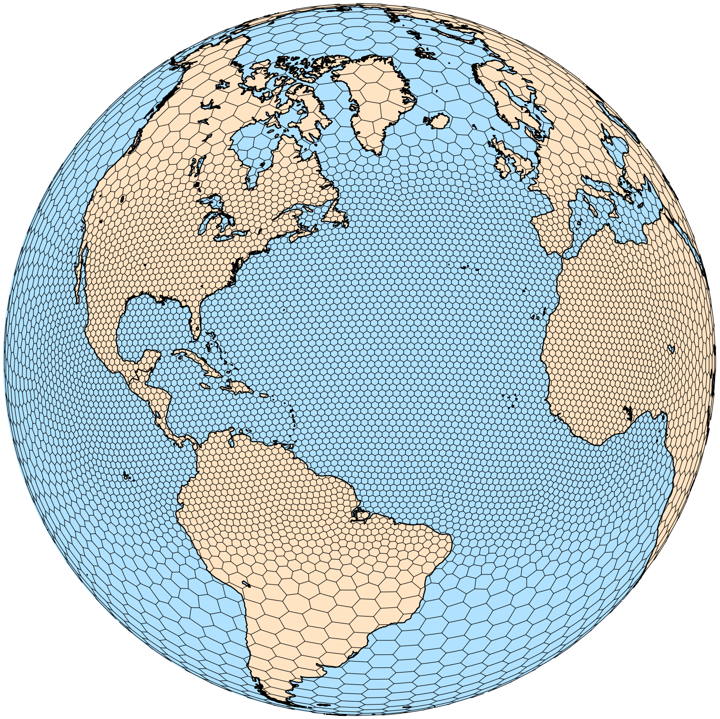
MPAS
Model for Prediction Across Scales



- Overview
- Meshes
- *Atmospheric solver,* physics
- Compiling and running MPAS
- Summary
- Practical session

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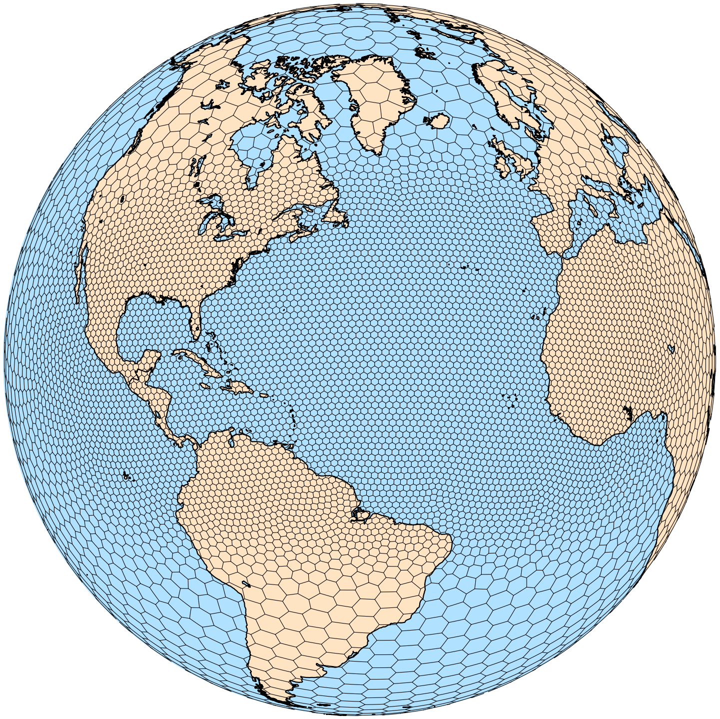
MPAS

Model for Prediction Across Scales



- Overview
- Meshes
- *Atmospheric solver*

  Vertical coordinate, horizontal discretization, gradients, flux divergence (transport), Coriolis term.

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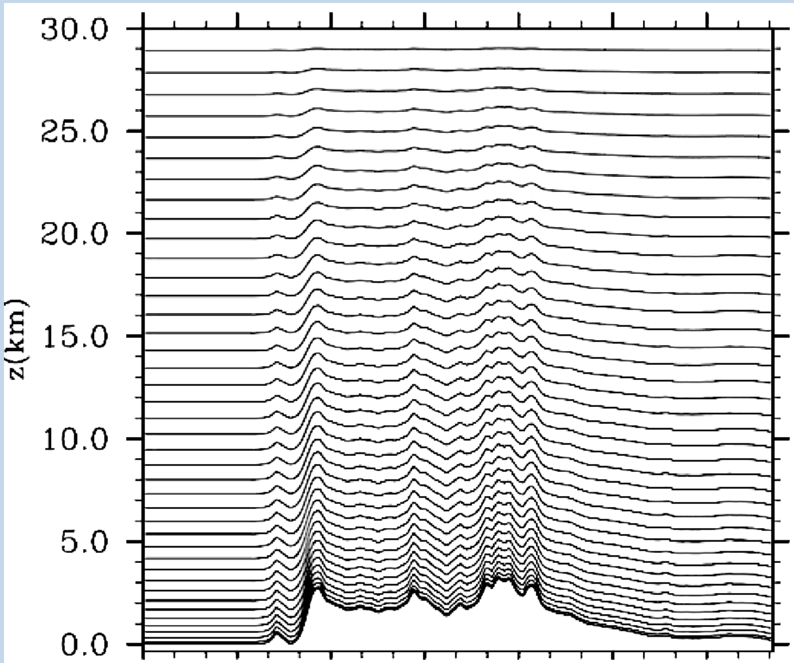
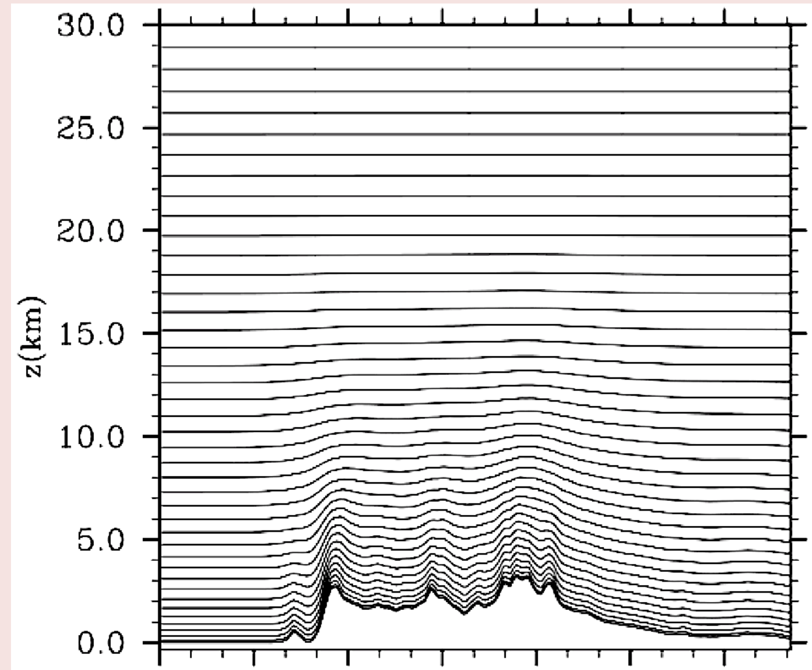
Why MPAS?

Significant differences between WRF and MPAS



WRF
Pressure-based terrain-following sigma vertical coordinate



MPAS
Height-based hybrid smoothed terrain-following vertical coordinate

- Improved numerical accuracy

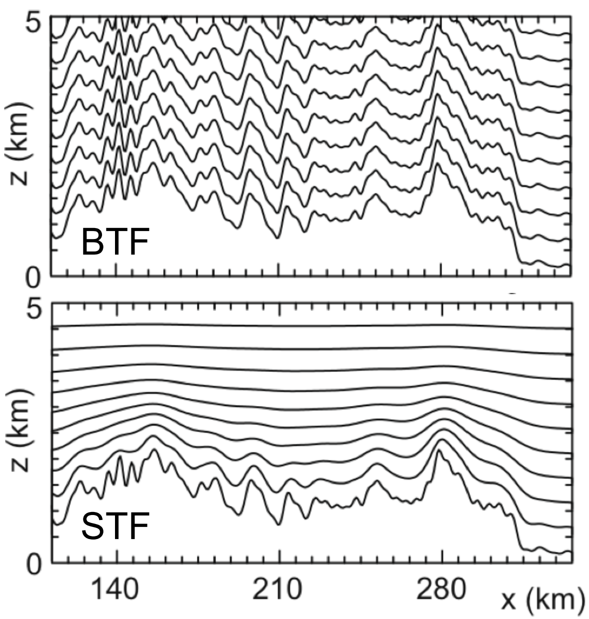
MPAS Vertical Mesh

MPAS Model for Prediction Across Scales

Specification of terrain:

- High resolution terrain data (30 arcsec) averaged over grid-cell area
- Terrain smoothing with one pass of a 4th order Laplacian

Smoothed Terrain-Following (STF) hybrid Coordinate



$$z(x, y, \zeta) = \zeta + A(\zeta) h_s(x, y, \zeta)$$

$A(\zeta)$ Controls rate at which terrain influences are attenuated with height

$h_s(x, y, \zeta)$ Terrain influence that represents increased smoothing of the actual terrain with height

Multiple passes of simple Laplacian smoother at each ζ level:

$$h_s^{(n)} = h_s^{(n-1)} + \beta(\zeta) d^2 \nabla_\zeta^2 h_s^{(n-1)}$$

STF progressively smooths coordinate surfaces while transitioning to a height coordinate

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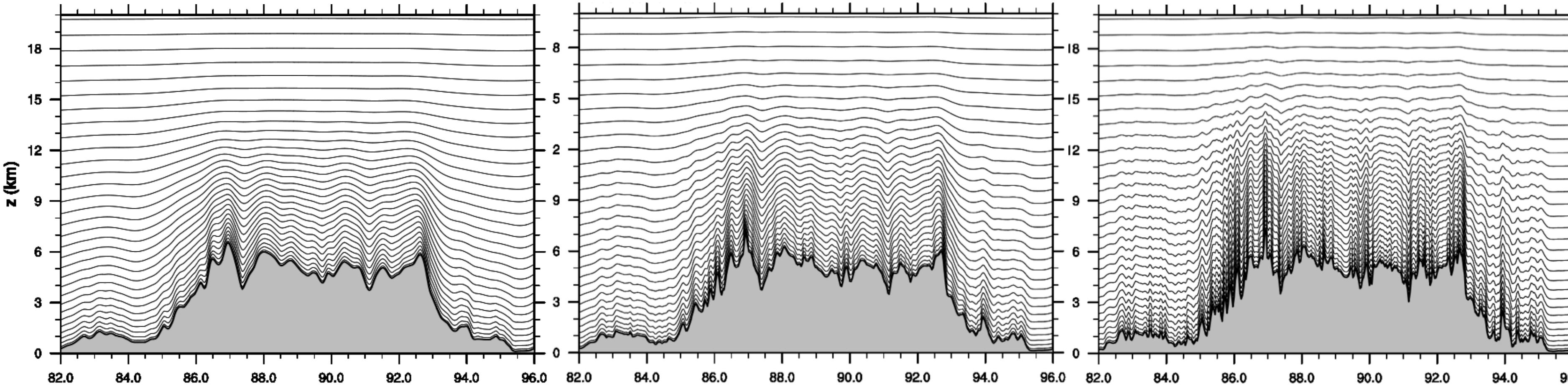
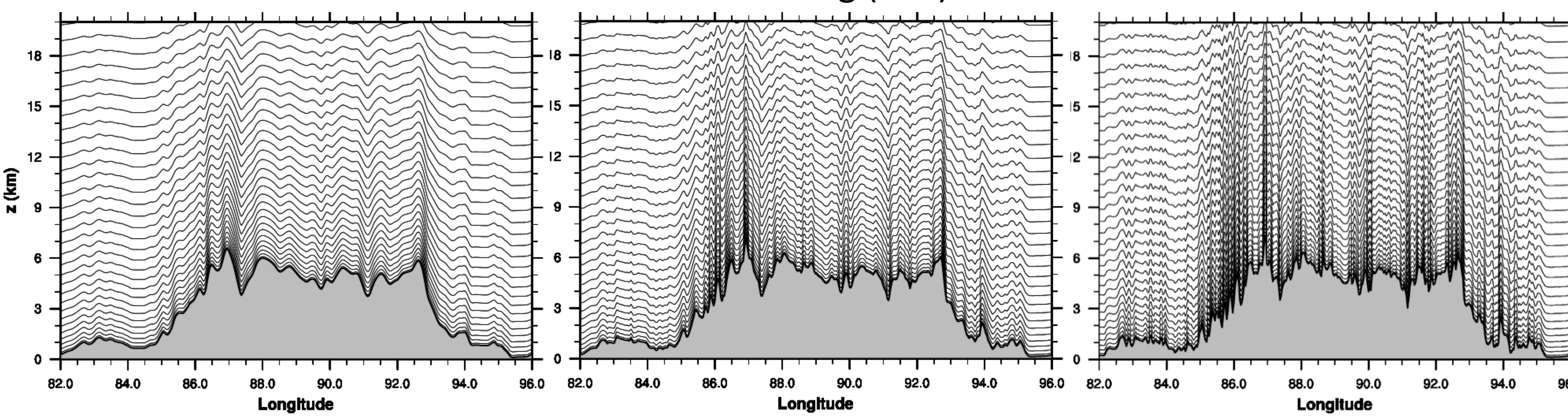
MPAS -Tibetan Plateau, 28^{o} N

15 km grid | 7.5 km grid | 3 km grid

Smoothed hybrid terrain-following (STF) coordinate



Basic terrain-following (BTF) coordinate



(Model top is at 30 km)

MPAS Nonhydrostatic Atmospheric Solver

MPAS
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<u>Nonhydrostatic formulation</u>

Equations

- Prognostic equations for coupled variables.
- Generalized height coordinate.
- Horizontally vector invariant eqn set.
- Continuity equation for dry air mass.
- Thermodynamic equation for coupled potential temperature.

Time integration scheme

As in Advanced Research WRF -
Split-explicit Runge-Kutta (3rd order)

Variables:

$$(U,V,\Omega,\Theta,Q_j) = \tilde{\rho}_d \cdot (u,v,\dot{\eta},\theta,q_j)$$

Vertical coordinate:

$$z = \zeta + A(\zeta)h_s(x,y,\zeta)$$

Prognostic equations:

$$\frac{\partial \mathbf{V}_H}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\nabla_\zeta\left(\frac{p}{\zeta_z}\right) - \frac{\partial \mathbf{z}_H p}{\partial \zeta}\right] - \eta\,\boldsymbol{k}\times\mathbf{V}_H - \boldsymbol{v}_H\nabla_\zeta\cdot\boldsymbol{V} - \frac{\partial \Omega \boldsymbol{v}_H}{\partial \zeta} - \rho_d\nabla_\zeta K - eW\cos\alpha_r - \frac{uW}{r_e} + \boldsymbol{F}_{V_H},$$

$$\frac{\partial W}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\frac{\partial p}{\partial \zeta} + g\tilde{\rho}_m\right] - (\nabla\cdot\boldsymbol{v}W)_\zeta + \frac{uU+vV}{r_e} + e(U\cos\alpha_r - V\sin\alpha_r) + F_W,$$

$$\frac{\partial \Theta_m}{\partial t} = -(\nabla\cdot\boldsymbol{V}\,\theta_m)_\zeta + F_{\Theta_m},$$

$$\frac{\partial \tilde{\rho}_d}{\partial t} = -(\nabla\cdot\boldsymbol{V})_\zeta,$$

$$\frac{\partial Q_j}{\partial t} = -(\nabla\cdot\boldsymbol{V}\,q_j)_\zeta + \rho_d S_j + F_{Q_j},$$

Diagnostics and definitions:

$$\theta_m = \theta[1 + (R_v/R_d)q_v] \qquad p = p_0\left(\frac{R_d\zeta_z\Theta_m}{p_0}\right)^\gamma$$

$$\frac{\rho_m}{\rho_d} = 1 + q_v + q_c + q_r + \dots$$

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MPAS Nonhydrostatic Atmospheric Solver

Prognostic equations:

$$\frac{\partial \mathbf{V}_H}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\nabla_\zeta\left(\frac{p}{\zeta_z}\right) - \frac{\partial \mathbf{z}_H p}{\partial \zeta}\right] - \eta\, \mathbf{k} \times \mathbf{V}_H$$
$$- \mathbf{v}_H \nabla_\zeta \cdot \mathbf{V} - \frac{\partial \Omega \mathbf{v}_H}{\partial \zeta} - \rho_d \nabla_\zeta K - eW \cos \alpha_r - \frac{uW}{r_e} + \mathbf{F}_{V_H},$$

$$\frac{\partial W}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\frac{\partial p}{\partial \zeta} + g\tilde{\rho}_m\right] - (\nabla \cdot \mathbf{v} W)_\zeta$$
$$+ \frac{uU + vV}{r_e} + e\left(U \cos \alpha_r - V \sin \alpha_r\right) + F_W,$$

$$\frac{\partial \Theta_m}{\partial t} = -(\nabla \cdot \mathbf{V}\, \theta_m)_\zeta + F_{\Theta_m},$$

$$\frac{\partial \tilde{\rho}_d}{\partial t} = -(\nabla \cdot \mathbf{V})_\zeta,$$

$$\frac{\partial Q_j}{\partial t} = -(\nabla \cdot \mathbf{V}\, q_j)_\zeta + \rho_d S_j + F_{Q_j},$$

(1) Gradient operators

(2) Flux divergence operators

(3) Nonlinear Coriolis term

MPAS
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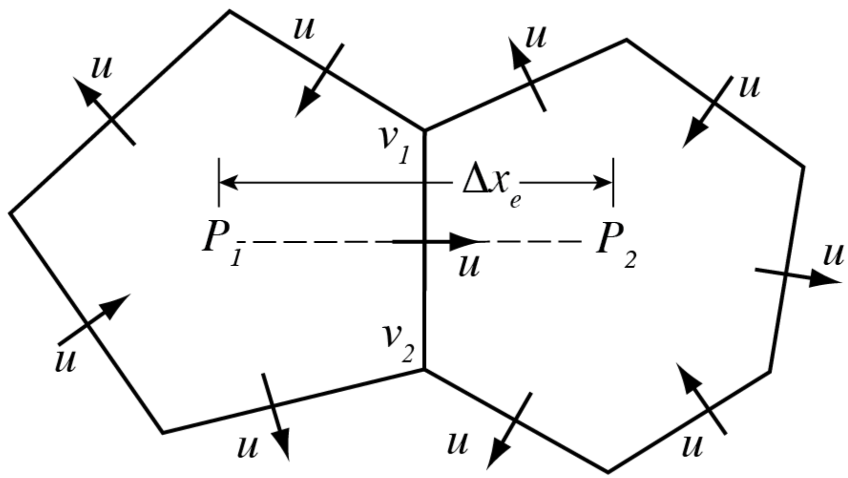
Operators on the Voronoi Mesh
Pressure and KE gradients

$$\frac{\partial \mathbf{V}_H}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\nabla_\zeta\left(\frac{p}{\zeta_z}\right) - \frac{\partial \mathbf{z}_H p}{\partial \zeta}\right] - \eta\,\mathbf{k}\times\mathbf{V}_H$$
$$- \mathbf{v}_H \nabla_\zeta \cdot \mathbf{V} - \frac{\partial \Omega \mathbf{v}_H}{\partial \zeta} - \rho_d \nabla_\zeta K - eW\cos\alpha_r - \frac{uW}{r_e} + \mathbf{F}_{V_H},$$



On the Voronoi mesh, P_1P_2 is perpendicular to v_1v_2 and is bisected by v_1v_2, hence $P_x \sim (P_2\text{-}P_1)\Delta x_e^{-1}$ is 2^{nd} order accurate.

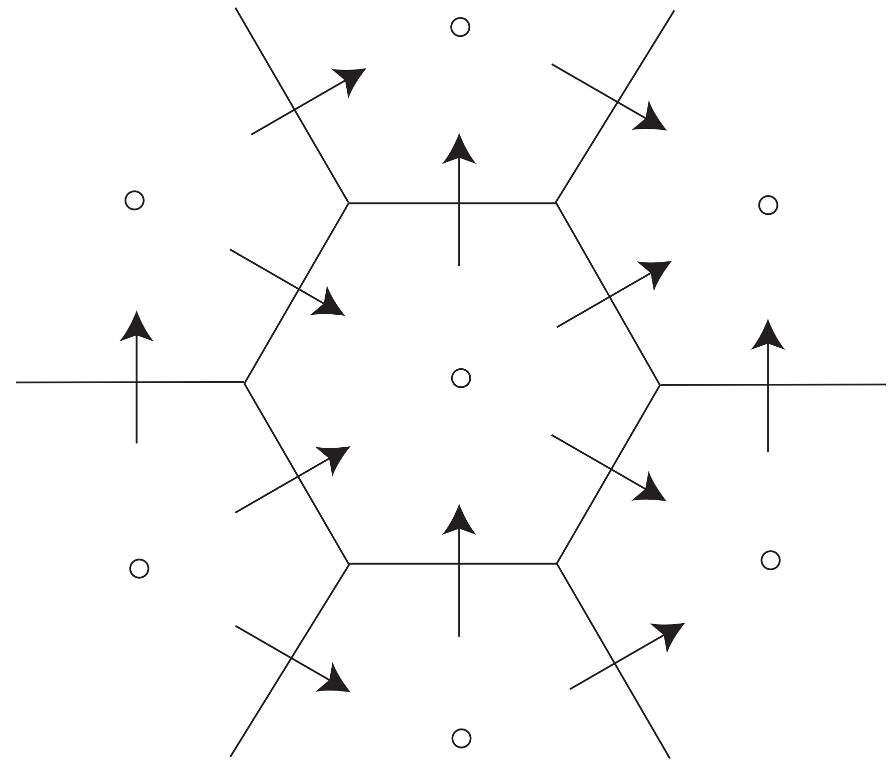
Operators on the Voronoi Mesh
cell-center KE evaluation

Cell center kinetic energy: KE_i

$$KE_i = (1-\beta)\sum_{e_i} w_{e_i} u_{e_i}^2 + \beta \sum_{v_j} w_{v_j} KE_{v_j}$$

Vertex kinetic energy: KE_v

$$KE_v = \sum_{e_v=1}^{3} w_{e_v} u_{e_v}^2$$



Operators on the Voronoi Mesh
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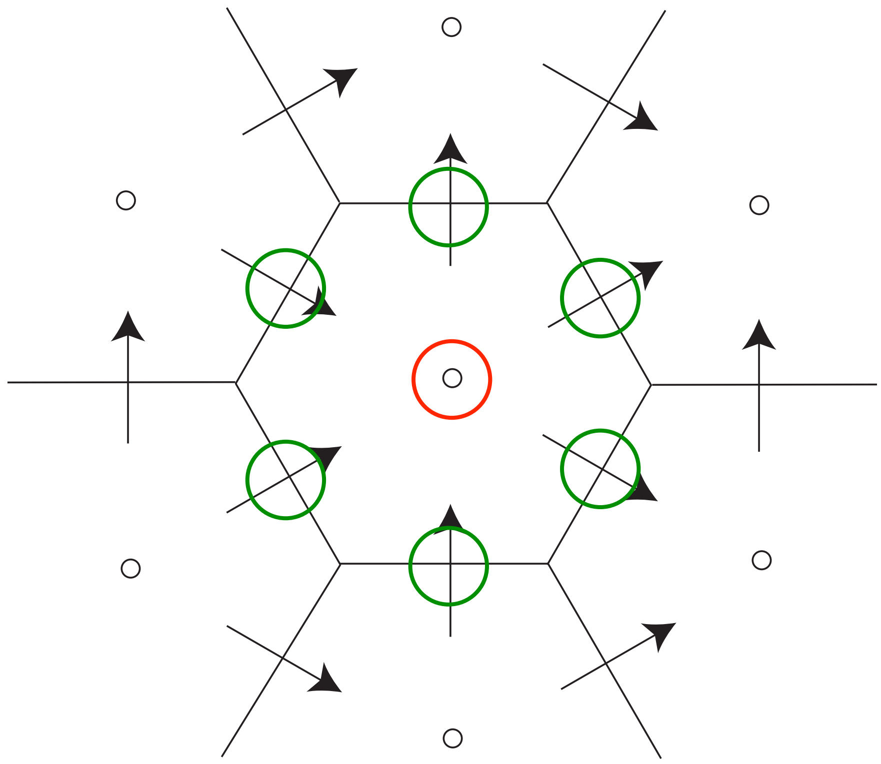
$$KE_v = \sum_{e_v=1}^{3} w_{e_v} u_{e_v}^2$$



Operators on the Voronoi Mesh
cell-center KE evaluation

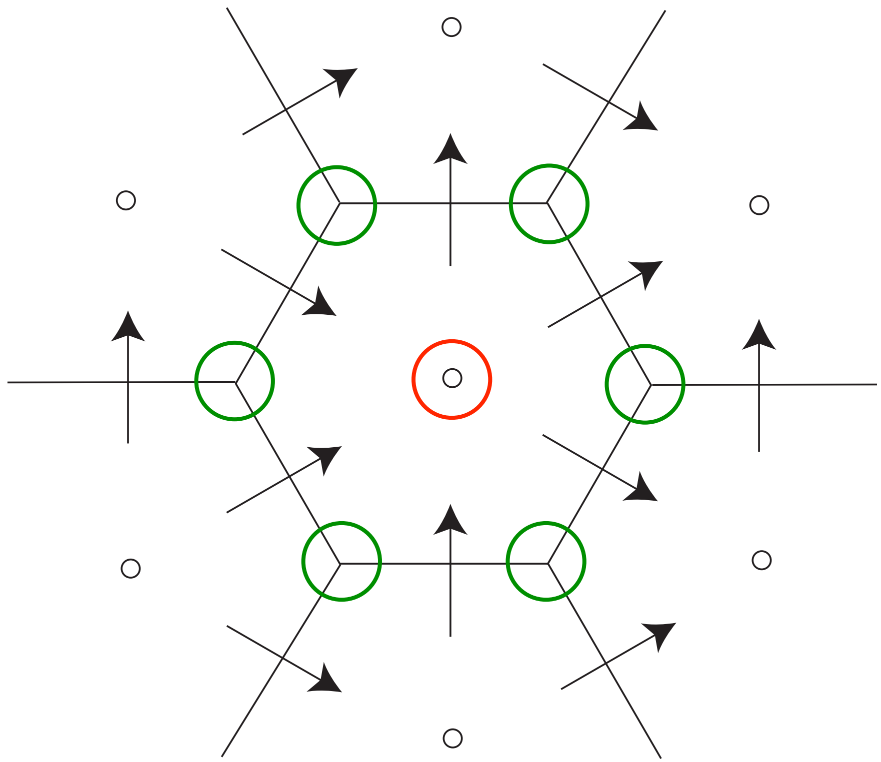
MPAS
Model for Prediction Across Scales

Cell center kinetic energy: KE_i

$$KE_i = (1-\beta)\sum_{e_i} w_{e_i} u_{e_i}^2 + \beta \sum_{v_j} w_{v_j} KE_{v_j}$$

Vertex kinetic energy: KE_v

$$KE_v = \sum_{e_v=1}^{3} w_{e_v} u_{e_v}^2$$



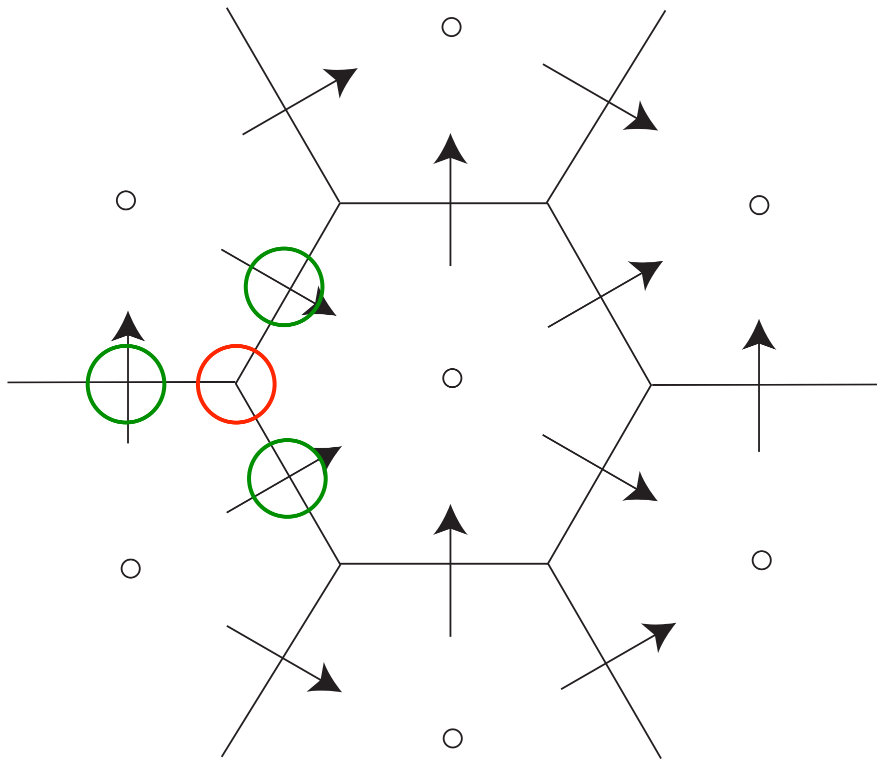
Operators on the Voronoi Mesh
cell-center KE evaluation

Cell center kinetic energy: KE_i

$$KE_i = (1-\beta)\sum_{e_i} w_{e_i} u_{e_i}^2 + \beta \sum_{v_j} w_{v_j} KE_{v_j}$$

Vertex kinetic energy: KE_v

$$KE_v = \sum_{e_v=1}^{3} w_{e_v} u_{e_v}^2$$



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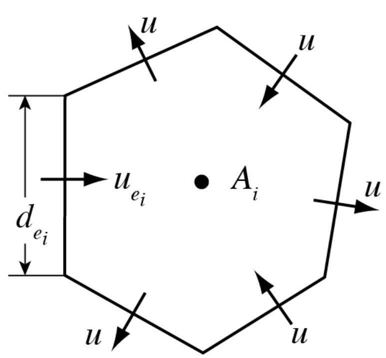
Operators on the Voronoi Mesh
Flux divergence and transport

Transport equation, conservative form: $$\frac{\partial(\rho\psi)}{\partial t} = -\nabla \cdot \mathbf{V}(\rho\psi)$$

Finite-Volume formulation, Integrate over cell: $$\int_D \left[\frac{\partial}{\partial t}(\rho\psi) = -\nabla \cdot \mathbf{V}(\rho\psi)\right] dV$$

Apply divergence theorem: $$\frac{\partial(\overline{\rho\psi})}{\partial t} = -\frac{1}{V}\int_\Sigma (\rho\psi)\, \mathbf{V} \cdot \mathbf{n}\, d\sigma$$

Discretize in time and space: $$(\rho\psi)_i^{t+\Delta t} = (\rho\psi)_i^t - \Delta t \frac{1}{A_i}\sum_{n_{e_i}} d_{e_i}\overline{(\rho\mathbf{V}\cdot\mathbf{n}_{e_i})\psi}$$



Velocity divergence operator is 2nd-order accurate for edge-centered velocities.

MPAS
Model for Prediction Across Scales

Flux divergence, transport, and Runge-Kutta time integration

Scalar transport equation for cell *i*:

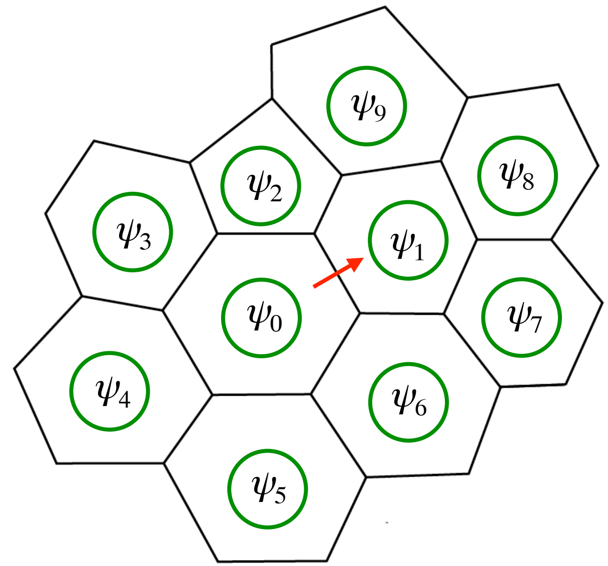
$$\frac{\partial(\rho\psi)_i}{\partial t} = L(\mathrm{V},\rho,\psi) = -\frac{1}{A_i}\sum_{n_{e_i}} d_{e_i}\left(\rho \mathrm{V}\cdot\vec{n}_{e_i}\right)\overline{\psi}$$

1. Scalar edge-flux value ψ is the weighted sum of cell values from cells that share edge and all their neighbors.

2. An individual edge-flux is used to update the two cells that share the edge.

3. Three edge-flux evaluations and cell updates are needed to complete the Runge-Kutta timestep.

4. Monotonic constraint requires checking the cell-value update and renormalizing edge-fluxes if the cell updates are outside specific bounds (on the final RK3 update).



$$(\rho\psi)^* = (\rho\psi)^t + \frac{\Delta t}{3} L(\mathbf{V},\rho,\psi^t)$$

$$(\rho\psi)^{**} = (\rho\psi)^t + \frac{\Delta t}{2} L(\mathbf{V},\rho,\psi^*)$$

$$(\rho\psi)^{t+\Delta t} = (\rho\psi)^t + \Delta t\, L(\mathbf{V},\rho,\psi^{**})$$

MPAS
Model for Prediction Across Scales

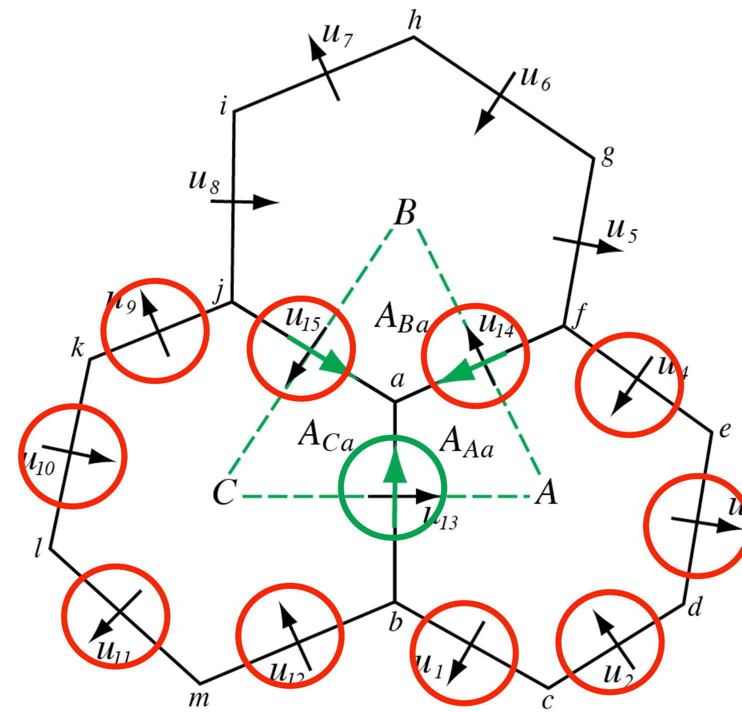
Operators on the Voronoi Mesh
'Nonlinear' Coriolis force

$$\frac{\partial \mathbf{V}_H}{\partial t} = -\frac{\rho_d}{\rho_m}\left[\nabla_\zeta\left(\frac{p}{\zeta_z}\right) - \frac{\partial z_H p}{\partial \zeta}\right] - \eta\,\boldsymbol{k}\times\mathbf{V}_H - \boldsymbol{v}_H \nabla_\zeta \cdot \boldsymbol{V} - \frac{\partial \Omega \boldsymbol{v}_H}{\partial \zeta} - \rho_d \nabla_\zeta K - eW\cos\alpha_r - \frac{uW}{r_e} + \boldsymbol{F}_{V_H},$$

Tangential velocity reconstruction: $v_{e_i} = \sum_{j=1}^{n_{e_i}} w_{e_{i,j}} u_{e_{i,j}}$

Nonlinear term:

$$[\eta\,\boldsymbol{k}\times\mathbf{V}_H]_{e_i} = \sum_{j=1}^{n_{e_i}} \frac{1}{2}(\eta_{e_i} + \eta_{e_{i,j}})\, w_{e_{i,j}} \rho_{e_{i,j}} u_{e_{i,j}}$$



The general tangential velocity reconstruction produces a consistent divergence on the primal and dual grids, and allows for PV, enstrophy and energy* conservation in the nonlinear SW solver.

Operators on the Voronoi Mesh
'Nonlinear' Coriolis force

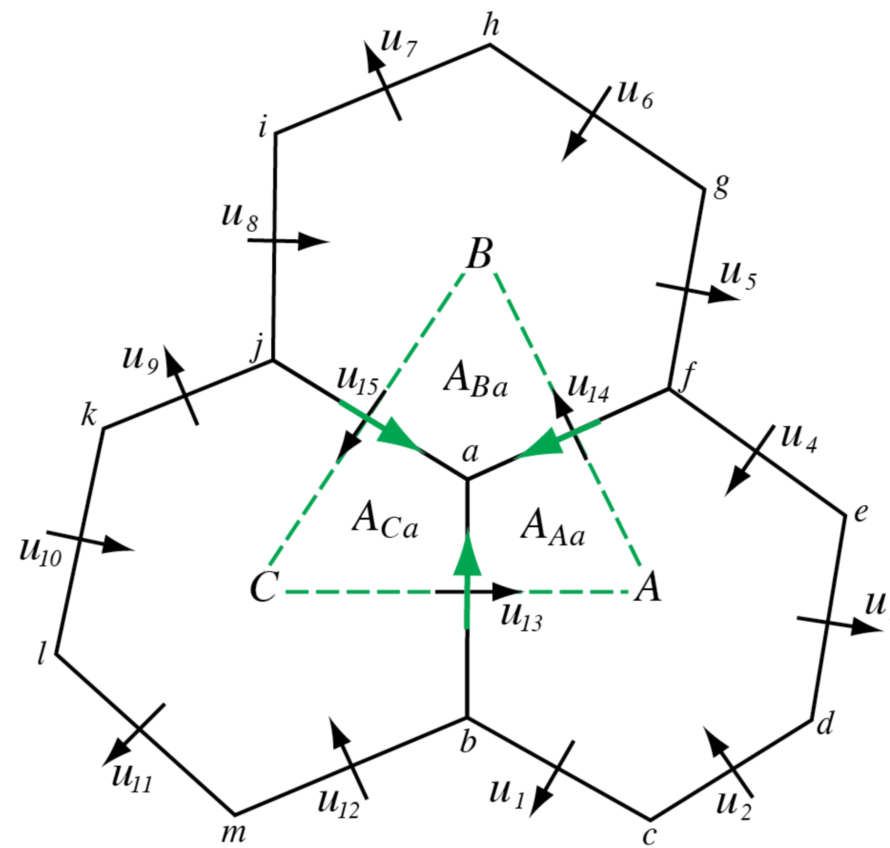
$$[\eta \boldsymbol{k} \times \mathbf{V}_H]_{e_i} = \sum_{j=1}^{n_{e_i}} \frac{1}{2}(\eta_{e_i} + \eta_{e_{i,j}}) w_{e_{i,j}} \rho_{e_{i,j}} u_{e_{i,j}}$$

Example: absolute vorticity at e_{13}

$$\eta_{13} = \frac{1}{2}(\eta_a + \eta_b)$$

Example: absolute vorticity at vertex a

$$\eta_a = f_a + \frac{\left(u_{13}\left|\overrightarrow{CA}\right| + u_{14}\left|\overrightarrow{AB}\right| + u_{15}\left|\overrightarrow{BC}\right|\right)}{Area(ABC)}$$



MPAS
Model for Prediction Across Scales

Time Integration
Dynamics and Scalar Transport Options

Default time integration

```
Call physics

Do dynamics_split_steps
    Do step_rk3 = 1, 3
        compute large-time-step tendency
        Do acoustic_steps
            update u
            update rho, theta and w
        End acoustic_steps
    End rk3 step
End dynamics_split_steps

Do scalar step_rk3 = 1, 3
    scalar RK3 transport
End scalar rk3 step

Call microphysics
```

ARW integration, option in MPAS

```
Call physics

Do step_rk3 = 1, 3
    compute large-time-step tendency
    Do acoustic_steps
        update u
        update rho, theta and w
    End acoustic steps
    scalar RK3 transport
End rk3 step

Call microphysics
```

config_split_dynamics_transport = true/false
config_dynamics_split_steps = 3
config_number_of_sub_steps = 2
(acoustic_steps)

Time Integration
Dynamics and Scalar Transport Options

Default time integration

Call physics

Do dynamics_split_steps
    Do step_rk3 = 1, 3
        compute large-time-step tendency
        Do acoustic_steps
            update u
            update rho, theta and w
        End acoustic_steps
    End rk3 step
End dynamics_split_steps

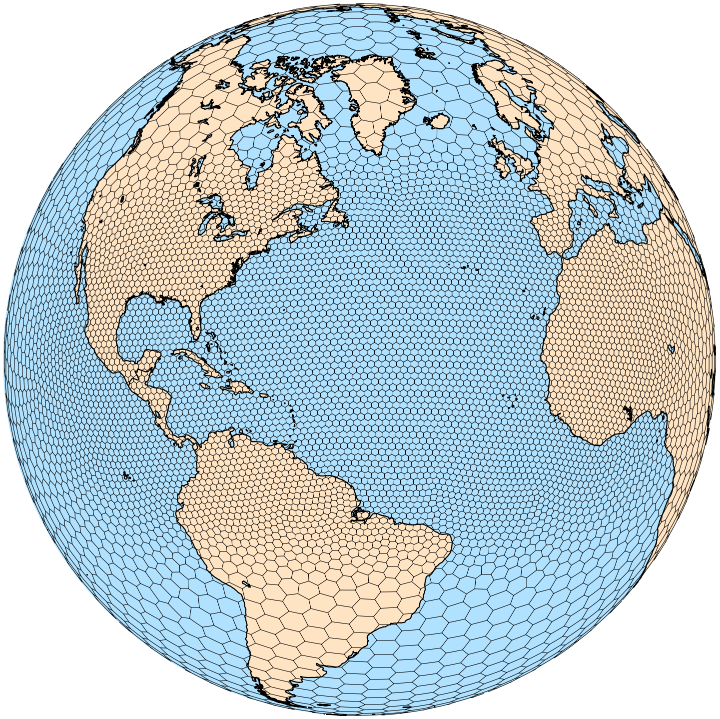
Do scalar step_rk3 = 1, 3
    scalar RK3 transport
End scalar rk3 step

Call microphysics

Allows for smaller dynamics timesteps relative to scalar transport timestep and main physics timestep.

We can use any FV scheme here (we are not tied to RK3)
Scalar transport and physics are the expensive pieces in most applications.

MPAS
Model for Prediction Across Scales



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Physics

Physics suite currently available in the public MPAS release (MPAS-v3.0):

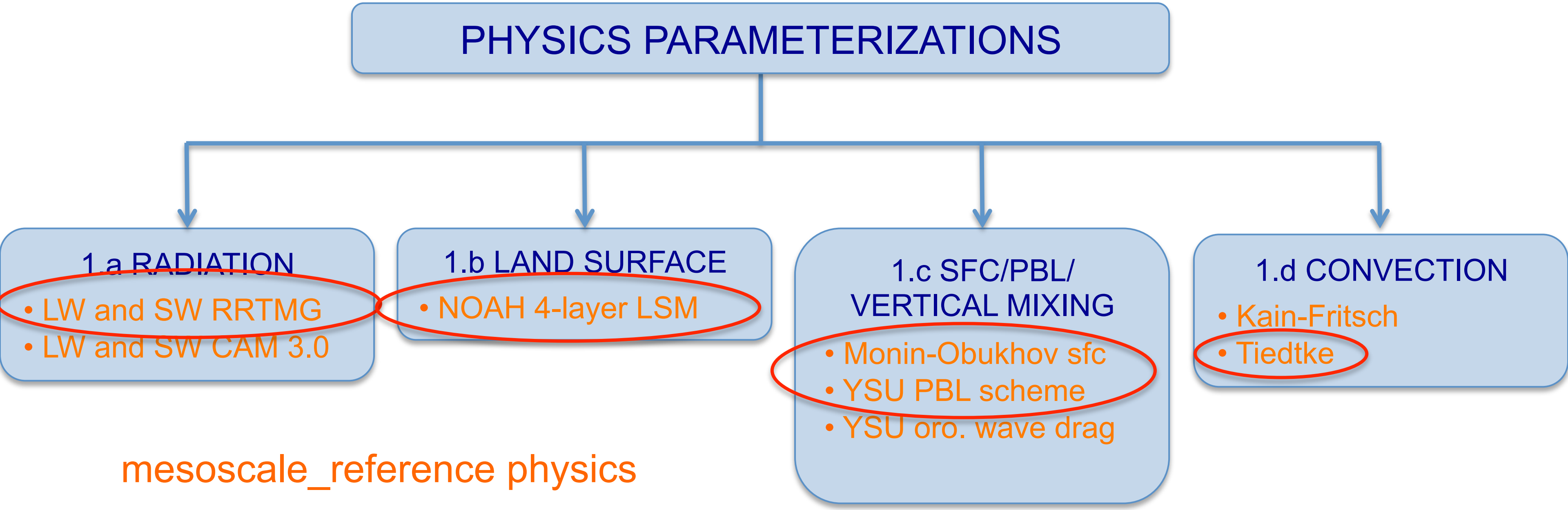
- Physics are from the Weather Research Forecast Model (ARW).
- Only a subset of the ARW physics are available.
- Individual physics schemes are typically those in the newest WRF release.
- Physics suite(s): Currently only one – *mesoscale_reference*, with a few options.

MPAS
Model for Prediction Across Scales

Physics

MPAS Timestep: 1. PHYSICS CALLED BEFORE DYNAMICAL CORE

- The physics parameterizations are called *sequentially*, i.e. they all use the same input surface and atmospheric conditions.
- They update the surface and top-of-the-atmosphere energy budgets.
- They calculates physics tendencies of temperature, momentum, water vapor, and water species (cloud water, cloud ice, rain, snow, graupel) for the dynamical core.



Physics

MPAS Timestep: 1. PHYSICS CALLED BEFORE DYNAMICAL CORE

MPAS Timestep: 2. DYNAMICS and SCALAR TRANSPORT

MPS Timestep: 3. CLOUD MICROPHYSICS AFTER DYNAMICAL CORE

CLOUD MICROPHYSICS
WSM6 ($T,q_v,q_c,q_r,q_i,q_s,q_g$)
Kessler(T,q_v,q_c,q_r)

- Unlike the other physics parameterization schemes, the cloud microphysics scheme directly updates the temperature, water vapor, and other water/ice species instead of calculating cloud microphysics tendencies.
- Calling the cloud microphysics parameterization after the dynamics integration ensures that the relative humidity does not exceed 100% at the end of the model time-step.

mesoscale_reference physics

Physics

config_physics_suite = 'mesoscale_reference' results in:

config_physics_suite = 'mesoscale_reference' results in:		*other options*
config_microp_scheme	= 'wsm6'	kessler, off
config_convection_scheme	= 'tiedtke'	kain-fristch, off
config_pbl_scheme	= 'ysu'	off
config_gwdo_scheme	= 'off'	ysu_gwdo, off
config_radt_lw_scheme	= 'rrtmg_lw'	cam_lw, off
config_radt_sw_scheme	= 'rrtmg_sw'	cam_sw, off
config_radt_cld_scheme	= 'cld_fraction'	off
config_sfclayer_scheme	= 'monin_obukhov'	off
config_lsm_scheme	= 'noah'	off

config_physics_suite = 'none' results in all physics options being set to 'off '

MPAS
Model for Prediction Across Scales

Configuring the dynamics and the physics

(namelist.atmosphere)

```
&nhyd_model
   config_dt = 720.0
   config_start_time = '2010-10-23_00:00:00'
   config_run_duration = '5_00:00:00'
   config_split_dynamics_transport = true
   config_number_of_sub_steps = 2
   config_dynamics_split_steps = 3
   config_h_mom_eddy_visc2 = 0.0
   config_h_mom_eddy_visc4 = 0.0
   config_v_mom_eddy_visc2 = 0.0
   config_h_theta_eddy_visc2 = 0.0
   config_h_theta_eddy_visc4 = 0.0
   config_v_theta_eddy_visc2 = 0.0
   config_horiz_mixing = '2d_smagorinsky'
   config_h_ScaleWithMesh = true
  config_len_disp = 120000.0
   config_visc4_2dsmag = 0.05
   config_w_adv_order = 3
   config_theta_adv_order = 3
   config_scalar_adv_order = 3
   config_u_vadv_order = 3
   config_w_vadv_order = 3
   config_theta_vadv_order = 3
   config_scalar_vadv_order = 3
   config_scalar_advection = true
   config_positive_definite = false
   config_monotonic = true
   config_coef_3rd_order = 0.25
   config_epssm = 0.1
   config_smdiv = 0.1
```

Configuring the dynamics and the physics

(namelist.atmosphere)

```
&nhyd_model
  config_dt = 720.0
  config_start_time = '2010-10-23_00:00:00'
  config_run_duration = '5_00:00:00'
  config_split_dynamics_transport = true
  config_number_of_sub_steps = 2
  config_dynamics_split_steps = 3
  config_h_mom_eddy_visc2 = 0.0
  config_h_mom_eddy_visc4 = 0.0
  config_v_mom_eddy_visc2 = 0.0
  config_h_theta_eddy_visc2 = 0.0
  config_h_theta_eddy_visc4 = 0.0
  config_v_theta_eddy_visc2 = 0.0
  config_horiz_mixing = '2d_smagorinsky'
  config_h_ScaleWithMesh = true
 config_len_disp = 120000.0
  config_visc4_2dsmag = 0.05
  config_w_adv_order = 3
  config_theta_adv_order = 3
  config_scalar_adv_order = 3
  config_u_vadv_order = 3
  config_w_vadv_order = 3
  config_theta_vadv_order = 3
  config_scalar_vadv_order = 3
  config_scalar_advection = true
  config_positive_definite = false
  config_monotonic = true
  config_coef_3rd_order = 0.25
  config_epssm = 0.1
  config_smdiv = 0.1
```

Time and time-steps

```
&nhyd_model
    config_dt = 720
    config_start_time = "2010-10-23_00:00:00"
    config_run_duration = "5_00:00:00"
    config_split_dynamics_transport = true
    config_number_of_sub_steps = 2
    config_dynamics_split_steps = 3
```

Timestep in seconds

Dynamics substeps per split step

Number of acoustic steps per timestep

MPAS
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Configuring the dynamics and the physics

Dissipation

(namelist.atmosphere)

```
&nhyd_model
  config_dt = 720.0
  config_start_time = '2010-10-23_00:00:00'
  config_run_duration = '5_00:00:00'
  config_split_dynamics_transport = true
  config_number_of_sub_steps = 2
  config_dynamics_split_steps = 3
  config_h_mom_eddy_visc2 = 0.0
  config_h_mom_eddy_visc4 = 0.0
  config_v_mom_eddy_visc2 = 0.0
  config_h_theta_eddy_visc2 = 0.0
  config_h_theta_eddy_visc4 = 0.0
  config_v_theta_eddy_visc2 = 0.0
  config_horiz_mixing = '2d_smagorinsky'
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  config_len_disp = 120000.0
  config_visc4_2dsmag = 0.05
  config_w_adv_order = 3
  config_theta_adv_order = 3
  config_scalar_adv_order = 3
  config_u_vadv_order = 3
  config_w_vadv_order = 3
  config_theta_vadv_order = 3
  config_scalar_vadv_order = 3
  config_scalar_advection = true
  config_positive_definite = false
  config_monotonic = true
  config_coef_3rd_order = 0.25
  config_epssm = 0.1
  config_smdiv = 0.1
```

```
&nhyd_model
    config_h_mom_eddy_visc2 = 0
    config_h_mom_eddy_visc4 = 0
    config_v_mom_eddy_visc2 = 0
    config_h_theta_eddy_visc2 = 0
    config_h_theta_eddy_visc4 = 0
    config_v_theta_eddy_visc2 = 0
    config_horiz_mixing = "2d_smagorinsky"
    config_len_disp = 15000.
    config_visc4_2dsmag = 0.05
    config_h_ScaleWithMesh = .true.
```

fixed viscosity m^2s^{-1}

Fixed hyper-viscosity m^4s^{-1}

Alternately "2d_fixed"

Δx_fine

4th order background filter coef, used with 2d_smagorinsky

Scale viscosities, hyperviscosities with local mesh spacing

MPAS
Model for Prediction Across Scales

Configuring the dynamics and the physics

Advection

(namelist.atmosphere)

```
&nhyd_model
  config_dt = 720.0
  config_start_time = '2010-10-23_00:00:00'
  config_run_duration = '5_00:00:00'
  config_split_dynamics_transport = true
  config_number_of_sub_steps = 2
  config_dynamics_split_steps = 3
  config_h_mom_eddy_visc2 = 0.0
  config_h_mom_eddy_visc4 = 0.0
  config_v_mom_eddy_visc2 = 0.0
  config_h_theta_eddy_visc2 = 0.0
  config_h_theta_eddy_visc4 = 0.0
  config_v_theta_eddy_visc2 = 0.0
  config_horiz_mixing = '2d_smagorinsky'
  config_h_ScaleWithMesh = true
  config_len_disp = 120000.0
  config_visc4_2dsmag = 0.05
  config_w_adv_order = 3
  config_theta_adv_order = 3
  config_scalar_adv_order = 3
  config_u_vadv_order = 3
  config_w_vadv_order = 3
  config_theta_vadv_order = 3
  config_scalar_vadv_order = 3
  config_scalar_advection = true
  config_positive_definite = false
  config_monotonic = true
  config_coef_3rd_order = 0.25
  config_epssm = 0.1
  config_smdiv = 0.1
```

```
&nhyd_model
  config_w_adv_order = 3
  config_theta_adv_order = 3
  config_scalar_adv_order = 3
  config_u_vadv_order = 3
  config_w_vadv_order = 3
  config_theta_vadv_order = 3
  config_scalar_vadv_order = 3
  config_positive_definite = .false.
  config_monotonic = .true.
  config_coef_3rd_order = 0.25
```

Advection scheme order (2,3, or 4)

PD/Mono options for scalar transport

Upwind coefficient (0 <-> 1), >0 increases damping

Configuring the dynamics and the physics

Other dynamics…

(namelist.atmosphere)

&nhyd_model

…

config_epssm = 0.1 ← *off-centering of vertically implicit integration*

config_smdiv = 0.1 ← *3D divergence damping*

/

&damping

config_zd = 37000. ← *height to begin gravity wave absorbing layer (m)*

config_xnutr = 0.2 ← *gravity-wave absorbing layer coefficient*

Configuring the dynamics and the physics

Physics schemes

(namelist.atmosphere)

```
&physics
   config_sst_update = false
   config_sstdiurn_update = false
   config_deepsoiltemp_update = false
   config_radtlw_interval = '00:30:00'
   config_radtsw_interval = '00:30:00'
   config_bucket_update = 'none'
   config_physics_suite = 'mesoscale_reference'
```

```
config_physics_suite = 'mesoscale_reference'
config_conv_deep_scheme    = ‘ysu’
config_radt_lw_scheme      = ’cam_lw'
config_radt_sw_scheme      = ’cam_sw'
```

Replaces mesoscale_reference options with these optional schemes.

MPAS Solver and Physics Information

http://mpas-dev.github.io/

MPAS
Model for Prediction Across Scales

MPAS Atmosphere Public Releases

MPAS Home

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- MPAS-Atmosphere
- MPAS-Land Ice
- MPAS-Ocean
- Data Assimilation
- Publications
- Presentations

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- MPAS-Ocean download

Resources

- License Information
- Wiki
- Bug Tracker
- Mailing Lists
- MPAS Developers Guide

MPAS Atmosphere 3.0 was released on 18 November 2014.

Any questions related to building and running MPAS-Atmosphere should be directed to the MPAS-Atmosphere Help forum. Posting to the forum requires a free google account. Alternatively, questions may be sent from any e-mail address to "mpas-atmosphere-help **AT** googlegroups.com"*. Please note that in either case, questions and their answers will appear on the online forum.*

- MPAS Atmosphere 3.0 release notes
- MPAS source code download
- MPAS-Atmosphere Users' Guide
- MPAS-Atmosphere tutorial presentations
- MPAS-Atmosphere meshes
- Configurations for idealized test cases
- Sample input files for real-data simulations
- Visualization and analysis tools

A variable resolution MPAS Voronoi mesh

MPAS Solver and Physics Information

http://mpas-dev.github.io/

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Model for Prediction Across Scales

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Error Characteristics of Two Grid Refinement Approaches in Aquaplanet Simulations: MPAS-A and WRF. Hagos, S., Leung, R., Rauscher, S. A., & Ringler, T., 2013, 141(9), 3022–3036. doi:10.1175/MWR-D-12-00338.1 (pdf)

2012

Exploring a Global Multi-Resolution Modeling Approach Using Aquaplanet Simulations. S. Rauscher, T. Ringler, W. Skamarock, and A. Mirin, 2012, J. Climate., 26, 2432-2452, doi:10.1175/JCLI-D-12- 00154.1 pdf

A Multi-scale Nonhydrostatic Atmospheric Model Using Centroidal Voronoi Tesselations and C-Grid Staggering. William C. Skamarock, Joseph B. Klemp, Michael G. Duda, Laura Fowler, Sang-Hun Park, and Todd D. Ringler. 2012 Monthly Weather Review, 240, 3090-3105, doi:10.1175/MWR-D-11-00215.1 pdf

2011

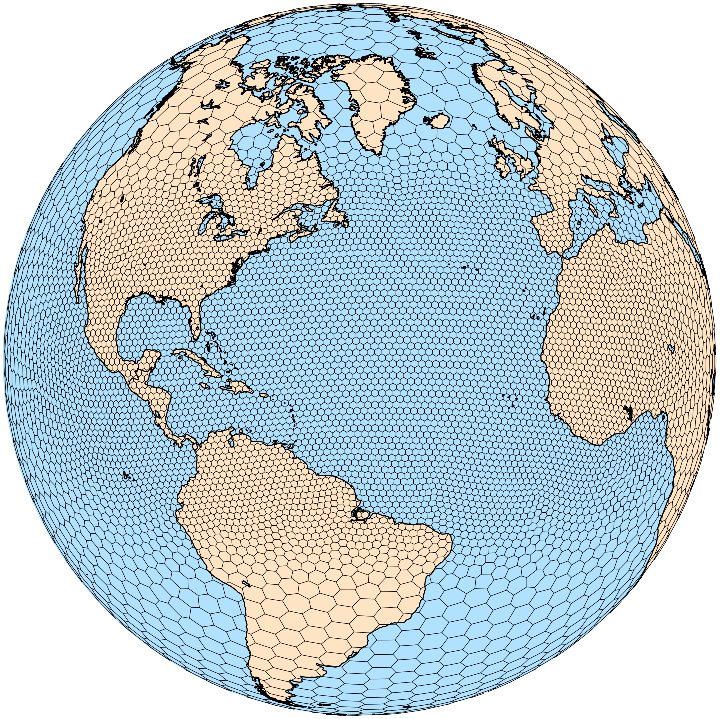
A Terrain-Following Coordinate with Smoothed Coordinate Surfaces. Joseph B. Klemp, 2011, Monthly Weather Review, 139(7), 2163–2169. doi:10.1175/MWR-D-10-05046.1

Conservative Transport Schemes for Spherical Geodesic Grids: High-Order Flux Operators for ODE-Based Time Integration. W. Skamarock and A. Gassmann, 2011, Monthly Weather Review, Vol. 139, pp. 2962-2975, doi:10.1175/MWR-D-10-05056.1 pdf

Exploring a Multi-Resolution Modeling Approach within the Shallow-Water Equations. Ringler, T., D.W. Jacobsen, M. Gunzburger, L. Ju, M. Duda and W. Skamarock, 2011, Monthly Weather Review, DOI:

MPAS

Model for Prediction Across Scales



- Overview
- Meshes
- Atmospheric solver, physics
- *Compiling and running MPAS*
- Summary
- Practical session

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Alternate slides

MPAS
Model for Prediction Across Scales

Physics

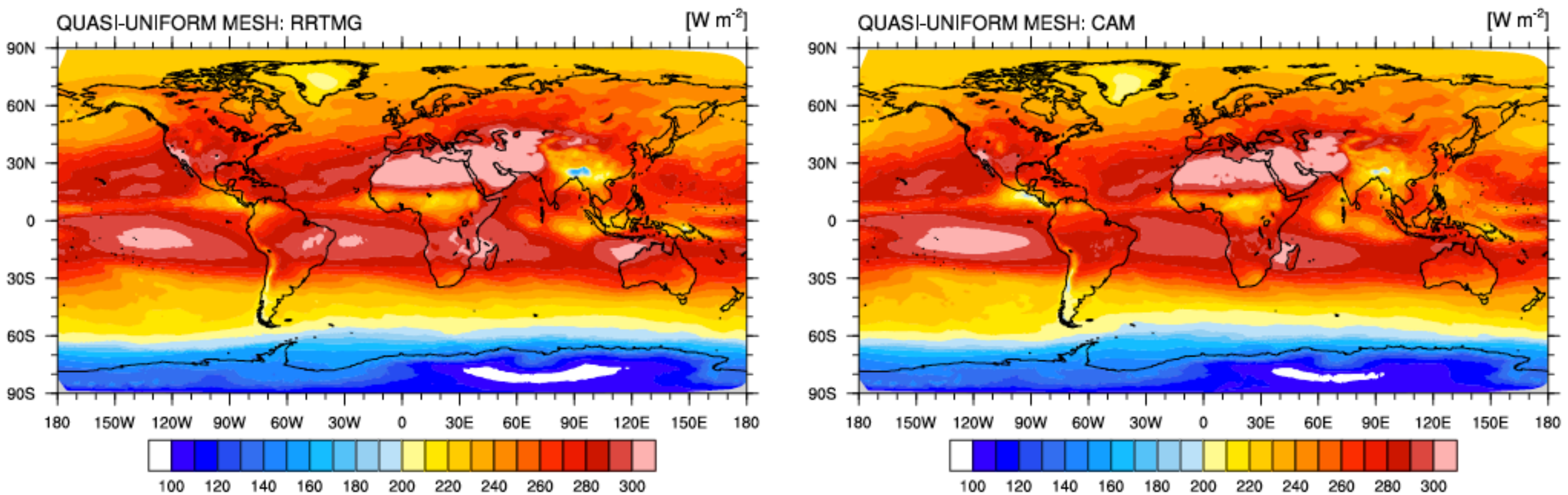
1a: Radiation

- Calculates the horizontal cloud fraction as a function of the relative humidity.
- Calculates SFC and TOA long- and short-wave radiation budgets.
- Calculates long- and short-wave radiation heating rates.

TWO OPTIONS:

- LW and SW RRTMG radiation codes (Iacono et al. 2008).
- LW and SW CAM radiation codes (Collins et al. 2004).

TOP-OF-ATMOSPHERE OUTGOING LONG WAVE RADIATION (W m^{-2})
JUNE 2005-JULY 2005-AUGUST 2005



Physics

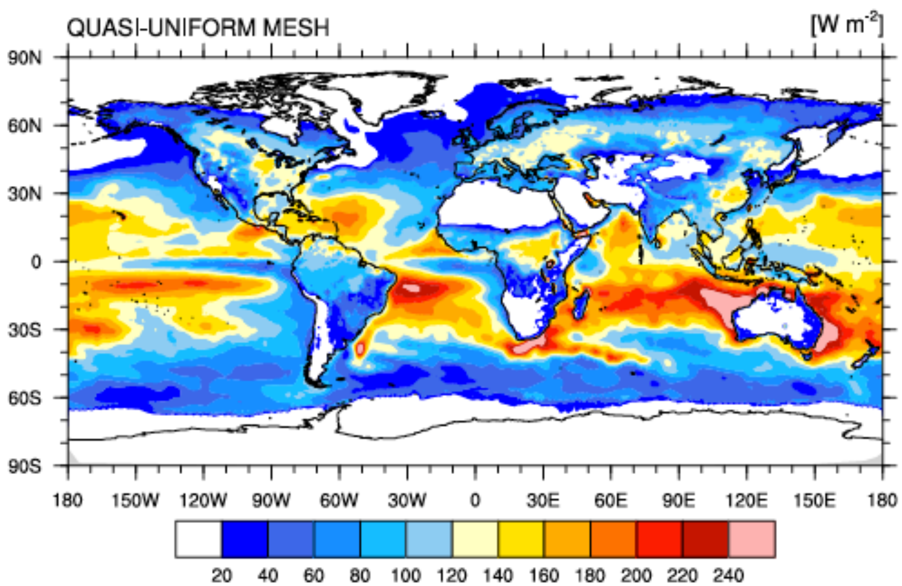
1b: Land-surface processes.

- Land-surface models parameterize the impact of soil and vegetation on the atmosphere.
- Land-surface parameterizations includes a vegetation model, a soil model, and a sea-ice model.

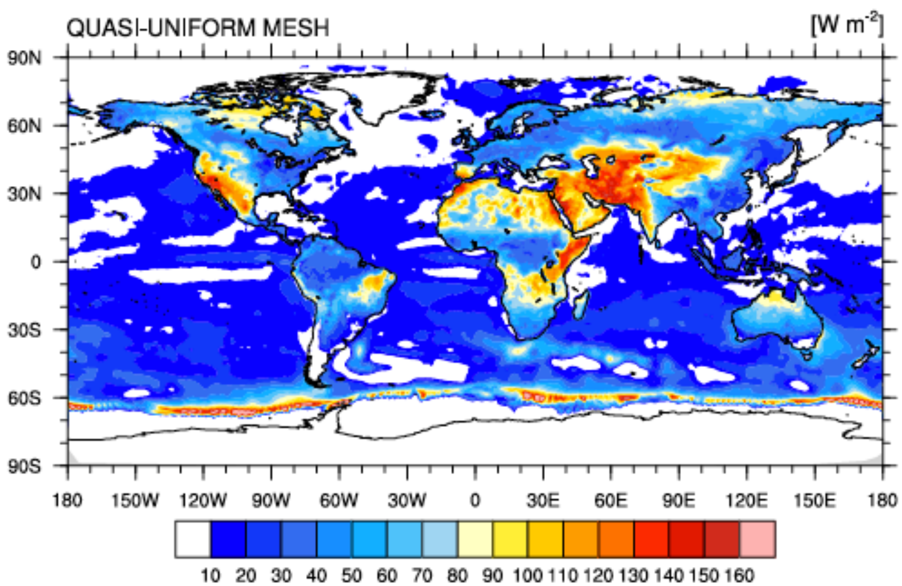
ONE OPTION:

- NOAH 4-soil layers land surface scheme (Chen and Dudhia 2001).

LATENT HEAT FLUX (W m^{-2})
JUNE 2005-JULY 2005-AUGUST 2005



SENSIBLE HEAT FLUX (W m^{-2})
JUNE 2005-JULY 2005-AUGUST 2005



MPAS
Model for Prediction Across Scales

Physics

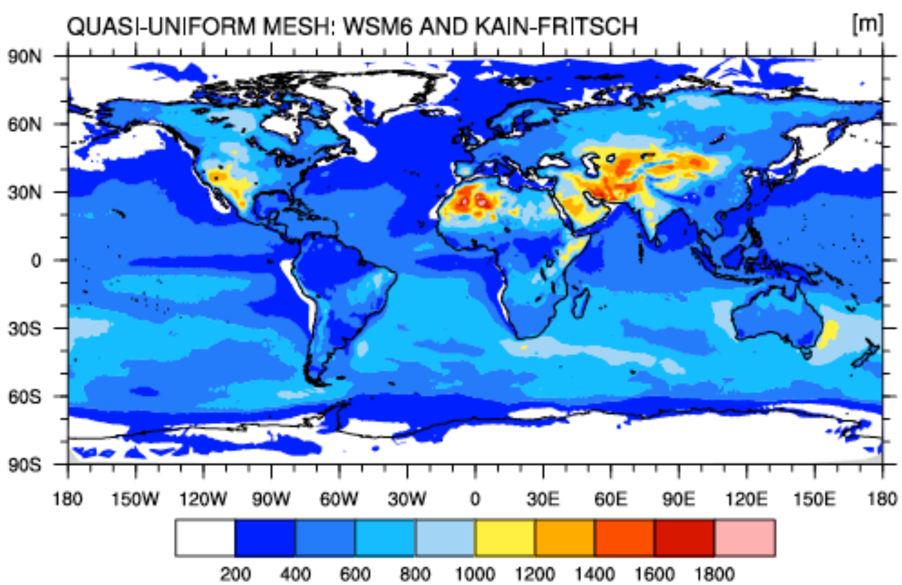
1c: Planetary Boundary layer and vertical mixing:

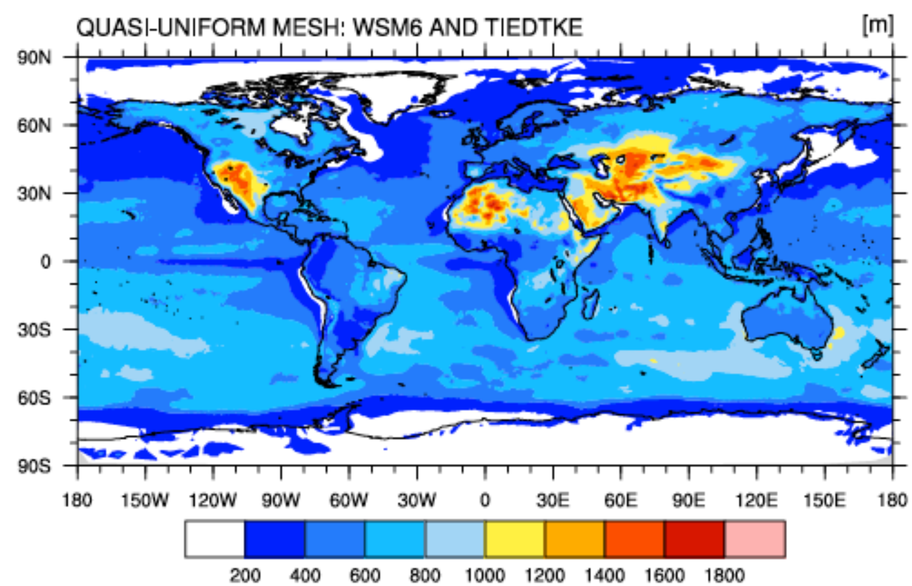
- Parameterizes the turbulent vertical transport of heat, momentum, and moisture between the Earth's surface and the free troposphere.
- Calculates the height of the PBL. Below the PBL top, the potential temperature is well mixed. Above the PBL top, the potential temperature monotically increases with height.

ONE OPTION:

- YSU PBL and YSU orographic wave drag (Hong and et al., 2006).

PLANETARY BOUNDARY LAYER HEIGHT (mm)
JUNE 2005-JULY 2005-AUGUST 2005





Physics

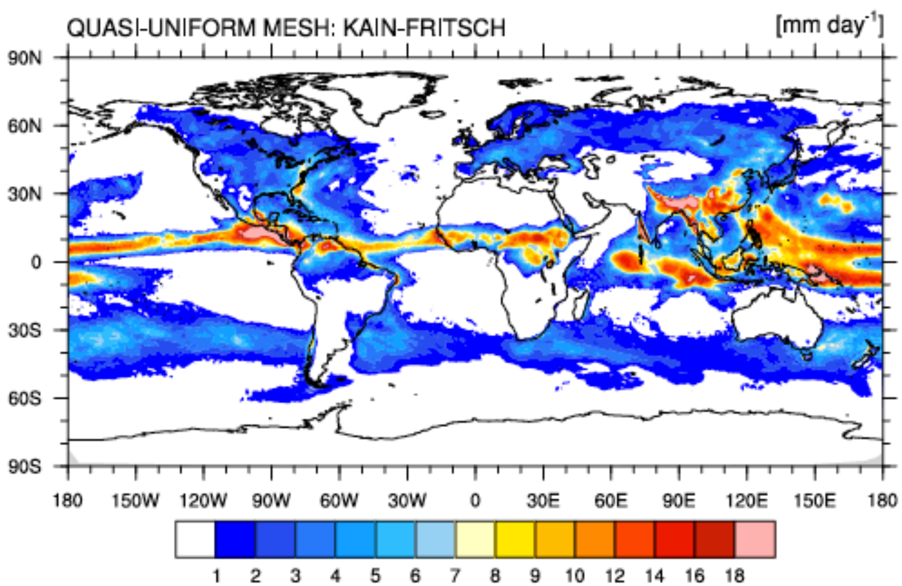
1d: Convection

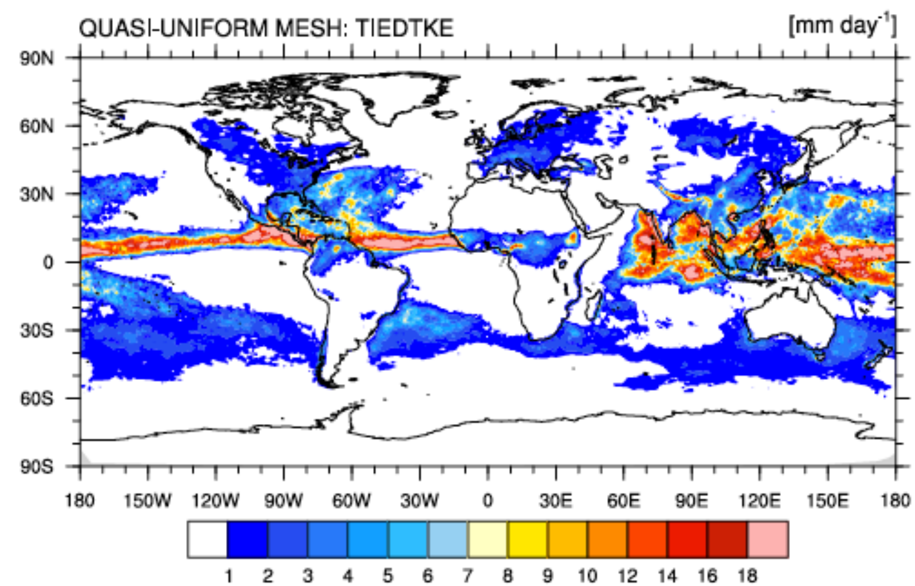
- Calculates convective heating and drying rates. Calculates detrainment rates of cloud water/ice, rain, and snow at the tops of convective updrafts.
- Calculates convective precipitation which falls instantaneously to the surface.

TWO OPTIONS:

- Kain-Fritsch (Kain, 2004; Kain and Fritsch 1990).
- Tiedtke (Tiedtke).

CONVECTIVE PRECIPITATION RATE (mm day^{-1})
JUNE 2005-JULY 2005-AUGUST 2005





MPAS
Model for Prediction Across Scales

Physics

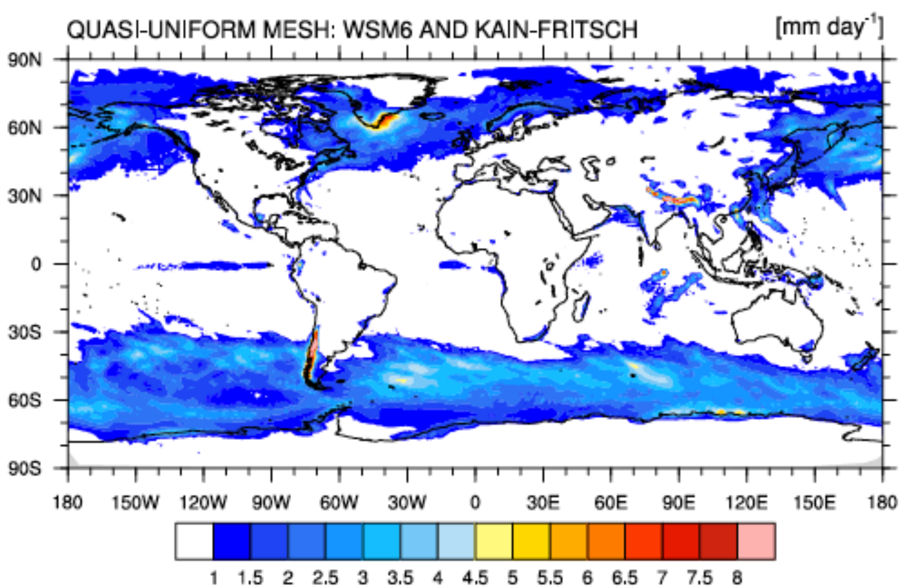
1e: Cloud Microphysics

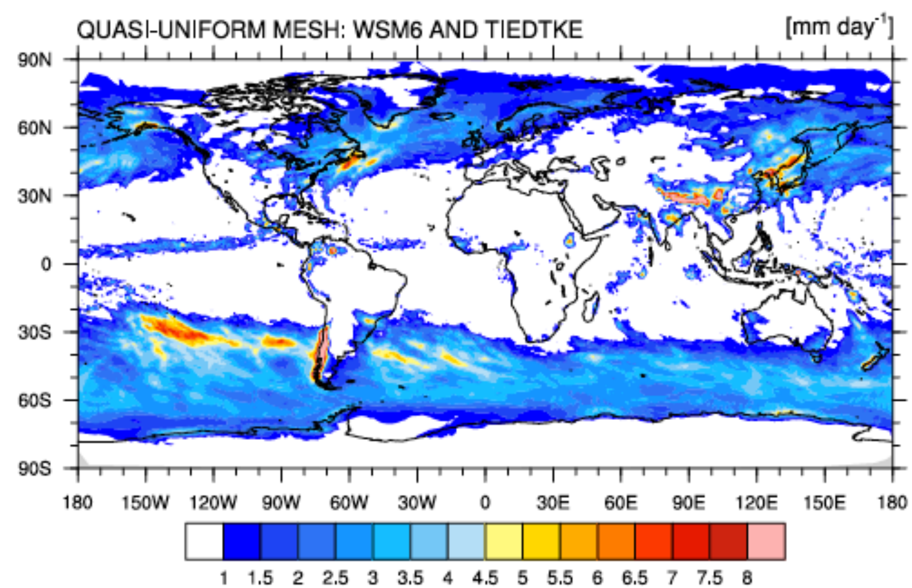
- Calculates changes in temperature, water vapor, and cloud water/ice species due to cloud microphysics processes.
- Grid-scale precipitation

TWO OPTIONS:

- WSM6 (Hong and Lim, 2006).
- Kessler (warm-rain).

GRID-SCALE PRECIPITATION RATE (mm day^{-1})
JUNE 2005-JULY 2005-AUGUST 2005





MPAS
Model for Prediction Across Scales

Configuring the dynamics and the physics

Physics schemes

(namelist.atmosphere)

```
&physics
  config_frac_seaice        = .false.
  config_sfc_albedo         = .true.
  config_sfc_snowalbedo     = .true.
  config_sst_update         = .false.
  config_sstdiurn_update    = .false.
  config_deepsoiltemp_update = .false.
  config_o3climatology      = .true.
  config_bucket_update      = 'none'
  config_bucket_rainc       = 100.0
  config_bucket_rainnc      = 100.0
  config_bucket_radt        = 1.0e9
  config_radtlw_interval    = '00:30:00'
  config_radtsw_interval    = '00:30:00'
  config_conv_interval      = 'none'
  config_pbl_interval       = 'none'
  config_n_microp           = 1
  config_microp_scheme      = 'wsm6'
  config_conv_deep_scheme   = 'tiedtke'
  config_lsm_scheme         = 'noah'
  config_pbl_scheme         = 'ysu'
  config_gwdo_scheme        = 'off'
  config_radt_cld_scheme    = 'cld_fraction'
  config_radt_lw_scheme     = 'rrtmg_lw'
  config_radt_sw_scheme     = 'rrtmg_sw'
  config_sfclayer_scheme    = 'monin_obukhov'
```

config_microp_scheme = 'wsm6' *(kessler, off)*

config_conv_deep_scheme = 'tiedtke' *(kain_fritsch, off)*

config_lsm_scheme = 'noah' *(off)*

config_pbl_scheme = 'ysu' *(off)*

config_gwdo_scheme = 'off' *(ysu_gwdo)*

config_radt_cld_scheme = 'cld_fraction' *(off, cld_incidence)*

config_radt_lw_scheme = 'rrtmg_lw' *(off, cam_lw)*

config_radt_sw_scheme = 'rrtmg_sw' *(off, cam_sw)*

config_sfclayer_scheme = 'monin_obukhov' *(off)*