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Twenty-two years of verification from the HIRLAM NWP system

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- Short history of HIRLAM at FMI
- Time-series for the years 1990 … 2012
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  - For 2004 … 2012
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Background

- Hirlam forecast systems have been run operationally at FMI since 2 January 1990
- Field verification implemented in July 1990
- Observation verification system operationally since 1995
- Three reasons to verify (Jolliffe and Stephenson 2003):
  - **Administrative**
  - Scientific
  - Economical

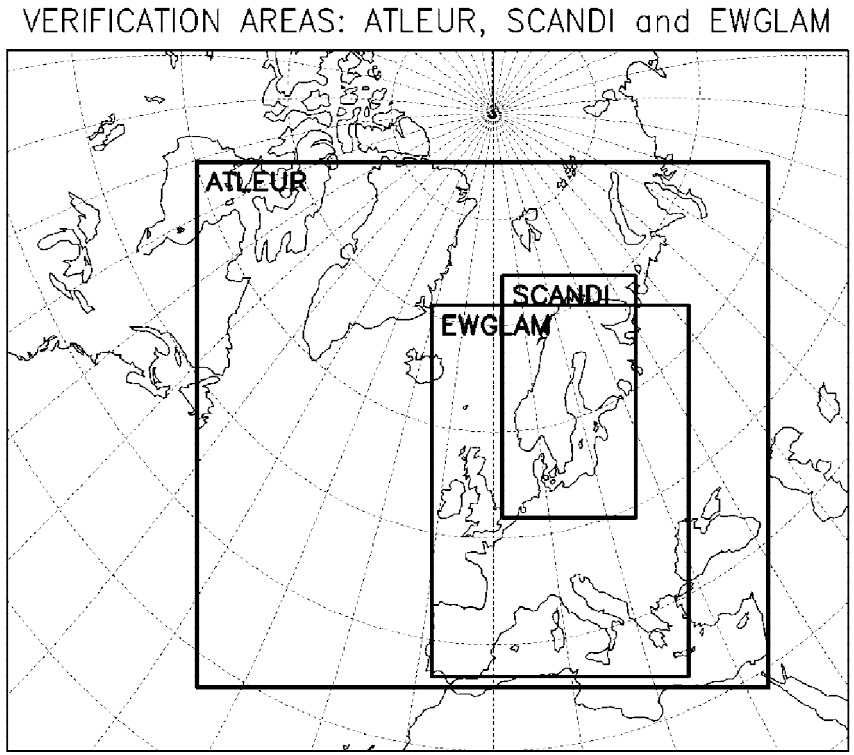
Short history of HIRLAM

- 13 different versions and many smaller changes
- From 2004 onwards RCR: running the official reference system
- Resolution improved:
  - Horizontal: 0.5 deg → 0.07 deg
  - Vertical: 16 levels → 65 levels
  - nx * ny * nz
    - 130 * 100*16 = 208 000
    - 1030*816*65 = 56 639 700
    - → ~ 272 times more gridpoints
- Increased computer power has made all improvements possible
- Some milestones in the table

Acronym	Period	$n_x \times n_y$	dx	Levels	Version	Remarks
FIN	01/1990 - 05/1994	130 × 100	0.5	16	Hirlam 1	31 level in 1992, Bdries twice/day in 1993
SFI	06/1994 - 08/1996	130 × 100	0.5	31	Hirlam 2	Savijärvi radiation New physiography
NSF	09/1996 - 11/1997	194 × 140	0.4	31	Hirlam 2.1	
ATL	12/1997 - 10/1999	194 × 140	0.4	31	Hirlam 2.5	
ATA	11/1999 - 02/2003	194 × 140	0.4	31	Hirlam 4.6.2	CBR, ECMWF bdries 4 times/day
ATX	03/2003 - 01/2004	256 × 186	0.3	40	Hirlam 5.1.4	3DVAR, ISBA semi-Lagrangian
V621	02/2004 - 05/2005	436 × 336	0.2	40	Hirlam 6.3	FGAT, First RCR, Digital filter
V637	06/2005 - 05/2006	438 × 336	0.2	40	Hirlam 6.4	
V641	06/2006 - 03/2007	438 × 336	0.2	40	Hirlam 7.0	Re-run concept
V71	04/2007 - 08/2008	583 × 448	0.15	60	Hirlam 7.1	
V72	09/2008 - 09/2010	583 × 448	0.15	60	Hirlam 7.2	4DVAR, Kain-Fritch
V73	10/2010 - 2/2012	583 × 448	0.15	60	Hirlam 7.3	Improved surface scheme
V74	3/2012 - -	1030 × 816	0.07	65	Hirlam 7.4	Flake lake model

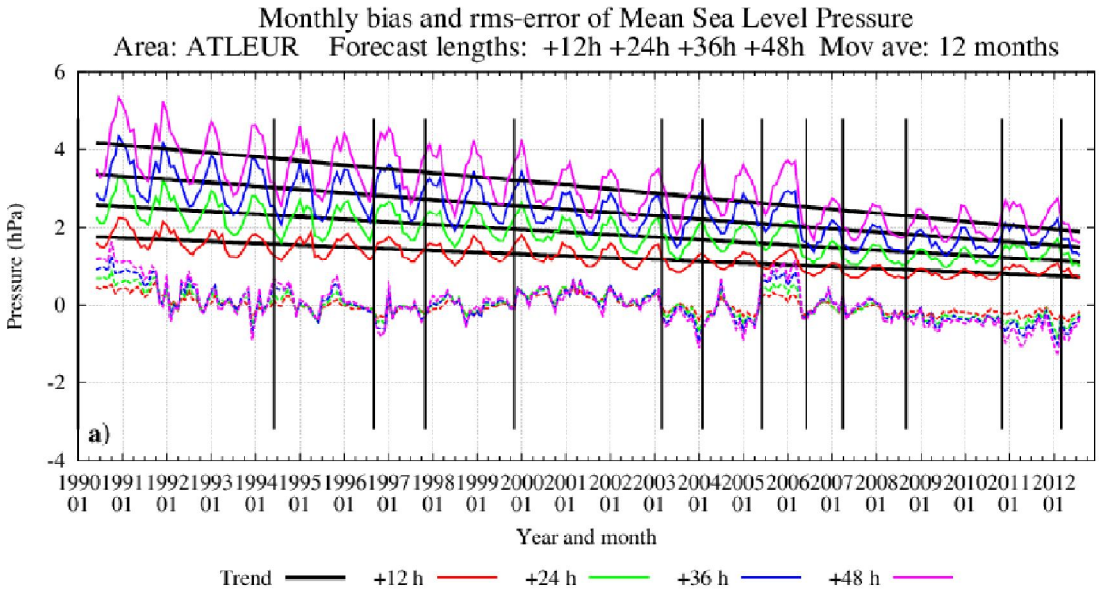
Statistical verification

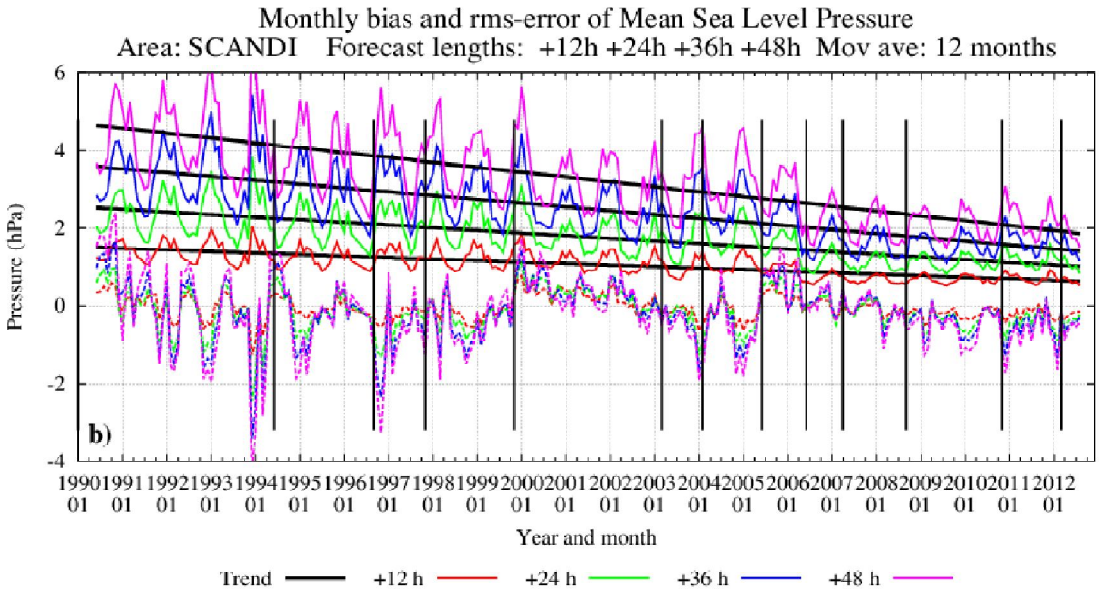
- Field verification: verifying against the HIRLAM numerical analysis
- Monthly scores for mean sea level pressure (mslp) and Temperature at 925 hPa
- RMS error and bias
- The results will be shown mainly on two areas:
  - **ATLEUR**: Atlantic-European area, largest common area to all FMI HIRLAMs
  - **SCANDI**: Scandinavian area is interesting for us
- Time series from July 1990 to August 2012, over 22 years
- Interpretation of RMS error:
  - A lot of discussion in the literature
  - Favors smooth fields and low resolution
  - Double penalty problem
  - Gives larger weight to large errors (squared)



Results with linear trend

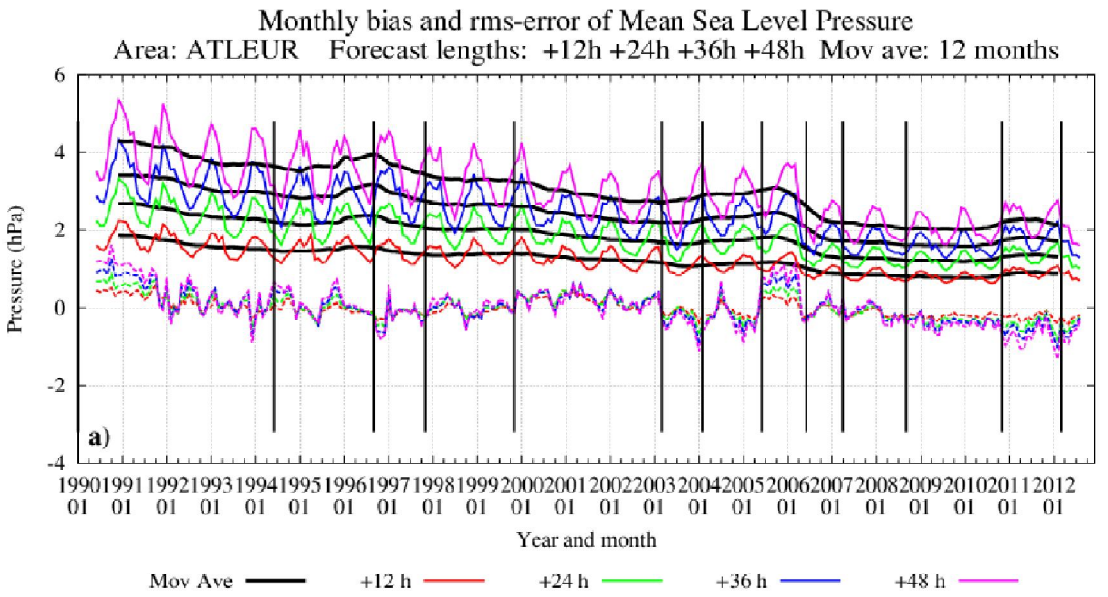
- July 1990 … August 2012
- RMS error and bias for the two areas
- Linear trend

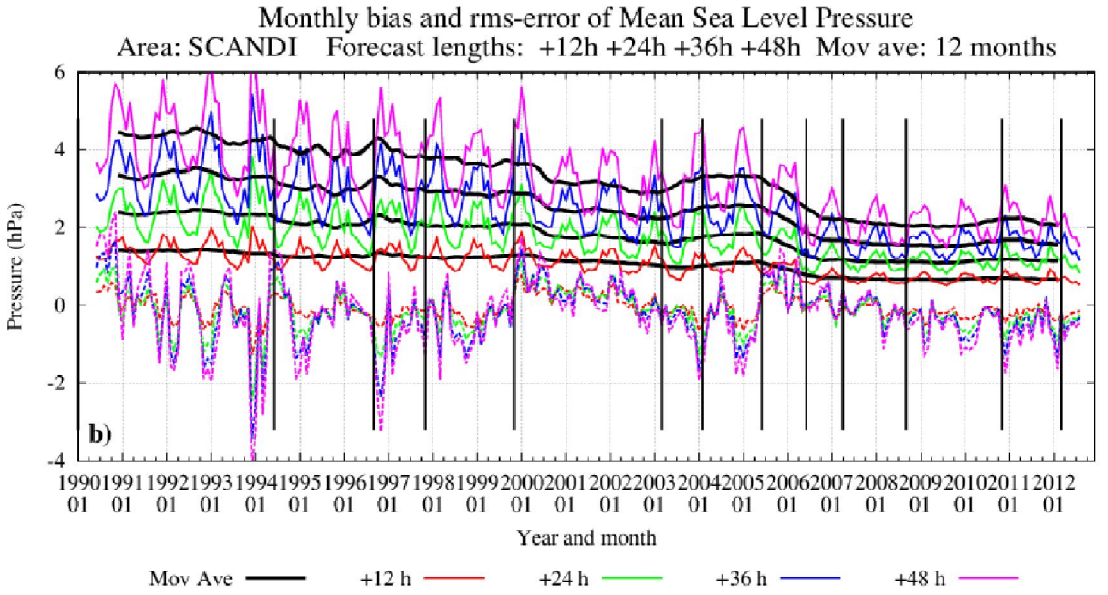




Results with moving average

- 13 months' moving average
- 2-day forecasts now better than 1-day forecasts 20 years ago
- Improvements not linear
- Reasons for improvements?
  - Model improvements?
  - Weather types (regimes)?
- Statistical scores do not tell the reason for improvements
- Can the improvements traced back to changes in the forecasting system?
  - In some cases yes
- Some examples of the reasons for improvements





Improvements in 2006, what happened?

Re-run concept:

- ECMWF lateral boundaries used always
- New: use the analysis of the previous cycle
- ECMWF analysis is superior to HIRLAM analysis
- Re-run the previous cycle
  - Analysis for this is combination of ECMWF and HIRLAM analysis
  - Large-scale structure from ECMWF
  - Preserve small-scale structure from HIRLAM
- Run a short forecast to get the best possible first guess for the current cycle

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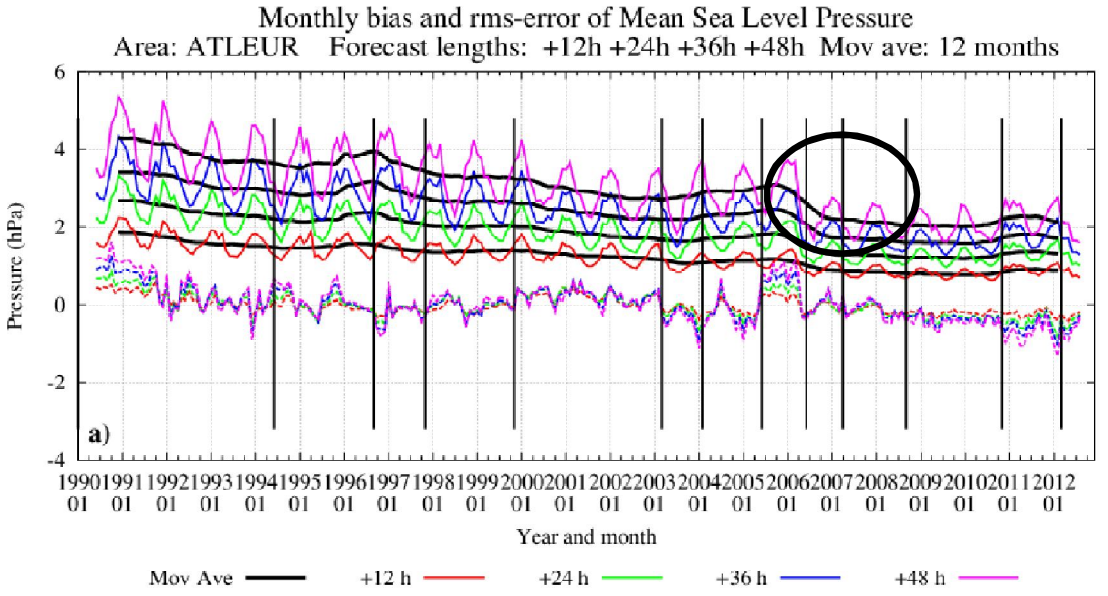
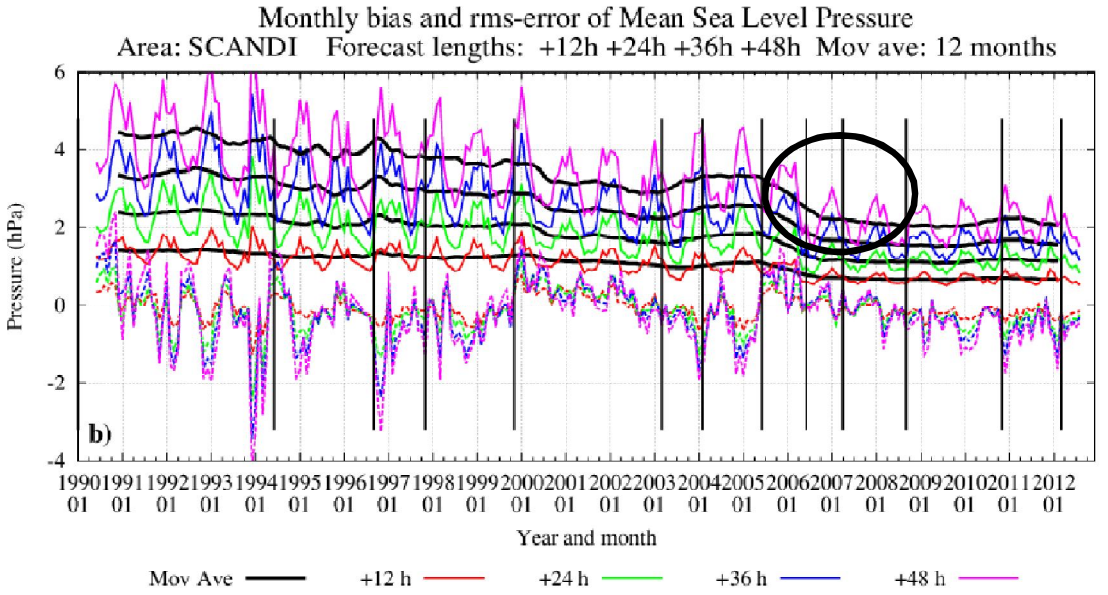


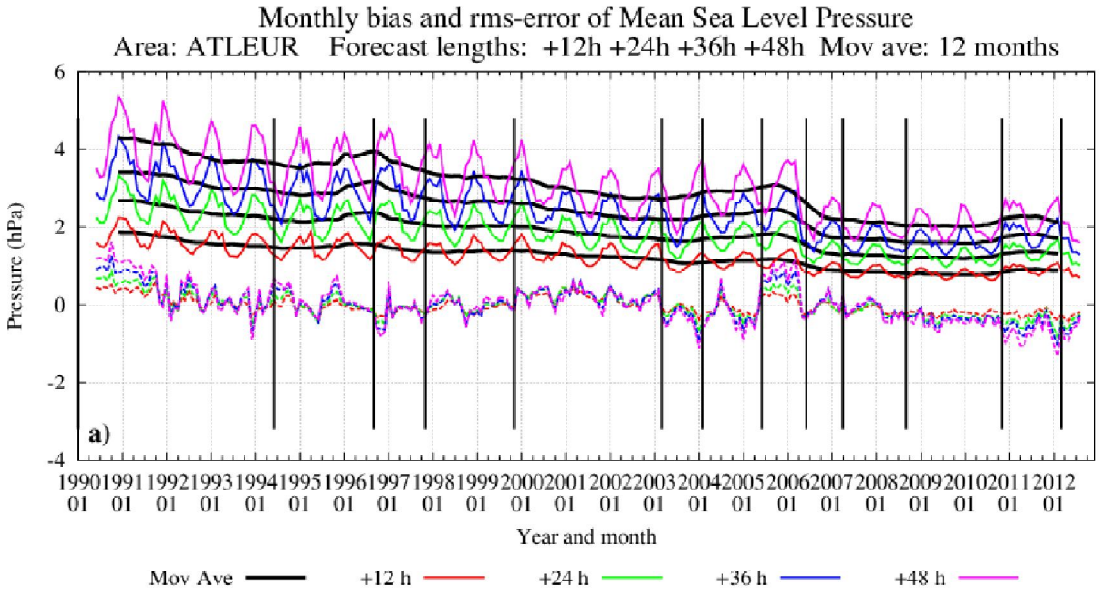


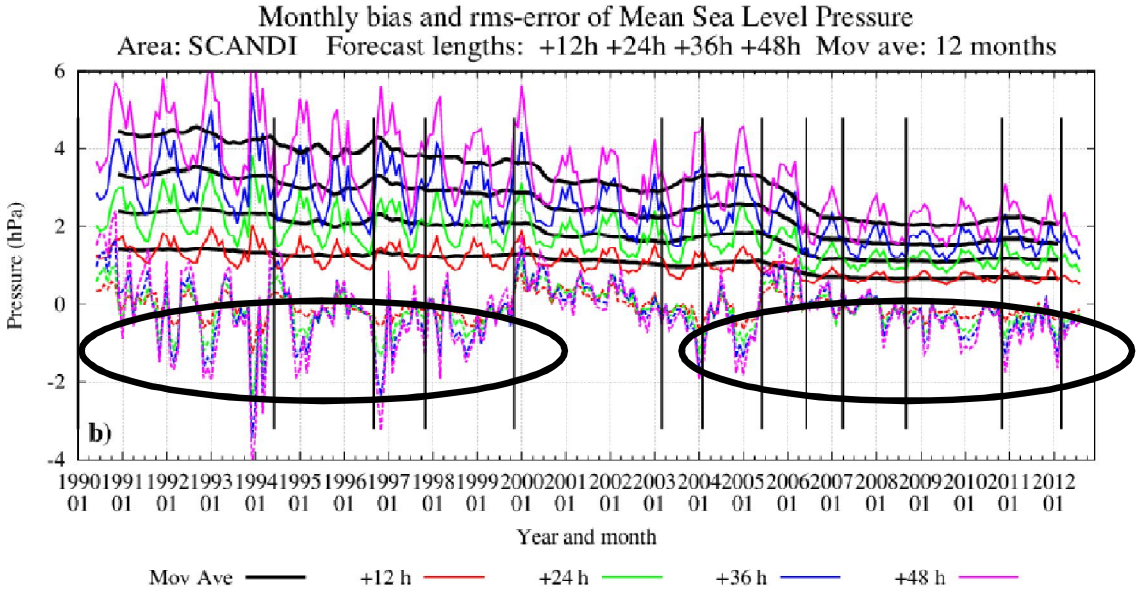
Negative bias in Scandinavia in winter

Large negative bias in winter in Scandinavia

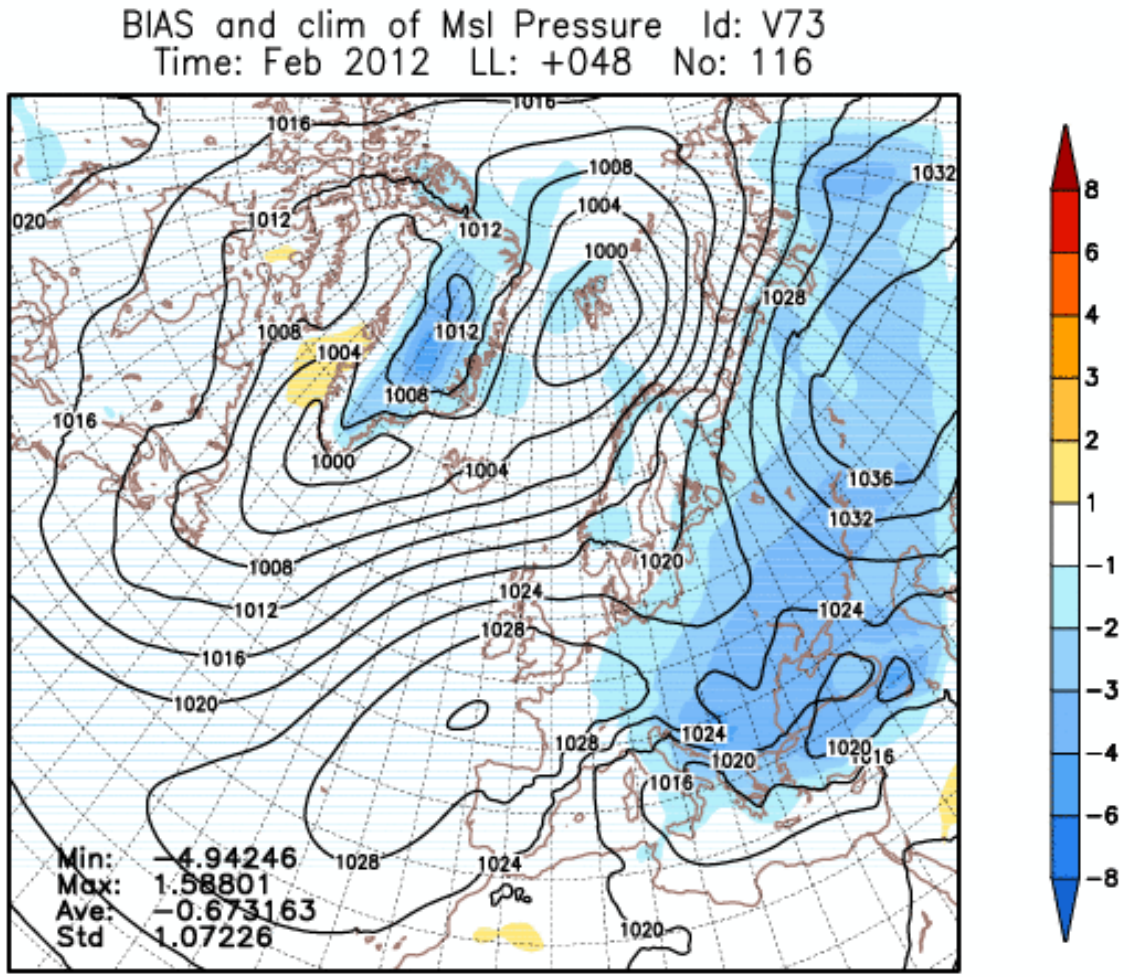
- Increasing with forecast length
- Very large in the first years
- In last two Januaries large bias
  - Weather regime?
  - HIRLAM system?

- Last two winters: large negative bias→ what happens next winter?
- Simo Järvenoja suggested in 2005:
  - Could it be the location of the eastern boundary?
  - Try with different horizontal areas, some extending more east
  - Turbulence scheme?
- We don't know the reason
- Statistical methods can describe the situation, but not explain the physical reason

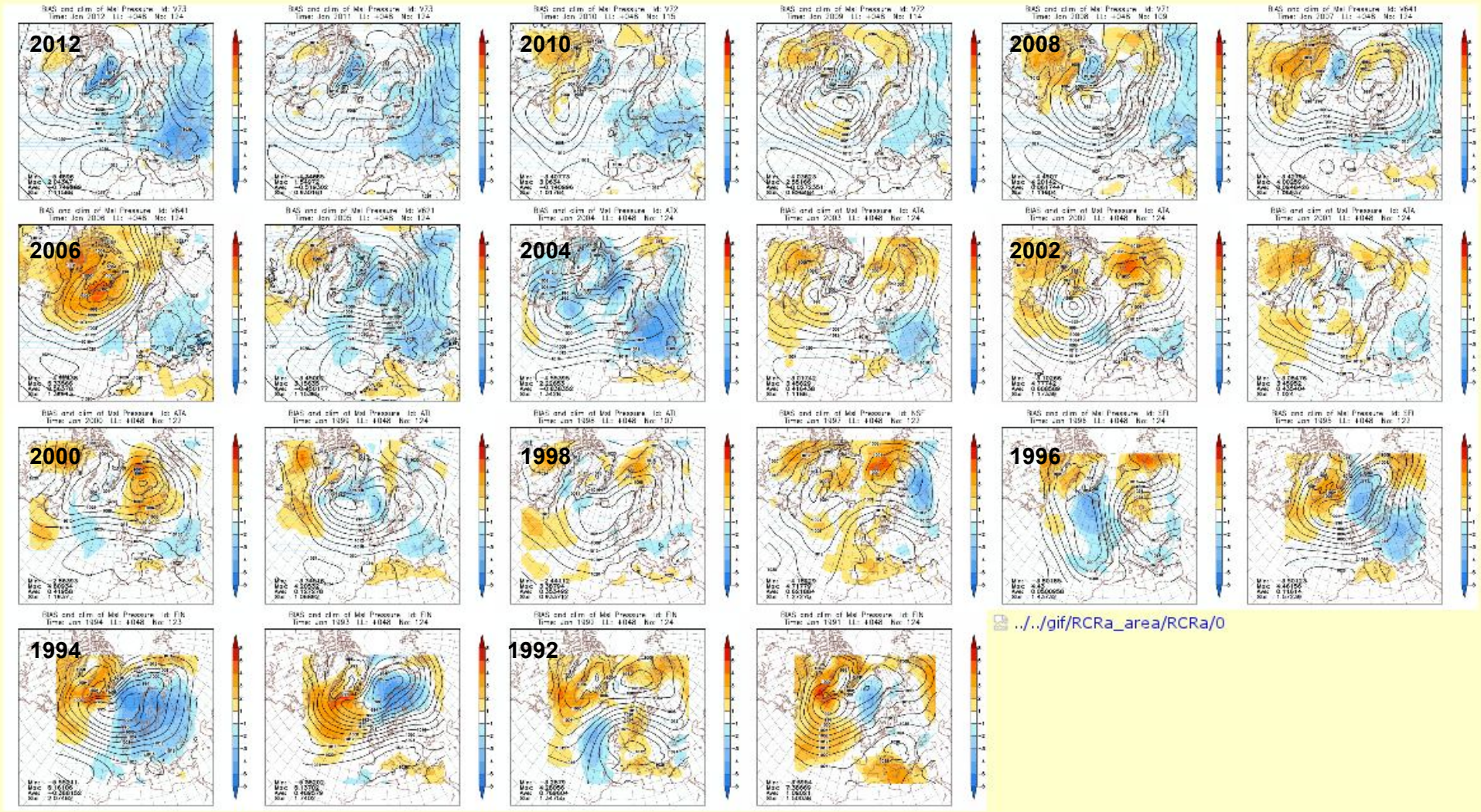




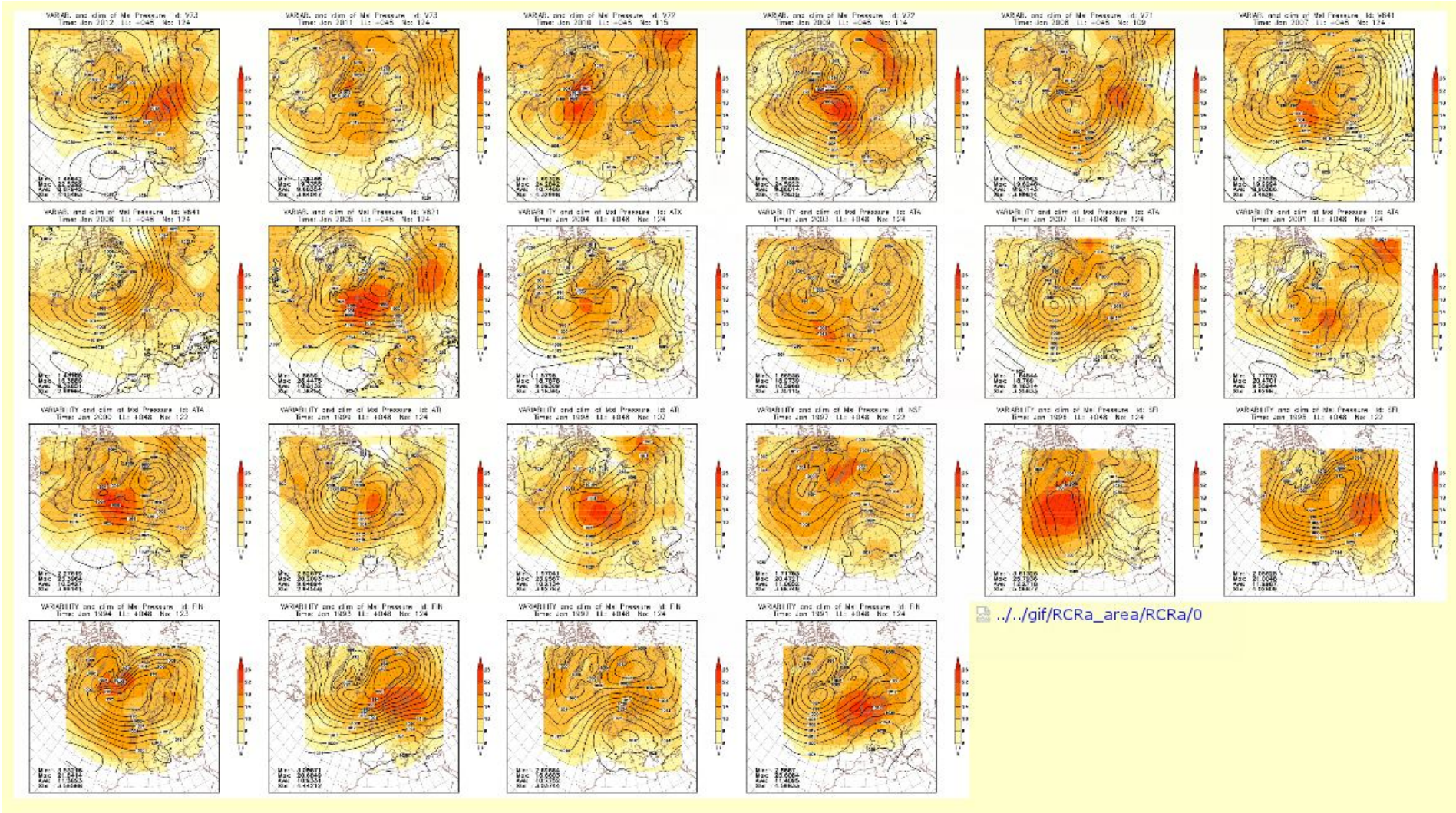
Just for orientation



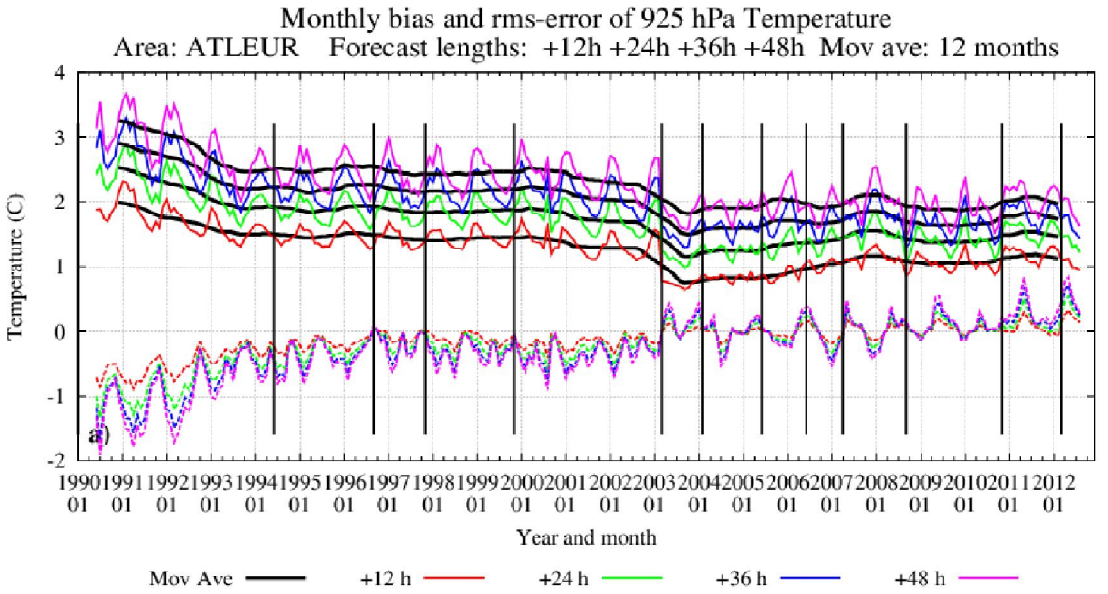
Monthly bias, +48 h, mslp, January 1991-2012

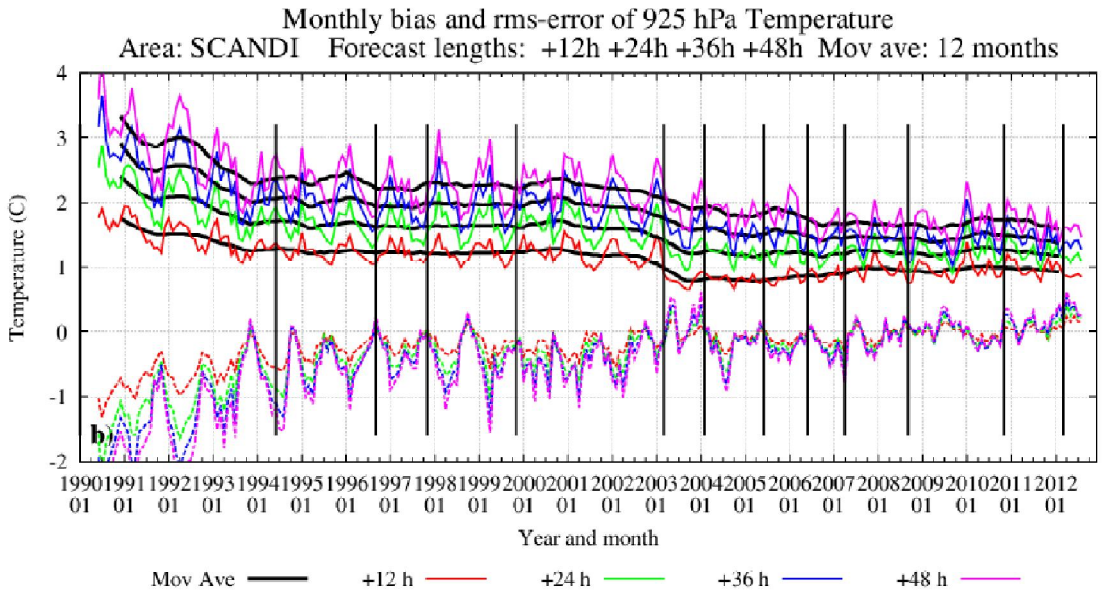


Monthly variability, +48 h, mslp, January 1991-2012



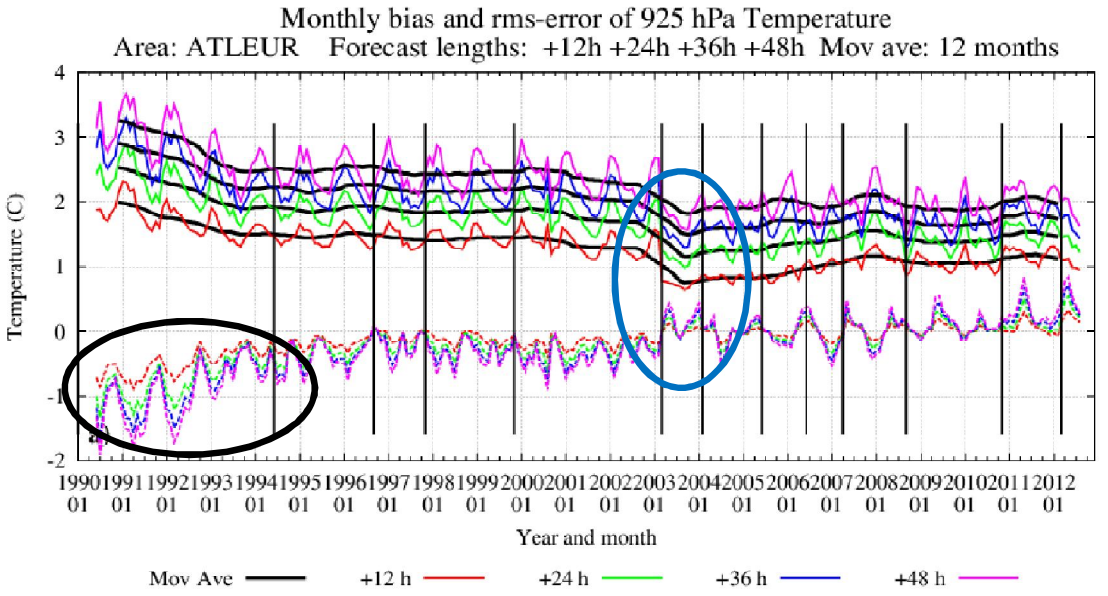
Bias and RMSE, T at 925

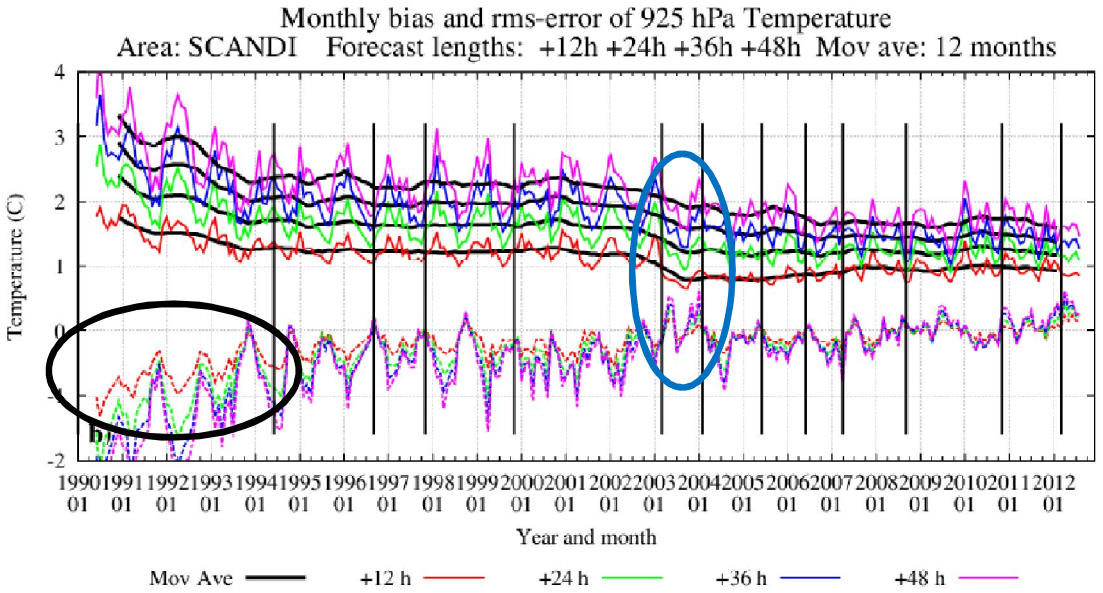




Bias and RMSE, T at 925

- Negative bias in early years
- Many experiments were runs to find the reason
  - The whole lower troposphere was too cold and moist
  - Caused permanent stratus cloud
  - Several corrections were tried
  - Two of them helped
    - Increase of vertical levels from 16 to 31
    - Savijärvi radiation scheme
- Improvement in 2003
  - In bias: negative bias -> slightly positive bias
  - Reduction in RMSE, especially in ATLEUR
  - Most probably due to the introduction of 3DVAR





Effect of weather type on scores in winter

- NAO-index is used widely to classify weather type in the North Atlantic
  - Positive NAO: westerly flow
  - Negative NAO: blocking
- Correlation between NAO and RMSE not very high, but:
  - In 1990's larger correlation between NAO and RMSE
  - In 2000's decreases

- Possible reasons for higher correlation in 1990s
  - Smaller horizontal area, boundaries closer
  - No satellite data
  - ECMWF boundaries only once or twice a day
  - No re-run concept

Correlation between RMSE of +48 h forecasts and NAO-index in winter

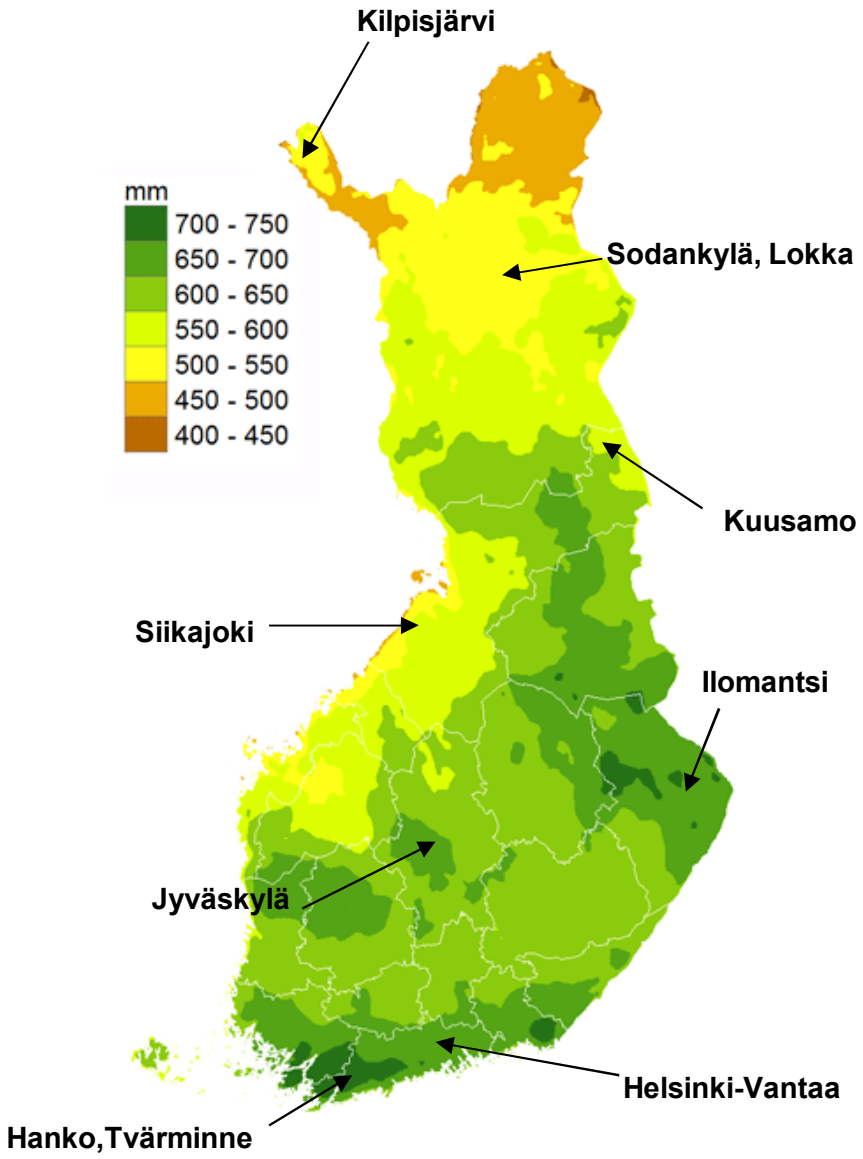
		All winters	Winters 1990-1999	Winters 2000-2011
SCANDI	mslp	0.36	0.42	0.21
	Z500	0.37	0.41	0.25
EWGLAM	mslp	0.35	0.46	0.16
	Z500	0.36	0.38	0.24

Observed and predicted monthly precipitation

- Some preliminary results
- Observations: rain gauge observations for 2004-2012
- Monthly precipitations sums from HIRLAM forecasts
  - Computed as an accumulation in 6 hours
  - For different forecast lengths:
    - +0…+6h, +6h…+12h, +12h…+18h, … , +42h…+48h
  - Are there differences in different lead times?
    - Spin-up problem?
    - Bias increasing/decreasing with lead time?

Yearly precipitation in Finland

- Normal yearly precipitation amount in Finland
- Some stations for which results will be shown



Observed and forecast (at different lead times) seasonal precipitation in Finland 2004-2012 and forecast precipitation in percents of observed

	Obs	+0 -> +6	+6-> +12	+12-> +18	+18-> +24	+24-> +30	+30-> +36	+36-> +42	+42-> +48
Winter	43	50	54	55	54	53	53	53	54
		115	126	127	125	124	125	125	126
Spring	36	44	51	51	51	51	51	51	51
		125	144	146	147	147	147	147	147
Summer	72	77	84	82	81	78	76	73	71
		108	116	113	113	109	105	102	99
Autumn	60	69	74	73	73	72	73	73	70
		115	124	123	122	121	123	122	118

What we have in the table?

- **Observed seasonal precipitation (mm)**
- **Different forecast lengths**
- **Predicted precipitation by HIRLAM at different lead times**
- **Predicted precipitation in percents of the observed precipitation**

Observed and forecast (at different lead times) seasonal precipitation in Finland 2004-2012 and forecast precipitation in percents of observed

	Obs	+0 -> +6	+6-> +12	+12-> +18	+18-> +24	+24-> +30	+30-> +36	+36-> +42	+42-> +48
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Autumn	60	69	74	73	73	72	73	73	70
		115	124	123	122	121	123	122	118

Seasonal verification, whole Finland

- Spin-up problem:
  - Shortest forecast gives systematically less precipitation at all seasons
- Effect of forecast length
  - There does not seem to be clear systematic increase/decrease for other forecast lengths

Observed and forecast (at different lead times) seasonal precipitation in Finland 2004-2012 and forecast precipitation in percents of observed

	Obs	+0 -> +6	+6-> +12	+12-> +18	+18-> +24	+24 -> +30	+30-> +36	+36-> +42	+42-> +48
Winter	43	50	54	55	54	53	53	53	54
		115	126	127	125	124	125	125	126
Spring	36	44	51	51	51	51	51	51	51
		125	144	146	147	147	147	147	147
Summer	72	77	84	82	81	78	76	73	71
		108	116	113	113	109	105	102	99
Autumn	60	69	74	73	73	72	73	73	70
		115	124	123	122	121	123	122	118

Different seasons

- HIRLAM overpredicts the seasonal precipitation
  - In winter and autumn by 20…30%
  - In spring by 40…50%
  - In summer by 10…20%
- Summer
  - More convective precipitation
  - Under-predicts the very large amounts (see later)
- Spring
  - Driest season
  - Overestimates the precipitation almost by 50%
- Winter and autumn similar

Observed and forecast (at different lead times) seasonal precipitation in Finland 2004-2012 and forecast precipitation in percents of observed

	Obs	+0 -> +6	+6-> +12	+12-> +18	+18-> +24	+24-> +30	+30-> +36	+36-> +42	+42-> +48
Winter	43	50	54	55	54	53	53	53	54
		115	126	127	125	124	125	125	126
Spring	36	44	51	51	51	51	51	51	51
		125	144	146	147	147	147	147	147
Summer	72	77	84	82	81	78	76	73	71
		108	116	113	113	109	105	102	99
Autumn	60	69	74	73	73	72	73	73	70
		115	124	123	122	121	123	122	118

- This dataset cannot distinguish heavy and small amounts of precipitation

Northern and southern

- **In southern Finland**
  - More precipitation observed
  - Over-prediction smaller in percents
  - What about mm?
- **In northern Finland**
  - Less precipitation
  - Less over-prediction in percents
  - What about mm?

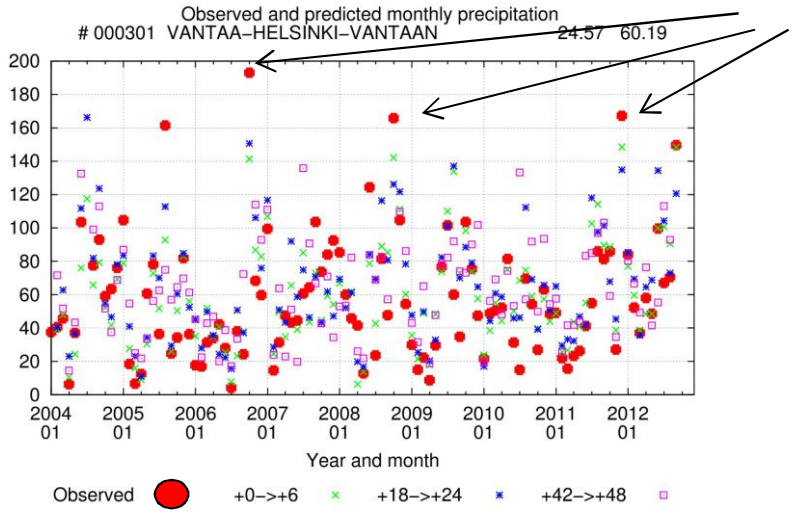
Observed and forecast (at different lead times) seasonal precipitation in southern Finland 2004-2012 and forecast precipitation in percents of observed

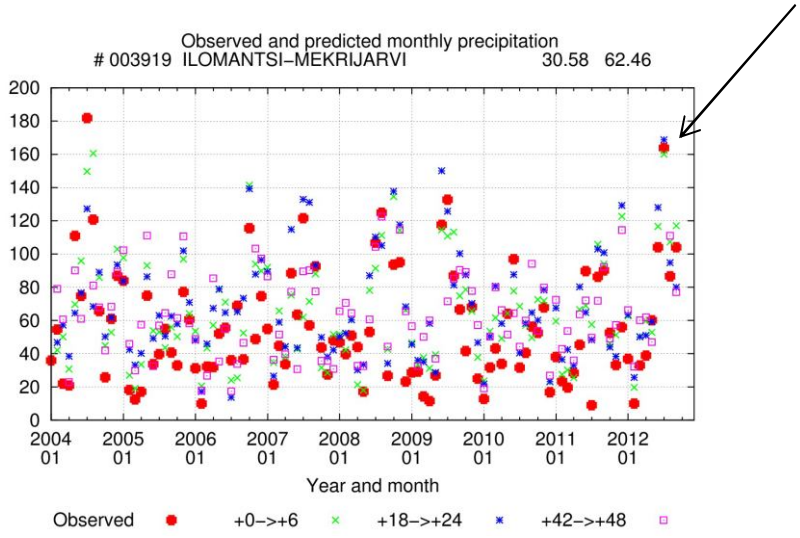
	Obs	+0 -> +6	+6-> +12	+12-> +18	+18-> +24	+24-> +30	+30-> +36	+36-> +42	+42-> +48
Winter	47	52	56	57	56	55	55	55	56
		109	119	119	118	117	117	118	120
Spring	37	41	48	47	47	48	48	48	48
		114	132	133	134	135	134	136	135
Summer	75	78	84	82	82	79	76	73	72
		104	112	110	110	105	102	98	96
Autumn	64	70	75	74	74	74	75	74	72
		109	117	116	116	115	118	117	113

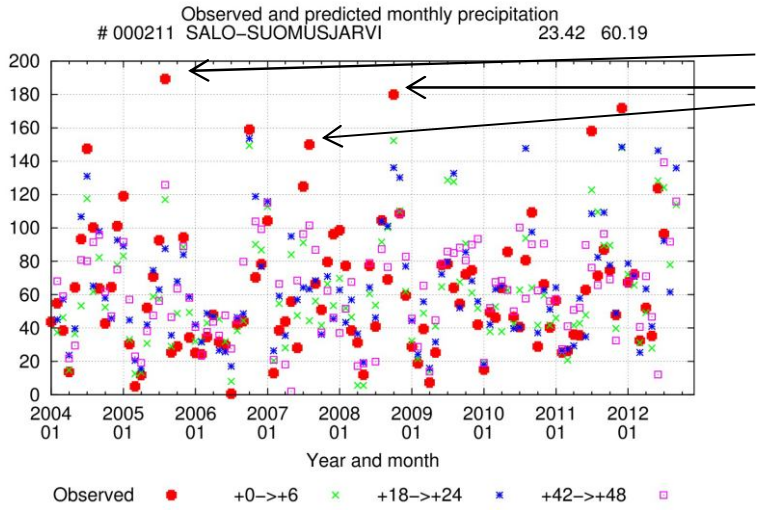
Observed and forecast (at different lead times seasonal precipitation in northern Finland 2004-2012 and forecast precipitation in percents of observed

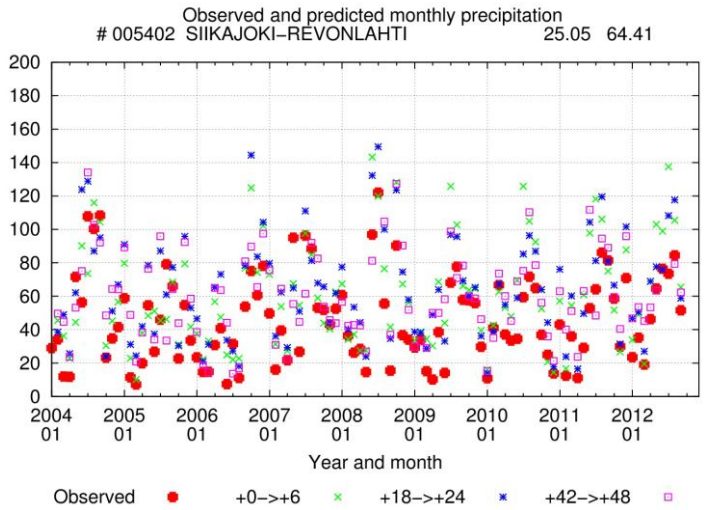
	Obs	+0 -> +6	+6-> +12	+12.-> +18	+18-> +24	+24-> +30	+30-> >+36	+36-> >+42	+42-> +48
Winter	34	45	50	50	50	50	49	49	49
		133	147	148	148	147	147	146	145
Spring	35	51	58	58	59	58	58	57	58
		151	170	174	176	175	174	172	174
Summer	66	76	83	80	78	77	74	73	69
		116	126	122	119	116	112	110	104
Autumn	50	67	72	71	70	68	68	68	66
		134	144	142	139	136	135	135	131

Monthly time-series from some stations









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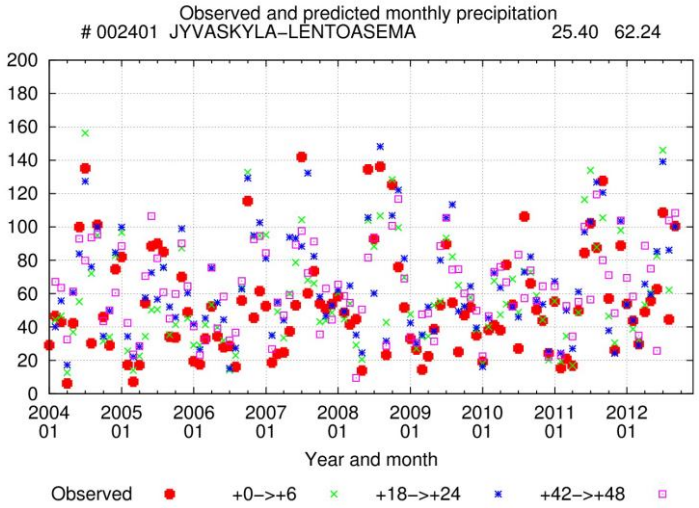
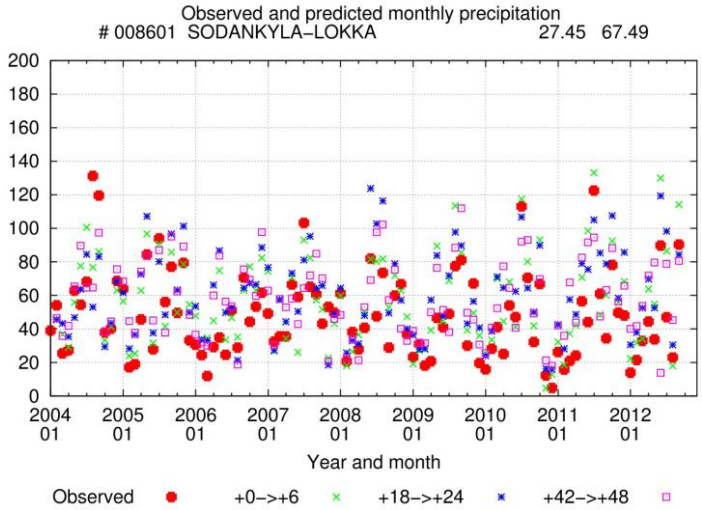
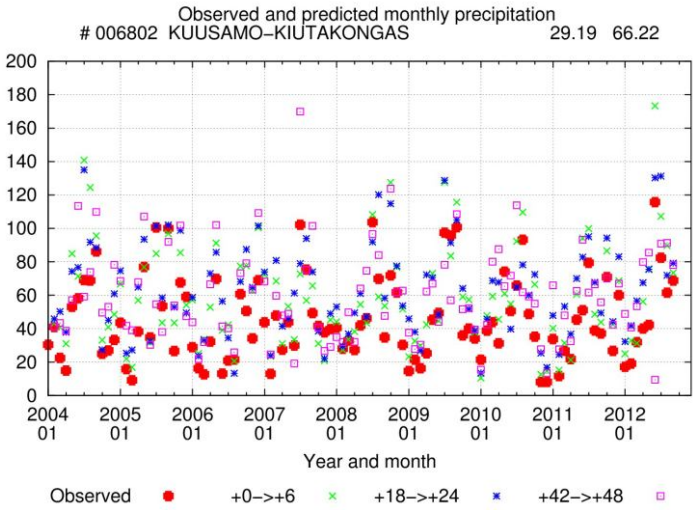
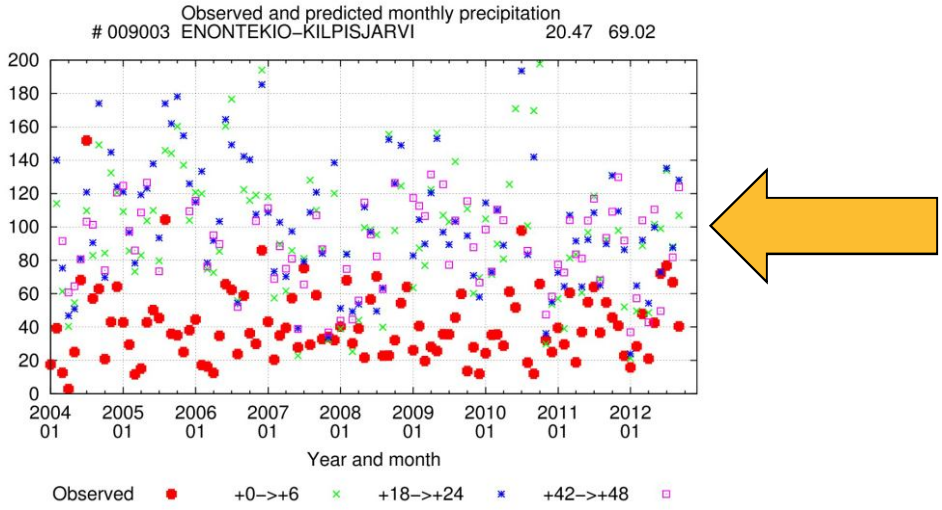
Monthly time-series from some stations









Summary

- **21 years of Hirlam forecasts have been verified**
- **2-day forecasts now better than 1-day forecasts 20 years ago**
- **Improvements not linear**
- **In many cases improvements can be traced back to system developments**
  - Re-run concept
  - Temperature at 925 hPa, radiation, no of levels
- **Some obvious weaknesses remain unexplained**
- **Less dependent of the weather regime now**
- Kalle Eerola: "Twenty-one years of verification from the HIRLAM NWP system“, accepted to Weather and Forecasting

- **8 years of HIRLAM monthly precipitations have been verified (preliminary results)**
- **Spin-up problem in short forecasts**
- **No clear drift during the forecast**
- **Over-forecasting in all seasons, especially in spring**