Overview of 3 phasing options for a Jason-1 / Jason-2 Tandem

G.Dibarboure
P.Escudier
A.Lombard

CENTRE NATIONAL D'ÉTUDES SPATIALES

Some questions for a tandem

Discussing phasing options basically answers 3 questions:

- How can we create a tandem?
- Do we want to mimic the TP/Jason1 tandem?
- Can we do better with Jason-1 / Jason-2?

There is no perfect tandem configuration so it boils down to

- What is the best option for each application?

Basics on tandem and Jason sampling

❖ Creating the tandem

- Change the satellite's altitude → Create an angular lag in the orbit plane → Longitude drift
- Side note: Jason-1 is able to travel much faster than T/P did (fuel ok, larger impulse possible)

❖ The Jason-orbit in a nutshell

- Circular, Altitude 1400km, Inclination 66°
- Repetitive ground track, 10 day cycle, 3 day sub-cycle
- 3000km in 1 day, 1000km in 3 days, 300km in 10 days (scanning pattern not linear)

❖ Sampling pattern

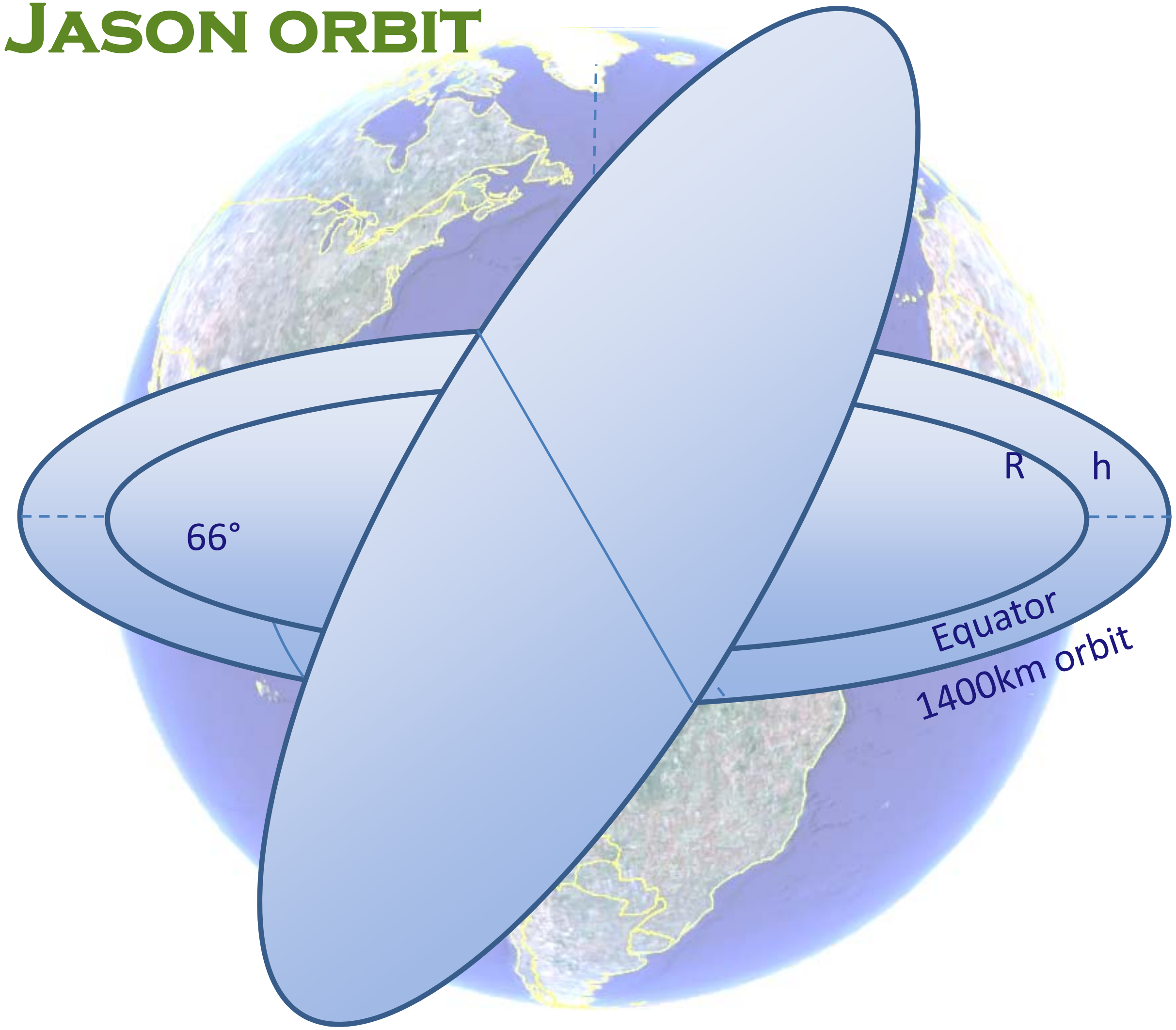
- Mono-satellite sampling and 3-day sub-cycle (interleaved patterns)
- Consequence on local resolution (offline science and near real-time applications)

❖ Impact on potential options for Jason-1 / Jason-2

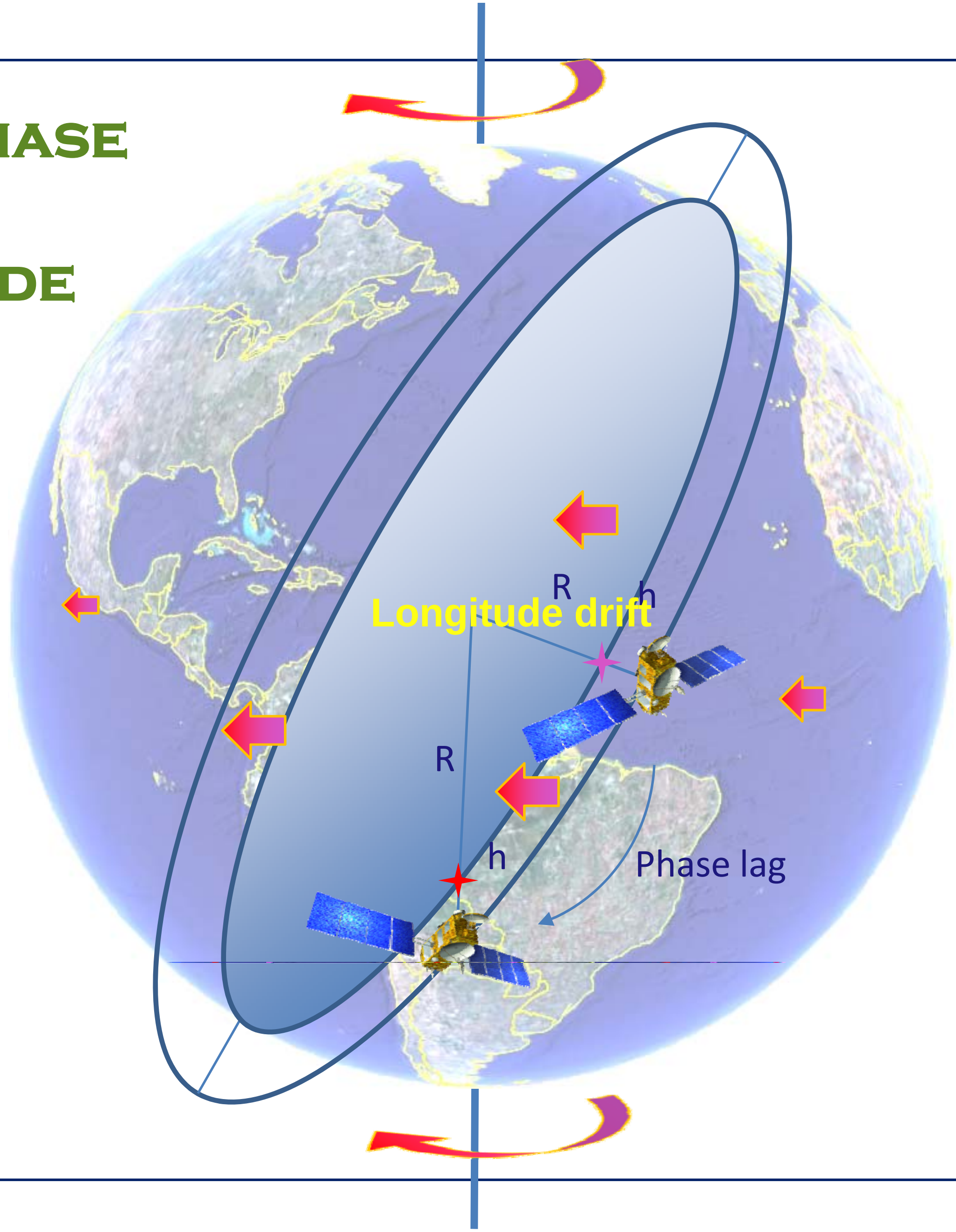
- Let Jason-1 drift to a specfic position (150km of a specific ground track of Jason-2)
- Limited number of interleaved options (time lags of 0, 1, 2… 10 days)

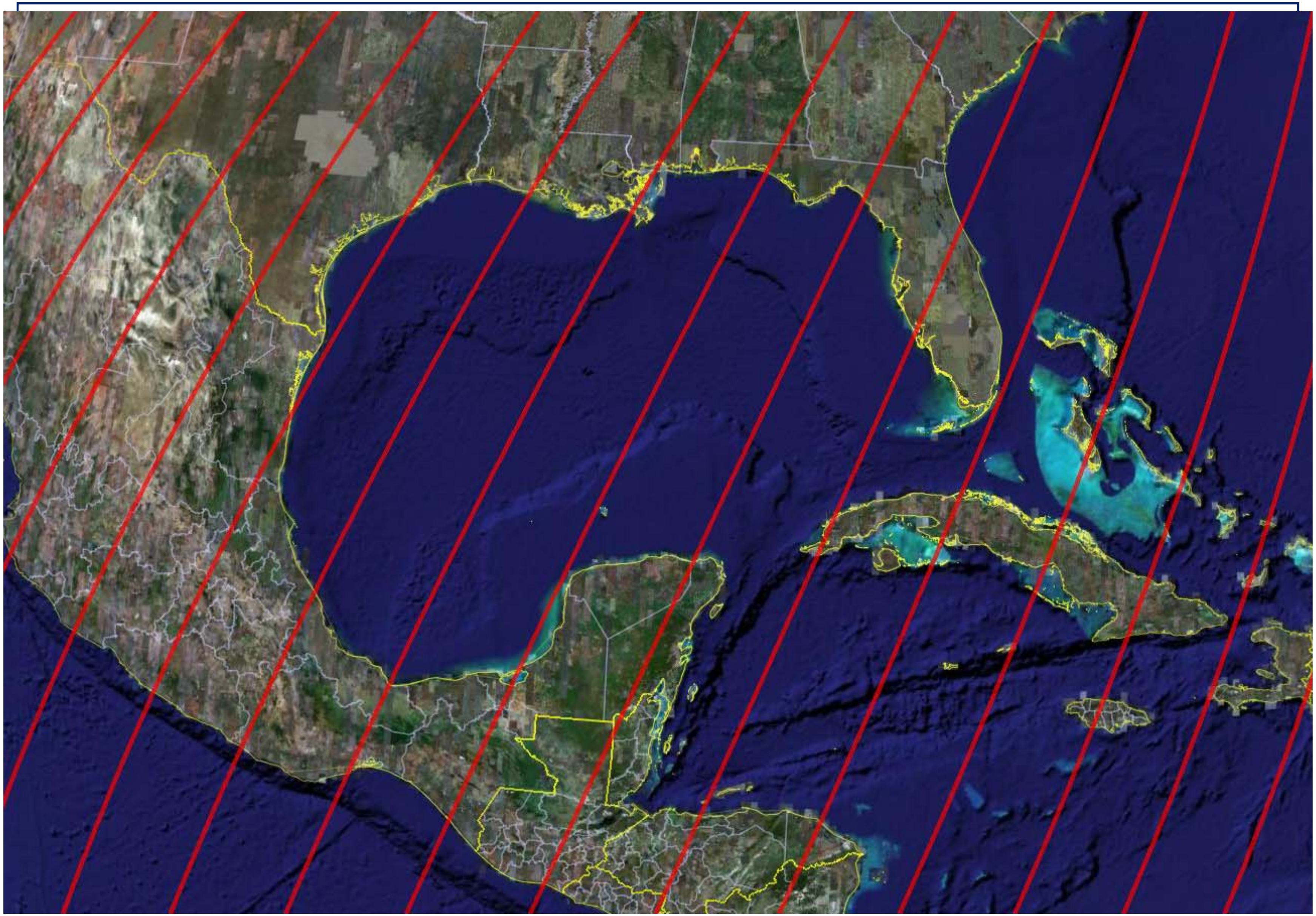
CLS

The Jason orbit



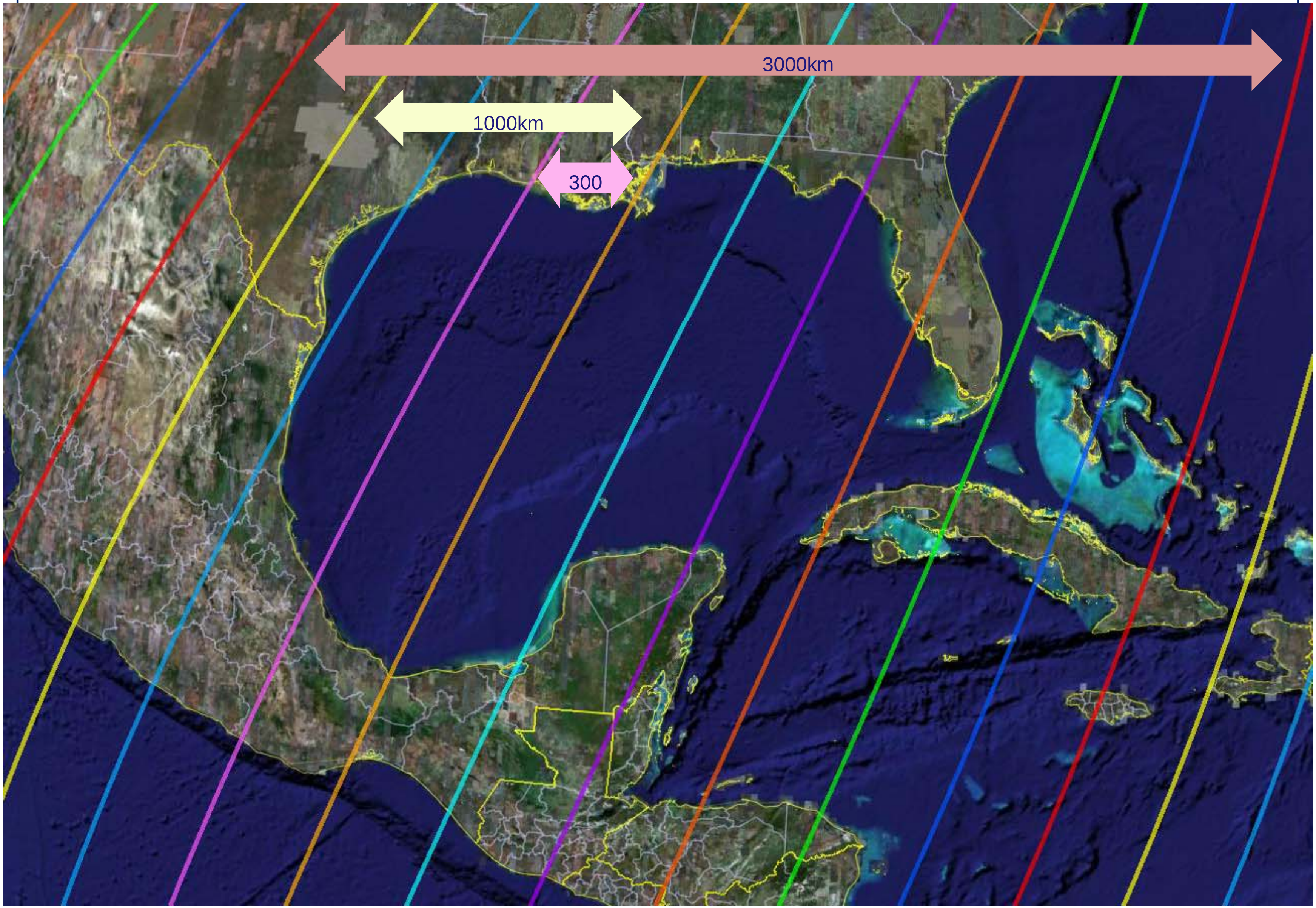
From phase lag to longitude drift



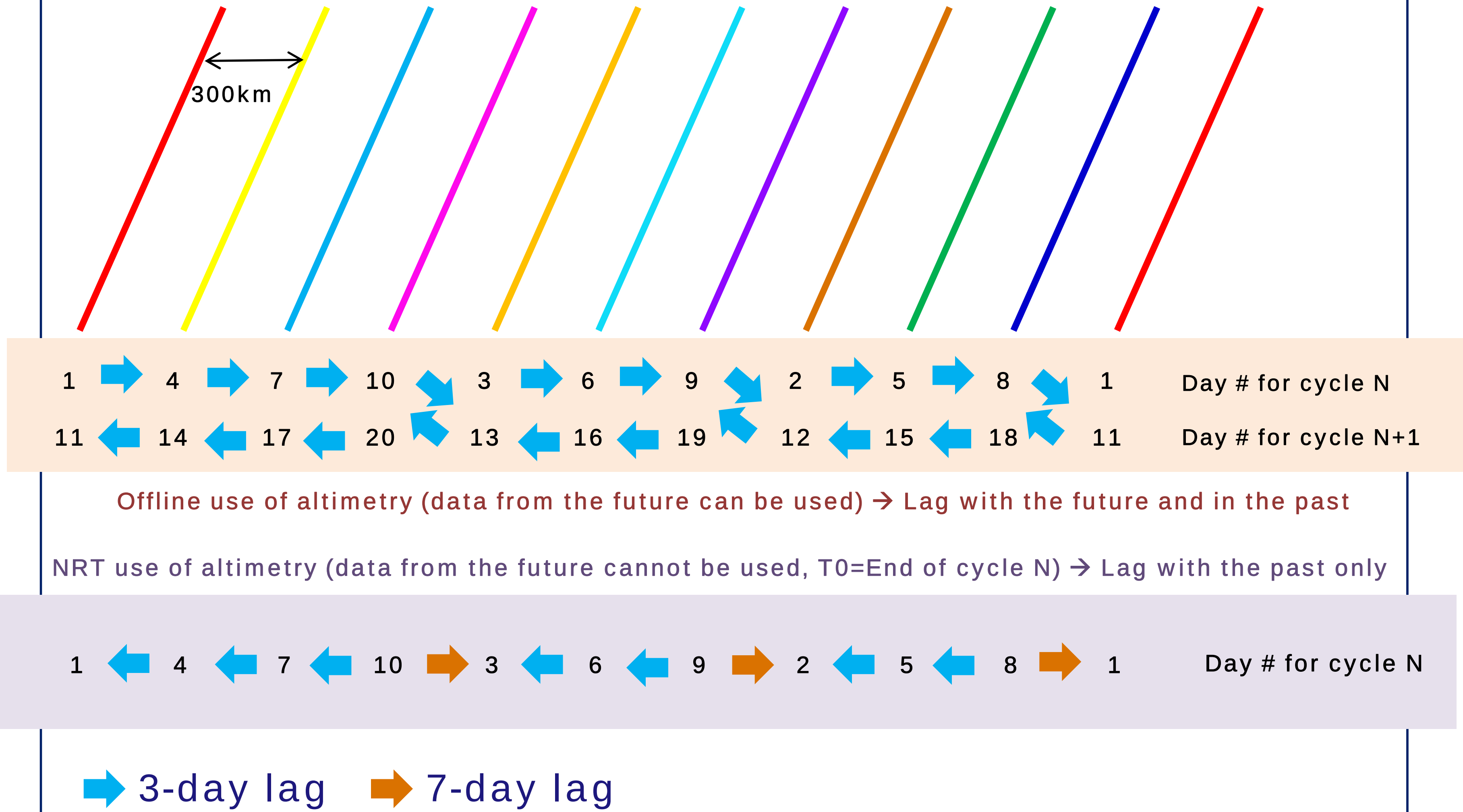


Day # in cycle

1	2	3	4	5	6	7	8	9	10

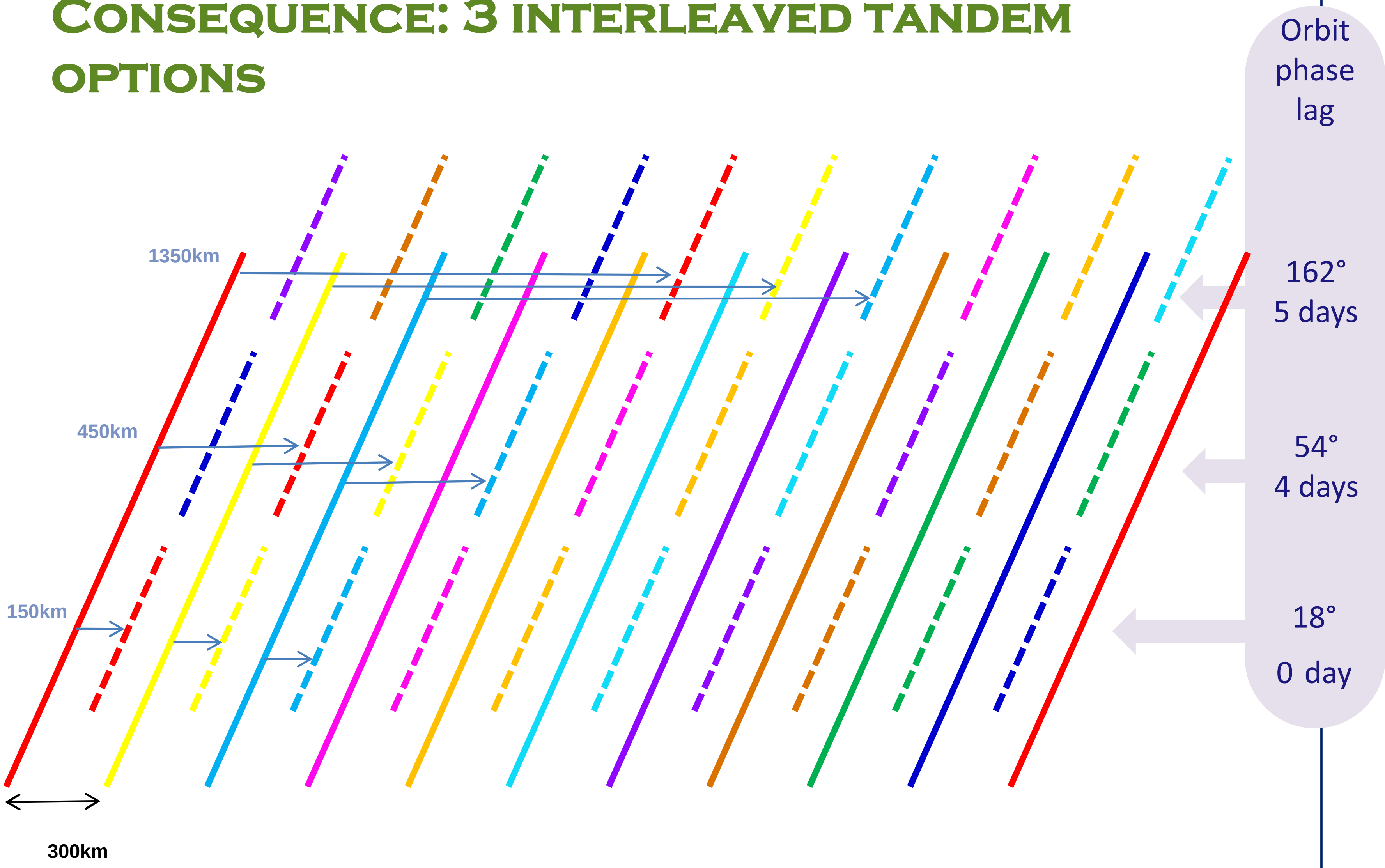


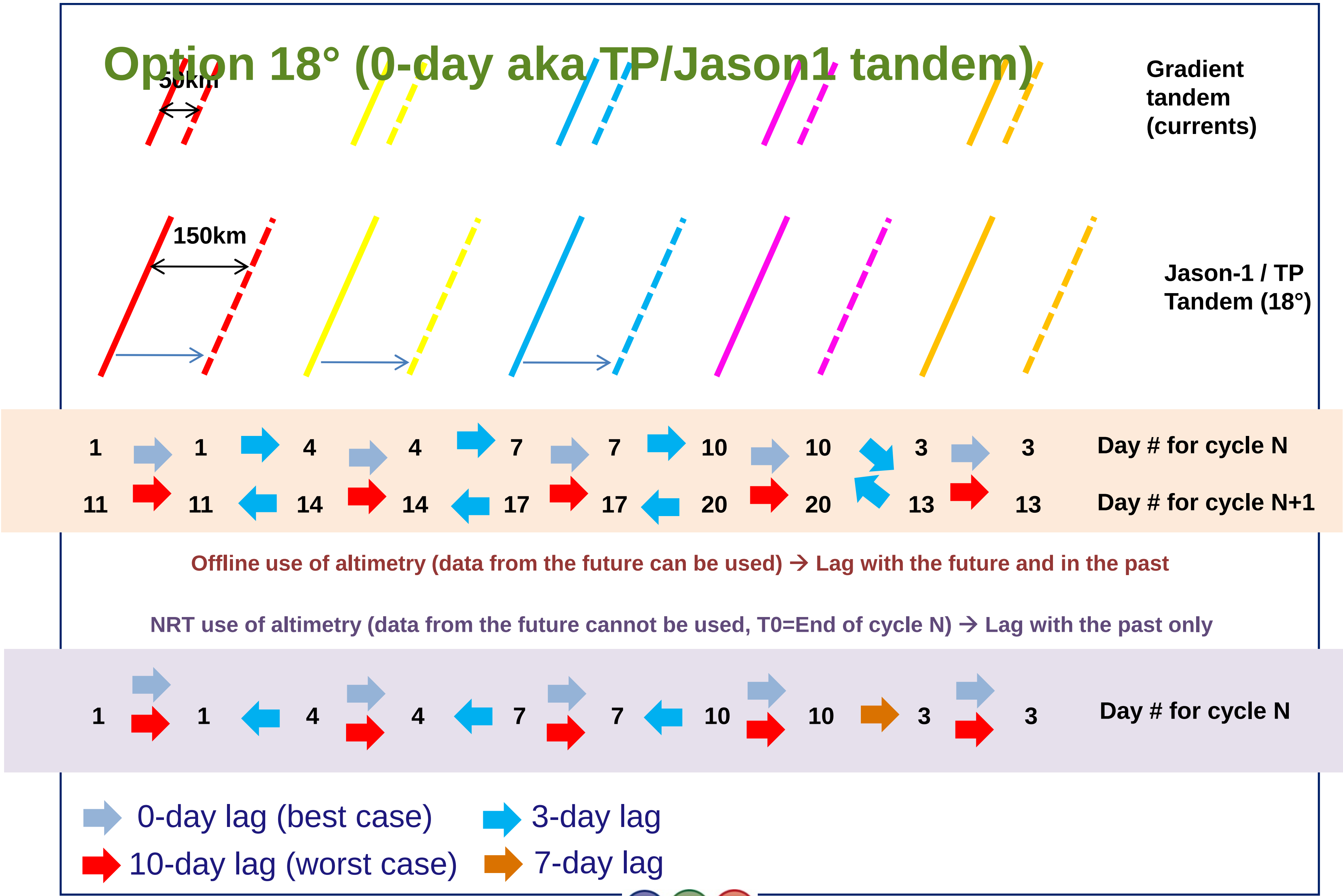
3-DAY SUBCYCLE: TIME LAGS BETWEEN DATASETS



CLS

Consequence: 3 interleaved tandem options





Option 18° (0-day aka TP/Jason1 tandem)
50km
Gradient tandem (currents)
150km
Jason-1 / TP Tandem (18°)
1 1 4 4 7 7 10 10 3 3
Day # for cycle N
11 11 14 14 17 17 20 20 13 13
Day # for cycle N+1
Offline use of altimetry (data from the future can be used) → Lag with the future and in the past
NRT use of altimetry (data from the future cannot be used, T0=End of cycle N) → Lag with the past only
1 1 4 4 7 7 10 10 3 3
Day # for cycle N
0-day lag (best case)
3-day lag
10-day lag (worst case)
7-day lag

CLS

Option 18° (0-day aka TP/Jason1 tandem)

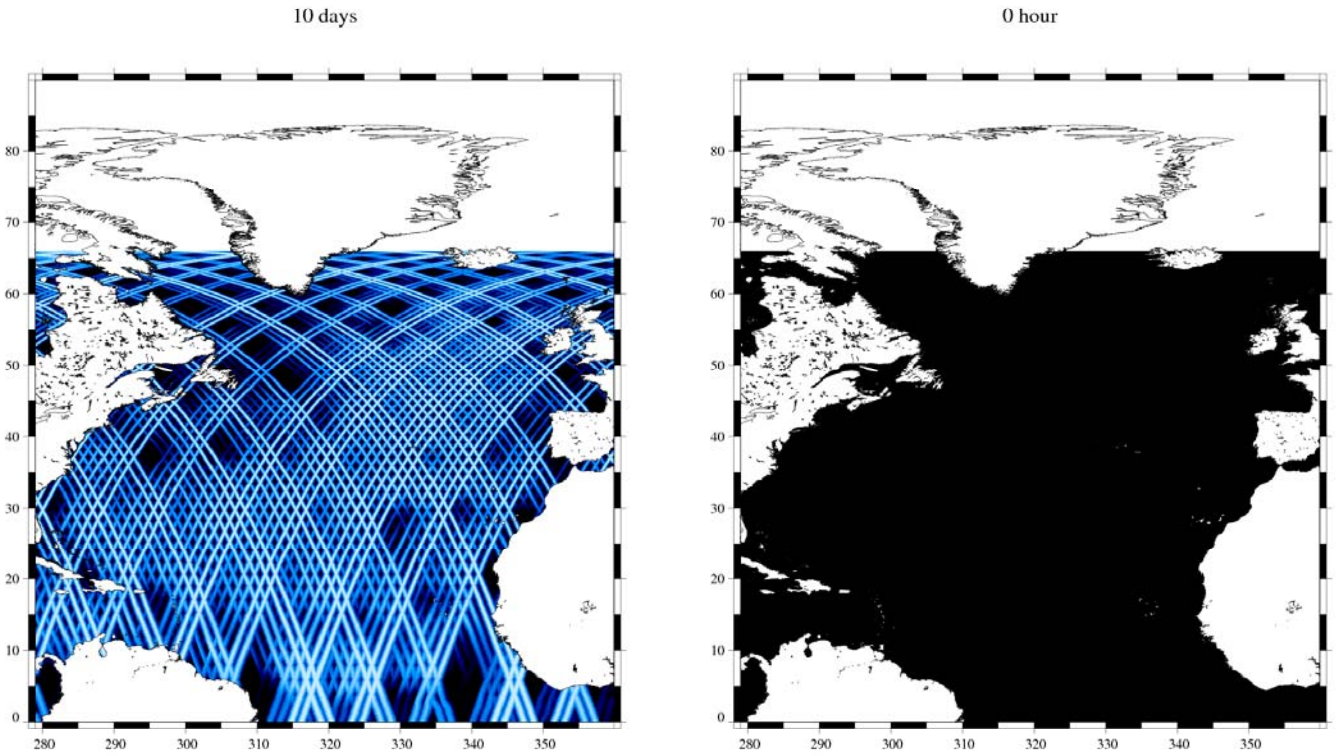
2 ground tracks scanning in parallel

3 day subcycle is the same for both tracks ➔block visual

Dark areas are coherent and moving slowly in phase

Artefacts more visible wherever the (observed) spatial decor-relation scale is shorter

Mesoscale | 1000km / 1day



Sampling of both satellites is redundant (difficult to see 2 data sets)

Impossible to resolve 1500km in 1day

Instantaneous observing capability

(best correlation between snapshots grid points and along-track data from the past)

CLS

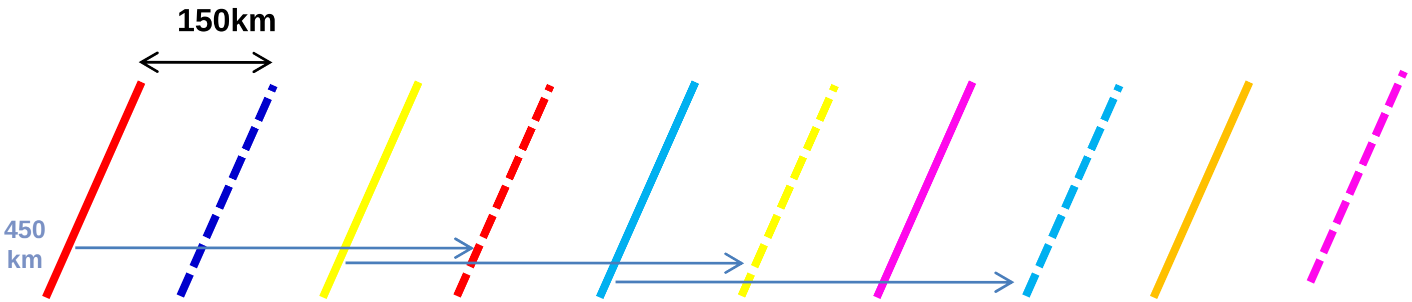
Summary: option 18° (0 day, TP/Jason1 tandem)

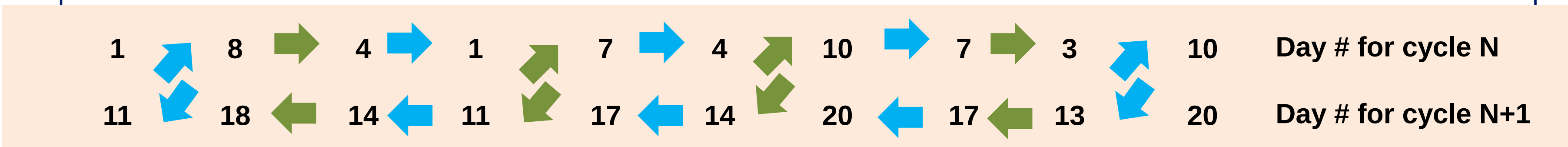
- The historical tandem in a nutshell
  - Longitude drift limited to 150km (T/P age and thrust capability)
  - Neighbour ground tracks are located on the same day in cycle (no time lag)
  - Standard Jason sampling time lag between the other ground track couples

- Pros
  - Already used and familiar (benefit published both theoretically and with actual data)
  - Excellent sampling when located wherever the tandem is (locally optimal)
  - Potentially better for some hydrology applications (not critical considering Jason-1 coverage)
  - Can be used to compute the SSH gradient (currents) directly
    - Variations on the ground track distance (e.g.: 50km) can improve this application…
    - …but the global space/time sampling must be sacrificed on SSH & SWH

- Cons
  - Spatially optimised but temporally weak
  - No new data for 10 days (next cycle) over 300km after each measurement
  - Sampling prone to aliasing of high-frequency signals

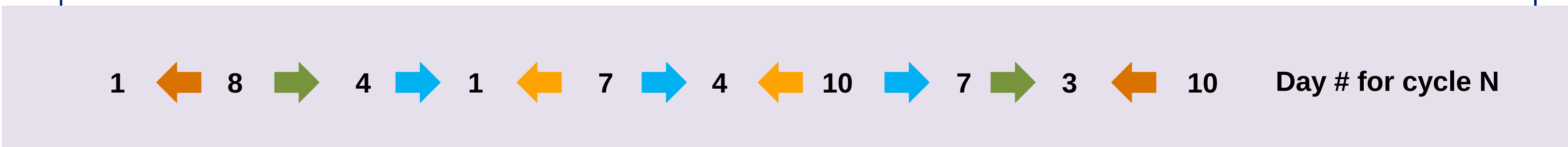
Option 54° (a.k.a 4-day option)





Offline use of altimetry (data from the future can be used) → Lag with the future and in the past

NRT use of altimetry (data from the future cannot be used, T0=End of cycle N) → Lag with the past only

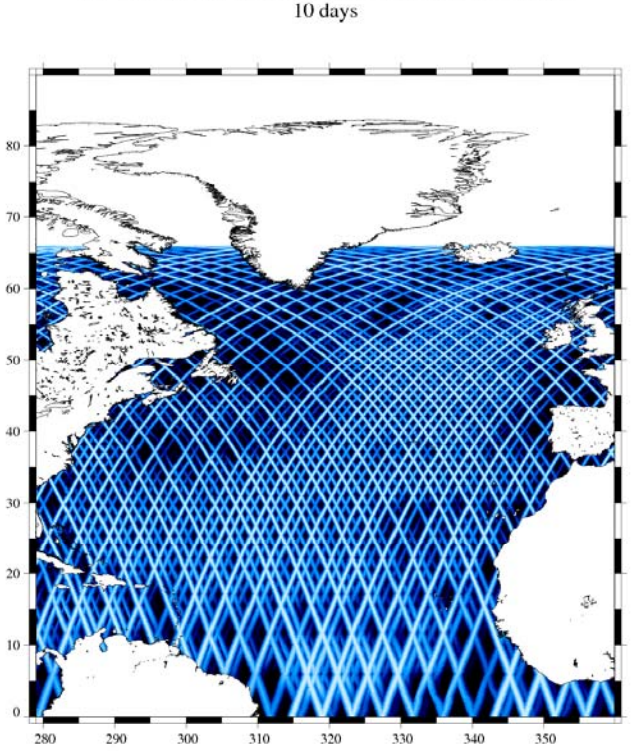


Option 54° (a.k.a 4-day option)

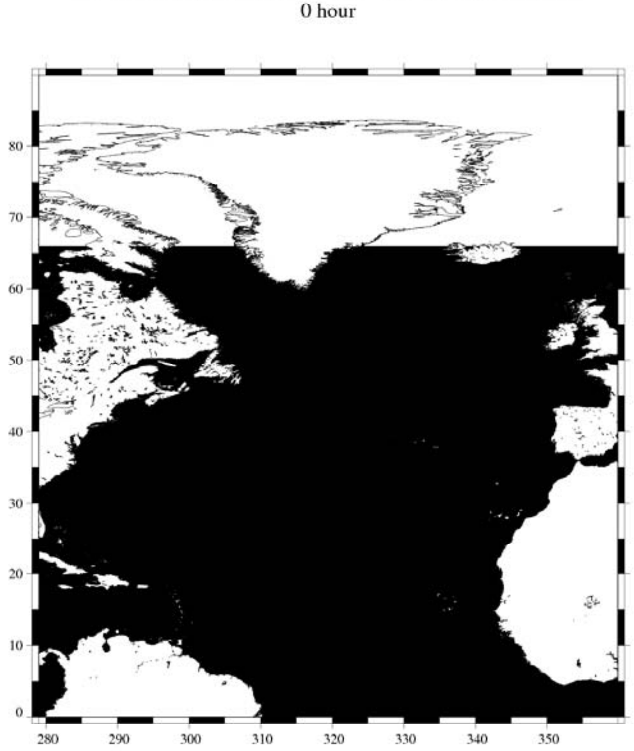
Homogeneous sampling for time scales of 10 days or more

Optimal interactions of the sub-cycle sampling pattern and phasing

Mesoscale



1000km / 1day



Sampling of both satellites is partly redundant

Some areas remain dark (unobserved) until a full sub-cycle is complete

Instantaneous observing capability

(best correlation between snapshots grid points and along-track data from the past)

Summary: Option 54° (aka 4-day option)

The option in a nutshell

- Longitude drift of ~450km (on the historical T/P tandem track with a time shift)
- Jason-1 ground tracks of day N are located nearby Jason-2 tracks of day N+3 or N+4
- The 3-day subcycle sampling pattern interacts with this interleaving

Pros

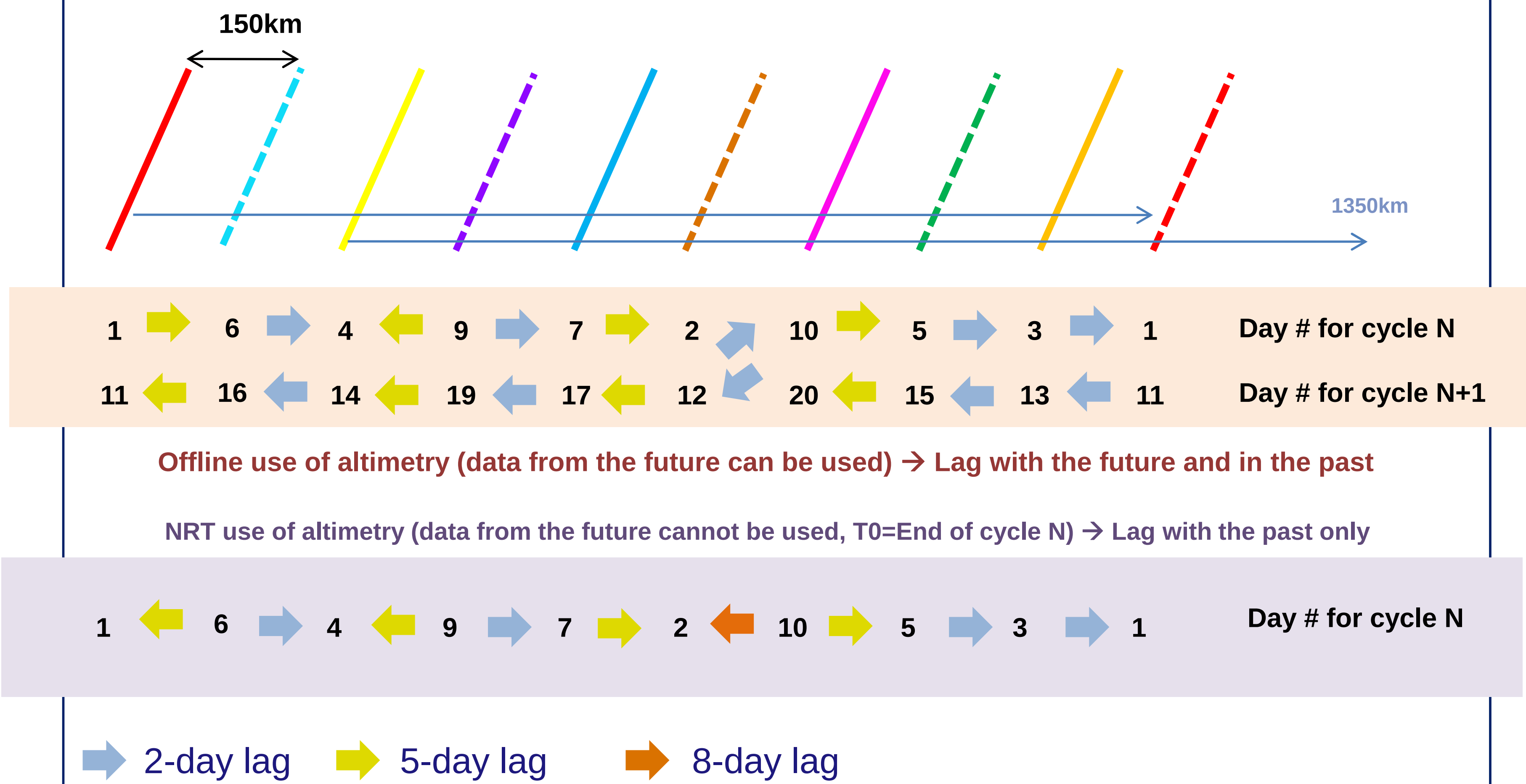
- As close as possible to the space / time optimal sampling of 150km / 3.5 days (aliasing minimised)
- Excellent for offline analyses/studies
- Nearby data set guaranted within 150km and 4 days
- Very homogeneous time lags (no 0-day vs 10-day problem)

Cons

- Not very good for near real time applications
- The optimal sampling requires datasets from the future to be achieved
- In NRT time lags are not homogeneous (50% in 3 or 4 days, and 50% in 6 or 7 days)
- Three full days are necessary to resolve 1000km signals, or to provide the next sample in a 10°-wide regional window (blind spots associated to the sub-cycle scanning pattern and longitude phasing)

CLS

Option 162° (aka 5-day option)



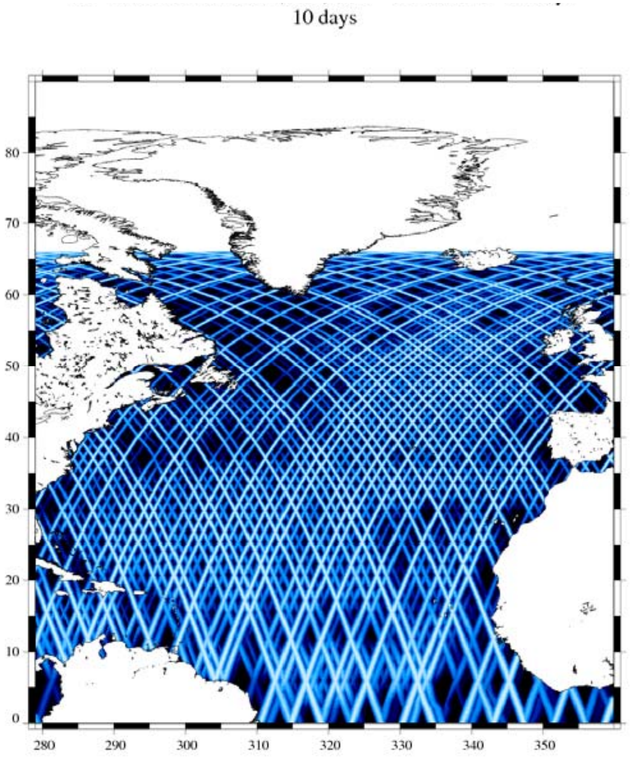
Option 162° (a.k.a 5-day option)

« Push-away » scanning pattern associated to the 5-day lag (each new track seems to push the neighbour away)

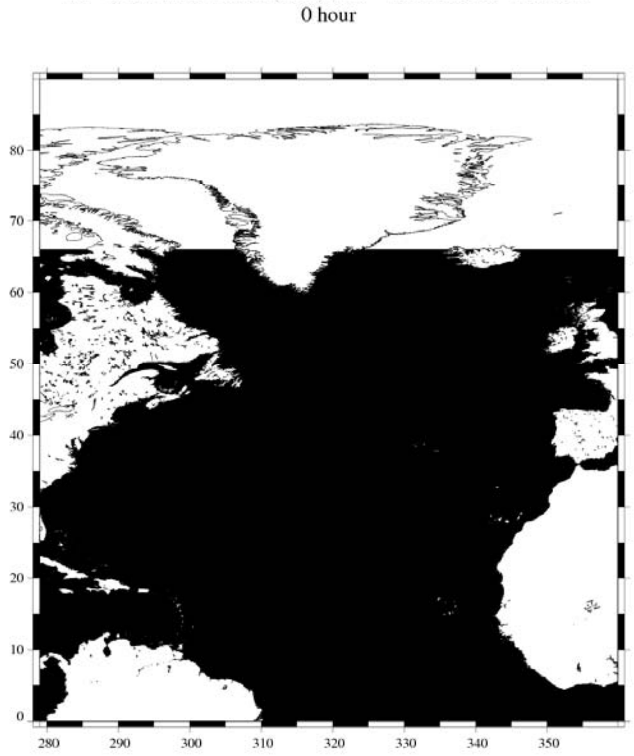
Sampling is visually not as regular as the 4-day option for signals with dt>10days

Dark areas are not coherent: split evenly in 2 days (tandem better than TP/JA1)

Mesoscale



1000km / 1day



Sampling of both satellites is evenly distributed (1500km in 1 day, 750 in 2 days, 500km in 3 days)

Minimal blind spots until a full sub-cycle is complete

Instantaneous observing capability

(best correlation between snapshots grid points and along-track data from the past)

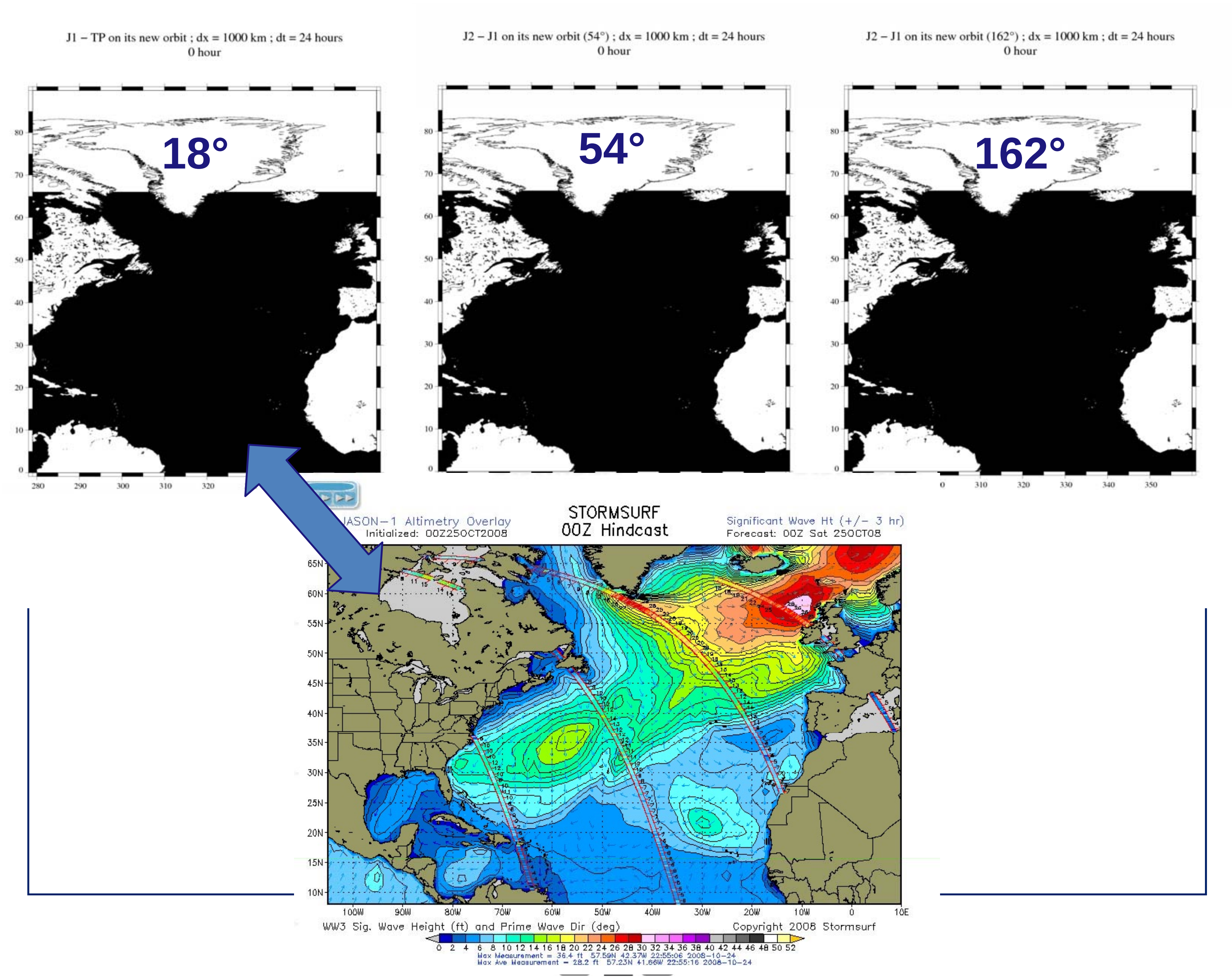

J1 – TP on its new orbit ; dx = 1000 km ; dt = 24 hours
0 hour
18°
J2 – J1 on its new orbit (54°) ; dx = 1000 km ; dt = 24 hours
0 hour
54°
J2 – J1 on its new orbit (162°) ; dx = 1000 km ; dt = 24 hours
0 hour
162°
JASON-1 Altimetry Overlay
Initialized: 00Z25OCT2008
STORMSURF
00Z Hindcast
Significant Wave Ht (+/- 3 hr)
Forecast: 00Z Sat 25OCT08
WW3 Sig. Wave Height (ft) and Prime Wave Dir (deg)
Copyright 2008 Stormsurf

Illustration: 48h sampling on the Gulf of Mexico

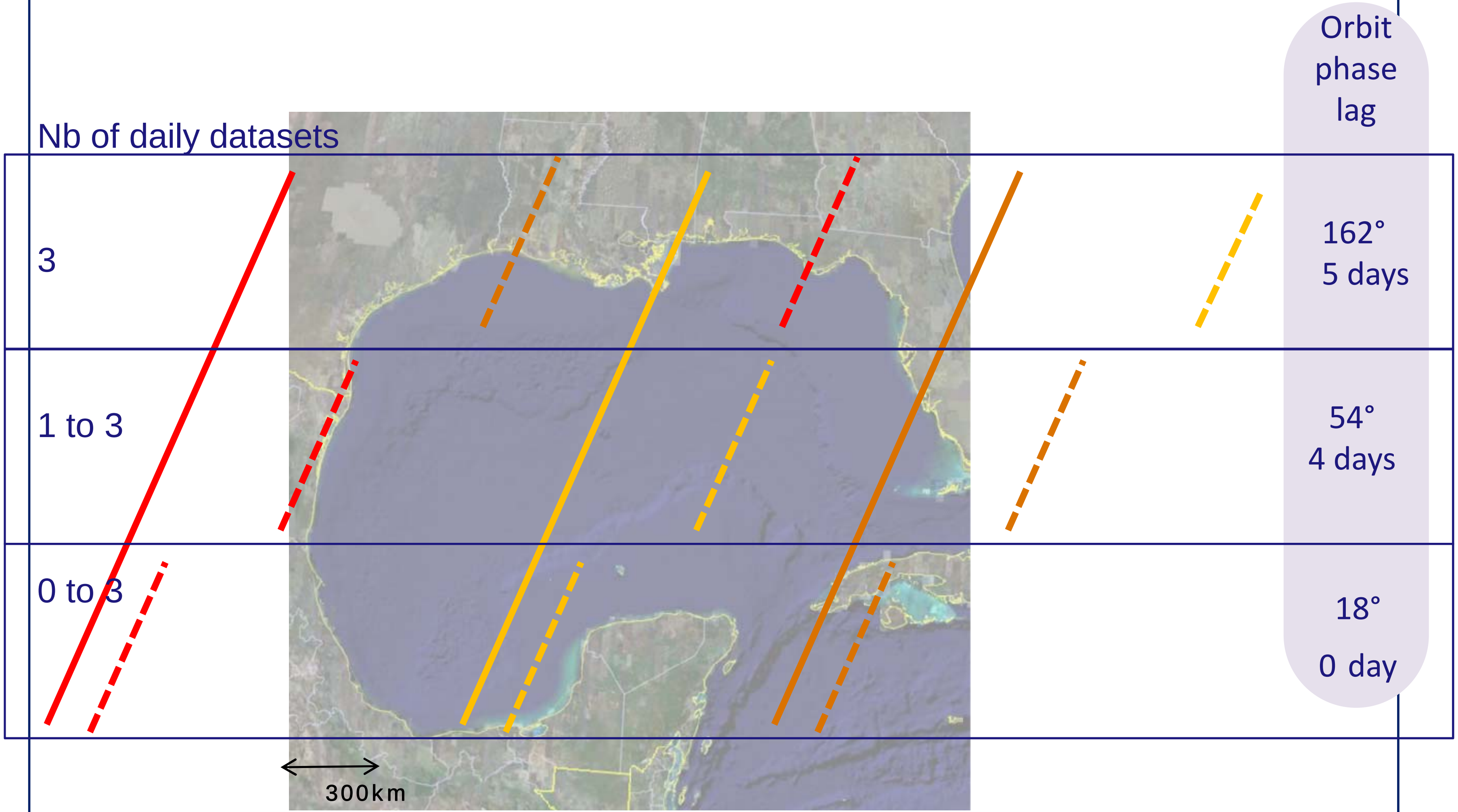
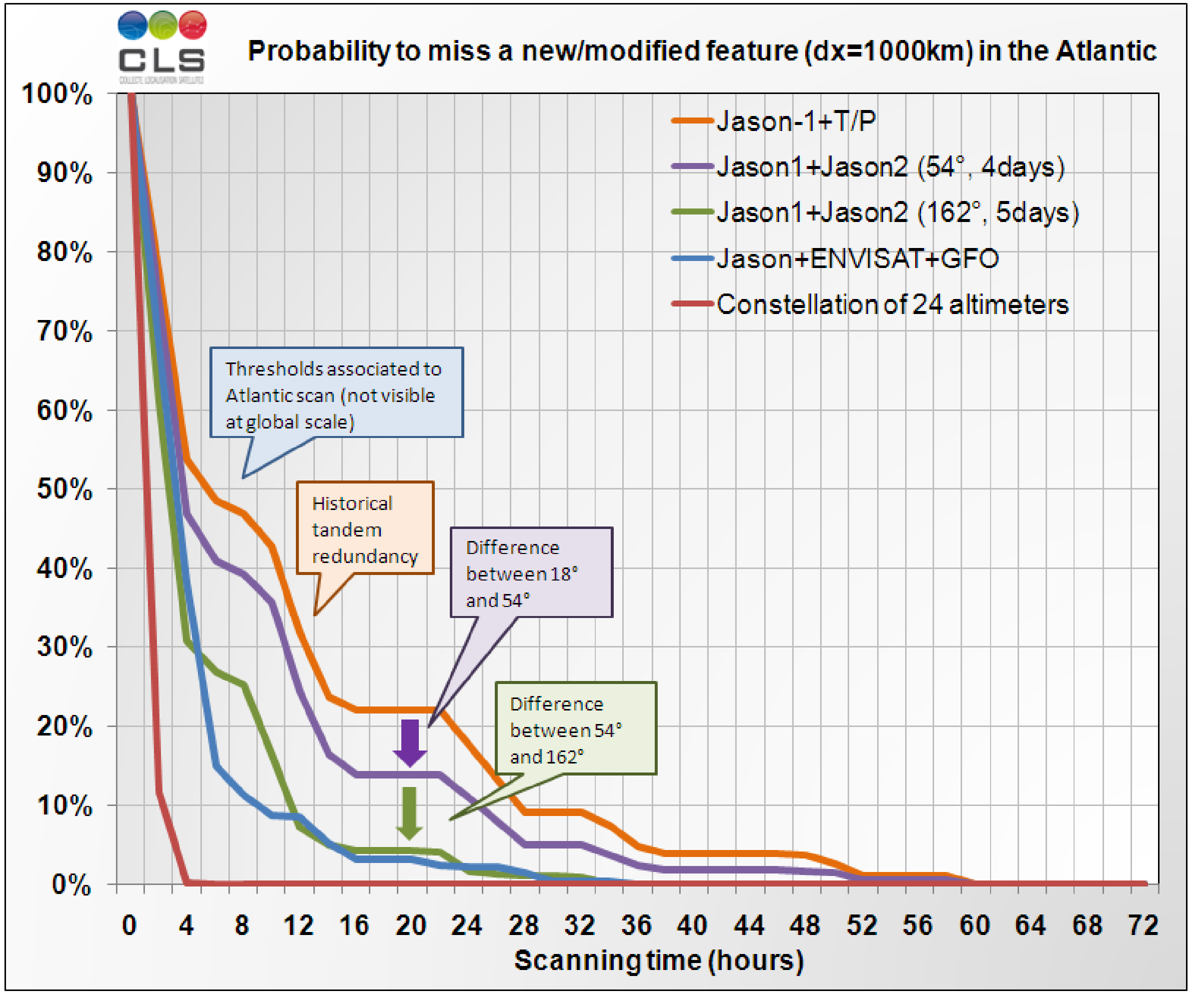


ILLUSTRATION: DETECTING EVENTS IN NRT



What is the probability to detect (or to miss) a structure/event ?

Simple geometrical simulation

Considered observed if one data within 2/3 of decorrelation scale dx

CLS

Summary: option 162° (aka 5-day option)

- The option in a nutshell
  - Longitude drift of 1350km (on the historical T/P tandem track with a time shift)
  - Jason-1 ground tracks of day N are located nearby tracks of day N+2 or N+5
  - The 3-day subcycle sampling pattern interacts with this interleaving
  - Jason-1 can reach this position in ~13 days (20km altitude change, 5 impulses, fuel ok)
- Pros
  - Better suited for near real time applications
  - NRT time lags are equivalent to the offline lags (5 / 2 day lags are achieved in NRT)
  - Only option able to resolve large scale / high frequency signals
    - 1500km resolved in 1 day,
    - 750km in 2 days,
    - after the full 3-day cycle is complete, equivalent to most options with 500km resolved
  - Good for regional applications (homogeneous and constant amount data available each day)
- Cons
  - Sampling not improved offline (using future data doesn't improve the local resolution)
  - Not optimal for offline analyses/studies (farther to the 3.5 days optimal scenario)
  - Neighbour pass guaranted within 5 days (vs 4 days for the best offline option)
  - Time lags are not homogeneous (2 vs 5-day lag, still vastly superior to the 0 / 10 day option)

CLS

Sumary: comparison table

	Drift		Time lags between 150km neighbour passes (days)		Time needed to sample large scales globally & Time needed to get 1 sample in a small area			
Scenario	Distance	New position reached in	Offline	Near-real time	1500km	1000km	750km	HF Aliasing
18° (TP/JA1)	150 km	8 days	0 or 10 (50%) 3 (50%)	0 or 10 (50%) 3 (35%)	4 days	4 days	10 days	Bad
54° (4 days)	450 km	~10 days	3 (50%) 4 (50%)	3 or 4 (50%) 6 or 7 (50%)	2 days	3 days	3 days	Good
162° (5 days)	1350 km	13 days	2 (50%) 5 (50%)	2 (43%) 5 (43%)	1 day	2 days	3 days	Average

	Time lags between 300km neighbour passes (days)		Time needed to sample large scales globally & Time needed to get 1 sample in a small area		
Reference: One Jason alone	Offline	Near-real time	1500km	1000km	750km
	3 (100%)	3 (70%) 7 (30%)	4 days	4 days	10 days

CLS

Conclusions

- ❖ All tandem options are using the interleaved ground track of T/P

  (unless we want to favour local gradient observation and to ignore global SSH & SWH sampling)
- ❖ Performances are limited by the number of satellites anyhow (second order tuning for most scales): only large scale and high frequency signals can be resolved globally by one option
- ❖ Option 1: Phase lag of 18° (0 day, aka TP/Jason-1 tandem)
  - Conservative approach (familiar and benefits known from 2002-2005)
  - Usable for gradient observation (albeit not optimal)
- ❖ Option 2: Phase lag of 54° (4 days)
  - As close as possible to optimal tandem (aliasing)
  - Benefits mostly offline analyses (cycle N+1 is necessary to be « optimal »)
  - Sampling degraded in NRT (notably regional applications & signals with time scales shorter than 7 days)
- ❖ Option 3: Phase lag of 162° (5 days)
  - Benefits NRT applications (notably regional or large scale + high frequency)
  - Minimum time lags can be achieved in NRT
  - Somewhat suboptimal for offline studies (time sampling & aliasing): 5+2 vs 4+3 for an optimum of 3.5
- ❖ Options 2 & 3 are superior to option 1 for SSH and SWH sampling (both in NRT & offline)