living planet symposium

esa

Enhancing Envisat ASAR WSM segments to detect oil spills in the framework of the "20 years of oil routes" project

VisioTerra

Université de Marne-la-Vallée

Serge RIAZANOFF VisioTerra serge.riazanoff@visioterra.fr

Kévin GROSS UPEMLV kgross01@etudiant.univ-mlv.fr

9–13 September 2013 | Edinburgh, UK

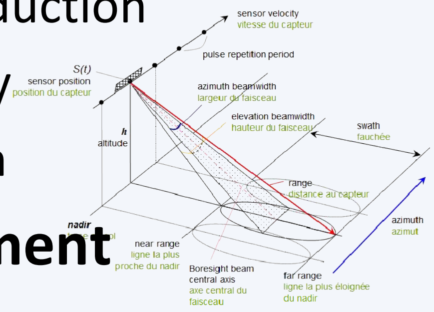
European Space Agency

Agenda

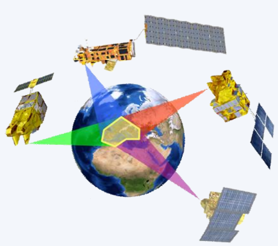
- **Presentation of VisioTerra**
  - Optical / Radar experience - Software development
  - Collaboration with ESA
  - The “20 years of oil routes” project
- **The Envisat ASAR WSM product**
  - Acquisition geometry
  - Normalized Radar Cross Section (NRCS)
  - Gain at sub-swath junctions
  - Homogenization of mean (m_0) and standard deviation (σ_0)
- **C-Models**
  - From Digital Number (DN) to sigma0
  - CMOD4, CMOD5, CMOD5.N
  - Retrieving V and ϕ
- **Sub-swath junctions**
  - Highlighting the defects
  - Piecewise adjustment
- **Conclusions**

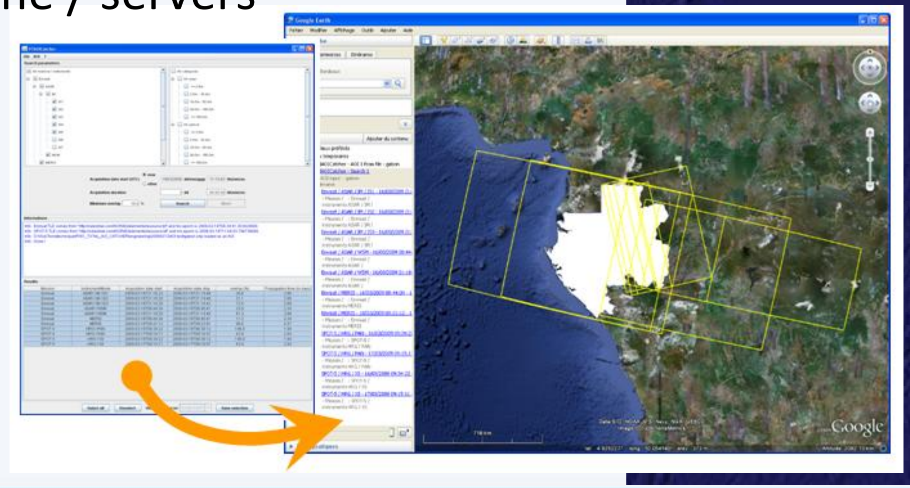
Presentation of VisioTerra

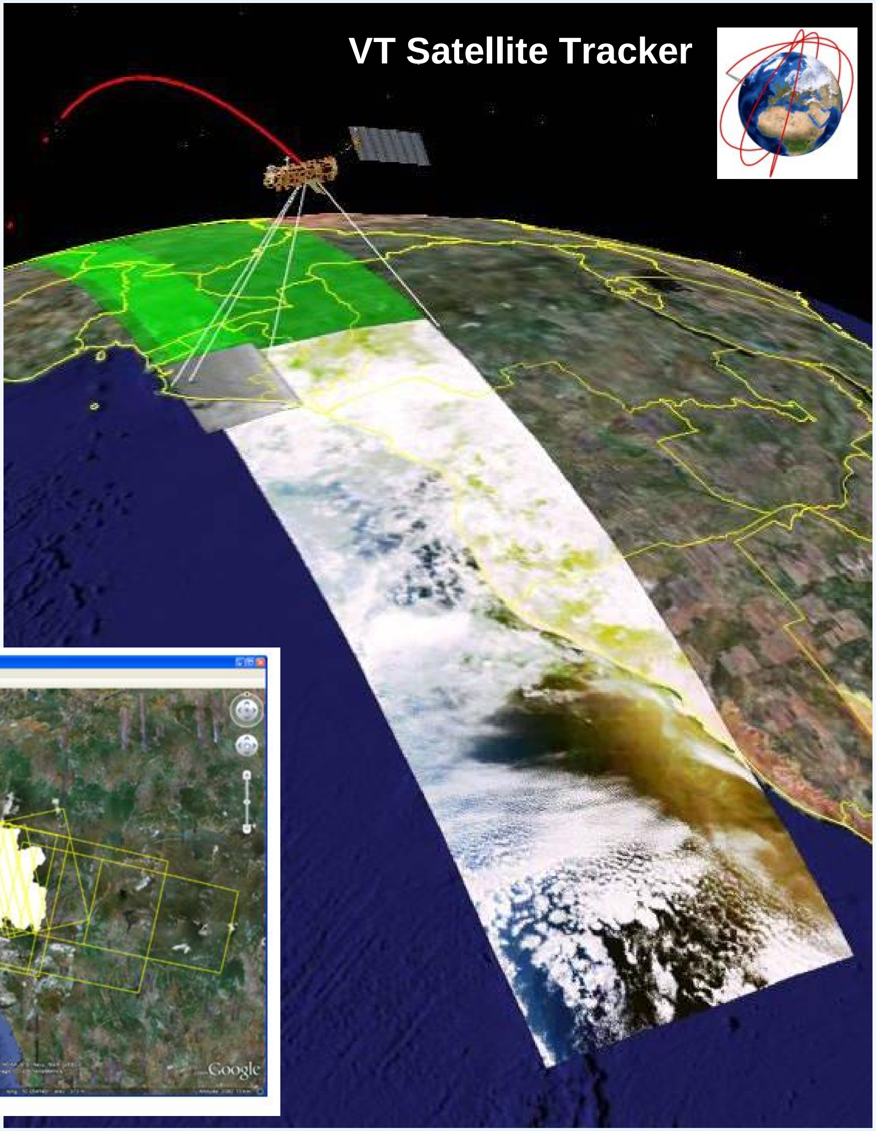
- **Optical / Radar experience**
  - Image processing (training)
  - Cartographic production
  - Viewing geometry
  - Orbit propagation



- **Software development**
  - Virtual globes
  - Stand-alone / servers



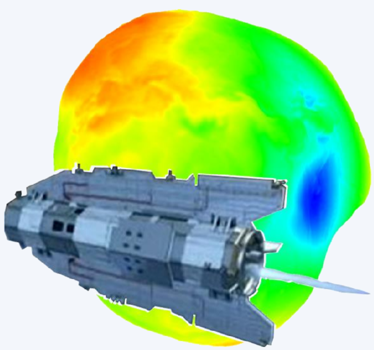


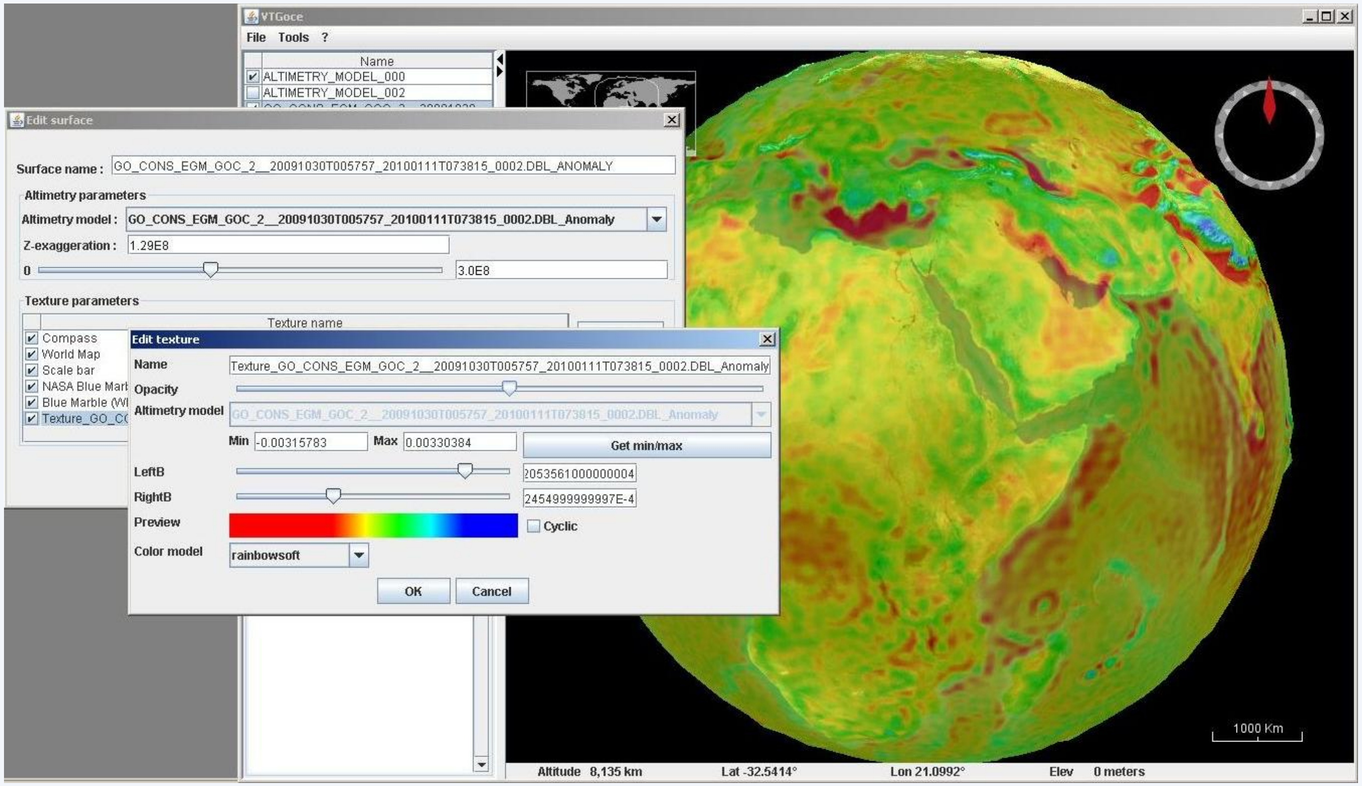


Presentation of VisioTerra

- **Collaboration with ESA**
  - GAEL Consultant - Since 1994
  - Quality control of ESA products
  - Envisat MERIS
  - VTGoce

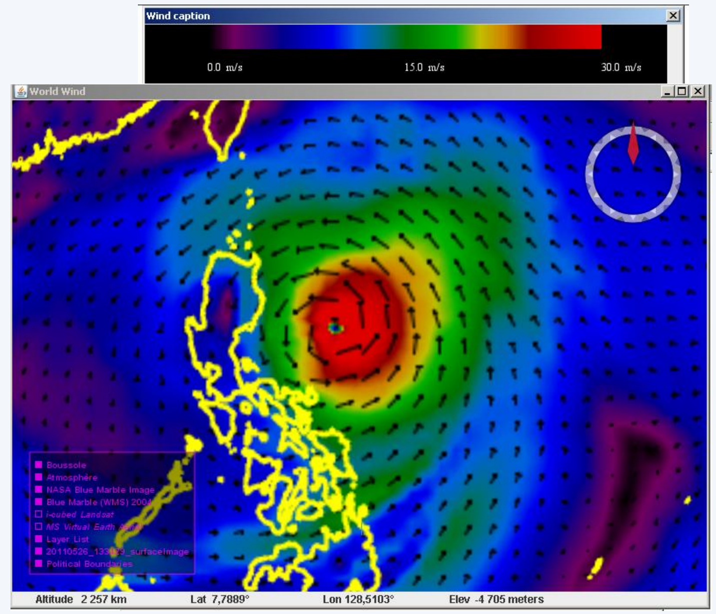
VTGoce



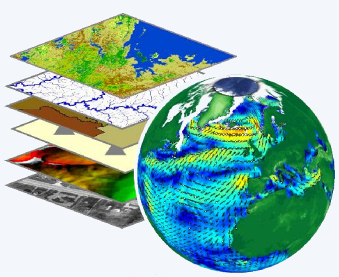


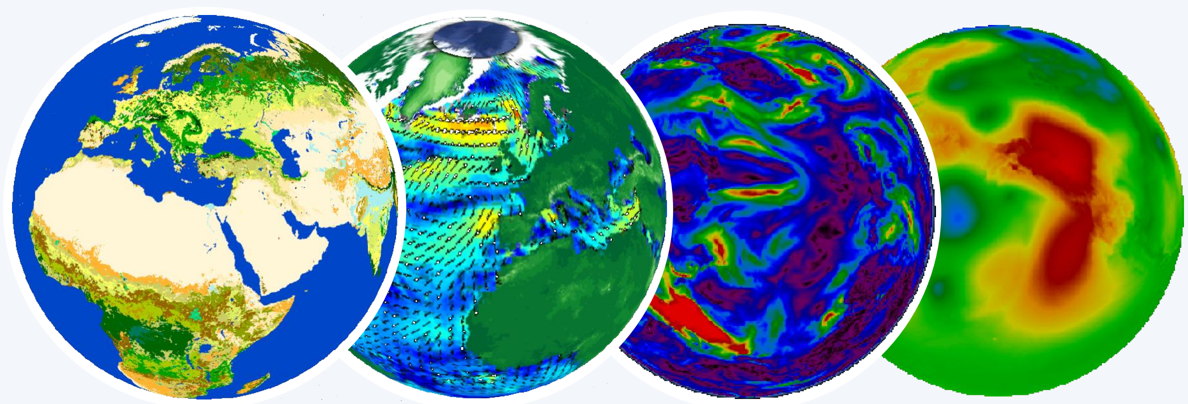
Presentation of VisioTerra

- **Diversity of data providers**
  - Huge amount of data Globcover (ESA)
  - More data providers
  - Free data policy
  - Interoperability OGC standards
  - Consumers may produce data



VT Escape

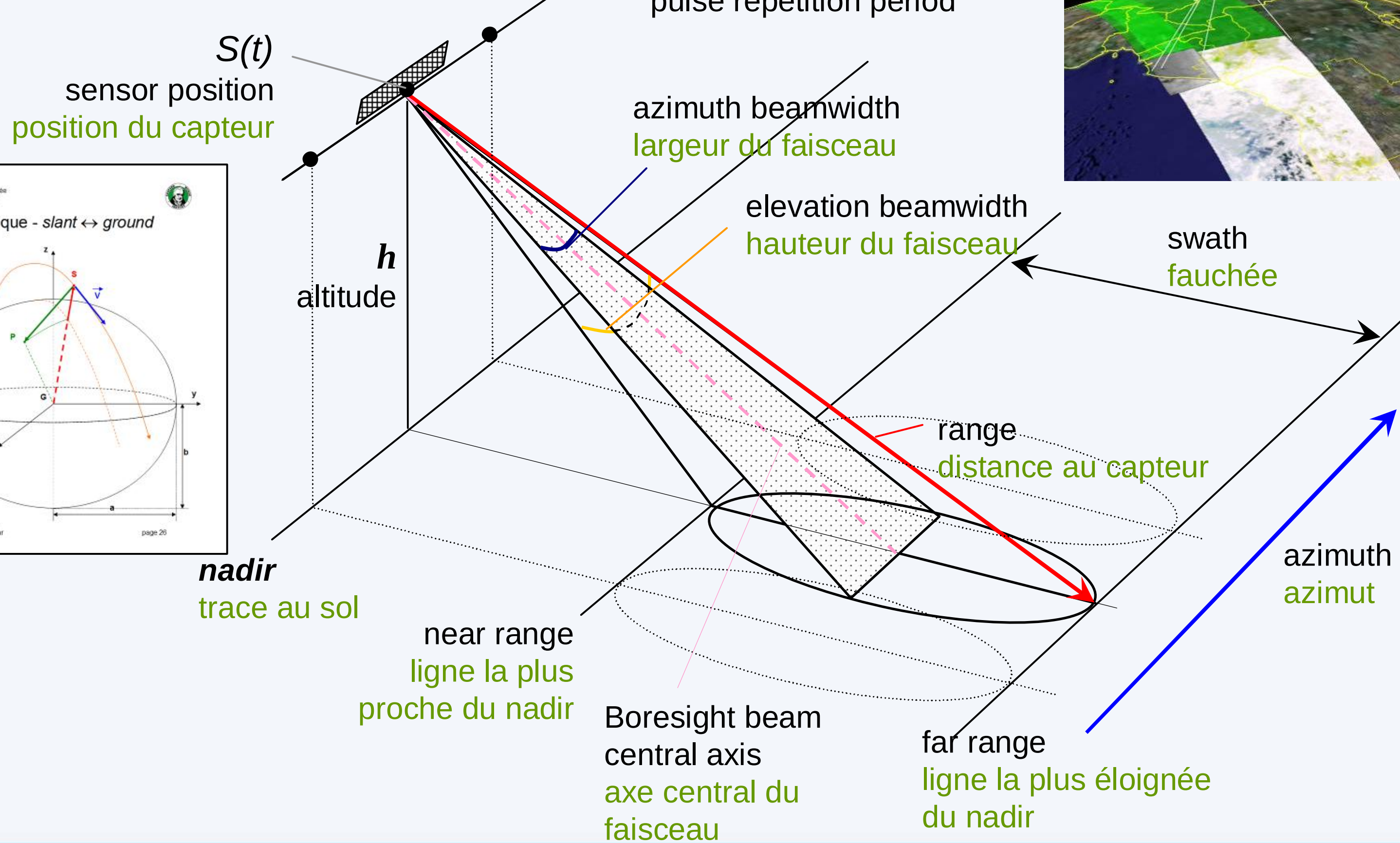


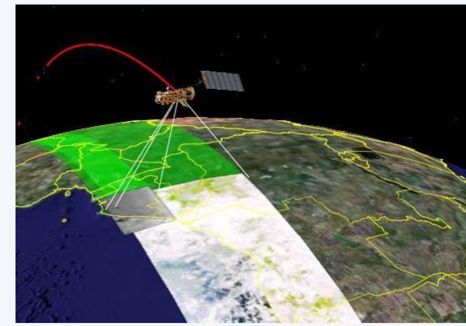


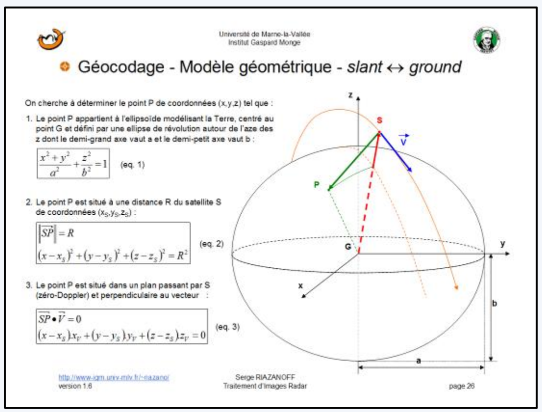
The Envisat ASAR WSM product

- **Acquisition geometry**

RADAR ↔ **RA**dio **D**etection **A**nd **R**anging







Université de Marne-la-Vallée
Institut Gaspard Monge

Géocodage - Modèle géométrique - *slant* ↔ *ground*

On cherche à déterminer le point P de coordonnées (x,y,z) tel que :

1. Le point P appartient à l'ellipsoïde modélisant la Terre, centré au point G et défini par une ellipse de révolution autour de l'axe des z dont le demi-grand axe vaut a et le demi-petit axe vaut b :

$$\frac{x^2+y^2}{a^2}+\frac{z^2}{b^2}=1 \quad \text{(eq. 1)}$$

2. Le point P est situé à une distance R du satellite S de coordonnées (x_S, y_S, z_S) :

$$\left\|\overrightarrow{SP}\right\| = R$$
$$(x-x_S)^2+(y-y_S)^2+(z-z_S)^2=R^2 \quad \text{(eq. 2)}$$

3. Le point P est situé dans un plan passant par S (zéro-Doppler) et perpendiculaire au vecteur :

$$\overrightarrow{SP}\bullet\overrightarrow{V}=0$$
$$(x-x_S).x_V+(y-y_S).y_V+(z-z_S).z_V=0 \quad \text{(eq. 3)}$$

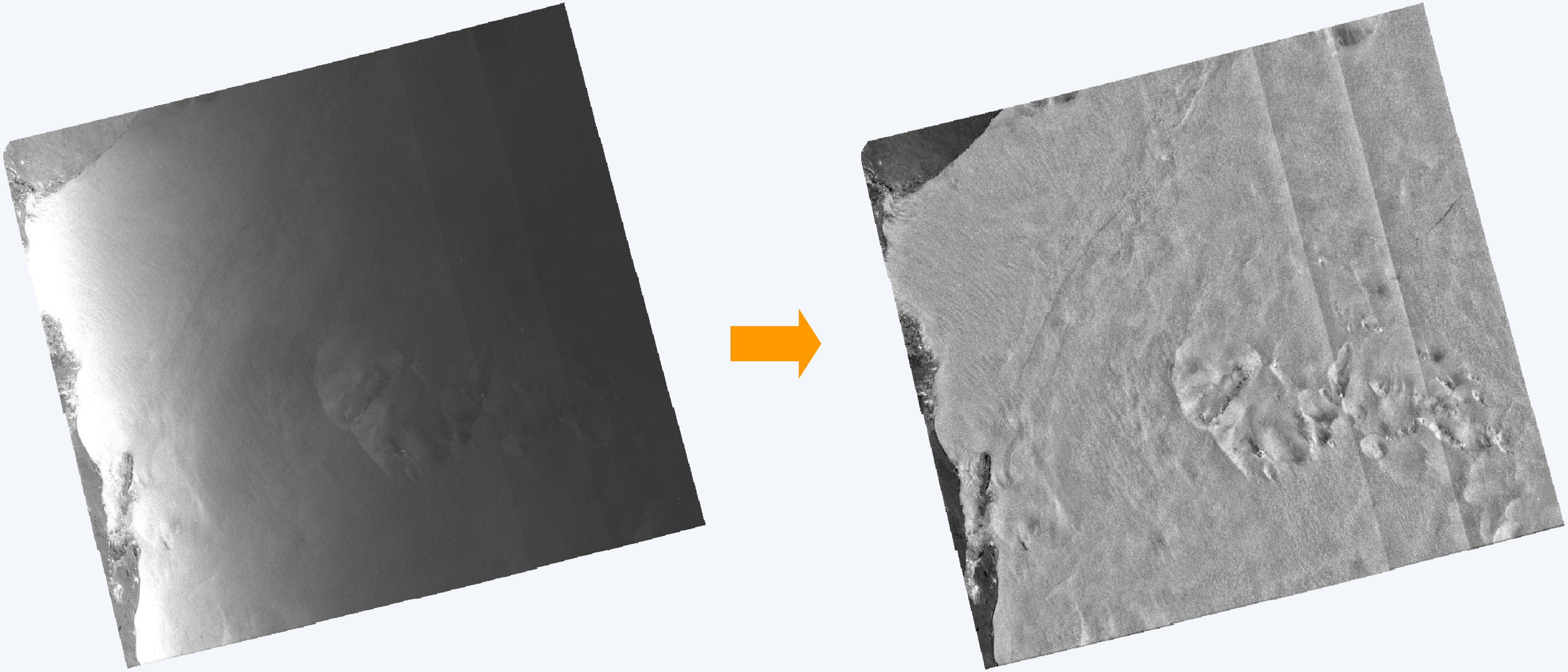
http://www-igm.univ-mlv.fr/~riazano/
version 1.6

Serge RIAZANOFF
Traitement d'Images Radar

page 26

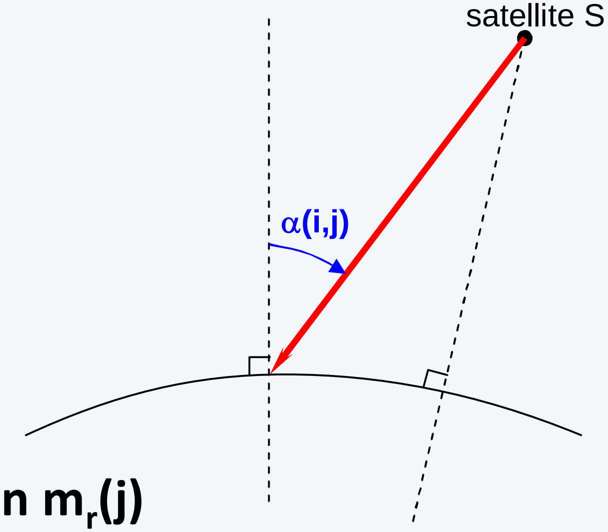
The Envisat ASAR WSM product

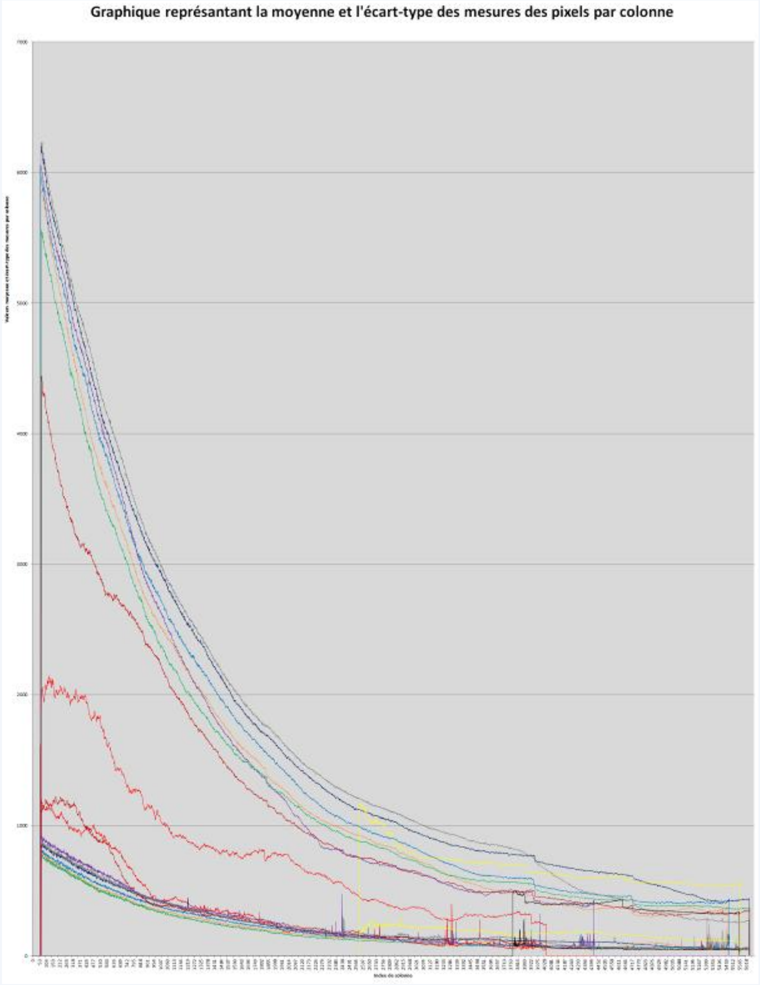
- **To normalize the mean (m_0) and the standard deviation (σ_0)**



The Envisat ASAR WSM product

- **Normalized Radar Cross Section (NRCS)**





  - **Mean $m_r(j)$**

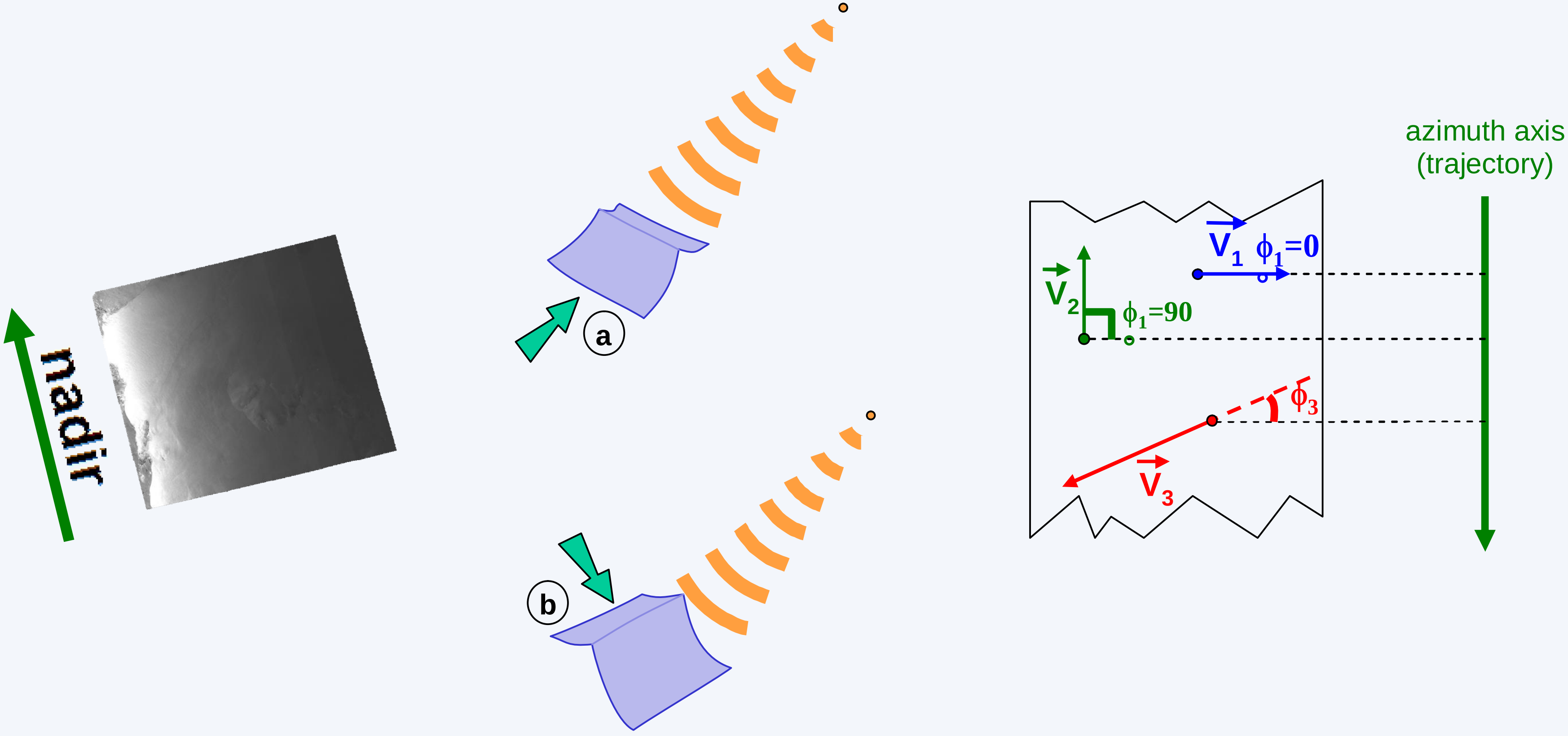
$$m_r(j) = \frac{1}{\sum_{i=0}^{M-1} \delta(i,j)} . \sum_{i=0}^{M-1} \delta(i,j) \times r(i,j)$$

  - **Standard deviation $\sigma_r(j)$**

$$\sigma_r(j) = \sqrt{\left(\frac{1}{\sum_{i=0}^{M-1} \delta(i,j)} . \sum_{i=0}^{M-1} \delta(i,j) \times r^2(i,j) \right) - \left(m_r(j) \right)^2}$$

C-Models

- **The backscattering coefficient (σ0) as a function of the wind speed (V) and azimuth (ϕ)**



C-Models

- **From Digital Number (DN) to sigma0 (M(j))**

$$\overline{M}(j) = b_{lin}(j) = \frac{\left(\overline{m_r}(j)\right)^2}{K} \times \sin(\overline{\theta}(j))$$

- **CMOD4**

$$\boxed{\dot{M}_{CMOD4}(V,\phi,\theta) = b_0\left(1 + b_1\cos\phi + b_3\tanh b_2\cos 2\phi\right)^{1.6}}$$

$$b_0 = b_R 10^{\alpha + \gamma . f_1(V+\beta)}$$

$$f_1 = \begin{cases} -10 & , \quad s \le 10^{-10} \\ \log(s) & , \quad 10^{-10} < s \le 5 \\ \sqrt{s}/3.2 & , \quad s > 5 \end{cases}$$

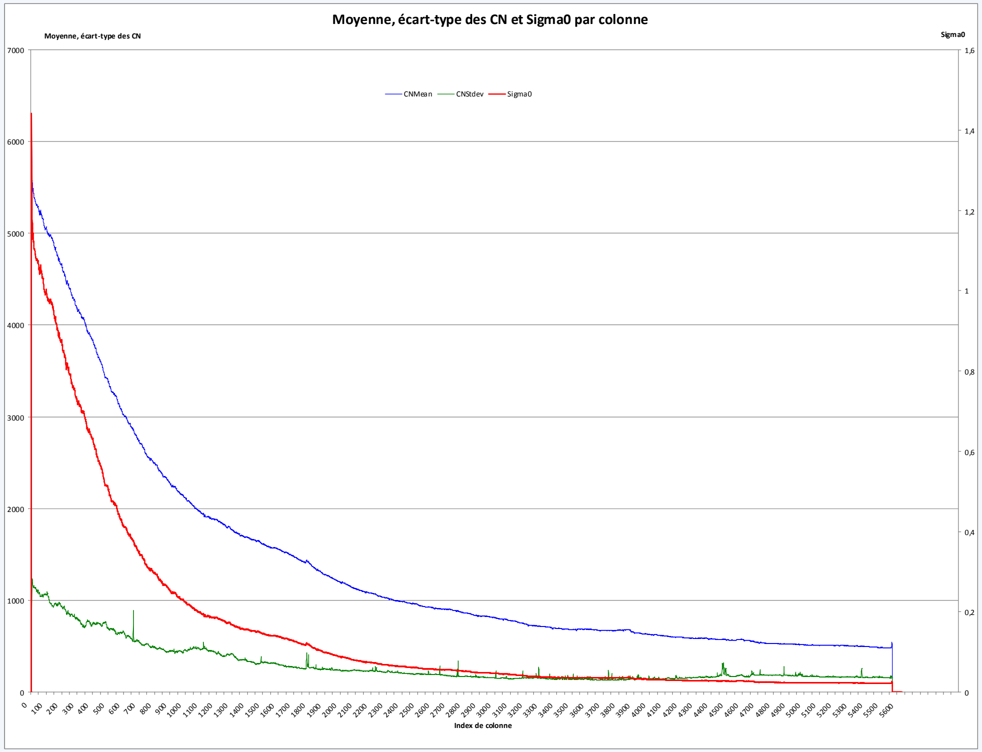
$$\alpha = c_1 P_0 + c_2 P_1 + c_3 P_2$$

$$\gamma = c_4 P_0 + c_5 P_1 + c_6 P_2$$

$$\beta = c_7 P_0 + c_8 P_1 + c_9 P_2$$

$$b_1 = c_{10} P_0 + c_{11} V + \left(c_{12} P_0 + c_{13} V\right). f_2(x)$$

…



Paramètre	Coefficient	Valeur	Paramètre	Coefficient	Valeur
α	c_1	-2.301523	b_1	c_{10}	0.014430
	c_2	-1.632686		c_{11}	0.002484
	c_3	0.761210		c_{12}	0.074450
γ	c_4	1.156619		c_{13}	0.004023
	c_5	0.595955	b_2	c_{14}	0.148810
	c_6	-0.293819		c_{15}	0.089286
β	c_7	-1.015244	b_3	c_{16}	-0.006667
	c_8	0.342175		c_{17}	3.000000
	c_9	-0.500786		c_{18}	-10.000000

θ (°)	b_R	θ (°)	b_R	θ (°)	b_R
16	1.075	31	0.927	46	1.054
17	1.075	32	0.923	47	1.053
18	1.075	33	0.930	48	1.052
19	1.072	34	0.937	49	1.047
20	1.069	35	0.944	50	1.038
21	1.066	36	0.955	51	1.028
22	1.056	37	0.967	52	1.016
23	1.030	38	0.978	53	1.002
24	1.004	39	0.988	54	0.989
25	0.979	40	0.998	55	0.965
26	0.967	41	1.009	56	0.941
27	0.958	42	1.021	57	0.929
28	0.949	43	1.033	58	0.929
29	0.941	44	1.042	59	0.929
30	0.934	45	1.050	60	0.929

C-Models

- **CMOD5**

$$\dot{M}_{CMOD5}(V,\phi,\theta)=b_0(1+b_1\cos\phi+b_2\cos 2\phi)^{1.6}$$

$$x=(\theta-40)/25$$

$$b_0=10^{a_0+a_1V}.f(a_2V,s_0)^{\gamma}$$

$$f(s,s_0)=\begin{cases}(s/s_0)^{\alpha}g(s_0) & , \quad s<s_0\\ g(s) & , \quad s\geq s_0\end{cases}$$

$$g(s)=\frac{1}{1+e^{-s}}$$

$$\alpha=x_0.[1-g(s_0)]$$

$$a_0=c_1+c_2x+c_3x^2+c_4x^3$$

$$a_1=c_5+c_6x$$

$$a_2=c_7+c_8x$$

$$\gamma=c_9+c_{10}x+c_{11}x^2$$

$$s_0=c_{12}+c_{13}x$$

$$b_1=\frac{c_{14}(1+x)-c_{15}V.[0.5+x-\tanh[4.(x+c_{16}+c_{17}V)]]}{1+e^{0.34(V-c_{18})}}$$

...

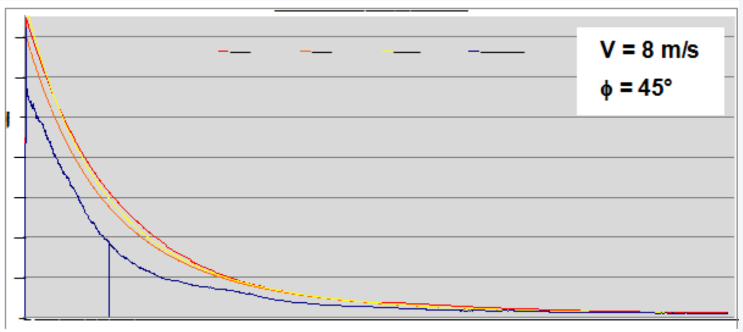
- **CMOD5.N**

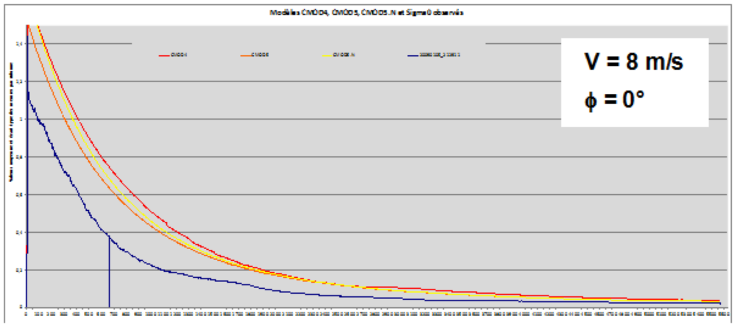
Paramètre	Coefficient	Valeur	Paramètre	Coefficient	Valeur
a_0	c_1	-0.688		c_{15}	0.007
	c_2	-0.793		c_{16}	0.33
	c_3	0.338		c_{17}	0.012
	c_4	-0.173		c_{18}	22.0
a_1	c_5	0.0	y_0	c_{19}	1.95
	c_6	0.004		c_{20}	3.0
a_2	c_7	0.111	V_0	c_{21}	8.39
	c_8	0.0162		c_{22}	-3.44
γ	c_9	6.34		c_{23}	1.36
	c_{10}	2.57	d_1	c_{24}	5.35
	c_{11}	-2.18		c_{25}	1.99
s_0	c_{12}	0.4		c_{26}	0.29
	c_{13}	-0.6	d_2	c_{27}	3.80
b_1	c_{14}	0.045		c_{28}	1.53

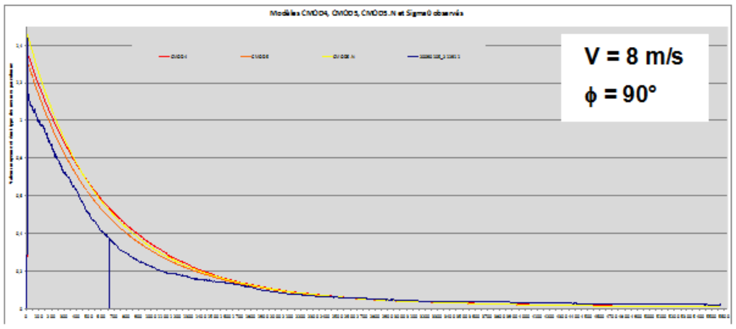
	CMOD5	CMOD5.N		CMOD5	CMOD5.N
c1	-0.6880	-0.6878	c15	0.0070	0.0066
c2	-0.7930	-0.7957	c16	0.3300	0.3222
c3	0.3380	0.3380	c17	0.0120	0.0120
c4	-0.1730	-0.1728	c18	22.000	22.700
c5	0.0000	0.0000	c19	1.9500	2.0813
c6	0.0040	0.0040	c20	3.0000	3.0000
c7	0.1110	0.1103	c21	8.3900	8.3659
c8	0.0162	0.0159	c22	-3.4400	-3.3428
c9	6.3400	6.7329	c23	1.3600	1.3236
c10	2.5700	2.7713	c24	5.3500	6.2437
c11	-2.1800	-2.2885	c25	1.9900	2.3893
c12	0.4000	0.4971	c26	0.2900	0.3249
c13	-0.6000	-0.7250	c27	3.8000	4.1590
c14	0.0450	0.0450	c28	1.5300	1.6930

C-Models

- **Best fit with one of the 3 models**







$$\overline{M}(j) \approx B(V,\phi) \times \dot{M}_{\text{mod}}(V,\phi,\overline{\theta}(j))$$

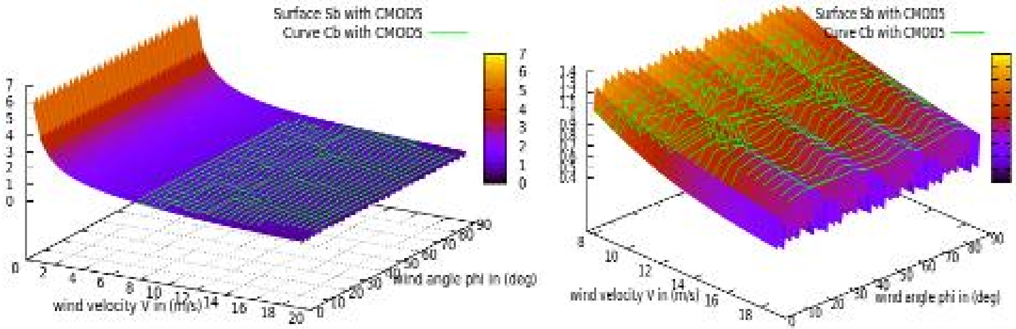
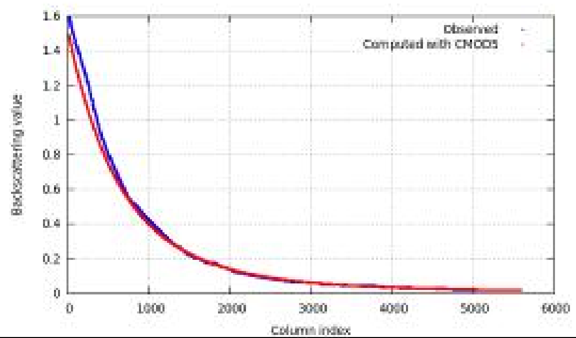
$$E(S_k, M, B, V, \phi) = \sqrt{\frac{1}{\sum_{j=0}^{N-1}\delta(j)} \times \sum_{j=0}^{N-1}\delta(j) \times \left[\overline{M}(j) - B \times \dot{M}_{\text{mod}}(V,\phi,\overline{\theta}(j))\right]^2}$$

$$\Rightarrow B(V,\phi) = \frac{\sum_{j=0}^{N-1}\delta(j) \times \overline{M}(j) \times \dot{M}_{\text{mod}}(V,\phi,\overline{\theta}(j))}{\sum_{j=0}^{N-1}\delta(j) \times \dot{M}_{\text{mod}}(V,\phi,\overline{\theta}(j))^2}$$

$$r(V,\phi) = \frac{\sum_{j=0}^{N-1}\delta(j) \times \left[\overline{M}(j) - \overline{\overline{M}}\right] \times \left[\dot{M}_{\text{mod}}(V,\phi,\overline{\theta}(j)) - \overline{\dot{M}_{\text{mod}}}(V,\phi)\right]}{\sqrt{\sum_{j=0}^{N-1}\delta(j) \times \left[\overline{M}(j) - \overline{\overline{M}}\right]^2} \times \sqrt{\sum_{j=0}^{N-1}\delta(j) \times \left[\dot{M}_{\text{mod}}(V,\phi,\overline{\theta}(j)) - \overline{\dot{M}_{\text{mod}}}(V,\phi)\right]^2}}$$

C-Models

- **Best fit results**

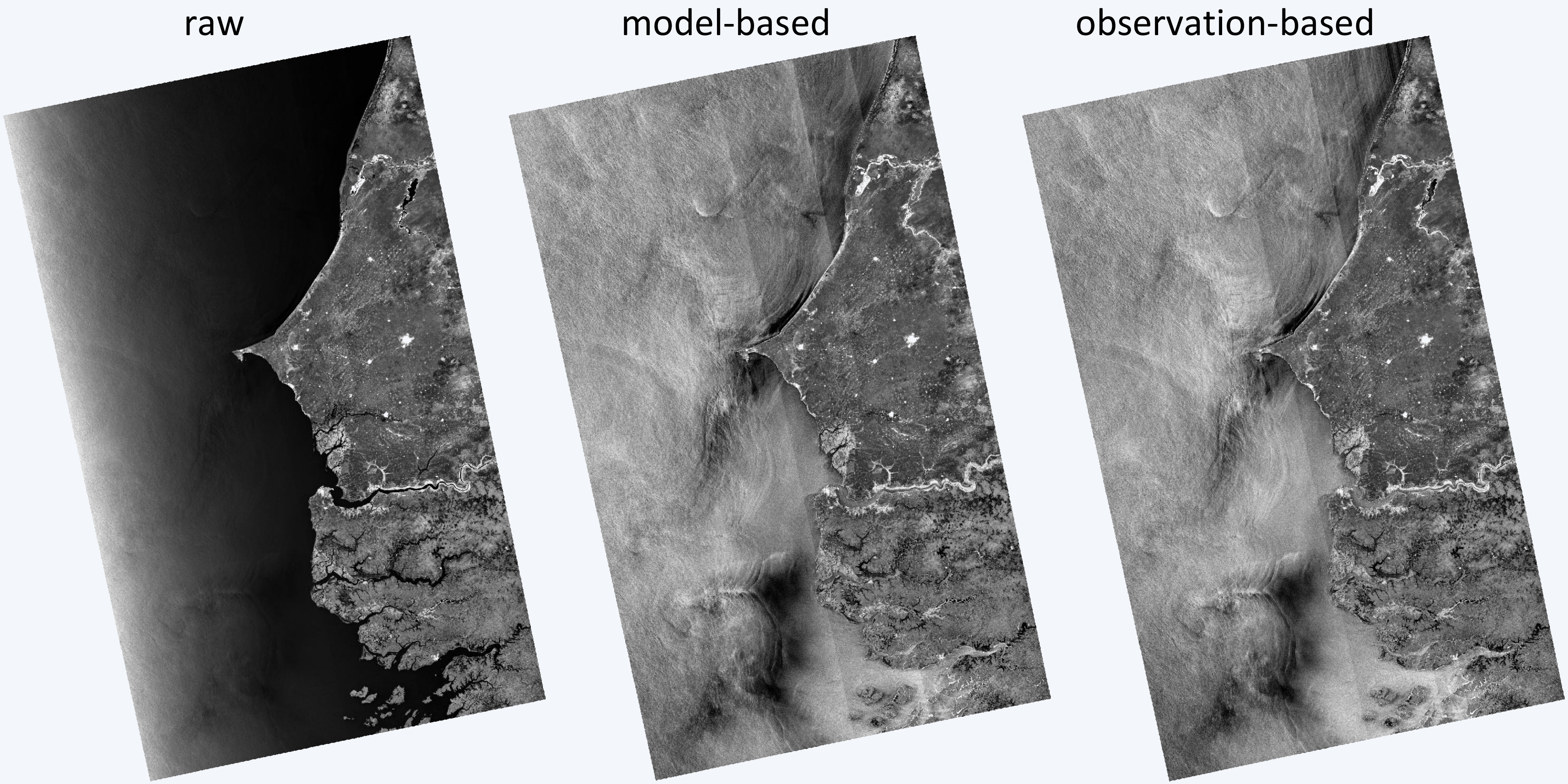
Moyenne	CMOD5
$S_b(v, \phi)$ C_b	
Meilleur tuple (v, ϕ, r_{max})	(9.00, 48.00, 0.999264)
Coefficient de rétrodiffusion	

0,930725	4,9	43,5	0,949304	5,5	37,0	0,947753	0,22
0,986569			0,986515			0,986314	

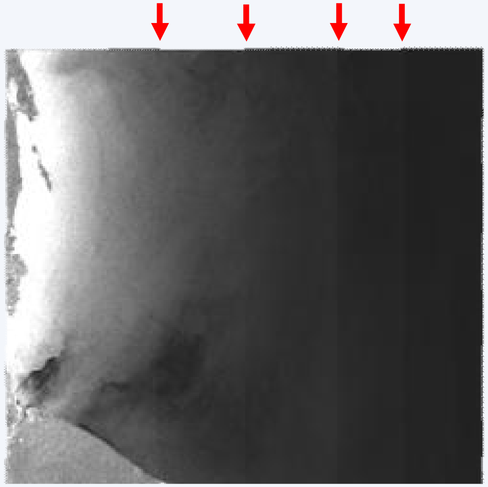
Image	B									α	r	K (ACF)	V moyen	V Ecart-type
	CMOD4			CMOD5			CMOD5N							
	V	ϕ	rmax	V	ϕ	rmax	V	ϕ	rmax					
ASA_WSM_1PNDPA20040309_085508	2,0	0	0,979619	1,5	0	0,967188	2,0	0	0,965554	0,222658	0,972531	7413102,5	1,8	0,29
							4,0	56	0,966026	0,224603	0,970043	7413102,5	3,3	0,58
							3,0	13	0,997512	0,172161	0,892623	7413102,5	2,7	0,29
							3,0	0	0,992299	0,386743	0,984809	6729766,5	2,7	0,29
							3,0	50	0,998974	0,247318	0,976672	6729766,5	2,7	0,29
							3,0	12	0,997700	0,247596	0,975561	6729766,5	2,7	0,29
							3,5	0	0,991543	0,267119	0,955440	6729766,5	3,3	0,29
							5,5	16	0,999627	0,145136	0,981957	6309573,5	5,2	0,29
							2,0	0	0,997486	0,448677	0,990901	7413102,5	2,0	0,50
							5,5	19	0,990840	0,150216	0,976307	7413102,5	4,7	0,76
							6,5	80	0,999789	0,165981	0,972629	6309573,5	5,2	1,53
							4,0	0	0,992506	0,279617	0,993095	6309573,5	3,8	0,29
							7,0	52	0,999847	0,139121	0,999211	7413102,5	5,5	1,80
							0,5	0	0,915226	0,482763	0,985998	7413102,5	0,2	0,29
							5,0	57	0,999081	0,172004	0,873289	6309573,5	4,5	0,50
							4,0	67	0,999610	0,254181	0,957350	6309573,5	3,5	0,50
							6,5	31	0,990703	0,158800	0,960978	6309573,5	6,0	0,50
							2,0	38	0,995947	0,307495	0,989291	6309573,5	2,0	0,50
							0,0	0	0,000000	0,189097	0,959806	7413102,5	0,0	0,00
							5,5	75	0,992029	0,159287	0,979251	6309573,5	5,0	0,50
							14,0	33	0,999626	0,150591	0,994095	6309573,5	11,2	4,48
							5,5	0	0,981503	0,159319	0,954971	6309573,5	5,2	0,29
							5,0	0	0,998077	0,143329	0,983929	6309573,5	4,8	0,29
							7,0	25	0,973962	0,264938	0,980741	7413102,5	6,3	0,76
							6,0	9	0,986243	0,175618	0,993046	7413102,5	5,2	0,76
							7,0	0	0,999521	0,148888	0,999448	7413102,5	7,0	0,50
							6,0	75	0,987692	0,155926	0,973341	7413102,5	5,5	0,50
							7,5	50	0,994686	0,155588	0,876381	7413102,5	6,7	0,76
							5,5	0	0,984081	0,195313	0,969611	6309573,5	5,2	0,29
							7,0	78	0,653188	0,159632	0,903391	7413102,5	6,3	0,58
							3,5	6	0,992602	0,341105	0,978103	7413102,5	3,2	0,29
							2,5	0	0,997735	0,188013	0,979524	6309573,5	2,3	0,29
							8,0	23	0,999404	0,145988	0,982818	7413102,5	6,8	2,02
							7,0	65	0,995953	0,166552	0,994185	6309573,5	6,2	0,76
							4,5	47	0,998849	0,155426	0,992356	6309573,5	4,2	0,29
							5,5	75	0,986083	0,163603	0,977424	6309573,5	5,0	0,50
							17,0	71	0,999301	0,191986	0,976534	7413102,5	13,8	5,06
							0,0	0	0,000000	0,421362	0,970336	7413102,5	0,2	0,29
							5,0	50	0,991891	0,181738	0,981276	7413102,5	4,3	0,58
							18,0	77	0,993032	0,157223	0,972129	7413102,5	14,5	5,22
							5,5	86	0,999067	0,234573	0,993237	7413102,5	4,5	1,32
							4,5	19	0,987530	0,225394	0,931581	7413102,5	4,0	0,50
							2,0	31	0,989099	0,455402	0,968279	7413102,5	1,8	0,29
							8,5	86	0,998792	0,166941	0,969013	7413102,5	7,0	2,18
							9,5	4	0,999286	0,145316	0,997914	7413102,5	8,0	2,18
							6,0	62	0,998235	0,174444	0,925287	7413102,5	5,0	1,32
							5,5	54	0,997053	0,247740	0,919923	7413102,5	5,5	0,50
							12,5	74	0,999213	0,179291	0,980349	7413102,5	10,3	3,33
							5,5	56	0,981277	0,204802	0,966440	7413102,5	4,8	0,58
							3,5	31	0,993283	0,294407	0,990075	7413102,5	3,2	0,29
							5,0	56	0,994266	0,229077	0,986333	7413102,5	4,5	0,50
ASA_WSM_1PNPDE20100610_154405	3,0	7	0,999184	3,0	81	0,998771	3,5	75	0,998740	0,279080	0,971708	7413102,5	3,2	0,29
ASA_WSM_1PNPDE20100613_032858	3,0	0	0,999110	3,5	0	0,999397	4,5	75	0,999365	0,283574	0,993109	7413102,5	3,7	0,76
Moyenne	4,1	37,2	0,930725	4,9	43,5	0,949304	5,5	37,0	0,947753	0,221939	0,969333		4,8	0,9
Moyenne (EQN 95)			0,986569			0,986515			0,986314					

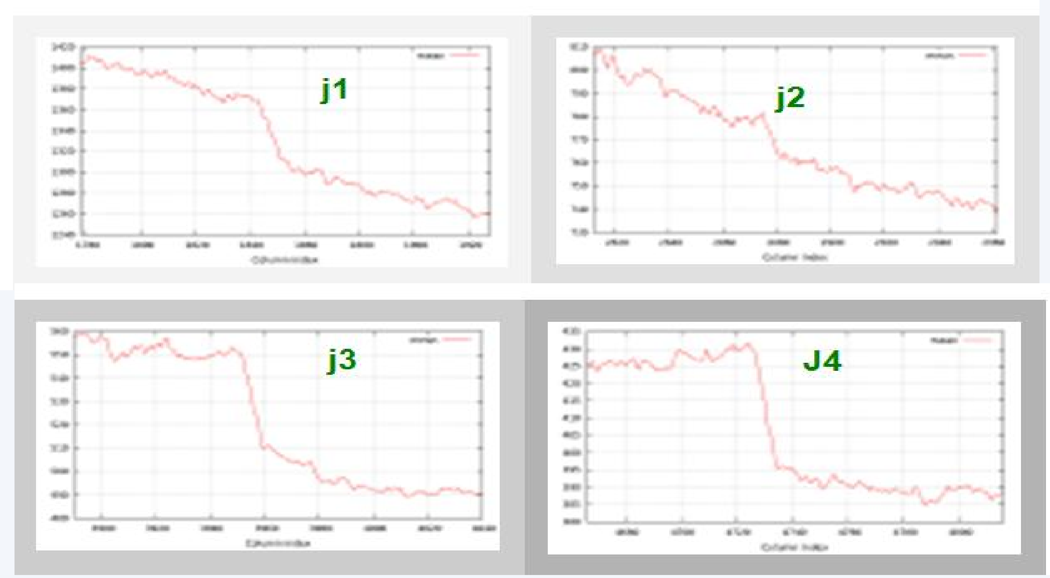
C-Models

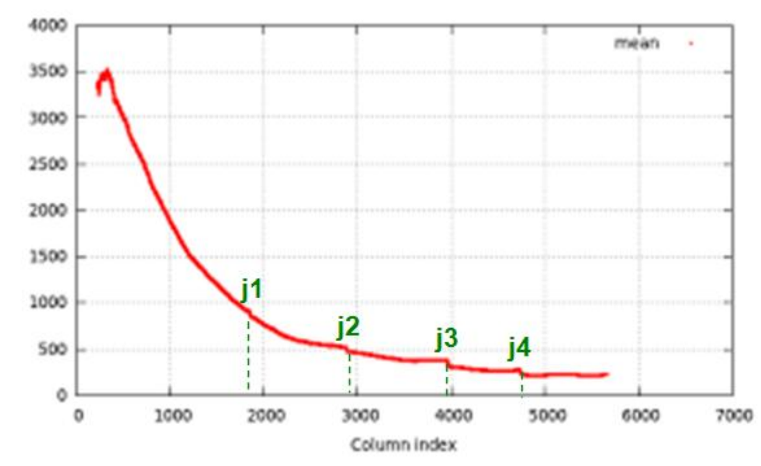
- **Applying a model-based equalization**

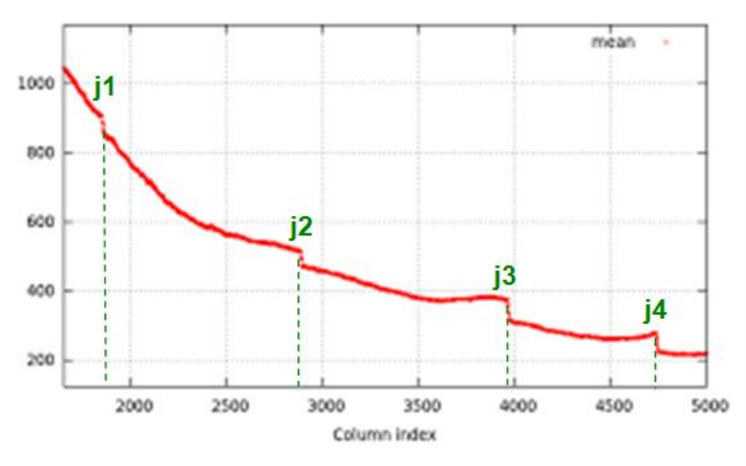


- **Observed defect**



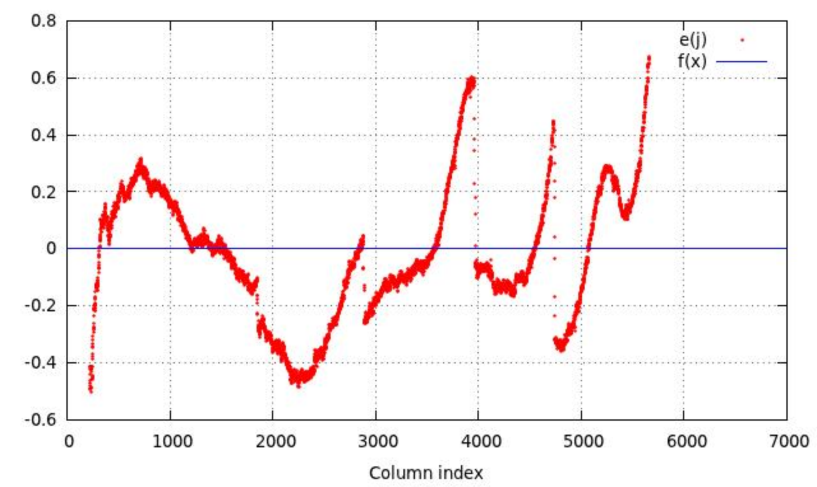


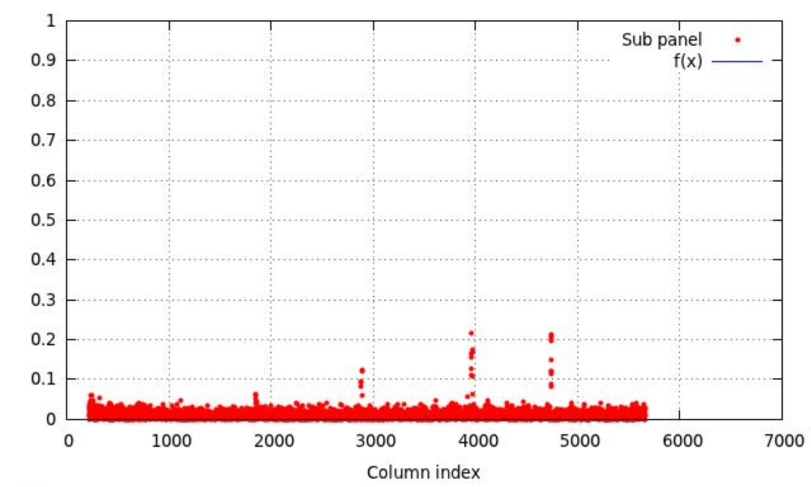




Sub-swath junctions

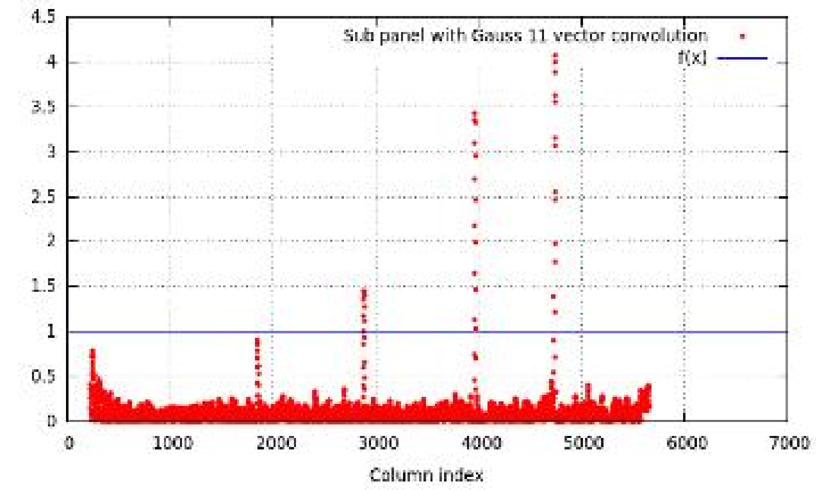
- **After C-MOD5 centering-reduction**





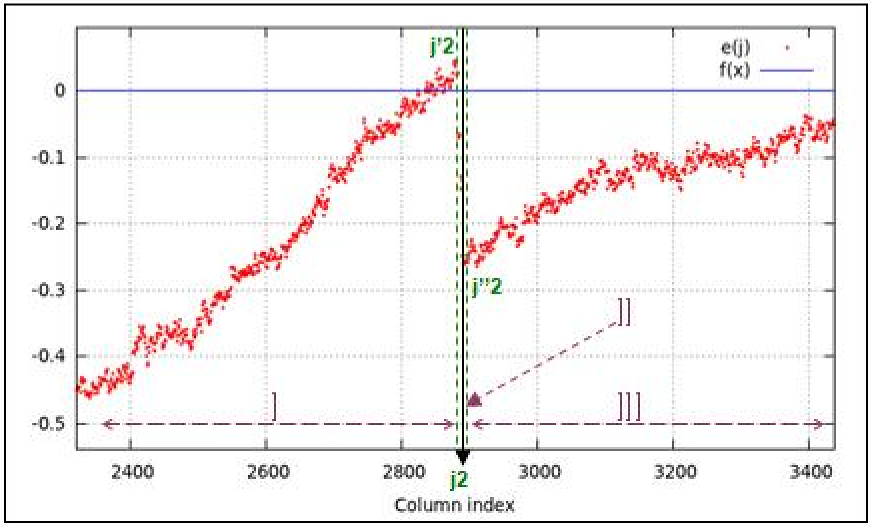
- **After differentiation**

- **After Gaussian convolution**

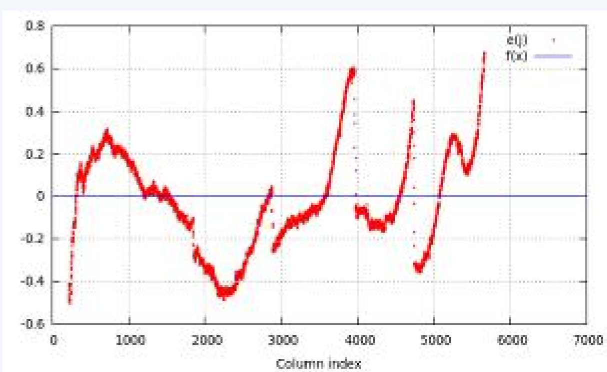


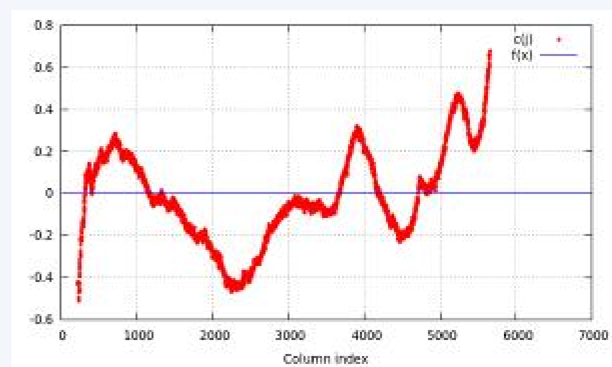
Sub-swath junctions

- **Semi-linear model**



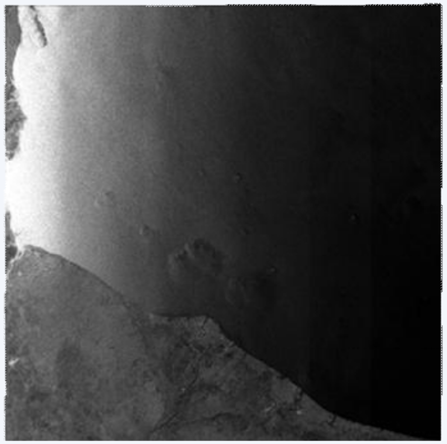
$$c_1(j) = \begin{cases} e(j) - \dfrac{e(j'_1) - e(j''_1)}{2} \times \dfrac{j}{j'_1} & si \quad 0 \le j \le j'_1 \\ \dfrac{e(j'_1) + e(j''_1)}{2} & si \quad j'_1 < j \le j'' \\ e(j) + \dfrac{e(j'_1) - e(j''_1)}{2} \times \dfrac{j - \dfrac{j_1 + j_2}{2}}{j''_1 - \dfrac{j_1 + j_2}{2}} & si \quad j''_1 < j \le \dfrac{j_1 + j_2}{2} \end{cases}$$

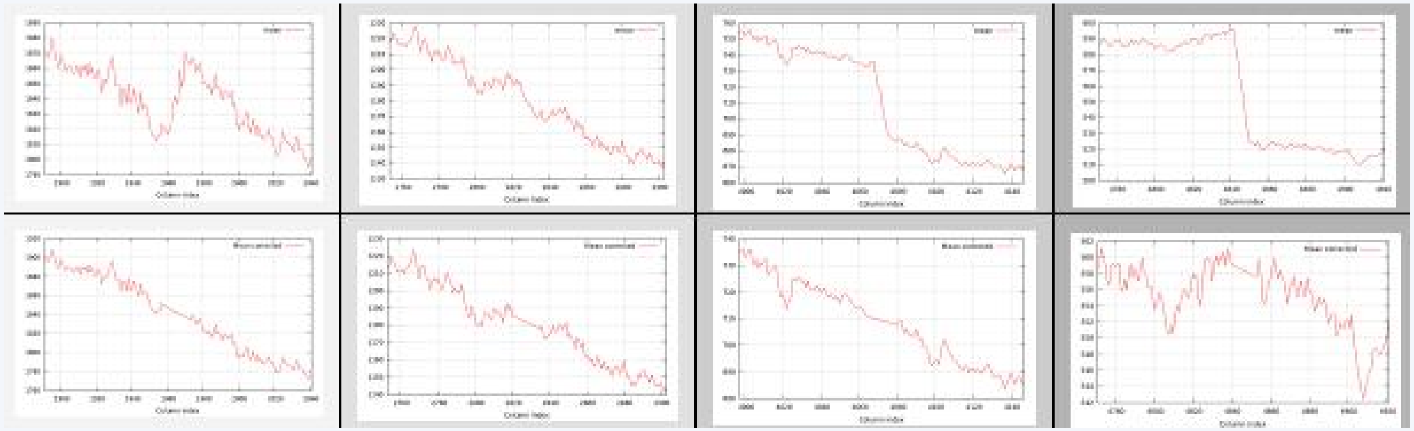


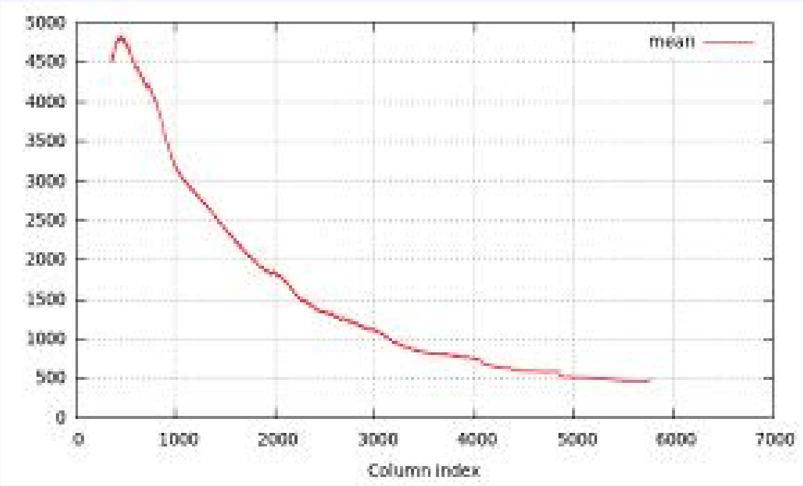


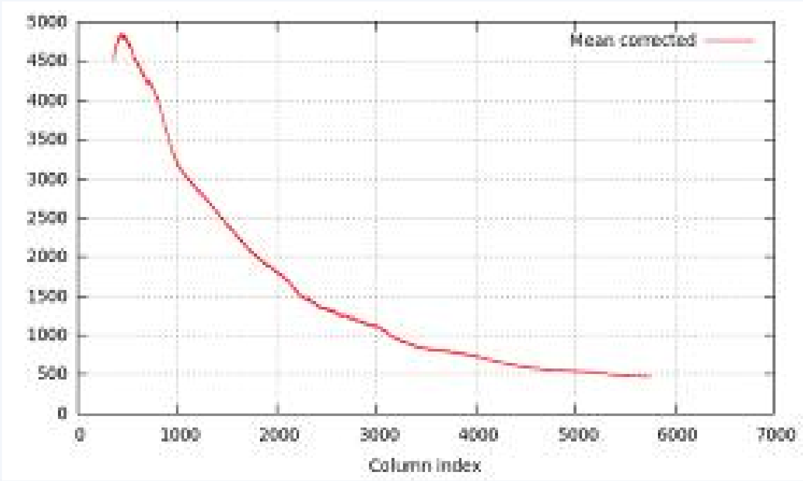
Sub-swath junctions

- **Inter-swath correction**





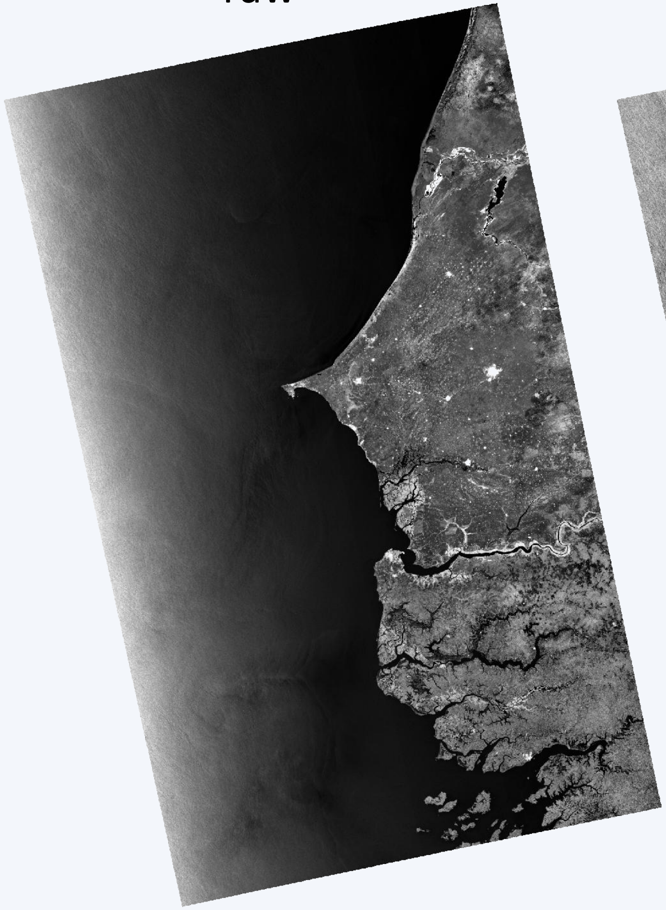




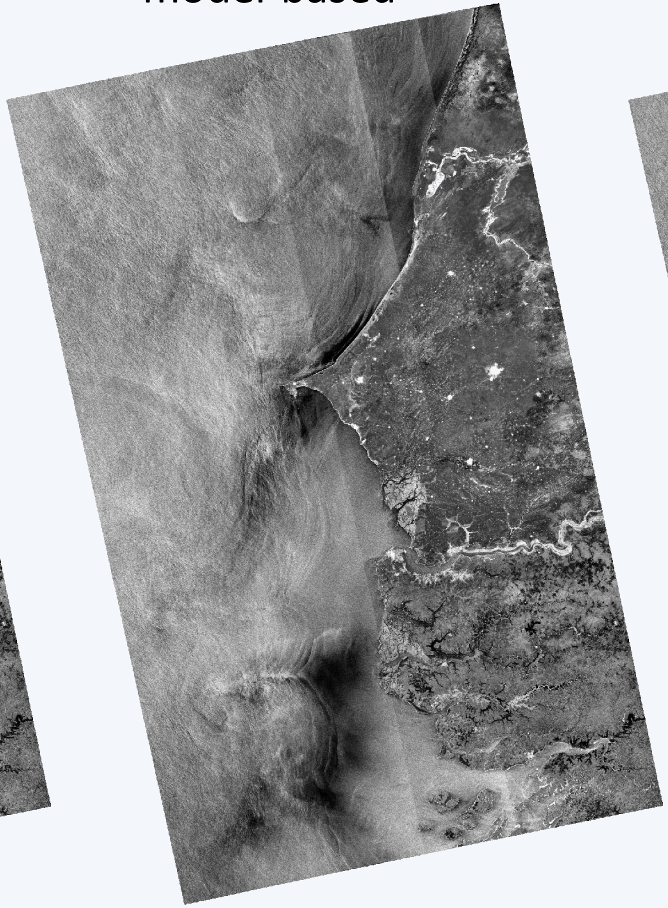
Sub-swath junctions

- **Applying a model-based equalization**

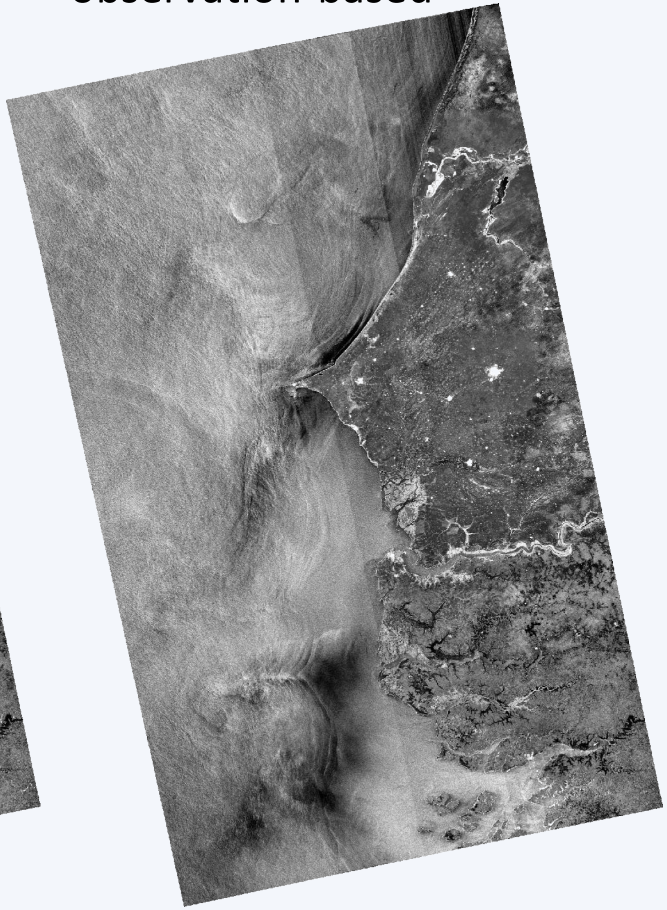
raw



model-based



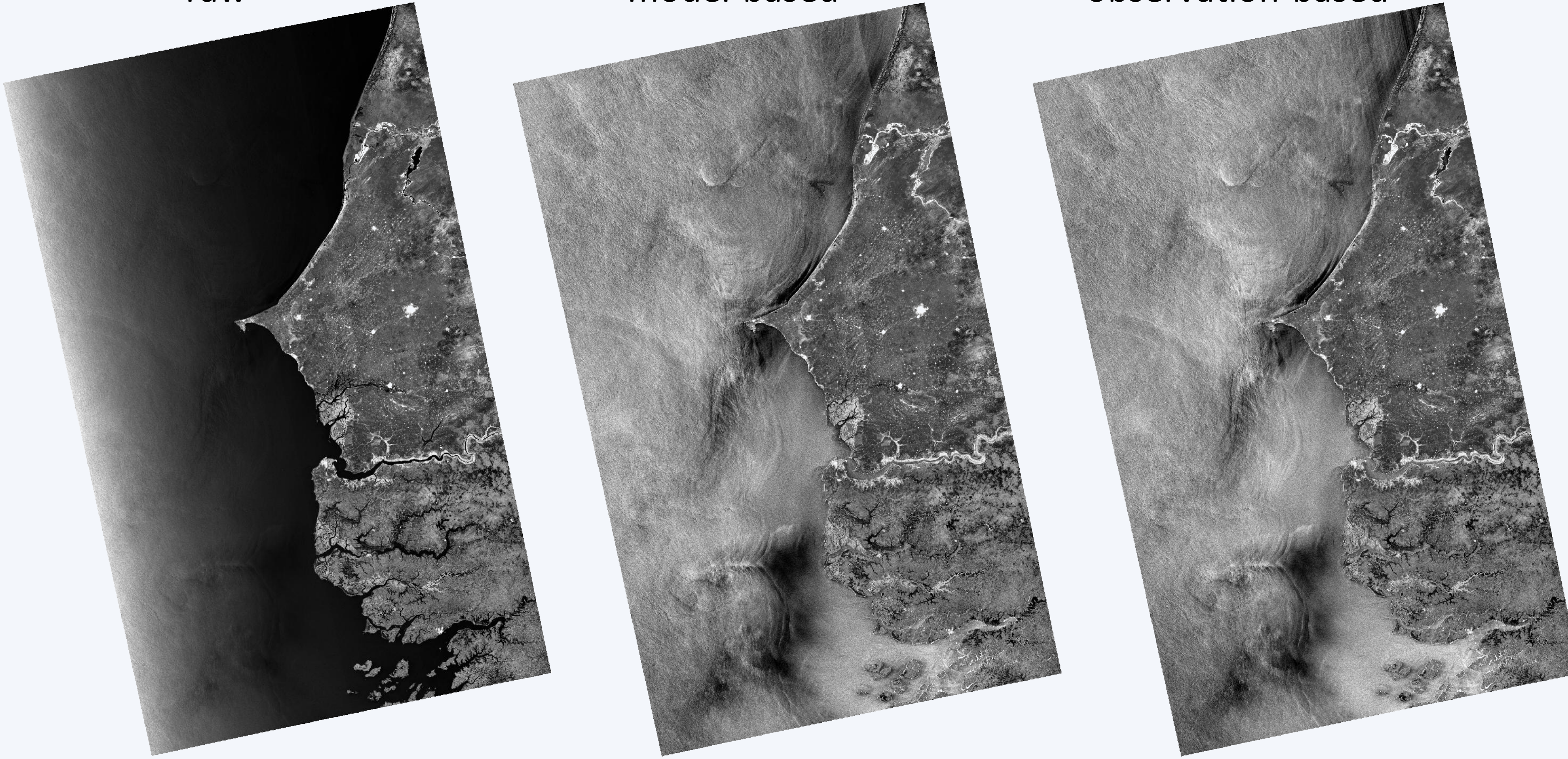
observation-based



Sub-swath junctions

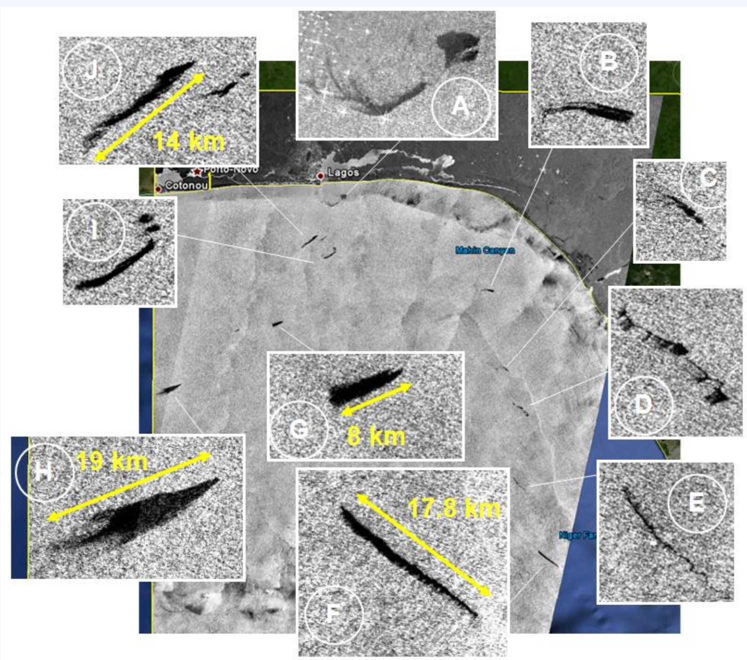
- **Applying a model-based equalization and inter-swath correction**

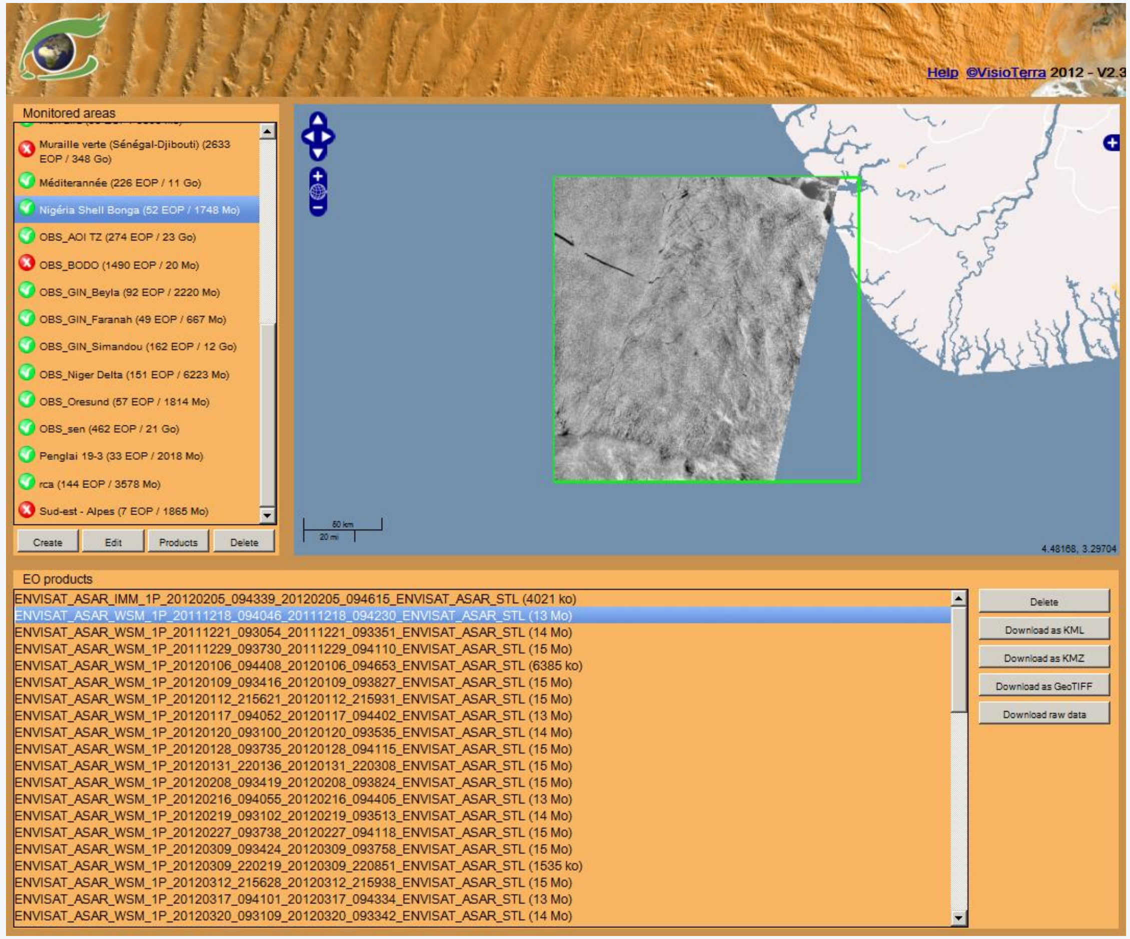
raw | model-based | observation-based



Conclusions

- **To help the photo-interpretation**
  - [20050714_110323 in Google Earth]
- **To make easier the oil slicks classification**





Thank you for your attention

Questions ?

Serge RIAZANOFF	VisioTerra	serge.riazanoff@visioterra.fr
Kévin GROSS	UPEMLV	kgross01@etudiant.univ-mlv.fr