PyPy's JIT for scientific python computations

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PyPy - what's that?

- A Python interpreter written in (a restricted subset of) Python
- A flexible compiler compiling restricted version of Python to lower level platform
- An open source project (MIT license)

Motivation behind the project

- CPython is not flexible enough
- Python is so much better to write in than C
- Let compiler do the hard work
- Psyco/stackless hard to maintain/extend
- "Psyco consumes one brain per inch of progress"

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Status of PyPy today

- Very compliant python interpreter (passes CPython test suite)
- Can run complex python applications (Django, twisted, ctypes)
- Pretty good garbage collector
- JIT - in progress (more later)

Python's performance

- Python as a language (not CPython)
- Highly dynamic
- Impossible to efficiently optimize statically
- Dynamic compilation to the rescue

JIT - motivation

- Psyco hard to maintain and extend
- Python, contrary to popular belief, is a very complex language
- We want to generate JIT out of interpreter's description
- ... instead of writing it by hand

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JIT details

- Interpreter + JIT automatically generated from the interpreter
- Tracing JIT (a-la tracemonkey)
- Written in a high-level language

Tracing JIT

- Modeled after dynamo VM by Michael Franz et al
- Looks at the single loop of a program while its executed
- Assumes the same path is commonly taken (a bit more complex than that)
- Compiles relatively little assembler

Tracing the interpreter

- Follows interpretation of each bytecode via internal interpreter calls
- Automatically inlines everything
- Creates assembler corresponding to a real interpreter path
- ... plus a couple of guards
- Works for any interpreter

JIT - status

- Simple numeric stuff - 20-30x performance boost
- ... which is similar to unoptimized C (gcc -O0)
- only x86 backend so far (ie no x87)
- More work needed
- Only about 2 man-year put so far

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Cloud modelling

Cloud processes cover tremendous range of scales, from thousands of kilometers to a fraction of a cm...

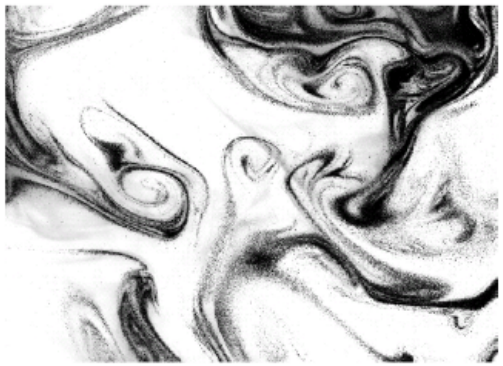
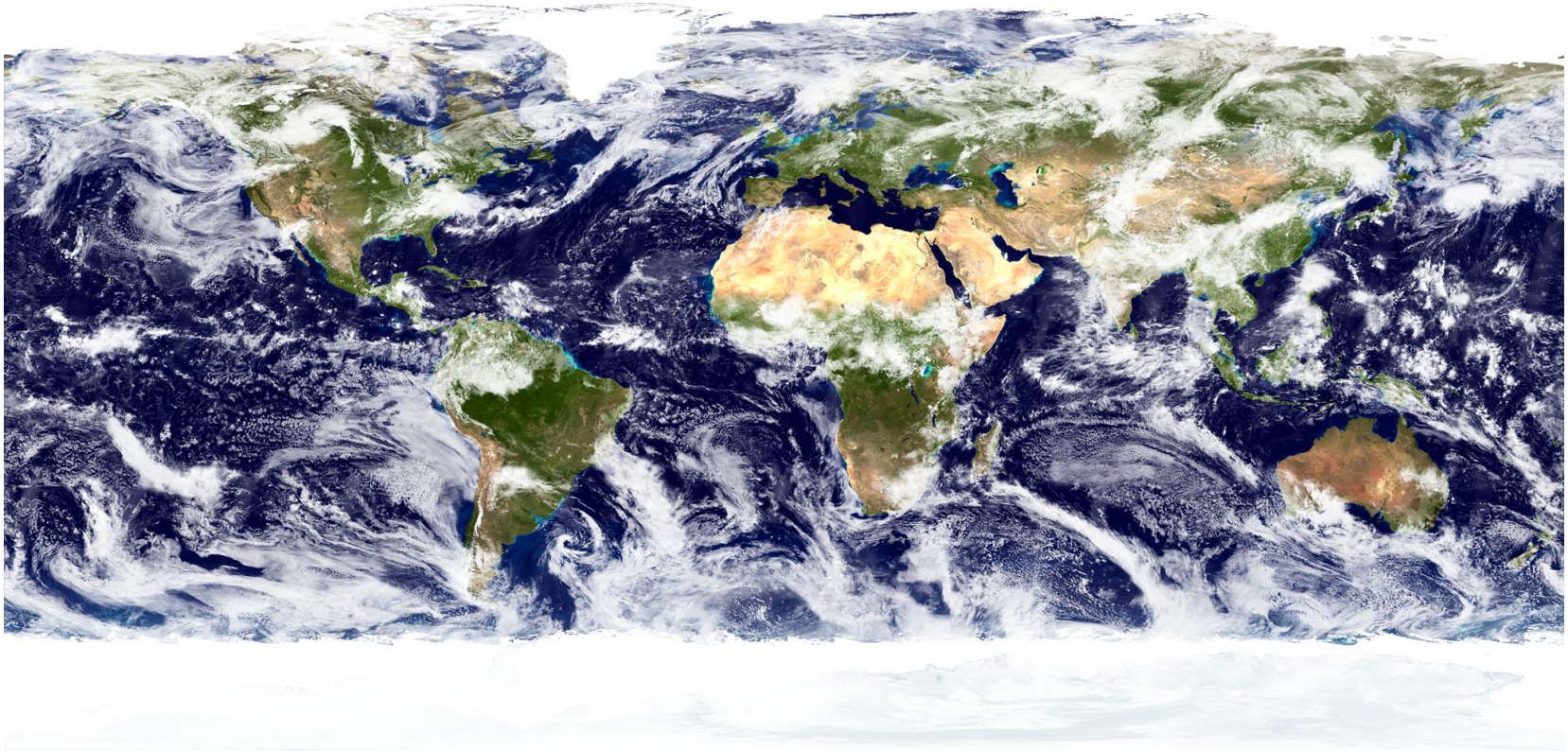


Figure 9. An example image from the cloud chamber. Dark pixels are occupied by cloud droplets. Image covers a physical area of $\sim 9 \times 6\,\mathrm{cm}^2$.

Global climate model

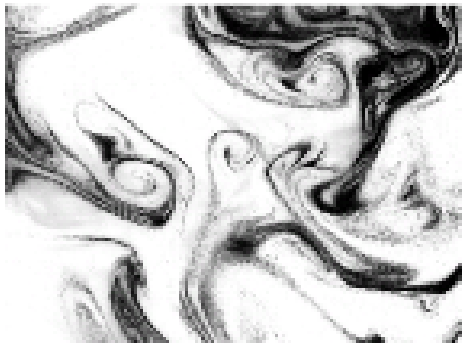
Horizontal grid size of Global Climate Models is $\sim$ 100km



Clouds have to be parametrized

Large Eddy Simulation (LES) Models

- processes, which scales are in a range of 100m could be calculated explicitly
- processes of smaller spatial scale, (e.g. turbulent mixing of a cloud with air from the environment) have to be still parametrized



Malinowski et al. 2008

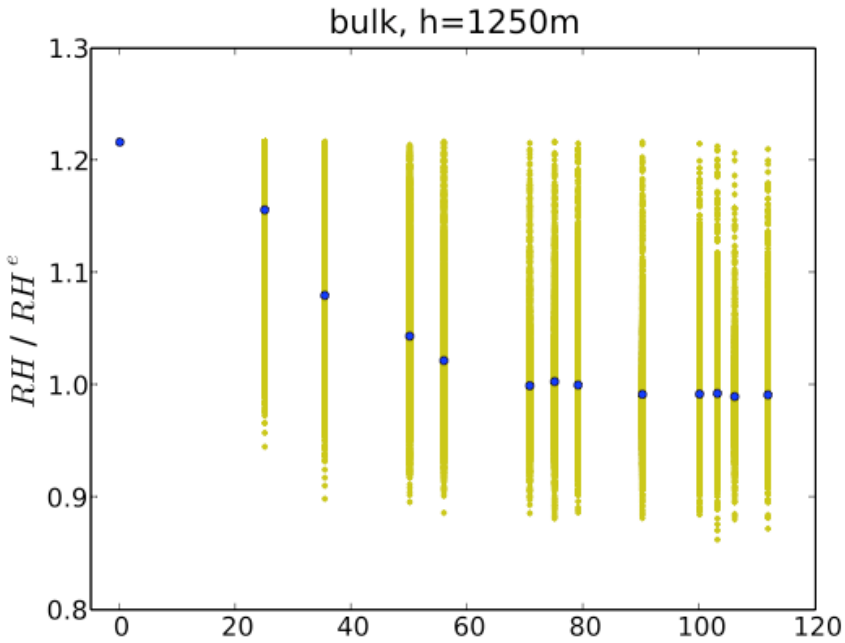
EULAG - numerical solver for all-scale geophysical flows

- developed in National Center for Atmospheric Research (NCAR), Boulder, Colorado, since '80
- written in Fortran 77
- many different developers and users
- lack of version control, good documentation and bug tracking system
- http://www.mmm.ucar.edu/eulag

Data used for analyzis

- written every 4 minutes
- last 4 hours of the simulation
- around 8 basic variables, e.g. velocities, temperature
- For each variable: 60*121*128*128=100M values

Analyzing model data



- checkin amount of liquid water in each box
- checkin for each “dry” grid box, distance to the cloud edge
- calculating relative humidity in each “dry” grid box

Data postprocessing

- Short programs (about 200 lines of code each)
- Relatively simple logic
- Numpy for operations, matplotlib for output
- Massive datasets (about 100M values)
- Sometimes require walking array elements
- Sometimes slow .....

Data postprocessing - solution

- Implement minimal version of numeric for PyPy
- Use the JIT for speedups

Results

- roughly 10x speedups over pure-python version on top of CPython
- Still about 4x slower than C or matrix operations
- ... but not everything can be expressed using matrix operations
- Due to limitations, programs needs to be carefully crafted

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JIT & Numpy

- Just started really
- 138 LOC
- only ints and simple operations

JIT & Numpy status

- No support from JIT **at all**
- General JIT progress gives speedups with numpy
- More work on numpy needed, but it's all very simple

JIT & Numpy - future

- Possible to optimize beyond C implementation
- Matrix operations like: a + b + c should not allocate immediate values
- Use of SSE operations can yield even bigger speedups (or whatever architecture permits)
- Make sure that unmodified programs run faster
- Future looking pretty good

Future directions

- Work more on JIT in general (inlining, x86_64 backend, etc.)
- Produce a release by the end of the year
- Release should speed up real-world program
- Work on numpy as time permits
- Seek more funding

How you can help?

- take over or fund numpy-on-PyPy work
- contribute extension modules
- contribute JIT backend
- organise a PyPy sprint, travel funding a plus
- fund feature or ext module development
- PyPy is open source, newcomer friendly!

Thank you! Questions?

- **PyPy**:

http://codespeak.net/pypy
http://morepypy.blogspot.com
pypy-dev@codespeak.net

- **Cloud modelling**:

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