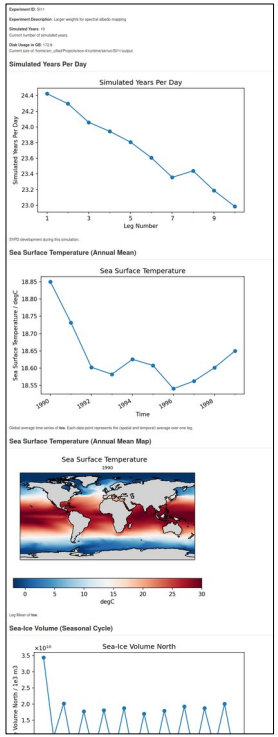
Monitoring Numerical Climate Simulations

A Tool for EC-EARTH4

Goal

```
domain_cfg.nc                       restart_0057.nc       restart_ice_0048.nc       srf000091310000.0011  srf000091310000.0111
domain_def_nemo.xml                 restart_0058.nc       restart_ice_0041.nc       srf000091310000.0012  srf000091310000.0112
EMPave.dat                          restart_0059.nc       restart_ice_0042.nc       srf000091310000.0013  srf000091310000.0113
EMPave_old.dat                      restart_0060.nc       restart_ice_0043.nc       srf000091310000.0014  srf000091310000.0114
field_def_nemo-ice.xml              restart_0061.nc       restart_ice_0044.nc       srf000091310000.0015  srf000091310000.0115
field_def_nemo-oce.xml              restart_0062.nc       restart_ice_0045.nc       srf000091310000.0016  srf000091310000.0116
field_def_nemo-pisces.xml           restart_0063.nc       restart_ice_0046.nc       srf000091310000.0017  srf000091310000.0117
file_def_nemo-ice.xml               restart_0064.nc       restart_ice_0047.nc       srf000091310000.0018  srf000091310000.0118
file_def_nemo-oce.xml               restart_0065.nc       restart_ice_0048.nc       srf000091310000.0019  srf000091310000.0119
file_def_nemo-pisces.xml            restart_0066.nc       restart_ice_0049.nc       srf000091310000.0020  srf000091310000.0120
fort.4                              restart_0067.nc       restart_ice_0050.nc       srf000091310000.0021  srf000091310000.0121
Goutorbe_ghflux.nc                  restart_0068.nc       restart_ice_0051.nc       srf000091310000.0022  srf000091310000.0122
grid_def_nemo.xml                   restart_0069.nc       restart_ice_0052.nc       srf000091310000.0023  srf000091310000.0123
grids.nc                            restart_0070.nc       restart_ice_0053.nc       srf000091310000.0024  srf000091310000.0124
ICMGGMO10INIT                       restart_0071.nc       restart_ice_0054.nc       srf000091310000.0025  srf000091310000.0125
ICMGGMO10INIUA                      restart_0072.nc       restart_ice_0055.nc       srf000091310000.0026  srf000091310000.0126
ICMSHMO10INIT                       restart_0073.nc       restart_ice_0056.nc       srf000091310000.0027  srf000091310000.0127
ifsdata                             restart_0074.nc       restart_ice_0057.nc       srf000091310000.0028  srf000091310000.0128
iodef.xml                           restart_0075.nc       restart_ice_0058.nc       srf000091310000.0029  srf000091310000.0129
leginfo.yml                         restart_0076.nc       restart_ice_0059.nc       srf000091310000.0030  srf000091310000.0130
leginfo.yml.j2                      restart_0077.nc       restart_ice_0060.nc       srf000091310000.0031  srf000091310000.0131
log                                 restart_0078.nc       restart_ice_0061.nc       srf000091310000.0032  srf000091310000.0132
masks.nc                            restart_0079.nc       restart_ice_0062.nc       srf000091310000.0033  srf000091310000.0133
mixing_power_bot.nc                 restart_0080.nc       restart_ice_0063.nc       srf000091310000.0034  srf000091310000.0134
mixing_power_cri.nc                 restart_0081.nc       restart_ice_0064.nc       srf000091310000.0035  srf000091310000.0135
mixing_power_pyc.nc                 restart_0082.nc       restart_ice_0065.nc       srf000091310000.0036  srf000091310000.0136
monitor                             restart_0083.nc       restart_ice_0066.nc       srf000091310000.0037  srf000091310000.0137
namcouple                           restart_0084.nc       restart_ice_0067.nc       srf000091310000.0038  srf000091310000.0138
namelist_cfg                        restart_0085.nc       restart_ice_0068.nc       srf000091310000.0039  srf000091310000.0139
namelist_ice_cfg                    restart_0086.nc       restart_ice_0069.nc       srf000091310000.0040  srf000091310000.0140
namelist_ice_ref                    restart_0087.nc       restart_ice_0070.nc       srf000091310000.0041  srf000091310000.0141
namelist_ref                        restart_0088.nc       restart_ice_0071.nc       srf000091310000.0042  srf000091310000.0142
namelist.runoffmapper               restart_0089.nc       restart_ice_0072.nc       srf000091310000.0043  srf000091310000.0143
nemo.exe                            restart_0090.nc       restart_ice_0073.nc       srf000091310000.0044  srf000091310000.0144
nemo-inittial-state.nc              restart_0091.nc       restart_ice_0074.nc       srf000091310000.0045  srf000091310000.0145
nout.000000                         restart_0092.nc       restart_ice_0075.nc       srf000091310000.0046  srf000091310000.0146
olfs.exe                            restart_0093.nc       restart_ice_0076.nc       srf000091310000.0047  srf000091310000.0147
olfs.exe.lnk                        restart_0094.nc       restart_ice_0077.nc       srf000091310000.0048  srf000091310000.0148
output                              restart_0095.nc       restart_ice_0078.nc       srf000091310000.0049  srf000091310000.0149
output.namelist.dyn                 restart_0096.nc       restart_ice_0079.nc       srf000091310000.0050  srf000091310000.0150
output.namelist.ice                 restart_0097.nc       restart_ice_0080.nc       srf000091310000.0051  srf000091310000.0151
rcf                                 restart_0098.nc       restart_ice_0081.nc       srf000091310000.0052  srf000091310000.0152
restart                             restart_0099.nc       restart_ice_0082.nc       srf000091310000.0053  srf000091310000.0153
restart_0000.nc                     restart_0100.nc       restart_ice_0083.nc       srf000091310000.0054  srf000091310000.0154
restart_0001.nc                     restart_0101.nc       restart_ice_0084.nc       srf000091310000.0055  srf000091310000.0155
restart_0002.nc                     restart_0102.nc       restart_ice_0085.nc       srf000091310000.0056  srf000091310000.0156
restart_0003.nc                     restart_0103.nc       restart_ice_0086.nc       srf000091310000.0057  srf000091310000.0157
restart_0004.nc                     restart_0104.nc       restart_ice_0087.nc       srf000091310000.0058  srf000091310000.0158
restart_0005.nc                     restart_0105.nc       restart_ice_0088.nc       srf000091310000.0059  srf000091310000.0159
restart_0006.nc                     restart_0106.nc       restart_ice_0089.nc       srf000091310000.0060  srf000091310000.0160
restart_0007.nc                     restart_0107.nc       restart_ice_0090.nc       srf000091310000.0061  srf000091310000.0161
restart_0008.nc                     restart_0108.nc       restart_ice_0091.nc       srf000091310000.0062  srf000091310000.0162
restart_0009.nc                     restart_0109.nc       restart_ice_0092.nc       srf000091310000.0063  srf000091310000.0163
restart_0010.nc                     restart_0110.nc       restart_ice_0093.nc       srf000091310000.0064  srf000091310000.0164
restart_0011.nc                     restart_0111.nc       restart_ice_0094.nc       srf000091310000.0065  srf000091310000.0165
```



automatically
at runtime
component-agnostic
customizable
extendable

Implementation

The Basis: ScriptEngine

execute YAML scripts
used to compile & run EC-Earth 4

```yaml
- echo:
    msg: "Hello, Rossby Centre!"
```

```python
msg = "Hello, Rossby Centre!"
echo = Echo(msg) # the Echo task
echo.run()       # execute Echo
```

/uwefladrich/scriptengine

ScriptEngine in Action: Compiling NEMO

```
- context:
    nemo:
      make_clean: True
      arch_name: ECEARTH

- echo: {msg: Configuring arch files for NEMO4.0.1}
- template:
    src: nemo/arch-ecearth.fcm.j2
    dst: "{{main.src_dir}}/nemo-4.0.1/arch/arch-ecearth.fcm"

- when: nemo.make_clean
  do:
    - echo: {msg: Cleaning up NEMO4.0.1}
    - command:
        name: ./makenemo
        args: [ -r, "{{nemo.arch_name}}",
                clean ]
        cwd:  "{{main.src_dir}}/nemo-4.0.1"
        ignore_error: Yes
```

EC-Earth 4 Monitoring: What

extendable set of ScriptEngine Tasks
→ users create monitoring scripts
→ they are executed at runtime

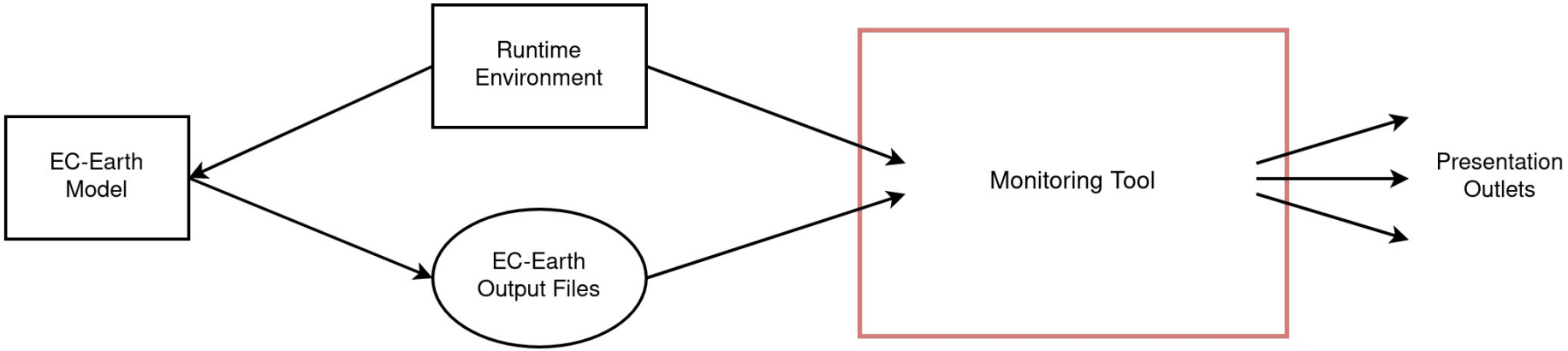
EC-Earth 4 Monitoring: How

open-source Python code
automated tests
user documentation & developing guidelines

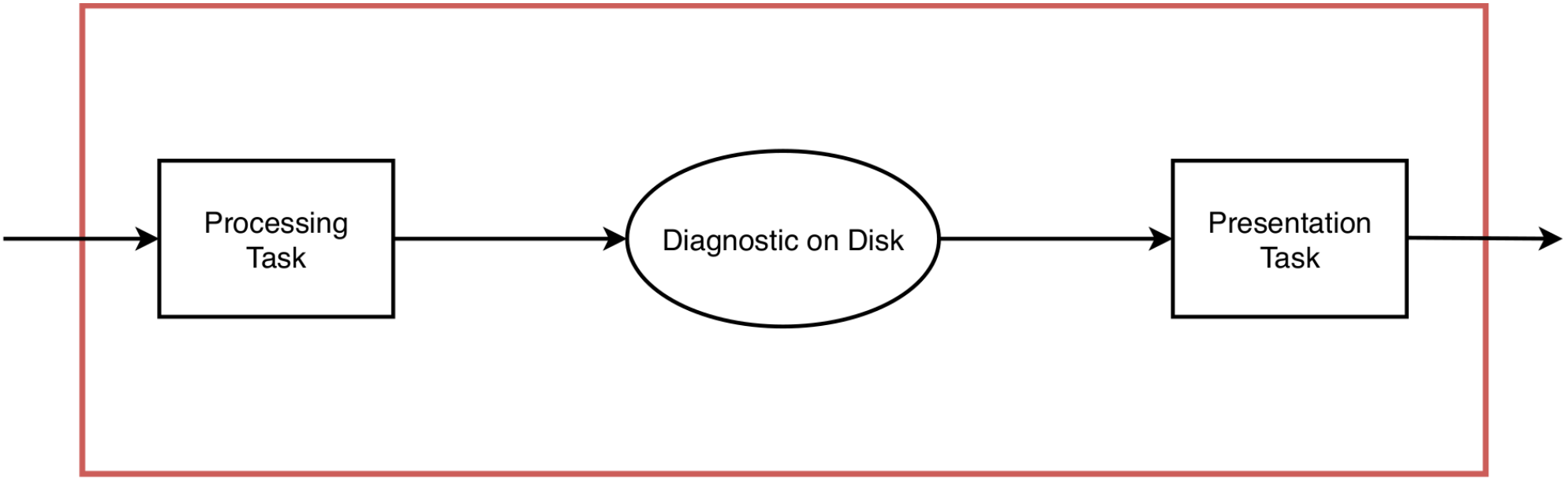
→ idea: easy to develop, easy to use

Concept

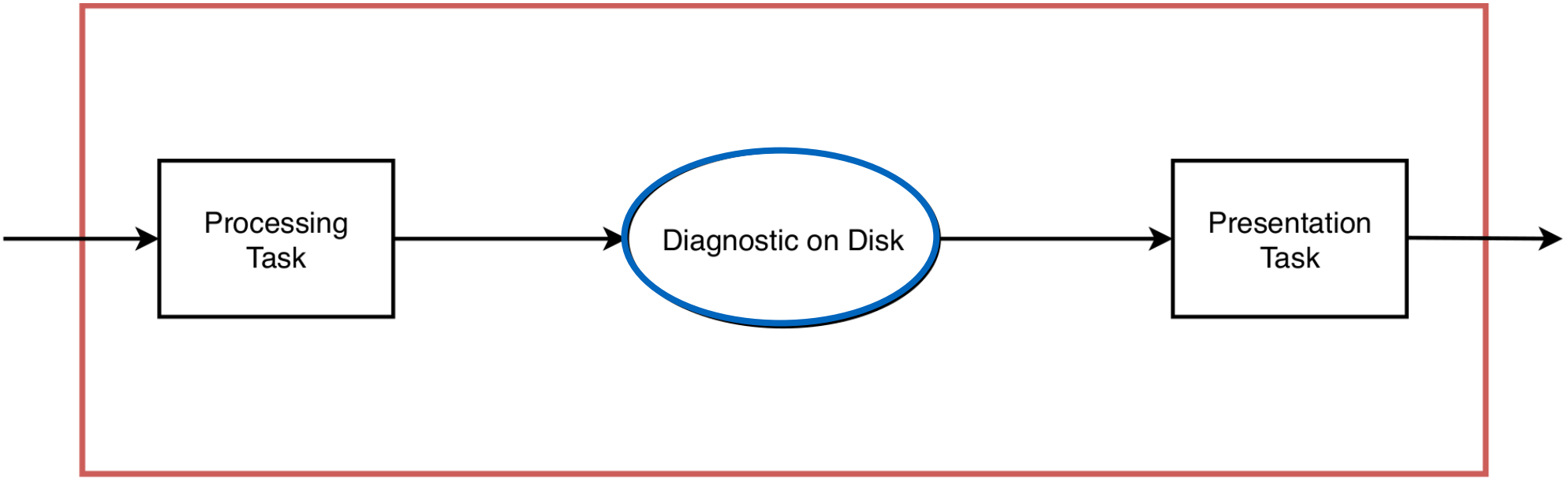
Concept


Runtime Environment
EC-Earth Model
EC-Earth Output Files
Monitoring Tool
Presentation Outlets

Concept



Concept



Diagnostics (on Disk)

standardized!

diagnostic types	scalars, time series, (temporal) maps
file types	YAML, NetCDF
(meta)data standards	CF conventions, CMIP data request
naming scheme	`variable_component_{domain_op...}_diagnostictype`

Hands On

EC-Earth 4 Monitoring: Where

 scriptengine-tasks-ecearth.rtfd.io

</>  /uwefladrich/scriptengine-tasks-ecearth

  /valentinaschueller/ece-4-monitoring-resources

What’s Next?

Try it out!

give feedback, create issues, extend it
… it’s open source ;)

Tack så mycket!

Questions?

Example

Processing Task
annual global mean of oceanic variable

Diagnostic
annual global mean of sea surface temperature
on disk:
`tos_nemo_global_mean_year_mean_timeseries.nc`

Presentation Task
create Redmine issue with all diagnostics

Implementation Examples

Scalars

```
- ece.mon.scalar:
    title: "Experiment Description"
    value: "{{main.experiment_description}}"
    dst: "{{main.mondir}}/description_scalar.yml"
- ece.mon.simulatedyears_rte_scalar:
    start: "{{schedule.start}}"
    end: "{{schedule.leg.end}}"
    dst: "{{main.mondir}}/simulatedyears_rte_scalar.yml"
```

Result: YAML Files

```yaml
title: Experiment Description
value: A monitoring test with EC-Earth 4
diagnostic_type: scalar
```

```yaml
title: Simulated Years
comment: Current number of simulated years.
value: 25
diagnostic_type: scalar
```

Time Series

```
- ece.mon.nemo_global_mean_year_mean_timeseries:
    src: "{{oce_t_files}}"
    varname: "tos"
    domain: "{{main.rundir}}/domain_cfg.nc"
    dst: "{{main.mondir}}/tos_nemo_global_mean_year_mean_timeseries.nc"

- ece.mon.oifs_global_mean_year_mean_timeseries:
    src: "{{atm_gg_files}}"
    dst: "{{main.mondir}}/2t_oifs_global_mean_year_mean_timeseries.nc"
    grib_code: 167
```

Result: NetCDF Files

```
(base) valentina@valentina-XPS-13-9360:~/monitor$ ncdump -h tos_nemo_global_mean_year_mean_timeseries.nc
netcdf tos_nemo_global_mean_year_mean_timeseries {
dimensions:
        time_counter = 25 ;
        bnds = 2 ;
variables:
        double tos(time_counter) ;
                tos:standard_name = "sea_surface_temperature" ;
                tos:long_name = "sea surface temperature" ;
                tos:units = "degC" ;
                tos:cell_methods = "time_counter: mean (interval: 1 month) area: mean" ;
                tos:coordinates = "nav_lat nav_lon" ;
        double time_counter(time_counter) ;
                time_counter:axis = "T" ;
                time_counter:bounds = "time_counter_bnds" ;
                time_counter:units = "seconds since 1900-01-01 00:00:00" ;
                time_counter:standard_name = "time" ;
                time_counter:long_name = "Time axis" ;
                time_counter:calendar = "gregorian" ;
                time_counter:time_origin = "1900-01-01 00:00:00" ;
        double time_counter_bnds(time_counter, bnds) ;
        float nav_lat ;
                nav_lat:bounds = "nav_lat_bnds" ;
                nav_lat:units = "degrees_north" ;
                nav_lat:standard_name = "latitude" ;
                nav_lat:long_name = "Latitude" ;
        float nav_lat_bnds(bnds) ;
        float nav_lon ;
                nav_lon:bounds = "nav_lon_bnds" ;
                nav_lon:units = "degrees_east" ;
                nav_lon:standard_name = "longitude" ;
                nav_lon:long_name = "Longitude" ;
        float nav_lon_bnds(bnds) ;

// global attributes:
                :comment = "Global average time series of **tos**. Each data point represents the (spatial and temporal) average over one leg." ;
                :diagnostic_type = "time series" ;
                :source = "EC-Earth 4" ;
                :title = "sea surface temperature (Annual Mean)" ;
                :Conventions = "CF-1.7" ;
}
(base) valentina@valentina-XPS-13-9360:~/monitor$
```

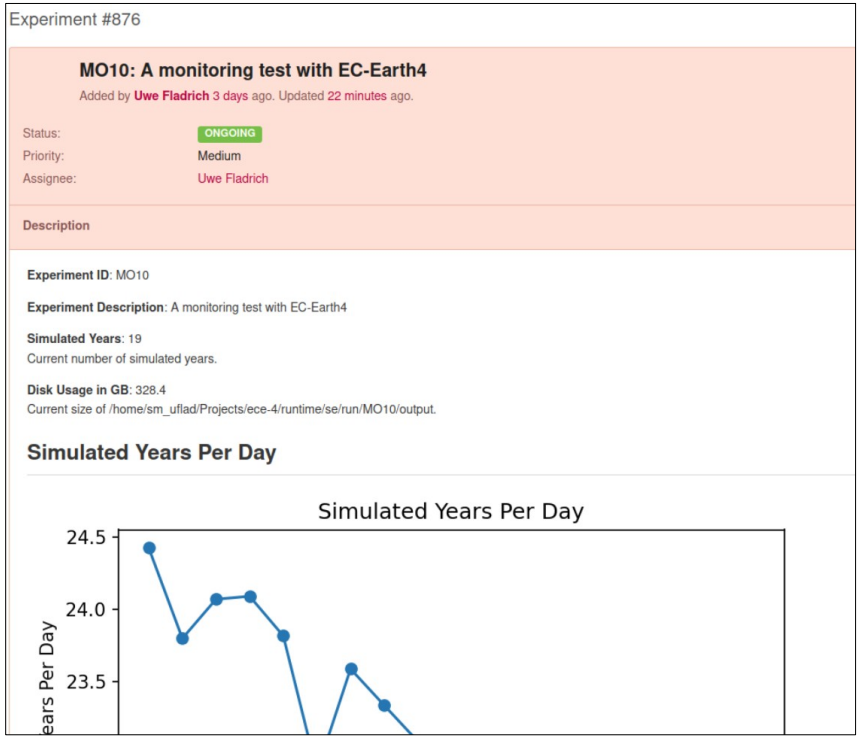
Redmine Presentation

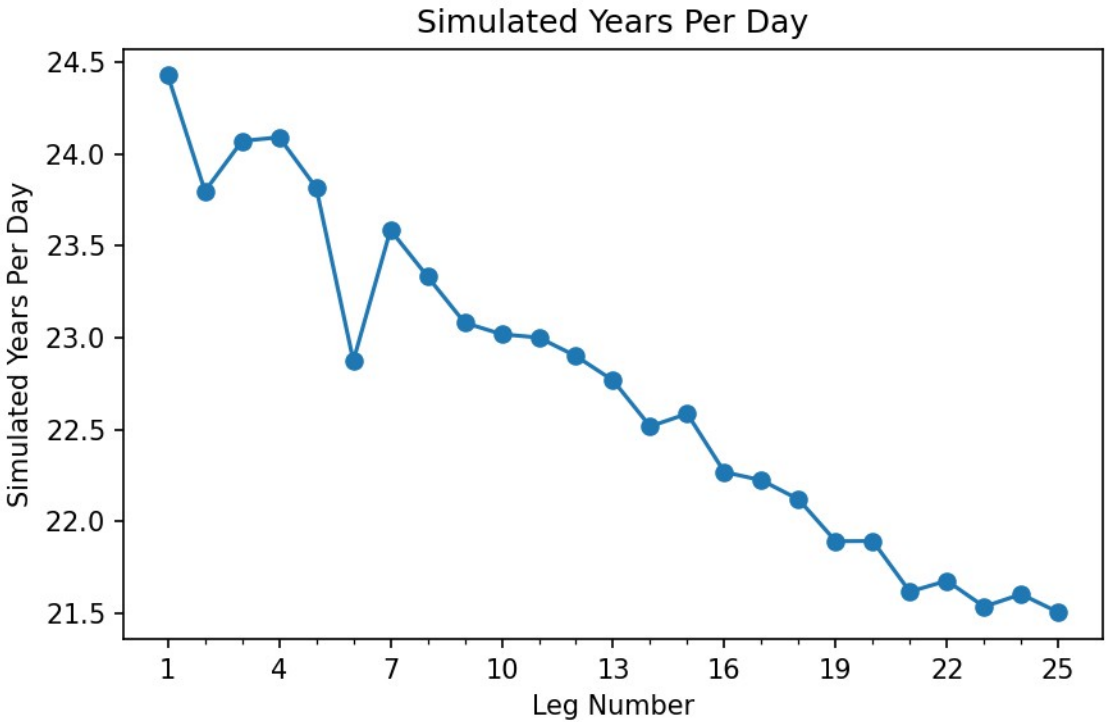
```
- ece.mon.presentation.redmine:
    src:
        - "{{main.mondir}}/expid_scalar.yml"
        - "{{main.mondir}}/description_scalar.yml"
        - "{{main.mondir}}/simulatedyears_rte_scalar.yml"
        - "{{main.mondir}}/sypd_timeseries.nc"
        - "{{main.mondir}}/tos_nemo_global_mean_year_mean_timeseries.nc"
        - path: "{{main.mondir}}/tos_nemo_year_mean_temporalmap.nc"
          value_range: [-2, 30]
        - "{{main.mondir}}/sivol_north_sum_mar+sep_mean_timeseries.nc"
        - "{{main.mondir}}/sivol_south_sum_feb+sep_mean_timeseries.nc"
        - path: "{{main.mondir}}/siconc_si3_north_point_mar_mean_temporalmap.nc"
          value_range: [0, 100]
          colormap: 'Blues_r'
        - path: "{{main.mondir}}/siconc_si3_north_point_sep_mean_temporalmap.nc"
          value_range: [0, 100]
          colormap: 'Blues_r'
        - path: "{{main.mondir}}/siconc_si3_south_point_feb_mean_temporalmap.nc"
          value_range: [0, 100]
          colormap: 'Blues_r'
        - path: "{{main.mondir}}/siconc_si3_south_point_sep_mean_temporalmap.nc"
          value_range: [0, 100]
          colormap: 'Blues_r'
        - "{{main.mondir}}/2t_oifs_global_mean_year_mean_timeseries.nc"
        - "{{main.mondir}}/2t_oifs_all_mean_map.nc"
        - "{{main.mondir}}/istl1_oifs_year_mean_temporalmap.nc"
    local_dst: "{{main.mondir}}/presentation/redmine"
    api_key: # api key
    subject: "EC-Earth 4 experiment: {{main.experiment_id}}"
    template: "scriptengine-tasks-ecearth/docs/templates/redmine_template.txt.j2"
```

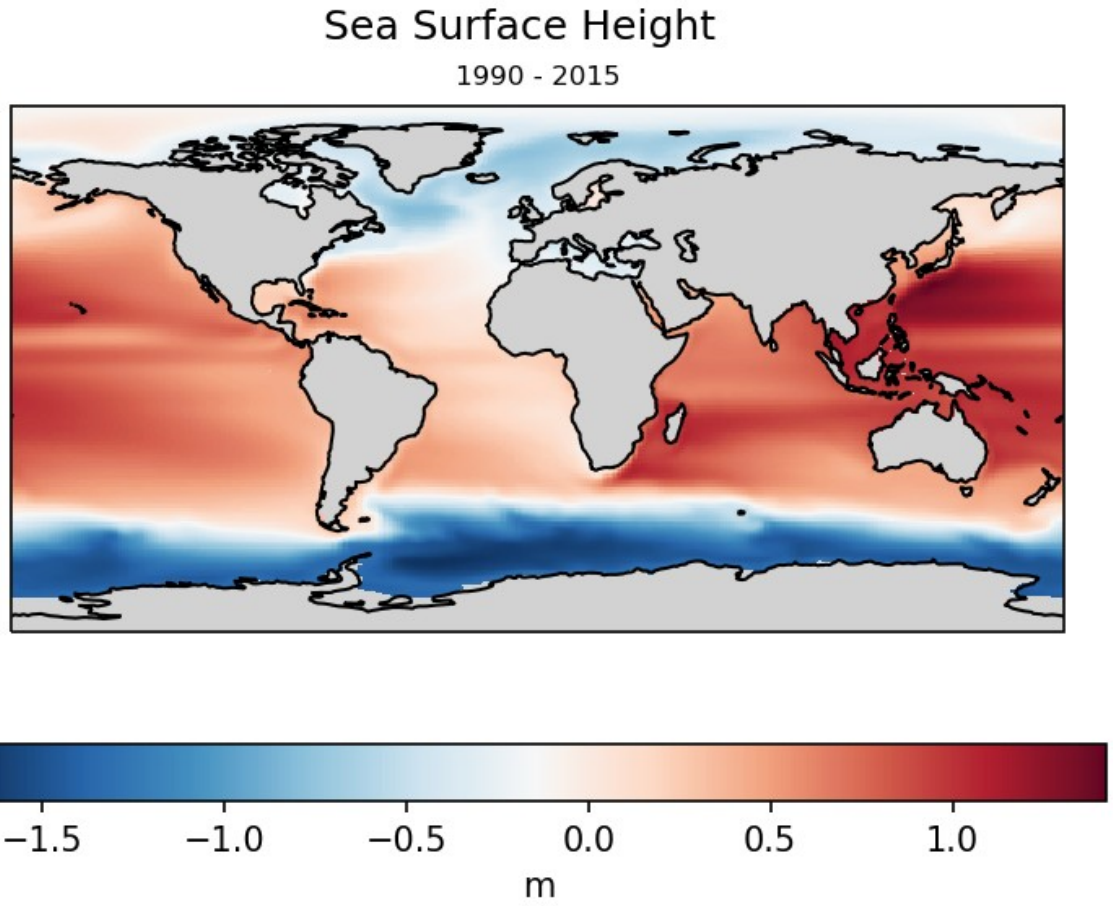
Result: Local Directory & Issue

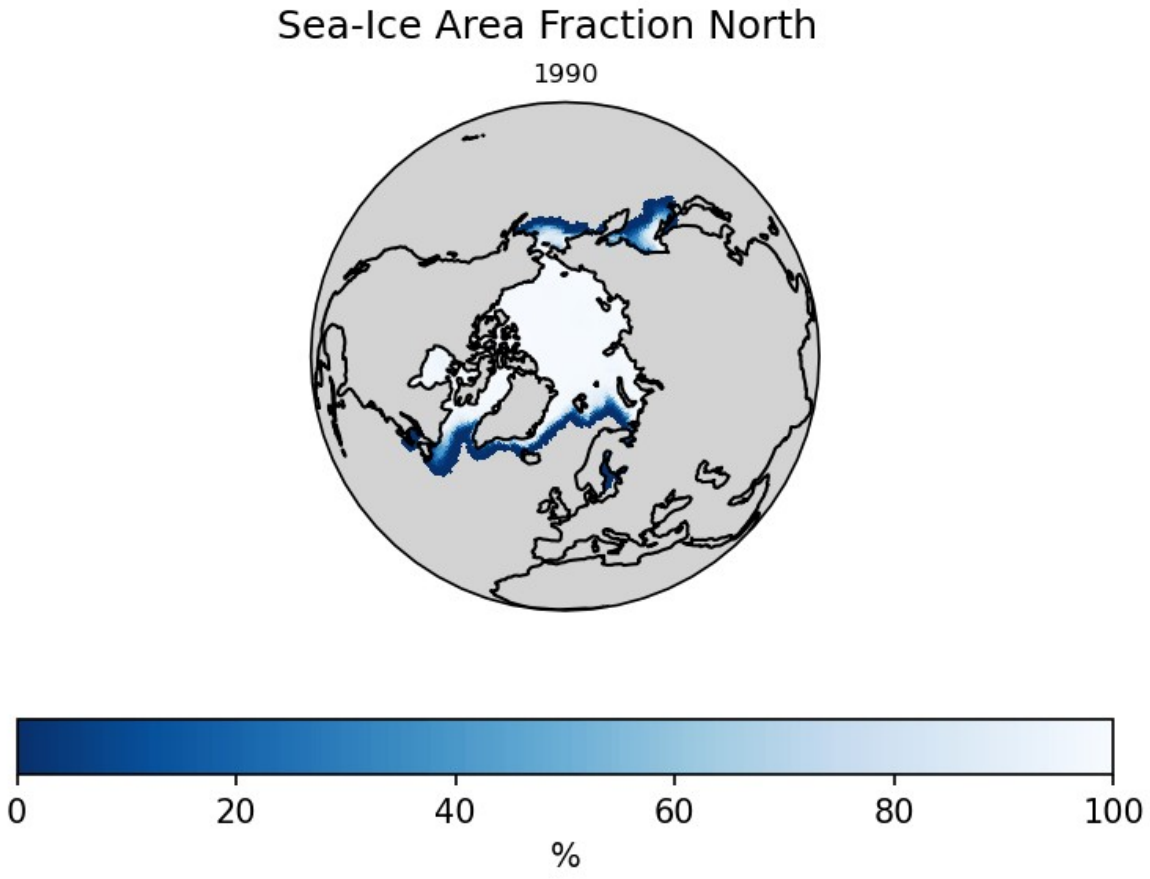
```
redmine/
├── 2t_oifs_all_mean_map.png
├── 2t_oifs_global_mean_year_mean_timeseries.png
├── issue_description.txt
├── istl1_oifs_year_mean_temporalmap.png
├── siconc_si3_north_point_mar_mean_temporalmap_frames
├── siconc_si3_north_point_mar_mean_temporalmap.gif
├── siconc_si3_north_point_sep_mean_temporalmap_frames
├── siconc_si3_north_point_sep_mean_temporalmap.gif
├── siconc_si3_south_point_feb_mean_temporalmap_frames
├── siconc_si3_south_point_feb_mean_temporalmap.gif
├── siconc_si3_south_point_sep_mean_temporalmap_frames
├── siconc_si3_south_point_sep_mean_temporalmap.gif
├── sivol_north_sum_mar_sep_mean_timeseries.png
├── sivol_south_sum_feb_sep_mean_timeseries.png
├── sypd_timeseries.png
├── tos_nemo_global_mean_year_mean_timeseries.png
├── tos_nemo_year_mean_temporalmap_frames
└── tos_nemo_year_mean_temporalmap.gif

5 directories, 13 files
```




Simulated Years Per Day
Simulated Years Per Day
24.5
24.0
23.5
23.0
22.5
22.0
21.5
1
4
7
10
13
16
19
22
25
Leg Number


Sea Surface Height
1990 - 2015
−1.5
−1.0
−0.5
0.0
0.5
1.0
m


Sea-Ice Area Fraction North
1990
0
20
40
60
80
100
%

Concept

Processing Task

create a diagnostic & save it

Concept

Presentation Task

visualize and summarize diagnostic(s)

Concept

Diagnostic

meaningful quantity about the physical or computational performance