Universität Hamburg

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Results of the dynamical core model intercomparison project (DCMIP): PUMA

Thomas Frisius

CliSAP Research group

Dynamical Systems, KlimaCampus, Universität Hamburg

DYNAMICAL SYSTEMS

Portable University Model of the Atmosphere (PUMA)

Dynamical core of the PlanetSimulator (Universität Hamburg)

Original version

- Global spectral general circulation model of the dry atmosphere (Hoskins-Simmons type)
- Numerical solution of hydrostatic EULER equations for an ideal gas on a rotating sphere
- Diabatic, dissipative processes: only Newtonian Cooling and Rayleigh friction

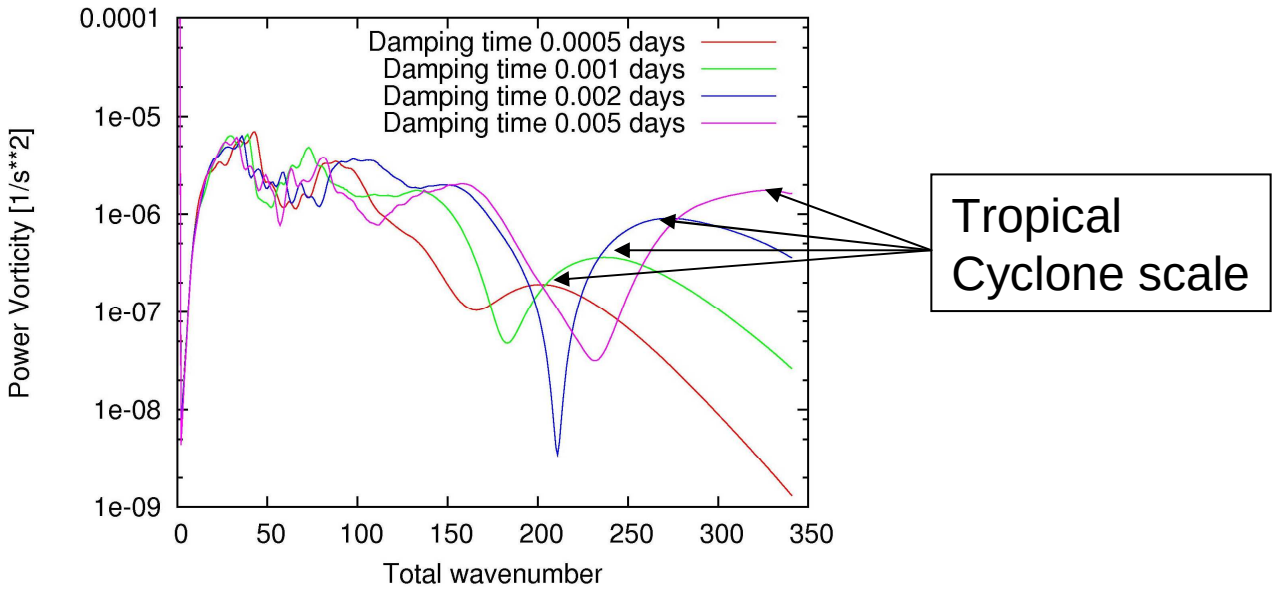
Simple physics extension

- Inclusion of a water vapor transport equation
- Boundary layer and condensation scheme by Reed and Jablonowski (2011)

DCMIP experiments

- Specify horizontal hyperdiffusion (6th order) before the experiments.
- Diffusion avoids heap up of energy at the smallest resolved scale.
- Analysis of model spectra for different hyperdiffusion coefficients.
- The tropical cyclone experiment (51) sets the standard

Spectra of vorticity at the lowest model level for experiment 51 at day 1 for different hyperdiffusion decay time scales of the highest wave number



DCMIP resolutions

The table gives information about the number of longitudes per latitude circle, spectral truncation, equatorial resolution and decay timescale of the highest total wavenumber mode by hyperdiffusion for the various DCMIP resolution configurations

DCMIP denotation	Longitudes	Truncation	Resolution at equator [km]	Decay timescale for 6^{th} order hyperdiffusion [d]
LOW	256	T85	156.4	0.032
MEDIUM	512	T170	78.2	0.008
HIGH	1024	T341	39.1	0.002
ULTRA	2048	T682	19.6	0.0005

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Test Category 1-X: Tracer Transport Experiments

Test 11: 3D Deformational Flow

Test 12: Hadley-like Merdional Circulation

Test 13: Horizontal Advection of Thin Cloud-like Tracers in the Presence of orography

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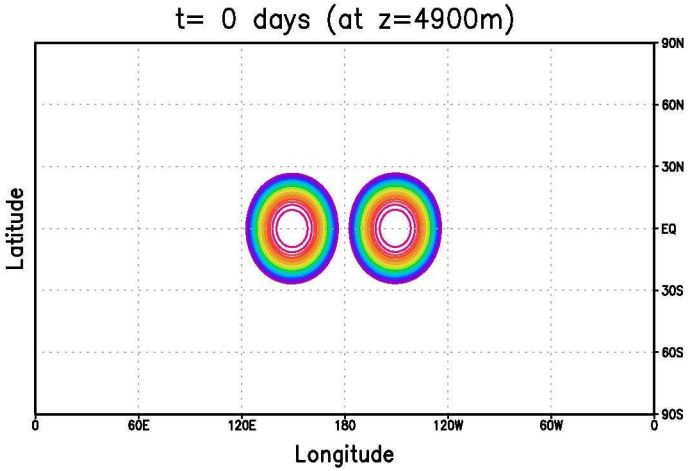
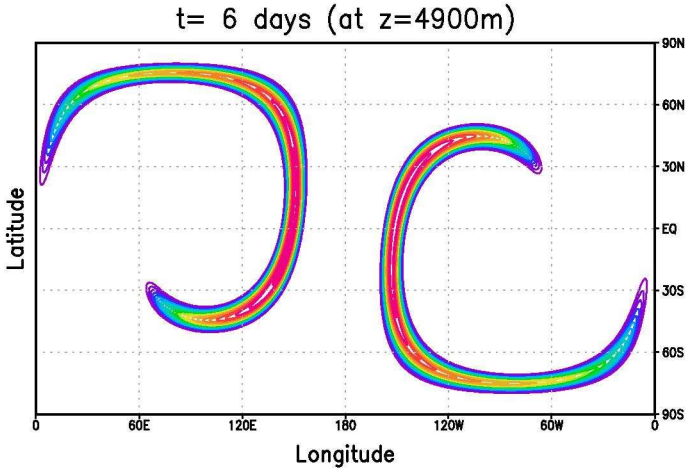
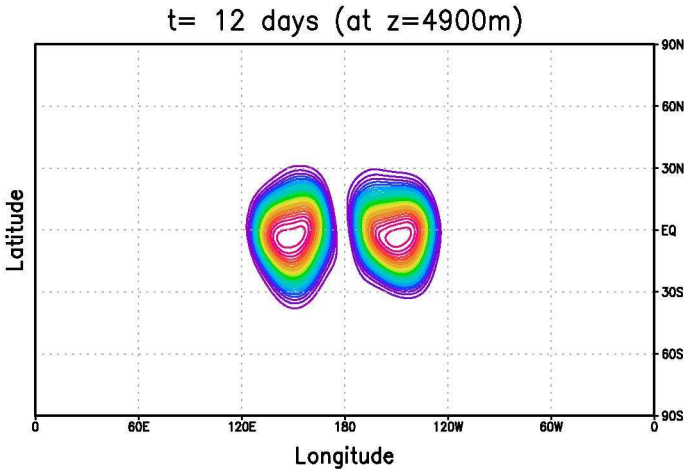
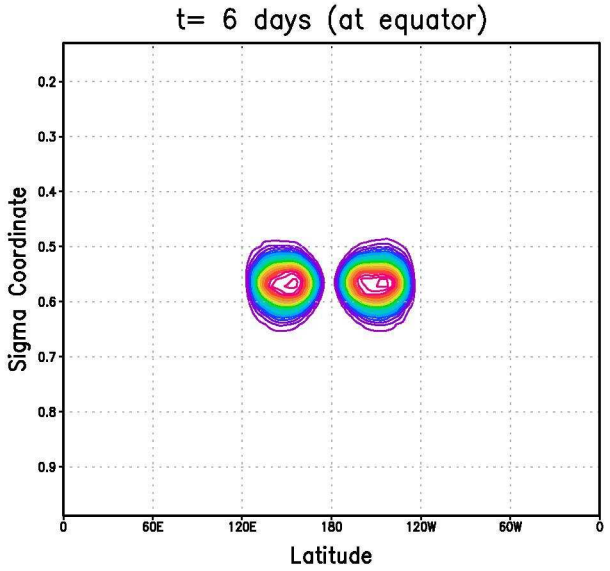
Experiment 11, tracer q1









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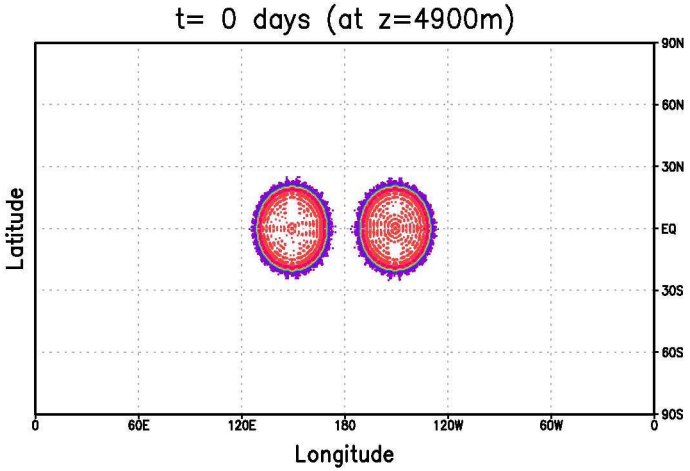
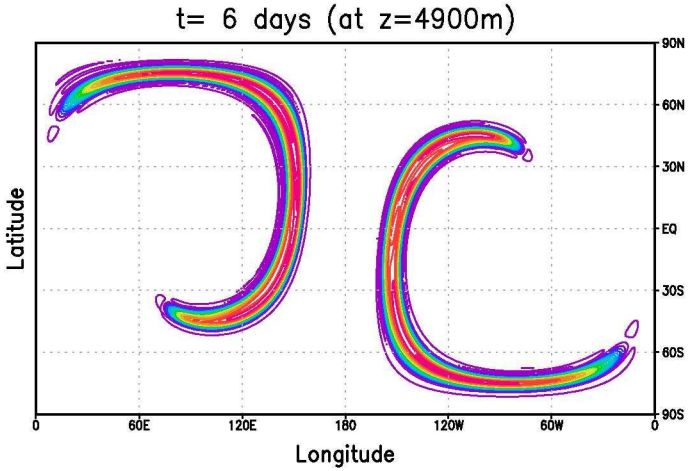
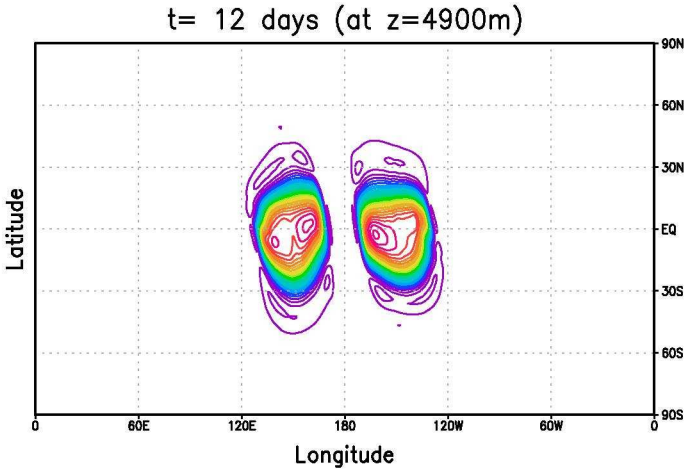
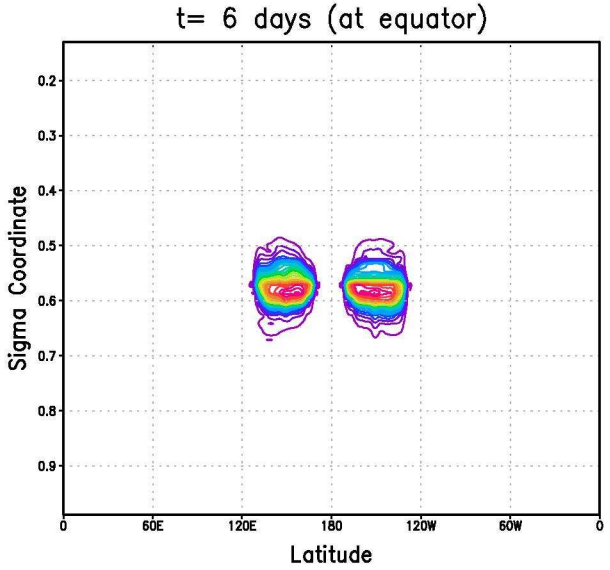
Experiment 11, tracer q3









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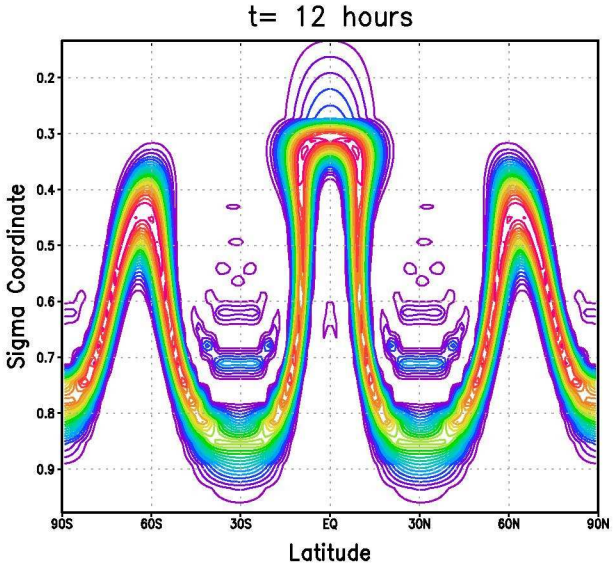
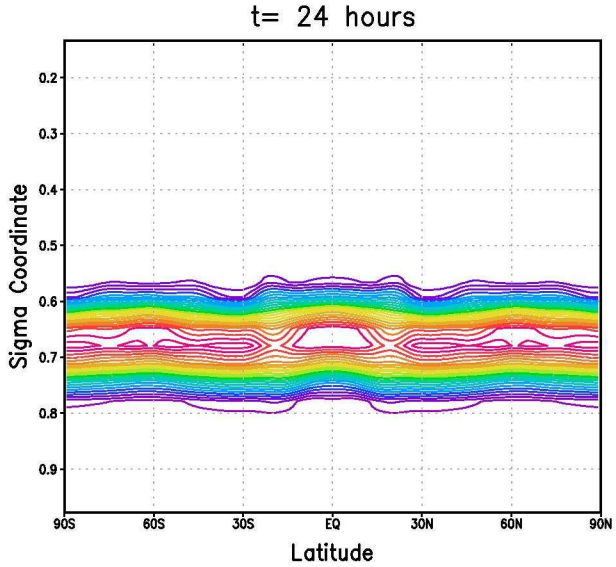
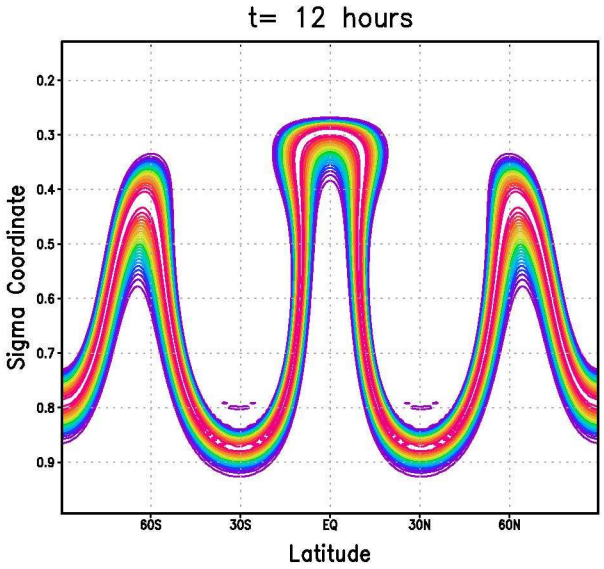
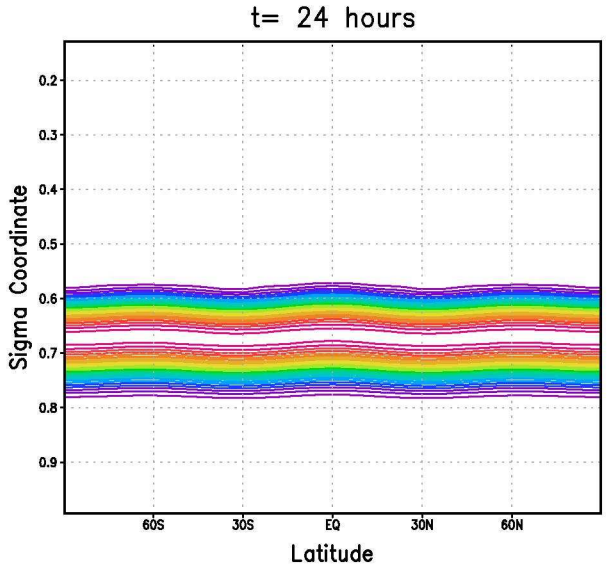
Experiment 12.low.L30, tracer q1





Experiment 12.high.L120, tracer q1





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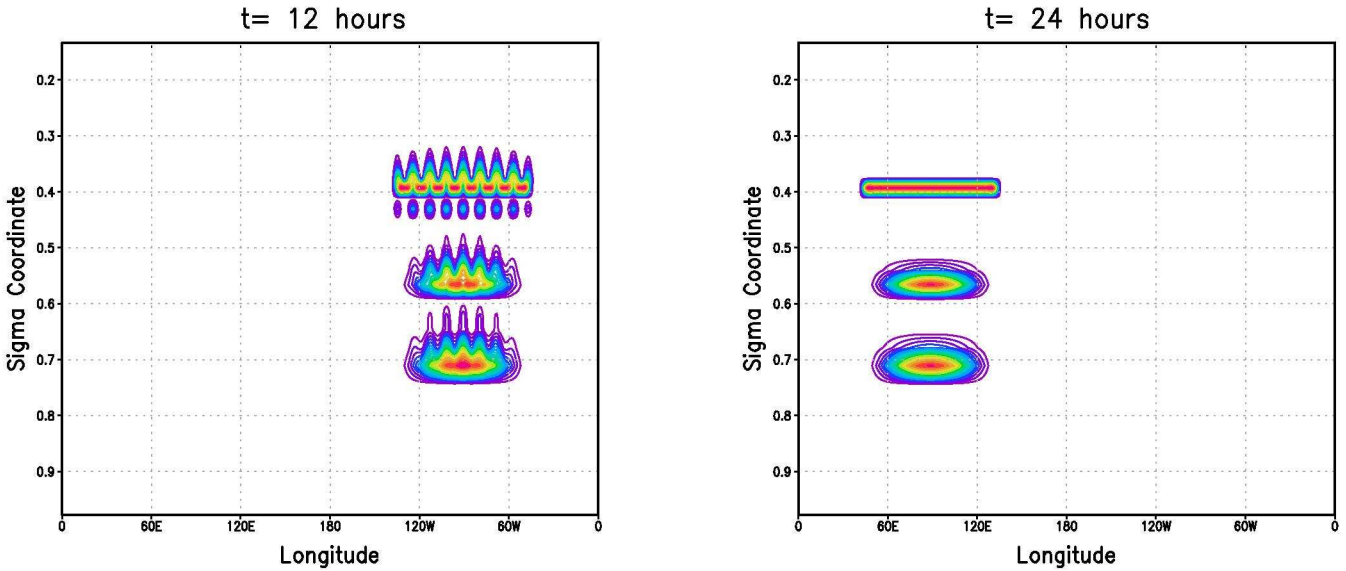
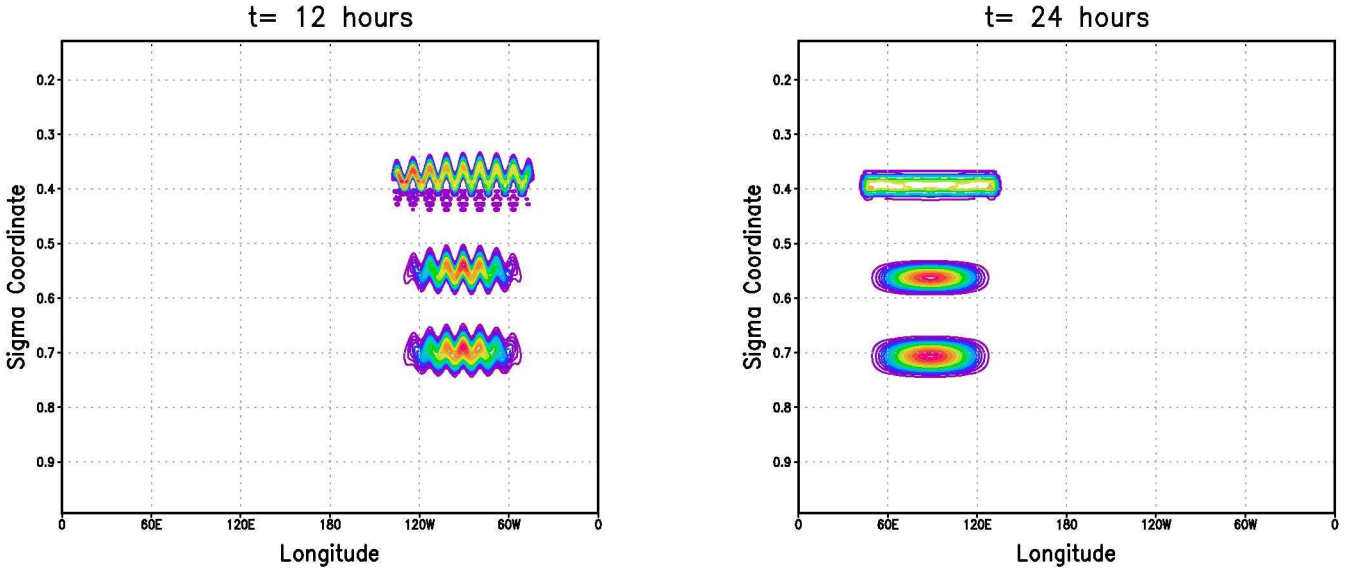
Experiment 13.medium.L30, tracer q4



Experiment 13.medium.L120, tracer q4



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Test Category 2-X: Impact of Orography on a Non-Rotating Planet

Test 21: Non-hydrostatic Mountain Waves over a Schär-type Mountain: Non-sheared Background Flow

Test 22: Non-hydrostatic Mountain Waves over a Schär-type Mountain: Sheared Background Flow

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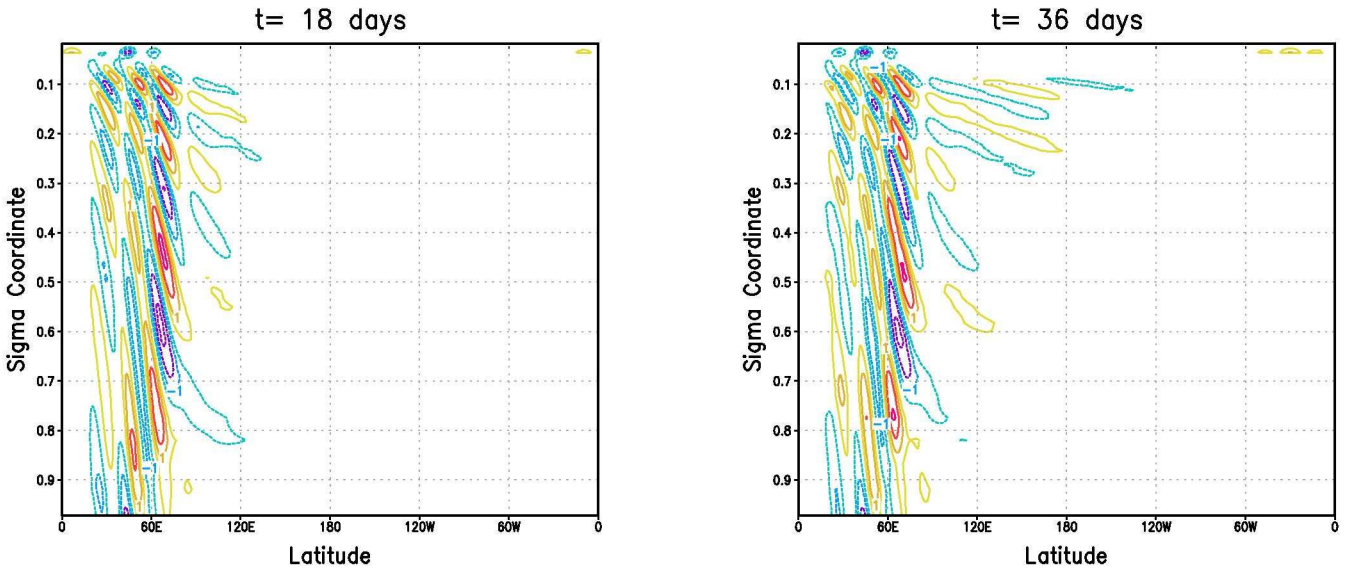
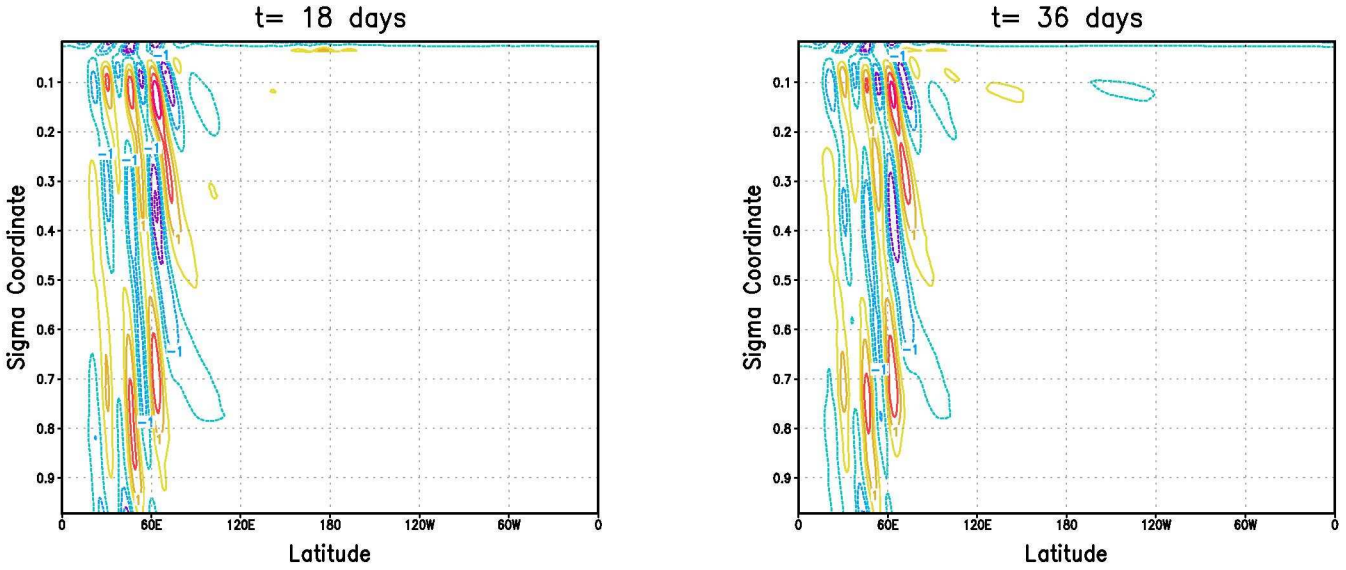
Experiment 21 (X=1.1574) Temperature anomaly [K]



Experiment 22 (X=1.1574) Temperature anomaly [K]



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Test Category 3: Non-Hydrostatic Gravity Waves

Test 31: Overlaid Potential Temperature Perturbation at the Equator

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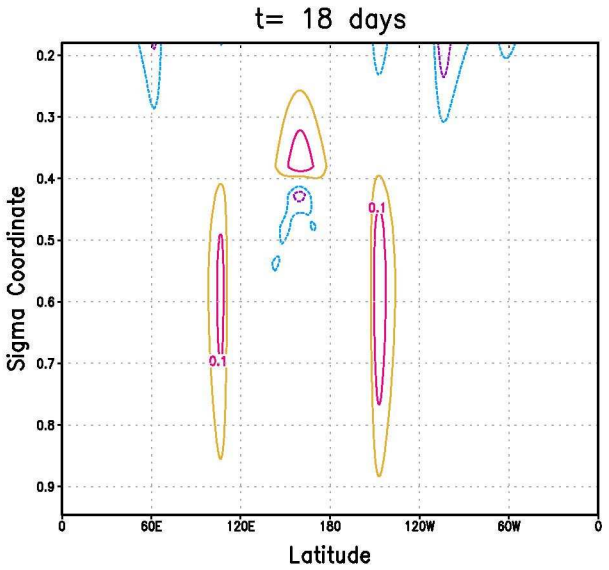
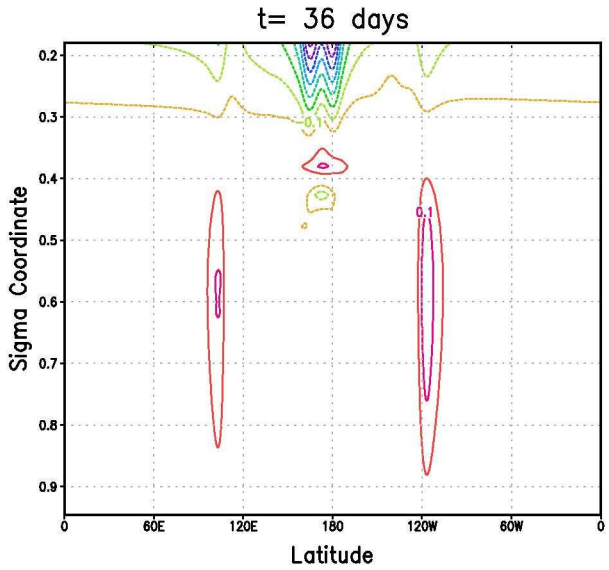
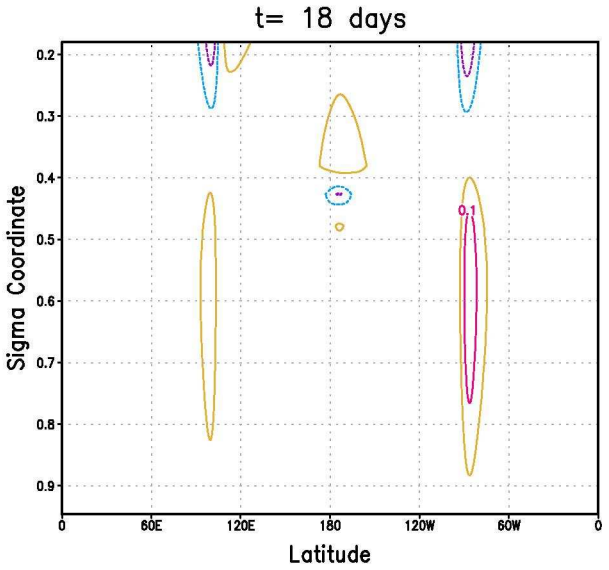
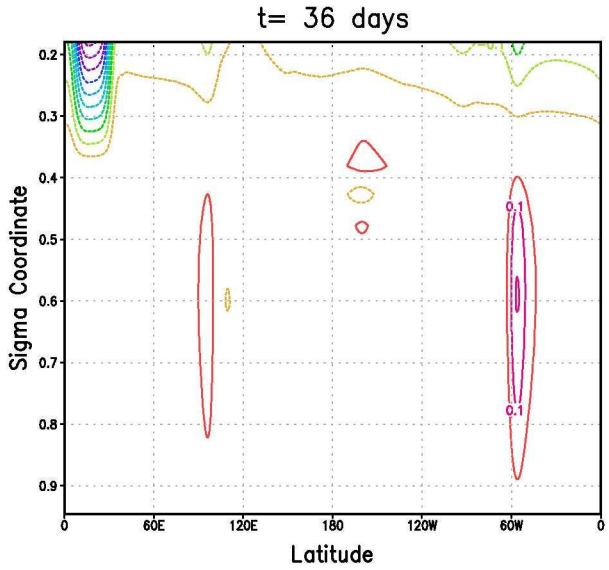
Experiment 31 (X=1.1574) potential temperature anomaly [K]









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Test Category 4-X: Baroclinic Instability

Test 41-X: Dry Baroclinic Instability on a Small Planet with Dynamic Tracers [Only 410 (X =1) has been conducted]

Test 42: Moist Variant of the Baroclinic Wave Test Case with Large-Scale Condensation

Test 43: Moist Variant of the Baroclinic Wave Test Case, driven by "Simple-Physics"

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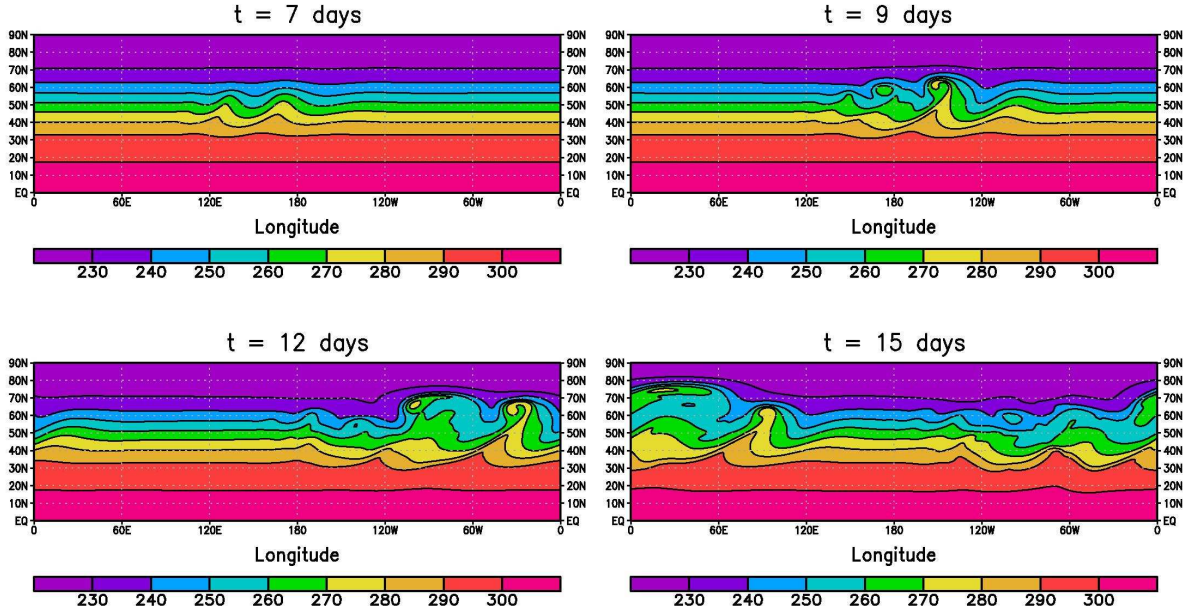
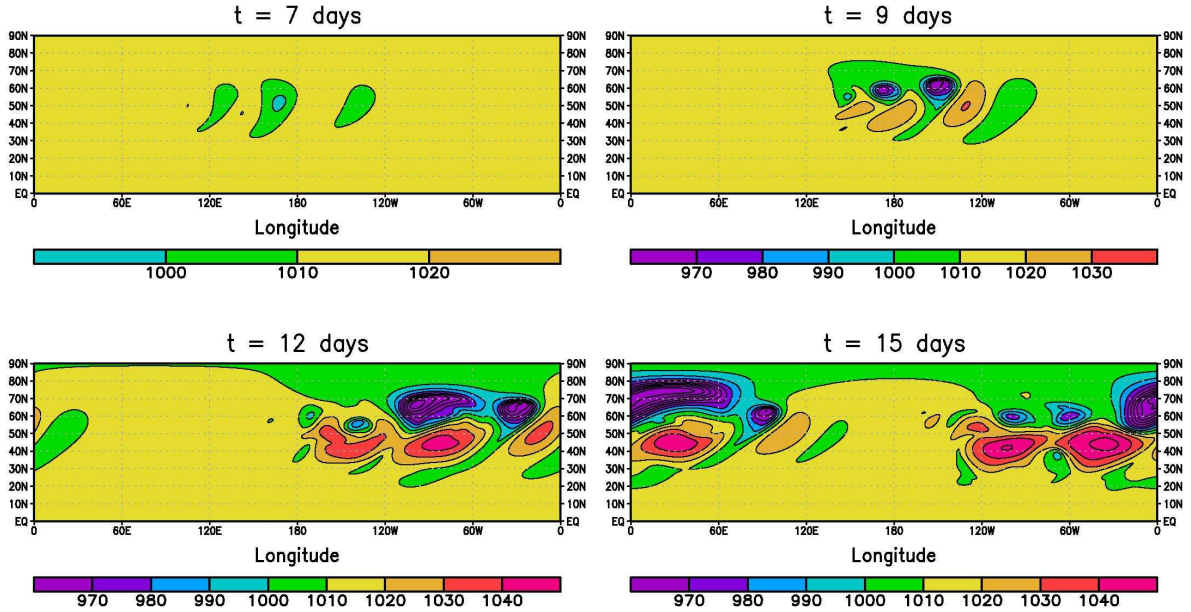
Experiment 410.medium: 850hPa Temperature (Contour interval 5K)



Experiment 410: Surface pressure (Contour interval 10hPa)



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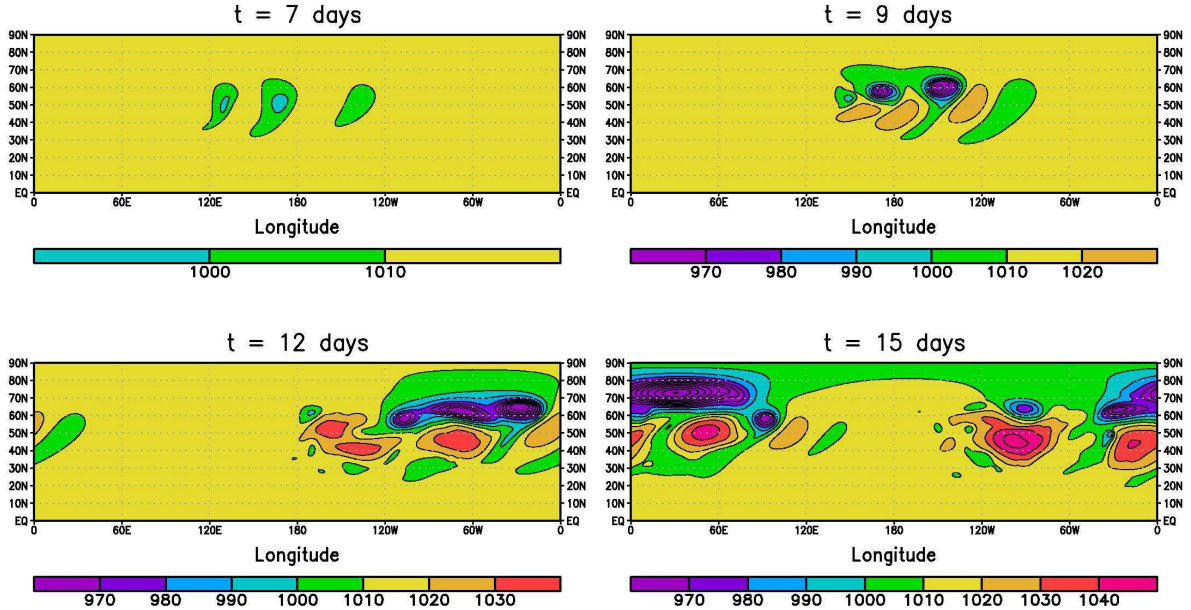
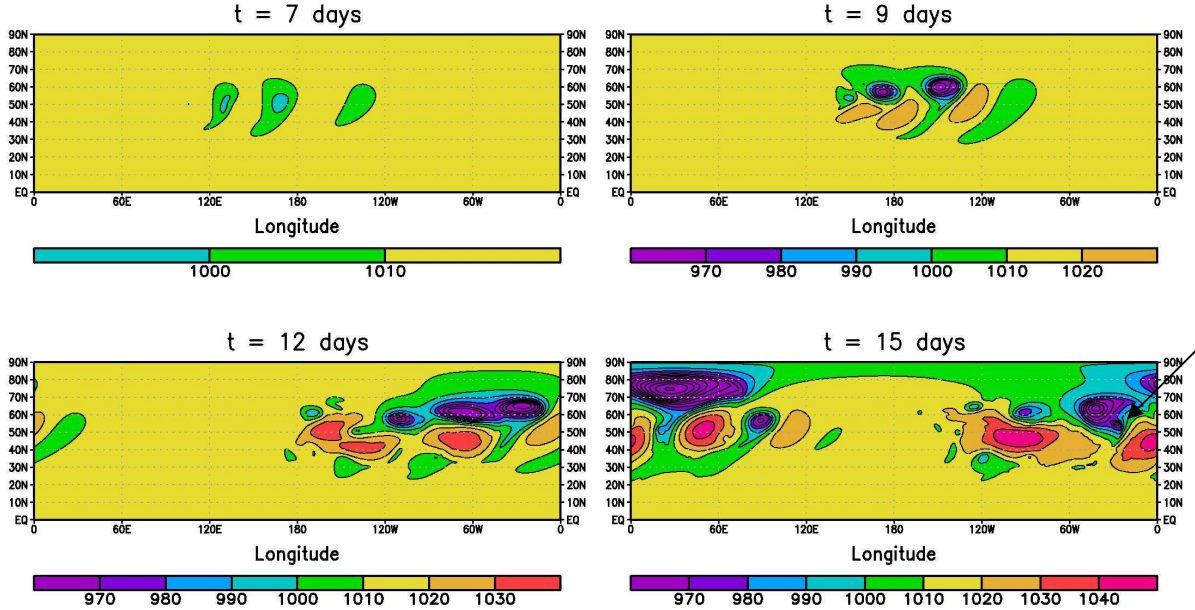
Experiment 42.medium: Surface pressure (Contour interval 10hPa)



Experiment 42.high: Surface pressure (Contour interval 10hPa)



Intense Mesocyclone!

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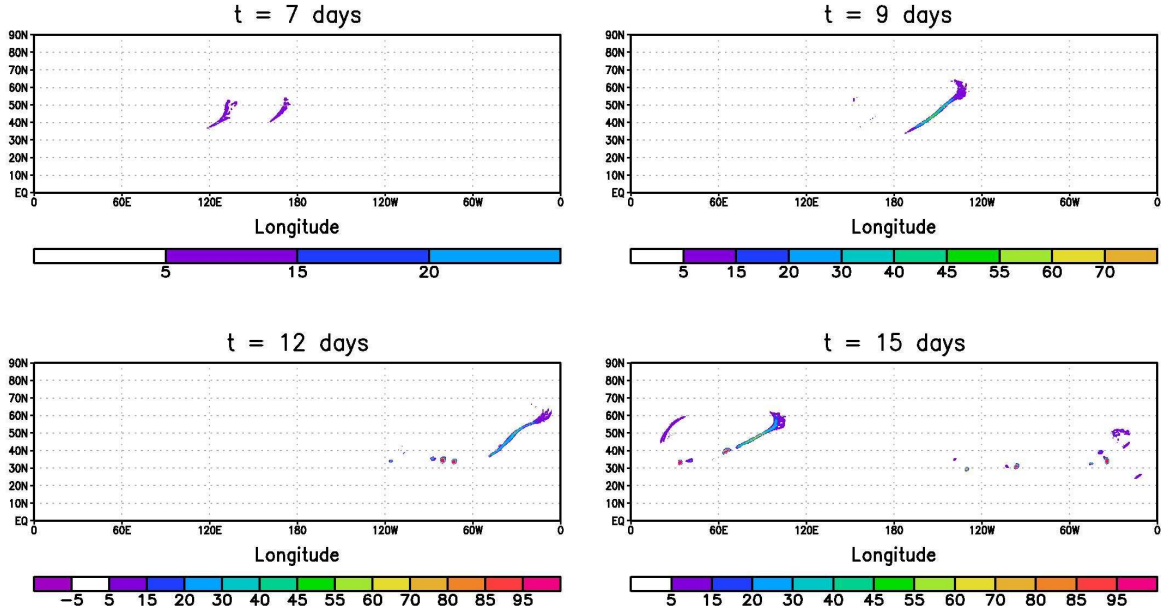
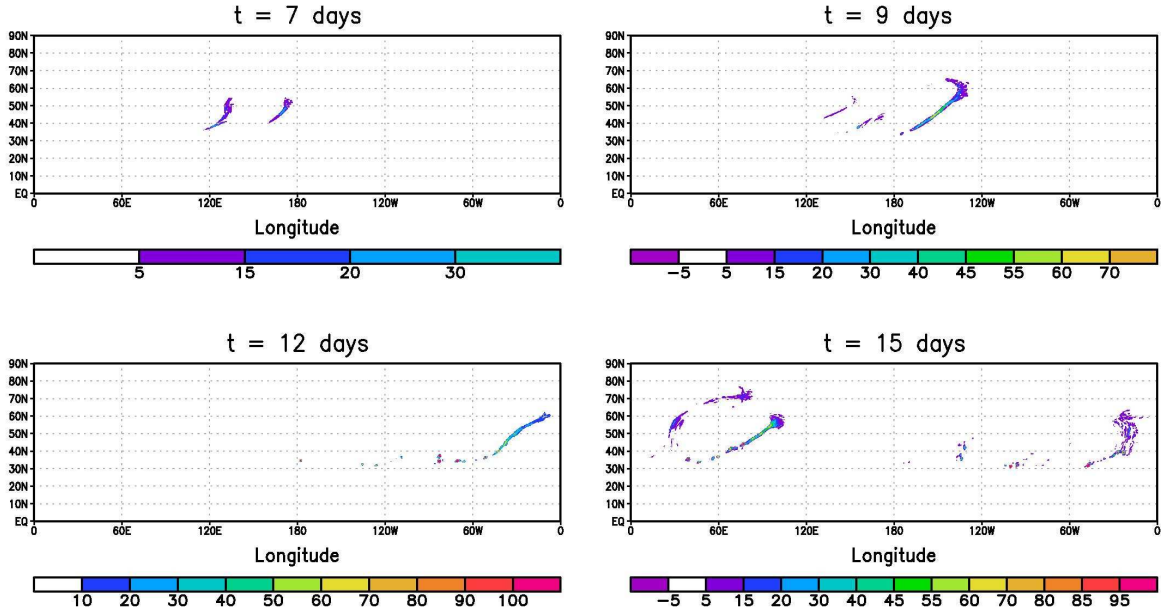
Experiment 42.medium: Precipitation (Contour interval 5mm/h)



Experiment 42.high: Precipitation (Contour interval 5mm/h)



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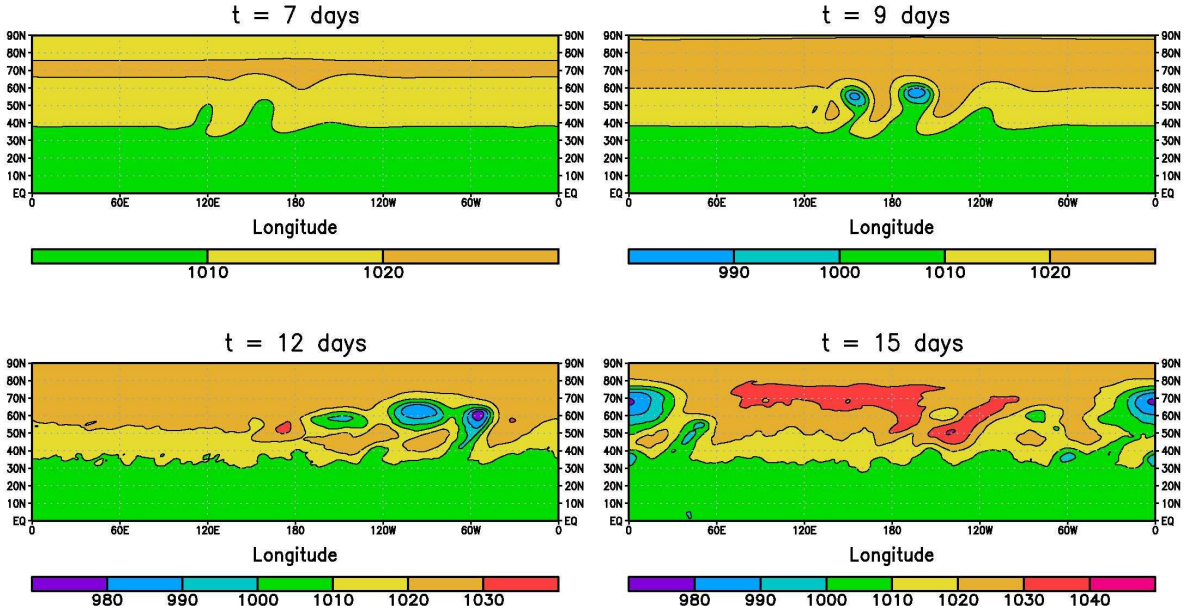
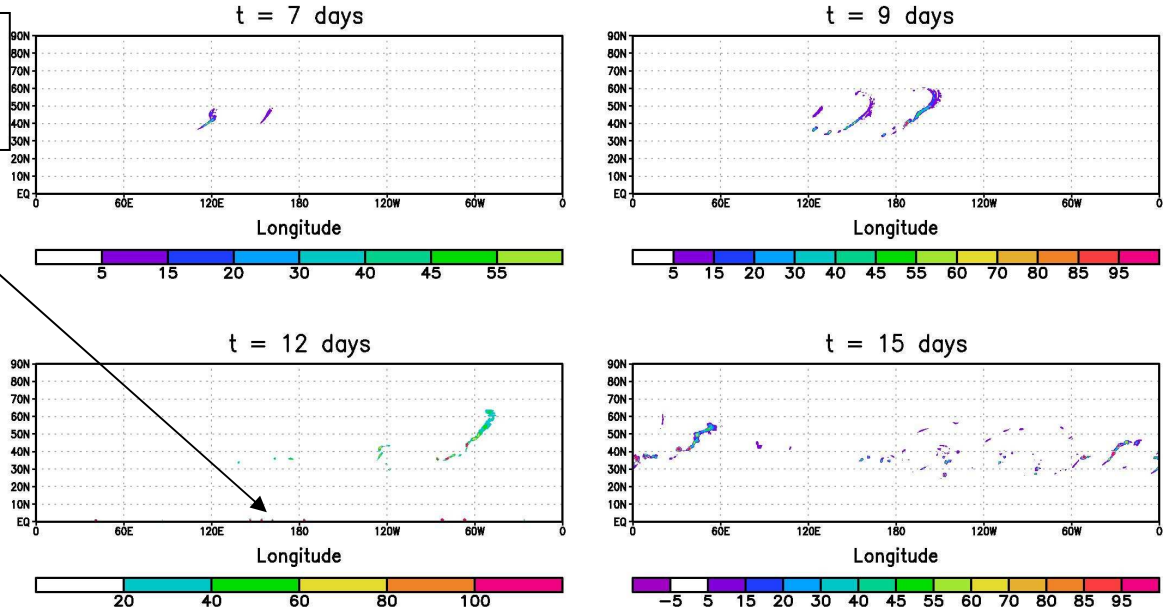
Experiment 43.high: Surface pressure (Contour interval 10hPa)



Experiment 43.high: Precipitation (Contour interval 5mm/h)

Intense Convection



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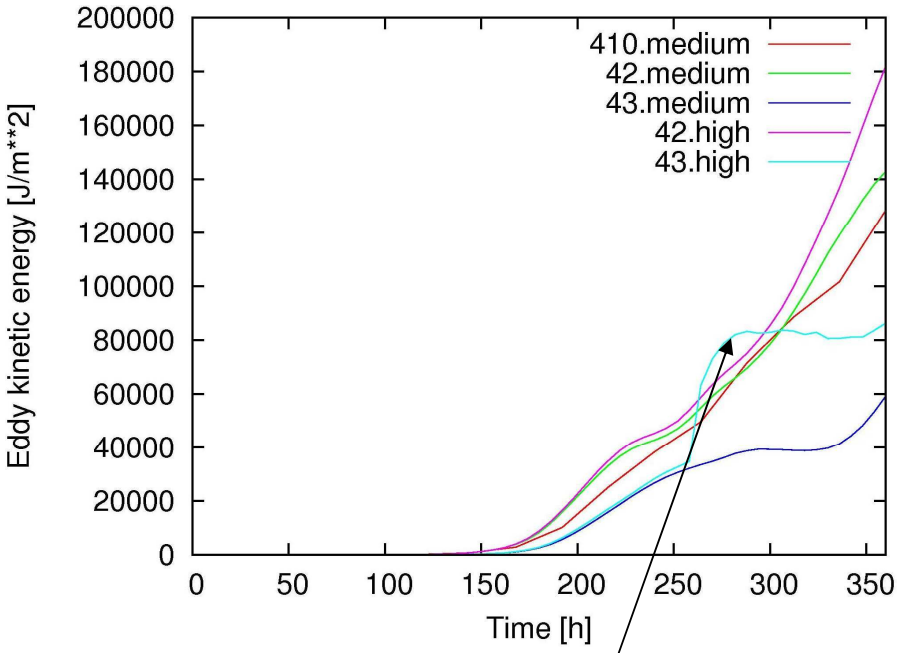
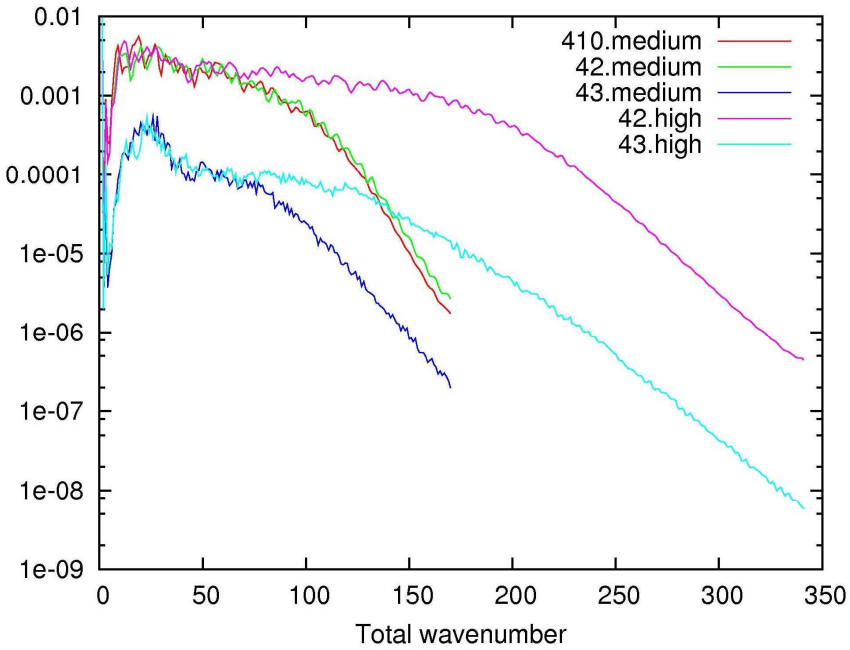
Time development of eddy kinetic energy



Spectra of vorticity at the lowest level at day 15



Development of convection at the Equator (ITCZ-development?)

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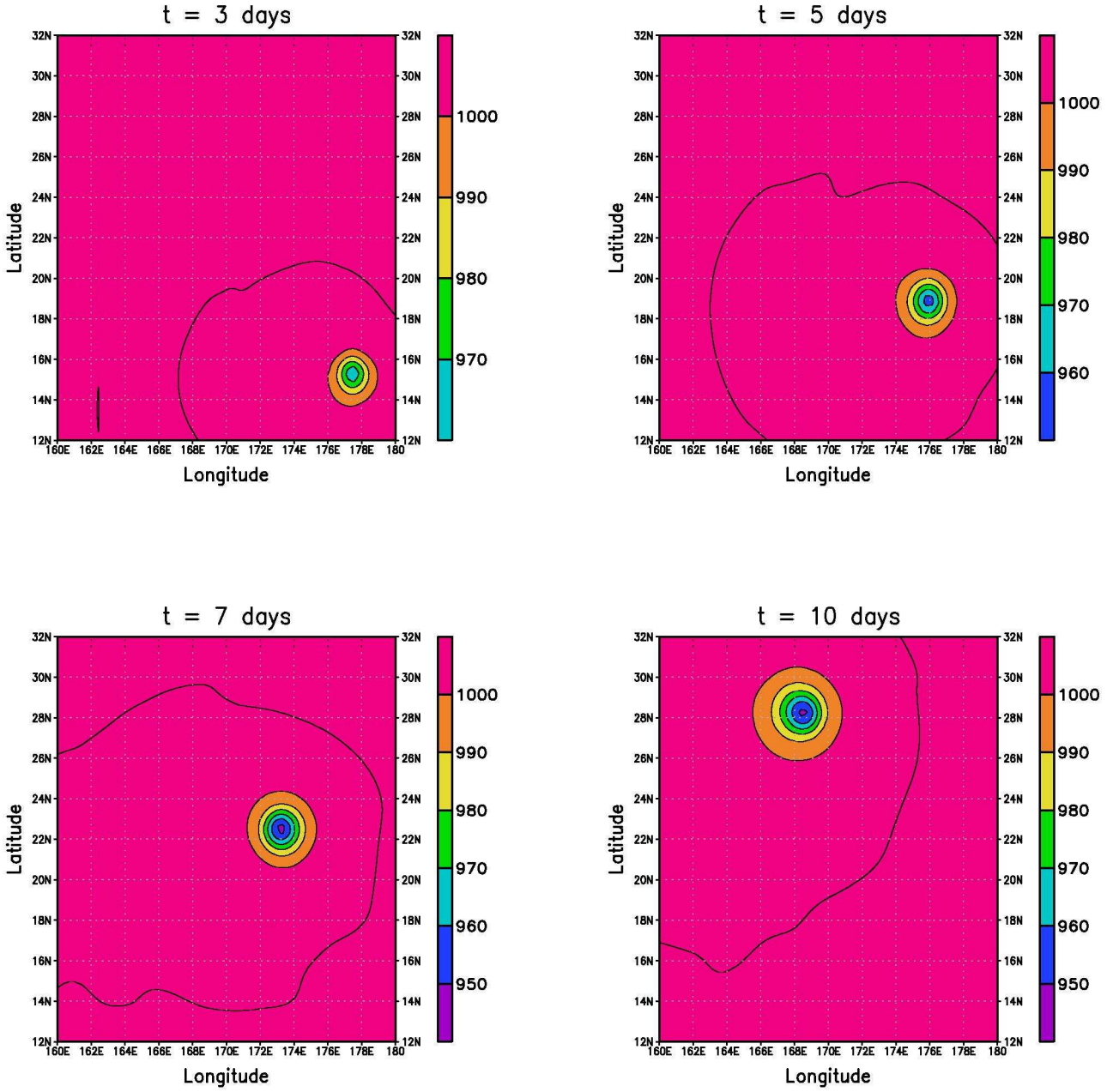
Test Category 5-X: Idealized Tropical Cyclone Experiments

Test 51: Coupling to the “Simple-Physics” Physical Parameterization

Test 52: Using the Model’s Full-Physics Aqua-Planet Mode with a constant SST of 28°C (not conducted)

Experiment 51.high: Surface pressure (Contour interval 10hPa)



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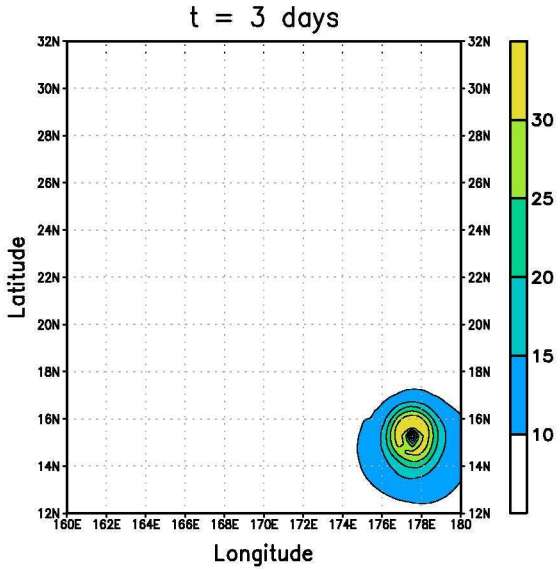
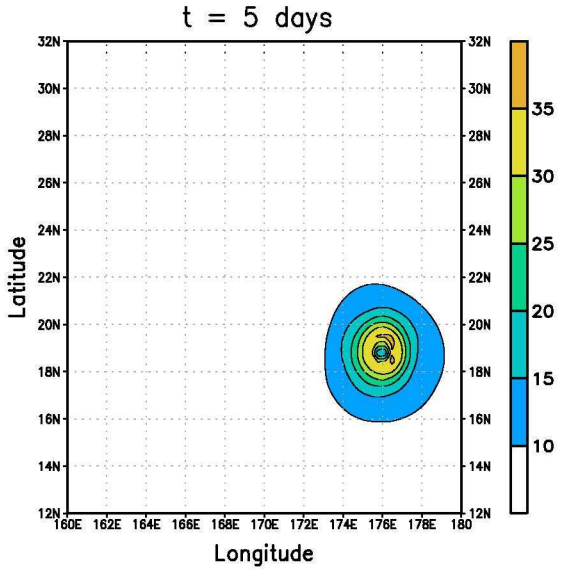
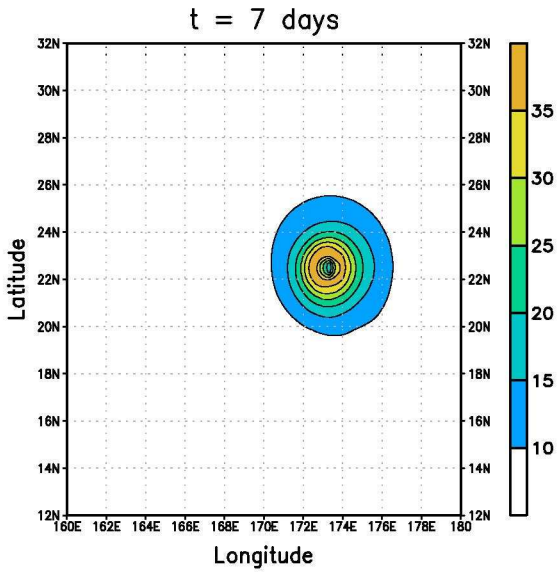
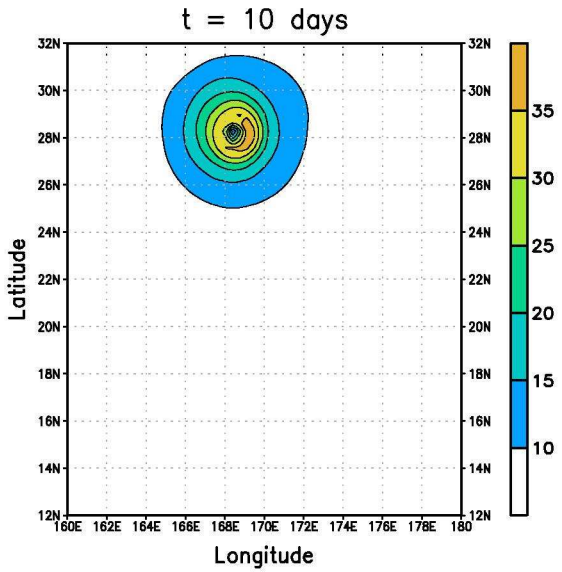
Experiment 51.high: Wind speed lowest level (Contour interval 5m/s)









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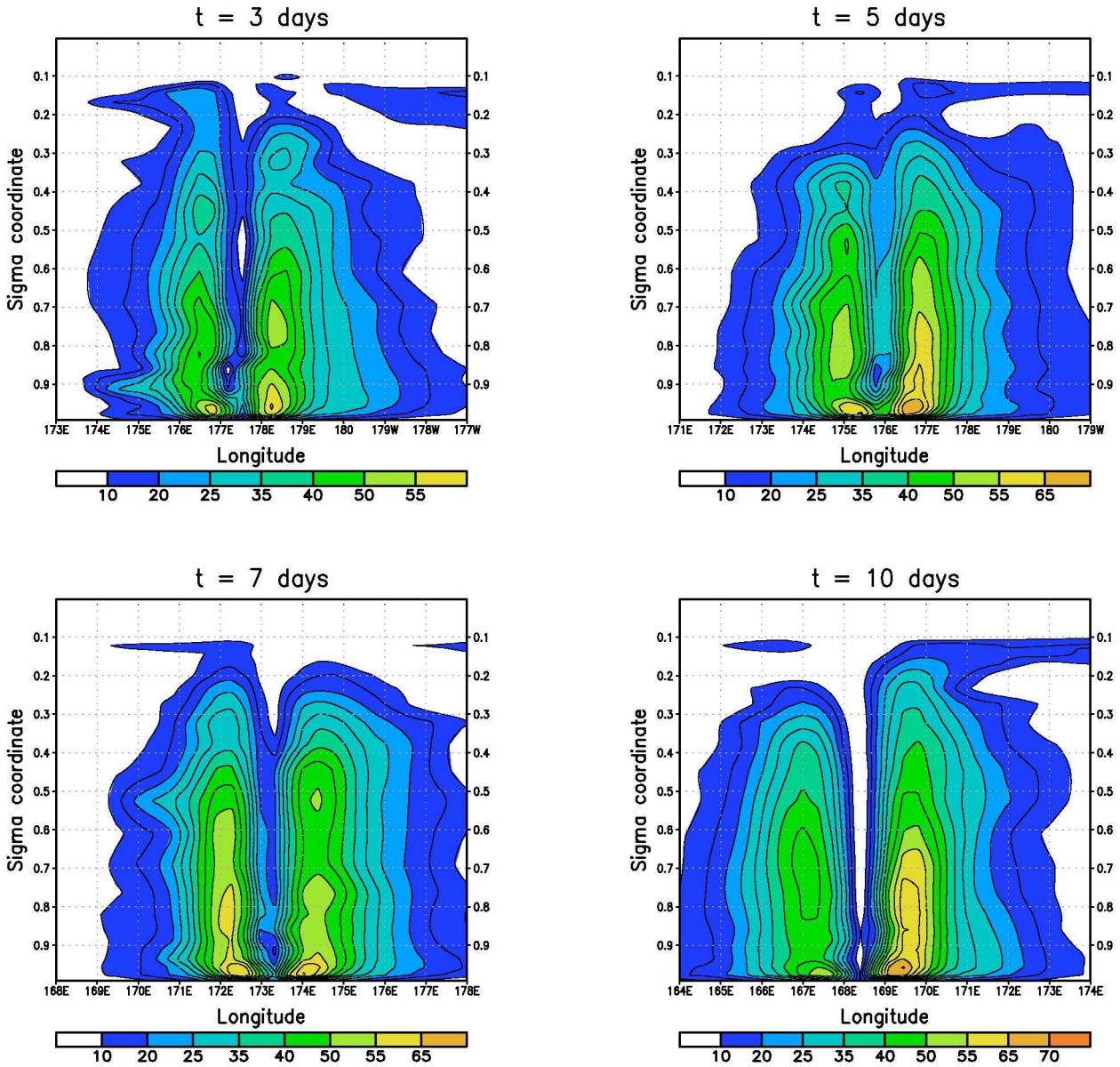
Experiment 51.high: Wind speed (Contour interval 5m/s)



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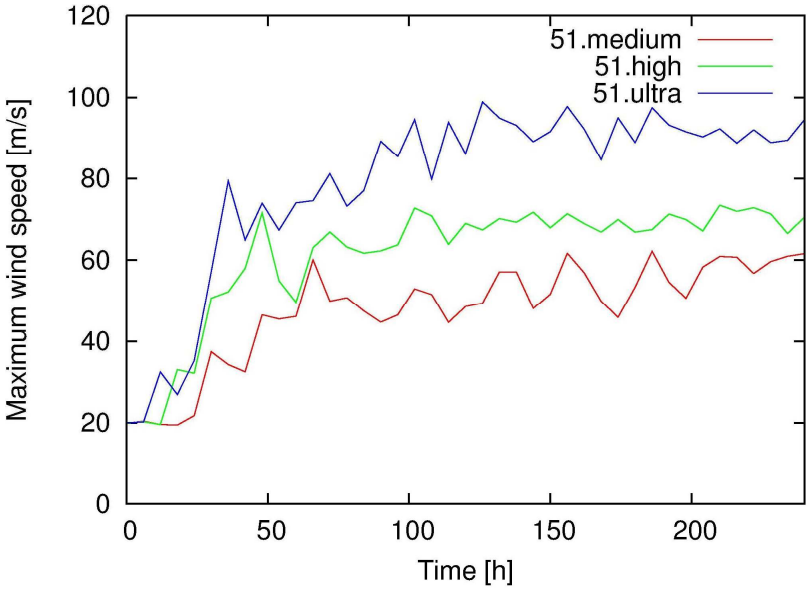
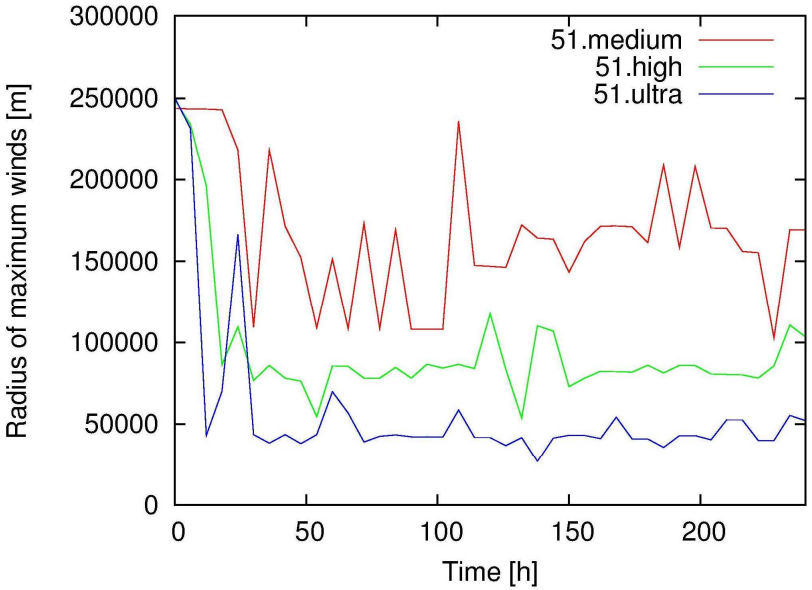
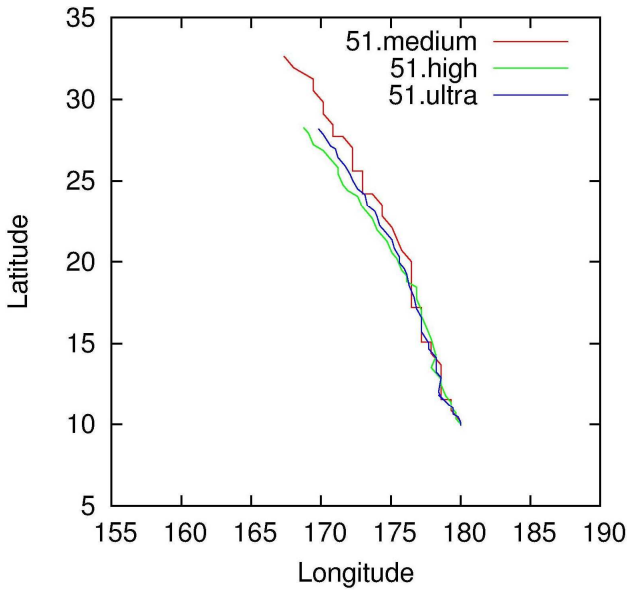
Development of maximum wind speed



Development of the radius of maximum wind



Cyclone tracks



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Conclusion

- For a large enough resolution the transport of the tracer within PUMA is reasonable. Difficulties arise for discontinuous fields since the spectral representation of such fields is problematic.

- The pure Sigma-coordinate in PUMA is possibly not a good choice for simulation of mountain induced gravity waves. Furthermore, the upper boundary condition of a rigid lid can hardly be mimicked within PUMA.

- Moist and dry baroclinic instability can reasonably be simulated by PUMA. Some phenomena (intense mesocyclones, ITCZ formation) arise only for the high resolution.

- The idealized tropical cyclogenesis experiments appear plausible. With increasing resolution the intensity increases and the radius of maximum winds decreases.

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