



Summer School in InSAR, time series processing and deformation modelling

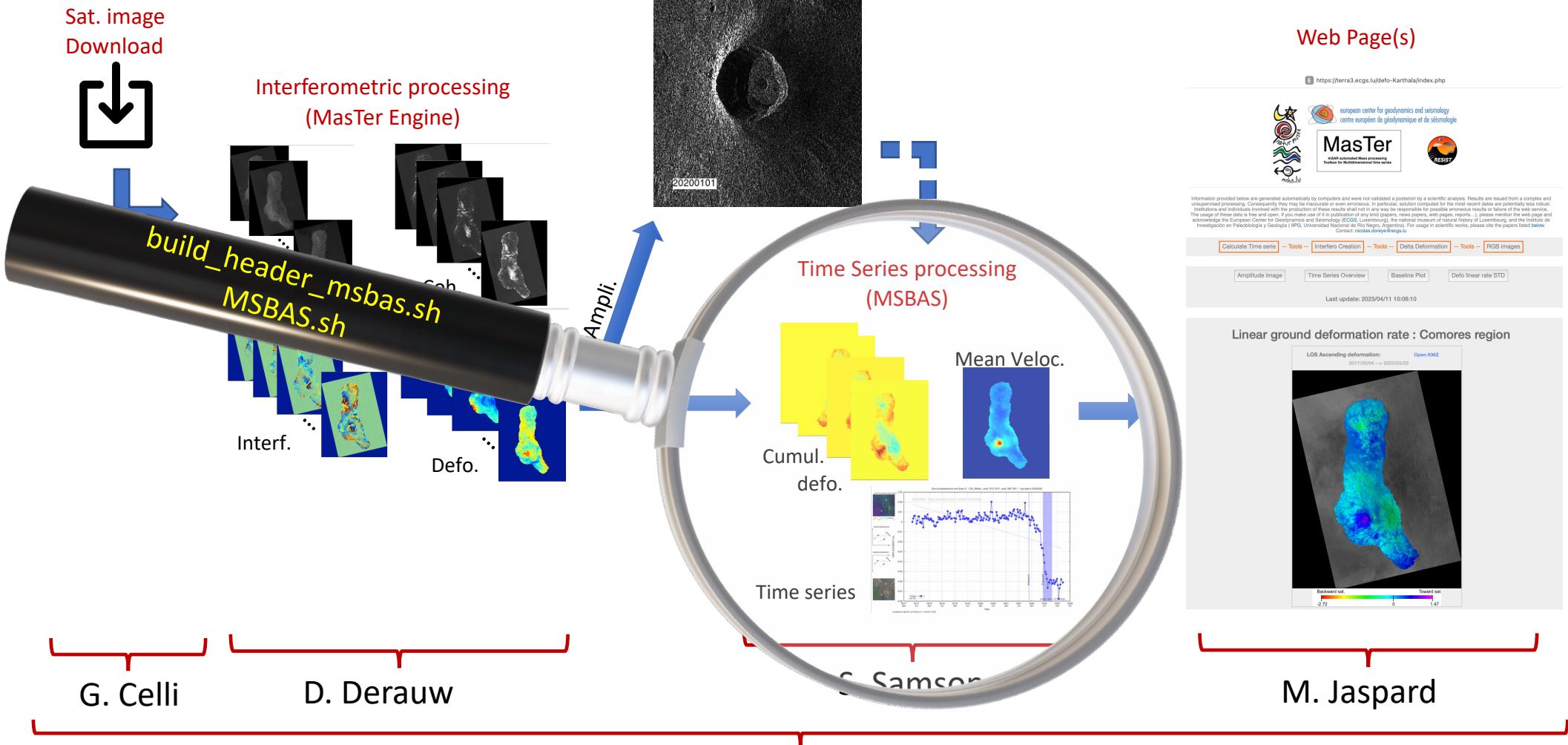
MSBAS inversion:

**Prepare the inversion, run the inversion,
best parameters selection,
additional pairs selection (coh, dates, phase closure).**

Nicolas d'Oreye



MasTer Toolbox



MSBAS & Exercise 3

Plan: Preparing the msbas inversion:

- build_header_msbas_criteria.sh
- The header.txt

Running the msbas inversion:

- MSBAS.sh
- SBAS, MSBAS 2D, MSBAS 3D

Selecting the best inversion parameters:

- test_lcurve.sh

Additional pairs selection:

- Coherence threshold
- Start – stop dates
- Optimisation (cfr Delphine) or Max 3 times
- Phase closure

Hands-on exercice 3 with data on
Domuyo - Laguna del Maule



MSBAS & Exercise 3

Preparing the msbas inversion:

- **build_header_msbas_criteria.sh**
 - First step consist in preparing the required files for MSBAS, that is
 - A directory where to run the inversion, e.g. [*\\$3602/MSBAS/YourRegion_and_Some_Info*](#)
 - A directory containing the (links to the) deformation maps for each mode to invert, e.g. [*\\$3602/MSBAS/YourRegion_and_Some_Info/DefoInterpolx2Detrendi*](#)
 - A file listing the deformation maps for each mode to invert along with some info, e.g. [*\\$3602/MSBAS/YourRegion_and_Some_Info/DefoInterpolx2Detrendi.txt*](#)

```
/Volumes/hp-D3602-Data_RAID5/MSBAS/_Domuyo_S1_Auto_20m_450days/DefoInterpolx2Detrend1.txt ↓
1 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20170517_Bp-11.2m_HA1247.m_BT18days_Head106.3deg -11.24840315551214 20170429 20170517
2 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20171113_Bp-14.2m_HA986.6m_BT198days_Head106.3deg -14.21692611793151 20170429 20171113
3 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20171125_Bp-7.15m_HA1960.m_BT210days_Head106.3deg -7.157866784961501 20170429 20171125
4 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20171207_Bp-8.19m_HA1711.m_BT222days_Head106.3deg -8.197533034650927 20170429 20171207
5 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20180205_Bp-6.20m_HA2259.m_BT282days_Head106.3deg -6.206981104693649 20170429 20180205
6 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20180313_Bp-2.82m_HA4967.m_BT318days_Head106.3deg -2.823428235143036 20170429 20180313
7 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20180406_Bp10.02m_HA-1398m_BT342days_Head106.3deg 10.02870116689994 20170429 20180406
8 DefoInterpolx2Detrend1/deformationMap.interpolated.flattened.UTM.50x50.bil.interpolated_S1_ARG_DOMU_LAGUNA_A_18-36.2deg_20170429_20180521_Bp14.57m_HA-061.m_BT390days_Head106.3deg 14.57809257251186 20170429 20180521
```

- A header file containing the description of the data sets and the chosen parameters for the inversion

```
FORMAT = 0
FILE_SIZE = 5361, 4801
WINDOW_SIZE = 0, 5360, 0, 4800
R_FLAG = 3, 0.04
T_FLAG = 0
C_FLAG = 0
V_FLAG=0
I_FLAG = 0
SET = 0, 232707, 344, 36.4002, DefoInterpolx2Detrend1.txt
SET = 0, 095628, -162.711, 36.2386, DefoInterpolx2Detrend2.txt
```



MSBAS & Exercise 3

Preparing the msbas inversion:

- **build_header_msbas_criteria.sh**

➤ To prepare these required files for MSBAS:

1. Create **and go into** a directory where to run the msbas **\$3602/MSBAS/YourRegion_and_Some_Info**
Here, do e.g.:

```
mkdir $3602/MSBAS/_Argentina_S1_20m_450days_NoOptim
```

```
cd $3602/MSBAS/_Argentina_S1_20m_450days_NoOptim
```

1. Run the **build_header_msbas_criteria.sh** script with the following parameters:

- the name of the mode (eg. **DefolInterpolx2Detrend**) and the number of modes

- Max **Bp** and **Bt** to select the pairs to invert

- the path to where the mass processed are stored for each mode (e.g. where **the Geocoded/** directory is), e.g.

```
...$PATH_3601/SAR_MASSPROCESS/SAT/TRK/SMCrop_SM_ZOOM_ML/
```

Here, do e.g.:

```
build_header_msbas_criteria.sh DefolInterpolx2Detrend 2 20 450
```

```
PATH_3601/SAR_MASSPROCESS/S1/ARG_DOMU_LAGUNA_A_18_SAMPLE/SMNoCrop_SM_20180512_Zoom1_ML4/
```

```
PATH_3601/SAR_MASSPROCESS/S1/ARG_DOMU_LAGUNA_D_83_SAMPLE/SMNoCrop_SM_20180222_Zoom1_ML4
```

➤ Note that it **must** be run in the directory where msbas will be run.



MSBAS & Exercise 3

Preparing the msbas inversion:

- **build_header_msbas_criteria.sh**

➤ Warning: it will need to access the deformation maps which are stored in the provided path, that is e.g.
`...$PATH_3601/SAR_MASSPROCESS/SAT/TRK/SMCrop_SM_ZOOM_ML/Geocoded/DefoInterpolx2Detrend`
but also access to some info (baselines, acquisition time, azimuth, look angle...) that are in the pair directories, eg.

`...$PATH_3601/SAR_MASSPROCESS/SAT/TRK/SMCrop_SM_ZOOM_ML/MAS_SLV/i12/...`

However, if you have cleaned these pair directories to spare room on your disk, you can use the script

`build_header_msbas_criteria_From_nvi_name_WithoutAcqTime.sh`

It will get approximate information found in the deformation maps names. However, it will not find the acquisition time, which you will have to add manually in the header file (even a dummy time, that is OK).

This script is however only for test purpose and may not be accurate !

- Incremental: slower the first time, faster the next one...



MSBAS & Exercise 3

Preparing the msbas inversion:

- build_header_msbas_criteria.sh
- The **header.txt**

Edit and change according to your needs (example below may differ from your data):

Possible crop	FORMAT = 0 FILE_SIZE = 5361, 4801 WINDOW_SIZE = 0, 5360, 0, 4800 R_FLAG = 3, 0.04
Inversion order and lambda factor	T_FLAG = 0 C_FLAG = 0 V_FLAG=0
Reference	I_FLAG = 2,/mnt/3602/MSBAS/_Domuyo_S1_Auto_20m_450days/Cln_Points_TS_Domuyo.txt SET = 0, 232707, 344, 36.4002, DefoInterpolx2Detrend1.txt SET = 0, 095628, -162.711, 36.2386, DefoInterpolx2Detrend2.txt
Time series	Acq. Time Azimuth heading Incidence look angle Data set

Set e.g.

R_FLAG= 2, 0.04

I_FLAG = 0



MSBAS & Exercise 3

Preparing the msbas inversion

Running the msbas inversion:

- **MSBAS.sh**

- Run the **MSBAS.sh** script with the following parameters:
 - a description used for naming directories where results will be sorted (eg. *_Order_Lambda_Info*)
 - a list of pixels for which you want to extract simple time series (with error bar)

Here, do e.g.:

MSBAS.sh _2_0.04_NoCrop

- It will run in parallel with all the available CPUs

In case of crash:

- Check *DefoInterpolx2Detrendi.txt* for bad links or duplicated lines: ***_Check_bad_DefoInterpolx2Detrend.sh***
- Check the baseline plot: ***PlotBaselineGeocMSBASmodeTXT.sh***
- Check non empty deformation in given zone: ***Check_Interfero_Not_Empty_In_Zone.sh***
- Check and remove broken links: ***Remove_BrokenLinks_and_Clean_txt_file.sh***
- Check that you have enough RAM; crop if needed
- If complains about KMLSUPEROVERLAY (only needed to create kml file), check gdal
- ...

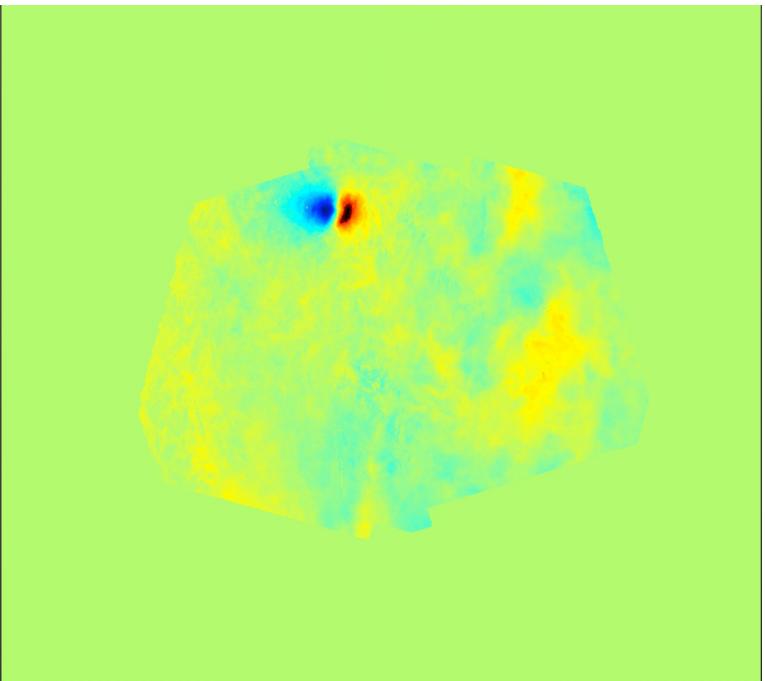
MSBAS & Exercise 3

Preparing the msbas inversion

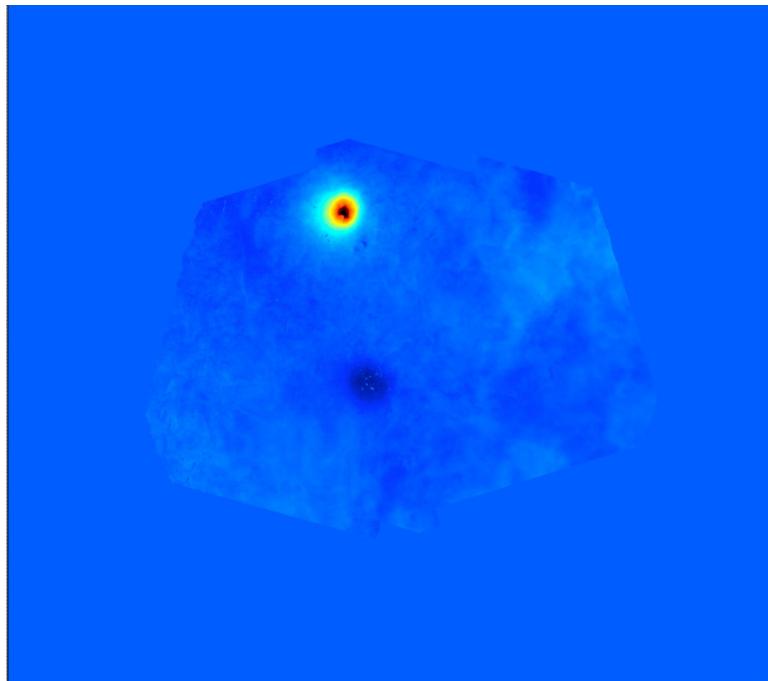
Running the msbas inversion:

- MSBAS.sh

Results:



EW linear rate



UD linear rate

.../3602/MSBAS/_Argentina_S1_20m_450days_NoOptim/zz_Comp_2_0.04_NoCrop



MSBAS & Exercise 3

Preparing the msbas inversion

Running the msbas inversion:

- **MSBAS.sh**
- **SBAS, MSBAS 2D, MSBAS 3D**

- If enough looking angle diversity is provided, msbas will perform a 2D decomposition.
- If only one mode is provided, or if similar incidence angles, it will perform a (mean) SBAS inversion
- To perform 3D inversion when movement is supposed to take place of the steepest slope, one needs additional constrains (i.e. gradient).
Change header file and add required files accordingly (see Sergey's talk).

Note that tools and plotting scripts might not be ready for that yet.

➔ commin soon...

MSBAS & Exercise 3

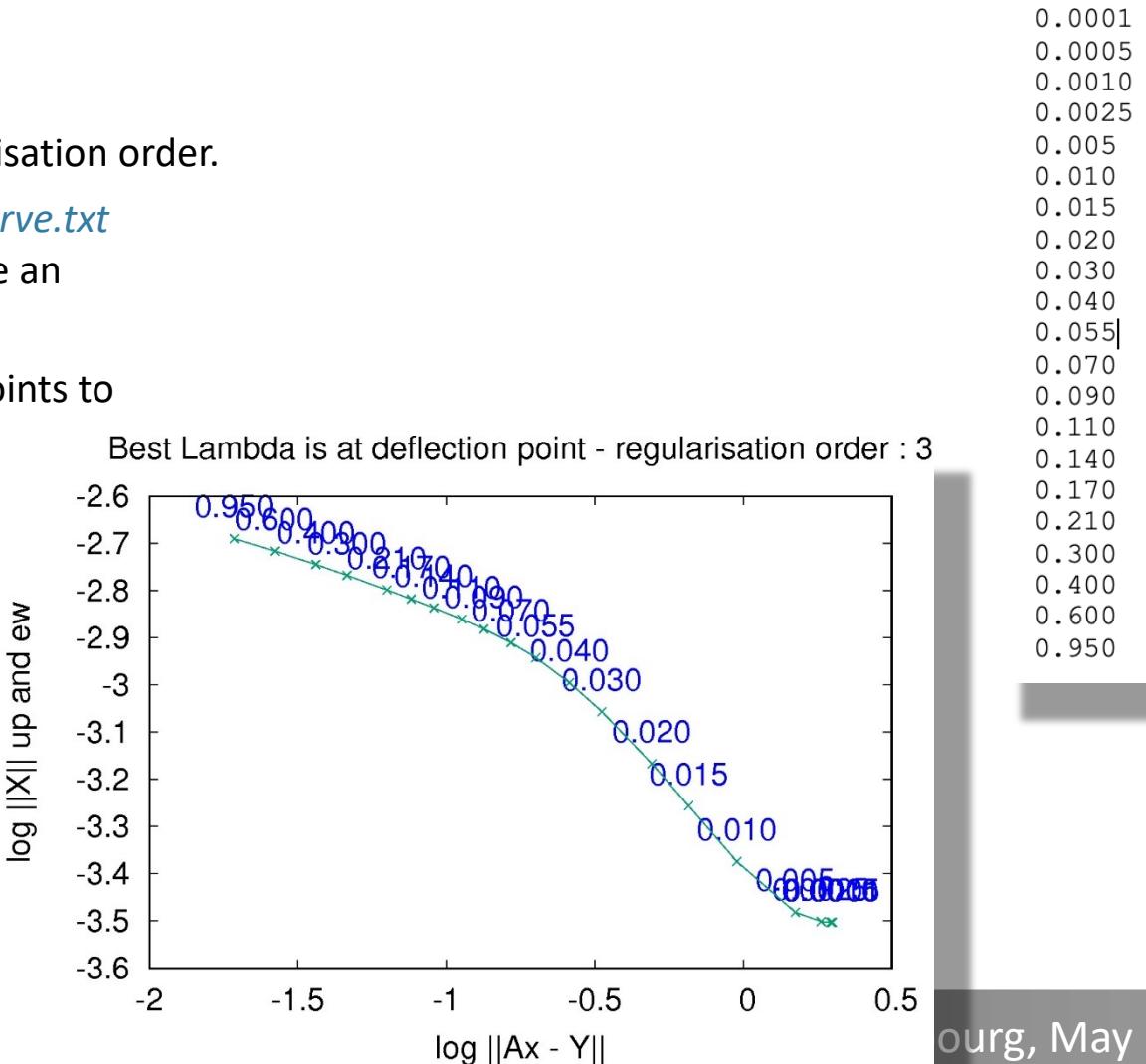
Preparing the msbas inversion

Running the msbas inversion

Selecting the best inversion parameters:

- `test_lcurve.sh`

- Search for best lambda factor for each regularisation order.
- Based on a table of steps of lambda `Steps_LCurve.txt`
(in `SCRIPTS_MT`) for which it will run each time an
msbas inversion (➔ time consuming !)
- Output l-curves where the kink in the curve points to
the best lambda factor.
Larger value will lead to stronger smoothing.



MSBAS & Exercise 3

Preparing the msbas inversion

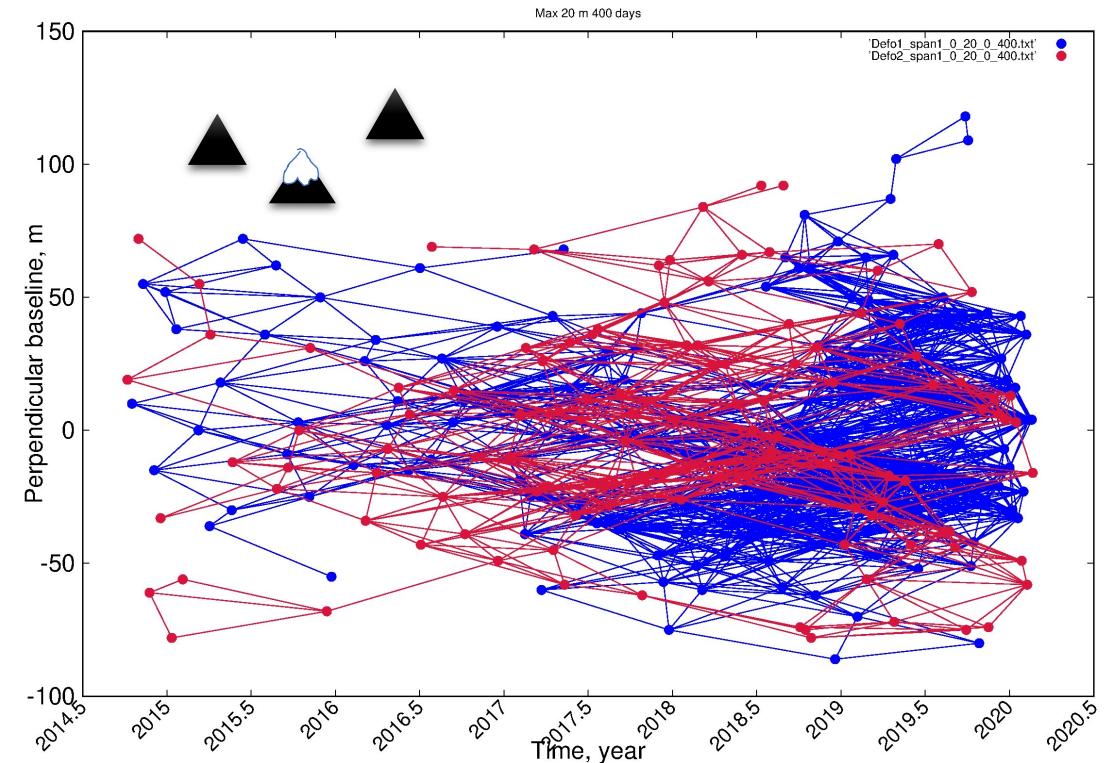
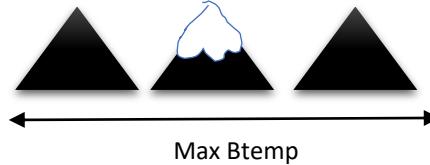
Running the msbas inversion

Selecting the best inversion parameters

Additional pairs selection:

- Coherence threshold

If the selected temporal baseline is long enough to keep coherent pairs from summer to summer, it may happen that, in the mean time, the winter would cause decorrelation between summer and winter time:



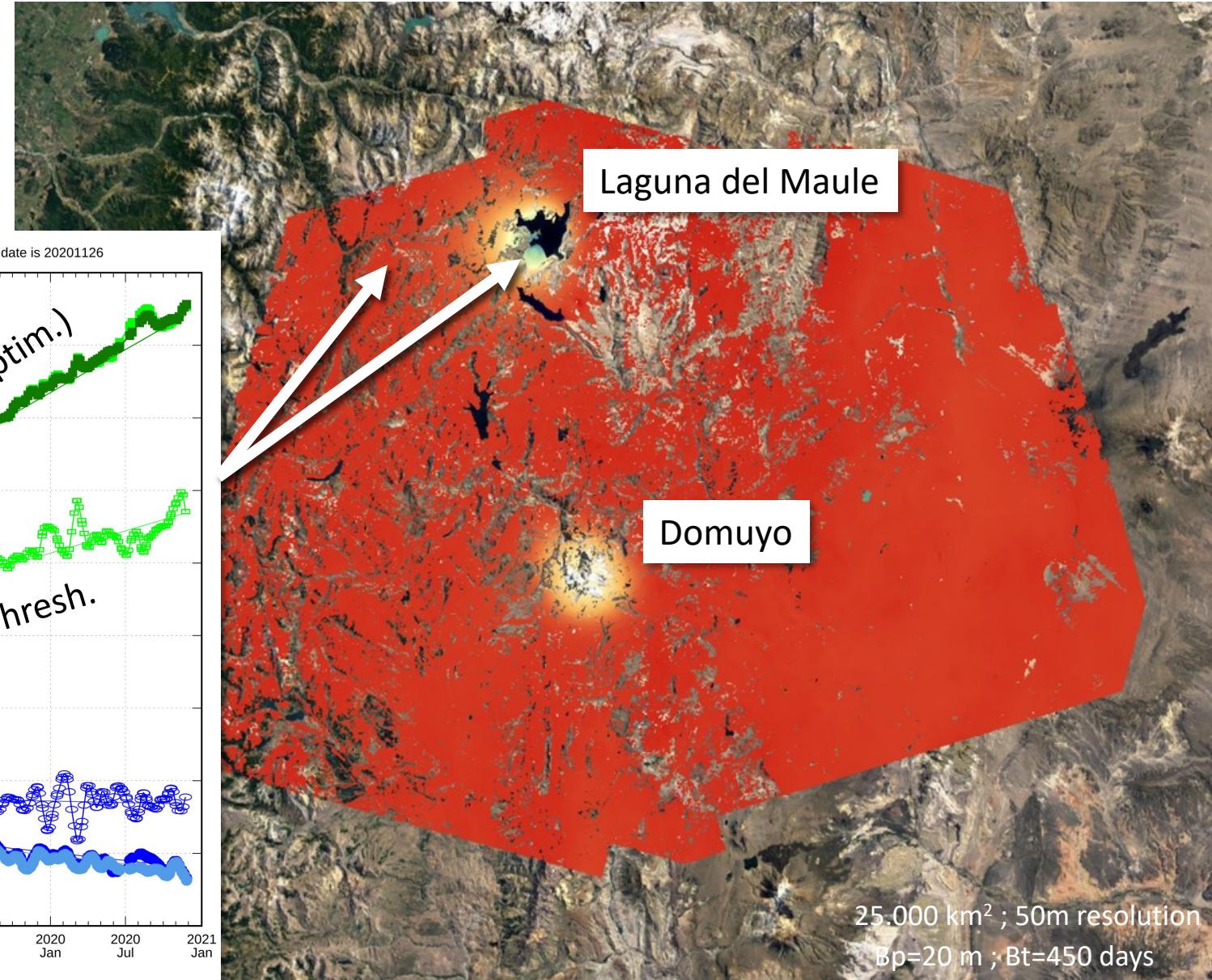
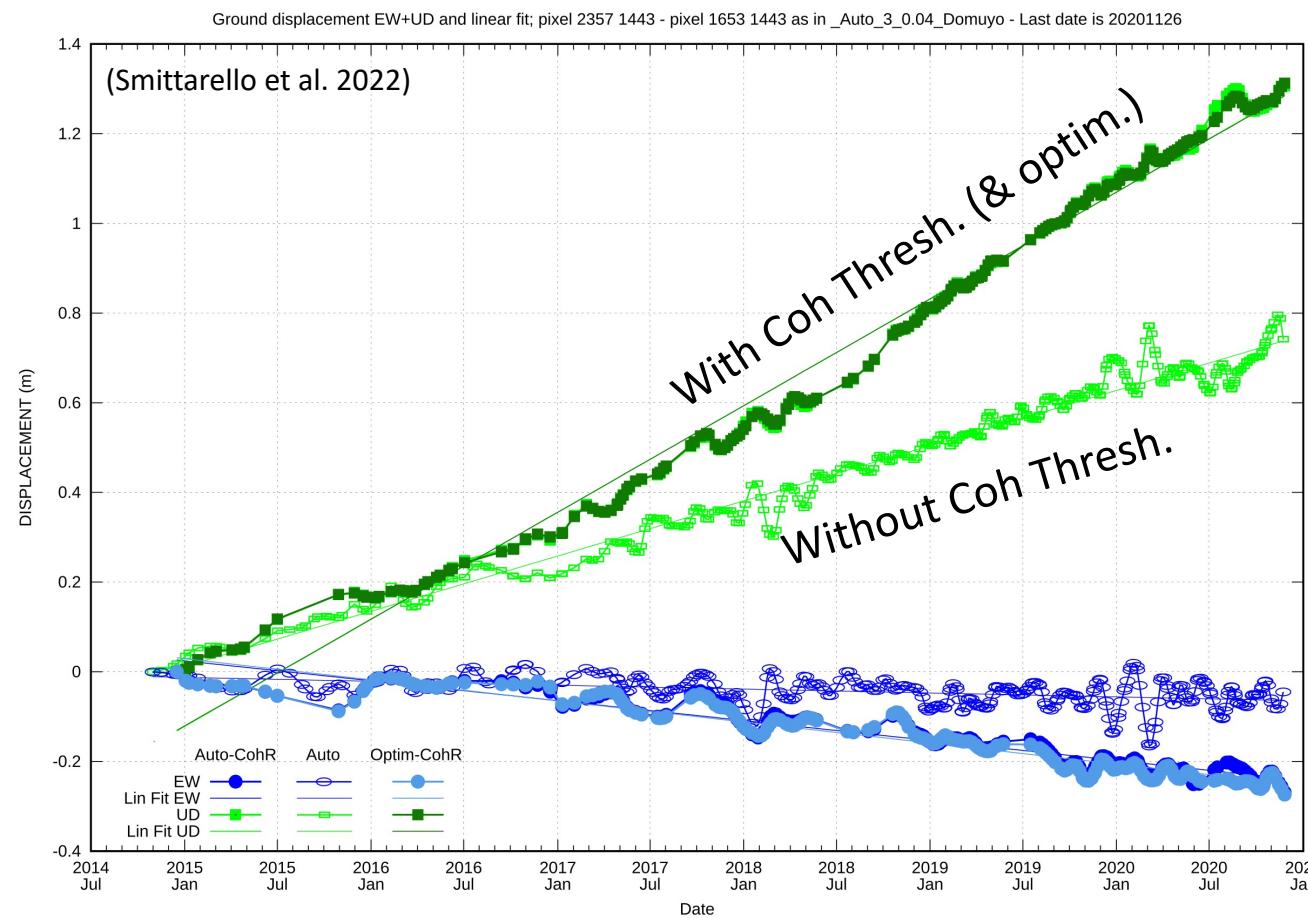
Studies have shown that it could lead to severe signal underestimation (Smittarello et al. 2022) !



MSBAS & Exercise 3

2014-2020: Sentinel 1:

- Full: 2666 interferograms
- With Coh Threshold: 1013
- Optimized => -75 %





MSBAS & Exercise 3

Preparing the msbas inversion

Running the msbas inversion

Selecting the best inversion parameters

Additional pairs selection:

- **Coherence threshold**

- Use the script ***restrict_msbas_to_Coh.sh*** with the following parameters:
 - Mode to clean, eg. **DefolInterpolx2Detrendi**
 - a coherence threshold
 - the path to a kml where mean coherence must be computed
 - the path to the directory where the geocoded coherence maps are stored, e.g **SAR_MASSPROCESS/SAT/TRK/REGION_ML/Geocoded/Coh**

=> it creates the necessary files in .../MSBAS_RESULTS/LOCATION/MODE*i*
- Use the script ***Exclude_Pairs_From_Mode.txt.sh*** with the following parameter:
\$3602/MSBAS/YourRegion_and_Some_Info/DefolInterpolx2Detrendi
- Execute ***MSBAS.sh*** as before (provides a meaningful text string for directory naming)
- Note: Coherence threshold selection is incremental → slower the first time, faster the next ones...



MSBAS & Exercise 3

Preparing the msbas inversion

Running the msbas inversion

Selecting the best inversion parameters

Additional pairs selection:

- Coherence threshold
- Start – stop dates

- To restrict the computation of MSBAS to images acquired before or after a given date, use the scripts:
 - *RemovePairsFromList_WithImagesAfter.sh*
 - *RemovePairsFromList_WithImagesBefore.sh*
- Similarly, to restrict the computation of MSBAS to images acquired between or without images acquired between a given pair of dates, use the scripts:
 - *RemovePairsFromTableList_Between_dates.sh*
 - *RemovePairsFromTableList_Outside_dates.sh*
- We will see later how we can plot ground deformation times series (from msbas results) for given pixels. These plots of time series can also be restricted to given dates, but that is not the same ! Here we restrict the inversion.



MSBAS & Exercise 3

Preparing the msbas inversion

Running the msbas inversion

Selecting the best inversion parameters

Additional pairs selection:

- Coherence threshold
- Start – stop dates
- **Optimisation (cfr Delphine) or restrict pair selection to Max 3 times**

- See next talk by Delphine for optimisation based on Coherence or Coherence proxy etc..
- To restrict the computation of MSBAS to images taken max 3 times as Master and 3 times as Slave, run these scripts (see manual or scripts):
 - *Extract_Baselines_3.sh*
 - *Keep_Pairs_From_Extract_Baseline_3.sh*



MSBAS & Exercise 3

Preparing the msbas inversion

Running the msbas inversion

Selecting the best inversion parameters

Additional pairs selection:

- Coherence threshold
- Start – stop dates
- Optimisation (cfr Delphine) or Max 3 times
- Phase closure

To search for possible interferograms affected by unwrapping error by checking phase closure consistency between triangles of pairs, run the following scripts:

- **Extract_Triangles.sh** to list all the triangles from the list of pairs
(eg [\\$PATH_1650/SAR_SM/MSBAS/Region/seti/table_0_MaxBp_0_MaxBt.txt](#))
saved in a file [_Triangles/List_Triangels.txt](#).
- **Check_Closure_All_Triangles.sh** to check unwrapping error in all triangles. It computes the mean phase based on a kml provided as parameter and consider that there is or there is no phase closure error based on an offset provided also as a parameter. It outputs 3 files in [.../SAR_MASSPROCESS/SAT/TRK/REGION_ML/Geocoded/_CheckTriangles.txt/](#):
[_Good_Closure.txt](#), [_Wrong_Closure.txt](#) and [_Pairs_To_Clean_From_WrongClosure_NotIn_GoodClosure.txt](#)
- Wrong pairs in [_Pairs_To_Clean_From_WrongClosure_NotIn_GoodClosure.txt](#) can be rejected from MSBAS by running **Remove_Pairs_From_BaselineOptimisation.sh**



MSBAS & Exercise 3

To test phase closure with Argentine dataset (**beware**: need ***Check_Closure_All_Triangles.sh*** at least **V1.4**):

- ***Extract_Triangles.sh*** \$PATH_1650/SAR_SM/MSBAS/ARGENTINE/set1/table_0_20_0_450.tx

lists **all** triangles in \$PATH_1650/SAR_SM/MSBAS/ARGENTINE/set1/_Triangles/*List_Triangles.txt* i.e. including those for which you do not have pair directories in SAR_MASSPROCESS ➔ make artificial list with only 2022 and 2023 pairs, eg.

grep 2022 *List_Triangles.txt* > *List_Triangles_2022-2023.txt*

grep 2023 *List_Triangles.txt* >> *List_Triangles_2022-2023.txt*

grep -v 2021 *List_Triangles_2022-2023.txt* > *List_Triangles_2022-2023-no2020.txt* (maybe also without 2020..)

- ***Check_Closure_All_Triangles.sh*** \$PATH_1650/SAR_SM/MSBAS/ARGENTINE/set1/_Triangles/*List_Triangles_2022-2023-no2020.txt*
\$PATH_3601/SAR_MASSPROCESS/S1/ARG_DOMU_LAGUNA_A_18_SAMPLE/SMNoCrop_SM20180512_Zoom1_ML4/Geocoded/DefolInterpolx2Detrend
\$PATH_1650/kml/ARGENTINA/LagunaDelMaule_TestPhaseClosure.kml 0.9

lists \$PATH_3601/SAR_MASSPROCESS/SAT/TRK/REGION_ML/Geocoded/_CheckTriangles.txt/_Good_Closure.txt
and \$PATH_3601/SAR_MASSPROCESS/SAT/TRK/REGION_ML/Geocoded/_CheckTriangles.txt/_Wrong_Closure.txt
and \$PATH_3601/SAR_MASSPROCESS/SAT/TRK/REGION_ML/Geocoded/_CheckTriangles.txt/_Pairs_To_Clean_From_WrongClosure_NotIn_GoodClosure.txt
(and ignore the triangles for which there is no pair directories in SAR_MASSPROCESS)

- Wrong pairs in _Pairs_To_Clean_From_WrongClosure_NotIn_GoodClosure.txt can be rejected from MSBAS by running
Remove_Pairs_From_BaselineOptimisation.sh \$PATH_3602/MSBAS/_Argentina_S1_20m_450days/DefolInterpolx2Detrend1
\$PATH_3601/SAR_MASSPROCESS/SAT/TRK/REGION_ML/Geocoded/_CheckTriangles.txt/_Pairs_To_Clean_From_WrongClosure_NotIn_GoodClosure.txt
- Do the same for DefolInterpolx2Detrend2 if required
- Run again ***MSBAS.sh*** after having renamed the ***DefolInterpolx2Detrend*i*_Optimized__Pairs_To_CleanPFrom....txt*** as ***DefolInterpolx2Derend*i*.txt***



MSBAS & Exercise 3

Plan: Preparing the msbas inversion:

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Running the msbas inversion:

- MSBAS.sh
- SBAS, MSBAS 2D, MSBAS 3D

Selecting the best inversion parameters:

- test_lcurve.sh

Additional pairs selection:

- Coherence threshold
- Start – stop dates
- Optimisation (cfr Delphine) or Max 3 times
- Phase closure

- DONE ! -