MATERHORN-Fog field project:
Overview and Initial Results

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Project goals

• Develop instrument system for ice fog measurements

• Better understand and predict Ifog/Wfog conditions over complex terrain
Definition of fog

**Warm fog**
- RHw\~100\% and Vis<1 km

**Cold fog**
- **Freezing fog**: \(T_g<=0\degree C; \text{RHw}\~100\%; \text{Ta}\sim 0\degree C\) (freezing at surface)
- **Frozen fog**: \(-10\degree C<T_a<=0\degree C; \text{RHw}\sim100\%\) (freezing happens in the air)
- **Ice fog**: \(T_a<-10\degree C; \text{RHi}>100\%\) (Depositional nucleation)
ICING AND FOG TYPE

Jan 7: IF
Jan 16: FF & IF
Jan 30: IF
Jan 7 Ice/FF Fog Case
Jan 7 Ice Fog Case
Jan 7 Ice Fog Case
PROFILING TOWERS

Heber City

T1

T2

T3

Salt lake City

EC-T1

EC-T2

Heber City

EC-T2

PROFILING TOWERS
REMOTE SENSING PLATFORMS FOR ATMOSPHERIC PROFILING

SODAR

CEILOMETER C31

LIDAR

PMWR
EC(Microphysics), UU, and NDU INSTRUMENTS

- Licor gas analyzer; provides CO2 and H2O turbulent fluxes
- CMP21 pyranometers (SW)
- CGR4 pyrgeometers (LW)
- Ultrasonic anemometer
- Thermocouples
- FMD Fog
- WXT-T/RH
- PWD52 Vis-Precip
- CAP Aerosol
- Light sensor
- LPM Precip spectra
- Licor turb flux analyzer
- Fog collector
- Vis-Precip WXT-T/RH
- Fog collector
- PWD52 Vis-Precip
- Ultrasonic anemometer
- Thermocouples
FOG TOWER

COMPACT MET UNIT

LPM PRECIP SENSOR

FD12P-VIS

MAP Nd (0.3-10 micron)

MINI-VIS

IR-SW SENSORS

IR BASE T

CAMERA

3d-WIND SENSOR
PRELIMINARY RESULTS

Backscatter CL31 Heber Valley

10 Jan 2015

Time (MST)

Height (m AGL)

Height (m ASL)

$\beta \text{ [m}^{-1} \text{ sr}^{-1}]$
LIDAR MEASUREMENTS

Backscatter and VAD winds

Time (MST)

Height (m AGL)

Time (UTC)

β [m⁻¹ sr⁻¹]

Height (m ASL)

5 m/s

FOG
RH time series Jan 7

- Relative Humidity [%]
- Time (MST)

Data from Tue Jan 06 00:00:00 2015 to Wed Jan 07 00:00:00 2015.
T time series Jan 7

The diagram shows a time series of temperature [°C] over a period from Jan 6, 2015, to Jan 7, 2015. The x-axis represents time (MST), with marks at 00:00, 06:00, 12:00, and 18:00. The y-axis represents temperature [°C], with values from -20 to 15. The data is color-coded for different depths, ranging from 1m to 28m, with specific depths marked on the right side of the graph.
IR AND SW RFLUX time series

- SW_IN
- SW_OUT
- ALBEDO
- ETR

- LW_IN
- LW_OUT

Irradiance [W m$^{-2}$]
Jan 16 ice fog case (Heber City)

LWC = 0.25 g m\(^{-3}\)

Nd = 300 cm\(^{-3}\)

N = 25 counts

50 micron
Na time series; >0.3 micron over 8 channels

Na/1000[cm-3]

FOG
LWC and Nd time series

LWC [gm⁻³]

Nd [cm⁻³]

24:00 UTC
ICE FOG

FREEZING FOG

T°C

VIS

1200 UTC
Jan 16 ICE FOG/FF
RH time series
IR AND SW IRRADIANCES FOR JAN 16 IF/FG
LWC (g/m^3)--Nd [cm^-3]

\[ y = 3 \times 10^{-7}x^2 + 0.0007x \]

\[ R^2 = 0.6824 \]
Visibility vs. \(1/(LWC \times N_d)\) (\(\Delta t = 1\) sec), 27-Jun-2006

\[ \text{Equation: } y = 0.87706 \times 0.49034\]
RMSE = 1.0713
Corr Coeff = 0.9673

\[ \text{vis} = 1.02(LWCxN_d)^{-0.52} \]
ICE FOG (<100 MICRON)
FOG DROPLET SIZE IMAGE

Fog Monitor Bin for: 23/05/2013

# Conc [#/cm^3]

Time [hh:mm:ss]

[Graph showing fog droplet concentration over time]
3D Ultrasonic anemometer for 1-s wind measurements

High wind speed caused by icing

Figure 14: Time series of 1Hz wind components from Young 3D anemometer sensor for Jan 17 (top box) and for Jan 18 (bottom box) 2013. Black solid line is for 60 sec-averaged vertical air velocity (green lines).
LPM PRECIP SPECTRA

Droplet fall velocity

DIAMETER;
Max=1 cm
Max size=1 cm

Nd=20 counts

MtPearl 12/31/2012 12:18:00 AM (1.357 mm/h)
**Fig. 6:** Sows incoming SW broadband radiative fluxes versus time for various days during FRAM-L1. The data points for the 17 June and 2 July 2006 represent clear air conditions. Others represent either foggy (e.g., 19 June) or foggy plus rainy conditions (e.g., 15 June). The days with lines are for foggy conditions except for the 15 June 2006 case. Mean and standard deviation for entire day for each case are also shown on the figure.
1. Parameters needed are for ice fog: IWC, Ni, RHi, and T
2. Parameters needed are for liquid fog: LWC, Nd, RHw, and T
3. A cloud model or a forecast model with a good resolution of time and space resolution that will resolve weather events e.g. fog
4. Then, Vis is obtained for fog regions with extinction calculations based on IWC and Ni
ICE MICROPHYSICAL ALGORITHMS FOR THE NUMERICAL CLOUD/FORECAST MODELS

1. Milbrandt and Yau
2. Morrison et al
3. Thompson et al

All these have some kind of assumptions related to IN and size distributions
Extinction versus $X_p$

$\beta_{ext}$ [Km$^{-1}$]

$X_p = \text{IWC} \cdot N_{i2ds}$ [g m$^{-3}$ L$^{-1}$]

1-s Observations
Averages
Fit to Averages
IWC water content ($\Delta t = 1 \text{sec}$), 10-Apr-2008

Ice Water Content [gm$^{-3}$] vs Ice Crystal Number Concentration [cm$^{-3}$]
Visibility vs. $1/(\text{IWC} \times \text{Ni})$ ($\Delta t = 1\text{ sec}$), 10-Apr-2008

Equation: $y = 0.24193 \times 0.51472$
RMSE = 0.0064109
Corr Coeff = 0.9744
ICE FOG MICROPHYSICAL PARAMETERIZATION FOR FORECAST MODELS

\[ \text{Vis} = 1.19 (IWC \bullet N_i)^{-0.5066} \]

To predict Ice fog visibility from the models, we need to estimate following parameters

- IWC (large uncertainty, 100%)
- Ni (large uncertainty, 100%)
- \( RHi (T, Tf) > 10\% \) in \( Rhi \)

AMS Bull. 2013; Gultepe et al
WRF MODEL SIMULATIONS OF ICE FOG DURING FRAM PROJECT

- a) Qv Millbrandt–Yau
- c) Qv Morrison
- e) Qv Thompson
- b) Ni Millbrandt–Yau
- d) Ni Morrison
- f) Ni Thompson
WRF MODEL SIMULATIONS OF ICE FOG DURING FRAM PROJECT

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.
FOG MEASUREMENT AND PREDICTION ISSUES
1. **We can’t predict fog using numerical models if measurements are not done properly.**

2. **We need accurate measurements of fog particles representing various meteorological conditions.**

3. **Time and space scales need to be resolved, for larger scales satellite-based fog predictions are needed.**
FUTURE WORK

- Do case studies for Jan 7 and Jan 30
- Evaluate statistics for Jan 2015 for Vis versus IWC and Ni
- Develop ice fog microphysical parameterizations
- Improve prediction of ice fog using WRF or other forecasting models