Ocean and Sea Ice SAF

ASCAT tandem coverage

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1 Introduction

In order to examine the coverage of a system of two identical satellite scatterometers, a study is made using ASCAT data from two different periods in time, corresponding to a certain time shift in orbit phase between the two satellites. This is relevant for tandem MetOp operation (A and B, B and C) and for Post-EPS tandem scatterometer coverage considerations. The latter may be useful in designing the scatterometer life time, which appears rather easily extended (ERS-1: 6 years; ERS-2: 14 years; QuikScat: 10 years).

Since a polar satellite covers the earth in 12 hours by its ascending and descending passes, we take the coverage specification over 7 tandem orbits, i.e., equivalent to 12 hours, as a benchmark for nowcasting and regional NWP applications.

2 MetOp-A orbit phase shift

This section contains the calculation of the orbit phase time shift for two orbits a certain time in days apart.

The MetOp-A orbit phase has a periodicity of 29 days or 412 orbits, e.g., the following orbits overlap almost exactly:

Orbit 11442 starting 20090102 01:33:11
Orbit 11854 starting 20090131 01:33:16

The time for one orbit is 29*24*60/412=41760/412= 101.359 minutes. For 7 orbits 709.5 minutes are needed, which is only 10.5 minutes short of 12 hours.

The orbit phase shift per day 21 minutes, i.e., 14 orbits take one day minus 21 minutes. This leads us to the fact that MetOp-A has a semi-repeat orbit cycle of 5 days, since the difference between 5 days and 71 full orbits is 3.5 minutes, such that in 5 days about exactly one additional orbit is cycled. The following table can be obtained (note the cyclic behaviour over 29 days).

Orbits	Days	Shift (minute)	Shift (minute)	Days	Orbits
170	12	-49	49	17	242
99	7	-45	45	22	313
28	2	-42	42	27	384
369	26	-38	38	3	43
298	21	-35	35	8	114
227	16	-31	31	13	185
156	11	-28	28	18	256
14	1	-21	21	28	398
213	15	-11	10	14	199
0	0	0	0	29	412

Table 1: Number of MetOp-A orbits (Orbits) over a number of days (Days) and the number of minutes (Shift) that the specified number of orbits take longer than the associated number of days.

By combining ASCAT swaths from two sets of 7 orbits, each on a different day, in one coverage plot, the coverage of a tandem ASCAT scatterometer system in the MetOp-A orbital plane with varying orbit phase shift is simulated below.

The following data with specified orbit start time are used from BUFR files:
11442: 20090102 01:33:11 & 11470: 20090104 00:51:17
11442: 20090102 01:33:11 & 11541: 20090109 00:47:49
11442: 20090102 01:33:11 & 11556: 20090110 02:08:10
11442: 20090102 01:33:11 & 11598: 20090113 01:05:17
11442: 20090102 01:33:11 & 11641: 20090116 01:43:45
11442: 20090102 01:33:11 & 11684: 20090119 02:22:12
11442: 20090102 01:33:11 & 11755: 20090124 02:18:43
11442: 20090102 01:33:11 & 11840: 20090130 01:54:15
11442: 20090102 01:33:11 & 11854: 20090131 01:33:16

3 ASCAT coverage

Figure 1 shows the ASCAT coverage for orbits 11442-11448 and 11598-11604. These are two periods of each 7 orbits, roughly 11 days apart. The bin size used for calculating this plot is 0.5^0 or approximately 55 km at the equator, about twice the ASCAT Wind Vector Cell WVC) dimension of 25 km. Any hit in a histogram bin will mark the bin as covered. At higher latitudes the longitudinal bin size in km is diminishing and will become smaller than the ASCAT WVC dimension at a certain latitude. Bins that are actually within the swath may be missed by the ASCAT WVC grid. To correct for this an algorithm is applied to fill most “holes”.

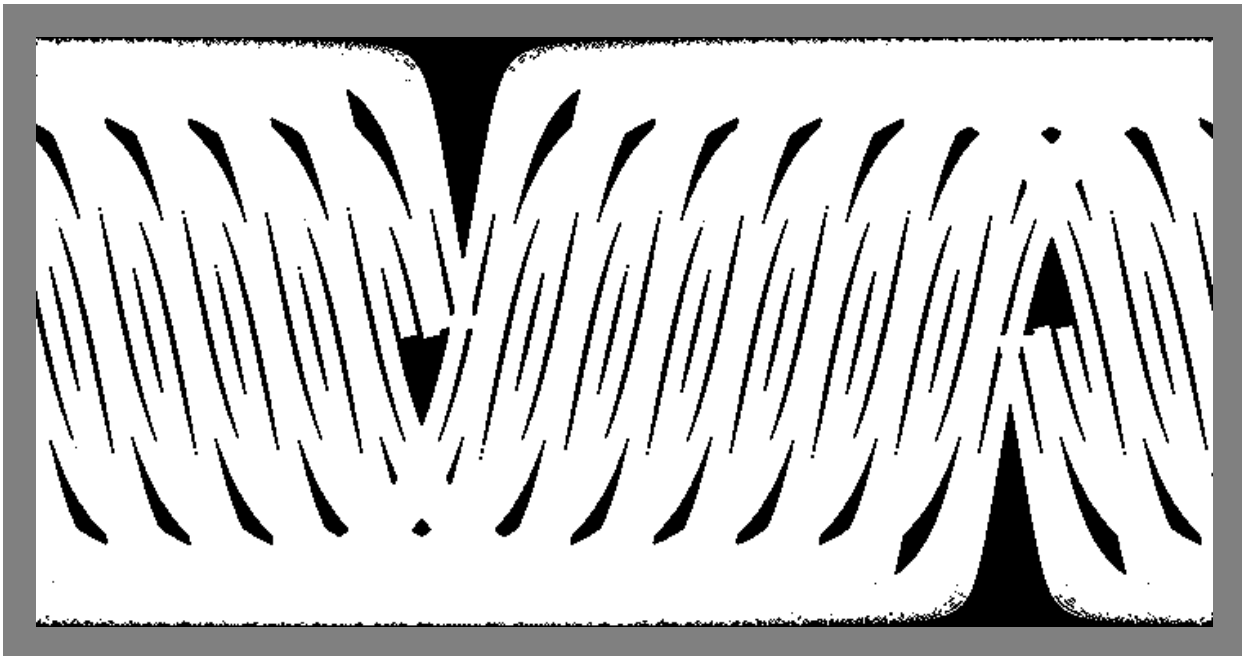


Figure 1 – ASCAT coverage for 2x 7 orbits, 11 days apart. Seven orbits starting 20090102 01:33 and starting 20090113 01:05 are used, orbit numbers 11442-11448 and 11598-11604; 11 days minus 28 minutes apart.

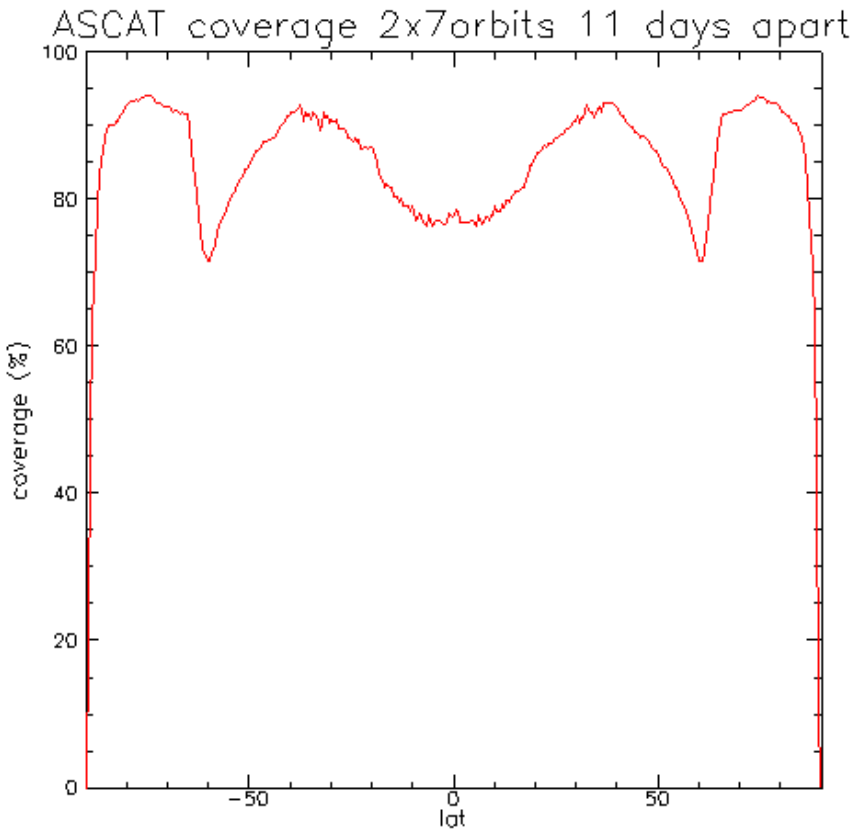


Figure 2 – Coverage percentage per latitude. Data from Figure 1 is used, 11 days minus 28 minutes apart.

In order to examine the coverage of ocean only, a land filter is introduced using the level 1b land flag. The ocean coverage percentage is calculated using one month of ASCAT data. The ocean coverage is slightly overestimated because any hit in a histogram bin over a period of 29 days will mark the bin as ocean. Because there are more orbits in one month of data then the 14 used in the tandem satellite simulation, there is a chance that a bin is marked as ocean in the histogram, covered by the 14 swaths, but in there indicated as land. This effect is expected to be smaller than 1%. Figure 3 shows the land mask over the 14 ASCAT swaths. In Figure 4a) the coverage percentage of the oceans is shown as well as the coverage percentage for ASCAT with land filter. Figure 4b) shows the coverage of ASCAT with respect to oceans only (quotient of both plots in Figure 4a)). Ocean coverage is around 80% and similar to figure 2.

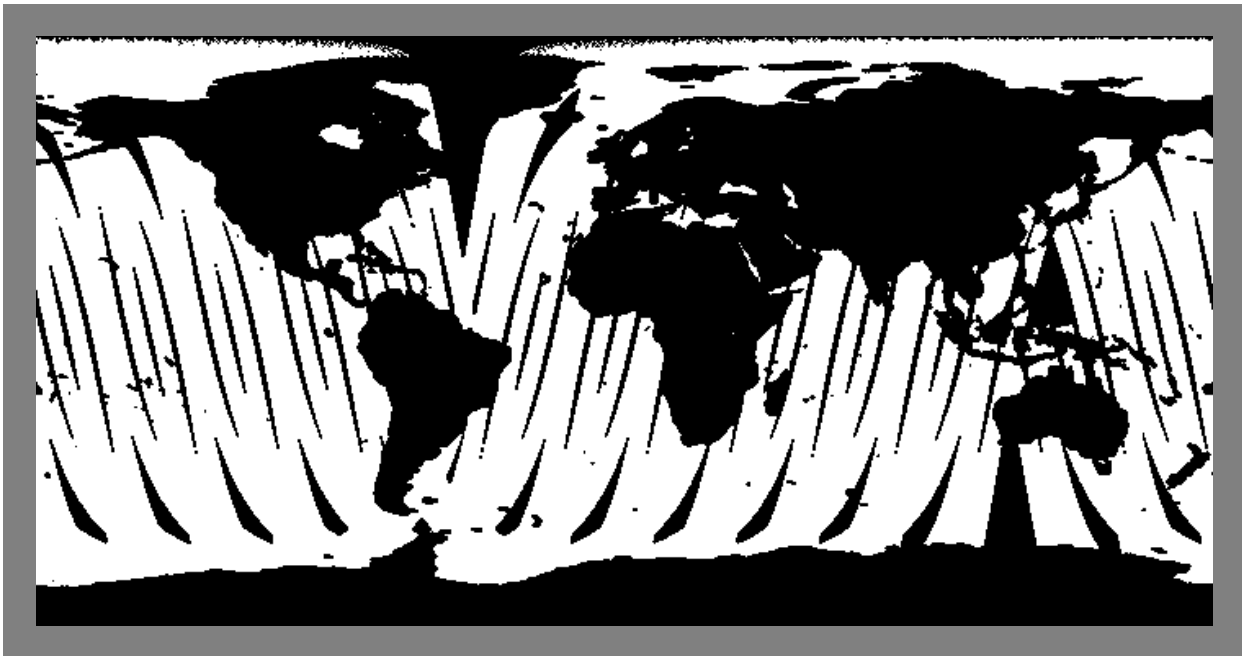
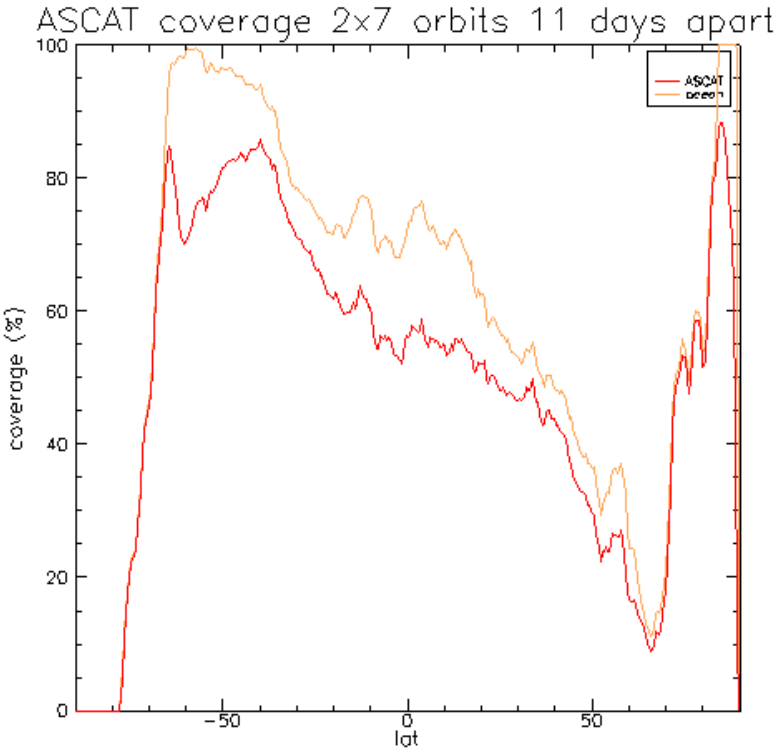
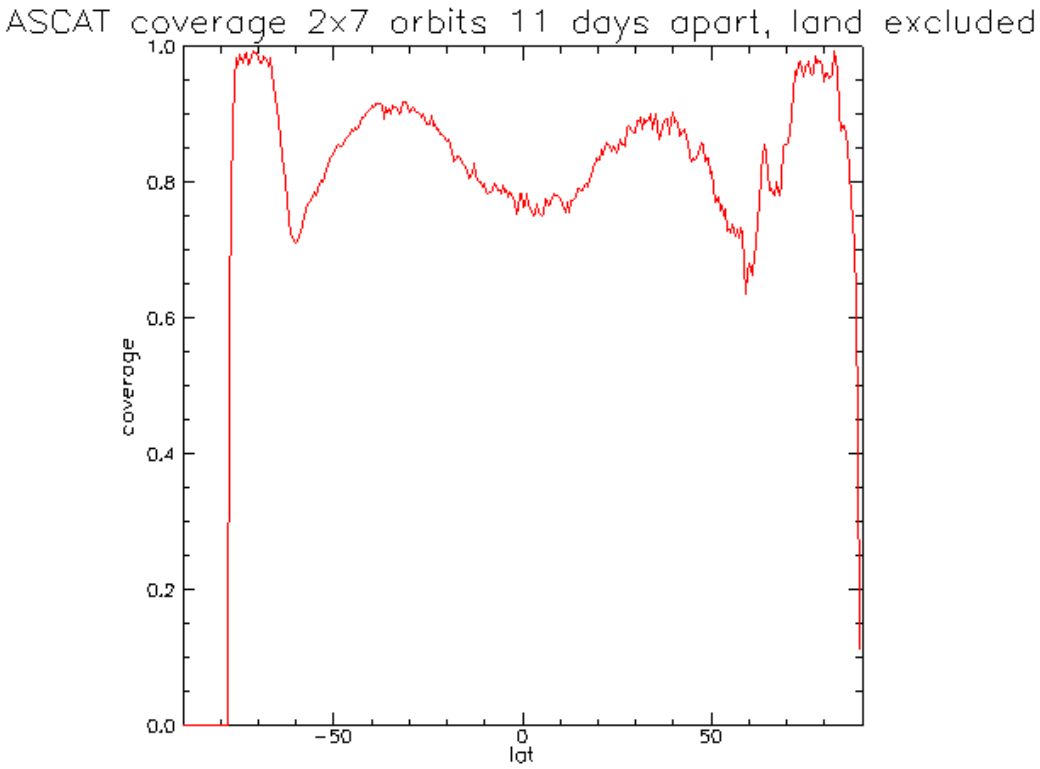


Figure 3 – As Figure 1 with land filtered out, 11 days minus 28 minutes apart.



a)



b)

Figure 4 – Coverage for 11 days minus 28 minutes apart.
a) For Figure 3 (red) and ocean (orange) with respect to the full latitude circle area.
b) For Figure 3 with respect to ocean area only

Figure 5 shows the ASCAT coverage for orbits 11442-11448 and 11541-11547. These are two periods of each 7 orbits, 7 days minus 45 minutes apart. Figure 6 shows the corresponding coverage percentage with respect to ocean area. In this case the ASCAT right orbit of one period overlaps with the ASCAT left orbit of the other period leading to poor coverage in the tropics and subtropics.

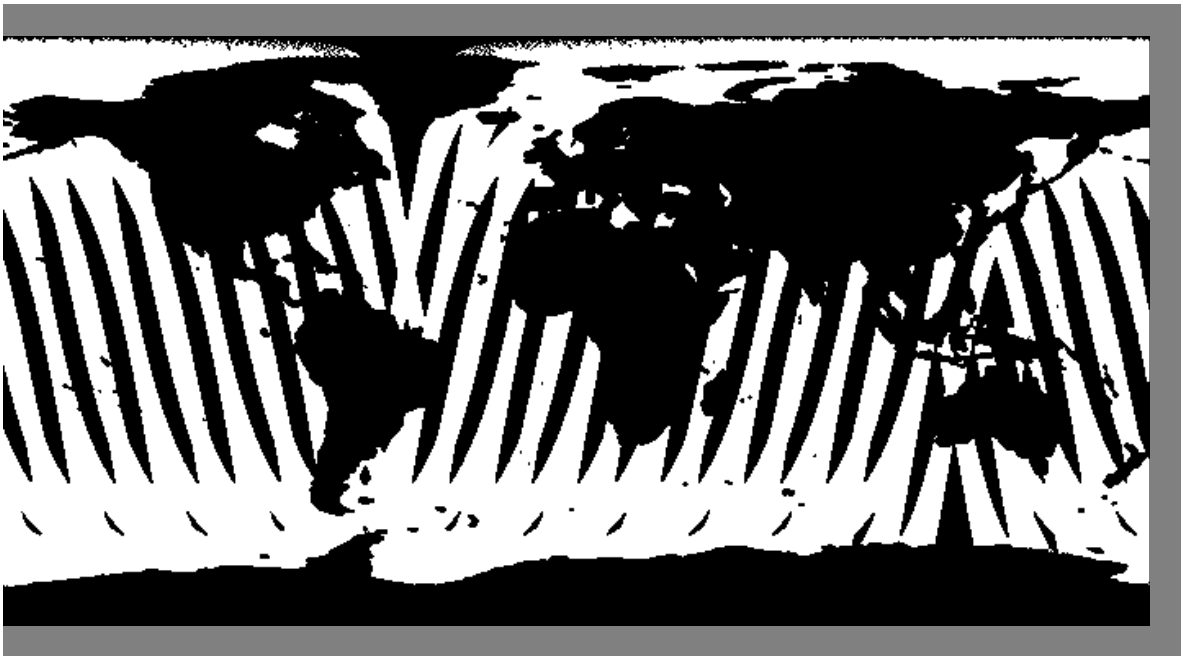


Figure 5 – ASCAT coverage for 2x 7 orbits, 7 days minus 45 minutes apart. Seven orbits starting from 20090102 01:33 and from 20090109 00:47 are used, orbit numbers 11442-11448 and 11541-11547.

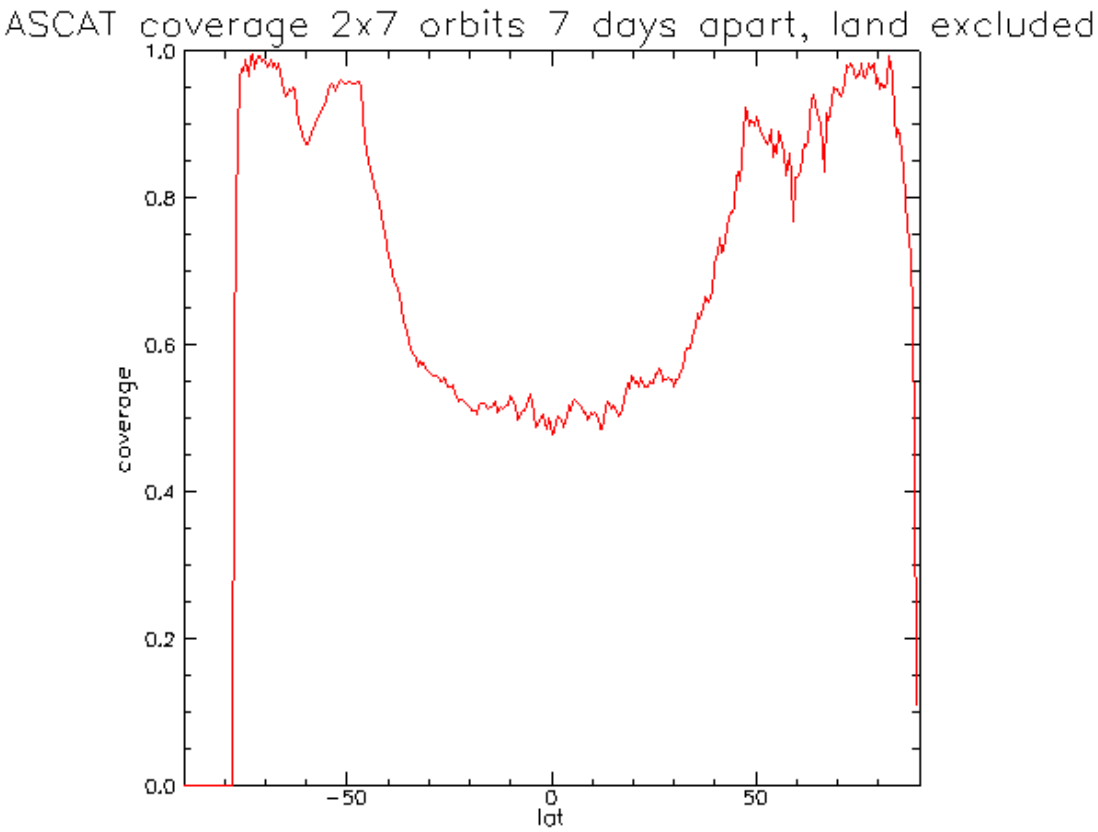


Figure 6 – Coverage for Figure 5 with respect to ocean.

In Figure 7 the ocean coverage of a tandem ASCAT system is shown for selected intervals between the two satellite tracks. The separation in days correspond to a certain time shift (see
Table 1) that has a large impact on for the shape of the curve.

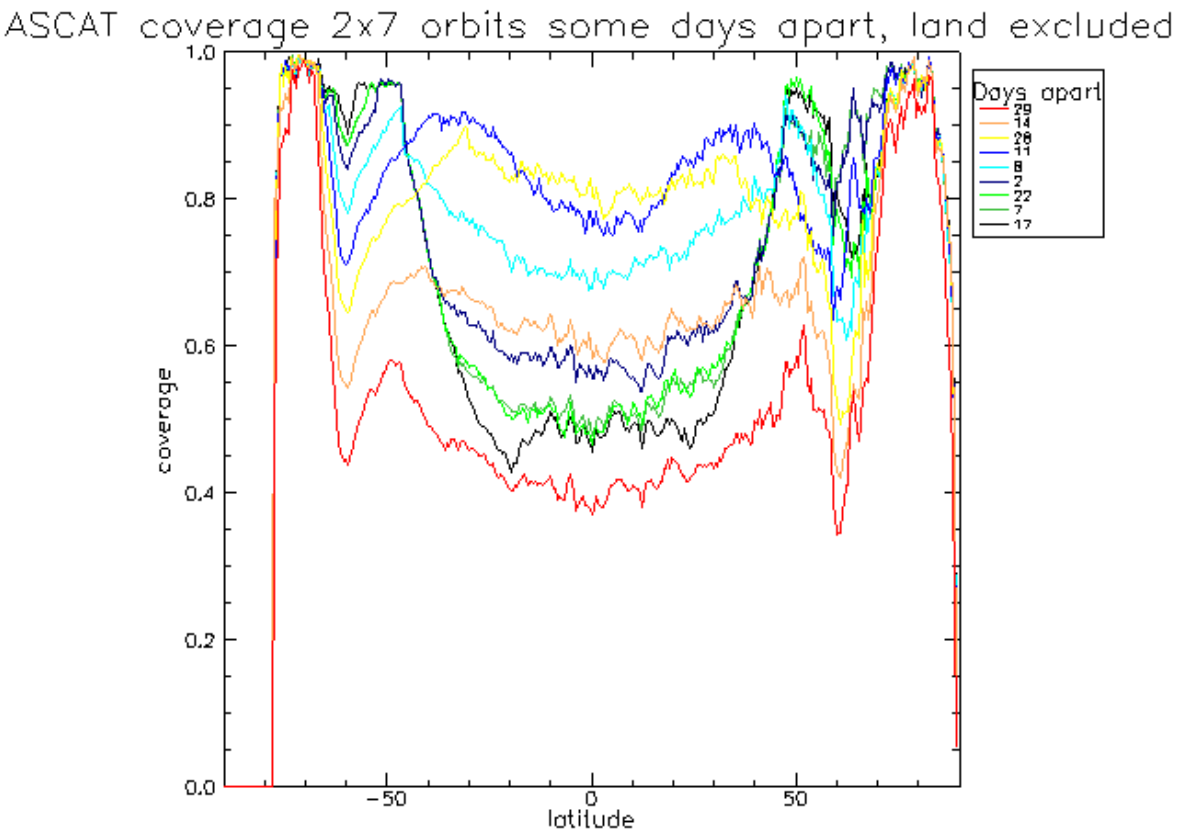


Figure 7 – ASCAT tandem coverage of the oceans as a function of latitude for selected separation in days between the 2x 7 orbits. The legend is ordered to ascending time shift (see Table **1**).

For the time shifts given in section 2 the average area coverage is calculated for the whole world, the tropics (-30<latitude<30) and the extratropics. The latitude fractional coverages of ASCAT and ocean are multiplied by the cosine of the latitude for each latitude row and added in order to obtain fractional area coverage. This leads to Figure 8 where a maximum in the coverage occurs for a value of the time shift around 20-30 minutes in all three areas. As expected, the extratropics corresponding to high latitudes give a higher coverage. A symmetry is present around a half orbit shift or 50.5 minutes. Such symmetry is slightly disturbed due to the distribution of land coverage around the globe.

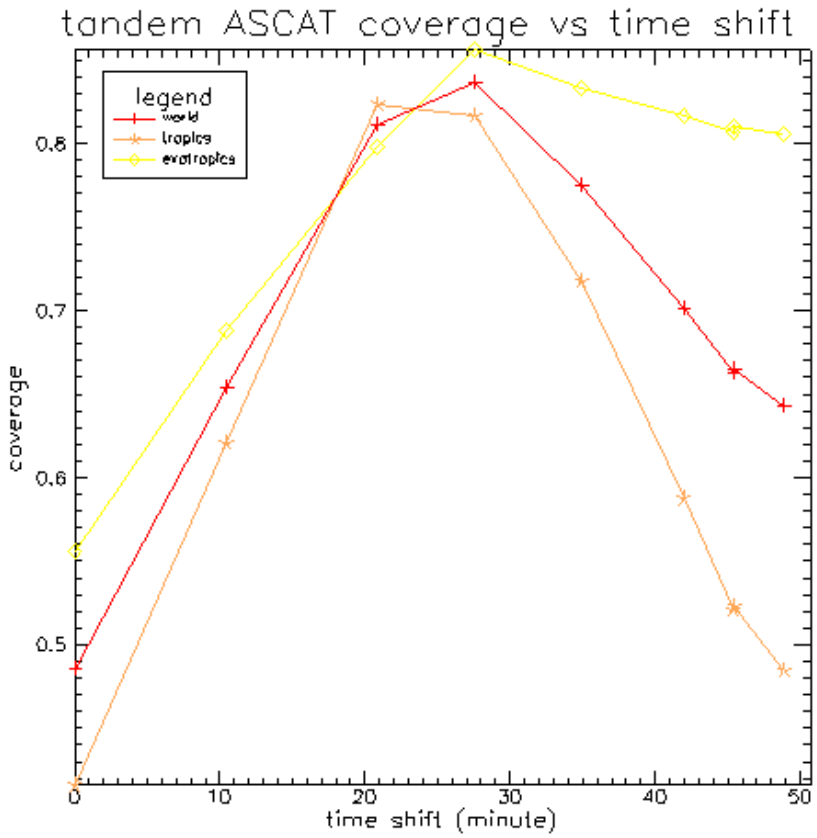


Figure 8 – Average ocean coverage of the whole world (red), the tropics (orange) and the extratropics (yellow) as a function of orbit time shift.

In order to get an estimate of the uncertainty in the calculation of coverage for a tandem system with a time shift of -28 minutes (7 orbits, 156 orbits apart) has been repeated five times, with a separation of 29 orbits between the start orbit numbers. The results are summarised in Table 2.

start orbits	**ocean coverage**	**ocean+land coverage**
11442-11598	0.8360838	0.8487891
11471-11627	0.8301203	0.8484066
11500-11656	0.84328854	0.8486896
11529-11685	0.8362519	0.84871715
11558-11741	0.8372007	0.849177
Mean	**0.837**	**0.847**
Standard Deviation	**0.005**	**0.003**

Table 2 – Spread in coverage

The spread in coverage leads to a standard deviation that is higher for the ocean coverage compared to the ocean+land coverage. This is due to the irregularity of the land area on the globe. The relative position of the satellite coverage pattern with respect to the land area gives an extra spread in the coverage. Small systematic error sources remain in the land mask and in the missed bins (“holes”) that are left over for the high latitudes. The values found for the standard deviation give confidence in the results as summarised in Figure 8.

4 Conclusion

While a single ASCAT scatterometer provides just less than 50% coverage of the world's oceans in 12 hours, a tandem ASCAT-type scatterometer could deliver over 80% ocean area coverage. Over the tropical oceans, below 30 degrees latitude, the second ASCAT could bring coverage even from 42% to 82%, i.e., almost a doubling in coverage of the tropical cyclone, ITCZ and trade regions. In the extratropics, above 30 degrees latitude, the second ASCAT can provide an increase in coverage from 56% to 86% over 12 hours.

These numbers are reached when the second satellite boarding ASCAT is shifted in the common orbital plane by 28 minutes. For a shift of half an orbit or about 50 minutes, the 12-hourly ocean coverage reduces from 86%, 84% and 82% to 81%, 65% and 49% for respectively the extratropical, global and tropical regions.

Coverages per latitude circle are provided as well here above. Of course, effects for other applications, like on soil moisture, could be verified as well, for instance by comparing daily (14 orbit) area coverages over land for different orbit shifts.