

# QUICKSTART GUIDE

## Coherent Structure Tracking (CST) codes

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**&**

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### Running CST with ifort compiler and SSWIDL software on Linux system

- **Download** the package source file CST\_V1.0.tgz from [MEDOC/TOOLS](#) webpage
- **ifort** compiler and **SSWIDL** software are required. Type the following linux commands:
- **tar -xvzf CST\_V1.0.tgz**
- **cd CST\_V1.0**
- **The directory contains 2 directories corresponding to 2 different cases** : a test case (29 Nov 2018 HMI observations – 30 min) to be able to check if your results are good (« **CST\_TEST\_30min** » directory), source codes to treat from 1 to 6 observation days (« **CST\_1\_TO\_6\_DAYS** » directory, adapted for the day 29 Nov 2018 HMI observations).
- **Each of these directories contains the following files:**
  1. **Fortran files (« codes\_CST\_Fortran » directory):**
    - cst\_labv7\_FS\_2017.f90 (main program)
    - Makefile.common (used to compile librairies that are in « lib » directory)
    - deriw2d.f90
    - detect.f90



- div\_curl.f90
- mres2d.f90
- opt\_scale.f90
- the\_name.f90 (contains thename module)
- segment.f90 (contains segmentation module)
- cg.f90
- interpol2d.f90
- interpol2dth.f90
- interpol2d\_routine.f90 (contains interpolationroutine module)
- interpol2d\_routine\_short.f90
- centre\_gravite.f90
- input.f90 (contains input subroutine)
- sub\_coef\_r.f90
- ftw3.inc, form\_num.inc, Makefile.inc
- « lib » directory contains librairies needed for compilation
- **Makefile (file to modify)**: variables CFLAGS and CFLAGS\_LIB are to be adapted according to your server (-I/usr/include/x86\_64-linux-gnu/c++/8)
- **script\_29nov2018.sh (file to modify)**: according to your server, you need to add or not the following commands :
  - « source /opt/intel/compilers\_and\_libraries\_2018.3.222/... » : path to Fortran ifort compiler
  - « ulimit -s unlimited »
- **param\_seq\_29nov2018\_EOS\_30mn (file to modify)** :  
the following parameters are to be adapted according to the HMI/SDO data:  
prefix, input\_file, arcsec, pixel

## 2. IDL files (« codes\_CST\_IDL »directory):

- reduction\_doppler\_intensity\_all\_days\_apres.pro
- reduction\_doppler\_intensity\_all\_days\_avant.pro
- transform\_uxuy\_vxvy\_all\_dates\_step\_30min.pro
- correct\_mvtSDO\_sur\_Vx\_et\_Vy\_precis\_all\_dates\_apres.pro
- correct\_mvtSDO\_sur\_Vx\_et\_Vy\_precis\_all\_dates\_avant.pro



- transfor\_Vx\_Vy\_Vdop\_vthe\_vphi\_vr\_all\_dates\_step\_30min.pro
- image\_cont.pro : to read the binary file « image\_cont » (see STEP 2)

- **Procedure to take HMI intensity and Doppler data** from [JSOC](#) (45s-cadence HMI files are not available at MEDOC) :

1. on the [JSOC](#) webpage, click on data access and then in look data (top of the page)
2. click on Fetch seriesname list
3. select hmi.Ic – continuum intensities with a cadence of 45s
4. write for example 30 mins on November, 29, 2018 :

hmi.Ic\_45s[2019.11.29\_08:00\_TAI-2019.11.29\_08:30\_TAI]

or for one day : hmi.Ic\_45s [2019.11.29/1d].

See examples on the web page for different requests

5. click on GetRecordCount (this gives you the number of files requested)
6. click on Export Data (top of the page)
7. click on Export (on the right)
8. click on method and get url-tar
9. fill the *notify* with your E\_mail address. An email will be sent to you to confirm your registration
10. fill *Requestor* with your name
11. click on *Check Params for Export*
12. when green click on *Submit Export Request*
13. an email will be sent to you with the link for downloading the data in tar format : JSOC\_20191104\_699.tar. Click on tar file link to download on your PC or type the linux command to get results from a server for example :

```
wget http://jsoc.stanford.edu/.../JSOC_20191104_699.tar
```

Type the following linux command:

```
tar -xvf JSOC_20191104_699.tar
```

You get 41 files from hmi.Ic\_45s.20181129\_080000\_TAI.2.continuum.fits up to hmi.Ic\_45s.20181129\_083000\_TAI.2.continuum.fits.

For 1 (HMI observation) day, we get 1920 files (one file each 45 seconds)



14. repeat operation at point 4 to download Doppler hmi.V\_45s – Dopplergrams with a cadence of 45s.

**Data size for 30 min** HMI observations (intensity and Doppler) is **2.7 G**.

**Data size for 1 day** HMI observations (intensity and Doppler) is **63 G**.

- CST codes can be run up to 6 days (cf « CST\_1\_TO\_6\_DAYS » directory) : the reference day is the 4th day (the reference of the center of the Sun and the Solar radius are taken at 00:00 of the 4th day). More precisely, for 6 days, **transfer the intensity and Doppler data in each directory corresponding to the day of the sequence:**

- « day3\_avant » directory: 1st day data
- « day2\_avant » directory : 2nd day data
- « day1\_avant » directory : 3rd day data
- « day1\_apres » directory : 4th day data (reference day)
- « day2\_apres » directory : 5th day data
- « day3\_apres » directory : 6th day data

**First, you must create these directories and second, put data inside.**

Note : to run CST codes for 4 days, the 2nd day is the reference day.

- For the test case of 30 min HMI observations, you must create « day1\_apres » directory and put the HMI data (intensity and Doppler) inside.
- **Create the result directories « treated\_day1\_ap » for 1 observation day (or for 30 observation min), « treated\_day1\_ap » and « treated\_day2\_ap » for 2 observation days, ...**
- **Adapt the following parameters in reduction IDL files** ( reduction\_doppler\_intensity\_all\_days\_apres.pro and reduction\_doppler\_intensity\_all\_days\_avant.pro) : **path, path\_out, rota** (=0 for standard rotation (quiet Sun) or =1 for rotation measured directly on the data), **path for « tmp » (temporary) directory** and check that tmp directory has free space in memory



- **STEP 1 : CST IDL PART**

To prepare input data for CST Fortran program, **type the following commands with SSWIDL for the test case (30 min HMI observations), in**

**« codes\_CST\_IDL » directory:**

1. `.r reduction_doppler_intensity_all_days_apres.pro`
2. `.r reduction_doppler_intensity_all_days_avant.pro` (depending of the treated case)

**For 1 to 6 days HMI, type the following commands with SSWIDL :**

1. `.r reduction_doppler_intensity_all_days_apres.pro`
2. `reduction_doppler_intensity_all_days_apres.pro,nombre_j,rota`
3. `.r reduction_doppler_intensity_all_days_avant.pro` (depending of the treated case)
4. `reduction_doppler_intensity_all_days_avant.pro,nombre_j,rota` (depending of the treated case)

The order in which the IDL codes are run is important : the reference day is chosen in the first code « `reduction_doppler_intensity_all_days_apres.pro` ».

**For example, for 1 observation day, the output files are (in FITS format) in « treated\_day1\_ap » directory :**

- `co_latitude_HMI_4096.fits`
- `co_latitude_HMI_586.fits`
- `day1_apres_int_derot_000.fits, ..., day1_apres_int_derot_1909.fits` (inputs for CST fortran code)
- `Doppler_derot_30mn.dat`
- `Doppler_derot_raw_0001.fits, ..., Doppler_derot_raw_1909.fits`
- `Doppler_derot_smooth_0001.fits, ..., Doppler_derot_smooth_1910.fits`
- `Doppler_limb4096_0001.fits, ..., Doppler_limb4096_1910.fits`
- `Doppler_raw_0001.fits, ..., Doppler_raw_1910.fits`
- `Doppler_smooth_0001.fits, ..., Doppler_smooth_1910.fits`
- `Doppler_with_rotation.dat`
- `latitude_HMI_4096.fits`
- `latitude_HMI_586.fits`
- `longitude_HMI_4096.fits`
- `longitude_HMI_586.fits`



- SDO\_Dop\_cormvt\_0001.fits, ..., SDO\_Dop\_cormvt\_1910.fits
- SDO\_seq\_doppler\_0001.fits, ..., SDO\_seq\_doppler\_1910.fits
- SDO\_seq\_int\_avec\_rot\_0001.fits, ..., SDO\_seq\_int\_avec\_rot\_1909.fits

**If there are not 1920 files (corresponding to 1 day), it is necessary to complete from the last (copy the last file).** So we have a measure of the last half hour with a lower amplitude.

**For 30 min HMI observations, we have :**

- ...
- day1\_apres\_int\_derot\_000.fits, ..., day1\_apres\_int\_derot\_41.fits
- ...

**For 6 days HMI observations, we have :**

- ...
- day1\_apres\_int\_derot\_000.fits, ..., day1\_apres\_int\_derot\_1909.fits
- day2\_apres\_int\_derot\_000.fits, ..., day2\_apres\_int\_derot\_1909.fits
- day3\_apres\_int\_derot\_000.fits, ..., day3\_apres\_int\_derot\_1909.fits
- day1\_avant\_int\_derot\_000.fits, ..., day1\_avant\_int\_derot\_1909.fits
- day2\_avant\_int\_derot\_000.fits, ..., day2\_avant\_int\_derot\_1909.fits
- day3\_avant\_int\_derot\_000.fits, ..., day3\_avant\_int\_derot\_1909.fits
- ...

**If there are not 1920 files for each day, it is necessary to complete from the last (copy the last file).**

**Warning: Data reduction uses the same ``temporary'' directory (/tmp) when reading SDO data. So you should not run the IDL code for 2 data sets at the same time, otherwise the SDO decompression files (in /tmp directory) will be destroyed by the 2nd IDL run.**

- **STEP 2 : CST FORTRAN PART**

**Choose 18 threads for an optimal run.** To compile and execute fortran files, here are the commands for SLURM, in « codes\_CST\_Fortran » directory:

*SBATCH script\_20nov2018.sh*

**The output files are for each 30 mn (in « JOB\_XXXX/results » directory) :**

- output.log : to check if CST code runs well



- image\_cont : last segmented image of the Sun in binary format (visualized by an IDL program « image\_cont.pro » (with SSWIDL : .r image\_cont.pro))
- param\_seq\_29nov2018\_EOS\_30mn : parameters used
- traject\_11\_0000 : trajectories of all selected granules. The second number of the first line is the total number of treated granules. Column 1 is the granule number, column 2 is x\_cent (gravity center), column 3 is y\_cent, column 4 is the number of the image where the granule is born, column 5 is the number of the image where the granule dies, column 6 is the lifetime of the granule in second, column 7 is the velocity ux (in km/s), column 8 is the velocity uy (in km/s)
- nb\_gran\_0000 : pixel size chosen for the spatial window, 1 arcsec in km, pixel size in arcsec, treatment threshold of CST code
- ux\_b\_0000, ux\_h\_0000, ux\_l\_0000, ux\_m\_0000, ux\_k\_0000
- uy\_b\_0000, uy\_h\_0000, uy\_l\_0000, uy\_m\_0000, uy\_k\_0000
- div\_b\_0000, div\_h\_0000, div\_l\_0000, div\_m\_0000, div\_k\_0000
- rot\_b\_0000, rot\_h\_0000, rot\_l\_0000, rot\_m\_0000, rot\_k\_0000
- err\_b\_0000, err\_h\_0000, err\_l\_0000, err\_m\_0000, err\_k\_0000
- ux,uy,div,rot, sampled on a regular grid , traj contains the trajectories of each granule .

ux\_b\_0000 file is for the first 30mn. The last 0 refers to time in 'time window unit' (and following ux\_b\_0001 for the following 30mn etc. the last 1 refers to time in 'time window unit').

- raw : b (brut) raw ux and uy from CST (586x586 pixels)
- high: h: first high resolution wavelet filter (Daubechies)
- middle: m second wavelet filtering (Daubechies) half resolution of "h"
- large : l third filtering by wavelet (Daubechies) resolution half of "m" p
- extra-large: k fourth filtering by wavelet (Daubechies) resolution half "l"

For example the most common with the SDO data the resolution will be (if we take bin\_sp = 7 (pixels) h = 2.5 Megameters (Mm), m = 5.0 Mm, l = 10Mm, k = 20 Mm output file speeds (ux, uy) on a size of **586x586 pixels**, latitude, longitude and Doppler files are also set to this size and directly superimposable.

In the Fortran main program (cst\_labv7\_FS\_2017.f90) which calculates horizontal speeds, a circular mask is used to properly zero the data outside the Sun. This mask is fixed once and for all in the program with the following parameters in pixels:

R\_sol = 1873 x\_cent = 2054.47 y\_cent = 2048.21.



As the diameter of the Sun changes with time, it is possible that in some times the mask is a little bit smaller than the solar disk. We can so modify  $R_{sol}$ ,  $x_{cent}$ ,  $y_{cent}$  if this needed. Anyway even with a mask smaller, the program output  $V_x$  and  $V_y$  speeds are surimposable to Doppler and latitude and longitude grids in 586x586 pixels.

- **STEP 3 : CST IDL PART**

1. **Copy all ux and uy files from the « JOB\_NNNN/results » directory to the « treated\_day1\_ap » directory.** These files are needed as input data for IDL codes above
2. **Adapt the following parameters in IDL files (in « codes\_CST\_IDL » directory):**
  - transform\_uxuy\_vxvy\_all\_dates\_step\_30min.pro : path, path\_out, day
  - correct\_mvtSDO\_sur\_Vx\_et\_Vy\_precis\_all\_dates\_apres.pro : path, path\_out, path for tmp
  - correct\_mvtSDO\_sur\_Vx\_et\_Vy\_precis\_all\_dates\_avant.pro : path, path\_out, path for tmp (depending of the treated case)
  - transfor\_Vx\_Vy\_Vdop\_vthe\_vphi\_vr\_all\_dates\_step\_30min.pro : path1, path, path\_out, day
3. **With SSWIDL, type the following commands :**
  - a) .r transform\_uxuy\_vxvy\_all\_dates\_step\_30min.pro
  - b) .r correct\_mvtSDO\_sur\_Vx\_et\_Vy\_precis\_all\_dates\_apres.pro
  - c) .r correct\_mvtSDO\_sur\_Vx\_et\_Vy\_precis\_all\_dates\_avant.pro (depending of the treated case)
  - d) .r transfor\_Vx\_Vy\_Vdop\_vthe\_vphi\_vr\_all\_dates\_step\_30min.pro

For example for 6 days HMI observations , **the output files are for each day after and before :**

- Vr\_Vtheta\_Vphi\_derot\_day1\_ap.dat
- Vr\_Vtheta\_Vphi\_derot\_day2\_ap.dat
- Vr\_Vtheta\_Vphi\_derot\_day3\_ap.dat
- Vr\_Vtheta\_Vphi\_derot\_day1\_av.dat
- Vr\_Vtheta\_Vphi\_derot\_day2\_av.dat
- Vr\_Vtheta\_Vphi\_derot\_day3\_av.dat





**Warning:** IDL codes of step 3 use the same « temporary » directory (/tmp) when reading SDO data. So you should not run the IDL codes for 2 data sets at the same time, otherwise the SDO decompression files (in /tmp directory) will be destroyed by the 2nd IDL run.

For example, « treated\_day1\_ap » directory (for 30 min HMI observations) size is 19 G and « JOB\_XXXX » directory size is 590 M (in « codes\_CST\_Fortran » directory).

For example, « treated\_day1\_ap » directory (for 1 day HMI observations) size is 854 G and « JOB\_4174 » directory size is 11 G (in « codes\_CST\_Fortran » directory).

As the volume of the result data is huge (« treated\_day1\_ap » directory), we will give only results of step 2 (Fortran part) and results of step 3 corresponding to 30 min HMI observations.

## CONTACTS

If you have any question about the installation or the run of CST codes, please send a mail to :

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## CST MEDOC WORKSHOP 2020

A workshop is dedicated to the training and use of the Coherent Structure Tracking (CST) software. It will take place on March 3-4, 2020 at IAS in Orsay, France : <https://cst2020-medoc.sciencesconf.org/>

We strongly encourage users to participate to this workshop in order to take themselves control of the codes.

Part of the workshop will be devoted to the explanation of the installation of this CST code on their own servers as well as the various precautions to take. Participants will have to come with their own computer equipment



**(PC, Mac, ...). This software is non-commercial. This workshop is open to all researchers and students of the international solar community.**

**This workshop is free but registration is mandatory before February, 10, 2020.**

