ThalesAlenia Space
A Thales / Finmeccanica Company

# Reaching sub-centimetre range noise on Jason-CS with the Poseidon-4 continuous SAR interleaved mode

L. Phalippou, E. Caubet, F. Demeestere, J. Richard, L. Rys, M. Deschaux-Beaume, TAS

R. Francis, R. Cullen, ESA

THALES

OSTST 2012

All rights reserved, 2007, Thales Alenia Space

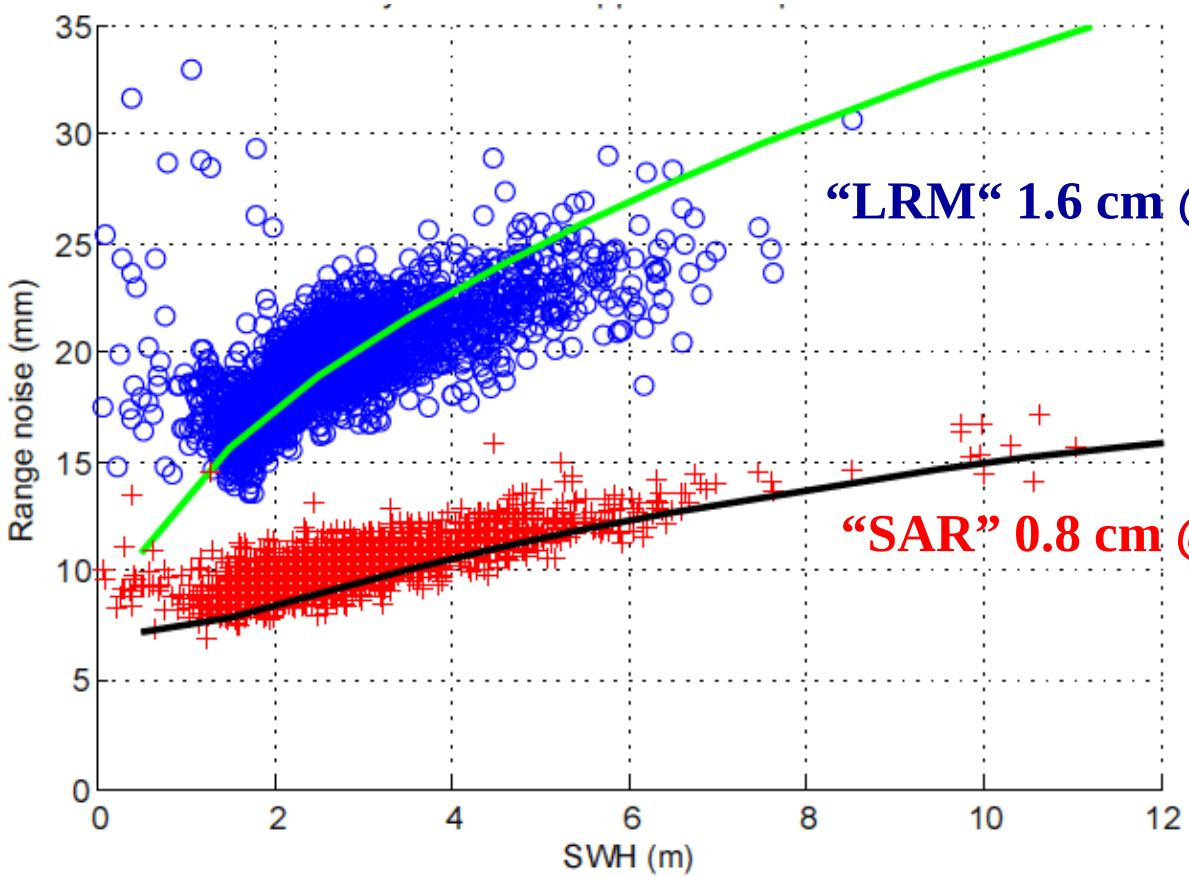
Template reference : 100181670S-EN

# History of SAR altimetry over open ocean

- K. Raney 1998
  - SAR mode improves range noise : heuristic assessment based on « rule of thumb ».
  - But ! nobody knew how to re-track the data - with a good accuracy !
- 2000-2006 many unformal discussions between Thales and radar altimeter scientists and engineers to convince them to look at numerical re-tracking (even for LRM !)
- 2007 : Phalippou and Enjolras : « Re-tracking of SAR altimeter ocean power-waveforms and related accuracies of the retrieved sea surface height, significant wave height and wind speed, IGARSS 2007 Barcelona”
- 2010 Launch of CryoSat 2 : 3 months later we knew internally in Thales that numerical re-tracking over ocean in SAR Mode was not just theory.
- 2012 : Similar findings by several groups : Jason-CS shall turn research into operation

All rights reserved, 2007, Thales Alenia Space

# OSTST 2011 : SIRAL 2 SAR RANGE NOISE




**“LRM“ 1.6 cm @ 1 sec @ SWH 2m**

**“SAR” 0.8 cm @ 1 sec @ SWH 2m**

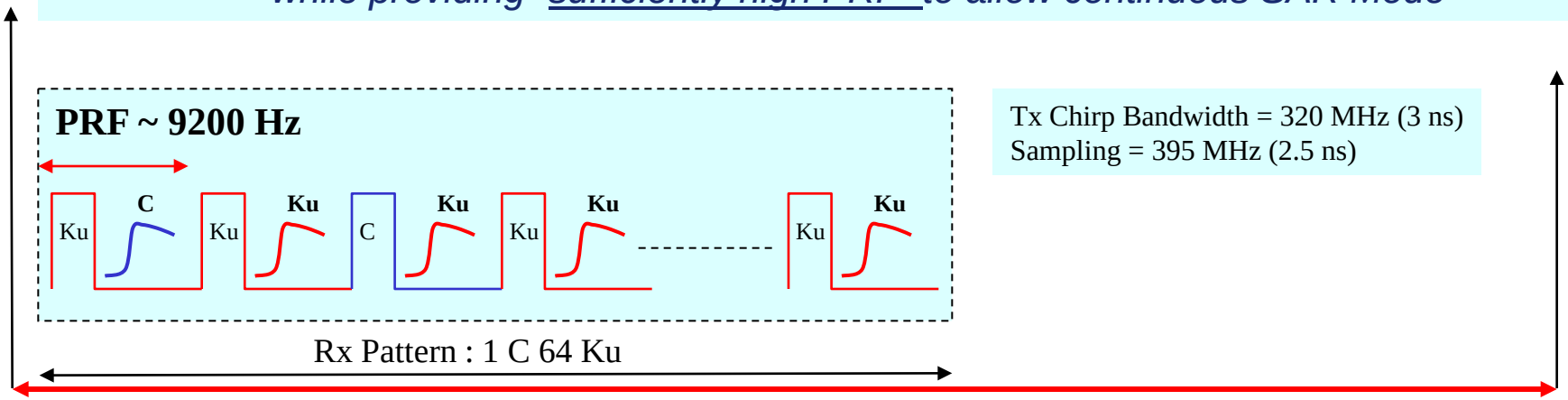
*Solid lines : Cramer-Rao bounds*
*See Phalippou & Enjolras 2007*

All rights reserved, 2007, Thales Alenia Space

# POS4 Interleaved Chronogram

- Chronogram trade-off
  - POS4 altimeter data shall provide continuity of demonstrated Poseidon-2,3,3B performances
  - Closed burst SAR chronogram (SIRAL, S3 like) are exclusive of LRM mode 2KHz
  - Altimeter / satellite constraints shall be accounted for (power, downlink ...)

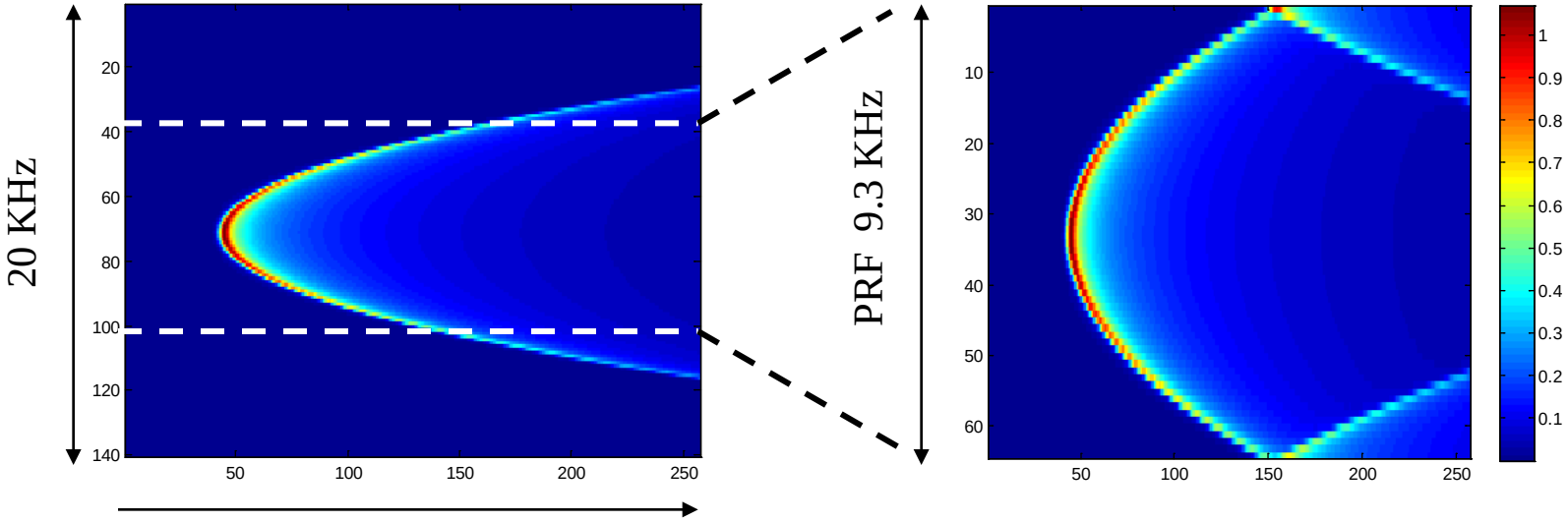
*The "interleaved mode" fulfils Jason data continuity - Low Resolution Mode - while providing "sufficiently high PRF" to allow continuous SAR Mode*




All rights reserved, 2007, Thales Alenia Space

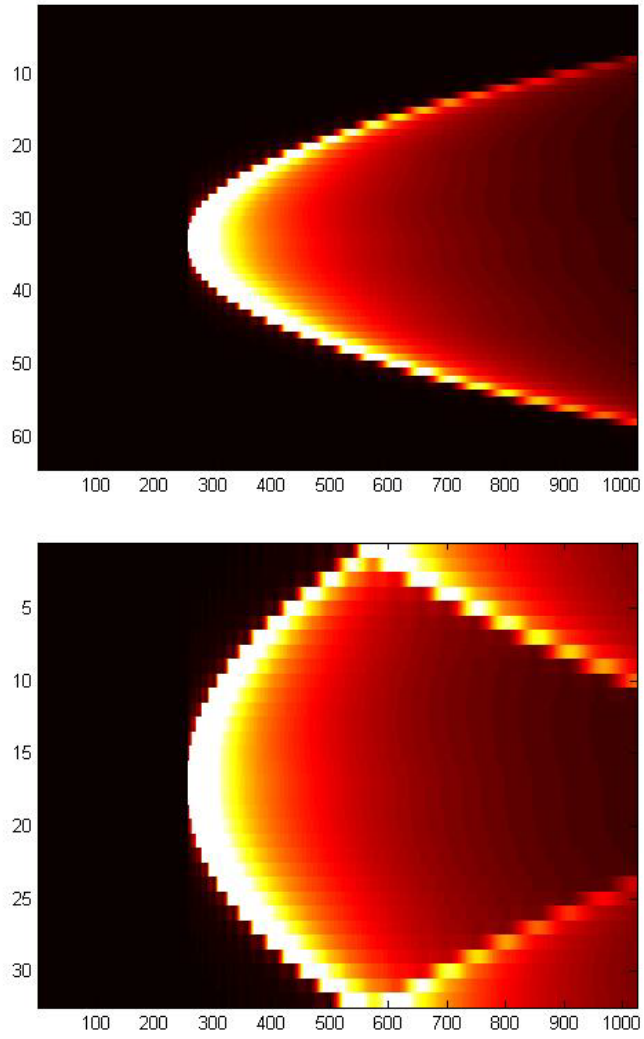
# PRF & Doppler

- **PRF < Doppler bandwidth creates aliasing but …**
  - Doppler aliasing occurs at the « end » of the trailing edge of SAR processed echoes
  - Doppler aliasing can be accounted for in the re-tracking
  - PRF has been selected as a trade-off between performance and space segment contraints



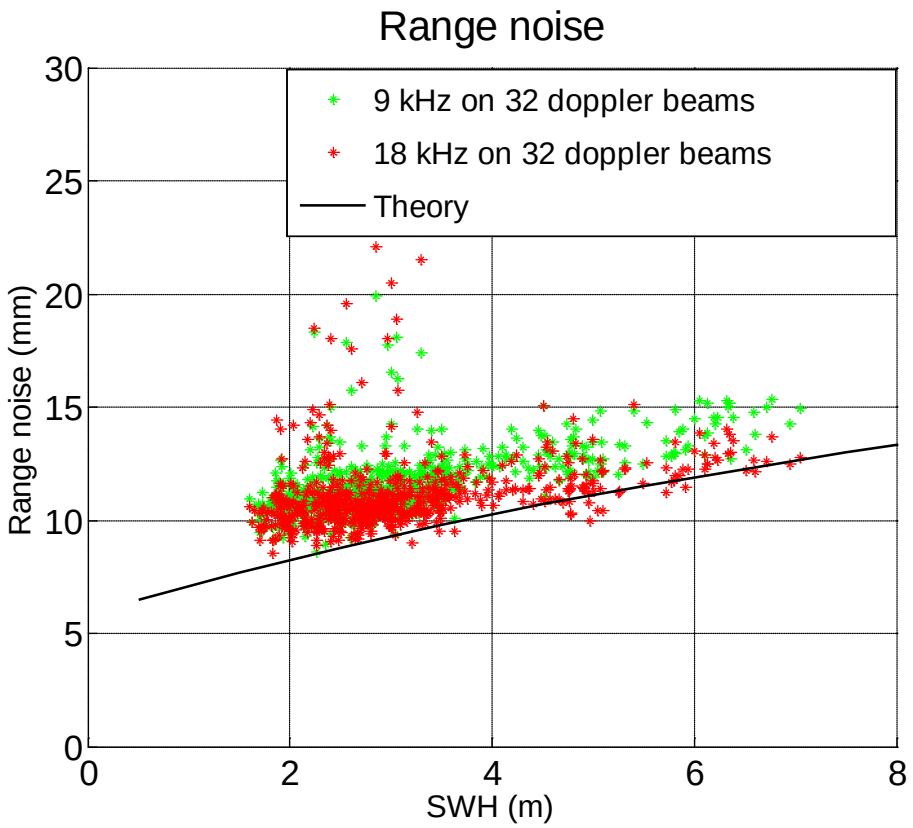

All rights reserved, 2007, Thales Alenia Space

# SIRAL re-tracking with aliasing




**18 KHz data are undersampled at 9 KHz and re-tracked**

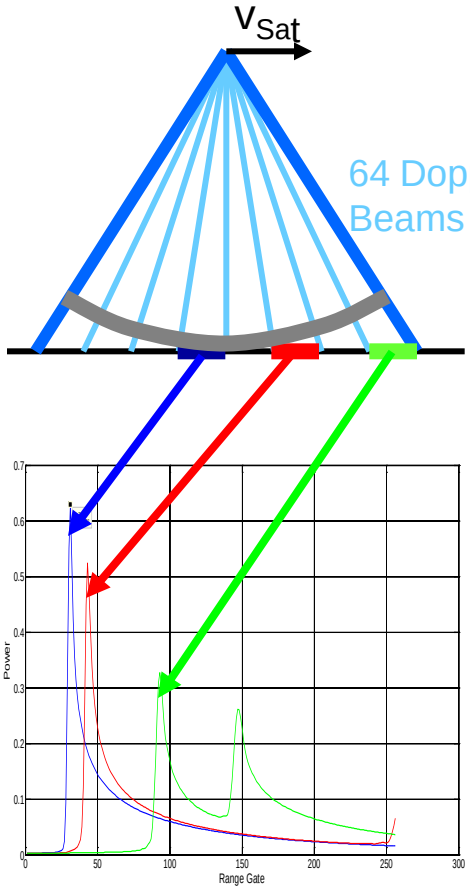
*Phalippou L. & Demeestere F. AGU 2011*

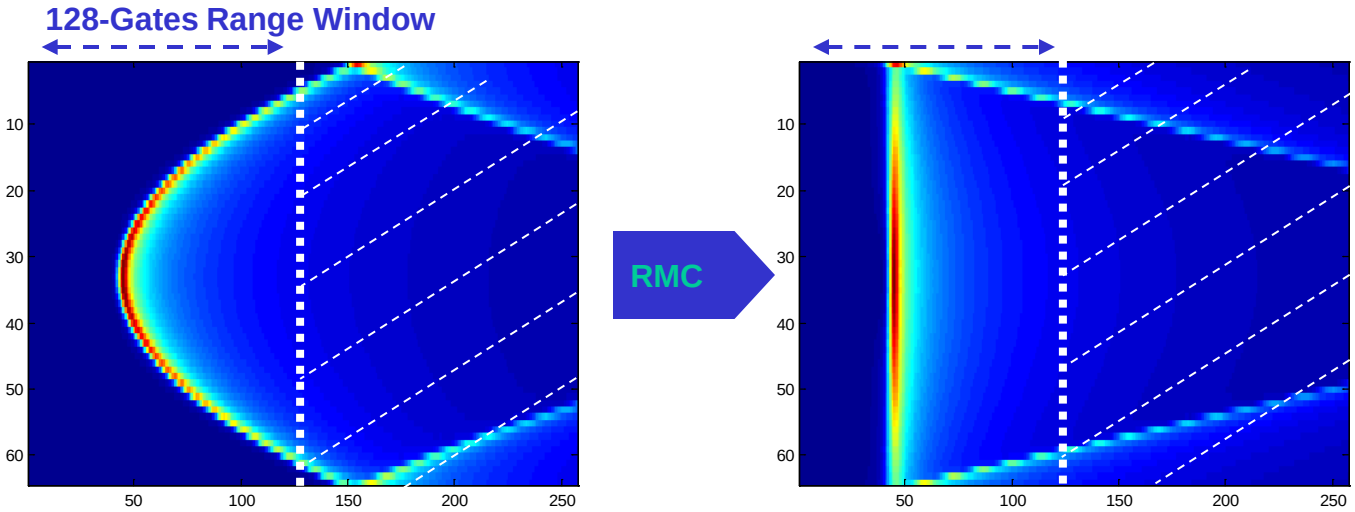



All rights reserved, 2007, Thales Alenia Space

# RMC processing principle for J-CS

- **Range Migration Correction (RMC)**
  - On board re-alignement to compensate range migration ~120 gates, in order to keep the most informative data
  - RMC shall be “reversible” on-ground
  - Complex data (I & Q data) after RMC will be downlinked

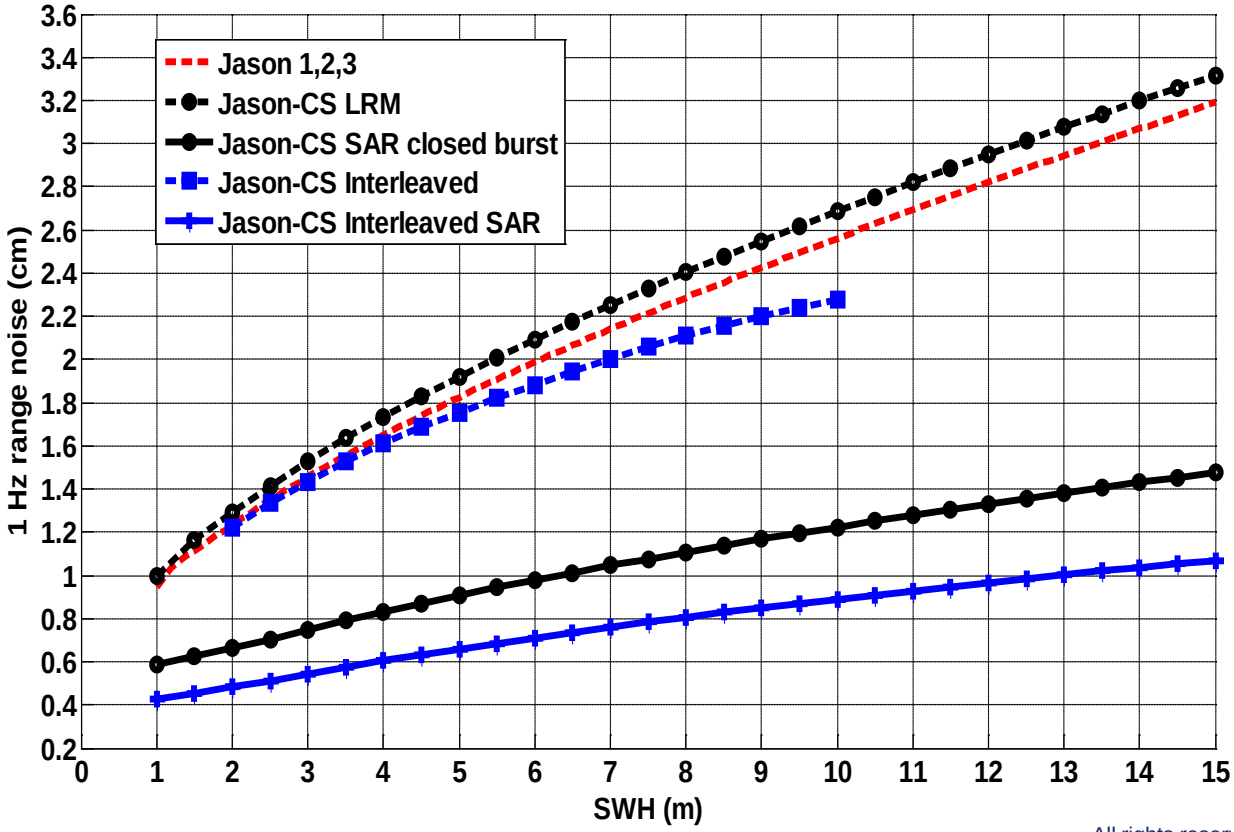



All rights reserved, 2007, Thales Alenia Space

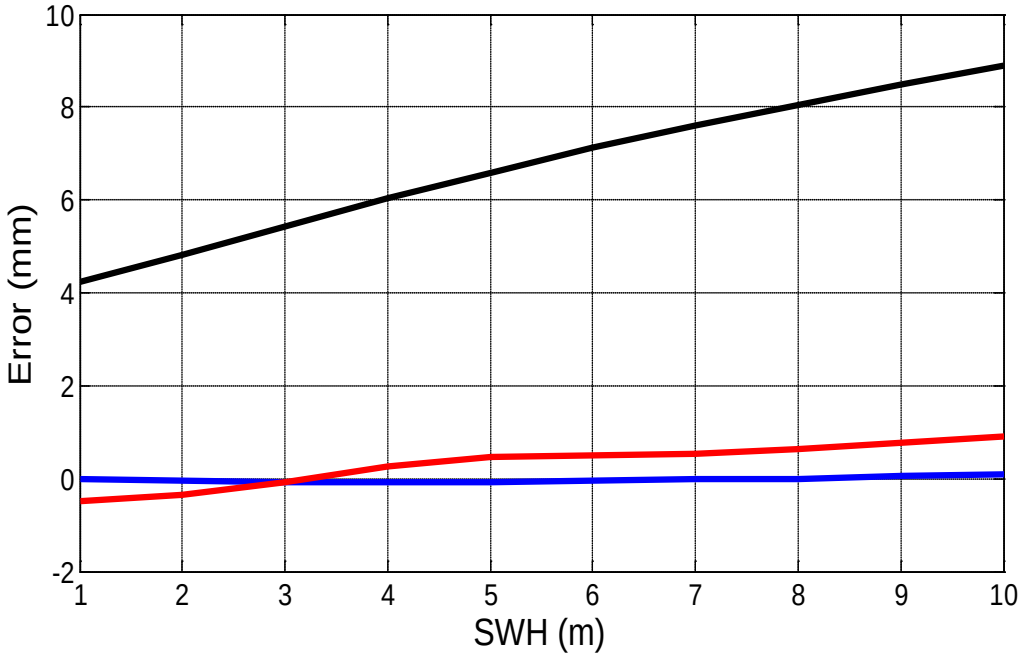
# J-CS POS-4 Range Noise

- **Range noise estimation**
  - Methodology and echo modeling validated against in flight SAR-SIRAL data
  - Numerical model of echoes including azimuth aliasing + speckle / thermal noise
  - RMC effect has also been assessed




All rights reserved, 2007, Thales Alenia Space

# Impact of RMC




**Range noise (1Hz)**

**Max error with RMC**

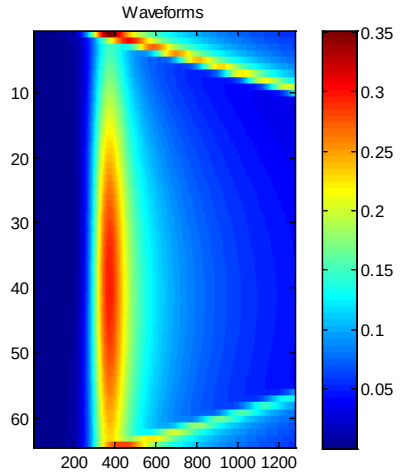
**Reference (no RMC)**

- **Re-tracking simulation with / without RMC**
- **Max error due to the RMC is less than 1mm [1-10 m] SWH**
- **Multi-looking strategy should reduce even further the RMC impact**
- **Keep in mind the residual of EMB correction !**

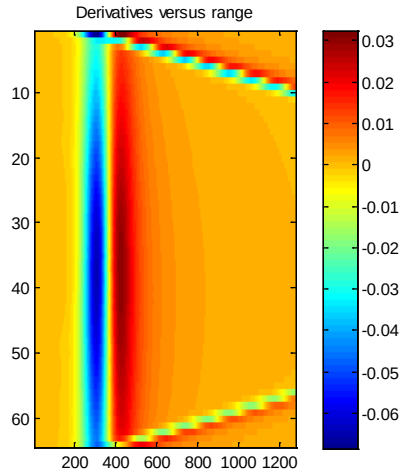
All rights reserved, 2007, Thales Alenia Space

# The antenna pointing issue

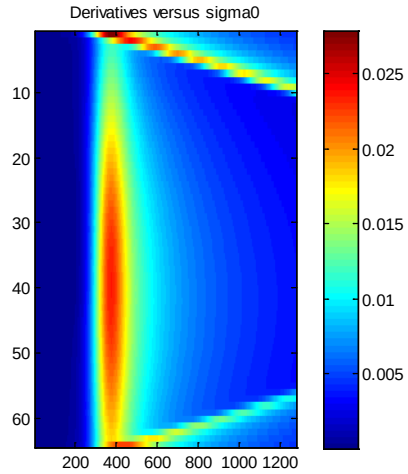
Power P



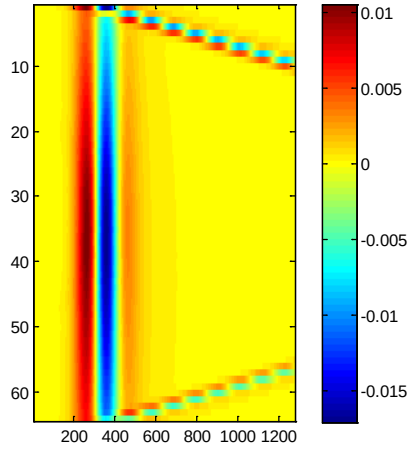

dP/dR



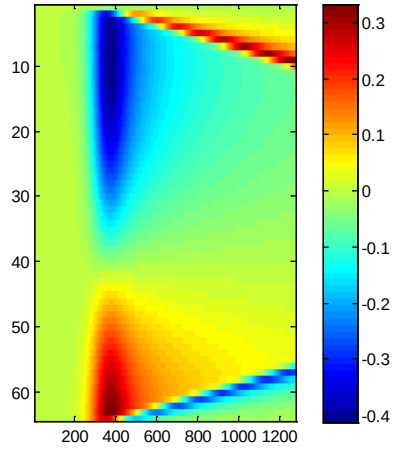

dP/dσo



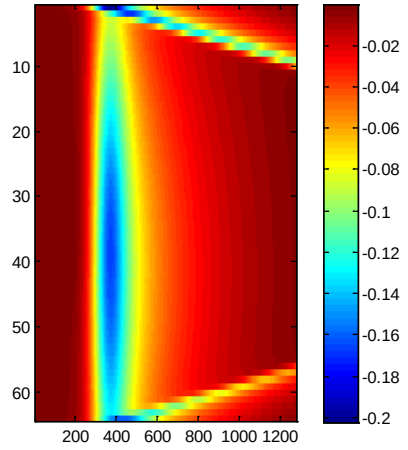

dP/dSWH




dP/dAT Ant. Pointing




dP/dXT Ant. Pointing

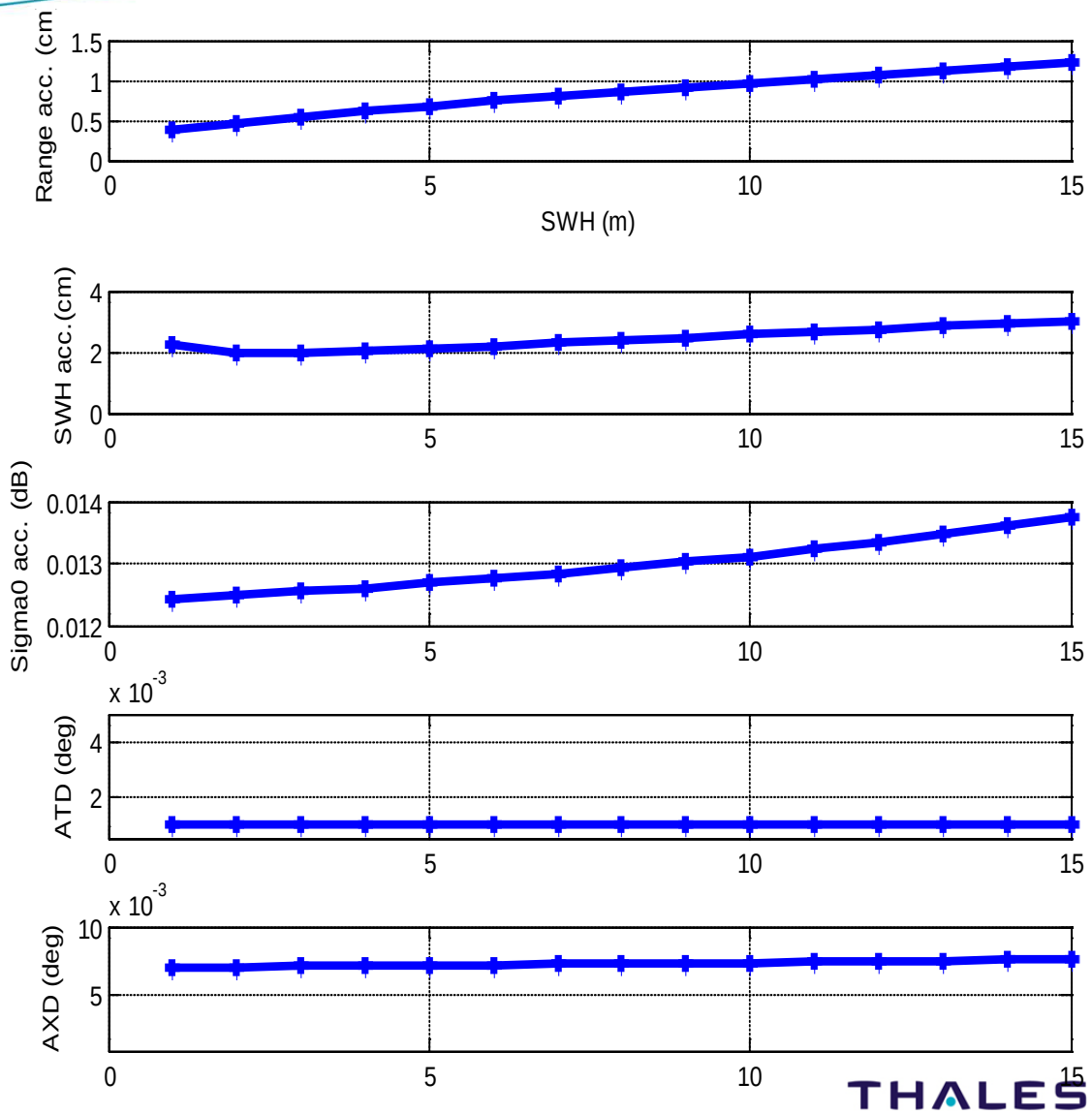



All rights reserved, 2007, Thales Alenia Space

# 2D Re-tracking : Retrieval Noise

**2D Retracking of :**

- **Range**
- **SWH**
- **Sigma0**
- **Along Track Depointing (ATD)**
- **Across Track Depointing (AXD)**




All rights reserved, 2007, Thales Alenia Space

# Conclusions

- Interleaved chronogram allows continuous data take over the ocean : data can be processed on ground either in the conventional LRM mode or in the SAR mode to improve significantly the range noise (factor 2-3)
- JCS : opportunity to compare and validate both mode against each other
- The Interleaved mode is well suited to the new hardware architecture of POS4 (range pulse compression instead of deramp)
- No risk : value for money !
- POS4 will pave the way to the future of operational altimetry with higher spatial resolution / smaller range noise
- 2D SAR data open a vast field of research for ocean / coastal / inland water

All rights reserved, 2007, Thales Alenia Space