The Influence of Orbit Precision in the Quality of ERS SAR Interferometric Data

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The knowledge of the position of the ERS satellites plays a major role when removing the component due to flat Earth in an interferogram. An almost linear range component has to be substracted from the interferogram so that the remaining phase according to null relief will be a constant and topography variation will be proportional to the phase variation. Relative drifts between the real satellites positions of the two passes and the coordinates used to specify these positions (given by the state vectors) may cause fringes patterns which are not related with the terrain relief, as a result of a change in the estimated signal travel path.
Only after this flattening stage some effects can be perceived. In interferograms corresponding to flat areas, where the phase should be constant, a certain number of fringes might appear. These can be caused by atmospheric artifacts, oscillations in the signal carrier frequency or differences between the actual ERS orbits and the ones used to perform the flattening. The number of fringes varies mainly as a function of the baseline and the wavelength and increases as the deviation from the actual orbit is higher.
This deviation is more evident during the processing of long acquisitions, as each orbit position is obtained propagating an initial point using the position and velocity information contained in an initial state vector. The propagation introduces an error which increases the difference along track between the real position and the calculated one. Distance between estimations and real orbit depends so, on the quality of the propagator itself and on the quality of the first state vector, its approximation to the satellite position and velocity. To avoid to create artificial fringes, caused by an error in the positioning of the satellite, a very accurate representation of the orbit is needed. The difference introduced by the interpolation should be minimized with the use of multiple state vectors equally spaced in time, which will ensure that every certain period the orbit data used is close to the satellite orbit, and that the errors due to propagation are cancelled.

Within ESA four types of orbit state vectors are usually used:

- **Predicted orbits**: These state vectors are calculated at ESOC using S-band tracking and fast delivery altimeter data acquired at the Kiruna station. They are daily updated with the disposal of new orbital information which improves their accuracy. Data from the last three days is processed to perform a prediction for the next nine days. Files contain the position and the velocity vectors only at the ascending node position with an error of prediction (in along-track) of about 400 m for a 6 days prediction, around 125 m for a 3 day s prediction and 25 m for 1 day prediction.
- **Restituted orbits**: Restituted (or operational) orbits are also produced at ESOC using the same information and processing as with the Predicted Orbits. In this case, instead, no prediction is performed and the central day of the three days moving window provides the final orbit. As a

result, the operational orbit is available with a delay of one day after the pass of the satellite. ItÕs information is specified every 60 seconds with a precision (comparing to precise orbits) currently estimated at 2-4 m along-track, 1-2 m cross track and about 50 cm radially.

- **Preliminary orbits**: Preliminary orbits are based on the fast delivery tracking data. They provide an improvement of the initial knowledge of the orbit but not the optimal fit. Values are written in continuous 7 days data files every 120 seconds with an spatial resolution of about 900 km and a radial accuracy of 8-10 cm. Produced by the D-PAF once per week they are available in CD-ROM and in the FTP server. Data disposal goes from 30-May-1993 to 21-July-1996 for ERS-1 and from 28-April-1995 to 20-May-1998 for ERS-2 (at the date of issue of this technical note).
- **Precise orbits**: The precise orbit products result from a computation using all available satellite tracking data and its correction with dynamical models. They achieve the most accurate model of representing the real orbit motion. The actual radial accuracy is in order of 8-10 cm and its values are ordered sequentially every 30 seconds in overlapping 5-7 days files. This product files are available at the D-PAF in CD-ROM and FTP server for users 2.5 months after the acquisition of the data with a spatial resolution of approximately 225 km. Data disposal goes from 27-July-1991 to 26-July-1996 for ERS-1 and from 28-April-1995 to 30-April-1998 for ERS-2 (at the date of issue of this technical note).

Delft Orbits: On the other hand the ERS orbits are also provided by DEOS. Delft Orbits are computed using SLR and altimeter tracking data and a new field gravity model (DGM-E04) which gives a radial precision of 5-6 cm. In this case output is given in a binary format and only contains the position of the satelliteÕs nominal centre-of-mass in intervals of 60 seconds. Data is available from 11 April 1992 to May 1996 for ERS-1 and from May 1995 to 13 November 1997 for ERS-2 in a NOAA FTP server (at the date of issue of this technical note).

To analyze the influence of the precision of these orbit state vectors, Tandem data over flat areas was processed with the Interferometric Quick Look (IQL). One of its outputs, the Interferometric Browse Product (IBP) is an image that shows the interferometric phase projected on a color wheel (in those regions where the coherence is higher than 0.2) and the average intensity image on a grey-scale elsewhere. IBP images are useful to quickly asses the quality of the interferometric fringes.
The IQL is able to handle not only different types of orbits, with different time resolution and propagate them with the ESA ERSORB propagator, but also to use multiple state vectors. In this case it performs a forward-backward propagation of vectors separated at one minute intervals from 30 seconds before the beginning of the image to 30 seconds after, and uses a linearly weighted average of the two results. The chosen test site correspond to a large flat area of about 200 km near Shanghai. As this zone is flat (USGS Global DEM, depicted in Fig. 1, showed that the height profile maintains under 20 m around the Yangtze delta) ideally there should not be any remaining fringe in the image. Only fringes due to atmospheric artifacts or orbit misalignment should appear. Images were processed using restituted and precise state vectors in the two modes of operation: propagating from one single state vector and propagating and interpolating multiple state vectors. Also combinations of Delft orbits positions and velocity components taken from the restituted and precise state vectors were used to test the performance at these new orbits positions.

Fig. 1 USGS Global DEM of Shangai.

It is to note that bad quality image of the DEM is due to graphical constraints, not to a bad quality of the data itself.

RESULTS

1.- Restituted state vectors.
2.- Precise state vectors.
3.- Delft orbits position.
4.- Precise state vectors with only laser traking

Restituted state vectors: A first IBP image processed using one single state vector is shown in Fig.2. Approximately 1.5 remaining fringes, which would correspond to a height variation of 135 m, (the altitude of ambiguity is around 90 m) can be seen along range. Those should not appear because the Yangtze delta is flat. Its shape cannot be attributed to atmospheric artifacts as it follows a regular pattern and can only be caused by an error in the orbit estimation. The same effect can be observed in Fig. 3, where multiple restituted state vectors have been used. In this case, however, the number of fringes has increased to 2 and they have also a certain component in azimuth, which indicates that the deviation between the nominal orbit and the one calculated by the IQL varies along the track direction. This variation was not initially expected (results should be better than using one single propagation) and indicates that either the interpolation performed by the IQL using multiple state vectors may introduce an error or that the single state vector used in Fig. 2 was, by chance, more accurate than those used in Fig. 3.

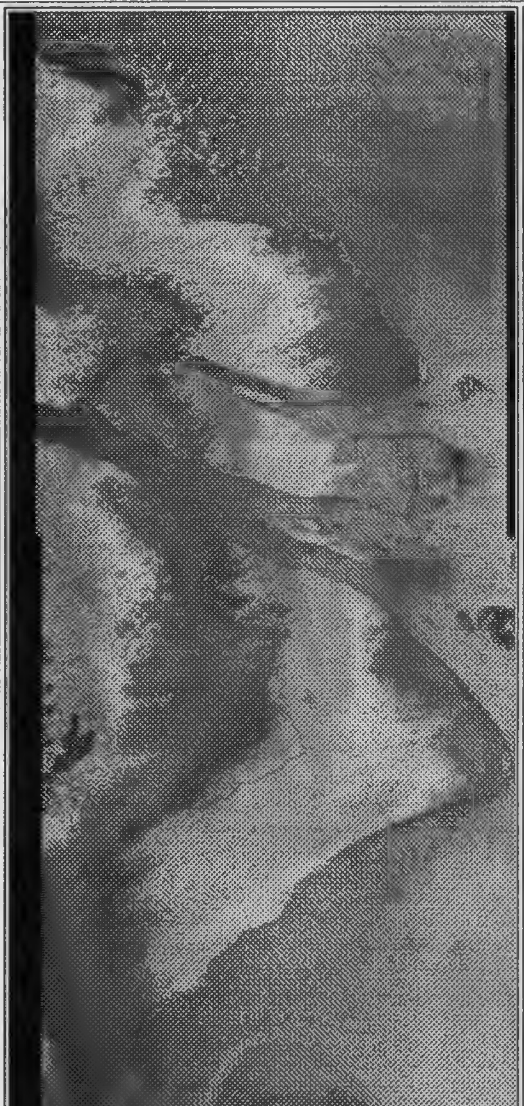

Fig. 2 IBP of Shangai area using one restituted state vector.

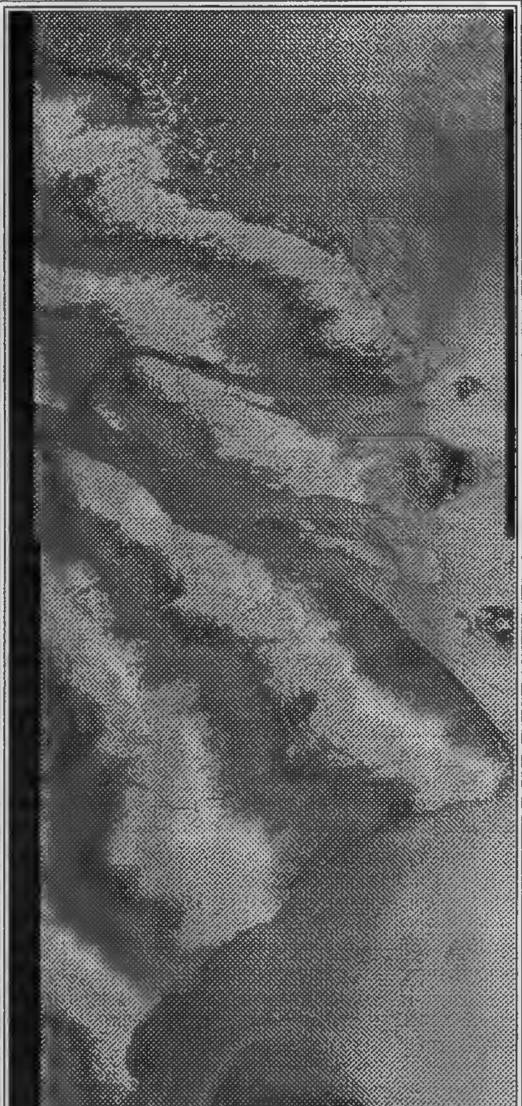

Fig. 3 IBP of Shangai area using multiple state vectors.

Precise state vectors: The scene was processed a third time using precise state vectors. Results can be

seen in Fig. 4. There has been a clear improvement comparing it with the previous images processed with restituted state vectors. Now the remaining fringes could be attributed either to a change in the terrain elevation, to a slight error in the orbit estimation or most probably to atmospheric artifacts, as channel 4 AVHRR images dated on the two acquisitions confirm that the area was covered by clouds. The same raw data was processed using multiple precise state vectors, results are shown in Fig. 5. The interferometric pattern is comparable to the one in Fig. 4 (except for an offset in the phase values). The number of fringes in the image is almost equal to the previous one and differences can hardly be appreciated. It seems that the image on the right (multiple state vectors) has less fringes, result that confirm what was initially expected, so that no obvious error was introduced by interpolation of multiple state vectors.

Fig. 4 IBP of Shangai area using one precise state vector.

Fig. 5 IBP of Shangai area using multiple state vectors.

Delft orbits: When analysing the performance of the Delft orbits a major problem occurs, only the

position coordinate is supplied and the orbit propagator cannot be properly initialized. To solve this inconvenient the interferometric processing has been done using the velocity information provided by the restituted and the precise state vectors. Images have also been obtained using single and multiple state vectors.

Combination of Delft position and restituted velocity: In Fig. 6 a combination of Delft orbits position and restituted velocity has been utilized, the remaining fringes are less than fully using the restituted state vectors and its quality is comparable to the images processed with the precise state vectors. Even in the northern part of the image it looks like there are less fringes than in Fig. 5. For the propagation using multiple of these "mixed" state vectors the quality of the image is the same than in Fig.6. Again the results are difficult to compare.

Fig. 6 IBP of the Shangai area using Delft position and restituted velocity.

Fig. 7 IBP of the Shangai area using multiple state vectors made of Delft postion and restituted velocity.

Combination of Delft position and precise velocity: Once again the Shanghai area was processed, this time creating new state vectors using the position information from the Delft orbits and the velocity from the precise ones. The quality of the images is also difficult to analyse, it is comparable to the ones generated using precise state vectors but not a considerable improvement can be appreciated. Propagating again using more than one of these state vectors no major changes occurred and the image remains the same as before.