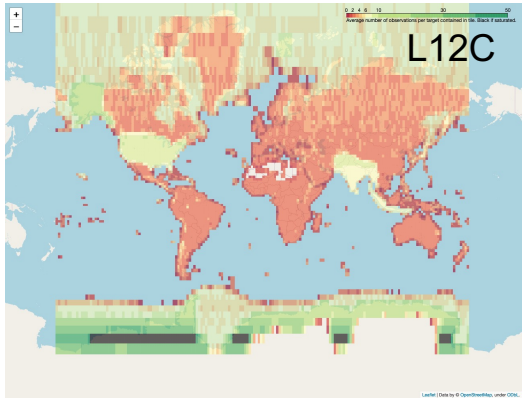
Polarization

1|12 Repeat Period (days)

Low radiometric accuracy
Low duty cycle
Possible representation of future commercial architecture

- 4 satellites are sufficient to cover 240km swath, but with 15% duty cycle, 12 of them are needed for L1A full global coverage in every cycle
- With 12 satellites, we have the capability to reduce the number of observations in high latitude (due to overlaps) and increase it in other areas (Over US in the map below)





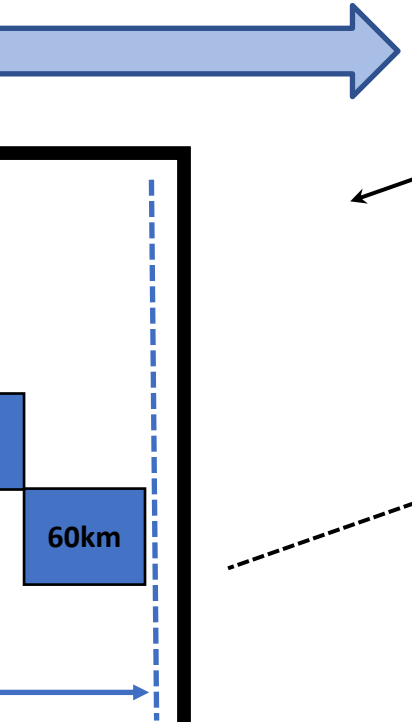
L12C (Continued)
Future Community Contribution

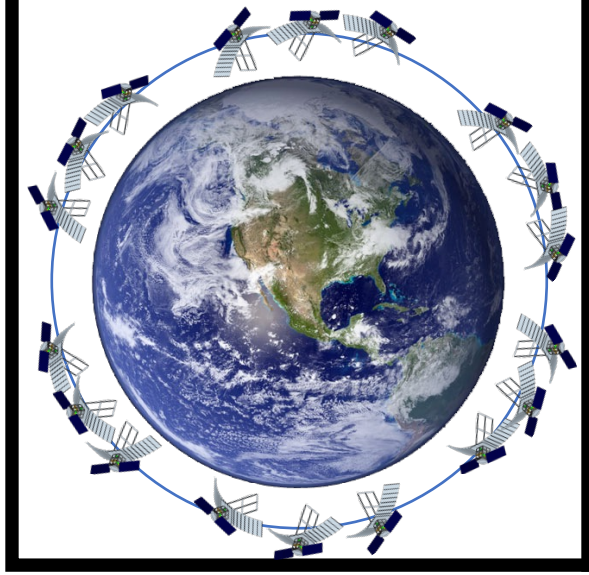
- Your Input
  - Identify the regions you want more observations at the expense of losing it in other regions

L18A

18

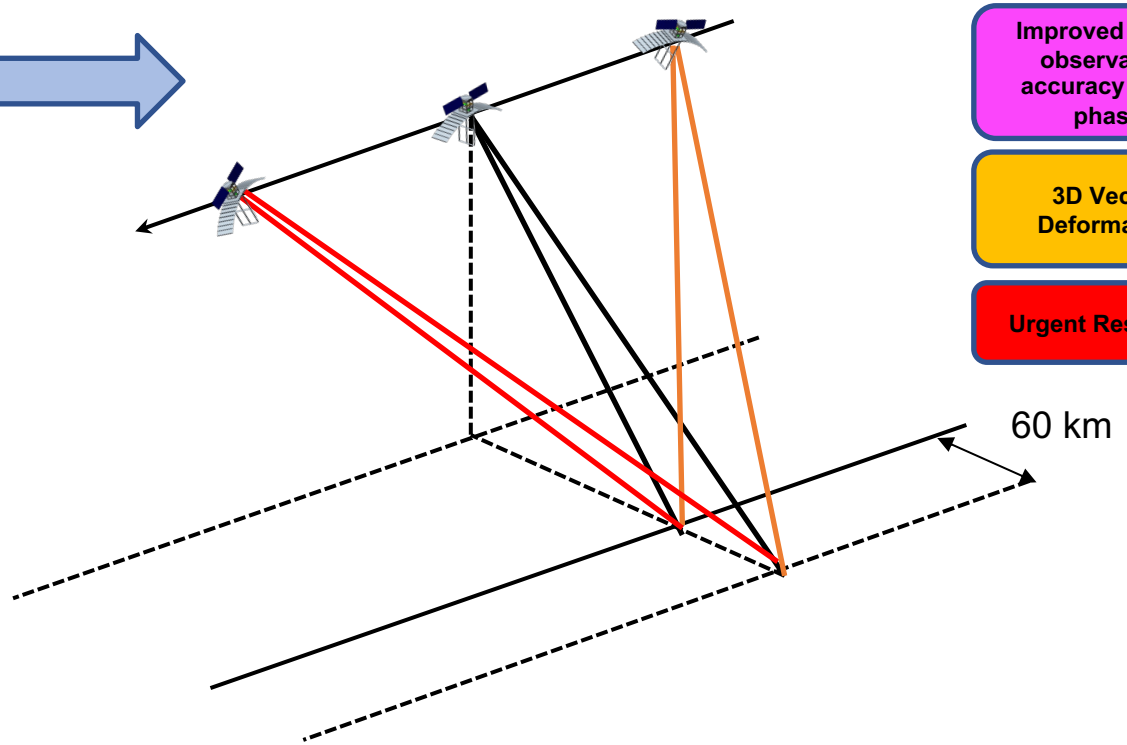
Satellites





- **Polarization**
- **2|12 Repeat Period (days)**

6 constellations of squinted geometry
Low radiometric accuracy
Low duty cycle



Improved single observation accuracy using phase

3D Vector Deformation

Urgent Response

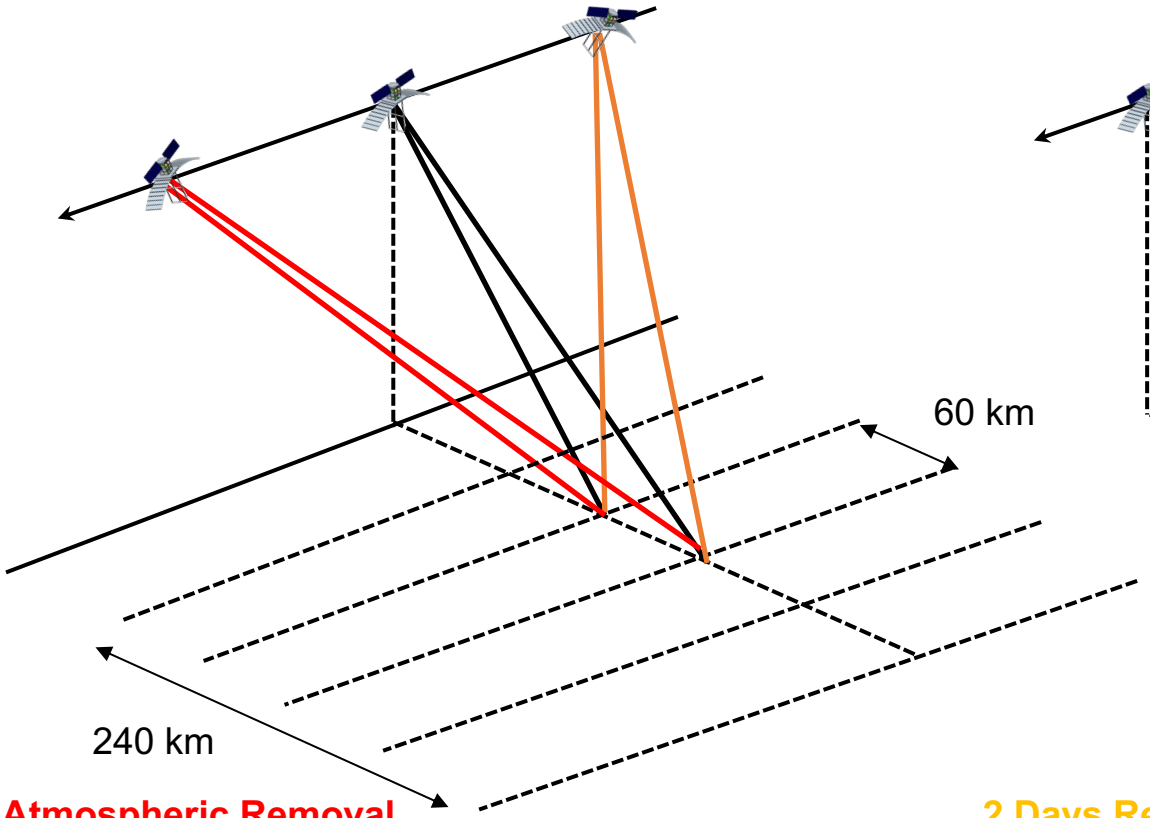
- Multiple real-time look angles enable:
  - accurate removal of atmospheric noise and better single observation accuracy
  - good estimation of all 3 spatial component (North, East, UP)

L18A (Continued)

Modes

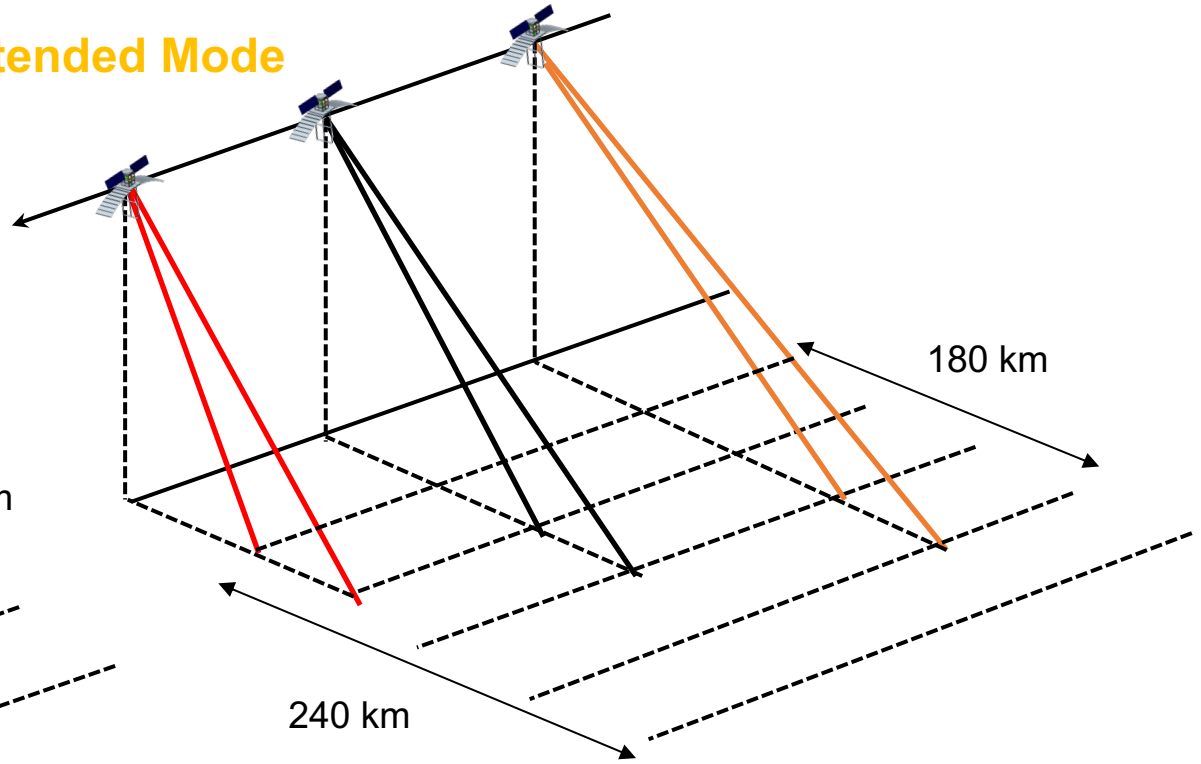
- Focus mode:
  - Mothership and co-flyers cover the same ground track of 60km
- Extended Mode:
  - The three satellites cover 180km of 240km swath

Focus Mode



Atmospheric Removal

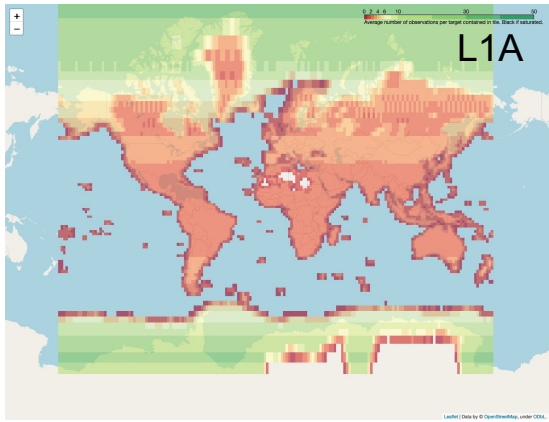
Extended Mode

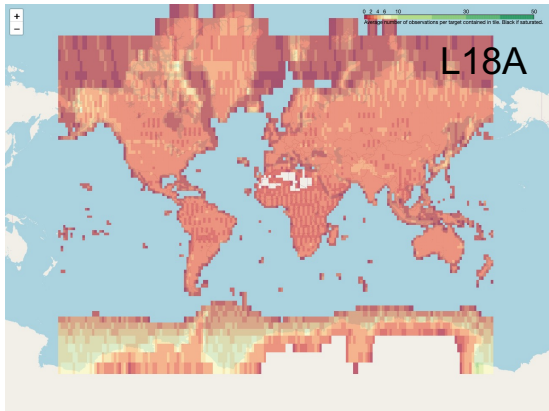


2 Days Revisit

L18A (Continued)

- 4 constellations in focus mode are needed to cover 240km swath, but with 15% duty cycle, 12 constellations in focus mode are needed (we have 6) for L1A full global coverage in every 12 days
  - As shown in the heat maps below, with L18A 6 constellations, we have spatial gaps (in polar regions) and less observations (compare to L1A) if in focus mode all the time
- We can use extended mode (at the expense of not removing atmospheric noise and no 3D vector deformation) to
  - Increase the number of observation and avoid spatial gaps by covering 180km of 240km swath by each constellation instead of 60km
  - Improve interferometry repeat time to 2 days





L18A (Continued)
Future Community Contribution

- Your Input
  - Define campaigns for
    - extended mode instead of focus mode for
      - 2 days interferometry at the expense of non-atmospheric removal
      - avoiding gaps in the coverage
      - For instance: Siberia in winter; troposphere is small and fast revisit in forested regions helps with temporal coherence