SMOS OPS PREPARATORY OPTIMISATION NOTE

Project code SO-TN-CBSA-SYS-0006-01.b
Version Draft
Date 28/07/2008

	Role	***Name***	***Date and signature***
Written by :			
Approved by**:**			
Approved by :			

DOCUMENT STATUS SHEET

version / Rév.	Date	Pages	Changes	Visa
1.a	20/07/2008		First version	
1.b	28/07/2008		Significant changes in sections 2 & 5	

DISTRIBUTION LIST

ESTEC/EEM:	
A. Hahne	
H. Barré	
M Martin-Neira	
K McMullan	

ESRIN:	
S. Mecklenburg	
ESTEC	

CNES	
SAG	
all	
OTHER	
CASA EADS	

REFERENCES

Kerr, Y., P. Waldteufel, P. Richaume, I. Davenport, P. Ferrazzoli and J.-P. Wigneron (2005). SMOS level 2 processor Soil moisture ATBD. Toulouse, SM-ESL (CBSA)**:** 110.

Kerr, Y. H. (2007), 2007. The SMOS Soil moisture retrieval algorithm (invited). In IGARSS 07, Barcelona Espagne, IEEE

Waldteufel, P., J. Boutin and Y. Kerr (2001), 2001. Selecting an optimal configuration for the SMOS mission. In MuRad 2001, Boulder, CO, USA

Waldteufel, P., J. Boutin and Y. Kerr (2003). Selecting an optimal configuration for the SMOS mission. Radio Science **38**(3): 10.1029/2002RS002744,.

ACRONYMS

DQX	Theoretical retrieval standard deviation
FOV	Field of view

TABLE OF CONTENTS

1. INTRODUCTION AND LIMITATIONS

This note is a first attempt at assessing considered SMOS OPS configurations. **It is not a full exercise** at it only considers one option, i.e. the "0° steer angle" currently considered as a choice for SMOS OPS. It does not compare it to other options and – consequently – **cannot be considered as an optimisation of the mission**. Moreover, the time allocated to this analysis (one month) does not allow performing a real analysis of the 0° steer angle configuration as we cannot use the tools now available to really prepare the optimisation. Finally, it must be understood that the validation of the approaches will only be possible once SMOS flies and allows making sure all hypothesis are valid.

In view of the above we have performed a simple analysis of the proposed 0° steer configuration and established, using the very same tools as those used for the similar exercise performed for SMOS in 2001(Waldteufel et al. 2001; Waldteufel et al. 2003). It enables to see what could be an optimum for this set up with all the caveats expressed above.

It should also be reminded at this level that the main conditions, if we want to have a credible SMOS Ops, are to have a satellite with the following objectives:

- Be a true SMOS follow-on in terms of science objectives
- Do not show dramatics changes but with a possible reduction in mass, power size; offer improved specifications with the following decreasing priorities: better sensitivity (and accuracy stability), better temporal coverage (revisit) and possibly improved spatial resolution if all previous objectives are achieved.

2. PARAMETERS OF THE STUDY

So as to perform this study, a number of assumptions have to be made: they are detailed below and this paragraph gives an outline of the limits of the exercise.

1.1. FIXED FEATURES

- Field of view (FOV) restricted to the fully alias free zone;
- one arm in orbit plane: steering (yaw) angle = 0°;
- No pitch angle;
- Arms: 4 elements forward on hub, 3x7 elements along deployable parts.

1.2. INSTRUMENT & L1 PARAMETERS

- A margin of 0.8 window width has been arbitrarily applied to the FOV;
- The radiometric uncertainty equation coefficients have been tuned for SMOSops at best, accounting for noise temperature and oversampling;
- The effect of backward elements essentially is to increase the sensitivity gain due to redundancies. This has been taken into account approximately by a reducing factor in the equation.
- The integration time (owing to simultaneous acquisition of both H and V) has been doubled for SMOS Ops.

1.3. VARIABLE FEATURES

These features are those which are considered in this optimisation:

- Spacing ratio d: from 0.765 upwards to 0.865, step 0.02
- Tilt (roll) t: from 5 to 40 step 5°
- Altitude z: from 650 to 850 km, step 25 km.

1.4. SIMULATION

- Representative set of geophysical parameters: soil moisture SM=20 (percentage), optical thickness TAU=0.26, physical temperature=293 K
- Model is Dobson/Kerr/Wigneron not updated from 2001(Waldteufel, Boutin et al. 2001; Waldteufel, Boutin et al. 2003), for the sake of comparison.
- Dual polarisation is selected, with retrieval in the antenna frame.
- Both single step and "Approximate dual step" are tested. "Approximate dual step" means assuming optical thickness is constrained using results of previous visits; the constraint (based on numerous simulations) is set to 0.06.
- Inversion on 3 parameters: soil moisture (fully free), vegetation optical thickness (free or constrained according to step mode selection), physical temperature (constrained to 2K) (see (Kerr et al. 2005; Kerr 2007)).

1.5. QUALITY PARAMETER

The quality parameter SW is the (half) swath complying with the 0.04 threshold for theoretical retrieval error (DQX) on soil moisture. This enables to assess the useful swath w.r.t. the retrieval possibilities over a "nominal" surface.

- Both strict criterion and "mild" criterion (applied to the **average** DQX over the complying swath) are available for estimating SW;
- Spatial resolution criterion is 50 km, assuming Blackmann 3 dB width;
- Elongation criterion is 1.5.

1.6. OUTPUT

The output consists of tables of SW as a function of d, t, z. Swath limits for the 3 constraints (elongation, spatial resolution, alias limit) are also indicated.

1.7. MAIN LIMITATIONS

- The direct model is not updated.
- Single scene characterisation

Results obtained for the SW quality parameter will not have a fully reliable absolute value. They should allow what is the primary goal of the preliminary exercise: comparative assessment within the ranges of variable features, and with SMOS, assuming the radiometric equation is consistent and properly transposed.

3. SWATH LIMITS

The actual half swath width SW is estimated in 4 cases (single/dual step, strict/mild criterion) and results from combining 4 constraints: alias limits, size limit, elongation limit, retrieved DQX. This section summarizes features of these constraints but the 4rth one.

3.1 ELONGATION LIMITS

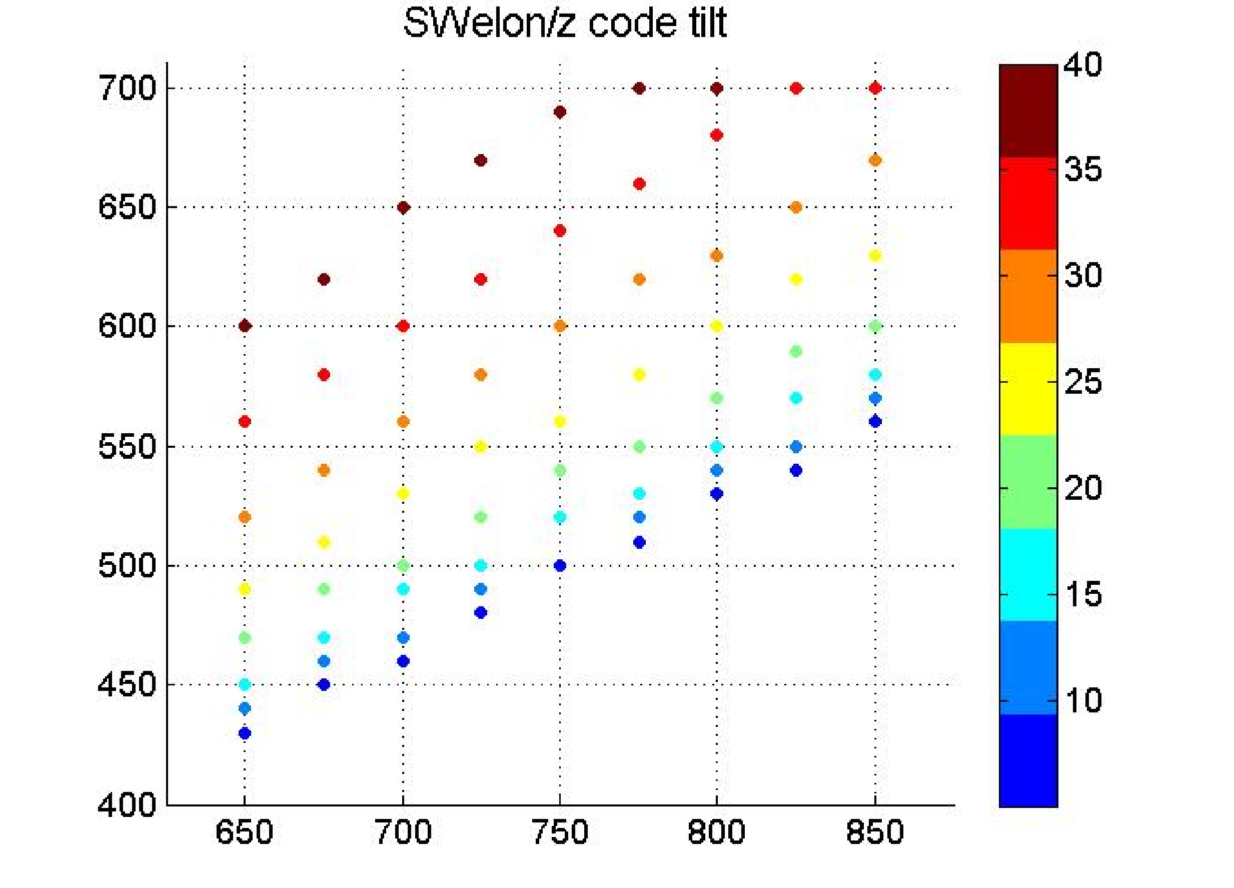

Figure 1

Here and for following figures, what is shown is the half swath (km). The selected abscissa is such that it retains a sufficient number of views, taken here as a minimal number, that is 2 views, yielding 4 brightness temperature data (compared to 3 retrieved parameters).

The elongation limit is the simplest: it depends only on altitude and tilt angle.

3.2 SIZE LIMIT

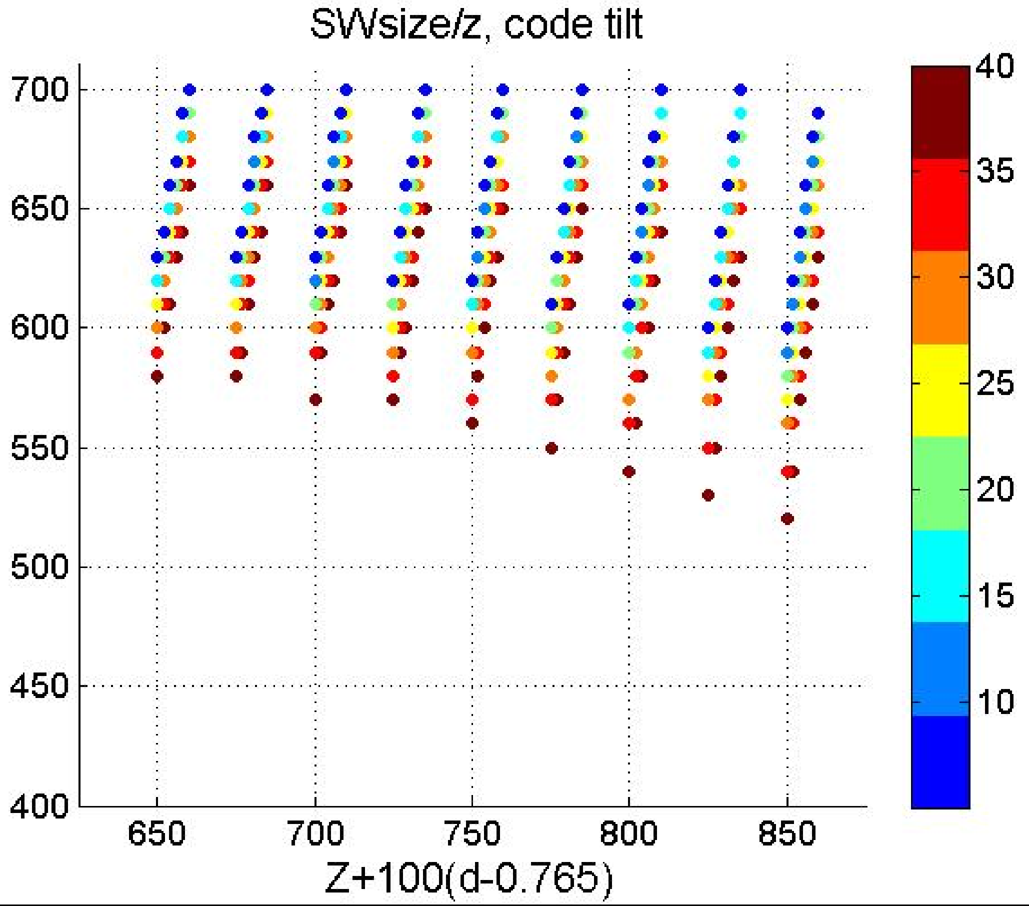

Figure 2

The size limit depends on all 3 altitude z, tilt and spacing ratio d. The dependence on spacing ratio is shown on a reduced scale for d attached to each z value, as shown by the formula along the horizontal axis.

The size limit becomes narrower with increasing altitude, and with increasing tilt; it broadens with d (since arms become longer when d increases).

3.3 ALIAS LIMITS

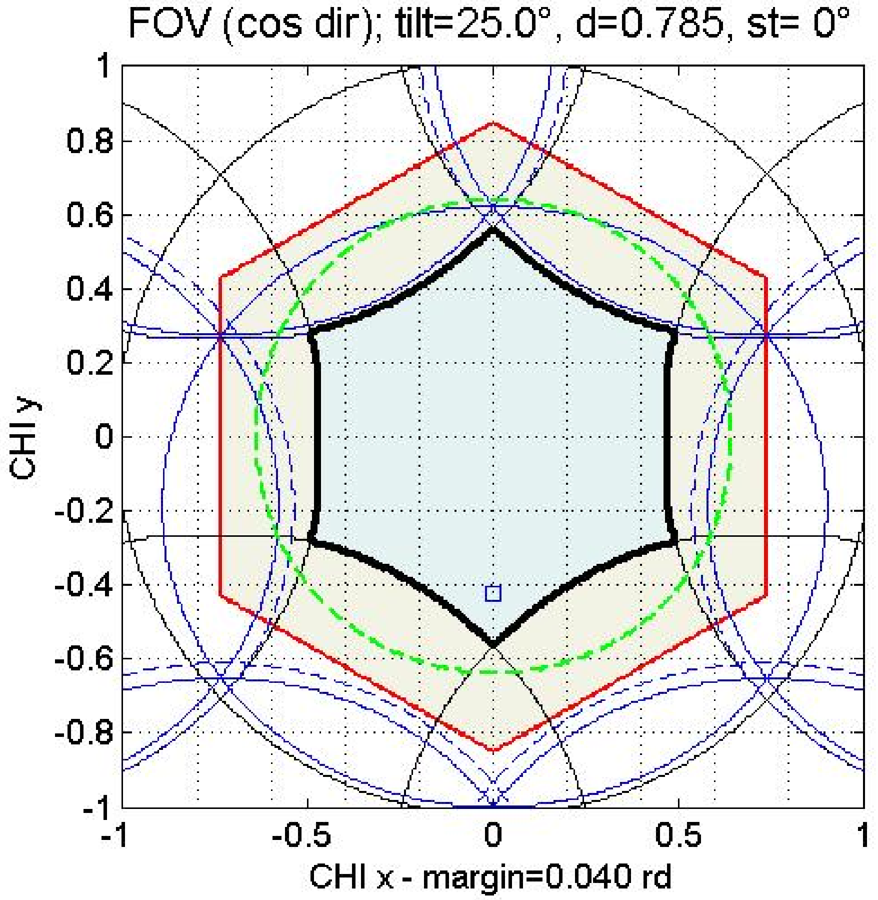

Figure 3

In the antenna frame, it seems natural to select the broadest swath value, which is located for this particular example for CHIy ~ ± 0.28 in the (CHIx, CHIy) frame.

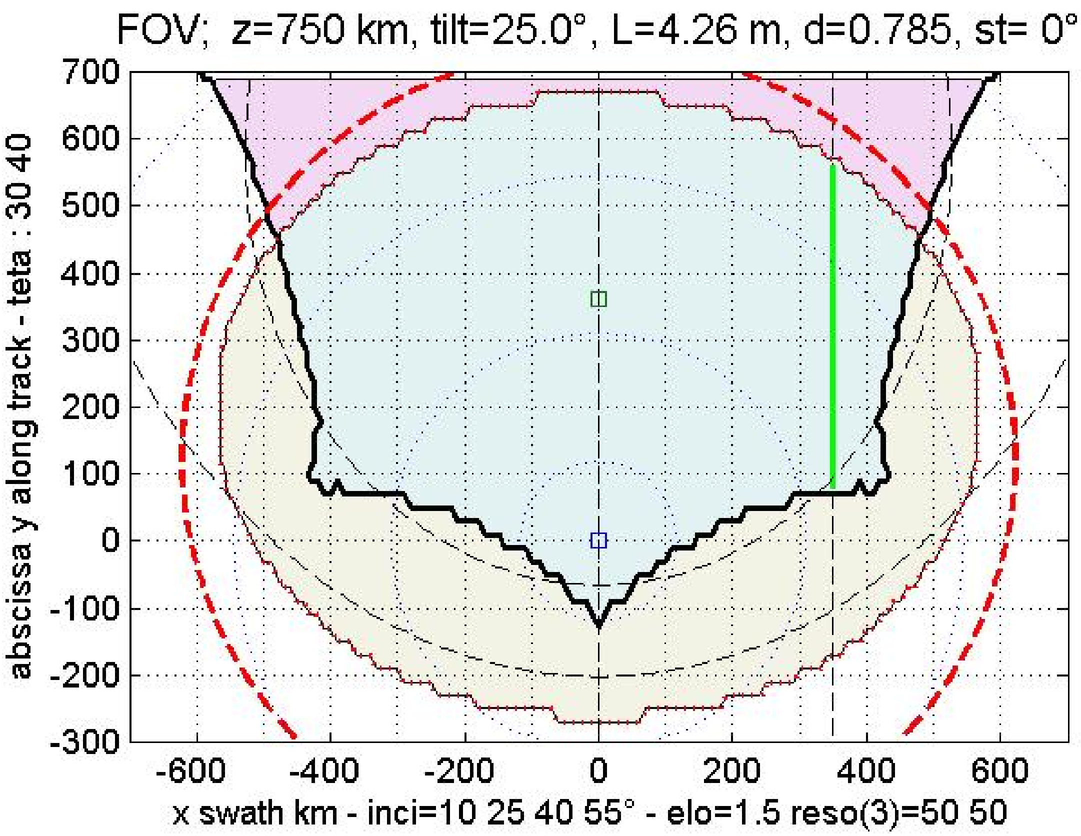

Figure 4

The geographical grid has been limited to a realistic area, keeping in mind the expected behaviours of the pixel geometrical requirements.

Even for moderate tilt angle, when transposing Figure 3 to the geographical frame, the value for positive CHIy becomes very large and ultimately meaningless.

In the following, the value for negative CHIy (around a 80 km along track abscissa here) will therefore be selected.

Figure 4 also helps to visualize the elongation limit (ellipse like zone) and the size limit (close to a circle, dashed thick line))

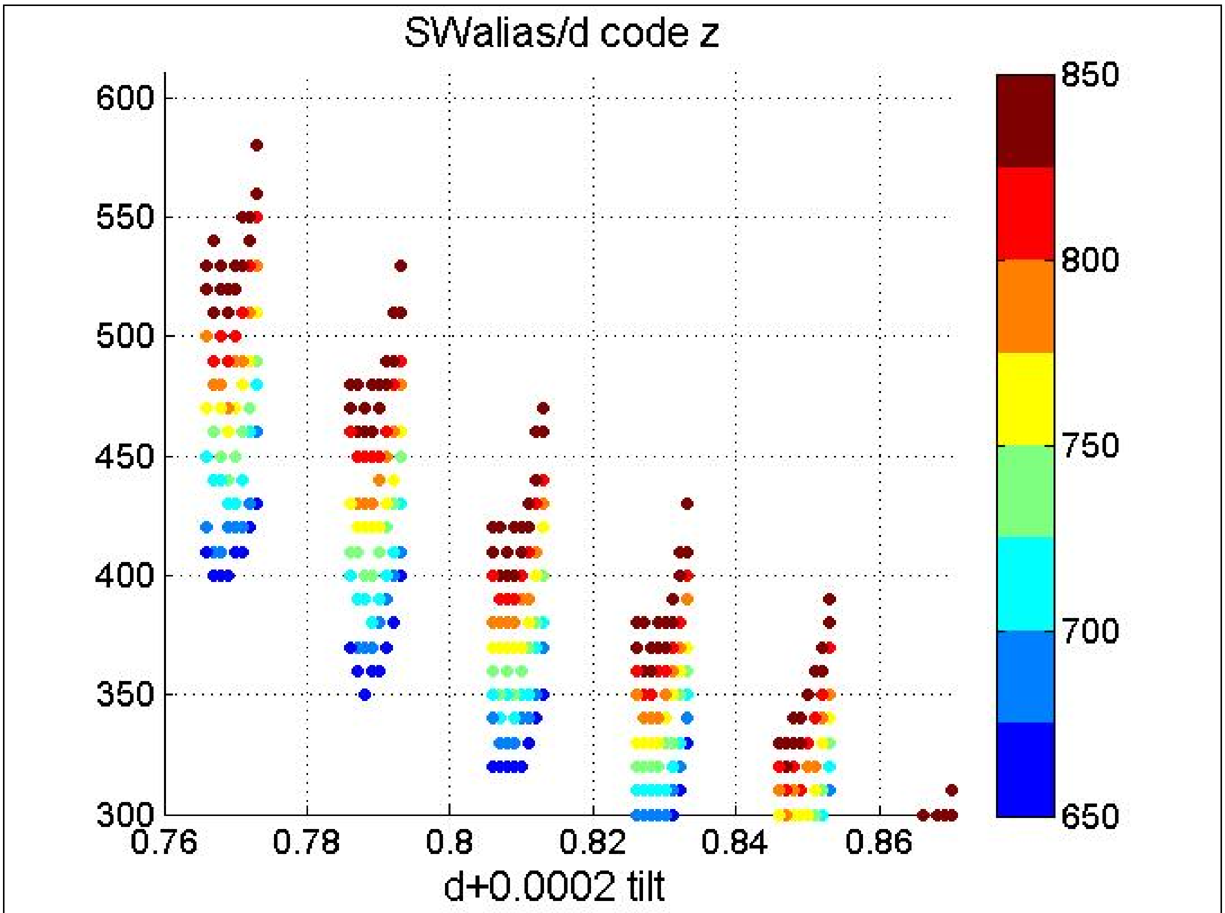

Figure 5

The alias limit estimated as said above decreases with spacing ratio d and increases with altitude (colour code).

The dependence on tilt is shown on a reduced scale attached to each d value, as shown by the formula along the horizontal axis.

Dependence with tilt is smaller and not always monotonous.

Note the scale for alias limit is shifted by 100km with respect to previous figures.

4. SELECTION OF BEST CASES

4.1 NARROW SELECTION

Table 1: SW2strict ≥ 500 km

0	tilt °	Hz km	d	n arm	arm length		SW alias	SW size	SW elon		SW1 strict	SW1 mild	SW2 strict	SW2 mild
43	5.0	825	0.765	21	4.10		520	600	540		490	510	500	510
49	5.0	850	0.765	21	4.10		530	600	560		510	520	520	520
97	10.0	825	0.765	21	4.10		510	600	550		500	510	510	510
103	10.0	850	0.765	21	4.10		540	590	570		510	530	520	530
145	15.0	800	0.765	21	4.10		500	600	550		480	510	500	510
151	15.0	825	0.765	21	4.10		520	590	570		500	520	520	520
157	15.0	850	0.765	21	4.10		530	590	580		520	540	530	540
199	20.0	800	0.765	21	4.10		490	590	570		490	520	510	520
205	20.0	825	0.765	21	4.10		510	590	590		500	530	520	530
211	20.0	850	0.765	21	4.10		520	580	600		520	540	530	540
253	25.0	800	0.765	21	4.10		500	590	600		490	520	500	520
259	25.0	825	0.765	21	4.10		520	580	620		480	530	520	530
265	25.0	850	0.765	21	4.10		530	570	630		450	540	540	540
307	30.0	800	0.765	21	4.10		510	570	630		430	520	510	520
313	30.0	825	0.765	21	4.10		530	570	650		420	530	520	530
319	30.0	850	0.765	21	4.10		550	560	670		410	550	540	550

Table 1 shows the cases for **highest values** of each of the 4 performance criterions SW1strct, SW1mild, SW2strict and SW2mild. The selection criterion for this table was: SW2strict ≥ 500 km.

All selected cases occur for the **smallest spacing ratio** (d=0.765) and for **high flight altitude** (z=800 to 850 km).

It has been pointed out that the definition of the alias limit is not fully satisfactory. This is illustrated by the fact that in some cases the available half swath exceeds slightly the alias limit SWalias, while this never occurs for the geometrical limits SWsize and SWelon.

Nevertheless, it appears clearly that **the alias limit prevails**. The largest swath values are obtained when the 3 limits become close (see e.g. case 319).

In single step, a further reduction of the swath is brought by the DQX requirement. The impact of the DQX requirement depends on the choice made for the physical quantities SM and TAU: while the selected values are "representative", both more and less favourable situations are bound to occur. In any case, it makes sense that the SW1strict criterion is the most sensitive to the DQX requirement.

Concerning the tilt angle, no clear preference is suggested here, provided it stays in the [10° 30°] interval.

4.2 BROADENED SELECTION

Table 2: SW1strict ≥ 450 km

0	tilt °	Hz km	d	n arm	arm length	SW alias	SW size	SW elon	SW1 strict	SW1 mild	SW2 strict	SW2 mild
25	5.0	750	0.765	21	4.10	470	620	500	450	460	460	460
31	5.0	775	0.765	21	4.10	500	610	510	460	470	470	470
37	5.0	800	0.765	21	4.10	500	610	530	480	490	490	490
43	5.0	825	0.765	21	4.10	520	600	540	490	510	500	510
44	5.0	825	0.785	21	4.20	470	620	540	450	480	470	480
49	5.0	850	0.765	21	4.10	530	600	560	510	520	520	520
50	5.0	850	0.785	21	4.20	480	620	560	460	500	480	500
79	10.0	750	0.765	21	4.10	460	620	500	450	470	460	470
85	10.0	775	0.765	21	4.10	480	610	520	460	480	480	480
91	10.0	800	0.765	21	4.10	490	610	540	480	500	490	500
97	10.0	825	0.765	21	4.10	510	600	550	500	510	510	510
98	10.0	825	0.785	21	4.20	460	620	550	450	480	460	480
103	10.0	850	0.765	21	4.10	540	590	570	510	530	520	530
104	10.0	850	0.785	21	4.20	480	610	570	460	500	480	500
133	15.0	750	0.765	21	4.10	470	610	520	450	480	470	480
139	15.0	775	0.765	21	4.10	480	610	530	470	490	480	490
145	15.0	800	0.765	21	4.10	500	600	550	480	510	500	510
151	15.0	825	0.765	21	4.10	520	590	570	500	520	520	520
152	15.0	825	0.785	21	4.20	460	610	570	450	490	460	490
157	15.0	850	0.765	21	4.10	530	590	580	520	540	530	540
158	15.0	850	0.785	21	4.20	470	610	580	470	510	480	510
187	20.0	750	0.765	21	4.10	460	610	540	450	490	470	490
193	20.0	775	0.765	21	4.10	470	600	550	470	500	480	500
199	20.0	800	0.765	21	4.10	490	590	570	490	520	510	520
205	20.0	825	0.765	21	4.10	510	590	590	500	530	520	530
206	20.0	825	0.785	21	4.20	460	610	590	450	500	470	500
211	20.0	850	0.765	21	4.10	520	580	600	520	540	530	540
212	20.0	850	0.785	21	4.20	480	600	600	470	510	480	510
241	25.0	750	0.765	21	4.10	470	600	560	460	500	470	500
247	25.0	775	0.765	21	4.10	490	590	580	470	520	490	520
253	25.0	800	0.765	21	4.10	500	590	600	490	520	500	520
254	25.0	800	0.785	21	4.20	450	610	600	450	500	460	500
259	25.0	825	0.765	21	4.10	520	580	620	480	530	520	530
260	25.0	825	0.785	21	4.20	470	600	620	460	500	470	500
265	25.0	850	0.765	21	4.10	530	570	630	450	540	540	540
266	25.0	850	0.785	21	4.20	480	590	630	450	510	480	510
289	30.0	725	0.765	21	4.10	460	590	580	460	500	460	500
295	30.0	750	0.765	21	4.10	480	590	600	460	510	480	510
301	30.0	775	0.765	21	4.10	490	580	620	450	520	490	520
302	30.0	775	0.785	21	4.20	450	600	620	450	490	450	490
308	30.0	800	0.785	21	4.20	460	590	630	450	500	460	500
337	35.0	700	0.765	21	4.10	460	590	600	450	490	460	490
343	35.0	725	0.765	21	4.10	470	580	620	450	500	470	500
349	35.0	750	0.765	21	4.10	490	570	640	450	510	480	510
385	40.0	675	0.765	21	4.10	460	580	620	450	490	460	490
391	40.0	700	0.765	21	4.10	480	570	650	450	490	470	490

Some of the cases selected above have disappeared due to the DQX criterion. Some cases with d just above the minimum of the explored range (d=0.785) appear. The tilt angle covers now the whole available range.

4.3 REDUCING ALTITUDE

Table 3: z ≤ 775 km & SWmild ≥ 500 km

0	tilt °	Hz km	d	n arm	arm length		SW alias	SW size	SW elon		SW1 strict	SW1 mild	SW2 strict	SW2 mild
193	20.0	775	0.765	21	4.10		470	600	550		470	500	480	500
241	25.0	750	0.765	21	4.10		470	600	560		460	500	470	500
247	25.0	775	0.765	21	4.10		490	590	580		470	520	490	520
289	30.0	725	0.765	21	4.10		460	590	580		460	500	460	500
295	30.0	750	0.765	21	4.10		480	590	600		460	510	480	510
301	30.0	775	0.765	21	4.10		490	580	620		450	520	490	520
343	35.0	725	0.765	21	4.10		470	580	620		450	500	470	500
349	35.0	750	0.765	21	4.10		490	570	640		450	510	480	510
355	35.0	775	0.765	21	4.10		510	570	660		440	510	480	510
397	40.0	725	0.765	21	4.10		490	570	670		430	500	470	500
403	40.0	750	0.765	21	4.10		510	560	690		430	510	460	510
409	40.0	775	0.765	21	4.10		530	550	700		420	530	450	530

The same selection is obtained here for SM1mild and SW2mild. The spacing ratio is always the smallest one allowed; preferred tilt values lie between 20° and 40°.

5. CONCLUDING REMARKS

5.1 SYNTHESIS OF RESULTS

This note shows, using exactly the same approach as that used for SMOS, what would be the optimal configuration should the 0° steer angle be selected. It is in no way a comparison or an endorsement of the 0° steer angle option. Strictly speaking, unlike for SMOS, no real optimum has been identified: the best configuration in terms of complying swath is found at the boundary of the domain allowed for mission parameters.

- With the selected 0° steer angle, and keeping only the pure alias free zone, the prevailing limit is set by the alias free FOV. Then **the spacing ratio should be as small as possible**.
- Since no marginal gain in size resolution was attempted, the size limit hardly enters into play.
- For the same reason, **best results are obtained for the highest altitudes**.
- The effect of the tilt angle is limited and non monotonous. If the highest part of the altitude range cannot be reached, preference should be given to **comparatively high tilt angles, around 30±10°.**

5.2 THE SMOS CASE

When optimizing parameters for SMOS, the dual step retrieval mode was modelled differently, through introducing a "narrow" swath with 5 days revisit time at the equator (as compared to 3 days for the nominal "wide" swath. This generated strong constraints on the allowed altitude ranges.

The optimised SW parameter was found close to 520km. As shown by previous tables, the expected performance found in this note will reach or exceed this value only for the high end of the altitude range.

The mandatory SW value for meeting the revisit time requirement is 460km; obtaining a larger value means that a margin exists in terms of dwell line length and thus in terms of the retrieval uncertainty requirement, with respect to the scene parameters (soil moisture, vegetation optical thickness) selected for the simulation.

5.3 NEXT STEPS

The next steps should consist in comparing the 0° and 30° steer angle configuration using the real state of the art modelling for the radiative transfer and retrieval algorithms, as well as the actual instrument description, together with the real instrument characteristics as measured on the ground. Ideally they should be validated with the “real” in flight SMOS measurements.

In this respect, a critical issue will be to determine to which extent the **extended** alias free zone can be used over continental surfaces for retrieving soil moisture.