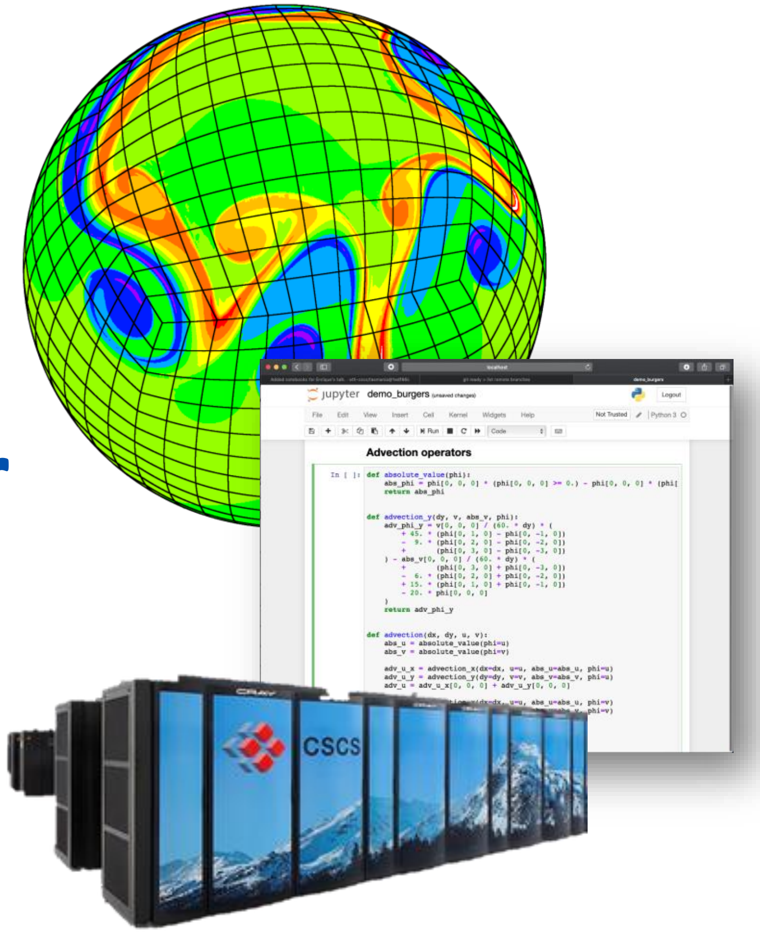
High Performance Computing for Weather and Climate (HPC4WC)

Content: Pace: A model in Python
Lecturer: Tobias Wicky
Block course 701-1270-00L
Summer 2022



Learning Goal

- See the DSL approach in action
- See some of the concepts we've learned applied in a real code

Who are we?

Oliver
Fuhrer

Johann
Dahm

Florian
Deconinck

Oliver
Elbert

Jeremy
McGibbon

Tobias
Wicky

Elynn Wu

Collaborators

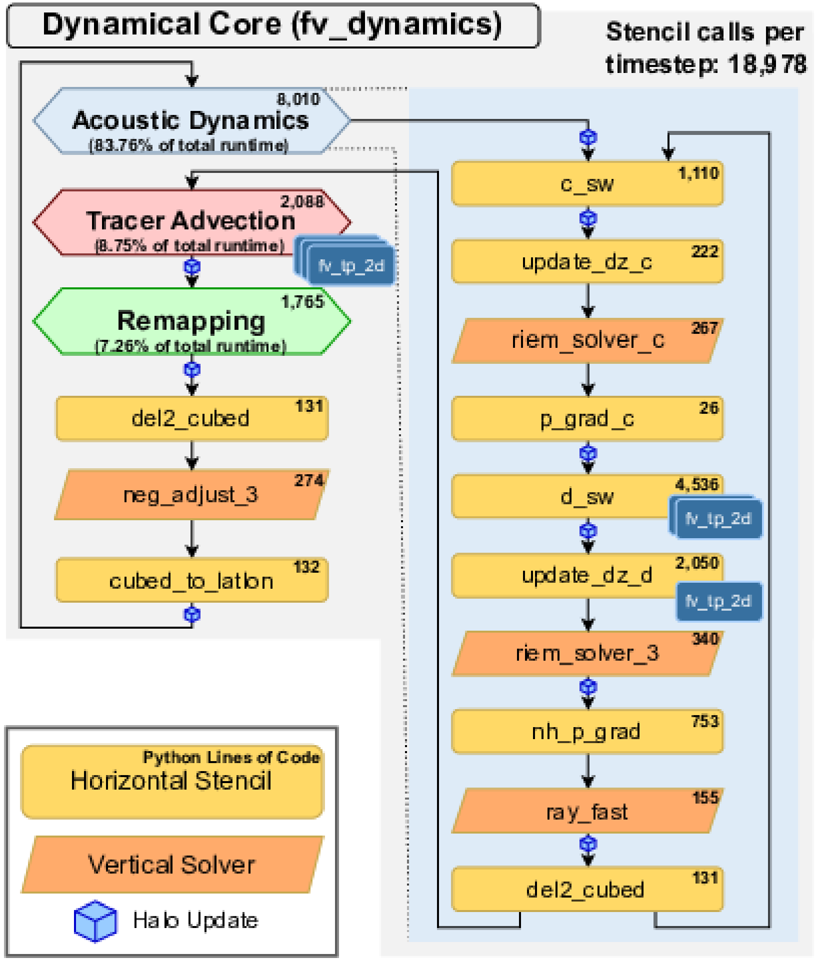
GFDL
NASA
CSCS
MeteoSwiss
ETH zürich
UNIVERSITY of WASHINGTON

Pace: Python based FV3

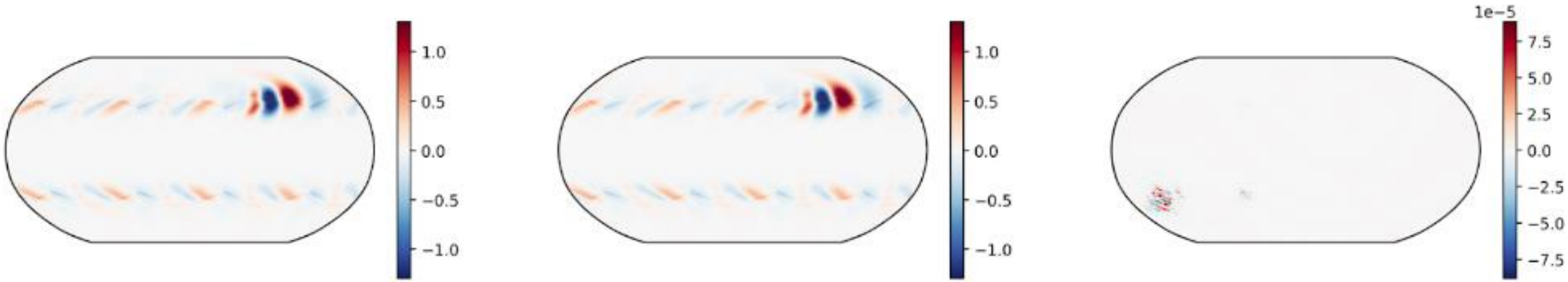
GFDL Finite-Volume Cubed-Sphere Dynamical Core (FV3)

Finite volume transport on a cubed sphere grid

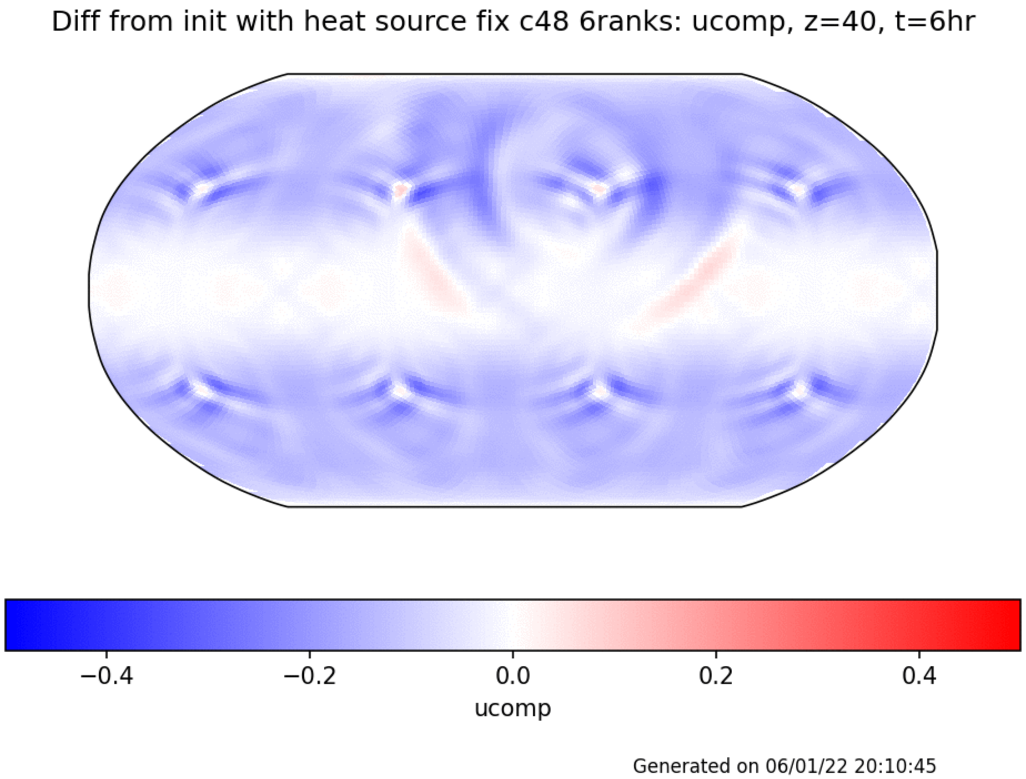
- Integrated into several models, including
  - Operational weather models (Global Forecast System)
  - Next Generation Global Prediction System



Validation



Validation


Diff from init with heat source fix c48 6ranks: ucomp, z=40, t=6hr
−0.4
−0.2
0.0
0.2
0.4
ucomp
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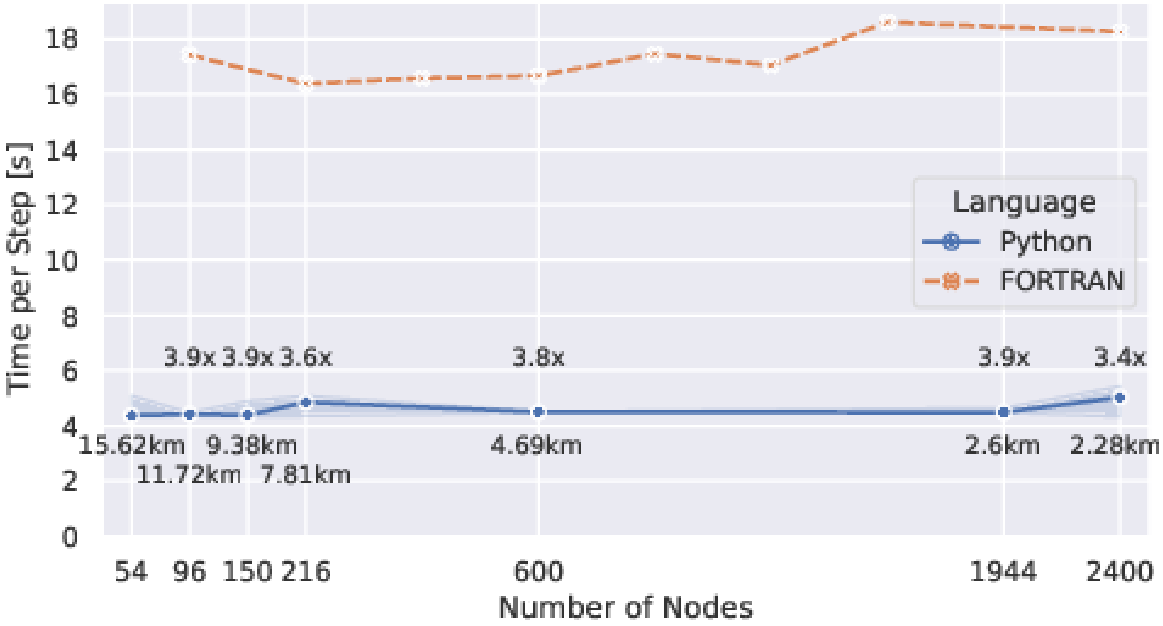
The Pace Model

Full program optimization

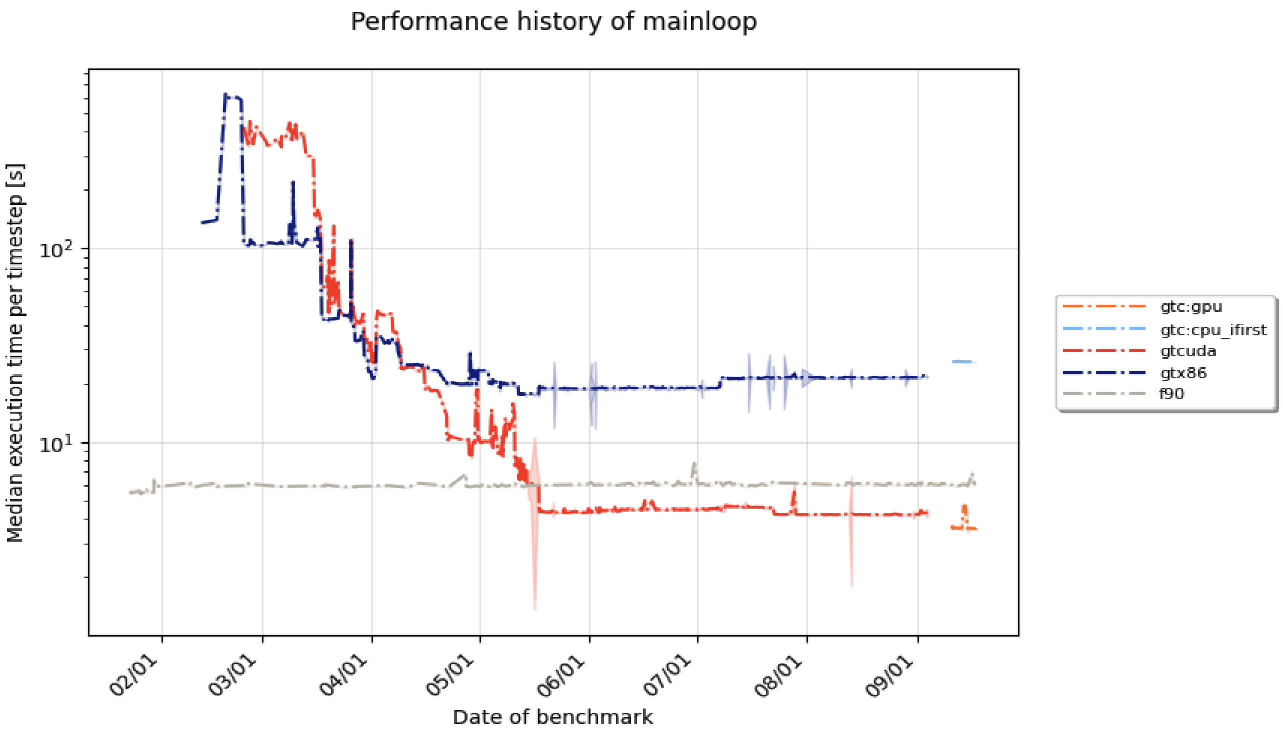
DSL coverage of all main numerical computation

Custom code for halo updates

New DSL concepts for FV3-specific motifs



The Pace Model



Why did you torture us for 4 days?

DSL still uses these concepts under the hood

```python
def visit_Stencil(self, node: oir.Stencil, **kwargs: Any) -> oir.Stencil:
    write_before_read_tmps = {
        symbol
        for symbol, value in kwargs["symtable"].items()
        if isinstance(value, oir.Temporary)
    }
    horizontal_executions = node.iter_tree().if_isinstance(oir.HorizontalExecution)

    for horizontal_execution in horizontal_executions:
        accesses = AccessCollector.apply(horizontal_execution)
        offsets = accesses.offsets()
        ordered_accesses = accesses.ordered_accesses()

        def write_before_read(tmp: str) -> bool:
            if tmp not in offsets:
                return True
            if offsets[tmp] != {(0, 0, 0)}:
                return False
            return next(
                o.is_write and o.horizontal_mask is None
                for o in ordered_accesses
                if o.field == tmp
            )

        write_before_read_tmps = {
            tmp for tmp in write_before_read_tmps if write_before_read(tmp)
        }

    return super().visit_Stencil(node, tmps_to_replace=write_before_read_tmps, **kwargs)
```

Why did you torture us for 4 days?

There are things that we still need to do manually:

- Halo updates

- Memory size reduction

What does Python bring us?

```
class Physics:

...
prepare_microphysics(physics_state)
microph_state = physics_state.microphysics
microphysics(microph_state)
```

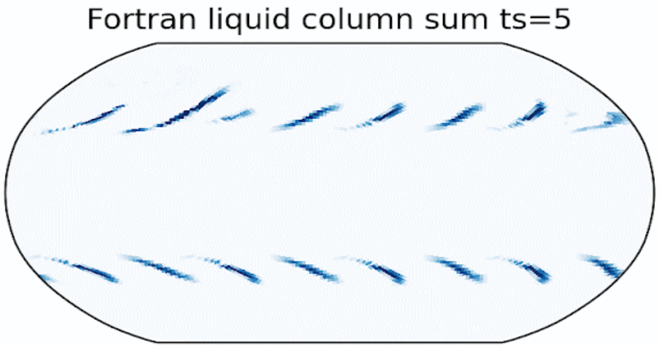
GT4Py stencil-based

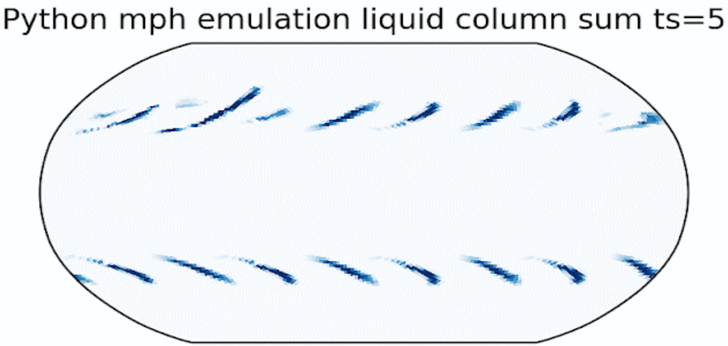
```
emulation_model = tf.keras.models.load_model("model.tf")

emulation_dict = prepare_emulation_data(physics_state.microphysics)
predictions = emulation_model(emulation_dict)
model_outputs = unpack_predictions(predictions, emulation_model.output_names, …)
```

ML-based microphysics

ML-based Microphysics



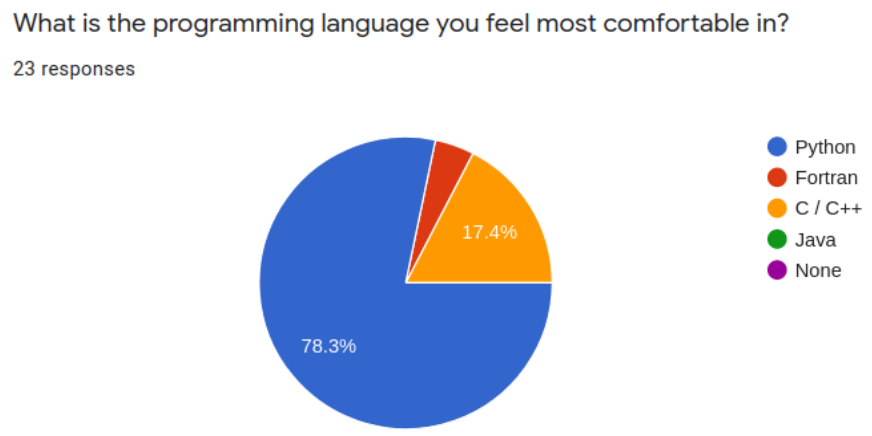


Why else is Python awesome?

The rich python ecosystem is valuable – new options for development

Testing is WAY easier!

You



Physical Parametrizations

	Microphysics	PBL & Turbulence	Sea-Ice	Shallow Convection	LSM	Radiation
Authors	 Mikael	 Chris Kung (NASA)	 Vera  Nadja  Nicolai	 Mikael  Chenwei  Langwen	 Safira	 Andrew
Scheme	**GFDL Cloud Microphysics Scheme**	GFS scale-aware EDMF PBL and Free Atmospheric Turbulence Scheme	GFS Sea Ice Scheme	GFS SAS-based Mass-Flux Scheme for Shallow convection	GFS Noah Land Surface Model	GFS RRTMG

Are we seeing what DSLs promise?

Overarching Goals (The 3 P's)

- **Productivity**
  Easy to implement.
  Easy to **read**.
  Easy to **maintain**.
- **Performance**
  Is **fast**.
- **Portability**
  Single **hardware-agnostic** application code.
  Runs efficiently on **different hardware** targets.

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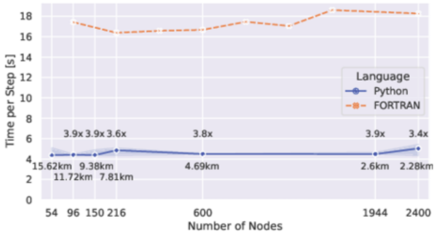
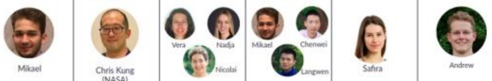


Physical Parametrizations



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```yaml
stencil_config:
  backend: numpy
  rebuild: false
  validate_args: true
  format_source: false
  device_sync: true
initialization:
  type: baroclinic
performance_config:
  performance_mode: false
  experiment_name: c12_baroclinic
comm_config:
  type: read
  config:
    path: comm
    rank: 0
nx_tile: 12
```