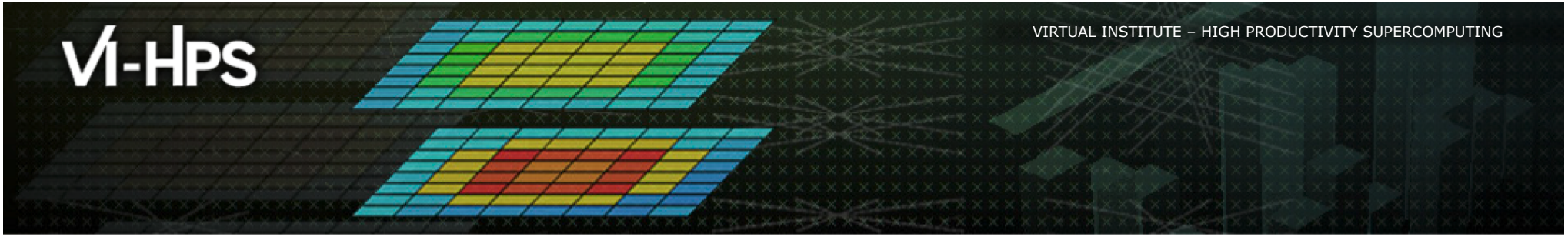


TECHNISCHE UNIVERSITÄT DARMSTADT

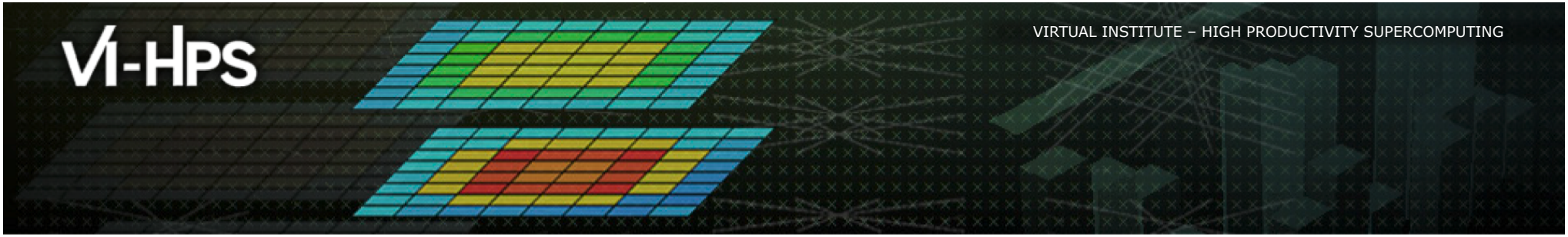
Performance Analysis and Modeling

Hands-on tutorial

Sergei Shudler

Outline

- Usage of Score-P
- Performance profiles and their analysis with Cube
- Live demonstration
- Usage of Extra-P
- Model output in text form
- Interactive visual analysis of model output with Cube



Using Score-P & Cube

Usage of Score-P

- Instrumentation tool (sampling support soon)
- Produces performance profiles (+ optional traces)
- Modules (on Lichtenberg): papi, openmpi/intel, scorep/intel/ompi/1.4.2
- Prepend compilation and linking with *scorep*:
  - *scorep* $(MPI_CC) $(CFLAGS) … / *scorep* $(MPI_CC) $(LDFLAGS) …
  - *scorep --user* to support user instrumentation directives

Score-P (common) environment variables

- SCOREP_EXPERIMENT_DIRECTORY=scorep_dir
- SCOREP_ENABLE_TRACING=0
  - Tracing is disabled by default
- SCOREP_METRIC_PAPI=PAPI_FP_OPS,PAPI_L3_TCM,PAPI_L2_TCM
  - Run *papi_avail* and *papi_native_avail* to get available events
- SCOREP_FILTERING_FILE=func.flt
  - Optional, use only if small functions cause significant perturbation

Functions filtering

- Format of the filter file:

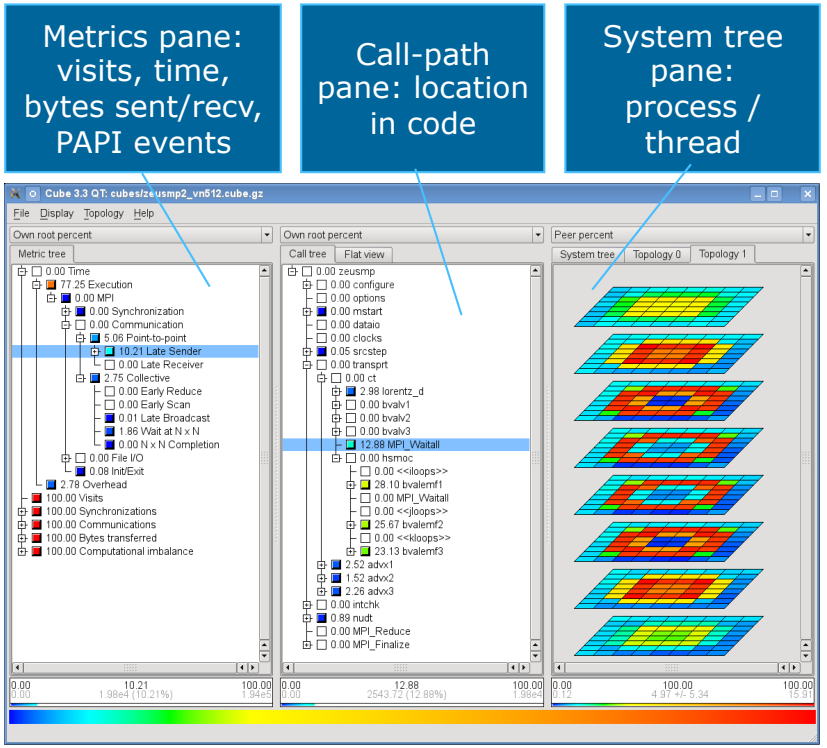
```
SCOREP_REGION_NAMES_BEGIN
  EXCLUDE atoi*
  EXCLUDE binbinsearch*
SCOREP_REGION_NAMES_END
```

Score-P output

- In SCOREP_EXPERIMENT_DIRECTORY:
  - scorep.cfg – configuration and environment variables
  - profile.cubex – performance profile
- Performance profile:
  - Cube file
  - 3 dimensions: metric, callpath location, system location (thread/process)
- scorep-score –r <scorep_dir>/profile.cubex
  - Estimate size for tracing
  - Estimate the results of specifying a filter file

Performance profile analysis

- Multiple Cube installs, use:
  - source /home/groups/da_lpp/modules/loadModules.sh
  - module load extrap/1.0
- Open the profile in Cube
  - cube <scorep_dir>/profile.cubex
- Pay attention to sum, min, max values of metrics



Live demonstration

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Using Extra-P

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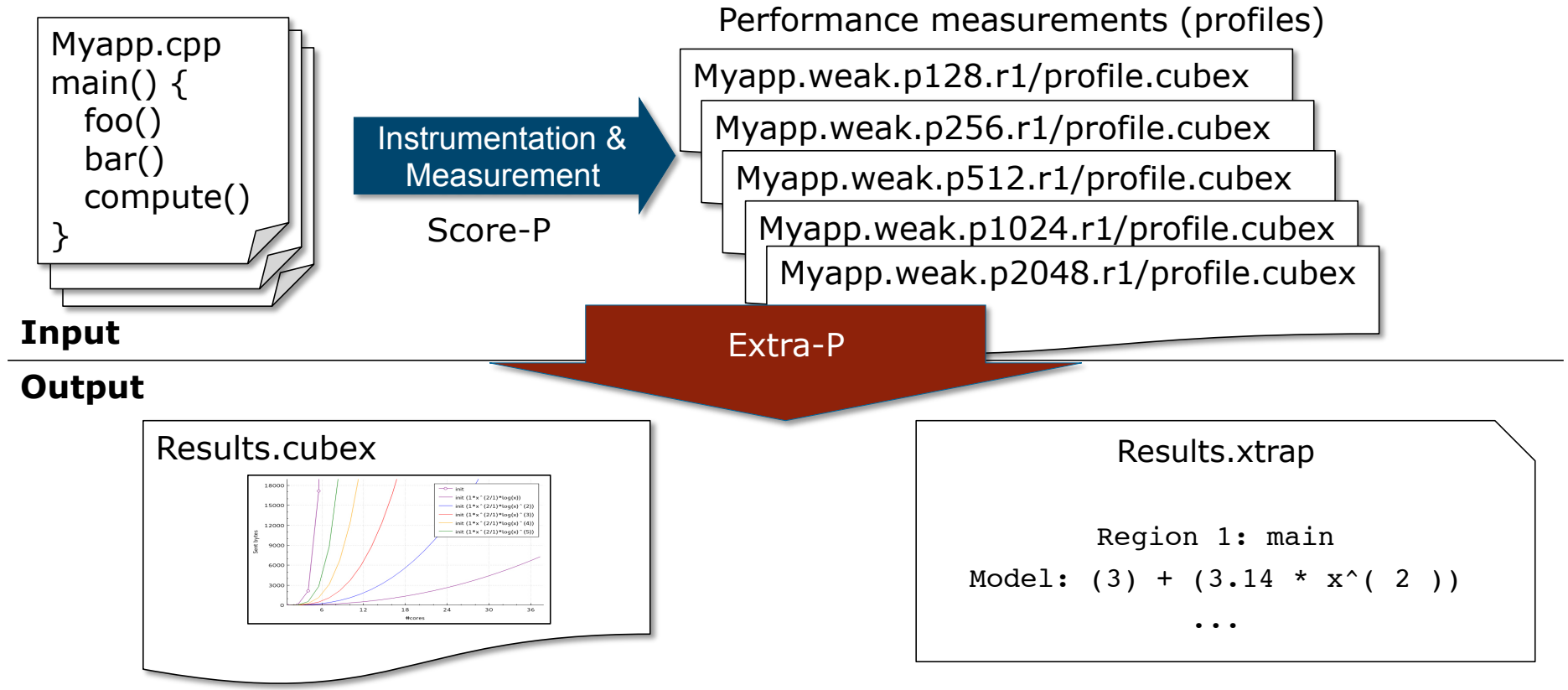
Automatic performance modeling with Extra-P



Extra-P – usage

- Load Extra-P module :
  - source /home/groups/da_lpp/modules/loadModules.sh
  - module load extrap/1.0

- Two modes are possible, both require a configuration file:

  - extra-p extra-p.conf
    (All other configuration details found in extra-p.conf)

or

  - extra-p extra-p.conf <inputfilename>
    (Overrides file name from extra-p.conf)

Extra-P configuration – example

```
# Name of the input file
INPUT cube_conf.txt

# Weak(1) or strong(2) scaling - measurements are averaged across all threads or summed up. If another parameter than processor is varied use 1
SCALING 1

# Input format.
# 1  - Cube files. Input file is expected to contain additional information. Use the cube_inputs.conf file as an example and template.
# 2  - Test. Input file is used to test modeling method. Use the input.txt file as an example and template.
# Other input types are not supported at this time

INPUT_TYPE 1

# output cube file will be placed at "cubes/<OUTPUT_CUBEX>.cubex"
OUTPUT_CUBEX extrap

# Maximum number of terms which can be part of a model (the constant term, or intercept, is counted). N=2 is usually the correct choice to identify unknown behavior as it only captures the dominant behavior
N 2

# Optional. Only experiments which have the parameter value modulo step-size 0 are used. Step-size 1 effectively disables this.
STEP_SIZE 1

# Term set. Each line <TERM a b c> generates a term of the form x^(a/b)*(log2(x))^c
TERM 0 1 1
….
```

Extra-P configuration – input

- INPUT <filename>
  - Test – file with actual values to be modeled
  - Cube – file with information about the path and naming scheme of Cube files with values to be modeled
- INPUT_TYPE <1|2>
  - Selects the type of input Extra-P should expect
    - 1 selects Cube files
    - 2selects the "Test" format used mainly for small examples or debugging
    - further options are undocumented but will soon become available (csv, tsv, hdf5)

Extra-P configuration – scaling

- SCALING <1|2>

- Useful when inputs are Cube files and the number of processes is the parameter to be varied

- Weak scaling: 1 – measured values averaged across processes / threads
- Strong scaling: 2 – measured values summed up across processes / threads

Extra-P configuration – output Cube

- OUTPUT_CUBEX <filename>
- Output file will be placed in "cubes/<filename>"
- Text output will also be generated "<date/time>.xtrap"
- More options for formatting output text can be made available. We are actively looking for user feedback about useful output formats

Extra-P configuration – model size

- N <1|2|3|4|5>
- Maximum number of terms which can be part of a model
- The constant term, or intercept, is counted
- N=2 is usually a good choice
  - Identifies dominant behavior
  - Reduces the chance for noise to be modeled

Extra-P configuration – step size

- STEP_SIZE <#>
- Useful when only a subset of a larger pool of measurements is to be modeled
- If step size if different from 1 only measurements where the parameter value modulo step size is zero are considered

Extra-P configuration – term definition

- TERM a b c
- Each line adds the term x^(a/b)*(log2(x))^c to the set of terms used to create models
- Default set allows most commonly encountered scaling behaviors to be modeled
- Performance model normal form can be expanded to allow more types of terms if deemed necessary

Extra-P input in text form

- Useful to debug or when a small data set must be modeled
- Example provided in input.txt

Parameter name
Useful for future compatibility
with multi-parameter modeling

```
X p
POINTS ( 1000) ( 2000  ) ( 4000 ) ( 8000 ) ( 16000  )
REGION region1
METRIC metric1
DATA 1 1 1 1 1
DATA 4 4 4 3.99 4.01
DATA 16 15.999 16.01 16.01 15.99
DATA 64 64 64 64.01 63.99
DATA 256.01 255.99 256 256
```

Extra-P input in text form

- Useful to debug or when a small data set must be modeled
- Example provided in input.txt

```
X p
POINTS ( 1000) ( 2000  ) ( 4000 ) ( 8000 ) ( 16000  )
REGION region1
METRIC metric1
DATA 1 1 1 1 1
DATA 4 4 4 3.99 4.01
DATA 16 15.999 16.01 16.01 15.99
DATA 64 64 64 64.01 63.99
DATA 256.01 255.99 256 256
```

Measurement points
Use at least 4, preferably 5,
but in general the more the better

Extra-P input in text form

- Useful to debug or when a small data set must be modeled
- Example provided in input.txt

```
X p
POINTS ( 1000) ( 2000  ) ( 4000 ) ( 8000 ) ( 16000  )
REGION region1
METRIC metric1
DATA 1 1 1 1 1
DATA 4 4 4 3.99 4.01
DATA 16 15.999 16.01 16.01 15.99
DATA 64 64 64 64.01 63.99
DATA 256.01 255.99 256 256
```

Region name

Metric name

Both used to determine the output Cube file hierarchical structure and identify separate data sets

Extra-P input in text form

- Useful to debug or when a small data set must be modeled
- Example provided in input.txt

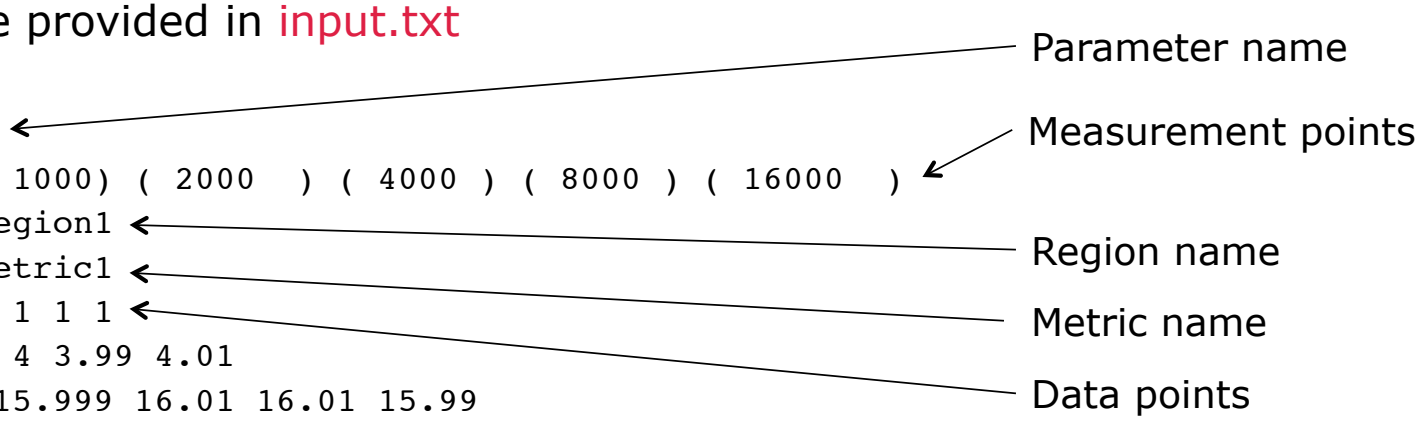
```
X p
POINTS ( 1000) ( 2000  ) ( 4000 ) ( 8000 ) ( 16000  )
REGION region1
METRIC metric1
DATA 1 1 1 1 1
DATA 4 4 4 3.99 4.01
DATA 16 15.999 16.01 16.01 15.99
DATA 64 64 64 64.01 63.99
DATA 256.01 255.99 256 256
```

Data points
Each row corresponds to a point; all values in a row are considered repeat measurements of the same experiment

Extra-P input in text form

- Useful to debug or when a small data set must be modeled
- Example provided in input.txt

```
X p
POINTS ( 1000) ( 2000  ) ( 4000 ) ( 8000 ) ( 16000  )
REGION region1
METRIC metric1
DATA 1 1 1 1 1
DATA 4 4 4 3.99 4.01
DATA 16 15.999 16.01 16.01 15.99
DATA 64 64 64 64.01 63.99
DATA 256.01 255.99 256 256
```



Extra-P configuration – example

- Edit extra-p.conf:

```
# Name of the input file
INPUT input.txt

# Weak(1) or strong(2) scaling - measurements are averaged across all threads or summed up. If another parameter than processor is varied use 1
SCALING 1

# Input format.
# 1  - Cube files. Input file is expected to contain additional information. Use the cube_inputs.conf file as an example and template.
# 2  - Test. Input file is used to test modeling method. Use the input.txt file as an example and template.
# Other input types are not supported at this time

INPUT_TYPE 2
....
```

- Run: extrap extra-p.conf

- Examine results: <datetime>.xtrap

Results in text form

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Extra-P output – .xtrap file

Measurements and model data for each metric:

```
REGION 4 main::MPI_Bcast
Metric: time
( 32,    8.5346 )+-(0.0, 0.101737)
( 64,    13.7296 )+-(0.0, 0.107976)
( 128,    19.7515 )+-(0.0, 0.26828)
( 256,    29.9048 )+-(0.0, 0.551215)
( 512,    44.724 )+-(0.0, 3.05437)
( 1024,    103.529 )+-(0.0, 0.767925)
( 2048,    132.864 )+-(0.0, 3.85616)
( 4096,    200.779 )+-(0.0, 1.61193)

AdjR2: 0.983131
RSS (fit error): 490.025
Procentual relative error: 3.99708%
Model: (-17.4593) + (3.38532 * x^( 0.5 ))
```

Metric name; either Score-P metrics (time, bytes, etc.) or custom metrics

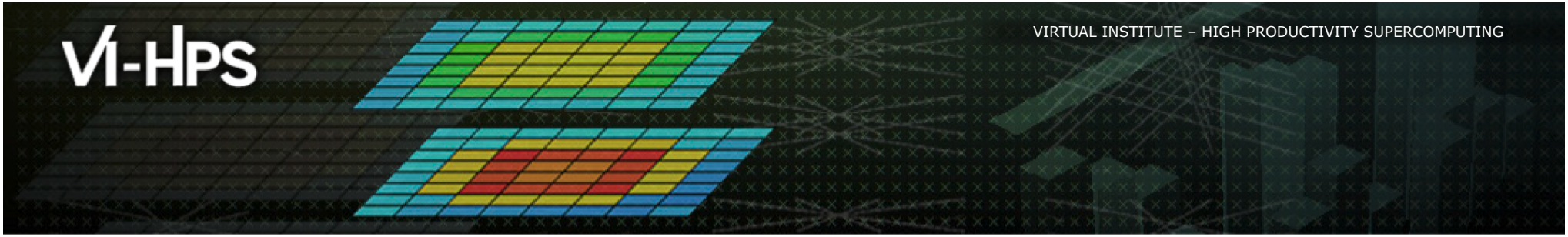
Measurements for each input element (e.g., #processes)

Adjusted R^2 (explained previously)

RSS: Residual sum of squares

Percentile relative error: Often provides a better intuition of the model's quality

Best-fit model



Modeling sets of Cube experiments

Extra-P configuration – Cube input description

- Template: cube_inputs.conf
- Modeling tool expects Cube files in the following format:
  <DIR>/<PREFIX><X><POSTFIX>.r<{1,..,REPS}>/<FILENAME>
- DIR, PREFIX, X, POSTFIX, REPS and FILENAME must all be defined.
  - X – value of varied parameter e.g. number of processes
  - REPS – number of repeated experiments with same parameter value

Extra-P configuration – Cube input example

```
…
X 64 256 512 1024 2048

# PREFIX
# Description: Prefix of your directories. Keep empty if no prefix
# Example: PREFIX abc-weak.
PREFIX scorep_scorep_weak.p

# POSTFIX
# Description: Postfix of your directories. Keep empty if no postfix
# Example: POSTFIX .def
POSTFIX

# Example: FILENAME profile.cubex
FILENAME profile.cubex

# DIR
# Description: Directory containing your input cube files/directories
# Example: /home/extra-p/inputs/
DIR /home/livetau/extrap/share/doc/examples/inputs/sweep3D/
```

```
# REPS
# Description: Allowed values >= 1. Number of repetitions per
experiment.
# Example: REPS 4
REPS 5

# USE_REPS_POSTFIX
# Description: Allowed values are '0' and '1'.
# If set to 0 no repetition postfix will be appended to the directory
names.
# If set to 1 a repetition postfix '.r<{1,..,REPS}>' will be appended to
the directory names.
USE_REPS_POSTFIX 1
```

Extra-P configuration – Cube input example

```
…
X 64 256 1024 4096 16384

# PREFIX
# Description: Prefix of your directories. Keep empty if no prefix
# Example: PREFIX abc-weak.
PREFIX blast.p

# POSTFIX
# Description: Postfix of your directories. Keep empty if no postfix
# Example: POSTFIX .def
POSTFIX

# Example: FILENAME profile.cubex
FILENAME profile.cubex

# DIR
# Description: Directory containing your input cube files/directories
# Example: /home/extra-p/inputs/
DIR /home/livetau/extrap/share/doc/examples/inputs/blast/
```

```
# REPS
# Description: Allowed values >= 1. Number of repetitions per
experiment.
# Example: REPS 5
REPS 5

# USE_REPS_POSTFIX
# Description: Allowed values are '0' and '1'.
# If set to 0 no repetition postfix will be appended to the directory
names.
# If set to 1 a repetition postfix '.r<{1,..,REPS}>' will be appended to
the directory names.
USE_REPS_POSTFIX 1
```

Extra-P configuration – example

- Edit extra-p.conf:

```
# Name of the input file
INPUT cube_inputs.conf

# Weak(1) or strong(2) scaling - measurements are averaged across all threads or summed up. If another parameter than processor is varied use 1
SCALING 1

# Input format.
# 1  - Cube files. Input file is expected to contain additional information. Use the cube_inputs.conf file as an example and template.
# 2  - Test. Input file is used to test modeling method. Use the input.txt file as an example and template.
# Other input types are not supported at this time

INPUT_TYPE 1
....
```

- Run: extrap extra-p.conf

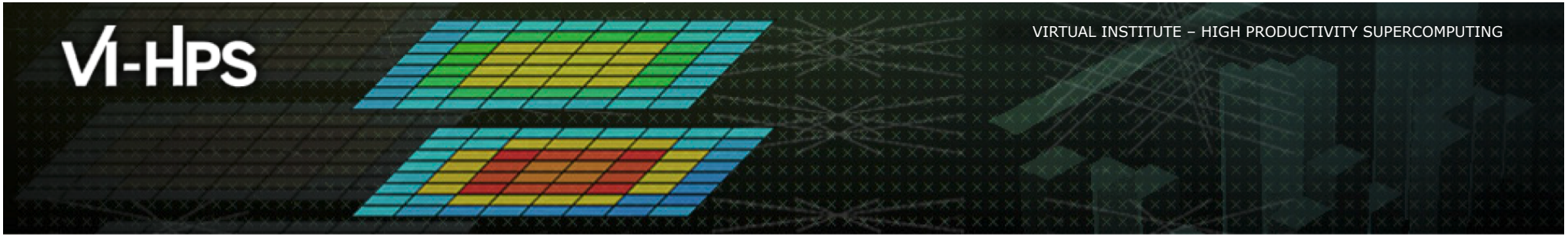
- Examine results: <datetime>.xtrap

Extra-P examples

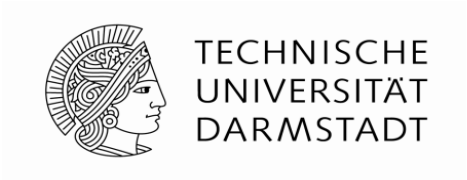
- Extra-P examples here:

/home/groups/da_lpp/modules/packages/extrap/1.0/share/doc/extra-p/examples/tutorial

- Both Sweep3D and Blast inputs:
  - Sweep3D – neutron transport problem
  - Blast – high-order finite element hydrodynamics code

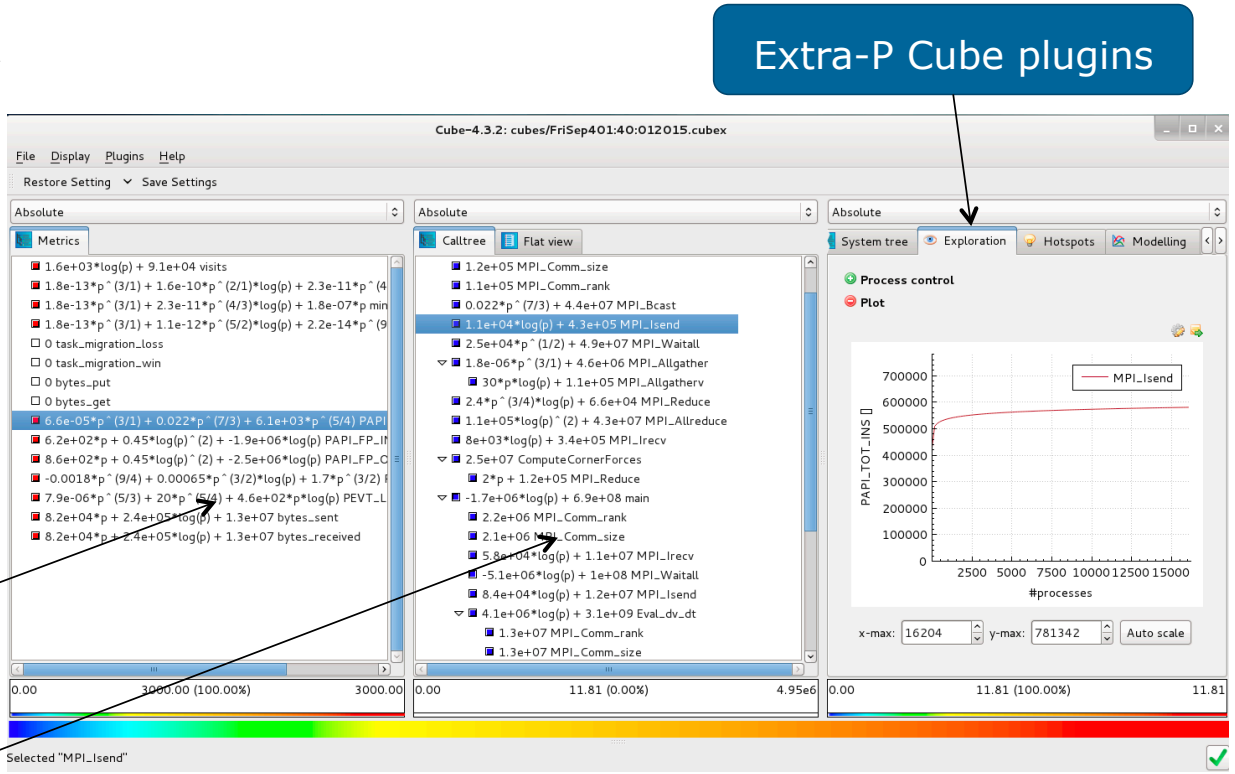


Visualization with Cube



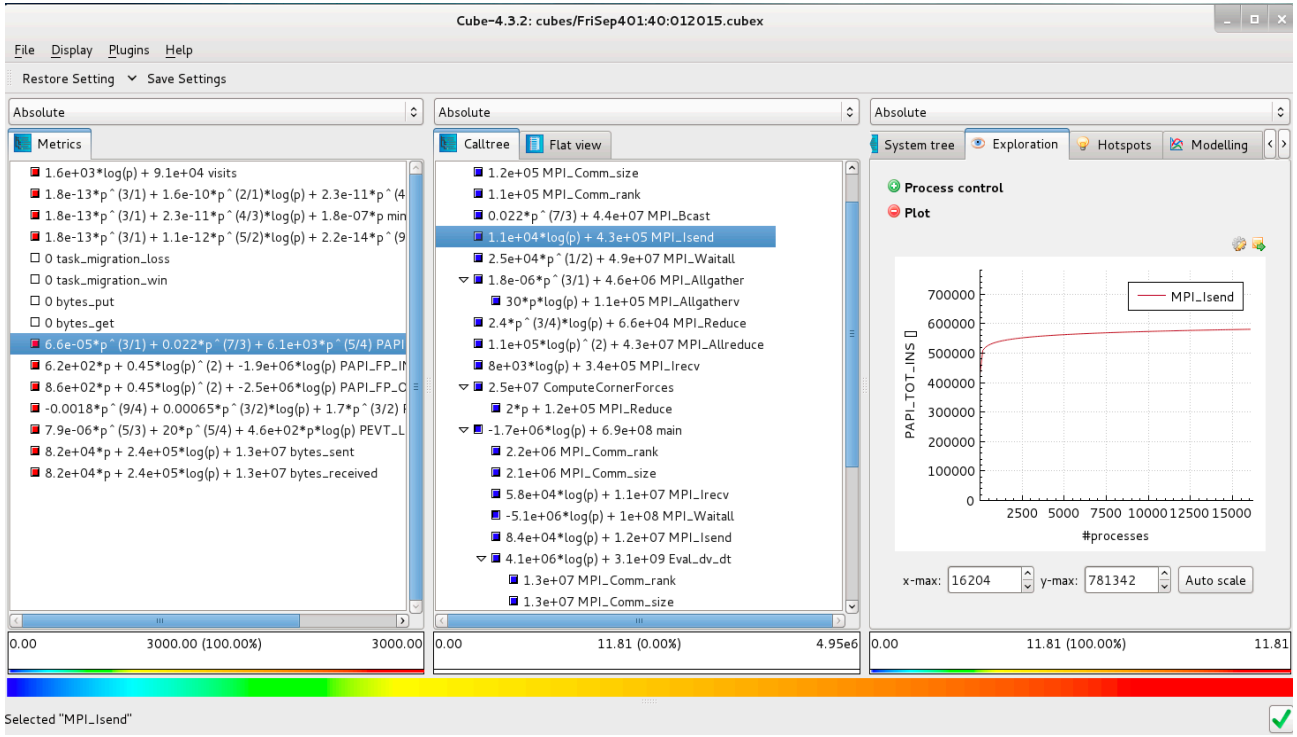
Extra-P output – merged Cube profile

- Stored in cubes/ sub-directory
- Open by running:
  `cube cubes/<name>.cubex`
- *Metrics* and *call-tree* nodes – two different dimensions



Extra-P Cube plugins – exploration

- Adjust *exploration* settings (as needed)
- Process control:
  Plot is shown for only one process or as a function

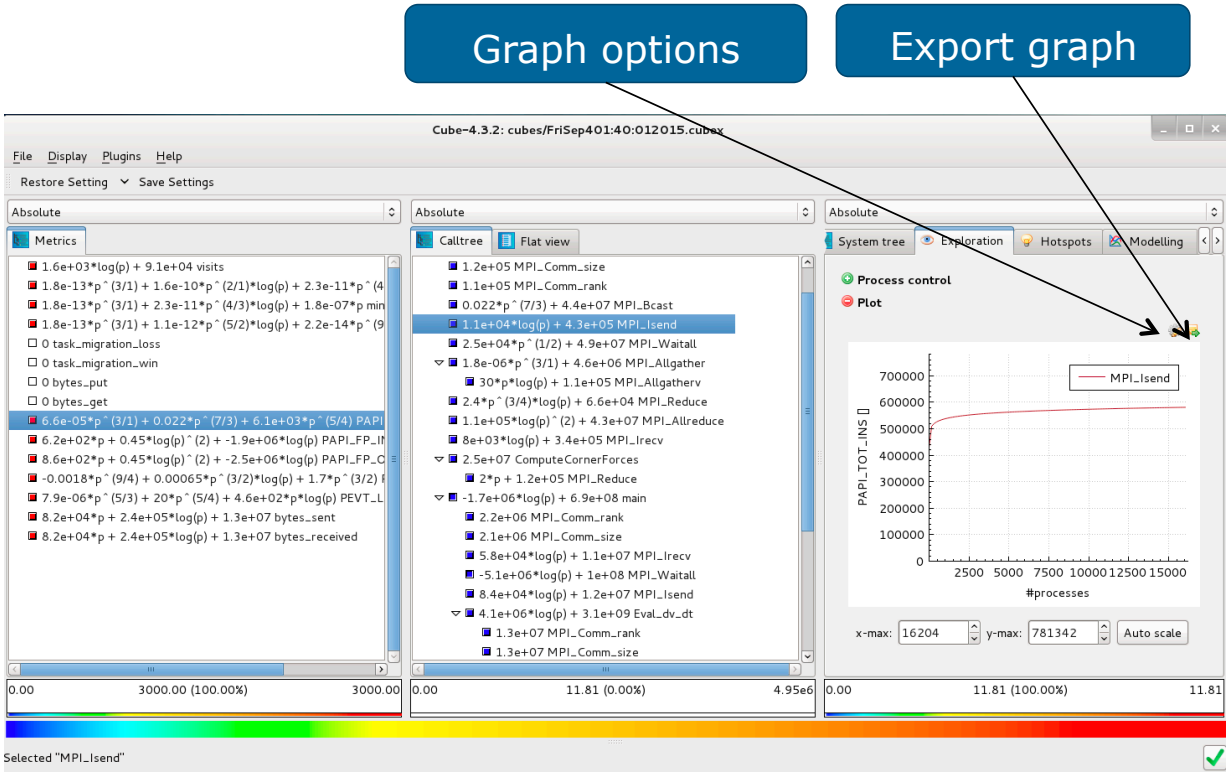


Extra-P Cube plugins – exploration (2)

- Plot:
  Shows the model as a plot

- Graph options:
  x-max, y-max
  Auto-scale

- Export graph:
  Plot can be exported to TikZ, PNG, and PDF



Extra-P Cube plugins – modeling

- Run Extra-P from Cube
- Configuration is similar to *extra-p.conf* parameters
- Uses stored data points as input