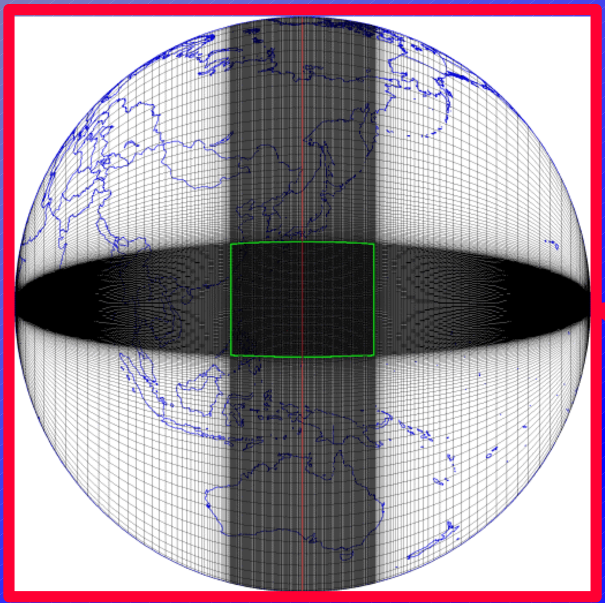
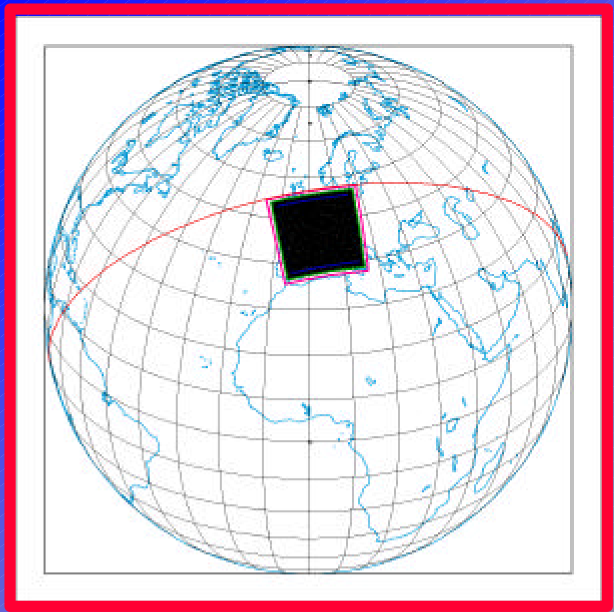
Limited Area Modelling with GEMDM

M. Desgagné, V. Lee

Recherche en Prévision Numérique
Environment Canada - MSC/RPN





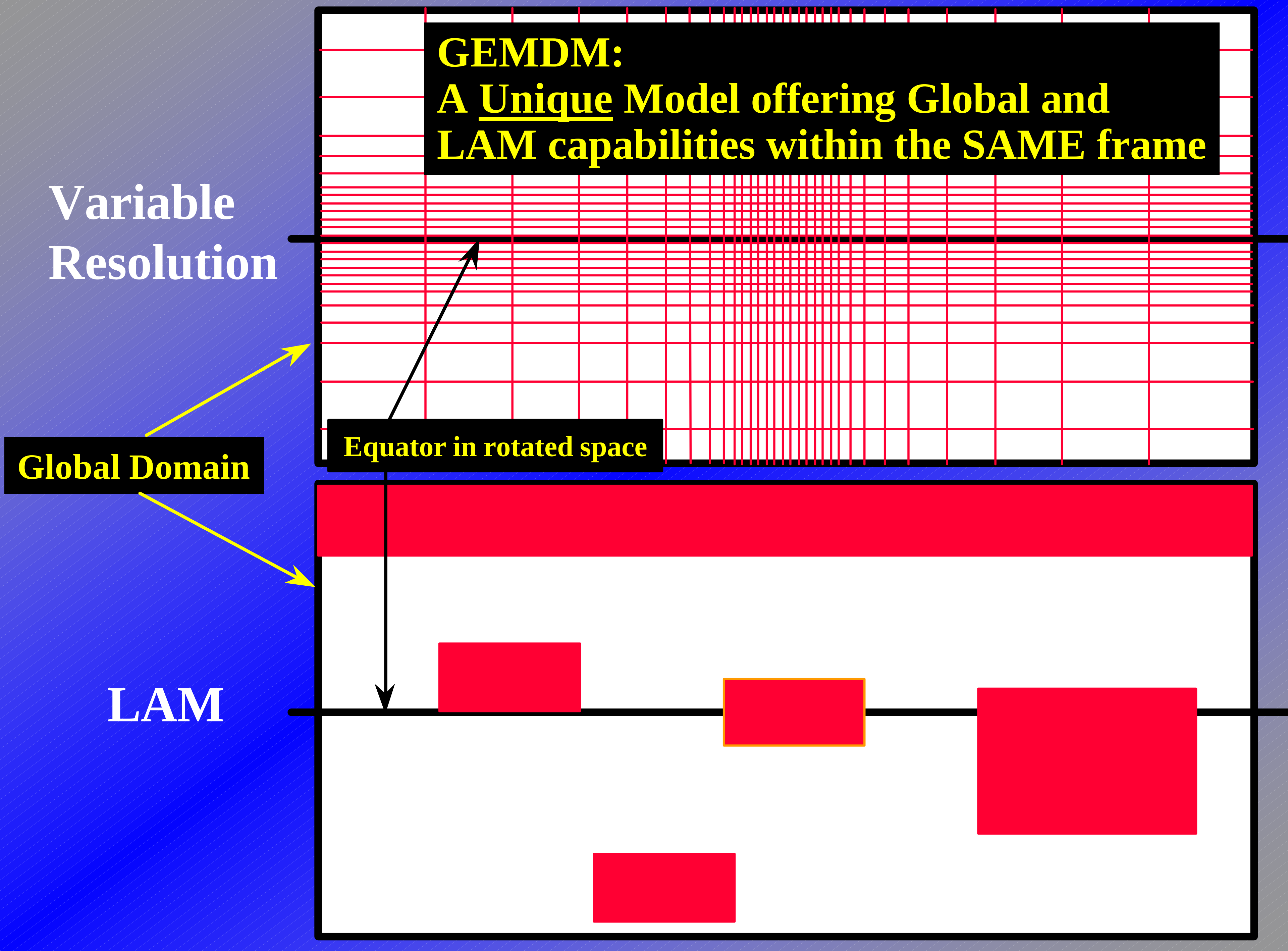
Environment Canada - MSC (formerly AES)

OUTLINE

- Details of LAM implementation in GEMDM
- Validation - a beginning:
  - 10 km horizontal resolution
  - 2 km horizontal resolution (not completed)
- Performance
- Remaining differences with MC2
- What’s ahead

Merci à: Michel Valin, Luc Corbeil, Jean Coté, Abdessamad Qaddouri, Claude Girard, Jocelyn Mailhot and Pierre Pellerin

GEMDM: A Unique Model offering Global and LAM capabilities within the SAME frame

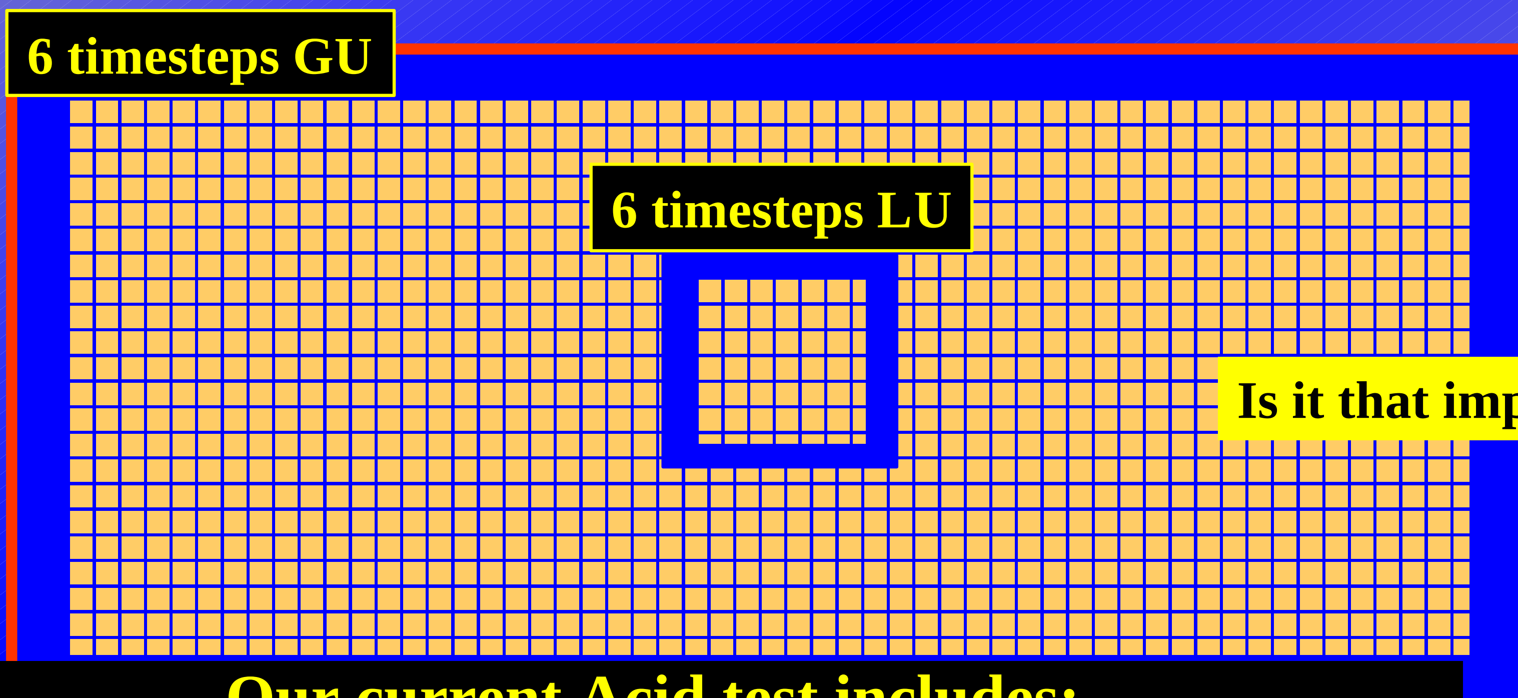


An Acid Test for LAM

Regional Modelling: A Theoretical Discussion

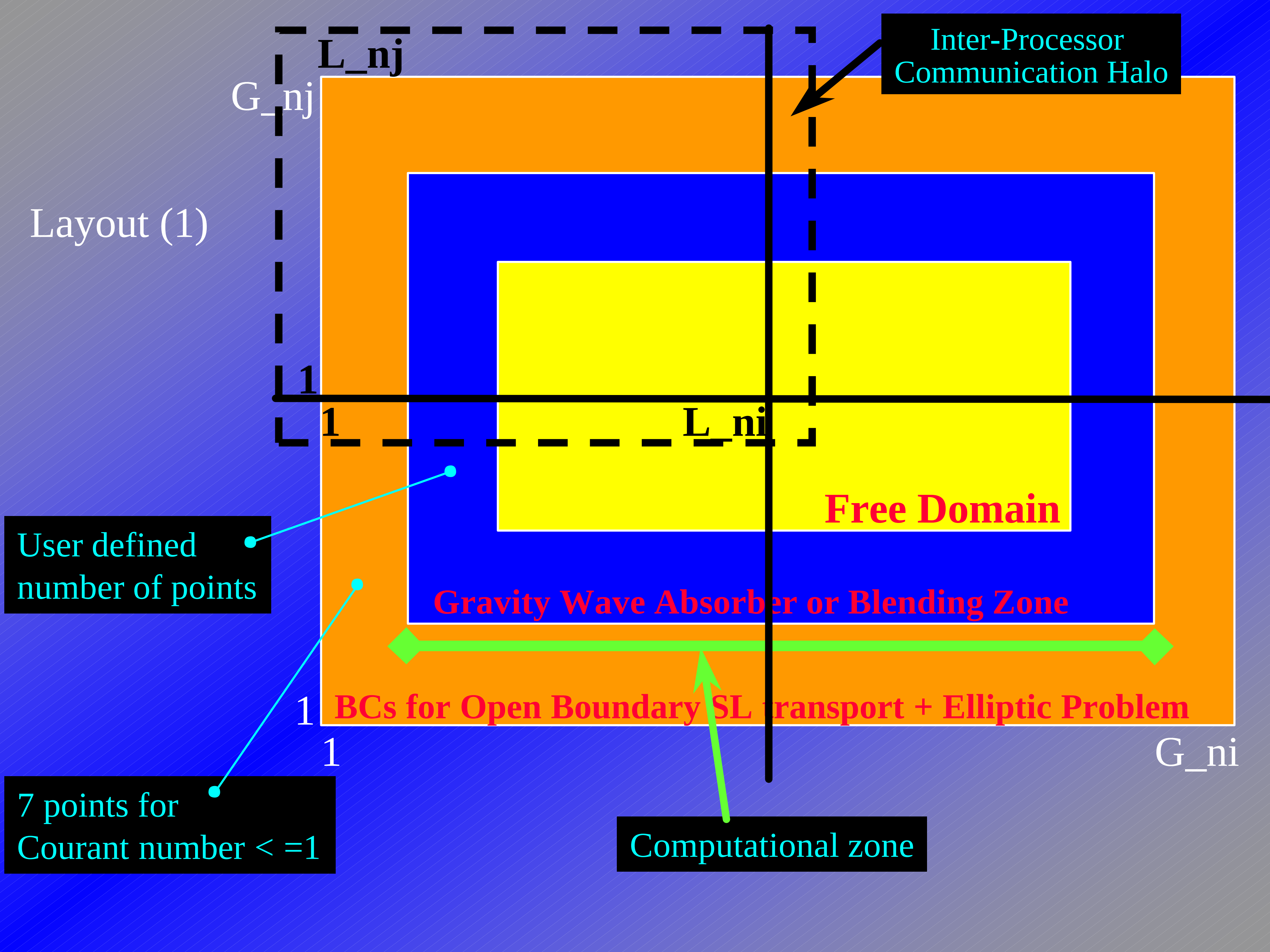
A. Staniforth, 1995 (Meteor. Atmos. Phys.)

At same horizontal and temporal resolution, how well can a LAM reproduce the solution of a large domain on any smaller subdomain

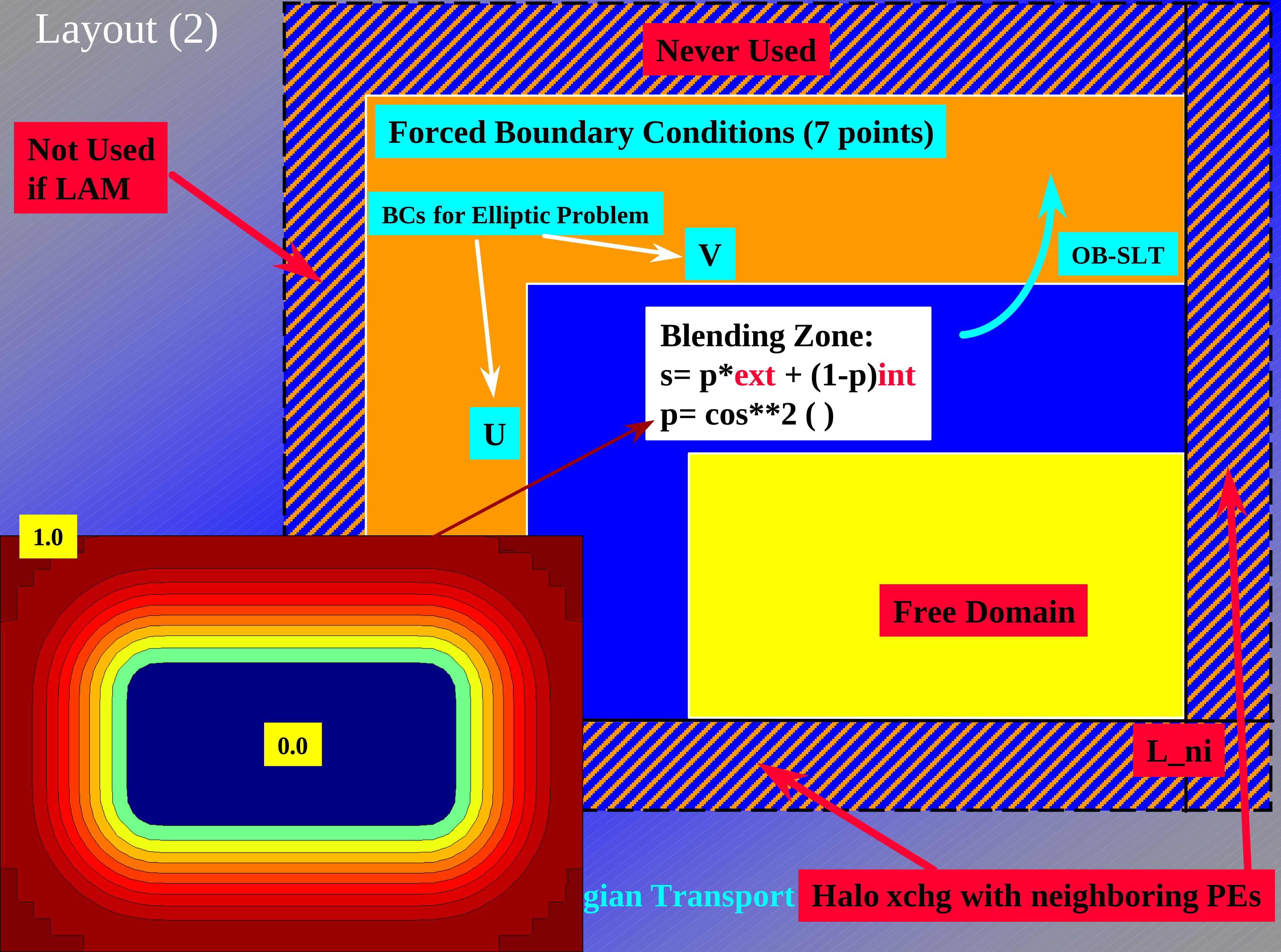


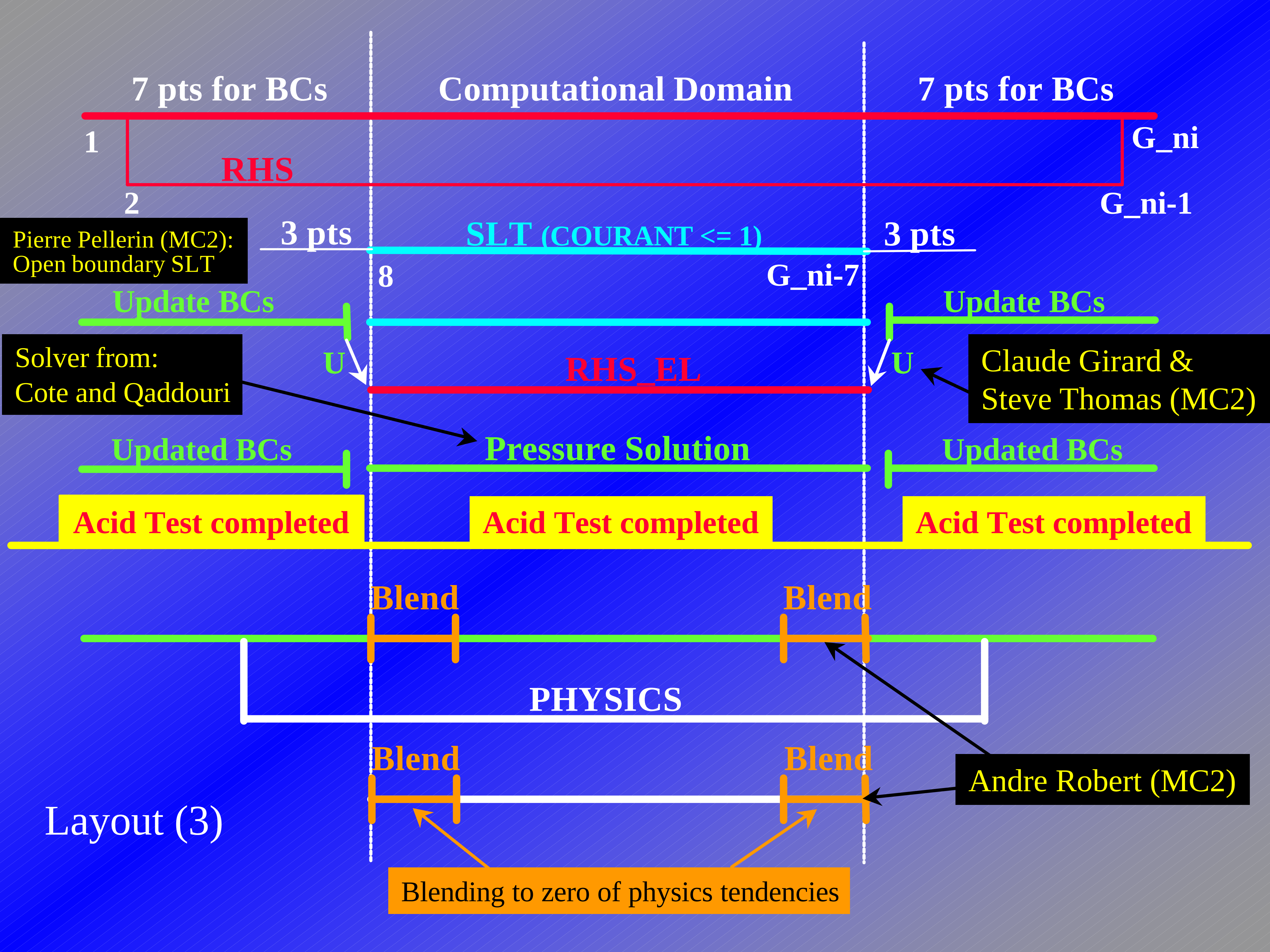
Is it that important?

Our current Acid test includes:
The whole diabatic kernel + horizontal diffusion


Layout (1)
L_nj
G_nj
Inter-Processor
Communication Halo
1
1
L_ni
Free Domain
User defined
number of points
Gravity Wave Absorber or Blending Zone
1
BCs for Open Boundary SL transport + Elliptic Problem
1
G_ni
7 points for
Courant number < =1
Computational zone

Layout (2)


Never Used
Not Used
if LAM
Forced Boundary Conditions (7 points)
BCs for Elliptic Problem
V
U
OB-SLT
Blending Zone:
s= p*ext + (1-p)int
p= cos**2 ( )
Free Domain
1.0
0.0
L_ni
gian Transport
Halo xchg with neighboring PEs


7 pts for BCs
Computational Domain
7 pts for BCs
1
G_ni
RHS
2
G_ni-1
Pierre Pellerin (MC2):
Open boundary SLT
3 pts
SLT (COURANT <= 1)
3 pts
8
G_ni-7
Update BCs
Update BCs
Solver from:
Cote and Qaddouri
U
RHS_EL
U
Claude Girard &
Steve Thomas (MC2)
Updated BCs
Pressure Solution
Updated BCs
Acid Test completed
Acid Test completed
Acid Test completed
Blend
Blend
PHYSICS
Blend
Blend
Andre Robert (MC2)
Layout (3)
Blending to zero of physics tendencies

Launching a LAM configuration: user perspective

LAM config

```
&grid
 Grd_typ_S='LU', Grd_ni=250, Grd_nj=331,
 Grd_iref= 125, Grd_jref= 166,
 Grd_latr= 0. , Grd_lonr= 180.,

 Grd_dx=0.09, Grd_dy=0.09,
 Grd_xlon1=-62., Grd_xlat1=45., Grd_xlon2=100., Grd_xlat2=45.,
 Grd_roule=.true.

&gement
 Pil_runstrt_S = "19980905.000000", Pil_nesdt = 3600
 Hblen_momentx = 10,   Hblen_tx  = 10,
 Hblen_massx   = 10,   Hblen_trx = 10,
```

```
&grid
 Grd_typ_S='GV', Grd_ni  = 353, Grd_nj  = 415,
                 Grd_nila= 216, Grd_njla= 297,

 Grd_dx=0.09, Grd_dy=0.09,
 Grd_xlon1=-62., Grd_xlat1=45., Grd_xlon2=100., Grd_xlat2=45.,
 Grd_roule=.true.
```

Variable resolution config

Validating GEMDM in LAM configurations

- LU_10km (10 km resolution):
  - EARL (5-6 Sept 1998): ET re-development
    - Thanks to Lubos Spacek
  - Winter Storm of 14-15 December 2000
    - Thanks to Sylvain Ménard & Richard Moffet
- LU_02km (2 km resolution)
  - Vortex case study (7-8 May 1995)
  - IOP2b of MAP-SOP (19 September 1999)

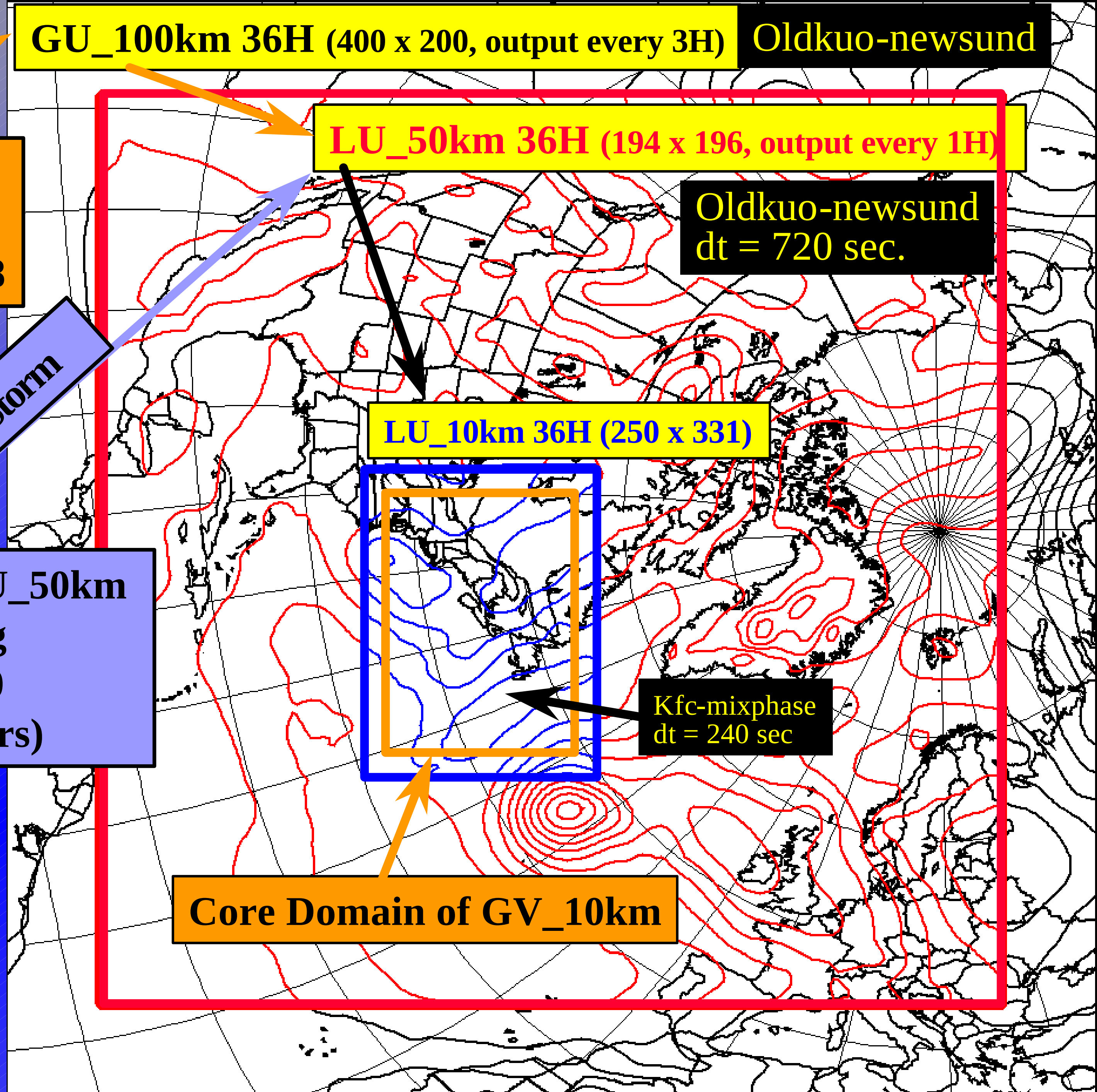
EARL

Initiate GU_100km with analysis of 00 UTC 5 SEPT 1998

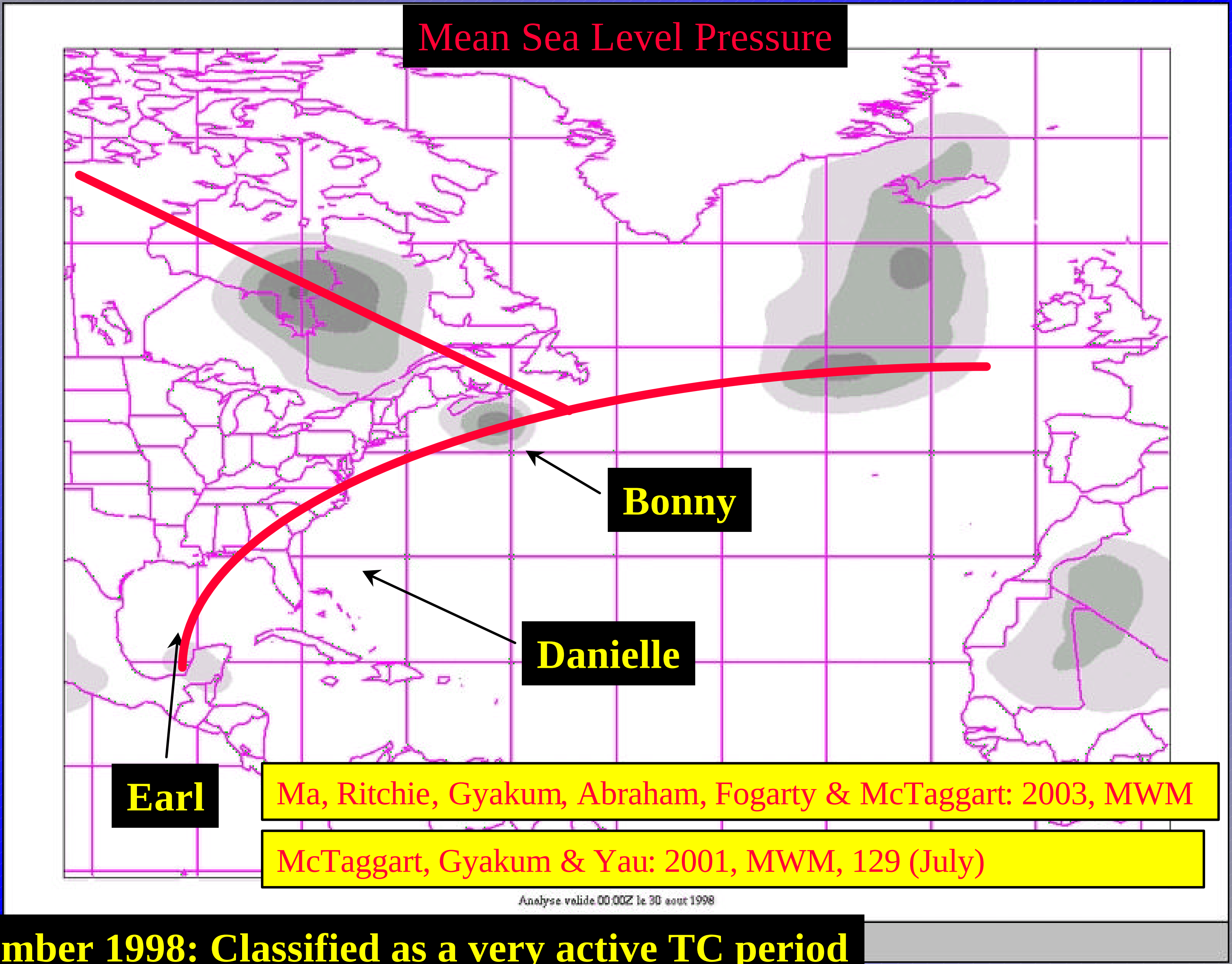
Winter Storm

Initiate and drive LU_50km with analysis starting 00 UTC 14 Dec. 2000 onward (every 6 hours)

Grid Strategy for LU_10km runs (10 km reso.)

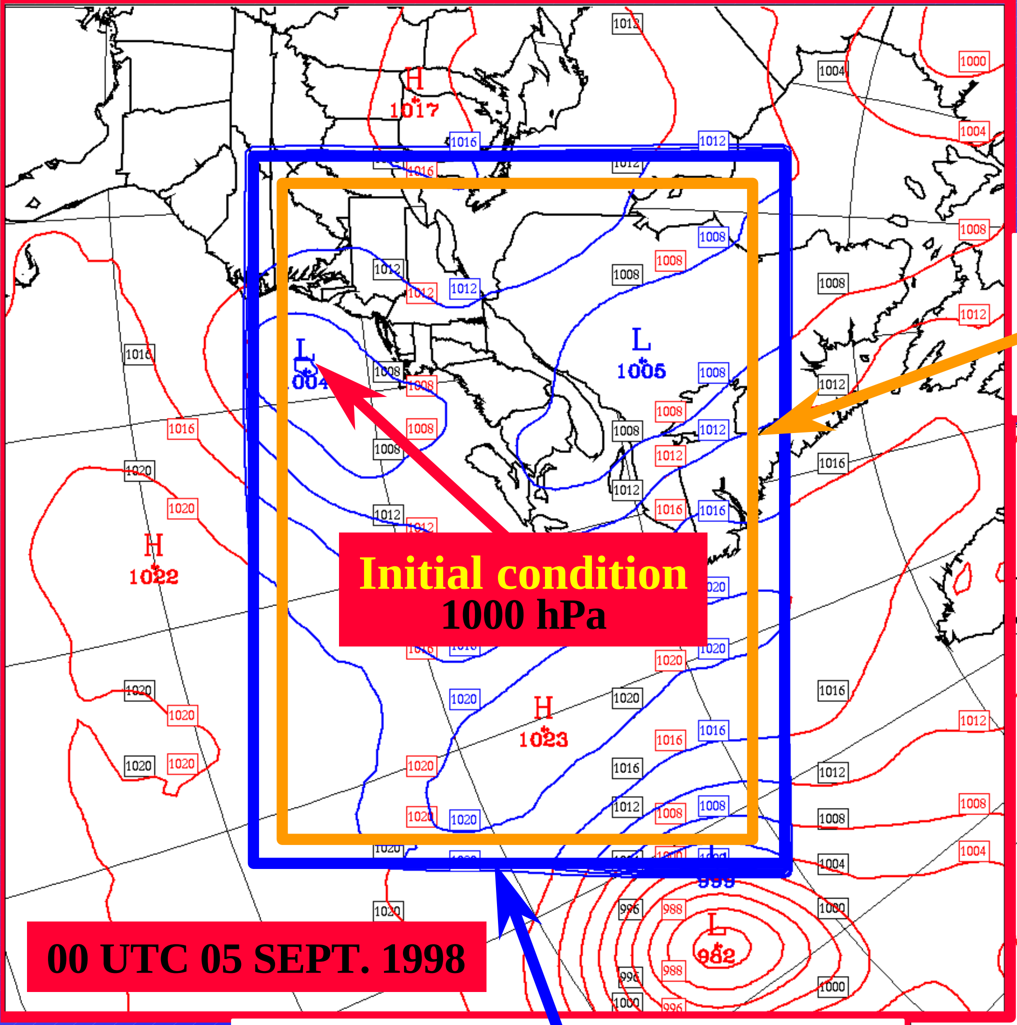


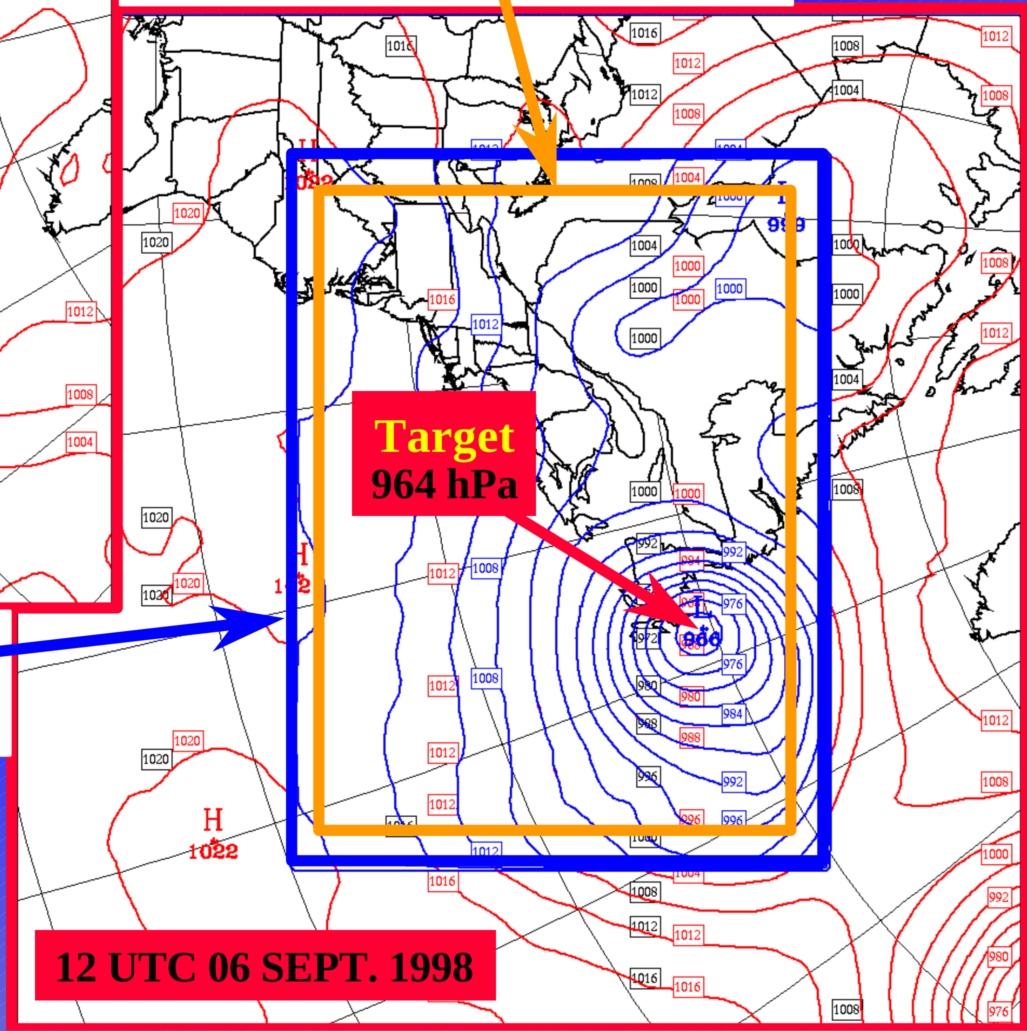
EARL: 30 August to 9 September 1998



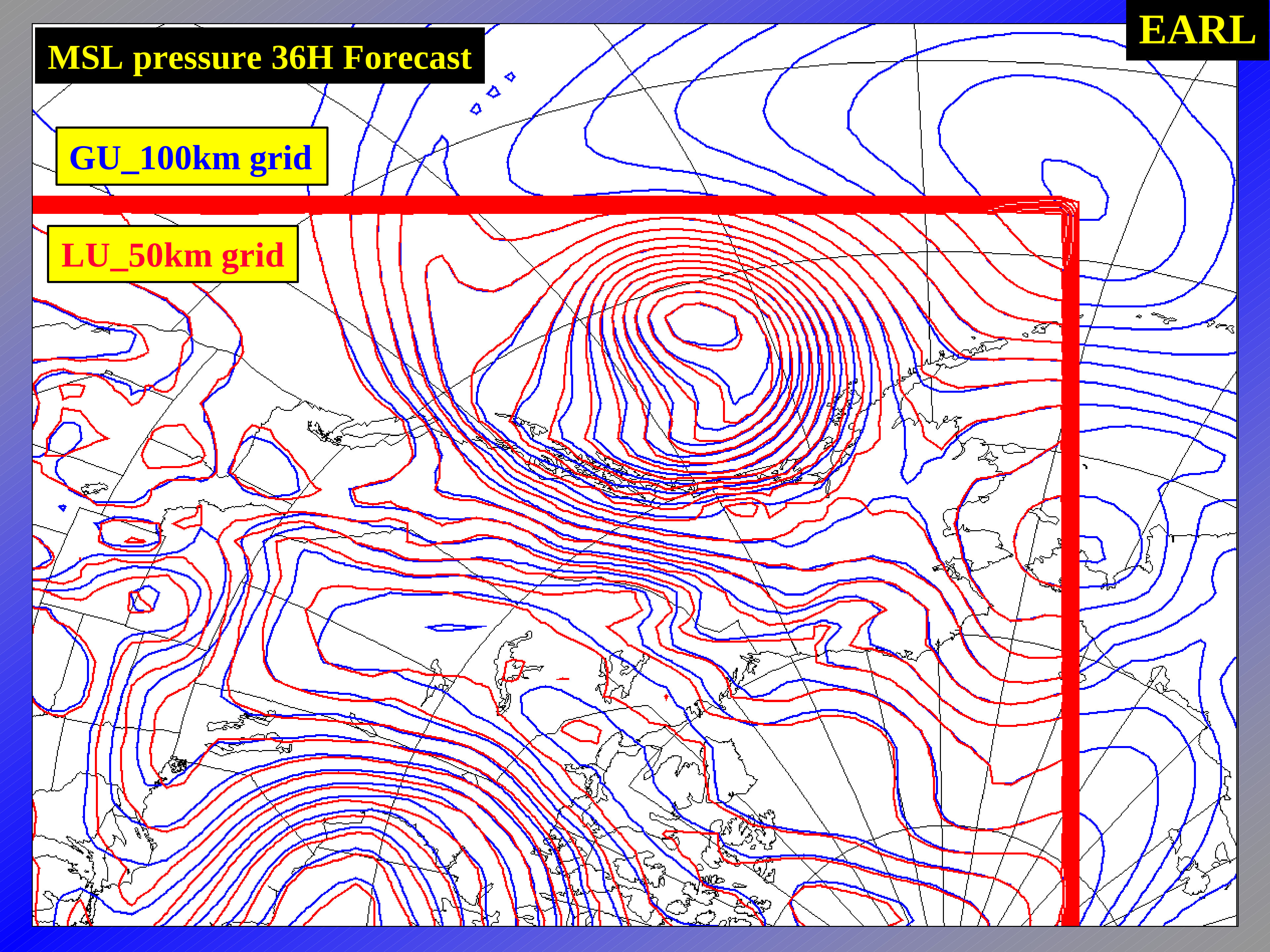
September 1998: Classified as a very active TC period

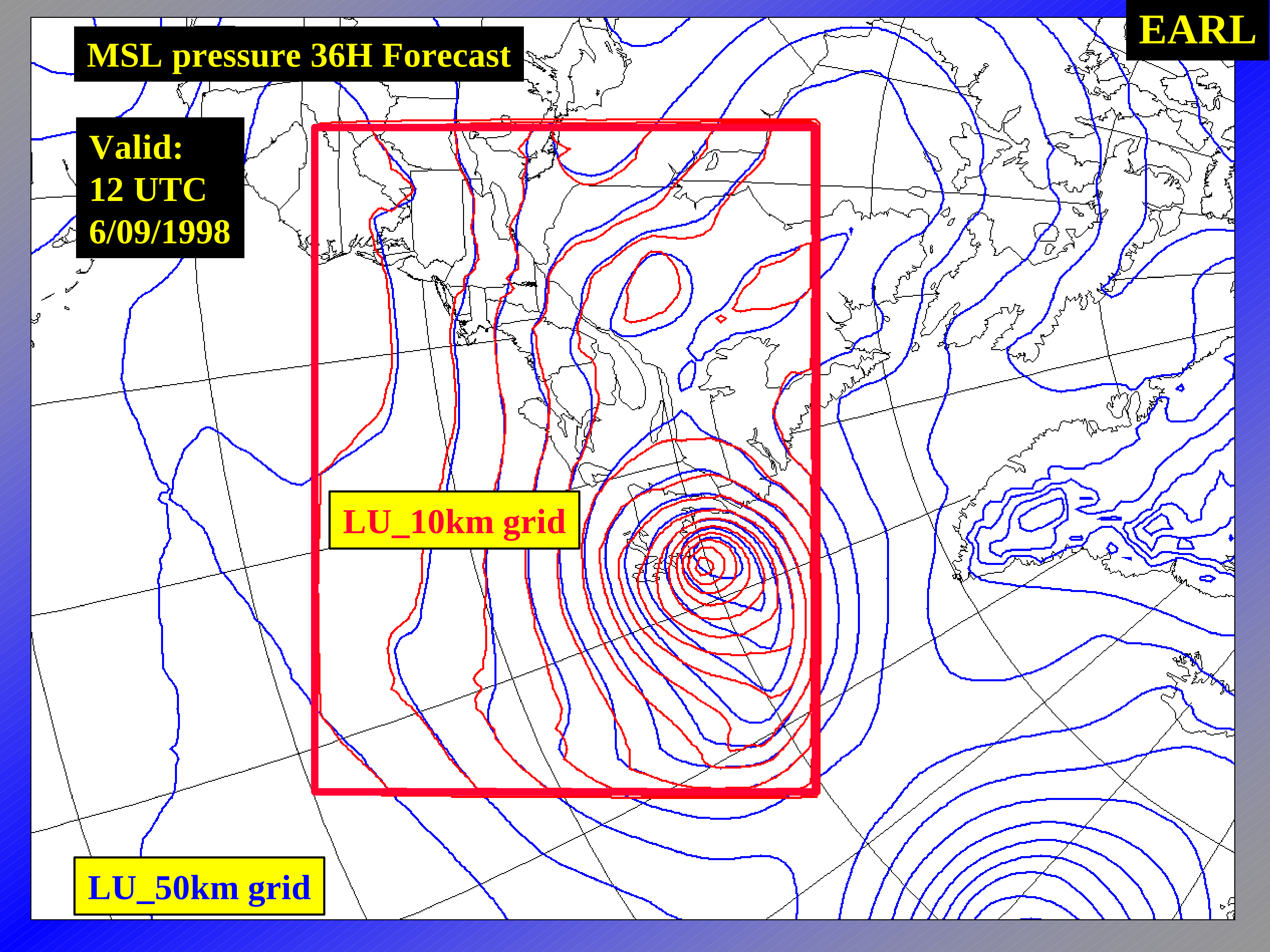
Earl: ET re-development
Sept 5-6 1998
36 hPa deepening in 36 hours





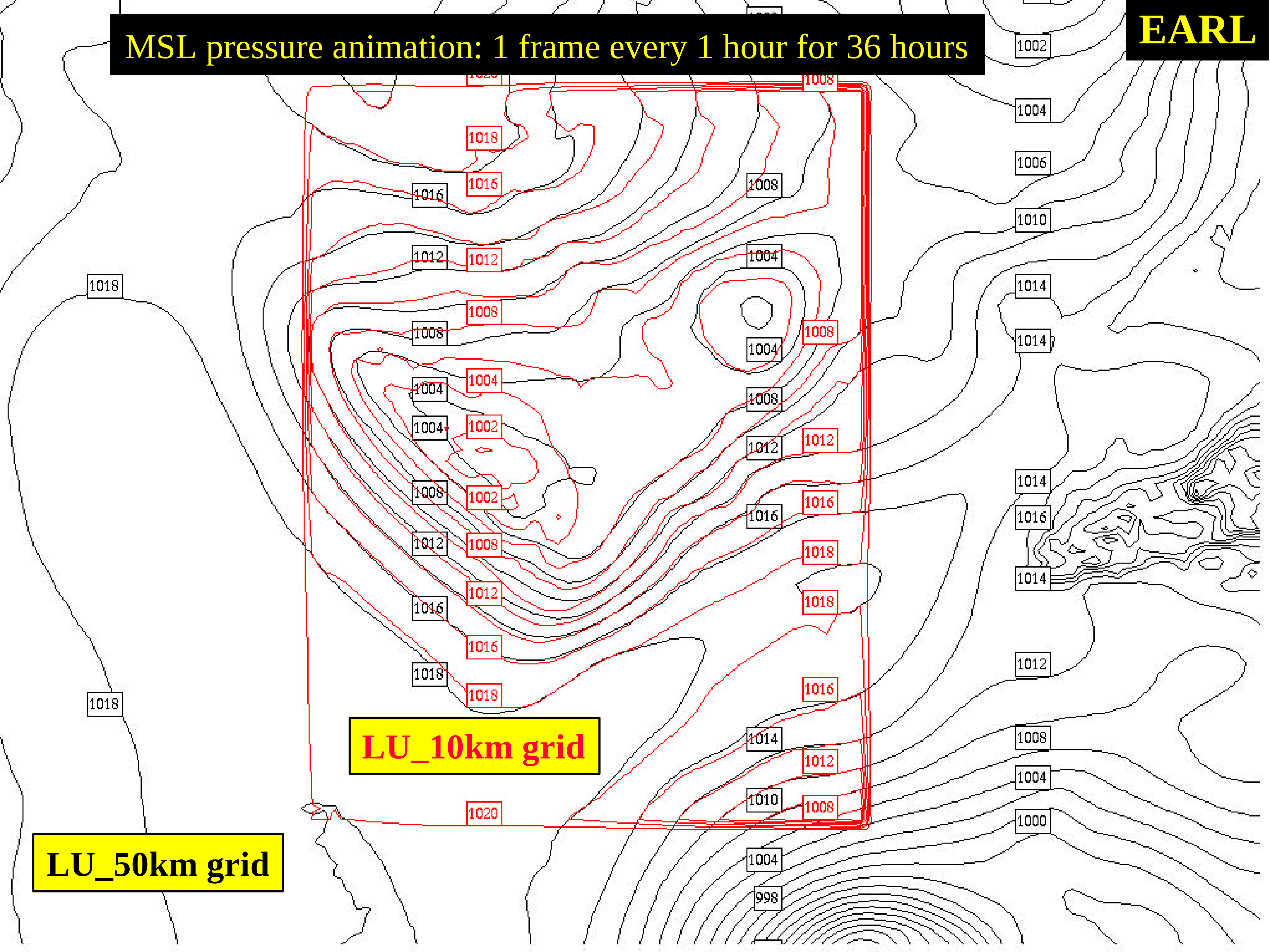
MSL pressure analysis


EARL
MSL pressure 36H Forecast
GU_100km grid
LU_50km grid


MSL pressure 36H Forecast
EARL
Valid:
12 UTC
6/09/1998
LU_10km grid
LU_50km grid

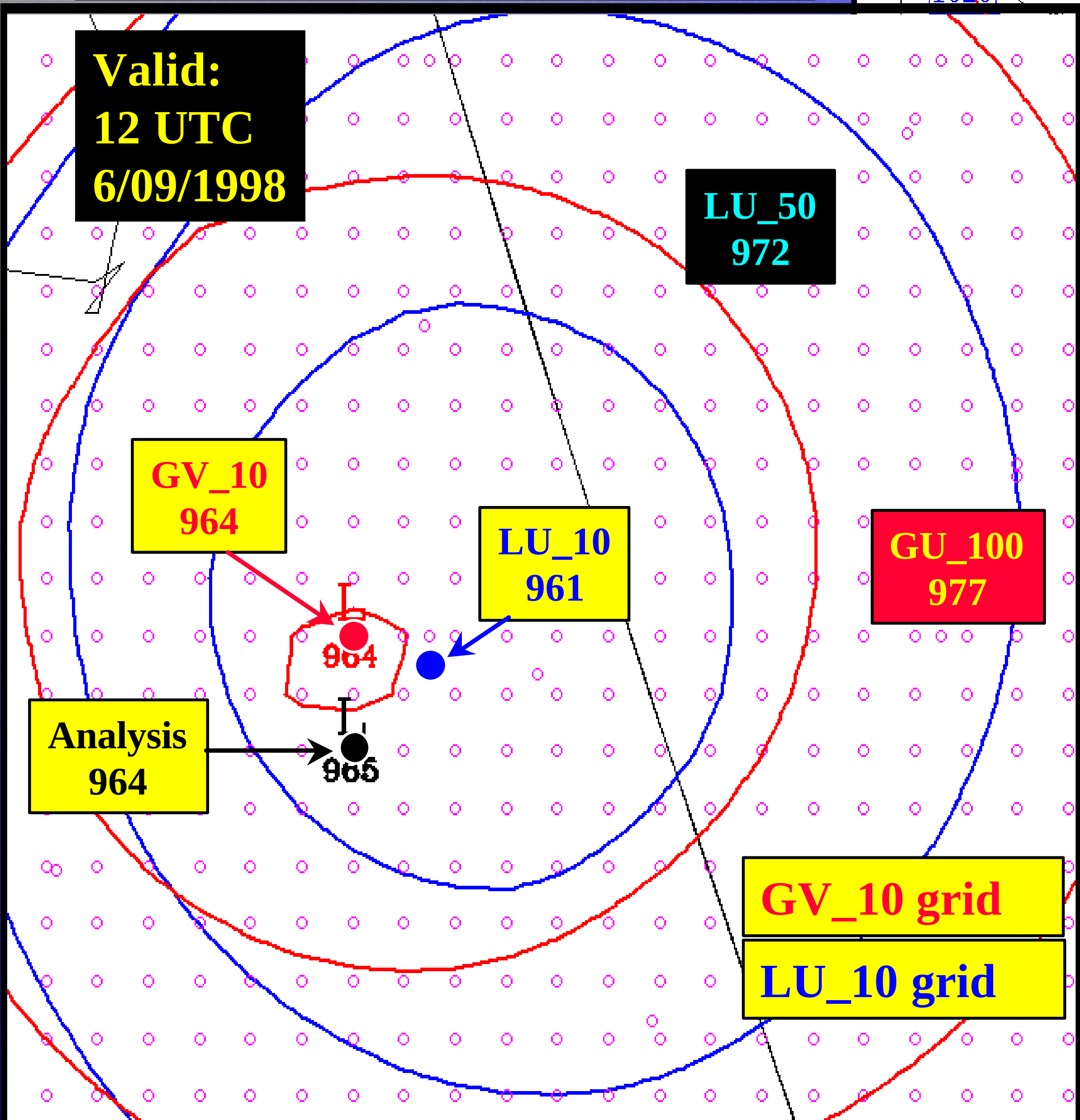
MSL pressure animation: 1 frame every 1 hour for 36 hours

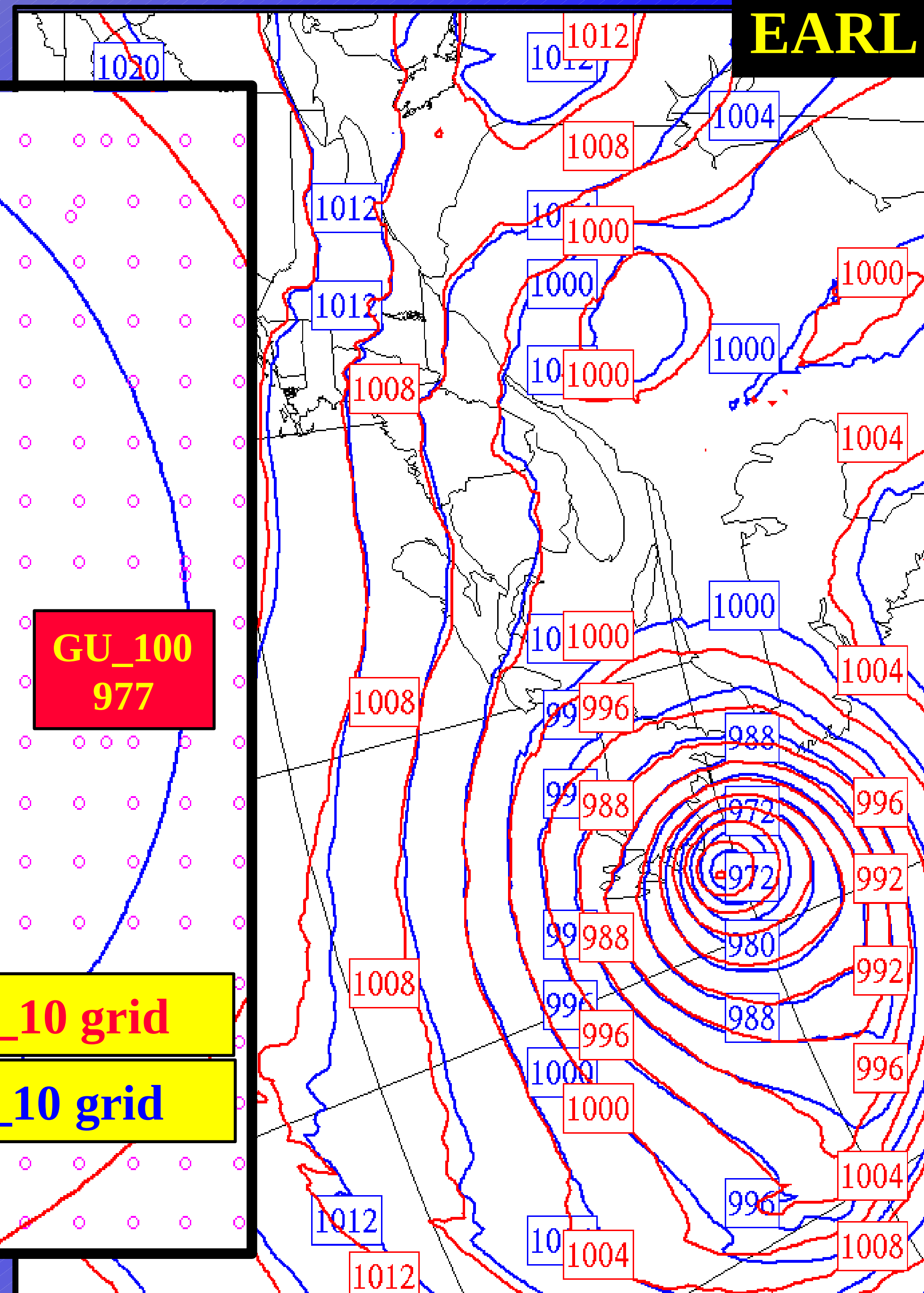
EARL



MSL pressure 36H Forecast (hPa)

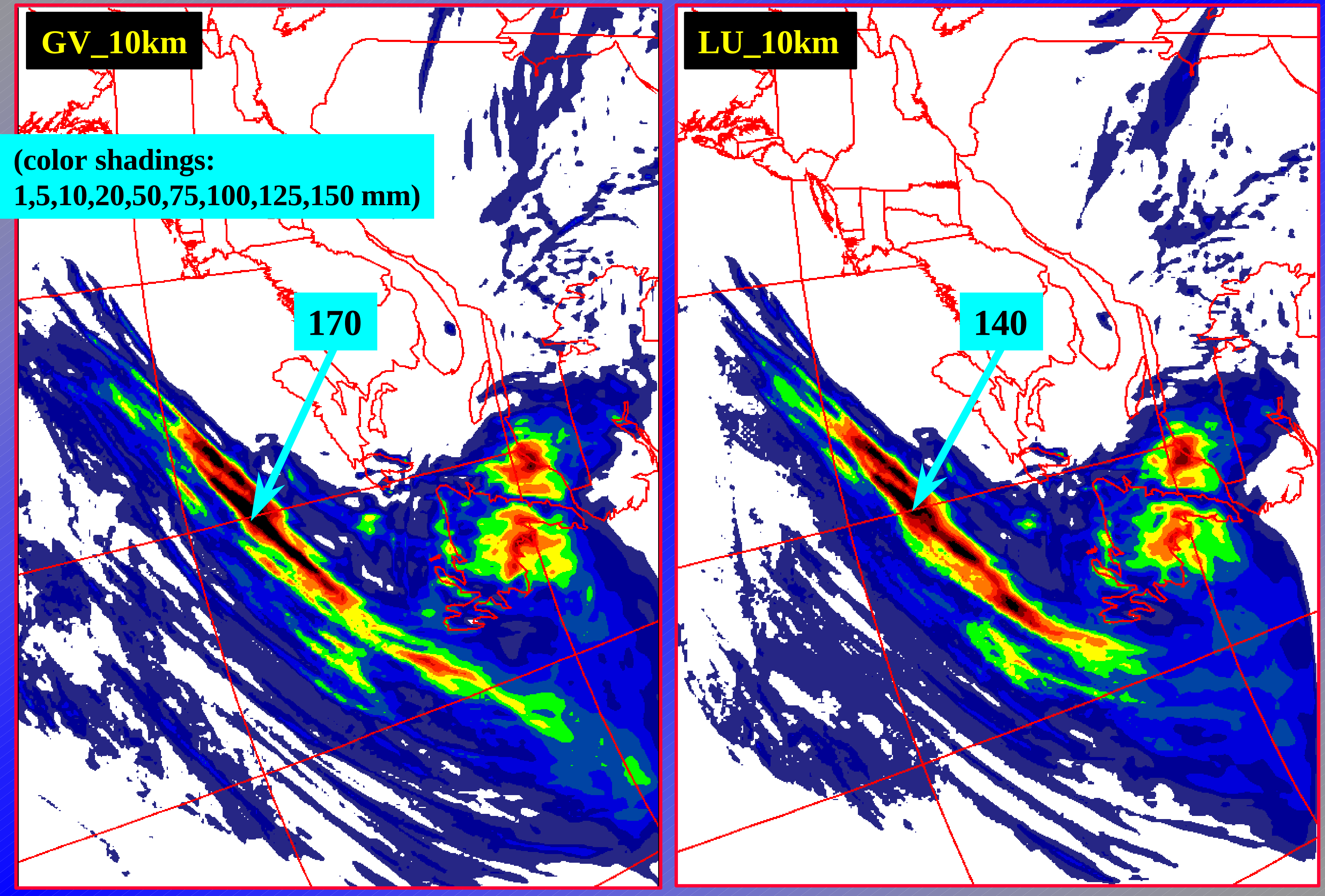
EARL

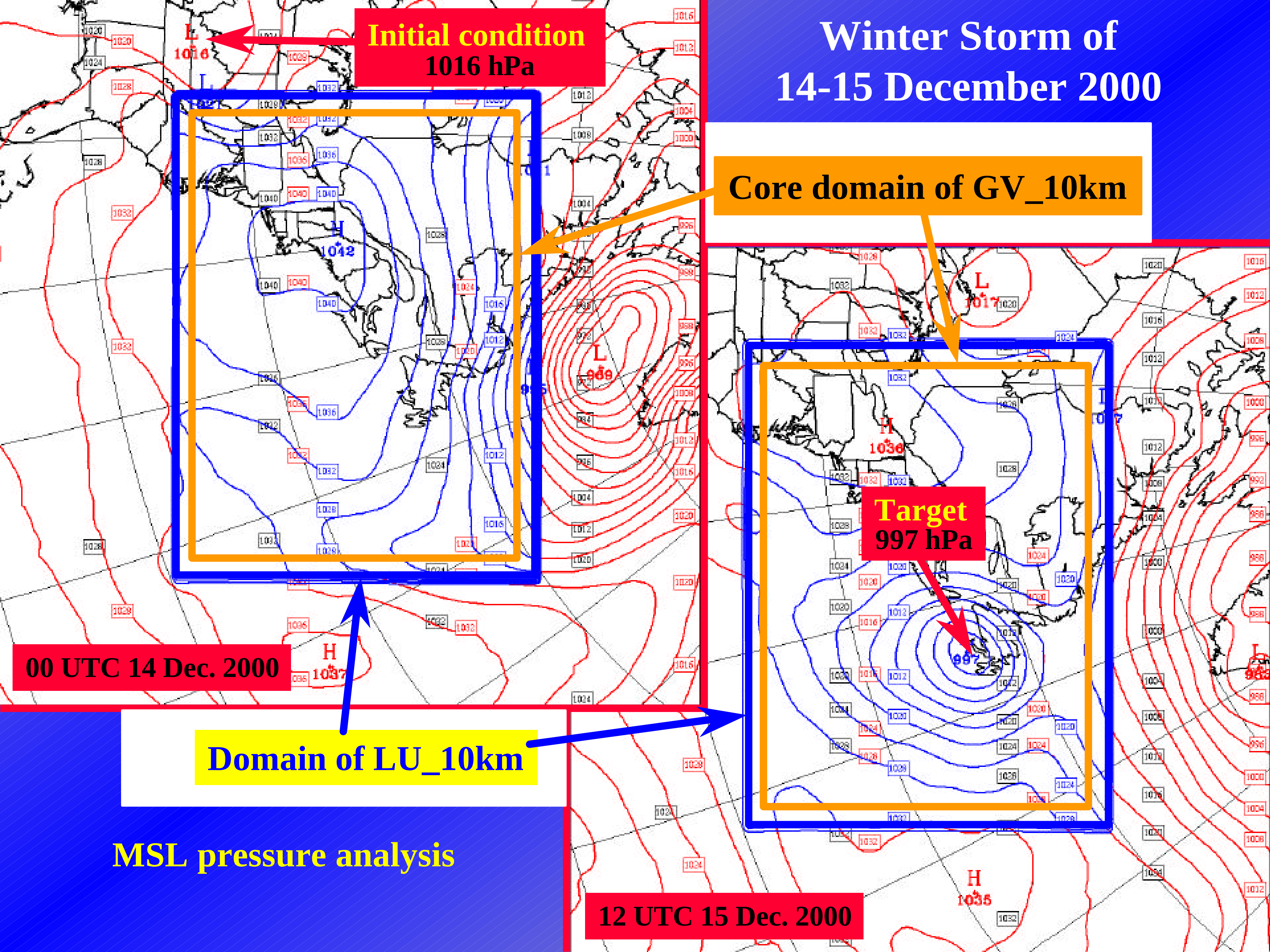




Earl Case Study

Total Accumulation of Precipitation over 36H (mm)



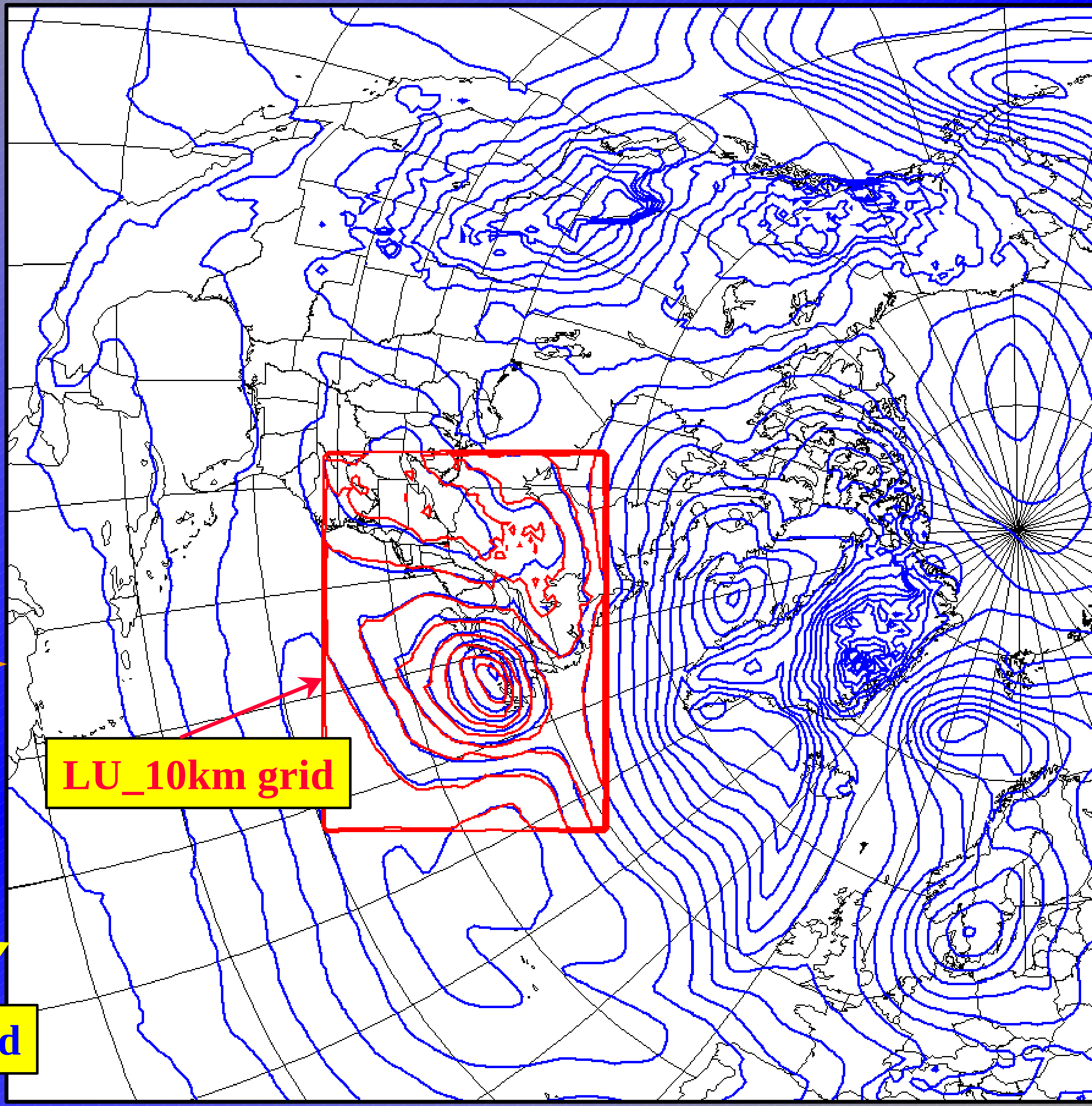

Winter Storm of
14-15 December 2000
Initial condition
1016 hPa
Core domain of GV_10km
Target
997 hPa
00 UTC 14 Dec. 2000
Domain of LU_10km
12 UTC 15 Dec. 2000
MSL pressure analysis

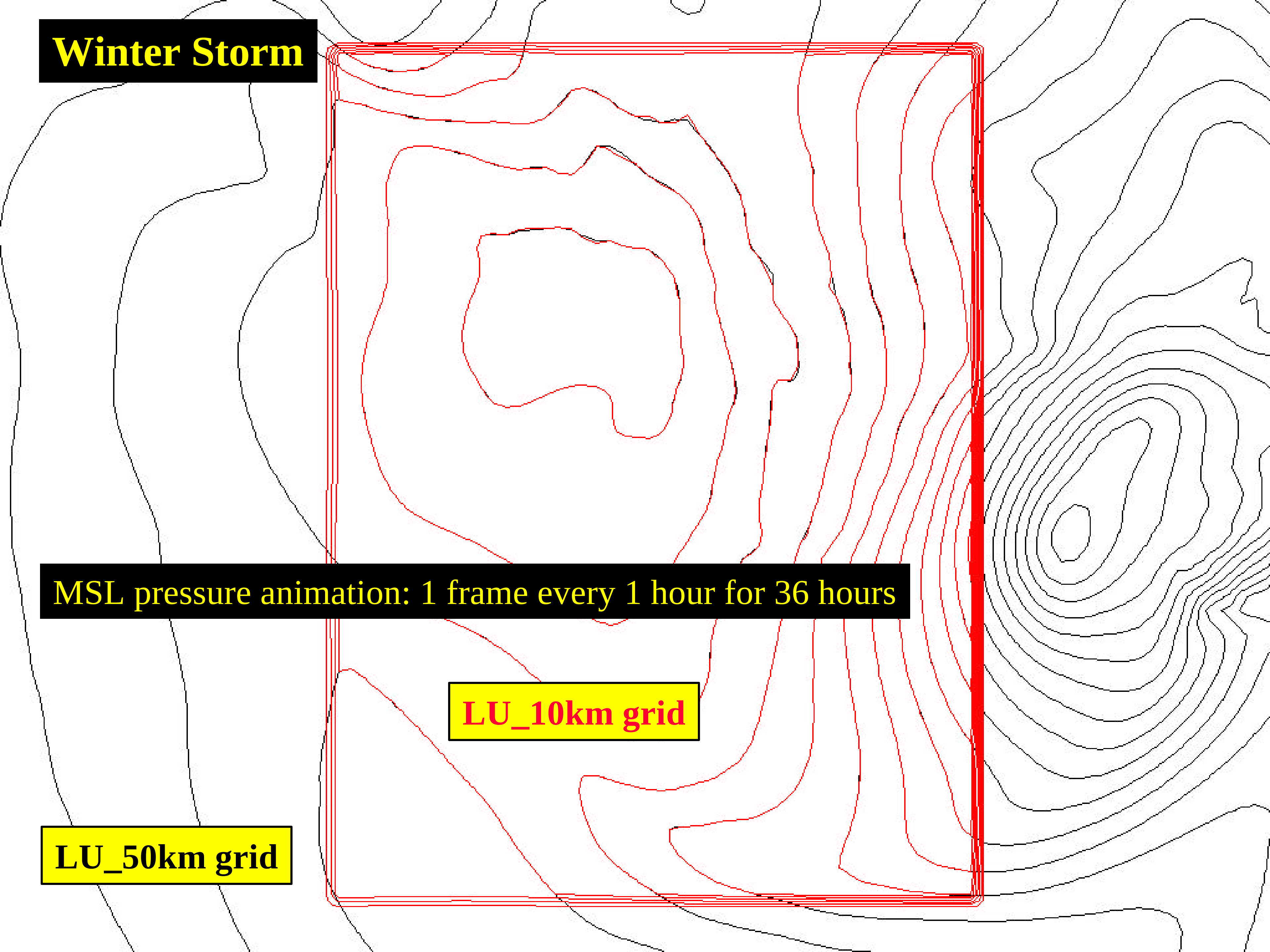
Winter Storm

MSL pressure
36H Forecast

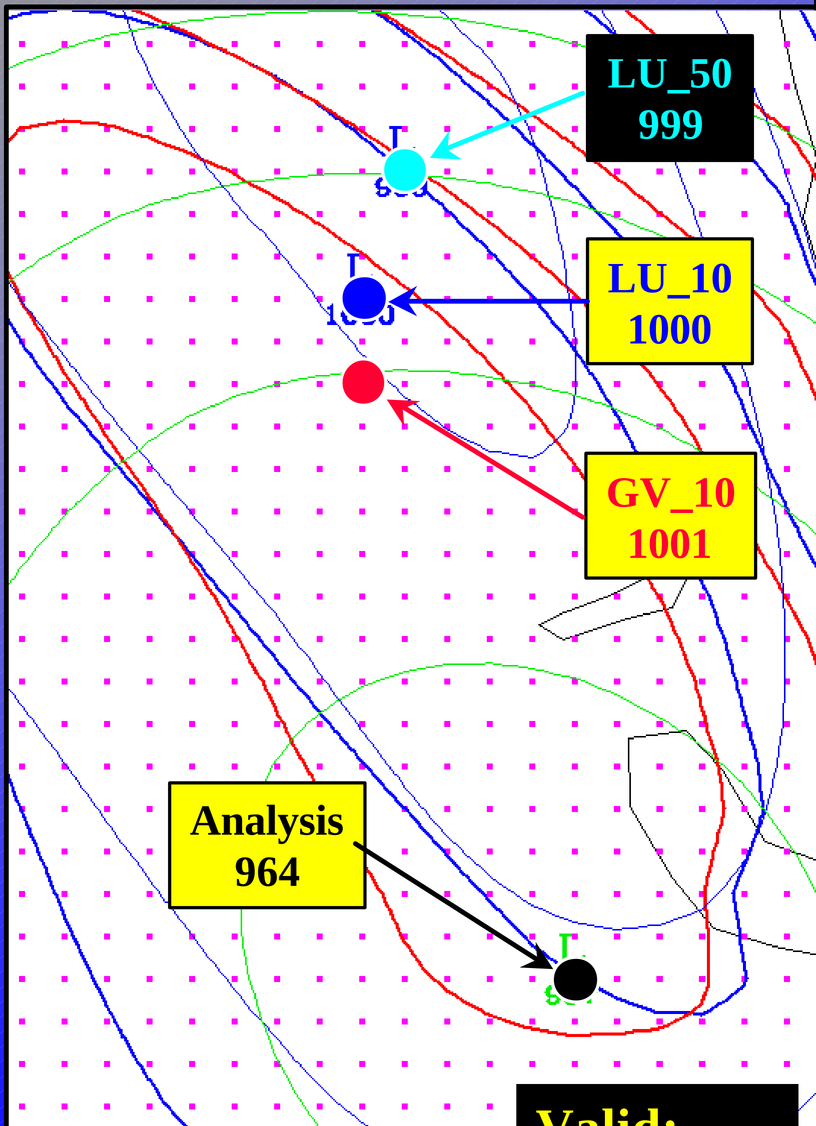
Valid:
12 UTC
15/12/2000

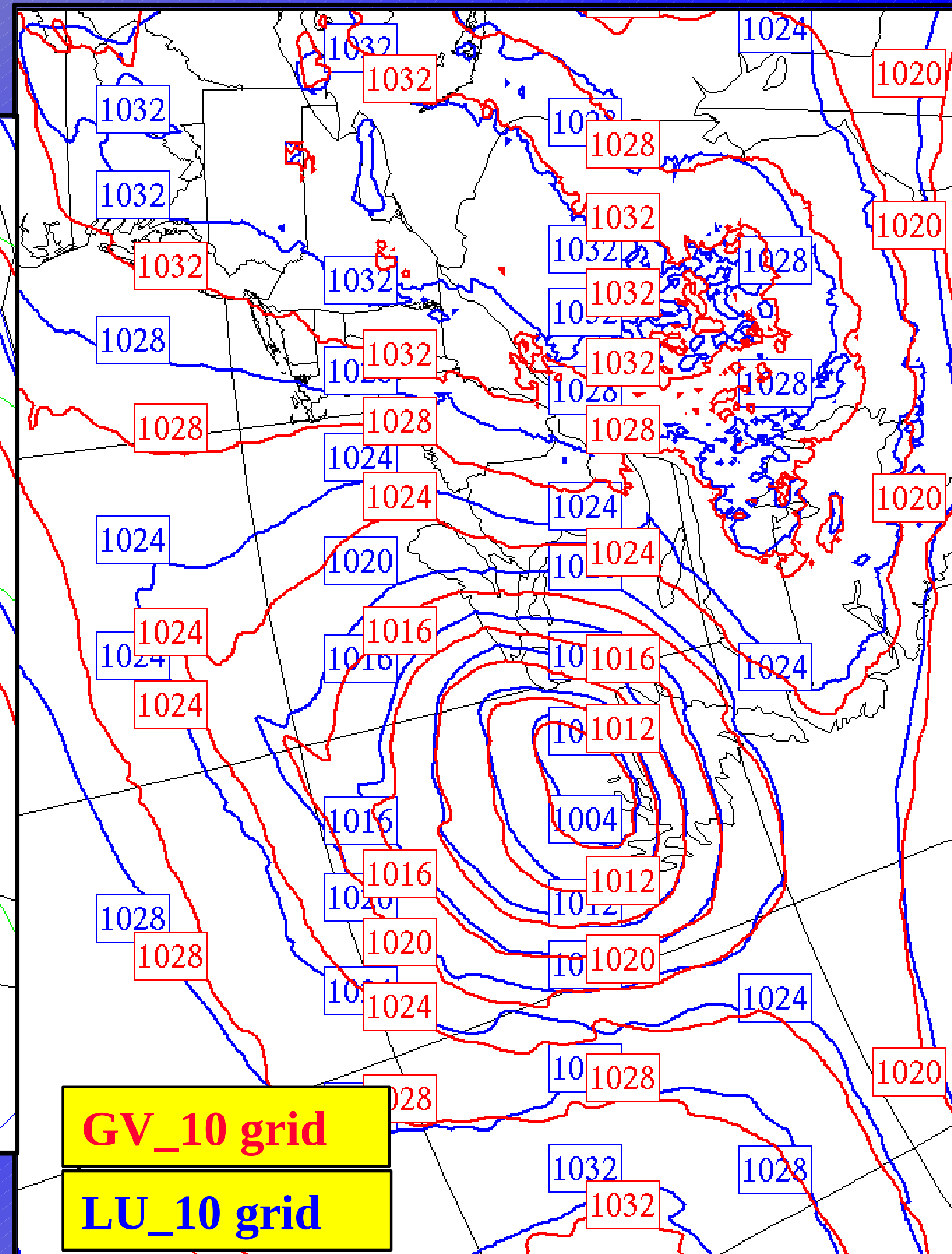
Initial and BCs from analysis every 6 hours




Winter Storm
MSL pressure animation: 1 frame every 1 hour for 36 hours
LU_10km grid
LU_50km grid

MSL pressure 36H Forecast (hPa)



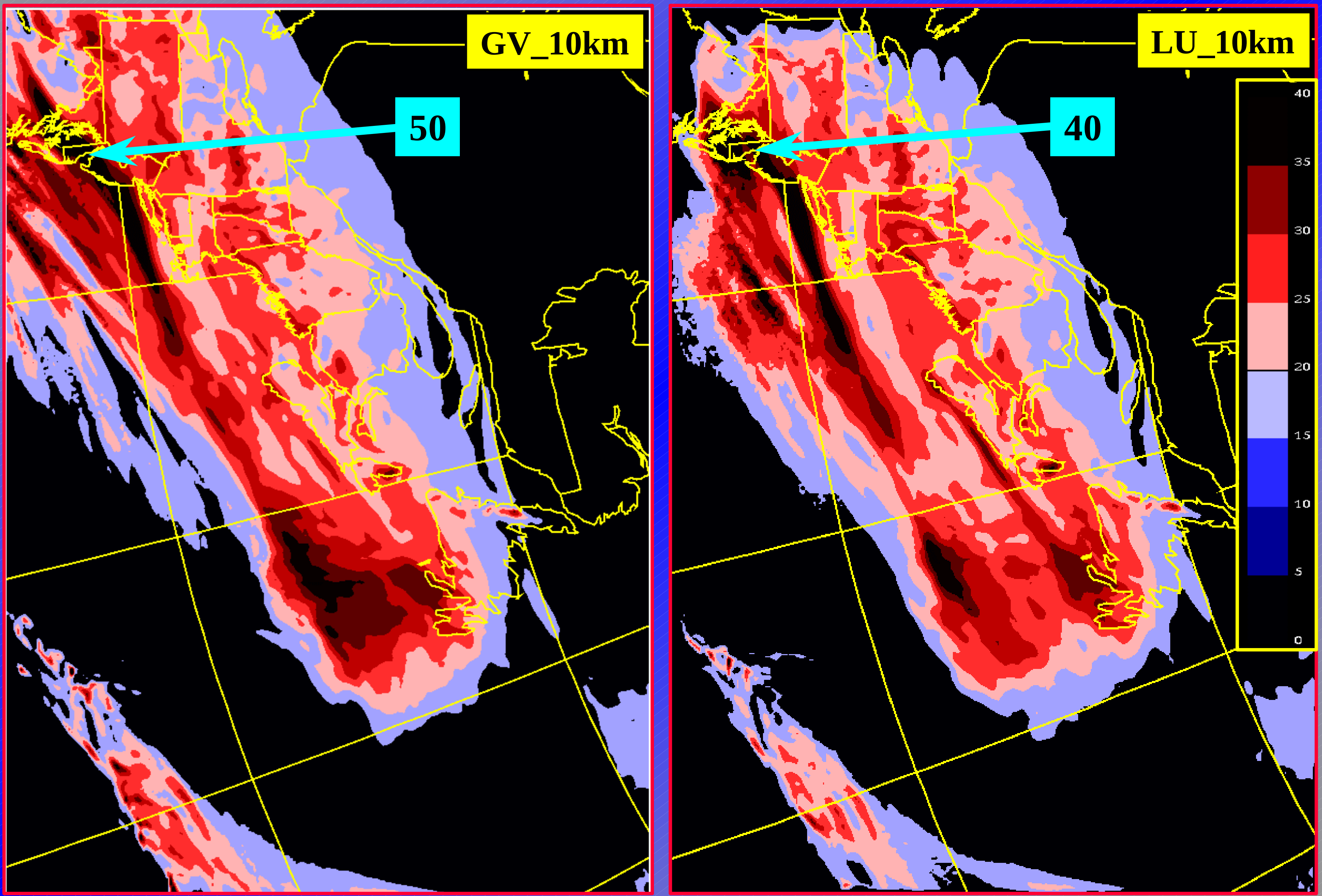


Valid:
12 UTC
15/12/2000

Winter Storm

Winter Storm Case Study

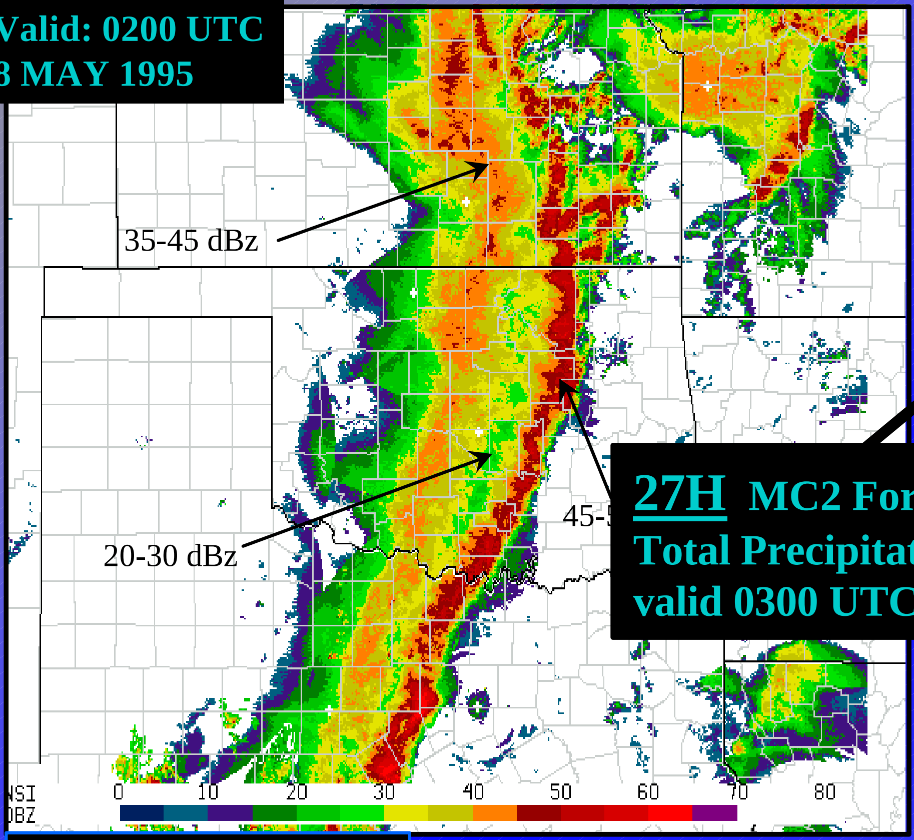
Total Accumulation of Precipitation over 36H (mm)



Higher resolution simulation with GEMDM in LAM configuration:

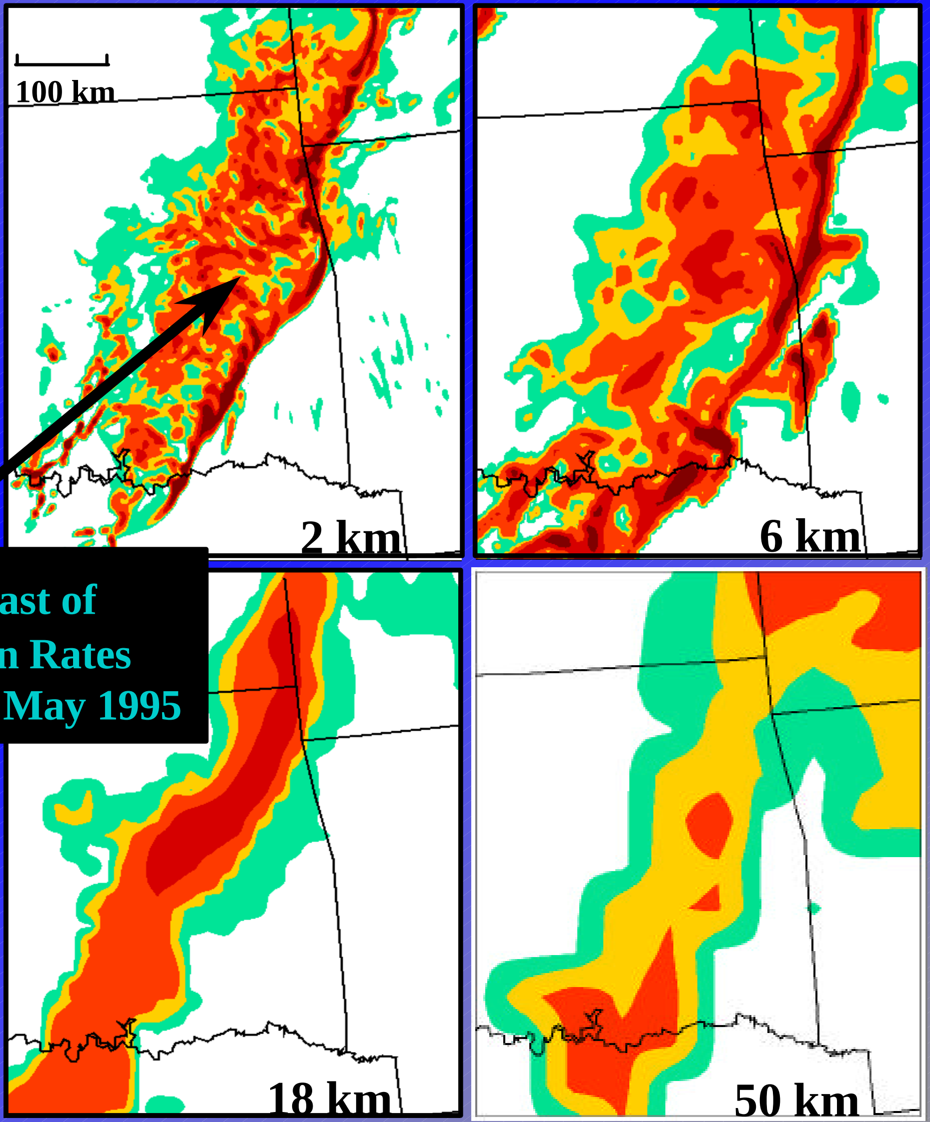
Vortex case study of 7-8 May 1995

Valid: 0200 UTC
8 MAY 1995



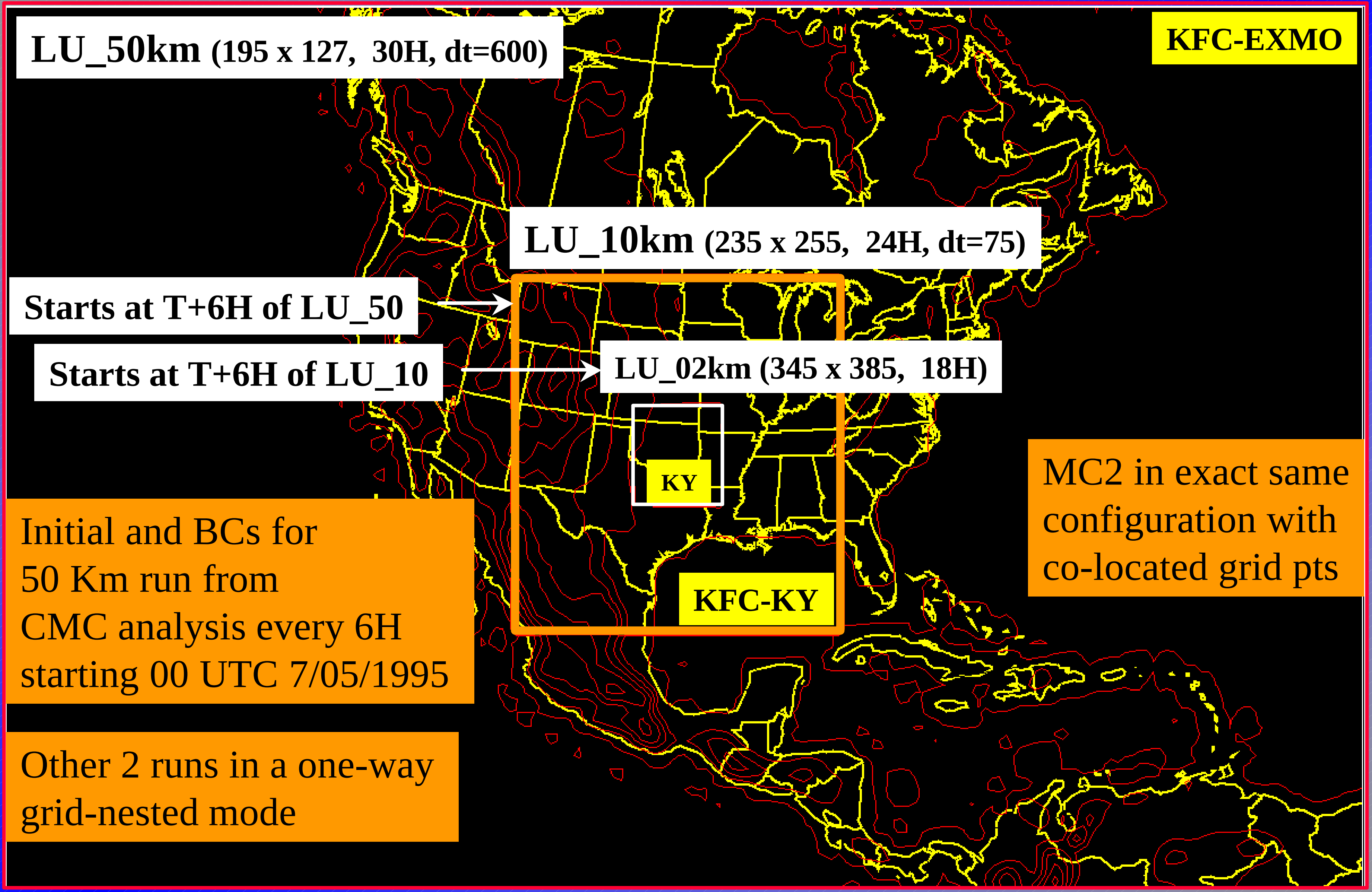
PPI Composite of Radar Reflectivities (shadings in dBz)

27H MC2 Forecast of Total Precipitation Rates valid 0300 UTC 8 May 1995

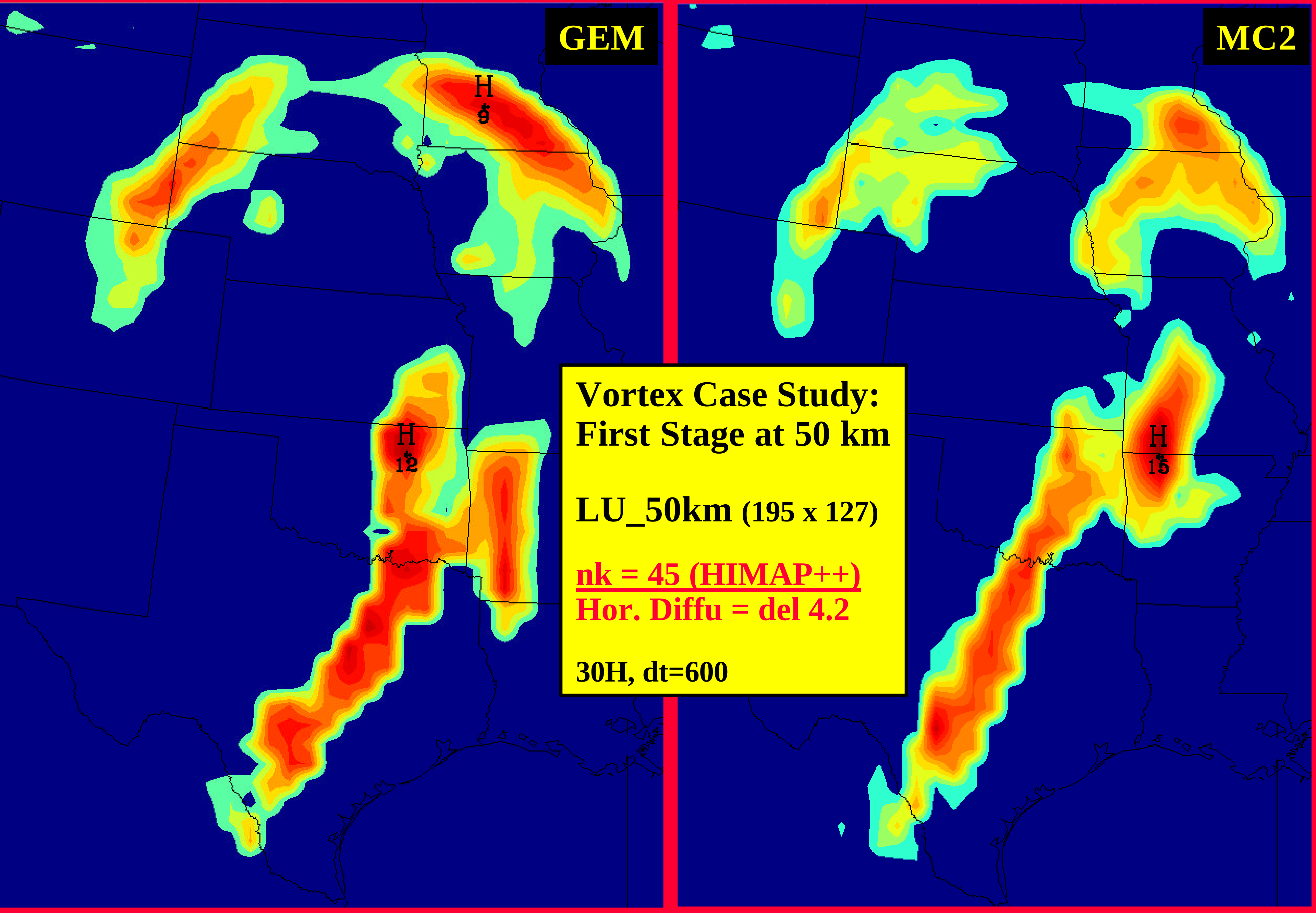


Belair & Mailhot, 2001: Impact of Horizontal Resolution on the Numerical Simulation of a Midlatitude Squall Line: Implicit vs Explicit Condensation. Mon. Wea. Rev., 129, 2362-2376

Grid Strategy for GEMDM-LAM: Vortex case study of 7-8 May 1995



27 H Forecast of Precipitation Rate (mm/h) valid 0300 UTC 8 May 1995



Vortex Case Study:
First Stage at 50 km

LU_50km (195 x 127)

nk = 45 (HIMAP++)
Hor. Diffu = del 4.2

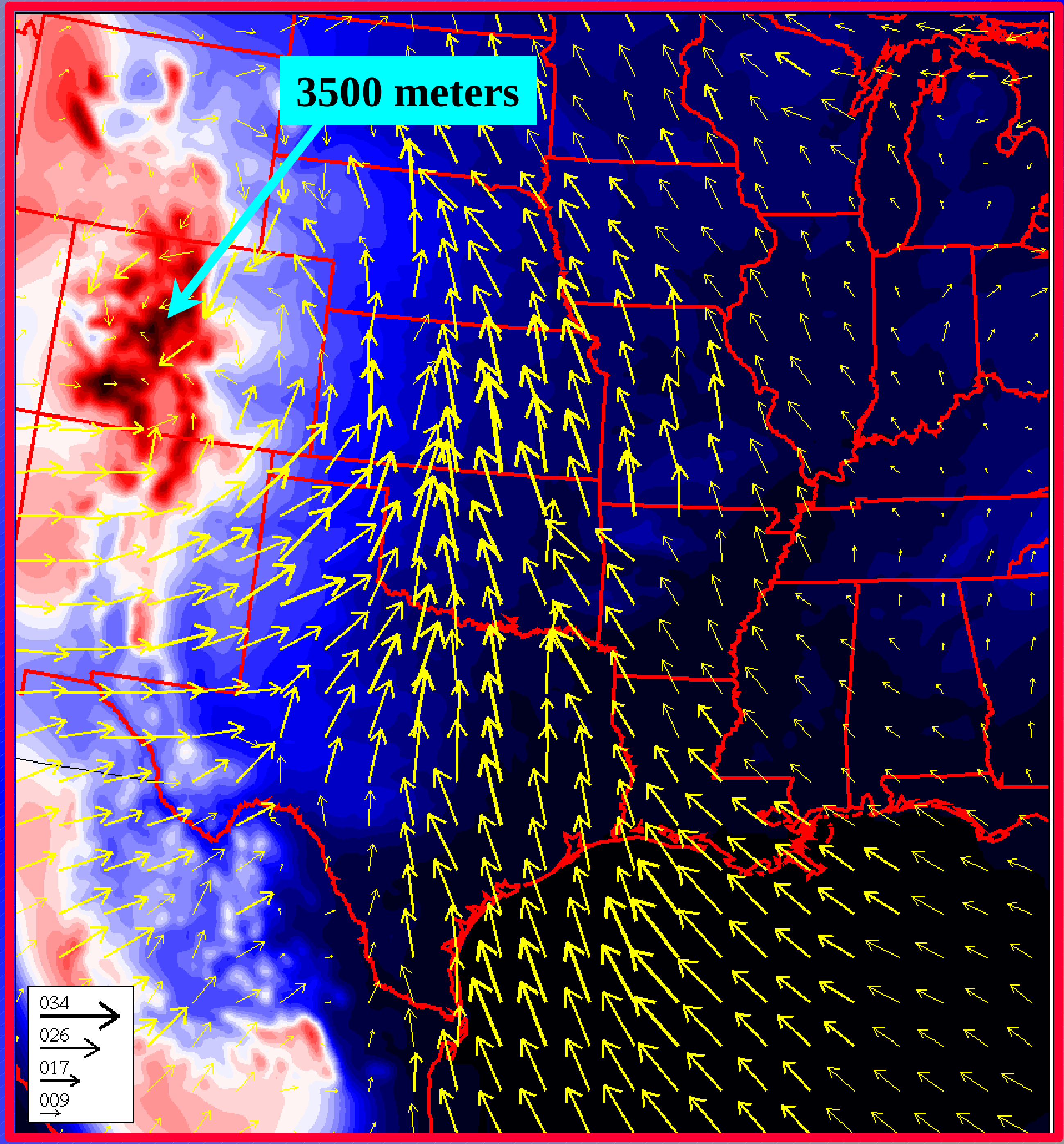
30H, dt=600

Vortex Case Study: Next Stage at 10 km

LU_10km (235 x 255)

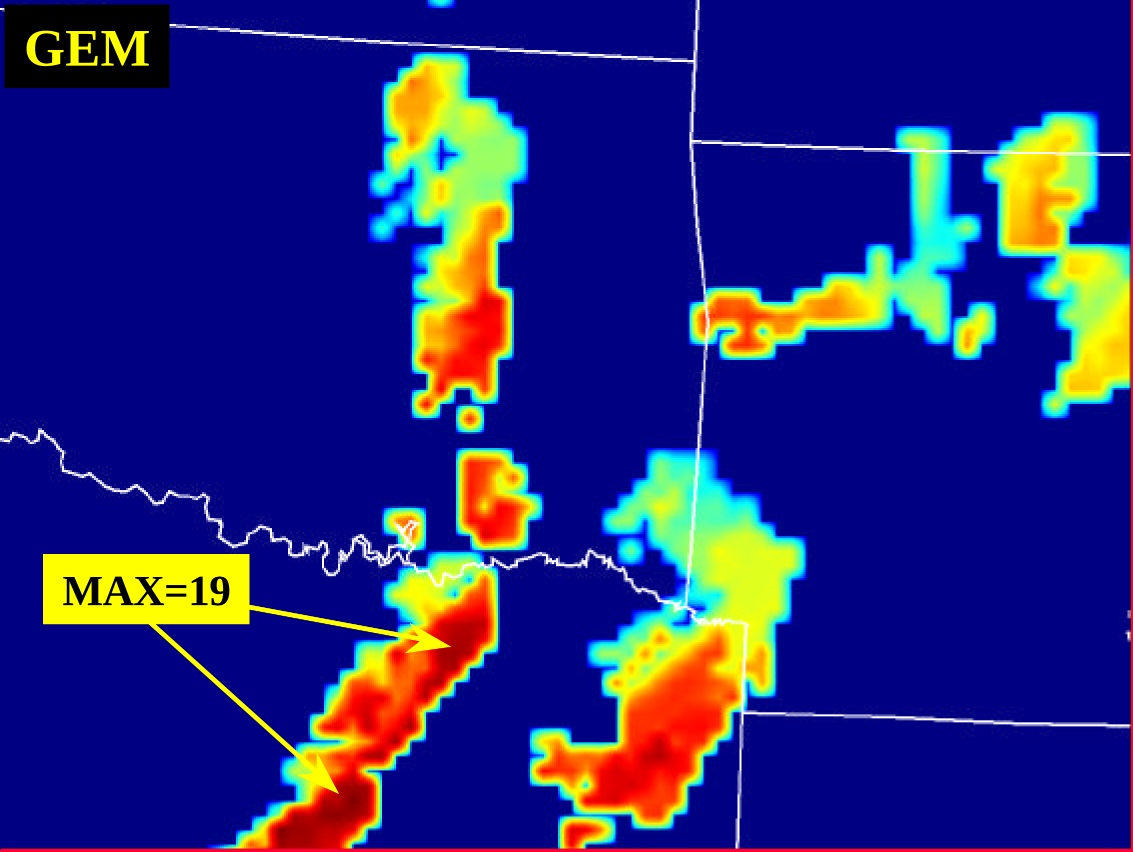
nk = 65
Hor. Diffu = del 4.2

24H, dt=75

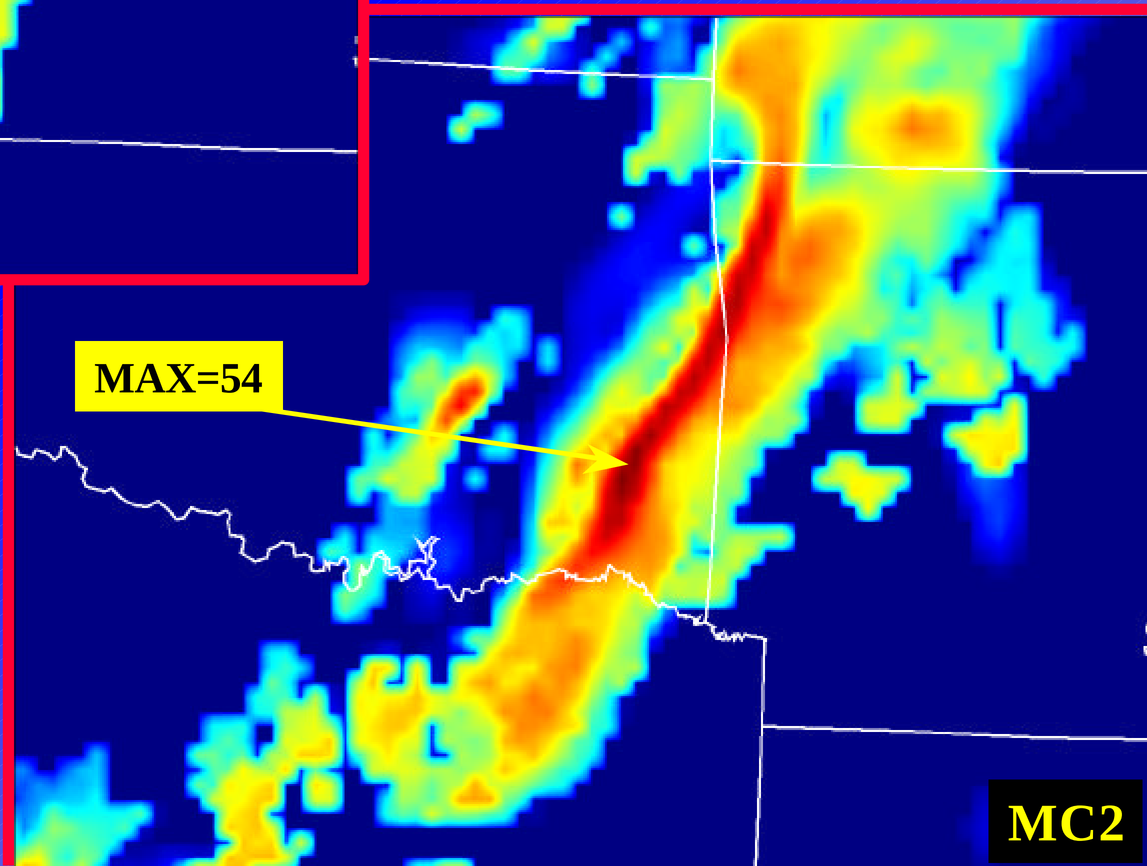


Color Shades: Topography

Arrow: Low level Flow
valid 16 UTC 07 May 1995



21 H Forecast of Precipitation Rate (mm/h) valid 0300 UTC 8 May 1995



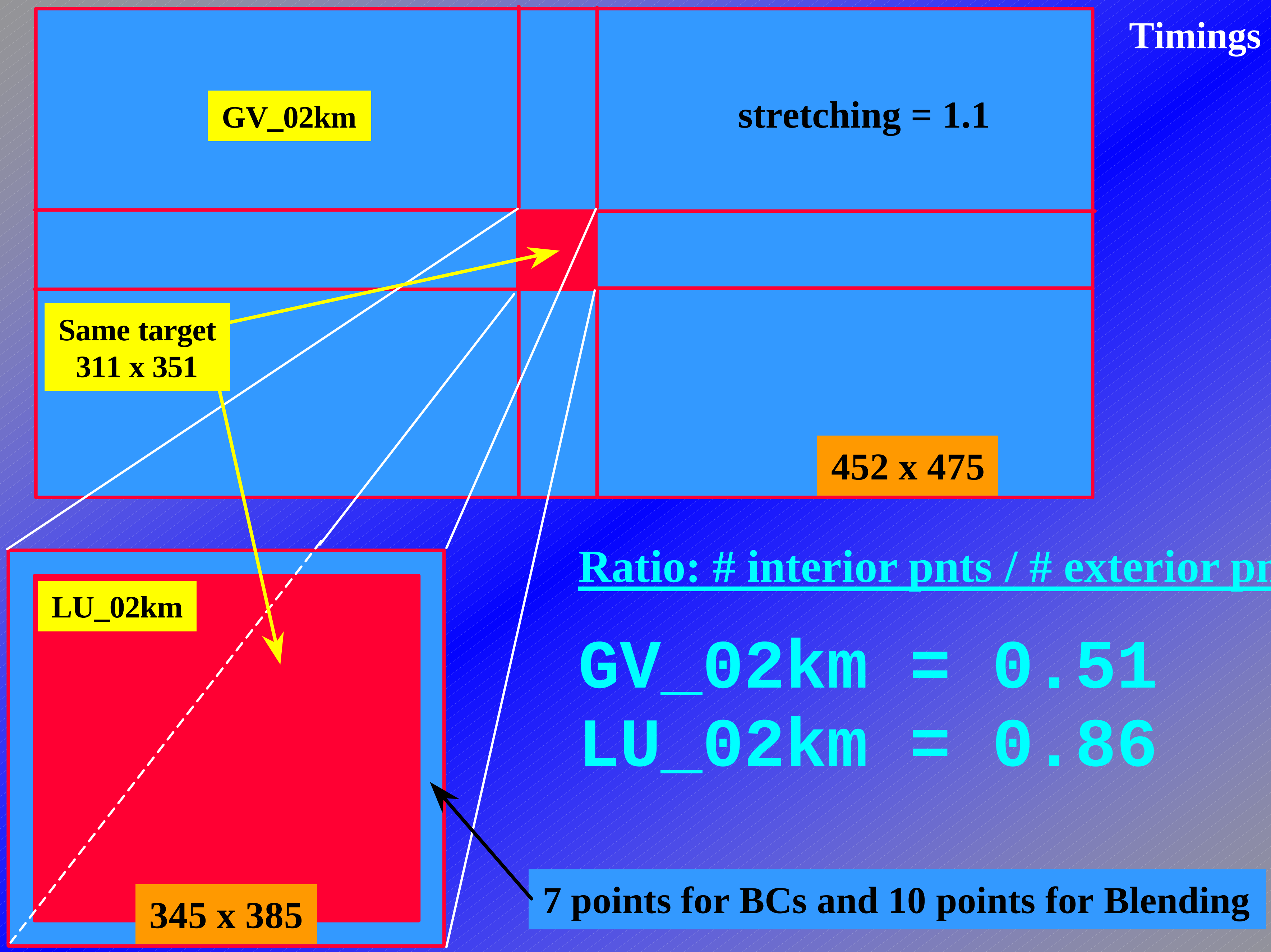
Vortex Case Study: Next Stage at 10 km

LU_10km (235 x 255)

nk = 65
Hor. Diffu = del 4.2

24H, dt=75

Timings (1)



Ratio: # interior pnts / # exterior pnts

GV_02km = 0.51

LU_02km = 0.86

Comparative Timings for 2 km resolution runs on SX6

	GEM LAM 345 x 385 1080 steps	MC2 345 x 385 2160 steps	GEM FFT-LAM 338 x 385 1080 steps	GEM VAR 452 x 475 1080 steps
CPU (hours)	34.0	28.7	**25.7**	**53.7**
FC (E+12)	**198.2**	**145.7**	119.0	394.8
Gflops/sec	1.6	1.5	**1.3**	**2.06**
Vector length	160	176	153	207
Mem (Gbytes)	11.5	7.4	9.0	11.8

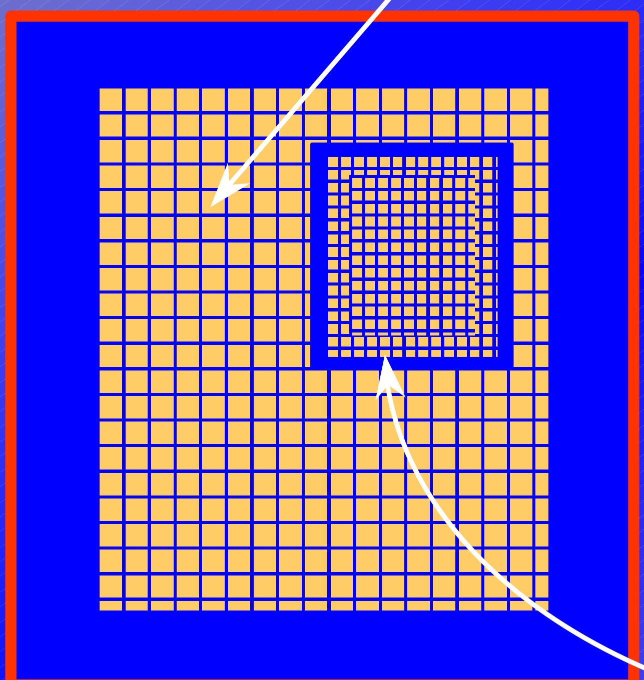
Remaining differences between GEM and MC2

	GEM	MC2
Time discretization	2 time level fully implicit	3 time level semi-implicit
Pressure solver	direct solver on nk planes	iterative fully 3D solver
Vertical coordinate	mass no-staggering	height Charney-Phillips staggering
SLT	1 set of trajectories	3 sets of trajectories
Change grid	mostly cubic	strictly linear
Physics interface	4 basic tendencies + 6 derivates including a heat term on mass fields	4 basic tendencies
Prognostics variables	14: 6 basics + 5 derivates + 3 pertub.	6
Topography	fixed	time dependent at startup

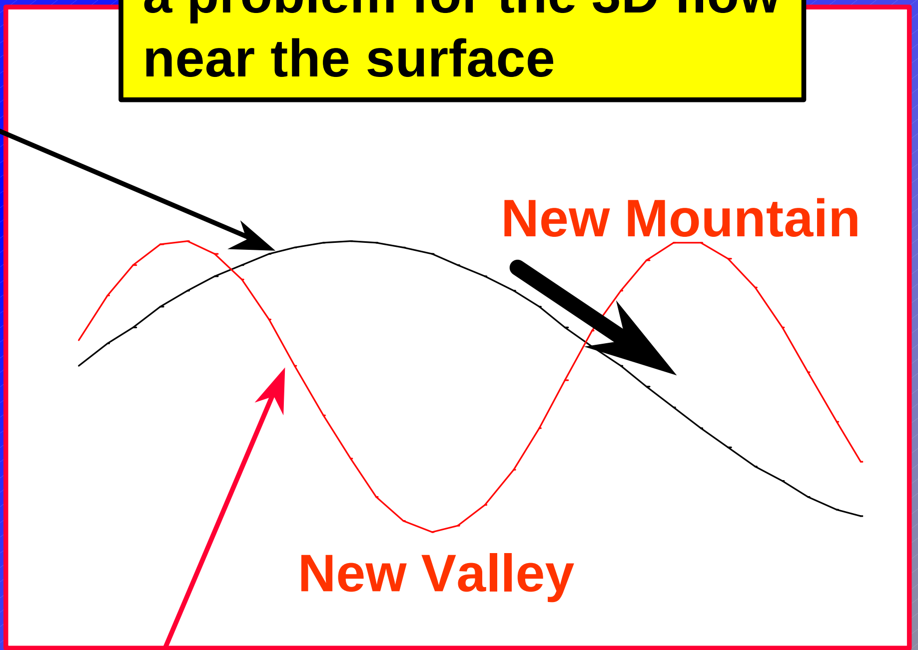
Time Dependent Topography

Improving Spinup when using high resolution topography: Claude Girard (spring 1999)

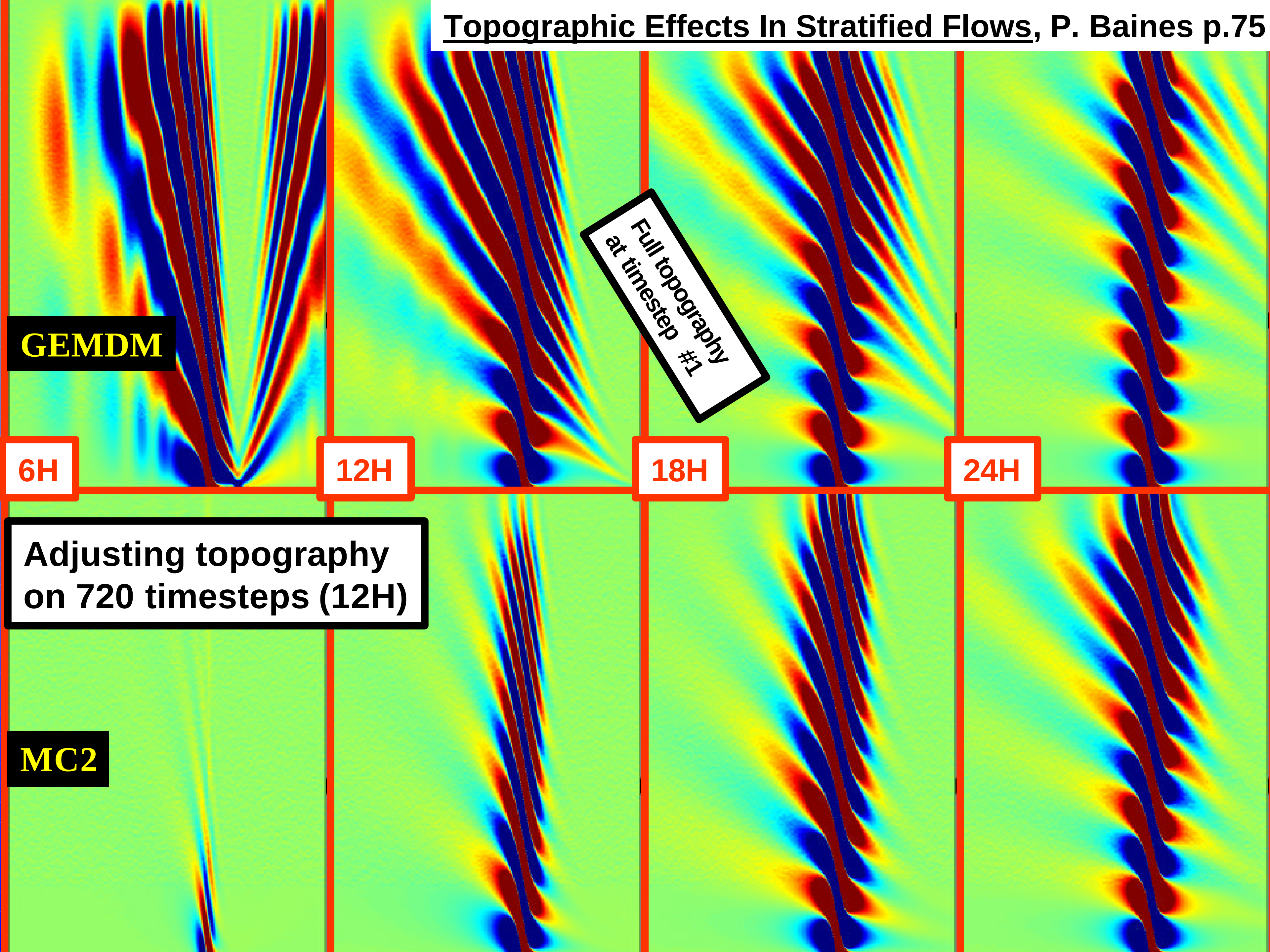
Initial and boundary conditions from well adjusted flow over coarser resolution topography of previous run



Vertical interpolation: a problem for the 3D flow near the surface



Higher resolution topography of current run



Topographic Effects In Stratified Flows, P. Baines p.75
GEMDM
Full topography at timestep #1
6H
12H
18H
24H
Adjusting topography on 720 timesteps (12H)
MC2

Conclusions & Future work

- LAM configurations for GEMDM are ready to explore (v_3.0.2 and up)
- Machine performance as expected
- Caution for high resolution simulations

- Canonical cases
- Pursue LAM validation at high resolution using MC2
- Formal comparisons between LAM and variable resolution method
- Operational LAM...

THE END

Thank You !

RPN

Environment Canada