ECCC FOG RESEARCH

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C-FOG PROJECT

Toward Improving Coastal Fog Prediction
Project Goal

• Comprehensive research program with emphasis:

• On sub-grid dynamic, thermodynamic, and microphysical processes relevant to NWP and other numerical forecasting models e.g., NOWCASTING

• Improve coastal fog prediction
ISSUES/RESEARCH

• Project design
• Microphysical issues
• Large scale processes
• Dynamical processes
• Radiation effects
• NWP issues
• Nowcasting/integration
• PREDICTIONS
INSTRUMENTS AND OBSERVATIONS

- Microphysical (fog and precip)
- Aerosols (CCN)
- Dynamical, turbulence, fluxes (wind and gust)
- Radiation (SW and IF BRF)
- Remote sensing sensors (Ceilometer, MWR, MRR, Gondola, and UAV.... Lidar, Balloon)
- Satellite observations e.g., GOES-R
- *Ship based observations*
- *Buoy based observations*
CCN parameterizations

Table 2. Values of the adjusted parameters for activation spectra described by Twomey's power law and by expression (10) for the polluted and clean air cases of Hudson and Li (1995).

<table>
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<tr>
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<th>$N_{CCN}$ = $C_{S^k_{u,w}}$</th>
<th>$N_{CCN}$ = $C_{S^k_{u,w}}F(\mu, -\beta_s^2_{max})$</th>
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<tbody>
<tr>
<td></td>
<td>$C$ (cm$^{-3}$) $k$</td>
<td>$C$ (cm$^{-3}$) $k$ $\beta$ $\mu$</td>
</tr>
<tr>
<td>Polluted air</td>
<td>986 0.64</td>
<td>1865 0.86 6.80 1.50</td>
</tr>
<tr>
<td>Clean air</td>
<td>243 1.57</td>
<td>1104 2.07 6.84 1.90</td>
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$N_{CCN} = C_{S^k_{u,w}}$ to fit realistic size range of $s_{u,w}$.

Figure 2. Observed versus predicted CCN concentrations for supersaturations ranging between 0.1 and 1%. The whole dataset used in this study is shown.
(a) **The UOIT PUMS supersite** for boundary layer research and aviation meteorology applications. The Data Acquisition System (DAS) is kept inside the trailer. Pluvio and 2D sonic wind measurements used for snow measurements within Double Fenced Intercomparison Reference (DFIR) system is seen on the right. The rest of the sensors are over the trailer or attached to the tressel. The WE-UAV is given in the inlet at the left top corner of the picture.
UAV Meteorological monitoring

CH4 and CO2

Na [cm^{-3}] >0.3 and 0.5 micron
Visibility and Precip Sensors

Figure 1b-h: Visibility sensors are given in (b) PWD50, (c) SWS, (d) Sentry, and (e) OSI, (f) LPM for precipitation, (g) FMD for fog spectra (DMT Inc.), and (h) for other precipitation sensors without shelters, as well as CL51 ceilometer.
FOG AND SNOW OBSERVATION TOWER (FSOS TOWER) FOR SATELLITE SITES
GCIP RAIN AND SNOW SPECTRA (10-1000 MICRON)

GROUND AND SKY IR TEMPERATURE

UAV MET SENSORS

SOLAR AND IR BROADBAND RADIATIVE FLUXES
GONDOLA FOR ICING SENSORS

ICING RESEARCH AT PUMS

FOG AND SNOW/DRIZZLE PROBE (CIP)

Rosemount Icing Detector (RID)
MWR
Profiles of T, RH, and Qv
Radiometrics MWR: LWP, RHi, and T (color bar)
LWP is shown by black solid line.

In the end of ice fog event, very small LWC is indicated by radiometer LWP.
Jan 14 2011 St. John’s; vis versus hydrometeor type

FD12P- Visibility: Jan 14 2011

Visibility [km]

Time [hh:mm:ss]

Clear
Haze
Mist
Fog
Indeterminant
Drizzle
Rain
Snow
Freezing Rain
Ice Pellets
Snow Grains
Ice Crystals
Rain Showers
Snow Showers
Hail Showers
ICE FOG

Both FMD and CAP sensors indicated ice fog conditions; Ni~100 cm$^{-3}$ and ~50 cm$^{-3}$, respectively. IWC reached 0.1 g m$^{-3}$.

Models can’t predict these conditions for ice fog.
Ice fog microphysical algorithms based FMD fog device

A cloud radar Z can be used for Vis nowcasting

Ice fog Vis can be predicted using IWC and Ni simulated by NWP models
Vis=f(SW+IR) can be used for fog dissipation prediction

Equation: $y = -4.5265e^{-0.05} x^2 + 0.047629 x + 0.51791$
- RMSE = 2.9703
- Corr Coeff = 0.9880; for Net RF

Equation: $y = 2.1417e^{-0.05} x^2 + 0.021488x + 0.065715$
- RMSE = 2.7038
- Corr Coeff = 0.9502; for Net SW RF

Equation: $y = 1.4368e^{-0.05} x^2 + 0.0065492 x + 0.10897$
- RMSE = 2.7077
- Corr Coeff = 0.9761; for SW incoming RF
SATellite Based Research
JUNE 13 2005
SST-NOAA-16
23 MAY 2018
WIND FORECAST
GOES-R IMAGES FOR C-FOG
Raman Lidar

David Whiteman
Howard University Research Campus, Beltsville, MD
Additional Processing of Oct 19 ALVICE Data

- Study Cirrus Clouds and RR Temperature Calculation
- Products
  - Water vapor mixing ratio
  - Temperature
    - time series under development
  - RH (water, ice)
    - under development
  - Cirrus
    - depolarization
    - backscatter coefficient
    - optical depth
    - Ext/back ratio
October 18, 2017

- ALVICE measurements of water vapor, cirrus clouds, temperature, aerosol depolarization
Water Vapor Profiling during PECAN

- Water vapor profiles can extend into the lower stratosphere
- Lidar charts time evolution of water vapor versus a single profile of the radiosonde
Proposed Instrumentation for C-FOG

AEROSOLS

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May 18, 2018
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Fog Inlet

- uses virtual impaction to separate droplets > 2.5 µm from interstitial aerosol
- measure aerosol properties of both dried droplet residuals and interstitial aerosols to understand droplet activation

Fog Droplets

Unactivated Particles

Measure:
- Aerosol Size Distribution
- Chemical Composition
- Hygroscopicity
Instruments

• Behind fog inlet
  – **Scanning Mobility Particle Sizer (SMPS)**
    • measures particle size distribution (10-500 nm)
  – **Aerosol Chemical Speciation Monitor (ACSM)**
    • measures particle chemical composition (100-800 nm)
  – **Cloud Condensation Nucleus Counter (CCNC)**
    • measures number of CCN at set supersaturation

• Outside
  – **Passive and active fog water collectors**
Instruments in the field

SMPS

ACSM
WRF model applications for fog forecasting

Figure 7: The $Q_v$, $N_i$, IWC, and Vis obtained from the WRF simulations (using 10 km grid resolution) on 08:00 LST, January 12 2011 over Yellowknife International Airport are shown in Figs. 7a-d for Milbrandt and Yau, in Figs. 7e-h for Morrison et al, in Figs. 7i-l for Thompson et al schemes, respectively.
DISCUSSIONS

• Scientific issues (nucleation,.....)
• Instrument issues (Gondola/UAV/Balloon etc)
• Instrument distribution e.g. fog devices
• Project design and instrumented sites
• IOPs and duration