Using the Weather Research and Forecasting (WRF) atmospheric model to predict explicitly the potential for icing

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Goals/Motivation

Develop an efficient and observations-based bulk microphysical parameterization:

• improves quantitative precipitation forecasts
  ➢ when compared to similar, existing schemes

• improves forecasts of water phase everywhere
  ➢ aloft=aircraft icing; surface=FZDZ/RA/SN

• incorporates recent microphysical observations
  ➢ AIRS / IMPROVE / ICE-L / NASA-SLDRP

• is sufficiently optimized/fast
  ➢ real-time needs (WRF-Rapid Refresh)

• uses clean, well-documented code
  ➢ can be modified rapidly to increase complexity and perform sensitivity studies
Cloud water characteristics

Assumed gamma distribution:
\[ N(D) = N_0 D^{\mu} e^{-\lambda D} \]

Produces realistic median volume diameters (MVD) that differ between maritime and continental air sources

Subsequently affects rain development
Physical process and code improvements

• Snow is considered non-spherical and its density varies inversely with size as observed.

• Autoconversion uses correctly computed characteristics diameters.

• Cloud droplet size distribution utilizes variable shape parameter dependent on number concentration, therefore mean size varies following observations by Martin et al, 1994.

• Graupel y-intercept parameter (and terminal velocity) attempts to mimic hail in strong updrafts.

• Rimed snow to graupel conversion does not utilize thresholds but varies gradually depending on riming-to-deposition growth rates.

• Snow terminal velocity gets boosted by 10–50% when heavy riming; also melted snow/graupel fall faster not slower.

• Collisions between hydrometeors with similar fallspeed (rain & graupel) uses explicit bin method to compute collection.

• Code:
  ‣ clean, well-documented
  ‣ generalized gamma distributions and simple mass/velocity–diameter relations
  ‣ look-up tables for most costly calculations (collection)
Recent research activities

• snow sensitivity tests: sphericity, density, and size distribution:

• comparisons to Geresdi bin scheme and other bulk schemes:
  ➢ Hong (WSM6), Morrison, Seifert

• real-time WRF ICE–L project simulations
  ➢ wave cloud, ice initiation, aerosols

• WMO workshop (Cozumel)
  ➢ 2-d/3-d squall line simulations

• two-moment rain introduced
  ➢ predicting rain number concentration

• Colorado Headwaters project
  ➢ high resolution orographic winter precip

• Case studies:
  ➢ Aircraft and structural icing
  ➢ Convection: supercells & squall lines
  ➢ Vancouver Olympics preparations
WRF forecasts for ICE–L project

NCAR C–130 wave cloud flight near Wheatland, WY 2035–2125 UTC 16 Nov 2007
WRF forecasts for ICE–L project

WRF (1.33–km grid) 21-hour forecast valid 2100 UTC 16 Nov 2007
Case studies: aircraft icing–1998Jan30

>95% of water mass in drops less than 30 microns
1998 Jan 30 model vs. obs
1998Feb04 – Aircraft icing

- Widespread, deep, glaciated cloud
- Classic “warm nose” with FZRA on WV/OH border
- Twin Otter experienced a “significant performance degradation”
Luosto fell test site, case 1 (19-20 Apr 2006)

- Ground structural icing cases
- Hirvonen et al, 2007
- WRF (v3.0.1.1)
  - spacing = 3.0 km
  - 85 vertical levels ($z_1 = 13$ m)

- Light/moderate icing
- Very light snow observed and forecast
- Intermittent icing observed and forecast
Luosto fell test site, case2 (15 Feb 2006)

- Moderate/severe icing
- Long duration, low-level stratus cloud
- Model predicted widespread, long-lived cloud with liquid water content approx 0.3 g m$^{-3}$
- Model does not predict end of event
Luosto fell test site, case3 (07-10 Feb 2006)

- Moderate/severe icing
- Long duration, low-level stratus cloud
- Model predicted long-lived, mixed-phase cloud with base above ground
- Intermittent light snow
Future research

• Vancouver 2010 Winter Olympics
  - fog, visibility, & other wx impacts to venues
  - high-resolution (~250–500 meters)
  - automated nowcast system

• Aircraft and ground structural icing
  - More case studies
  - Higher resolution (at or below 1 km)
  - Apply Markonen accretion equations
  - Present latest results at IWAIS (Andermat, Sep 2009)

• Two-moment cloud water and CCN activation

• Add dust/mineral category
  - initiate ice
  - Pac-DEx, ICE–L field project data
Icing on dog (Guinness)
Thank you

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