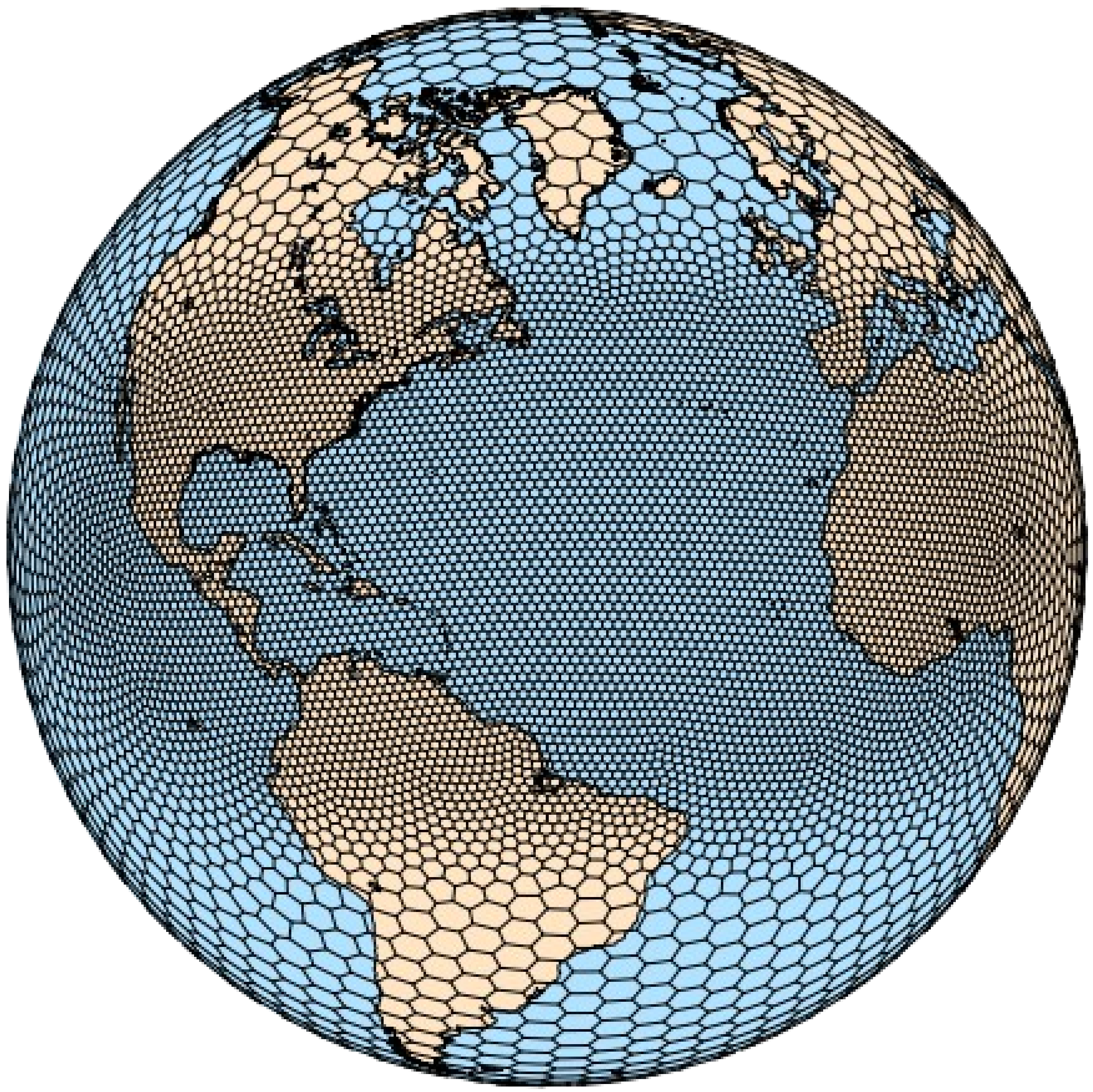
MPAS
Model for Prediction Across Scales

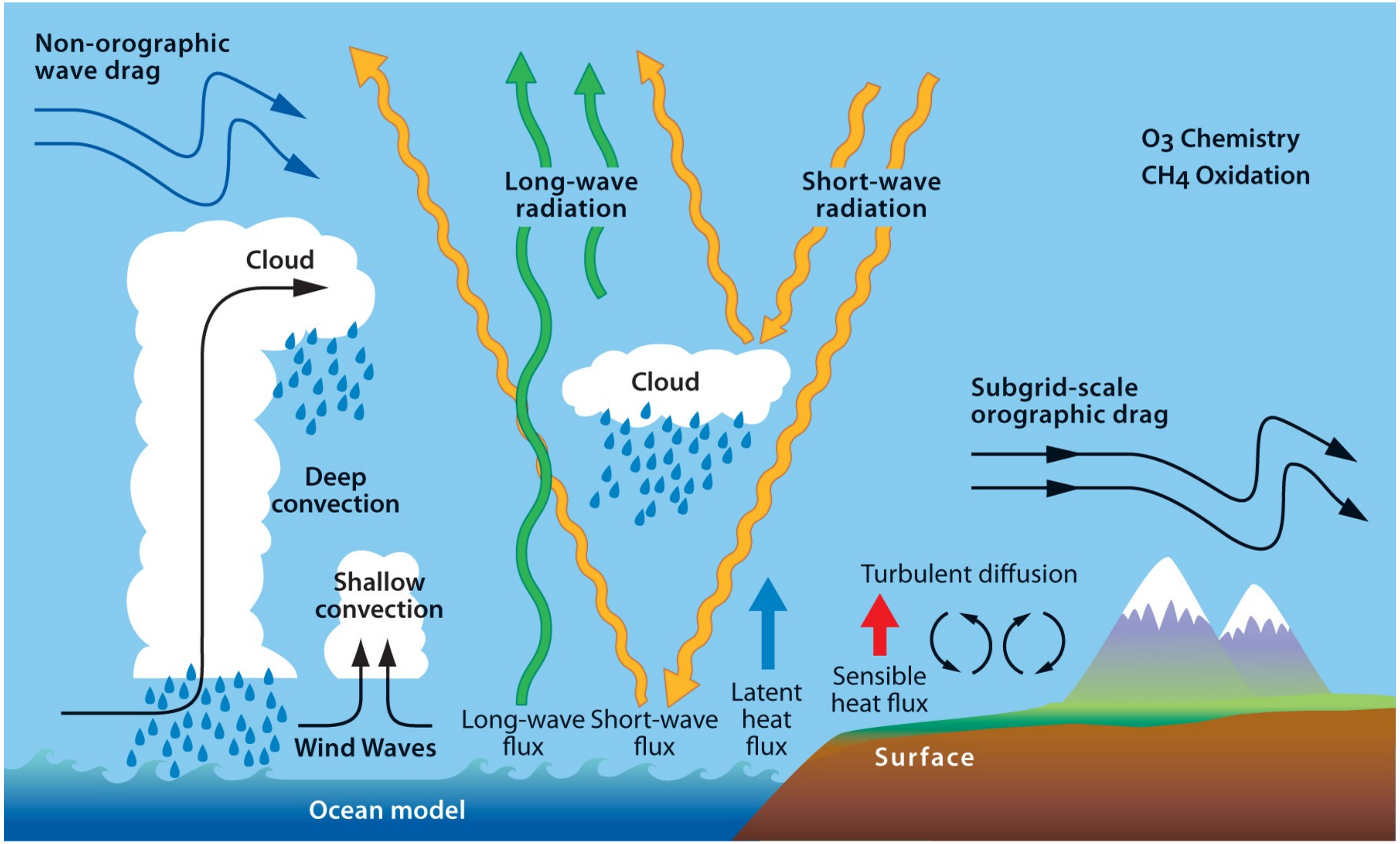
Physics and Physics Configurations in MPAS



Atmospheric Physical Processes

Atmospheric physics model processes not explicitly contained in the Navier Stokes equations (e.g. radiation), or provide boundary conditions to the atmospheric model (e.g. ocean and land models).

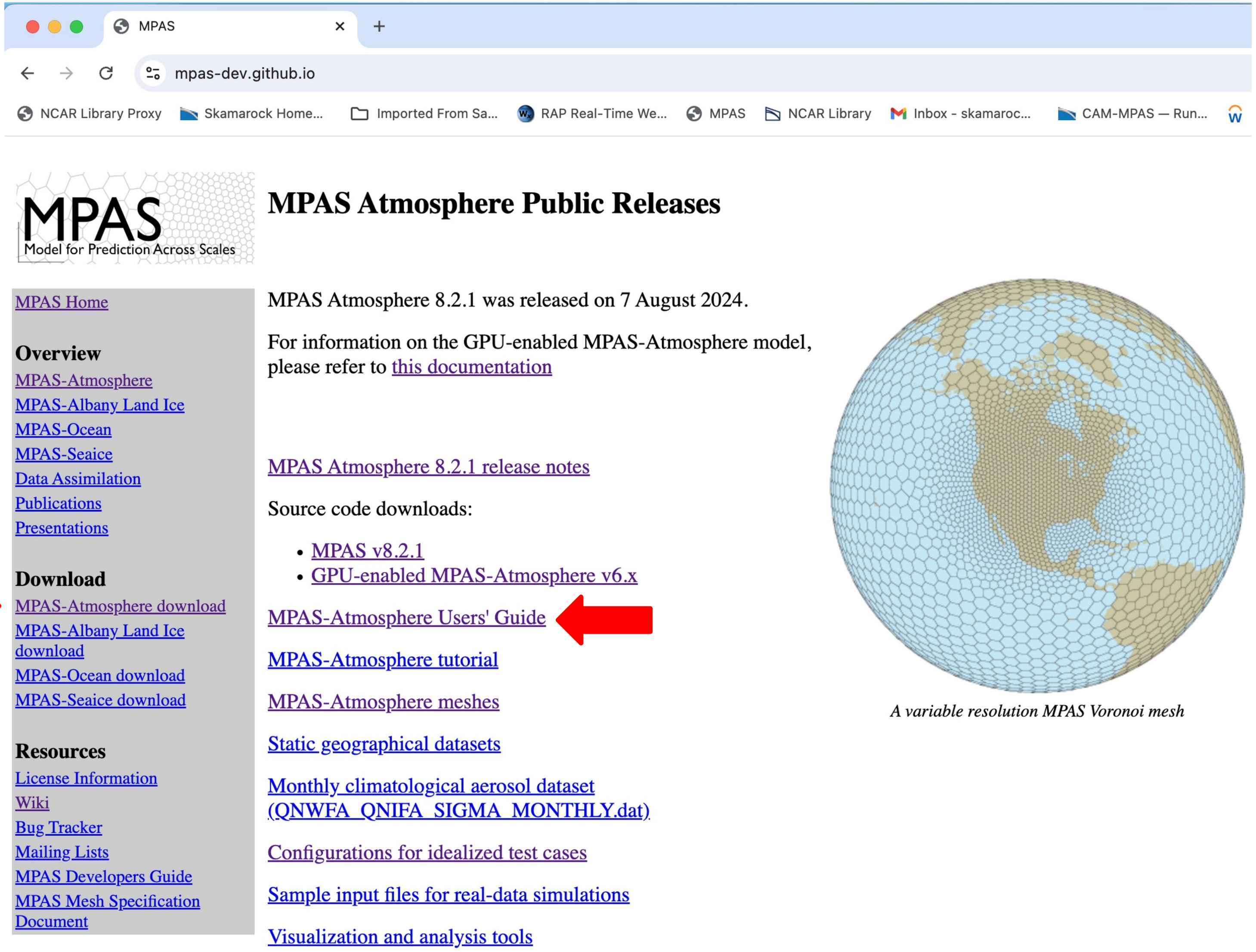
MPAS-Atmosphere contains physics options to cover most of these processes, and includes a land model.



(From ECMWF)

MPAS-Atmosphere Resources

MPAS-Atmosphere Users' Guide: On the MPAS-Atmosphere download page


MPAS
mpas-dev.github.io
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- MPAS Developers Guide
- MPAS Mesh Specification Document

MPAS Atmosphere 8.2.1 was released on 7 August 2024.

For information on the GPU-enabled MPAS-Atmosphere model, please refer to this documentation

MPAS Atmosphere 8.2.1 release notes

Source code downloads:

- MPAS v8.2.1
- GPU-enabled MPAS-Atmosphere v6.x

MPAS-Atmosphere Users' Guide

MPAS-Atmosphere tutorial

MPAS-Atmosphere meshes

Static geographical datasets

Monthly climatological aerosol dataset (QNWFA_QNIFA_SIGMA_MONTHLY.dat)

Configurations for idealized test cases

Sample input files for real-data simulations

Visualization and analysis tools

A variable resolution MPAS Voronoi mesh

Physics Schemes in MPAS v8.2

From the MPAS-Atmosphere Users' Guide

Table 6.3: Possible options for individual physics parameterizations. Namelist variables should be added to the &physics namelist record.

Parameterization	Namelist variable	Possible options	Details
Convection	config_convection_scheme	cu_tiedtke	Tiedtke (WRF 3.8.1)
		cu_ntiedtke	New Tiedtke (WRF 4.5)
		cu_grell_freitas	Modified version of scale-aware Grell-Freitas (WRF 3.6.1)
		cu_kain_fritsch	Kain-Fritsch (WRF 3.2.1)
Microphysics	config_microp_scheme	mp_wsm6	WSM 6-class (WRF 4.5)
		mp_thompson	Thompson non-aerosol aware (WRF 3.8.1)
		mp_thompson_aerosols	Thompson aerosol-aware (WRF 4.1.4)
		mp_kessler	Kessler
Land surface	config_lsm_scheme	sf_noah	Noah (WRF 4.5)
		sf_noahmp	Noah-MP 5.0.1
Boundary layer	config_pbl_scheme	bl_ysu	YSU (WRF 4.5)
		bl_mynn	MYNN (WRF 3.6.1)
Surface layer	config_sfclayer_scheme	sf_monin_obukhov	Monin-Obukhov (WRF 4.5)
		sf_monin_obukhov_rev	Revised Monin-Obukhov (WRF 4.5)
		sf_mynn	MYNN (WRF 3.6.1)
Radiation, LW	config_radt_lw_scheme	rrtmg_lw	RRTMG (WRF 3.8.1)
		cam_lw	CAM (WRF 3.3.1)
Radiation, SW	config_radt_sw_scheme	rrtmg_sw	RRTMG (WRF 3.8.1)
		cam_sw	CAM (WRF 3.3.1)
Cloud fraction for radiation	config_radt_cld_scheme	cld_fraction	Xu and Randall (1996)
		cld_incidence	0/1 cloud fraction depending on $q_c + q_i$
		cld_fraction_thompson	Thompson cloud fraction scheme
Gravity wave drag by orography	config_gwdo_scheme	bl_ysu_gwdo	YSU (WRF 4.5)

Specifying Physics in MPAS

Example shown the ‘mesoscale_reference’ suite:

```
&physics
     config_physics_suite       = 'mesoscale_reference'
     config_convection_scheme = 'cu_ntiedtke'
     config_microp_scheme       = 'mp_wsm6'
     config_pbl_scheme          = 'bl_ysu'
     config_sfclayer_scheme     = 'sf_monin_obukhov'
     config_lsm_scheme          = 'sf_noah'
     config_radt_lw_scheme      = 'rrtmg_lw'
     config_radt_sw_scheme      = 'rrtmg_sw'
     config_radt_cld_scheme     = `cld_fraction’
     config_gwdo_scheme         = 'bl_ysu_gwdo’
/
```

See Chapter 6 and B11 in the User’s Guide

Specifying Physics in MPAS

Physics is configured by using namelist record &physics. It can be defined as a suite, or individual options, or combination of both.

```
&physics
    config_physics_suite       = 'mesoscale_reference'
    config_convection_scheme = 'cu_ntiedtke'
    config_microp_scheme       = 'mp_wsm6'
    config_pbl_scheme          = 'bl_ysu'
    config_sfclayer_scheme     = 'sf_monin_obukhov'
    config_lsm_scheme          = 'sf_noah'
    config_radt_lw_scheme      = 'rrtmg_lw'
    config_radt_sw_scheme      = 'rrtmg_sw'
    config_radt_cld_scheme     = `cld_fraction’
    config_gwdo_scheme         = 'bl_ysu_gwdo’
/
```

See Chapter 6 and B11 in the User’s Guide

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Specifying Physics in MPAS

Physics Suites	Options
‘mesoscale_reference’	RRTMG, Xu-Randall cloud fraction, Noah, YSU, MM5 sfclay, new Tiedtke, WSM6, GWDO
‘convection_permitting’	RRTMG, Xu-Randall cloud fraction, Noah, MYNN, MYNN sfcaly, Grell-Freitas, Thompson, GWDO

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Model for Prediction Across Scales

Specifying Physics in MPAS

Physics Suites	Options
'mesoscale_reference'	RRTMG, Xu-Randall cloud fraction, Noah, YSU, MM5 sfclay, new Tiedtke, WSM6, GWDO
'convection_permitting'	RRTMG, Xu-Randall cloud fraction, Noah, MYNN, MYNN sfcaly, Grell-Freitas, Thompson, GWDO

- You can replace one or more options in a suite:

```
&physics
    config_physics_suite       = `convection_permitting'
    config_convection_scheme = 'cu_ntiedtke'
/
```

Specifying Physics in MPAS

Along with these physics options, also consider the following – all have corresponding options in WRF:

```
&physics
    config_radtlw_interval = '00:15:00'
    config_radtsw_interval = '00:15:00'
    config_o3climatology = true
    config_sfc_albedo = true
    config_sfc_snowalbedo = true
    config_sst_update = false
    config_sstdiurn_update = false
    config_deepsoiltemp_update = false
/
```

radiation related

longer simulations

See Chapter 6 and B11 in the User's Guide

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Physics code in MPAS

MPAS-Model/src/core_atmosphere/physics/

access to data files

initialization of separate physics process

```
ccpp_kinds.F                              mpas_atmphys_functions.F
checkout_data_files.sh                    mpas_atmphys_init.F
Makefile                                  mpas_atmphys_initialize_real.F
mpas_atmphys_camrad_init.F                mpas_atmphys_init_microphysics.F
mpas_atmphys_constants.F                  mpas_atmphys_interface.F
mpas_atmphys_control.F                    mpas_atmphys_landuse.F
mpas_atmphys_date_time.F                  mpas_atmphys_lsm_noahinit.F
mpas_atmphys_driver_cloudiness.F          mpas_atmphys_manager.F
mpas_atmphys_driver_convection.F          mpas_atmphys_o3climatology.F
mpas_atmphys_driver.F                     mpas_atmphys_packages.F
mpas_atmphys_driver_gwdo.F                mpas_atmphys_rrtmg_lwinit.F
mpas_atmphys_driver_lsm.F                 mpas_atmphys_rrtmg_swinit.F
mpas_atmphys_driver_lsm_shared.F          mpas_atmphys_todynamics.F
mpas_atmphys_driver_microphysics.F        mpas_atmphys_update.F
mpas_atmphys_driver_oml.F                 mpas_atmphys_update_surface.F
mpas_atmphys_driver_pbl.F                 mpas_atmphys_utilities.F
mpas_atmphys_driver_radiation_lw.F        mpas_atmphys_vars.F
mpas_atmphys_driver_radiation_sw.F        physics_mmm/
mpas_atmphys_driver_sfclayer.F            physics_wrf/
mpas_atmphys_finalize.F
```

physics modules

drivers for separate physics process

MPAS
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MPAS Model Simulation Sequence

Initialize model state, physics

Do timesteps

Call physics

Do dynamics_split_steps
Do rk3_step = 1, 3
compute large-time-step tendency
Do acoustic_steps
update u rho, theta and w
End acoustic_steps
End rk3_step
End dynamics_split_steps

Do scalar_rk3_step = 1, 3
scalar RK3 transport
End scalar_rk3_step

Call microphysics

End timesteps

<u>Physics drivers</u>

- All physics see the same model state
- Each physics component contributes to state-variable tendencies
- Physics are only evaluated once per timestep

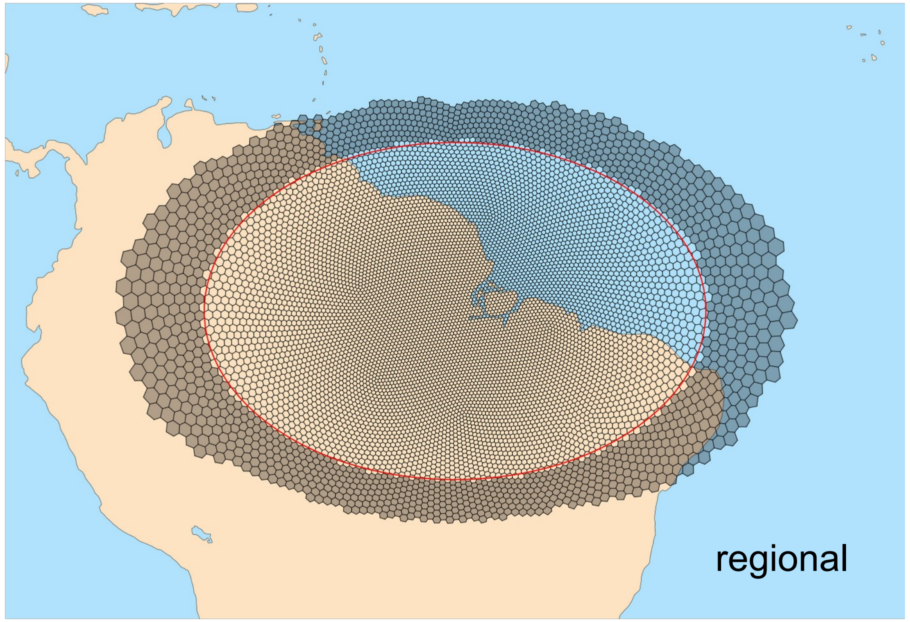
- Clouds, longwave and shortwave radiation
- Surface layer
- Land surface
- Planetary boundary layer
- GWDO driver
- Convection

Result – state variable tendencies

Microphysics directly updates the model state (theta, q).
The heating (θ) tendency from the microphysics is also used in the dynamics.

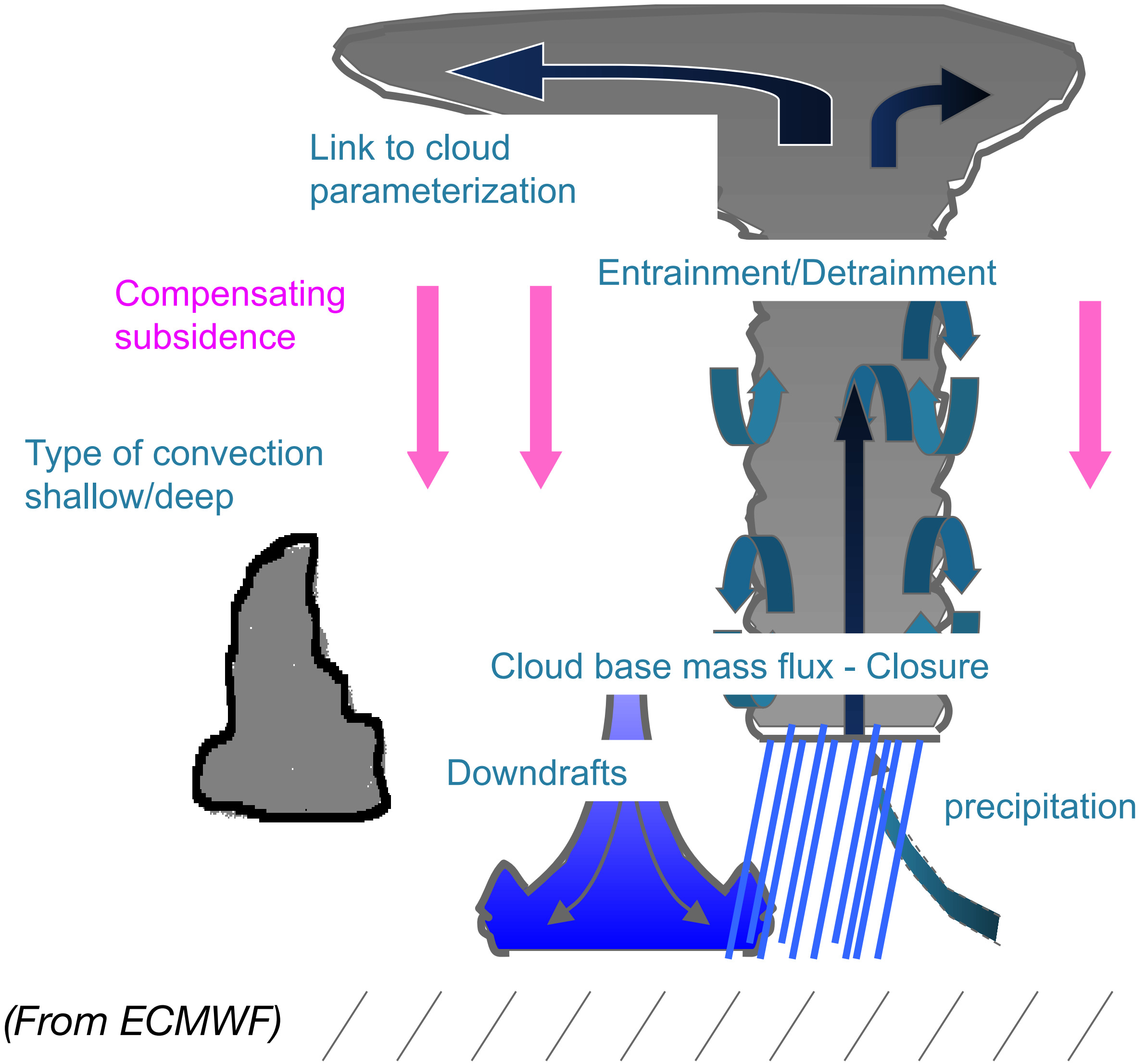
Scale-Aware Convection Schemes

For variable resolution applications with mesh sizes ranging from mesoscale to cloud-permitting scale, we need to consider physics that is ‘scale-aware’.



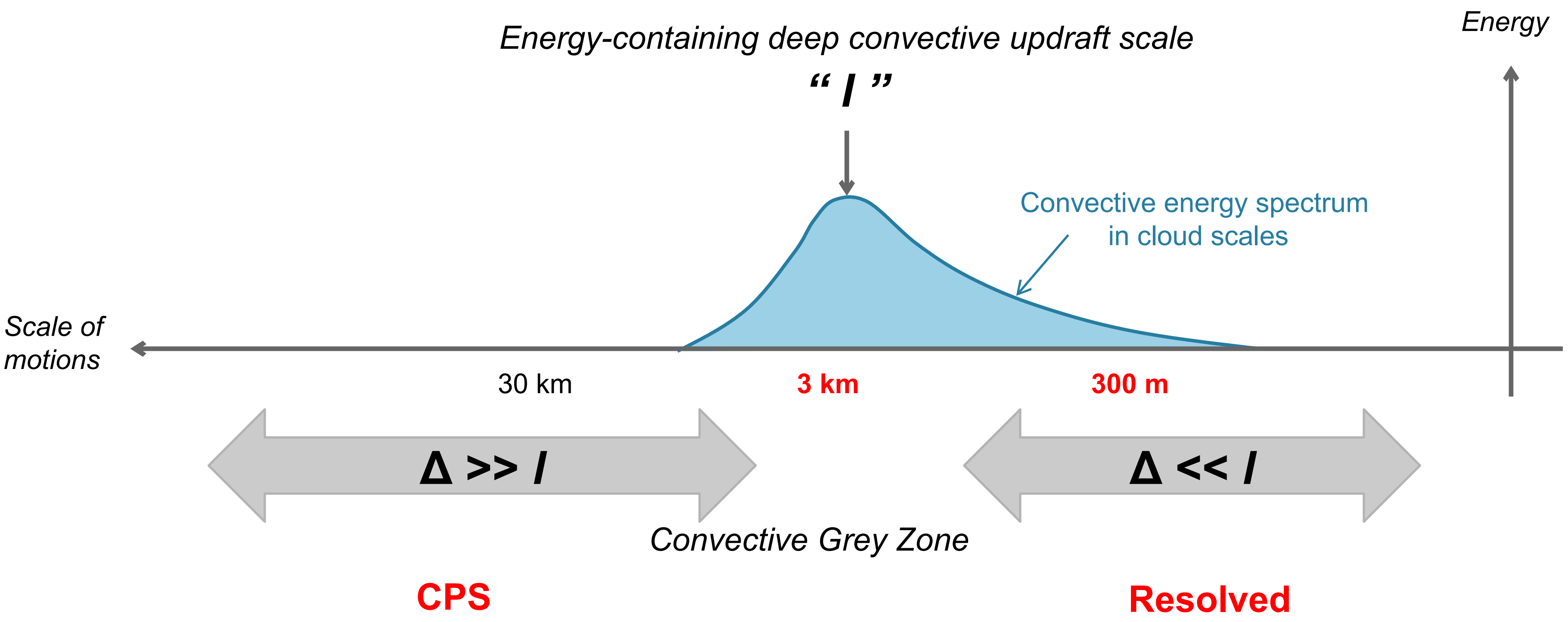
Cumulus Convection Processes

- A convective or cumulus scheme parameterizes convective transport of heat and moisture and its effect on grid scale.
- Includes both *deep* and *shallow* convection.
- A scheme needs to determine where and when convection occurs and how strong it is.
- Cloud species can be detrained to grid scale.
- All CPS schemes in MPAS are mass-flux type. Some schemes consider momentum transport. Some are scale-aware.



(From ECMWF)

Scale-Aware Convection Schemes



A schematic showing the energy spectrum in a horizontal plane as a function of model grid distance.

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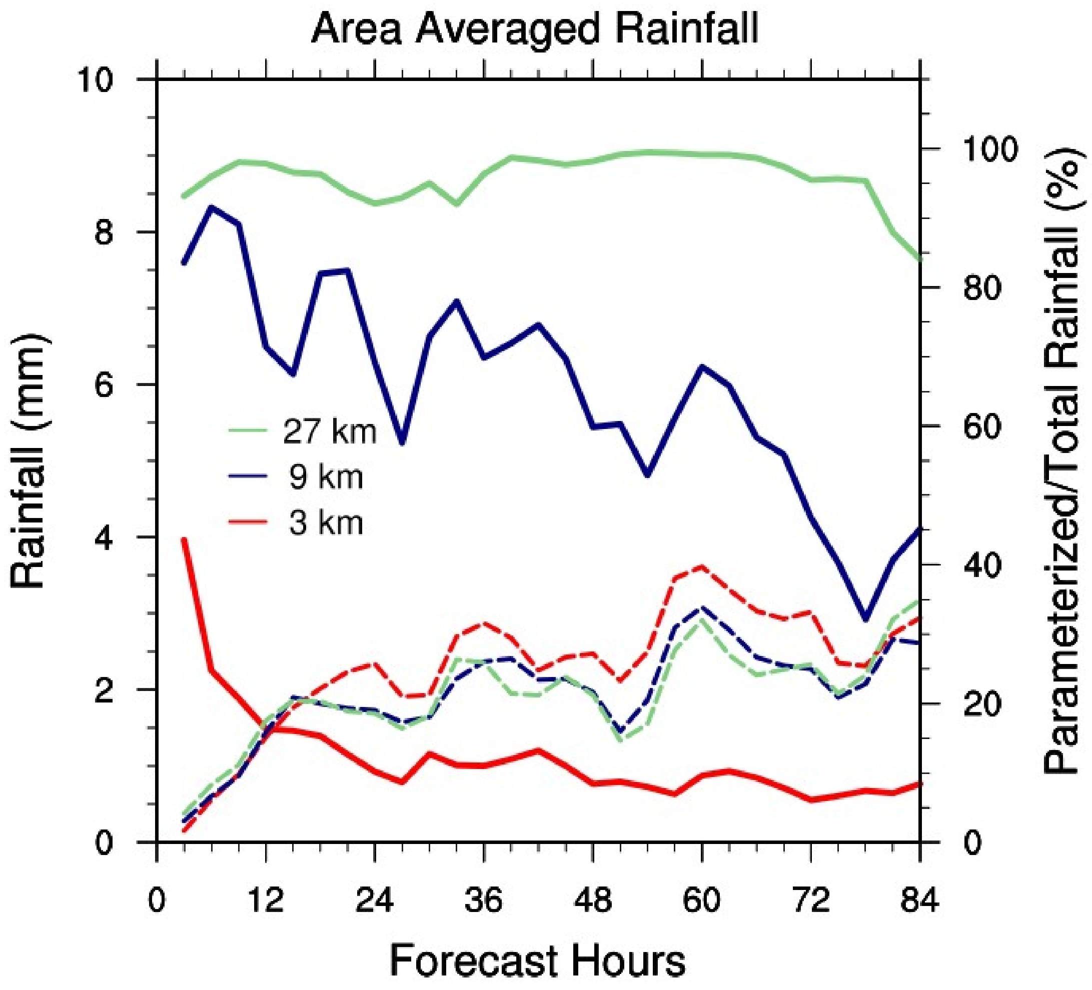
Scale-Aware Convection Schemes

- Hurricane Harvey simulations at 27, 9 and 3 km with WRF
- The convective portion of the rainfall decreases as the grid size decreases from 27 km (green) to 3 km (red)



Solid lines: ratios
Dashed: 3 hrly rainfall

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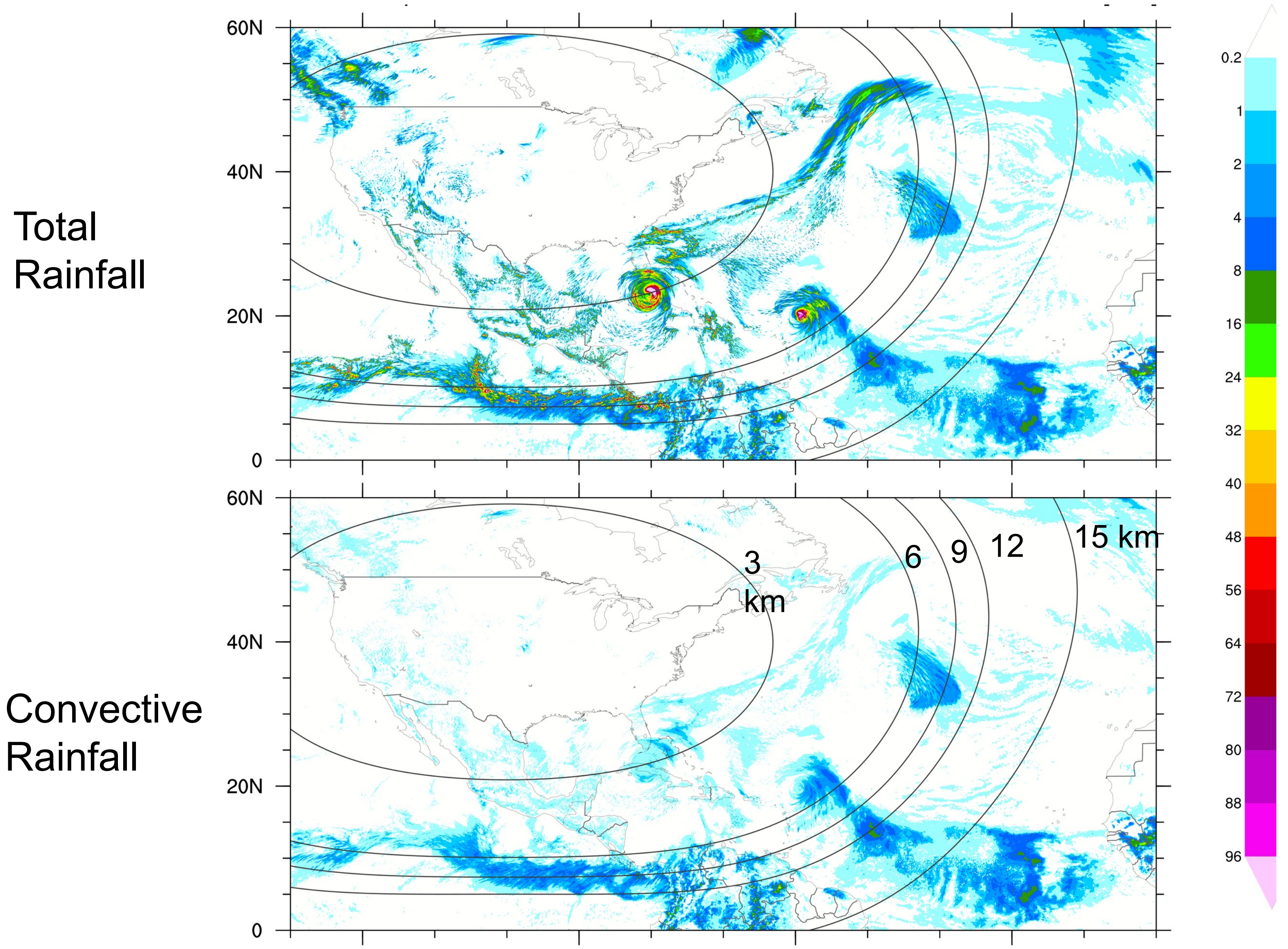
Simulation of Hurricane Irma with a 15-3 km Mesh



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Summary

1) MPAS has a fairly complete collection atmospheric and land surface physics, including two "suites".
2) It is not difficult to add a new physics – follow the examples of existing physics.
3) New physics coming into the repository is expected to be CCPP-compliant (CCPP: Common Community Physics Package).
4) Modeling physics is still very challenging, and improving model physics can improve model simulations.

For references to various physics schemes and detailed physics talks:

1. https://www2.mmm.ucar.edu/wrf/users/physics/phys_references.html
2. https://www2.mmm.ucar.edu/wrf/users/tutorial/tutorial.html

The authoritative list of physics is in the MPAS-A Users' Guide.