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

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

- 66°
- R
- h
- Equator
- 1400km orbit
From phase lag to longitude drift
Warning: 3-day/300km signals cannot be resolved by 2 satellites

3-day subcycle: Time lags between datasets

Day # for cycle N
1 4 7 10 3 6 9 2 5 8 1
11 14 17 20 13 16 19 12 15 18 11

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

3-day lag 7-day lag
Consequence: 3 interleaved tandem options

- Orbit phase lag
  - 162°
  - 5 days
  - 54°
  - 4 days
  - 18°
  - 0 day

- Orbit heights
  - 1350km
  - 450km
  - 150km
  - 300km
Option 18° (0-day aka TP/Jason1 tandem)

Gradient tandem (currents)

Jason-1 / TP Tandem (18°)

150km

30km

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

0-day lag (best case) → 3-day lag

10-day lag (worst case) → 7-day lag

Day # for cycle N

Day # for cycle N+1
Option 18° (0-day aka TP/Jason1 tandem)

Mesoscale

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 decorrelation scale is shorter

1000km / 1day

10 days
0 hour

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

Sampling of both satellites is redundant (difficult to see 2 data sets)
Impossible to resolve 1500km in 1day
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

3-day lag  4-day lag  6-day lag  7-day lag
Option 54° (a.k.a 4-day option)

Mesoscale

1000km / 1day

Homogeneous sampling for time scales of 10 days or more

Optimal interactions of the sub-cycle sampling pattern and phasing

10 days

0 hour

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 guaranteed 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)
Option 162° (aka 5-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

2-day lag  5-day lag  8-day lag
Option 162° (a.k.a 5-day option)

Mesoscale

1000km / 1day

« 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>10 days

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

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)
**Illustration: 48h sampling on the Gulf of Mexico**

<table>
<thead>
<tr>
<th>Nb of daily datasets</th>
<th>Orbit phase lag</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>162° 5 days</td>
</tr>
<tr>
<td>1 to 3</td>
<td>54° 4 days</td>
</tr>
<tr>
<td>0 to 3</td>
<td>18° 0 day</td>
</tr>
</tbody>
</table>

- **3 datasets**
  - **Orbit phase lag:** 162° 5 days
- **1 to 3 datasets**
  - **Orbit phase lag:** 54° 4 days
- **0 to 3 datasets**
  - **Orbit phase lag:** 18° 0 day

300km
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
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 guaranteed 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)
## Summary: comparison table

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Distance</th>
<th>New position reached in</th>
<th>Drift</th>
<th>Time lags between 150km neighbour passes (days)</th>
<th>Time needed to sample large scales globally &amp; Time needed to get 1 sample in a small area</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>18° (TP/JA1)</td>
<td>150 km</td>
<td>8 days</td>
<td>Offline</td>
<td>0 or 10 (50%) 3 (50%)</td>
<td>4 days</td>
<td>100%</td>
</tr>
<tr>
<td>54° (4 days)</td>
<td>450 km</td>
<td>~10 days</td>
<td>Offline</td>
<td>3 (50%) 4 (50%)</td>
<td>2 days</td>
<td>50%</td>
</tr>
<tr>
<td>162° (5 days)</td>
<td>1350 km</td>
<td>13 days</td>
<td>Offline</td>
<td>2 (50%) 5 (50%)</td>
<td>1 day</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Table 2: Time lags between 300km neighbour passes (days) & Time needed to sample large scales globally & Time needed to get 1 sample in a small area

<table>
<thead>
<tr>
<th>Reference: One Jason alone</th>
<th>Time lags between 300km neighbour passes (days)</th>
<th>Time needed to sample large scales globally &amp; Time needed to get 1 sample in a small area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offline</td>
<td>Near-real time</td>
<td>1500km</td>
</tr>
<tr>
<td>3 (100%)</td>
<td>3 (70%) 7 (30%)</td>
<td>4 days</td>
</tr>
</tbody>
</table>
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)