

# Automated processing of Altimetry-derived River Water Levels at Global Scale – A new “L3” Processor

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## Overview of the “Global Scale River Water Level” L3 Processor

The “Global Scale River Water Level Processor”, currently in development, is designed to automatically produce water level time series at the crossing of rivers and satellite tracks, covering all of the planet, ingesting data from the many altimetry missions.

### Highlights

- Designed for **automated processing with real time update capabilities** (new incoming L2 files)
- Able to process **input data from any Altimetry mission** (LRM, SAR, SARin)
- **L3 output files organised by basins** for better integration in applications
- **Easy integration with SWOT** mission & products (includes SWORD meta-data)
- Comes with a **powerful embed mini-language** (see “Read & Unify input Altimetry data”)
- Written in Python 3 with care (limited CPU & memory usage, parallel processing of some stages, native CPU bytecode for low level routines, etc.)

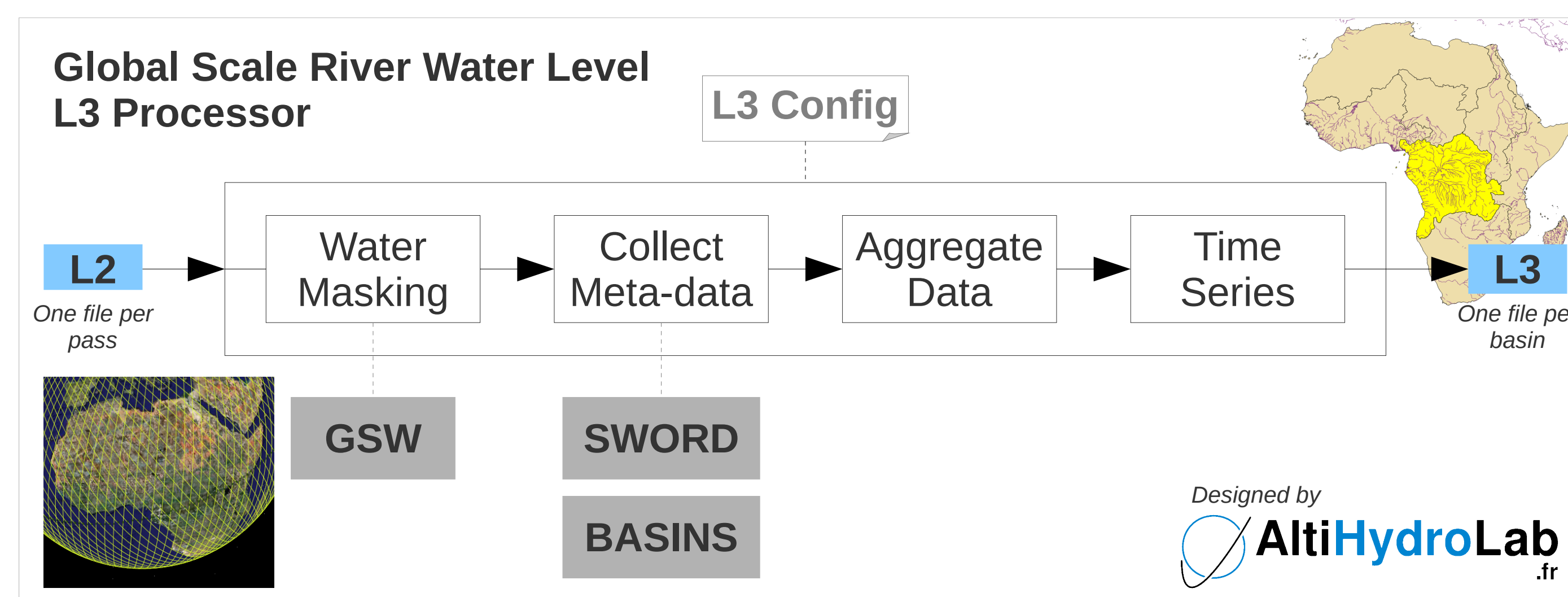
### Work in progress & Milestones

- The processor is currently under heavy development
- A preliminary version of the L3 output product format has been defined (cf. ESA HYDROCOASTAL project)
- Version 1.0 of the Global Scale River Water Level to be ready by Fall 2021
- First L3 output data products (and validation results) will follow and disseminated via <http://www.althydrolab.fr/> portal

## Design & Development

### Inputs, outputs & auxiliary data

- **Inputs** – (Real time) L2 Altimetry data product files (netCDF and possibly other)
- **Outputs** – L3 River Water Level time series (netCDF) organised by basins at “Level-2” (cf. HydroSHEDS/BASINS)
- **Auxiliary Data Bases** – Currently in use: GSW (Pekel, 2016), SWORD (Alteneau, Pavelsky, Durand & Frasson, 2021) and HydroSHEDS/BASINS (Lehner, 2014)



### Processing stages

- **Water Masking** – Confine Altimetry data records that fall over rivers water surface using raster or vector data bases. Supports several Data Bases such as GSW, SWBD and other GIS files.
- **Collect Meta-data** – Meta-data attributes gathered from the SWORD and the HydroSHEDS/BASINS data bases are affected to Altimetry data records (river width, river reach\_id/node\_id, basin\_id, etc.).
- **Aggregate Data** – Following the hydrographic network, Altimetry data records are assembled together at the crossing of rivers and repetitive pass locations (repeat-orbit cases) to form “Virtual Stations”. For geodetic/drifted orbit cases (CryoSat-2), an experimental aggregation scheme is developed to produce space-time series of water level (Altimetry data are distributed in space and time along the course of rivers). Another strategy is being developed for CryoSat-2 SARin data specifically.
- **(Space-)Time series** – For each Virtual Station, Altimetry data records are processed in order to remove outliers and conditioned as full-featured (space-)time series L3 output files.

### Read & Unify input Altimetry data

Able to read all netCDF Altimetry data, **the processor comes with a powerful mini-language** to help to:

- **Define groups of data variable that match a “processing chain”** (e.g.: time, lon, lat, surf\_height) symbolically defined using free and convenient attributes such as the *posting rate*, *radar frequency band*, *altimeter mode*, *retracker ID*, etc. E.g.: “@20Hz / Ku-band / SARM / ALES+ retracker”.
- **Unify the variables naming scheme**: /20hz/ku/ice1/{time, lon, lat, surf\_height}, /20hz/geoid, /1hz/corr\_tropo\_wet
- Automatically **interpolate low rate variables** (e.g., corrections) and **memory-align variables** for later algebraic operations.
- **Enumerate variables & evaluate expressions** thanks to “meta expressions”:  
/20hz/<band>/<rtk>/surf\_height = /20hz/alt - (/20hz/<band>/<rtk>/range + /1hz/<band>/corr\_iono + /1hz/corr\_tropo\_wet + ...) - /20hz/geoid

## Objectives

- **Unleash 30 years of Altimetry data** “From the Topex/Poseidon & ERS era to the Sentinels and SWOT”
- **A tool for research and real life applications**

## Challenges

The processing of rivers water level at global scale faces several challenges:

### Scientific challenges

- Confine altimetry record measurements over rivers water surface with a good level of consistency, despite river width changes throughout the year. Attach altimetry records to a consistent hydrographic network data base.
- Automatically geo-aggregate the altimetry data records, then derive water level (space-)time series. Account for obstructions along the course of the rivers flow (dams, waterfalls, etc.).
- Implement an efficient scheme for the rejection of outlier measurements in the construction of the time series.
- For each of the retracker outputs available in L2 input files, derive a dedicated water level time series.

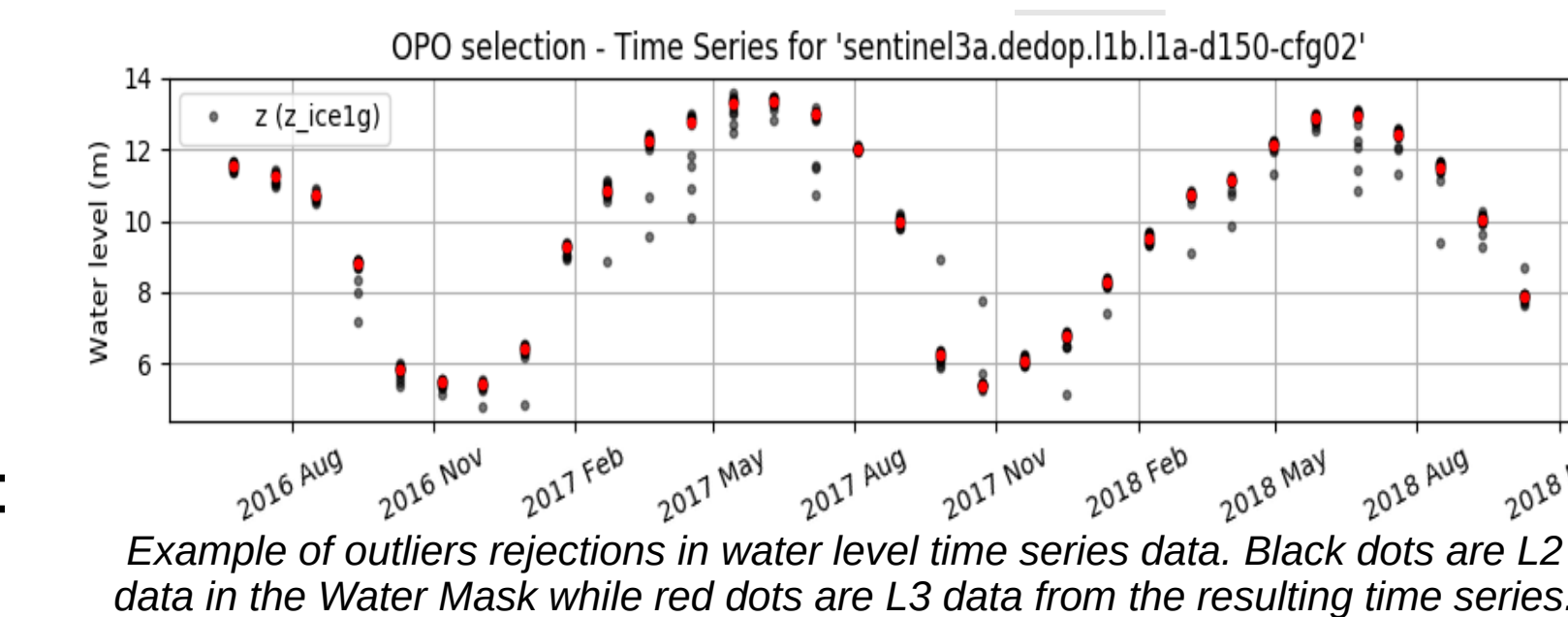
### Technical challenges

- Design the processor to be automated, fast, easy to configure and run
- High degree of structuration: complex data flow, processing stages interfaces, I/O files organisation, many internal concepts
- Unify input L2 Altimetry data that have heterogeneous organisational models
- Make the L3 outputs to suit users needs.

## Ensure data quality

Validation example in the frame of the **ESA HYDROCOASTAL** project, using custom L2 input from partners:

- **First evaluation of data quality to be performed on L3 Test Data Set (TDS) over the Amazon basin** (by AltiHydroLab.fr). The input L2 TDS contains seven different retracker implemented by project partners. The performance of the TDS will be evaluated in details with a set of agreed metrics. Other selected areas studied by partners are Rivers Ob and Rhine (NUIM, U Bonn), Rivers Po and Mississippi (CNR-IRPI).
- From the evaluation of the TDS, retracking algorithms will be selected to generate a “Global” river data set for selected “large to medium” rivers. The “Global” products will be made freely available via the project website at <https://www.satoc.eu/projects/hydrocoastal/>.



## Applications

Applications of the “Global Scale River Water Level” **L3 Processor**:

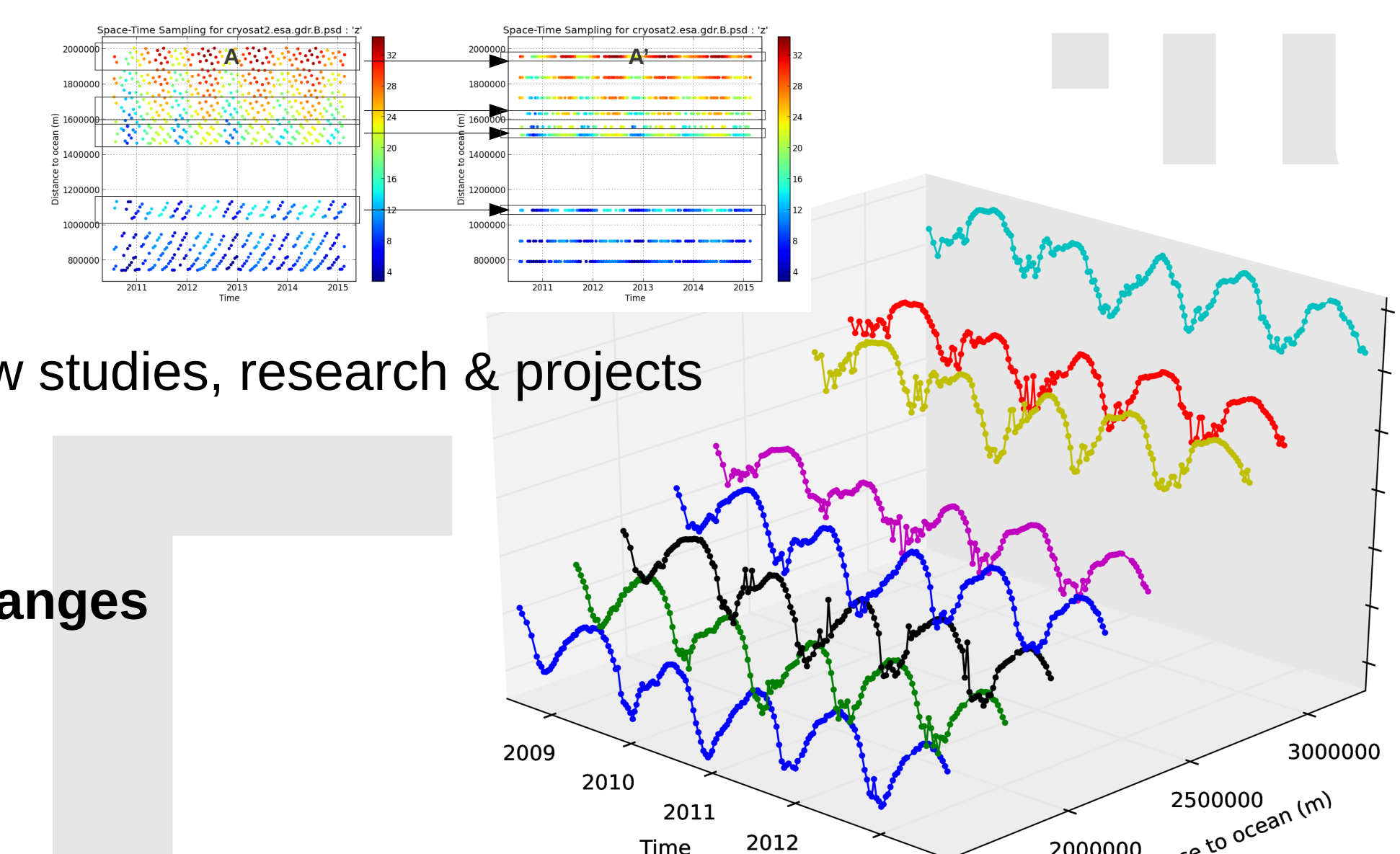
- At first, the processor is a **framework for research**
- Designed to be **evolutive & flexible**
- Will be **updated regularly** with methodology outcomes from new studies, research & projects

Applications of the Global River Water Level **L3 Products**:

- Input for **regional and global river discharge models**
- Worldwide **gridded products of low frequency water level changes**
- **Climate change & water cycle analysis**
- River Water Level **forecasting**

Some other applications:

- Systematic validation (in routine) over selected areas
- Regional studies, tailored analysis, on-demand expertise



Example of L3 time series of river water levels derived from CryoSat-2 space-time data, Amazon river. Initial space-time series data (A), spread all along the course of the river, have been redistributed in space (A') in order to derive usual time series (3D plot).

## Acknowledgment

The “Global Scale River Water Level” L3 Processor is an internal work funded by AltiHydroLab.fr with support from the ESA HYDROCOASTAL project. The author thanks partners from the HYDROCOASTAL project and the producers of the awesome altimetry & auxiliary data bases listed in this poster.