The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

Spring Colloquium on
'Regional Weather Predictability and Modeling'
April 11 - 22, 2005

1) Workshop **on Design and Use of Regional Weather Prediction Models,** *April 11 - 19*

2) Conference on **Current Efforts Toward Advancing the Skill of Regional Weather Prediction. Challenges and Outlook,** *April 20 - 22*

301/1652-20

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the HIRLAM strategy for the development of LAM forecasting

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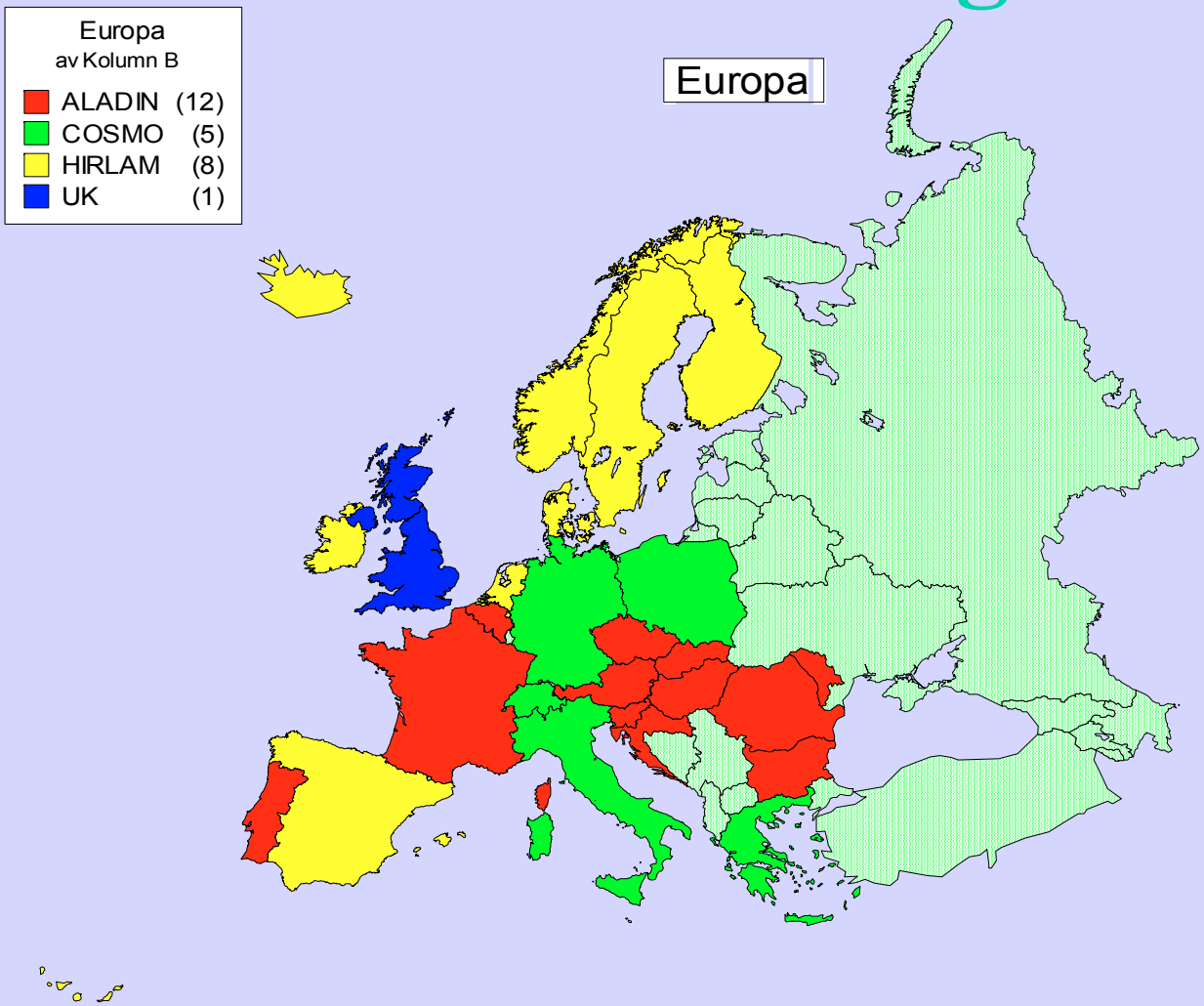
Swedish Meteorological & Hydrological Institute (Smhi)
Sweden

The HIRLAM strategy for development of LAM forecasting



Per Undén
HIRLAM-6

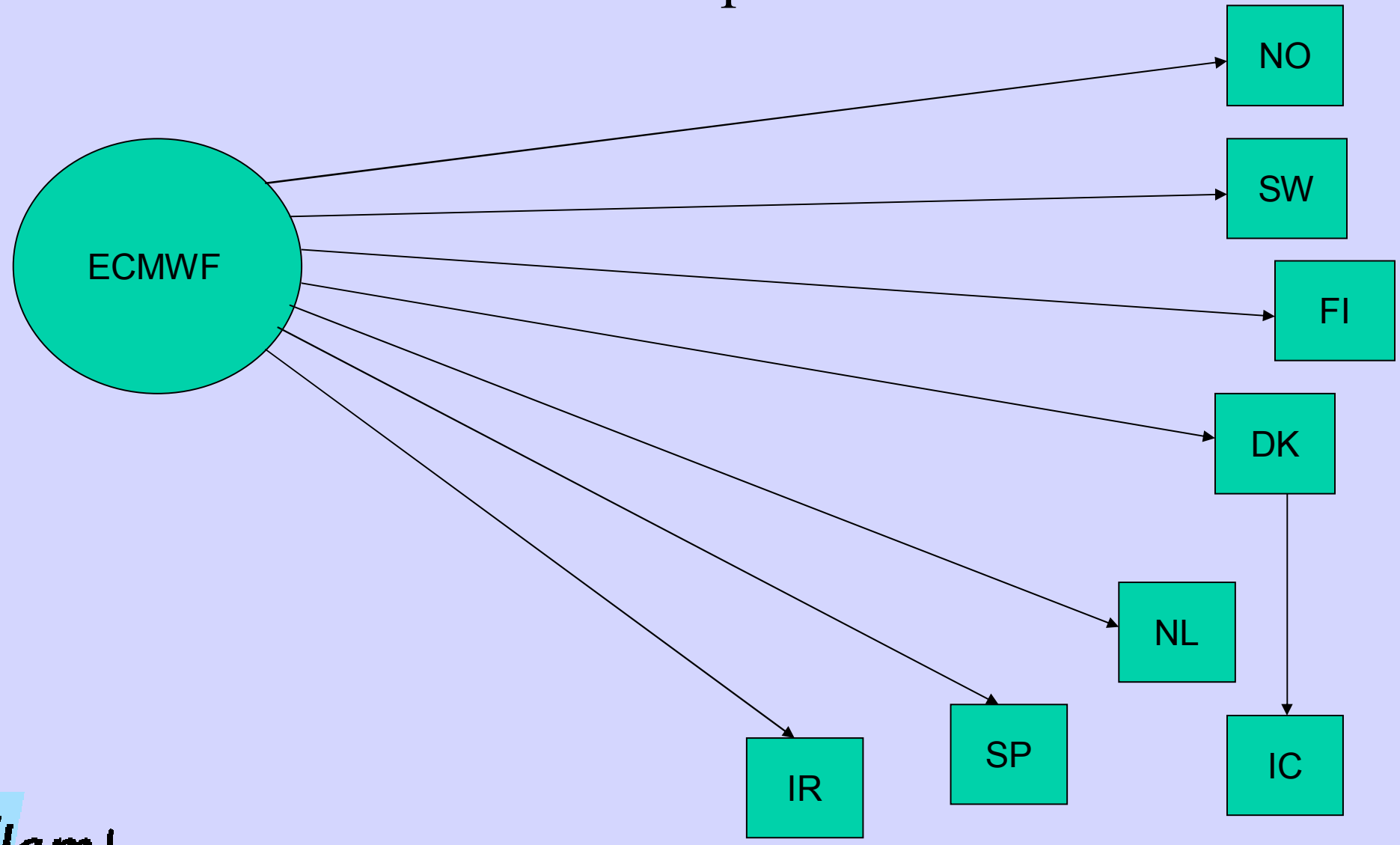
HIRLAM Programme definition

- Projects 1985- -- 2005 ; Programme 2005-
- Objectives
  - Maintain common NWP software in the form of a high quality Reference system
  - Run the Reference system (RCR) (Finland)
  - Common NWP research for development of the Reference system
  - Serve as a common expert group
  - Foster scientific collaboration
  - Optionally, joint production for some NWP
    - For the future ….

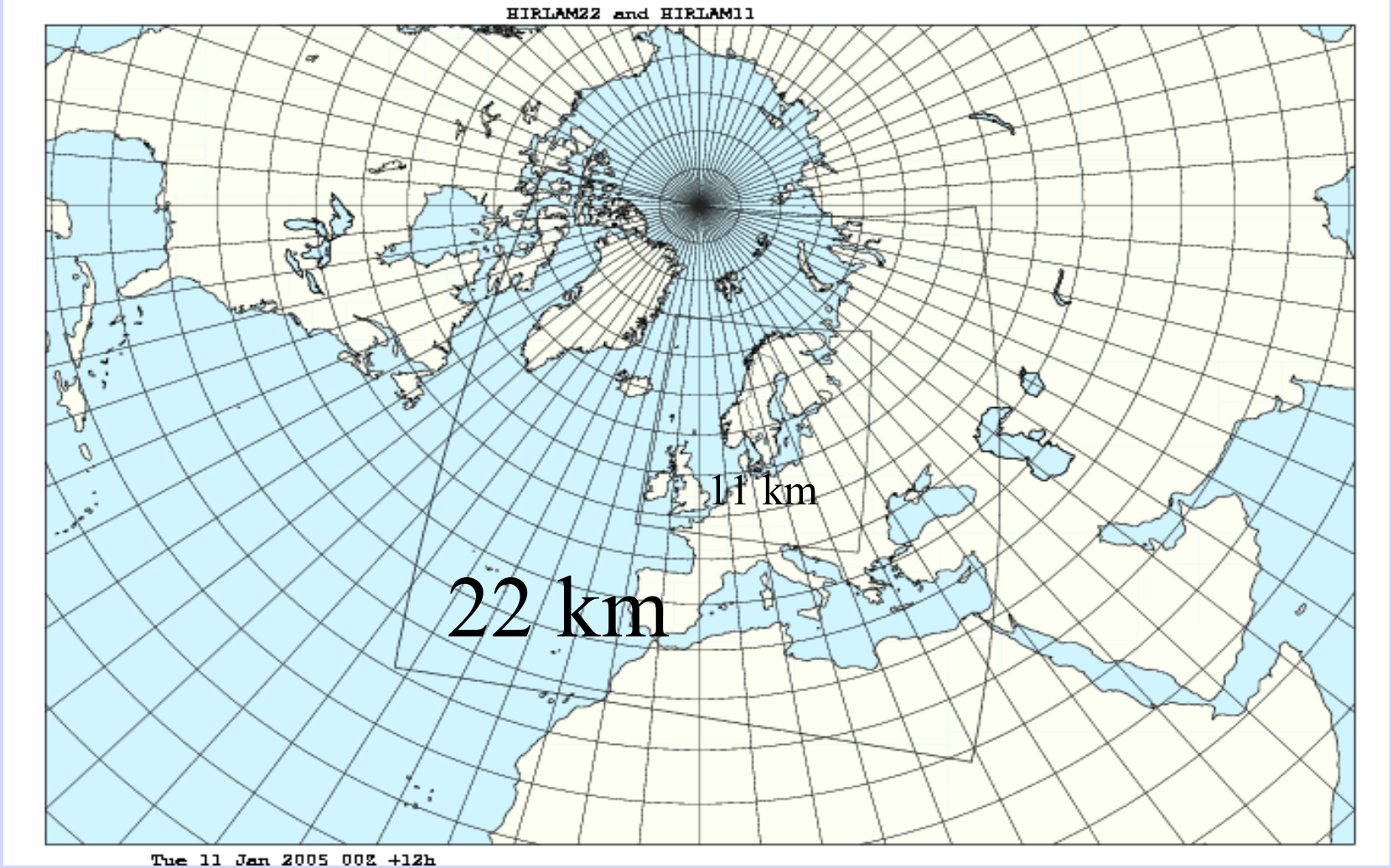
HIRLAM long term strategy
2005-2015

- General development in the surroundings:
  - Increased international cooperation and coordination
  - HIRLAM shall be one of the 4-5 leading Regional NWP centres in Europe
  - Synoptic scale LAM will be needed even beyond 2010
  - Meso-scale 3-1 km models will be operational
    - New demands for nesting, assimilation, initialisation, postprocessing and probabilistic forecast products
  - Short range EPS developed and in use
  - Earth system modelling – support for chemistry, bio- and hydrosphere

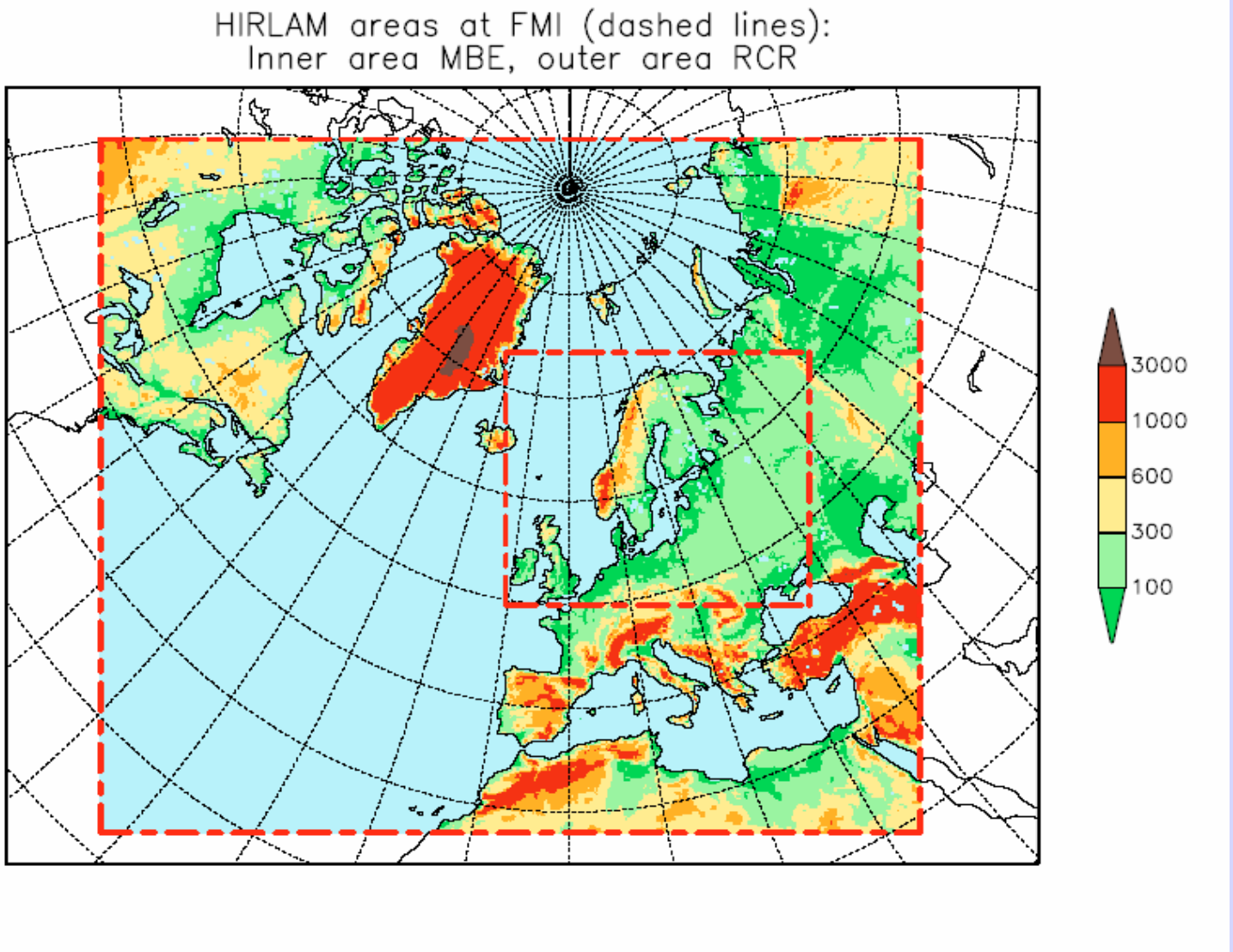
Current HIRLAM operations



Nesting



Areas of different HIRLAM suites at FMI



HIRLAM status

- Hydrostatic 2 TL SL-SI LAM
- Non-hydrostatic p-anelastic kernel (Tartu)
- Reference at 22 km – 40 levels
- (50 km) – 30 – 22 – 17 – 11 – 5 km (2.5)(1.4)
- Comprehensive physics for synoptic scales
  - (meso-β 40-10 km)
  - SW/LW simple radiation
  - CBR TKE 1D turbulence advected TKE
  - ISBA surface tiled scheme with assimilation/snow/soil
  - STRACO conv/cond (Kuo-Sundqvist type)
  - Kain-Fritsch/Rash-Kristjansson alternative
  - Meso-scale orography/Sub grid scale implementing

HIRLAM Data Assimilation

- SC/OI surface analysis (SST, snow, soil W T …
- 3D OI Upper air phased out (ECMWF box method)
- 3D-VAR spectral operational
  - Balanced or statistical background formulation
- 4D-VAR spectral SL multi-incr ready
- Synop, Air(amdar), buoy, TEMP, Pilot, ATOVS
    - AMSU-A, AMSU-B work
  - Quikscat backscatter – some
  - Doppler radar winds or VAD – experimental
  - WIND profilers ready
  - GPS ZTD developed , MODIS research

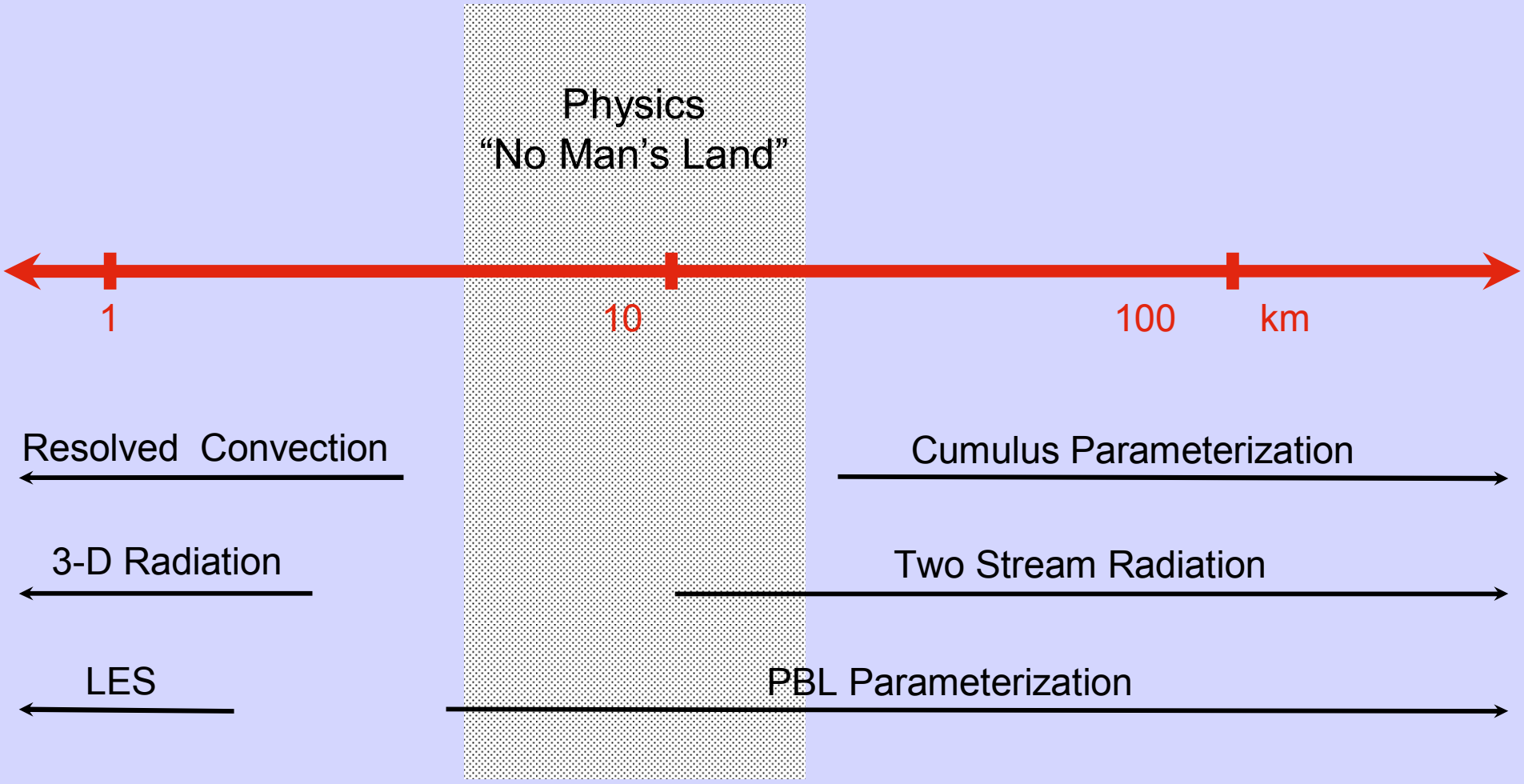
Meso-scale forecasting system

- Best available 2.5 km meso-scale modelling system operational in most of the HIRLAM countries 2010 – for parts or all of the territory – and applicable for 1 km **BECAUSE it is**
  - Necessary for forecasting in mountainous regions
  - Needed for very-short range prediction of severe weather, particularly with convection
  - Needed for high resolution applications, air quality, dispersion, disastrous releases etc.

The meso-scale forecsting system requires:

- Non-hydrostatic (non approximated equations) and efficient dynamics (long time steps possible)
- Advanced meso-scale physics, particularly for clouds and precipitation species and turbulence (convection mainly resolved except shallow)
- Advanced data assimilation that initialises particularly the moist processes (rain and clouds) and that can utilise many new data sources – Takes time …..
- Probabilistic forecasting and integrated system for estimating the probabilities
- Transparent boundary treatment

Model Physics in High Resolution NWP



Klemp (2002) Dublin WS

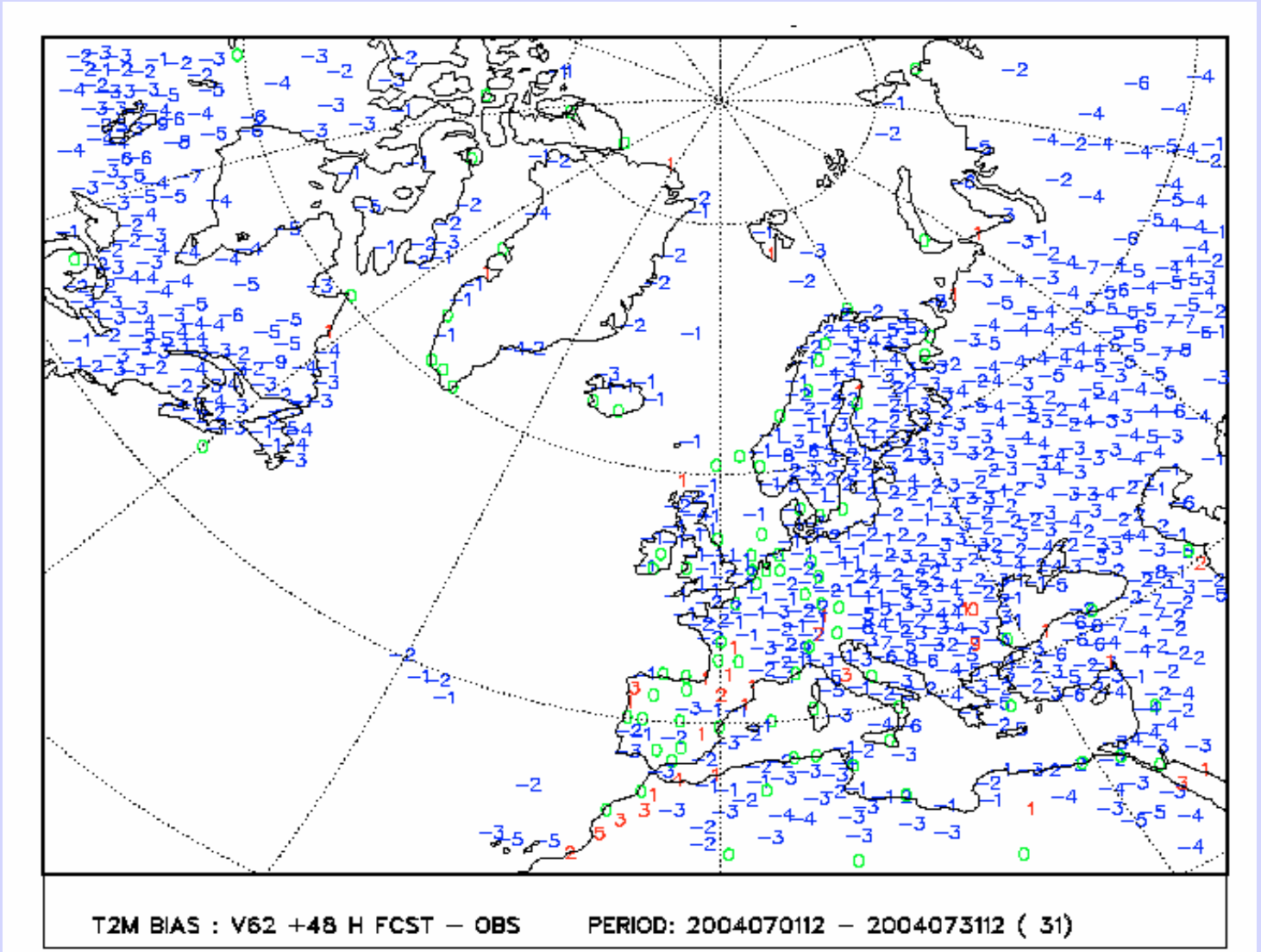
Synoptic scale 10 km model

- Model for regional forecasting tightly coupled to ECMWF (will not be done by ECMWF <2015)
- To provide best forecasts of synoptic disturbances with short data cut off **
- To provide a comprehensive (high resolution in space and time) set of forecast variables for applications and other models
- To provide coupling to the meso-scale model with high resolution in space and time
- Consistent physics with meso-scale model

**) depends on developments at and for ECMWF too

Synoptic HIRLAM work 2005

- 3D-VAR improvements
- 4D-VAR to be made operational (almost)
- More satellite use
- Surface analysis SST , ice, SAF products
- Turbulence developments and moist version
- Surface scheme, fluxes, new snow scheme
- Meso-scale / sub-grid scale orography
- KF convection, statistical cloud scheme
- SL dynamics
- Transparent boundary conditions
- Verification and diagnostics
- CVS code maintenance and unification -HIRLAM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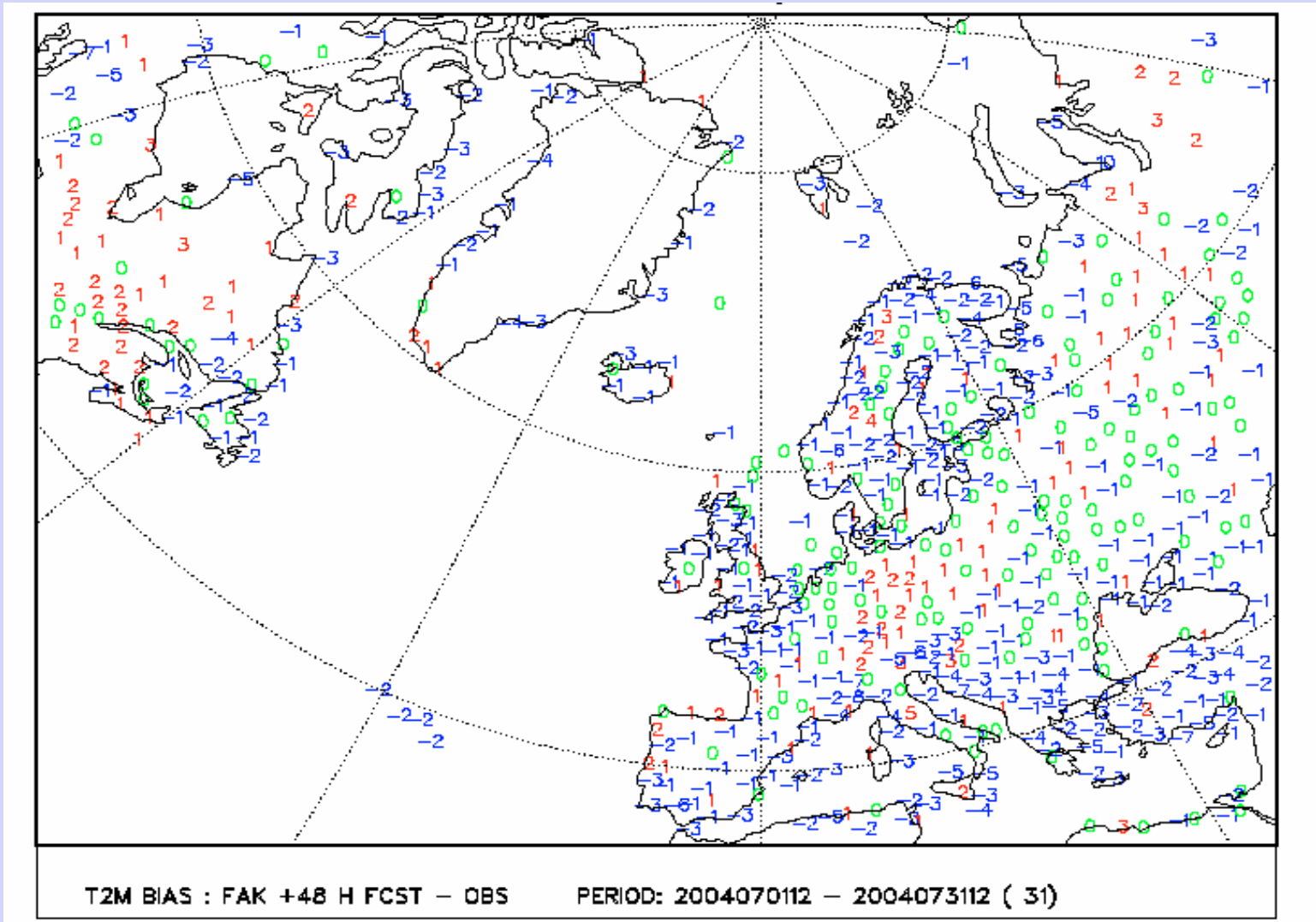
PERIOD: 2004070112 – 2004073112 (31)


T2M BIAS : FAK +48 H FCST – OBS
PERIOD: 2004070112 – 2004073112 (31)

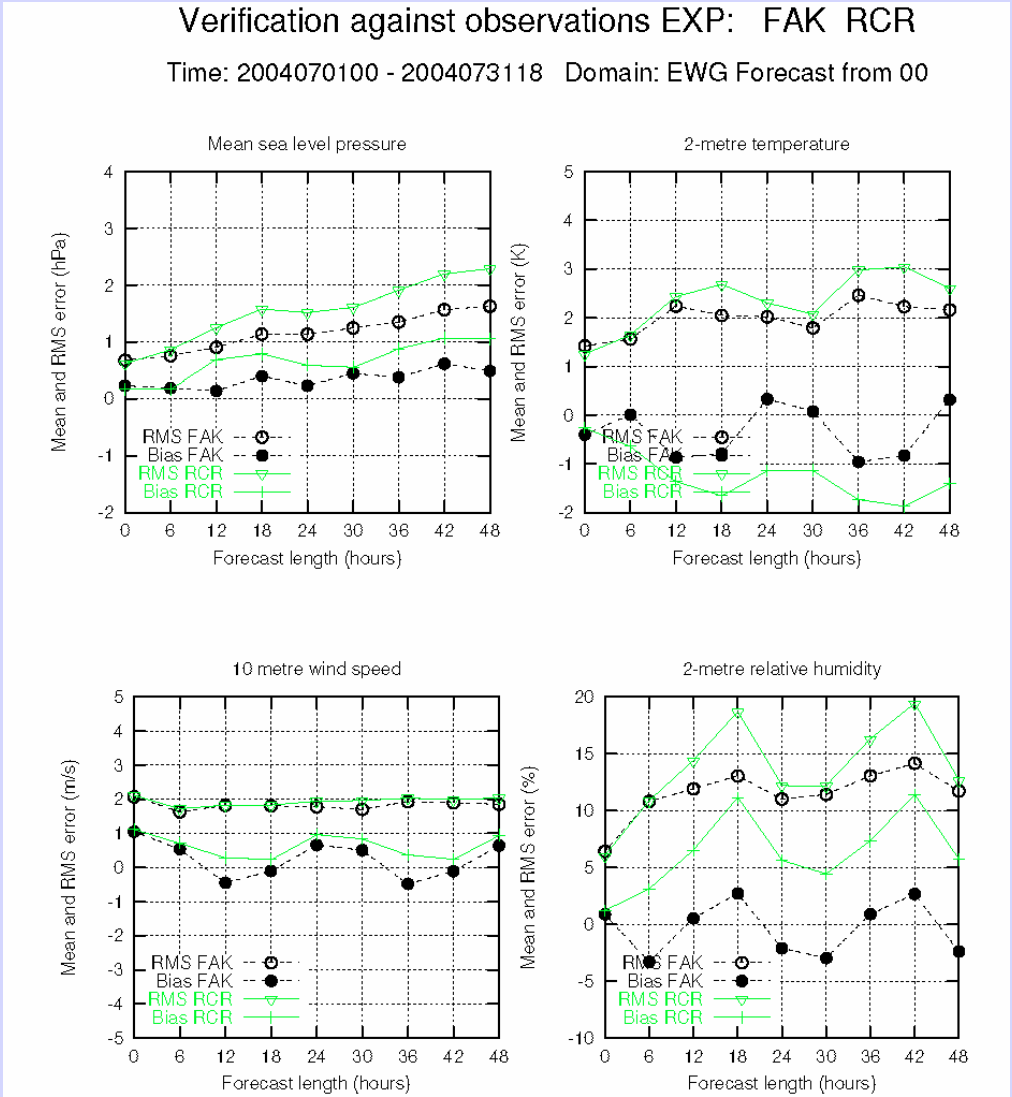
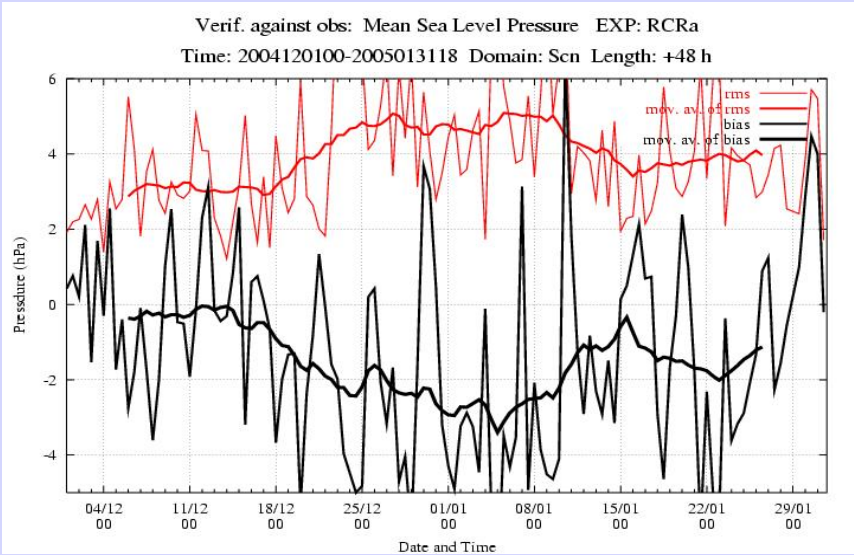


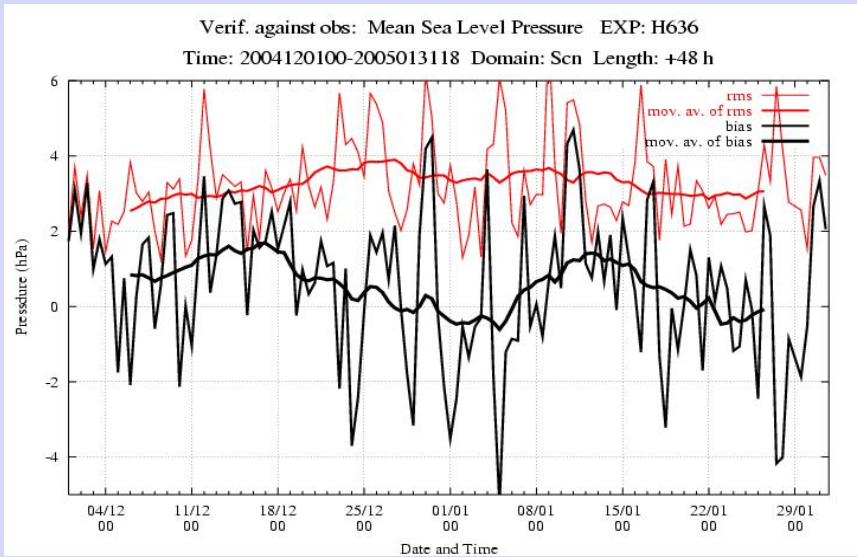
Figure 12: *Observation verification (EWGLAM stations) scores of surface pressure, 10-metre wind speed, 2-metre temperature and 2-metre relative humidity as a function of forecast length, for FAK and RCR runs in July 2004. Forecasts from 00 UTC analyses are included only.*

Time-series of verification scores (bias,rms)

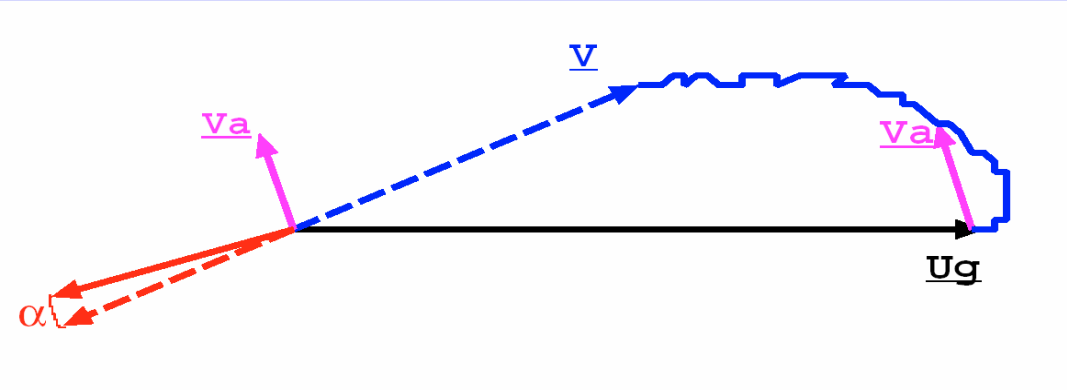
- All Scandinavian stations
- Time-series of bias and rms-error of surface pressure for Dec/2004 – Jan/2005
- Moving average of seven days

- The amplitude of bias is smaller in H636
- In RCR some very large bias values
- mid-December – mid-Janurary very active period



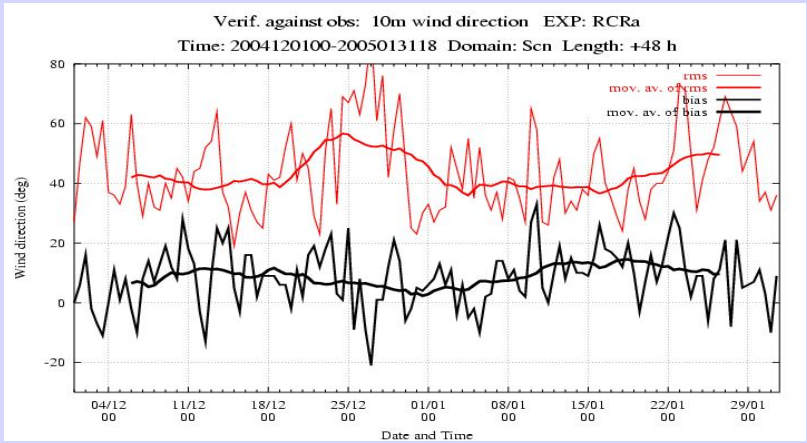


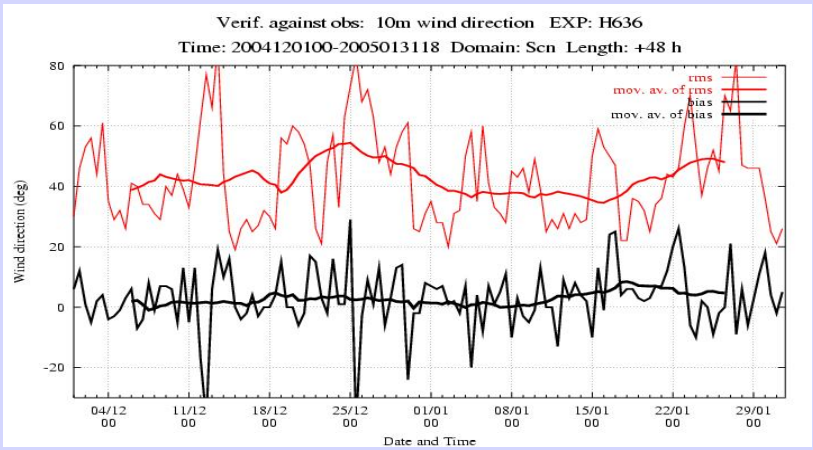
10-metre wind direction



- All Scandinavian stations
- The bias of 10 metre wind seems to be slightly smaller in H636
- In Scandinavia almost zero in H636
- Rms-error very similar

- Here should be divided according to observed value

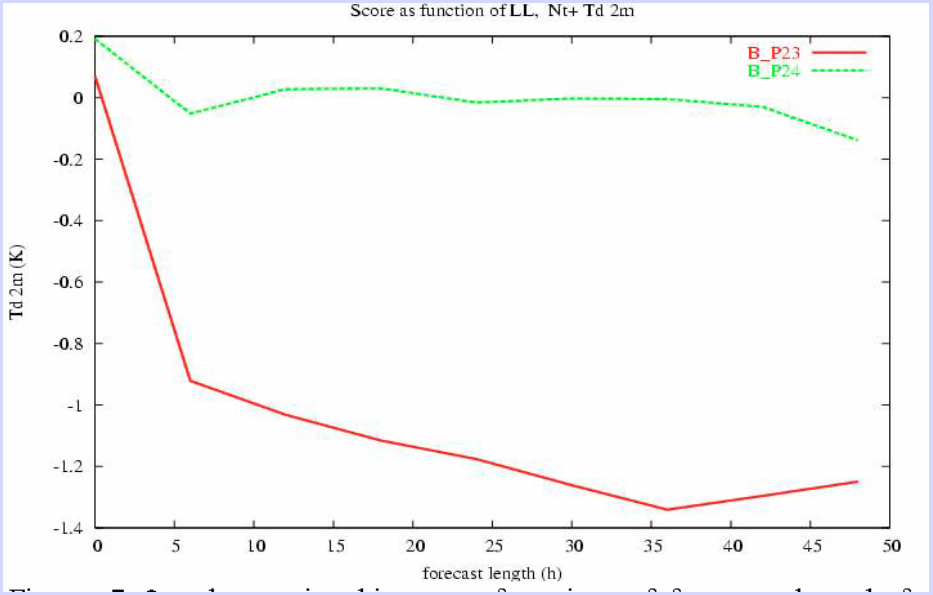


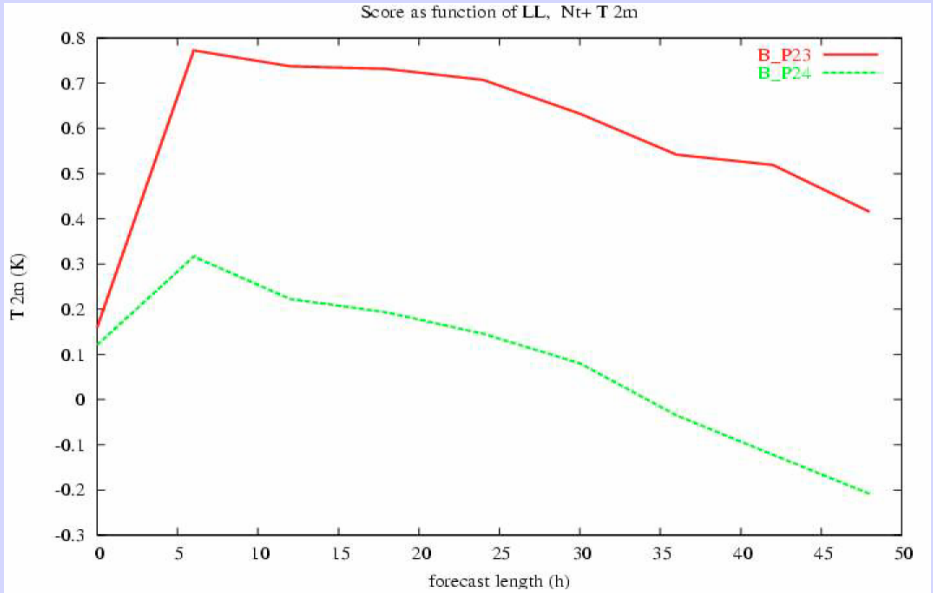


Ändring av VEG index – jämnare årlig variation

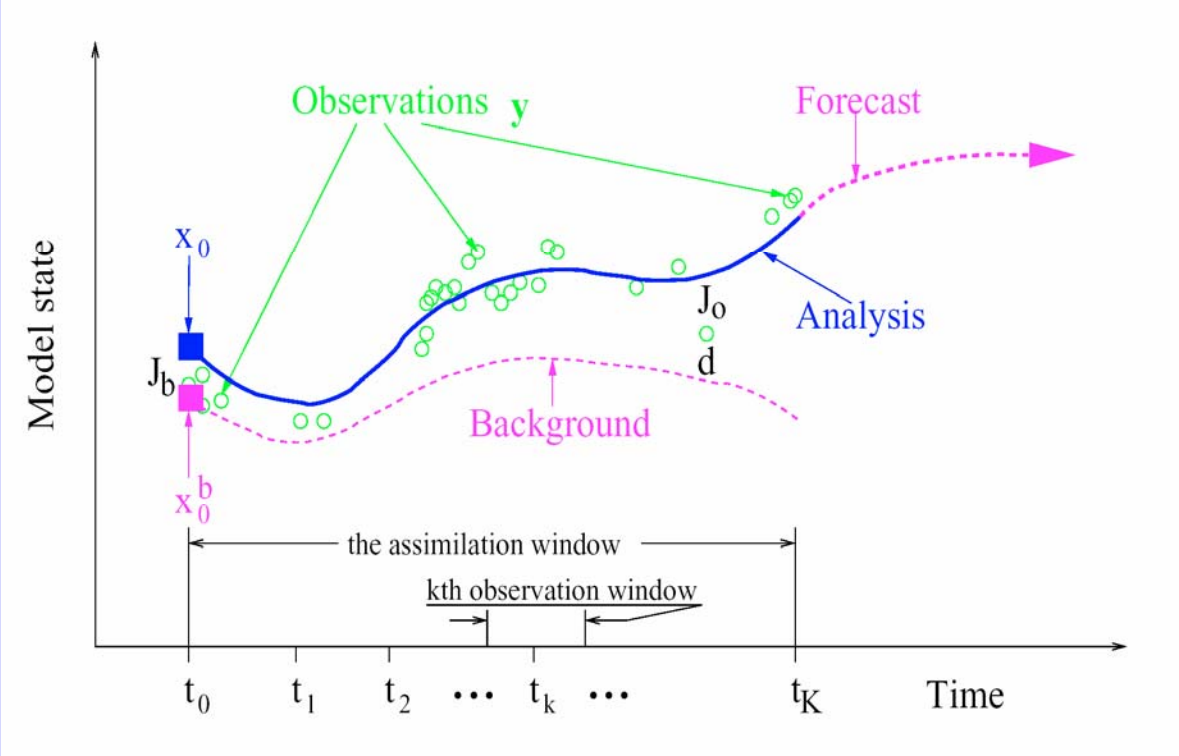
	J	F	M	A	M	J	J	A	S	O	N	D
LAI_o	0.1	0.1	0.1	0.5	1.0	2.0	2.0	3.5	4.0	0.1	0.1	0.1
LAI_n	1.0	1.0	1.0	1.4	1.8	2.4	3.0	3.5	4.0	2.0	1.5	1.0
VEGI_o	.05	.05	.05	.10	.20	.40	.80	.80	.90	.05	.05	.05
VEGI_n	.25	.25	.25	.30	.35	.65	.80	.85	.90	.60	.40	.30

Table 1: Monthly old and new values for the leaf area index (LAI) and the vegetation index (VEGI) as used in the reference experiment (old, P23) and the adjusted experiment (new, P24).





4D-VAR Data Assimilation



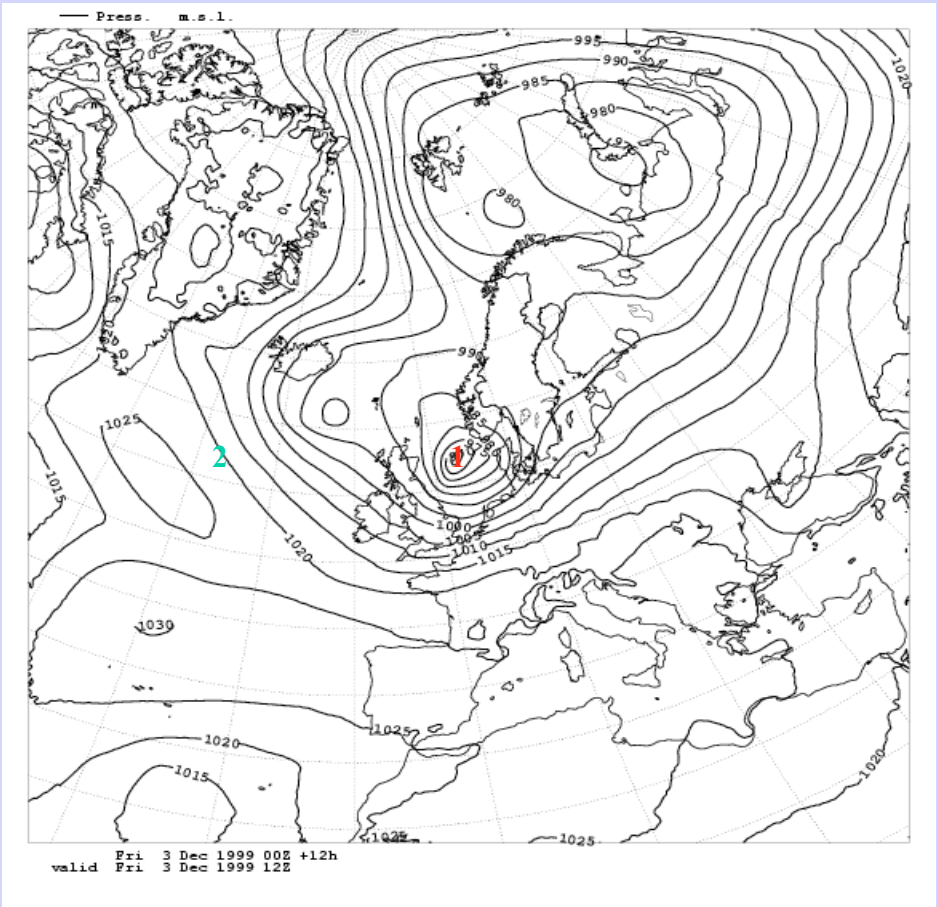
- Adjoints of semi-Lagrangian spectral model
- Multi-incremental minimisation - low resolution
- Optimisations of transforms
  - > significant gain in economy, feasible for operations

Single observation experiment with HIRLAM 4D-Var;

What is the effect of a single surface pressure observation increment of -5 hPa at + 5 hours in the assimilation window?

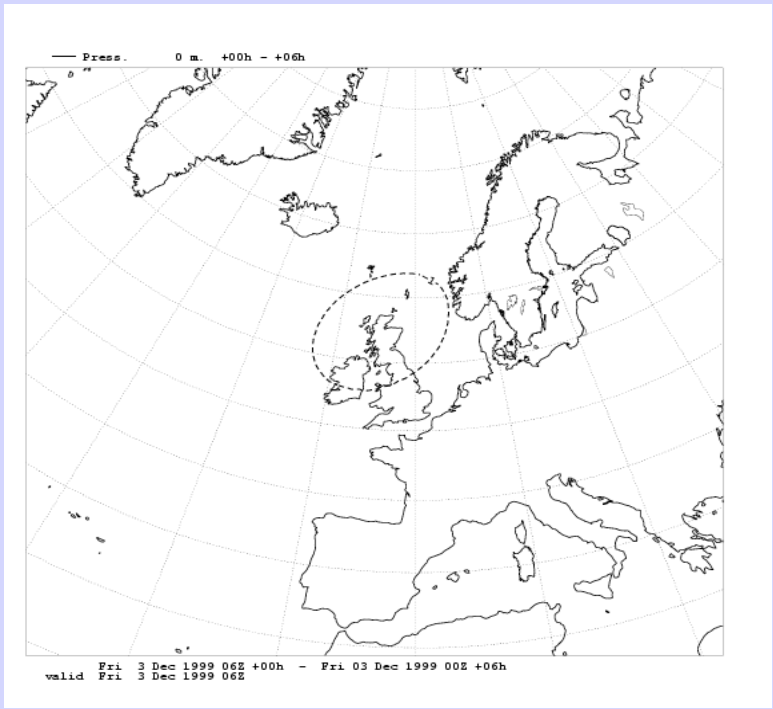
1: In the center of a developing low

2. In a less dynamically active area

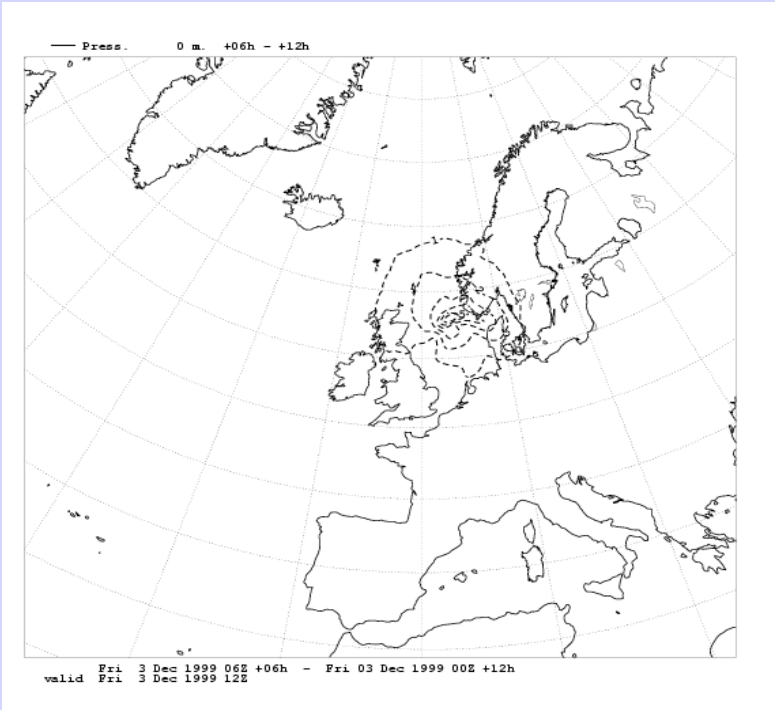


Effects of -5 hPa surface pressure observation increment at +5 h in a dynamically active area

Surface pressure assimilation increment at +0 h

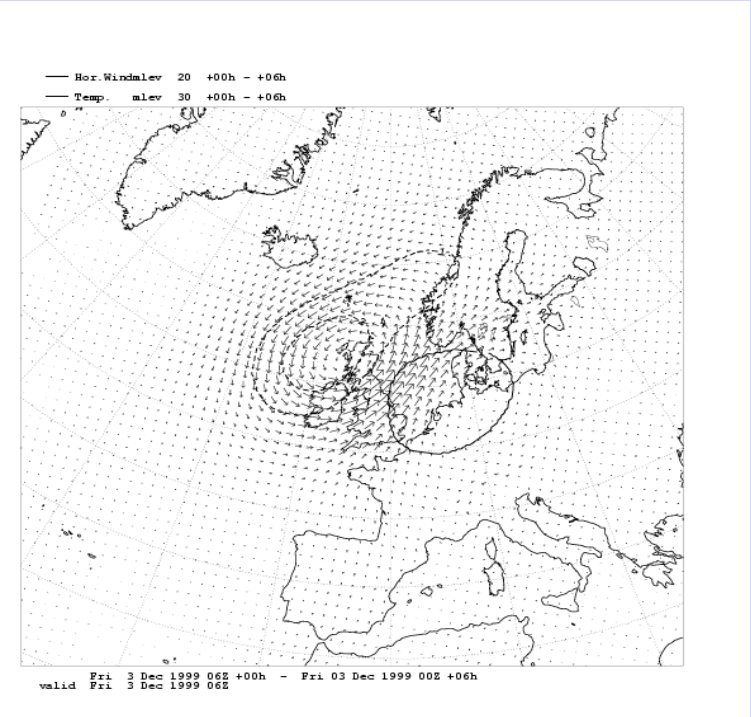


Difference between non-linear forecasts at +6 h with and without the 4D-var increment

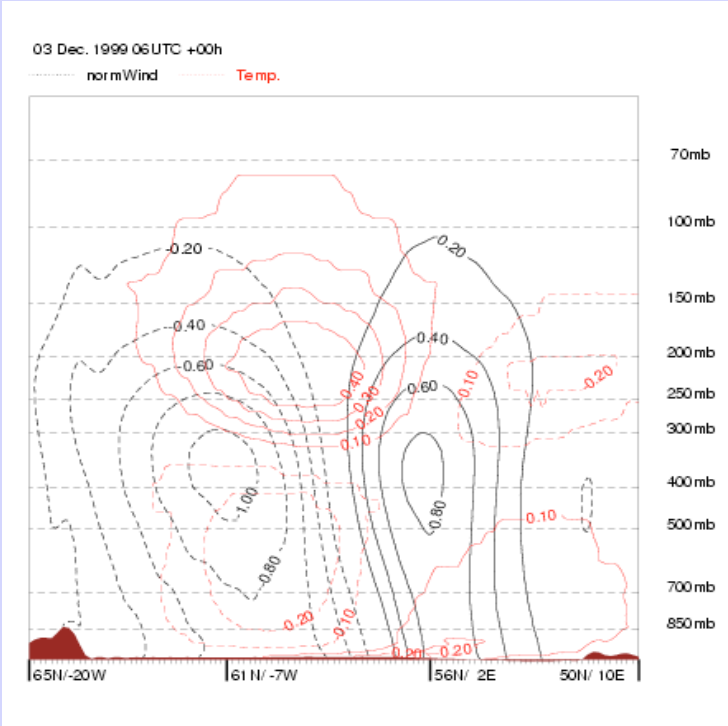


Effects of a -5 hPa surface pressure observation increment at +5 h on the initial wind and temperature increments

Winds at model level 20 (500 hPa) and temperatures at level 30 (below)



NW-SE cross section with temperatures and normal winds



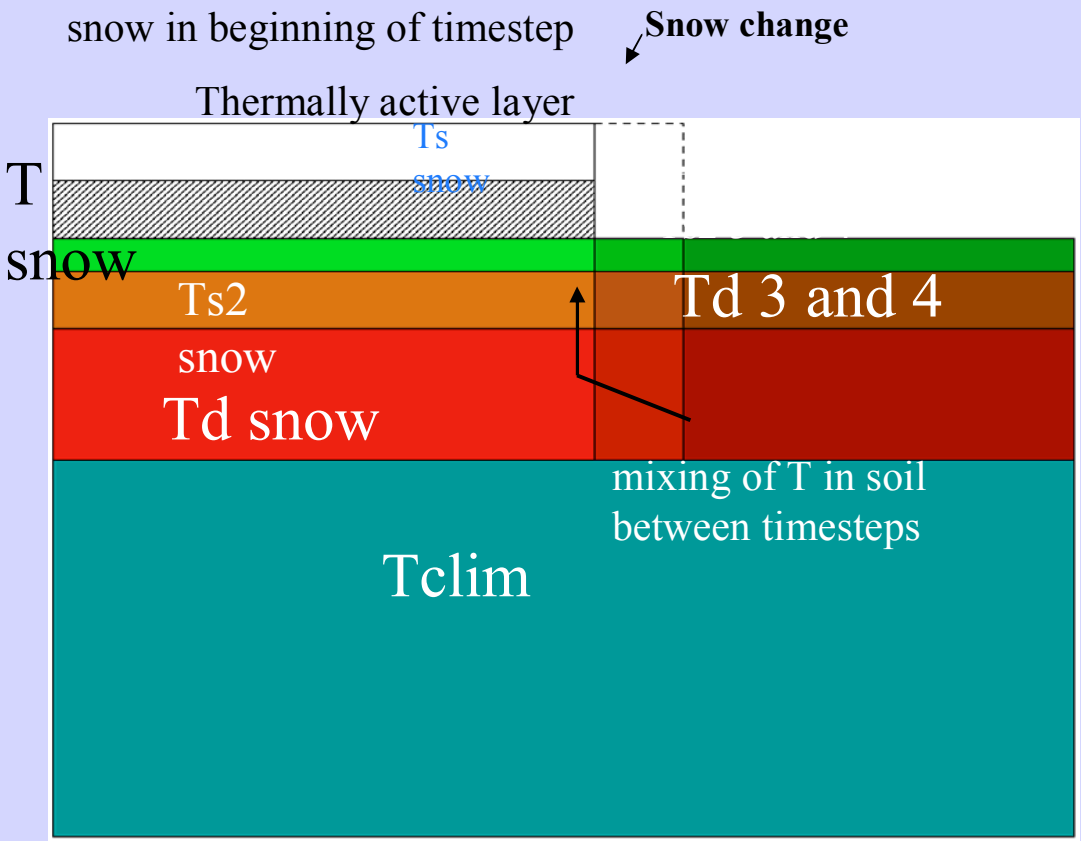
4D-VAR argument

- Optimal solution in time including all information
- Iterativ method enabels non-linear operators -
  - possible in 3D too, **but** :
- Non-linear analysis can transfer a vortex
- The model analyses non-observed quantaties
- Possible to use integrated observations
- Enables high time resolution of data and time sequence can be utilised - e.g. radar
- Model generated structure functions
  - necessary for meso-scale

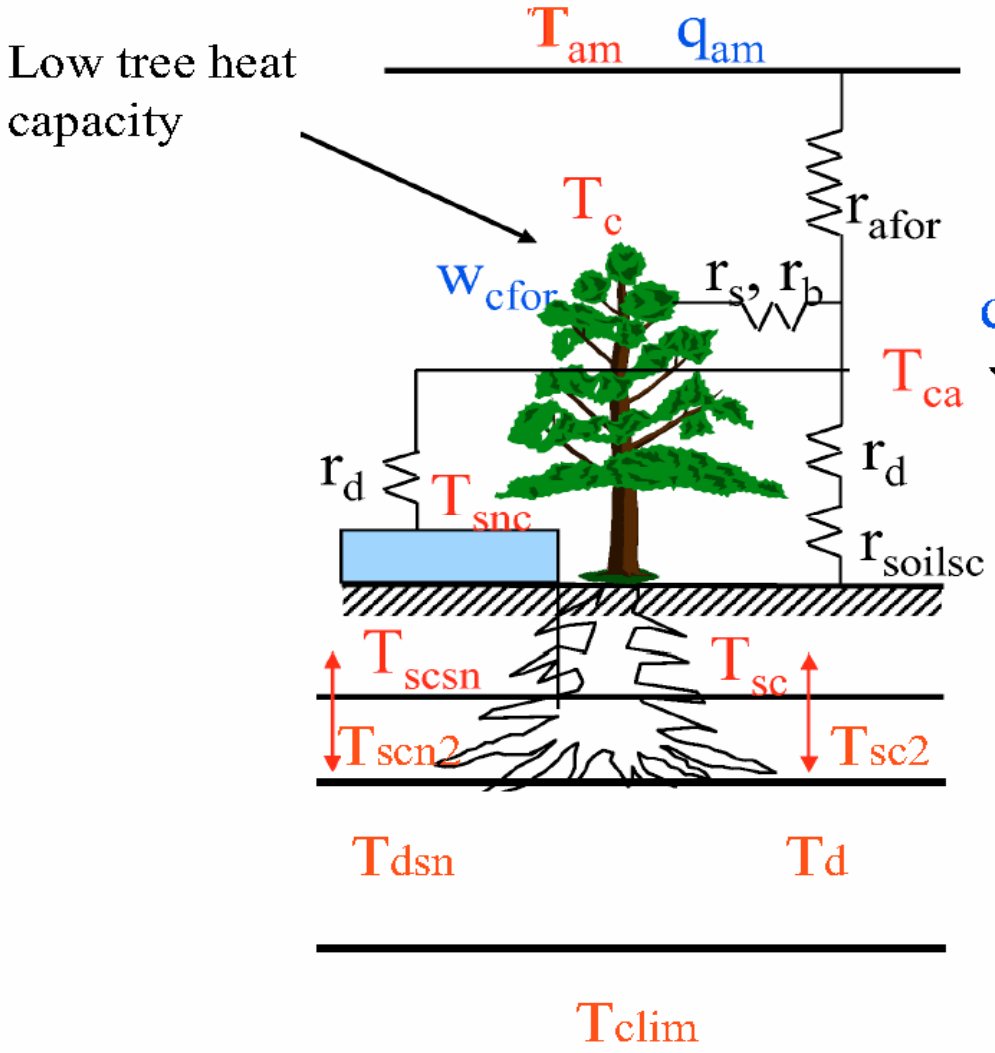
ISBA: snow covering parts of fractions 3 and 4

Features of the snow scheme:

- move the snow from fractions 3 and 4 to fraction 6 every timestep
- one layer of the snow, with a thermally active layer < 15 cm
- water in the snow, which can refreeze
- varying albedo and density
- mirroring of temperature profile in the ground to assure correct memory



Snow scheme for forest tile



$$H_{for} = \rho c_p \frac{T_{ca} - T_{am}}{r_{afor}} =$$

$$= H_c + frsn * H_{snc} + (1 - frsn) H_{sc}$$

Canopy air temperature and humidity

Calculations of r_b and r_d follows Choudbury and Monteith, 1988

Develop EPS for all time ranges

- First for synoptic forecasting 24-48 (-72) h
  - (Almost no HIRLAM-5 and -6 resources given (officially)) – requires more resources –
  - Science not really developed for short range –
  - Natural for Operational collaboration between institutes (GRID)
  - Pursue in a wider European context – similar work in several places and of operatoinal kind, exchanges
- Absolutely necessary for meso-scale
  - Very expensive
  - Science not at all developed

  => Alternative methods (probabilistic postprocessing, using something from EPS at larger scales ?)

Requires more resources

- More activities – meso –synoptical- EPS !
- Achieved through:
  - Collaboration
    - With ALADIN/MF shared code (meso-scale first)
    - Indirectly with ECMWF through the IFS code, Met Office scientific exchange, intercomparison through met.no ‘s runs
    - Other European exchange of ideas and results
  - Synoptic model to be transferred to ALADIN/IFS with HIRLAM options
  - Synergy between meso- och synoptic scale work
  - Synergy with Nowcasting !
  - External funding (not under direct HIRLAM control)
  - Staff increases may be possible for specific purposes

And:

- Operational collaboration on synoptic system (can be one common area) will be investigated – a lot of potential – SMHI Workshop with interested institutes in autumn

➢ Will save a lot of manpower

➢ Will ensure enough manpower to ensure quality

  ➢ E.g. satellite and other data monitoring

➢ For HIRLAM to be one of the 4-5 regional NWP centres in Europe (Met Office NWP vision for Europe)

- Collaborate with ALADIN and AROME on meso-scale system
  - Re-gain lost time of development
  - Sharing and distributing work with partners
    - Actively contributing in several key areas
    - Relying on partners for other things
  - Wide range of work apart from model dynamics and physics
    - Data assimilation
    - Observations
    - Probabilistic modelling
    - Verification
  - Enough critical mass in all areas in the whole HIRLAM-ALADIN community

Why ALADIN and AROME ?

- HIRLAM and ALADIN are closely related scientifically
  - ✓ Spectral LAM and analysis with extension zones
- Both born out of ECMWF and ECMWF similarities
  - ✓ ECMWF code commonality in ALADIN
- ALADIN non-hydrostatic model breakthrough
- Advanced meso-scale physics through Meso-NH -> AROME
- Advance Data Assimilation developing
- Meteo-France participates in HIRLAM since 1992
  - ✓ Good experience of MF collaboration in HIRLAM
  - ✓ Informal offers in 2003 to use ALADIN NH dynamics
  - ✓ Likely to be a true collaboration from both sides
- Many partners of different size
- Organisation more dispersed than HIRLAM

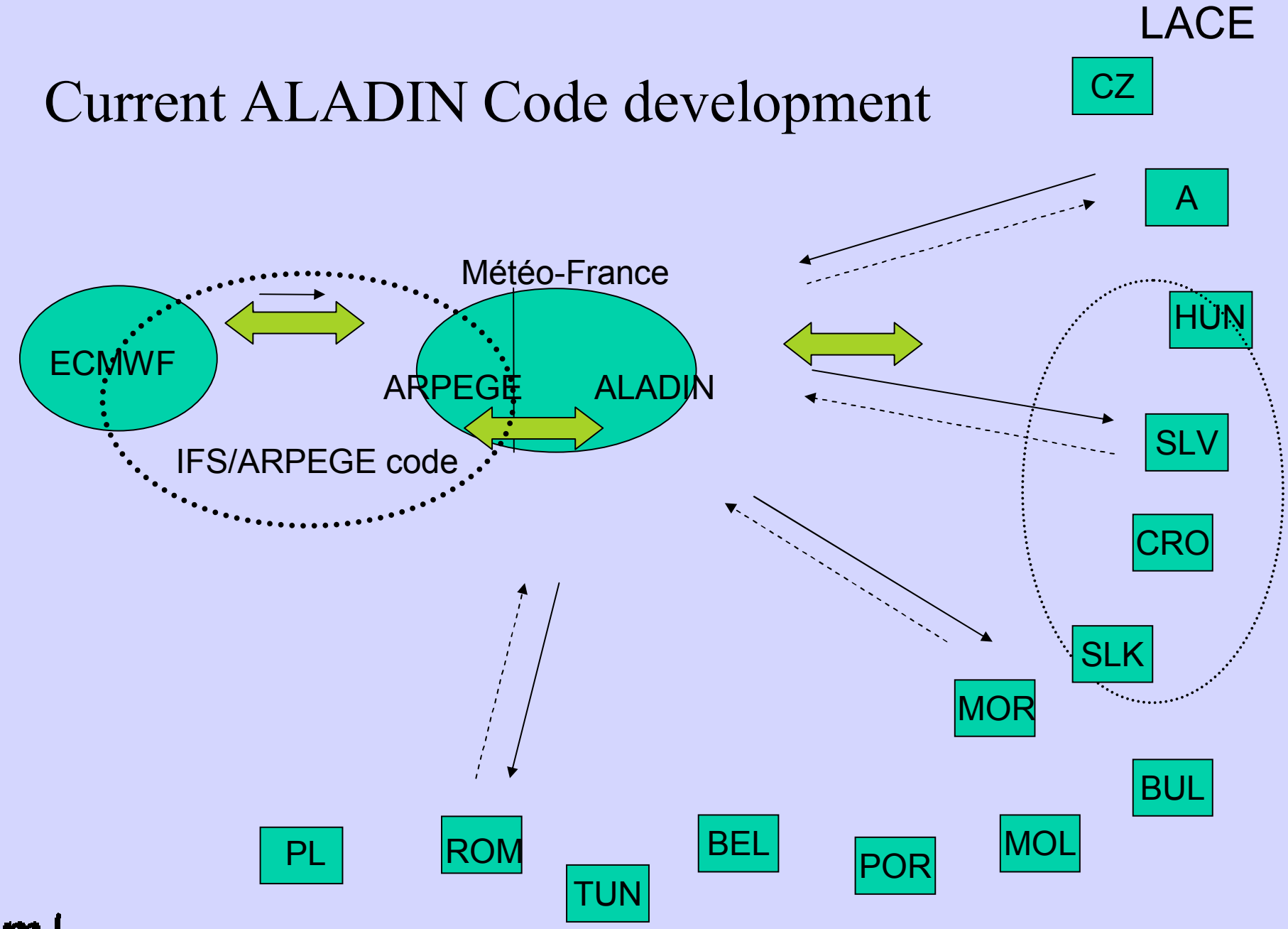
HIRLAM in ALADIN/IFS

- Establish that hydrostatic model equivalent:
  - Spectral hydrostatic dynamics, extension zone, variational analysis equivalent
- Establish HIRLAM physics package under switches in ALADIN / AROME
- Use HIRLAM physics as appropriate for synoptic system and parts for meso-scale? – Synoptic model migrated to ALADIN/IFS , bef. 2010
- Meso-scale work and contributions on AROME physics + HIRLAM physics
- Possible to collaborate and contribute with HIRLAM physics for the 10 km AROME (ALARO)

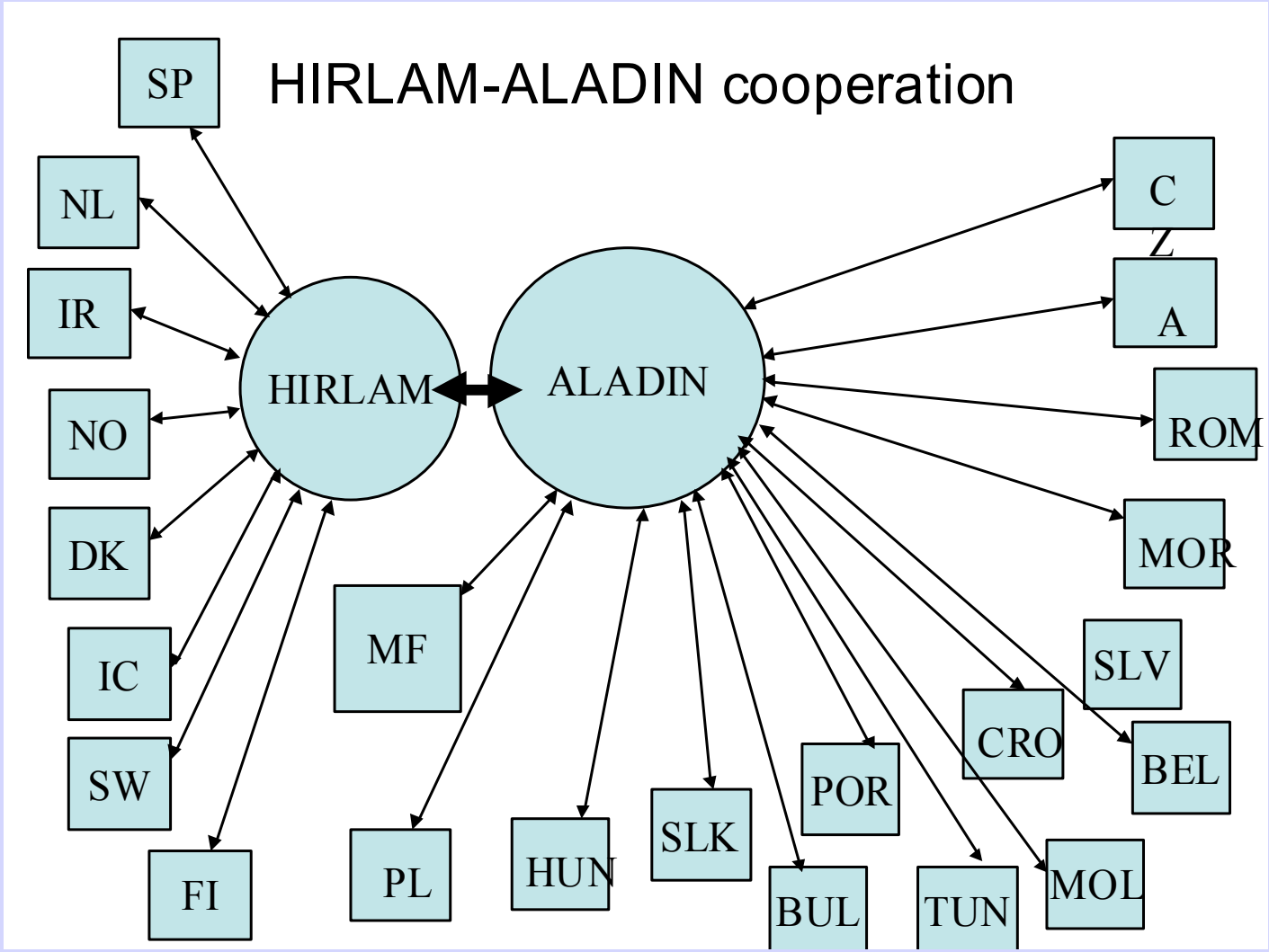
HIRLAM in ALADIN/IFS (cont)

- Data assimilation merge BIG step technically
  - Large code
  - ODB
  - ➢ Brings ECMWF/IFS developments into the system
  - ➢ A large potential for HIRLAM contribution in a joint system – and expectations e.g. 4D-VAR, radar, satellite data, …

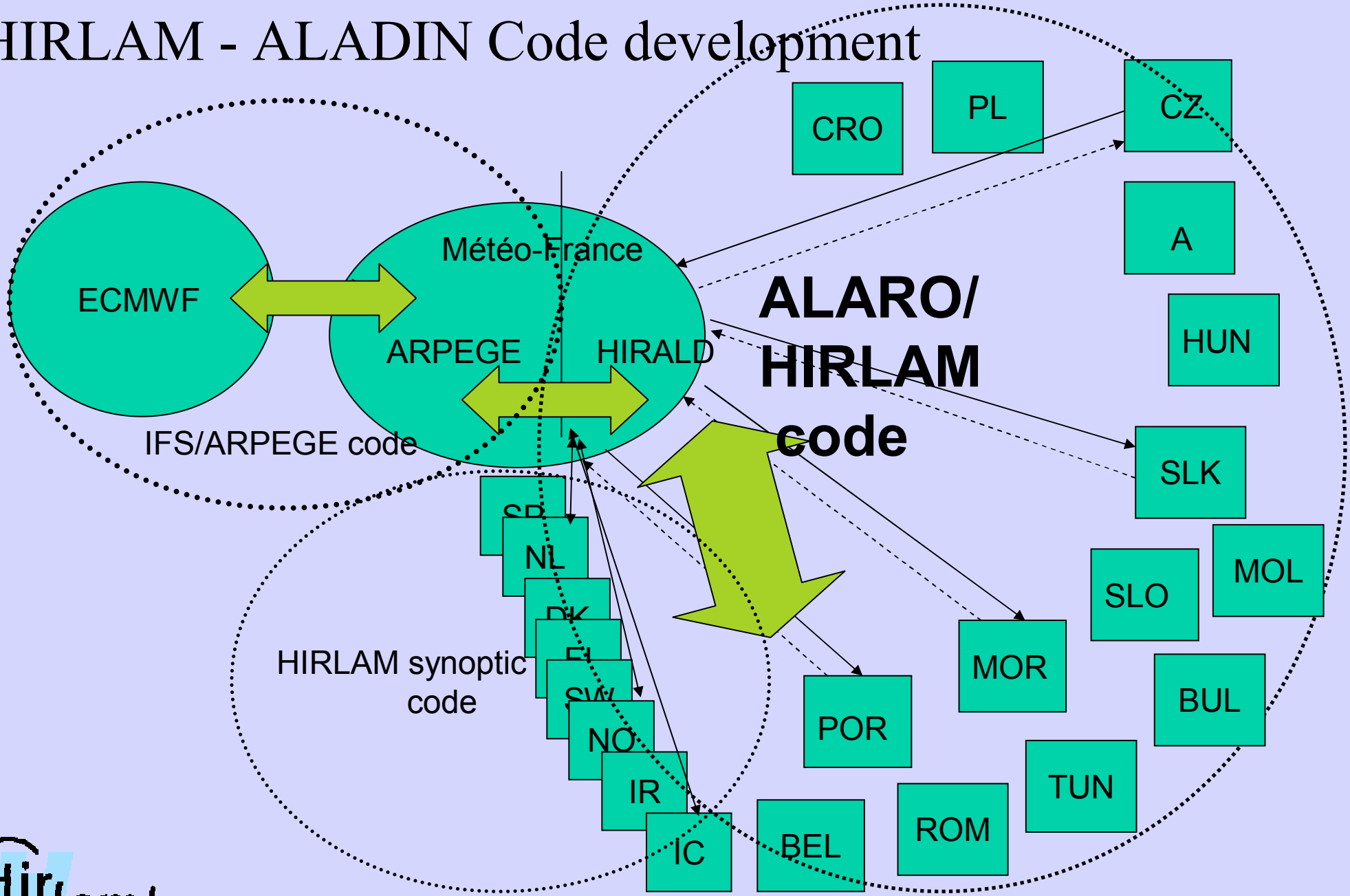
Current ALADIN Code development



HIRLAM strategy - meso-scale



HIRLAM - ALADIN Code development



HIRLAM components for Meso-scale

- Surface scheme – ISBA, snow, soil models
  - Still mainly horizontally uncoupled – upper air flow couples but flux aggregation ?
  - Tiled or untiled ? – tiles still exist below 1 km
- Turbulence scheme – CBR TKE - moist
  - 1D or 3D ? 1D at 3 km and 3D at 1 km?
  - Interactions with cloud scheme and convection
  - Shallow convection ?
- Radiation scheme – slopes considered
  - 3D ? - More advanced – more species
- Cloud scheme – more advanced and more species
- MSO/SSO
  - MSO relaxed but SSO needed at 1 km

AROME and ALADIN components

- Turbulence CBR – HIRLAM 1d
- Externalised ISBA – HIRLAM tiled
- (Kain-Fritsch – synoptic scale - HIRLAM)
- Town model
- Advanced cloud physics
- Radiation scheme (Morcrette, ECMWF)
- Chemical modelling

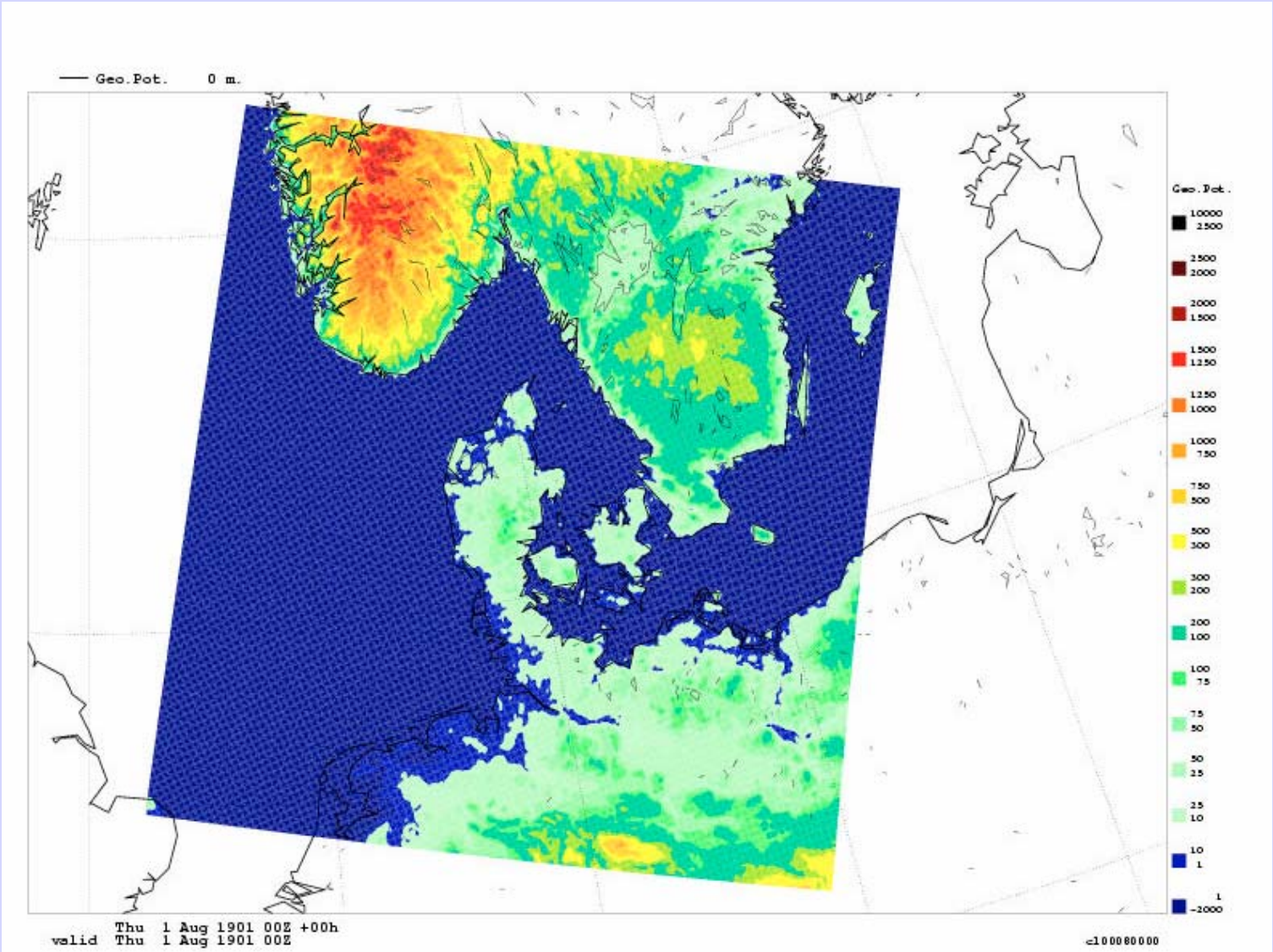
HIRLAM research topics for the coming years
Strong contributions to ALADIN in collaboration

- HI physics improvements
- HI physics interfacing, 2005
- Meso-scale physics choices 2006-2007
- Synoptic scale 4D-VAR 2005-2007
- Meso-scale 3D-VAR 2005-2006
- Meso-scale 4D-VAR 2007-

- Meso-scale observations
  - radar winds 2005-
  - reflectivity 2006 -
  - GPS moisture 2005-
- Surface and SST assimilation
- Cloud imagery
- Large scale coupling
- Meso-scale validation
- Short range EPS / prob

HIRLAM meso-scale group

- Learning - set up of ALADIN - climate - coupling
- DMI-SMHI-FMI-INM -
- Set up of domain(s)
- Physics interface - temporary - general HIRLAM and AROME
- First experiments
- Coupling with HIRLAM outer model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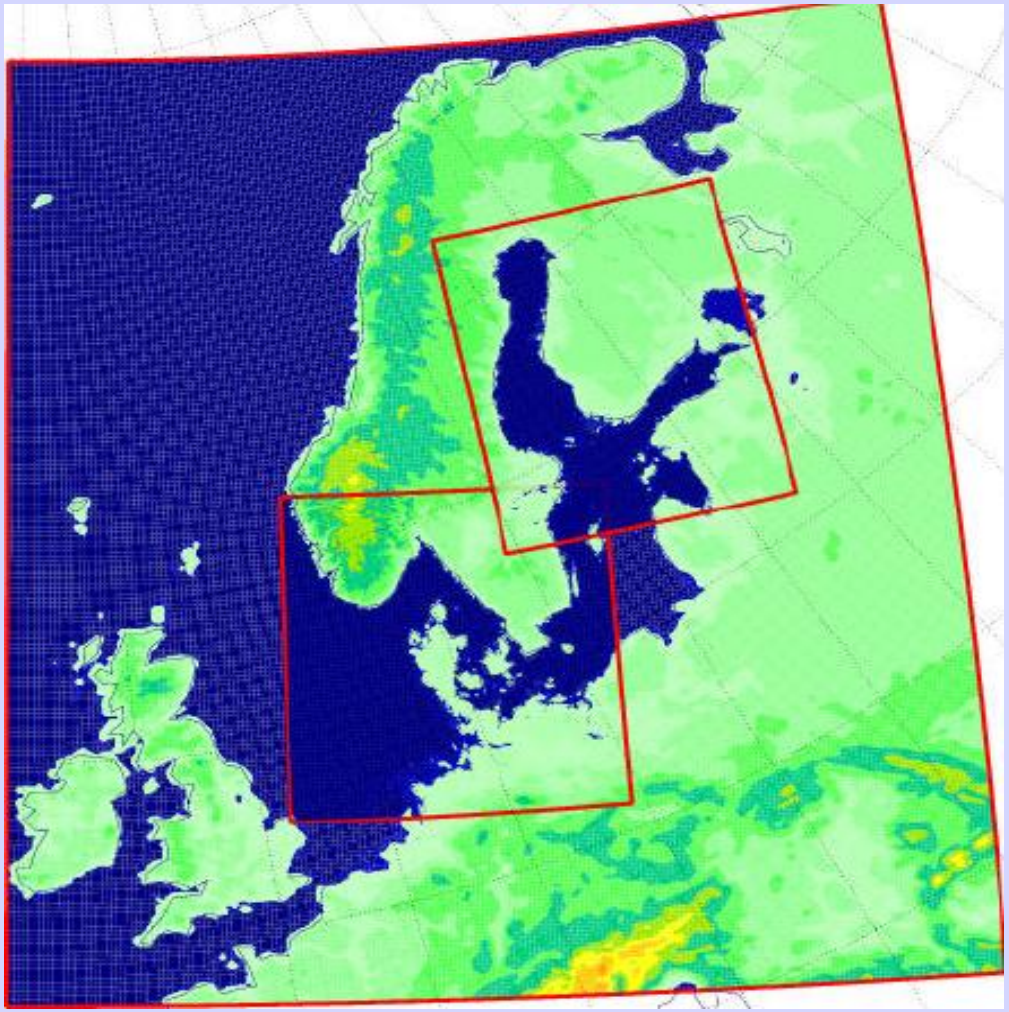
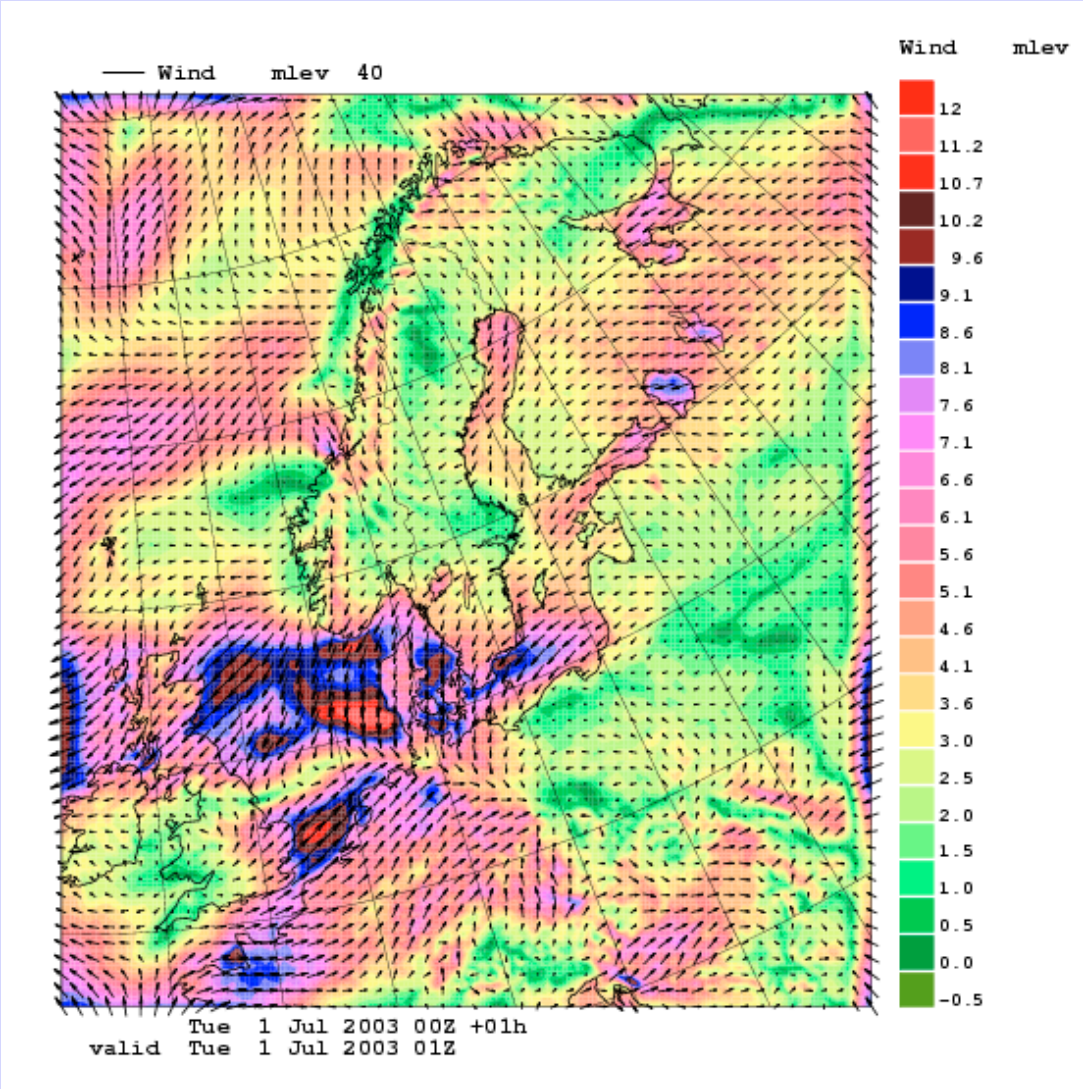
HIRLAM work with ALADIN in 2005

- Make experiments at 11 and 2.5 km
- Interface HI -ALADIN coupling-boundaries
- Interface some HI physics
- Implement climate generation software
- Introduce AROME system
- Experience from AROME from events -evaluate some HI physics
- Develop meso-scale diagnostics

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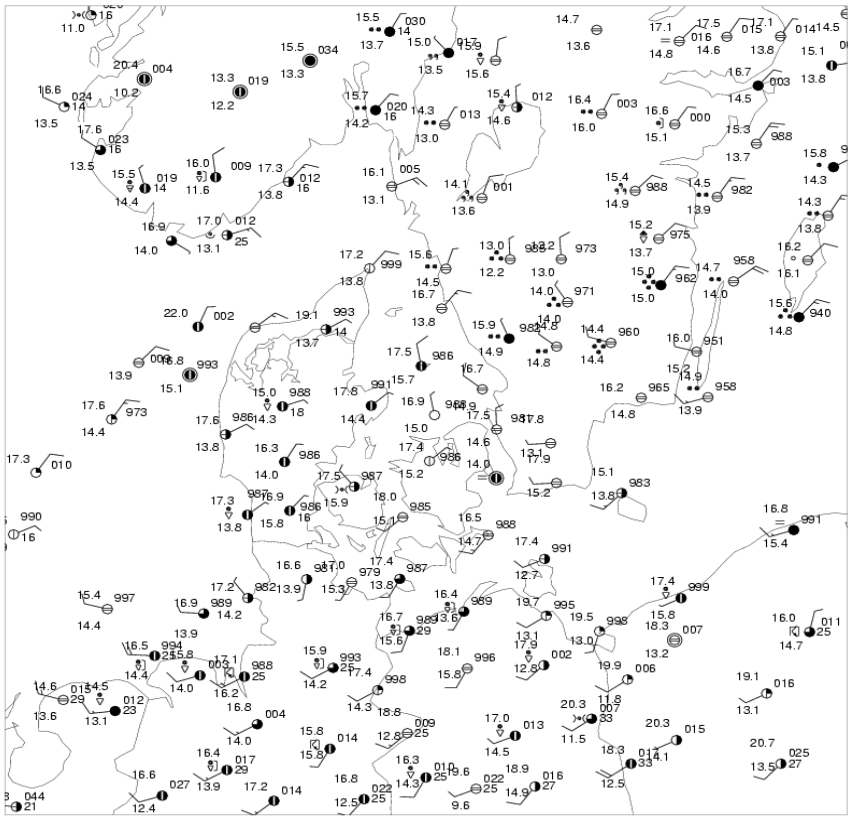
Experiments

- Test period 1st-7th og July 2003

  Convective precipitation over Danish area
- No data-assimilation
- Physics is from ARPEGE (not NH physics yet)

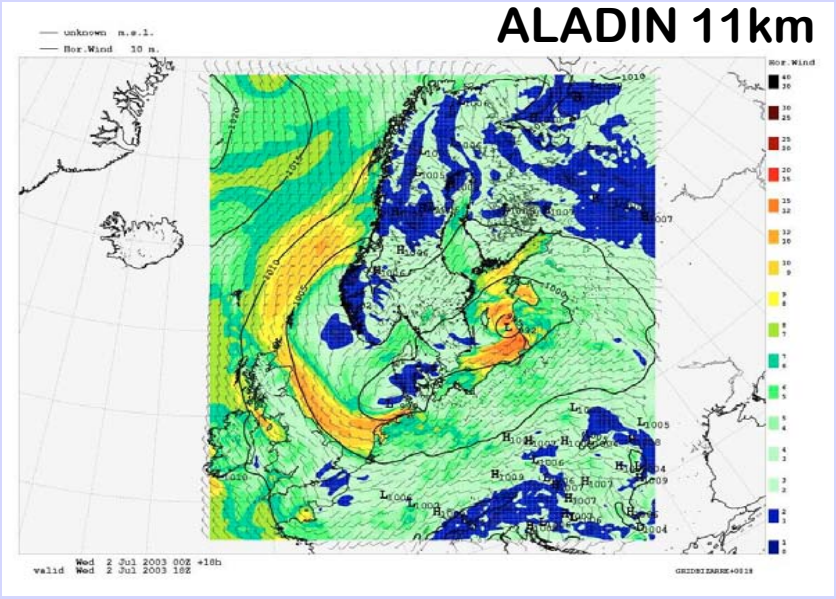
  One case the 2nd of July

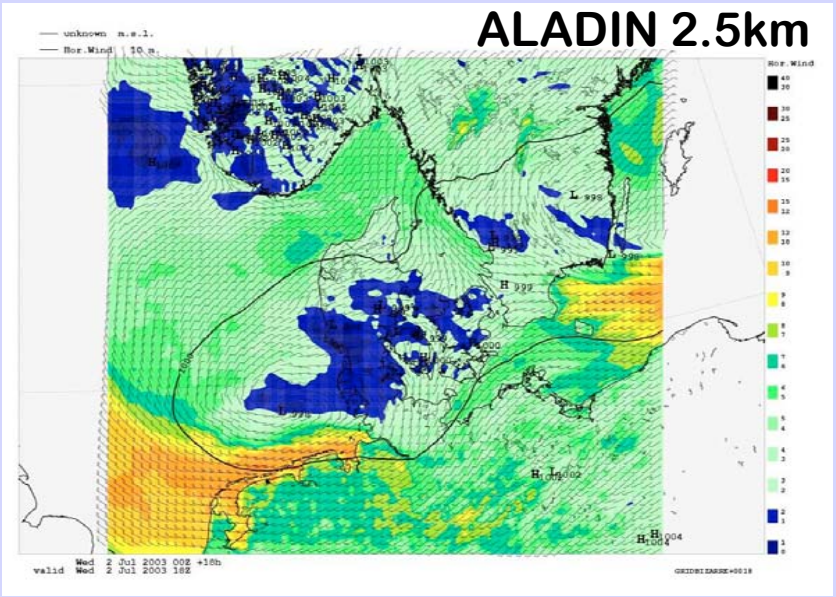
Observations 2nd of July 2003 18 UTC

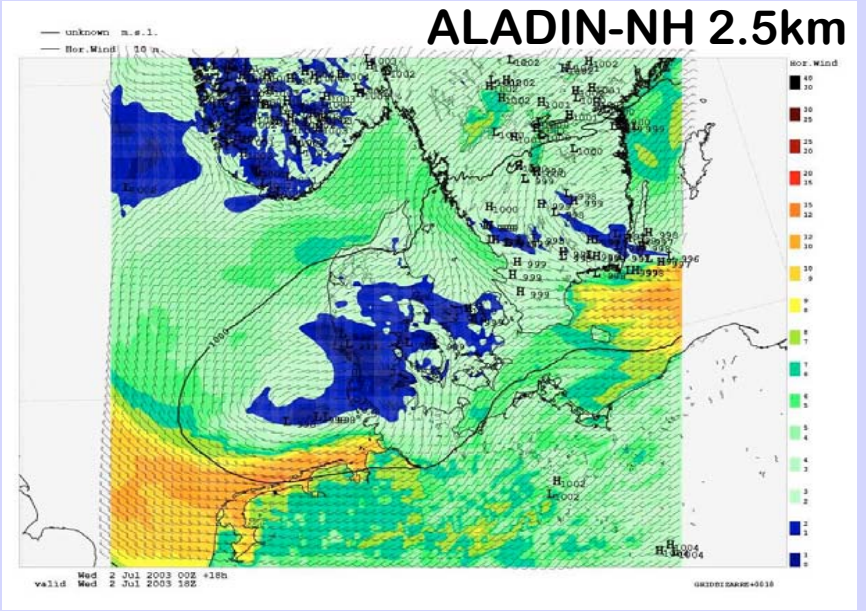


2. juli 2003, 18:00 UTC
Temperatur, Dugpunkt, Vind, Vindstød, Vejr, Tryk, Skydække,

Aladin forecast 2nd of July 2003 18 UTC

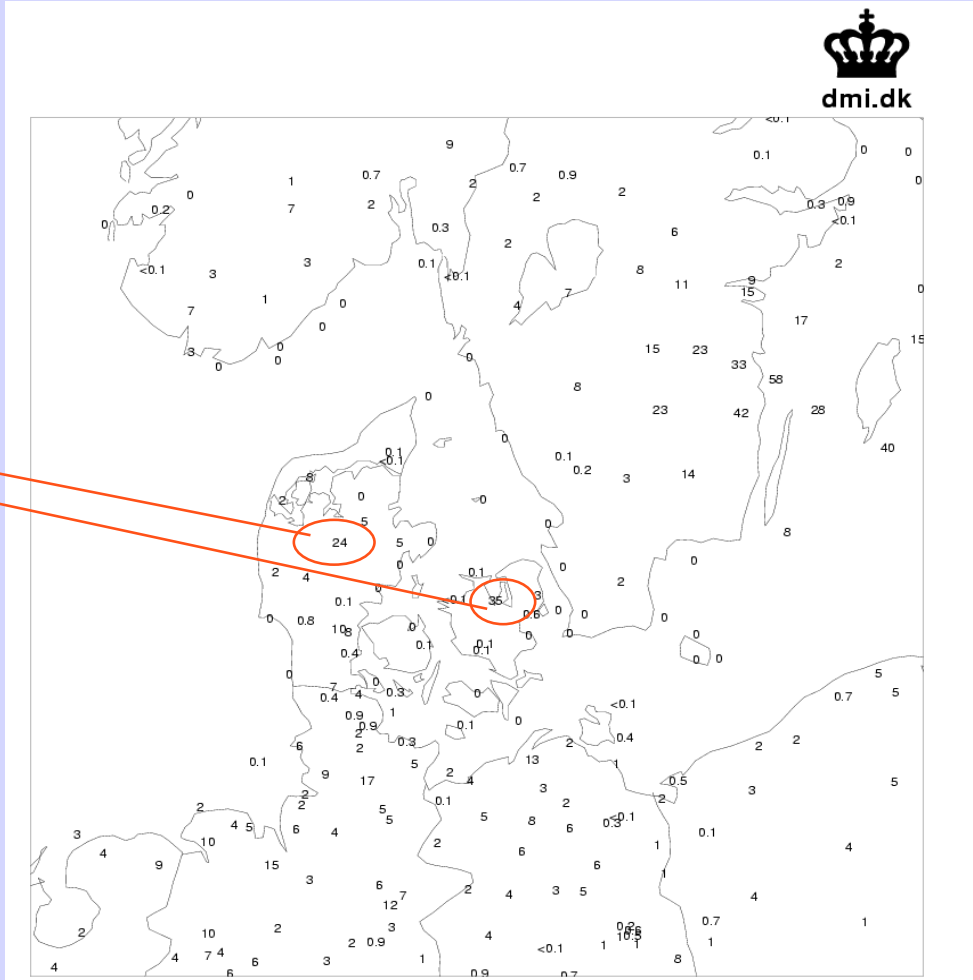






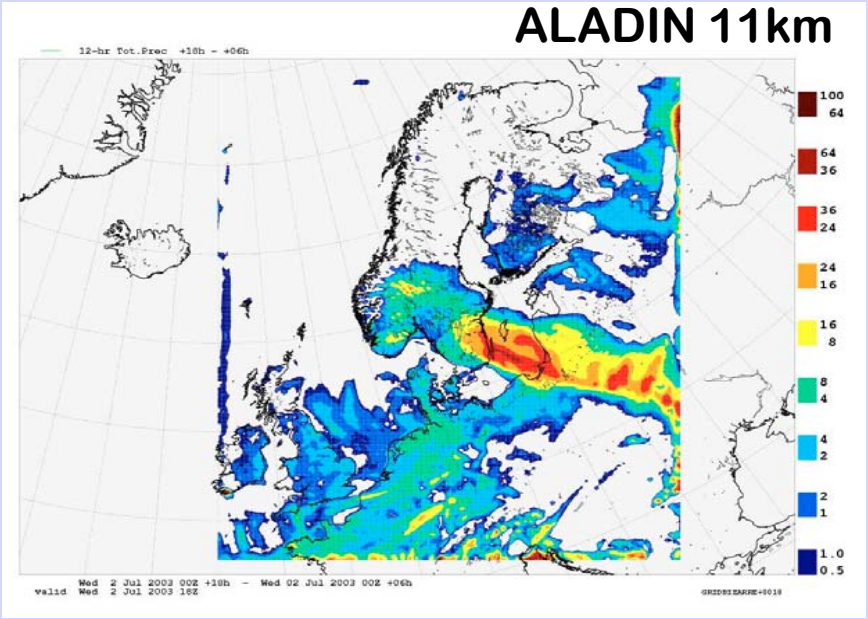
Precipitation observations

Heavy precipitation

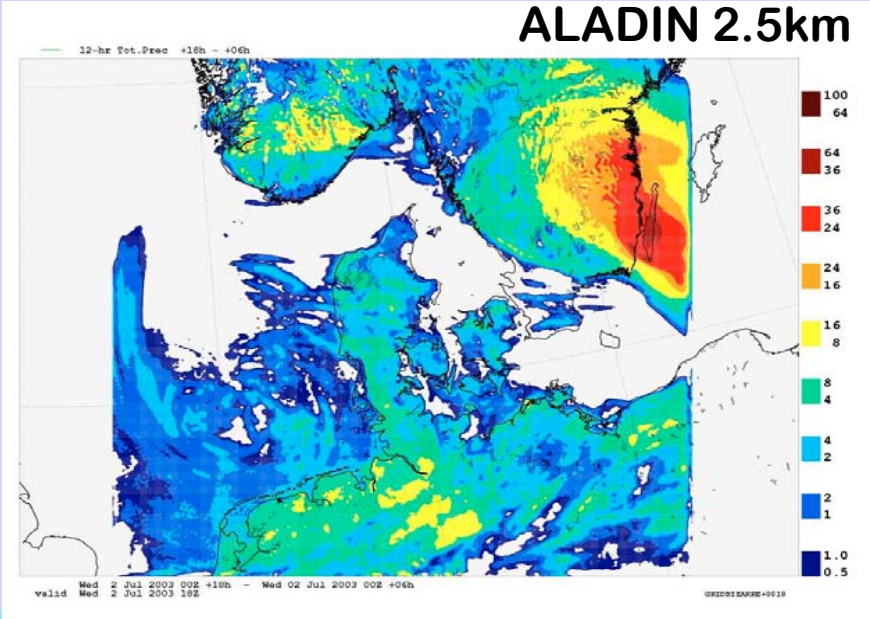


ALADIN model simulations (12 hours accumulated precipitation)

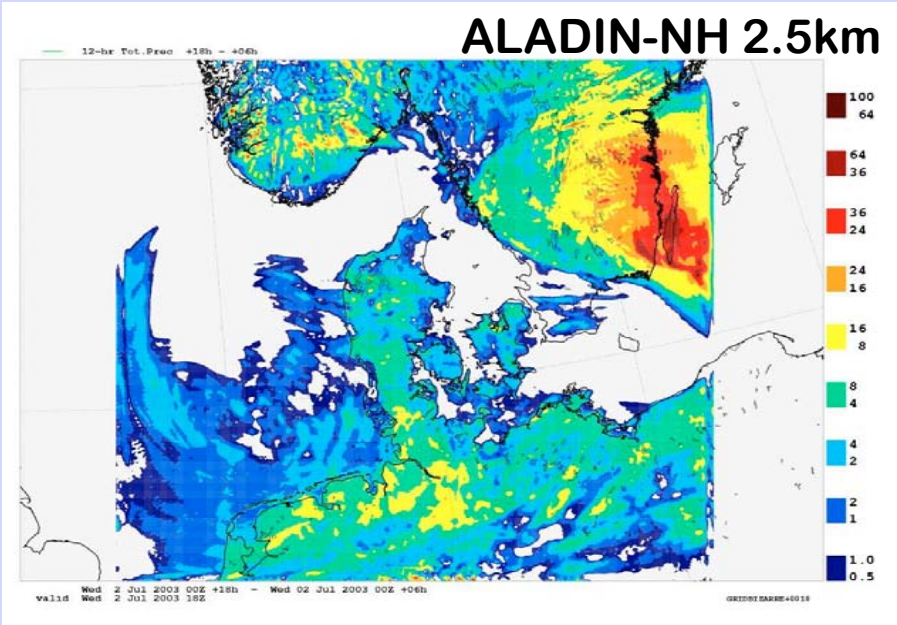
ALADIN 11km



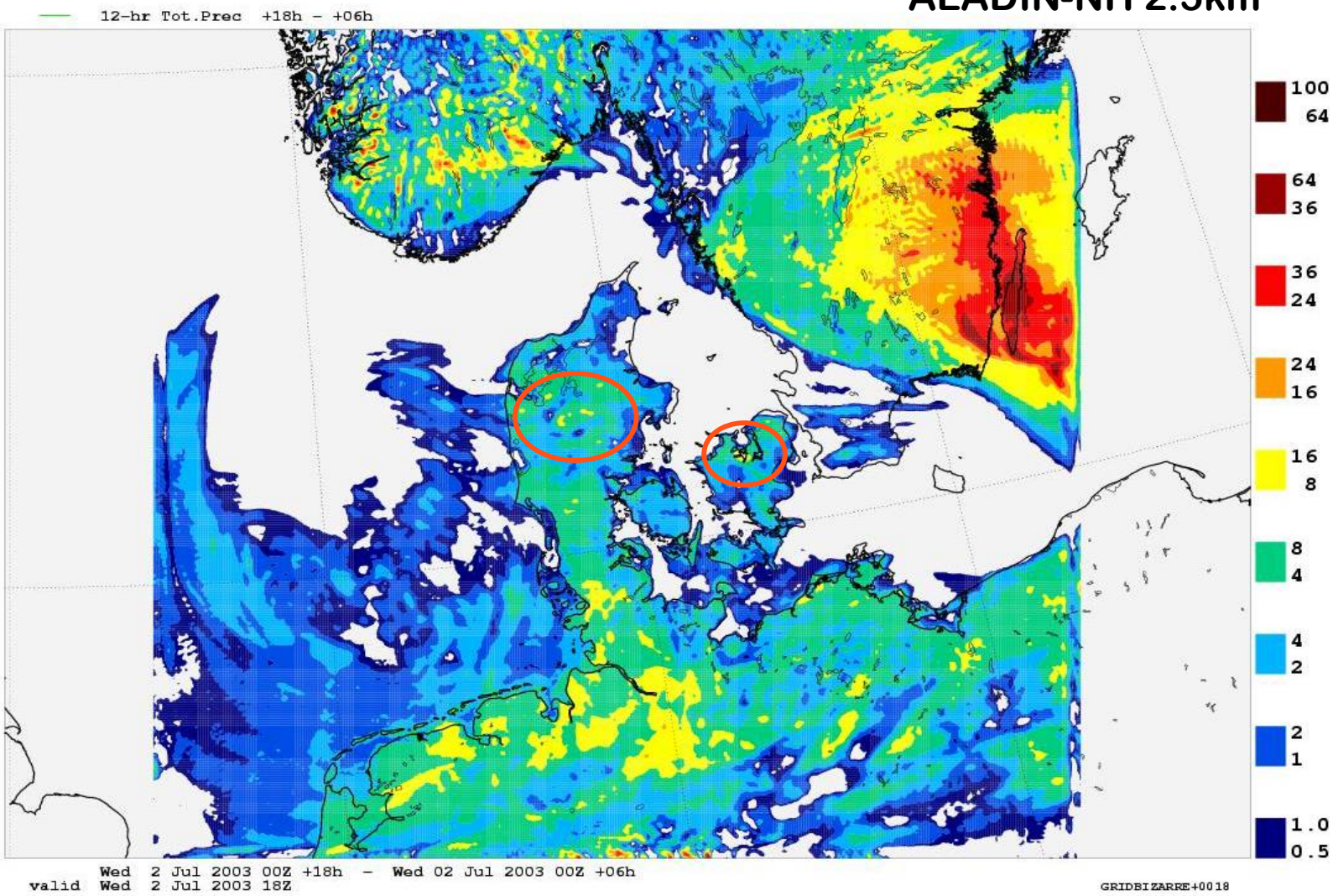
ALADIN 2.5km



ALADIN-NH 2.5km



ALADIN-NH 2.5km



Summary

- Long term MoU and strategy
- More active areas – more resources
- Collaboration necessary – ALADIN – and also merge other components
- HIRLAM profile in joint code AND and active contributor and corresponding influence
- HIRLAM with authority over staff