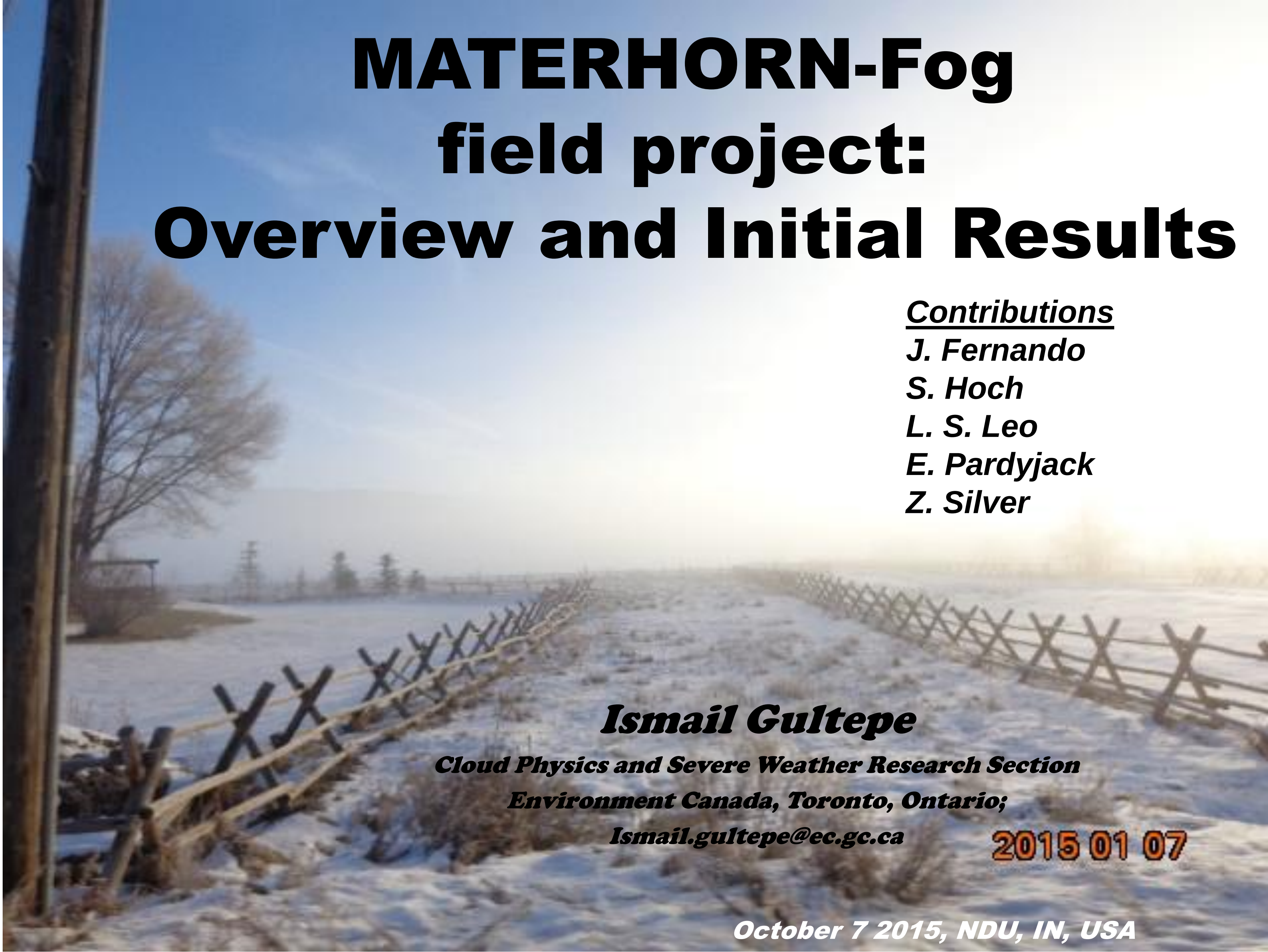
MATERHORN-Fog field project: Overview and Initial Results

Contributions
J. Fernando
S. Hoch
L. S. Leo
E. Pardyjack
Z. Silver

Ismail Gultepe
Cloud Physics and Severe Weather Research Section
Environment Canada, Toronto, Ontario;
Ismail.gultepe@ec.gc.ca



October 7 2015, NDU, IN, USA

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:** Tg<=0C; RHw~100%; Ta~0C (freezing at surface)

→ **Frozen fog:** -10C<Ta<=0C; RHw~100% (freezing happens in the air)

→ **Ice fog:** Ta<-10C; 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

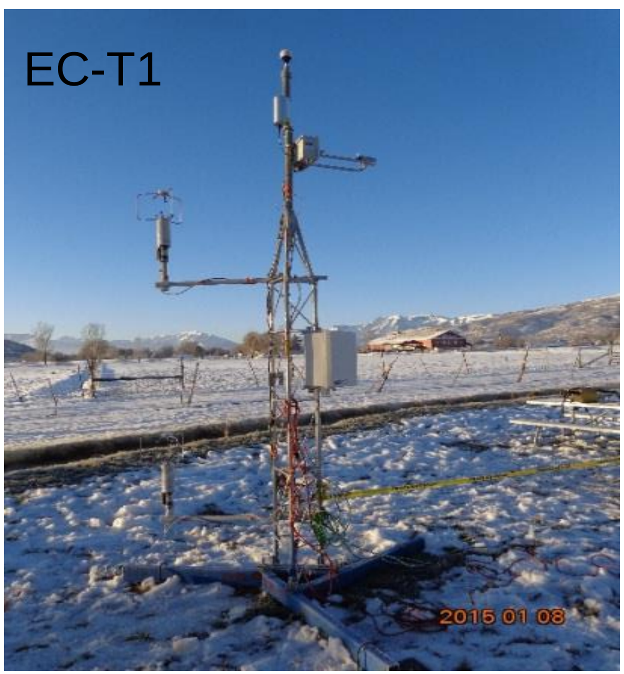
EC Towers

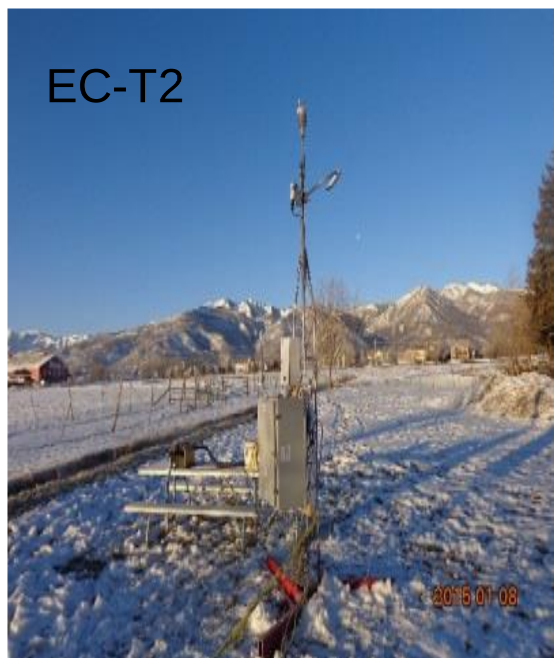
PROFILING TOWERS

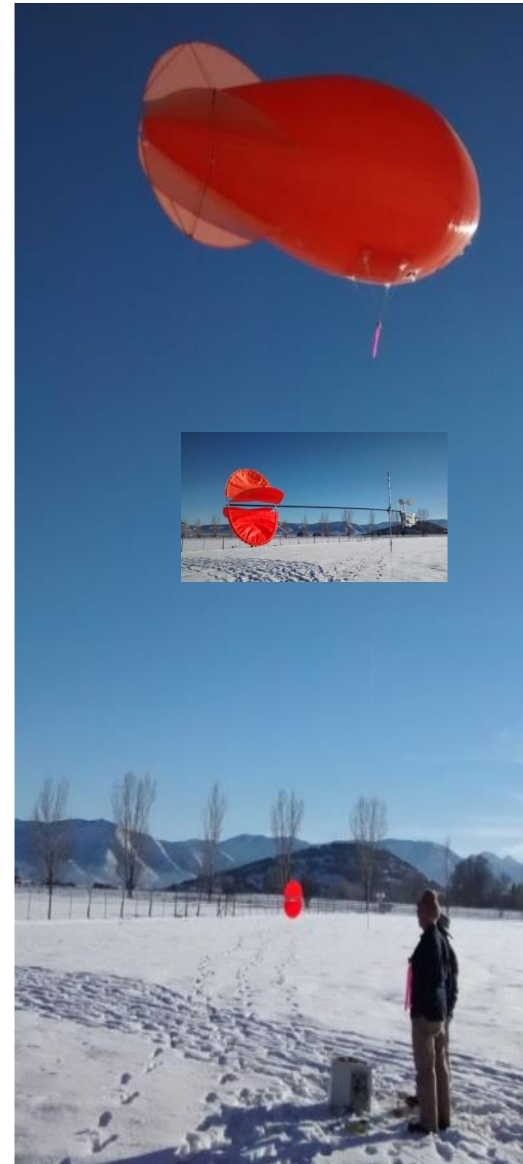
Heber City

Heber City

Salt lake City







REMOTE SENSING PLATFORMS FOR ATMOSPHERIC PROFILING

SODAR

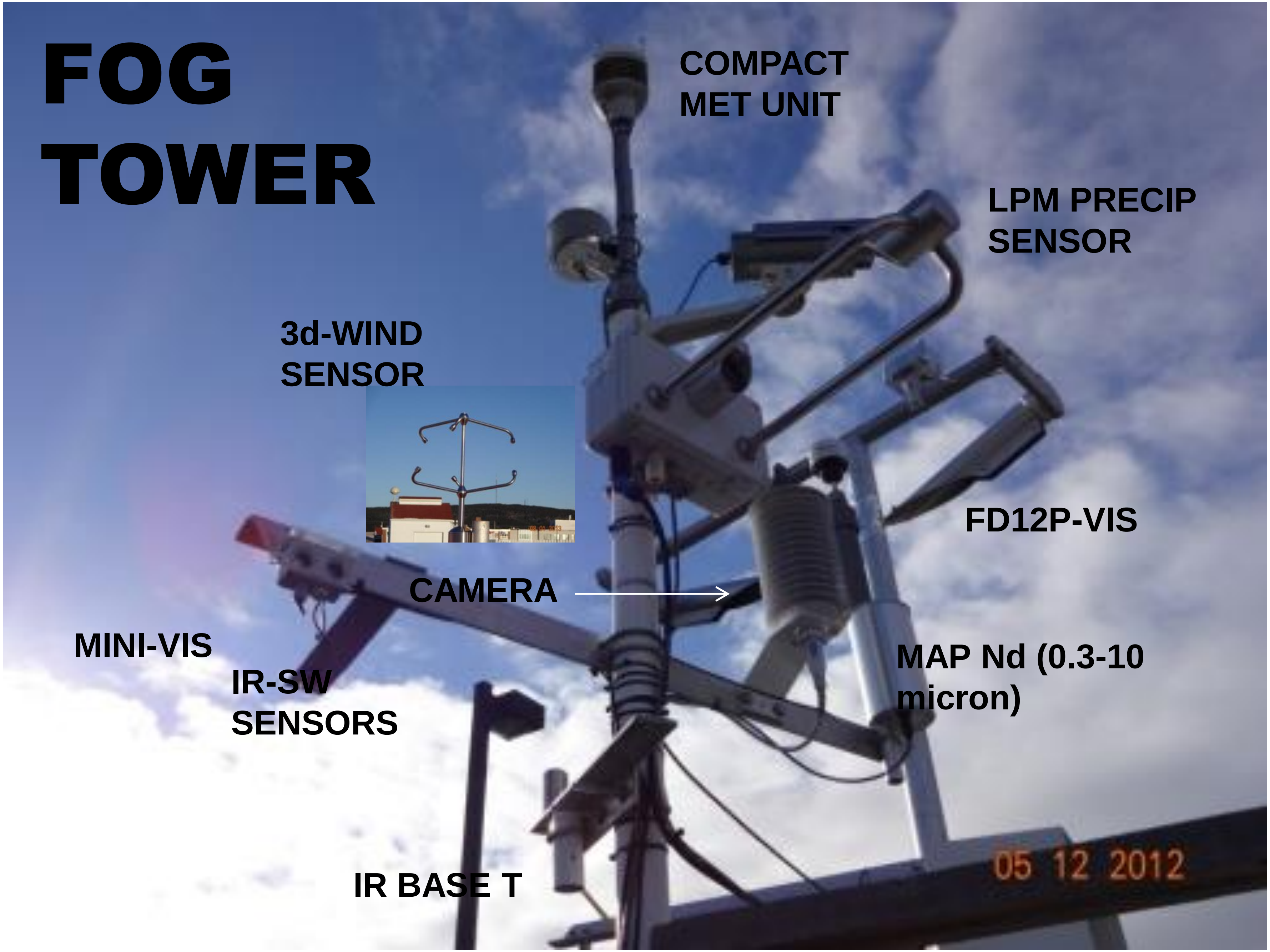
CEILOMETER
C31

LIDAR

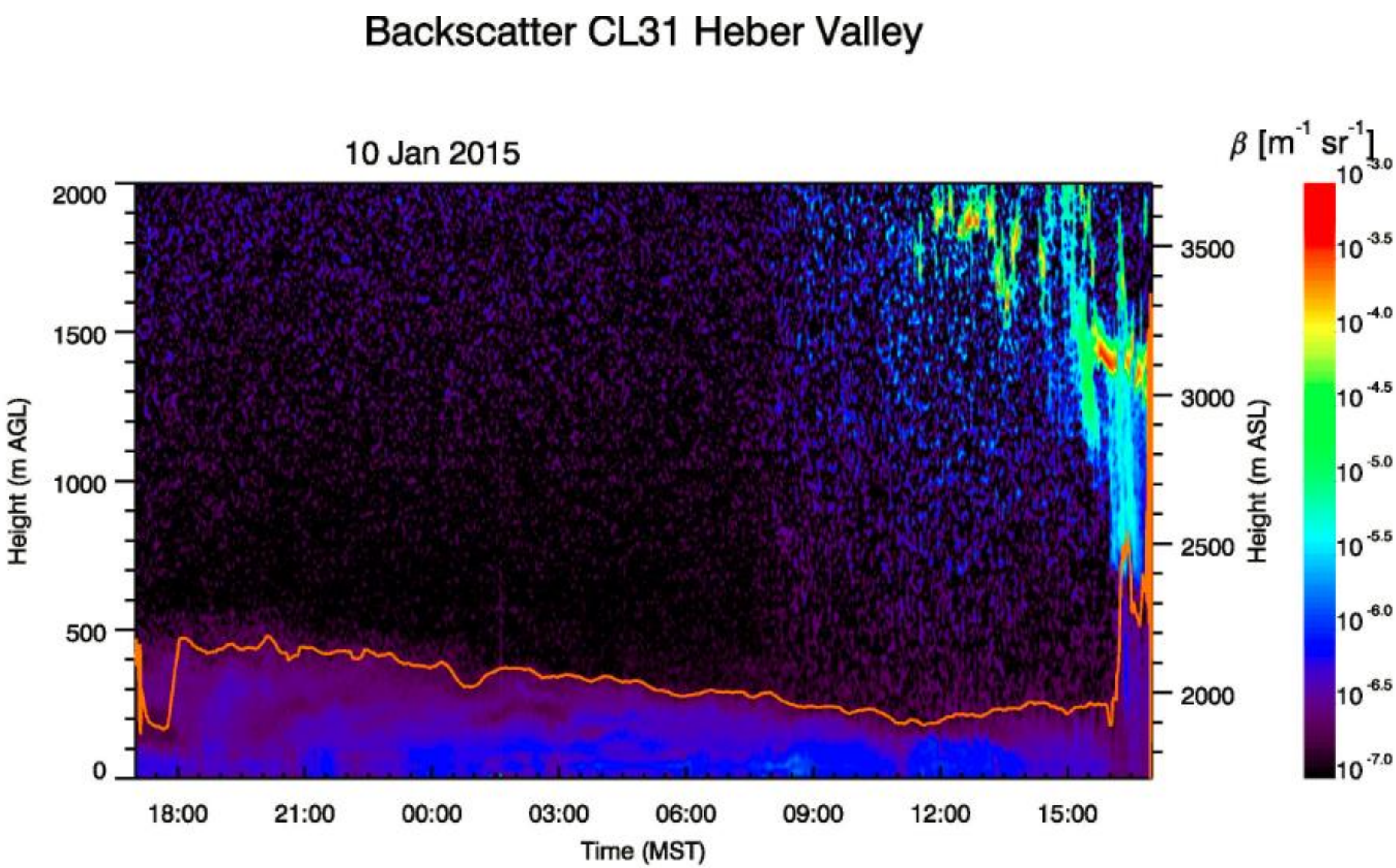
PMWR

EC(Microphysics), UU, and NDU INSTRUMENTS

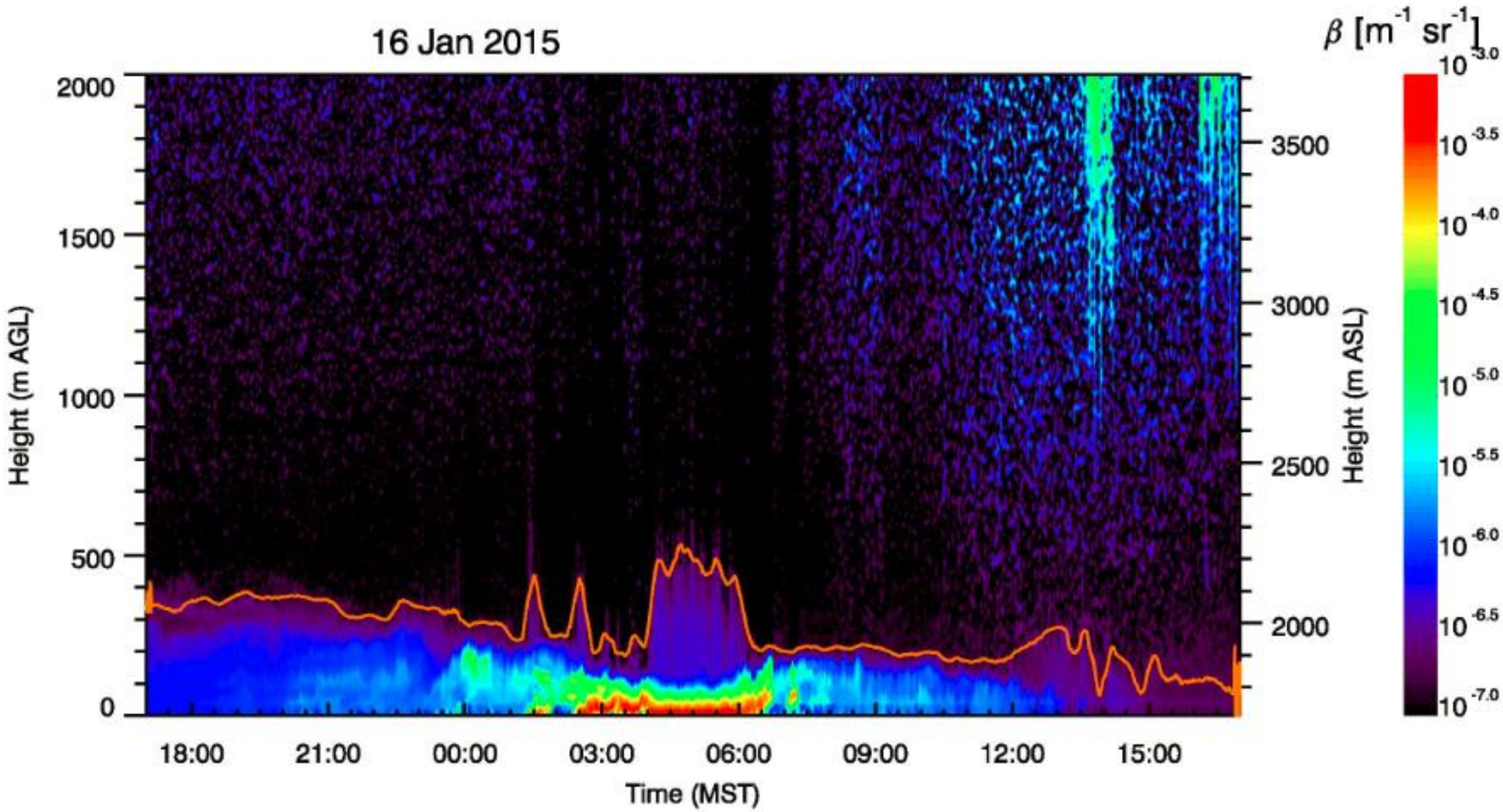
Licor gas analyzer; provides CO2 and H2O turbulent fluxes

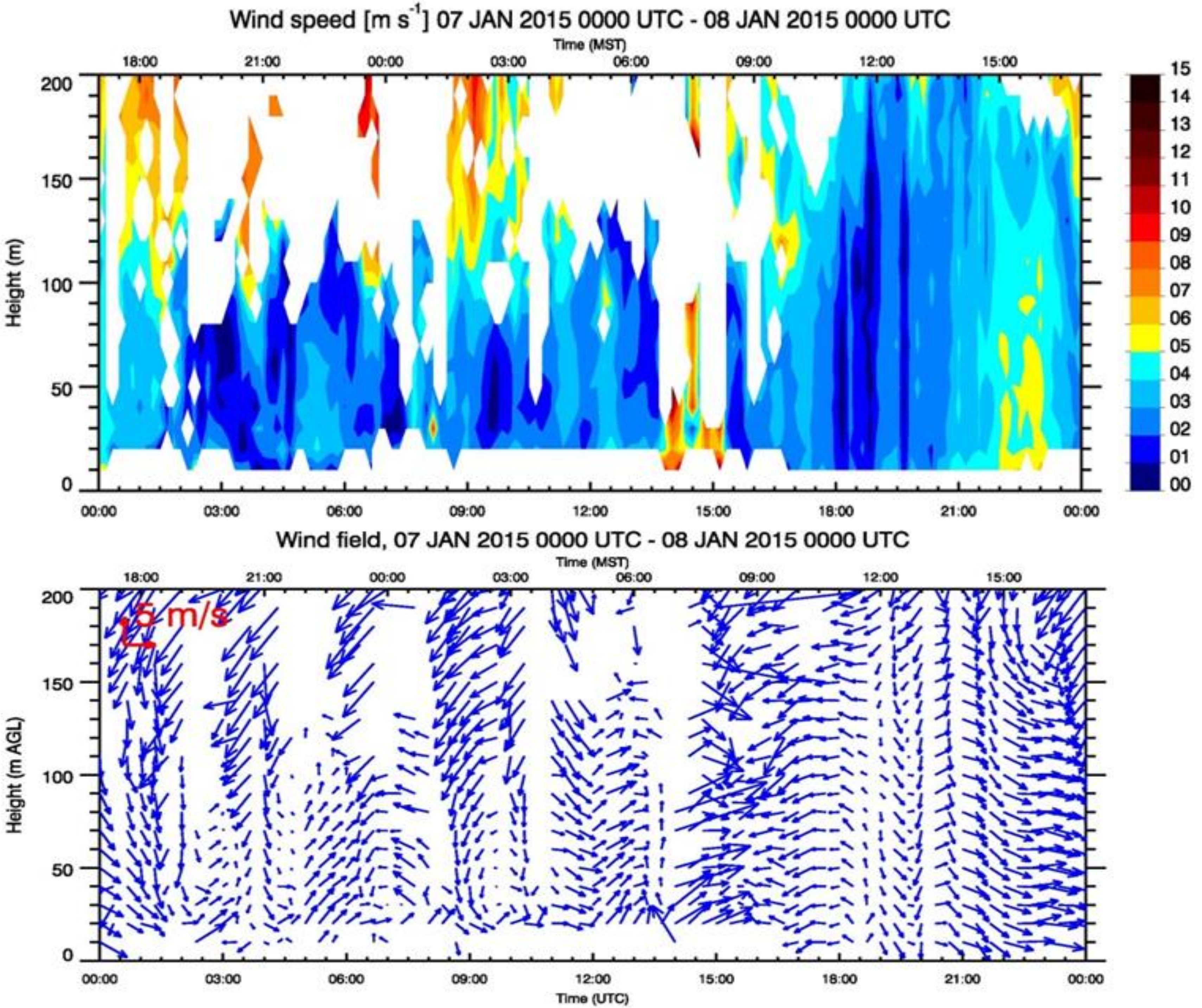

FOG
TOWER
COMPACT
MET UNIT
LPM PRECIP
SENSOR
3d-WIND
SENSOR
FD12P-VIS
CAMERA
MINI-VIS
IR-SW
SENSORS
MAP Nd (0.3-10
micron)
IR BASE T
05 12 2012

PRELIMINARY RESULTS



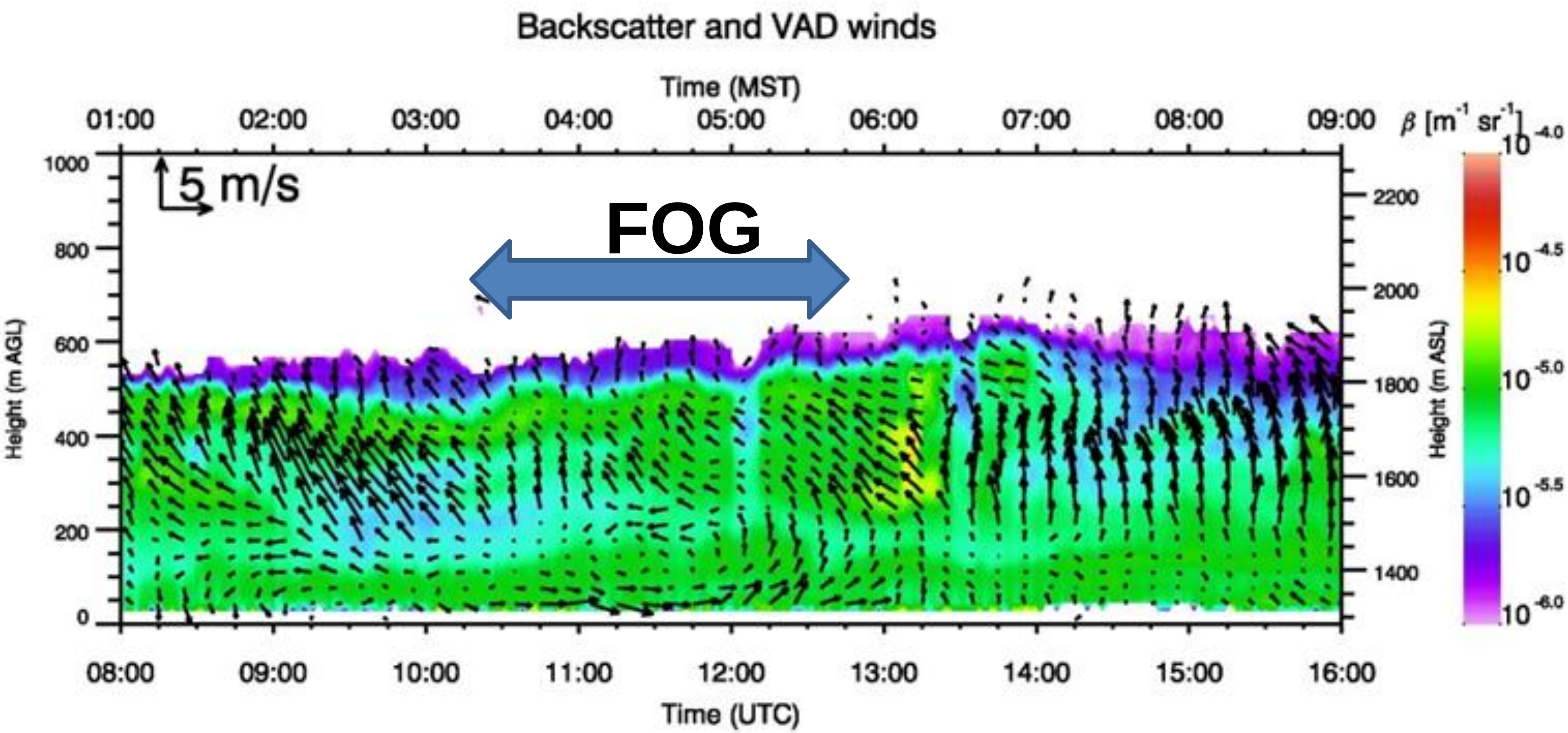
CL31 CEILOMETER



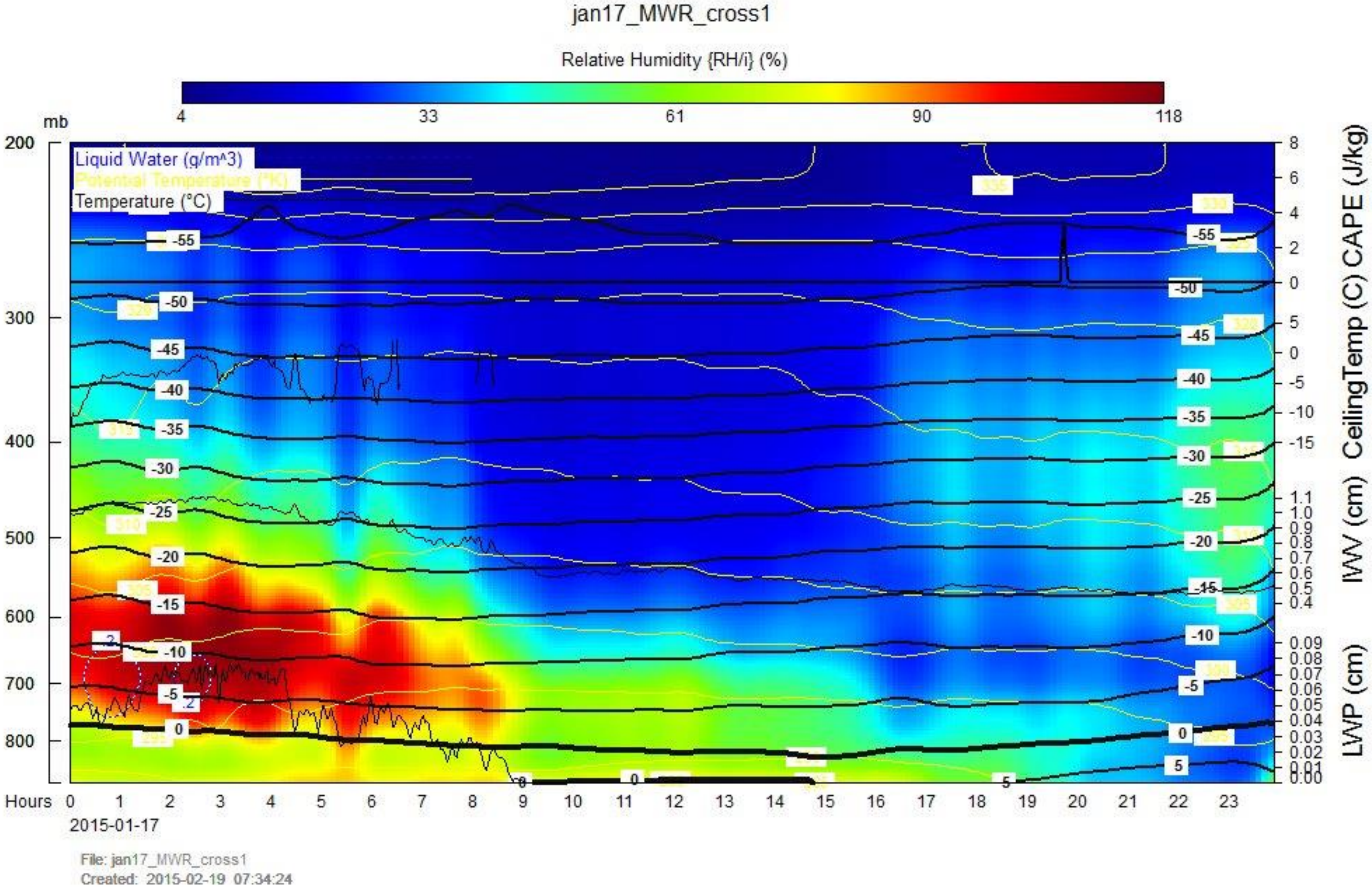


Wind speed [m s-1] 07 JAN 2015 0000 UTC - 08 JAN 2015 0000 UTC
Time (MST)
18:00
21:00
00:00
03:00
06:00
09:00
12:00
15:00
Height (m)
200
150
100
50
0
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
00:00
15
14
13
12
11
10
09
08
07
06
05
04
03
02
01
00
Wind field, 07 JAN 2015 0000 UTC - 08 JAN 2015 0000 UTC
Time (MST)
5 m/s
Height (m AGL)
Time (UTC)

LIDAR MEASUREMENTS

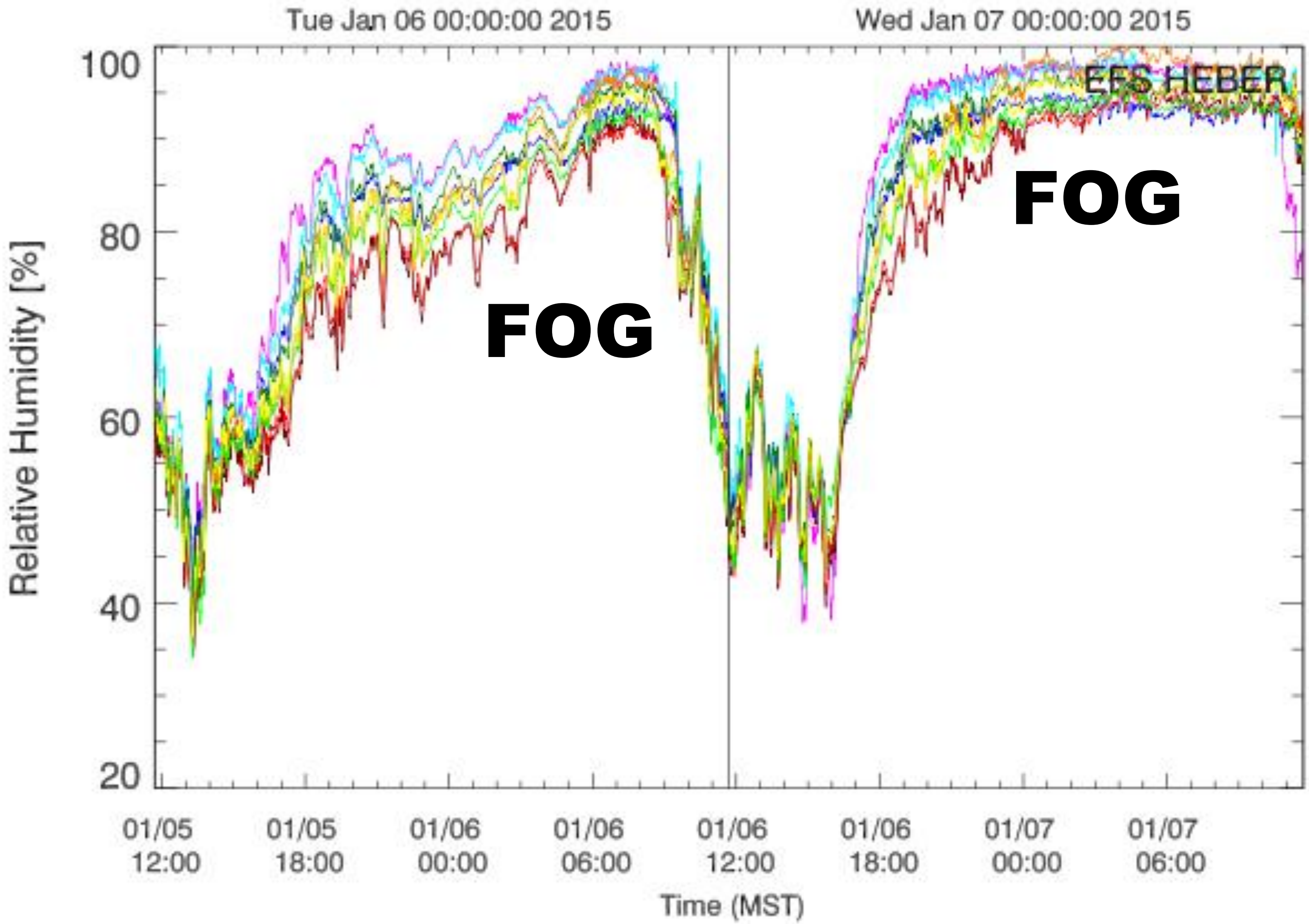


Jan 17 PMWR

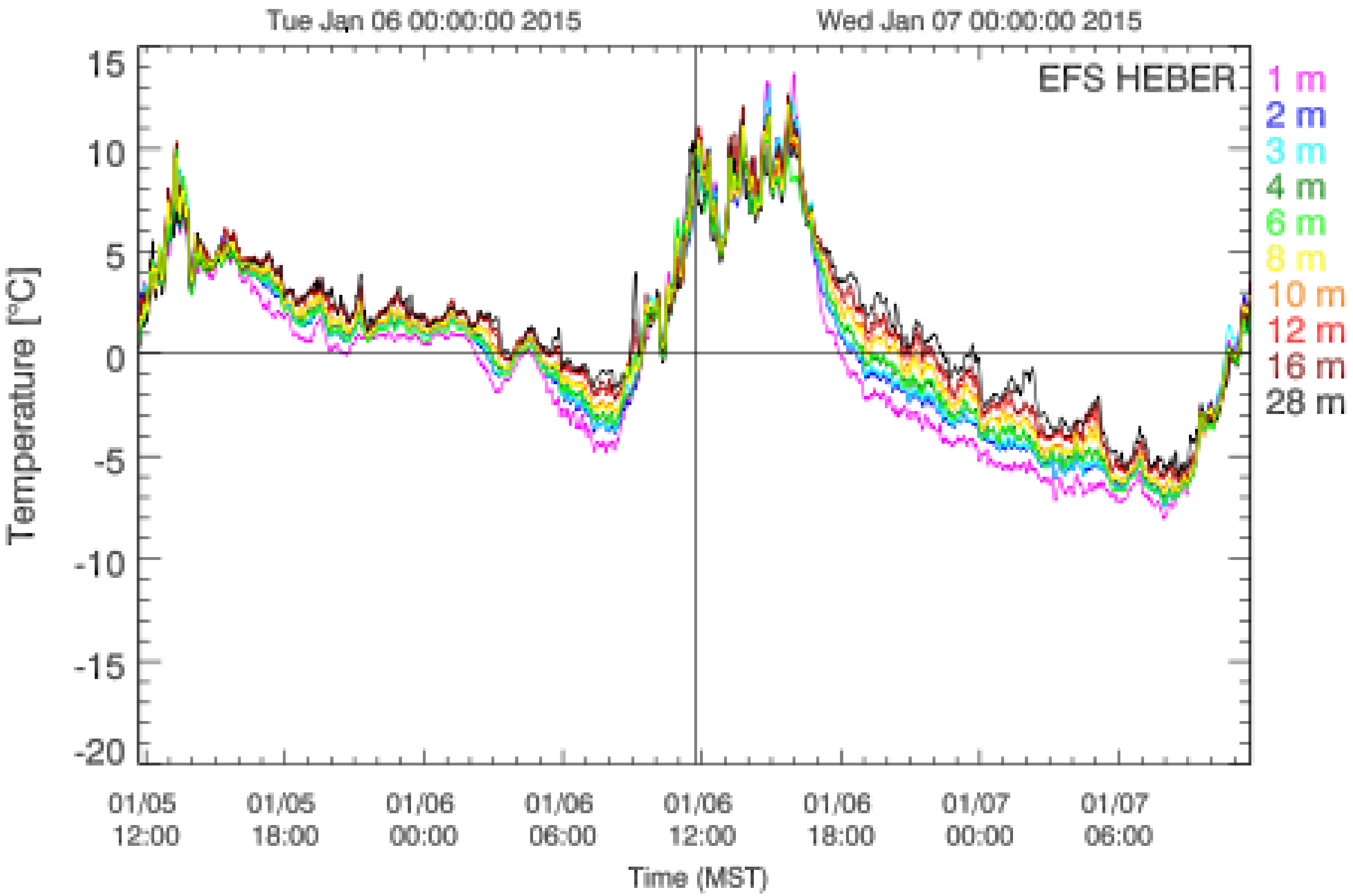


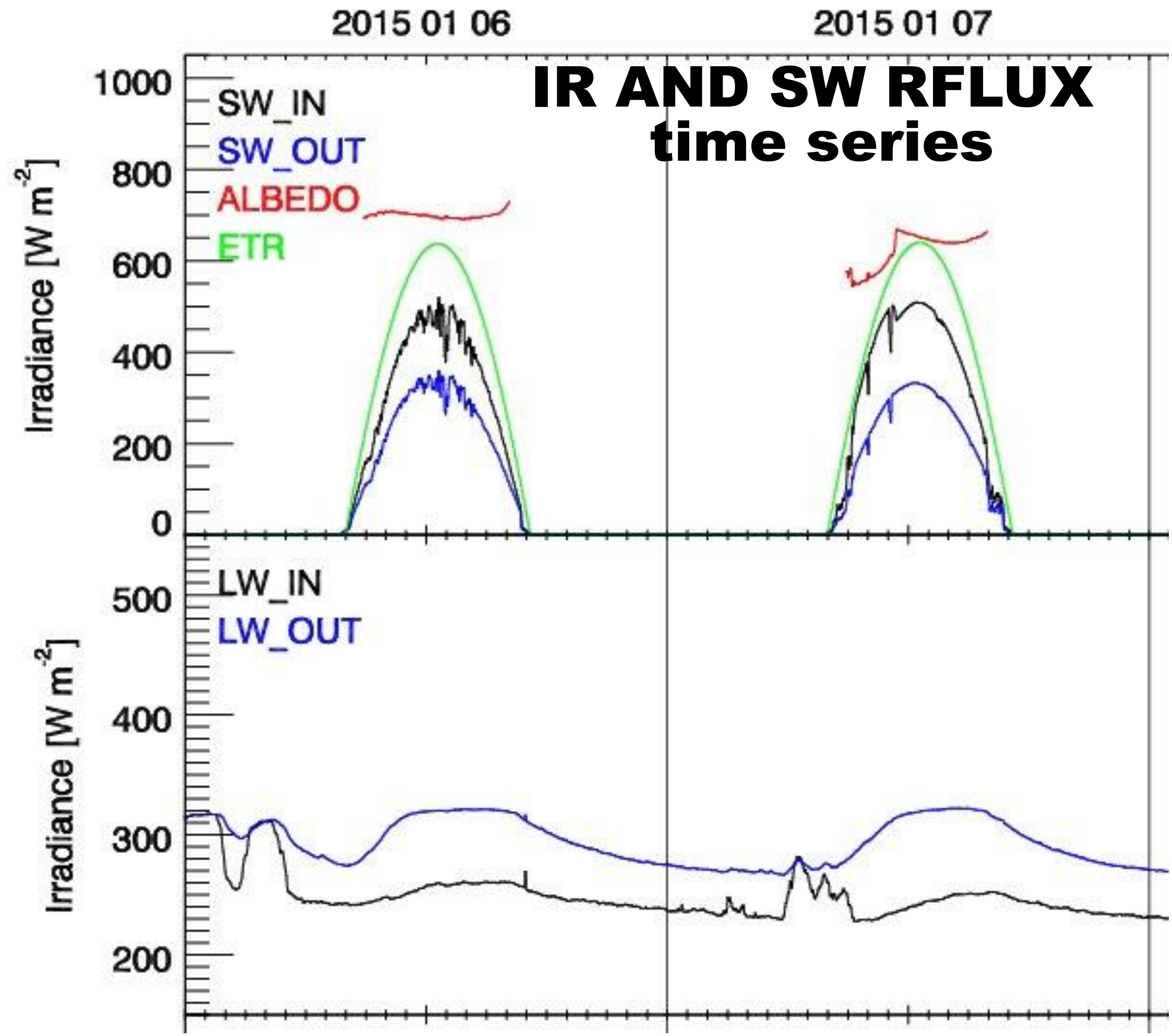
RAOB Config #1:

RH time series Jan 7



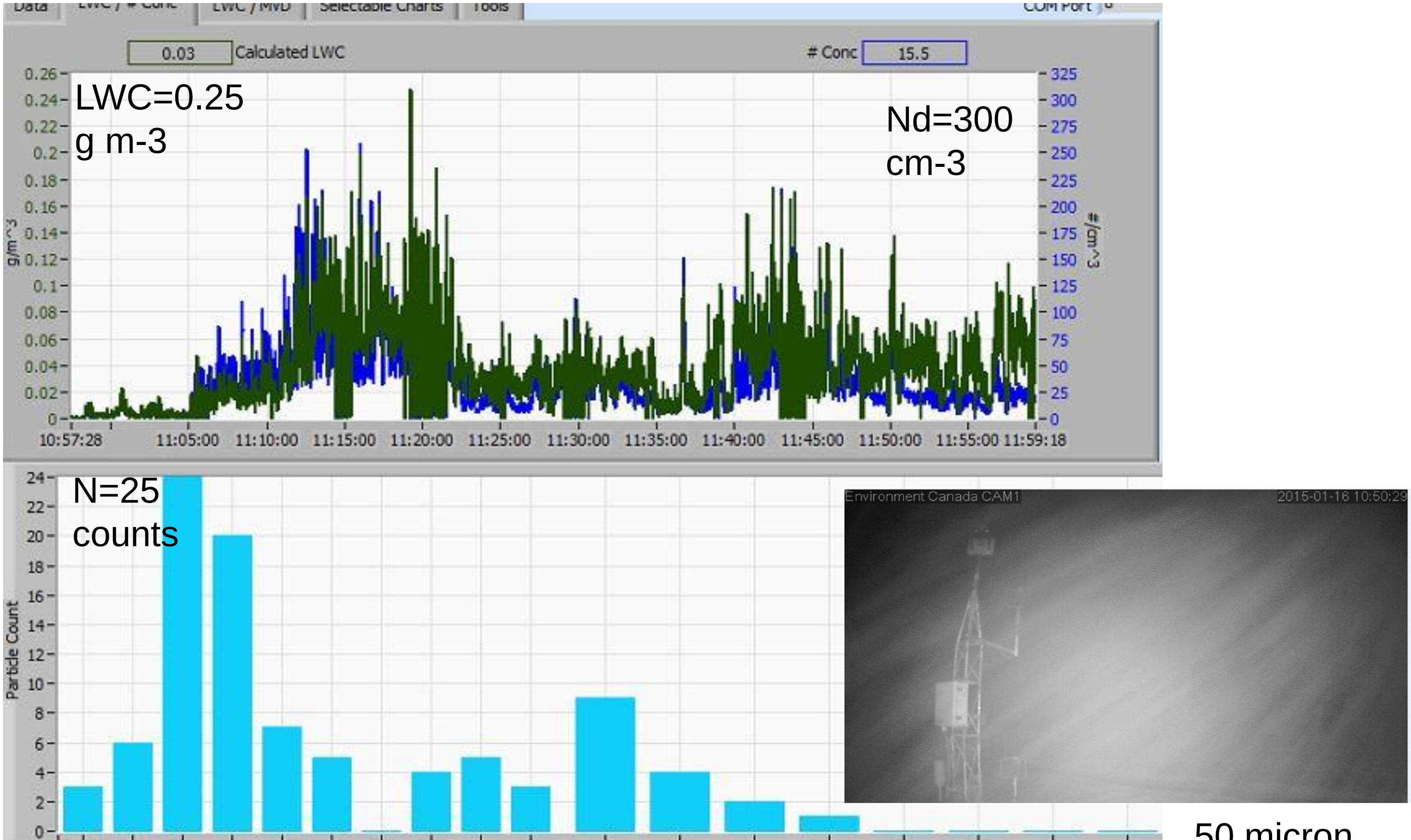
T time series Jan 7





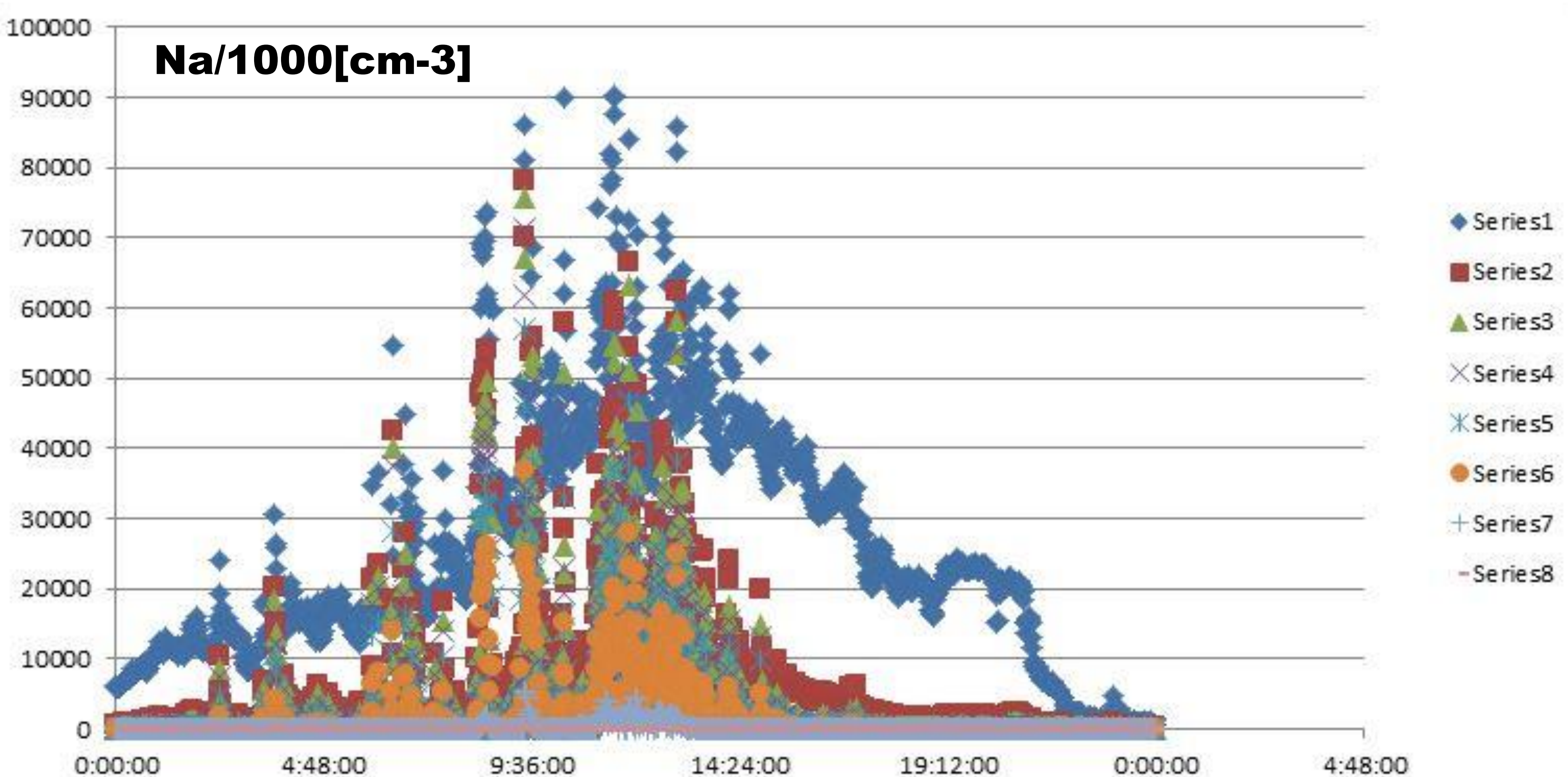
IR AND SW RFLUX
time series
2015 01 06
2015 01 07
SW_IN
SW_OUT
ALBEDO
ETR
Irradiance [W m^-2]
1000
800
600
400
200
0
LW_IN
LW_OUT
500
400
300
200

Jan 16 ice fog case (Heber City)

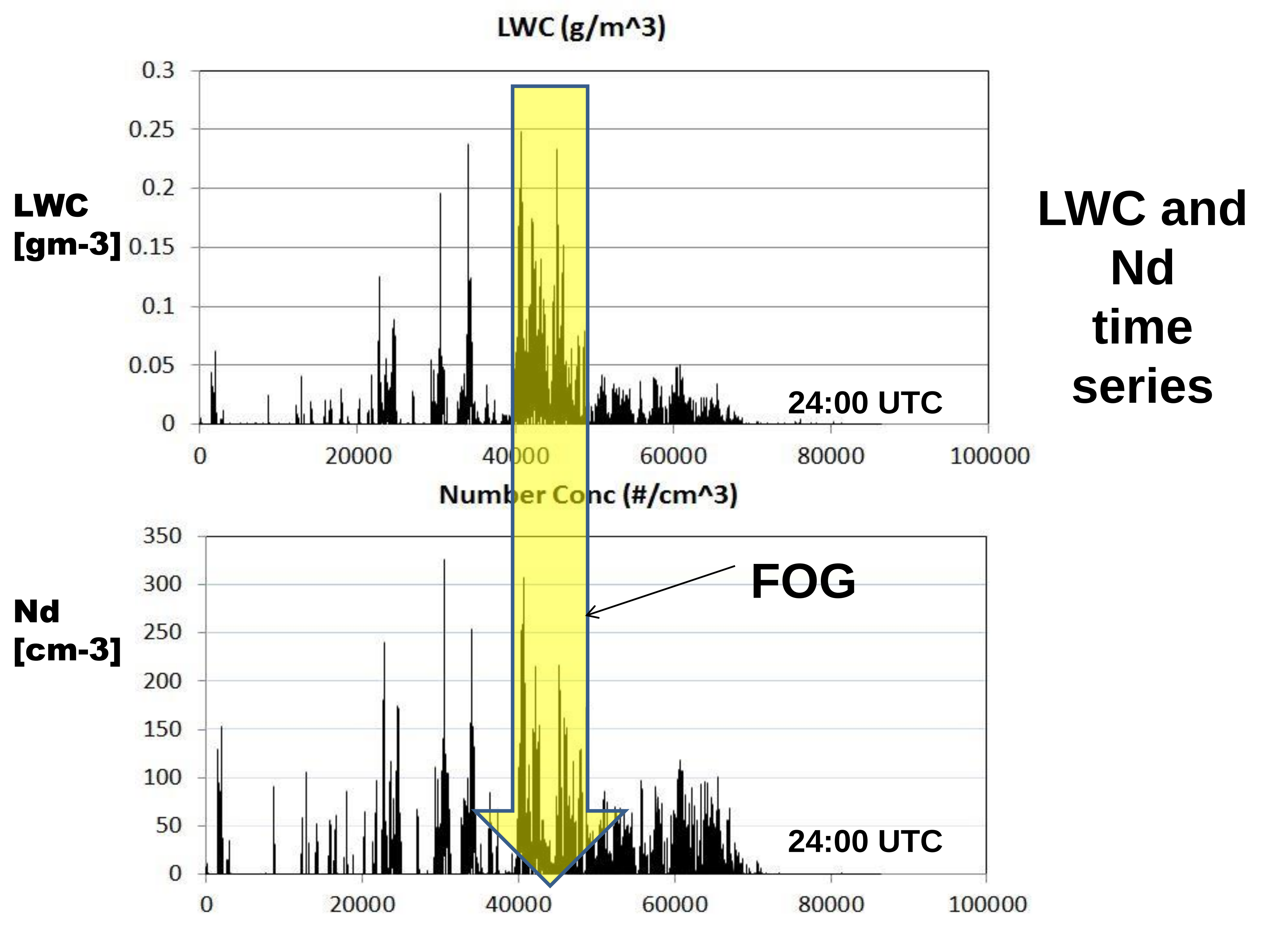


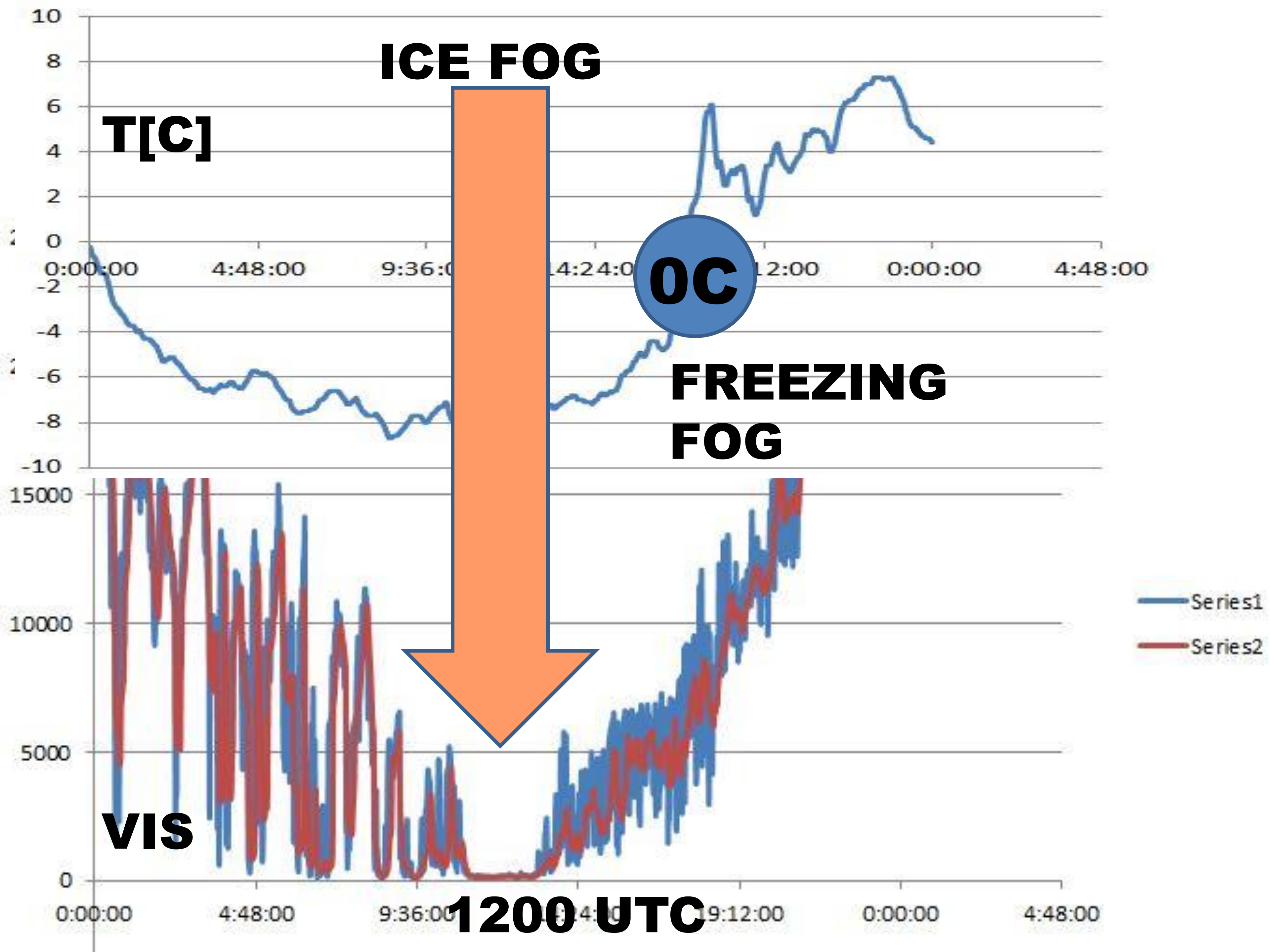
50 micron

Na time series; >0.3 micron over 8 channels



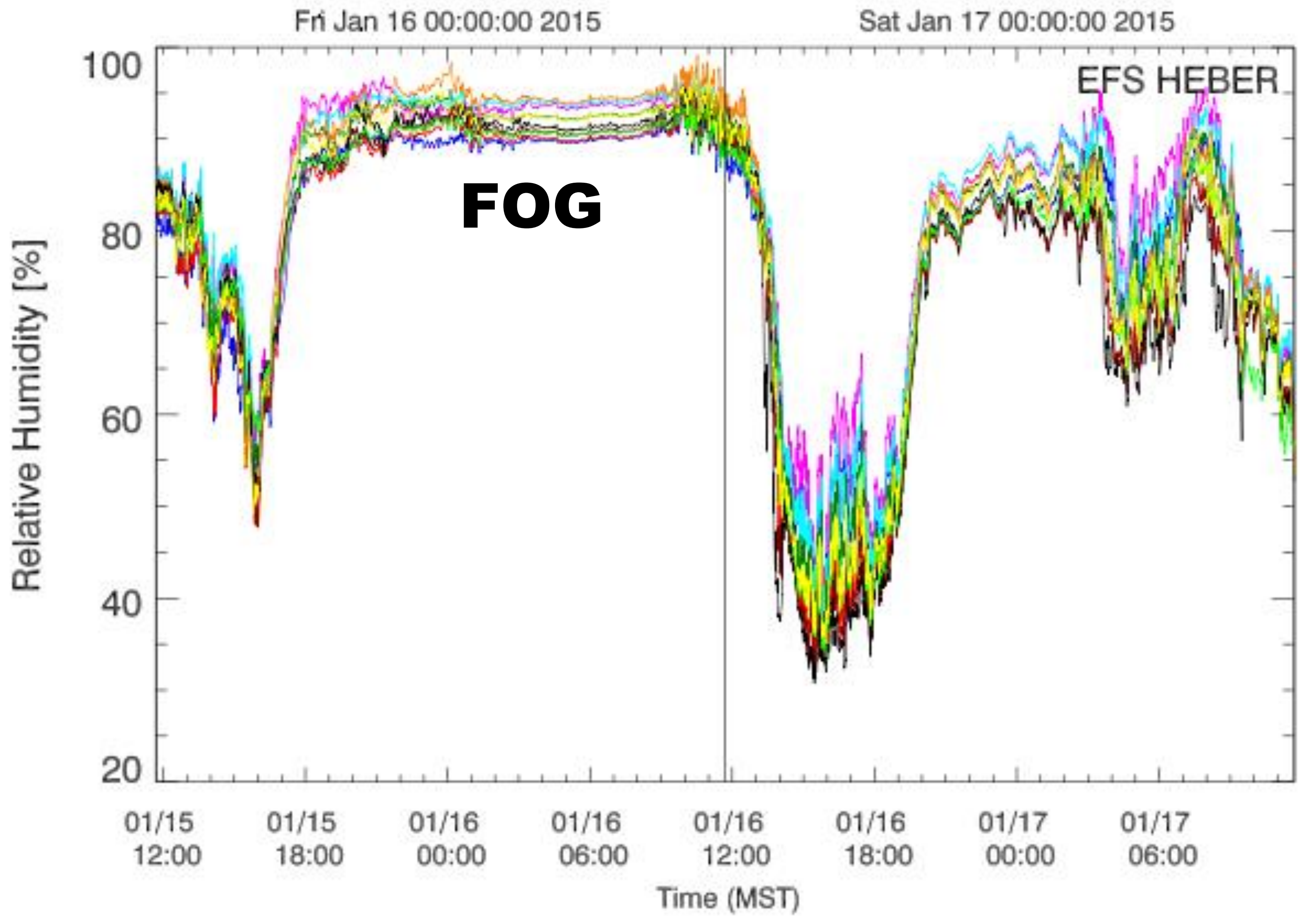
FOG


LWC (g/m^3)
LWC [gm-3]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
20000
40000
60000
80000
100000
24:00 UTC
Number Conc (#/cm^3)
Nd [cm-3]
350
300
250
200
150
100
50
0
0
20000
40000
60000
80000
100000
24:00 UTC
FOG
LWC and Nd time series

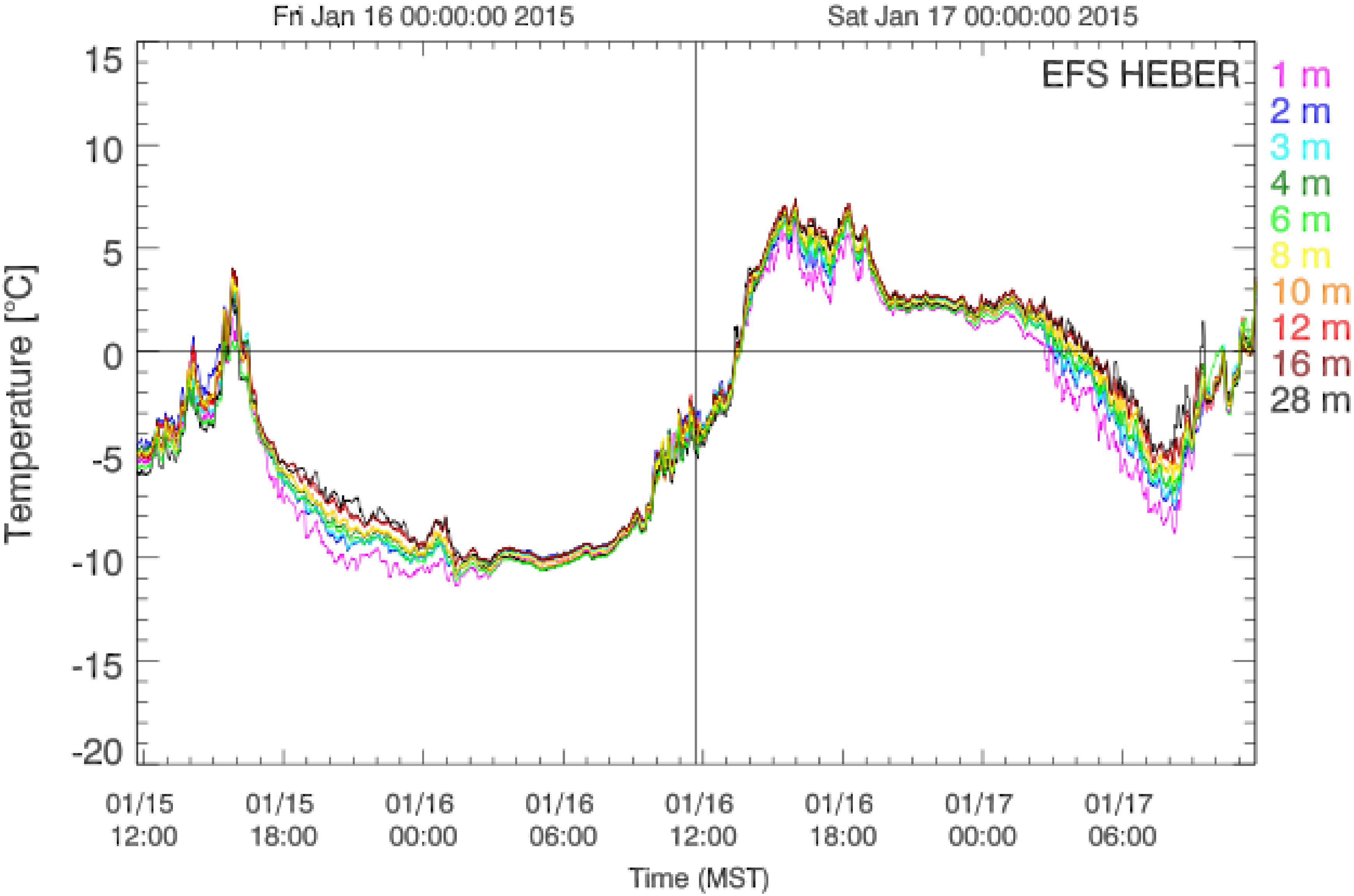


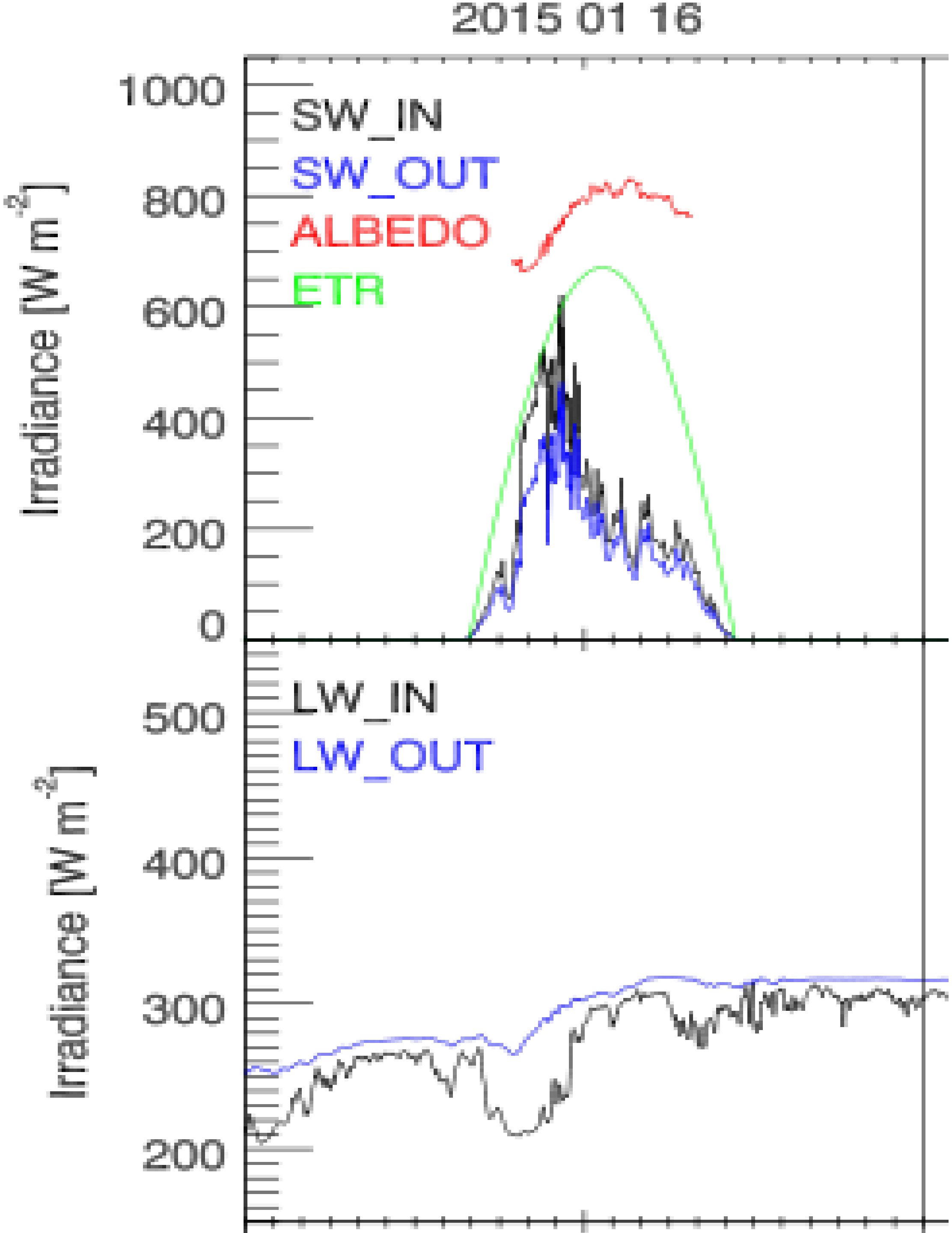
ICE FOG
T[C]
0C
FREEZING
FOG
VIS
1200 UTC
10
8
6
4
2
0
-2
-4
-6
-8
-10
0:00:00
4:48:00
9:36:00
19:12:00
0:00:00
4:48:00
15000
10000
5000
0
Series1
Series2

Jan 16 ICE FOG/FF RH time series

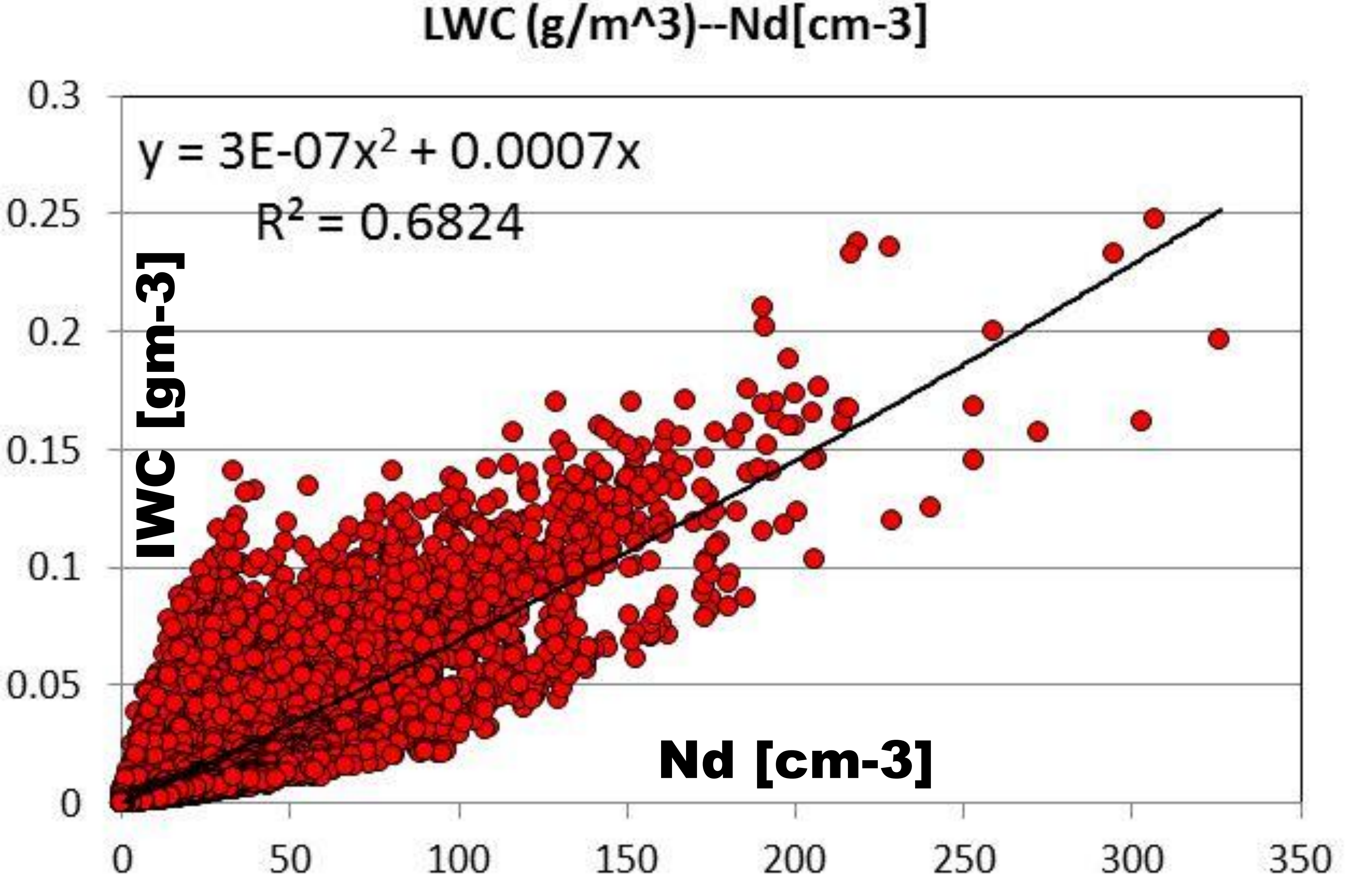


Jan 16 ICE FOG/FF T[C]

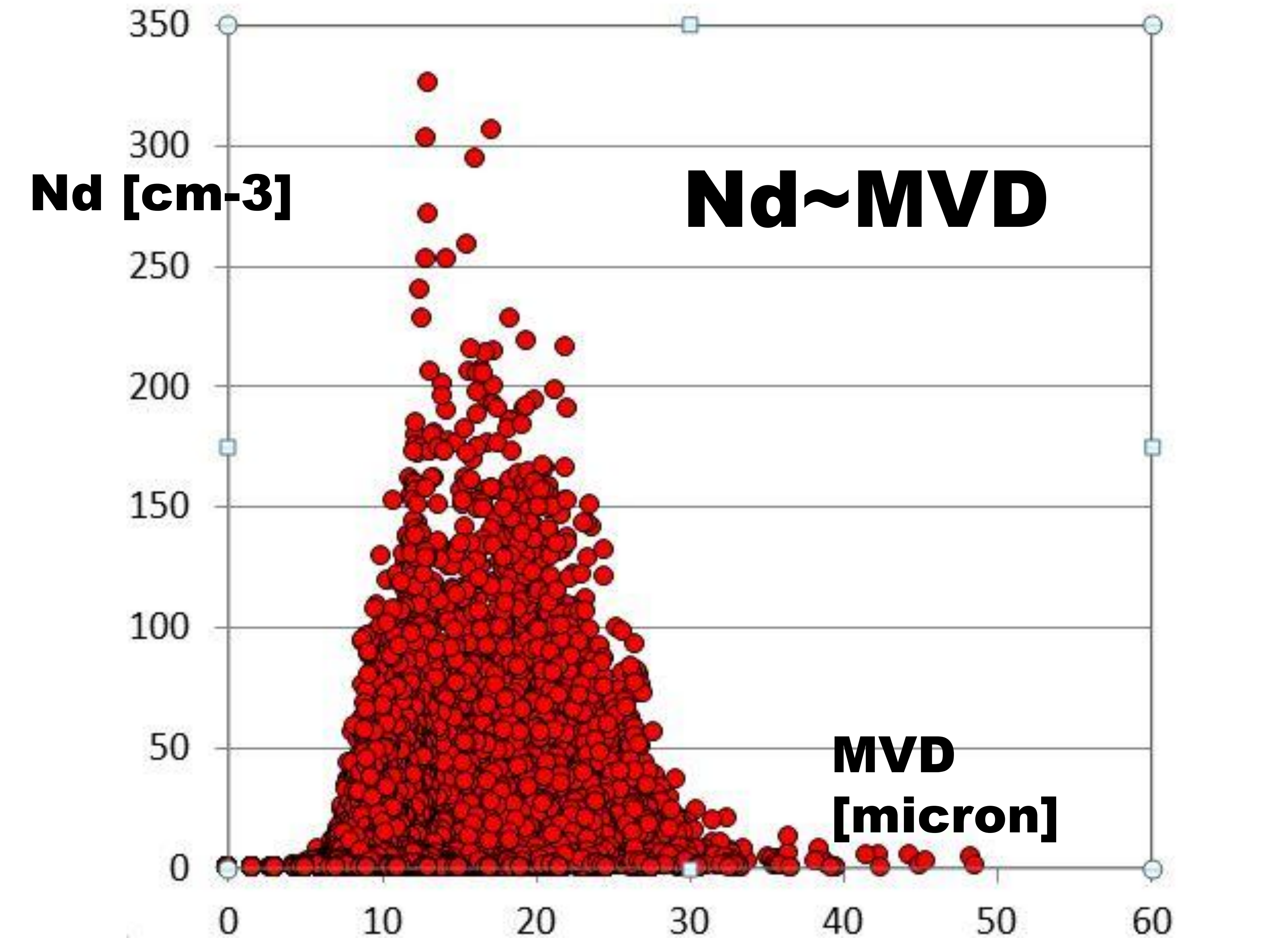


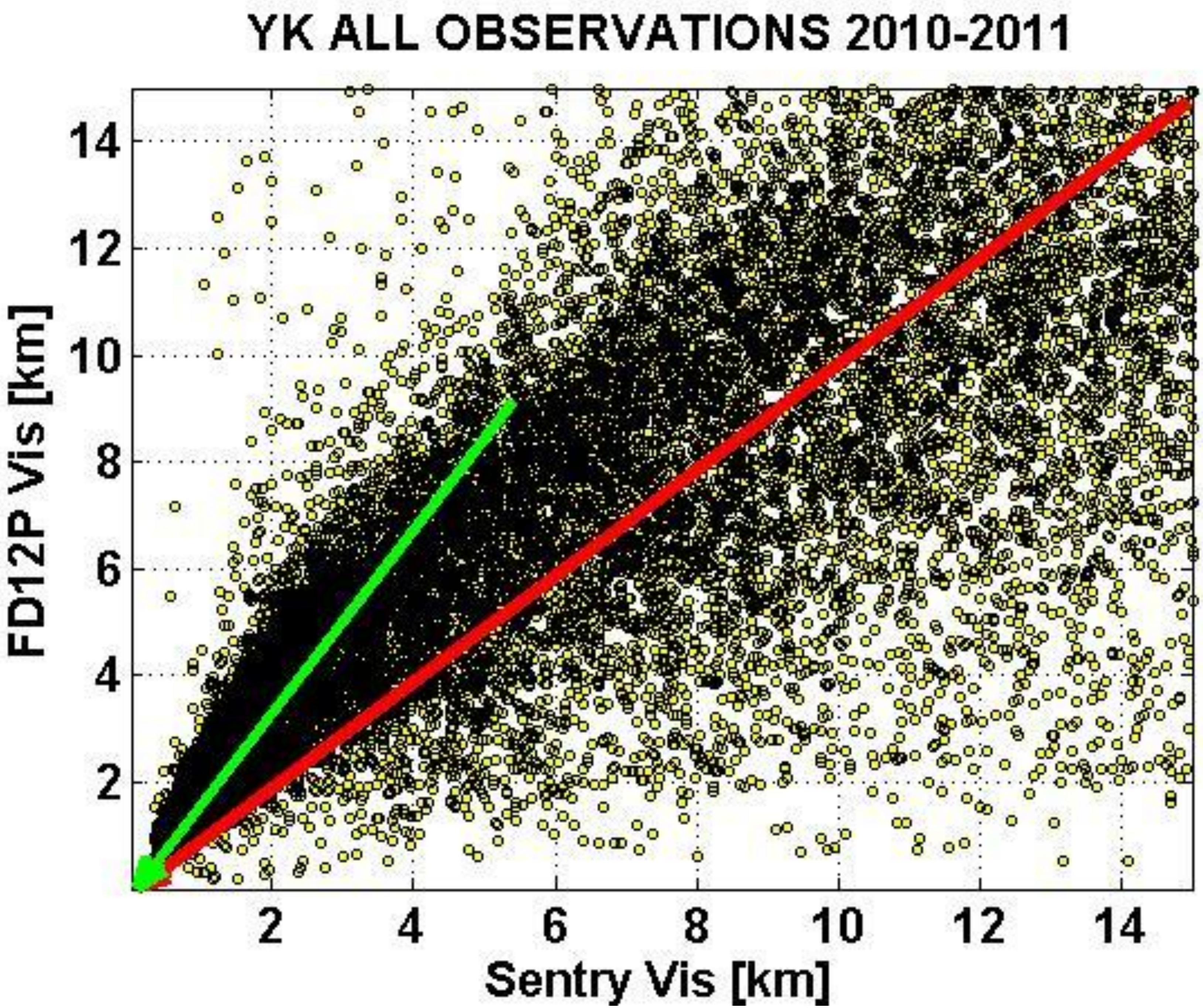


IR AND SW IRRADIANCES FOR JAN 16 IF/FG

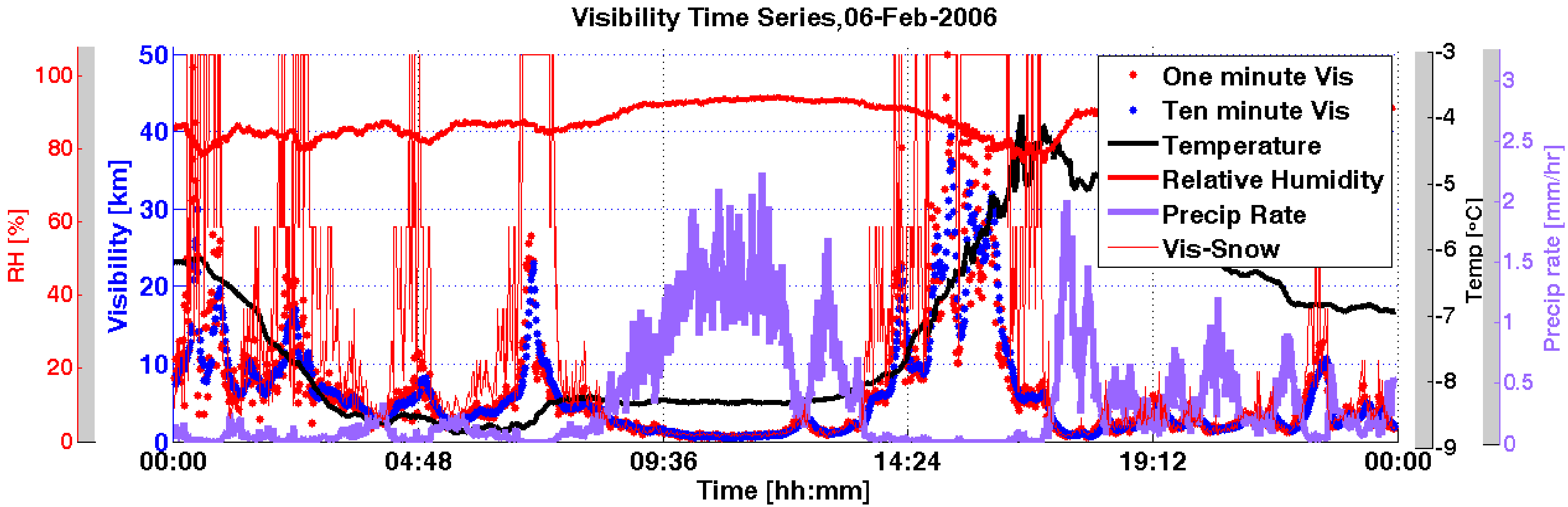


LWC (g/m^3)--Nd[cm-3]
y = 3E-07x2 + 0.0007x
R2 = 0.6824
IWC [gm-3]
Nd [cm-3]
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
300
350

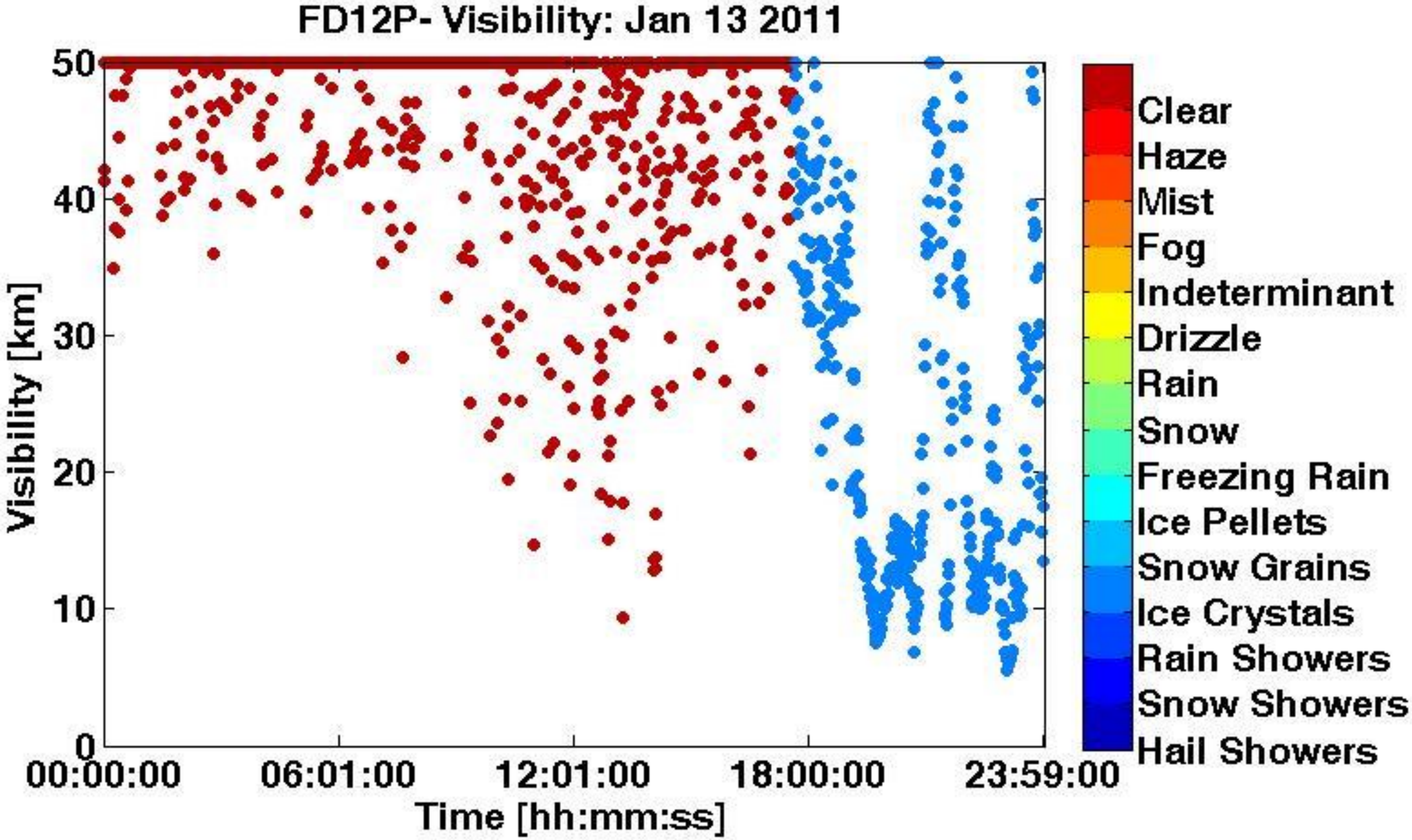

Nd [cm-3]
Nd~MVD
MVD [micron]
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60


YK ALL OBSERVATIONS 2010-2011
FD12P Vis [km]
Sentry Vis [km]
2
4
6
8
10
12
14

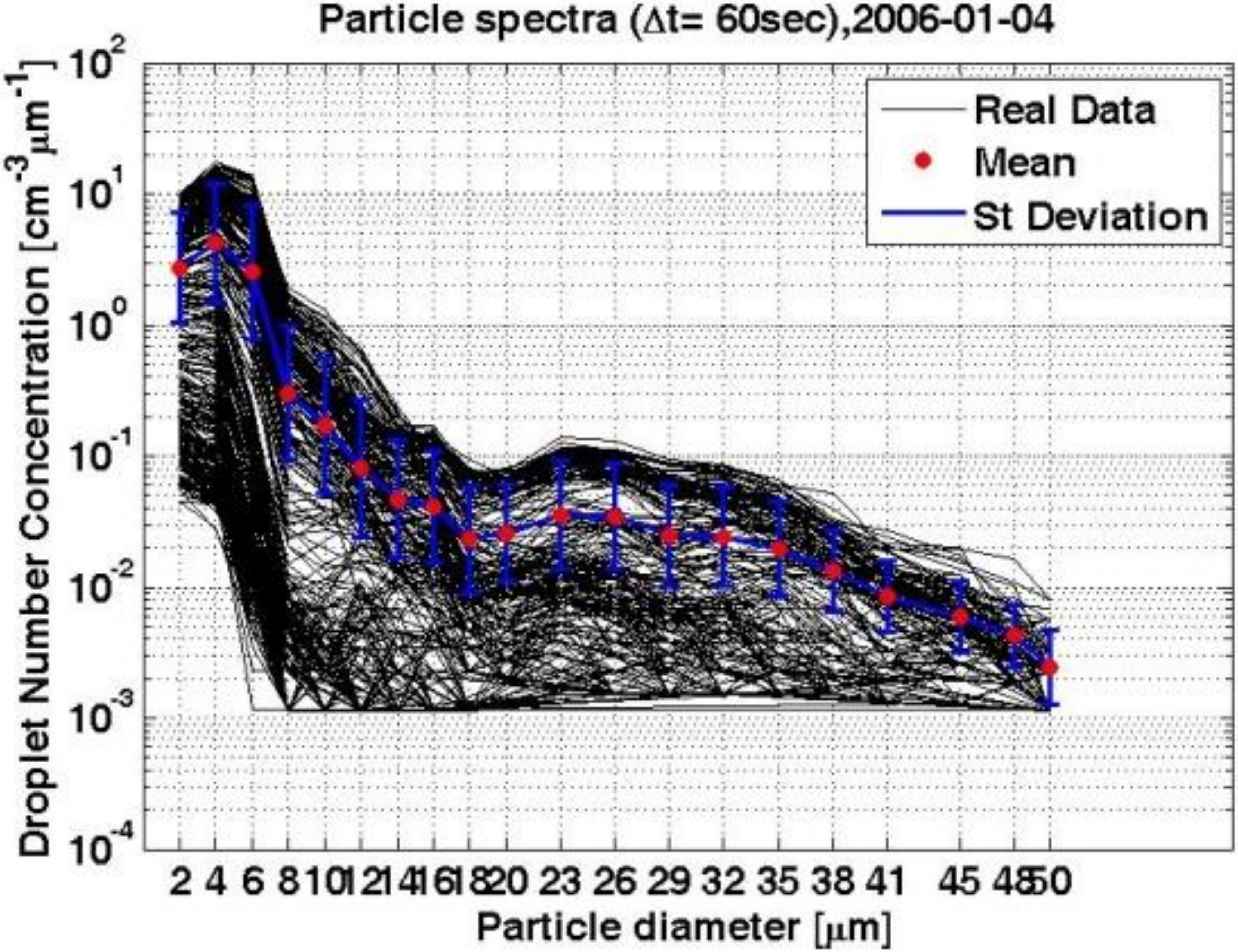
PWD VIS TIME SERIES



Jan 13

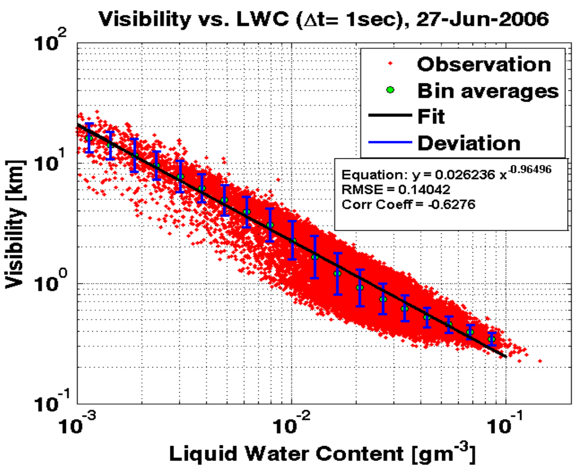


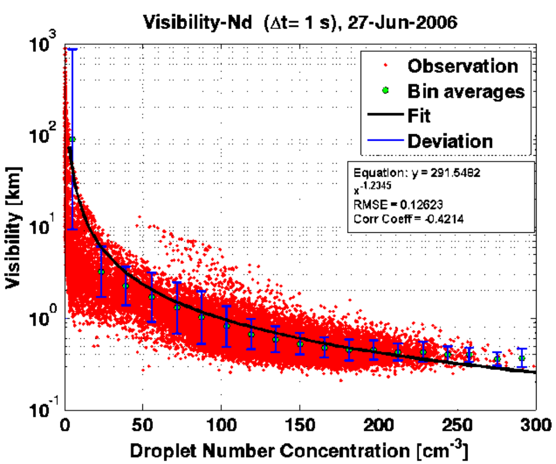
FD12P- Visibility: Jan 13 2011
Visibility [km]
50
40
30
20
10
0
00:00:00
06:01:00
12:01:00
18:00:00
23:59:00
Time [hh:mm:ss]
Clear
Haze
Mist
Fog
Indeterminant
Drizzle
Rain
Snow
Freezing Rain
Ice Pellets
Snow Grains
Ice Crystals
Rain Showers
Snow Showers
Hail Showers

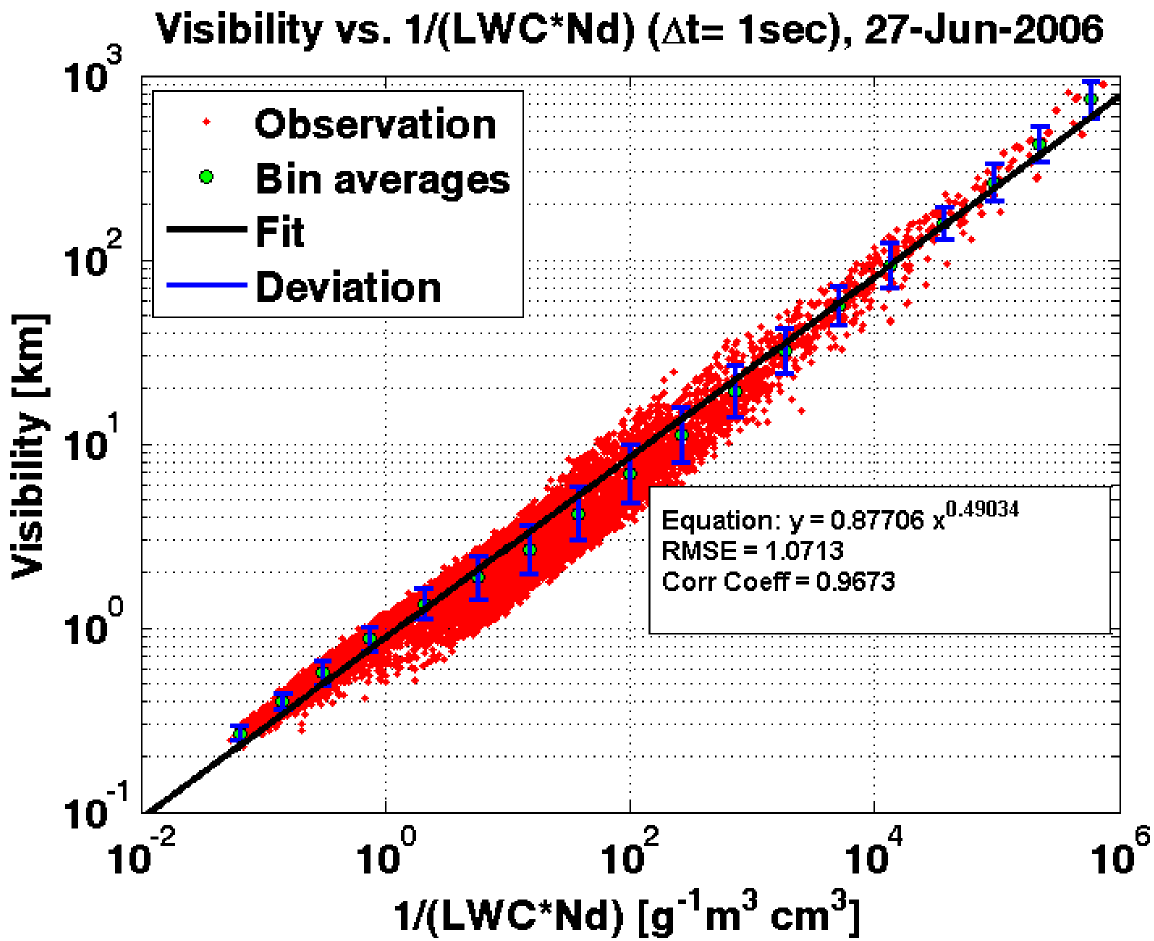


Particle spectra (Δt= 60sec),2006-01-04
Droplet Number Concentration [cm-3 μm-1]
Particle diameter [μm]
Real Data
Mean
St Deviation
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
2 4 6 8 10 12 14 16 18 20 23 26 29 32 35 38 41 45 48 50

FOG PARAMETERIZATION/FORECAST MODELS



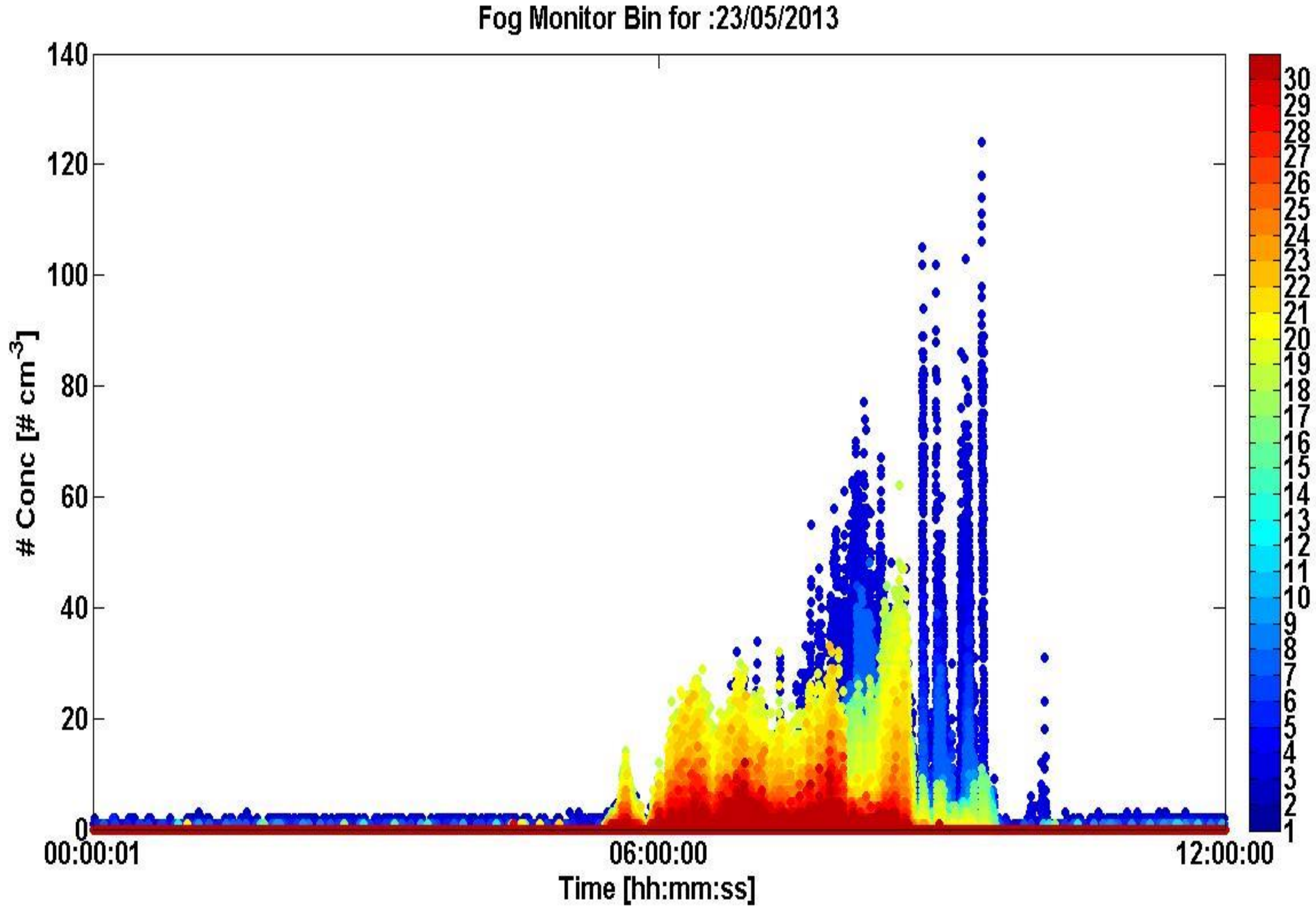




$$vis = 1.02\left(LWCxN_d\right)^{-0.52}$$

ICE FOG (<100 MICRON)

FOG DROPLET SIZE IMAGE



3D Ultrasonic anemometer for 1-s wind measurements

High wind speed caused by icing

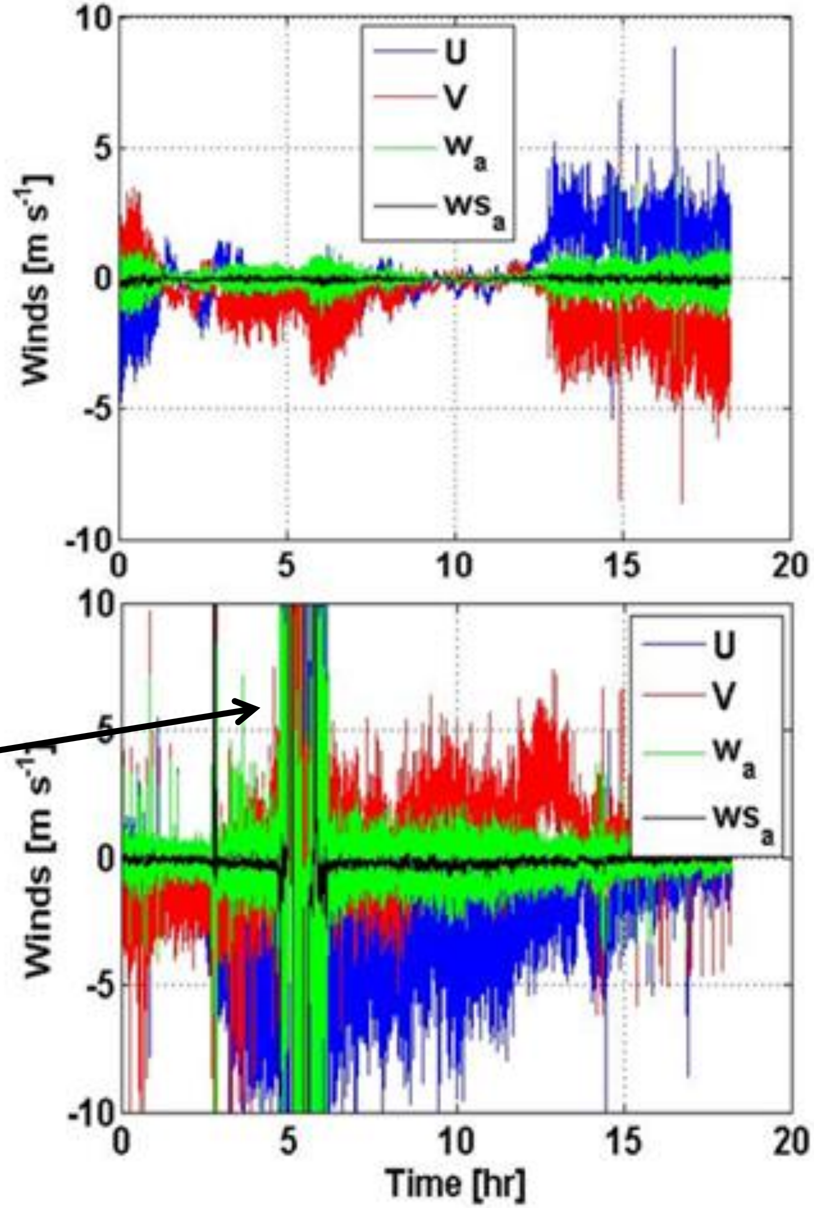
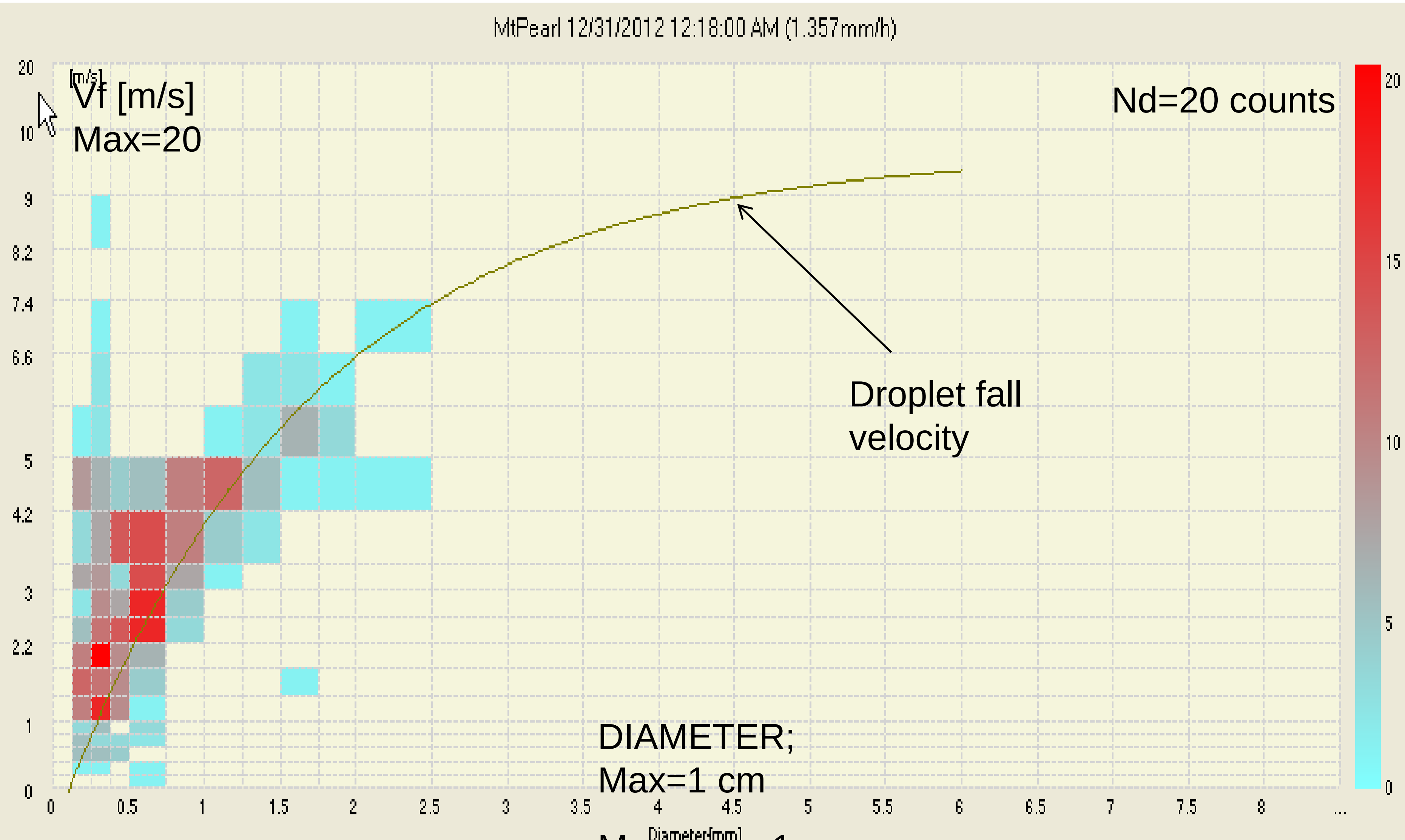


Figure 14: Time series of 1Hz wind components from Young 3D anemometer sensor for Jan 17 (top box) and for Jan 18 (bottom box) 2013: Black solid line is for 60 sec-averaged vertical air velocity (green lines).

LPM PRECIP SPECTRA



Max size=1 cm

JUNE 19 FOG CASE

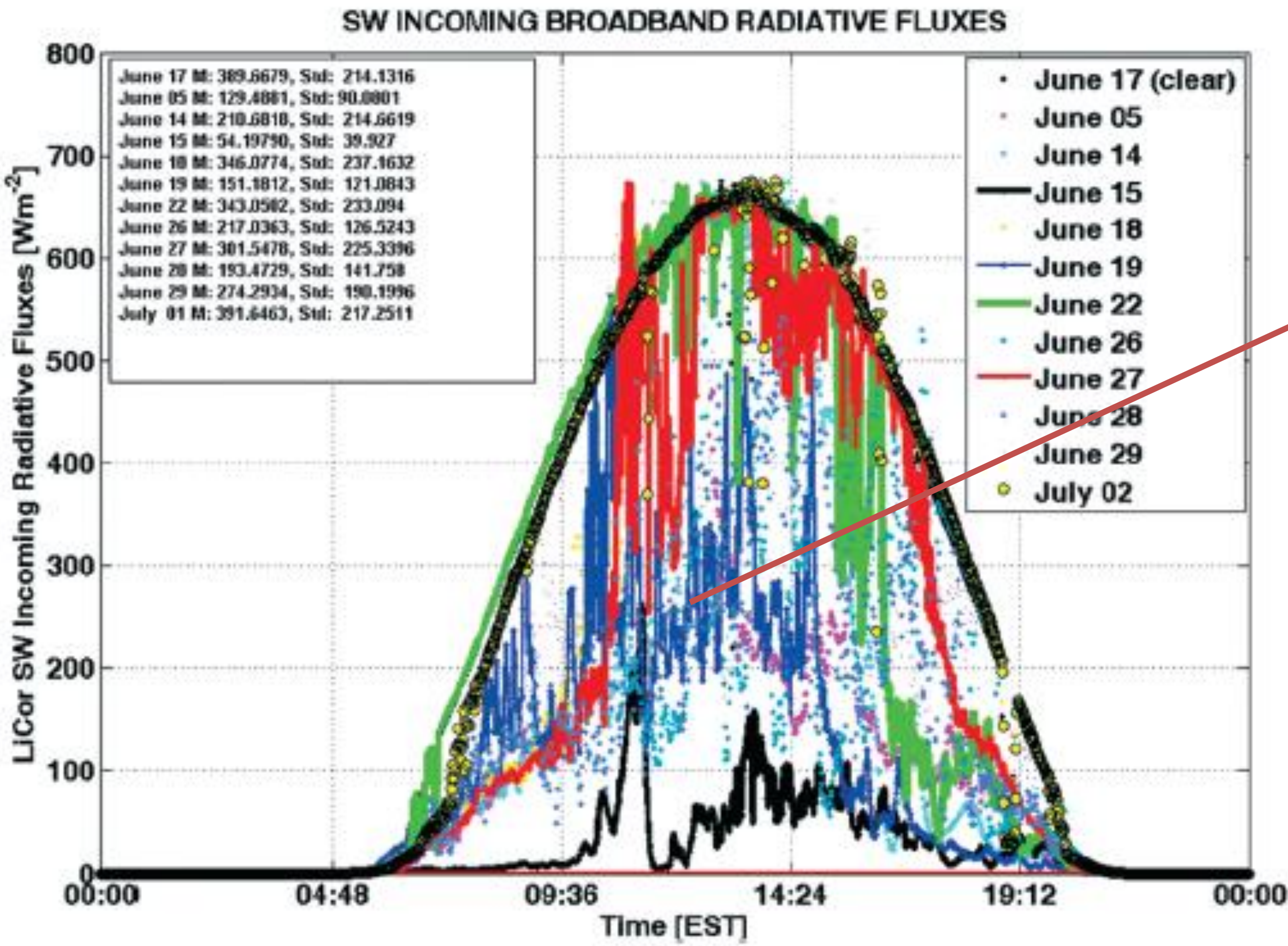


FIG. 6: Sows incoming SW broadband radiative fluxes versus time for various days during FRAM-L1. The data points for the 17 June and 2 July 2006 represent clear air conditions. Others represent either foggy (e.g., 19 June) or foggy plus rainy conditions (e.g., 15 June). The days with lines are for foggy conditions except for the 15 June 2006 case. Mean and standard deviation for entire day for each case are also shown on the figure.

AMS Bull 2007
Gultepe et al

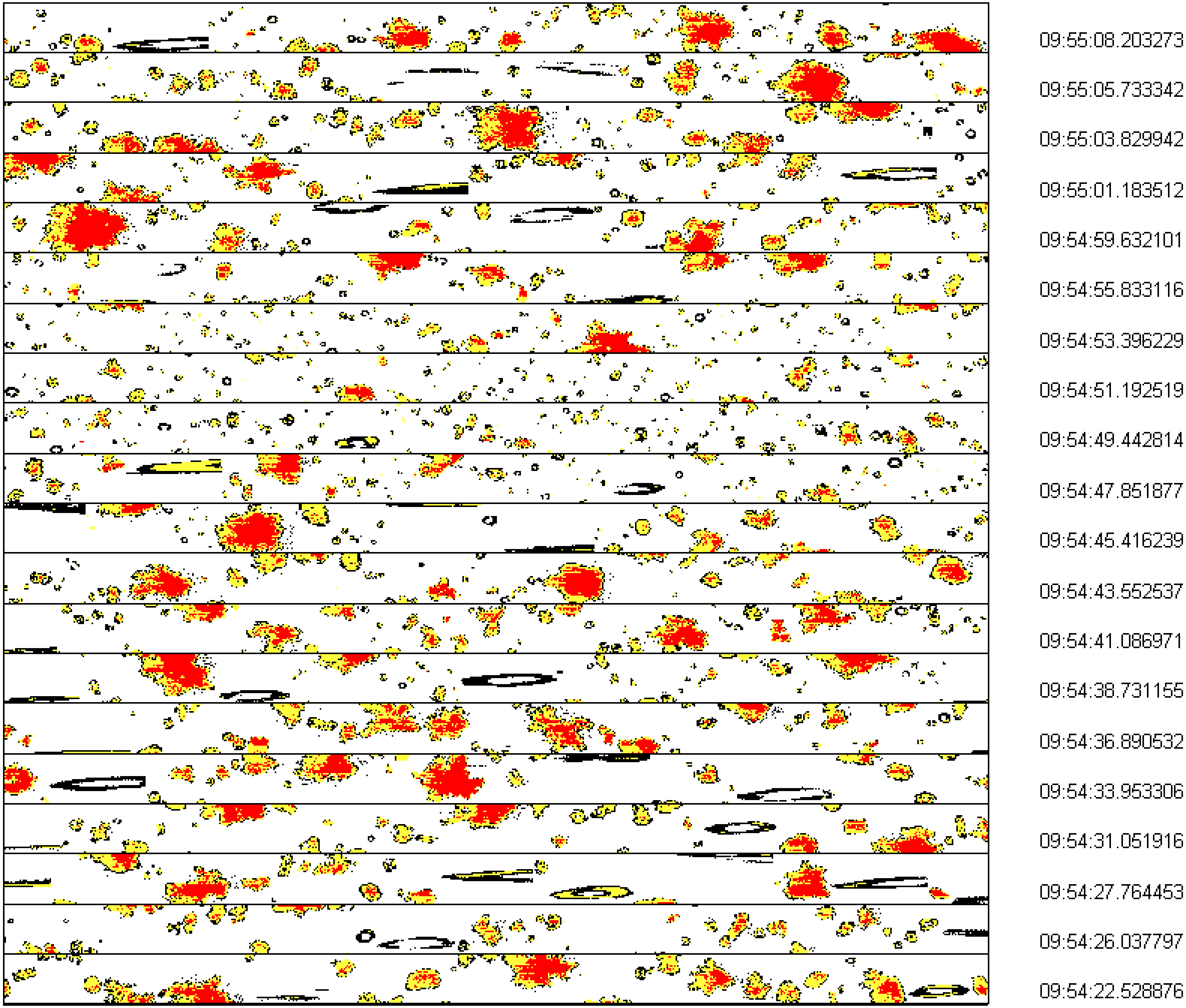
FOG PARAMETERIZATION

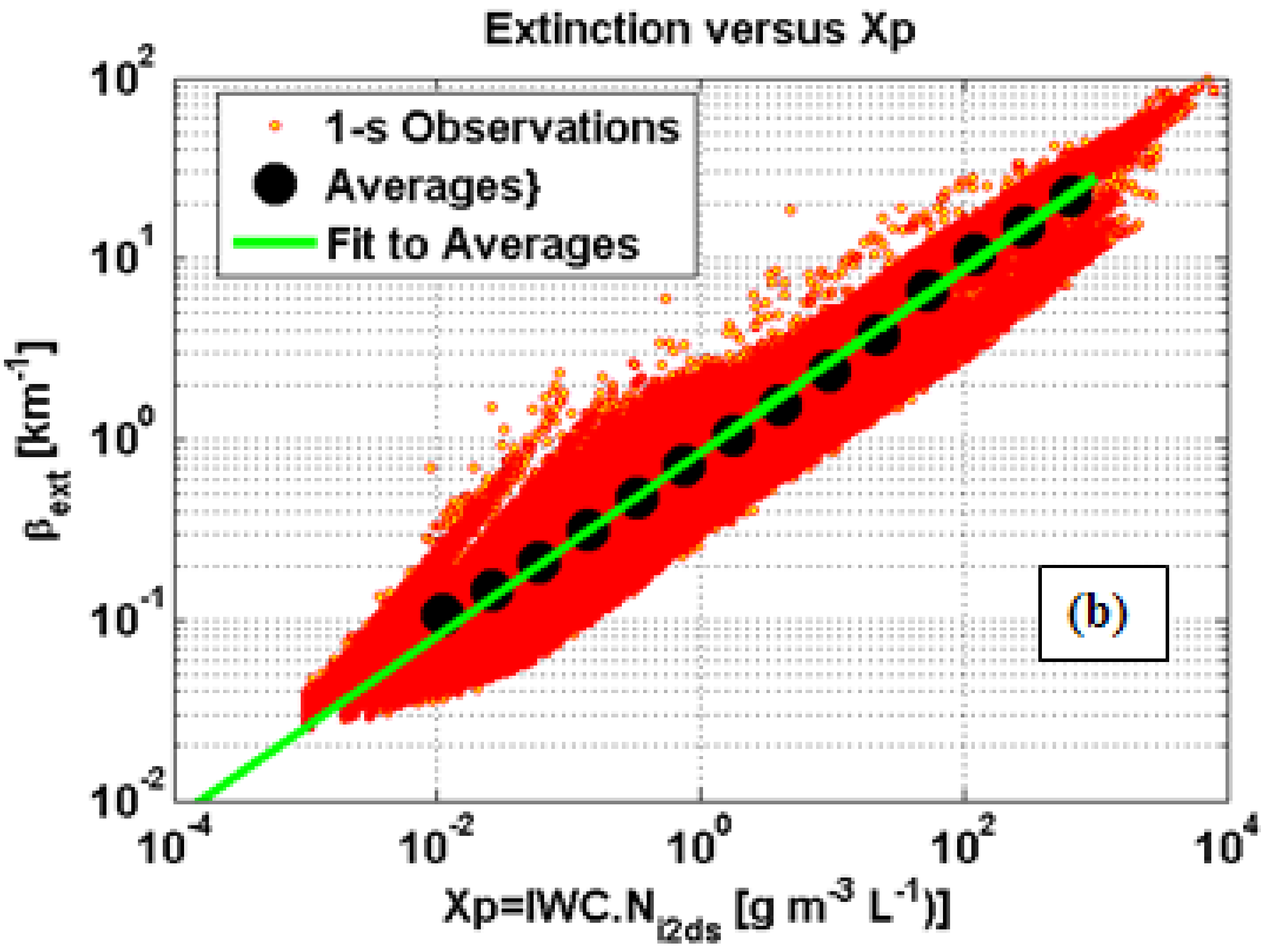
1. Parameters needed are for ice fog: IWC, Ni, RHi, and T
2. Parameters needed are for liquid fog : LWC, Nd, RHw, and T
3. A cloud model or a forecast model with a good resolution of time and space resolution that will resolve weather events e.g. fog
4. Then, Vis is obtained for fog regions with extinction calculations based on IWC and Ni

ICE MICROPHYSICAL ALGORITHMS FOR THE NUMERICAL CLOUD/FORECAST MODELS

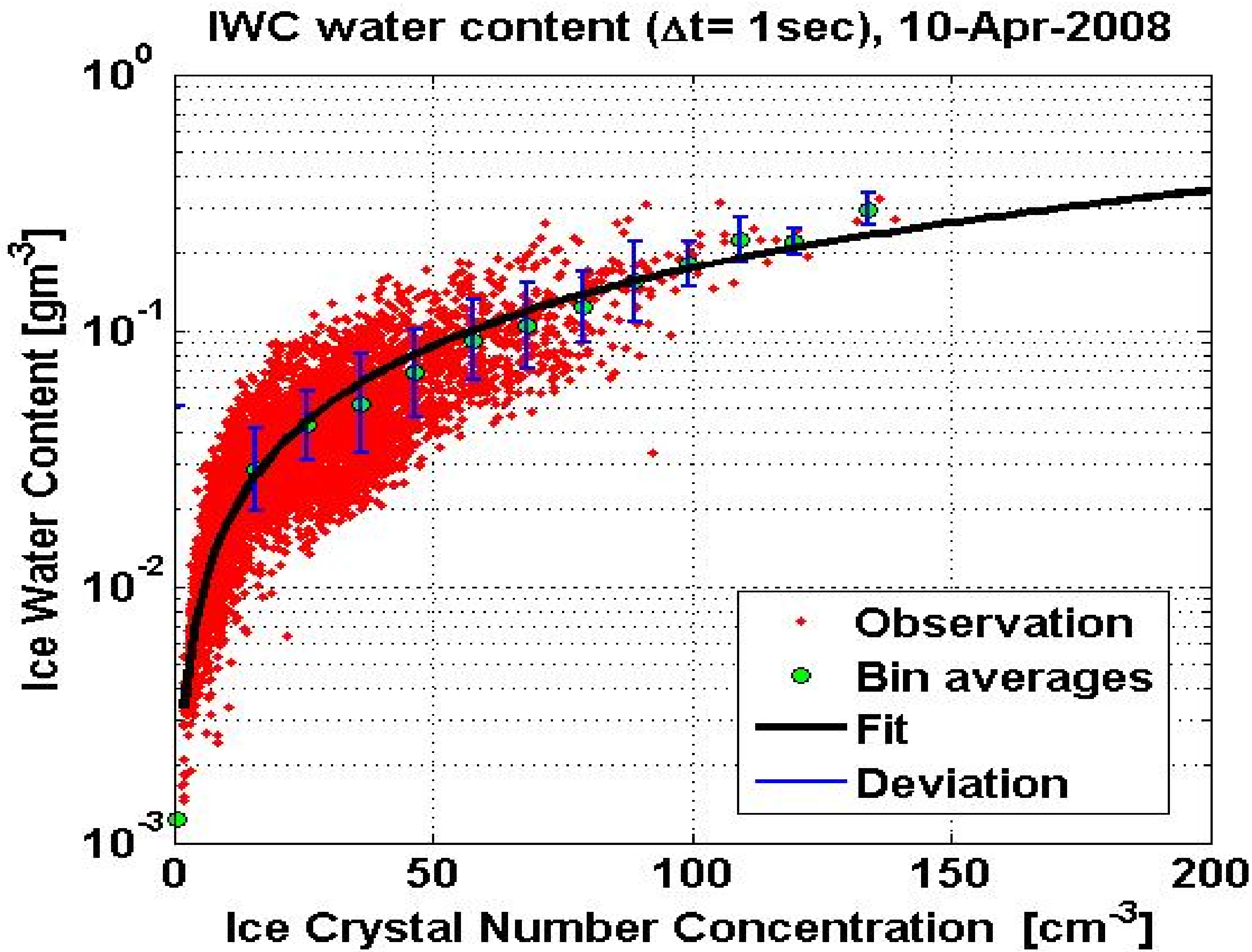
1. Milbrandt and Yau
2. Morrison et al
3. Thompson et al

All these have some kind of assumptions related to IN and size distributions

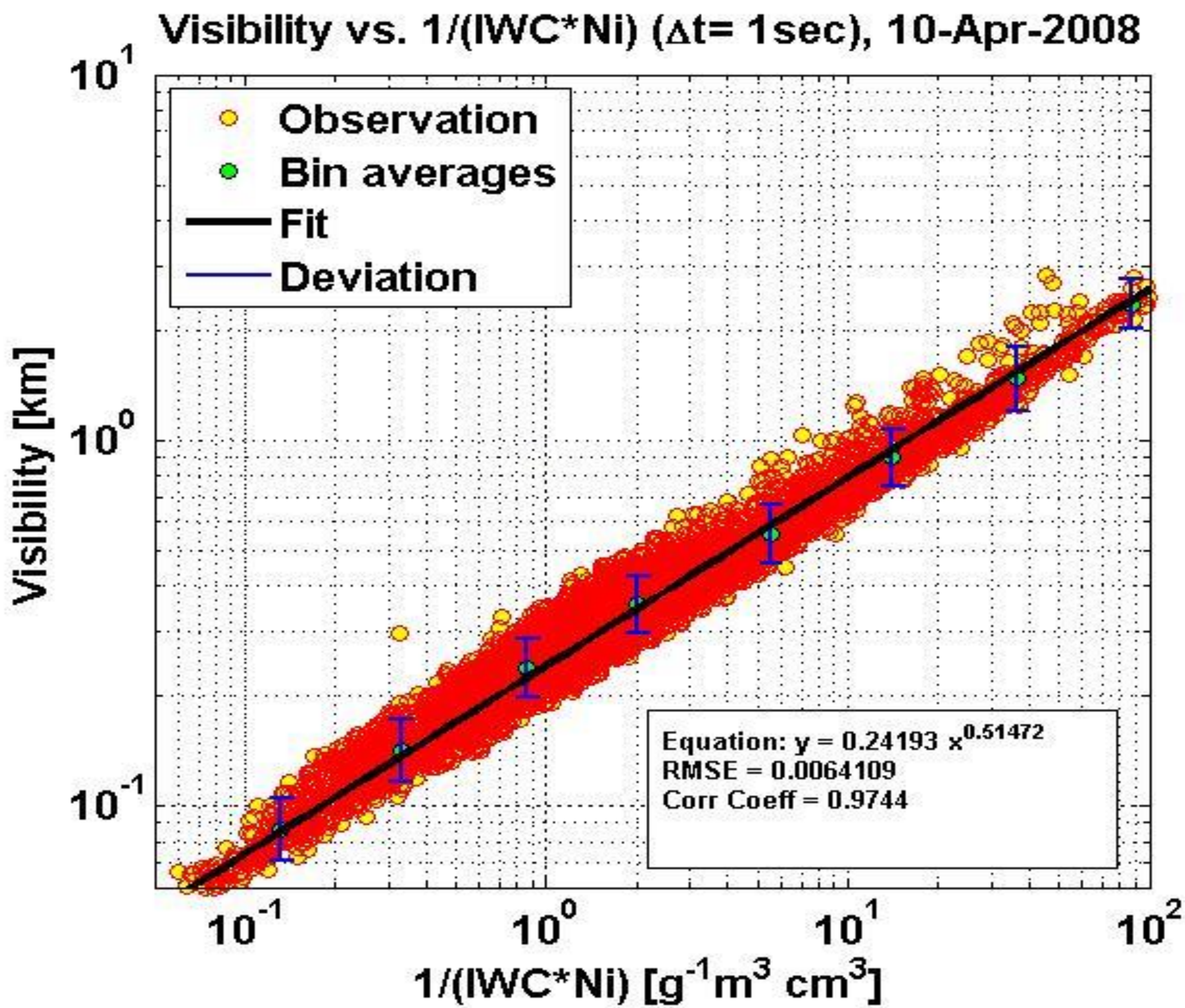

09:55:08.203273
09:55:05.733342
09:55:03.829942
09:55:01.183512
09:54:59.632101
09:54:55.833116
09:54:53.396229
09:54:51.192519
09:54:49.442814
09:54:47.851877
09:54:45.416239
09:54:43.552537
09:54:41.086971
09:54:38.731155
09:54:36.890532
09:54:33.953306
09:54:31.051916
09:54:27.764453
09:54:26.037797
09:54:22.528876



Extinction versus Xp
1-s Observations
Averages}
Fit to Averages
(b)
β_{ext} [km^{-1}]
Xp=IWC.N$_{t2ds}$ [g m^{-3} L^{-1})]
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-4}
10^{-2}
10^{0}
10^{2}
10^{4}



IWC water content (Δt= 1sec), 10-Apr-2008
Ice Water Content [gm^-3]
Ice Crystal Number Concentration [cm^-3]
10^0
10^-1
10^-2
10^-3
0
50
100
150
200
Observation
Bin averages
Fit
Deviation


Visibility vs. 1/(IWC*Ni) (Δt= 1sec), 10-Apr-2008
Observation
Bin averages
Fit
Deviation
Equation: y = 0.24193 x^0.51472
RMSE = 0.0064109
Corr Coeff = 0.9744
Visibility [km]
1/(IWC*Ni) [g^-1m^3 cm^3]
10^1
10^0
10^-1
10^-1
10^0
10^1
10^2

ICE FOG MICROPHYSICAL PARAMETERIZATION FOR FORECAST MODELS

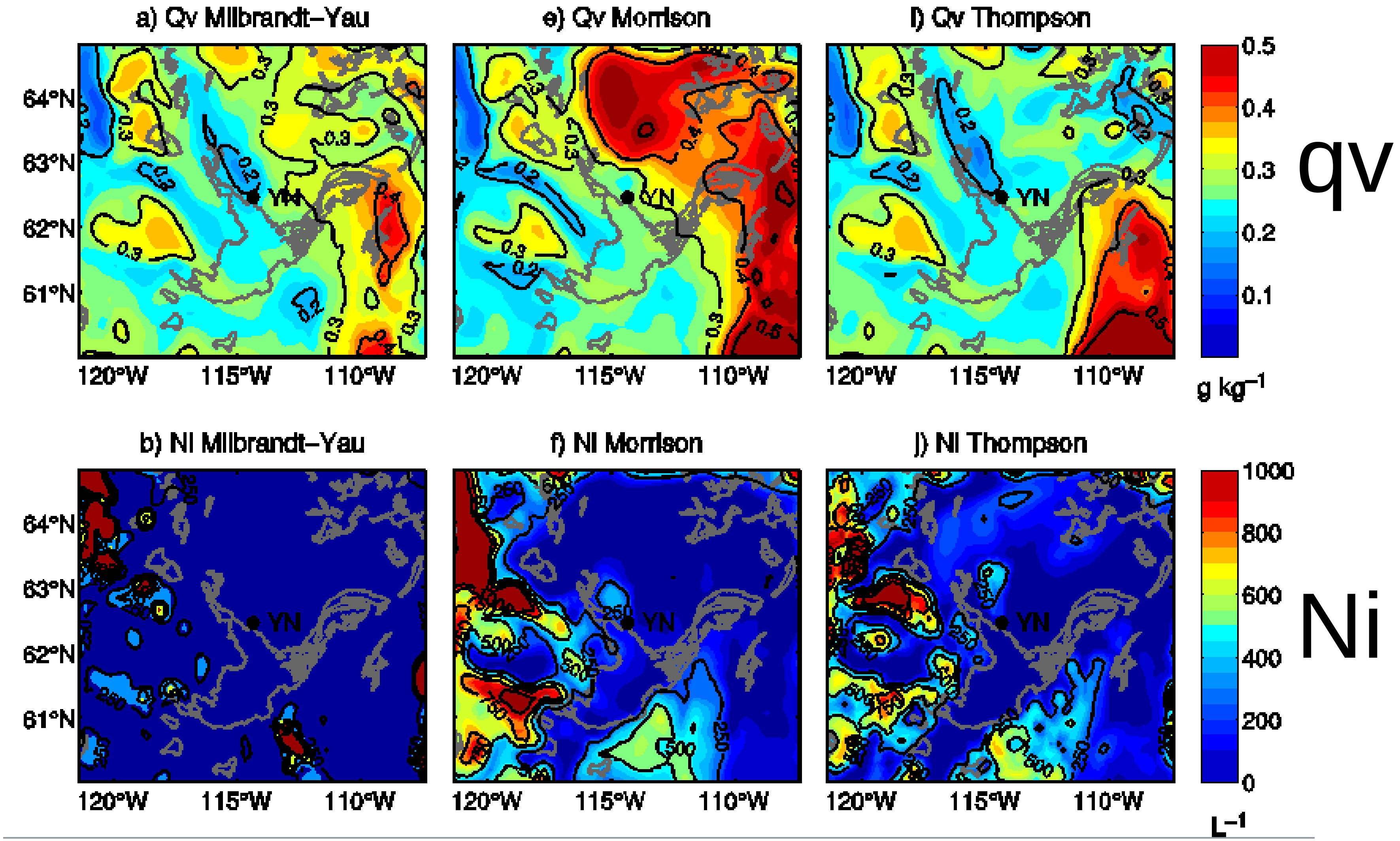
$$Vis = 1.19(IWC \bullet N_i)^{-0.5066}$$

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



WRF MODEL SIMULATIONS OF ICE FOG DURING FRAM PROJECT

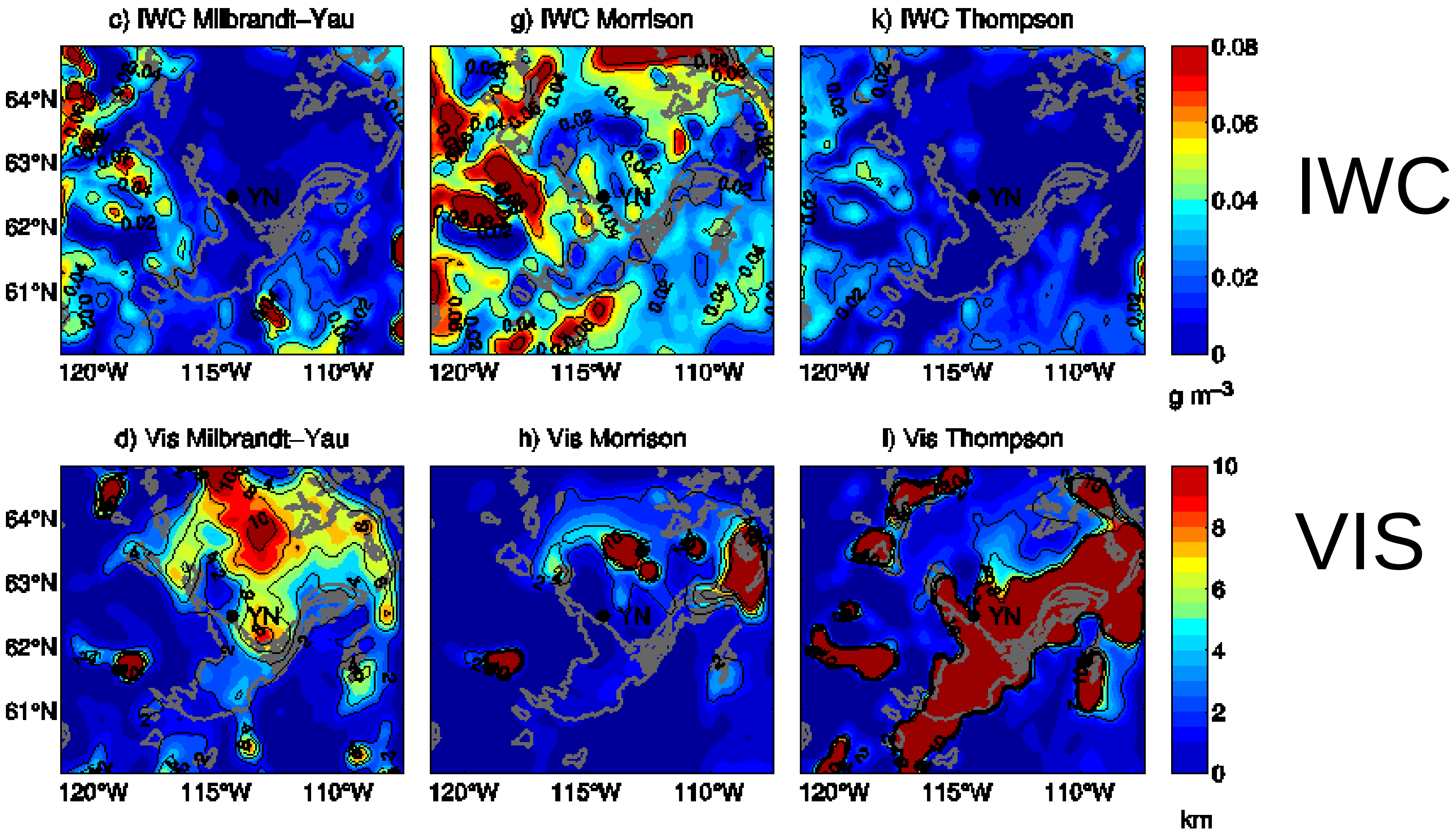
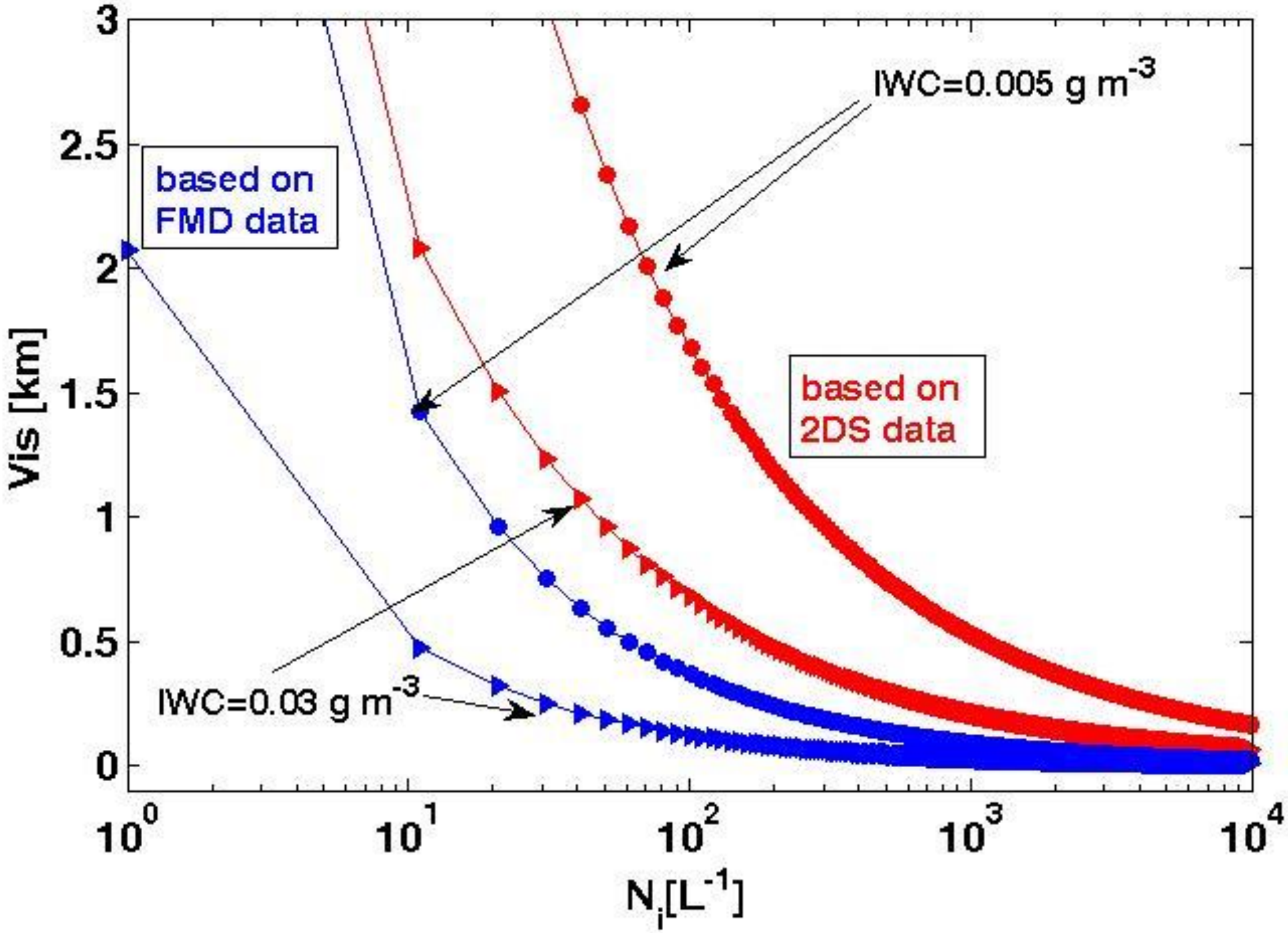


Figure 7: The Q_v, N_i, IWC, and Vis obtained from the WRF simulations (using 10 km grid resolution) on 08:00 LST, January 12 2011 over Yellowknife International Airport are shown in Figs. 7a-d for Milbrandt and Yau, in Figs. 7e-h for Morrison et al, in Figs. 7i-l for Thompson et al schemes, respectively.

FOG MEASUREMENT AND PREDICTION ISSUES



FOG MEASUREMENT AND PREDICTION ISSUES

1. ***WE CANT 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