Parallelization of HIRLAM

Model Parallelization and Asynchronous I/O

HIRLAM Optimizations

- Two major projects:
  - ⑥Model scalability improvement
  - ⑥Asynchronous I/O optimization
- Both projects funded by DMI and NEC

HIRLAM Parallelization

Message Passing Optimization

HIRLAM Scalability Optimization

- Methods
- Implementation
- Performance

Optimization Focus

- Data transposition
  - from 2D to FFT distribution and reverse
  - from FFT to TRI distribution and reverse
- Exchange of halo points
  - between north and south
  - between east and west

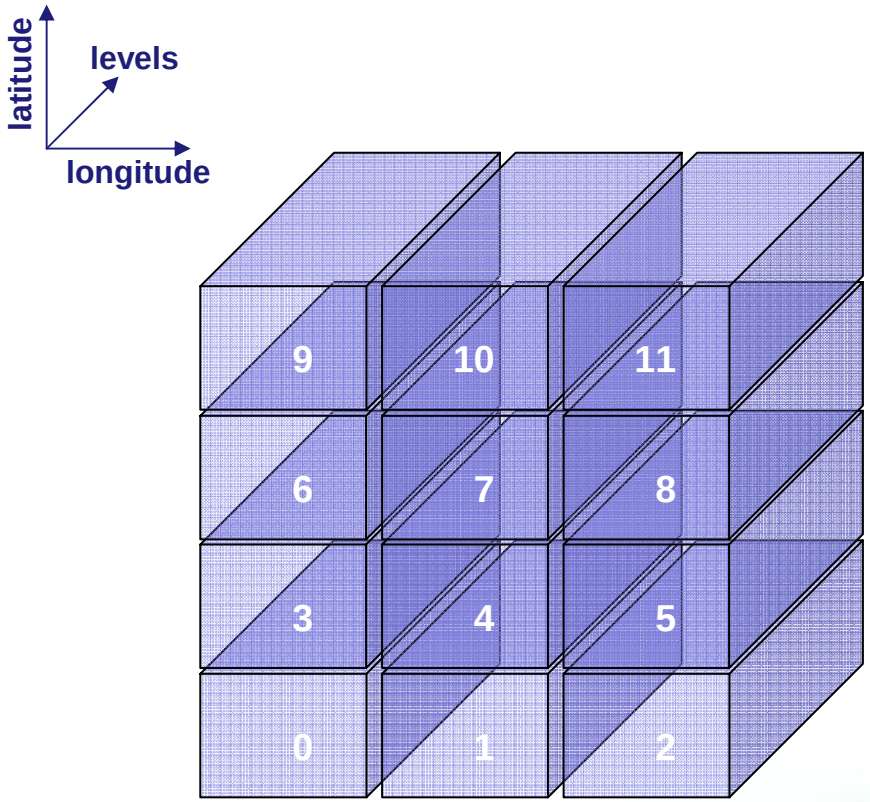
Approach

- First attempt: straight-forward conversion from SHMEM to MPI-2 put/get calls
  - It works, but:
  - Too much overhead due to fine granularity
- Original plan shattered, now what?
  - Panic (mild form)
- More to do: in-depth analysis of how things *really* work
- Human memory: retention at least 6 years

Approach

- Redesign of transposition based on method used in initiative by met.no called PARLAM (Dag Bjørge and Roar Skålin, 1995)
- Redesign of halo swap routines
- Benefits:
  - ➨less and larger messages
  - ➨independent message passing process groups

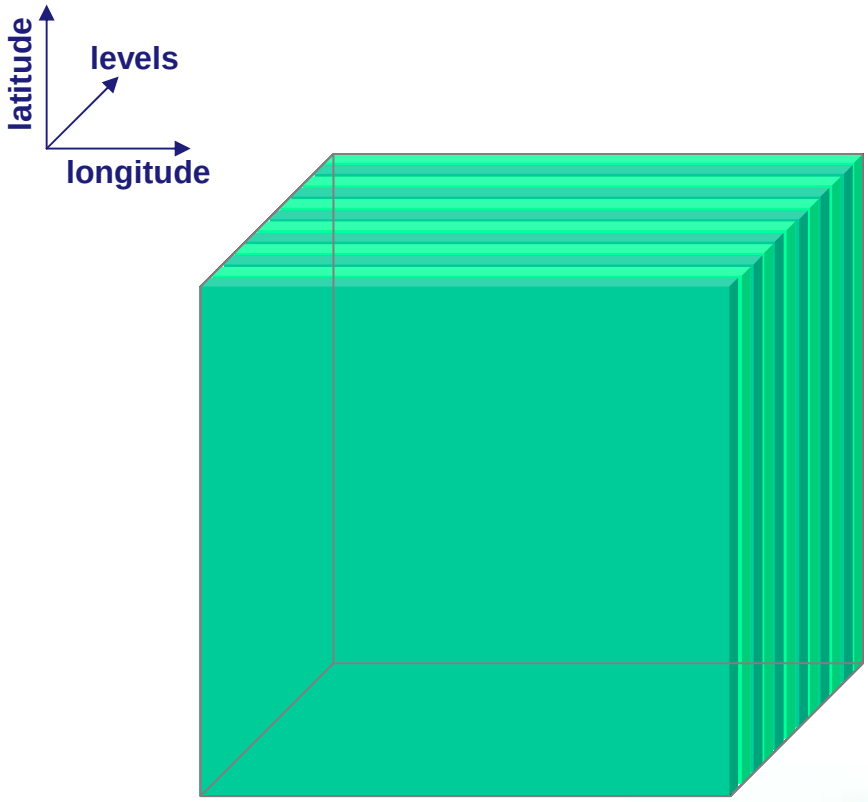
2D Sub Grids



- HIRLAM sub grid definition in TWOD data distribution
- Processors:

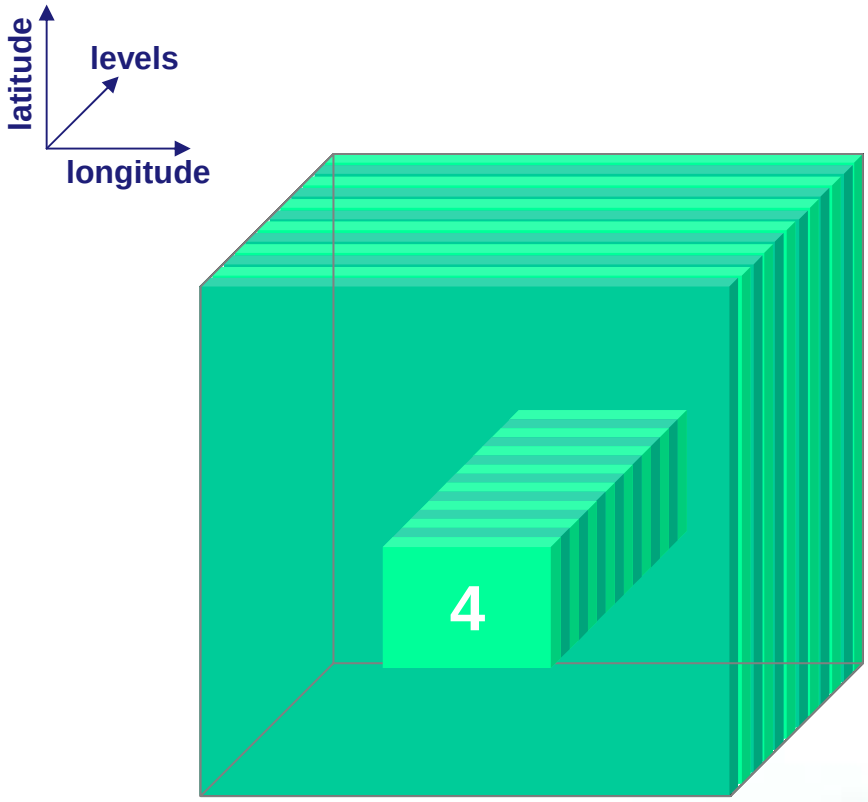
$$nproc = nprocx \cdot nprocy$$

Original FFT Sub Grids



- HIRLAM sub grid definition in FFT data distribution
- Each processor handles slabs of full longitude lines

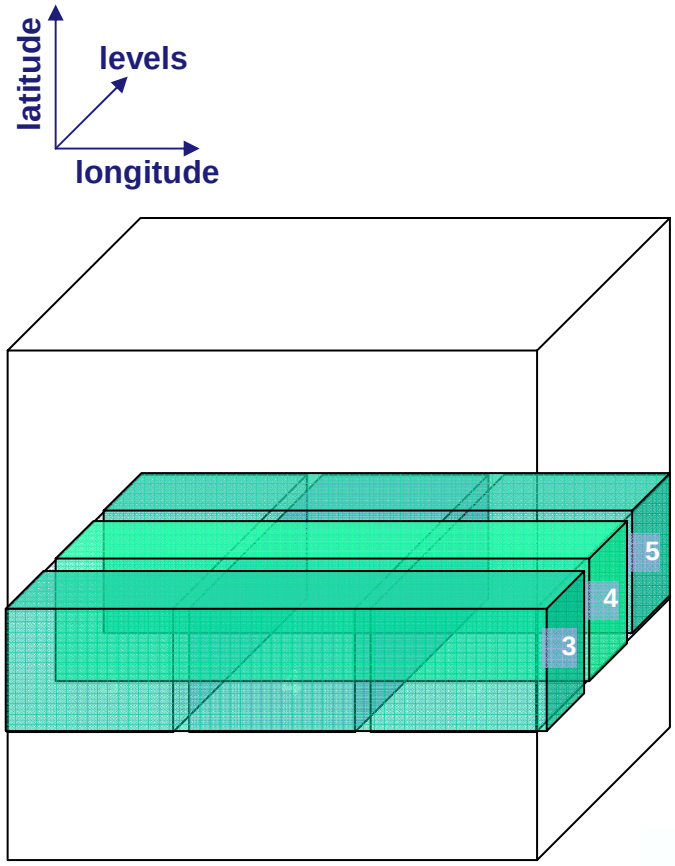
2D↔FFT Redistribution



Sub grid data to be distributed to **all processors**:

nproc^2 send-receive pairs

2D↔FFT Redistribution



- Sub grids in east-west direction form full longitude lines
- *nprocy* independent sets of $nprocx^2$ send-receive pairs
- Total nr of pairs:

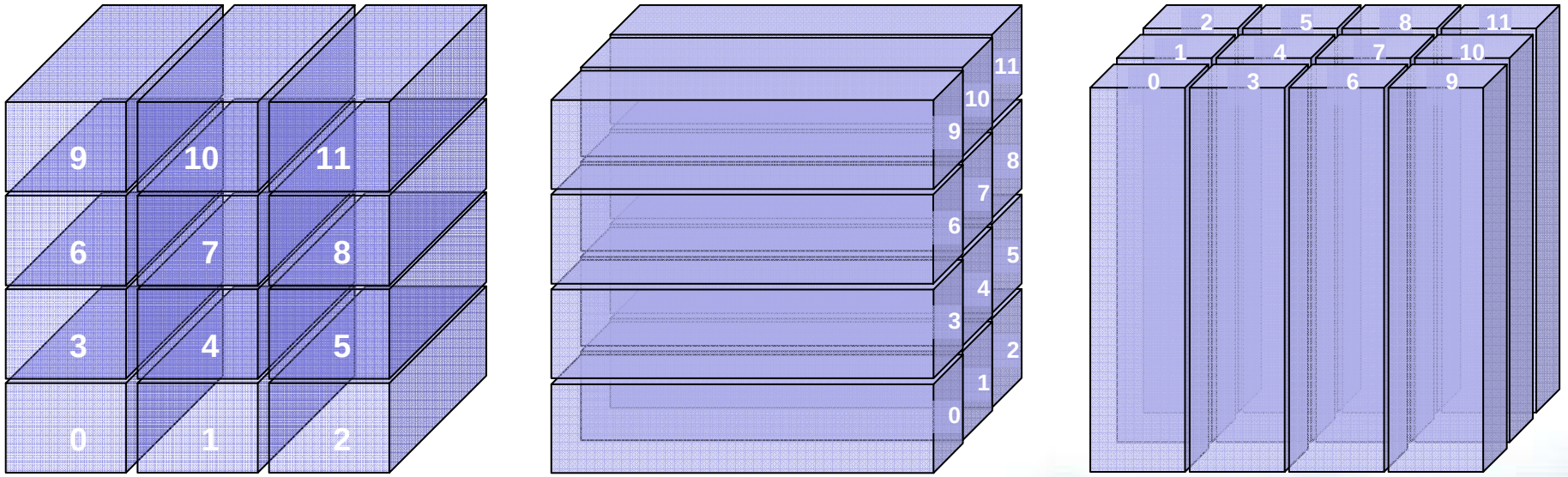
  $nprocy \cdot nprocx^2$

  or:

  $nproc^2 / nprocy$

- ***nprocy* times less messages**

Transpositions 2D↔FFT↔TRI



MPI Methods

- Three transfer methods tried:
  - Remote Memory Access: *mpi_put, mpi_get*
  - Async Point-to-Point: *mpi_isend, mpi_irecv*
  - All-to-All: *mpi_alltoallv, mpi_alltoallw*
- Buffering vs. direct
  - Explicit buffering
  - *MPI derived types*

(Method selection by environment variables)

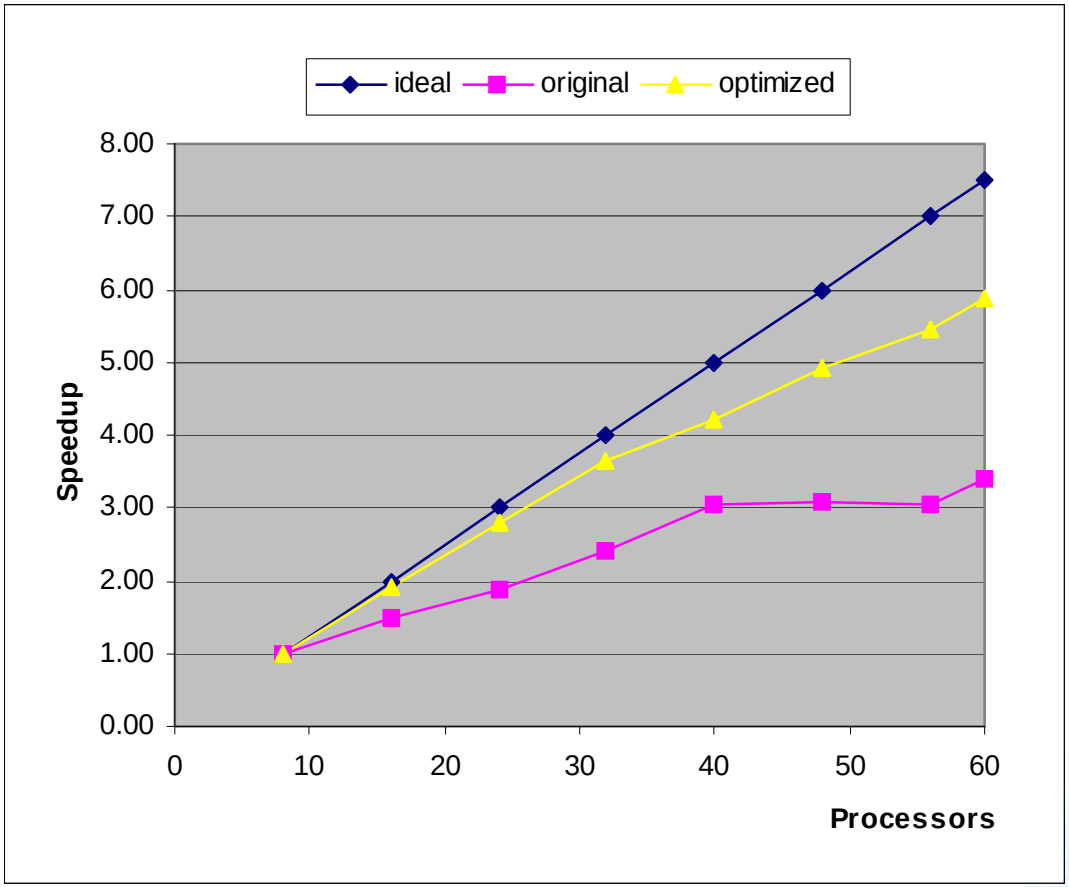
SHMEM Support

- Integrated in new design
- Not much specific SHMEM code left: same buffer structures used for MPI and SHMEM
- Very similar to MPI-2 RMA code part
- New SHMEM code ported to SHMEM architecture by Ole Vignes, met.no

Performance

Test grid Details		
Longitude	602	points
Latitude	568	points
Vertical	60	levels
NSTOP	40	steps
Initialization	none	
Time step	180	seconds

Parallel Speedup on NEC SX-6



- Cluster of 8 NEC SX-6 nodes at DMI
- Up to 60 processors:
  - 7 nodes with 8 processors per node
  - 1 node with 4 processors
- Parallel efficiency 78% on 60 processors

Performance – Observations on SX-6

- New data redistribution method much more efficient (78% vs. 45% on 60 processors)
- No performance advantage with RMA (one-sided MP) or All-to-All over plain Point-to-Point method
- Elegant code with MPI derived types, but explicit buffering faster

Performance – Observations on SGI Origin

- Tests executed at met.no with grid size 468x378x40 points on 196 processors
- Time step times:
  - Old SHMEM: 1.4 s
  - New SHMEM: 1.15 s
  - MPI: 0.85 s
- Conclusions regarding SHMEM:
  - New SHMEM code faster than old SHMEM code
  - New MPI code faster than new SHMEM code
  - End of SHMEM version?

HIRLAM GRIBfile Server

Asynchronous I/O

HGS Overview

HIRLAM GRIBfile Server

- Purpose:

  Take both input and output processing out of the time stepping loop

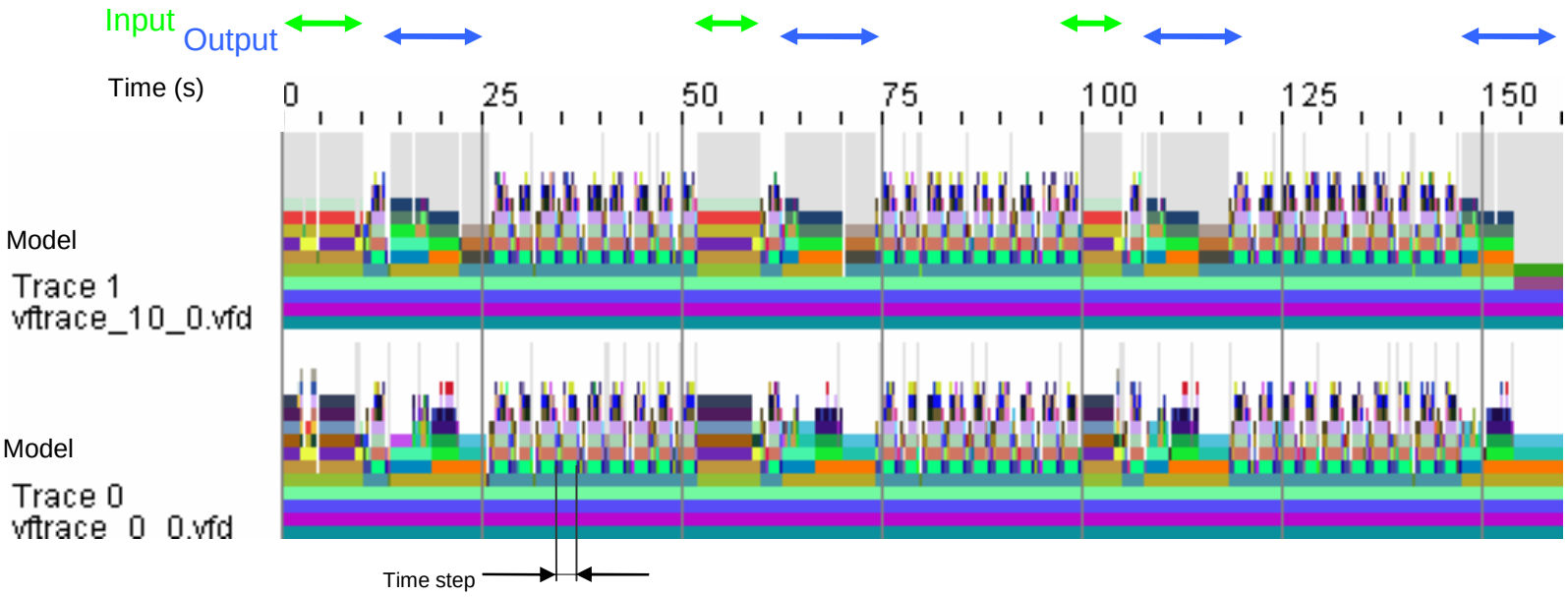
- *Server* is a virtual concept, not a separate application or system
- Integrated in model source
- Enabled/disabled at runtime

HGS Overview

Brief history

1. HGS originally written for shared memory architecture (IPC) (Sun, Jan Boerhout, 2001)
2. Similar initiative for distributed memory architecture (MPI), output only (CSC, Jussi Heikonen and FMI, Kalle Eerola, 2001)
3. HGS rewrite for MPI, based on ideas from 1 and 2 (met.no, Ole Vignes, 2002)
4. Recently optimized for faster data exchange (NEC, Jan Boerhout, 2004; funded by DMI)

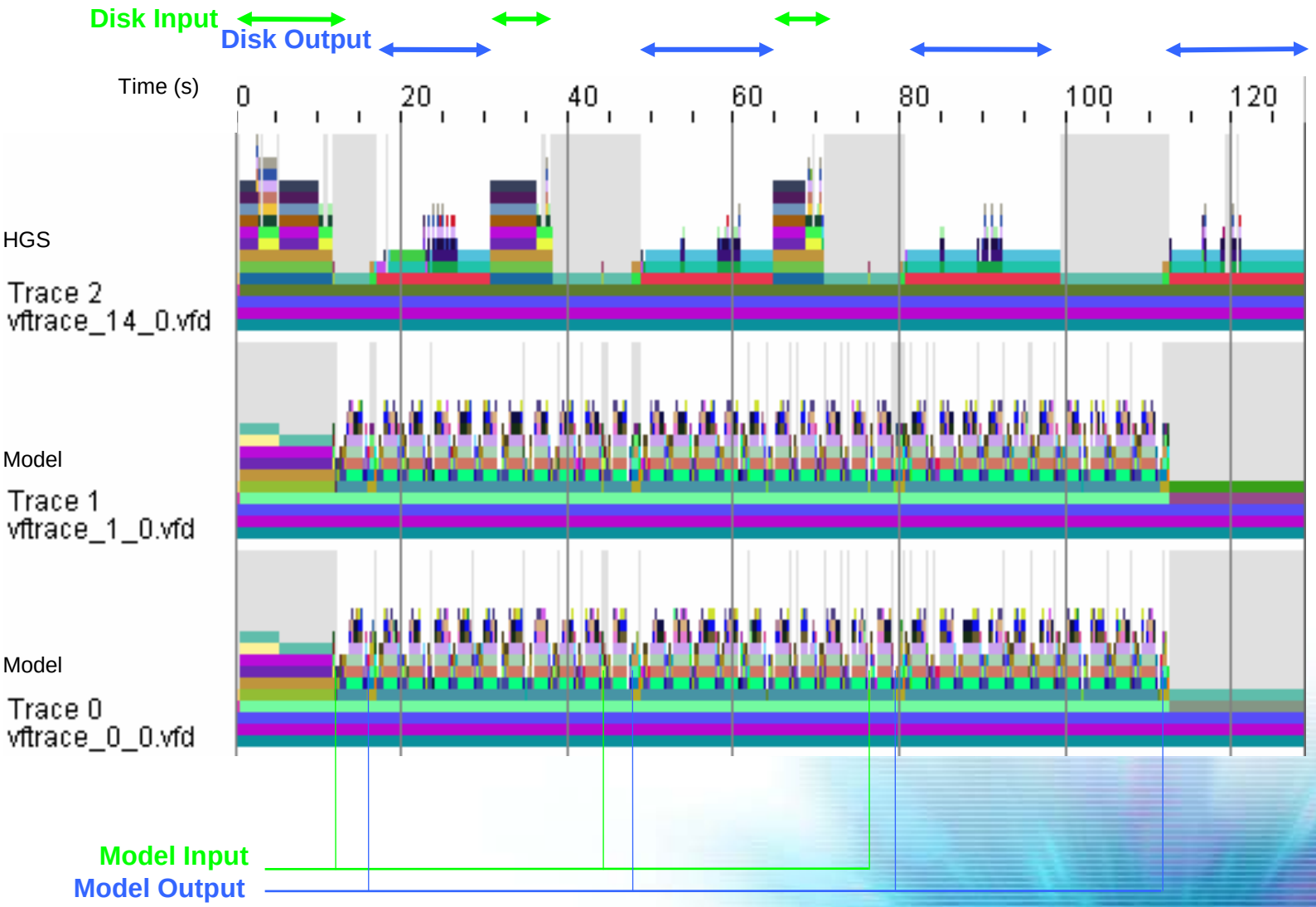
HIRLAM I/O Activity - Sequential



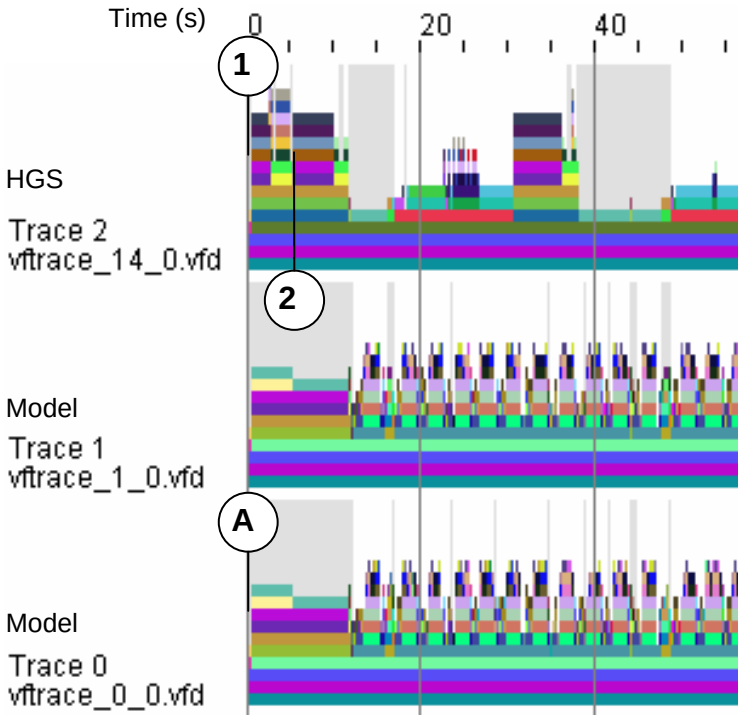
- 3 hours forecast
- 610 x 568 x 40 points
- 15 SX-6 processors (8GF peak)

- Hourly input and output
- Time step 360 seconds
- Graph shows function call stack on time line

HIRLAM I/O Activity - Asynchronous



HIRLAM I/O Activity - Asynchronous



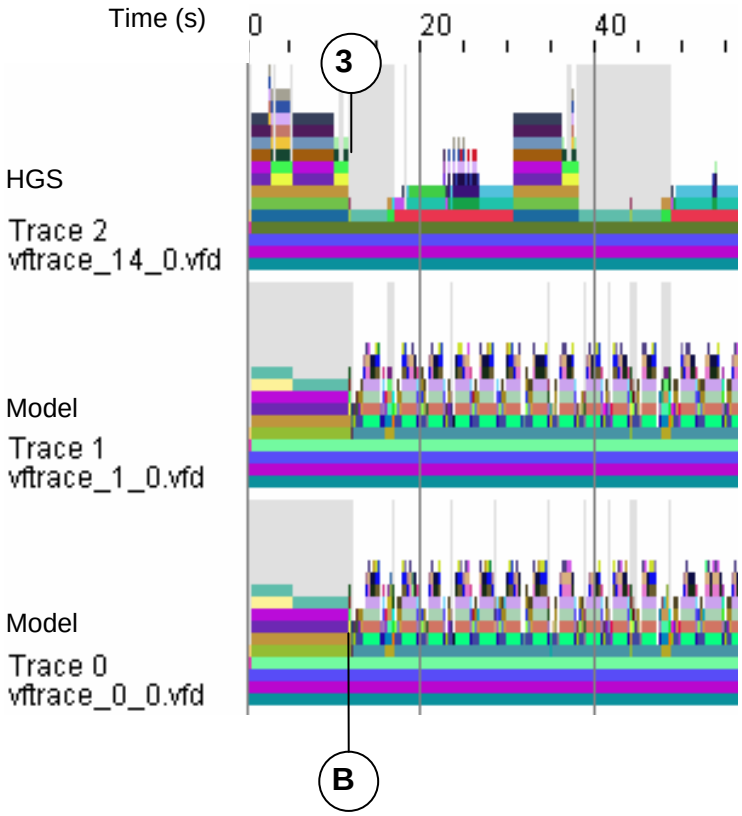
HGS:

1. Receives preread request and reads first input file
2. Reads second input file

Model:

A. Sends HGS request to pre-read first two input files and waits for HGS availability confirmation

HIRLAM I/O Activity - Asynchronous



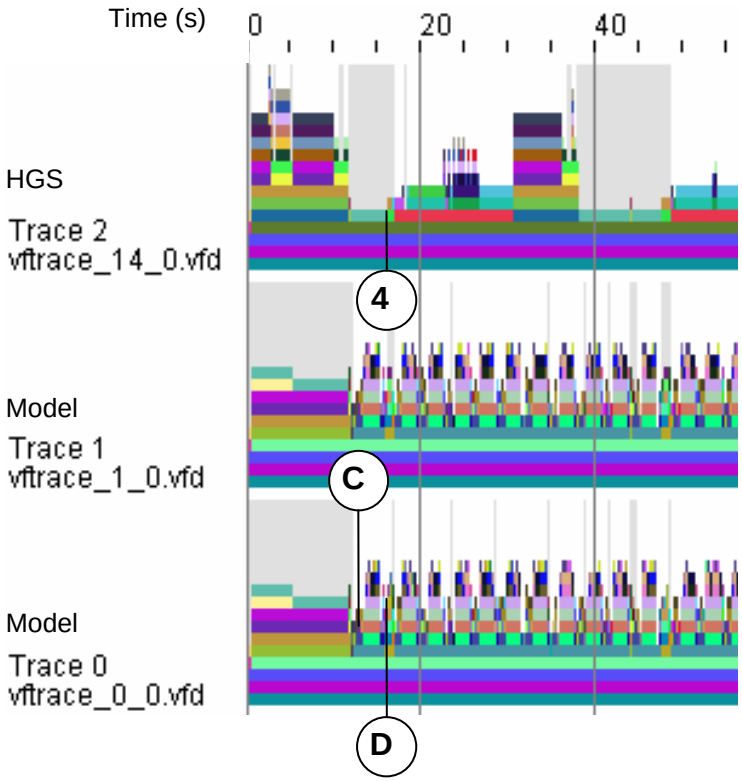
HGS:

3. Sends data from first two input files

Model:

B. Receives data from first two input files

HIRLAM I/O Activity - Asynchronous



HGS:

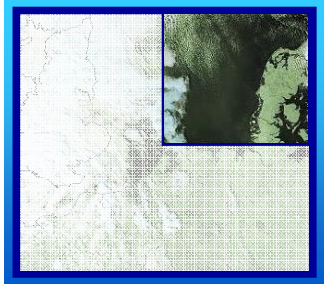
4. Collects data for first output files

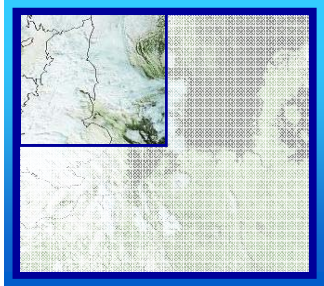
Model:

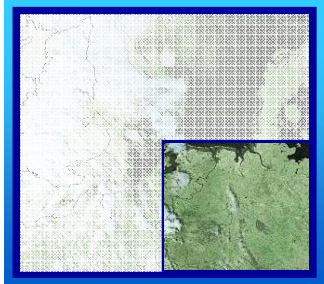
C. First time step

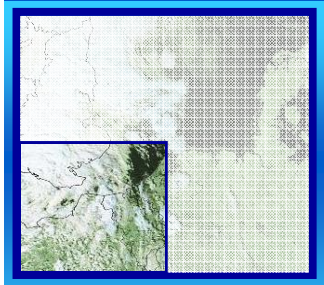
D. Sends data for first three output files

HIRLAM Model and HGS Animation



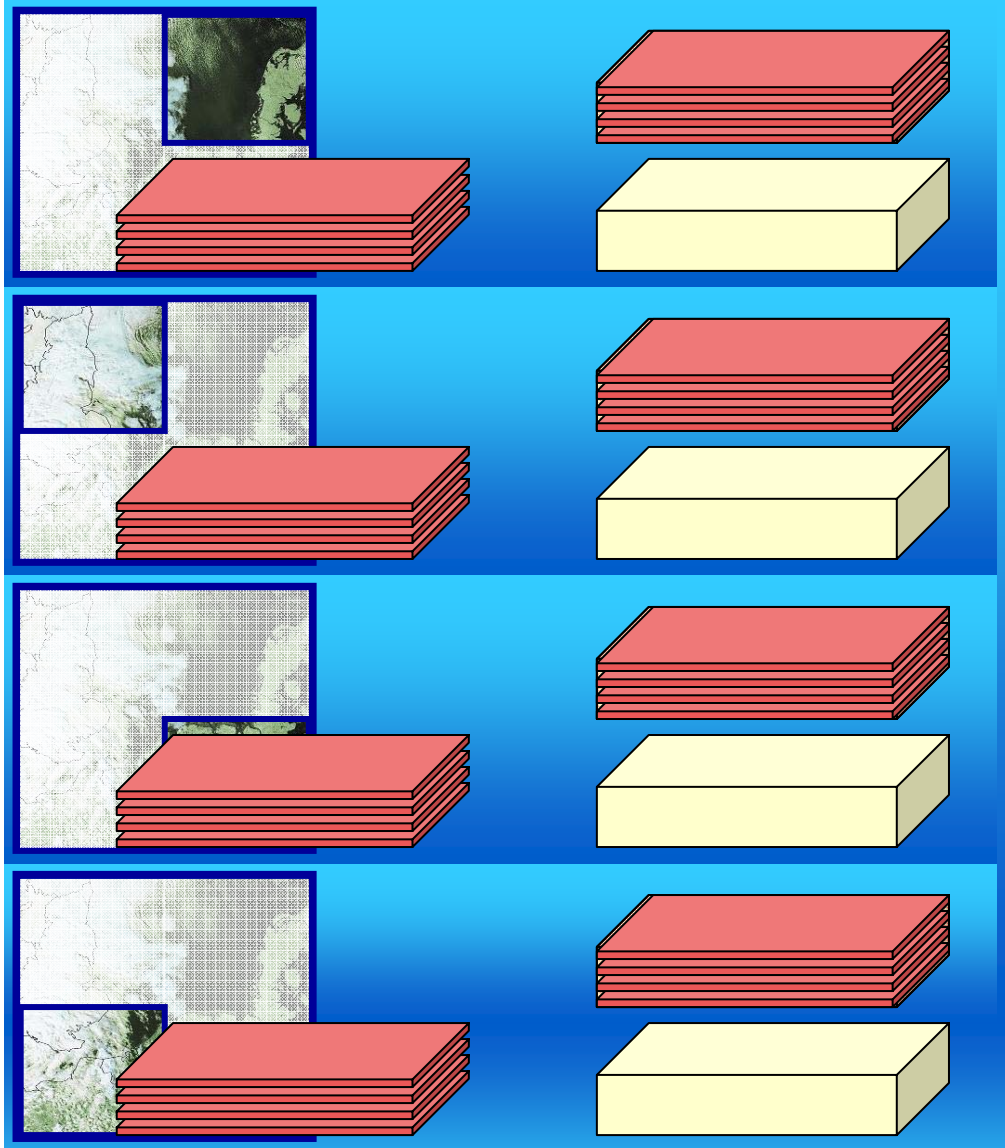






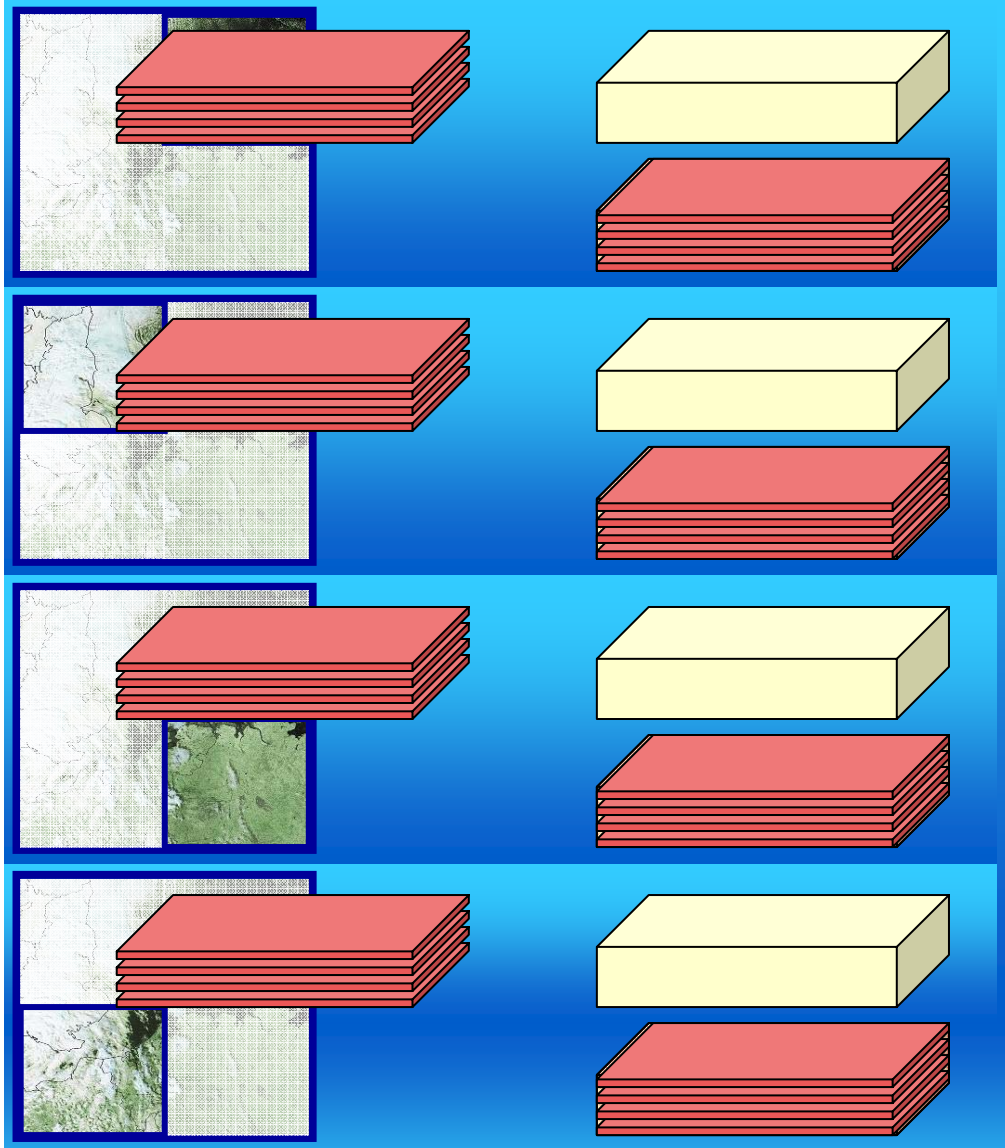
- Demonstration of output (input very similar)
  - Four model sub grids
  - One HGS process
  - Buffer block size: 4 fields (in reality: 100)
- Model running...
- Next slides: model writes output, HGS collects and stores the data

HGS Collects Output

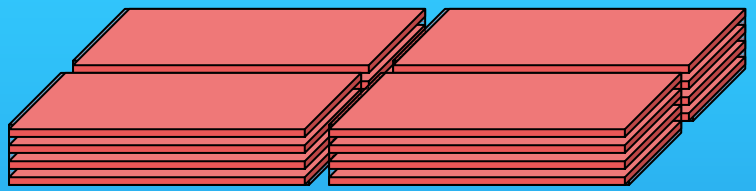


GRIBfile Server

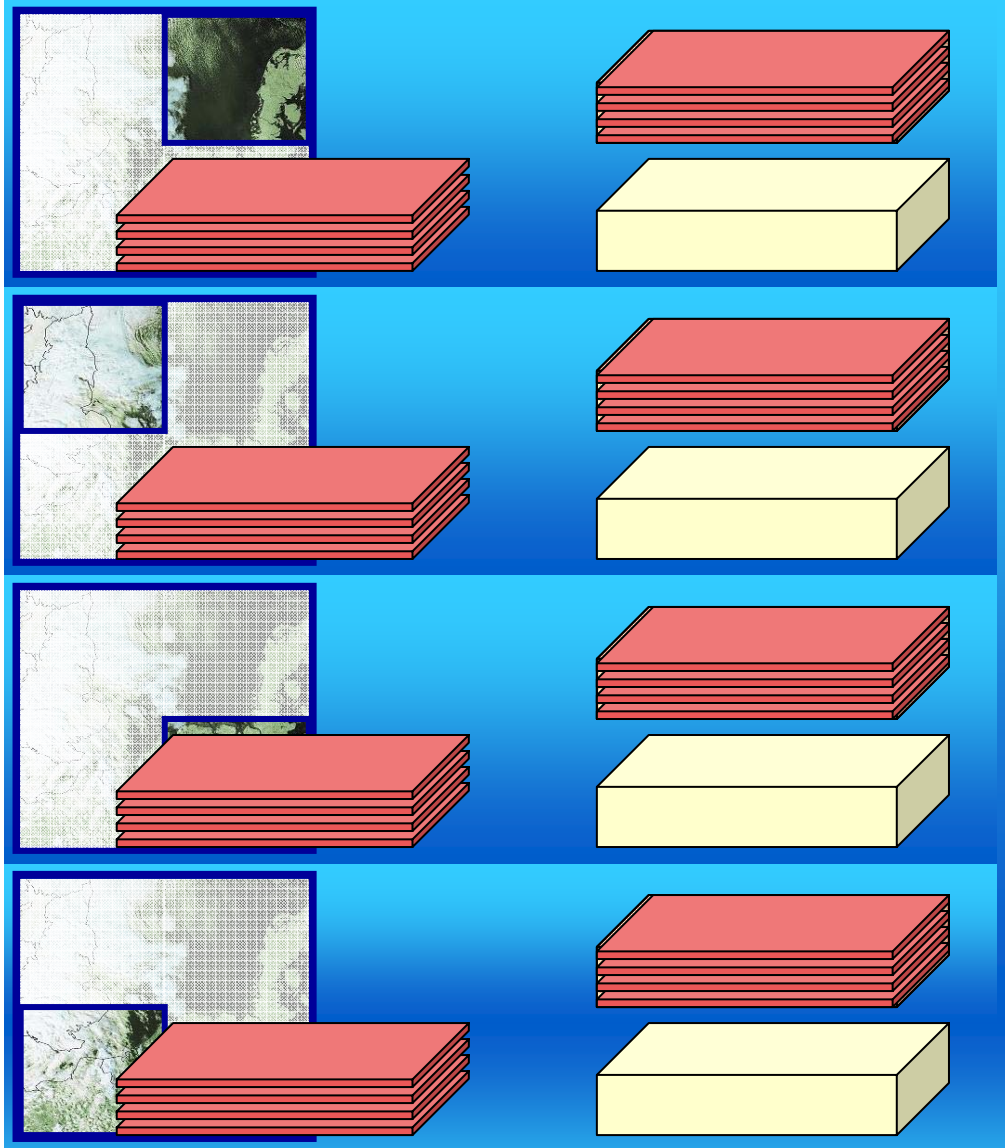
HGS Collects Output



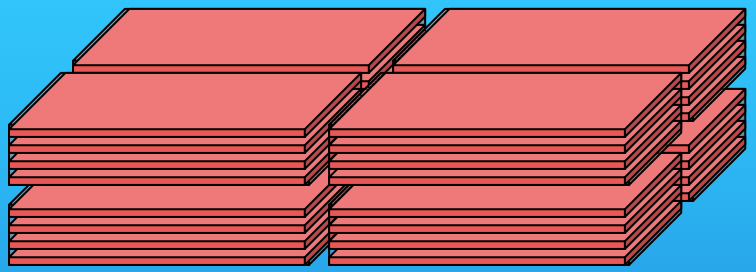
GRIBfile Server



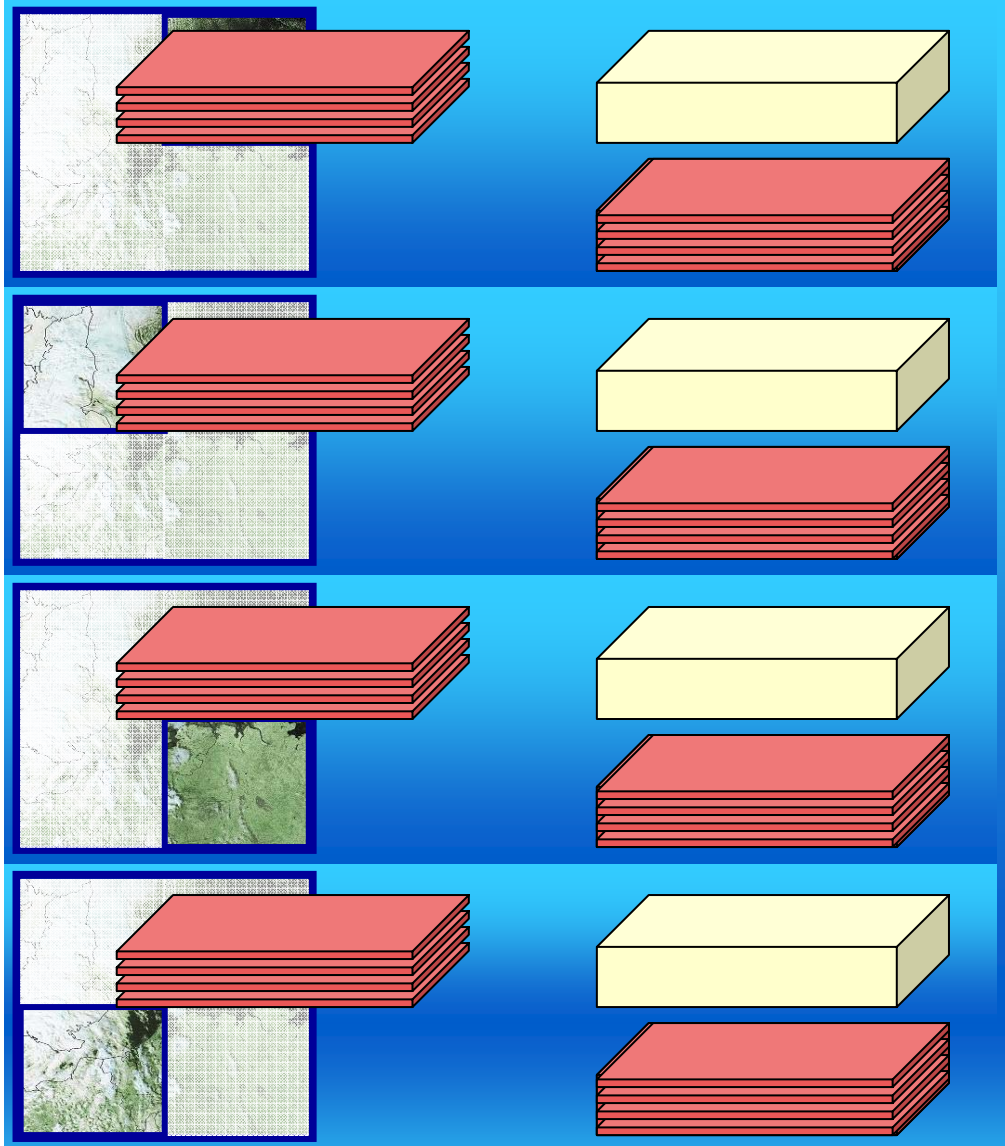
HGS Collects Output



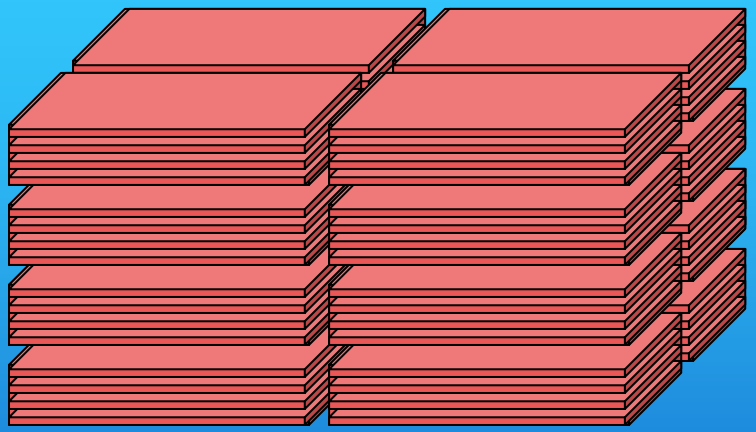
GRIBfile Server



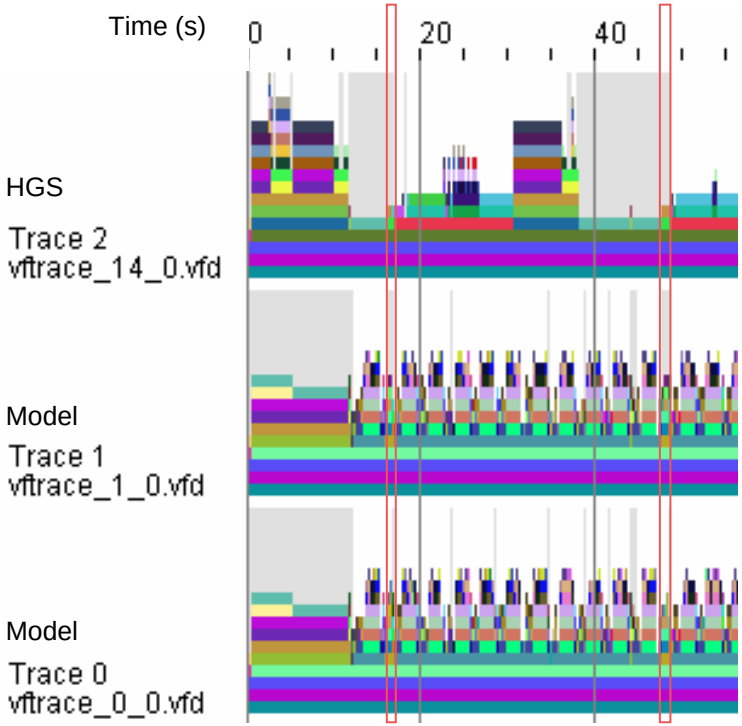
HGS Collects Output



GRIBfile Server



HIRLAM I/O Activity - Output

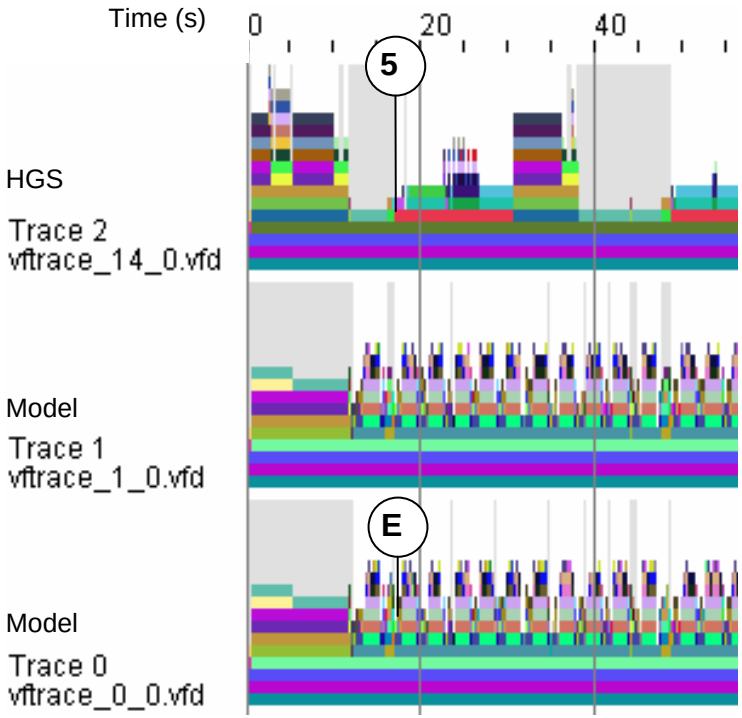


Output:

Short model communication time

Will be even shorter with DMI's new MSLP algorithm

HIRLAM I/O Activity - Asynchronous



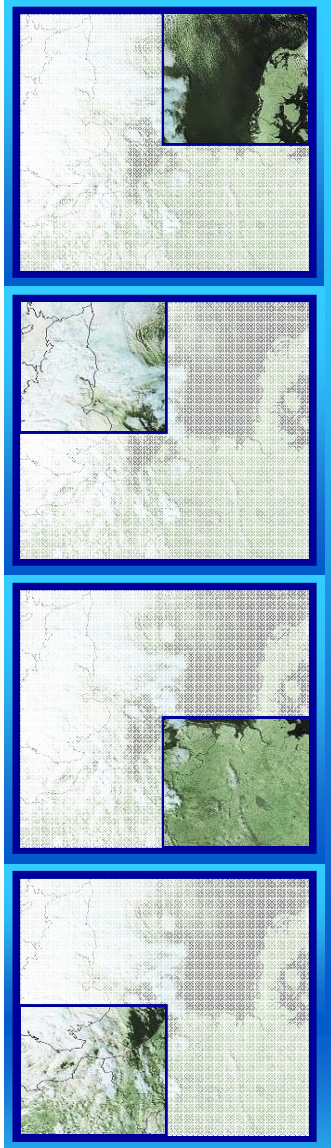
HGS:

5. Writes output files to disk

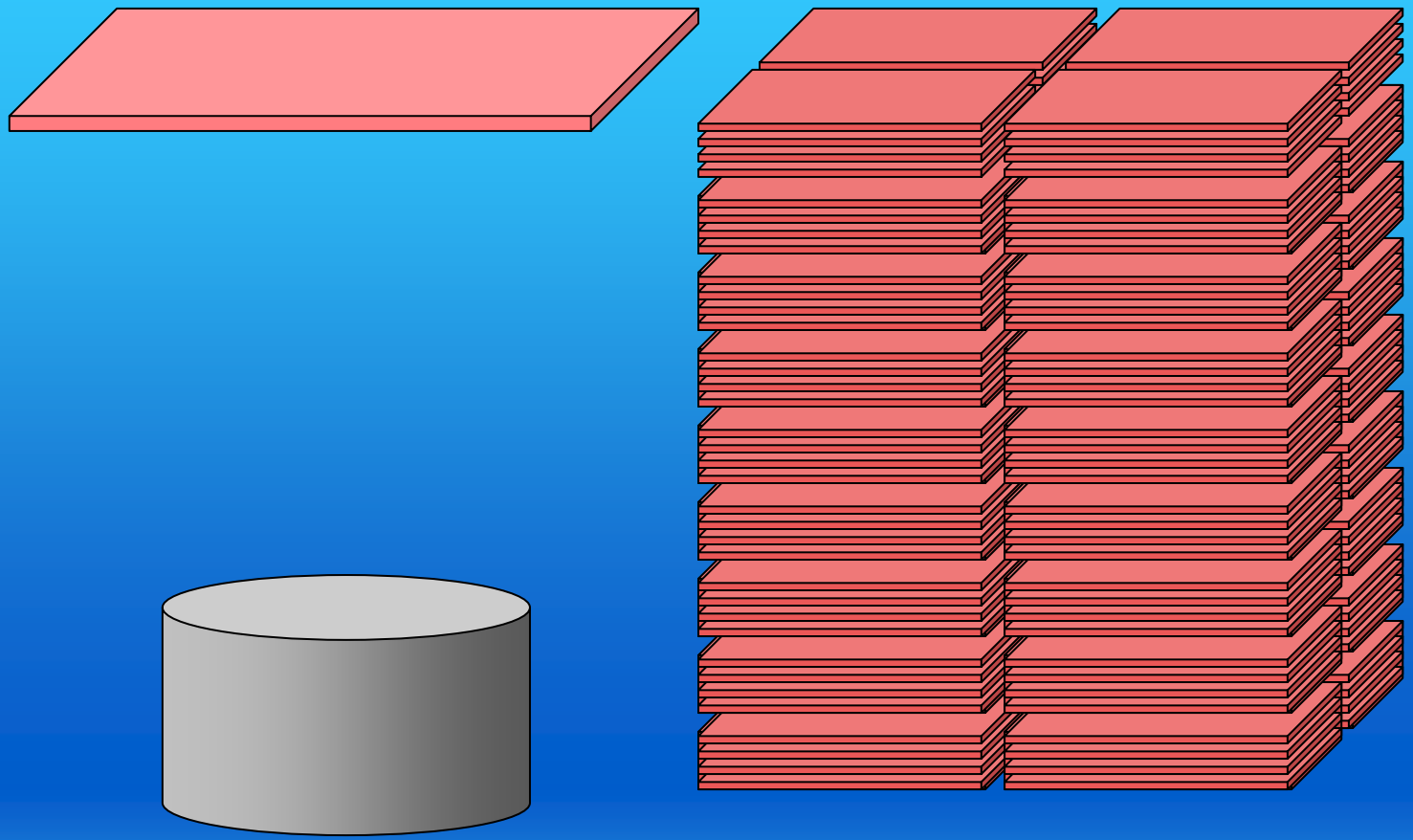
Model:

E. Sends requests to store output and pre-read next input, then continues

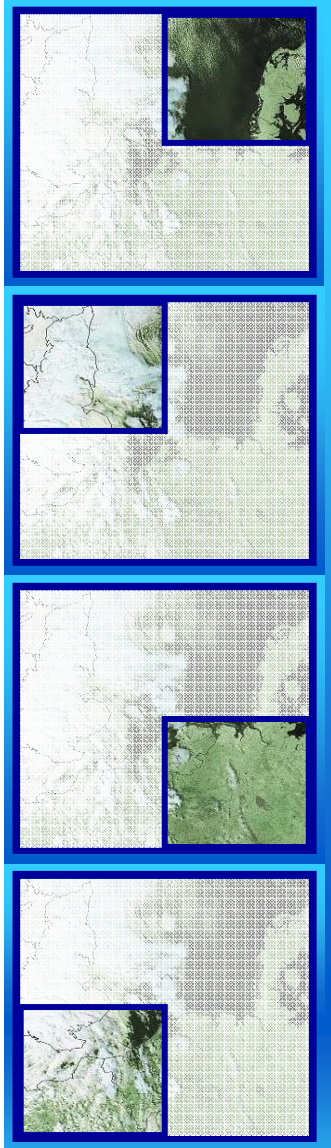
Model continues while HGS Writes to Disk



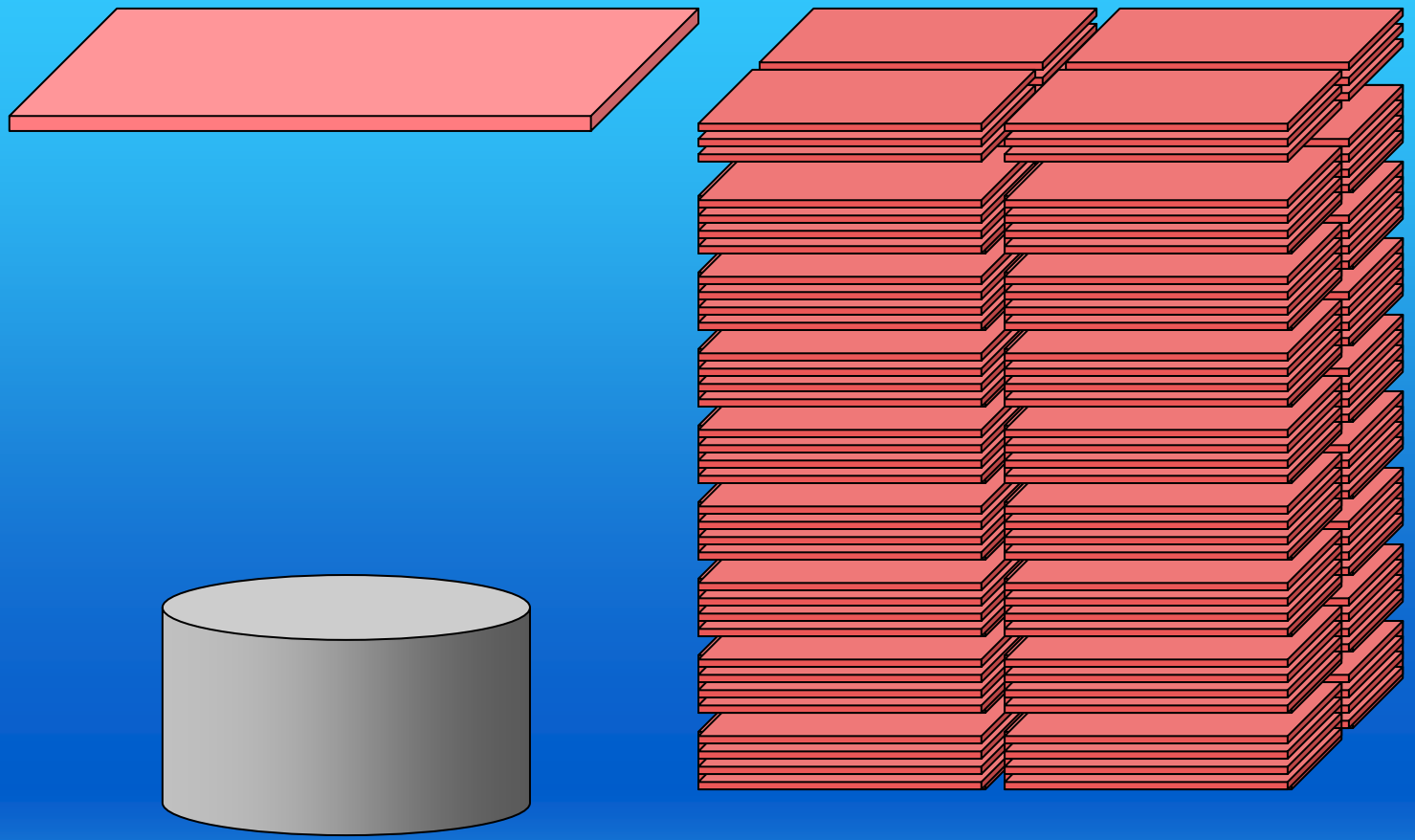
GRIBfile Server



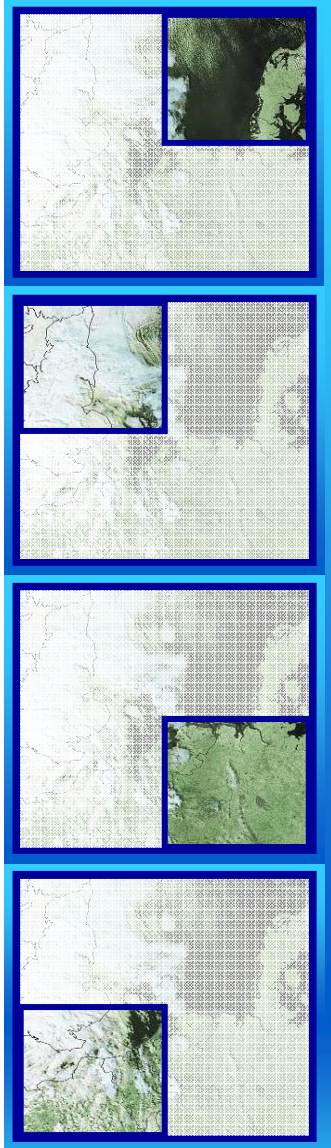
Model continues while HGS Writes to Disk



GRIBfile Server



Model continues while HGS Writes to Disk



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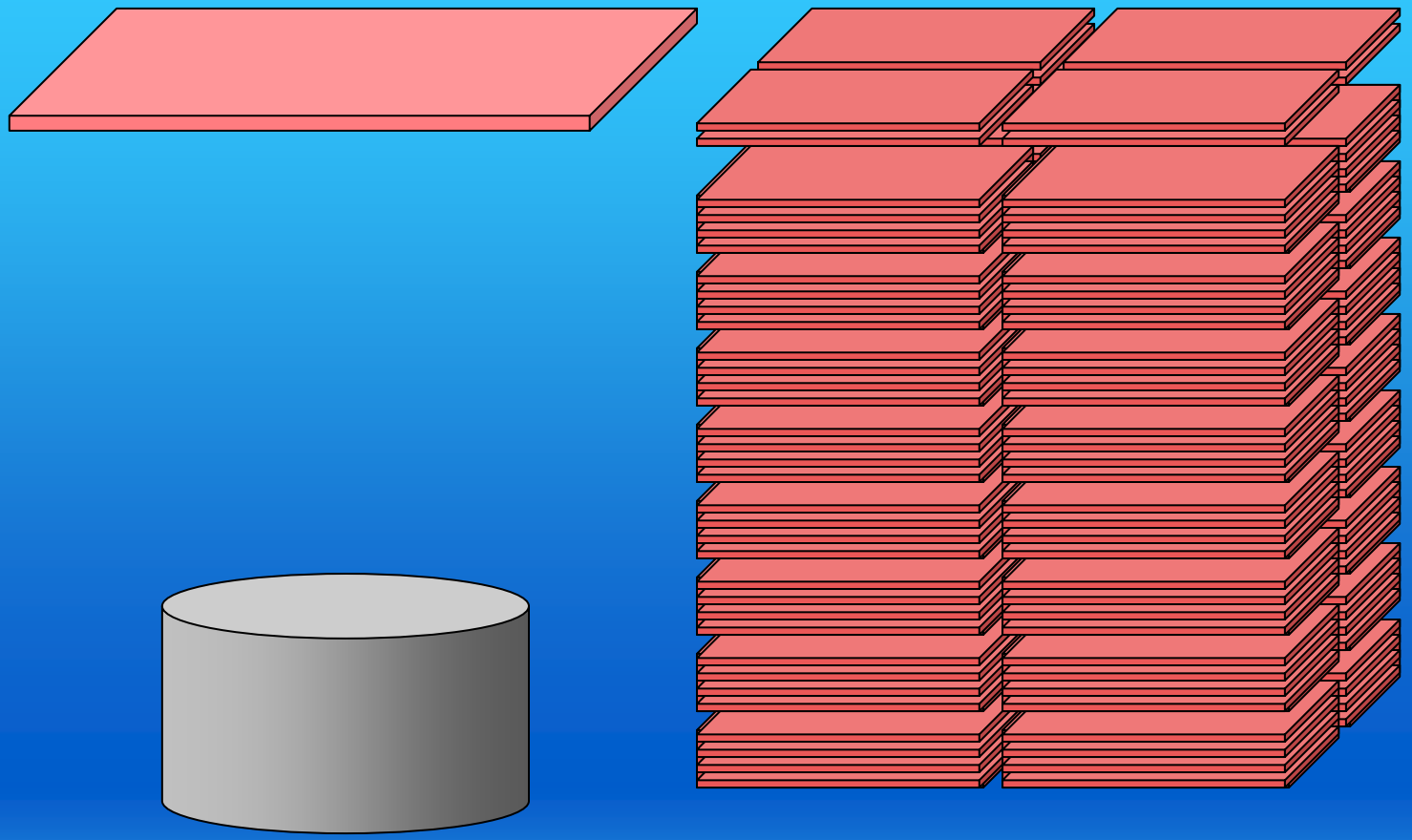

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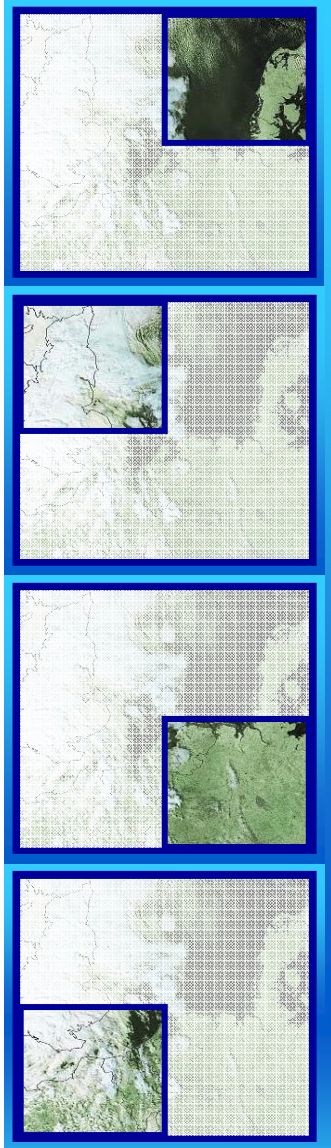

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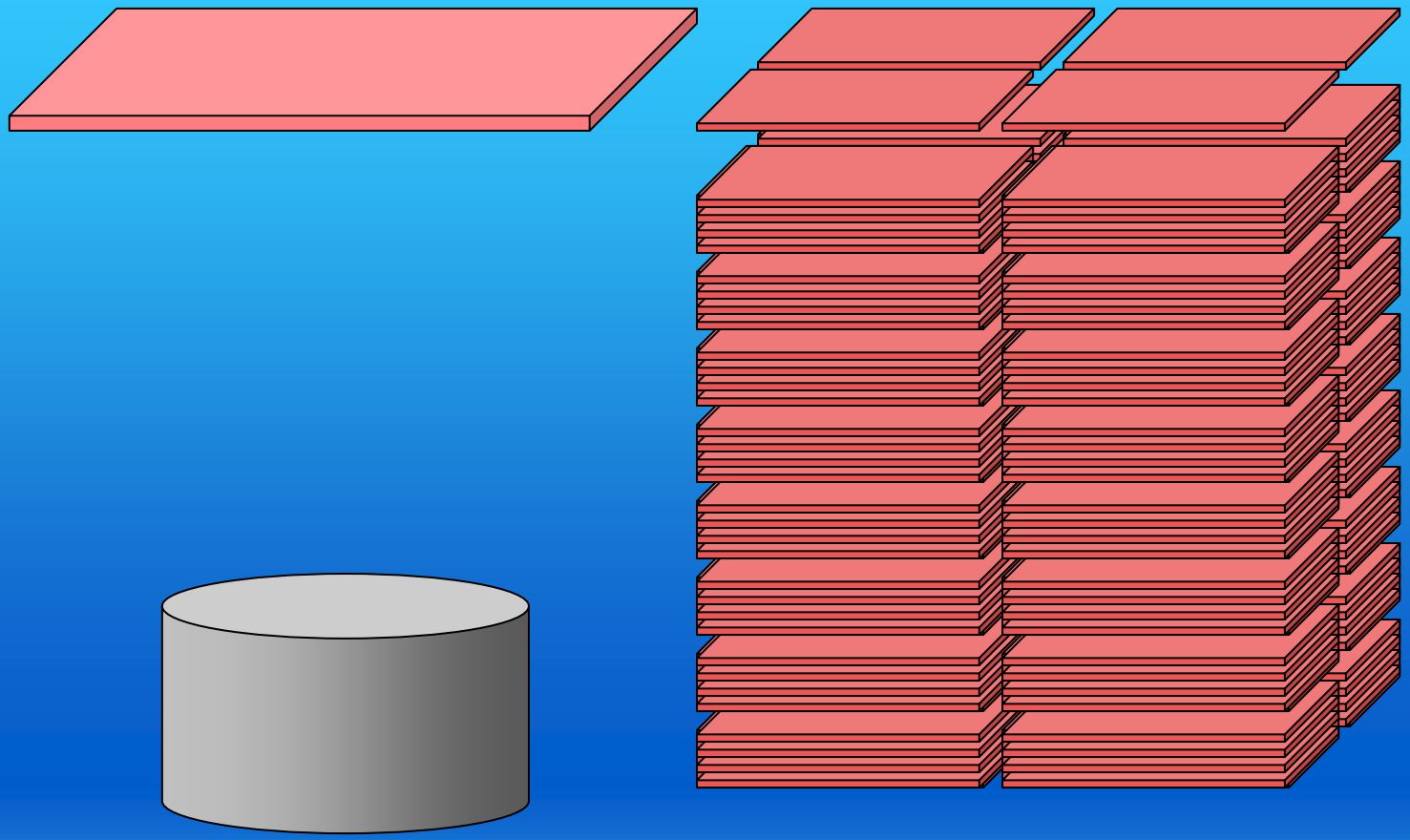

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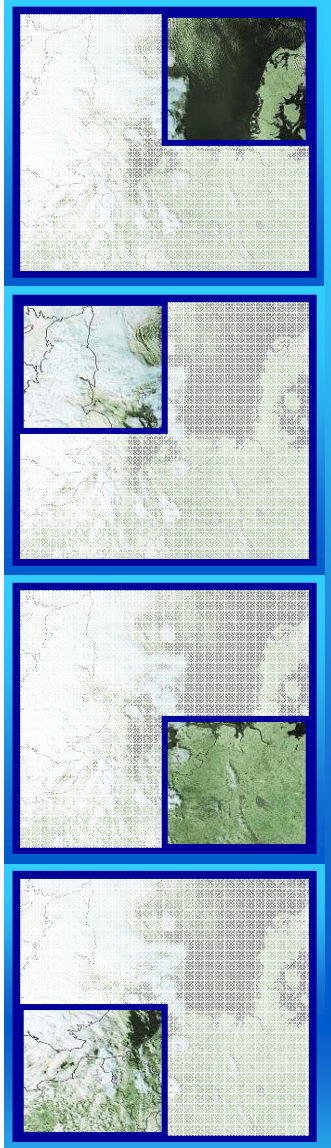

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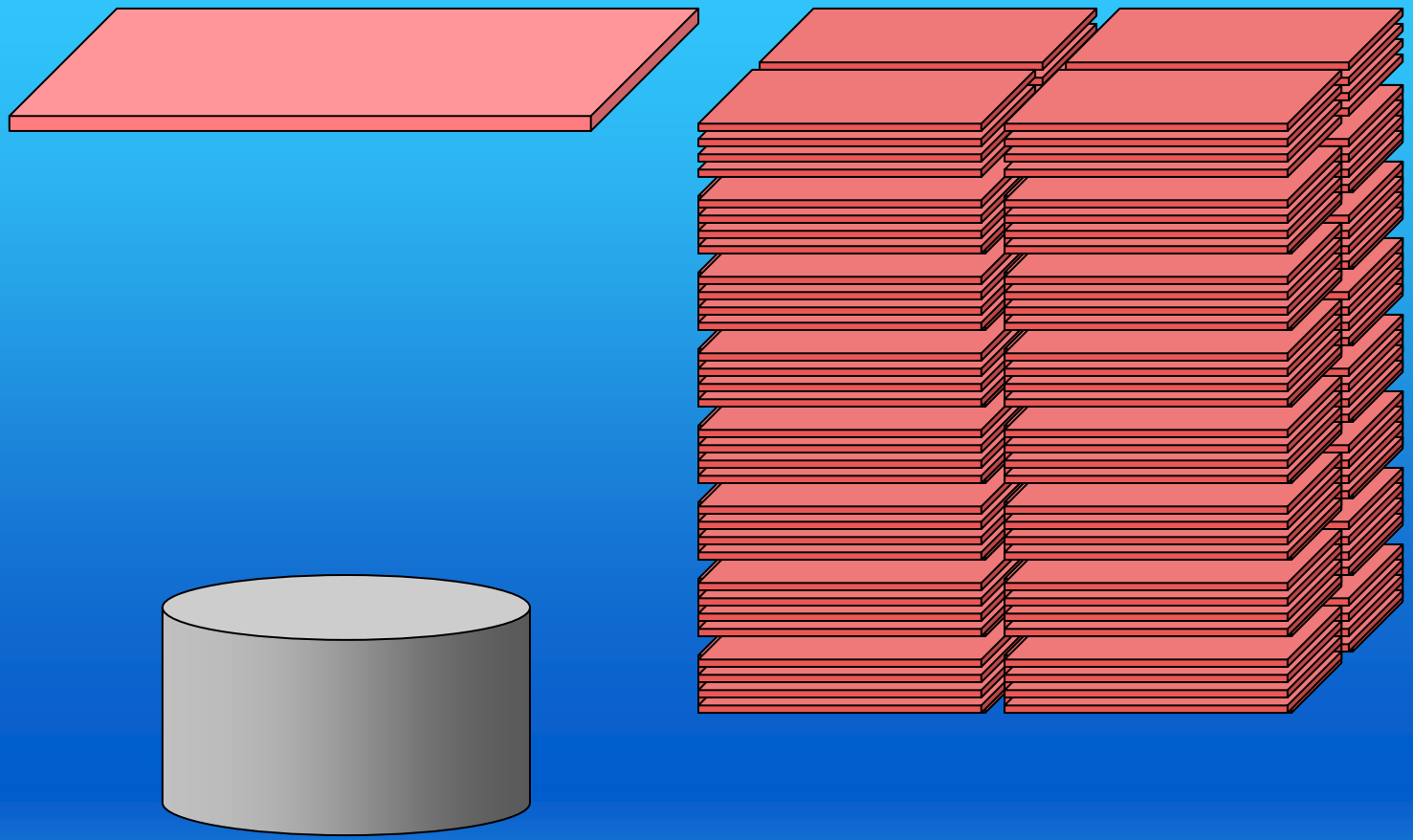
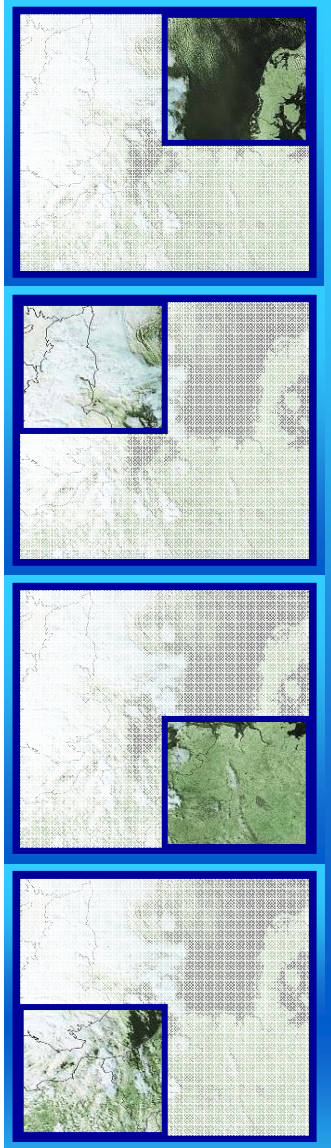
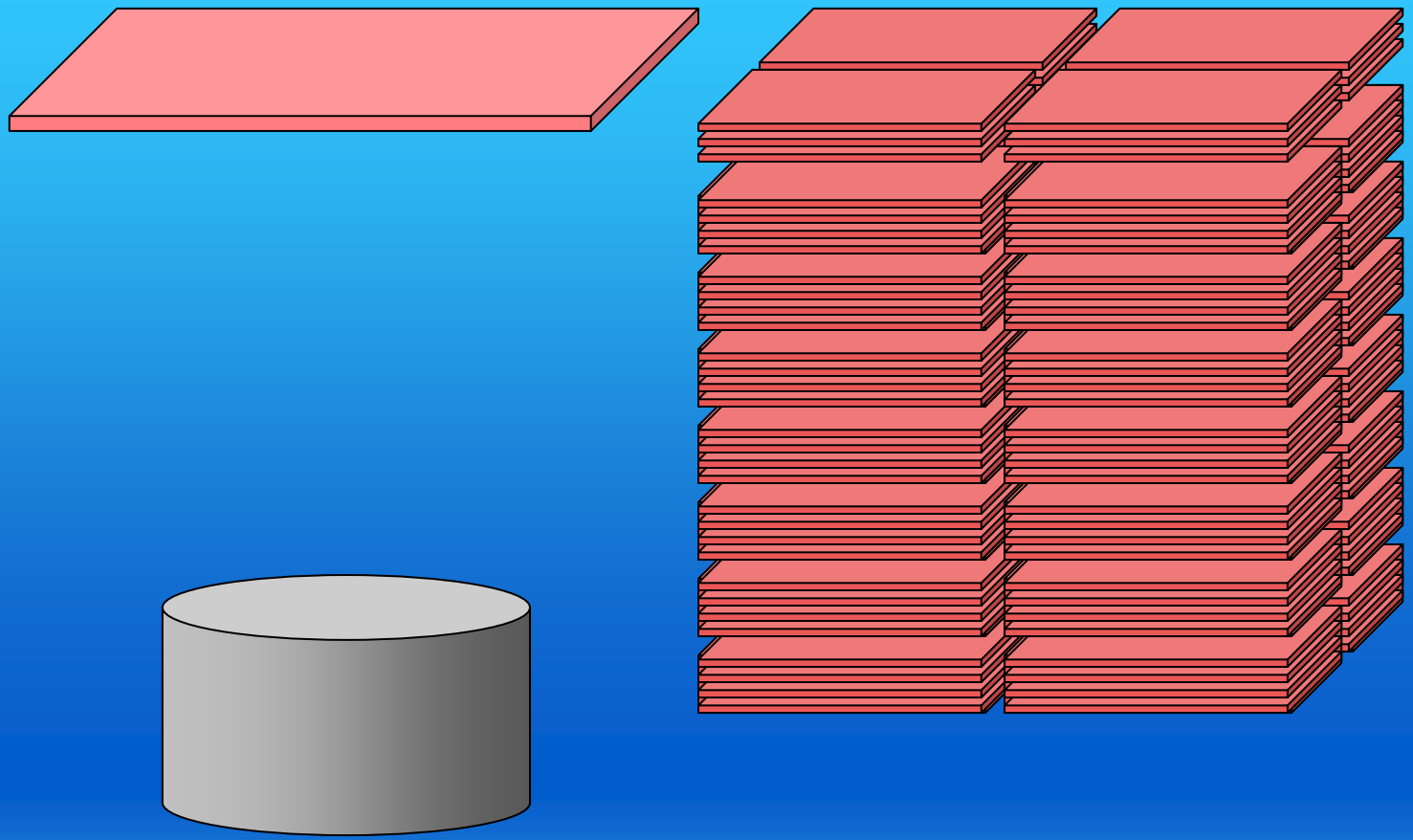


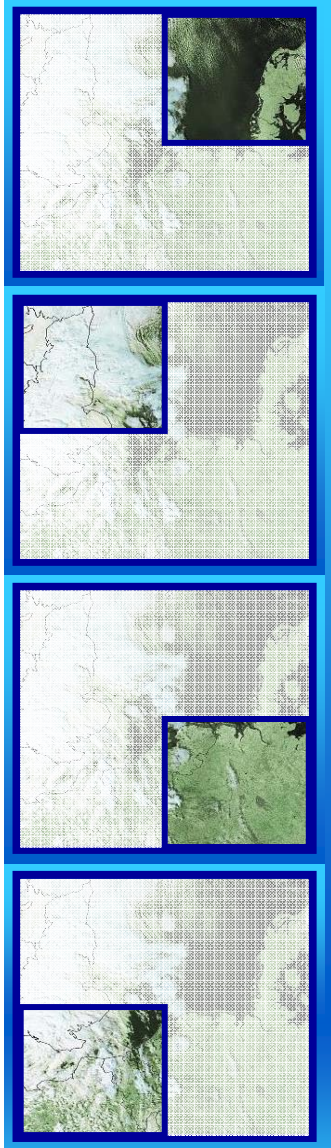
Model continues while HGS Writes to Disk



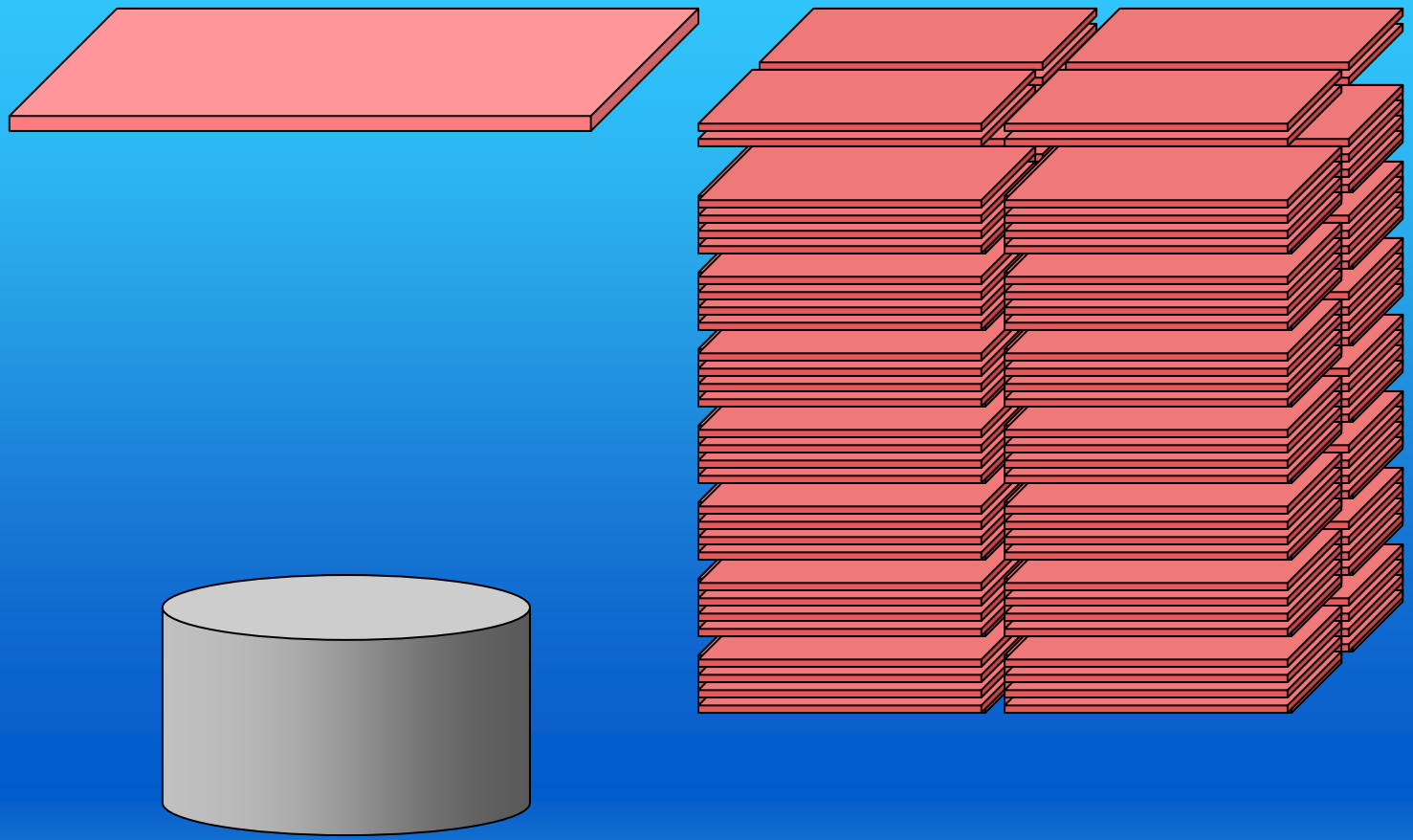
GRIBfile Server



Model continues while HGS Writes to Disk



GRIBfile Server



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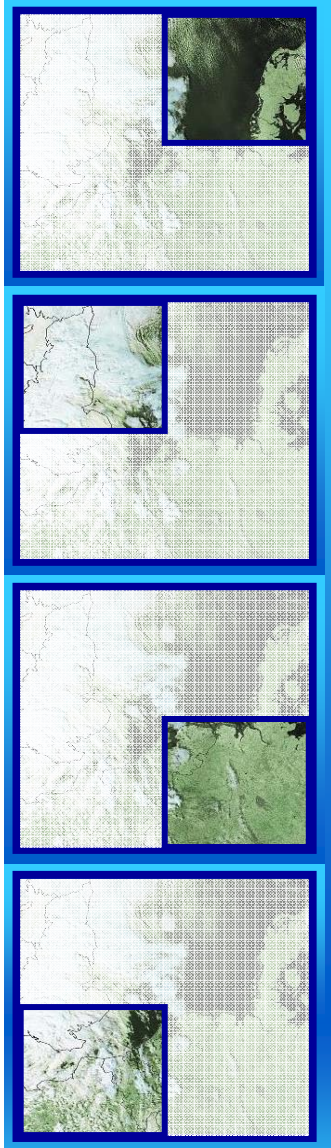
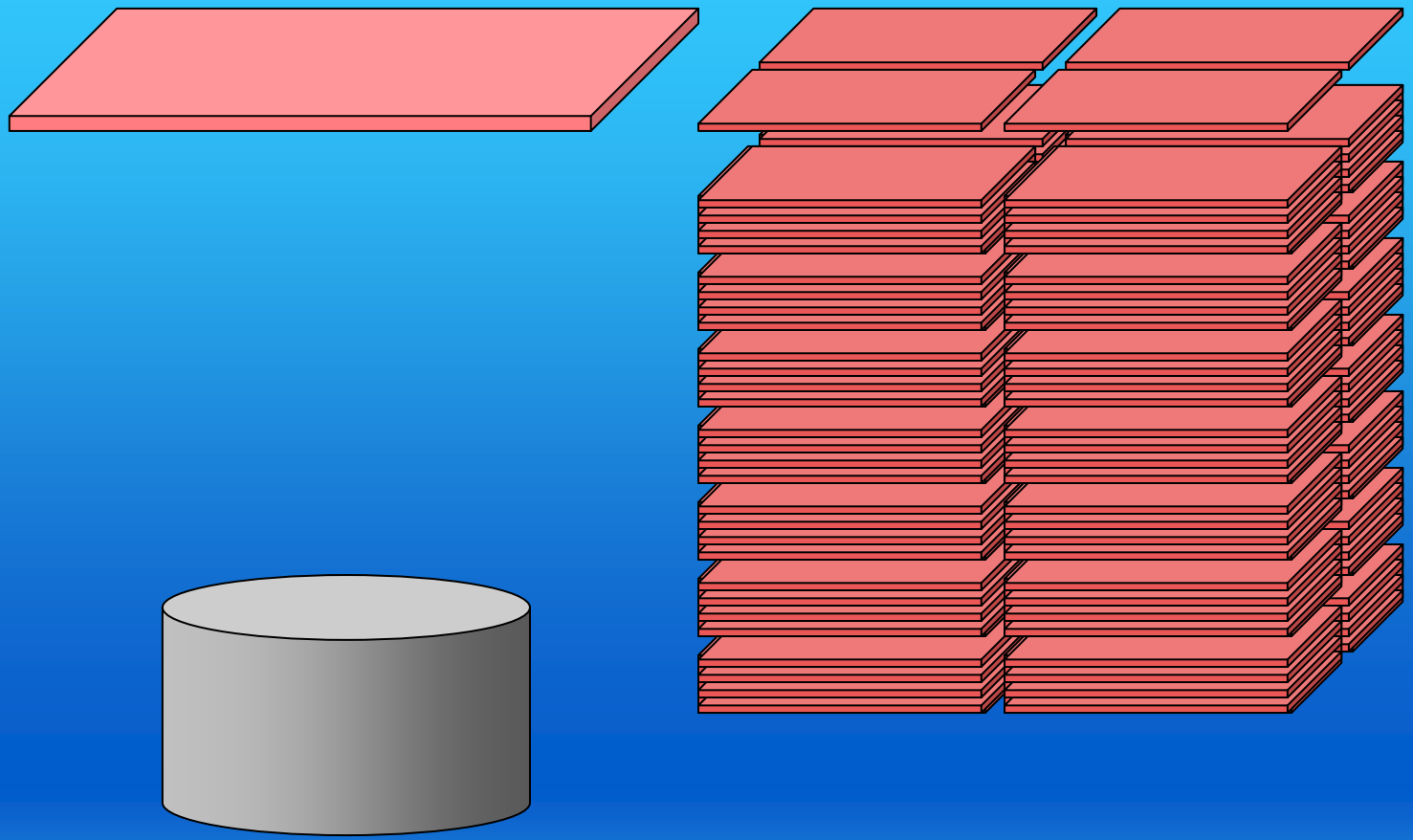
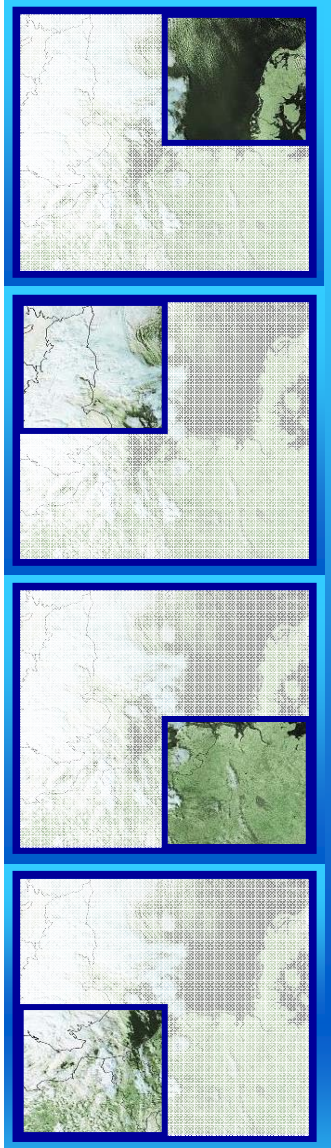


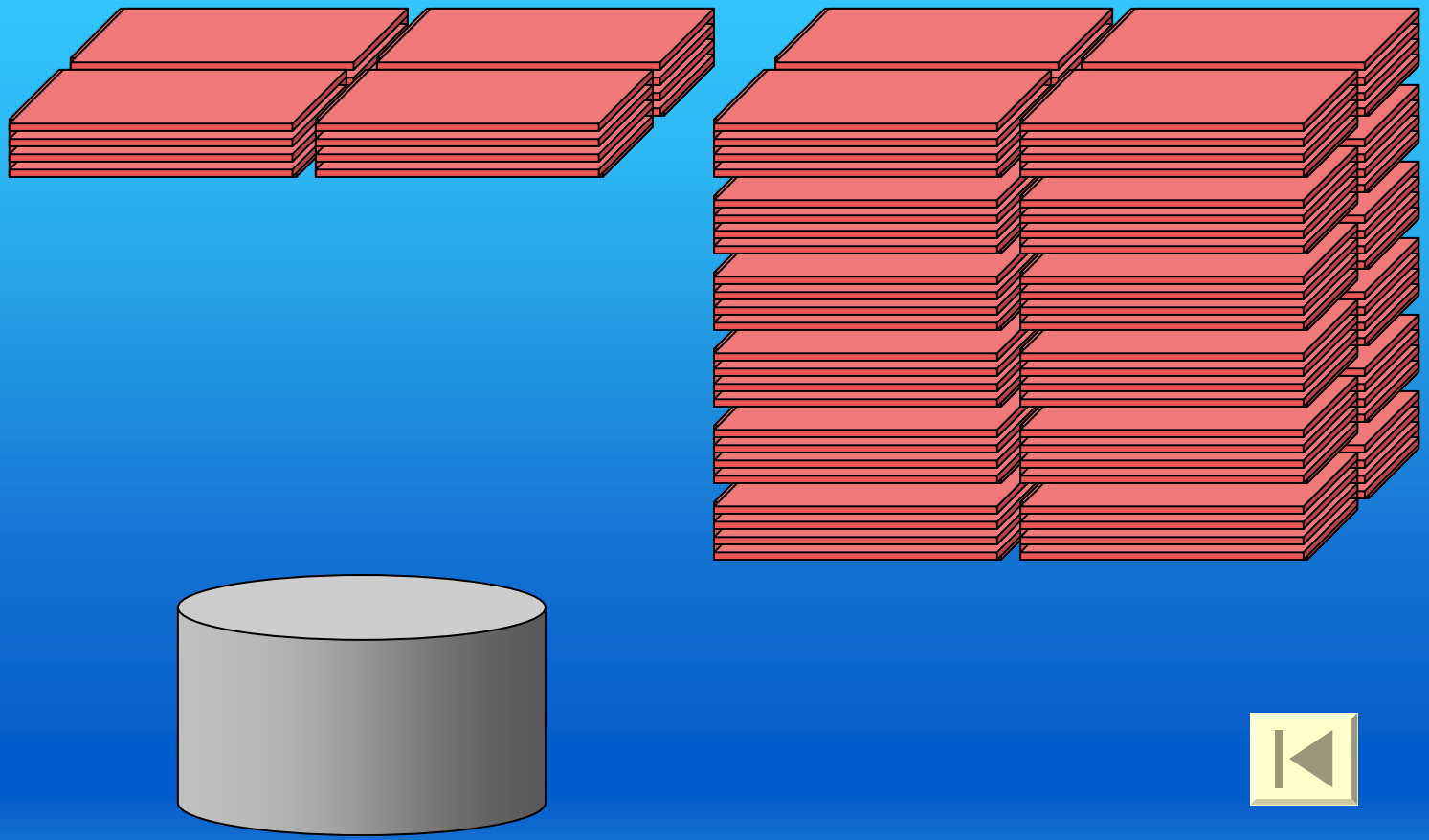
GRIBfile Server



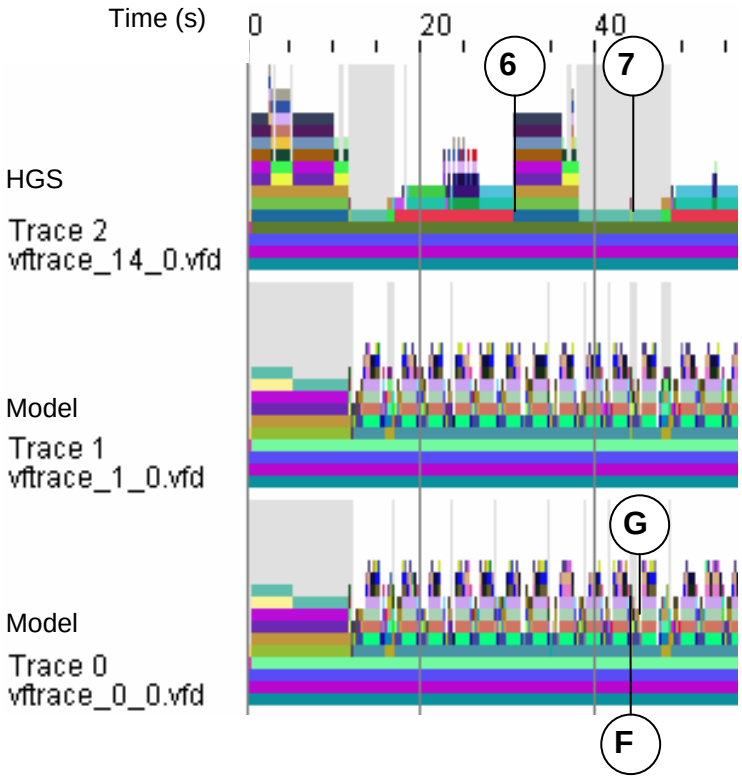
Model continues while HGS Writes to Disk



GRIBfile Server



HIRLAM I/O Activity - Asynchronous



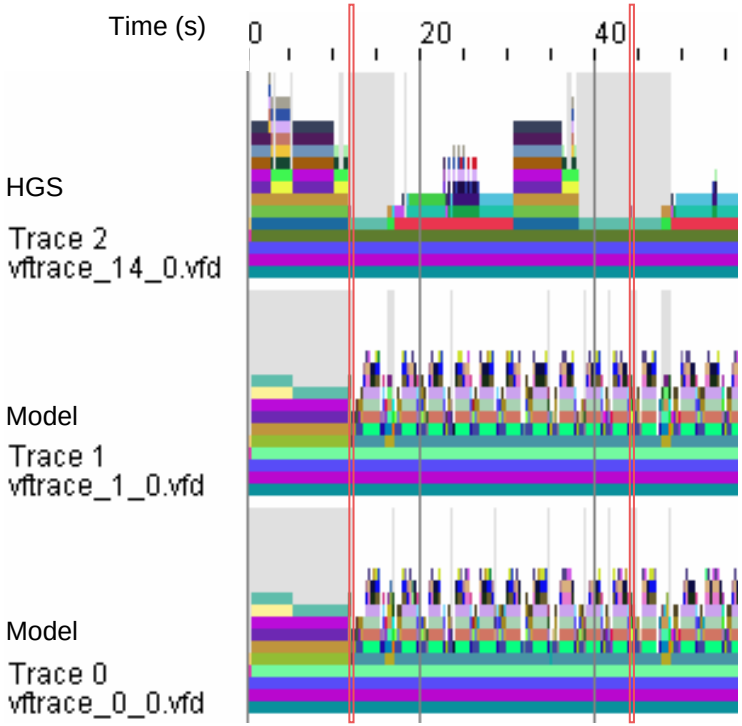
HGS:

6. Reads next input file
7. Sends input data

Model:

F. Sends requests to receive input data
G. Next time step

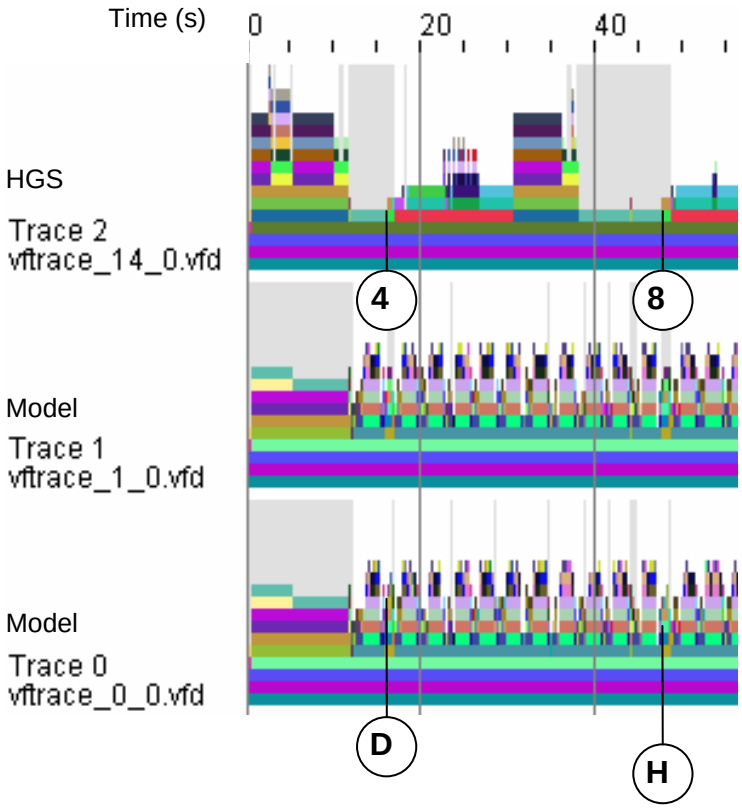
HIRLAM I/O Activity - Input



Input:

Very short model communication time

HIRLAM I/O Activity - Asynchronous



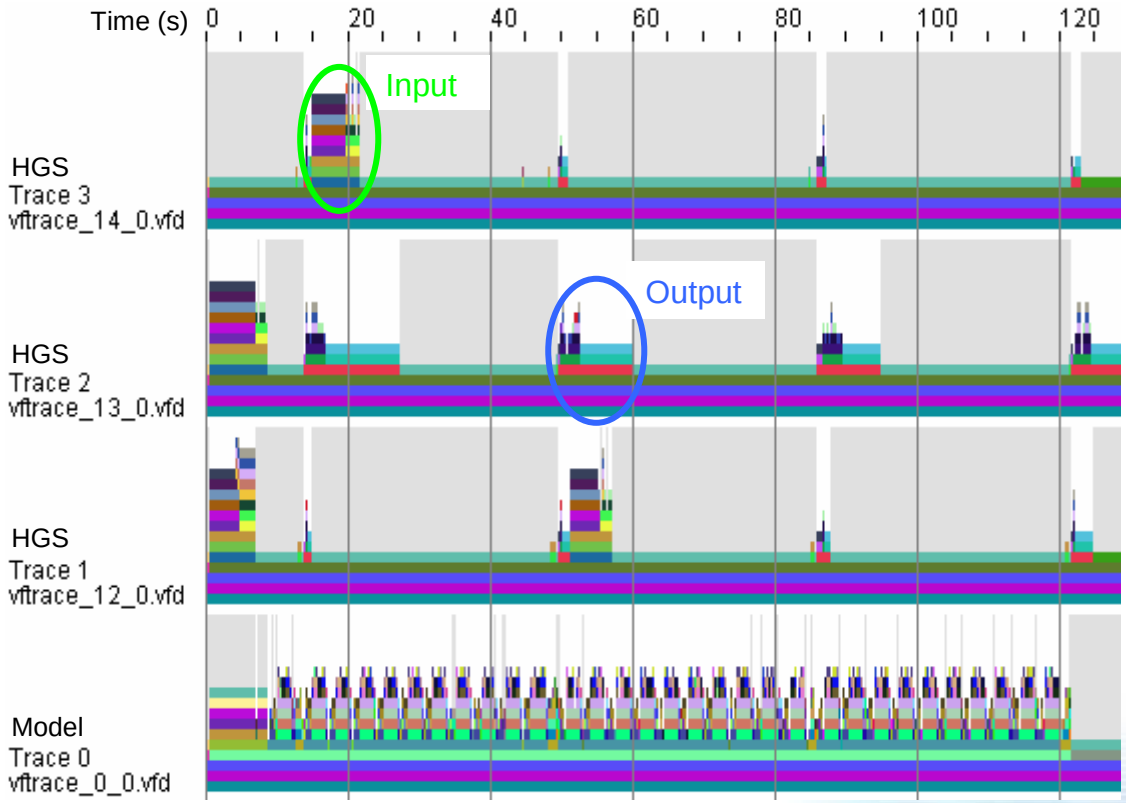
HGS:

8. Collects output data (repeat of 4)

Model:

H. Sends output data (repeat of D)

Multiple HGS Tasks Supported



Multiple HGS tasks: 3 HGS, 12 model (1 shown)

HGS Documentation

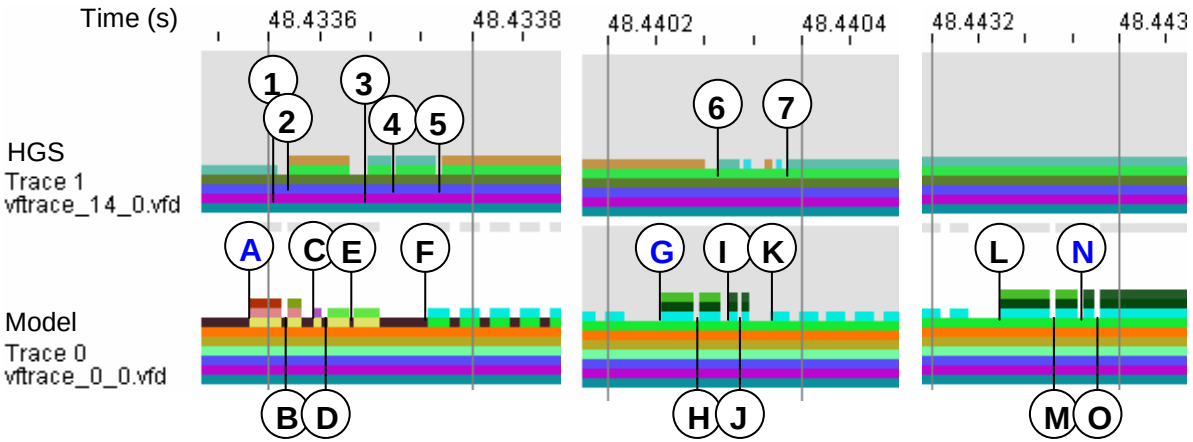


Figure 4.4 – Model sends output data - overview

- More detailed descriptions in HGS documentation
- To be published as HIRLAM Newsletter, see: http://hirlam.knmi.nl

- Graphs generated with Vftrace, free tool for NEC SX users, see http://vftrace.jboerhout.nl

Questions?

- Thank you!