Transforming Earth's atmosphere into a discreet world

Vladimir Đurđević and Zaviša Janjić

УНИВЕРЗИТЕТ У БЕОГРАДУ ФИЗИЧКИ ФАКУЛТЕТ

With contributions: Ratko Vasic, Goran Pejanovic, Marija Djordjevic, Borivoj Rajkovic, Ana Vukovic, Mirjam Vujadinovic Mandic

HRVATSKO METEOROLOŠKO DRUŠTVO

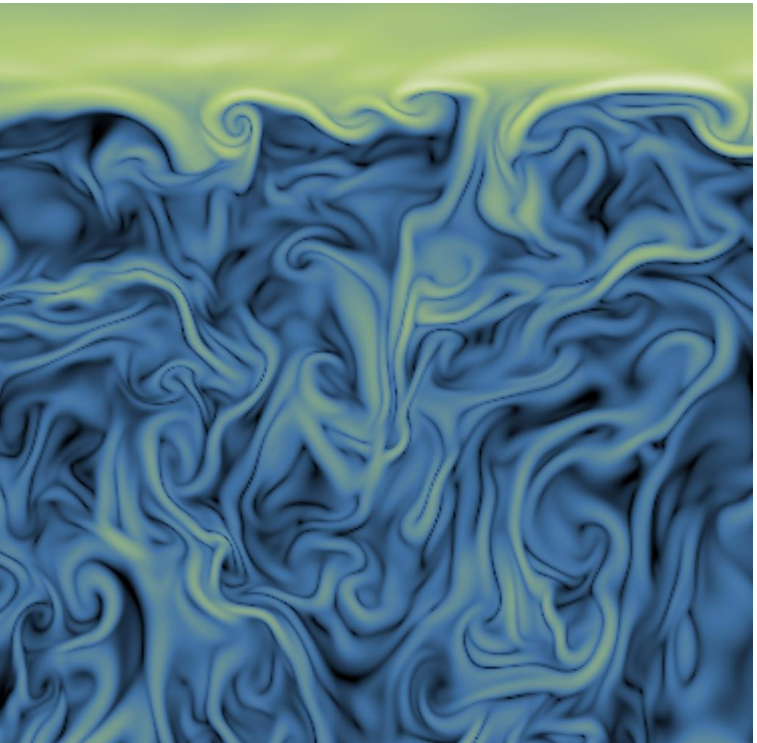
ZNANSTVENO-STRUČNI SKUP S MEĐUNARODNIM SUDJELOVANJEM
15. – 16. studenog 2018.
KRAŠ Auditorium, Ravnice 48, Zagreb

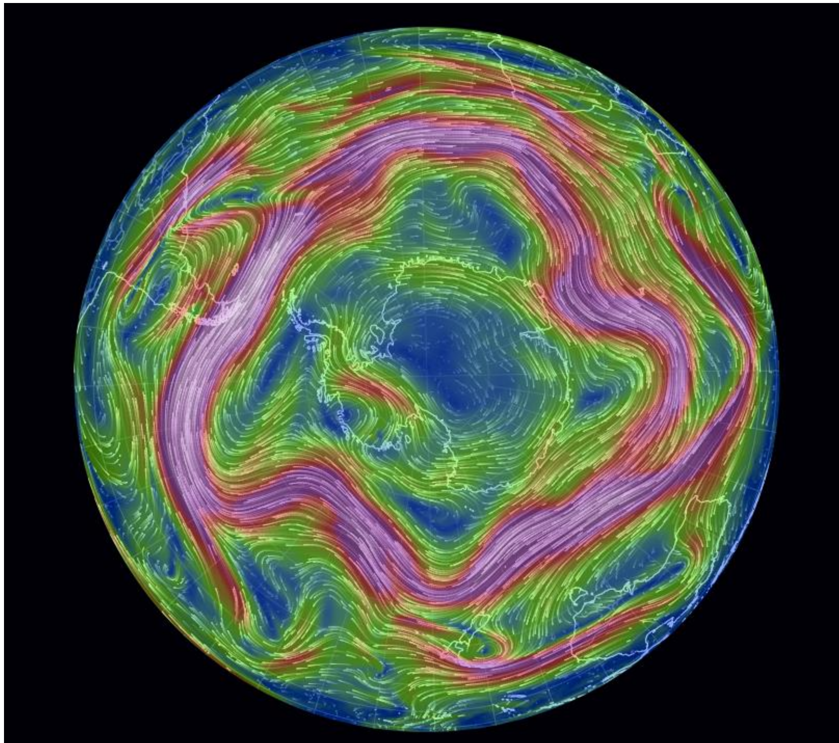
Meteorološki izazovi 6

Navier–Stokes equation

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla)\mathbf{v} = -\nabla p + \nu \Delta \mathbf{v} + \mathbf{f}(\boldsymbol{x}, t)$$

Turbulence → **Planetary waves**





Equation discretization on sphere

Spectral $u = \sum_{|n|=0}^{\infty} A_n(t)\exp(i\omega_n x)$ $u = \sum_{|n|=0}^{N} A_n(t)\exp(i\omega_n x)$

Advantage: no pole problem

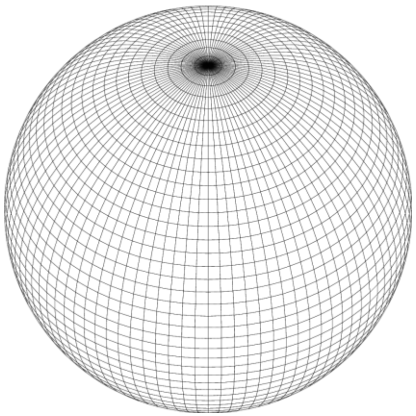
Disadvantage : code scalability

Grid-point $$\left(\frac{\partial u}{\partial y}\right)_{i+1,j} = \frac{u_{i+1,j+1} - u_{i+1,j-1}}{2\Delta y} + \cancel{\mathcal{O}(\Delta y)^2}$$

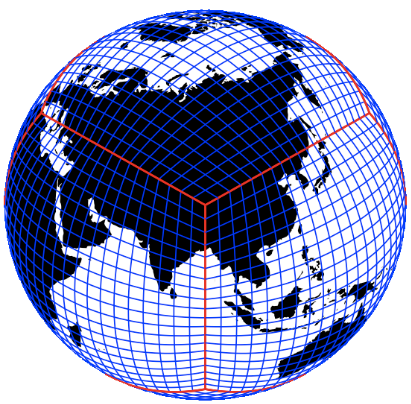
Advantage: code scalability

Disadvantage : pole problem

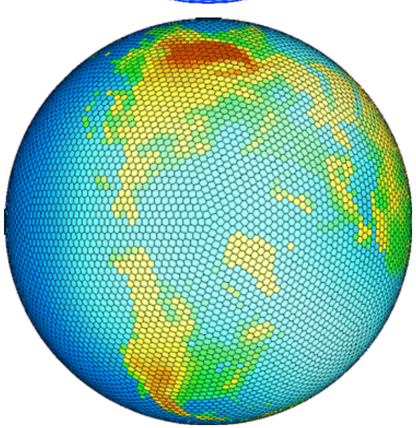
Grid-point different geometries



latitude-longitude grid - “lat-lon”

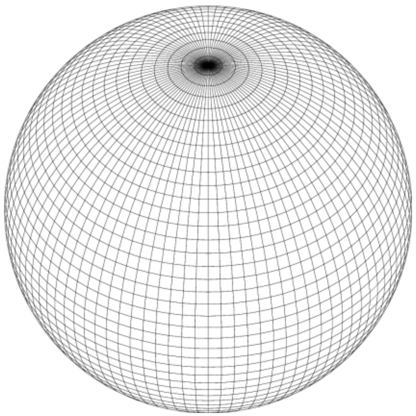


cubed-sphere - “cube”

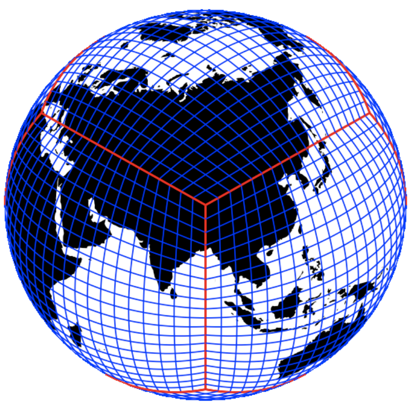


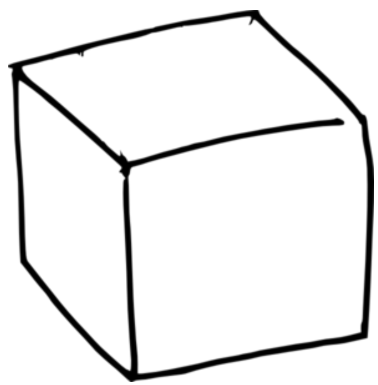
hexagon-pentagon grids -“hexa”

Grid inhomogeneity

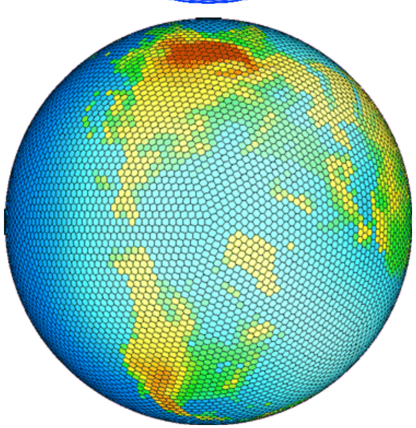


2 pole points





4 corners per hemisphere

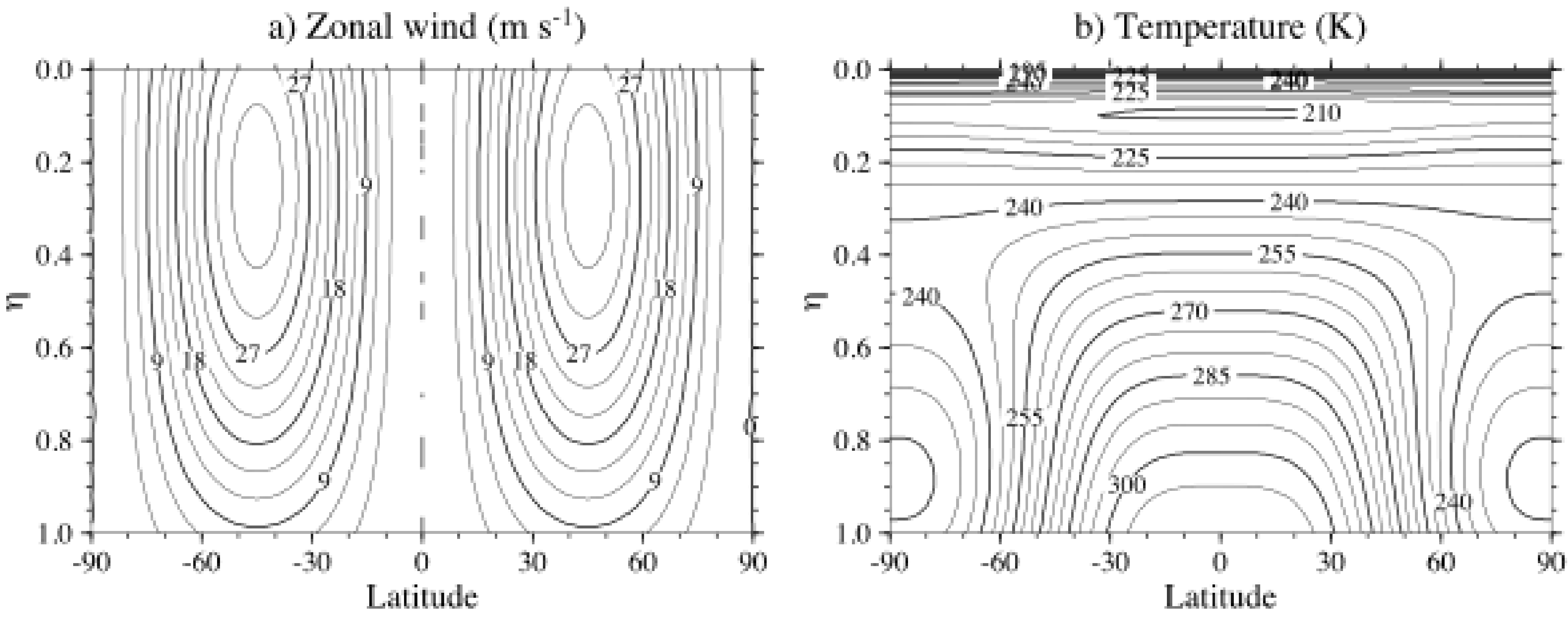


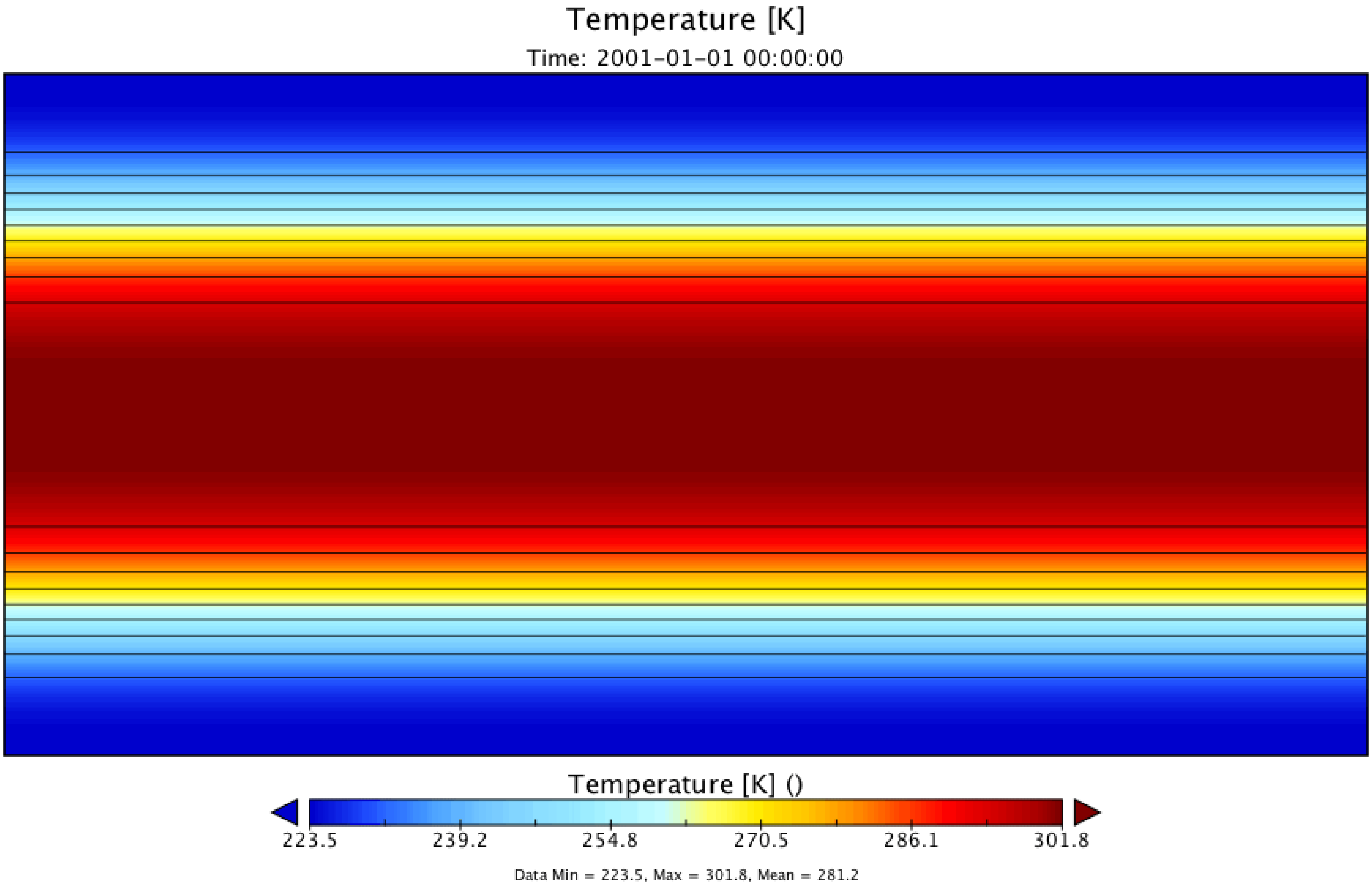
6 pentagons per hemisphere,
1 on the pole and 5 in mid-lats

Dry baroclinic instability test: concept and initial condition

The response of 3D atmospheric models to a controlled evolving instability (Jablonowski 2004; Jablonowski and Williamson 2006).

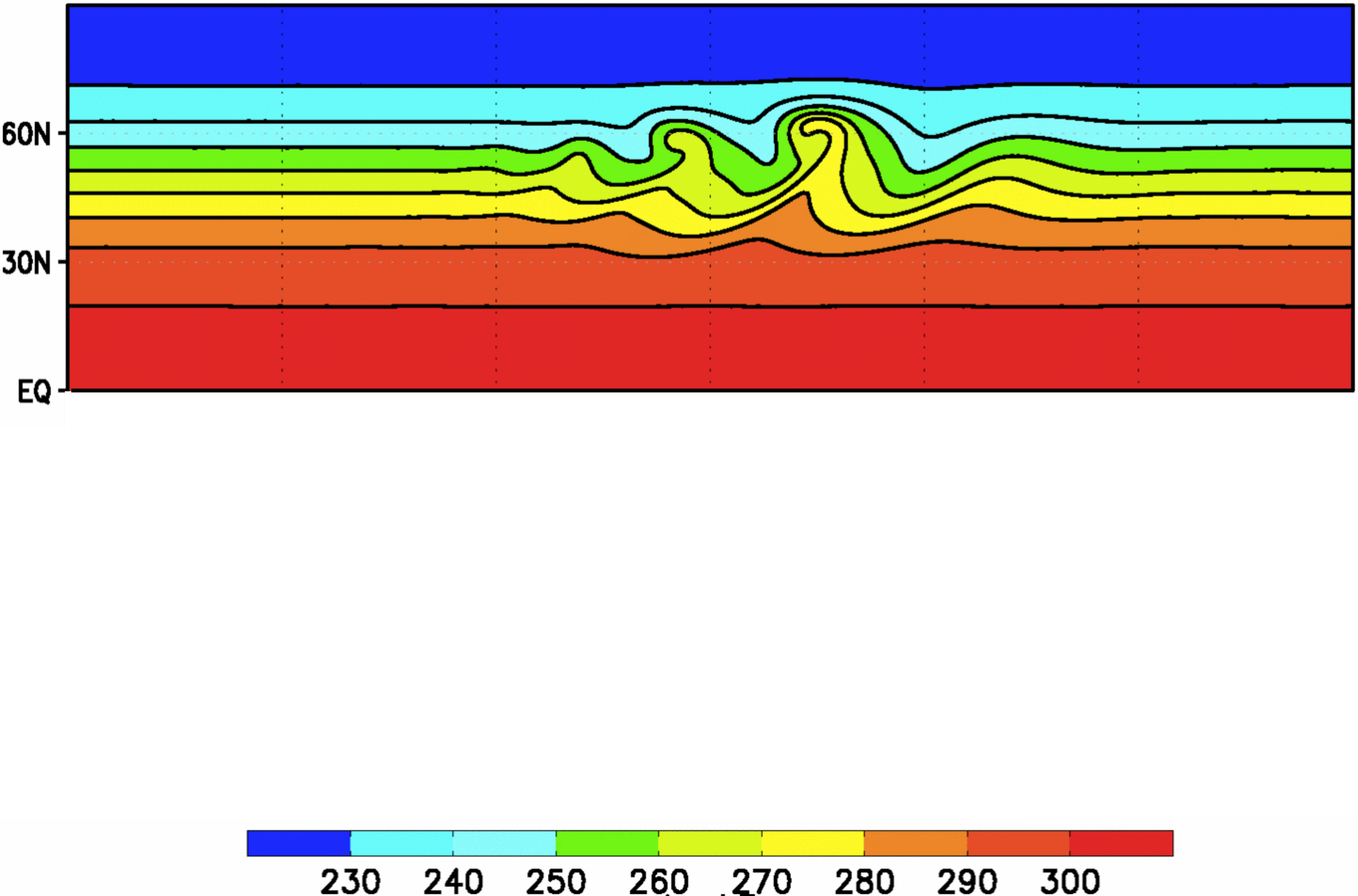
The balanced initial flow field comprises a zonally symmetric basic state with jet in mid-latitudes of each hemisphere and a quasi-realistic temperature distribution. Local nonperiodic perturbation of zonal wind is defined in mid-latitudes.




Temperature [K]
Time: 2001-01-01 00:00:00
Temperature [K] ()
223.5
239.2
254.8
270.5
286.1
301.8
Data Min = 223.5, Max = 301.8, Mean = 281.2

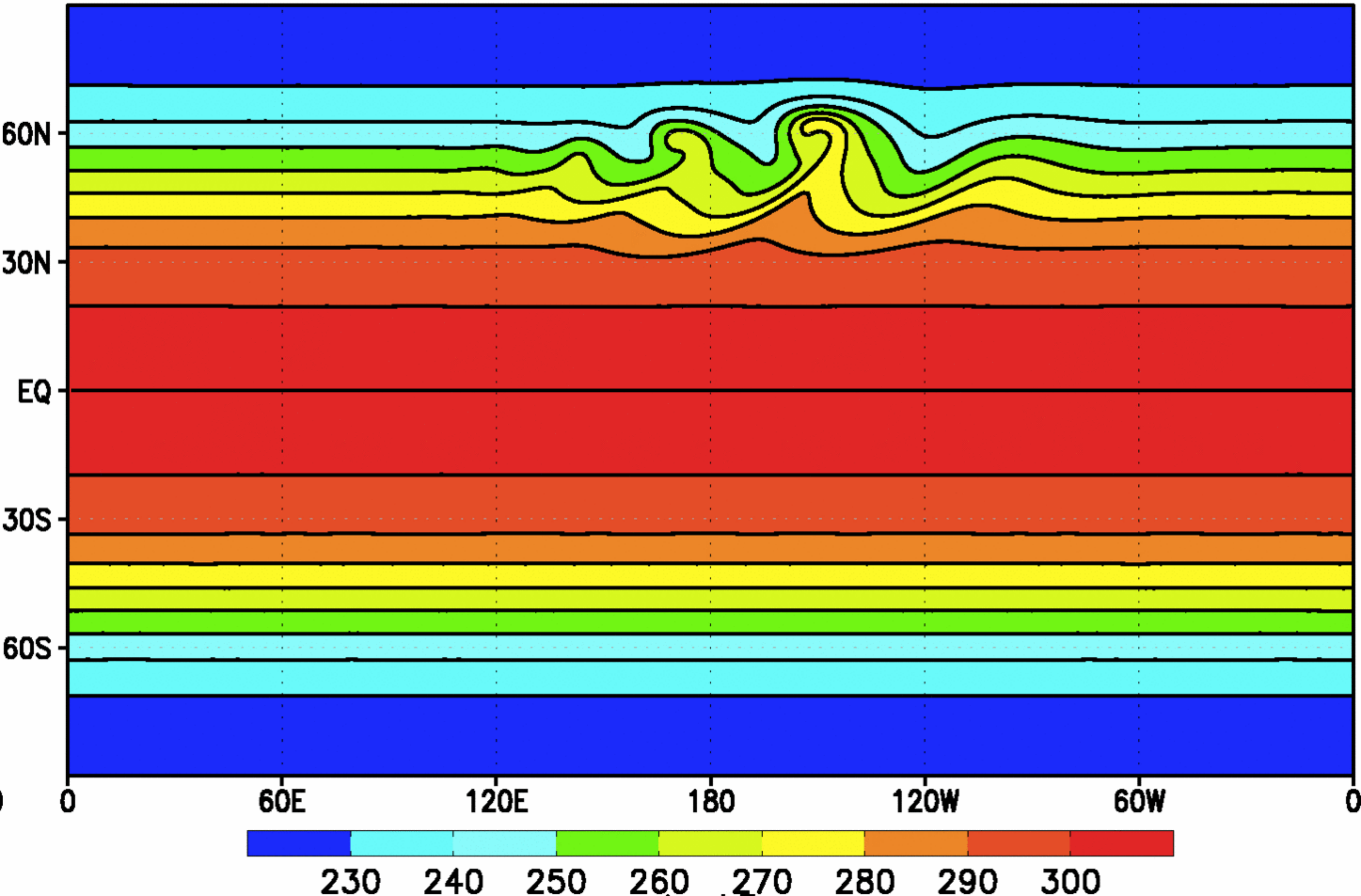
Typical figure from test:

Temperature on 850 hPa, day = 9

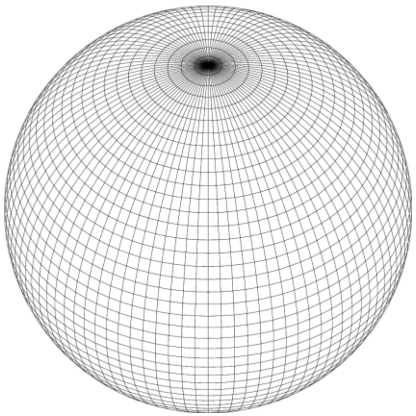


Typical figure from test:

Temperature on 850 hPa, day = 9

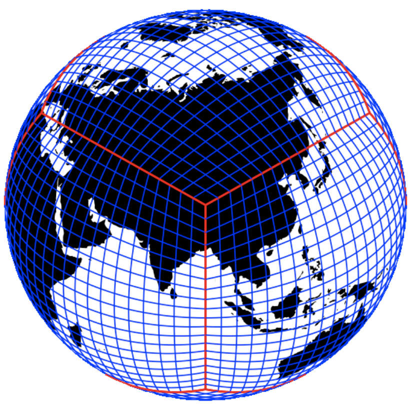


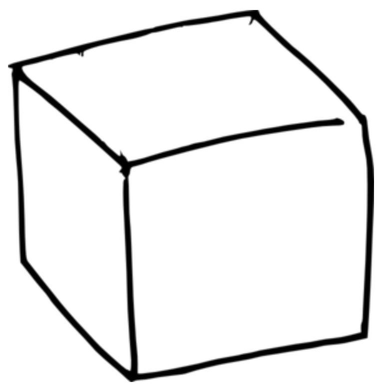
Models & grids



NMM-B

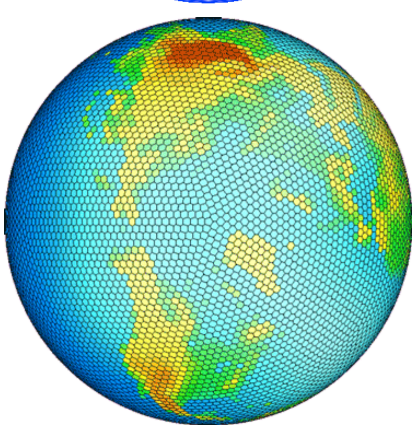
Nonhydrostatic Multiscale Model on the B-grid; lat-lon grid, both hydrostatic and non-hydrostatic; both global and regional; Janic 2005; Janjic and Gall 2012





FV3

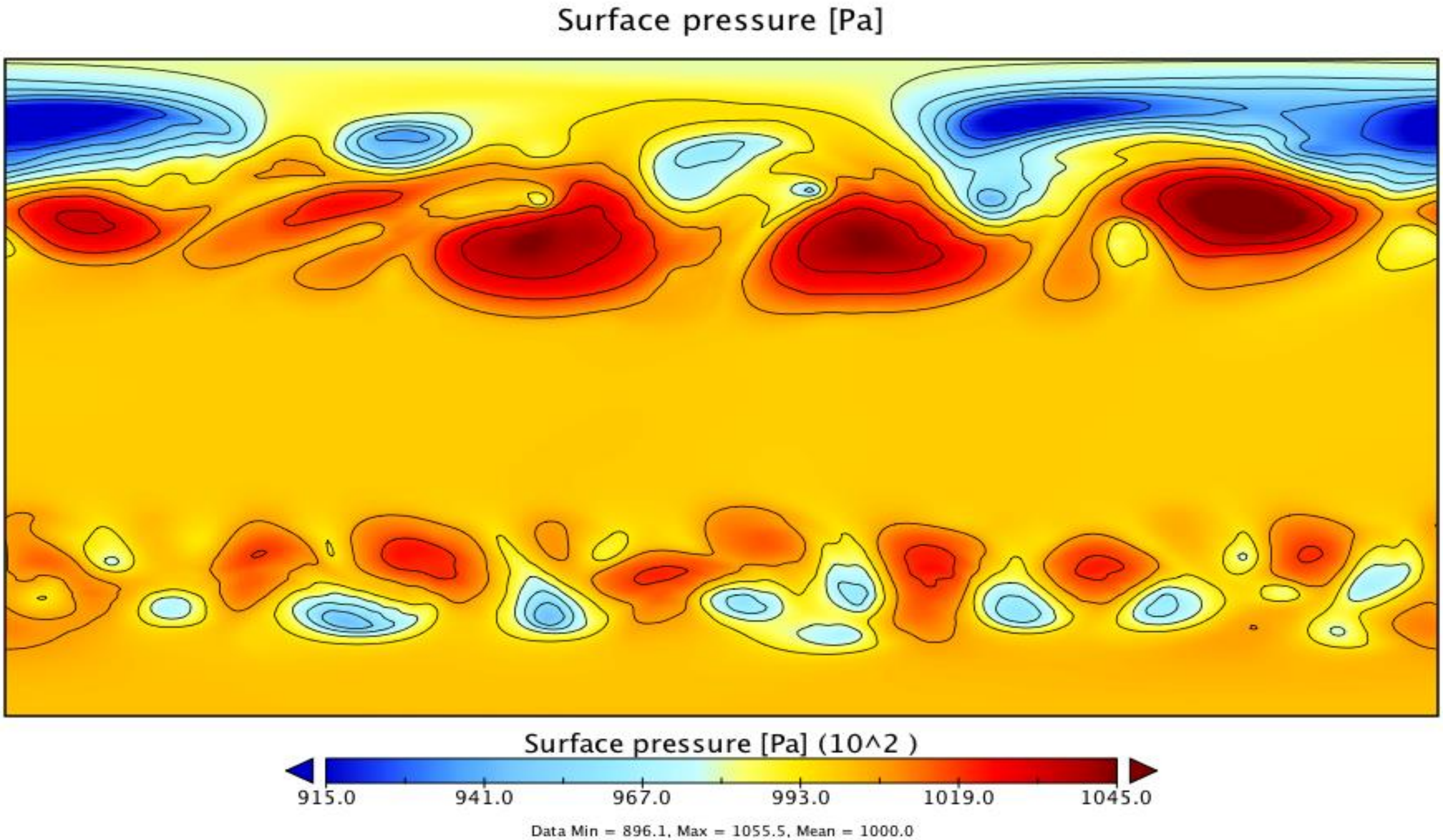
GFDL Finite-Volume cubed-sphere dynamical core; both hydrostatic and non-hydrostatic; Putman and Lin (2007) and Harris and Lin (2013)



MPAS

The Model for Prediction Across Scales
Unstructured Voronoi meshes; subset of the Advanced Research WRF (ARW); nonhydrostatic dynamics;
(Skamarock et al.,2012)

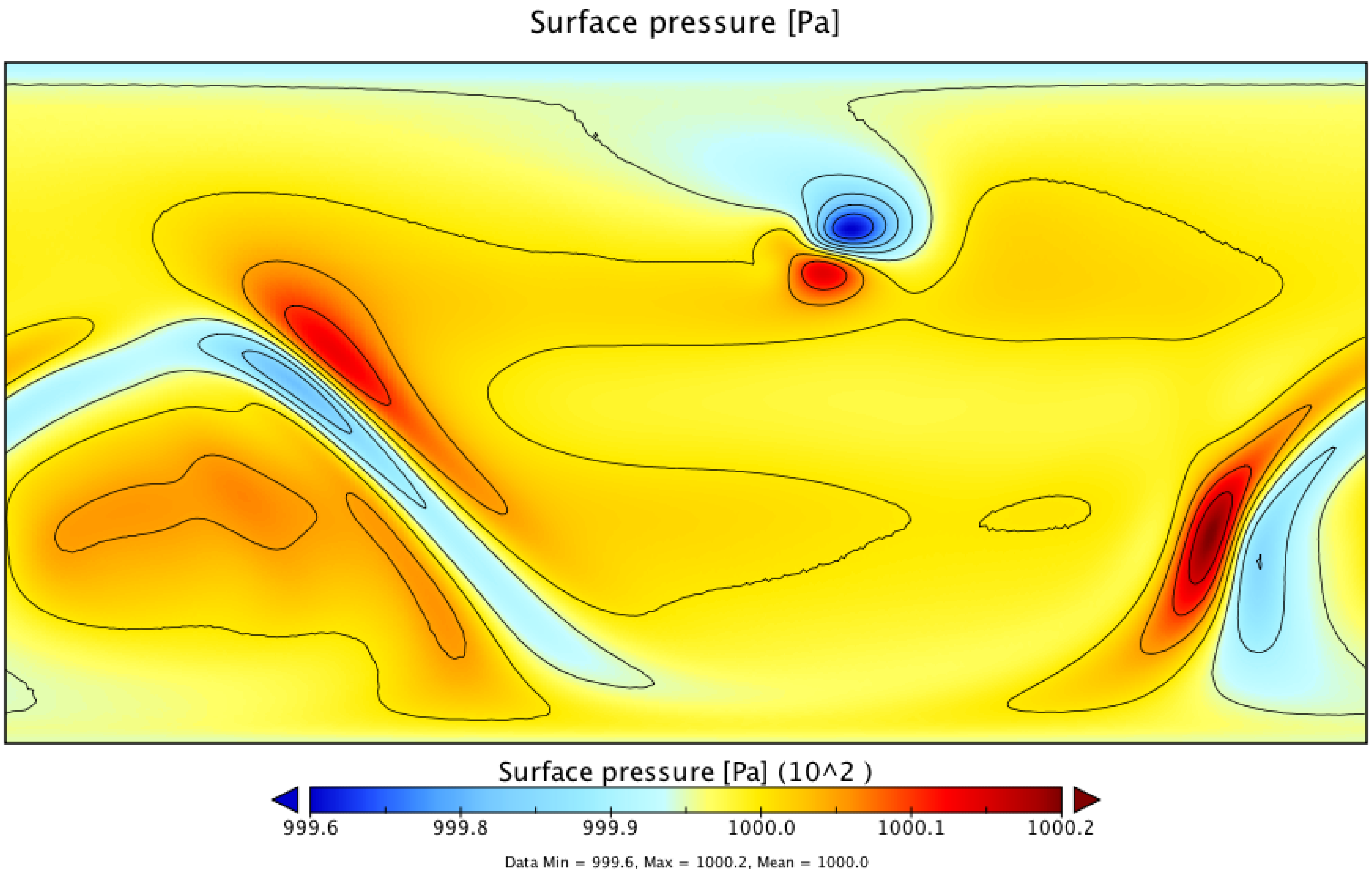
NMMB: surface pressure – day 20
(1°/L30)



Transfer of perturbation to Southern hemisphere

“Perturbations are introduced into the Southern Hemisphere by truncation errors and by gravity waves which arise from the geostrophic adjustment associated with the imposed unbalanced perturbation in the Northern Hemisphere and which propagate into the Southern Hemisphere" (Jablonowski and Williamson 2006).

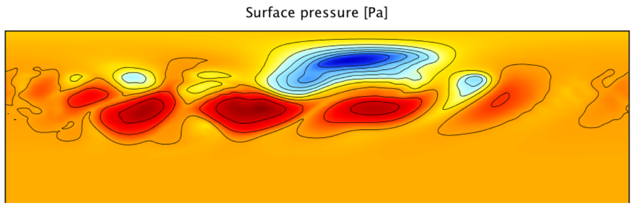
NMMB: Surface pressure after day 1 (1º/L30)

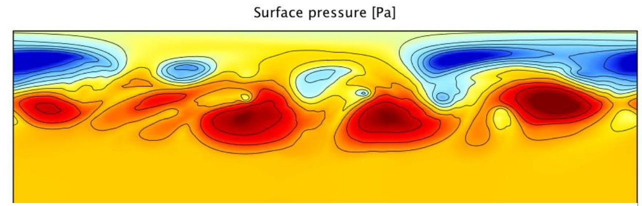


Comparison between models – surface pressure (north hemisphere)

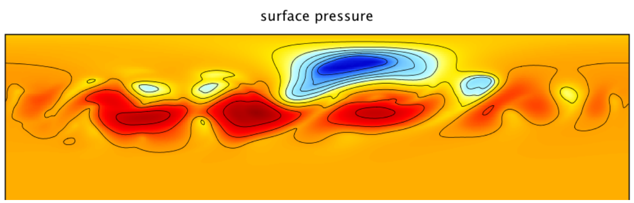
(1º/L30) **DAY 15** **DAY 20**

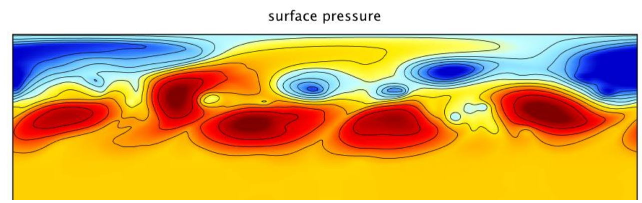
NMMB



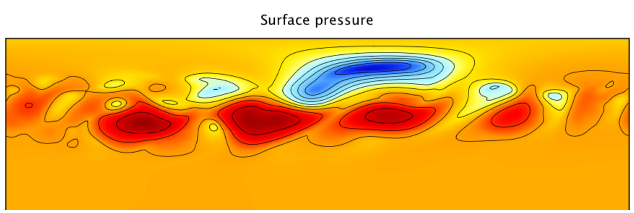


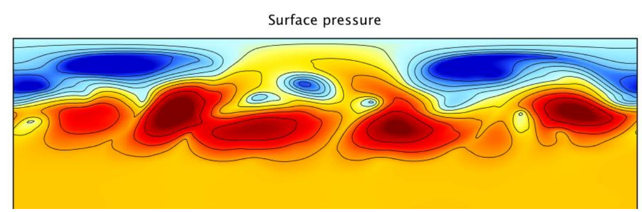
FV3





MPAS





Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

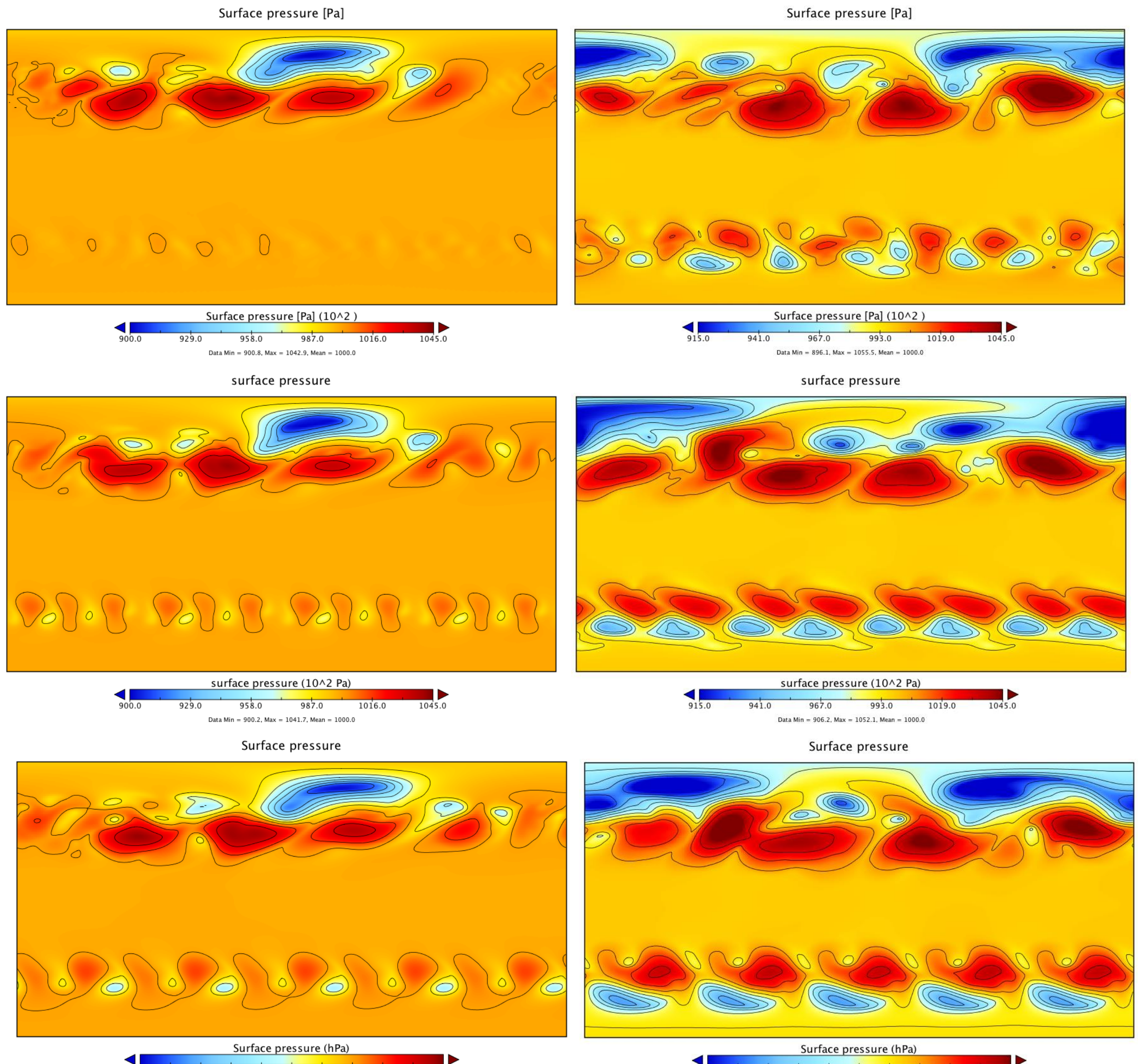
Comparison between models – surface pressure (both hemispheres)

(1°/L30) **DAY 15** **DAY 20**

NMMB

FV3

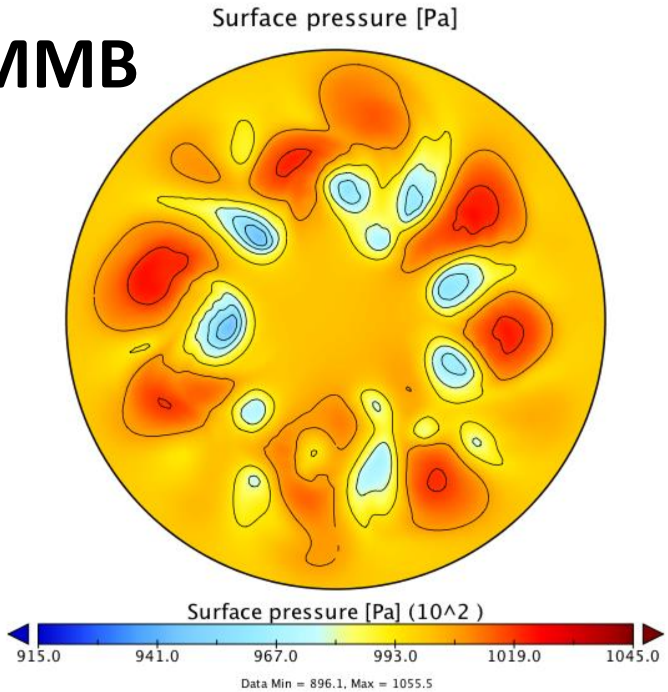
MPAS



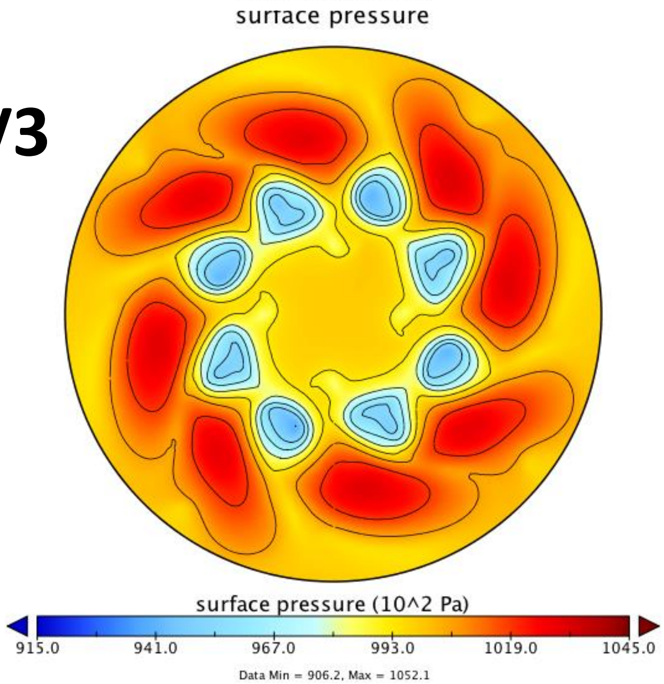
Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Surface pressure – day 20
South Hemisphere
(1°/L30)

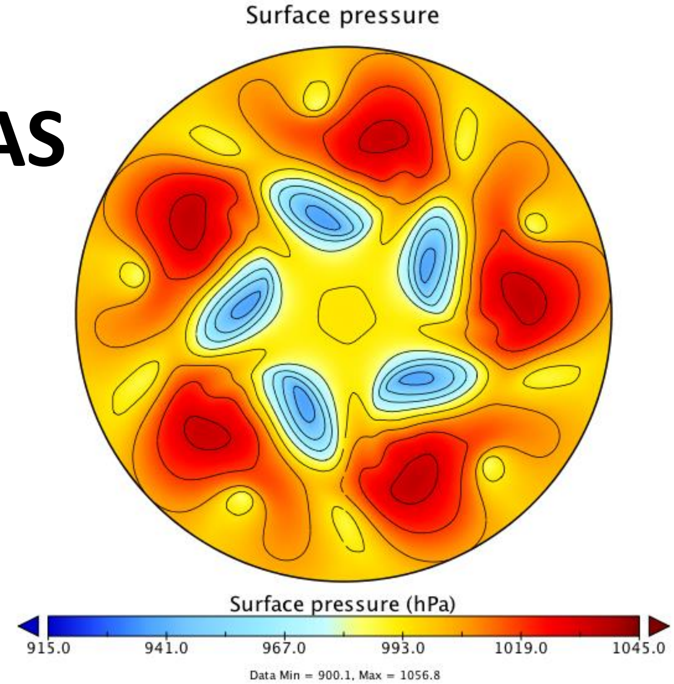
NMMB



FV3



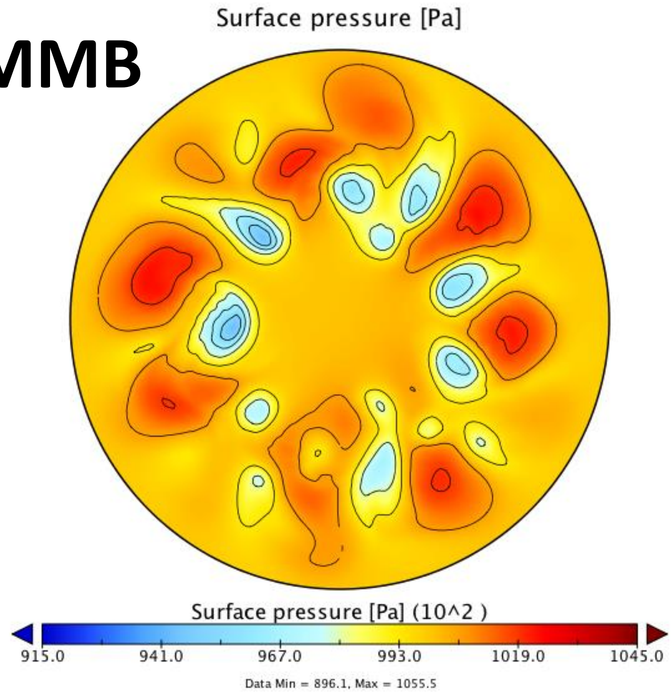
MPAS



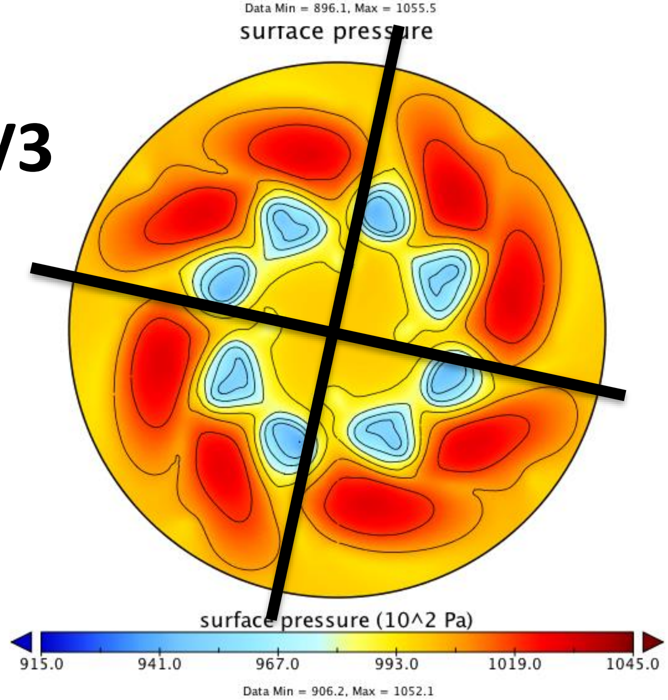
Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Surface pressure – day 20 South Hemisphere (1°/L30)

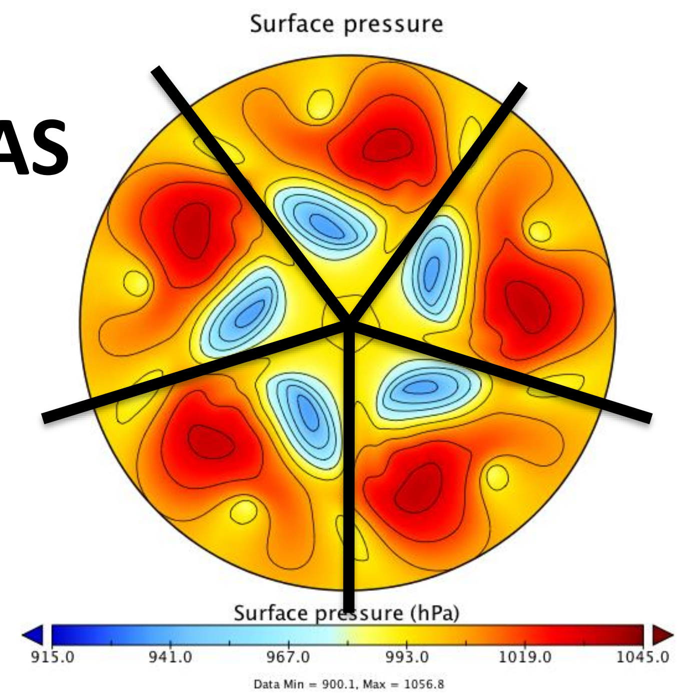
NMMB



FV3



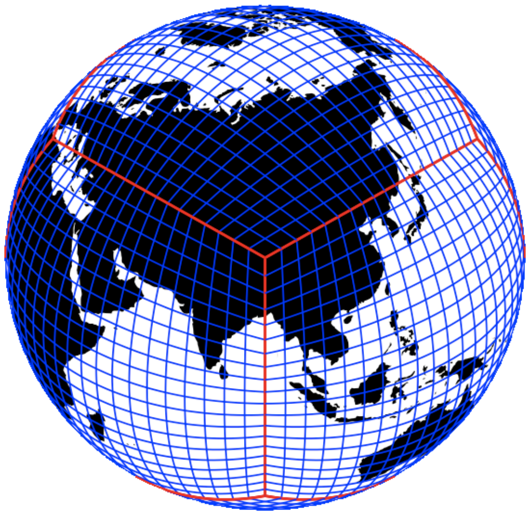
MPAS

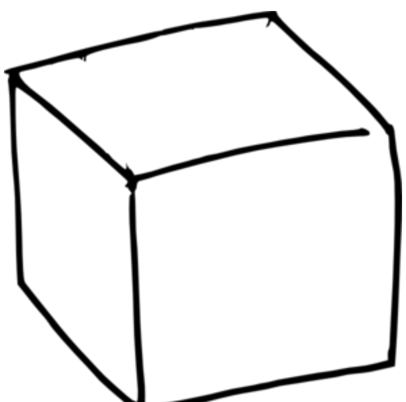


Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Grid-imprinting on cubed-sphere and hexagon-pentagon grids

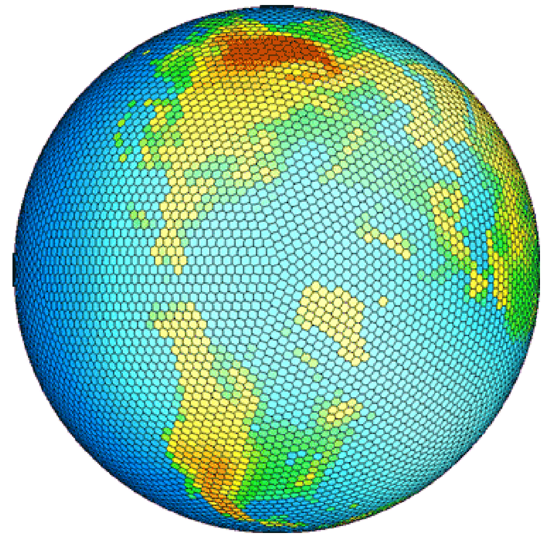
"cube"





4 corners per hemisphere

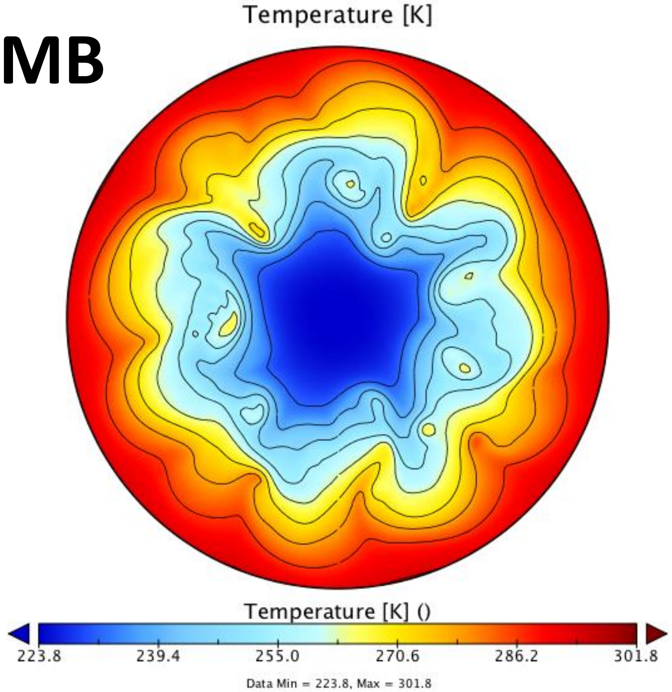
"hexa"



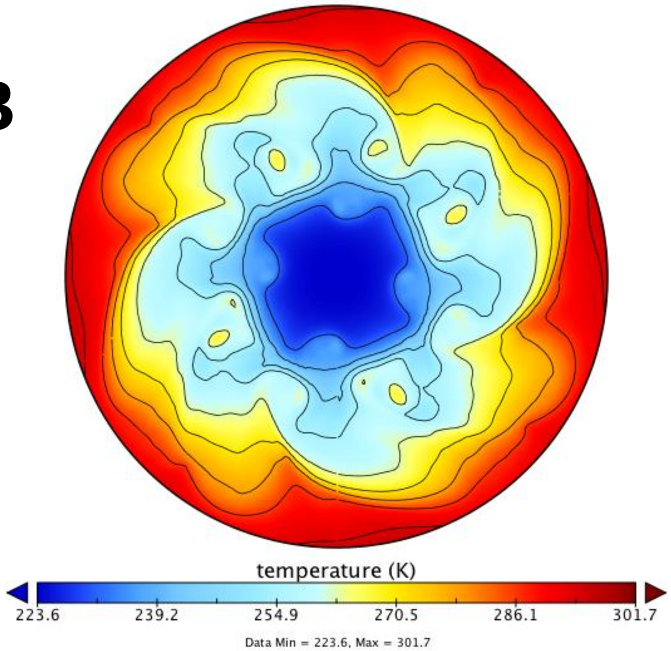
5 pentagons in mid-lats

Temp 850mb - day 20
South Hemisphere
(1°/L30)

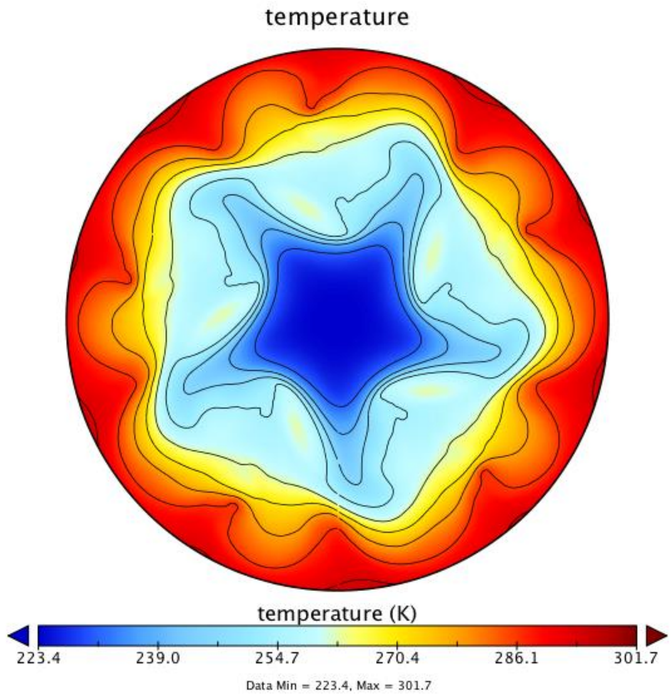
NMMB



FV3



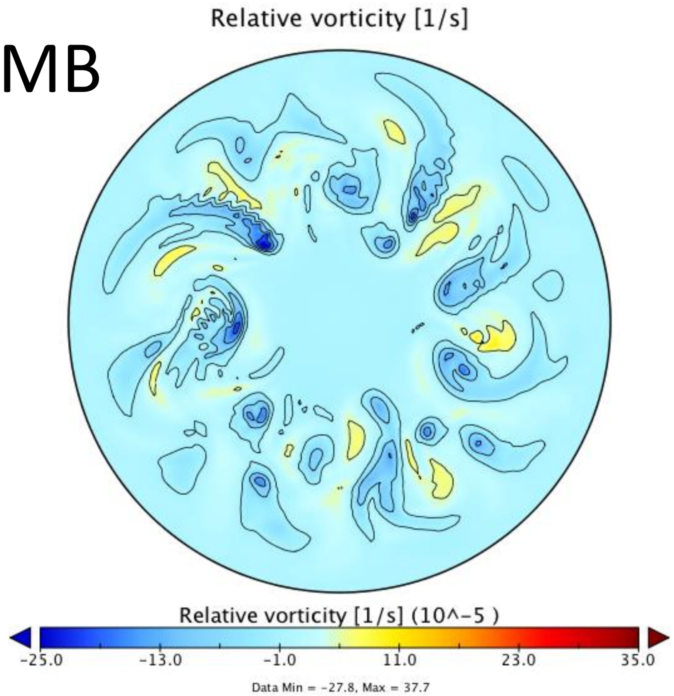
MPAS



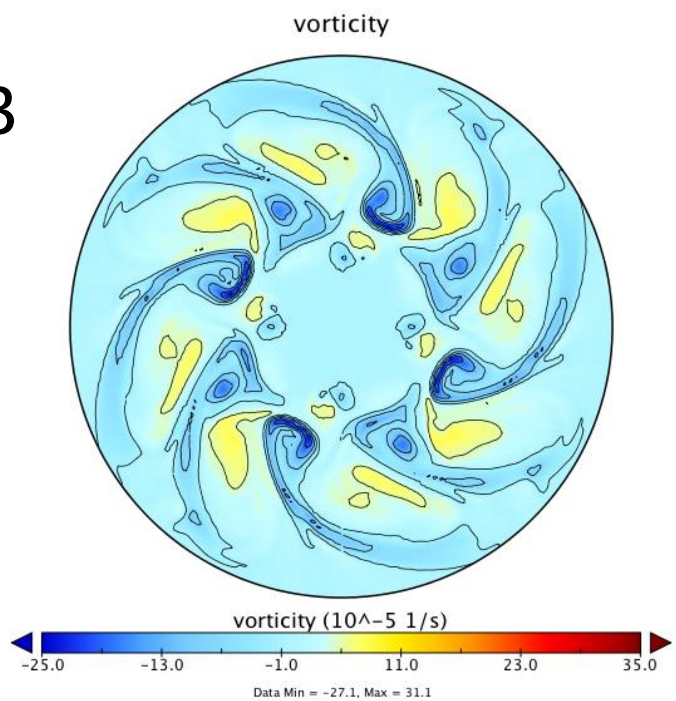
Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Relative vorticity 850mb day-20 South Hemisphere (1^o/L30)

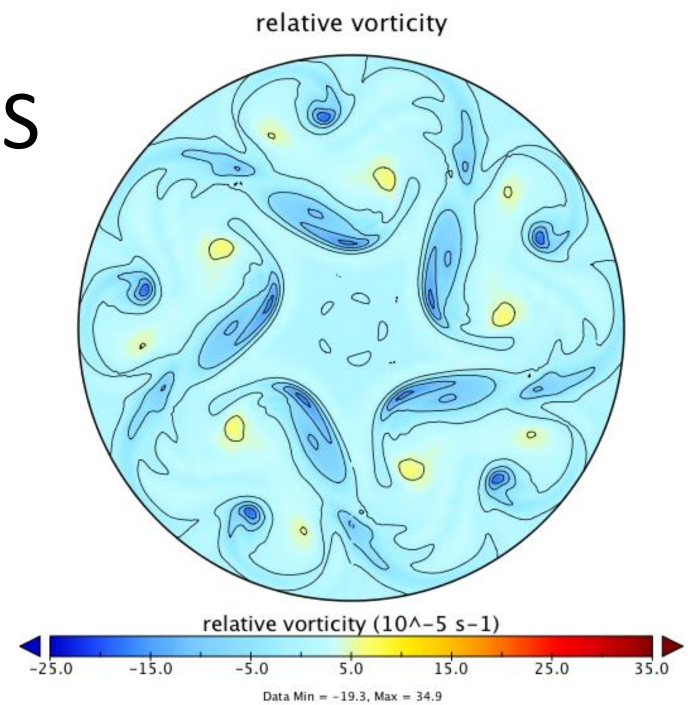
NMMB



FV3



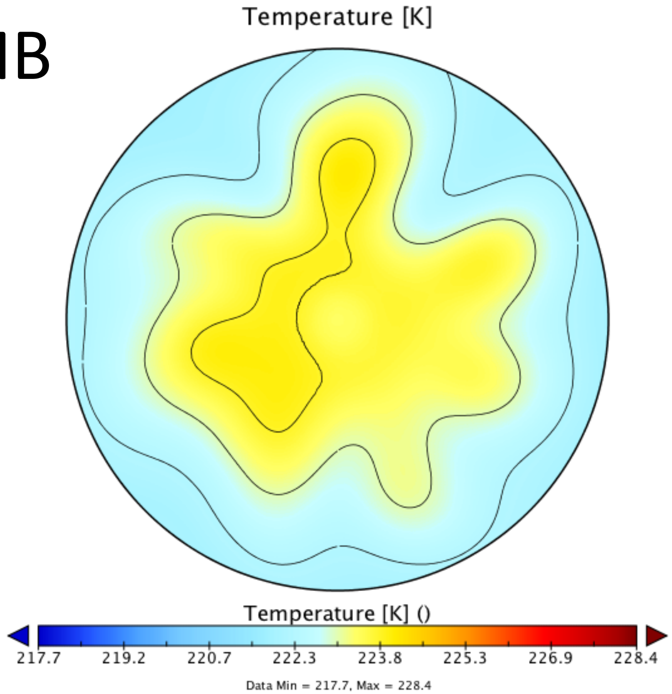
MPAS



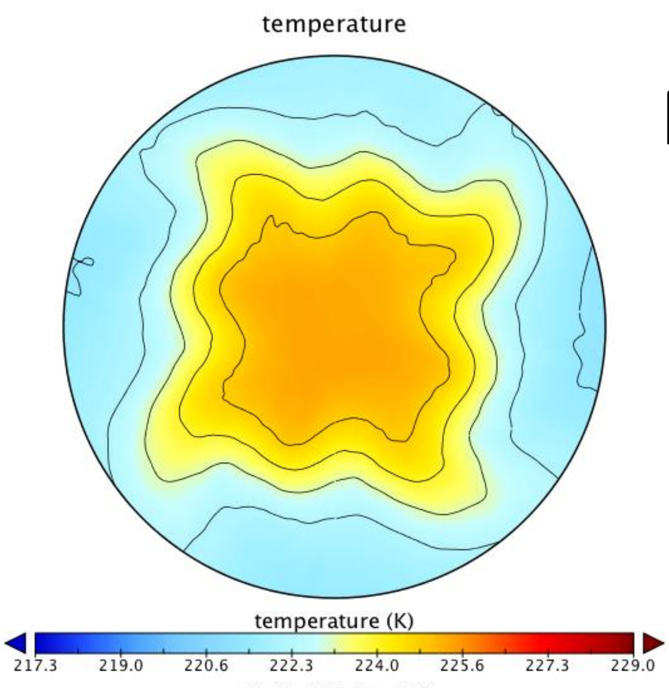
Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Temp 30 mb day-20 South Hemisphere (1^o/L30)

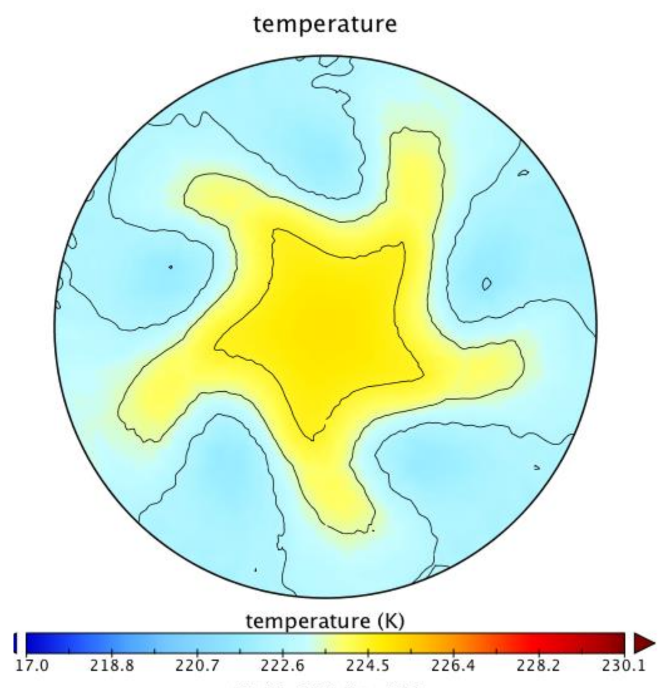
NMMB



FV3



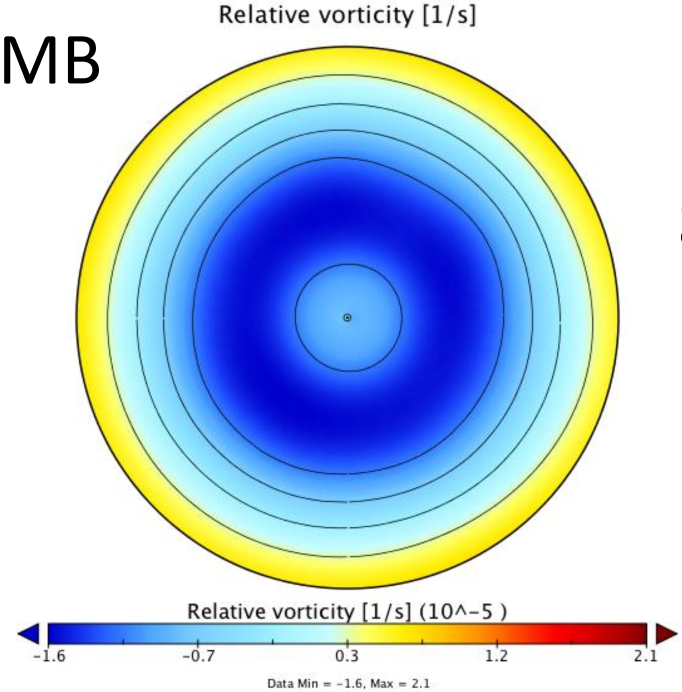
MPAS



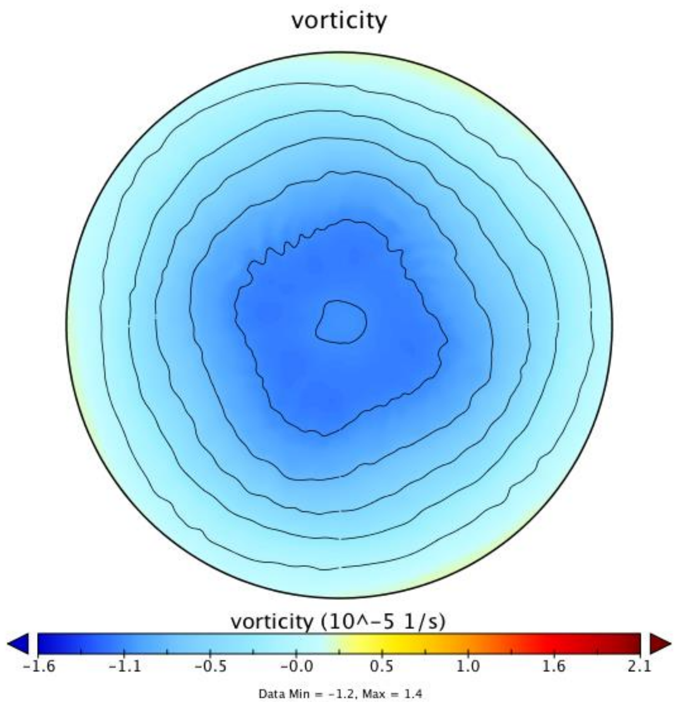
Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Relative vorticity 10 mb day-20 South Hemisphere (1^o/L30)

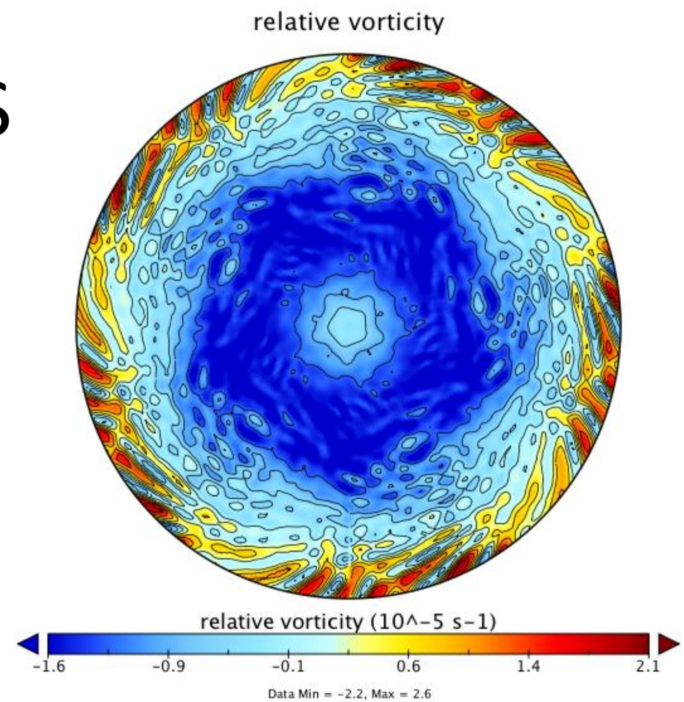
NMMB



FV3



MPAS



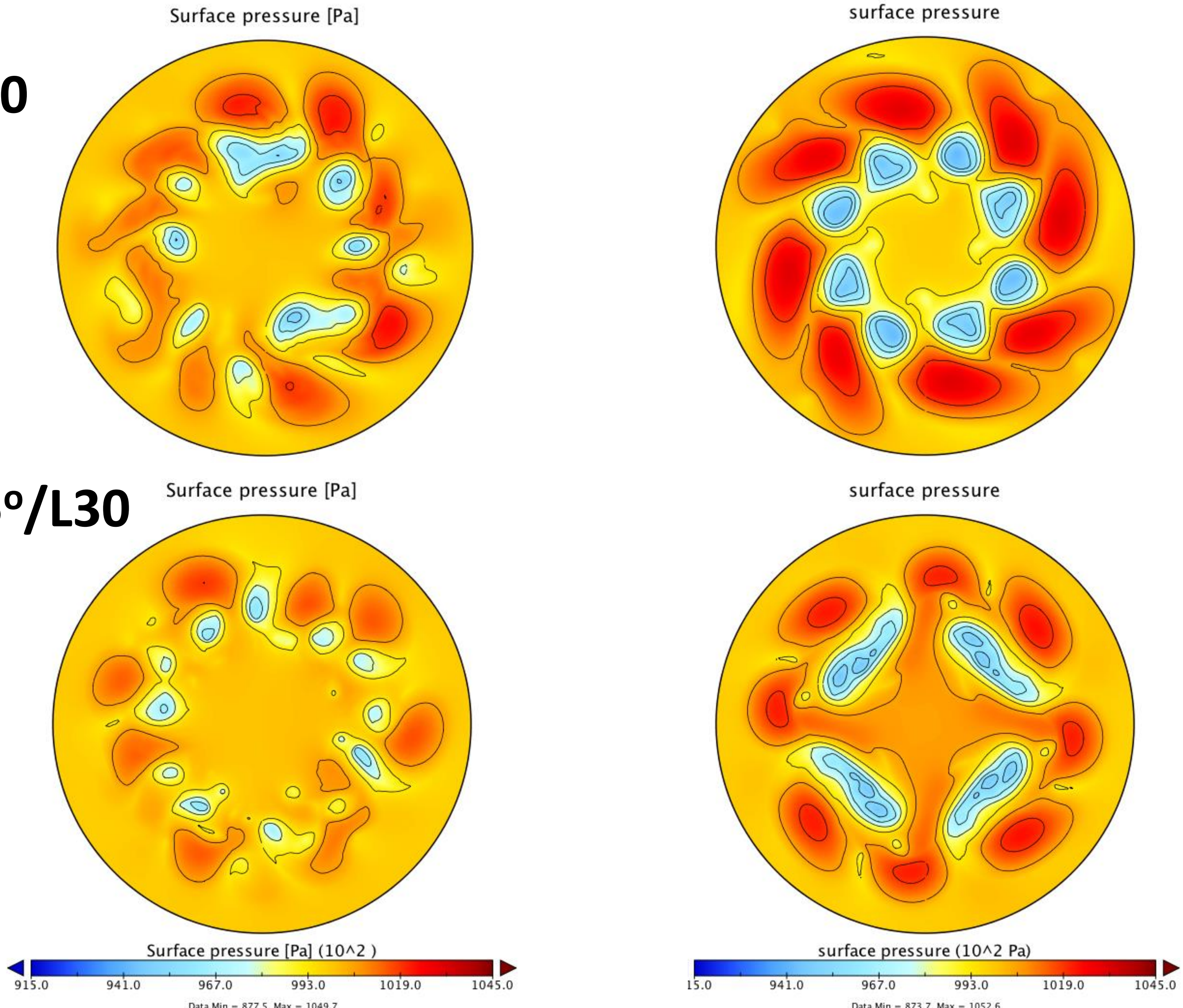
Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

NMMB

FV3

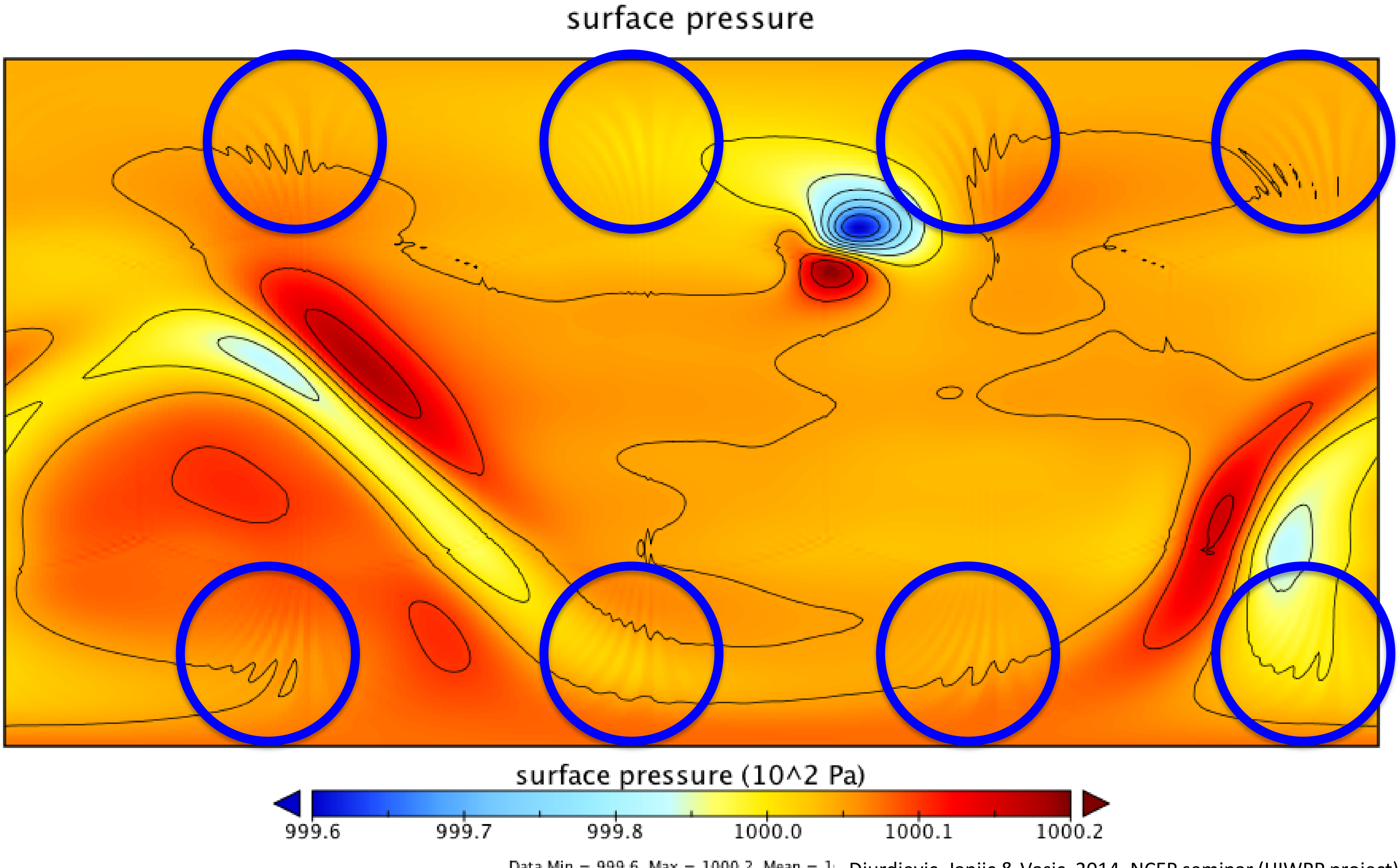
1°/L60

0.125°/L30



Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Imprint is visible after 24h of integration (FV3)



Djurdjevic, Janjic & Vasic, 2014, NCEP seminar (HIWPP project)

Grid imprinting problems/questions

- Problem

- Grid imprinting is present in all variables, on all levels and in all different resolution setups, and becomes more visible as integration progresses,
- Presumably problem is hard-coded in the grid geometry,
- Imprint is wave-number 4 and 5 so that lateral diffusion is ineffective.

- Question

- How to control, remove or extract error from solution especially during longer integrations (medium, monthly, seasonal, climate scale)?

NMM-B model characteristics

•Grid point model on Arakawa B grid,

•Sigma vertical p-hybrid coordinate, Lorenz vertical grid,

•Easily can be run as global or regional model,

•Novel implementation of the nonhydrostatic,

•Dynamical core with horizontal differencing that preserves many important properties of differential operators and, conserves a variety of basic and derived quantities including energy and enstrophy,

•Two land surface packages: NOAH and LISS,

•Two radiation schemes: RRTM and GFDL,

•Two microphysics: Ferrier and Zhao,

•Bets-Miller-Janjic convection,

•Melloer-Yamada-Janjic turbulence.

(Janjic, 2005; Janjic and Black, 2007; Janjic et al., 2001, 2011,2013)

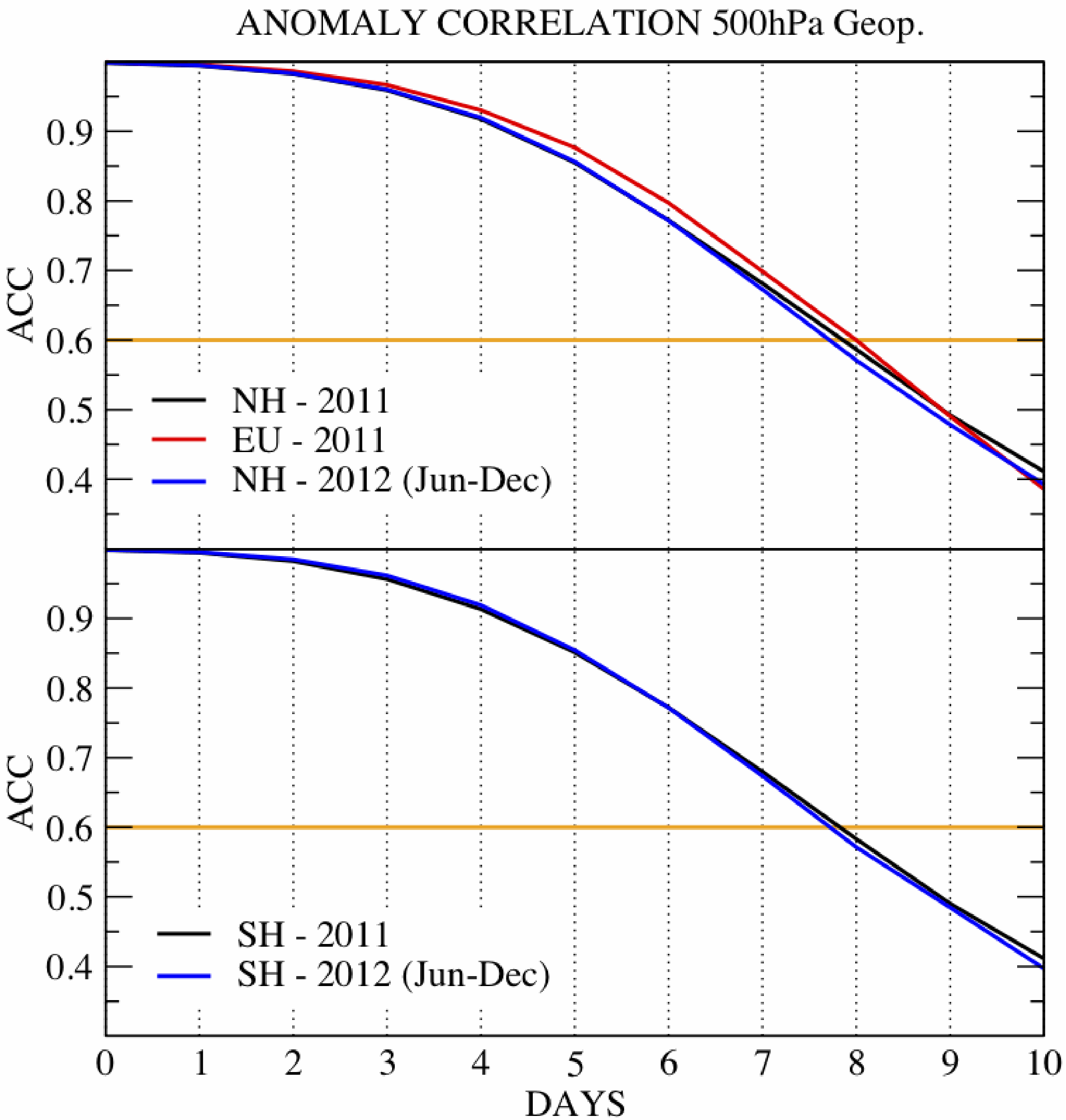
NMMB-global; RHMSS implementation

- Operational since 1st January 2011
- 10days (medium range) forecast
- One run per day, 00Z cycle
- Horizontal resolution: 0.47^{o}x0.33^{o} (769x541 grid points.; ~37km)
- Vertical resolution: 64 levels
- Initial fields: GFS 00Z analysis

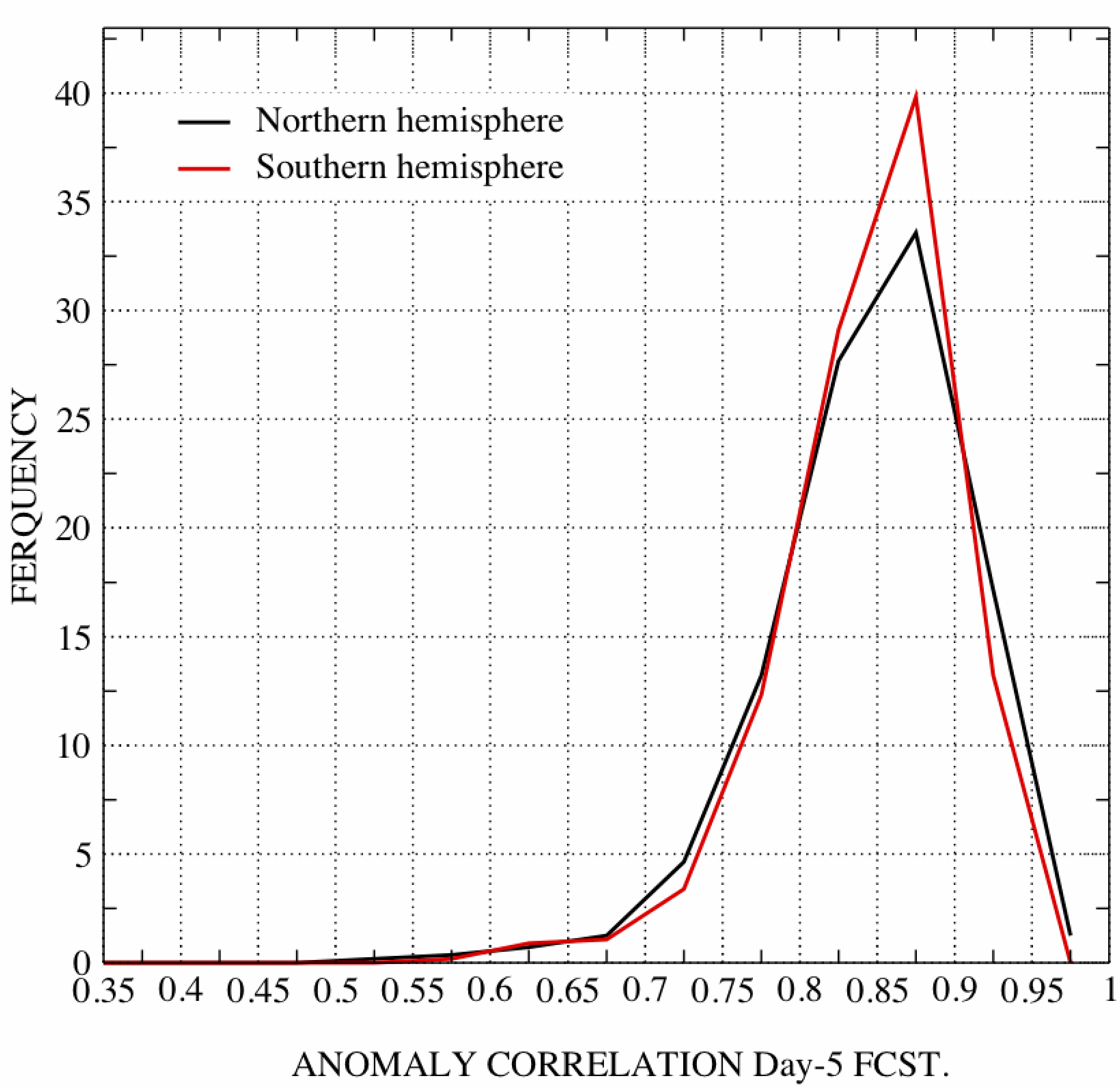
- 128 cores allocated for run; CPU time ~120min
(with pre- and post-processor)

http://www.hidmet.gov.rs/ciril/prognoza/nmmb.php
http://seevccc.rs/NMMB/

NMMB-global; Scores for 2011 and 2012



NMMB-global; Scores for 2011 and 2012



NMMB-global; Dropouts 2011

- Investigate impact of analyses on Drop-outs (Busts) in forecast

- Drop-outs or busts – significant decrease of forecast quality
    - anomaly correlation day-5 forecast less then 0.7

- 32 selected dates in 2011 when GFS had drop-out or near drop-out

- For selected dates we made two runs, with GFS and ECMWF analyses

- Both analyzes are not dependent on the model

NMMB-global; Dropouts 2011

Anomaly correlation day-5 forecast

North Hemisphere

DATE	GFS	NMMB (GFS)	NMMB (ECMWF)
20110304	0.72	0.77	0.85
20110317	0.71	0.79	0.89
20110430	0.69	0.88	0.89
20110616	0.75	0.84	0.83
20110617	0.74	0.73	0.84
20110618	0.73	0.81	0.88
20110619	0.62	0.64	0.81
20110620	0.70	0.61	0.72
20110629	0.63	0.79	0.88
20110702	0.63	0.90	0.94
20110713	0.71	0.38	0.55
20110718	0.68	0.59	0.58
20110806	0.72	0.83	0.84
20110807	0.71	0.73	0.83
20110808	0.73	0.87	0.91
20110813	0.69	0.84	0.85
20110912	0.71	0.76	0.81

South Hemisphere

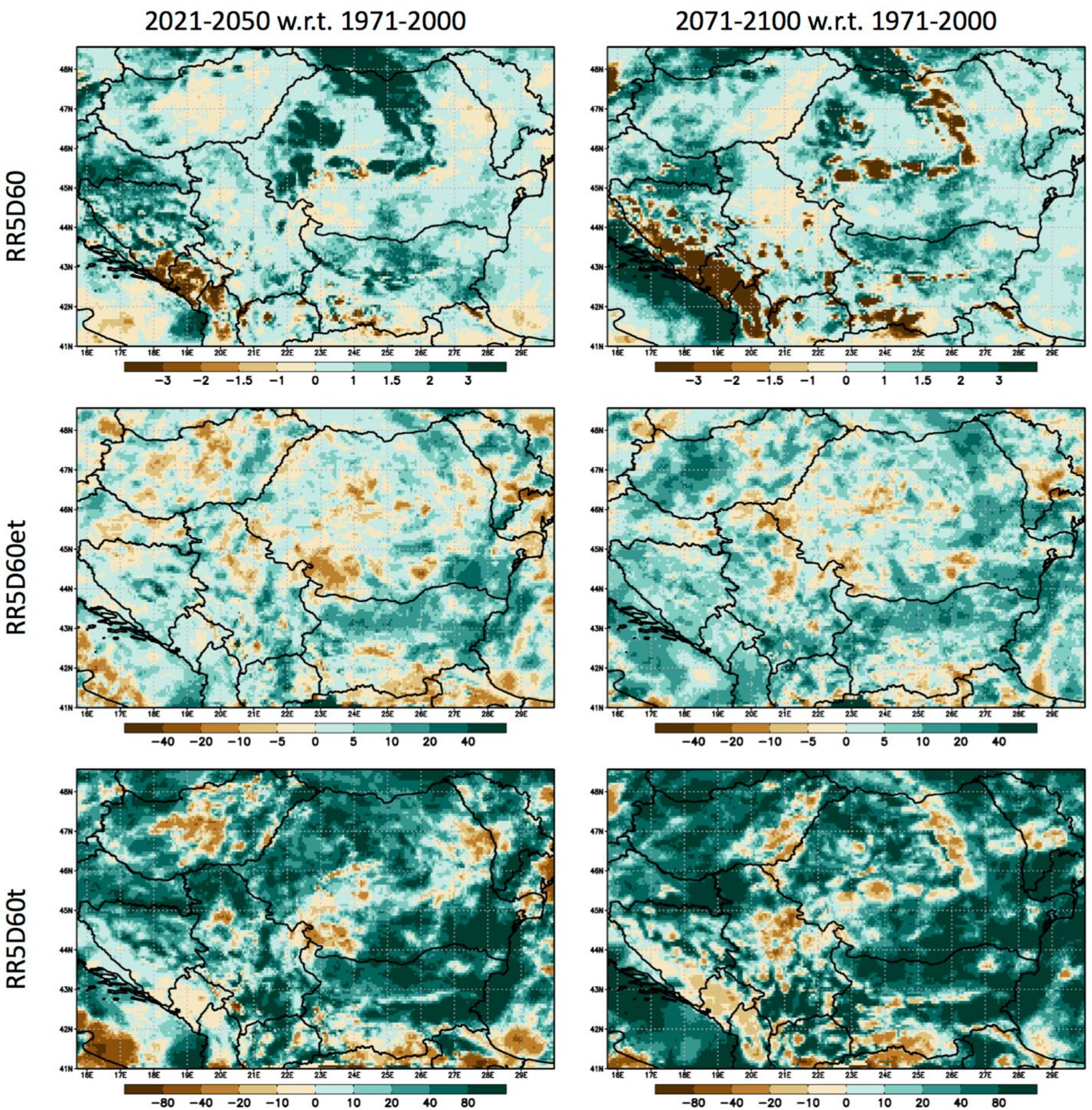
DATE	GFS	NMMB (GFS)	NMMB (ECMWF)
20110131	0.75	0.81	0.87
20110209	0.75	0.77	0.88
20110222	0.70	0.75	0.81
20110306	0.65	0.69	0.84
20110320	0.71	0.86	0.88
20110325	0.62	0.69	0.70
20110327	0.72	0.66	0.76
20110403	0.75	0.64	0.74
20110414	0.72	0.72	0.75
20110421	0.75	0.78	0.90
20110506	0.68	0.66	0.90
20110507	0.72	0.84	0.88
20110725	0.75	0.88	0.90
20110728	0.72	0.88	0.90
20110925	0.73	0.73	0.84

- 11/32 significant improvement with both analysis
- 12/32 significant improvement with ECMWF analysis in comparison with run with GFS analysis
- 17/32 improvement in comparison to GFS with same analysis
- 2/32 score remain less then then 0.7 with both analysis

- On average better scores with ECMWF analyses

NMMB as a Regional Climate Model

8km RCP8.5



Grid-imprinting

- Still open question.

Experience with NMMB

- NMMB global forecast quality comparable with other global models even with lower resolution and with out it’s own DAS,
- Capable to keep up in operational cycle with moderate HPC configuration.

T H A N K Y O U!

Vladimir Đurđević and Zaviša Janjić

HRVATSKO METEOROLOŠKO DRUŠTVO

ZNANSTVENO-STRUČNI SKUP S MEĐUNARODNIM SUDJELOVANJEM
15. – 16. studenog 2018.
KRAŠ Auditorium, Ravnice 48, Zagreb

Meteorološki izazovi 6