





TRAINING KIT – CRYO02

GLACIER VELOCITY WITH SENTINEL-1 USING SNAP S-1 TOOLBOX – PETERMAN GLACIER, GREENLAND











Research and User Support for Sentinel Core Products

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Table of Contents

1	Intro	roduction					
2	Trai	ning.		3			
	2.1	Dat	a used	3			
	2.2	Soft	ware in RUS environment	3			
3	Reg	ister to RUS Copernicus					
4	Req	equest a RUS Copernicus Virtual Machine					
5	Step by step						
	5.1	Dat	a download – ESA SciHUB	3			
	5.2	SNA	AP — open and explore data1	1			
	5.3	Pre	-processing1	2			
	5.4	Cor	egistration and Offset tracking1	5			
	5.4.	1	Read10	ô			
	5.4.2 DEM-assisted co		DEM-assisted coregistration10	ô			
	5.4.3 Subset		Subset	ô			
	5.4.4 Offset Tracking		Offset Tracking	7			
	5.4.	5	Write operators	3			
	5.5	Stac	ck the products	Э			
	5.6	Teri	rain correction	C			
	5.7	Visu	Jalize2	1			
	5.8	Con	npare to existing velocity datasets 22	2			
6	Oth	er su	ggested steps2	5			
	6.1	Exp	ort velocity2!	5			
	6.1.	1	OPTION 1 – No error	ô			
	6.1.	2	OPTION 2 – SNAP versions with error 20	ô			
	6.2	Visu	ualize in QGIS	Э			
	6.3	Add	l vector Velocity fields	C			
7	' Further reading and resources						

1 Introduction

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes preinstalled on virtual machines, to handle and process data acquired by the Copernicus Sentinel satellites constellation.



Sentinel-2 image of Petermann Glacier tongue on 10 Sept. 2017 (Credits: contains modified Copernicus Sentinel data)

Greenland ice sheet is the second largest ice mass on Earth. As climate changes, the ice sheet surface melt is increasing and more and more fresh-water flows to the ocean, contributing to the global sea-level rise.

Glacier velocity is a vital part of glacier monitoring and understanding the glacier system dynamics as well as its contribution to the global sea level. Satellite data is a perfect tool for monitoring glacier velocity over large areas. Two methods are commonly used

to derive the speed of the ice flow from the satellite data: 1) SAR interferometry; 2) feature/speckle tracking (optical/SAR data) between consecutive acquisitions. In this tutorial we will use the second method applied to Sentinel-1 data.

The Petermann Glacier is a large tidewater glacier draining more than 4% of the Greenland ice sheet through the 90 km long Petermann Fjord and terminating in a floating ice tongue, which currently covers an area of 900 km². Estimated 12 billion tonnes of ice are drained to the ocean annually with estimated ice flow speed of 1 km/year.

2 Training

Approximate duration of this training session is one hour.

The Training Code for this tutorial is CRYO02. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the <u>RUS portal</u> and open a User Service request from Your RUS service \rightarrow Your dashboard.

2.1 Data used

 Two Sentinel-1A IW GRDH images with HH & HV polarization acquired on 9 September 2017 and 21 September 2017 [downloadable @ <u>https://scihub.copernicus.eu/]</u> S1A_IW_GRDH_1SDV_20170909T113539_20170909T113604_018298_01EC67_A5EC.zip S1A_IW_GRDH_1SDV_20170921T113539_20170909T113604_018473_01F1C7_1CE3.zip

2.2 Software in RUS environment

Internet browser, SNAP + Sentinel-1 Toolbox, (Extra steps: QGIS)

3 Register to RUS Copernicus

To repeat the exercise using a RUS Copernicus Virtual Machine (VM), you will first have to register as a RUS user. For that, go to the RUS Copernicus website (<u>www.rus-copernicus.eu</u>) and click on *Login/Register* in the upper right corner.

CORRUS Research and User Support	
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	
	Senth
	News from RUS
	One year on!
	Copernicus Info Session - Reykjavik - 19 September 2018
	SPIE Remote Sensing 2018 – Berlin (Germany) – 11-12 September 2018
	SIWI World Water Week 2018 – Stockholm – 26-31 August 2018
	MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018
	RUS Webinar – Special edition "AskRUS – Sentinel-1" – 12 July 2018
Welcome to Research and User Support	RUS Training Session – Valencia – 22 July 2018
	IGARSS 2018 - Valencia - 22-27 July 2018
Welcome to the Copernicus Research and User Support (RUS) Service portal!	The RUS agenda
The RUS Service is the "New Expert Service for Sentinel Users" funded by the European Commission,	Conferences & Workshops

Select the option *Create my Copernicus SSO account* and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click *Register*.



Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the email to activate your account.

You can now return to <u>https://rus-copernicus.eu/</u>, click on *Login/Register*, choose *Login* and enter your chosen credentials.

Login / Register	Credentials		_	-
Login / Kegister The registration system to access the RUS service platform has moved toward the COPERNICUS Single Sign On authentication server. • New Users who have not yet registered to the RUS portal shall first create a COPERNICUS SSO account. Note that your Copernicus SSO account will be activated only after the reception of the third email sent by the Copernicus service. We advise you to consult this document and this page to facilitate your registration procedure. REGISTER COPERNICUS SSO account Users who already have a COPERNICUS SSO account can login here: Login	CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close	•	0000
Close		Forgot your password?		

Upon your first login you will need to enter some details. You must fill all the fields.

The RUS Service * The RUS C	Do you want t	o subscribe for a new RUS account?	Î	
	Your ESA-SSO subscription	data:	We will be be a	- www.aligna.com/des
+ Your RUS service	Login			A .
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· Your profile stadies way mine	Last Name	Teachers .	US-	
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* Your training allows you to come	Country	-	The Descriptions Monthly	to Data - Wanter
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	Where did you hear about the RUS service? Select one or more items	outreach event colleagues newsletter conference social media	atten thives - Francis men - Paland - 6. 9-4 dam - Foulana - 26	0 - 12-16 (m) 0 & 17 Nov 2020 5 27 Oct. 2018
		other		
	Institution type	Select one item	× Ud	
	Phone number Italy (IT):	+39	print spin	a second
	Title	Select one item		

4 Request a RUS Copernicus Virtual Machine

Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on **Your RUS Service** → **Your Dashboard**.

CORRUS Research and User Support	Hello, Miguel
The RUS Service * The RUS Offer * The RUS Library * The RUS Community * Sour RUS service * Your RUS service	Vice > You are here: Home > Your RUS service
 Your RUS service Your space related to your RUS services: Your profile: displays your personal information linked to your ESA SSO and RUS accounts, Your dashboard: Hows you to access your private dashboard, Your training: allows you to register to a training session you have been invited to participate in. 	News from RUS One year on! Copernicus Info Session - Reykjavik - 19 September 2018 SPIE Remote Sensing 2018 - Berlin (Germany) - 11-12 September 2018 SIWI World Water Week 2018 - Stockholm - 26-31 August 2018 MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018
	RUS Webinar - Special edition "AskRUS - Sentinel-1" - 12 July 2018 RUS Training Session - Valencia - 22 July 2018 IGARSS 2018 - Valencia - 22-27 July 2018

Click on *Request a new User Service* to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.

CORRUS Green Research and User Support	t an and she the	reito, Miguel 🛔
The RUS Service * The RUS Offer *	The RUS Library * The RUS Community * Star Your RUS service *	You are here: Home > Your RUS service > Your dashboard
Your dashboard		
Request a new User Service		Chat with Support Desk
Copyright © 2017 Research and User Support	ó	ontact Us Terms and conditions Glossary Acronyms FAA

If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.

Please help us learn more about your background by answering information will be stored in your User Profile.	a few questions. Th
How many years of experience in Remote Sensing do you have?	
Choose one Item	
Have you already downloaded Copernicus data via the Copernicus Open acco	ess hubs?
® Yes	
© No	
Have you already handled/processed Copernicus data?	
Yes	
© No	
Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, plo (hold down CTRL key for multiple selections).	ease select your choice
HAZA01 - Flood Mapping in Malawi	
HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland	
LAND01 - Crop Mapping in Seville	
LAND04 - Land Monitoring in Cyprus OCEA01 - Ship Detection in Guif of Trieste	*
If you wish to request another tutorial exercise that doesn't appear in the abo	ove list, please type here
its name or code. Note that you can request multiple tutorial exercises.	

Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.

summary mornadon on your request.		
This is a collection of information selected	d across the USR forms.	
You can go back and edit this information	if necessary.	
General information on your request:		
Years of experience in Remote Sensing	5-10 years	
Downloaded Copernicus data?	1	
Handled/processed Copernicus data?	1	
Webinar codes	HAZA02, LAND04	
About your RUS project:		
Thematicarea	Cryosphere (ice and snow)	
Operations to perform on RUS	Algorithm development	
Preference for downloading process	Self-downloading	
Foreseen activities and support needs	Develop a land cover classification	
Project name	RUS_Project1	
Earth Observation Data information:		
Type of Earth Observation Data:		
Sentinel-1	1	
	S1-Product 1	
S1 - Product type	GRD	
S1 - Sensor mode		
S1 - Polarisation	a .	
S1 - Orbit direction		
Sentinel-2	x	
Sentinel-3	x	
Other	x	
I don't know	×	
Region of Interest: Min Latitude	30 3303	
MaxLatitude	40 5977	
Min Longitude	-46736	
MaxLongitude	-2 7205	
Reference polygons	2,7203	
Data acquisition data/el-		
Alana		
Additional data specifications		
I have read and agree to the Terms and	conditions of RUS Service.	

Further to the acceptance of your request by the RUS Helpdesk, you will receive a notification email with all the details about your Virtual Machine. To access it, go to **Your RUS Service** → **Your Dashboard** and click on **Access my Virtual Machine**.

							You are here: Home >	Your RUS service > Your dash
Your dashboard								
Request a new L	Jser Servi	ce					5	Chat with Support Desk
Project Name	ID	Date of submission	Status		Actions		Virtual	Environment
	1	-		Follow my project	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
RUS_training1	231	2017-08-31	Open		Get a webinar kit	Rate my service	Freeze my Virtual	Report a technical

Fill in the login credentials that have been provided to you by the RUS Helpdesk via email to access your RUS Copernicus Virtual Machine.



This is the remote desktop of your Virtual Machine.

Applications						1.1.1
ale System	(Refer		BIRAT Schuseblar	() 385	RESERVE	SNAP
	Commented Sta			Canada Ca	Lupy Kar Assessed	Address and
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5 Step by step

5.1 Data download – ESA SciHUB

In this step, we will download the Sentinel-1 scenes from the Copernicus Open Access Hub using the online interface. Go to **Applications** \rightarrow **Network** \rightarrow **Firefox Web Browser** or click the link below.

Go to https://scihub.copernicus.eu/



Go to "**Open HUB**", if you do not have an account please register by going to "**Sign-up**" in the LOGIN menu in the upper right corner.

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Incort search ethinsis	Note: Note: <td< th=""><th>Please login to access our services Please login to access our services Please login to access our services</th></td<>	Please login to access our services Please login to access our services Please login to access our services
esa opernicus	Copernicus Open Access Hub	± 0 A
	Register new account	199

Register ne	w account	
Sentinel data access is free and open to all.		
On completion of the registration form below you will receive an e-mail with a limit to validate Username field accepts only lowercase alphanumeric characters plans" * "" and "" Password field accepts only alphanumeric characters push """ of "" says "" Password fields mmmun length to 8 characters.	is your e-mail address. Following this you can start to download the data $a_{a}a_{a}a_{a}a_{a}a_{a}a_{a}a_{a}a_{a$	
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Usermen		
Filmenned	Librofilms (The specime)	
Eduk	Genterr Bonue	
Select Duman •		
Subsci Usaga •	· · · · · · · · · · · · · · · · · · ·	
Selied your country		
By registering in this website you are deemed t	have accepted the T&C for Sentinel data use	
	REGISTE	R

After you have filled in the registration form, you will receive an activation link by e-mail. Once your account is activated or if you already have an account, "LOGIN".

Navigate to the north of Greenland (approximate area – blue rectangle). Switch to drawing mode and draw a search rectangle approximately as indicated below.



Open the search menu by clicking to the left part of the search bar and specify the following parameters:

Sensing period: From 2017/09/09 to 2017/09/21 Mission: Sentinel-1 Satellite Platform: S1A* Product Type: GRD (Ground-range-detected product) Sensor Mode: IW Relative Orbit Number: 26

	Copernicus Open Access Hub	10 A
E Ameri Marci cilera	- Contraction	0 977
Advanced Search Sort By: Injection Date	Clear I	12-0
« Order By: Descending		
Sensing period Prom: 2013/08/09 to: 24 Indestion period From: to:		1 . 30
B Mission: Sentinel-1		
Satellice Madorm Product type S1A_+ GRD Polarisation Sensor Mode		
Relative Orbit Number (from 1 to 175)		
26 Mission: Sentinel-2		
Satellite Platform Product Type Relative Orbit Number (from 1 to 143) Cloud Cover % (e.g.[0 TO 9.4		
O Mission: Sentinel-3		
Product Type Timeliness		0

In our case, the search returns 2 results, depending on the exact search area defined. Download scenes:

*S*1A_*IW_GRDH_1SDV_20170909T113539_20170909T113604_018298_01EC67_A5EC.zip S*1A_*IW_GRDH_1SDV_20170921T113539_20170909T113604_018473_01F1C7_1CE3.zip*



Move downloaded scenes from desktop (/home/rus) to: /shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Original

TIP 1: It may sometimes happen that the data used to create this exercise are temporarily unavailable. In such case, you can use other date period for the same location to find two images 12 days apart in the same orbit.

5.2 SNAP - open and explore data

Open **SNAP Desktop** (icon located on the desktop); click **Open Product** *(icon located on the desktop)*; click **Open Product** *(icon located to: shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Original*)

and open both downloaded products:

S1A_IW_GRDH_1SDV_20170909T113539_20170909T113604_018298_01EC67_A5EC.zip S1A_IW_GRDH_1SDV_20170921T113539_20170909T113604_018473_01F1C7_1CE3.zip

The opened products will appear in **Product Explorer** window. Click + to expand the contents of product [1] from 9 September 2017, then expand **Bands** folder and double click on *Intensity_HH* band to visualize it.



We can see that the view appears as if "mirrored": this is because the scene was acquired during **descending** pass (the satellite was moving in direction from north to south, looking to the right (in this case west)) and the view shows the pixels in order of the data acquisition, as the image is not yet projected into cartographic coordinates.

5.3 Pre-processing

We need to apply identical pre-processing steps to both of our scenes. However, processing the data step by step and product by product would be time consuming and inconvenient, luckily, we can use the **Batch Processing** tool available in SNAP to apply all steps to both images in one go (this also saves disk space as only the final product is physically saved).

To use the tool, we first need to define the process we want to apply and all its steps. We can do this using the **GraphBuilder** tool.

So let's build our graph. Go to **Tools** \rightarrow **GraphBuilder**.

Die Edit View Analysis Løyer Vector Raster Optical Radar Tools Window Help							Q		
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Product Explo X In-Situ Data Acc Pixel info 🖬 🔲 [3] Sigma0_HH X 🔲 [4] Sigma	file Graphs								• • • •
	Read	Right click here to add an operator	Write				22		Contraction in the second
Alanigano Colour M. World X Löver Edt 📄	Read Write Source Product Name		•			A CARACTER STATE			
	[1] SIA_IW_GRDH_1	1501; 20170997113559; 20170997113604_019296_01EC67_ASEC							
 off ciebe	Loan	d 🔄 Seve 🔰 Citar 🛛 😰 Note 🛛 🔃 Holo	D Ren			ll.			

At the moment, the graph has only two operators: **Read** (to read the input) and **Write** (to write the output).

In the first step, we will update the orbit metadata (See \square NOTE 1). To add the operator right-click the white space between the existing operators and go to Add \rightarrow Radar \rightarrow Apply-Orbit-File.

NOTE 1: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product. The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated. (SNAP Help)

A new operator rectangle appeared in our graph and new tab appeared below. Now connect the new **Apply-Orbit-File** operator with the **Read** operator by clicking to the right side of the **Read** operator and dragging the red arrow towards the **Apply-Orbit-File** operator.



In the next step we will remove the thermal noise (See \square NOTE 2). We do this by right-clicking the white space somewhere left of the resample operator and going to Add \rightarrow Radar \rightarrow Radiometric \rightarrow ThermalNoiseRemoval. Connect the ThermalNoiseRemoval operator with the Apply-Orbit-File operator.



Now we can add the **Calibration** operator. The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data (See \square NOTE 3). To add the operator go to Add \rightarrow Radar \rightarrow Radiometric \rightarrow Calibration. Connect the Calibration operator, to both the ThermalNoiseRemoval operator and Write operator.



NOTE 3: Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains. The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison of SAR images acquired with different sensors or acquired from the same sensor but at different times, in different modes, or processed by different processors. (*SNAP Help*)

For the moment, do not change anything in the parameter tabs and save the graph as **Graph_preprocess.xml** to:

/shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Processing by clicking Save at the bottom of the window. After you have saved it, close the GraphBuilder window.

In the **Product Explorer** window, select (highlight) the product [1] (9 September 2017). Open the **Batch Processing** tool (**Tools** \rightarrow **Batch Processing**).

We will add both opened products by clicking **Add Opened** on the upper right (second icon from the top) and then click **Refresh** (second icon from the bottom). Then we click **Load Graph** at the bottom of the window and navigate to our saved graph and open it. We see that new tabs have appeared at the top of window corresponding to our operators with the exception of **Write**; this is correct as these parameters will be set in the **I/O Parameters** tab.

In the I/O Parameters tab set "Directory" to

/shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Processing and make sure the "Keep source product name" option is selected ✓ (See ¹ NOTE 4).

NOTE 4: The product file names will be identical to the input file names. If you set your output directory to the folder that contains your input data the input data will be overwritten.

ne orapna							
I/O Parameters Apply-	Orbit-File	Thermal	loiseRemoval	Calibratio	n		
File Name		Туре	Acquisition	Track	Orbit	+	
518_W_GRDH_1SDH_2017 51A_W_GRDH_1SDH_2017	921T11	GRD	22Aug2017 21Sep2017	26	7052		Add opened
						T	
						4	
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						- ♦ ₩ ♦ ↓	
Target Folder						2 Products	
Target Folder Save as: BEAM-DIMAP						2 Products	
Target Folder Save as: BEAM-DIMAP Directory:		1				2 Products	
Target Folder Save as: BEAM-DIMAP Directory: /shared/Training/CRY002	GlacierVe	locity_Gree	nland_TutorialK	it/Processir	ng	2 Products	Refresh
Target Folder Save as: BEAM-DIMAP Directory: /shared/Training/CRYD02	GlacierVe	locity_Gree	nland_TutorialK	it/Processir	ng	2 Products	Refresh

In the Apply-Orbit-File tab we can accept the default settings.

N	Batch Process	ing : Graph_preproce	ss.xml	• = ×
File Graphs				
1/O Parameters	Apply-Orbit-File	ThermalNoiseRemoval	Calibration	
Orbit State Vectors	Sentinel Precise	(Auto Download)		-
Polynomial Degree:	3			
	🔲 Do not fail if i	new orbit file is not found		

In the **ThermalNoiseRemoval** tab select HH polarization and make sure that the "**Remove Thermal Noise**" option is selected.

	Batch Proce	ssing : Graph_preproc	ess.xml	(+ = ×
File Graphs				
I/O Parameters	Apply-Orbit-File	ThermalNoiseRemoval	Calibration	
Polarisations:	НН			
Remove Therm	HV al Noise			
Re-Introduce T	nermal Noise			

In the **Calibration** tab we will also accept all default settings and then click **Run**.

	Batch Proce	essing : Graph_prepro	cess.xml	1 2 8
File Graphs				
I/O Parameters A	pply-Orbit-File	ThermalNoiseRemoval	Calibration	_
Polarisations:	HH			
Save as complex o	ndpui			
V Output sigma0 bar	nd			
Output gamma0 ba	and			
Output beta0 band			Ŷ	
				10

You should have 2 new products in the **Product Explorer** window. Close the **Batch Processing** window.

5.4 Coregistration and Offset tracking

To simplify the process, we will also create a new graph for the next processing steps. Let's open the **Graph Builder** again (**Tools** \rightarrow **Graph Builder**).

First, we need to delete the Write operator. Right click on it and select "**Delete**". Then we need to add a second Read operator. Right-click in the white space and go to Add \rightarrow Input-Output \rightarrow Read.

We will add the **DEM-Assisted Coregistration** operator by going to **Add** \rightarrow **Radar** \rightarrow **Coregistration** \rightarrow **DEM-Assisted-Coregistration** and connect both **Read** operators to it.



Next, we will add the **Subset** operator (Add \rightarrow Raster \rightarrow Geometric \rightarrow Subset) and connect the DEM-Assisted-Coregistration operator to it.

Since we want to continue to Offset Tracking and save this subset separately as well, we will add the **Offset-Tracking** operator (Add \rightarrow Radar \rightarrow SAR Applications \rightarrow Offset-Tracking) and the Write operator (Add \rightarrow Input-Output \rightarrow Write). Connect the Subset operator to both Offset-Tracking and Write operator.



As the last step, we will add another Write operator (Add \rightarrow Input-Output \rightarrow Write) and connect the Offset-Tracking operator to it in order to save the final product (See ? TIP 2).



Tabs corresponding to each of the operators have appeared below the graph. We will go through them one by one to set all the parameters.



5.4.1 Read

First let's go to the first **Read** tab and make sure that the pre-processed product [3] from 9-Sept 2017 is selected as the Source product. Then go to the **Read(2)** tab and set the pre-processed product [4] from 21-Sept 2017 as the Source product.

Read	Read(2)	DEM-Assisted-Coregistration	Subset	Offset-Tracking	Write	Write(2)	
Source	e Product						
Name							
(3) 51	LA IW GRDH	1SDH_20170909T113539_2017	0909T1136	04_018298_01EC6	ASEC		
Data	Format. Read(2)	BEAM-DIMAP DEM-Assisted-Coregistration	Subset	Offset-Tracking	Write	Write(2)	1
Source Name:	e Product		1				
(4) 51	LA_IW_GRDH	15DH_20170921T113539_2017	0921T1136	04_018473_01F1C	1CE3		• • • • •
Data	Format	BEAM-DIMAP					

5.4.2 DEM-assisted coregistration

Image coregistration is the process of geometrically aligning two or more images so that corresponding pixels represent identical area on earth surface. It is possible to coregister two or more products using only orbit state vectors, however for the purpose of offset tracking we need more precise coregistration. Therefore, we use additional information provided by digital elevation model (DEM).

Go to the **DEM-Assisted-Coregistration** tab and set "Digital Elevation Model": ACE30 (Auto Download)

Read Read(2) DEM-Assis	ted-Coregistration Subset Offset-Tracking Write(2) Write	_
Digital Elevation Model:	ACE30 (Auto Download)	-
DEM Resampling Method:	BICUBIC_INTERPOLATION	-
Resampling Type:	BISINC_5_POINT_INTERPOLATION	-
Tile Extension (%):	50	
Mask out areas with no elev	vation	

5.4.3 Subset

Since our Area of Interest (AOI) is quite small and there is no need to process the whole image, we start with sub-setting the scene to a more manageable size. This will reduce the processing time in

further steps and is recommended when the analysis is focused only over a specific area and not at the complete scene. Go to the **Subset** tab and at "**Pixel Coordinates**" set:

<: 1500	Width: 16000	Y: 5000	Height: 11000
Read Read(2)	DEM-Assisted-Coregistration	Subset Offset-Tracking	Write(2) Write
Source Bands:	Sigma0_HH_mst_095ep2017 Sigma0_HH_slv1_21Sep2017		
✓ Copy Metadata ● Pixel Coordinate	Geographic Coordinates		r been
X	1500	Υ:	5000
Width:	16000	height:	11000

5.4.4 Offset Tracking

Offset Tracking is used to estimate the motion of a feature between two acquisitions through crosscorrelation on selected Ground Control Point (GCP) in coregistered images (master and slave) in both slant-range and azimuth direction. The movement velocity is then computed based on the offsets estimated by the cross-correlation (See INOTE 5). The velocities computed on the GCP grid are interpolated to create velocity map. It is a method frequently used for glacier motion estimation.

NOTE 5: The Offset Tracking is performed in the following sub-steps (ESA Snap):

- For each point in the user-specified GCP grid in master image, compute corresponding pixel position in slave image using normalized cross-correlation.
- If the computed offset between master and slave GCP positions exceeds the maximum offset (computed from user specified maximum velocity), then the GCP point is marked as outlier.
- Perform local average for the offset on valid GCP points.
- Fill holes caused by the outliers. The offset at missing point will be replaced by a new offset computed by local weighted average.
- Compute the velocities for all points on GCP grid from their offsets.
- Finally, compute velocities for all pixels in the master image from the velocities on GCP grid by interpolation (final product has same pixel size as the input data).

To perform the **Offset-Tracking**, we need to set several parameters. First, we need to set the GCP grid spacing in pixels in range and azimuth directions (determines the resolution/level-of-detail of our velocity product). We will set the spacing to 60 pixels (600m) in both directions, this balance between the level of detail and smoothness of our output, is sufficient for our purposes (also: the higher the resolution => the longer the processing time).

Next, we need to set the Registration Window dimensions; the size of the registration window depends on the maximum velocity of the glacier (from literature of historical data) and the period between the data acquisitions. Our images were acquired 12 days apart and the maximum speed of the Petermann Glacier is close to 5 m/day, this means that the glacier surface will shift by maximum 60 meters. This means that we can keep the default setting of 128 pixels (1280x1280m). To filter out false high values we also set the known maximum glacier velocity to 5 m/day. So, we need to set:

Grid Azimuth Spacing (in pixels): 60 Grid Range Spacing (in pixels): 60

Max Velocity (m/day): 5.0

Grid Azimuth Spacing (in pixels): Grid Range Spacing (in pixels): Grid Azimuth Spacing (in meters) Grid Range Spacing (in meters): Grid Azimuth Dimension: Grid Range Dimension: Total Grid Points:	60 60 600.0 600.0 183 266 48678	Registration Window Width: Registration Window Height: Cross-Correlation Threshold: Average Box Size: Max Velocity (m/day): Radius for Hole Filling:	128 128 0.1 5 5.0 4	•		
Resampling Type:		BICUBIC_INTERPOLATION				
		Spatial Average				

5.4.5 Write operators

In the **Write** tab (connected to the **Subset** operator), set the product name to *Subset_S1A_IW_GRDH_20170909_20170921_Stack* and the target directory to */shared/Training/CRY002_GlacierVelocity_Greenland_TutorialKit/Processing*.

Read	Read(2)	DEM-Assis	sted-Coregistrati	on Subset	Offset-Tracking	Write	Write(2)	
Target F	Product							
Name:								
Subset	SIA W G	RDH_201709	909_20170921_S	tack				
Save as	BEAM-DI	MAP	-					
Dire	ctory:							
	1		Clasion/alasib/	Croopland Tut	arialVit/Drassesies			

In the Write(2) tab (connected to the Offset-Tracking operator), set the product name to Subset_S1A_IW_GRDH_20170909_20170921_Stack_vel and the target directory to /shared/Training/CRY002_GlacierVelocity_Greenland_TutorialKit/Processing.

Read	Read(2)	DEM-Assisted-Coregistration	Subset	Offset-Tracking	Write	Write(2)	
Target	Product						
Name:							
Subset	SIA IW G	RDH_20170909_20170921_Stack	vel				
Save a	s: BEAM-DI	MAP					
Dire	ectory:						
/sh	ared/Traini	ng/CRYO02_GlacierVelocity_Gree	enland_Tuto	orialKit/Processing			
						+	
	(PE)	ad Assaula Scilar	ar 🗔	Note 0 He		Pup	
	Lo	au Save Scien		Note I I He he	il di	Run	

Click **Save** to save the graph with the name "**Graph_offset_tracking**", at the following directory: /shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Processing.

Click **Run**. This might take a while. *Approximate processing time: 35 minutes.*

After the processing is completed, close the **Graph Builder** window. Two new products [5] and [6] have appeared in the **Product Explorer** window. Expand the **velocity product** [5] and double click the **Velocity_slv1_21Sep2017** band to open it in the **View** window. On top of the velocity map we can see

the geolocation point grid that obscures our view. We can hide it by going to Layer Manager on the right side (or go to Layer \rightarrow Layer Manager to open it) and deselect the vector folder.



5.5 Stack the products

Let's join the two outputs to a single product, for this we will use the **Band Math** function. Right-click product [5] and open **BandMath** dialog. Set "Name" to *Sigma0_HH_09Sep2017* and **deselect** the **Virtual (save expression only, don't store data)** option because we want to store the data.

Then click on the Edit Expression... and a new dialog will open. Set Product to:

[6] Subset_S1A_IW_20170909_20170921_Stack.

Then in Data Sources, click on \$6.Sigma0_HH_mst_09Sep2017 band.

	Band Maths	+ = ×	Band !	Maths Expression Ed	litor	* i ×
Target product:			Product [6] Subset SIA IW 20170	909 20170921 Stack		-
[5] Subset_SIA	IW_20170909_20170921_Stack_Vel	-	Data sources		-	Expression
Name:	Sigma0_HH_09Sep2017	1	\$6.Sigma0_HH_mst_09Sep2017	(u + (u	>	\$6.Sigma0_HH_mst_09Sep2017
Description:		Í	\$6.Sigma0_HH_slv1_21Sep2017	G - G	-	
Unit				0.1.0	-	
Spectral wavelen	gth: 0.0			6 . 6	_	
/irtual (save	expression only, don't store data)			0/0		
Replace NaN	and infinity results by	NaN		(@)		
	oristed uppertainty hand			Constants	-	_
Band maths expr	ression			Operators	-	
serve interne engi				Functions	-	
			🕑 Show bands		-	
Load	Save Edit Express	sion	Show masks			
Louis			Show tie-point grids			📑 🗎 🤉 🔁 🗐 errors.
	<u>Q</u> K <u>C</u> ancel	Help				QK <u>Cancel</u> <u>H</u> elp

Click **OK** in both windows. Repeat the process to add also the second band. This time set "Name" to *Sigma0_HH_21Sep2017* and in **Data Sources**, click on *\$6.Sigma0_HH_slv1_21Sep2017* band. The new bands will automatically open in the view. Go to the **Layer Manager** in the upper right corner and **deselect the Vector folder** in both images.



In the Product Explorer Window, select products [1] to [4]; right-click and select Close 4 Products.

5.6 Terrain correction

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. We need to apply **Terrain Correction** to compensate for the distortions and reproject the scene to geographic projection. (See **NOTE 6**)

NOTE 6: The geometry of topographical distortions in SAR imagery is shown on the right. Here we can see that point B with elevation h above the ellipsoid is imaged at position B' in SAR image, though its real position is B". The offset Δr between B' and B" exhibits the effect of topographic distortions. (SNAP Help)



Click Radar → Geometric → Terrain Correction → Range-Doppler Terrain Correction

In the **I/O Parameters** tab set as "Source Product" the **product [5] (velocity product)**. In "Target Product", keep the default name and set the "Directory" to:

/shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Processing.

In the Processing Parameters tab set:

Digital Elevation Model: ACE30 (Auto Download)

Map Projection: Click on it, choose Predefined CRS and click on "**Select**". In "Filter" search for **32621** (EPSG: 32621 – WGS84 / UTM Zone 21N) and when you find it click **OK** to both windows.

C Range Doppler Terrai	n Correction 🛛 🗧 🗟	Range D	oppler Terrain Correction	4.5.4
File Help		File Help		
VO Parameters Processing Parameters		VO Parameters Processing Para	meters	
Source Product source: [5] subset SIA IW 20170905 20170921 Stack V Toract Product Name		Source Bands:	Velocity_siv1_21Sep2017_HH Sigma0_HH_09Sep2017 Sigma0_HH_21Sep2017	
Subset SIA (W 20170909 20170921 Stack Vel 1	c]			
Save as: BEAM-DIMAP		Digital Elevation Model.	ACE30 (Auto Download)	
Directory:		DEM Resampling Method	BILINEAR_INTERPOLATION	-
/shared/Training/CRYOD2_GlacierVelocity_Gre	enland_TutorialKit/Processing	Image Resampling Method:	BILINEAR_INTERPOLATION	*
Dpen in SNAP		Source GR Pixel Spacings (az x rg): Rivel Spacing (m)	10.0(m) × 10.0(m)	
		Pixel Spacing (deg):	8 9831528411952156.5	
		Map Projection:	WGS 84 / JITM zone 21N	
	<u>Bun</u> <u>C</u> lose	Mask out areas without elevation Output bands for: Selected source band Incidence angle from ellipsoid Apply radiometric normalization Save Sigma0 band Save Sigma0 band Save Belau band Austrary File (ASAR only)	n DIHput complexulata	intude Inclidence angle
Map Projection -	😑 🗶 Select Coordina	ate Reference System	* . *	
	Filter: 32621	Well-Known Text (WKT):		
Coordinate Reference System (CRS) Custom CRS Geodetic datum Projection Projection Projection Projection Bacameters Prodefined CRS S 84 / UTM zone 21N Select	EPSG 22621 - WGS 84 / UTM zone 21N	PROJECTIVICS 84 / UTM zone 21N". GEOCGSTWOS 84", DATUM zone 21N". DATUMI World Geodetic System 1984", SPHEROLIWOS 84", 657137 0. 298 J AUTHORITYTEPSG", "6326")]. PRIMEMI"Greenwich". 0. AUTHORITYTE UNITT'degree". 0. 01 A53292519943295] AXISI'Geodetic lattude", EASTI. AXISI'Geodetic lattude", CASTI. AXISI'Geodetic lattude", MORTHI. AUTHORITYTEPSG", "4326"]]. PROJECTION/Transverse Mercator", AUTH PARAMETERI'Central meridian", -57.0]. PARAMETERI'false morthing". 50000.0]. PARAMETERI'false morthing". 50000.0]. PARAMETERI'false morthing". 5001. UNITT'm", 1.0]. AXISI'Feasting", EASTI. AXISI'Feasting", EASTI. AXISI'Feasting", MORTHI.	S722356 PSG***85 40RITY["E	
QK <u>C</u> ancel	Help	<u></u> K	Cancel	

Keep defaults values for the other parameters. Click Run. Approximate processing time: 2.5 minutes.

5.7 Visualize

Close **Range Doppler Terrain Correction** window. Let's overlay the velocity data on top of the original data. Expand the new georeferenced product [7] and open the *Sigma0_HH_21Sep2017* band in View window. We can stretch the histogram a little in the **Colour Manipulation** tab (move the white slider on the right, to approx. 0.45).

Then go to the Layer Manager in the top right corner and in the Vector data folder deselect Velocity. Then click on I to add an overlay layer, select Image of Band / Tie-Point Grid and select the *Velocity_slv1_21Sep2017_HH*. Then click Finish.

	Add Layer	+ = ×	Add Layer	+ © ×
	S	elect Layer Source	Select Ba	nd / Tie-Point Grid
Available layer so ESRI Shapefile Image of Band Layer Group Mapping Tools RGB Image from	urces: / Tie-Point Grid n File	Compatible	bands and tie-point grids: Subset_S1A_IW_GRDH_20170909_20170 Velocity_slv1_21Sep2017_HH Sigma0_HH_09Sep2017 Sigma0_HH_21Sep2017	921_Stack_vel_TC
	÷			
	< ģremous Next > Eimsh	Cancel Help	< Previous Next > Finish	Cancel Holp

Now, we can see the velocity band overlaid over the original image, we can adjust the **transparency** by going to the **Layer Manager**, selecting the **Velocity_slv1_21Sep2017** and moving the transparency slider on the bottom of the tab.



We can also make the layer semi-transparent. In **Layer Manager**, select the overlaid *Velocity* layer and move the transparency slider at the bottom of the tab.



5.8 Compare to existing velocity datasets

In the *Auxdata* folder you can find a CSV file (tab delimited) containing a velocity data from two external sources, both also based on Sentinel-1. Let's see how our results compare to them.

The first dataset was acquired from the *CPOM Ice Sheet Outlet Glacier Velocity Service* (<u>Centre for Polar</u> <u>Observation and Modelling Data Portal</u>), a portal providing near real-time velocity maps produced by tracking moving features (offset-tracking) in Sentinel-1 data between two consecutive acquisitions (Hogg, Shepherd, & Gourmelen, 2015). The CPOM velocity data we will use here, correspond to period 15 -21 September 2017 (our results correspond to 9-21 September 2017).

The second dataset contains values extracted from the *ENVEO Greenland ice velocity map 2016/2017 from Sentinel-1* (ENVEO Cryoportal) also derived using feature tracking in Sentinel-1 data. Compared to the CPOM dataset, the ENVEO velocity uses 12 day period between image pairs and the final product is generated by pixel-scale averaging of velocities estimated from image pairs acquired between 23 December 2016 and 22 February 2017 (Nagler, Rott, Hetzenecker, Wuite, & Potin, 2015).

The final product is then resampled to 250m grid. Apart from the overall horizontal velocity product we will use, the dataset also includes separate velocity components (vx, vy, vz) valid pixel count and uncertainty estimates.

We can load the CSV file by going to the **Product Explorer** window and selecting the product [7]. Then go to **Vector** \rightarrow **Import** \rightarrow **Vector from CSV**.

Navigate to /shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Auxdata and select PetemannGlacier_Velocity_points.csv

In the **Import CSV Data** window selected **Predefined CRS**, click on "**Select**" and in the "Filter" search for "4326", select "EPSG: 4326 - WGS 84" and click OK only to the 2 first windows.

Import CSV Data	* T *	🥧 Select Coord in	nate Reference System 🛛 🏠 🗉 🗙
The vector data are not associated will coordinate reference system (CRS).	th a	Filter: 4326	Well-Known Text (WKT):
Please specify a CRS so that coordinat interpreted correctly. Coordinate Reference System (CRS)	tes can be	EPSG: 4326 - WGS 84	GEOGCS["WGS 84". DATUM["World Geodetic System 19 SPHEROID["WGS 84". 6378137.0,
💭 Use target CRS			AUTHORITY["EPSG","6326"]]. PRIMEM["Greenwich", 0.0, AUTHORI
Custom CRS			UNIT["degree". 0.01745329251994 AXIS["Geodetic longitude", EAST].
Geodetic datum:			AUTHORITY["EPSG","4326"]]
Projection:	1050 mm -		
Projection Pa	aramaters		
Predefined CRS	Select		
<u>O</u> K <u>C</u> a	ncel <u>H</u> elp		<u>OK</u> <u>Cancel</u>

In the **Point Data Interpretation** window, select "**Interpret each point as track point**" and then click **OK**.





Now let's compare the profiles. In the **Product Explorer** window, in the product [7], highlight the **Velocity_slv1_21Sep2017_HH** band. Then go to **Analysis** and click on **Profile Plot**.

Select ✓ the Use ROI mask and choose *PetermannGlacier_Velocity_points* Deselect Compute in-between points.

Select **V** Use correlative data and set:

Point data source: *PetermannGlacier_Velocity_points* Data field: *CPOM_Vel_20170915_20170921*



We can see that the CPOM data show more variability but otherwise agree quite nicely with our estimation. The increased variability is likely a result of shorter time period between used acquisitions (6 days, compared to 12 days period for our input images) and much finer GCP grid spacing (100 m, compared to our 600 m).

Now change the correlative Data field to ENVEO_Vel_20161223_20170222.



We can see that our estimation agrees with the ENVEO velocity almost perfectly. The ENVEO velocity uses the same time period between images (12 days), but the estimated velocities are averaged over 3-month period which is likely responsible for the minor differences. Glacier velocity changes over time as it is partly driven by the melt, therefore we can expect that the velocity would be slightly lower during the winter months compared to early fall.

6 Other suggested steps

6.1 Export velocity

Now we can export our results to an ESRI Shapefile (.shp) format that is more manageable and can be processed and visualized further in software such as QGIS. The shapefile will contain following information:

- Coordinates of GCP point in master image (9 Sept)
- Coordinates of corresponding point in slave image (21Sept)
- The distance travelled
- Velocity in m/day
- Heading in degrees (East from North)
- Range shift
- Azimuth shift

In order to view this, expand the "Vector Data" folder of the product [7] and double click on Velocity.

Velocity	mst lat	mst lon	sly lat	sly lon	distance	velocity	heading	range shift	azimuth shift	geometry	style rss
post 0	80.569	-54.166	80.569	-54.166	0.613	0.05	36.865	0.061	0.602	POINT (55	fill: #0000f
post 1	80.571	-54.194	80.571	-54.194	0.578	0.047	36,371	0.053	0.567	POINT (55	fill:#0000f
post_10	80.596	-54.448	80.596	-54.448	1,807	0.15	253.27	-1.224	-1.316	POINT (54	fill:#0000f
post 100	80.834	-57.058	80.834	-57.058	0.851	0.07	201.03	0.108	-0.834	POINT (49	fill:#0000f
post 1000	80.68	-55.602	80.68	-55.602	0	0.063	-1	0,369	-0.655	POINT (52	fill:#0000f
post 10000	80.95	-62.261	80.95	-62.261	0.435	0.036	215.802	-0.104	-0.422	POINT (40	fill:#0000f
post 10001	B0.952	-62.293	80.952	-62.293	0.514	0.043	216.655	-0.13	-0.496	POINT (40	fill:#0000f
post 10002	80.954	-62,324	80.954	-62.324	0.596	0.05	216.28	-0.148	-0.577	POINT (40	fill:#0000f
post 10003	80.956	-62,356	80.956	-62.356	0.903	0.075	216.59	-0.229	-0.87	POINT (40	fill:#0000f
post 10004	80.958	-62.387	80.958	-62.387	0.835	0.069	212.744	-0.157	-0.816	POINT (40	fill:#0000f

Depending on the version of SNAP you have there might be a reoccurring bug that prevents simple export of the detections to ESRI shapefile format. Outlined below is a method to export for **versions** without the bug (OPTION 1) and a work-around method for **versions with the bug (OPTION 2)**.

6.1.1 OPTION 1 – No error

In **Product Explorer** window, expand the product [7] and open the **Vector Data** folder. Right-click on the **Velocity** layer and select **Geometry as a Shapefile**. Save the layer to the **Processing** folder with the name "**Velocity.shp**".



6.1.2 OPTION 2 – SNAP versions with error

If the approach described in OPTION 1 does not work for you then the version of SNAP installed on your machine likely contains the mentioned error.



Click **OK** and make the following steps.

The detections are stored in the output product folder as a CSV file. The CSV file can be loaded directly to QGIS and converted into shapefile.

In your VM, go to **Applications** \rightarrow **Processing** and open **QGIS Desktop.** Now, click on the "Add **Delimited Text Layer**" and the vertical menu on the left of the window. In the window that opens, click **Browse** and navigate to:

/shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Processing/, open

subset_S1A_IW_GRDH_1SDV_20170909_20170921_Stack_Vel_TC.data folder, then open *vector_data* folder, select *Velocity.csv* and click "Open".

A table will appear in the bottom of the window. Select **Custom delimiters**, and select **Tab**, unselect all other delimiters and in **Other Delimiters** type delete all.

In Record options, set Number of header lines to discard to 3 and select the "First record has field names" option. Finally, in the Geometry definition, select "Well known text (WKT)" and set Geometry Field to "geometry:Point".

=		Create a Laye	er from a Delimited Text I	File		* D :
File Name Glacie	rVelocity_Greenland_TutorialKit/Proces	sing_2/Subset_S1A	_IW_GRDH_15DH_20170909	9_20170921_Stack_Vel_T	C.data/vector_data/Velo	city.csv Browse
Layer name Velo	ocity				Encoding UT	F-8 💌
File format	C CSV (comma separated values)	(Custom delimiters	r R	egular expression delin	iter
	Comma III 1 Other delimiters	Quote	F Space	Escape	☐ Sem	colon
Record options	Number of header lines to discard	3 ÷ ▼ First	record has field names			
Field options Geometry definiti	Trim fields T Discard empty fi ion T Point coordinates	ields 🦵 Decimal s	separator is comma Vell known text (WKT)	ŕN	o geometry (attribute o	nly table)
	Geometry field geometry:Point		· Geometry t	ype Detect 💌		
Layer settings	🗂 Use spatial index	F	Use subset index	Γw	atch file	
org.esa.sr	nap_geometry_05Nov2018T16.15.10	Velocity:String	geomet	ry:Point	mst_lat:Double	mst_lon:Doubl_
1 ID00000000		post_0	POINT (551824.933391169	92 8946326.543199053)	80.5686945734575	-54.16597631953
2 ID00000001		post 1	POINT (551294.562013890	02 8946607.957540108)	80.57144333143283	-54.194190647621
3 ID00000002		post_10	POINT (546534.071356247	79 8949152,560736438)	80.59618215321073	-54.44812120564!
4 ID00000003		post_100	POINT (498960.124014874	486 8974626.375815913	80.83355757297747	-57.05847076521-
5 ID0000004		post 1000	POINT (525281.773246288	88 8957759.159295281)	80.67972191376523	-55.60156735952

Then, click **OK**. The following window will appear. In **"Filter**", type **32621** and you will see that in the **"Coordinate reference systems of the world**" tab, the **"WGS 84 / UTM zone 21N**" Coordinate Reference System will appear. Select it and click **OK**.

Coordinate Reference Syst	tem Selector	I II X
Specify CRS for layer Velocity		
Filter 32621		10
Recently used coordinate reference systems		
Coordinate Reference System	Authority ID	
Coordinate reference systems of the world	☐ Hide dep	recated CR5s
Coordinate Reference System	Authority ID	
Im Projected Coordinate Systems Universal Transverse Mercator (UTM)	1	
WGS 84 / UTM zone 21N	EP5G:32621	
4		1.1
Selected CRS: WGS 84 / UTM zone 21N		
+proj=utm +zone=21 +datum=WGS84 +units=m +	no_defs	
	OK Cancel	Help

The new layer Velocity will appear in the Layers Panel.



Click **OK**. Then right-click on the layer again and go to **Save as**. In the window that opens, set:

Format: ESRI Shapfile

Filename: /shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Processing/Velocity_ Point.shp (Click "Browse", navigate to the following path: /shared/Training/CRYO02_GlacierVelocity_ Greenland_TutorialKit/Processing/, select the Velocity_Point.shp file and click Save.) CSR: Selected CRS (EPSG:32621, WGS 84 / UTM zone 21N)

Format	ESRI Shapefile		
File name	ierVelocity_Greenland	_TutorialKit/Processing/Velocity_Point	shp Browse
layer name [1		
CRS [Selected CRS (EPSG:3	2621, WG5 84 / UTM zone 21N)	
Encoding		System	×
Save only	selected features		
> Select fie	elds to export and th	heir export options	
Add saved	file to map		
Symbology ex	kport	No symbology	
Scale-		1:50000	
• Geometr	у —		
Geometry t	ype	Automatic	•
F Falce m	itti-type		
E Include z	odimension		
F Exten	t (current: layer) —		
▼ Laver Op	tions		
RESIZE NO			
SHPT			
and 1			

Then click **OK**.

To the following window that appears, click "Overwrite file".



Now you have the layer saved as an ESRI Shapefile. Close QGIS.

6.2 Visualize in QGIS

Minimize the SNAP window and open or re-open QGIS (Applications \rightarrow Processing \rightarrow QGIS Desktop). Once the QGIS is loaded let's open the Velocity raster band.

Navigate to the *Processing* folder in the **Browser Panel** on the left side of the window, expand the *Subset_S1A_IW_20170909_20170921_Stack_Vel_TC.data* folder and double-click the *Velocity_slv1_21Sept2017_HH.img*.

The raster layer will be opened and added to the Layers Panel below the Browser Panel.



To change the appearance right-click the layer in Layer Panel, go to "Properties" and in Style tab set: Render type: "Singleband pseudocolor"

You can select any colour pallet and adjust the classes to your liking, however for our purposes we will use predefined colour pallet and classes saved as a text file in the *Auxdata* folder. To load it, click **Color map from file**" (indicated on the image below), then navigate to /shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Auxdata and select Glacier_velocity_ColourPallet.txt

Click OK.



6.3 Add vector Velocity fields

In the **Browser Panel** double click the *Velocity_point.shp* layer to load it. We need to filter the layer a little since the point grid is too dense for our purposes.



The simplest way to do this is to create subset with every n^{th} point (or for example random selection). Select the *Velocity_point.shp* in the **Layer Panel** and in the upper tool panel click $\stackrel{\text{loc}}{=}$ (above) and set **Expression**: (\$id \$ 30) = 0

3	select by expression - Velocity_Point	+ E ×
Expression Function Edit	or	
= + - / * ^ II () (\$id % 30) = 0	J Image: Search	
Output preview: 1	Record String Variables Recent (Selection)	Select V Close

Click **Select** and then close the window. Go to the **Processing Toolbox** at the right side of the window, in the search box type "**Save**" and press **Enter**. Then double-click on the **Save selected features** tool and set "**Selection**" to */shared/Training/CRYO02_GlacierVelocity_Greenland_TutorialKit/Processing* (choose "**Save to file...**") and write as "**File name**": *Velocity_point_sel30.shp*. Click **Save** and press **Run**.

(Save selected features	-6 E
Parameters Log	Run as batch process	Save selected features
Velocity_Point [EPSG:32621] Selection	<u></u> 9	This algorithm creates a new layer with all the selected features in a given vector layer.
hg/CRYO02_GlacierVelocity_Greenla	and_TutorialKit/Auxdata/Velocity_point_sel30.shp	If the selected layer has no selected features, all features will be added to the resulting feature.
	Set output directory	
		0%
		Run Close

New point layer *Selection* appeared in Layers Panel. Deselect the original *Velocity_point* layer in the Layers Panel to hide it.



To visualize the velocity vector fields, we need to use the **Vector field renderer** plug-in 22 or install it (if it is not already installed). We can do this by going to the **Plugins** menu on the top of the QGIS window (indicated above) and go to **Manage and Install Plugins...**

In the Plugins dialog search for Vector field, select Vector field renderer and press Install plugin.

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ali 💦	Search vector field	-	-63
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Not installed Digradeable Settings		Vector field renderer Draw a point layer with arrow symbols Renders a point layer with arrows representing vectors. T size and orientation of the arrow is data defined. Typically	
		Upgrade all Install	l plugin Help

Close the dialog. Now make sure the *Selection* layer is highlighted in the Layers Panel and then click on *Apply vector renderer to current layer* in the toolbar at the top of the window.

At the Vector field tab, set as:

Vector field type: Polar (length, angle) field Length attribute: velocity Angle attribute: heading Arrow format: Size: Head (relative): 0.20 Shaft width: 0.20 and Base size: 0.20 Scale: 1.5

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Click OK.

Now we can inspect the direction of the ice flow. As a last step we can add a base map. Go to Web \rightarrow OpenLayers plugin \rightarrow Bing Maps \rightarrow Bing Aerial.

Drag the **Bing Aerial** layer **to the bottom** of all layers in the **Layers Panel** to visualize the result.

Click on the **Display the vector scale box** *L* icon, in **Location** choose **"Top right",** in **Box** deselect **"Fill Box"** and click **OK.**

THANK YOU FOR FOLLOWING THE EXERCISE!

7 Further reading and resources

Hogg, A., Shepherd, A., & Gourmelen, N. (2015). A first look at the performance of Sentinel-1 over the West Antarctic Ice Sheet. Presented at the FRINGE 2015, Frascati, Italy.

Nagler, T., Rott, H., Hetzenecker, M., Wuite, J., & Potin, P. (2015). The Sentinel-1 Mission: New Opportunities for Ice Sheet Observations. *Remote Sensing*, 7(7), 9371–9389. https://doi.org/10.3390/rs70709371

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