Aerosols effects on Numerical Weather Prediction through impacts to the microphysics

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Objective

Examine the sensitivity of aerosol effects on short-term NWP.

- Implement aerosol processing into the 2-moment *Milbrandt and Yau (2005)* bulk microphysics scheme
- Focus on warm-phase clouds, in a first step
- Explicitly predict the concentration of available aerosols (N_{aero})
- Nucleate cloud droplets from explicit N_{aero}

Budget equation for N_{aero}

$$\frac{dN_{aero}}{dt} = -\left(\begin{matrix}\text{rain collecting}\\ \text{aerosols}\end{matrix}\right) - (\text{CCN activation}) + \left(\begin{matrix}\text{cloud and rain}\\ \text{evaporation}\end{matrix}\right) + \left(\begin{matrix}\text{surface}\\ \text{emissions}\end{matrix}\right)$$

Thompson and Eidhammer (2014)

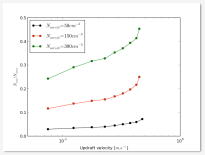
Milbrandt and Yau (2005)

CCN activation

- Extended from *Cohard et al. (2000)*
- Bounded activation spectra:

$$N_{CCN} = C\,S_{\max}^{k}\,F\left(S_{\max},\mu,k,\beta\right)$$

- Diagnostic maximum supersaturation S_{max}
- μ,k,β indirectly from the type of aerosol: Continental vs Maritime
- C from the type and the initial input $N_{aero,0}$



Fraction of activated CCN as a function of W for Maritime aerosol at different $N_{aero,0}$

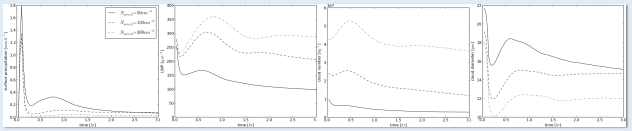
Kinematic idealized case

Objective Employ a kinematic cloud model - Kinematic Driver (KiD) to compare microphysics schemes when considering in-cloud processing aerosol.

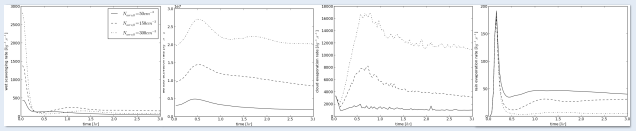
Stratocumulus 2D idealized case study:

(Morrison and Grabowski, 2007)

- Sensitivity to the **aerosol chemical composition**
- Sensitivity to the **aerosol number concentration**
- Sensitivity to the **vertical velocity**, *W*



Time series of domain-averaged surface precipitation rate, LWP, droplet number concentration and diameter for W=0.50 m.s^{-1} and Maritime type aerosol, at different initial aerosol number concentrations.



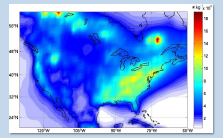
Time series of domain-averaged wet scavenging rate, aerosol activation rate, cloud evaporation rate and rain evaporation rate for W=0.50 m.s^{-1} and Maritime type aerosol, at different initial aerosol number concentrations.

3D real case

Initial input aerosol

(Thompson and Eidhammer, 2014)

- Combination of primary aerosol sources: sulfates, organic carbon and sea salts
- Monthly climatology from GOCART model with 0.5°(lon) x 1.25°(lat) spacing
- Mass converted to number concentration by assuming log-normal distributions
- Using a Land-Sea mask to determine the activation spectra coefficients (Continental vs Maritime)

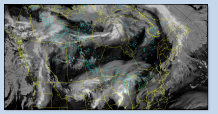


July aerosols climatology at model level near the surface.

NWP context

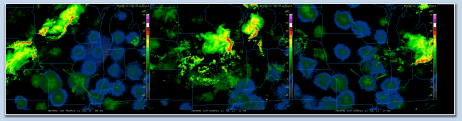
Env. Canada's High Resolution Deterministic Prediction System (HRDPS)

- 4 x 48h forecasts daily (as of Nov 18, 2014)
- GEM (Global Environmental Multiscale)
- 2.5 km grid spacing
- pan-Canadian LAM (Limited Area Model) domain
- nearly all clouds and precipitation represented by bulk microphysics scheme
- Currently limitation:
  N_{aero} is constant in time and space

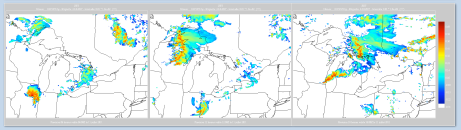


HRDPS pan-Canadian domain Column maximum reflectivity

July 11, 2011: Derecho event near Great Lake



NEXRAD 1km MOSAIC (UTC – dBZ)



Equivalent Reflectivity 1km from GEM-2.5 km (UTC – dBZ)

References

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