

Earthquake Monitoring: SeisComP3 at the Swiss National Seismic Network

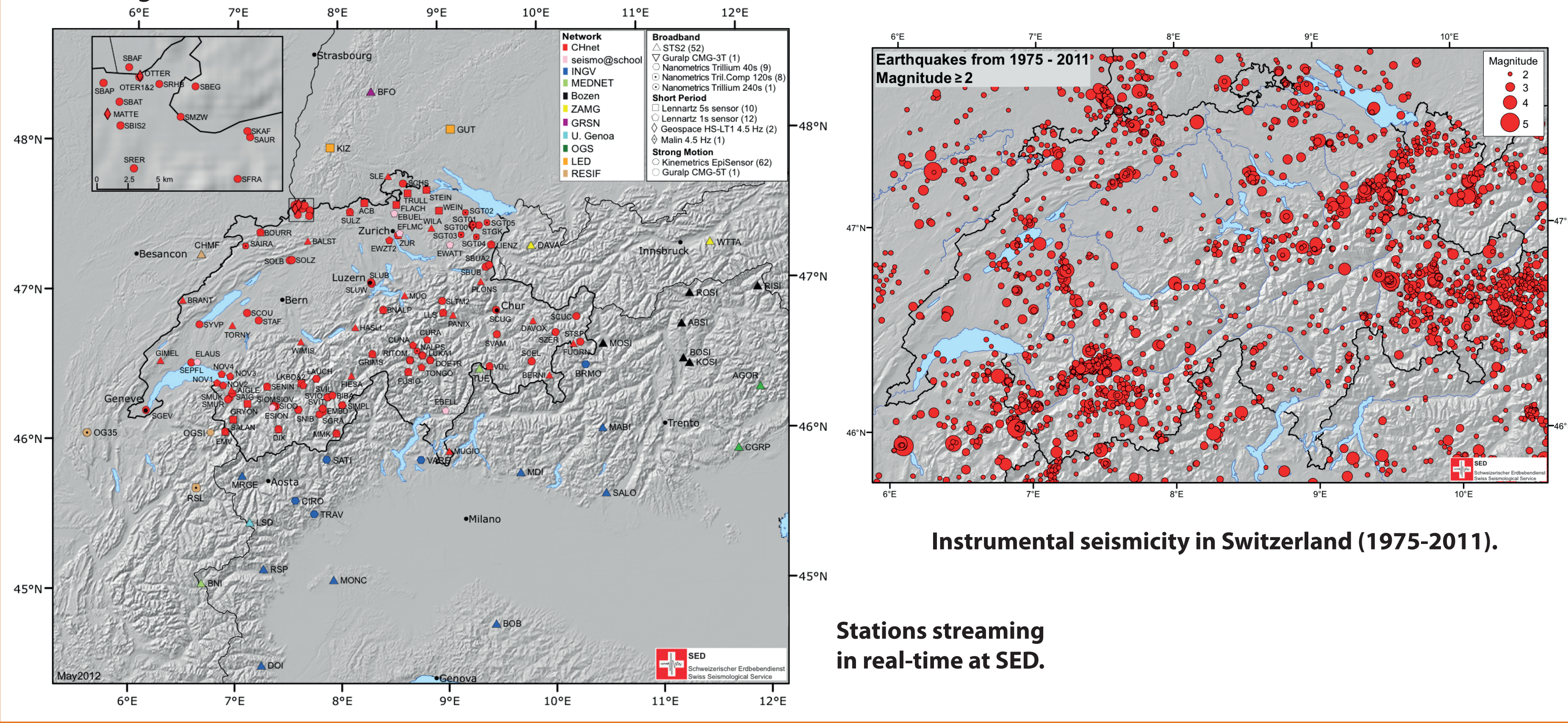
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Seismic Monitoring in Switzerland

The Swiss Seismological Service (SED) has an ongoing responsibility to improve the seismicity monitoring capability for Switzerland. This is a crucial issue for a country with low background seismicity but where a M6+ earthquake is expected in the next decades. With over 30 stations with spacing of ~25km, the SED operates one of the densest broadband networks in the world, which is complemented by ~50 real-time strong motion stations. The strong motion network is expected to grow with an additional ~80 stations over the next few years. Furthermore, the backbone of the network is complemented by broadband data from surrounding countries in Austria, France, Germany, Italy and temporary sub-networks for local monitoring of microseismicity (e.g. near geothermal mining and tunnel construction projects).

The variety of seismic monitoring responsibilities as well as the ongoing densifications of our network demand highly flexible processing software. The existing “in-house” monitoring software cannot easily integrate the growing monitoring tasks nor scale with significant network expansion. Therefore, we are transitioning all software to the SeisComP3 (SC3) framework. SC3 is a fully featured automated real-time earthquake monitoring software developed by GeoForschungZentrum Potsdam (GFZ) in collaboration with gempa GmbH, a commercial software firm. It is in its core open source, and becoming a community standard software for earthquake detection and waveform processing for regional and global networks across the globe. SC3 was originally developed for rapid characterisation of potentially tsunamigenic earthquakes at the regional and global scales. In order to fulfil the requirements of a local network recording moderate seismicity, SED has had to tune and extend configurations, and ultimately to develop several (open source) modules, with collaboration with gempa, GFZ and GNS in New Zealand.

In this contribution, we present our SC3 implementation strategy based on development, testing, and observation of the last two years with focus on detection and identification of seismicity on local to regional scales. SC3 is expected to replace the existing monitoring software in 2012.

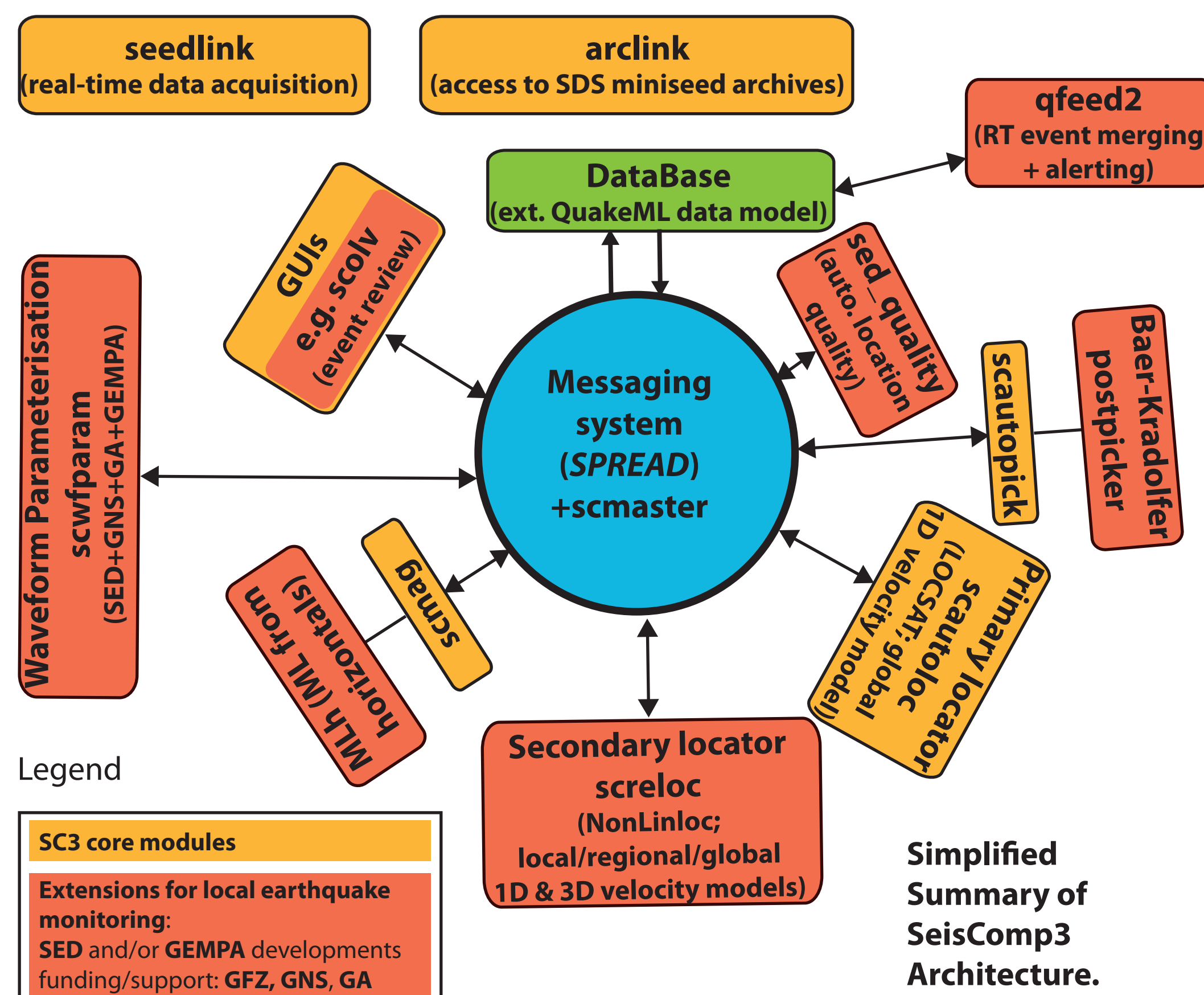


The SeisComP3 Monitoring Software & SED Contributions

SeisComP3 (SC3) is a complete solution for earthquake monitoring, and includes tools for real-time acquisition (**seedlink**), modules for real-time processing (such as detection, location, magnitude estimation, etc.), GUIs e.g. for manual review of solutions, archiving (**slarchive**), and dissemination of waveform/event/metadata (**arclink**). The core of the SC3 system is the TCP/IP based messaging system (SPREAD), which receives information (e.g. picks) from modules and distributes it between the different modules. In order to operate different parallel processing pipelines, different messaging groups can be defined. Relevant information is written to a database. The data model of the SC3 system is based on **QuakeML**. The core of SC3 is open source.

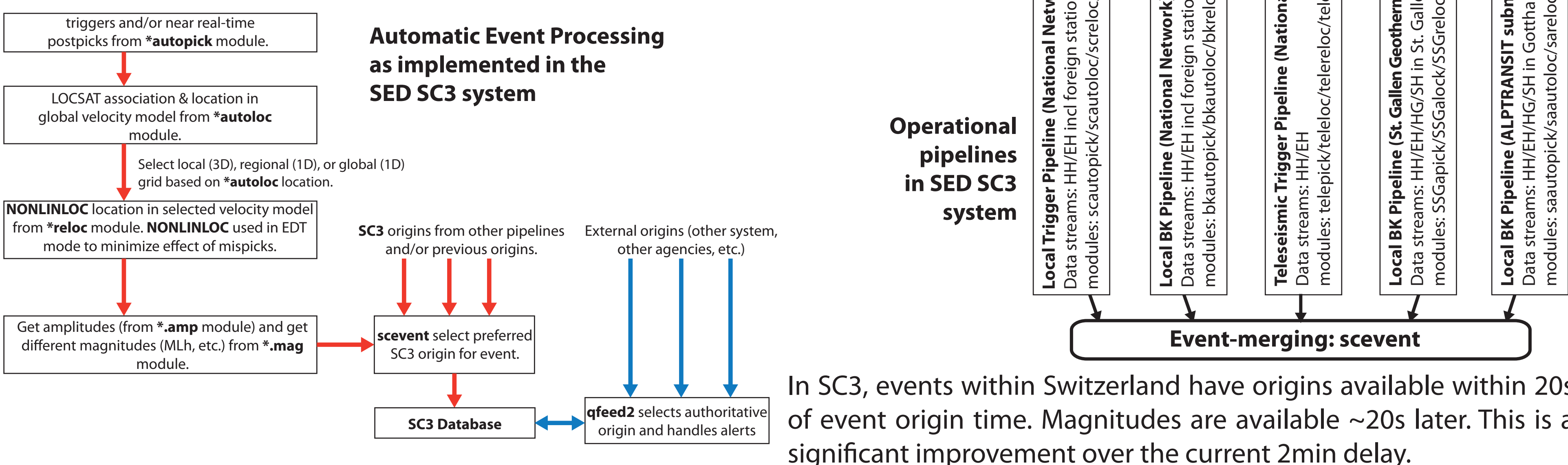
SC3 was developed in the framework of the German Indonesian Tsunami Early Warning System (GITEWS) and therefore the focus was on rapid detection and quantification of large earthquakes at mainly teleseismic distances. As a local network recording moderate seismicity, the SED has needed to tune configurations and added several modules.

The fundamental goal for a transition to SC3 is to replicate the performance of the existing system, in terms of event detection and quantification, manual relocation, and catalogue completeness. To be consistent with existing SED processing procedures, the **NonLinLoc** algorithm was implemented for manual and automatic locations using 1D and 3D velocity models; and plugins for improved automatic phase picking (**Baer-Kradolfer** algorithm) and a **ML** computation using the horizontal amplitudes allowing locally calibrated attenuation were developed; and the graphical user interface (**scolv**) for manual review was extended. The SED alerting software, **qFeed2**, was also rewritten to operate within the SC3 database.



Real-time Processing I: Event detection

We operate several parallel processing “pipelines” to detect and locate local, regional and global seismicity. Additional pipelines with substantially lower detection thresholds can be defined to monitor seismicity within dense subnets of the network.

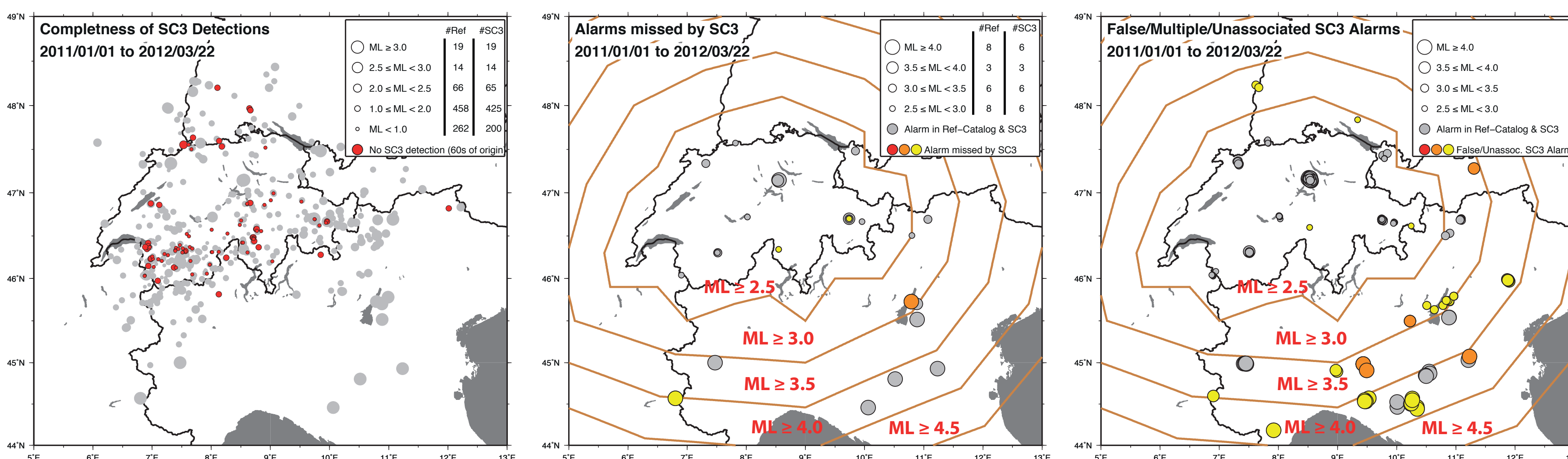


In SC3, events within Switzerland have origins available within 20s of event origin time. Magnitudes are available ~20s later. This is a significant improvement over the current 2min delay.

Event Catalogue and Automatic Location Quality

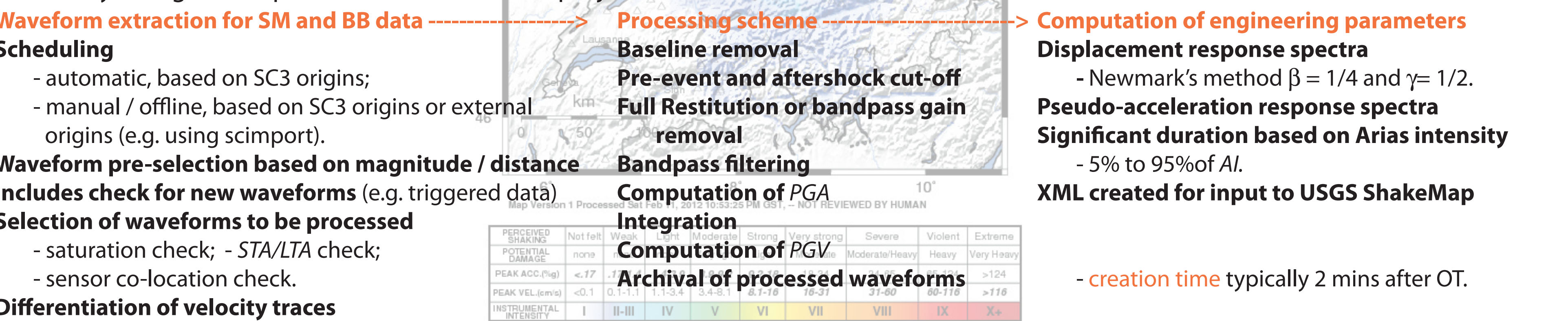
The SED does not operate a 24-hour on-site service. Manual locations will only be available within 60mins of an event. For all events $\geq M2.5$ within Switzerland, automatic locations need to be distributed to the public, and hence we require a quality threshold to ensure distribution of only high quality SC3 automatic origins. The quality definition must apply to LOCSTAT and NLL EDT/L2 locations. We compare locations and magnitudes of different SC3 pipelines with the manual catalogue solutions between January 2011 - March 2012. The proposed origin quality is determined using the individual station travel-time residuals, dt . Each dt is assigned a quality class (A to D; A: highest quality; D: lowest quality). The quality of each origin corresponds to the class with the highest number of residual counts (the mode). If the number of stations in the modal class is less than the minimum number of phases required for a location ($obsmin$, here 6), the location quality is successively lowered, until the cumulative sum of residuals of this quality or higher is greater or equal to $obsmin$. **Only origins with Quality A/B/C would be used for alerting.**

Quality A: $|dt| \leq 0.15$ s Quality C: $0.30 < |dt| \leq 0.60$ s Cut-off parameters (resulting in quality D):
Quality B: $0.15 < |dt| \leq 0.30$ s Quality D: $|dt| > 0.60$ s Gap $> 270^\circ$; distance to closest station > 200 km; rms > 0.5 s



Real-time Processing II: Waveform Parameterisation

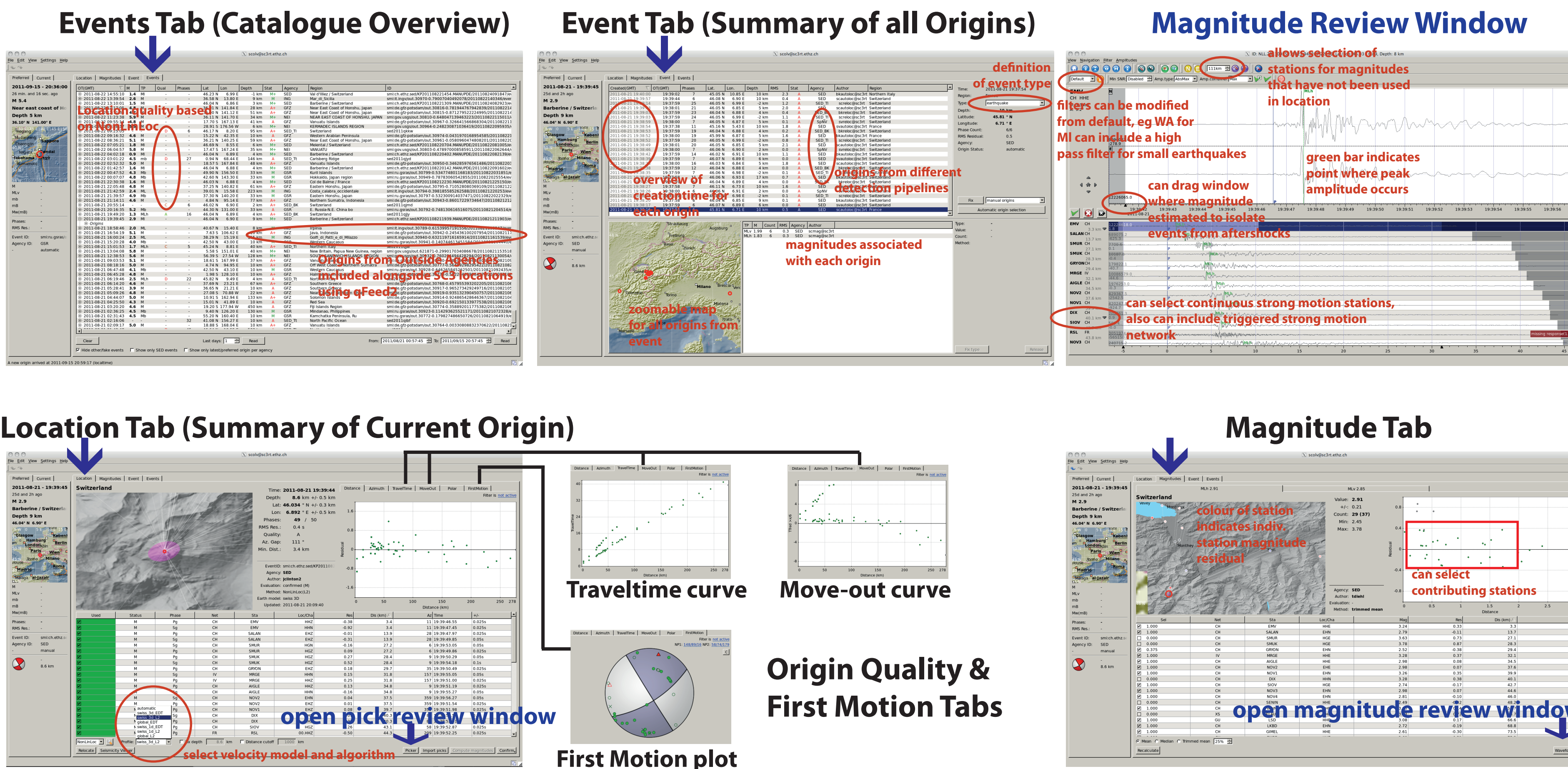
A new SC3 module, **scwparam** has been developed (with gempa) to parameterise event waveform data in near real-time. This will support integrated SC3 ShakeMap creation (ShakeMap XML is an output for the module), and can provide rapid access to a parameterised strong motion catalogue. This tool will also be the core processing component of the European Near Real-time Strong Motion Database currently being developed within the EU NERA project.



Manual Event Review: The scolv GUI

In order to reproduce the functionality of the existing SED event review software, the SC3 graphical user interface for manual review (**scolv**) was extended in collaboration with gempa GmbH.

Features added included pick uncertainty definition, first motion focal mechanisms, interactive review of station magnitude waveforms, full inclusion of strong motion data, and a variety of quality-check options. Highlighted in the snapshots are some key features of the relocation GUI (not necessarily all part of the SED/gempa extension).

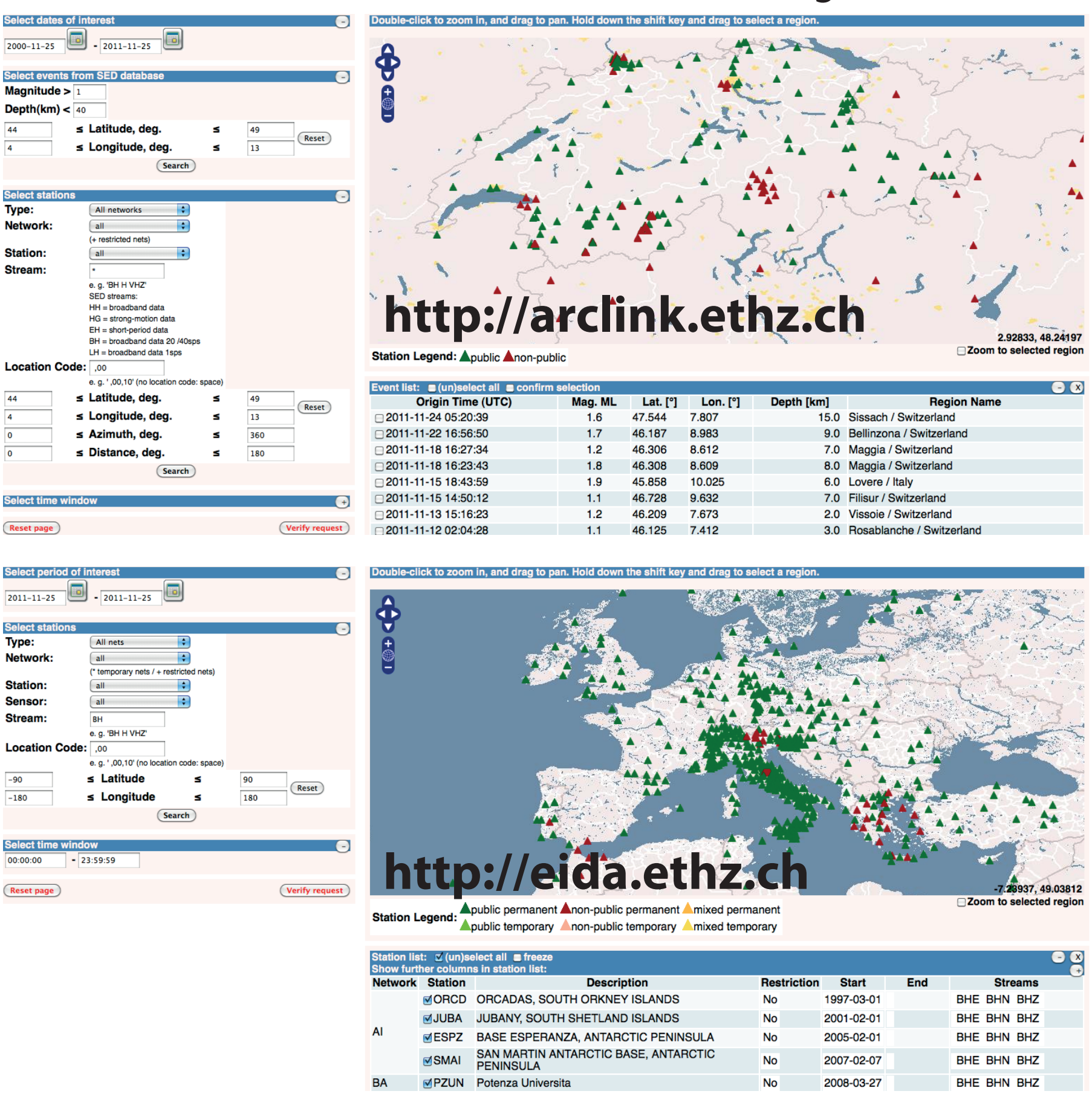


Data Dissemination: ARCLINK & EIDA

The SED is able to take advantage of the existing **arclink** based SC3 tools for data dissemination, both command line and web. All waveforms, (broadband and strong motion) are available from the SED archives for the duration of the modern CH network, beginning 1999.

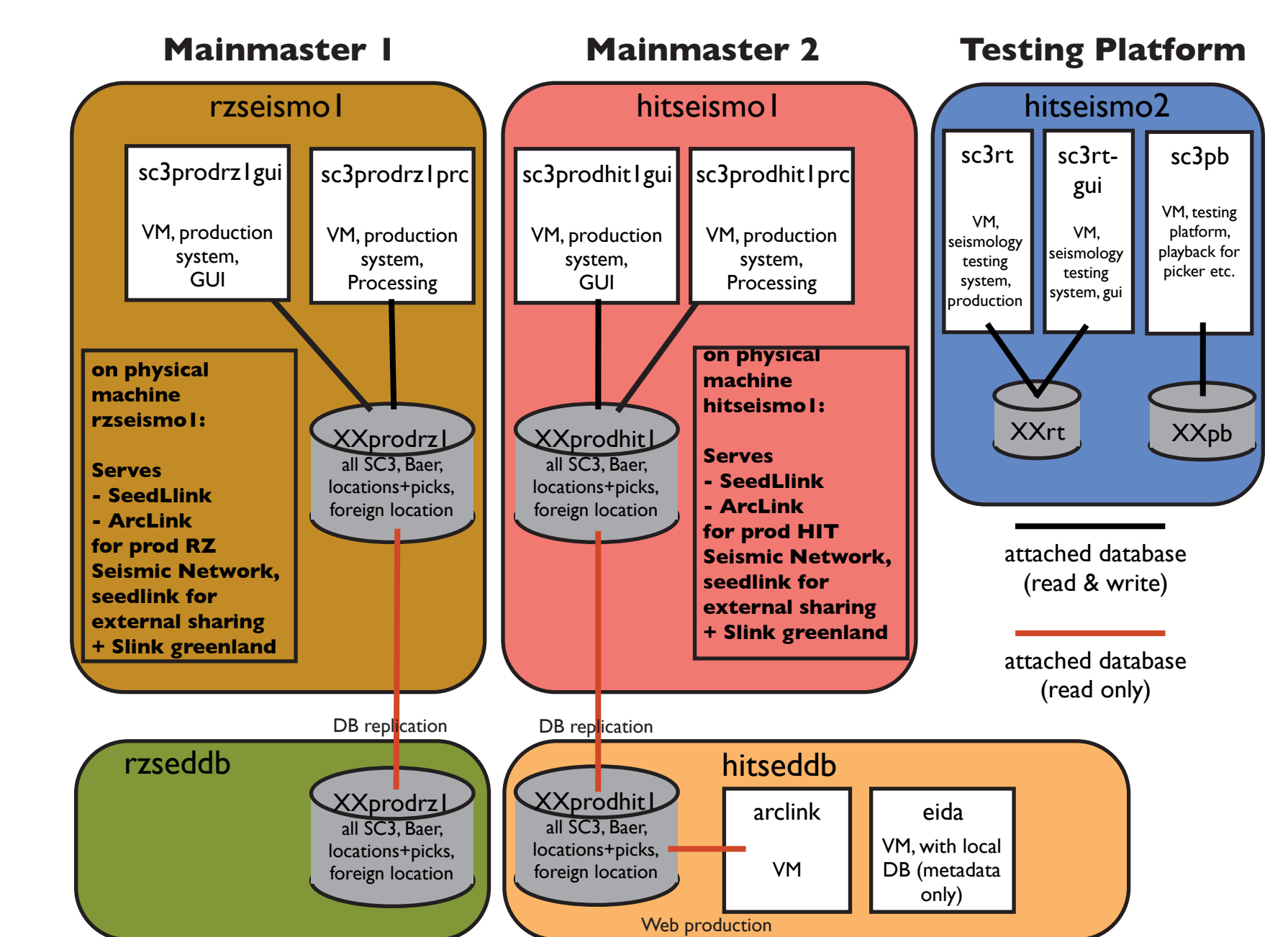
Over 10TB of CH data is available from the CH network via the public European Integrated Data Archive (EIDA). SED operates an EIDA webpage, <http://eida.ethz.ch/>, which allows an independent web access to the EIDA community.

A second public webpage, <http://arclink.ethz.ch/> accesses a dataset comprising all Swiss owned datasets: EIDA, strong motion, short period and off-line project data. This webpage accesses the Swiss earthquake catalogue and supports event based waveform requests. Triggered dial-up strong motion event data in Switzerland is also available using this service.



Outlook: Towards Primary Production System & Beyond

SC3 is expected to replace the existing monitoring software in fall 2012. The development and testing phase are near completion. SC3 can now replicate the features of the current in-house software as well as providing a wealth of new functionality. As an emerging, widely used community software, it adds a new flexibility that should allow it to be used at the SED for many years to come. The majority of scientific developments are complete. We continue to test database functionality and harden the IT setup. To provide a maximal operational stability, we will operate a fully redundant set of duplicate servers running acquisition and processing separated by 5 km across Zurich. Web access is completely decoupled from the operational dB.



Beyond:

- Customise and make the SC3 Moment Tensor operational
- Improved integration of existing SED products within SC3: Dreger regional Moment Tensors Spectral Mw estimates Virtual Seismologist (VS) magnitudes (early warning)
- Near real-time double-difference locations
- Automated S-picking