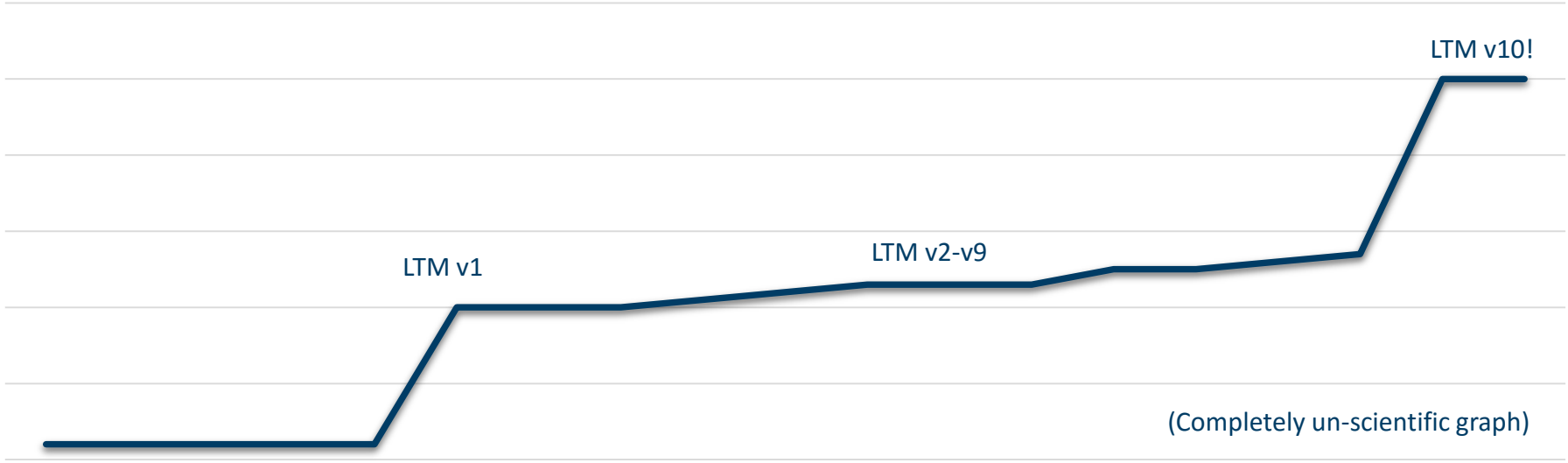
LTM V10

Knut Skogstrand Gjerden & the rest of the team

Presenting: LTM v10!

One large step for us …

- One of the largest single upgrades of the LTM models since day 0 in late 1960s.



- Has taken time, effort and dedication of several scientists.

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Contributors

(based on current repository, covers only last ≈20 years)

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New in version 10!

Changed storage formats

New possibilities

Python

New interfaces

XML

New applications

API

Upgrade_10

Ltm

Calendar

Time series

Emps

HDF5

Eops

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Not new in version 10

- If you want them to , most applications act and feel the same.
- Still possible to use old flex-input.

Invisible changes in version 10

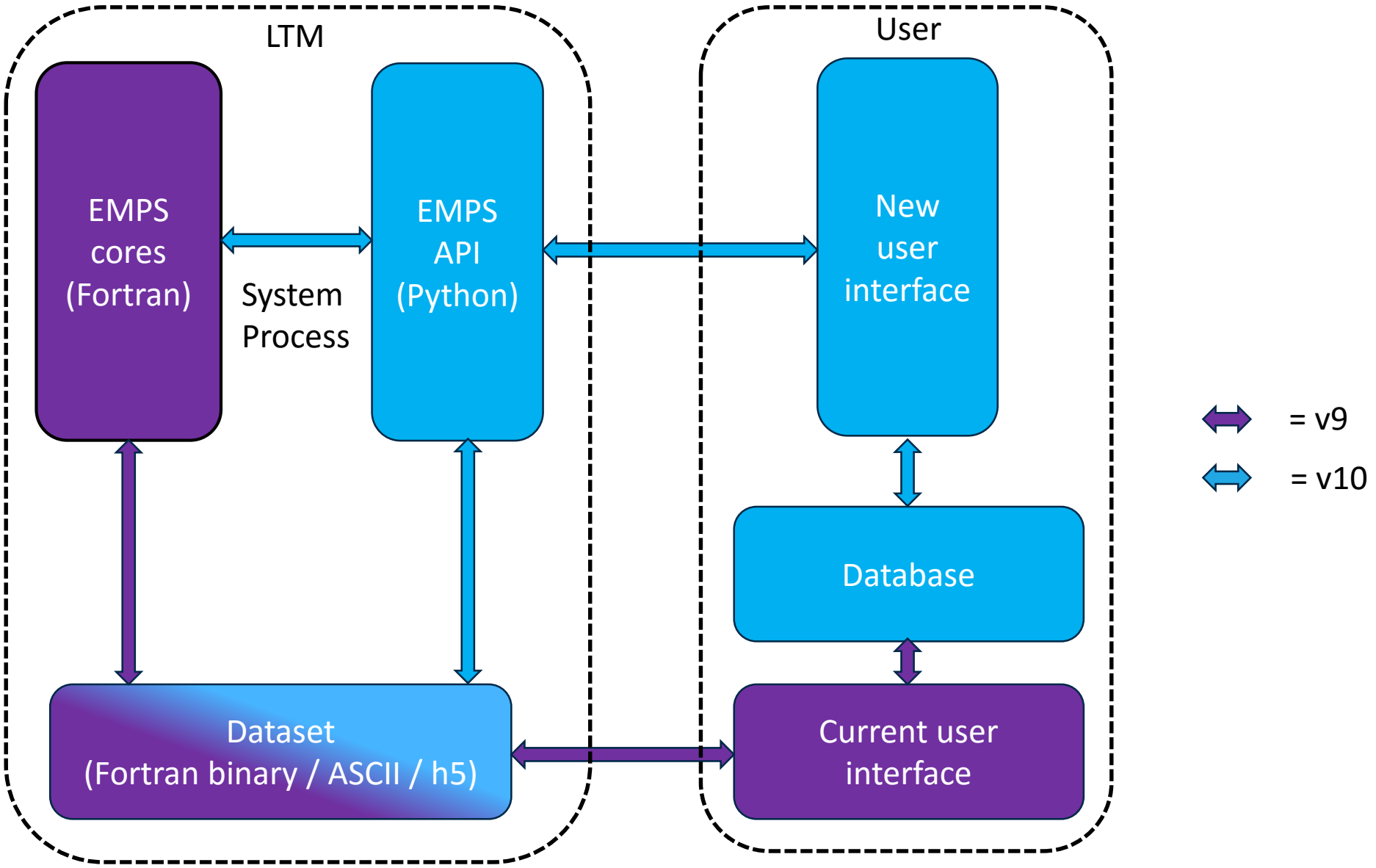
- Many internal changes, updates and improvements
- Code
  - modernization
  - restructuring
    - med-files and vann-files are gone
    - new internal structures

Not yet in version 10

- Combination short term prognosis + Snomod.
  - This is achievable in Python using the new API.

Overview of version 10

New architecture of v10



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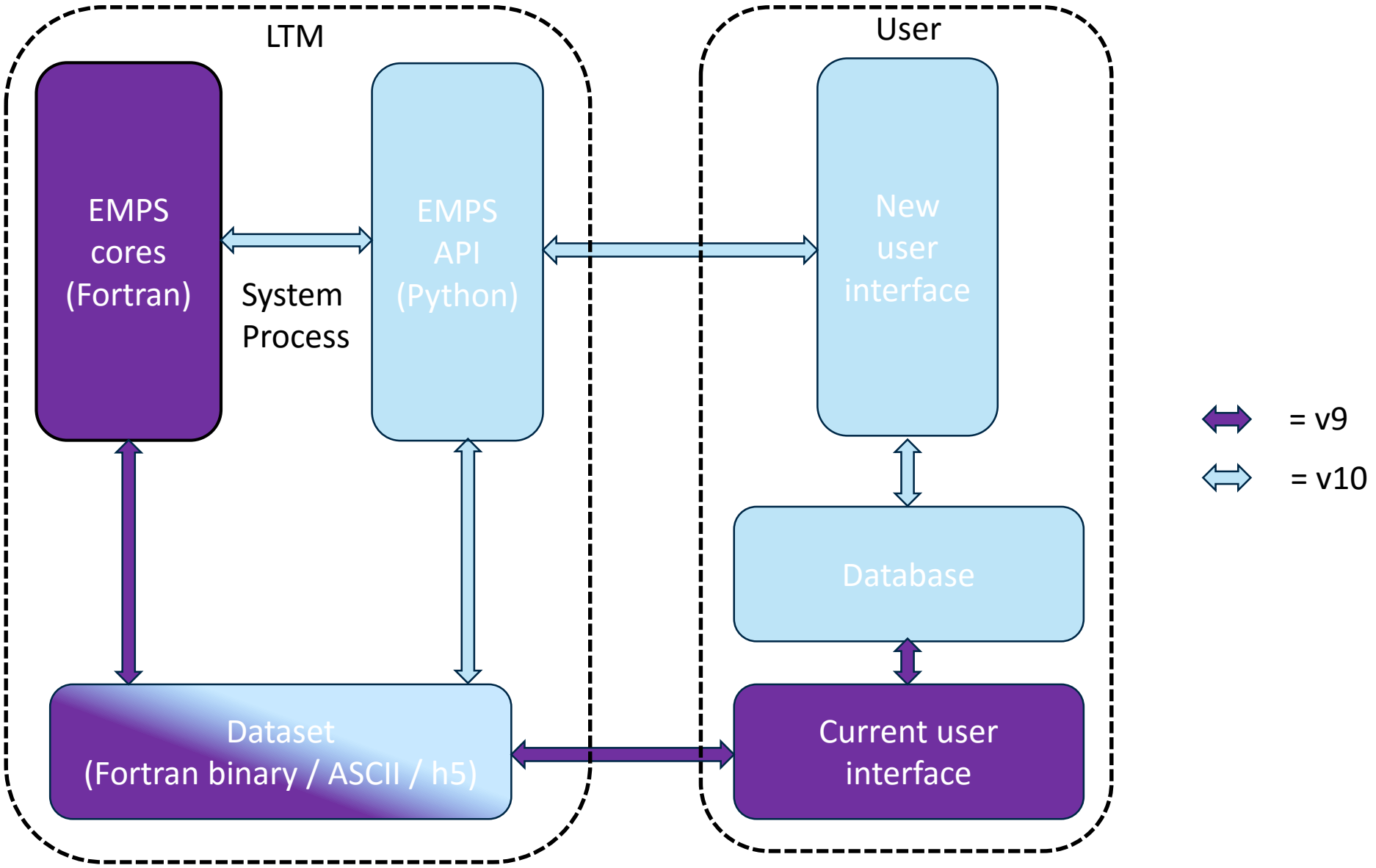
New architecture of v10



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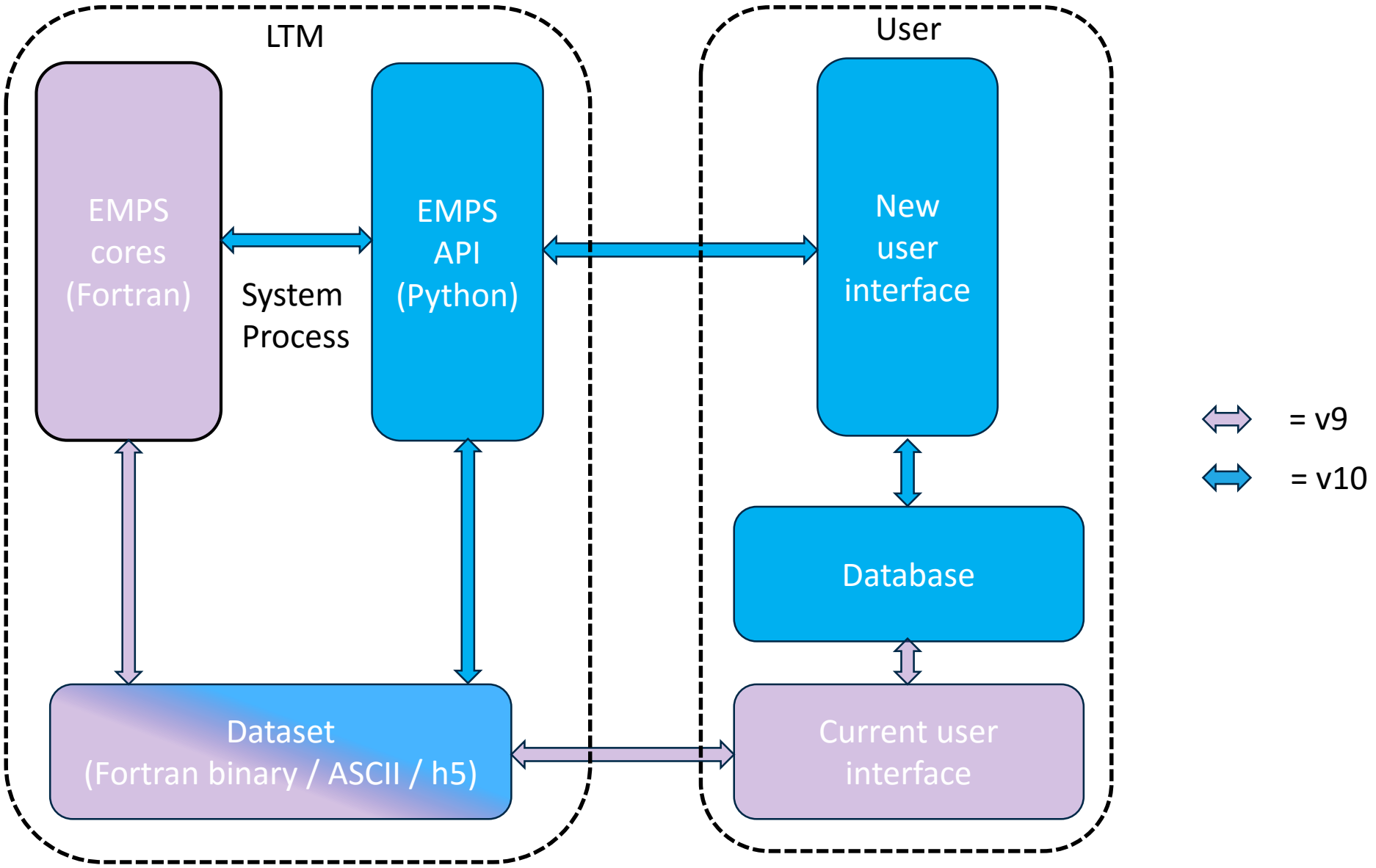
New architecture of v10



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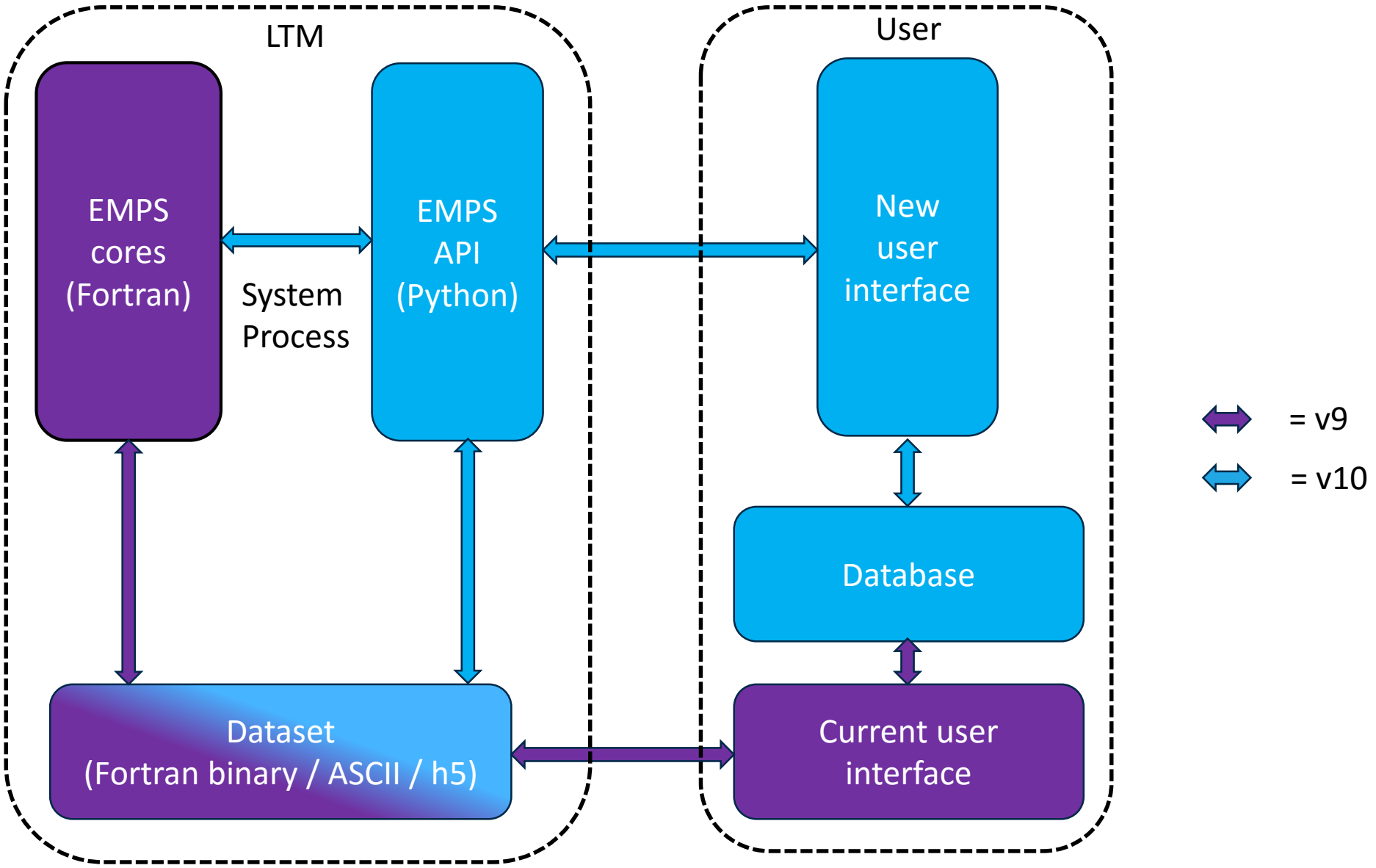
New architecture of v10



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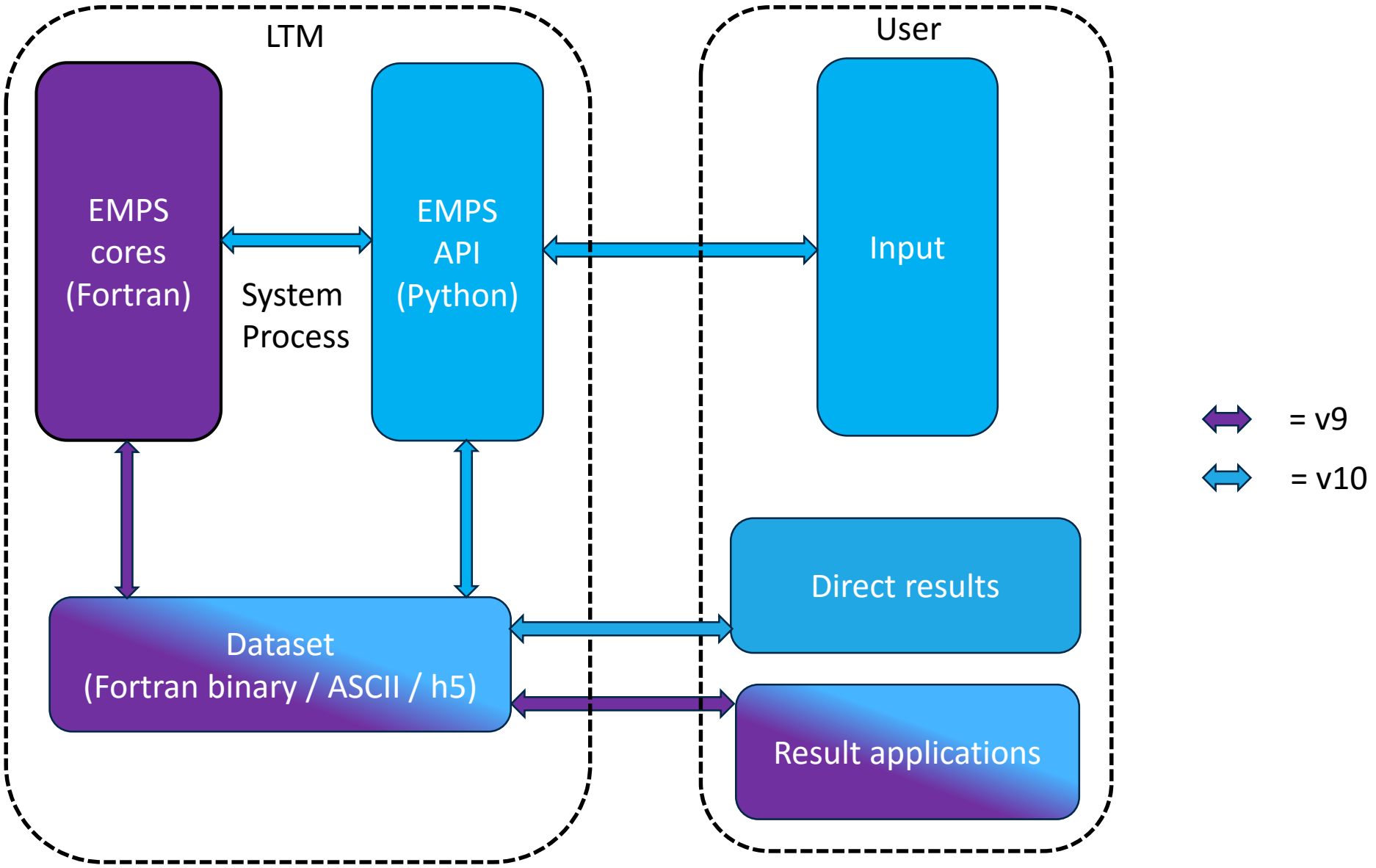
Input and results

- New API to set input.
- API is not complete.
  - Some input still "manual": *.enmd, *.detd.
  - Application control not in API.
- Input can be set through the API.
- Results can be read from hdf5-files, no specific API for this.
  - HDF5-API well documented and in much use.

Organization of input and results



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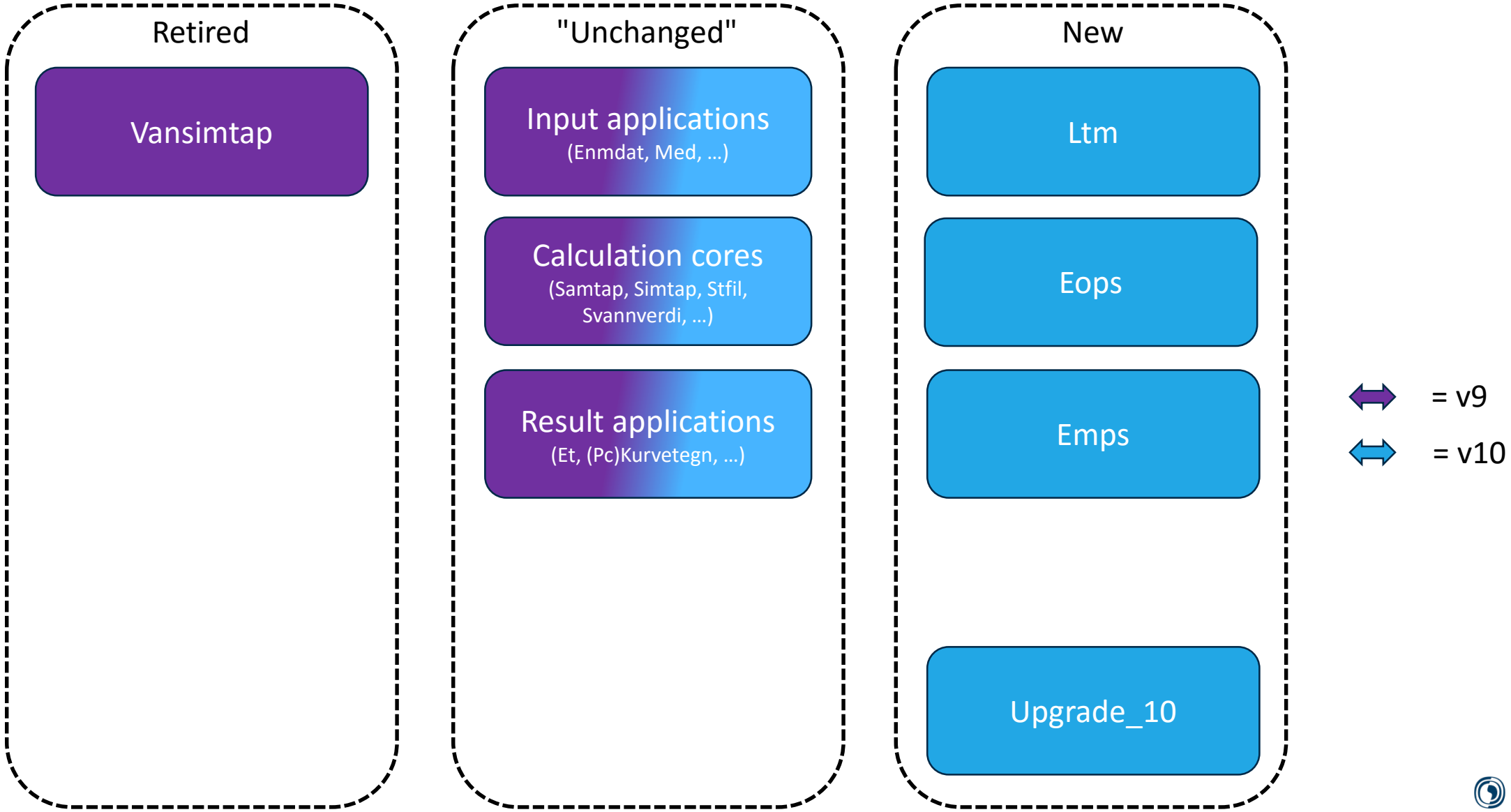
Changes in the application suite

Changes in application suite



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Changes in applications – Retired

- The application Vansimtap is retired.
- This only applies to the control of execution, the processes/tasks Vansimtap performed is moved to a new application.

Changes in applications – New flow and control

- Control application Ltm and execution applications Eops and Emps.
- Ltm
  - Provides single interface for interacting with dataset. Generates xml-files used to run Eops and Emps.
- Eops
  - Takes over tasks from Vansimtap.
- Emps
  - Single start point for EMPS-tasks and processes.

Changes in applications – New flow and control

- Eops and Emps are task-centered.
  - Example run steps from Emps: Establish model, run strategy, run draw down model.
- Defined in xml-file, single or multiple files per task, you choose and set up in Ltm ...
- … or generate your own!
  - Establish model -> LtmSystem_establish.xml
  - Run strategy (water value calculation) -> emps_run_strat_calc.xml
  - Run simulation (draw down model) -> run_my_simulation.xml
  - Multiple combinations possible -> run_everyting_I_want_with_a_single_call.xml

Examples:

- [set up through Ltm or own xml-generator]

- emps LtmSystem_establish.xml
- emps emps_run_strat_calc.xml
- emps run_my_simulation.xml
- eops run_my_simulation.xml
- eops run_everyting_I_want_with_a_single_call.xml

Examples:

```
</Model>
<HistoricalPeriod HistStartYear="1931" HistNumberYear="50" />
<SeasonData PlanningHorizonSes="1" EndWeekSes="52" AutoCorrPrice="0.0000" PriceLevelFirs
<SimulationConditions>
 <SimulationPeriod SimAltSerial="F" SimStartDate="2017.01.02" SimNumberWeek="260" />
 <RealInterestRate Rate="0.0000" />
 <ExogPriceLevWaterValCalc Active="F" />
 <CalcSnowReservoir Active="F" />
 <NoProcessors Number="1" />
 <NoLapInflowCalibration Number="1" />
 <ResetStrategyFactors Active="F" />
 <HistRandomYear Active="F" RandomYear="" />
</SimulationConditions>
<Simulation>
 <InflowCalculation Active="F" />
 <MarkedPrepApi Active="F" />
 <FillMarkedApi Active="F" NameApiProc="ApiFill" />
 <InitializationOfEMPS Active="F" />
 <WaterValueCalculation Active="F" />
 <DischargeHeuristic Active="F" />
 <SystemPriceCalculation Active="F" />
 <CalibrationNewInflow Active="F" />
 <OneAreaModell Active="F" />
 <SeasonalModel Active="F" />
</Simulation>
</LTM>
```

```
 ::::: :: ::   :: :::::: :::::: ::::::
::     :: :::  ::   ::   ::     ::
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::::::  :: ::   ::   ::   :::::: ::    Energi AS

LangTidsModell - X.X/Release/xxxx - 2019.xx.xx
---------------------------------------------------------------
Brukerveiledning..: Vansimtap
Sintef Support....: support.energy@sintef.no, Tel: 40471700/Senb: 73597200
Kj|retidspunkt....: 11. mars 2019, kl 15:23:15



Datamodell
Nr     Omraade-          Ant.kon- Ant.  Ant.vind Vannkraft         Ant.    Ant.    Gruppe  Forbindelse
       navn              trakter  trinn parker   modell            moduler pumper          til

  1,  NUMEDAL                 2     47       0  numedal               17      0     1      2,
  2,  TEV                     7     52       0  tev                   12      0     1      3,
  3,  OTRA                    1     56       0  otra                  21      1     1      1,  4,
  4,  TERM                    1     15       1  Ingen vannkraft                     2

Historisk tilsigsstatistikk:          F/rste aar:       1931
                                      Ant. aar:           50
Prisavsnitt inndeling                 Ant. akkumulerte:    4
                                      Ant. sekvensielle:  17
Dataperiode                           F/rste aar:       2017
                                      Ant. aar:            5
Simuleringsperiode:                   Startdato:  2017.01.02
                                     (Startuke:            1)
                                      Sluttuke:          260
                                     (Antall:
Simuleringsmodus:                                 Parallell
Realrente                             Rente (%):        0.00

Det eksisterer en fil med magasinfylling.
Magasinfylling maa oppdateres ved endring av betingelser


Velg HIST PERIODE START SERIE MAG DBMAG DATAMOD
 GRUPPER PRISAV PROGNTIL SIMUL RENTE FAKTST ALTERN
 AARSIM PRES SAMTAP AVSLUTT , ........................... :
```


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Examples:

Tasks

- Calculate energy inflow (R/U30) and establish internal files (Detmod)
- Calibrate inflow/prognosis using Samtap
- Prepare model (Saminn)
- Water value calculation (Stfil/Svannverdi)
- One area simulation
- Simulation using draw down model (Samtap)
- Seasonal model
- System price calculation (Samtap system price)

XML

- InflowCalculation
- CalibrationNewInflow
- InitializationOfEMPS
- WaterValueCalculation
- OneAreaModell
- DischargeHeuristic
- SeasonalModel
- SystemPriceCalculation

Ltm

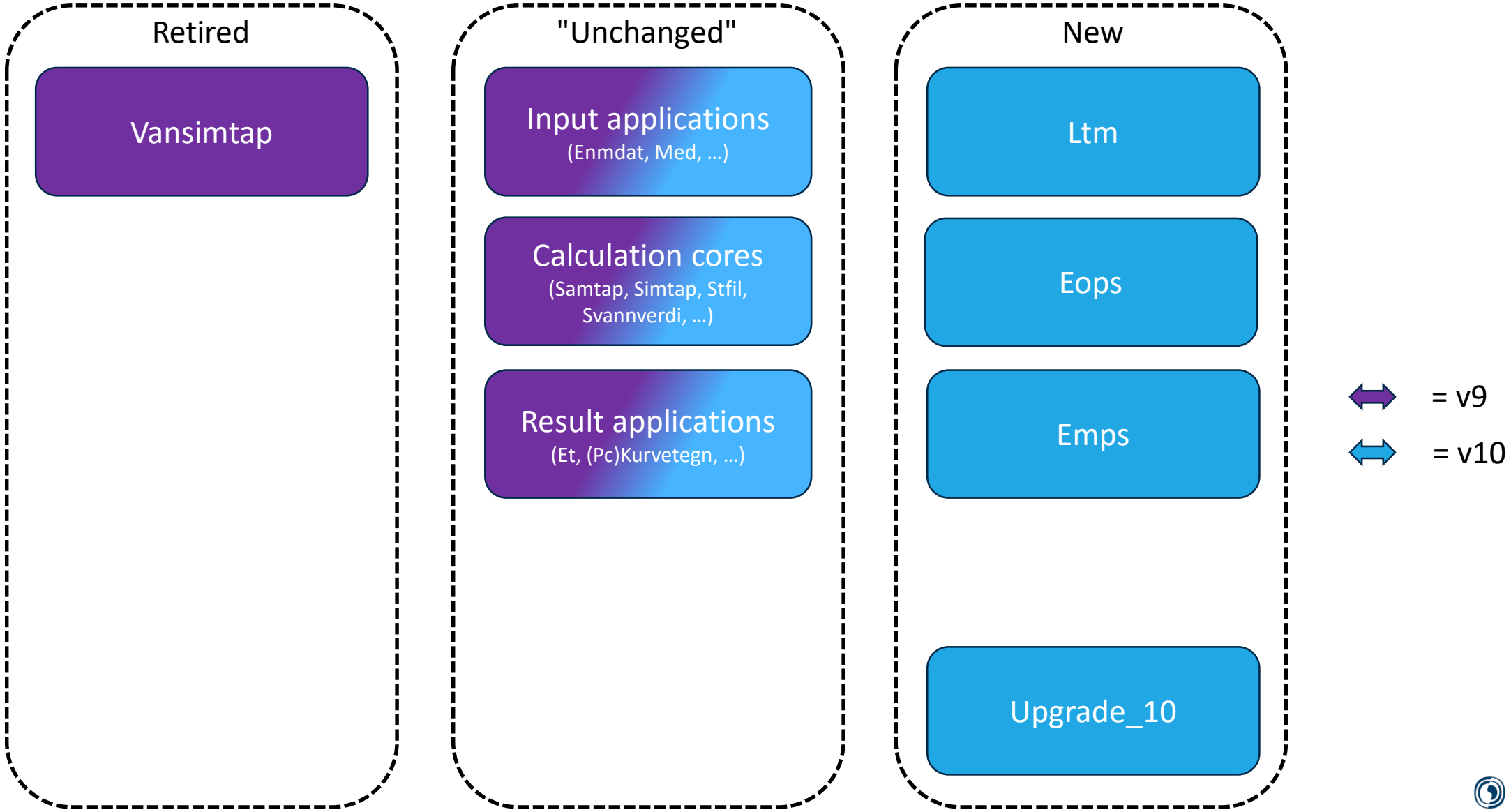
- Tilsetb
- Tpkalib
- Etbmod
- Strat
- Enmag
- Tapp
- Ses
- Systpris

Changes in applications – Getting started

- Introducing application Upgrade_10.
- This application provides a "fresh copy" of a data set upgraded to version 10.
- Example:

```
mkdir dataset_v10
cd dataset_v10
[set your ltm run environment]
upgrade_10 /path/to/complete/dataset/v9
```

Changes in applications



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Alt+tab for demo

Demo contents

- Successful demo showing:
  - Using upgrade_10 to obtain prepared catalog with data set.
  - Using Ltm to get an overview of the data set.
  - Using Ltm to set simulation parameters and to run initial task.
  - Using Ltm to generate an xml-file.
  - Launching Emps using xml-files to perform tasks.

New possibilities

- For you

Data as time series

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New possibilities in input

- V10 introduces time series (TS).
- Resolution can be
  - Hourly,
  - Daily,
  - Weekly.
- Set through the new API in Python.
- What does this cover?

Set-functions for time series data

- Market data ((scenario dependent) load segments + price elastic market description)
- Price-sensitivity (market description: re-purchase)
- Transfer capacities (Maskenett) [TRANSCAP_HOUR.DATA]
- Wind power [V30-files]
- Temperature profiles (load segments + CHP) [TEMPPROFIL.ARCH & kraftvarmeprofiler.sdv]
- Consumer flexibility [FLEKS-files]
- Revisions on hydro production [REVISJONSPLAN.STAS]

Set-functions for time series data

- Inflow
  - New archive format (historical.h5 replaces TARC-files)
  - Historical water mark series (historical.h5 via API, fetch from data base via Powel TSS-API)
  - Prognosis (water mark series, temperature and snow (EMPS))

  Note: Prognosis can be supplied for the entire simulation period.
- Price data

Example in Python:

- Using package setuptools:
  - python -m easy_install sintef.ltm_store-x.yz-py3.6.egg
- Use documentation to get started, and remember that you can always ask (for) help
  - help(sintef.ltm_store.LtmModelRepository.set_load)

```python
import os

from sintef.ltm_store import create_model_service
from sintef.ltm.h5_model_convert import model_convert
from sintef.ltm_store._ltm_store_api import Model, PowerModuleDict

def get_all_wind_in_model_as_dict(model: Model) -> PowerModuleDict:
    # Type hinting is not necessary, just good
    wind_dict = dict()
    for area in model.area:
        for pm in area.data().power_modules:
            if pm.data().wind_type_id > 0:
                wind_dict[pm.data().id] = pm.data()
    return wind_dict


if __name__ == '__main__':
    print('-> This script should be run in an EMPS data set directory')
    emps_data_set_dir = os.getcwd()

    print('-> Init model service for writing h5-files to the EMPS data set directory')
    ms = create_model_service(emps_data_set_dir)

    print('-> Read in the EMPS model description, and convert to a Python model')
    h5_model_file = 'model.h5'
    model_fpath = os.path.join(emps_data_set_dir, h5_model_file)
    model_id = model_convert(model_fpath, ms)

    print('-> Get all the time series for wind already present in the data set')
    model = ms.get_model(model_id)
    wind_dict = get_all_wind_in_model_as_dict(model)

    print('-> Edit the data...')

    print('-> Set the new data')
    ms.set_wind(model_id, wind_dict)
```


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New possibilities in output

- Results available on time series format with sequential time resolution (i.e., price segment resolution [prisavsnitt]).
- This means that you decide the output resolution.

- Common format on the files:
  - Mapping info: Mapping to area/module et cetera.
  - Time series info/data: Info on data series.
  - Other data: Data not on time series format
  - Other info: Run time, simulation parameters et cetera.

Results available on h5-files

- Market results
  - Corresponding to options VA & SA in Kurvetegn
  - Market results and area results
  - Corresponding to the files:
    - SAMRES.SAMK and UTVEKSLING.SAMK in older versions (SAMRES.h5 in newer)
    - ENMRES.DATA (same type of results from EOPS and ProdRisk, now on ENMRES.h5)
- Detailed hydro power results
  - Corresponding to options SI & SE in Kurvetegn
  - Simulation results for detailed hydro (includes aggregated results per area)
  - Corresponding to the file(s):
    - DETSIMRES_hyperslab.h5 or DetRes/* in older versions (detsimres.h5 in newer)

Implementation choices

- API based on Python, hdf5 introduced as file format.
- Why Python and h5?
- Python is a widely used (scripting and programming) language with very broad library support.
  - from the_world import anything
- HDF5 (next four pages).

HDF5 - technology

- A *versatile* data model that can represent *very complex* data objects and a *wide variety of metadata*.
- A *completely portable* file format with *no limit* on the number or size of data objects in the collection.
- A *software library* that runs on a *range of computational platforms*, from laptops to massively parallel systems, and implements a high-level API with C, C++, Fortran 90, and Java interfaces.
- A rich set of integrated performance features that allow for access *time and storage space optimizations*.
- *Tools* and applications for managing, manipulating, viewing, and analyzing the data in the collection.

Design of HDF5

- For high volume and/or complex data (but can be used for low volume/simple data)
- For every size and type of system (portable)
- For flexible, efficient storage and I/O
- To enable applications to evolve in their use of HDF5 and to accommodate new models
- To be used as a file format tool kit (many formats use HDF5 under the hood)
- Allows hierarchical data objects (similar to directories and files)

- ***https://support.hdfgroup.org/HDF5/***

HDF5 - terms

- File:
  - "Container" that holds variety data objects (called datasets)
- Group
  - Structure containing instances of zero of more groups or dataset (with metadata)
  - Organize data objects
  - Contain other groups or links to objects (in other files)
- Dataset
  - Organize and contain "raw" data
  - Contain metadata
  - Data (different *datatypes*, properties (e.g., chunks/*slices*) and *dataspaces* (array dimension))
  - Compound dataset (table of data, allows different datatypes)
- Attributes
  - Metadata: name and value

Some HDF5 Tools

- *HDFView* *:* A java browser to view HDF (HDF4 and HDF5) files
- *H5diff* : Command-line utility to compare HDF5 files.
- H5dump : Command-line utility to display or *dump* contents of HDF5 file in text
- H5ls : Command-line utility to display or *list* contents of HDF5 file in text

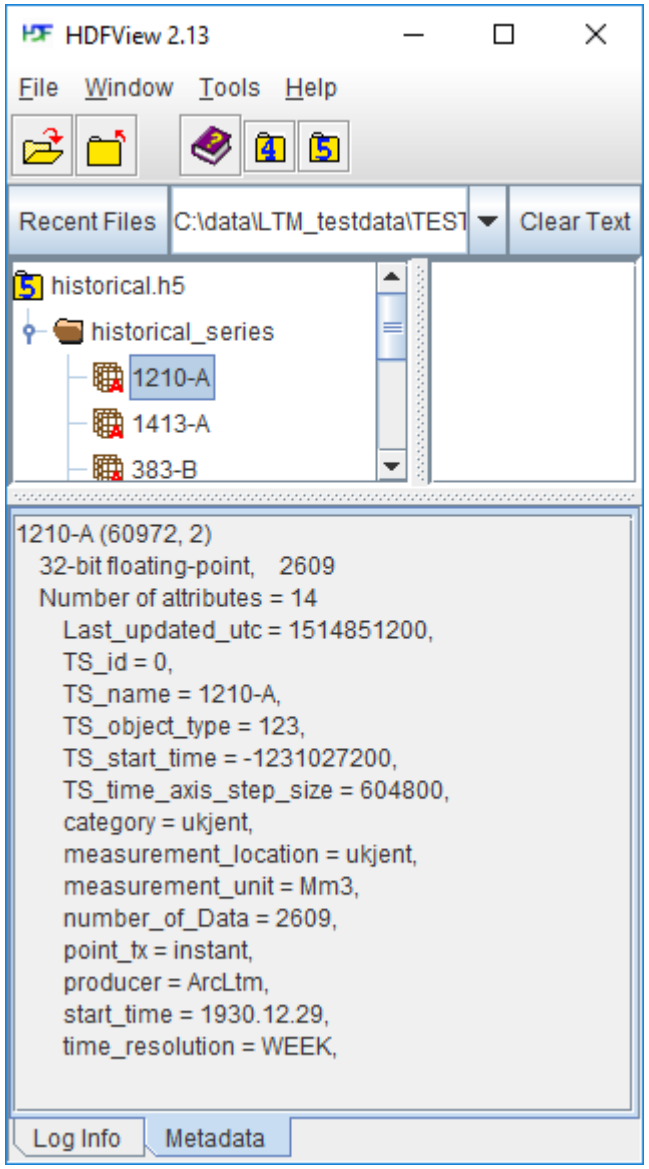
- There are various HDF5 command-line tools to edit files in different ways (h5copy, h5jam, ...)

A deeper look at some of the new files

- Categories: some are *input*, some are *internal*, some are *output*.
- Input files are accessed through the API.
- This gives us freedom to change format of file without affecting use of applications.
- Internal files are only meant to be written and read by the applications, but they can be *viewed*.
- Output files contain results and are read by results applications. They are also meant to provide you with freedom to view and access results in a completely new way.

historical.h5

- Replaces TARC
- One dataset per water mark/temperature series
- TS-format
- Extra attributes:
  - Producer
  - Time-resolution



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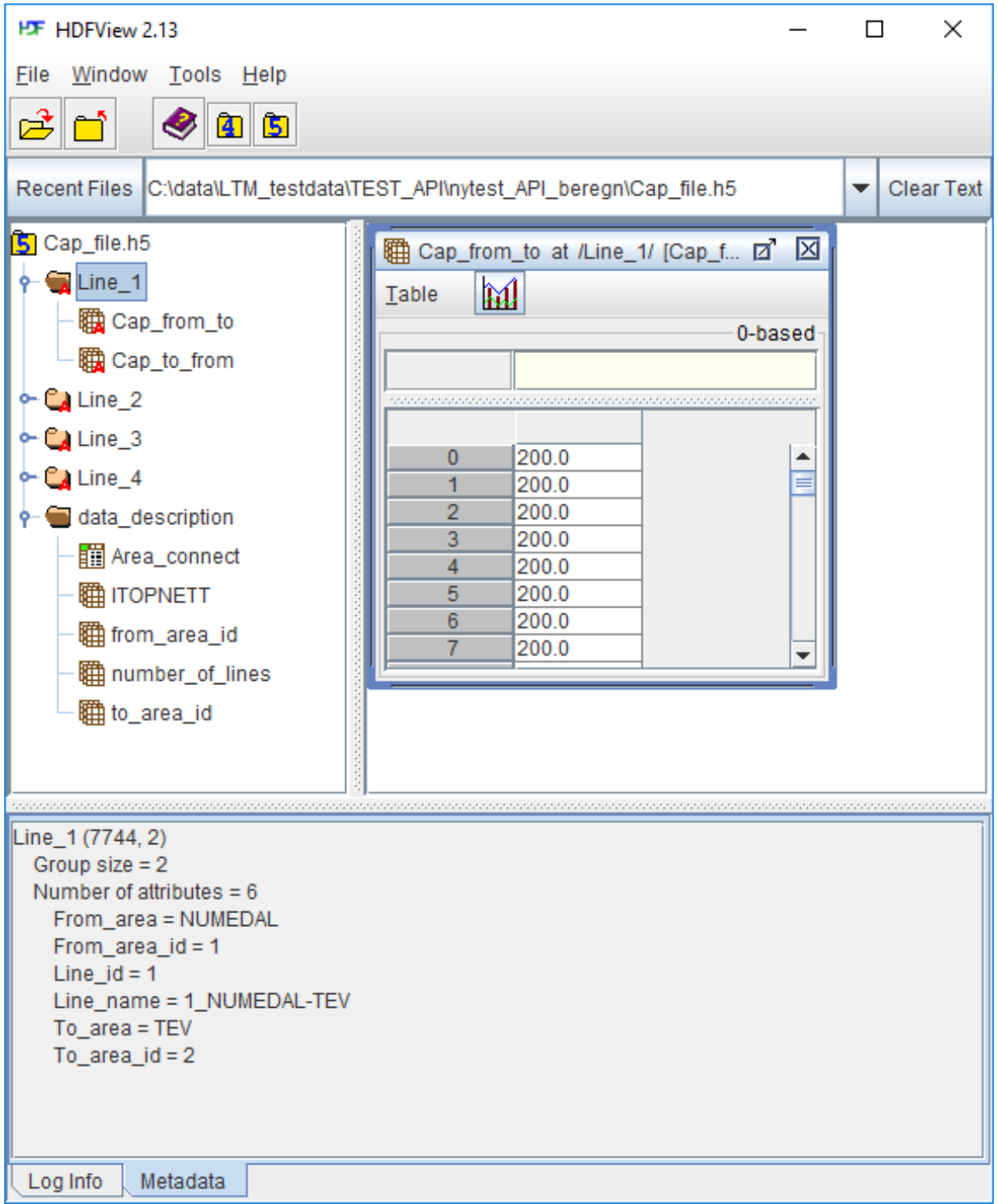
Cap_file.h5

- TS-data for transfer capacities



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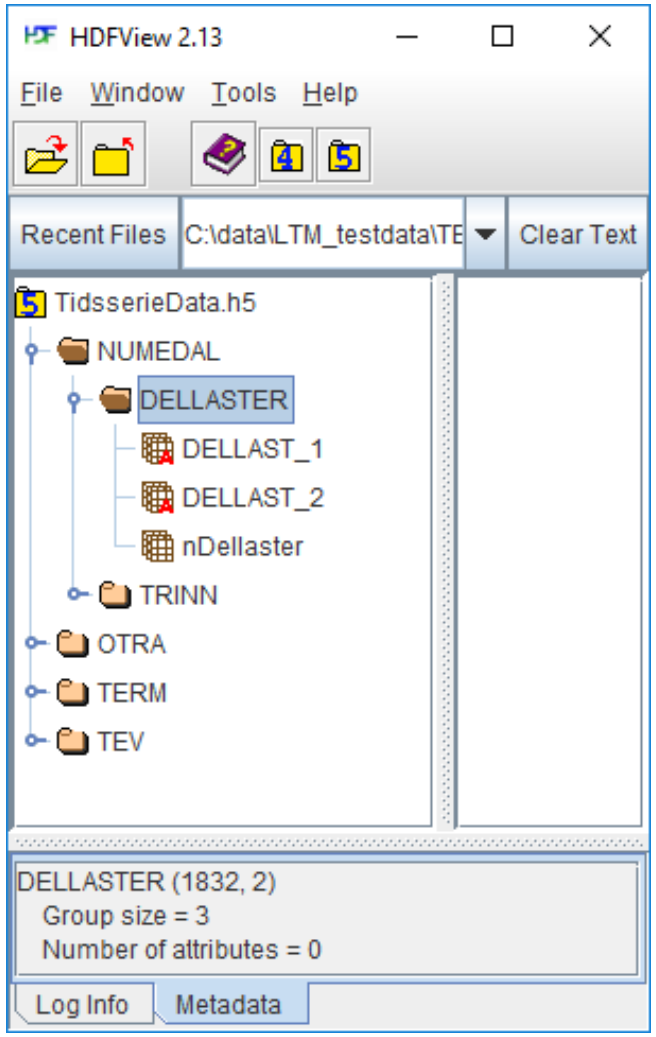
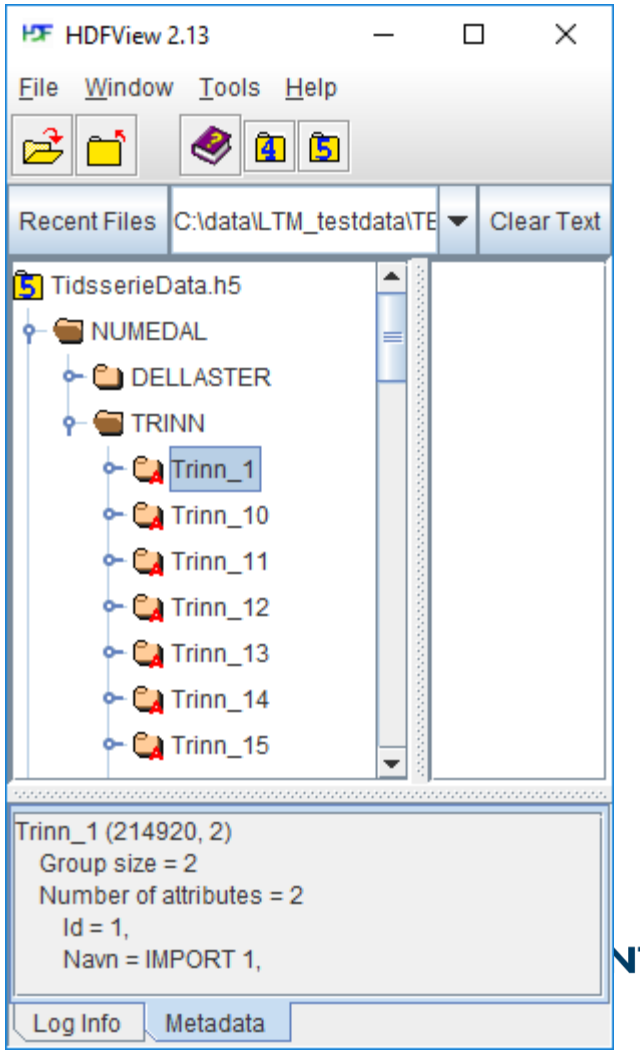
TidsserieData.h5

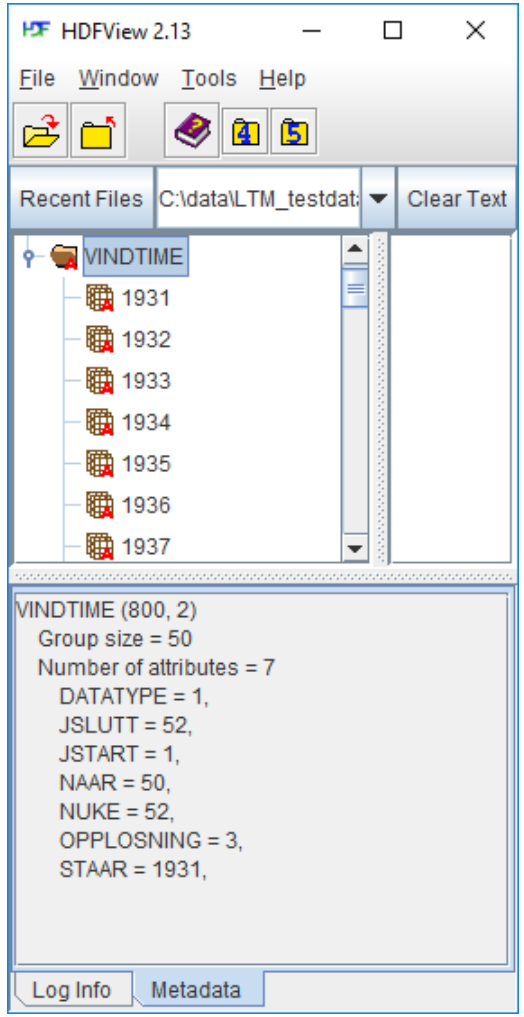
- TS data for new contract types in ENMD-description:
  - Load series: STSER, KTSER
  - Preference-segments: STSER, KTSER, TS_GJ
  - ID is contract number in ENMD-file





wind_data.h5

- Energy series for wind and solar, replaces *.V30
- Data for each scenario is given as an h5-dataset: name = scenario
- Each h5-dataset = TS-object
- H5-dataset begins using data from first time step in scenario



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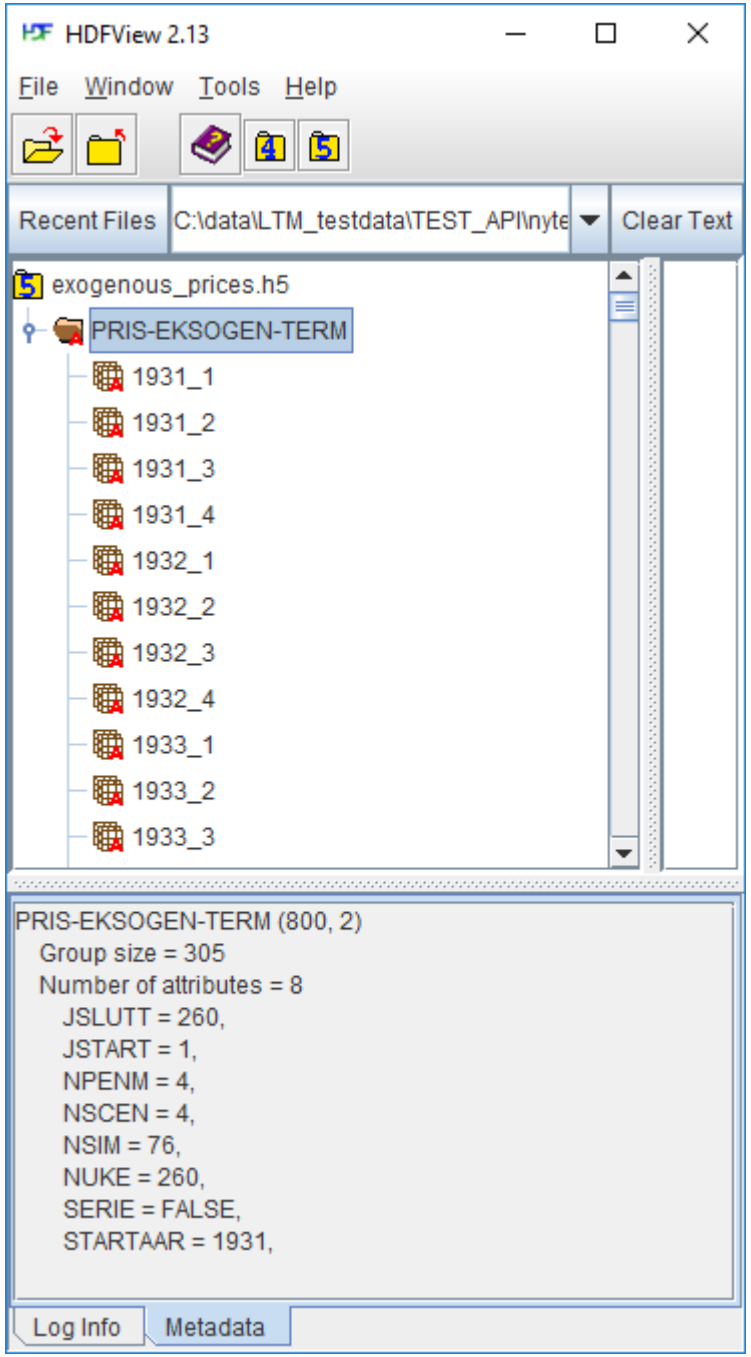
exogenous_prices.h5

- Price series using name from ENMD
- Area name for PRIS-option in INDVV
- Data for each scenario is given as an h5-dataset: name = scenario(_<price scenario>)
- H5-dataset begins using data from first time step in scenario



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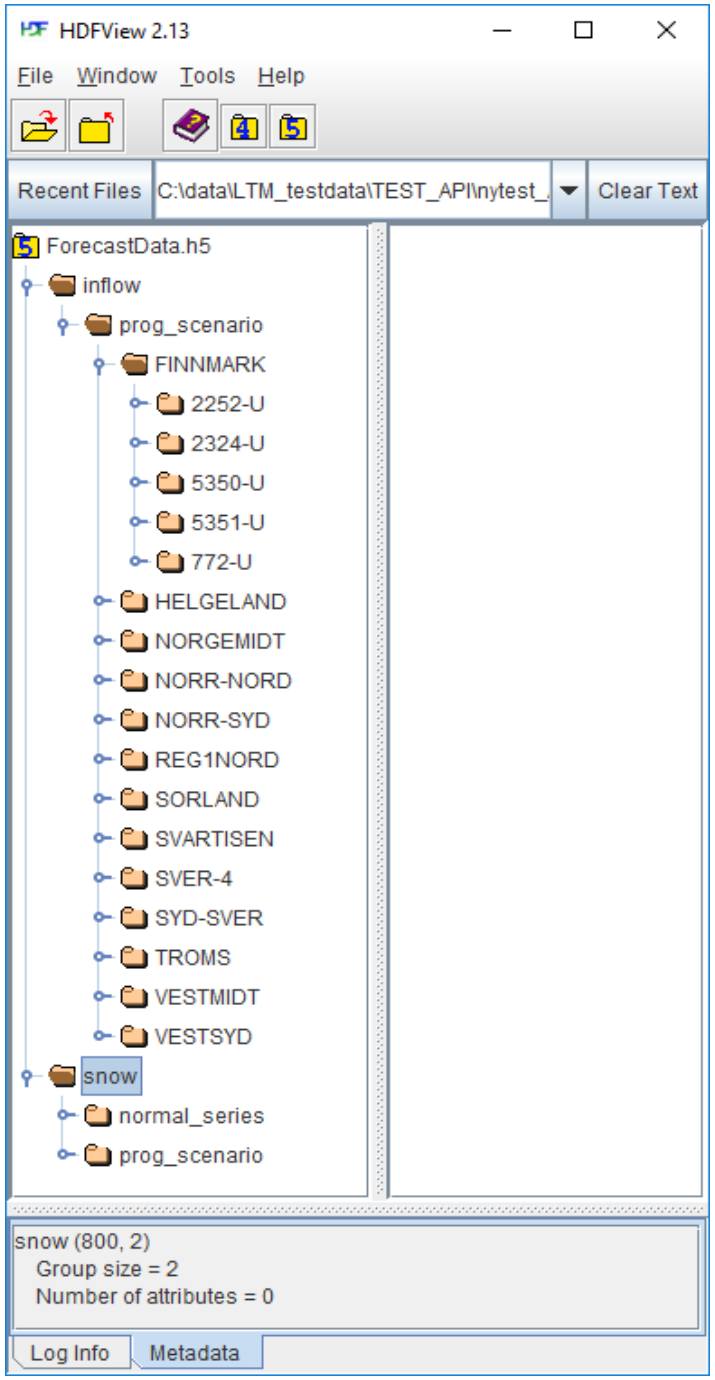
ForecastData.h5

- Contains data for inflow and snow.
- Prognosis for water mark.
- Given per area.
- Is used from *start date* and with given *duration/length*.
- Length could be from the first value up until covering the entire simulation period. TS data is first read from ScenarioData.h5 and then data from this file *replaces* data in forecast period.



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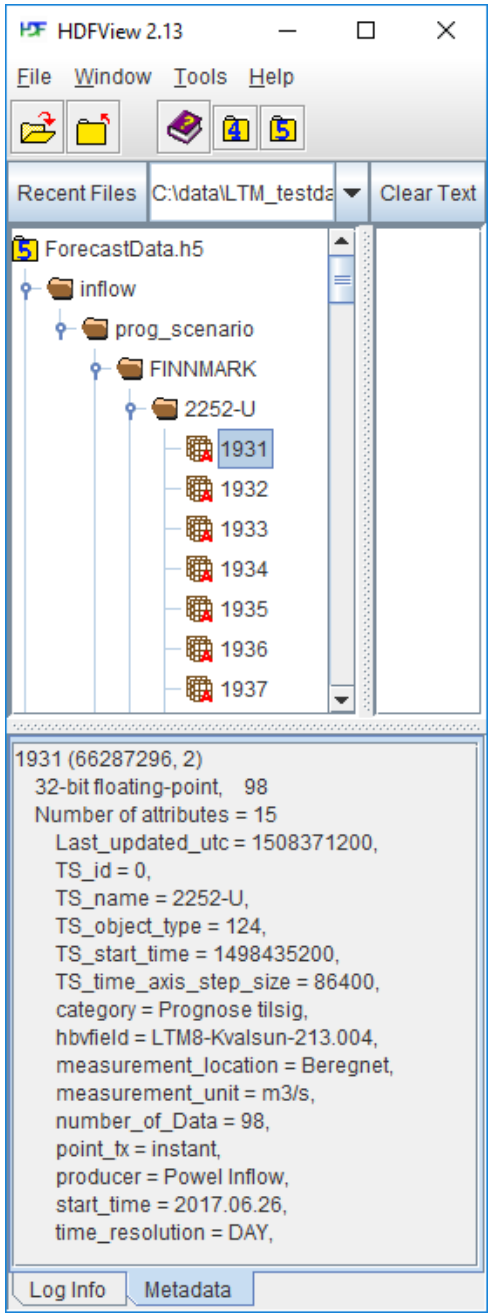
ForecastData.h5: inflow

- One dataset per scenario
- Prognosis can cover the entire simulation period



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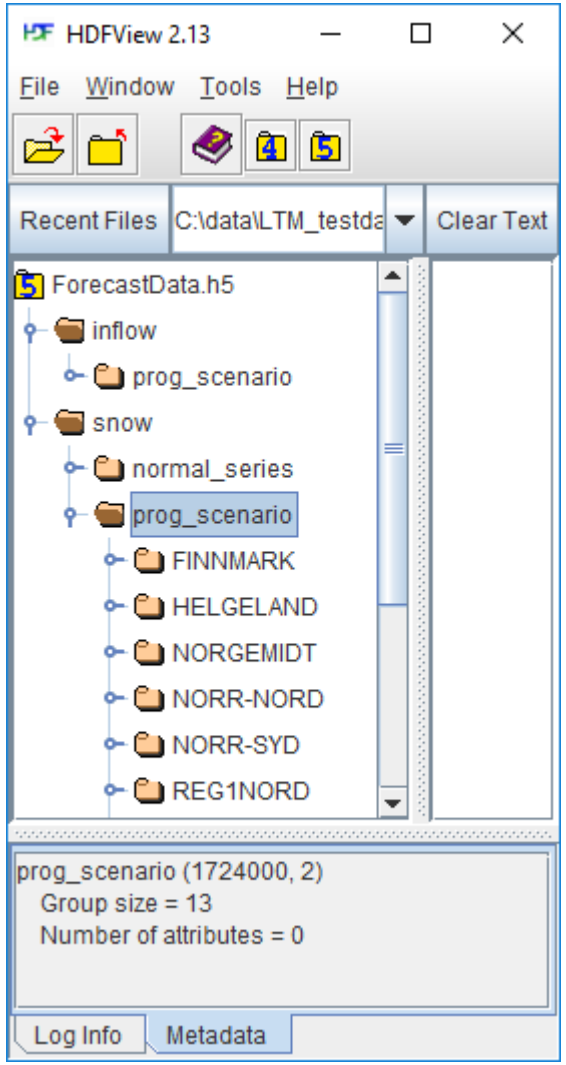
ForecastData.h5: snow

- Snow forecast (prog_scenario) has same format as inflow forecast



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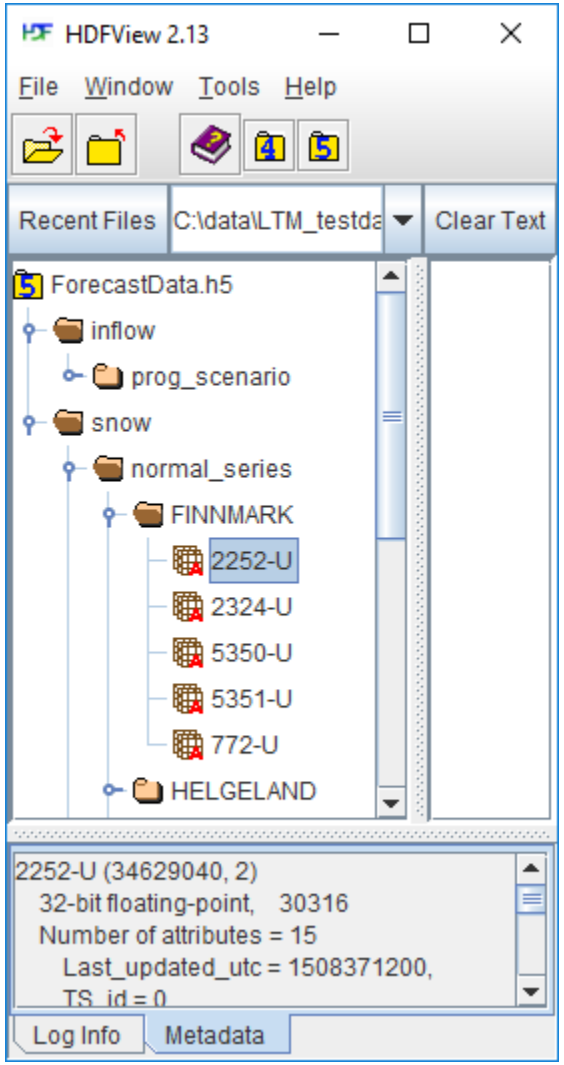
ForecastData.h5: normal snow

- Normal snow given as one data set per water mark
- Format for dataset same as historical.h5 (covers entire historical period)
- Water mark given per area



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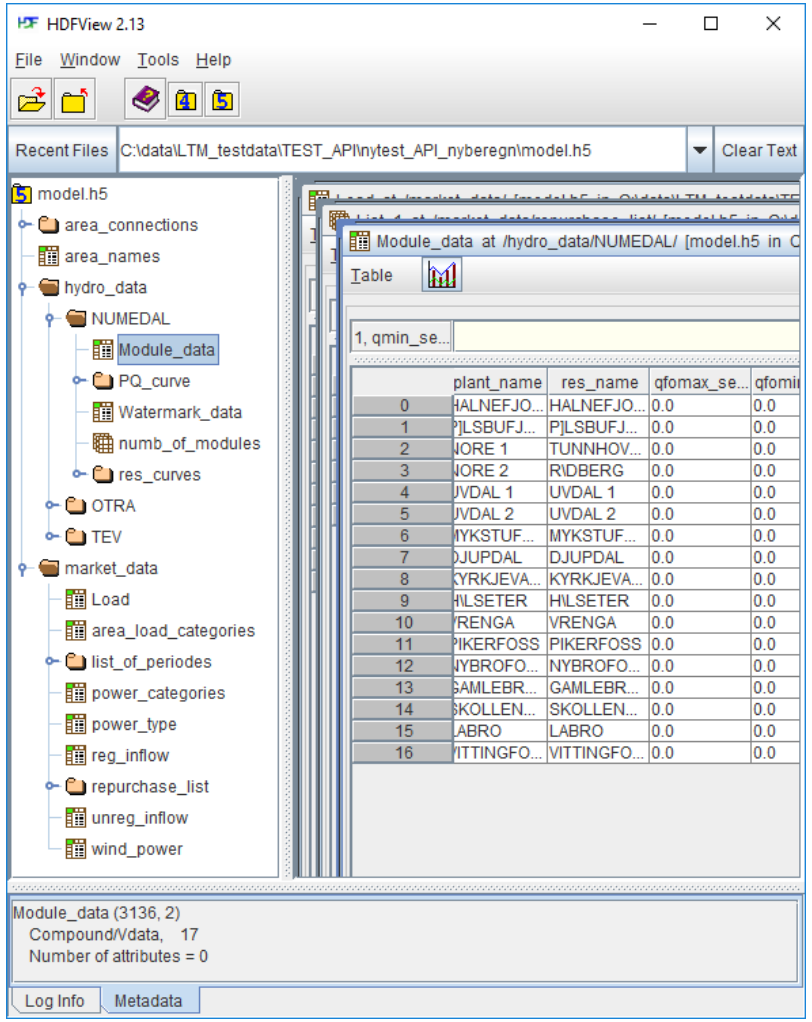
model.h5: link between LTM and API

- Area connections
- Market data
  - Load segments
  - Price elastic market description (including link between repurchase and load segments)
  - Energy inflow (regulated, non-regulated and wind)
- Hydro power data
  - PQ curves
  - Reservoir curves
  - All module data (except restrictions)



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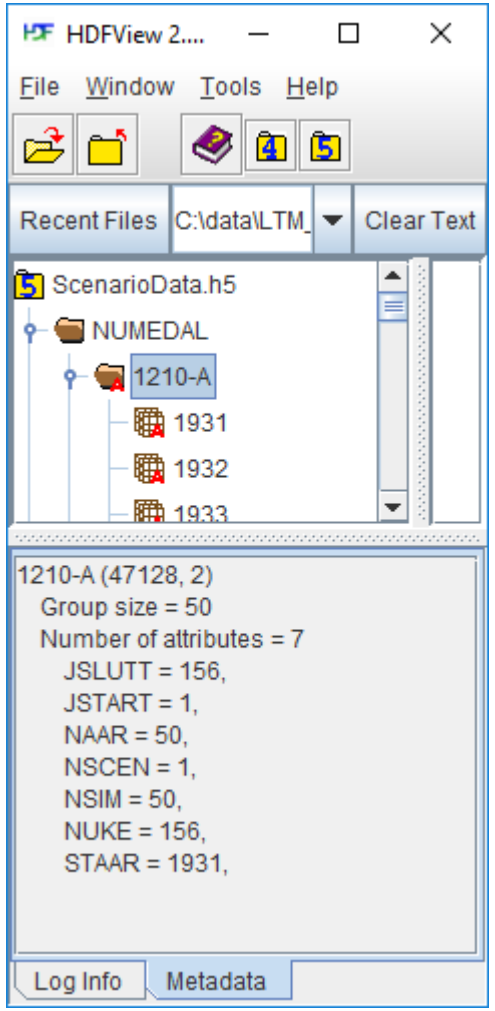
ScenarioData.h5

- Pre-processed inflow data from Detmod
- Data given per area
- Inflow data covering the entire simulation periode for each scenario



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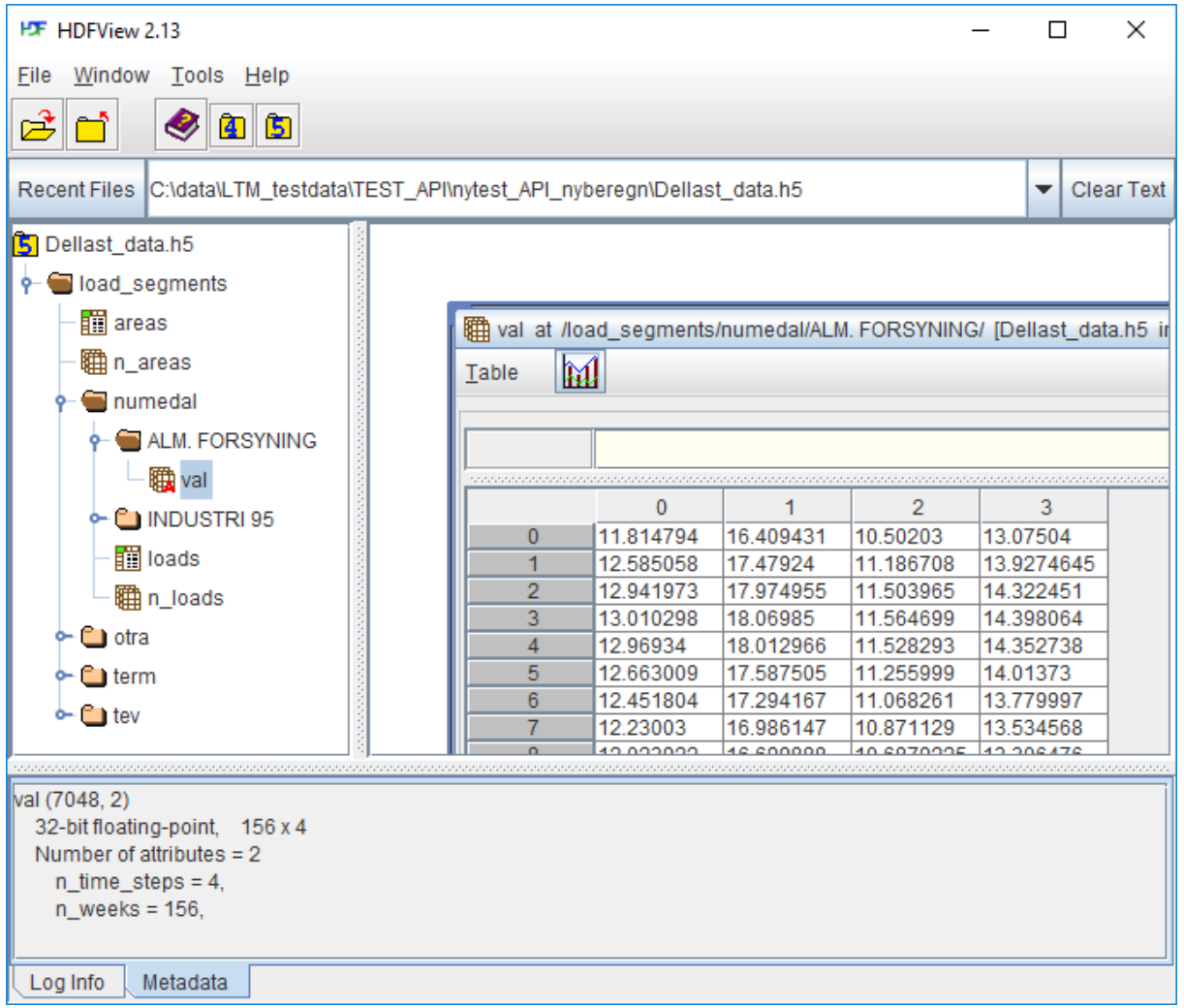
Dellast_data.h5

- Data for load segments (except temperature corrections)
- Data have price segment time resoution (NPENM,NUKE)



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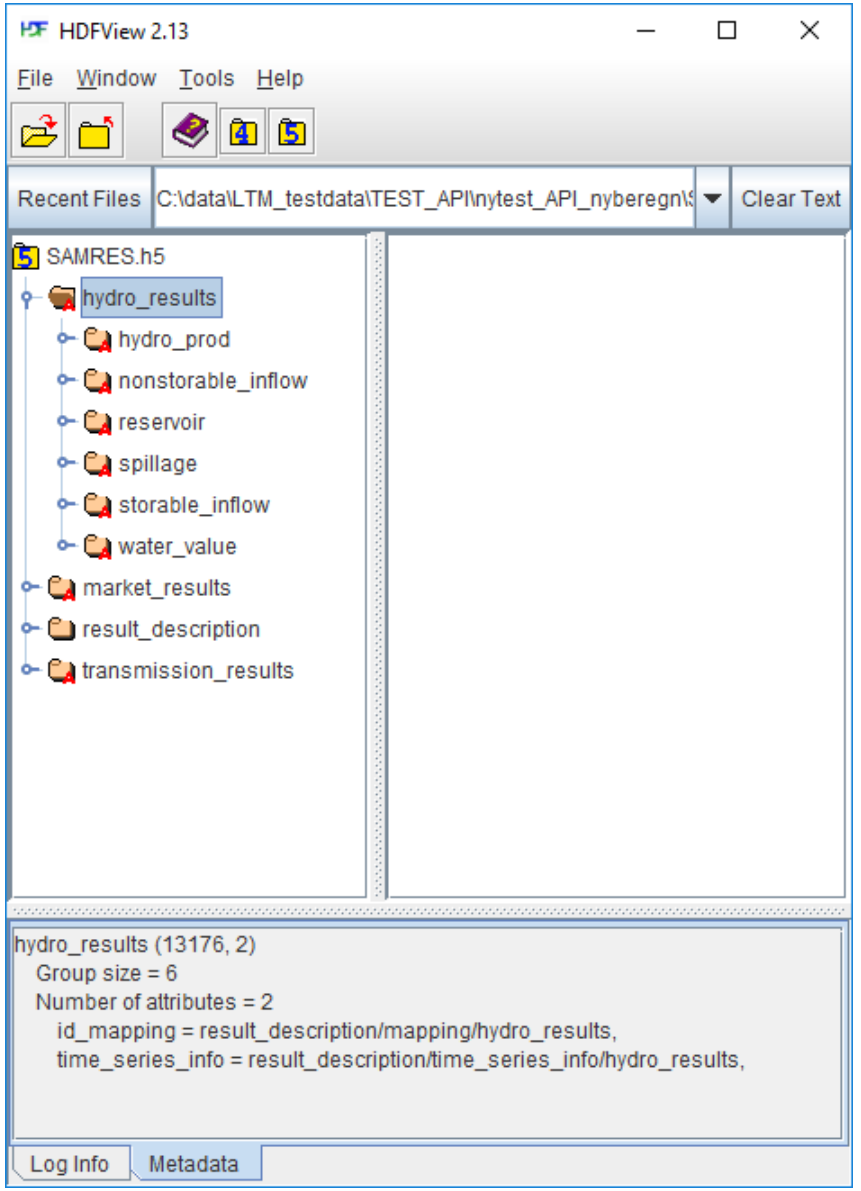
SAMRES.h5 and ENMRES.h5

- Market results and exchange
  - SA and VA options in (pc)kurvetegn
- Replaces: SAMRES.SAMK and UTVEKSLING.SAMK (Samtap) or ENMRES.DATA (Simtap)
- Separate "directory" per result type
- ENMRES has some additional result types



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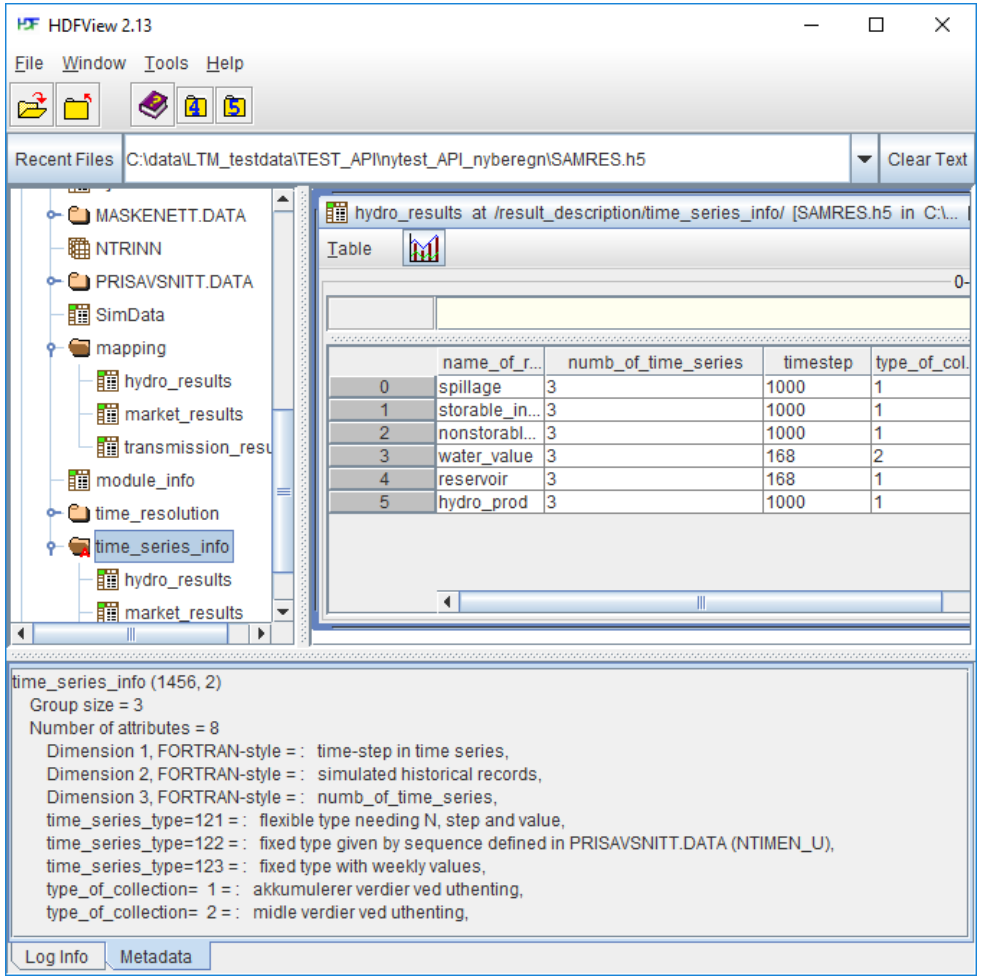
SAMRES.h5 and ENMRES.h5

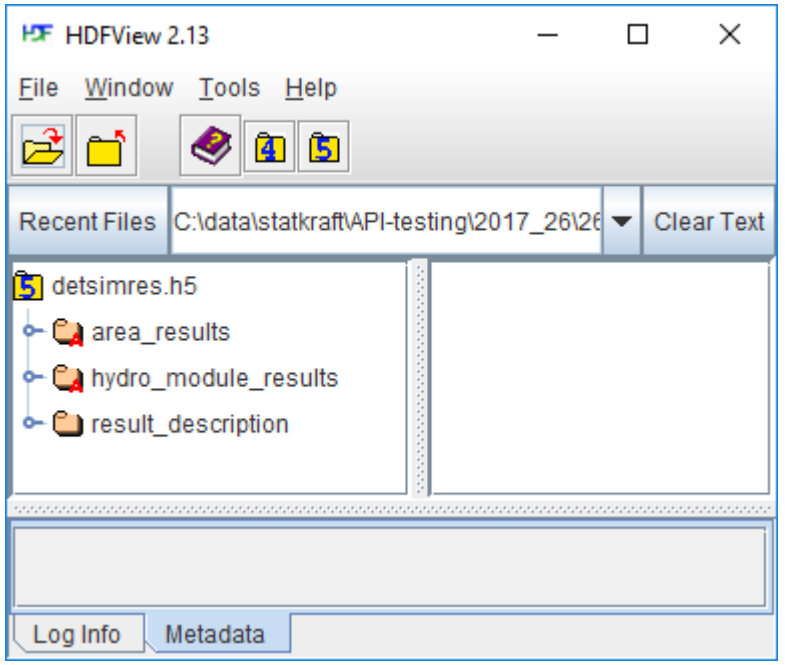
- Data stored as matrices (3 dim.)
- Description of each dimension in data matrix
- Mapping to area
- Other information (units and other attributes)



SINTEF

detsimres.h5

- Similar to SAMRES.h5
- Types of results:
  - Aggregated results per area (water course for Seasonal model)
  - Detailed results per module
- Separate file for:
  - Normal simulation: detsimres.h5
  - System price : detsimres_syst.h5
  - Seasonal model: detsimres_ses.h5



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Calendar functionality

- Calendar functionality implemented.
- Not tested to same degree as "normal" v10 – but no indications of errors.
- Freely available, choose to run with or without.
- Requirements on input: x*52*7 ≠ y*365+z*366 => longer time series!
- Covers historical data and TS-contracts for market data.
- Do not mix calendar correct data set and non-calendar correct data set.
- Some effects mandatory: historical.h5 is calendar correct by definition

New possibilities

- For us

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Boundaries and freedom

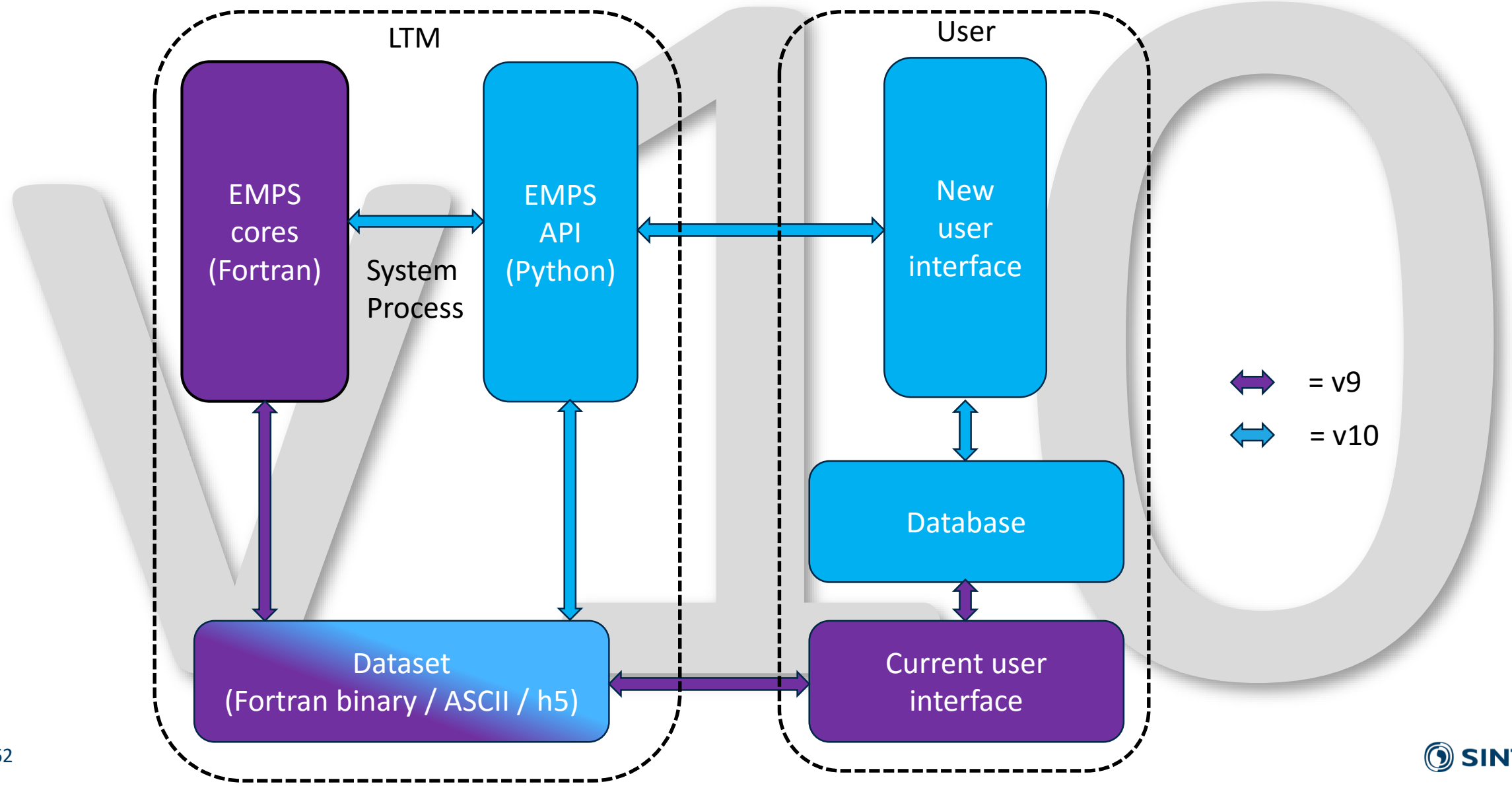
- Already mentioned: API provides a separation layer in which we can change more freely the internal mechanics whilst keeping the interface fixed. Should provide more freedom for us and more stability for users.
  - Note: API still in early version, can change slightly.
- New file formats simplify testing and debugging.
- As API-use develops, old applications can be retired (input and results).

When and what?

- Starting April 1st!
- Application suite and documents with user information and examples.

Key take-aways on version 10

- Clearer separation of input and calculation routines.
- Possible to run almost entirely based on xml-input.
- Can set input to a much greater detail and control through API.
- API will be expanded in the future.
- More available data.
- Overall, more transparent flow, control and data.
- New possibilites for how you use the models (input manipulation, automation …).
- Available from April 1st.


LTM
User
EMPS
cores
(Fortran)
System
Process
EMPS
API
(Python)
New
user
interface
Database
Dataset
(Fortran binary / ASCII / h5)
Current user
interface
= v9
= v10

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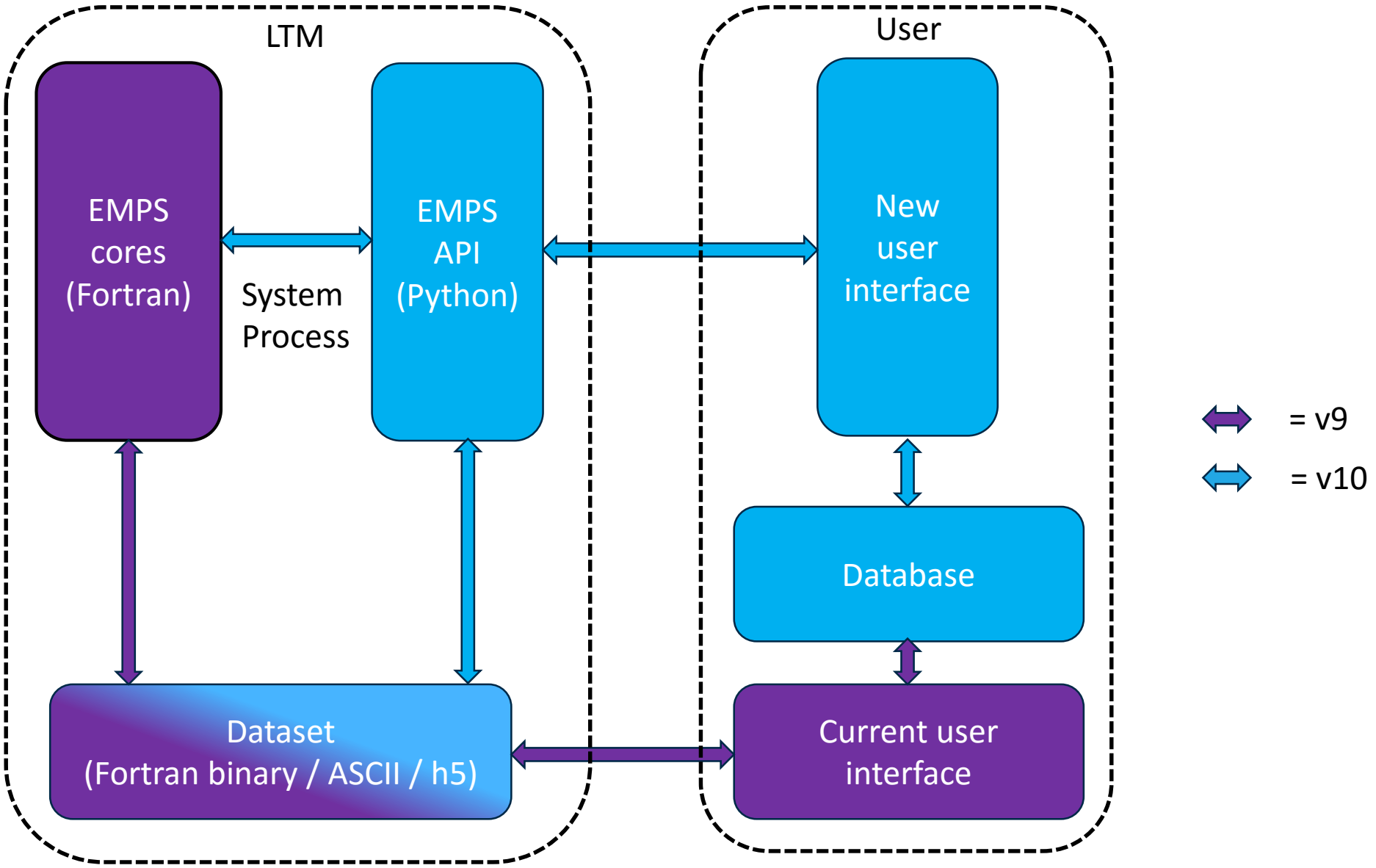
Key illustrations

New architecture of v10



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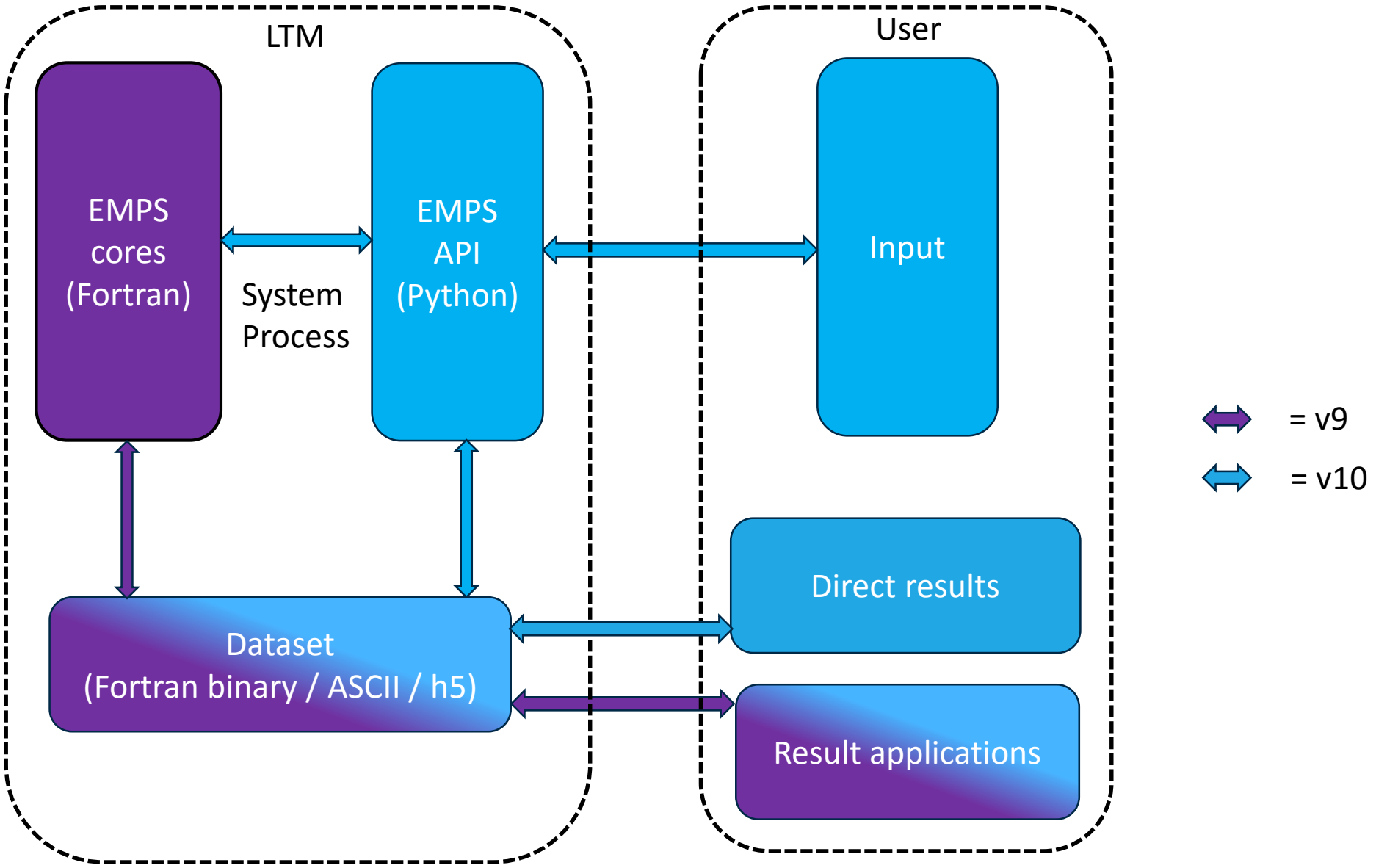
Organization of input and results



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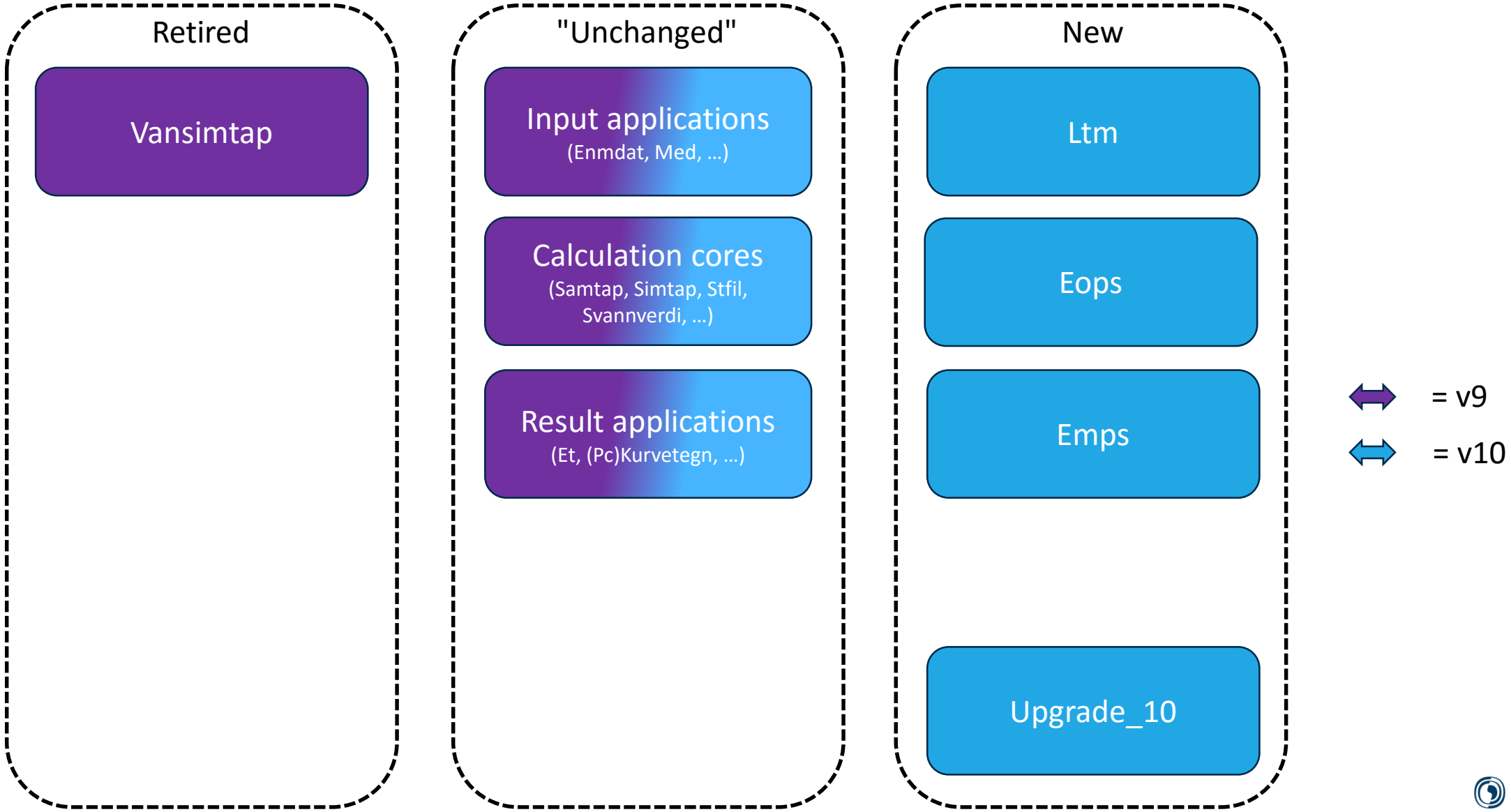
Changes in application suite



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