Tab 'Conjunction search'

Brief overview

Searching for conjunctions with the CST is divided in 4 steps:

1. The user first has to pick the instruments he/she wants to conjugate and to set the hemisphere(s) concerned by the search (Pick the facilities to conjugate" panel);
2. The time period over which the conjunctions are searched has to be set ("Pick the time period" panel);
3. The region or area of conjunction has to be chosen ("Pick the region" panel);
4. At last, a couple of quality criteria may be imposed ("Pick the quality factors" panel).

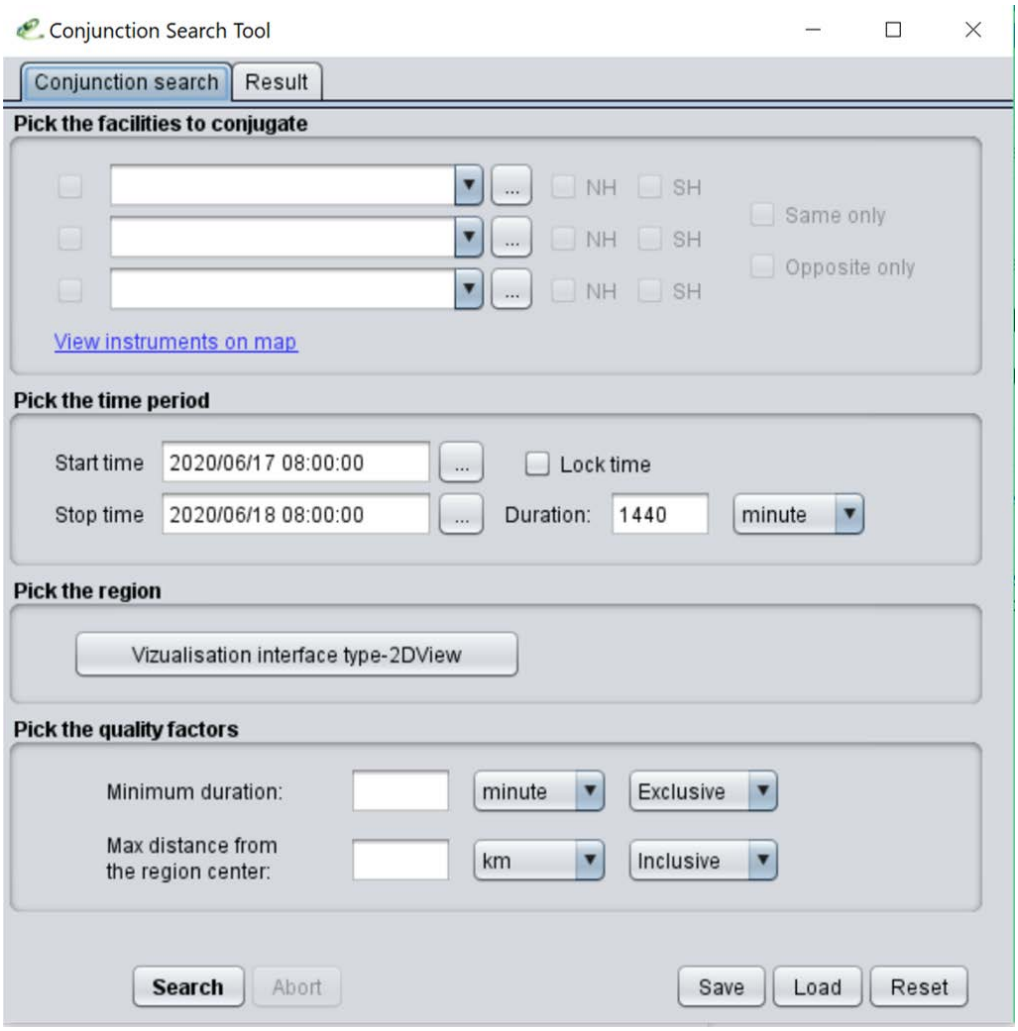


Figure 1 – General view of the CST tab

Menu "Pick the facilities to conjugate"

1. Conjunctions between 2 instruments

In this first example (see Figure 2), conjunctions are foreseen between two different spacecraft (satellites -> HEO): Cluster-centre (CI0) and Polar. A specific Cluster spacecraft can be selected or Cluster-centre which corresponds to the barycentre of the 4 Cluster satellites (or of 3 of them, if the fourth is too far, see below). We choose to search conjunctions between both spacecraft when they are located in the northern hemisphere only (both 'NH' boxes ticked).

Note concerning the barycentre:
In the case of missions in tetrahedral formation (e.g. Cluster, MMS), the barycentre calculation will not be done if at least two satellites are at distances greater than 1 Earth radius from the other two, or the calculation will be done on 3 satellites only, if the fourth is at a distance greater than 1 Earth radius from the other 3. The search for conjunctions will only be carried out on periods when the barycentre can be calculated. When the user chooses the barycentre for such a mission, a "warning popup" will open to specify for example the following message: "Warning, conjunctions will be searched only when barycentre is defined (inter-distance between 3 spacecraft min below 1 RE)".

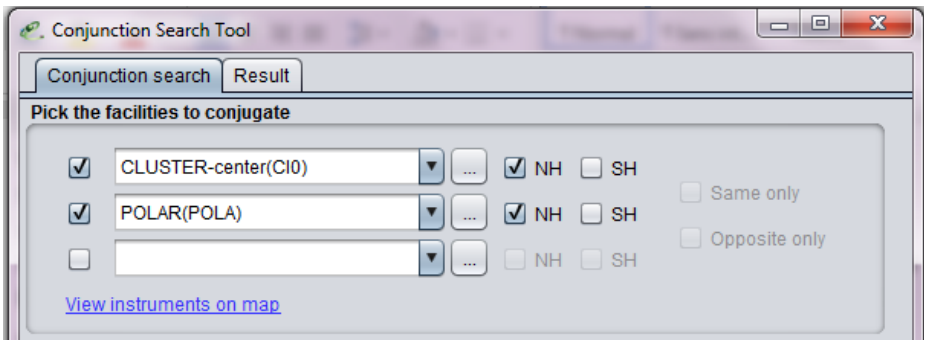


Figure 2 – search between two spacecraft

It is also possible to search for conjunctions where Cluster can be either in the northern or in the southern hemispheres ('NH' and 'SH' boxes ticked), while Polar ('SH' box ticked) is always in the northern allowing conjunctions in the same hemisphere or in opposite hemispheres (taking into account magnetic conjugacy) to be searched for (see Figure 3).

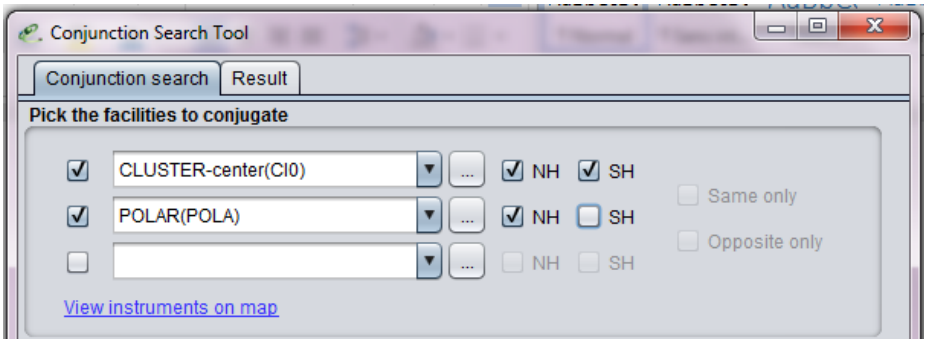


Figure 3 – search between two spacecraft and in two different hemispheres

Finally, it is also possible to search for conjunctions in both hemispheres by ticking all the 'NH' and 'SH' boxes simultaneously. When doing this, the two boxes 'Same only' and 'Opposite only' are activated. Then, if the 'Same only' box is selected, conjunctions in the same hemisphere will be searched for (see Figure 4). On the contrary, if the 'Opposite box' is selected, conjunctions in opposite hemispheres (taking into account magnetic conjugacy) will be searched for. If neither of these "Same only" or "Opposite only" boxes are selected, all possible conjunctions in same and opposite hemispheres will be searched for.

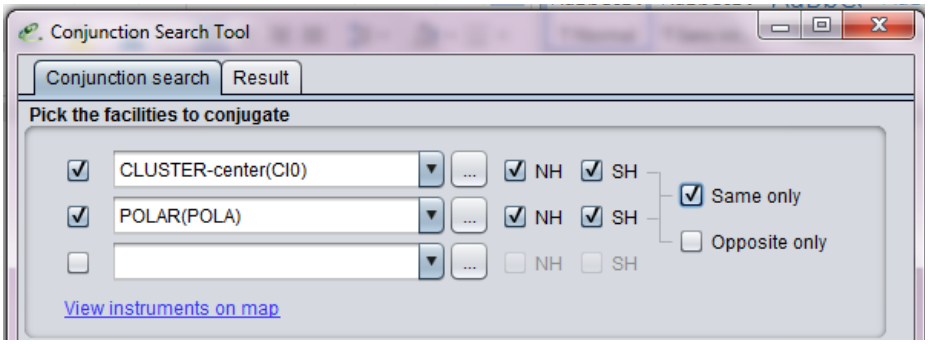


Figure 4 – search between two spacecraft and in each hemisphere separately

In this second example (see Figure 5), conjunctions between one spacecraft (Cluster-centre) and one ground instrument (Eiscat-Tromso VHF) are searched for. When adding a ground instrument, the boxes 'NH' and 'SH' will be greyed out, with the ticked box for the hemisphere where the instrument is located. Here, the conjunctions will be searched between Eiscat-Tromso VHF in the northern hemisphere and Cluster-centre either in the northern or in the southern hemispheres. The IS radar (as EISCAT-Tromso) have a very limited field-of-view while the magnetometers have none. In these cases, a 1000km diametre circle around the ground instruments is used by default for search for the conjunctions.

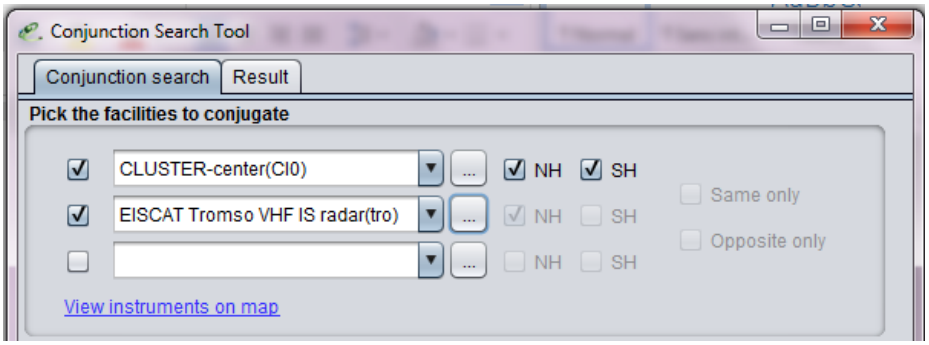


Figure 5 – search between one spacecraft and one ground facility

In case of doubt, concerning the position of a specific ground instrument, it is possible to click on the "View instruments on map" link. This will open a geographic view of the Earth (either equatorial or polar), on which it will be possible to make appear one or several specific set of ground instruments (HF radars, IS Radars, magnetometers, all-sky cameras).

The first example presents a polar view with all the SuperDARN HF Radars and all the IS Radars (see Figure 6).

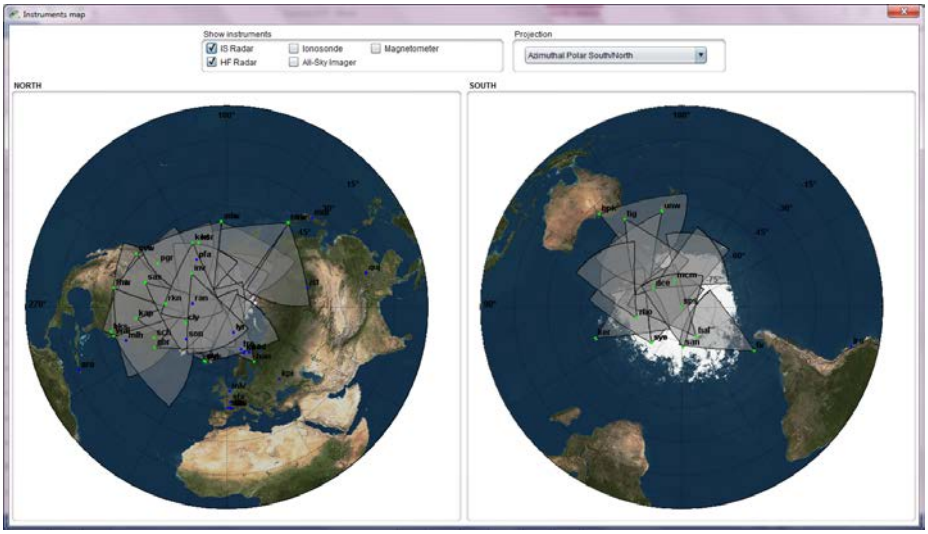


Figure 6 – polar view of all SuperDARN radars

The second example presents a cylindrical equatorial view with all the Intermagnet magnetometers (see Figure 7).

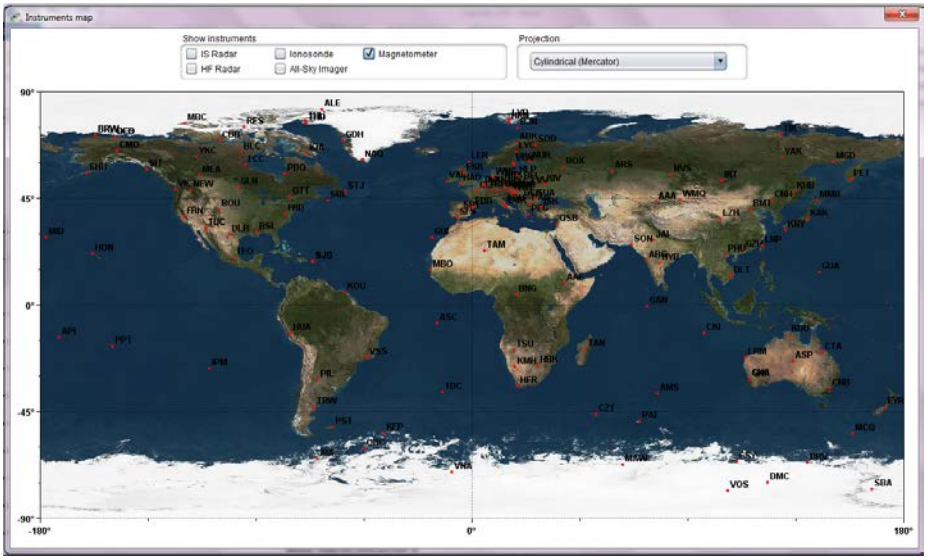


Figure 7 – equatorial view of all Intermagnet magnetometers

2. Conjunctions adding a third instrument (spacecraft or ground instrument)

When adding a third instrument (here the FAST spacecraft: polar -> MEO or the SuperDARN radar Hankasalmi), all the retrieved conjunctions will contained at least the two first instruments and optionally the third one (see Figure 8).

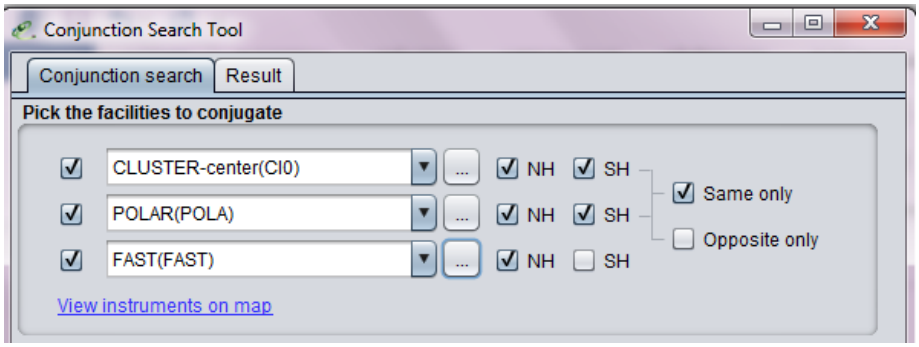


Figure 8 – search between three spacecraft

Again, the conjunctions with the third ground instrument will only be searched for in the corresponding hemisphere ('NH' in the case of the SuperDARN Hankasalmi radar presented in the example on Figure 9 below).

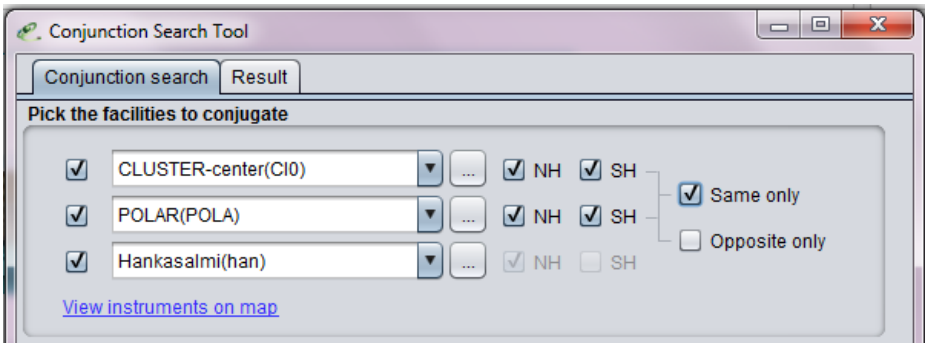


Figure 9 – search between two spacecraft and one ground experiment (Han radar)

3. Conjunctions including a family of instruments

Although, the Conjunction Search Tool is in principle limited to three different instruments. It is nevertheless possible to search for conjunctions between one to two instruments with a certain family of instruments. Such mode of search being CPU-time consuming, the time period is then limited to ** hours of a specific day and of a specific hemisphere (in case of polar view search). Below an example is presented, where conjunctions between the Cluster barycentre is combined with all the DMSP satellites (see Figure 10).

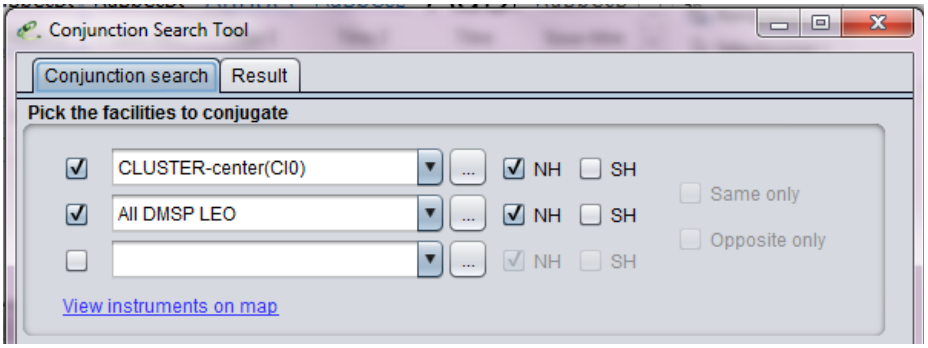


Figure 10 – search between Cluster and the family of DMSP satellites

Below is also presented an example where the ground SuperDARN radar of Hankasalmi will be combined with all the LEO satellites on polar orbits (see Figure 11).

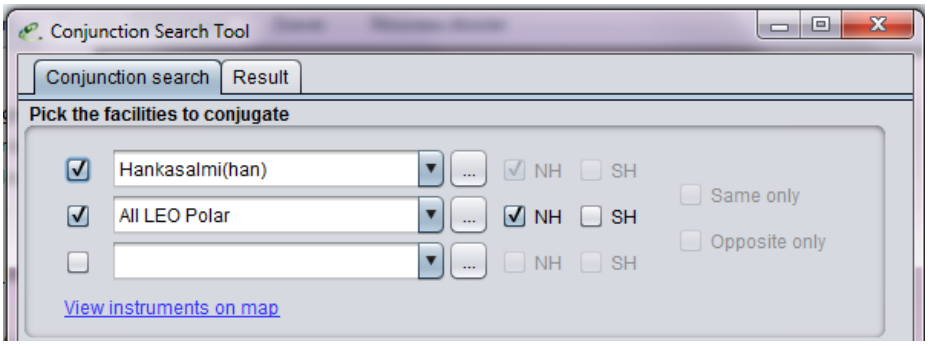


Figure 11 – search between one ground experiment (Han radar) and the family of DMSP satellites

4. Conjunctions between all instruments

Although the Conjunction Search Tool is in principle limited to three different instruments, it is possible to search for conjunctions between all available instruments contained in the CST. Such mode of search being CPU-time consuming, the time period is then limited to 1 hour of a specific day and of a specific hemisphere (in case of polar view search). Below an example is presented, where conjunctions between all instruments are searched for in the northern hemisphere (see Figure 12).

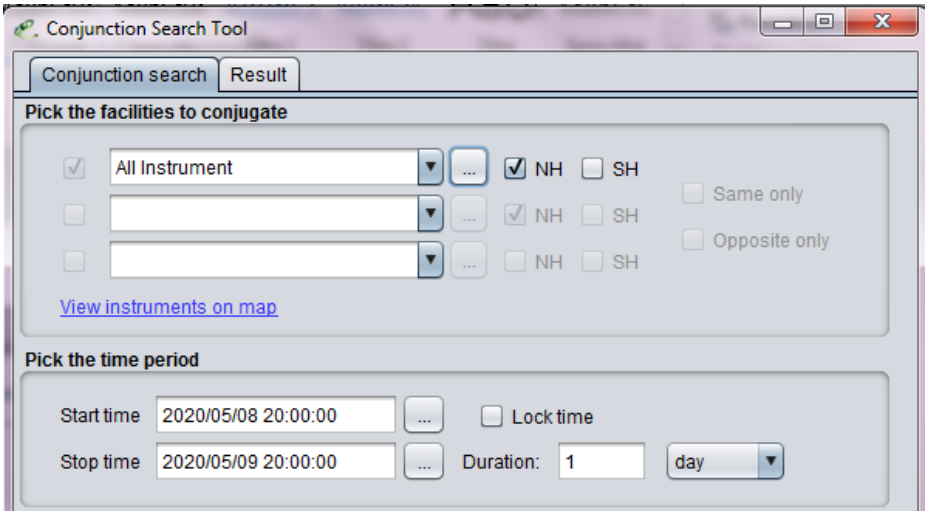


Figure 12 – search between "all" instruments over 1 hour

Menu "Pick the time period"

The time period is automatically given as the intersection of the validity period of the two first selected instruments. The time period can be adapted by the user and the box "lock the time" can be ticked to freeze the time of computation and to avoid the time to be re-updated if one new instrument is selected in the previous menu. It does not preclude the user to change the selected date or time manually. Here we reduce the time period to 3 years between 2001 and 2003 (see Figure 13).

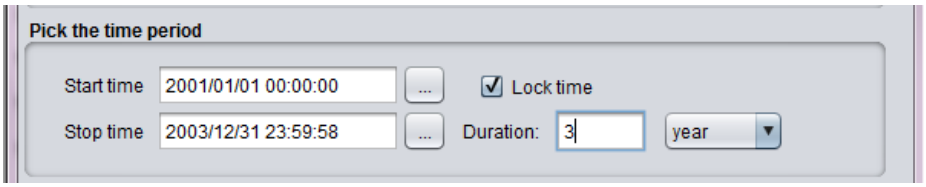


Figure 13 – menu of time period with search over 3 years

The duration of the time period is automatically limited to * hours when a family of instruments is selected in the previous menu or to 1 hours when the 'all instruments' option is selected.

Menu "Pick the region"

In this new interface, the default view is geographic hemispheric polar views. If a ground instrument is chosen as part of the first menu (Menu "Pick the facilities to conjugate"), then the default region (blue circle of 1000 km diametre) will be centreed on this instrument. Below, the northern hemisphere circle is for instance centreed on the Eiscat-Tromso radar (see Figure 14).

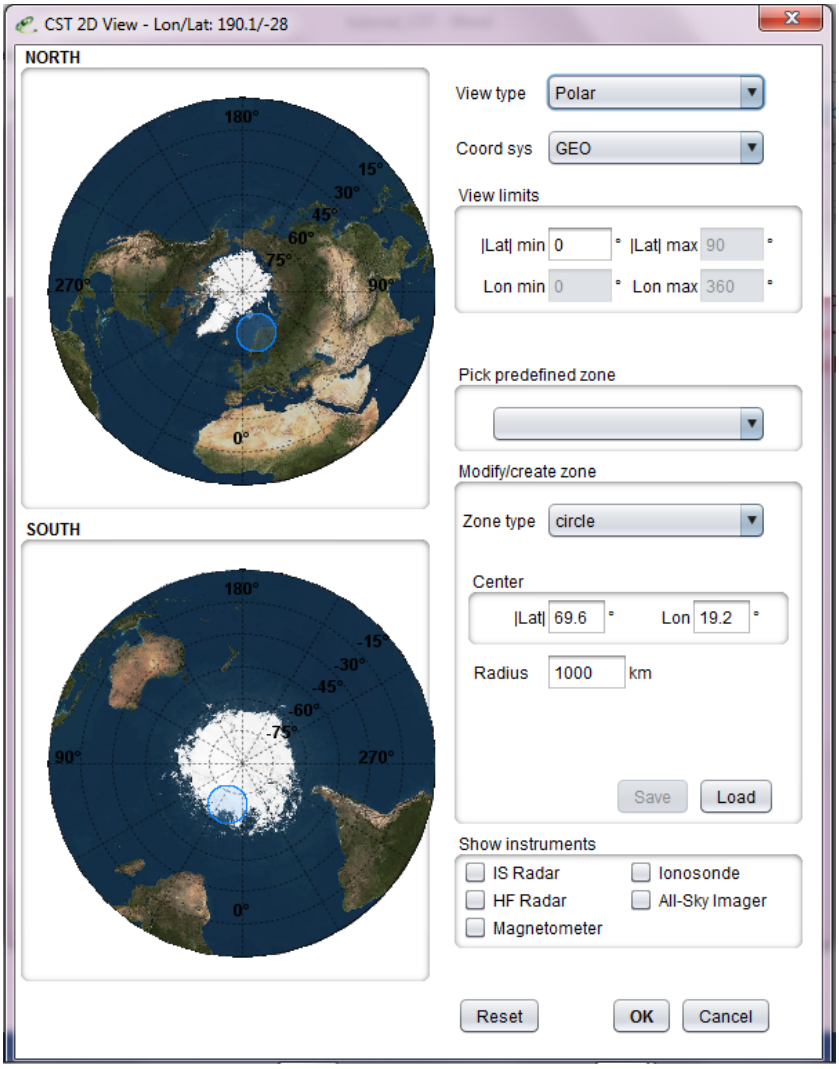


Figure 14 – polar search centred on the Eiscat-Tromso radar

It is possible to choose the view (magnetosphere *currently disabled*, polar ground or equatorial ground), as well as the coordinate system. In ground views, conjunctions will be searched at the ground level (satellites footprints) using a mapping of the satellites orbits along magnetic field lines (Tsyganenko-96 model).

To search in a specific region, it is then possible to choose for a certain type of zone (interval, circle, pre-defined or customized area). The limit of the zones can be directly entered in the corresponding boxes or the user can use its mouse to select a zone and its size (by maintaining pressed the left mouse button). If a geographic view is chosen, it is also possible to select instruments in the bottom right part of the menu ('Show instruments'), the instruments (or their corresponding field-of view) even partly enclosed in the selected zone used for conjunctions search will then automatically appear in the map(s) on the left. Two example are presented below. One with SuperDARN radars on a polar geographic view (see Figure 15).

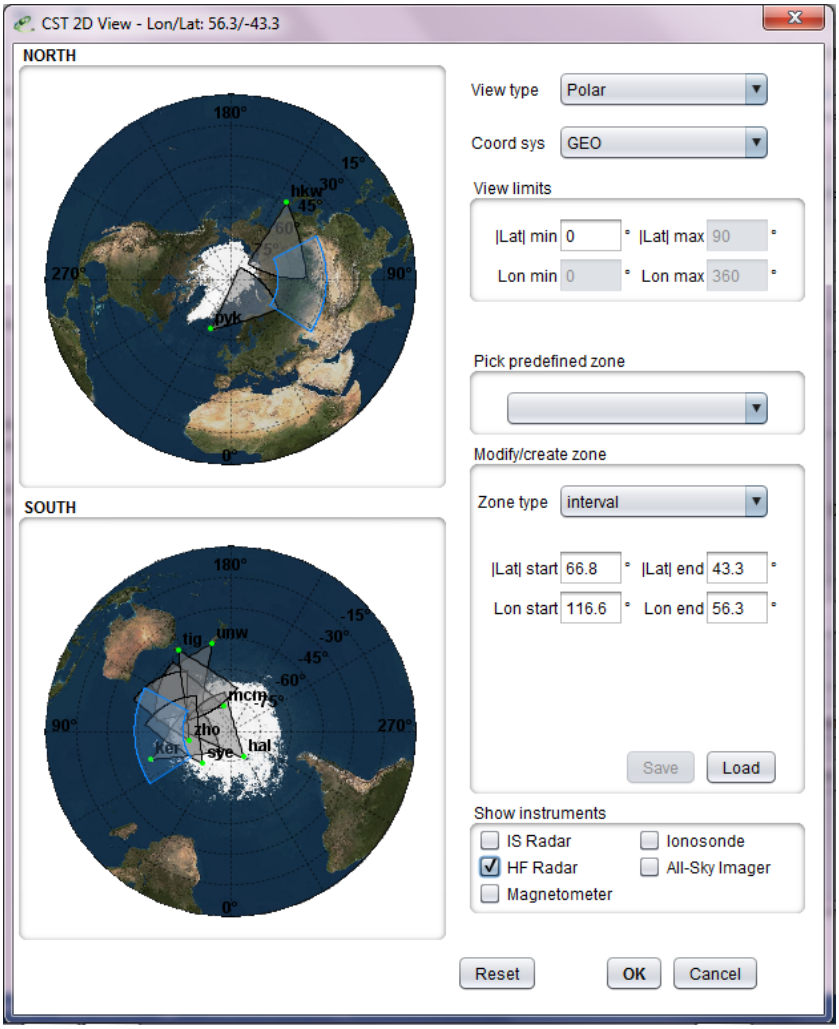


Figure 15 – polar search with SuperDARN radars

One with Intermagnet magnetometers on an equatorial geographic view (Figure 16).

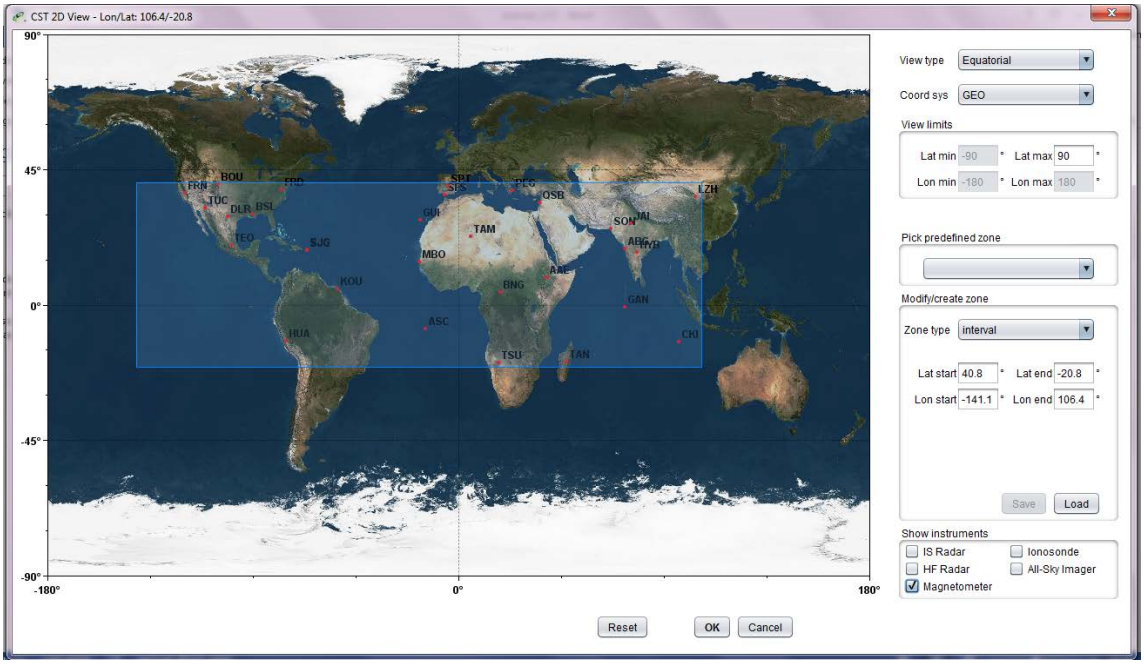


Figure 16 – equatorial search with intermagnet magnetometers

Here, if we want to search for conjunctions in the polar cusp, it is easier to select a “polar” view with a “MLT” coordinate system, which corresponds to a Magnetic Local Time (MLT) / Magnetic Latitude (MLAT) system. Then, we choose an interval zone between 60 and 80° MLAT and between 9 and 15 MLT which is a relatively good approximation of the projection of the cusp on ground. The selected zone appears automatically as a blue area (here simultaneously in the polar view of both hemispheres, see Figure 17).

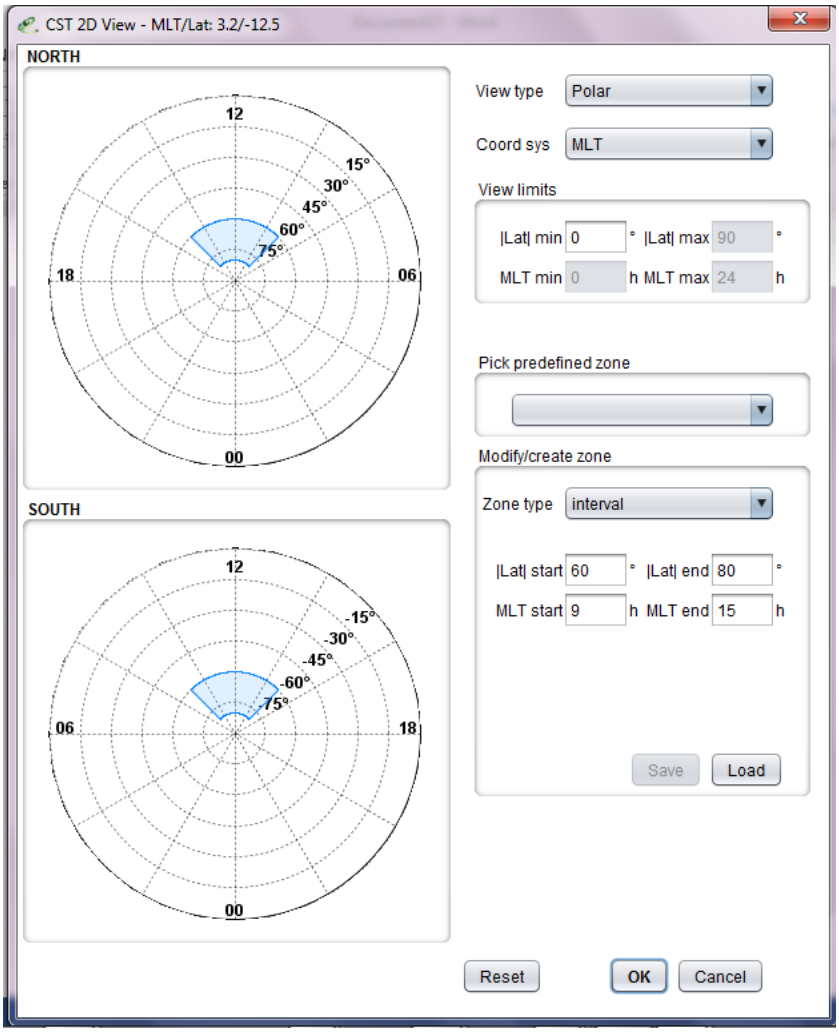


Figure 17 – polar search for magnetic cusp area defined by the user

A pre-defined cusp region (obtained from statistics) is also possible (see Figure 18).

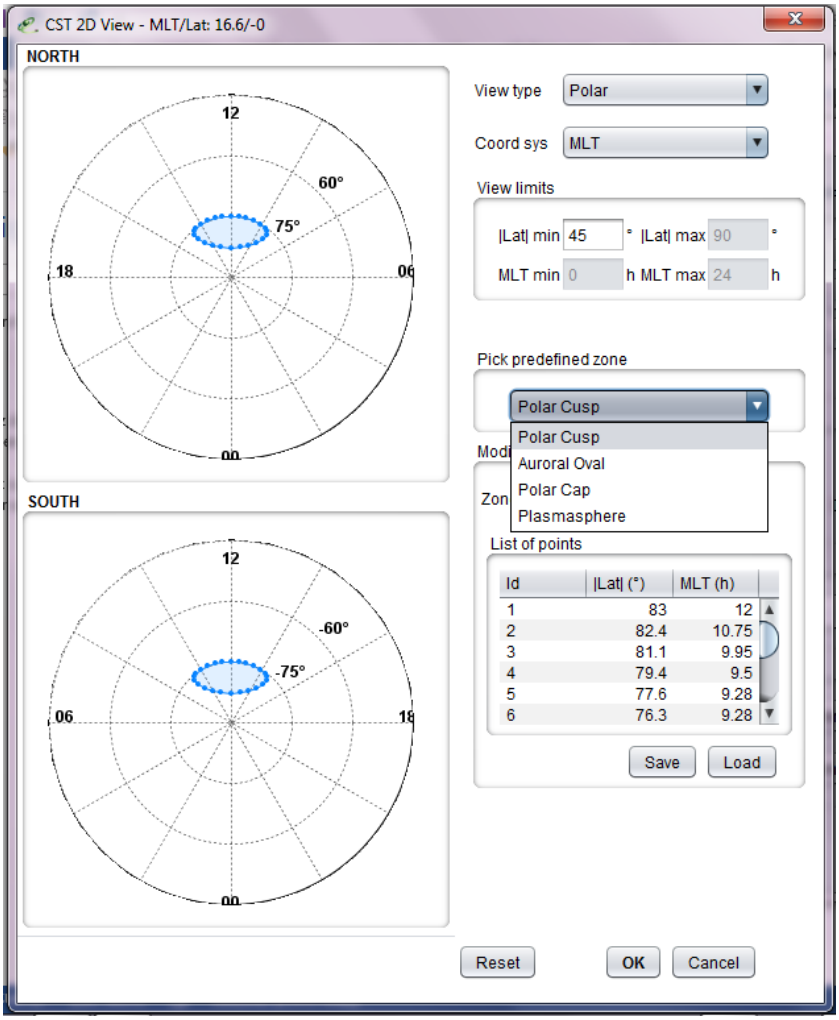


Figure 18 – polar search for magnetic cusp area with pre-defined boundaries

In the case of a customized zone ('area' in the scrolling menu 'Modify/create zone'), the user can create his/her own zone by entering as many points as wanted (in the corresponding coordinate system). The zone (or conjugated zones, in case of polar view) can even be saved (locally on the user's computer) and reloaded for a later search. Below, an example of customized conjugated zones made of 6 points in geographic coordinates in polar view is shown (see Figure 19).

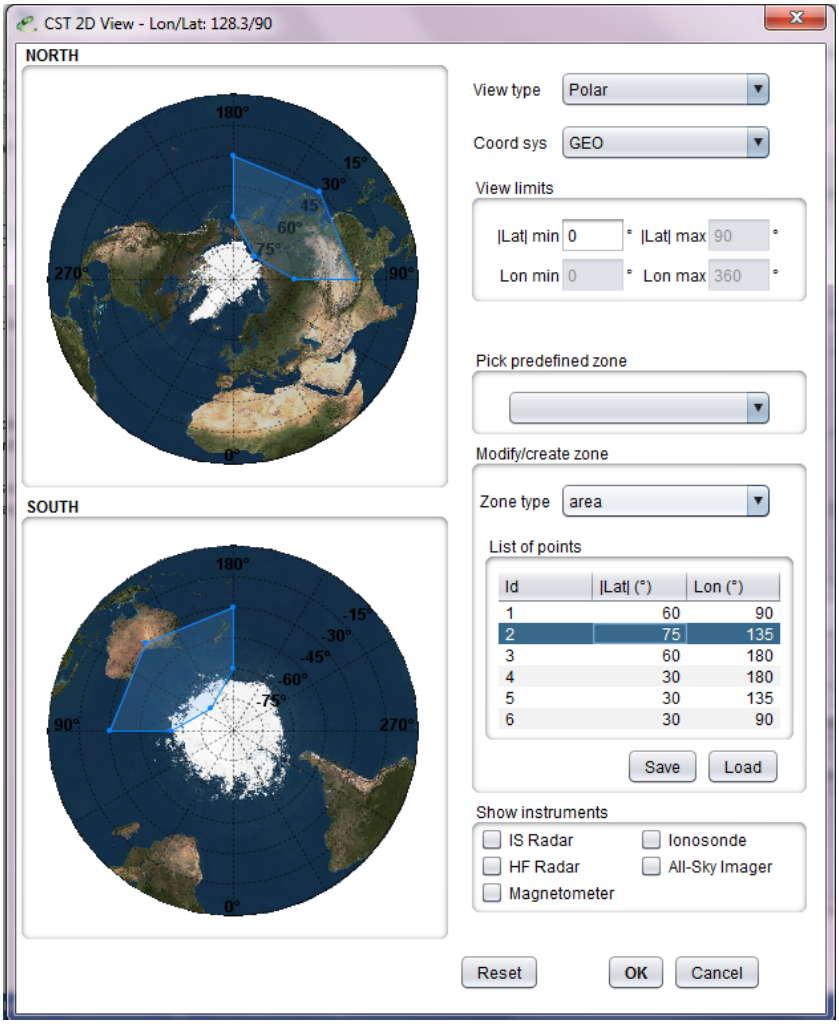


Figure 19 – polar search for customized area by the user

The 'Reset' button reset entirely this specific menu and the 'Cancel' button allows to come back to the main menu without changing the zone already predefined. Finally, hitting the 'Ok' button allows returning in the main interface. If this region is correctly defined a green message "Region correctly picked!" will appear (see Figure 20).

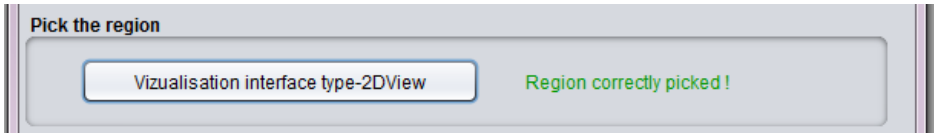


Figure 20 – green message if region correctly picked

Menu "Pick the quality factors"

The user has the possibility to enter specific quality factors to characterize the conjunctions. These factors are: 1) the minimum duration of the conjunction and 2) the maximum distance from the centre of the area picked in the previous menu "Pick the region" (see Figure 21). These criteria can be exclusive, in that case no conjunction will be retrieved if these conditions are not met. These criteria can be inclusive, in that case all the conjunctions will be retrieved and displayed even if these conditions are not met. With these factors, the conjunctions will be flagged according to their quality (high, medium, low) and colour-coded accordingly (green, yellow, red).

If these quality factors are intentionally left blank (see example below), then all conjunctions will be retrieved and displayed, regardless of conjunction duration and distance from the centre of the area, provided that at least two instruments are present in the selected area at any given time.

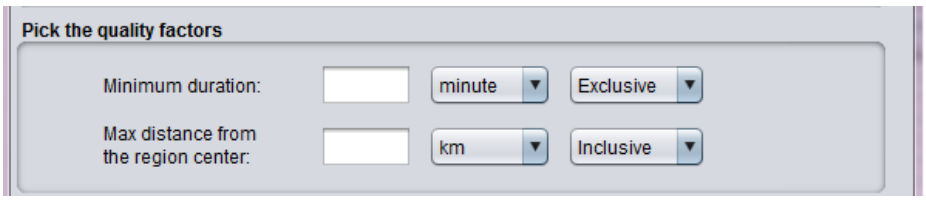


Figure 21 – menu of quality factors

In that case, the conjunctions list displayed in the 'Result' tab will not be discriminated by quality and all conjunctions will be flagged as 'high' and coded in green (see Figure 22). If duration of the conjunctions will be displayed, the distance from the area centre will be not.

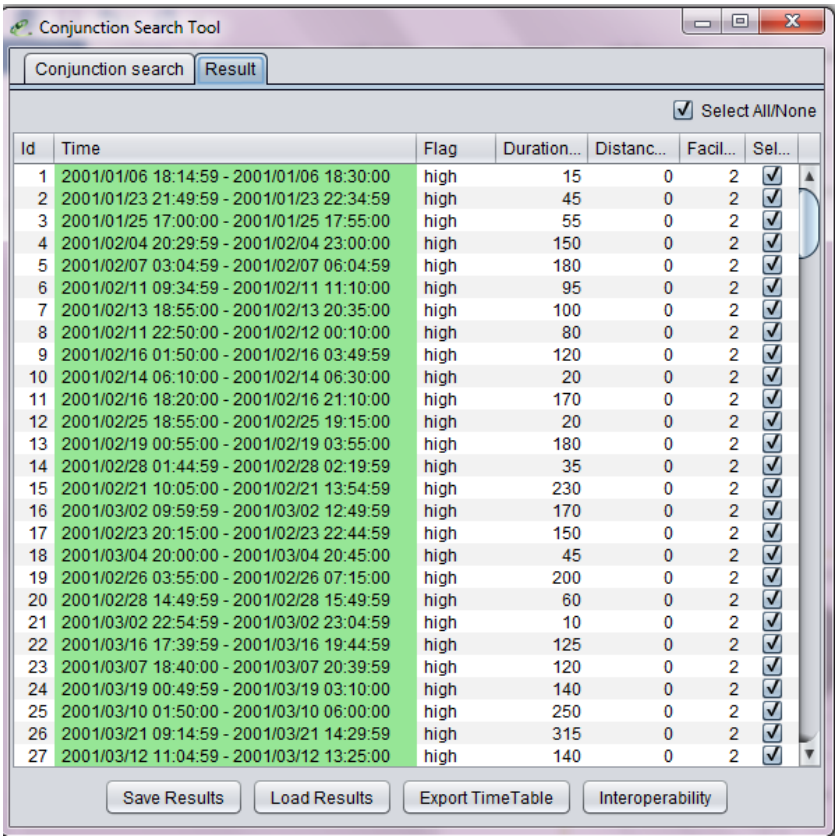


Figure 22 – list of conjunctions displayed on the "Result" tab

In the following example (Figure 23), the quality factor of duration is set to 5 minutes exclusively, so that no conjunction shorter than 5 minutes will be displayed and the quality factor of distance is set to 1000 km inclusively, so that all conjunctions will be displayed regardless of the distance to the area centre.

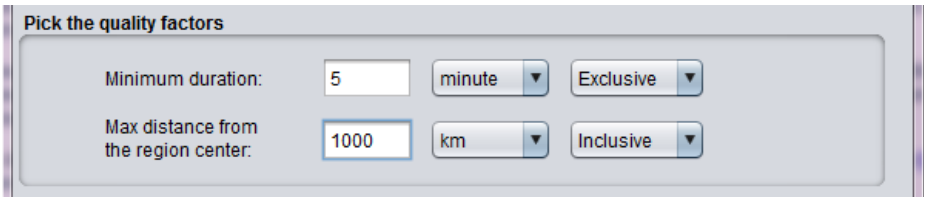
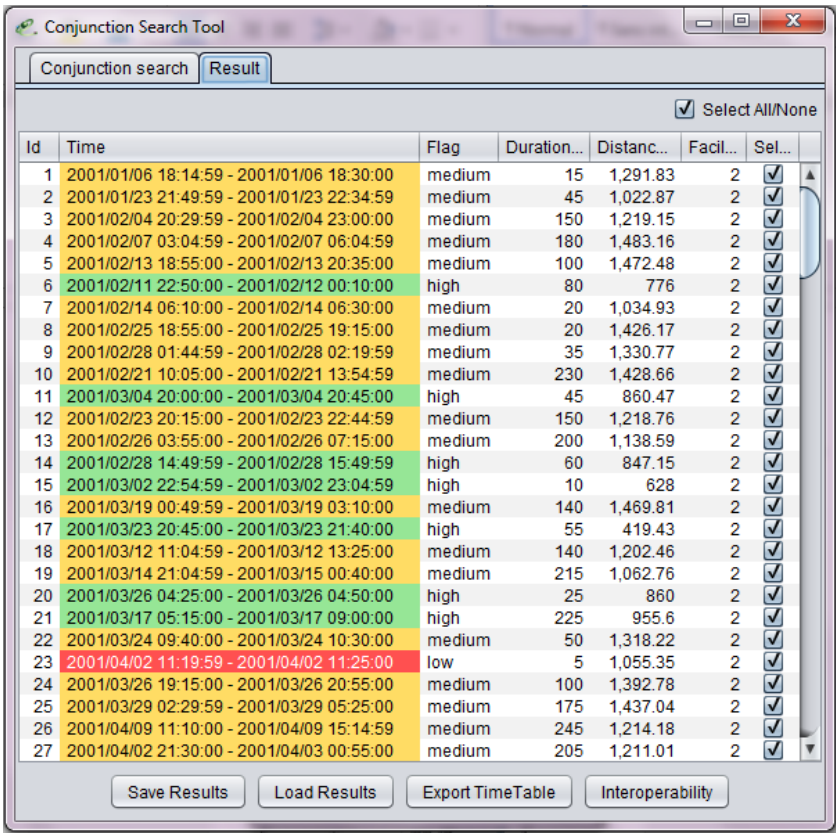


Figure 23 – menu of quality factors filled in

The conjunctions list displayed below (see Figure 24) shows that high quality conjunctions (colour-coded green) meet both criteria (duration higher than 5 minutes and distance to area centre lower than 1000km). Medium quality conjunctions (colour-coded yellow) correspond to conjunctions where the duration criteria is met but not the distance criteria (inclusive factor). Finally, low quality conjunctions (colour-coded red) correspond to conjunctions where the duration criterion is very close to the limit set by the user (exclusive factor) and the distance criterion is not met. Finally due to the exclusive nature of the duration factor, no conjunctions shorter than 5 minutes are displayed in the list.



Id	Time	Flag	Duration...	Distanc...	Facil...	Sel...
1	2001/01/06 18:14:59 - 2001/01/06 18:30:00	medium	15	1,291.83	2	☑
2	2001/01/23 21:49:59 - 2001/01/23 22:34:59	medium	45	1,022.87	2	☑
3	2001/02/04 20:29:59 - 2001/02/04 23:00:00	medium	150	1,219.15	2	☑
4	2001/02/07 03:04:59 - 2001/02/07 06:04:59	medium	180	1,483.16	2	☑
5	2001/02/13 18:55:00 - 2001/02/13 20:35:00	medium	100	1,472.48	2	☑
6	2001/02/11 22:50:00 - 2001/02/12 00:10:00	high	80	776	2	☑
7	2001/02/14 06:10:00 - 2001/02/14 06:30:00	medium	20	1,034.93	2	☑
8	2001/02/25 18:55:00 - 2001/02/25 19:15:00	medium	20	1,426.17	2	☑
9	2001/02/28 01:44:59 - 2001/02/28 02:19:59	medium	35	1,330.77	2	☑
10	2001/02/21 10:05:00 - 2001/02/21 13:54:59	medium	230	1,428.66	2	☑
11	2001/03/04 20:00:00 - 2001/03/04 20:45:00	high	45	860.47	2	☑
12	2001/02/23 20:15:00 - 2001/02/23 22:44:59	medium	150	1,218.76	2	☑
13	2001/02/26 03:55:00 - 2001/02/26 07:15:00	medium	200	1,138.59	2	☑
14	2001/02/28 14:49:59 - 2001/02/28 15:49:59	high	60	847.15	2	☑
15	2001/03/02 22:54:59 - 2001/03/02 23:04:59	high	10	628	2	☑
16	2001/03/19 00:49:59 - 2001/03/19 03:10:00	medium	140	1,469.81	2	☑
17	2001/03/23 20:45:00 - 2001/03/23 21:40:00	high	55	419.43	2	☑
18	2001/03/12 11:04:59 - 2001/03/12 13:25:00	medium	140	1,202.46	2	☑
19	2001/03/14 21:04:59 - 2001/03/15 00:40:00	medium	215	1,062.76	2	☑
20	2001/03/26 04:25:00 - 2001/03/26 04:50:00	high	25	860	2	☑
21	2001/03/17 05:15:00 - 2001/03/17 09:00:00	high	225	955.6	2	☑
22	2001/03/24 09:40:00 - 2001/03/24 10:30:00	medium	50	1,318.22	2	☑
23	2001/04/02 11:19:59 - 2001/04/02 11:25:00	low	5	1,055.35	2	☑
24	2001/03/26 19:15:00 - 2001/03/26 20:55:00	medium	100	1,392.78	2	☑
25	2001/03/29 02:29:59 - 2001/03/29 05:25:00	medium	175	1,437.04	2	☑
26	2001/04/09 11:10:00 - 2001/04/09 15:14:59	medium	245	1,214.18	2	☑
27	2001/04/02 21:30:00 - 2001/04/03 00:55:00	medium	205	1,211.01	2	☑

Figure 24 – list of colour-coded conjunctions displayed in the "Result" tab

List of buttons at the bottom of the menu

Five different buttons can be found at the bottom of the 'Conjunction search' Tab (see Figure 25). The 'Search' button launches a new search. The 'Abort' button is used to stop a search in progress. The 'Save' button is used to save locally (on the user's computer) the specific conditions of a search (instruments, time period, area and quality factors). The 'Load' button allows reloading previously saved search conditions with the 'Save' button. Finally, the 'Reset' button allows resetting all the menus of the Conjunction Search Tool.

Figure 25 – bottom part of the CST menu

Hitting the 'Search' button starts the tool. The search duration depends on several factors: the number of instruments, the time duration and the availability of satellites footprints in the database of the tool. If the satellites footprints are not available (most footprints are pregenerated), then they will be computed on the fly, significantly increasing search time.

Finally, at the start of the search, if the selected search area has no intersection with the picked instruments positions (geographic position in case of ground instrument or trajectory location in case of satellites), then an error message appears as follows (see Figure 26).

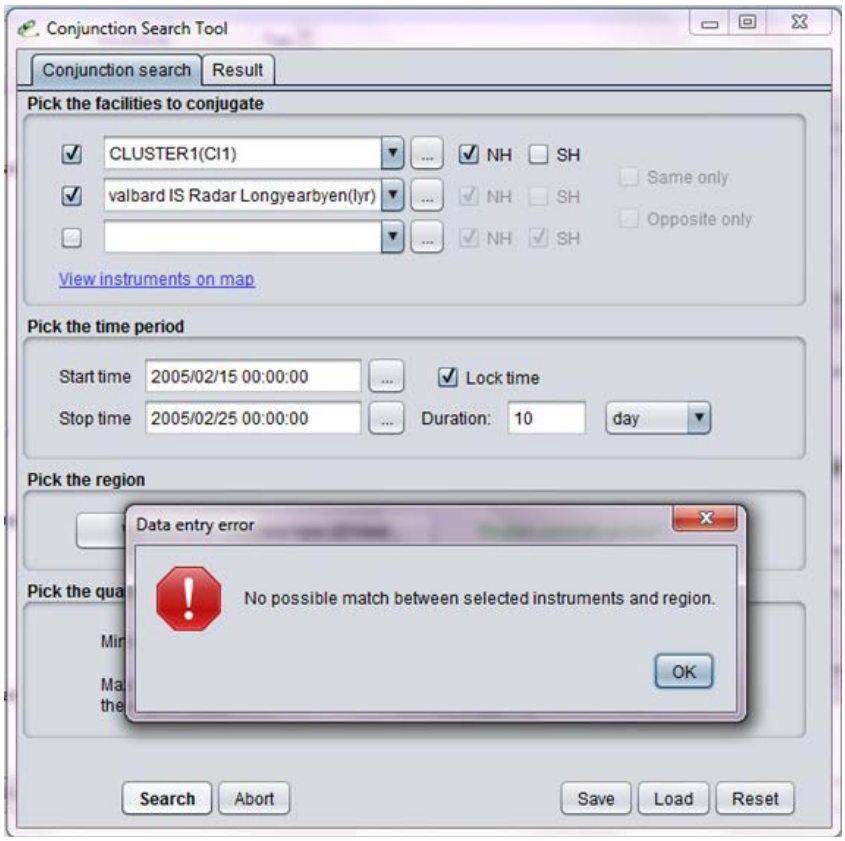
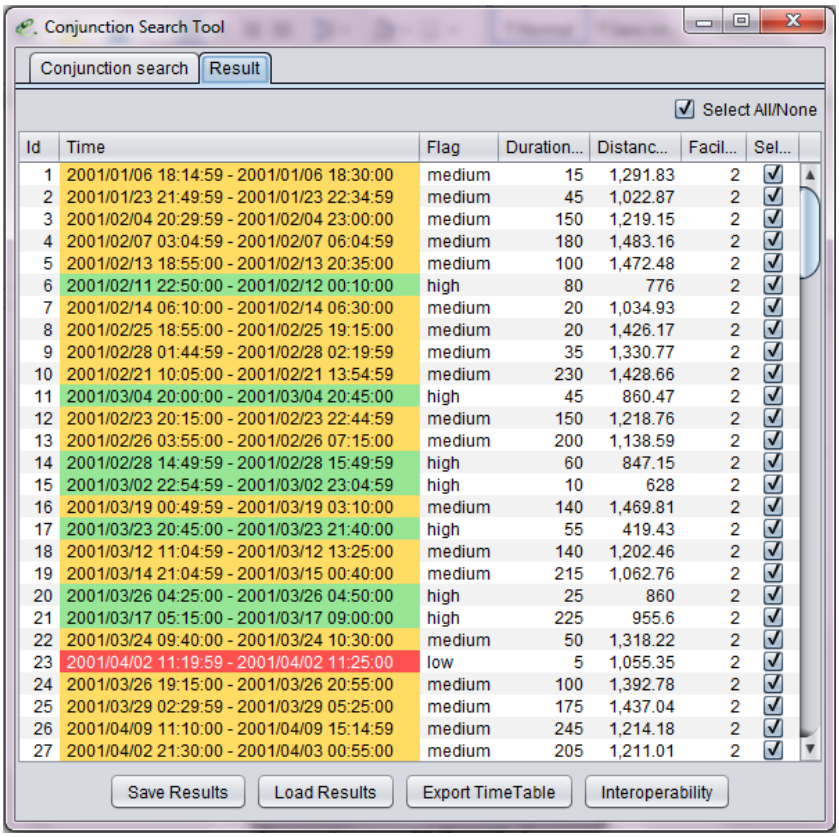


Figure 26 – error message if no intersection between picked area and instruments

Tab 'Result'

The tab 'Result' displays the list of conjunctions found by the Conjunction Search Tool (see Figure 27). Seven different columns are displayed for each conjunction: 1) Id number, 2) Time: start and end time, 3) Flag: quality factors: high, medium, low, 4) Duration, 5) Distance from the area centre, 6) number of instruments present in the conjunction. The quality of the conjunctions is also colour-coded, green: high, yellow: medium, red: low.



Id	Time	Flag	Duration...	Distanc...	Facil...	Sel...
1	2001/01/06 18:14:59 - 2001/01/06 18:30:00	medium	15	1,291.83	2	☑
2	2001/01/23 21:49:59 - 2001/01/23 22:34:59	medium	45	1,022.87	2	☑
3	2001/02/04 20:29:59 - 2001/02/04 23:00:00	medium	150	1,219.15	2	☑
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5	2001/02/13 18:55:00 - 2001/02/13 20:35:00	medium	100	1,472.48	2	☑
6	2001/02/11 22:50:00 - 2001/02/12 00:10:00	high	80	776	2	☑
7	2001/02/14 06:10:00 - 2001/02/14 06:30:00	medium	20	1,034.93	2	☑
8	2001/02/25 18:55:00 - 2001/02/25 19:15:00	medium	20	1,426.17	2	☑
9	2001/02/28 01:44:59 - 2001/02/28 02:19:59	medium	35	1,330.77	2	☑
10	2001/02/21 10:05:00 - 2001/02/21 13:54:59	medium	230	1,428.66	2	☑
11	2001/03/04 20:00:00 - 2001/03/04 20:45:00	high	45	860.47	2	☑
12	2001/02/23 20:15:00 - 2001/02/23 22:44:59	medium	150	1,218.76	2	☑
13	2001/02/26 03:55:00 - 2001/02/26 07:15:00	medium	200	1,138.59	2	☑
14	2001/02/28 14:49:59 - 2001/02/28 15:49:59	high	60	847.15	2	☑
15	2001/03/02 22:54:59 - 2001/03/02 23:04:59	high	10	628	2	☑
16	2001/03/19 00:49:59 - 2001/03/19 03:10:00	medium	140	1,469.81	2	☑
17	2001/03/23 20:45:00 - 2001/03/23 21:40:00	high	55	419.43	2	☑
18	2001/03/12 11:04:59 - 2001/03/12 13:25:00	medium	140	1,202.46	2	☑
19	2001/03/14 21:04:59 - 2001/03/15 00:40:00	medium	215	1,062.76	2	☑
20	2001/03/26 04:25:00 - 2001/03/26 04:50:00	high	25	860	2	☑
21	2001/03/17 05:15:00 - 2001/03/17 09:00:00	high	225	955.6	2	☑
22	2001/03/24 09:40:00 - 2001/03/24 10:30:00	medium	50	1,318.22	2	☑
23	2001/04/02 11:19:59 - 2001/04/02 11:25:00	low	5	1,055.35	2	☑
24	2001/03/26 19:15:00 - 2001/03/26 20:55:00	medium	100	1,392.78	2	☑
25	2001/03/29 02:29:59 - 2001/03/29 05:25:00	medium	175	1,437.04	2	☑
26	2001/04/09 11:10:00 - 2001/04/09 15:14:59	medium	245	1,214.18	2	☑
27	2001/04/02 21:30:00 - 2001/04/03 00:55:00	medium	205	1,211.01	2	☑

Figure 27 – list of colour-coded conjunctions displayed on the "Result" tab

When hovering the mouse over the 'Time' column of a specific conjunction, a thumbnail displays the geometry of the conjunction within the search area in the type of view specified in the menu. A summary of the characteristics of the conjunction is also recalled on the right-hand side of the thumbnail (see below Figure 28).

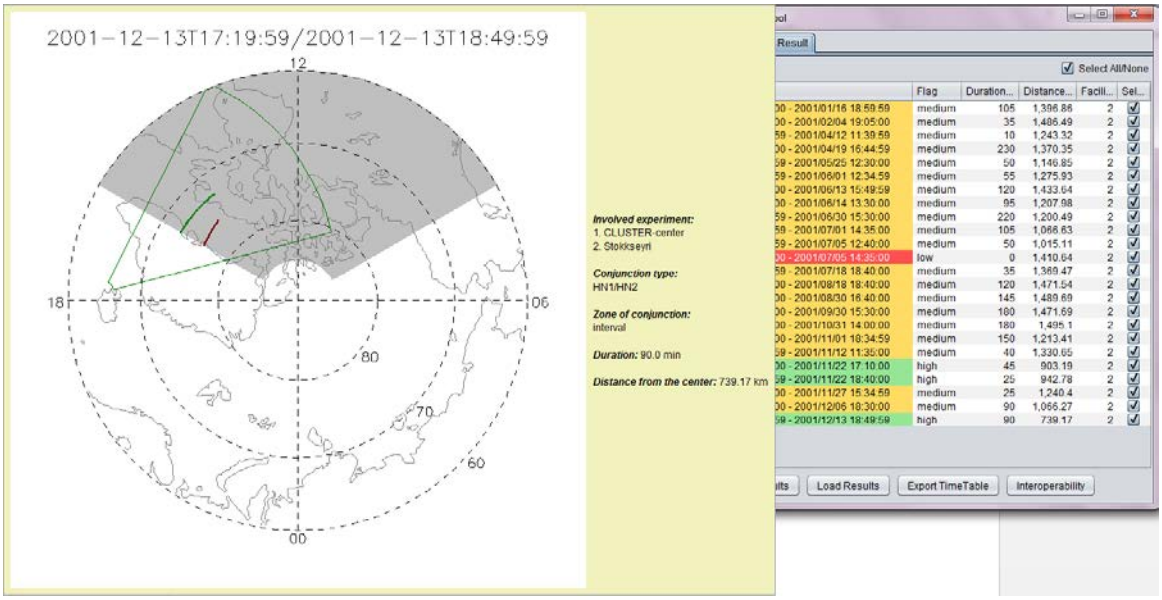

Figure 28 – thumbnail showing the geometry of the conjunction

When clicking on the right button of the mouse on a specific conjunction, it is possible to plot it in 3DView either on a current (already generated) scene or in a new one (see below left on Figure 29). It is also possible to download locally (on the user's computer) the ephemeris of the conjunction either in an XML or an ASCII format (see below right on Figure 29).

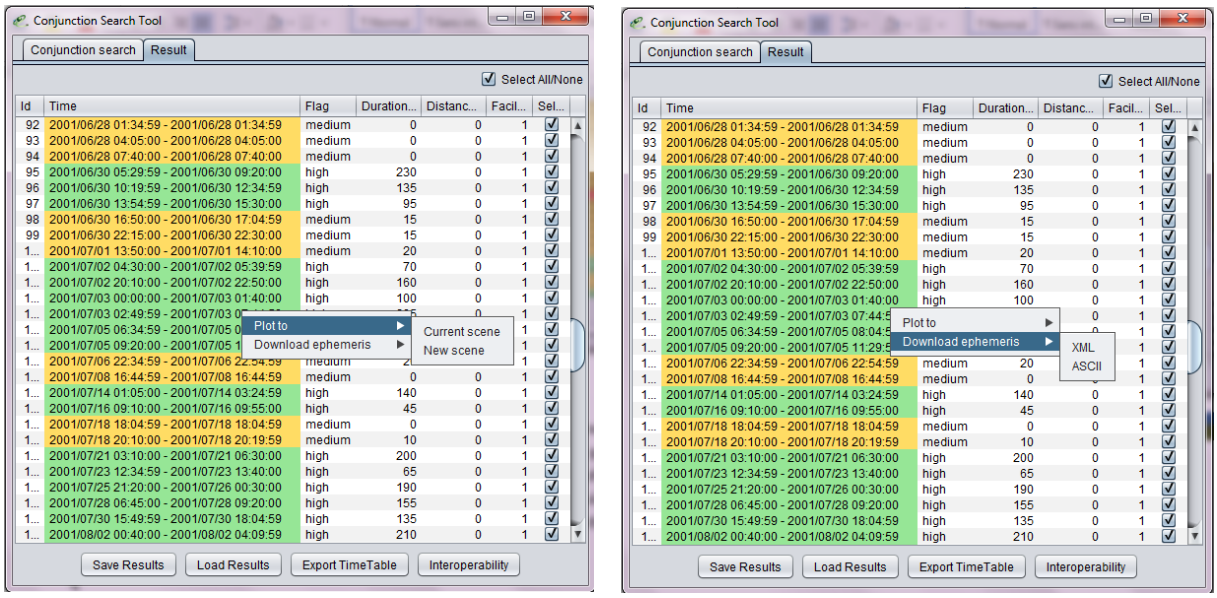

Figure 29 – menu to send to manage scene or to download data

Four different buttons can be found at the bottom of the 'Result' tab (see Figure 29). The 'Save results' button is used to save a list of conjunctions (locally on the user's computer). The 'Load results' button allows reloading list of saved conjunctions with 'Save results' button. The 'Export TimeTable' button is used to save the list of conjunctions in a time table format (locally on the user's computer in XML format) and the 'Interoperability' button allows to directly send the same time table of conjunctions in other webtools, either by sending a VOTable or by using the SAMP protocol (e.g. it is possible to send the time table to the AMDA webtool). For these four actions, the list can be manually modified by selecting/deselecting conjunctions in the right boxes.