



ESA-MOST Dragon 4 Cooperation

## ADVANCED LAND REMOTE SENSING INTERNATIONAL TRAINING COURSE

## "龙计划4"高级陆地遥感国际培训班

20–25 November 2017 | Yunnan Normal University Kunming, Yunnan Province, P.R. China 2017年11月20日——11月25日 云南师范大学,中国, 昆明







## GLACIER - SAR INSAR DATA PROCESSING IN SNAP

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- Familiarize with ESA SNAP
- Training on Glacier InSAR data Using Differential Interferometry (DInSAR)
- Provide instruction on stey-by-step processing of ALOS1 data
  - (incl. parameters, tips etc.)
- End-to-End show case



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Interferometric Processing







- Open a pair of ERS SLC Products
- Apply InSAR Optimized Coregistration
- Generate Interferogram and Coherence
- Apply Topographic Phase Removal
- Goldstein Phase Filtering
- Phase Unwrapping(SANPHU)
- Convert Differential Phase to glacier velocity



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**₹**南好彩大辈



## **Part one:** Open a pair of ERS SLC products

Step1-Open the products: Use the Import button in the top toolbar and browse for the location of the products. Select the ERS 1/2 CEOS file from the product folder and press Import Product.

cuit view Analysis Layer	vector Kaster Optical Rad	ar roois window Help			Q. Search ((
Open Product	GCP 🐻 🐝 👪 🕨	/ 🖤 🔍 👎 📭 🔪 🔜 🌚 🕻			
Reopen Product	>				
Product Library	ito				
Close Product					
Close All Products					
Close Other Products					
Save Product					
Save Product As					
ession	>				
mport	> DEM >			1	
xport	> Generic Formats >		SNAP - Import Pro	duct	
Exit	Optical Sensors →		Lash int 📃 10	0060402	
	SAR Formats >		LOOK IN.	5500422	
	SAR Sensors >	ALOS PALSAR CEOS		DF DAT	Subset
	Vector Data >	ALOS 2 CEOS			<b>P</b> 11 1
		Cosmo-Skymed			File size: <
		ENVISAT ASAR	較近使用		
		ERS 1/2 CEOS			
	·	ERS1/2 SAR (.E1, .E2)			
Eation Colour m	anib oncertainty	JERS CEUS			
	Arctic Orean	RADARSAT-1 CEOS	泉山		
Re .	2				
		TerraSAR-X			
Ale and	No.	TanDEM-X			
ASIA	it a station of the		文档		
		1.31			
A CAN	Star Lead				
	water a start				
			此电脑		
			File r	name: VDF_DAT.001	Import Produc
Indian Oce			网络 Files	of type: FRS CROS Products	Cancel

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#### Step2-View the product:

In the Products View you will see the opened products. Within the product bands, you will find three bands containing the real(i) , imaginary(q) and intensity .

#### 22-APR-1996 04 32 31 - [E:\Dongkemadi glacier\ERS\19960422\VDF DAT.001] - [Intensity] - SNAP Raster Optical Radar Tools Window Help Q. Search (Ctrl+I) 🕵 ඎ ଛ 🧶 � ♀ ♀ ↘ ⊋ 🗖 🌗 🕒 🎂 🔨 📖 🗆 🖿 Product Explorer × Pixel Info [1] Intensity × [1] ERS-1\_SAR\_SLC-ORBIT\_24942\_DATE\_22-APR-1996\_04\_32\_31 - 🚞 Metadata - 💼 Vector Data 🗄 🧰 Tie-Point Grids - 🔄 Bands Intensity [2] ERS-2\_SAR\_SLC-ORBIT\_5269\_DATE\_23-APR-1996\_04\_32\_31 Navigation ---- Colour Manip--- Uncertainty --- World View Off Globe X - Y - Lat - Lon - Zoom - Level -

#### **Products View**

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## Part two: Coregistering the Data

Drag and drop first the subset product. This will be your master image. Then drag and drop the other product. This will be your slave image.



#### Add products into the Coregistration Dialog

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In the Create Stack tab, the bands for master image and slave images should already be selected for you based on the order of the products given in the previous table.

Cross-Correlation the In tab. specify the number of Ground Control Points (GCPs) to use. The GCPs will be used as the center of a cross correlation window which will find the corresponding position from the slave image to the master image.

Coregistration			×		
ProductSet-Reader Creat	eStack Cross-Correlation Warp Write				
aster:	ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APF	R-1996_04_32_31			
sampling Type:	NONE		$\sim$		
itial Offset Method:	Orbit		$\sim$		
put Extents:	Master		$\sim$		
Find Optimal Master					
		Coregistration			
		ProductSet-Reader CreateStack	Cross-Correl	ation Warp Write	
		Number of GCPs:		2000	
		Test GCPs are on land	Apply Fine Registration for SLCs		
Create S	otack	Coarse Registration		Fine Registration	
		Estimate Initial Coarse Off:	set	Fine Window Width:	32 🗸
		Coarse Window Width:	128 🗸	Fine Window Height:	32 🗸
		Coarse Window Height:	128 ~	Cross-Correlation based registrat	ion
		Row Interpolation Factor:	4 ~	Fine Accuracy in Azimuth:	16 ~
	Telp Kun	Column Interpolation Factor:	4 ~	Fine Accuracy in Range:	16 ~
		Max Iterations:	10	Fine Window oversampling factor:	16 🗸
		GCP Tolerance:	0.25	O Coherence based registration	
				Use Coherence Sliding Window	
				Coherence Window Size:	3
				Coherence Threshold:	0.6
	De	fine the Corro	elatio	on Windows	

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In the Warp tab, the warp polynomial order applies a linear translation for order 1. Higher order warps should only be used when the images have been greatly distorted.

In the Write tab, specify the output folder and the target product name.

Coregistration		×
ProductSet-Reader CreateStack	Cross-Correlation Warp Write	
RMS Threshold (pixel accuracy):	0.05	
Warp Polynomial Order:	1 .	×
Interpolation Method:	Cubic convolution (6 points)	×
Show Residuals		
	1	Coregistration X
		ProductSet-Reader CreateStack Cross-Correlation Warp Write
		Target Product
Specify the	Significance Level via the	
]	RMS Threshold	
		Name:
		ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32_31_Stack
		Save as: BEAM-DIMAP V
		Directory:
	V help Kun	
		✓ Open in SHAP
		Specify the output name, format and

folder Run

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The interferogram is formed by cross multiplying the master image with the complex conjugate of the slave. The amplitude of both images is multiplied while the phase represents the phase difference between the two images. The interferometric phase variation  $\Delta \emptyset$  is then proportional to  $\Delta R$  divided by the

transmitted wavelength  $\lambda$ .

$$\phi_1 = \frac{4\pi R}{\lambda}$$
$$\phi_2 = \frac{4\pi (R + \Delta R)}{\lambda}$$

$$\Delta \phi = \phi_2 - \phi_1 = \frac{4\pi\Delta R}{\lambda}$$

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Stand Form



Part three: Interferogram Formation and Coherence Estimation

Step4-For	111		ule	Ra
Interferog	ram:	Select	the	
stack	and	se	elect	
Interfero	gram	Forma	tion	
from the	InSAI	R Prod	ucts	
menu				

dar Tools Window Help								
Apply Orbit File		7 🔲 🥎 📿 🚵 🖆	+ 🔨					
Radiometric	>							
Speckle Filtering	>	96 🛄 [5] topo_phase_22Apr1996_23Apr1996 🗙 🛄 [6] Phase_ifg_srd_22Apr19						
Coregistration	>	ALL DAY						
Interferometric	>	Products	>	Interferogram Formation				
Polarimetric	>	Filtering	>	Coherence Estimation				
Geometric	>	Unwrapping	>	Topographic Phase Removal				
Sentinel-1 TOPS	>	InSAR Stack Overview	v	Three-pass Differential InSAR				
ASAR WSS	>			Phase to Height				
Feature Extraction	>							
SAR Utilities	>			Phase to Displacement				
Complex to Detected GR				Phase to Elevation				
Multilooking								

#### **Select Interferogram Formation**

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In the interferogram formation step we shall remove the flat-Earth phase. The flat-Earth phase is the phase present in the interferometric signal due to the curvature of the reference surface.

Interferogram Formation	< 🔍 😳 Inte
File Help	File H
<pre>I/O Parameters Processing Parameters Source Product [3] ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32 v Target Product Name:</pre>	I/O Pa ✓ Sul Degree Number Orbit
ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32_31_Stack_ifg  Save as: BEAM-DIMAP Directory: E:\Dongkemadi glacier	∑ Sqi Cohere Cohere
♥ Open in SNAP	
Run Close	

💿 Interferogram Formation		×
File Help		
I/O Parameters Processing Parameters		
Subtract flat-earth phase		
Degree of "Flat Earth" polynomial	5	~
Number of "Flat Earth" estimation points	501	~
Orbit interpolation degree	3	~
✓ Include coherence estimation		
🗹 Square Pixel	Independent Wi	indow Sizes
☑ Square Pixel Coherence Range Window Size	Independent Wi	indow Sizes
☑ Square Pixel Coherence Range Window Size Coherence Azimuth Window Size	Independent Wi 10 50	indow Sizes
☑ Square Pixel Coherence Range Window Size Coherence Azimuth Window Size	Independent Wi 10 50	indow Sizes
☑ Square Pixel Coherence Range Window Size Coherence Azimuth Window Size	Independent Wi 10 50	indow Sizes
☑ Square Pixel Coherence Range Window Size Coherence Azimuth Window Size	Independent Wi 10 50	indow Sizes
☑ Square Pixel Coherence Range Window Size Coherence Azimuth Window Size	Independent Wi 10 50	indow Sizes
☑ Square Pixel Coherence Range Window Size Coherence Azimuth Window Size	Independent Wi	indow Sizes

#### **Interferogram Dialog**

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- Zoom - Level -

X - Y - Lat - Lon





C Topographic Phase Removal X	💿 Topographic Phase Removal 🛛 🕹 🗙
File Help	File Help
<pre>I/O Parameters Processing Parameters Source Product [4] ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32 ∨ Target Product Name: .SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32_31_Stack_ifg_dinsar Save as: BEAM-DIMAP ∨ Directory: E:\Dongkemadi glacier Open in SNAP</pre>	I/O Parameters Processing Parameters Orbit Interpolation Degree: 3 Digital Elevation Model: SRTM 3Sec (Auto Download) Topo Phase Band Name: Tile Extension [%] ACE2_5Min (Auto Download) ACE2_5Min (Auto Download) ASTER 1sec GDEM GETASSE30 (Auto Download) SRTM 1Sec Grid SRTM 1Sec (Auto Download) SRTM 3Sec (Auto Download) SRTM 3Sec (Auto Download) External DEM
Run Close	Run Close

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Step6-PhaseFiltering:Selectthe Interferogram product andgo to the InSAR ToolsSelectGoldsteinPhaseFiltering.

Rad	ar lools Window Help					
	Apply Orbit File		7 [	I 🕤 🖓 🖓 🚵	4	
	Radiometric	>				· · · · · · · · · · · · · · · · · · ·
	Speckle Filtering	>	GB	[4] Phase_ifg_srp_22A	pr199	6_23Apr1996 × 🛄 [4] coh_22Apr1996
	Coregistration	>	11			
	Interferometric	>		Products	>	
	Polarimetric	>		Filtering	>	Spectral Filtering >
	Geometric	>		Unwrapping	>	Goldstein Phase Filtering
	Sentinel-1 TOPS	>		InSAR Stack Overview		
	ASAR WSS	>				
	Feature Extraction	>				
	SAR Utilities	>				
	Complex to Detected GR					
	Multilooking					

#### **Select Phase Filtering**

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Goldstein Phase Filtering ×	🛃 Goldstein Phase Filtering	×
File Help	File Help	
I/O Parameters Processing Parameters Source Product [5] ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32 ∨ Target Product Name: \_SLC-ORBIT_24942_DATE_22-APR-1996_04_32_31_Stack_ifg_dinsar_flt Save as: BEAM-DIMAP ∨ Directory: E:\Dongkemadi glacier ✓ Open in SNAP	I/O Parameters Processing Parameter Adaptive Filter Exponent in (0,1]: FFT Size: Window Size: Use coherence mask Coherence Threshold in [0,1]:	ers 0.5 64 ~ 3 ~ 0.2
Run Close		Run Close

#### **Phase Filtering Dialog**

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# **Part five:** Phase Filtering







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## Part six: Phase Unwrapping





Step7-ExporttoSnaphu:ExportthefilteredflattenedinterferogramSNAPHU.

#### Radar Tools Window Help 🔲 🌗 📮 🎼 🏤 🔨 💷 🗏 🗀 Apply Orbit File Radiometric Ъ 📕 [5] topo\_phase\_22Apr1996\_23Apr1996 🗙 📕 [6] Phase\_i Speckle Filtering > ALL D Coregistration > Interferometric > Products > Polarimetric > Filtering > Geometric > Unwrapping > Snaphu Export Sentinel-1 TOPS > InSAR Stack Overview Snaphu Import ASAR WSS > Feature Extraction > SAR Utilities > Complex to Detected GR Multilooking

#### **Export to Snaphu**

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### Part six: Phase Unwrapping

#### Select **DEFO** for deformation mapping.

C Snaphu Export X	C Snaphu Export X
Read       SnaphuExport         Source Product       Name:         [6]       ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32_31_Stack_ifg_dimsar_flt         Data Format:       Any Format	Read     SnaphuExport       Target folder:     E:\Dongkemadi glacier\snaphul       Statistical-cost mode:     DEFO       Initial method:     MCF       Number of Tile Rows:     10       Number of Tile Columns:     10       Number of Processors:     4       Row Overlap:     0       Column Overlap:     0       Tile Cost Threshold:     500
💽 Help 🕞 Run	Run 🕞

#### **Snaphu Export**

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# Part seven: Unwrapping with SNAPH & \*\*



Snaphu is available for Linux only. Linux users simply need to install the software package by

### apt-get install snaphu

Windows users can download a Linux VMWare virtual machine and use it to unwrap the phase.

http://sourceforge.net/projects/s1tbx/files/snaphu\_vm/SAR%20Mint%2064.zip/ download

The free VMWare Workstation Player can be downloaded from

https://my.vmware.com/web/vmware/downloads

Open the VMware player and browse for the virtual machine.

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# **Part seven:** Unwrapping with SNAPH®\*\*\*



Increase the memory to suit your computer. Depending on the size of your images, you may need at least 8GB. Under the options tabs, add a shared folder. Select 'Always Enable'.

dware Options	Memory Specify the amount of memory allocated to this virtual machine. The memory size must be a multiple of 4 MB. Memory for this virtual machine: 4096 MB 64 6B - 32 6B - 16 6B - 8 6B - 4 6B - 6 Maximum recommended memory (Memory swapping may common block of the blo	Hardware Options Settings General Power Shared Folders Unity Autologin	Summary Mint 64 Disabled Time sync off Not supported	Folder sharing         ▲       Shared folders expose your files to programs in the virtual machine. This may put your computer and your data at risk. Only enable shared folders if you trust the virtual machine with your data.         ●       Disabled         ●       Always enabled         ●       Enabled until next power off or suspend         Folders       Name
	2 GB - 28596 MB 1 GB - 28596 MB 512 MB - 384 MB 128 MB - G4 MB - Guest OS recommended minimum 32 MB - 32 MB 16 MB - 32 MB 16 MB - 4 MB - 32 MB			Vmshare C:\VM\vmshare

#### **Increase Memory**

**Enable a Shared Folder** 

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### Part seven: Unwrapping with SNAPHU



Login: sar

Password: sar01

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## **Part seven:** Unwrapping with SNAPH



Go to the data folder in /mnt/hgfs/ and open the snaphu.conf file.

cd /mnt/hgfs/vmshare/data/target\_snaphu/

gedit snaphu.conf



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## Part seven: Unwrapping with SNAPHU

Cesa

Copy the snaphu command and paste it into the command terminal and then run it.

snaphu -f snaphu.conf Phase\_ifg\_srd\_22Apr1996\_23Apr1996.snaphu.img 4903



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## **Part seven:** Unwrapping with SNAPHU

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SNAPHU uses an iterative optimization procedure; its execution time depends on the difficulty of the interferogram. Unwrapping can use a lot of memory. If the unwrapping fails due to there being not enough memory, you could create a subset of your area of interest and try with SNAPHU again.

Terminal - + 2	×
Unwrapping tile at row 9, column 7 (pid 3434)	
Unwrapping tile at row 9, column 8 (pid 3436)	
Unwrapping tile at row 9, column 9 (pid 3438)	
Assembling tiles	
Running optimizer for secondary network	
Flow/increment: 10 (Total improvements: 0)	
765 incremental costs clipped to avoid overflow (0.001%)	
Treesize: 402188 Pivots: 3312980 Improvements: 39890	
Flow increment: 2 (Total improvements: 39890)	
145 incremental costs clipped to avoid overflow (0.000%)apru.img 4903	
Treesize: 402188 Pivots: 53 Improvements: 0	
Flow increment: 3 (lotal improvements: 39890)	
144 incremental costs clipped to avoid overtiow (0.000%)	
Flow increments 4 (Tetal improvements: 20200)	
Flow Increment: 4 (Total Improvements: 59690)	
Treesize: 402188 Divots: 0 Tmprovements: 0	
Integrating secondary flows	
Output written to file UnwPhase ifg srd 22Apr1996 23Apr1996 snaphu img	
Program snaphu done	
Elapsed processor time: 3:43:32.16	
Elapsed wall clock time: 0:58:48	
sar@Mint64 /mnt/hgfs/ERS-1 SAR SLC-ORBIT 24942 DATE 22-APR-1996 04 32 31 Stack	
ifg_dinsar_fltc\$h_22Apr1996_23Apr1996.snaphu.img	V

Plain Text 🔻 🛛 Tab Width: 8 🔻

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Step8-OpentheUnwrappedphasehdr file



#### **Open Unwrapped Phase Dialog**

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Step9-Import the Unwrapped phase: Select Snaphu Import from the interferometric menu

Rad	ar Tools Window Help			
	Apply Orbit File		7 🖪 🎓 🗬 🚵 🏤 🔨	
	Radiometric	>		•
	Speckle Filtering	>		
	Coregistration	>		
	Interferometric	>	Products >	
	Polarimetric	>	Filtering >	
	Geometric	>	Unwrapping >	Snaphu Export
	Sentinel-1 TOPS	>	InSAR Stack Overview	Snaphu Import
	ASAR WSS	>		
	Feature Extraction	>		
	SAR Utilities	>		
	Complex to Detected GR			
	Multilooking	-		

### **Import Unwrapped Phase Dialog**

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Select the wrapped phase in the read phase tab.

Select the unwrapped phase product in the read unwrapped phase tab.

C Snaphu Import X	C Snaphu Import	×
1-Read-Phase 2-Read-Unwrapped-Phase 3-SnaphuImport 4-Write	1-Read-Phase 2-Read-Unwrapped-Phase 3-SnaphuImport 4-Write	
Source Product Name: [1] ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32_31_Stack_ifg_dinsar_flt v Data Format: Any Format v	Source Product Name: [2] UnwPhase_ifg_srd_22Apr1996_23Apr1996. snaphu Data Format: Any Format \	
🕐 Help 🕞 Run	🕢 Help 🕞 Run	

#### **Snaphu Import Dialog**

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📀 Snaphu Import 🛛 🗙	C Snaphu Import X
1-Read-Phase 2-Read-Unwrapped-Phase 3-SnaphuImport 4-Trite	1-Read-Phase 2-Read-Unwrapped-Phase 3-SnaphuImport 4-Write Target Product
	Name: ERS-1_SAR_SLC-ORBIT_24942_DATE_22-APR-1996_04_32_31_Stack_ifg_dinsar_flt_unwrapping Save as: BEAM-DIMAP Directory: E:\Dongkemadi glacier Open in SNAP
💽 Help 🕞 Run	Image: Computing raster data     Z%     Cancel

#### **Snaphu Import Dialog**

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phase





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### **Part nine:** Convert the Differential phase to glacier velocity

Using the ENVI bandmath tools to process

$$\Delta \phi_{disp} = -\frac{4\pi}{\lambda} \Delta r = -\frac{4\pi}{\lambda} v_l \Delta t$$

$$v_l = -\frac{\lambda \Box \Delta \phi_{disp}}{4\pi \Box \Delta t}$$

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## Part nine: Convert the Differential phase to glacier velocity

Raster	Optical Radar Tools Window	Help					
Band Maths							
F	Filtered Band						
C	Convert Band						
Р	Propagate Uncertainty						
G	Geo-Coding Displacement Bands						
S	Subset						
G	Geometric Operations >						
D	EM Tools	>					
N	1asks	>					
D	ata Conversion	>					
Ir	mage Analysis	>					
E	xport	>					

Band Maths ×							
Target product:							
$\label{eq:loss} \begin{tabular}{lllllllllllllllllllllllllllllllllll$							
Name: Velocity_glacier							
Description:							
Unit:							
Spectral wavelength: 0.0							
✓ Virtual (save expression only, don't store data)							
Replace NaN and infinity results by NaN							
Generate associated uncertainty band							
Band maths expression:							
(2.3* Unw_Phase_ifg_23Apr1996_22Apr1996 )/(4* PI*1)							
Load Save Edit Expression							
Click it OK Cancel Help							

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## Part nine: Convert the Differential phase to glacier velocity

Band Maths Expression Editor			×
Product: [10] subset_1_of_ERS-2_SA	R_SLC-ORBIT_5269_DATE_	_23-APR-1996_04_32_31_Stack_ifg_dinsar_flt_uwm	~
Data sources:		Expression:	
i_ifg_srd_23Apr1996_22Apr1996	@+@	(2.3* Unw_Phase_ifg_23Apr1996_22Apr1996 )/(4* PI*1)	
q_ifg_srd_23Apr1996_22Apr1996	@ - @		1
Intensity_ifg_srd_23Apr1996_22Apr1996			
Phase_ifg_srd_23Apr1996_22Apr1996	@*@		
topo_phase_23Apr1996_22Apr1996	@/@		
coh_23Apr1996_22Apr1996	(@)		
Unw_Phase_ifg_23Apr1996_22Apr1996	Constants ~	(2.3*Unw Phase)/(4*pi*1)	
	Operators 🗸		
Show masks	Functions V		
Show tie-point grids			
Show single flags			Ok, no errors.
		ОК С	ancel Help

#### **Band Maths Expression Editor Dialog**

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### Part nine: Convert the Differential phase to glacier velocity

ERS-1\_SAR\_SLC-ORBIT\_24942\_DATE\_22-APR-1996\_04\_32\_31\_Stack\_ifg\_dinsar\_flt\_unwrapping.dim] - SNAP



**Glacier Velocity** 

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