# History of the partnership between SMHI and NSC

Per Undén

SMHI

# Outline

- Pre-history and NWP
- Preparations – parallelisation
- HPD Council
  - Decision and early developments
- Climate modelling
- Other applications
- HPD Project at SMHI
- Further experiences and developments
  - Conclusions

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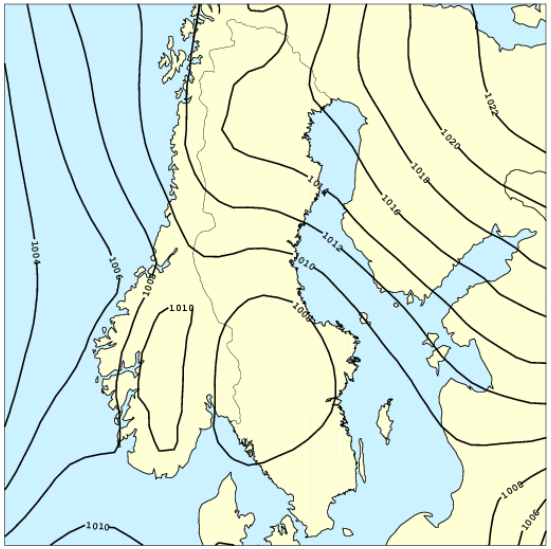
# Pre-history : Swedish NWP before NSC

- Numerical Weather Prediction (NWP) came to Sweden 1954
  - Started in 1949 Eniac in US (J v Neuman, Fjörtoft, Rossby)
  - 1954 at Stockholm University Inernational Met Institute, Air Force
  - BESK computer
  - One level model, initial data from radio sondes
  - 1-2 day forecasts of general flow
- SMHI involved and own computers
  - Data Saab D21 (1962, own one 1964)
  - D22, D23 (1975) (-> 0.1 MFlop/s
  - Univac 1121 (-> 0.3 )
  - Vax computers (1980's)
- SMHI and Swedish Air Force
  - CONVEX 3840 4 vector processors (1992-1997) (300 MFlop/s)
  - Security issues – communication SMHI-underground base

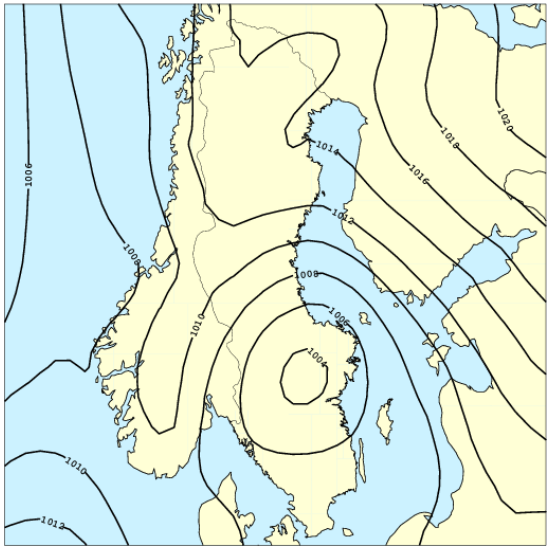
# Numerical Weather Prediction SMHI

initial state



$T,u,v,w,q,p_s$

forecast



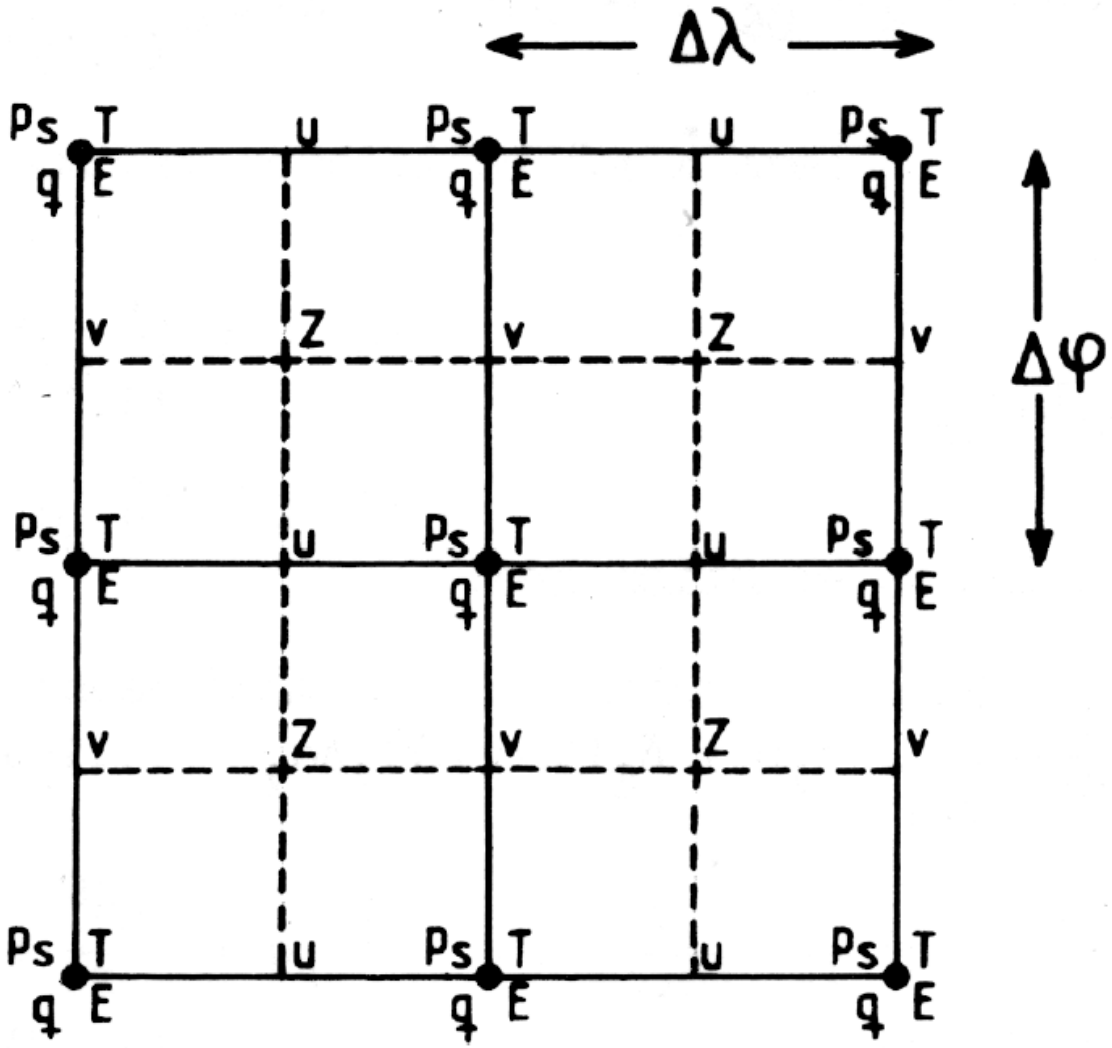
Continuity $$\therefore \frac{\partial \rho}{\partial t} = -\nabla.(\rho \tilde{V})$$

Gas law $p=\rho RT$

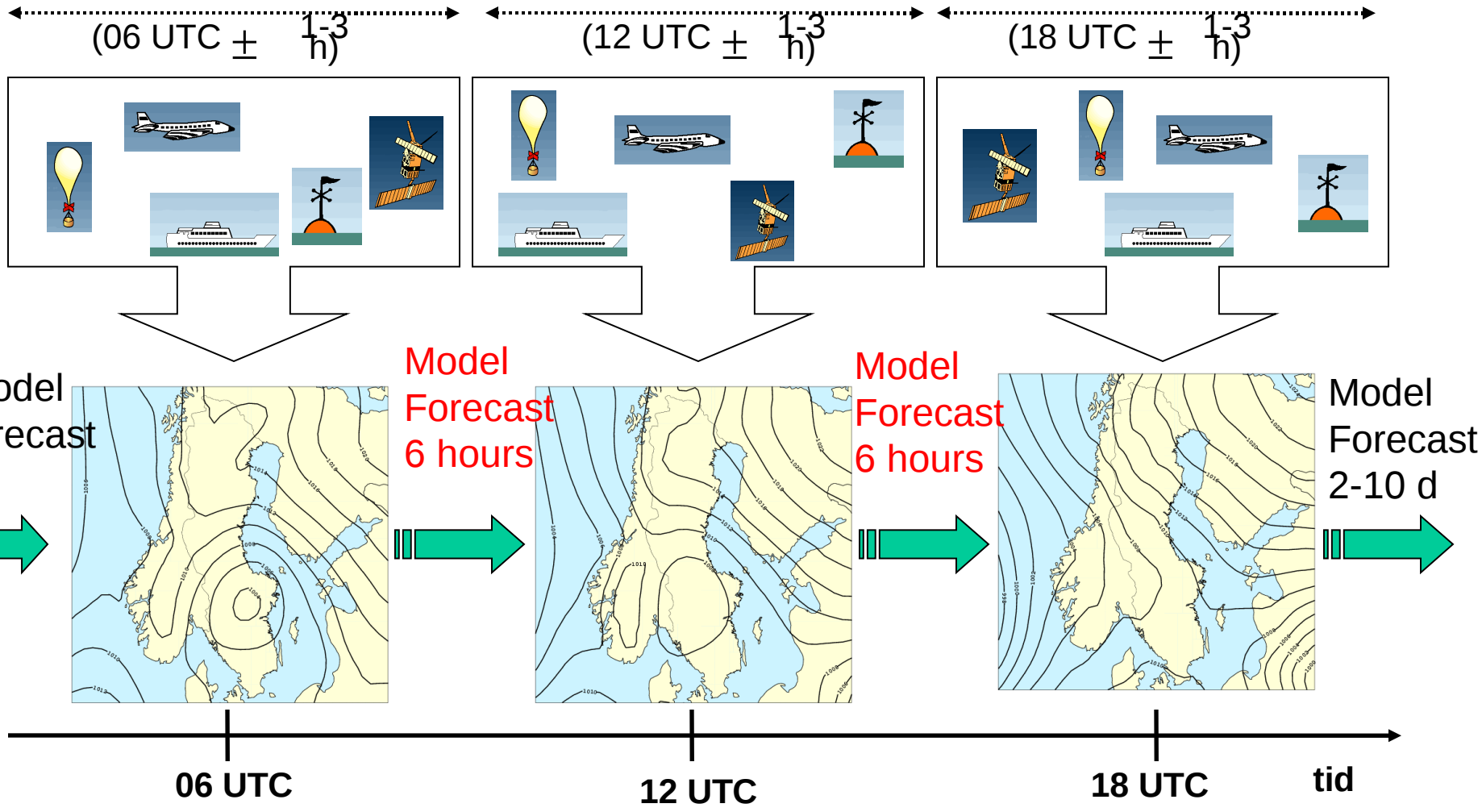
Momentum $$\frac{d\tilde{V}}{dt} = -2\tilde{\Omega}\times\tilde{V} - \alpha\nabla p - g\tilde{k} + \tilde{\tau}$$

Humidity $dq/dt = E - C$

Temperature $$c_p \frac{dT}{dt} = Q + \frac{RT}{p}\omega$$


Δλ
Δφ
Ps
T
u
q
E
v
Z

# NSC 20y Intermittent data assimilation SMHI




Surface and upper air and satellite data

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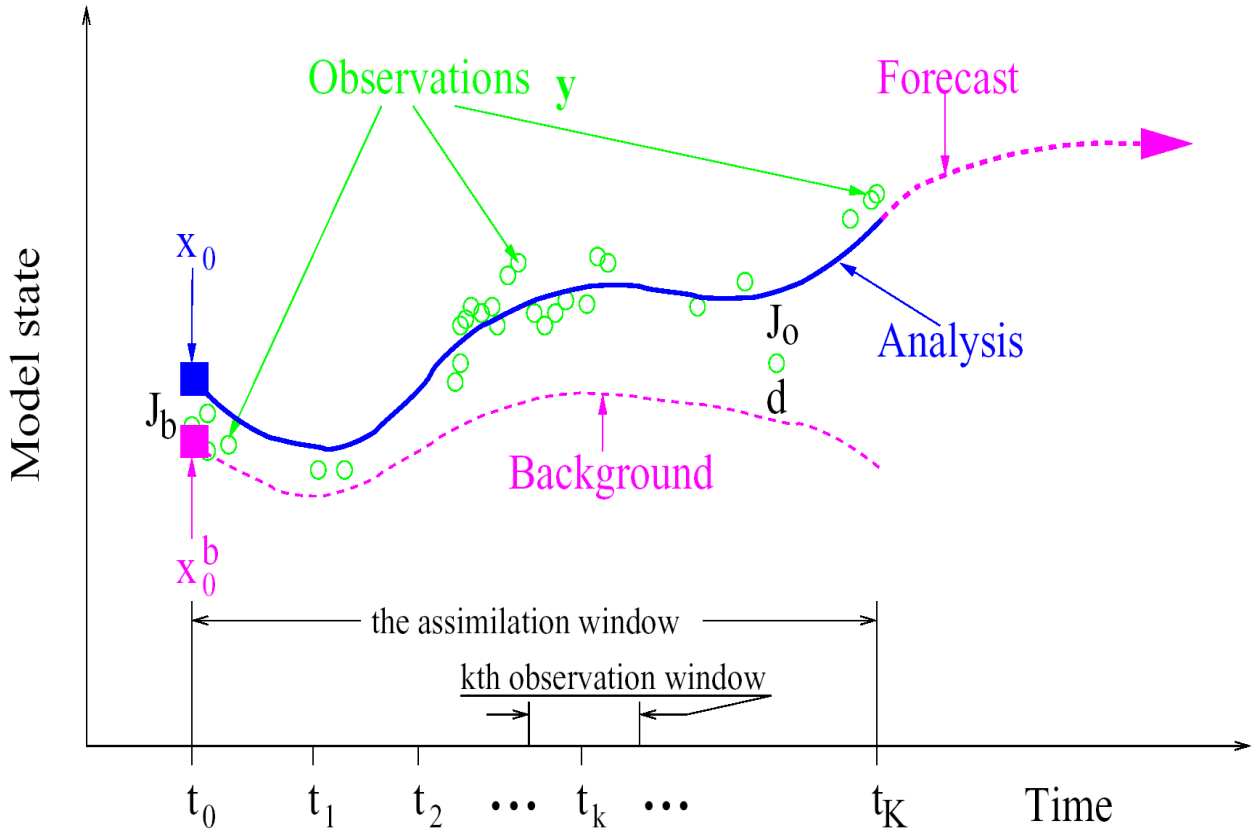
# 4 Dimensional Variational Data Assimilation
## Iterative fitting of a Forecast trajectory to observations
## Over a time window 6-12 hours



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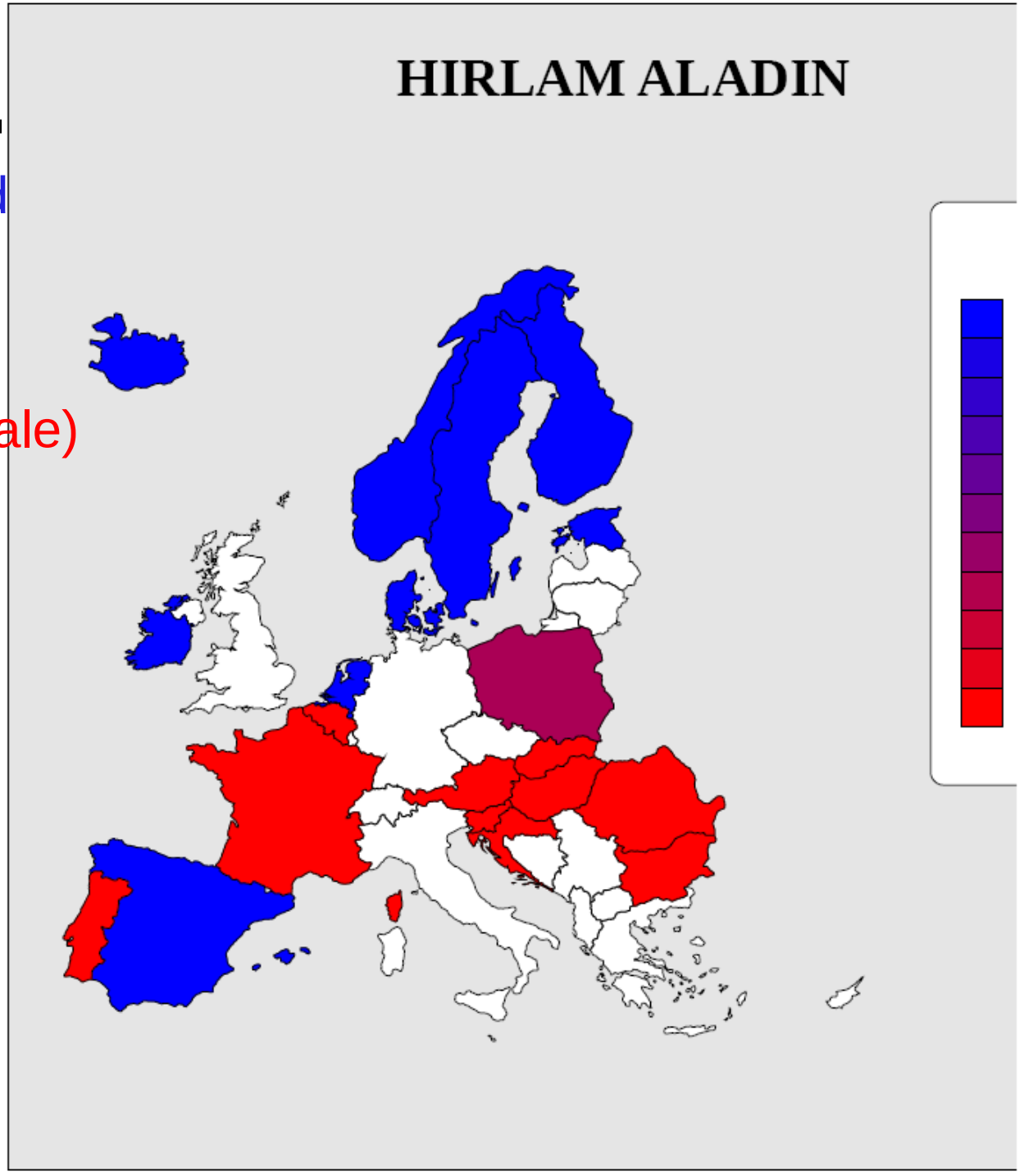
# Preparation for parallel HPC system for SMHI

- Resolution of HIRLAM model
  - 55 km 19 levels
  - 44 km 19 levels
  - 22 km 31 levels
- Saturated system
- Price of vector computers very high
- MPPs coming on line –
  - experience with MASPAR 600 MFlops/s eff.
  - and CRAY T3D (900 MFlop/s eff.)
  - HIRLAM parallelised (SHMEM and MPI)
    - Nils Gustafsson and Deborah Salmond
  - Also oceanographic model HIROMB parallelised
    - Jarmo Rantakokko,Tomas Wilhelmsson,

NSC 20y

# High Resolution Limited Area Modelling

(Aire Limitee Adaption Dynamique InterNationale)



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# HPD Council, NSC and the Agreement

- Urgent need of HPC facility for SMHI
- HPD Council and SMHI involvement
  - Lars Moen, SMHI
  - Jörgen Nilsson, SMHI and Anders Söderman, Armed Forces
  - Anders Ynnerman, NSC
  - Visionary move to cooperate with NSC and SAAB
    - Note: high security solution!
- PDC (KTH) or NSC (LiU) ?
- LiU and SAAB SCANIA and KTH agreement and SMHI
  - Share a HPC of highest international class
  - Both vector and MPP
  - Into effect 1995
  - SMHI needed 10 GFlops/s eff. During 4*1.5 hours
  - Proposal for PVC 3-4 Gfl and MPP 64 Gfl (PDC)

SMHI

# The Early developments and installations

- May 1995 38M SEK allocated to PDC for a MPP
- 37.5M to NSC for a PVC
- CRAY YMP C90 with 6 vector processors to NSC
  - October 1996
- CRAY T3E eventually 256 PE
  - Late 1996 – spring 1997
- ATM link NSC – SMHI 2 Mbits/s
  - Worked well (until later)

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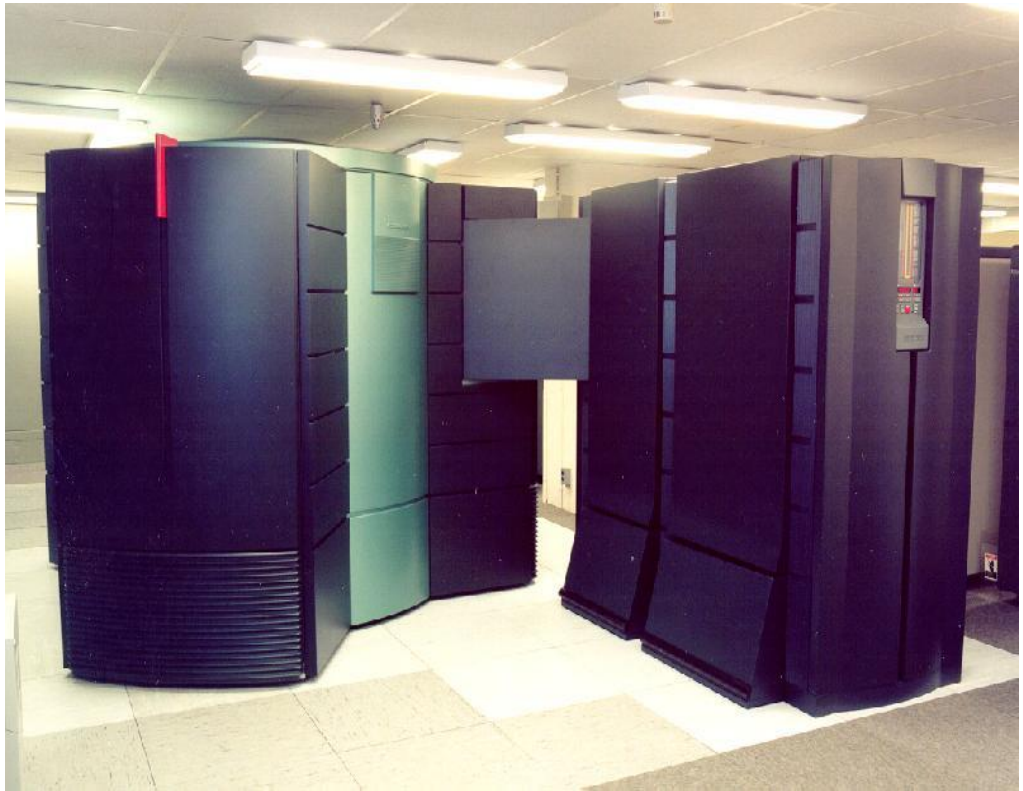
# CRAY C94 and T3E

- T3E 216 PE:s-> 256 PE:s
- C90 6 (4 planned) PV shared mem



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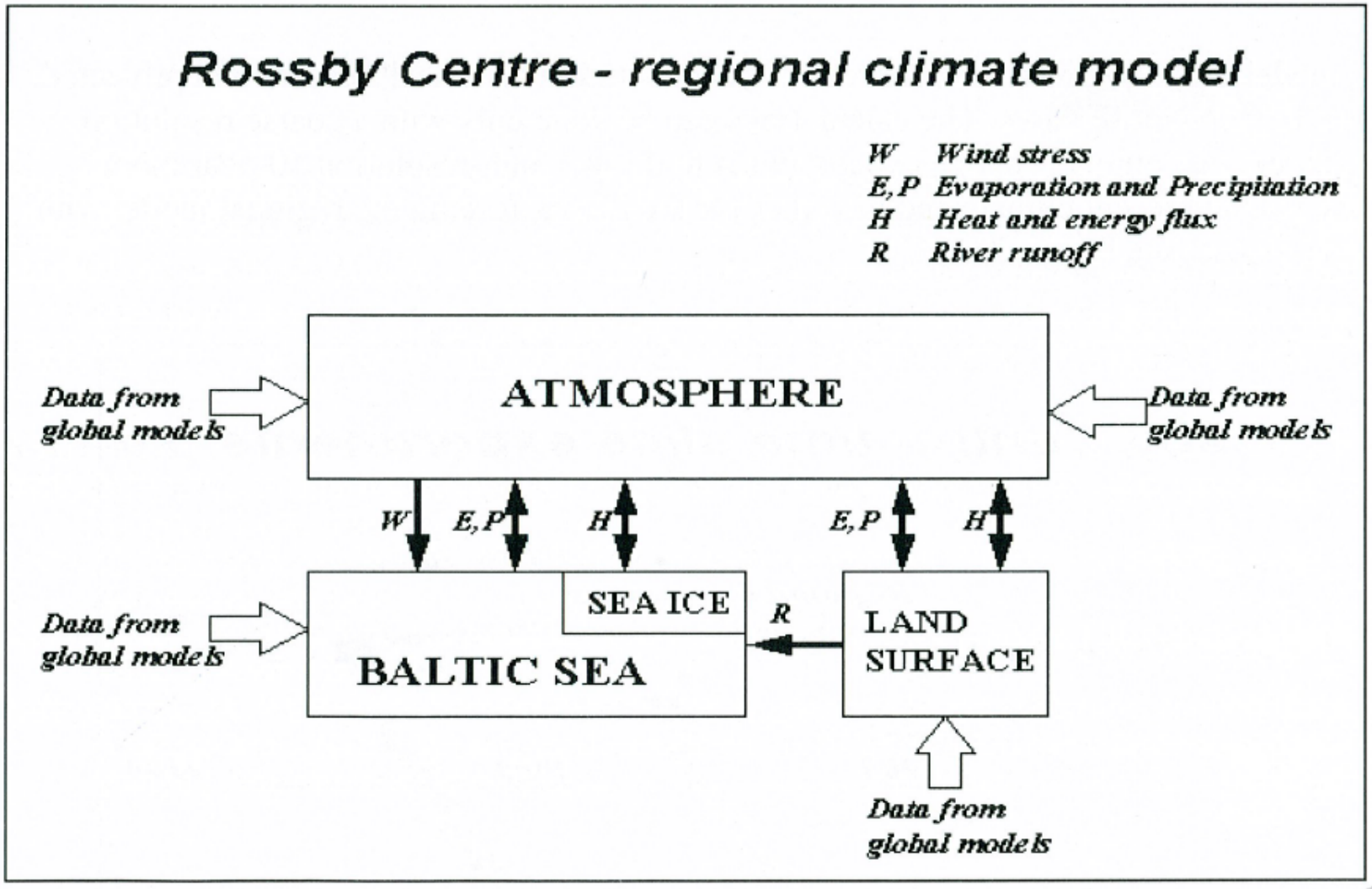
# Climate modelling at SMHI and NSC

- MISTRA funding for Swedish climate modelling mid 90's
- SWECLIM programme from 1997
- Initially 1-4 Gflops/s needed
  - More resources needed at NSC
  - Later much more
- SMHI Rossby Centre formed
  - Erland Källén
  - Lars Moen
  - Marku Rummukainen
- HIRLAM model used as well
  - Climate version for long term budgets correctbut parallised
  - Coupling with ocean models
- Much increasing demands 2000, 2002, 2005, 2007
  - Monolith 400 cores, Tornado, KWA Ekman/Vagn

SMHI


Rossby Centre - regional climate model
W Wind stress
E,P Evaporation and Precipitation
H Heat and energy flux
R River runoff
Data from global models
ATMOSPHERE
Data from global models
W
E,P
H
E,P
H
Data from global models
SEA ICE
BALTIC SEA
R
LAND SURFACE
Data from global models

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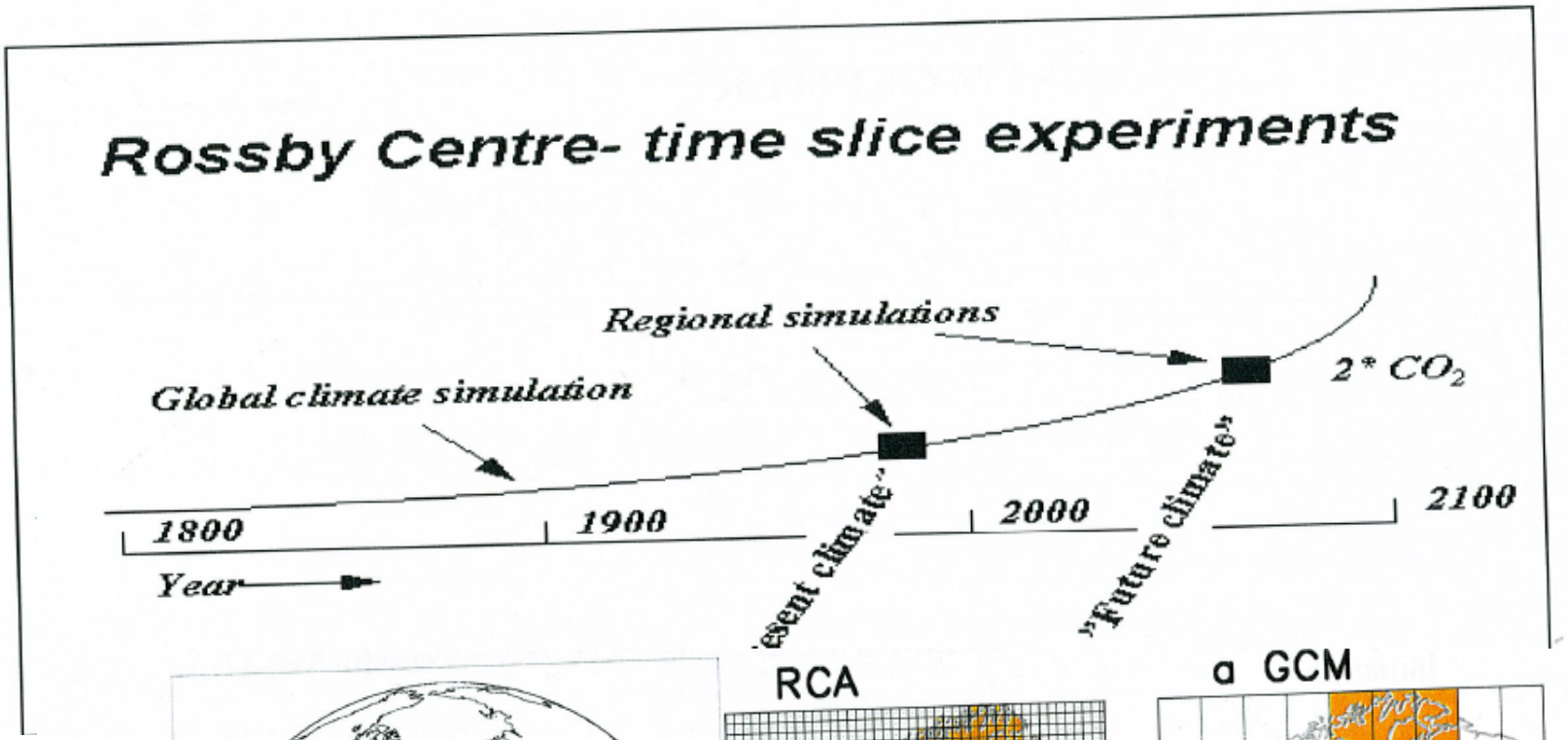


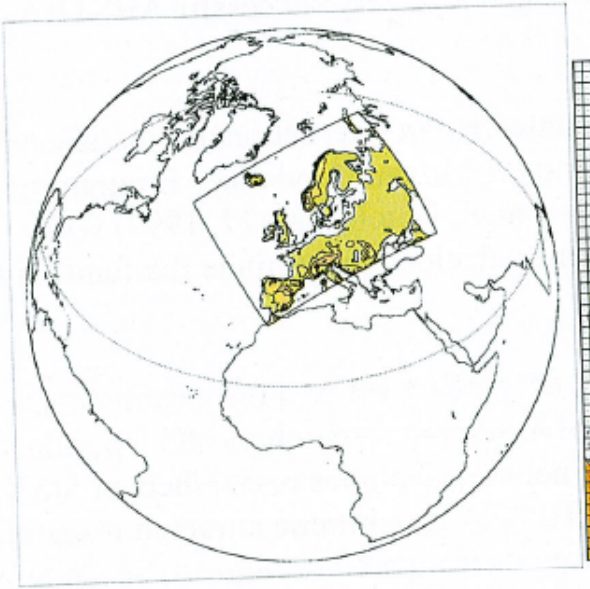

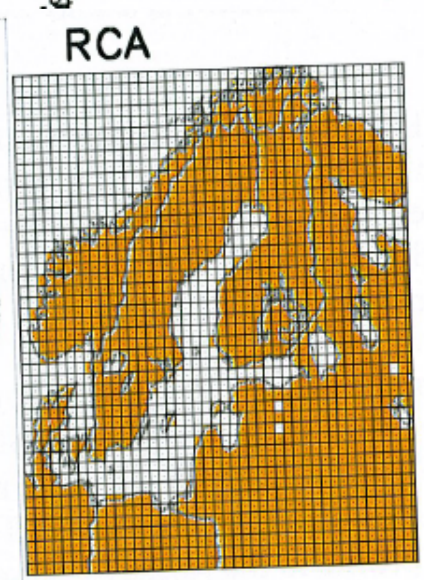


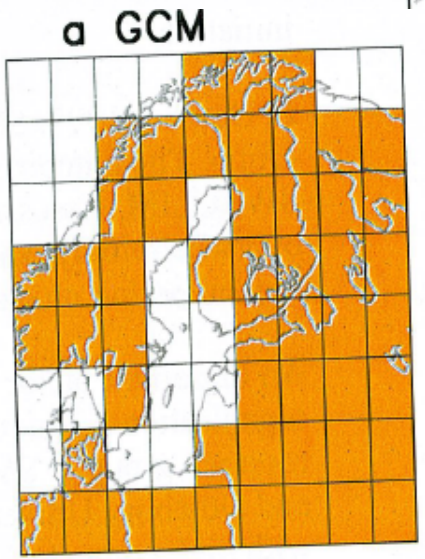


First:
Time slices
10-30 y
Then 100-140
Years
+ ensembles

# More applications SMHI-NSC

- Global Earth System Modelling – EC-EARTH consortium
  - Based on ECMWF seasonal prediction system
  - IFS atmospheric model and NEMO oceanographic
  - Going from scenarios (50-100 years) to decadal prediction
- Rossby Centre Oceanographic model RCO
  - Coupled with climate model
- High Resolution Ocean Model for the Baltic HIROMB
  - 3-dimensional 3 – 1 N Mile
  - Real time forecasting coupled from HIRLAM NWP
- MATCH Meteorological Aerosol Transport and CHemistry model
  - Driven by HIRLAM or ECMWF

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# The HPD Project at SMHI

- Operationalisation of HIRLAM at NSC
  - Use of MPP, parallel version of HIRLAM
  - Pre-processing at SMHI (observations)
  - Post-processing at SMHI (field interpolations)
  - Communication
  - Control and supervise job sequence
- Errors in the HIRLAM pre-processing of observations at SMHI
- Errors in the formulation of the Semi-Lagrangian advection scheme
  - Took time to correct
  - Eulerian version operational on C90 december 1997
    - Took more time than anticipated
  - Semi Lagrangian model corrected and T3E operational end of 1998

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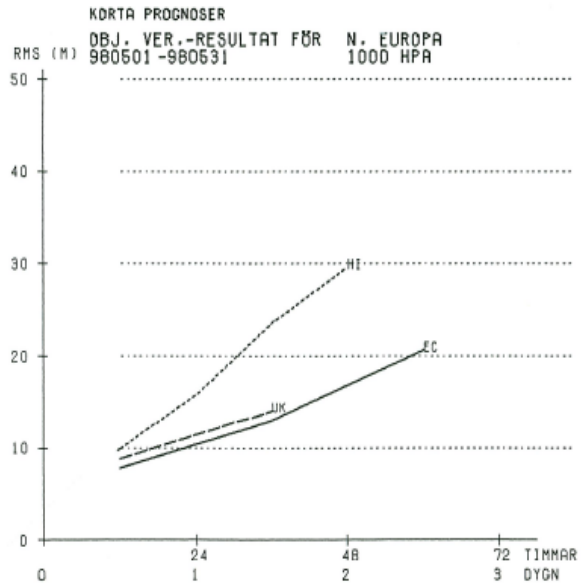
# Dynamics

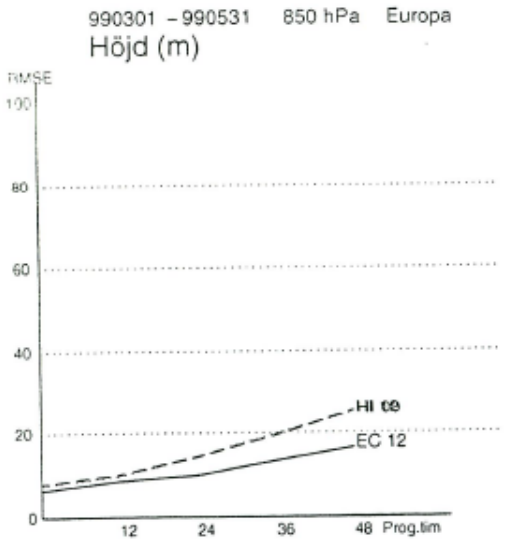
## Semi-Lagrangian advection

$$du/dt = \quad L + N + P$$

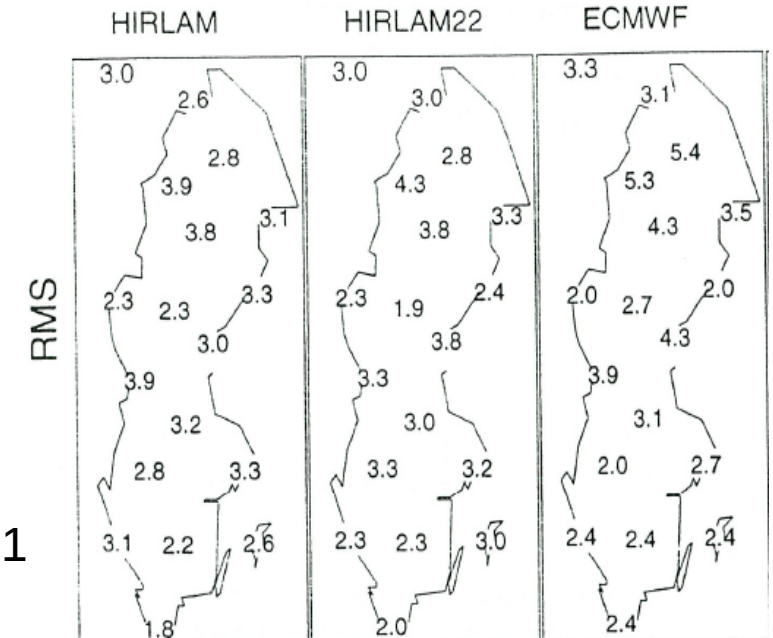
## Eulerian advection

$$\partial u/\partial t = \quad -u\delta u/\delta x + L + N + P$$




RMS forecast errors of height near surface BEFORE




RMS errors Of height at 850 hPa AFTER corrections

Typical temperature RMS errors 1999 for 1 Day model forecasts

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# The HPD Project at SMHI (II)

- Correction of the observational pre-processing 1998
- Correction of the semi-Lagrangian scheme 1998
  - On T3E first
  - T3E operational machine
- Reliability of T3E poor -> always keep a back-up machine!
  - C90 backup machine

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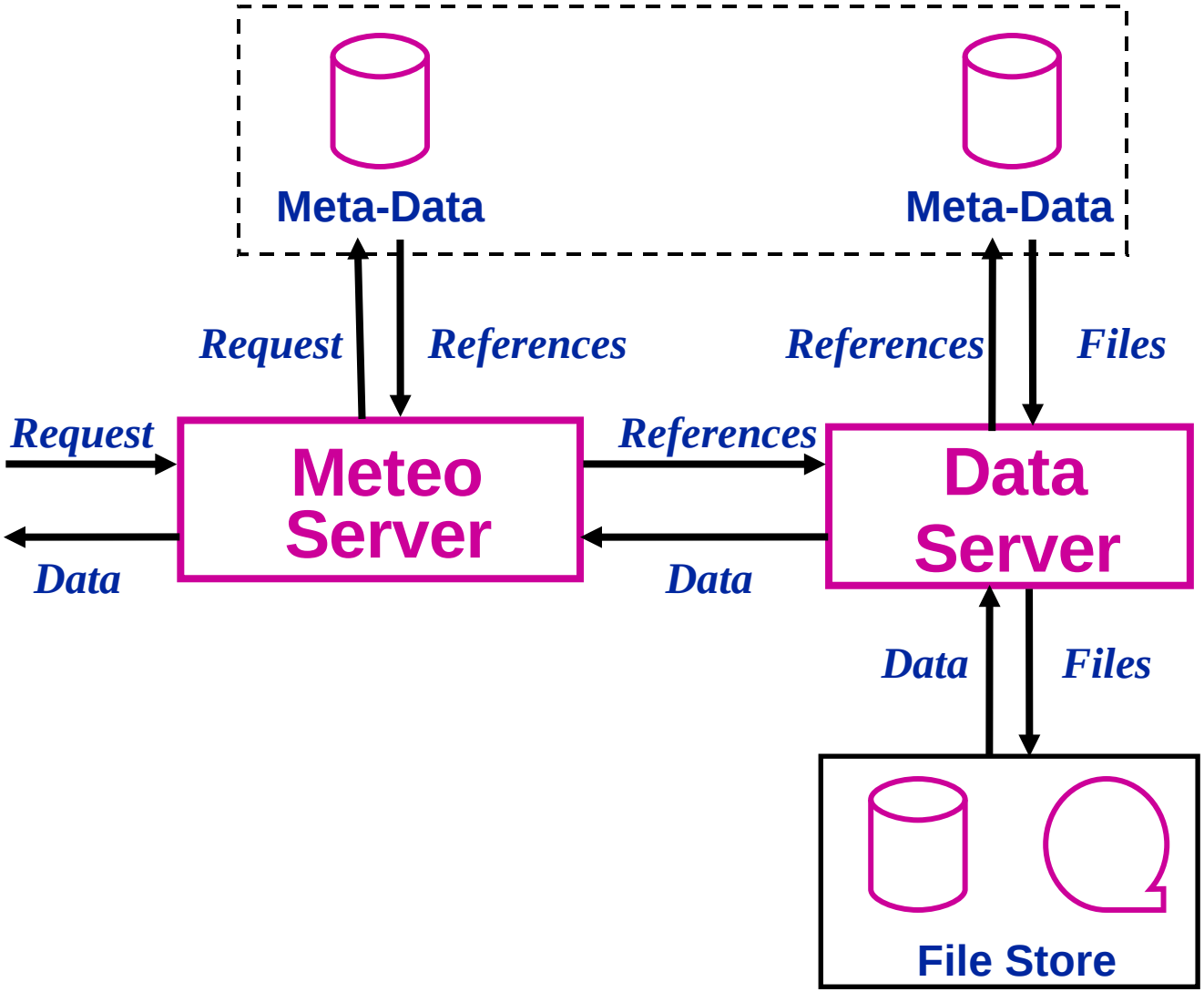
# Further (+) experiences and later developments

- 3 and 4 dimensional variational assimilation developed on the T3E
  - Good vehicle for research developments and high capacity
- C90 getting old towards 1999
- SGI 2000 procured 2000 – SGI 3800
  - Used together with T3E
- The era of Linux clusters!
  - SMHI NWP on Bris 36 cores 2002
  - Blixt 2005 174 cores (dual CPU)
- Dedicated clusters operations- research- other users etc.
- One cluster at SMHI – eliminate communication problems
- SUNET is now used
- MARS Meteorological Archiving and Retrieval System installed 2007-2009

# MARS Server Architecture

SMHI



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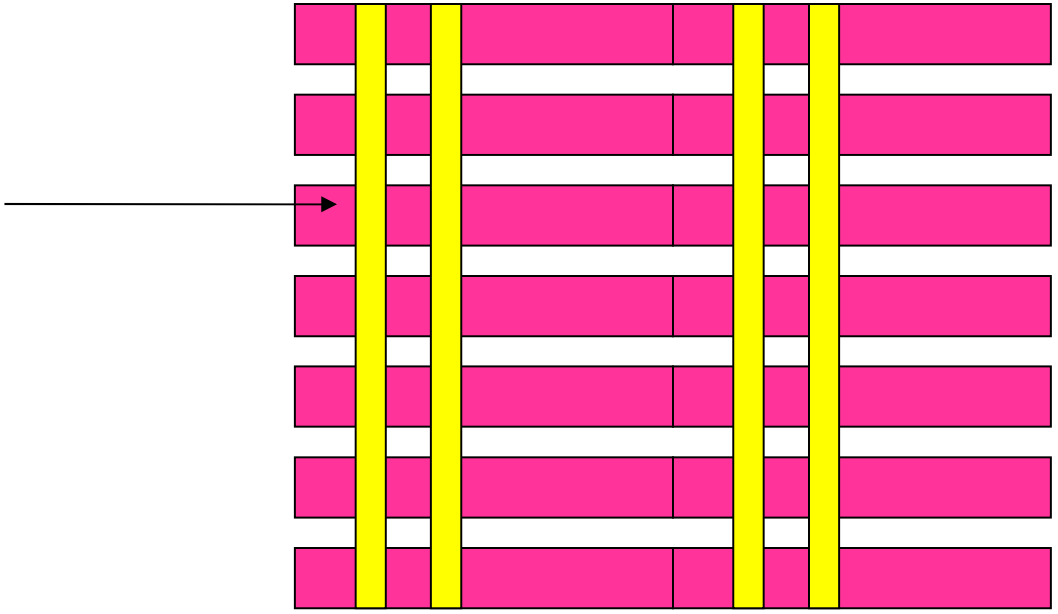
# A meteorological language

```
Retrieve,
    date        =    20010101/to/20010131,
    parameter   =    temperature/geopotential,
    type        =    forecast,
    step        =    12/to/240/by/12,
    levels      =    1000/850/500/200,
    grid        =    2/2,
    area        =    -10/20/10/0
```

MARS data stored in hyper-cubes
Possible to extract data along any “direction”
Computational operations possible on data



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# Conclusions

- A very successful partnership over 15 years !
- High Performance Computing power has been provided at best possible price / performance ratio
- Provided for
  - Weather forecasting
  - Ocean forecasting
  - Climate modelling
- Super computer expertise and optimisation of our codes
- Efficient and cost-efficient storage solutions
  - For HPC users
  - For other SMHI file servers as well
- Back up machine to provide reliable operational service
- Communication links crucial