Cloud modeling for Manaus region using OLAM

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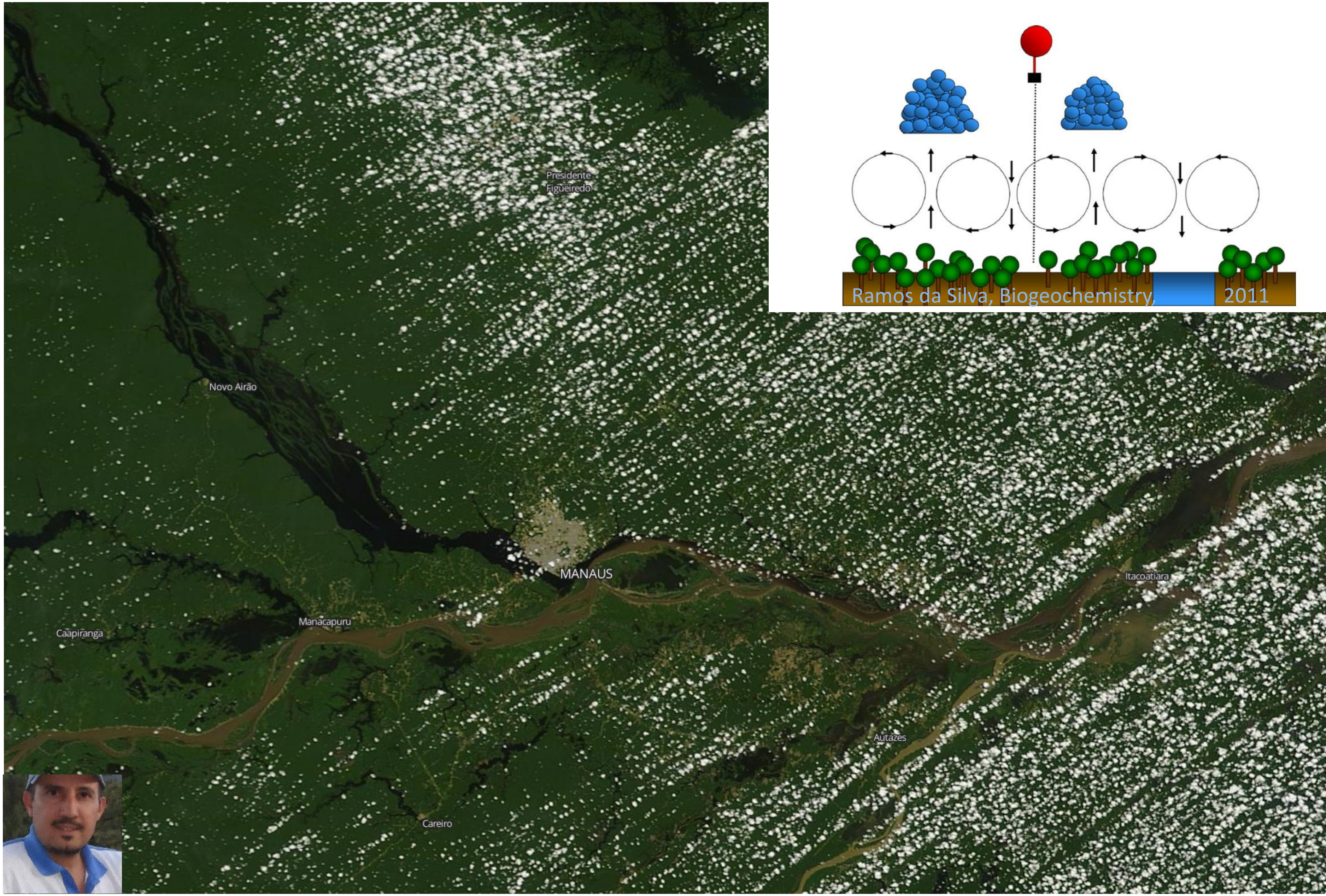
ACRIDICON-CHUVA:

Aerosol, Cloud, Precipitation, and Radiation Interactions and Dynamics of Convective Cloud Systems

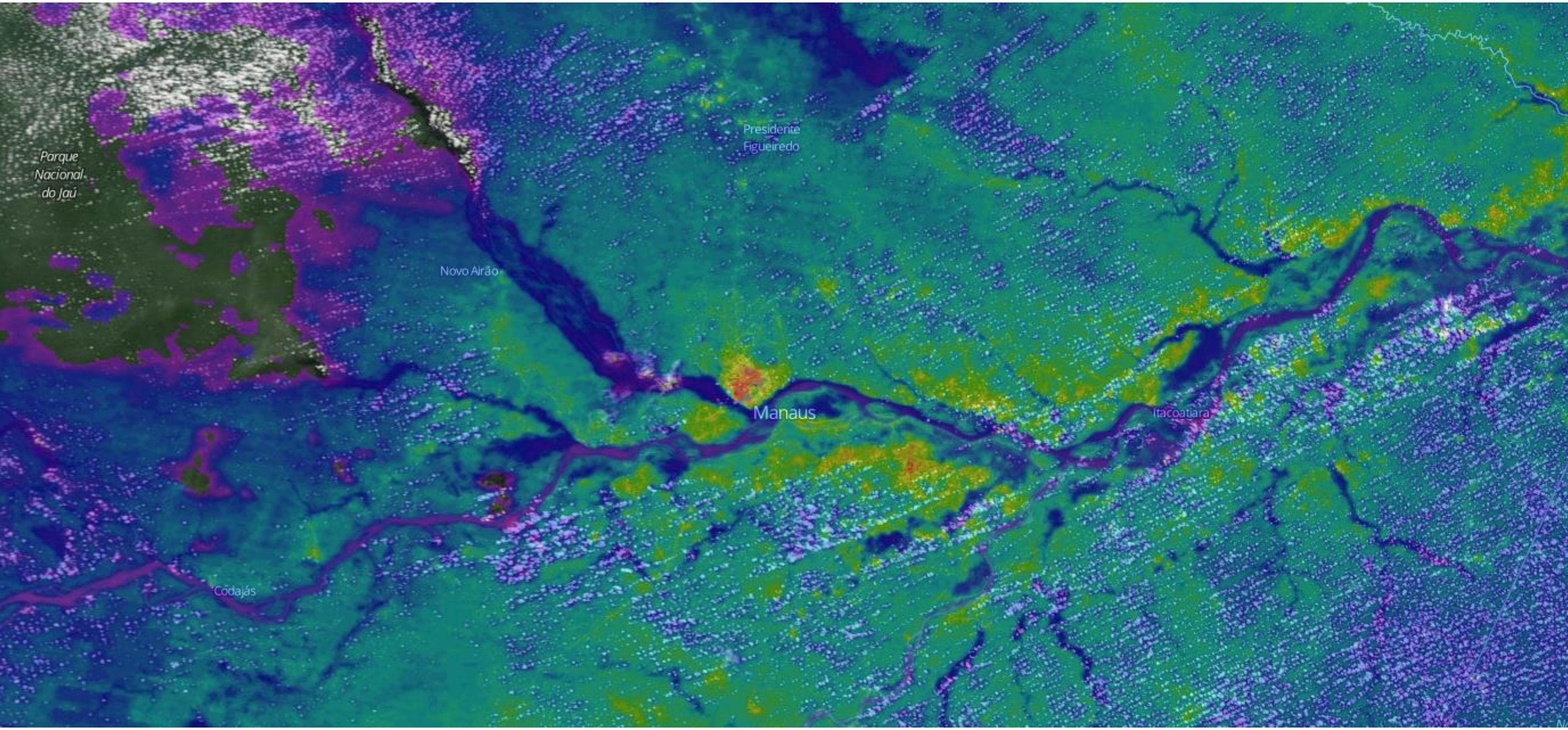
Cloud processes of the main precipitation systems in Brazil: A contribution to cloud resolving modeling and to the GPM (GlobAl Precipitation Measurement)

ILHABELA 02 March 2016



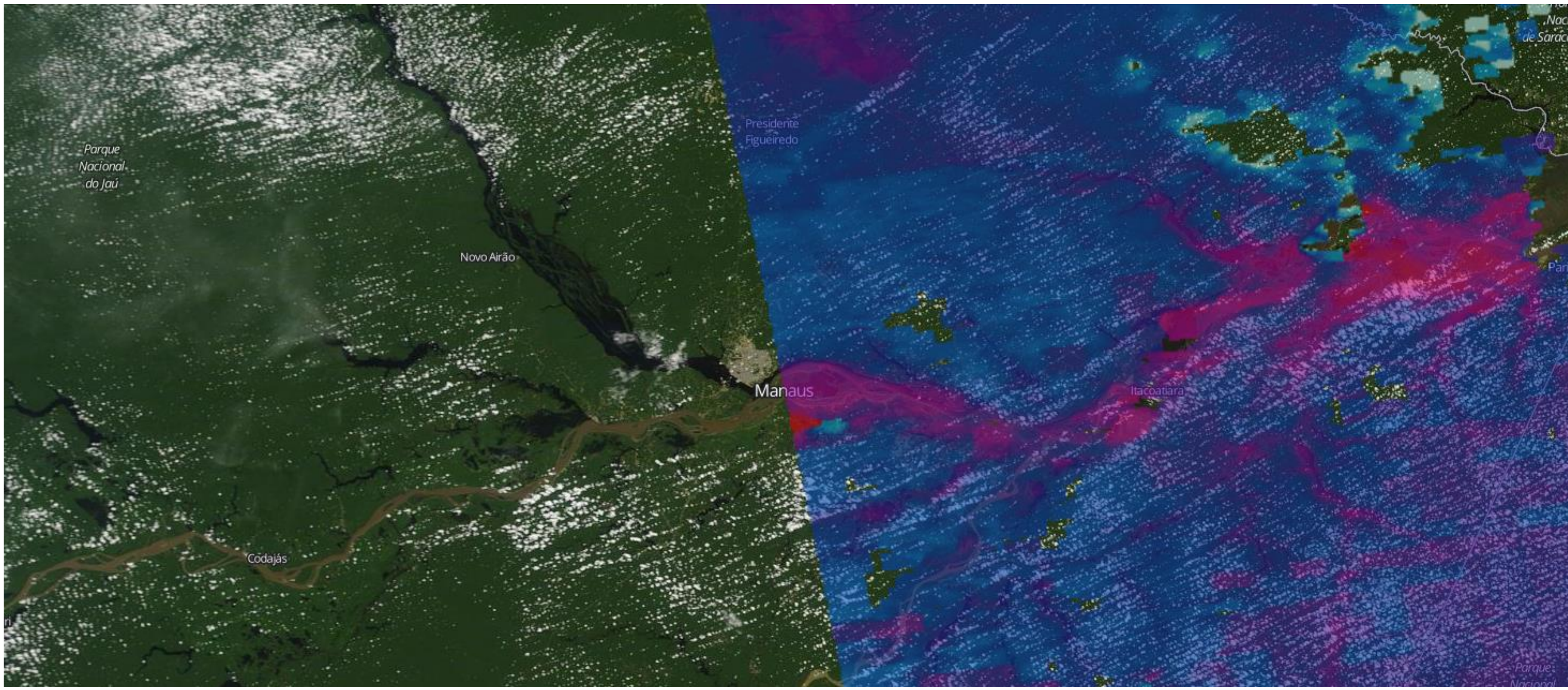
Terra Satellite - MODIS Sensor – 02 September 2014 (Cloud streets)

Surface Temperature estimated from Terra Satellite at daytime: City of Manaus (~ 39 ^oC); Rivers (~27-28 ^oC)



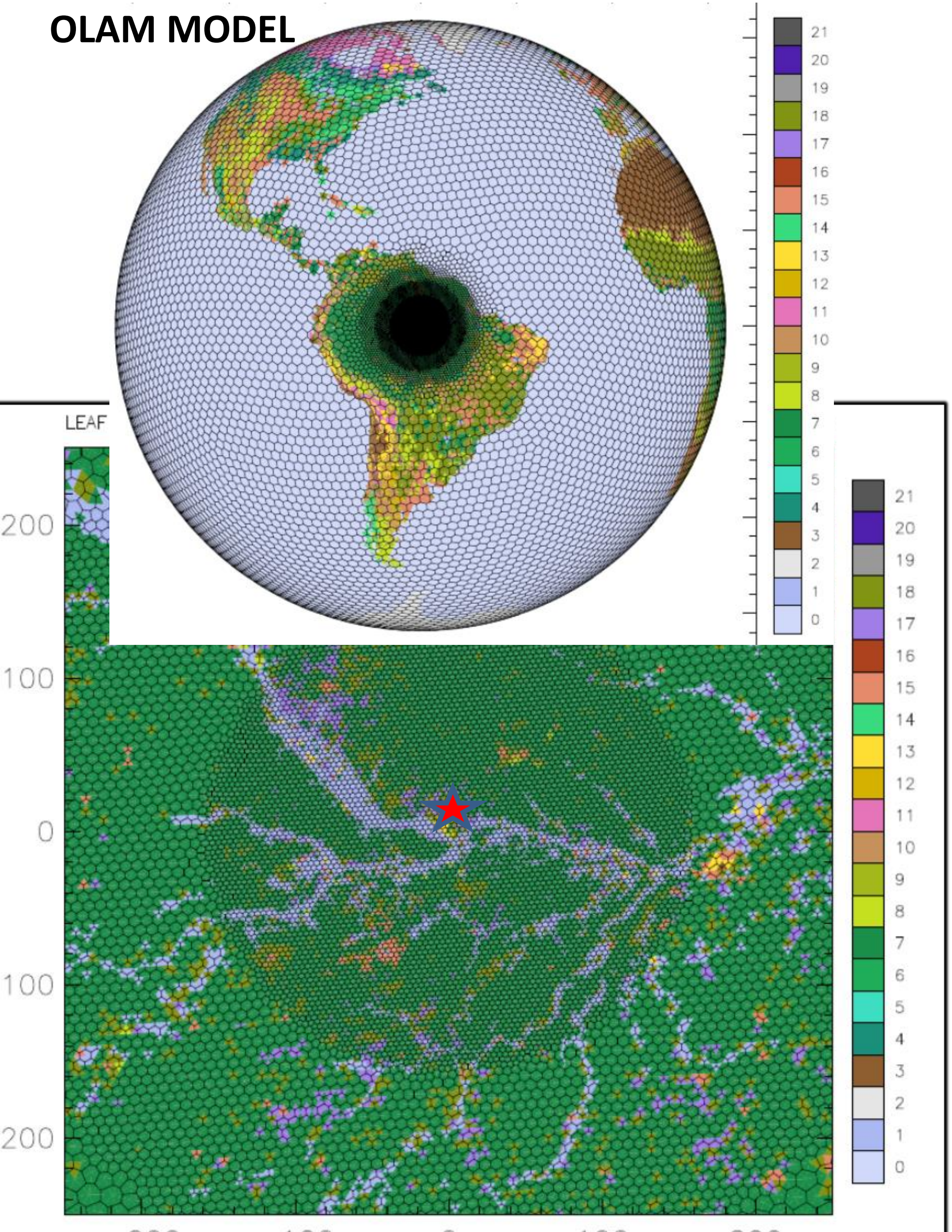
Terra Satellite - MODIS Sensor – 11 September

Surface Temperature estimated from Terra Satellite at nighttime: Rivers (~27-28 ^{o}C); Forest (~ 22 ^{o}C)



MODIS Sensor – 11 September 2014 – Temperature Night Time

OLAM MODEL



- Global Domain
- Non-structured Icosahedric hexagonal grid
- Finite volume integration
- RAMS - physics

- Innermost grid = 3.2 km
- Center (3.2S, 60W)
- 90 vertical levels (35 km height)
- Initial 00:00 UTC
- NCEP – Reanalysis
- September / March 2014
- Timestep = 2s
- LEAF (Soil/Veg model)
- Radiation = Harrington
- Turbulent flux = Smagorinski
- Kain-Fritsch cumulus
- Cloud Microphysics

OLAM Walko & Avissar (MWR, 2008)

OLAM – MODEL – Microphysics parametrization

Microphysical Processes

- Cloud droplet nucleation
- Ice nucleation
- Vapor diffusional growth
- Evaporation/sublimation
- Heat diffusion
- Freezing/melting
- Shedding
- Sedimentation
- Collisions between hydrometeors
- Secondary ice production

Hydrometeor Types

C 1. Cloud droplets

R 2. Rain

P 3. Pristine ice

S 4. Snow

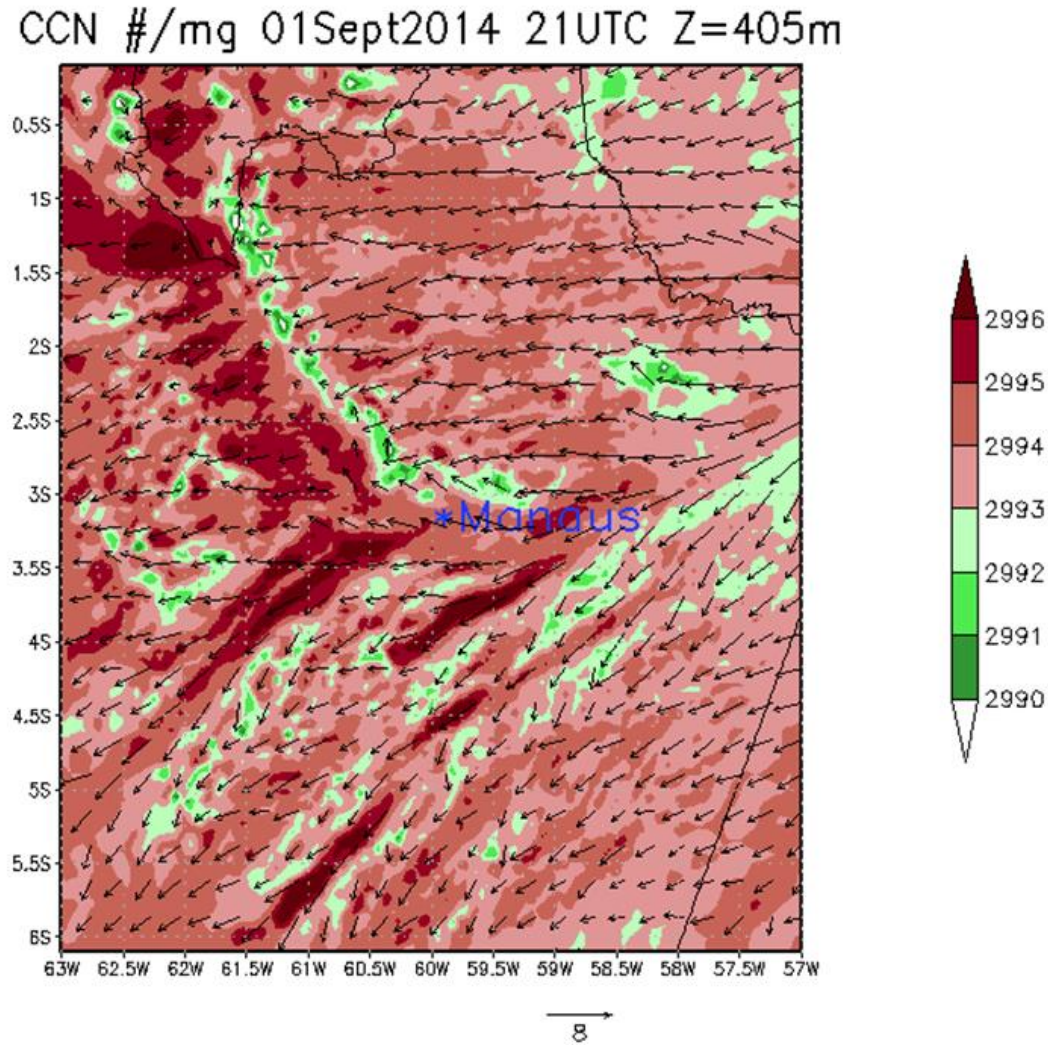
A 5. Aggregates

G 6. Graupel

H 7. Hail

D 8. Drizzle

OLAM - MODEL

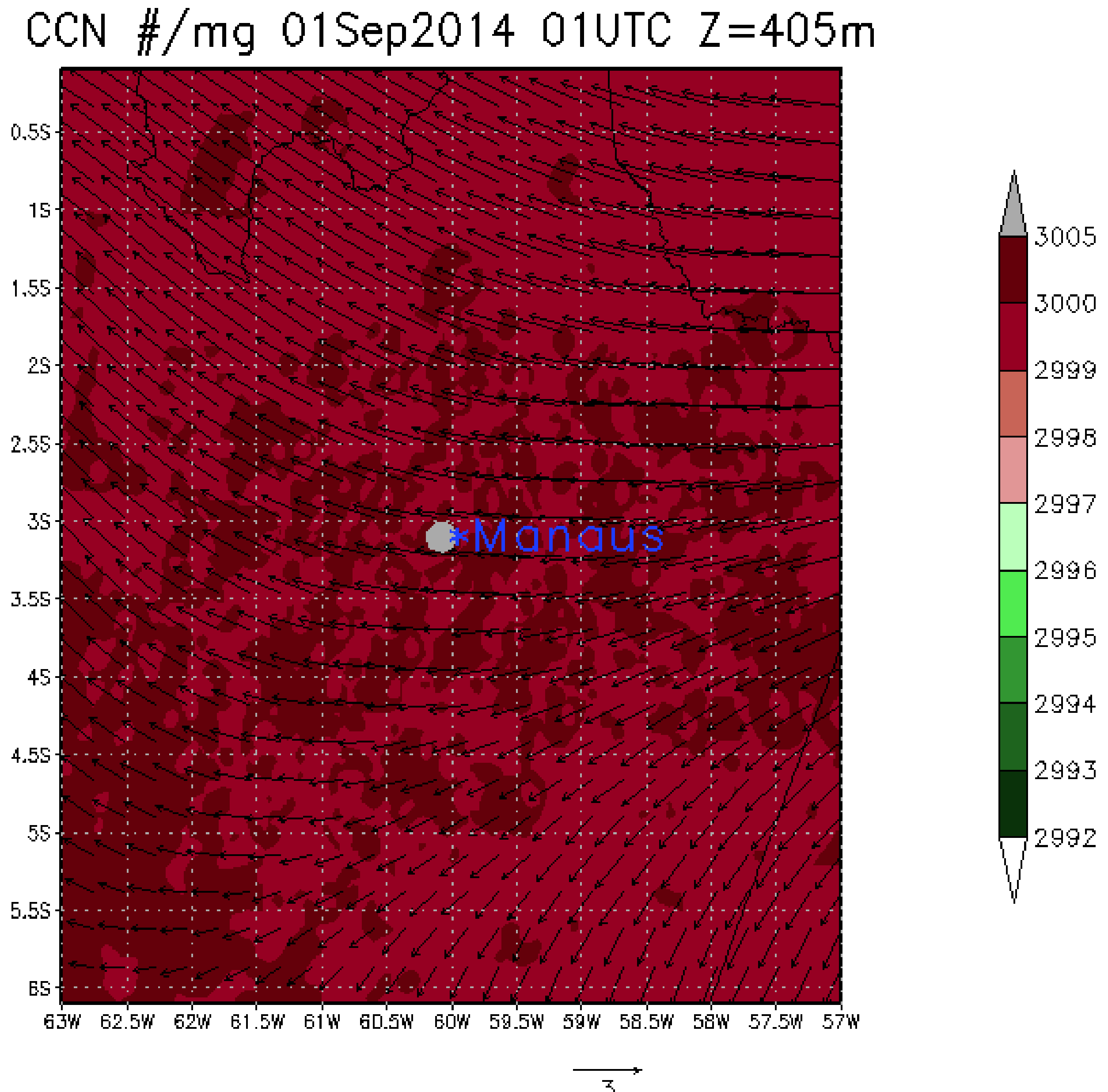


OLAM CCN Concentration (#/mg) 1st September 2014 21:00 UTC at z=405 meters

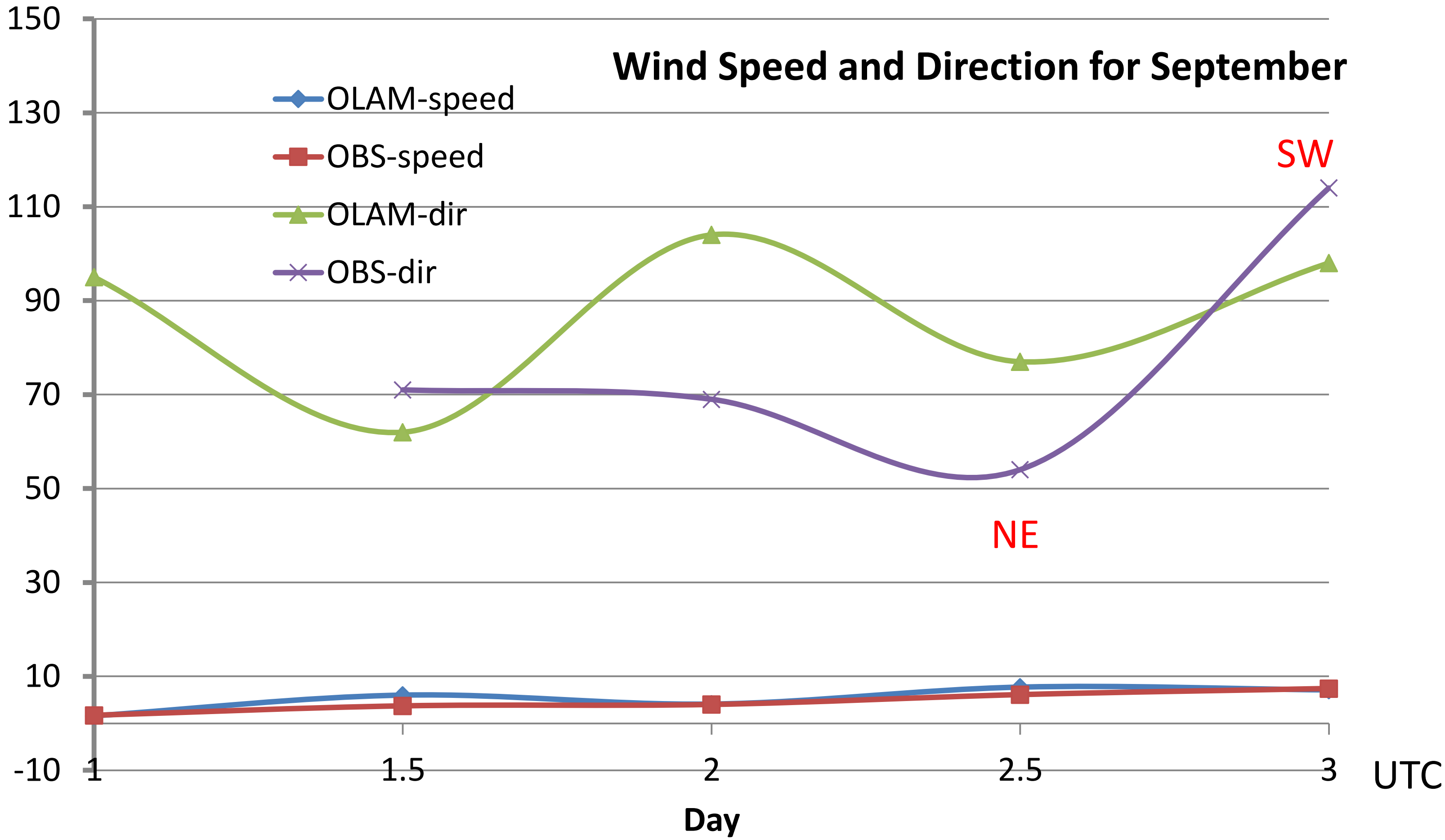
OLAM Initial CCN Concentration
Background = 3000 (#/mg)
Initial time: 1st Sep 2014 00:00 UTC

Land-cover heterogeneity and winds sets the dynamics and spatial distribution of the CCN concentrations
At the afternoon CCN concentration shows that the land-river interfaces has fundamental effects on the spatial distribution.
At the south of Manaus the CCN organization follows the cloud streets aligned with the wind flow.
At the north of Manaus the CCN has influence of the colder air advection that flows over the Negro river setting a more stable atmosphere.
At this region the CCN concentration is higher.
Diffusion and Convection are the main physical processes.

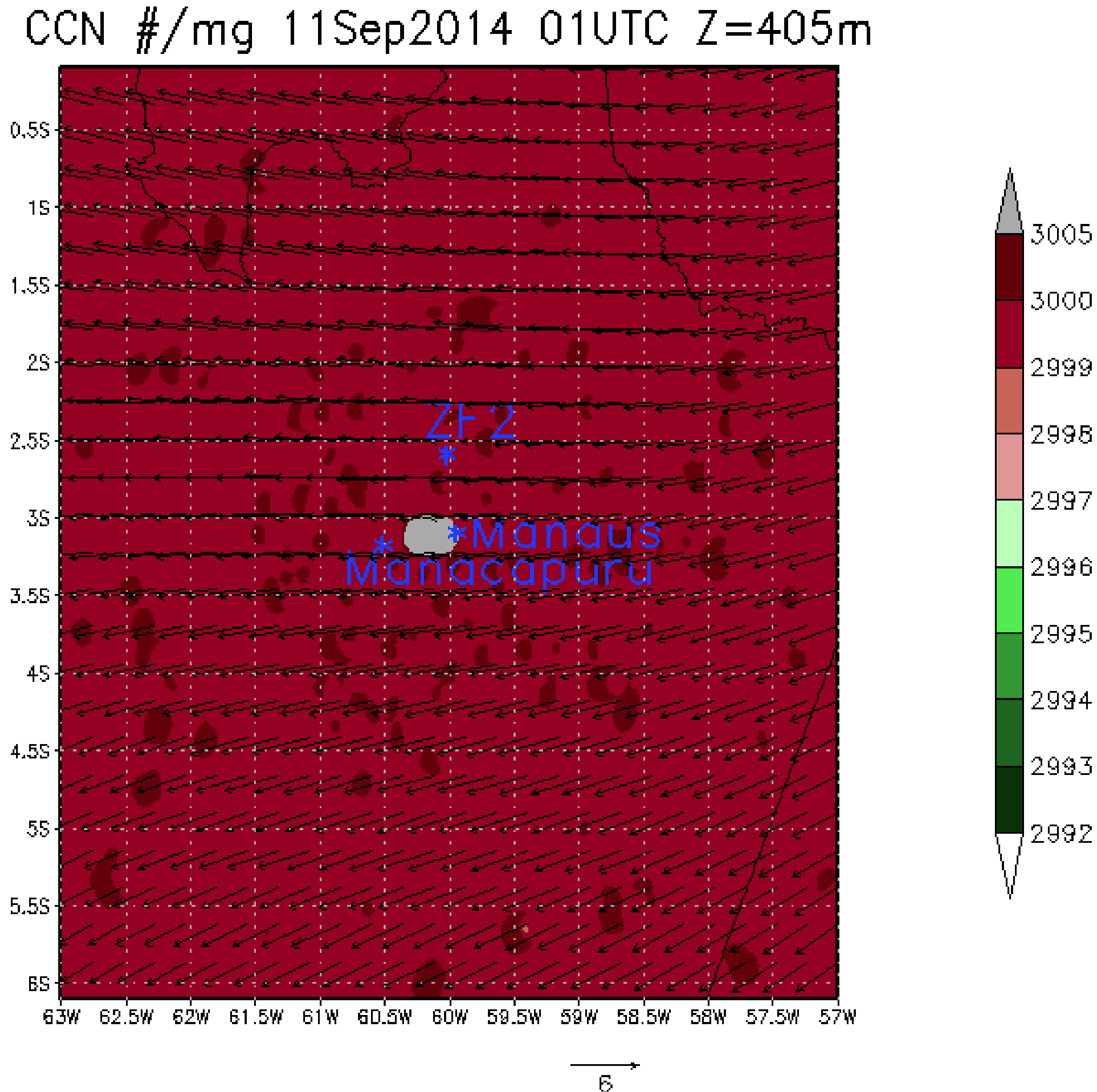
OLAM CCN & winds / Manaus emission at 00 UTC (only)



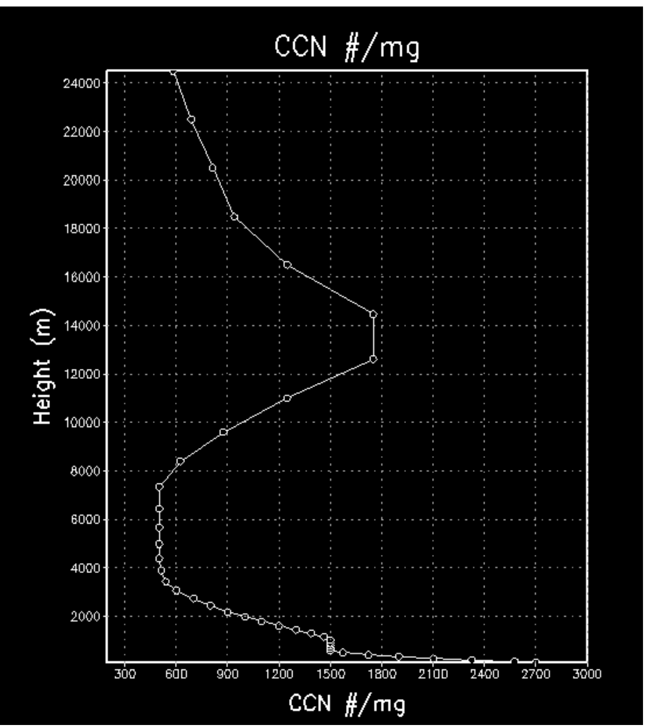
Wind speed and direction for September 2014 at the model height **405** meters OLAM and radiosounding at the site T3 (-60.6 W; -3.21 S). The small wind direction change is important for the plume location.

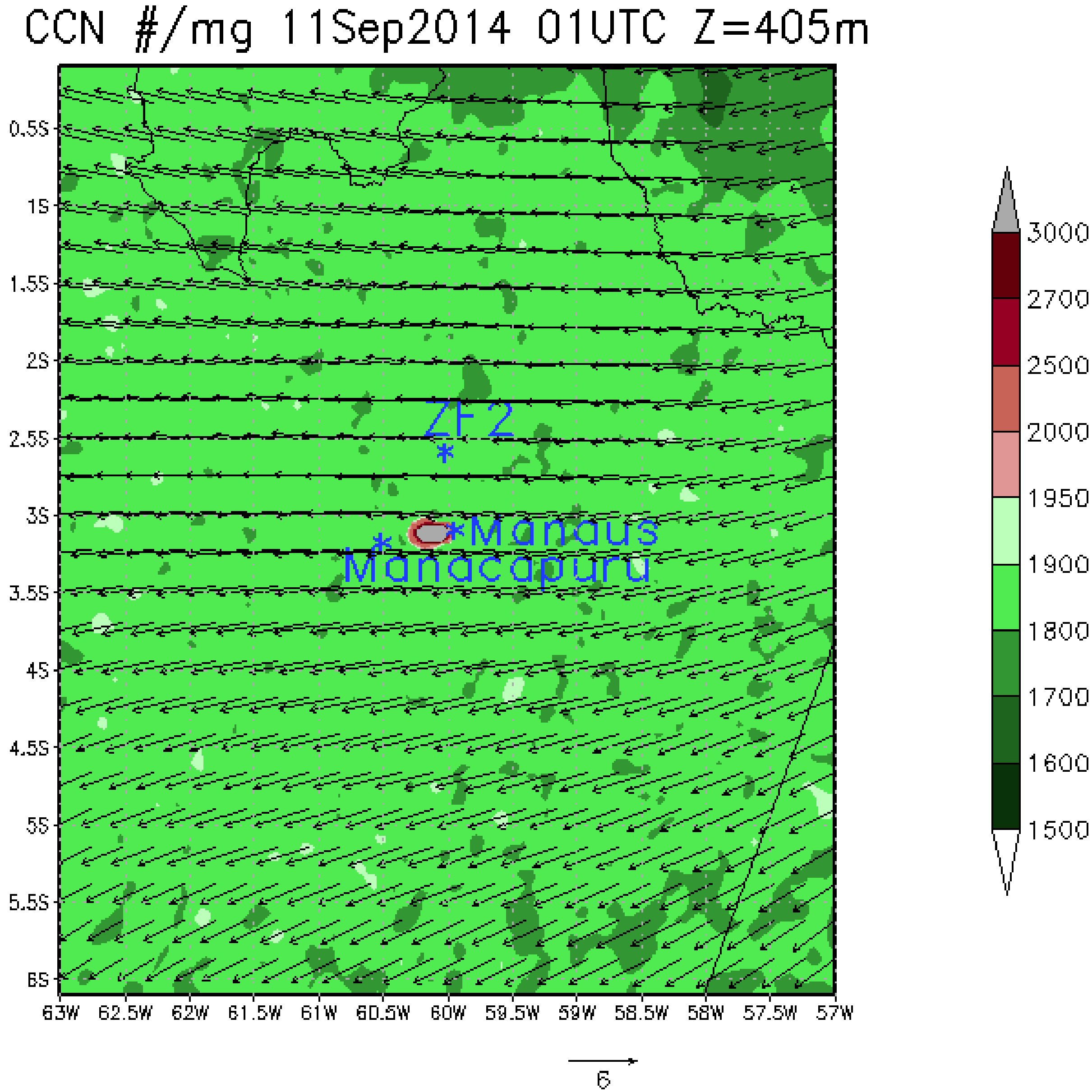


OLAM – Model simulation of the CCN plume dynamics from Manaus – **continuous emission**



OLAM – New CCN profile background based on the **HALO** measurement





G1 Flight 11/Sep/2014

G1 Flight 11/Sep/2014

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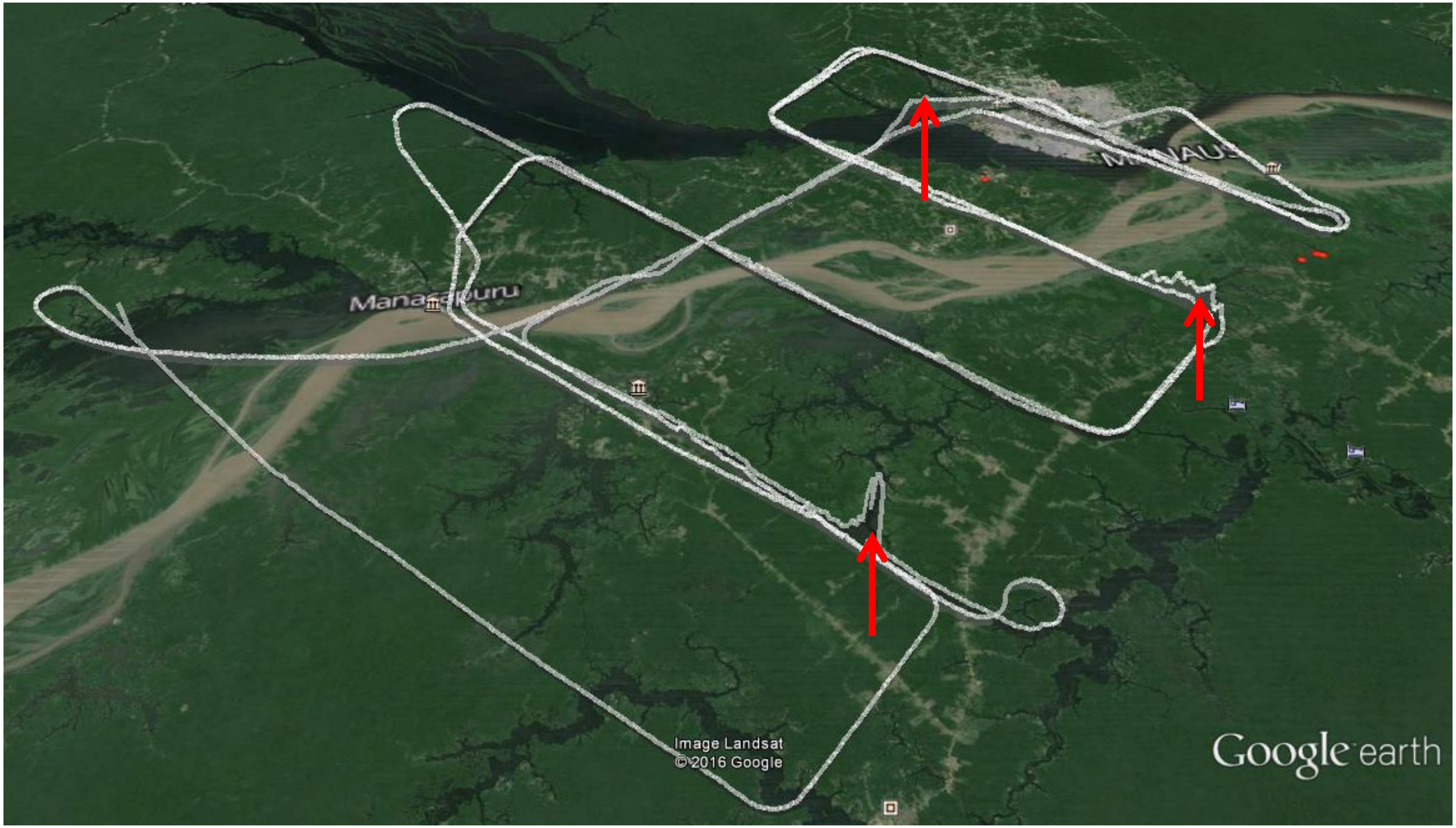
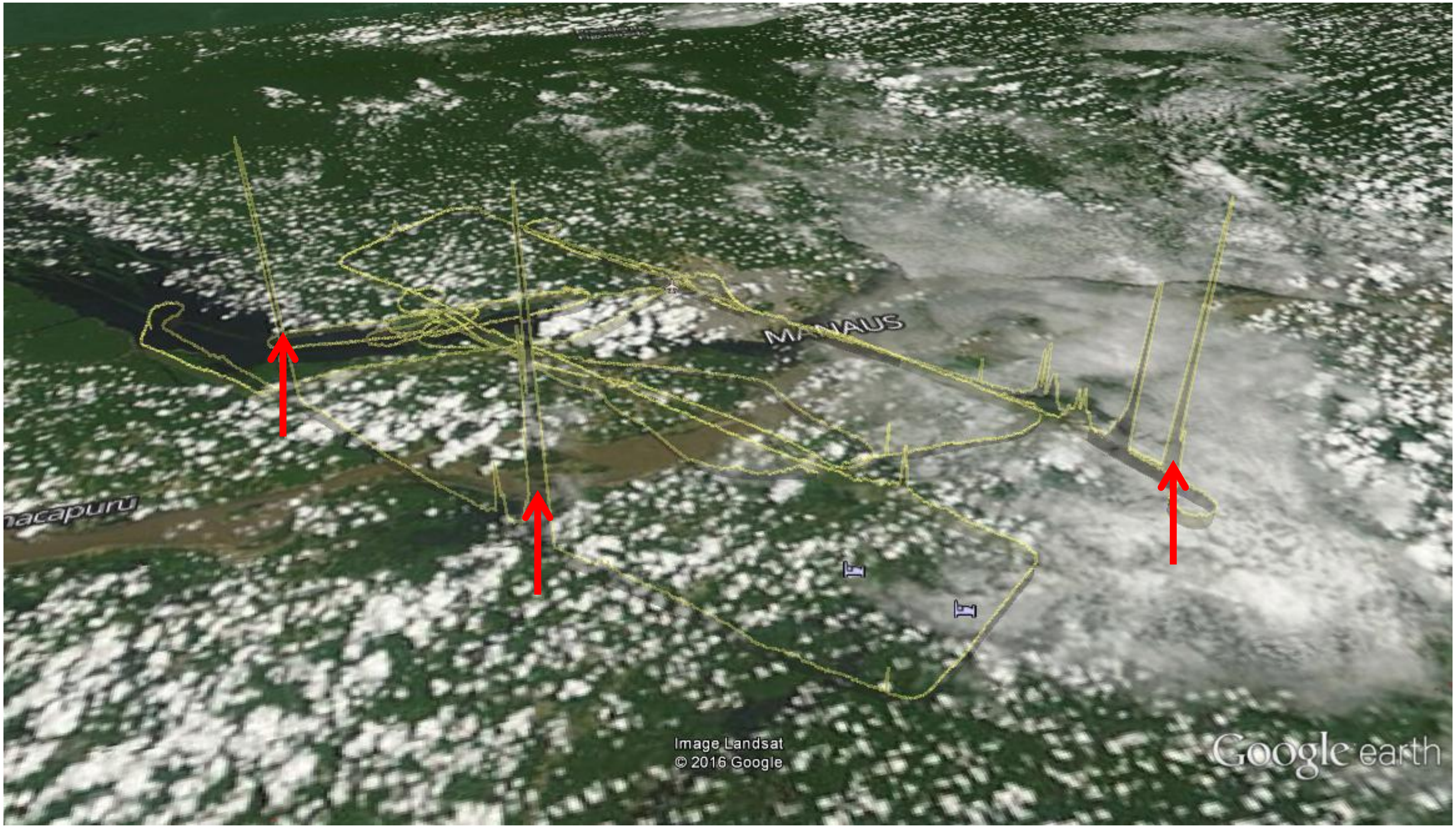
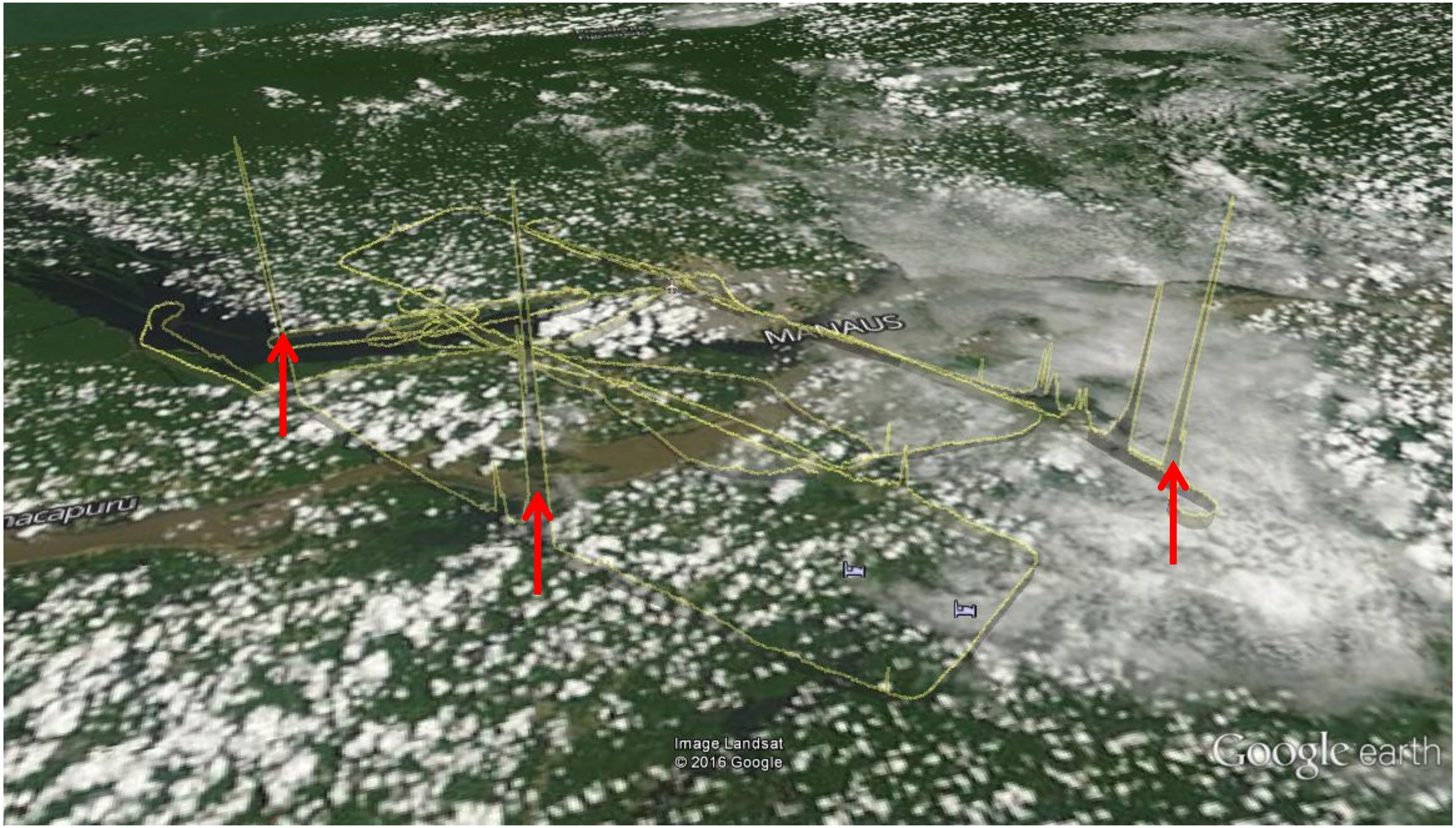


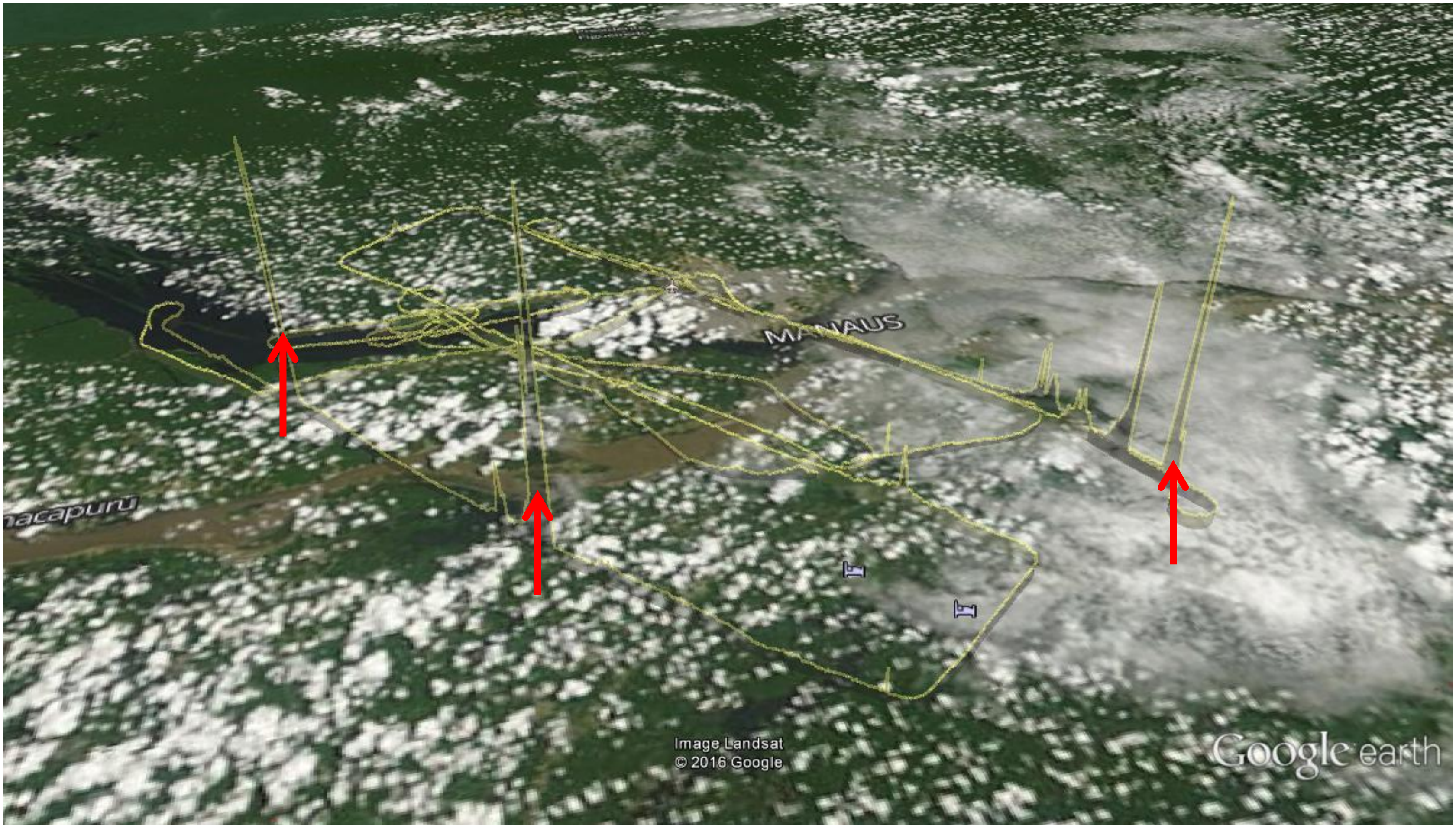
G1 Flight 25/Sep/2014



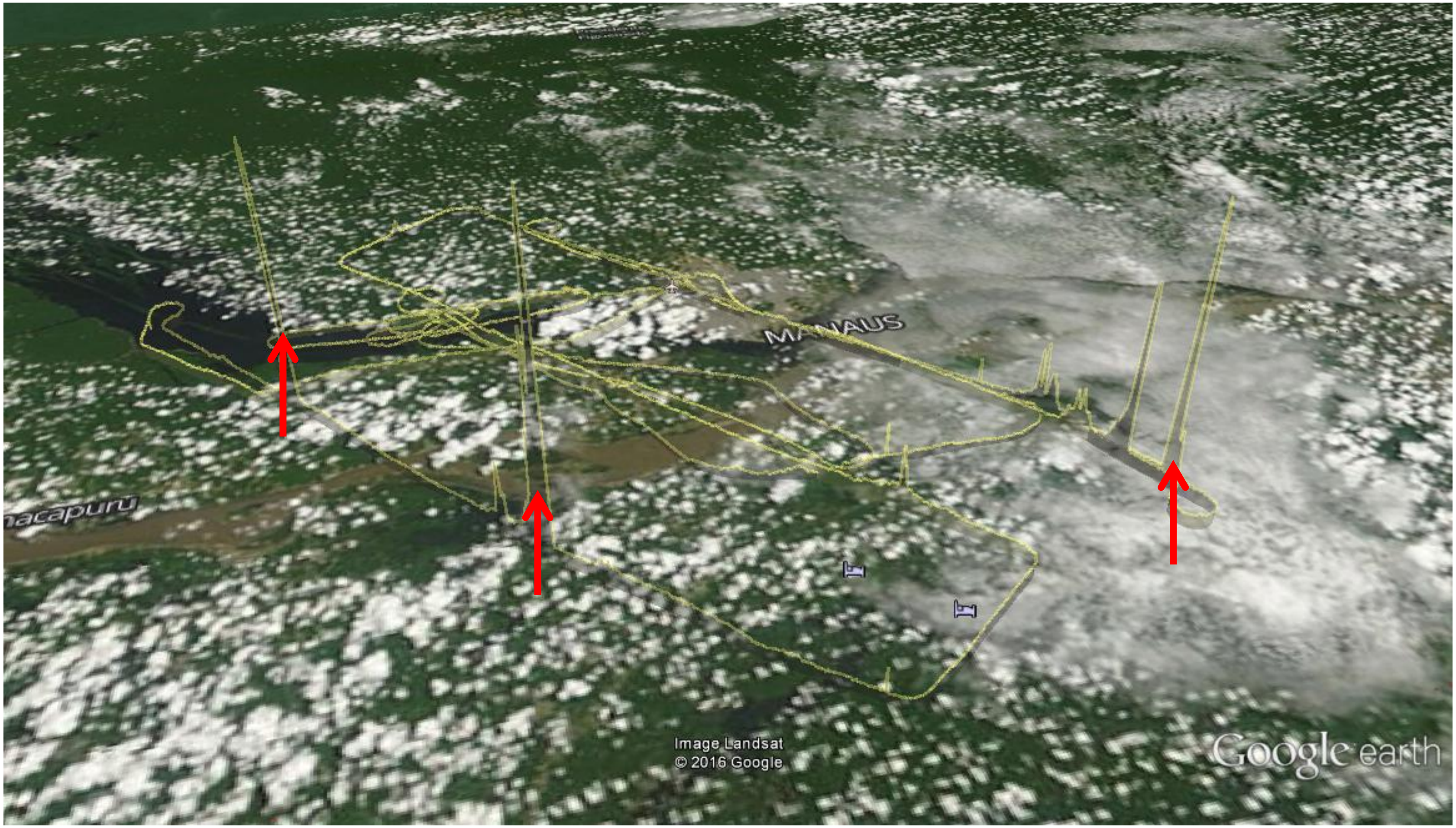
G1 Flight 25/Sep/2014



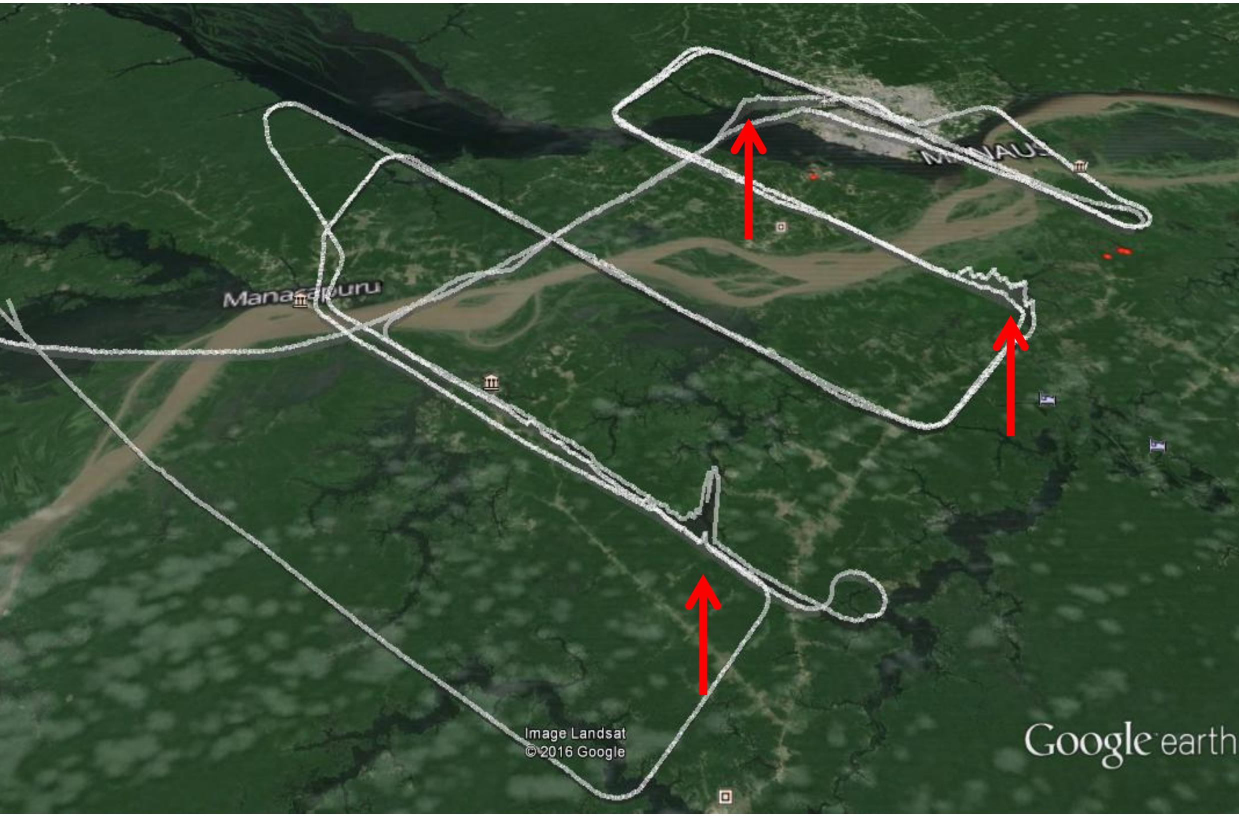
G1 Flight 25/Sep/2014

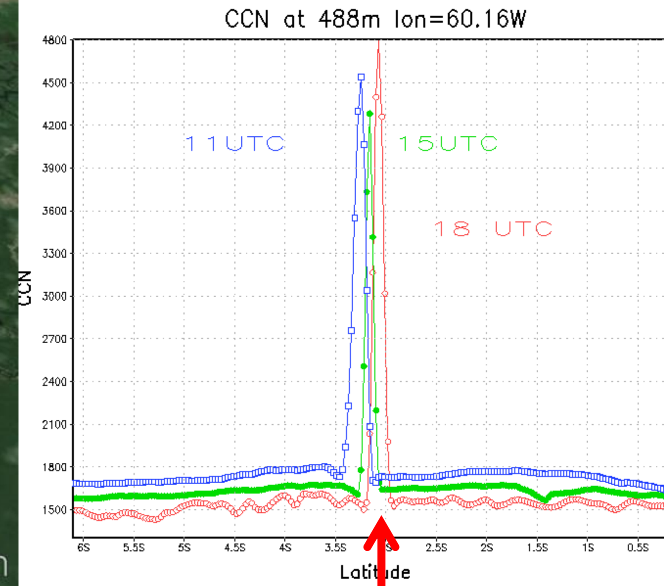


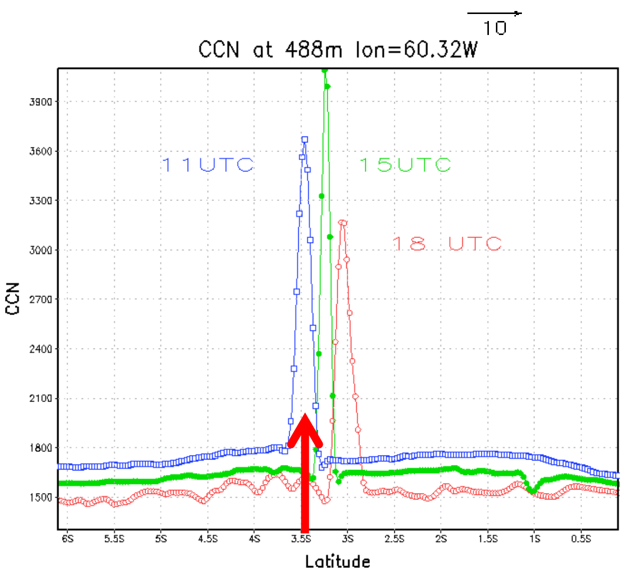
G1 Flight 25/Sep/2014



OLAM CCN N-S





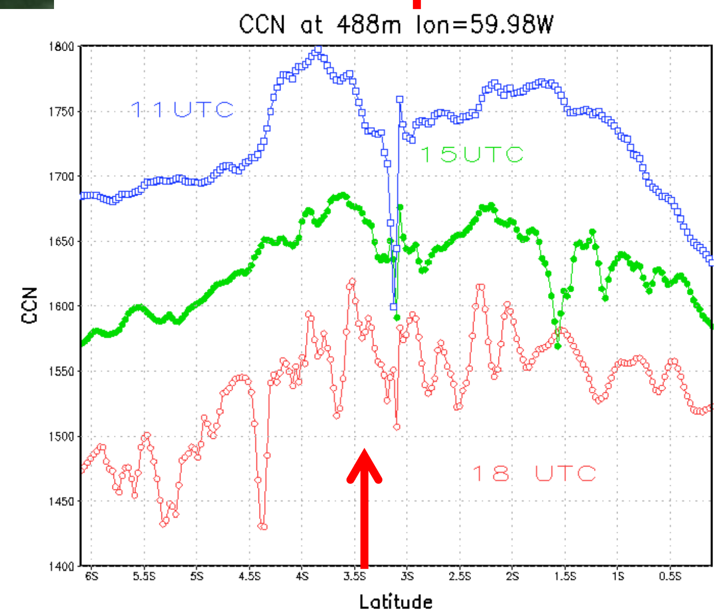


LAT; LON

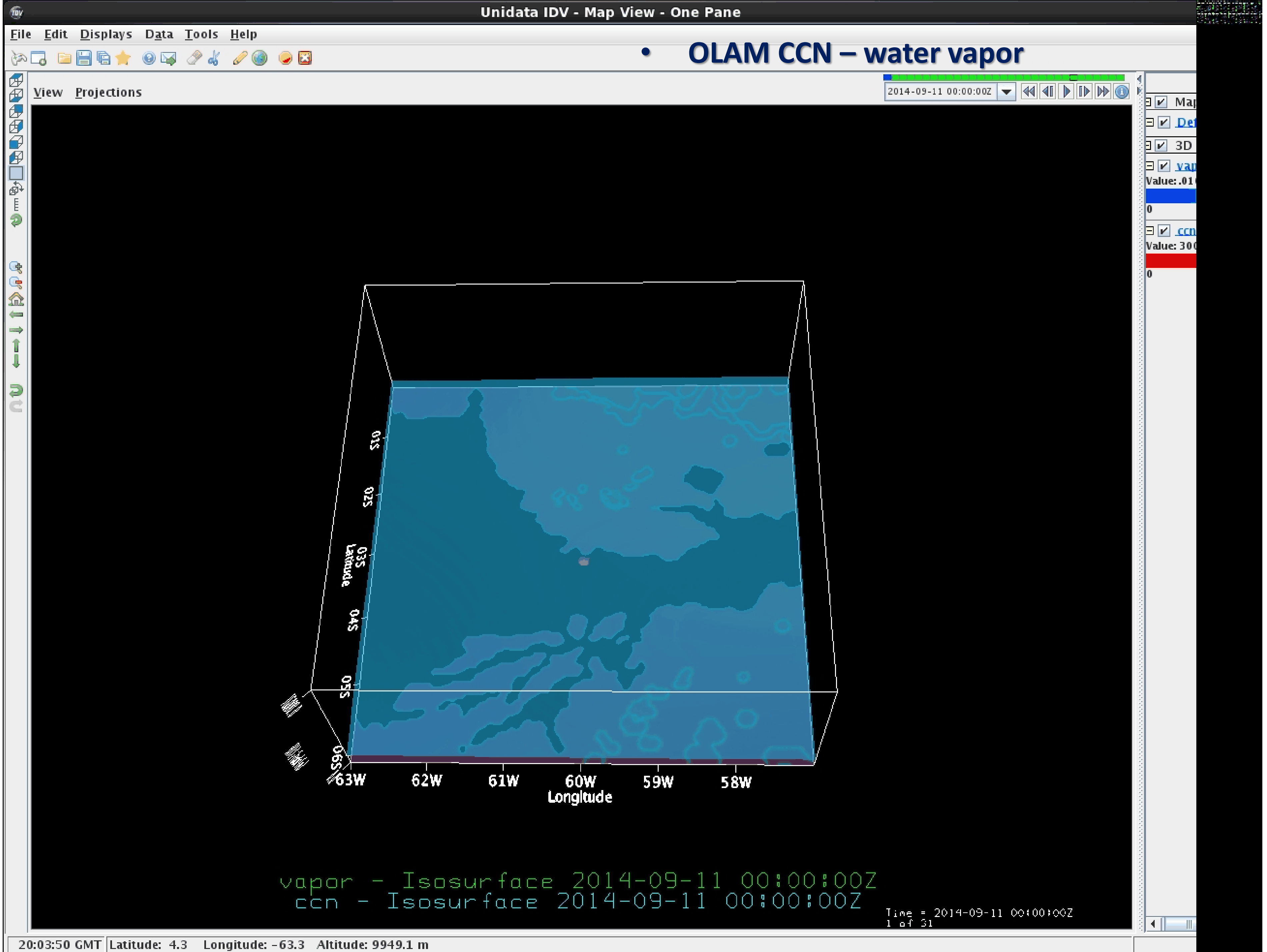
-3.05; 60.16

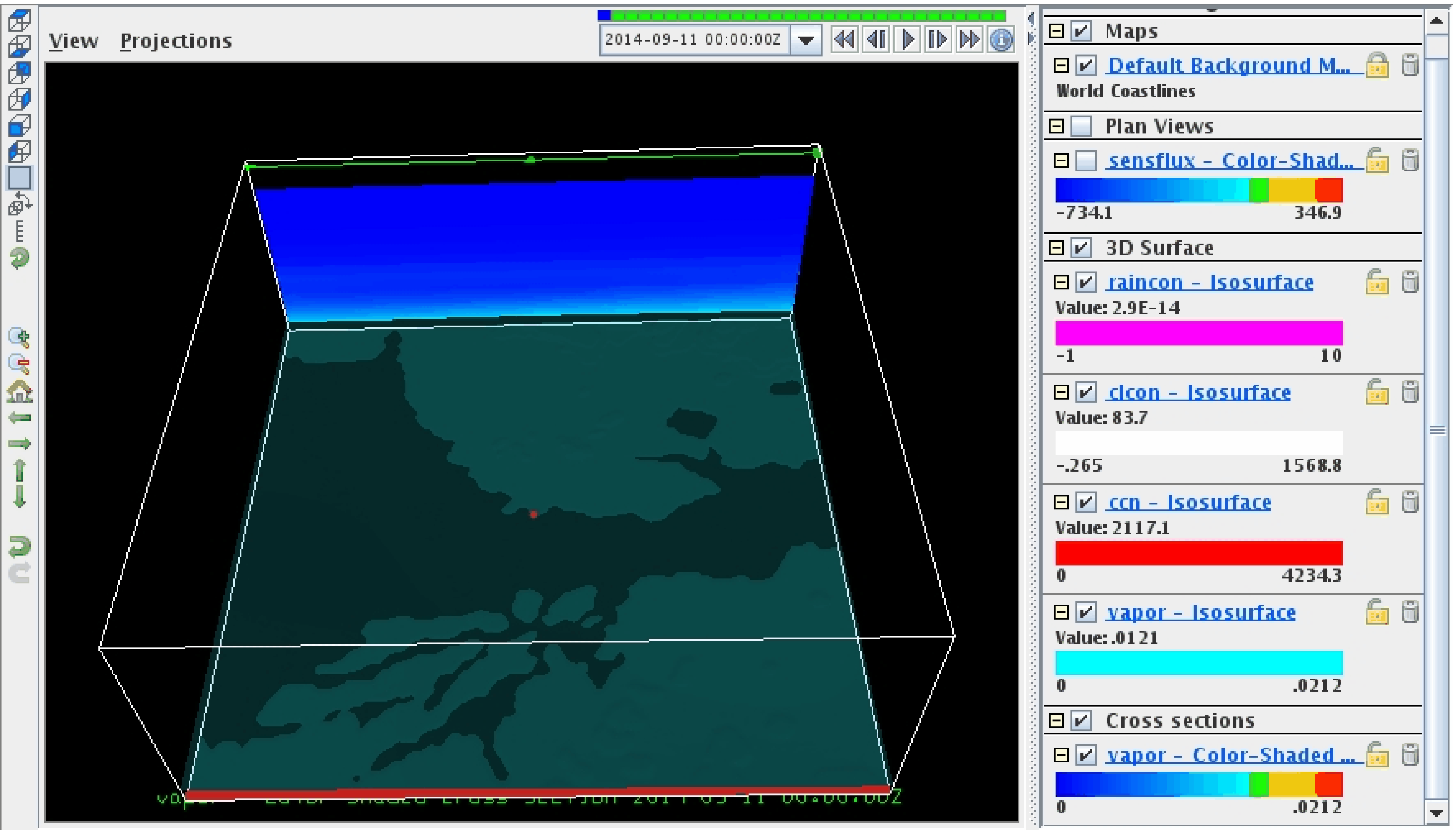
-3.61; 60.32

-3.40; 59.98

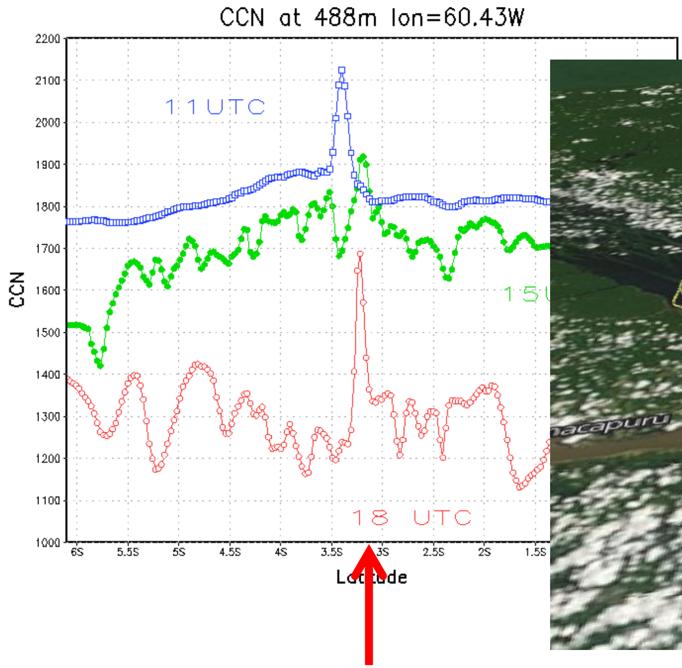


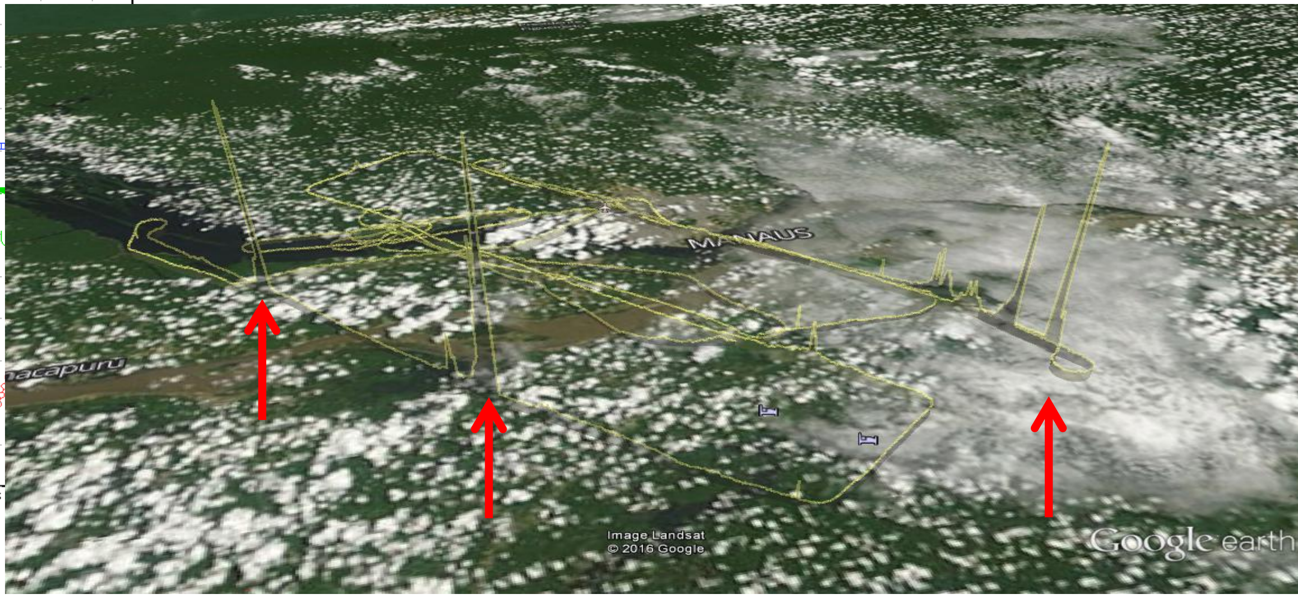
- **OLAM CCN – water vapor**

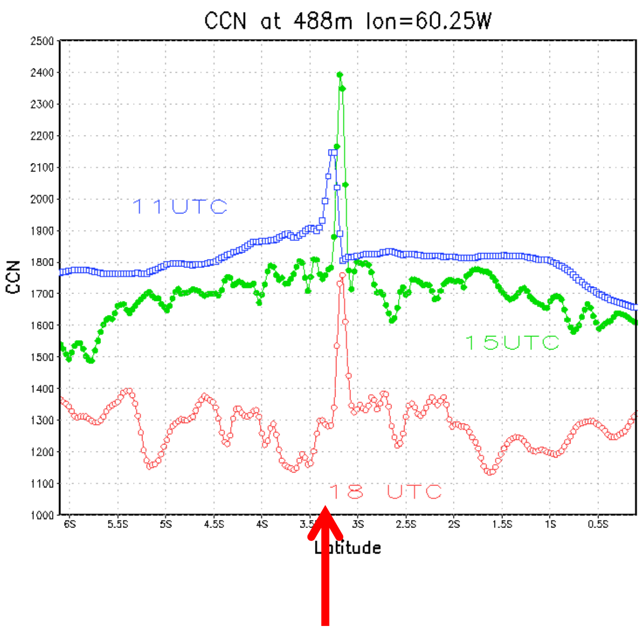



View
Projections
2014-09-11 00:00:00Z
Maps
Default Background M...
World Coastlines
Plan Views
sensflux - Color-Shad...
-734.1
346.9
3D Surface
raincon - Isosurface
Value: 2.9E-14
-1
10
clcon - Isosurface
Value: 83.7
-.265
1568.8
ccn - Isosurface
Value: 2117.1
0
4234.3
vapor - Isosurface
Value: .0121
0
.0212
Cross sections
vapor - Color-Shaded ...
0
.0212

• OLAM CCN – Plume location (G1 & OLAM Sep 25





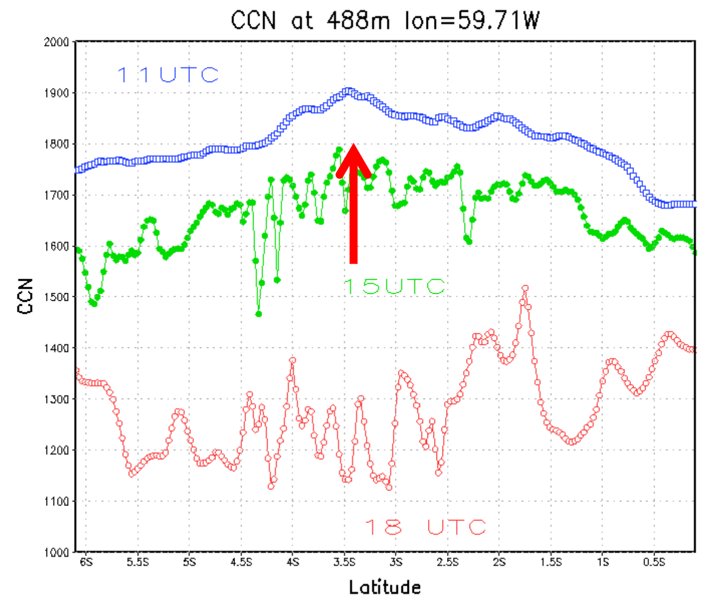


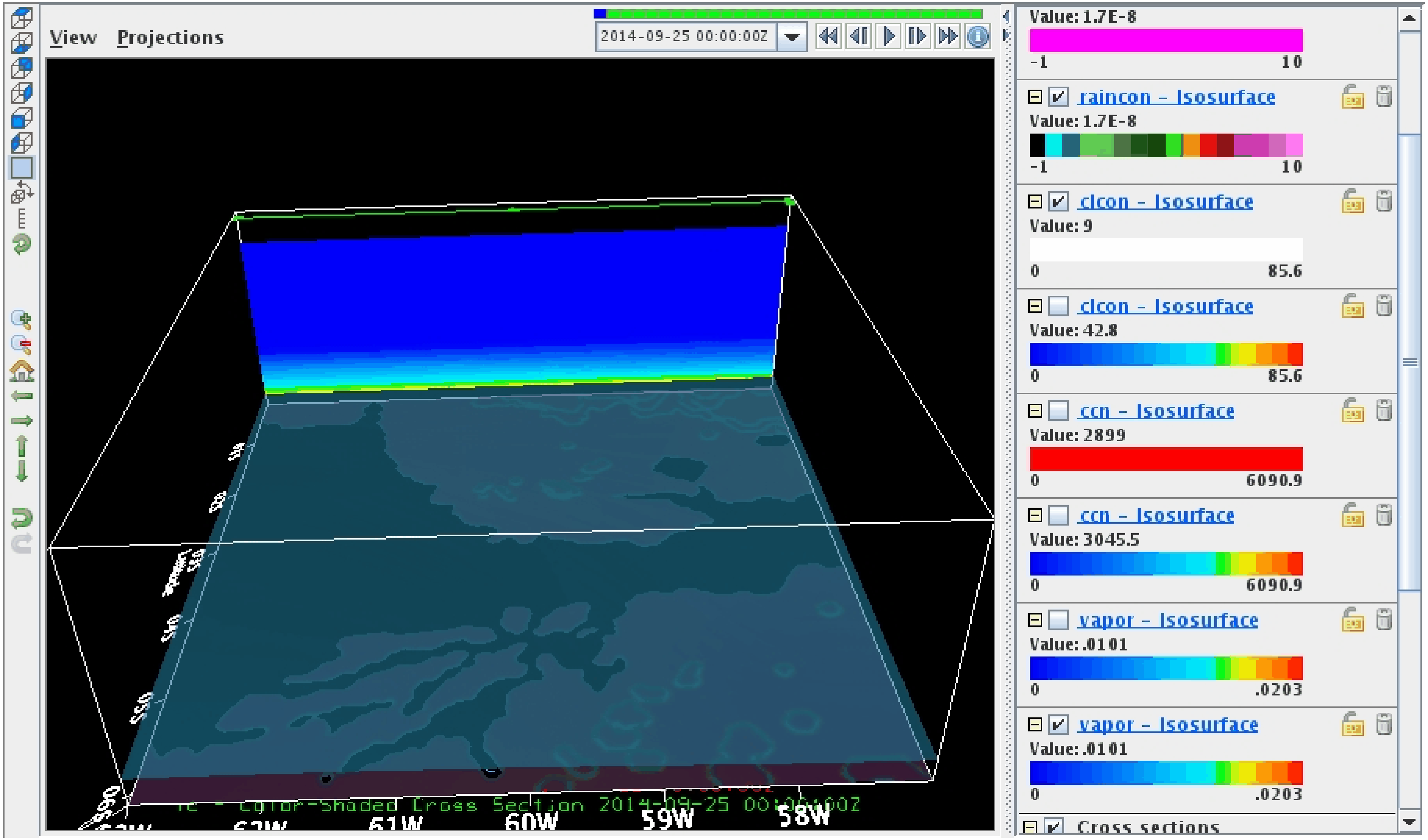
LAT; LON

-3.17; -60.43

-3.40; 60.26

-3.46; 59.71




View
Projections
2014-09-25 00:00:00Z
Value: 1.7E-8
-1
10
raincon - Isosurface
Value: 1.7E-8
-1
10
clcon - Isosurface
Value: 9
0
85.6
clcon - Isosurface
Value: 42.8
0
85.6
ccn - Isosurface
Value: 2899
0
6090.9
ccn - Isosurface
Value: 3045.5
0
6090.9
vapor - Isosurface
Value: .0101
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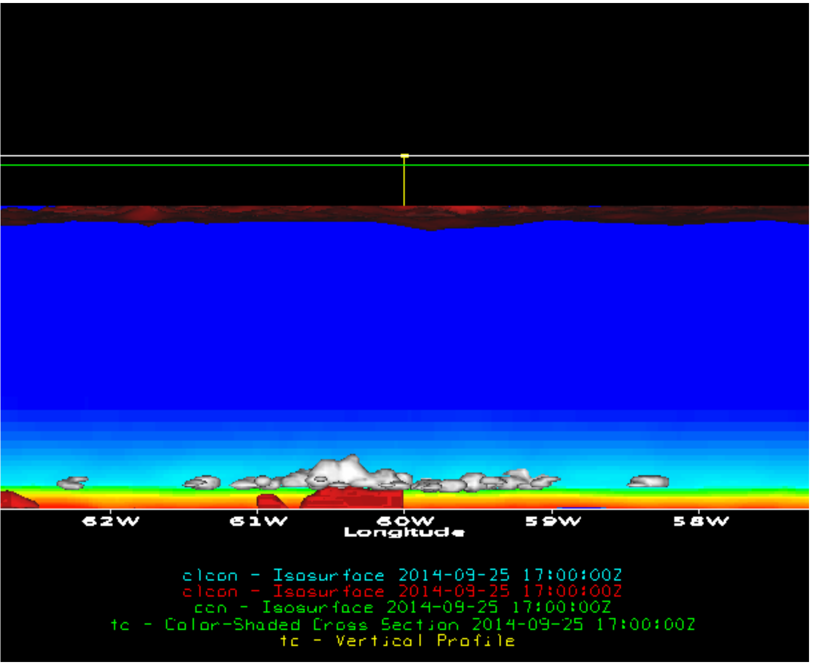
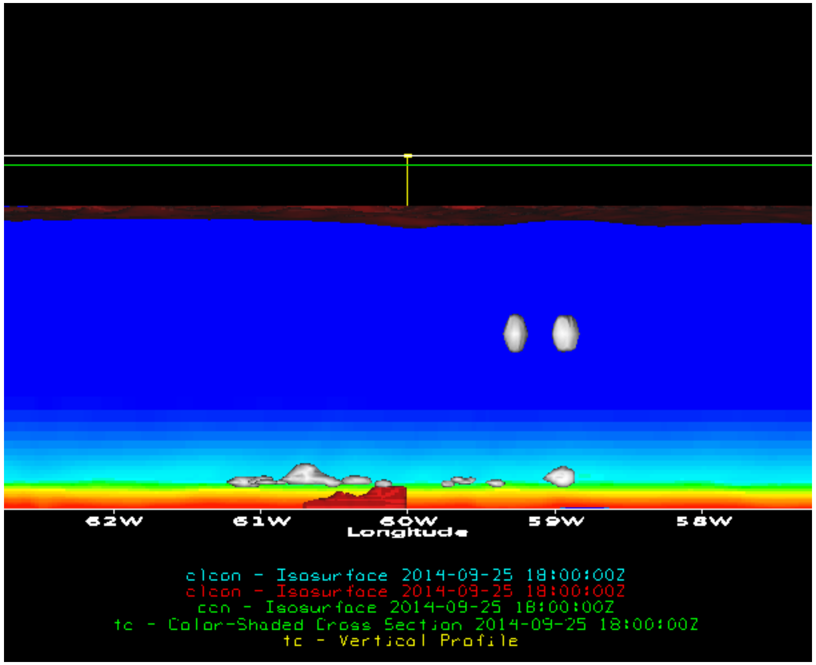
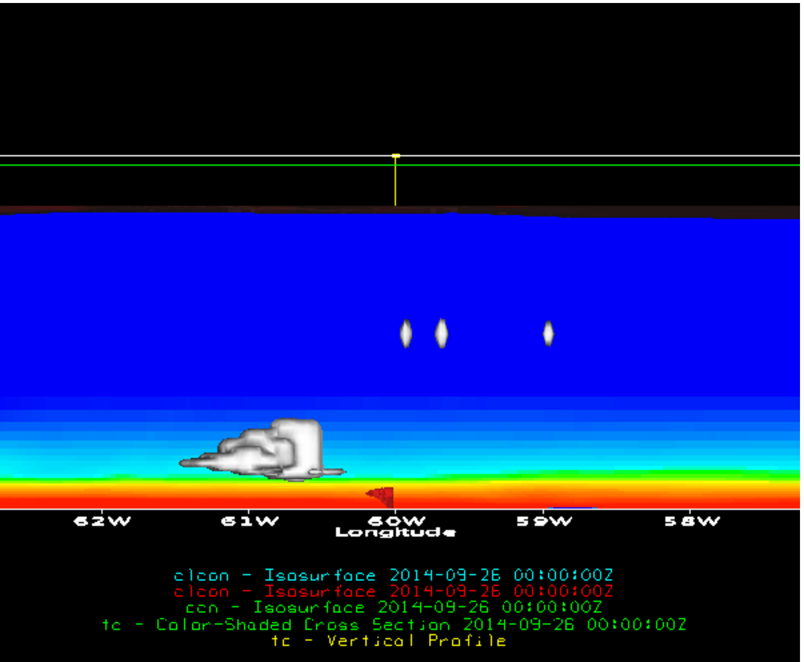
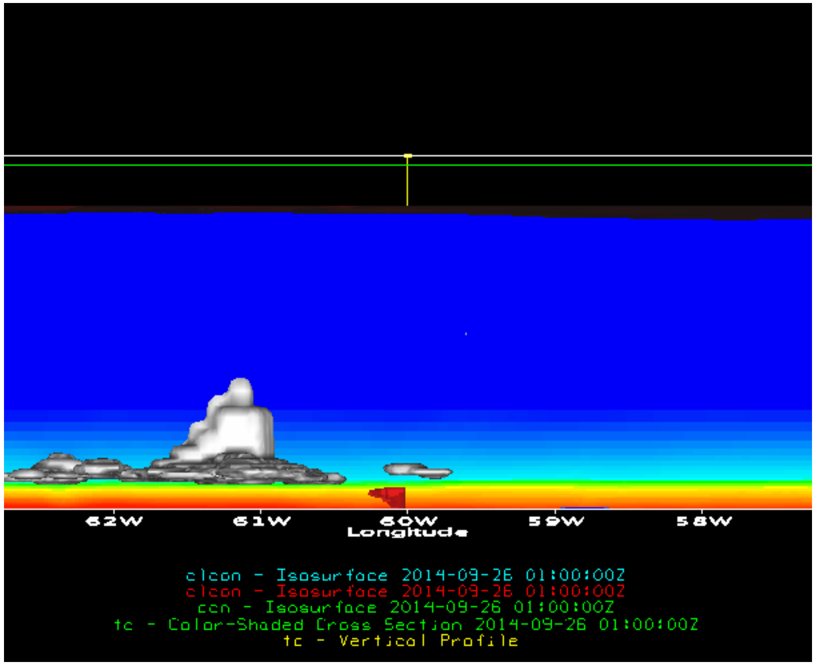
.0203
vapor - Isosurface
Value: .0101
0
.0203
Cross sections
62W
61W
60W
59W
58W

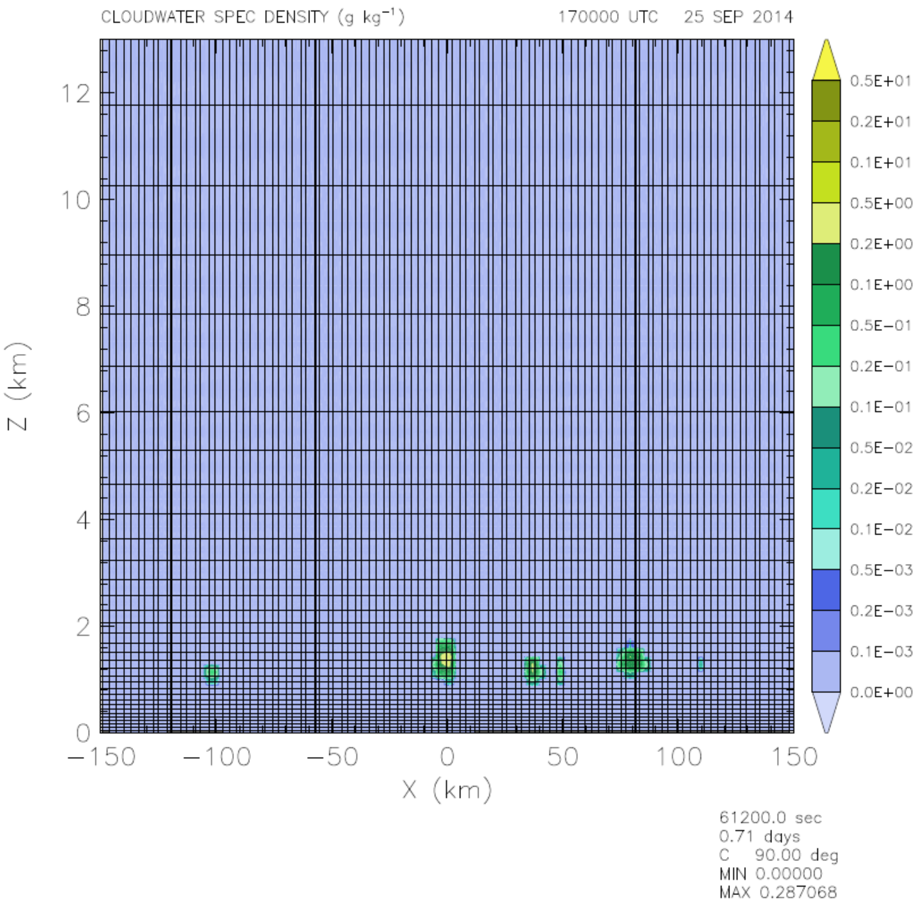

62W
61W
60W
59W
58W
Longitude
clcon - Isosurface 2014-09-25 17:00:00Z
clcon - Isosurface 2014-09-25 17:00:00Z
ccn - Isosurface 2014-09-25 17:00:00Z
tc - Color-Shaded Cross Section 2014-09-25 17:00:00Z
tc - Vertical Profile

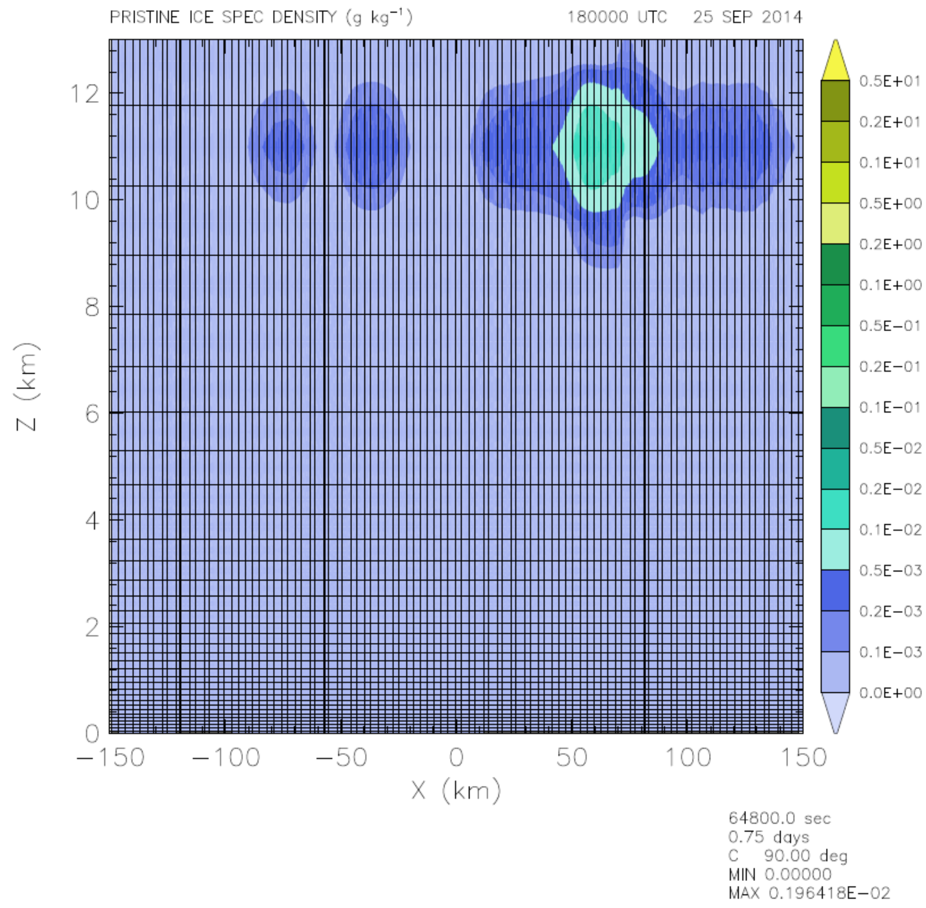

62W
61W
60W
59W
58W
Longitude
clcon - Isosurface 2014-09-25 18:00:00Z
clcon - Isosurface 2014-09-25 18:00:00Z
ccn - Isosurface 2014-09-25 18:00:00Z
tc - Color-Shaded Cross Section 2014-09-25 18:00:00Z
tc - Vertical Profile


62W
61W
60W
59W
58W
Longitude
clcon - Isosurface 2014-09-26 00:00:00Z
clcon - Isosurface 2014-09-26 00:00:00Z
ccn - Isosurface 2014-09-26 00:00:00Z
tc - Color-Shaded Cross Section 2014-09-26 00:00:00Z
tc - Vertical Profile


62W
61W
60W
59W
58W
Longitude
clcon - Isosurface 2014-09-26 01:00:00Z
clcon - Isosurface 2014-09-26 01:00:00Z
ccn - Isosurface 2014-09-26 01:00:00Z
tc - Color-Shaded Cross Section 2014-09-26 01:00:00Z
tc - Vertical Profile

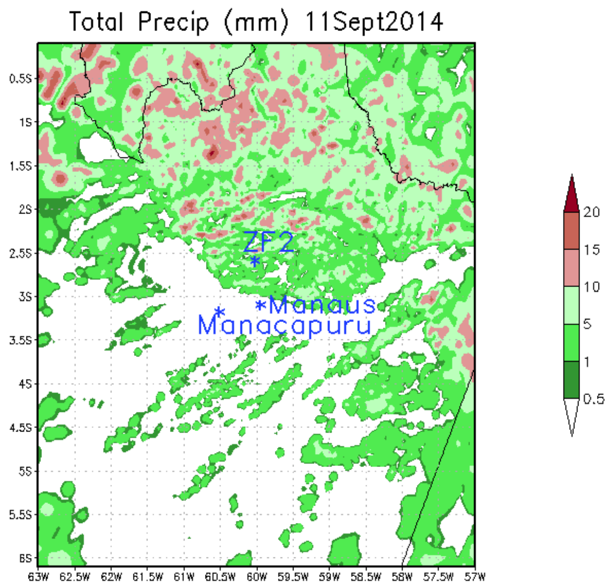
OLAM: Cloud streets at the boundary layer & Pristine ice at the top due to the presence of Ice nucleai.

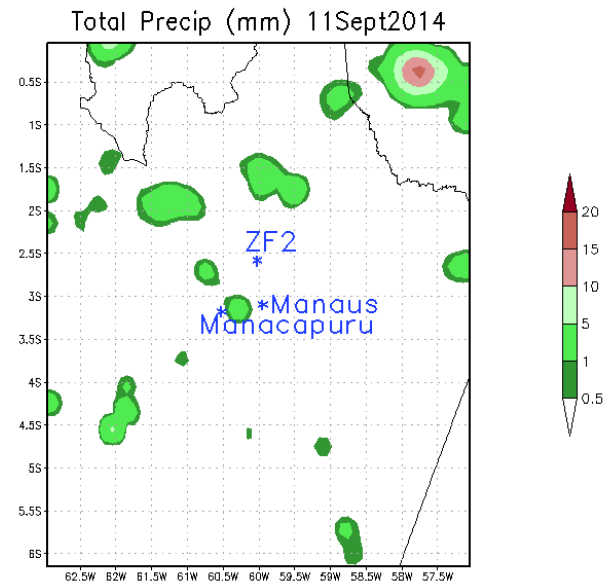


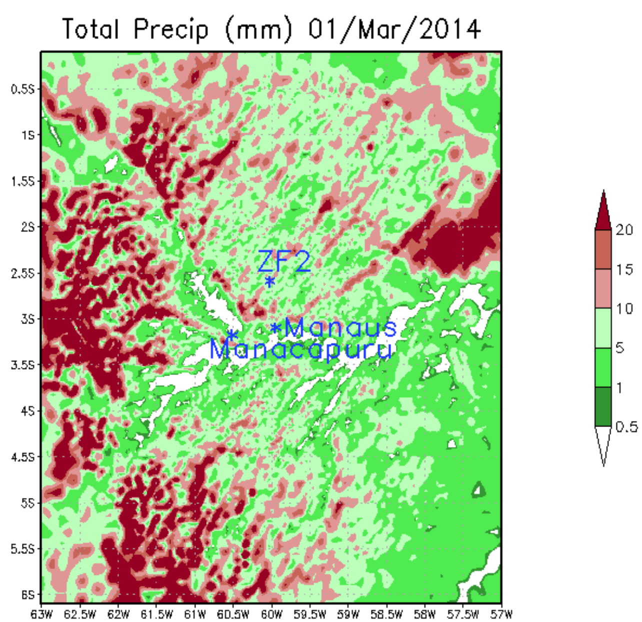


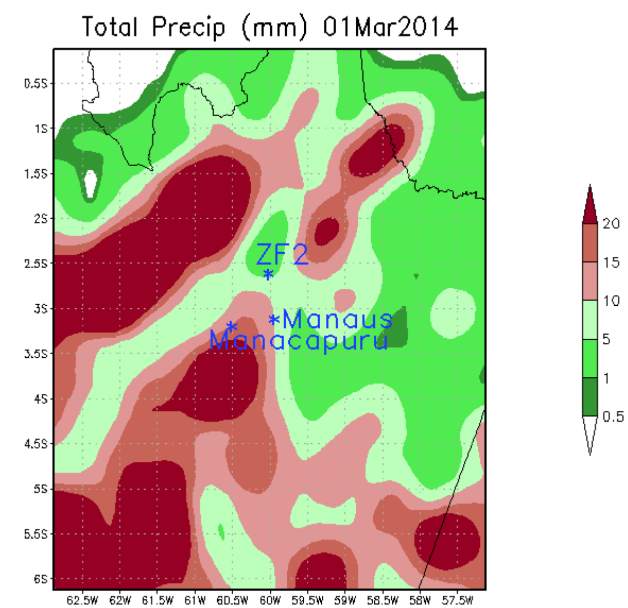
OLAM - MODEL

GPM - OBS

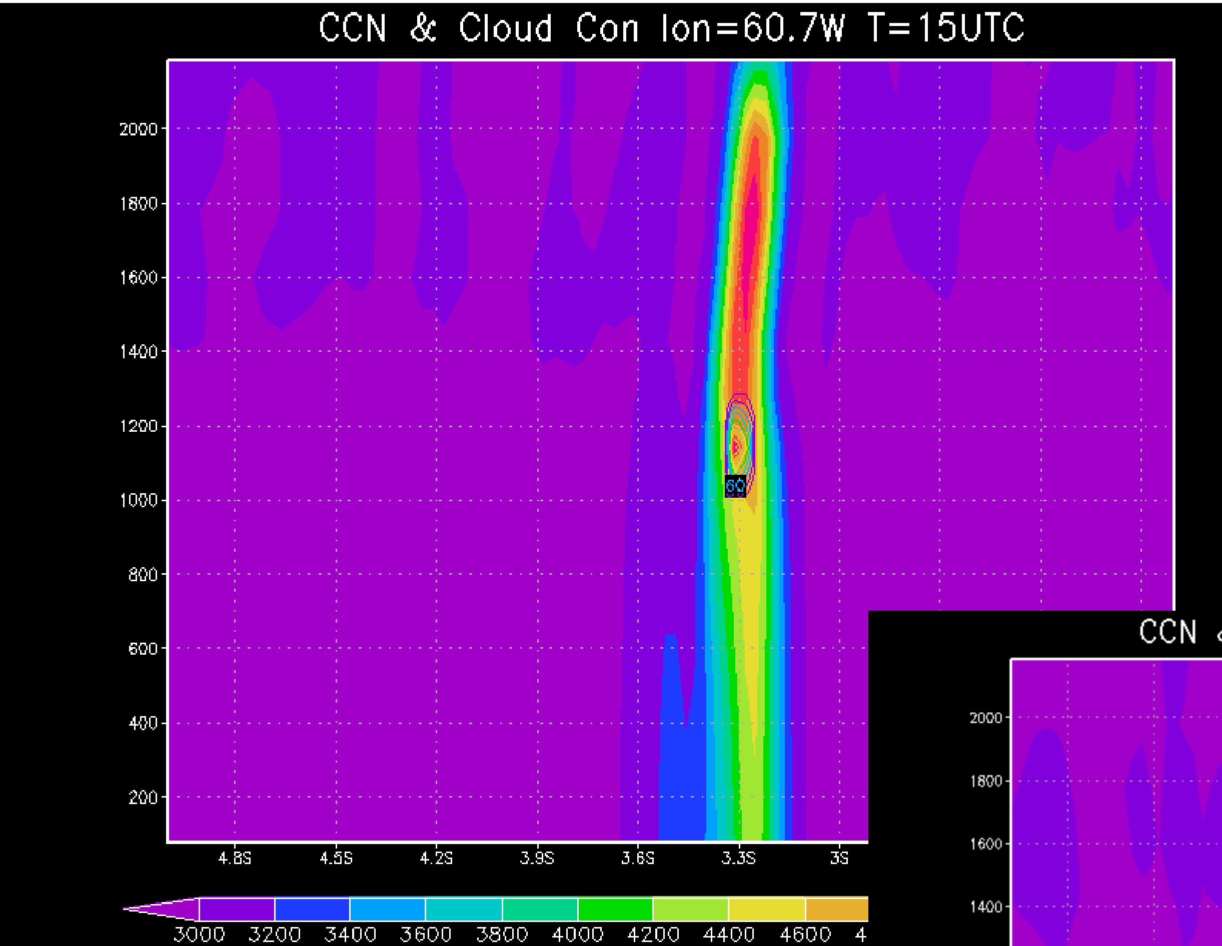


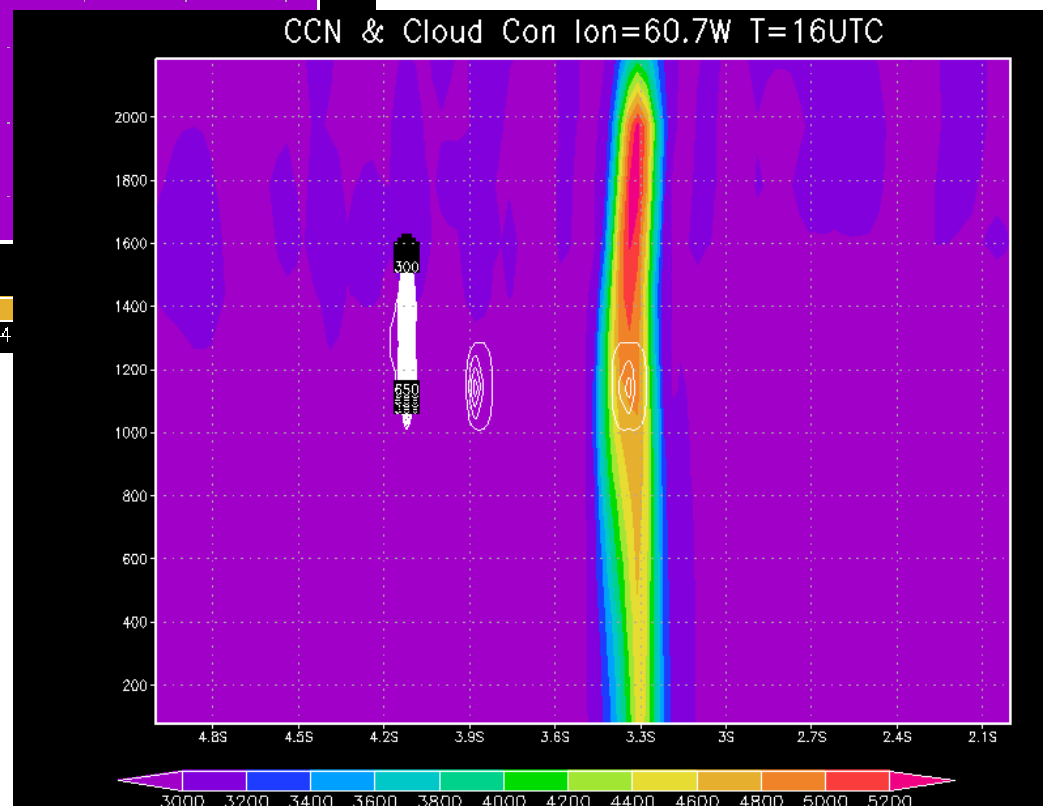






How CCN impact cloud water?





Summary

- Model simulations supported by observations shows that land surface characteristics has important impact on the cloud condensation nucleai (CCN) distribution and rainfall over the region.
- At the south of Manaus the atmospheric dynamics is dominated by the cloud streets that are aligned with the trade winds and the Amazon River.
- At the north of Manaus the Negro River influences the advection of a more stable atmosphere causing a higher CCN concentration. The land-atmosphere interaction sets important dynamics on the Manaus plumes downwind.
- Assuming a high CCN concentration at the Manaus boundary layer region. The model shows that the CCN plume moves along with the flow towards southwest of Manaus.
- HALO profile of CCN can produce pristine ice about 11 km

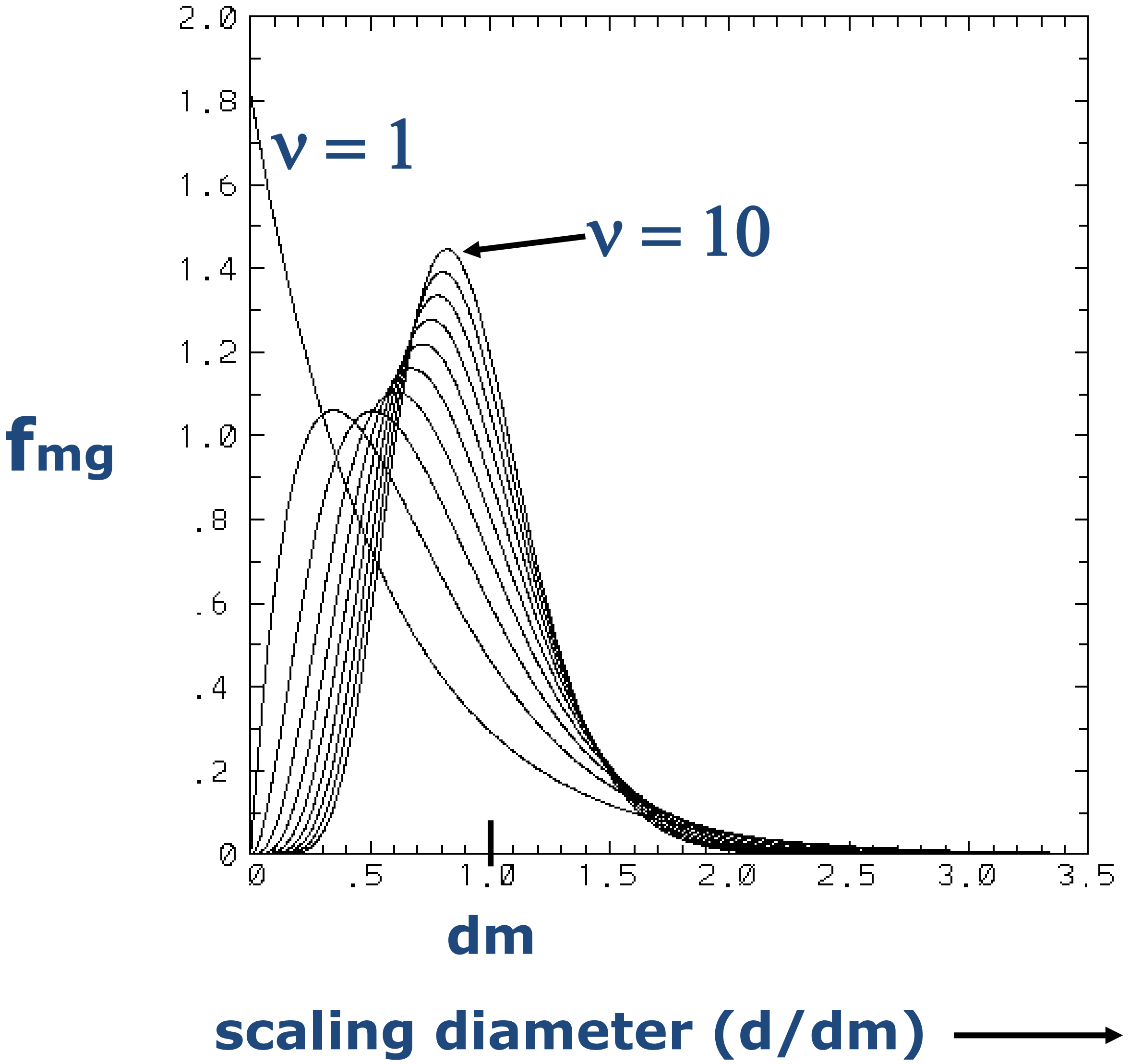
Future Steps

- Further modeling experiments
- Explore higher resolution
- Intercomparison with the observations
- Evaluate the cloud microphysics parameters
- Impact of the high CCN on clouds & rain
- Understand the physical mechanisms
- Improve model parametrizations
- OLAM - Atmospheric chemistry transport and feedbacks using CMAQ (EPA)!
- Collaborations...

A bulk microphysics representation of each hydrometeor category provides the best compromise between accuracy and efficiency for most model applications.

A bulk model treats different sizes of a hydrometeor category, such as rain or hail, with a single distribution function. RAMS uses the modified gamma distribution function:

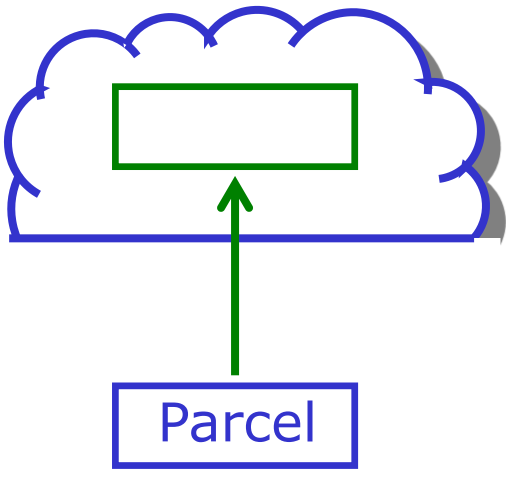
$$f_{mg}(D) = \frac{1}{\Gamma(\nu)} \left(\frac{D}{D_n} \right)^{\nu - 1} \frac{1}{D_n} \exp\left(-\frac{D}{D_n} \right)$$

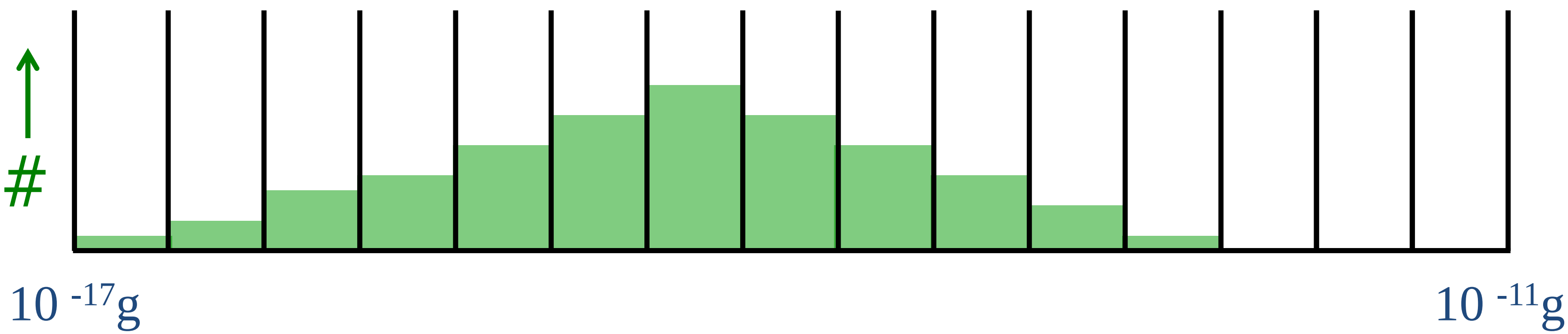

2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
ν = 1
ν = 10
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
dm
f_{mg}
scaling diameter (d/dm)

Parcel-Bin Model

Specify environment: T_o , P_o , w, X_o

Specify CCN distribution: N, $\overline{m}$, σ

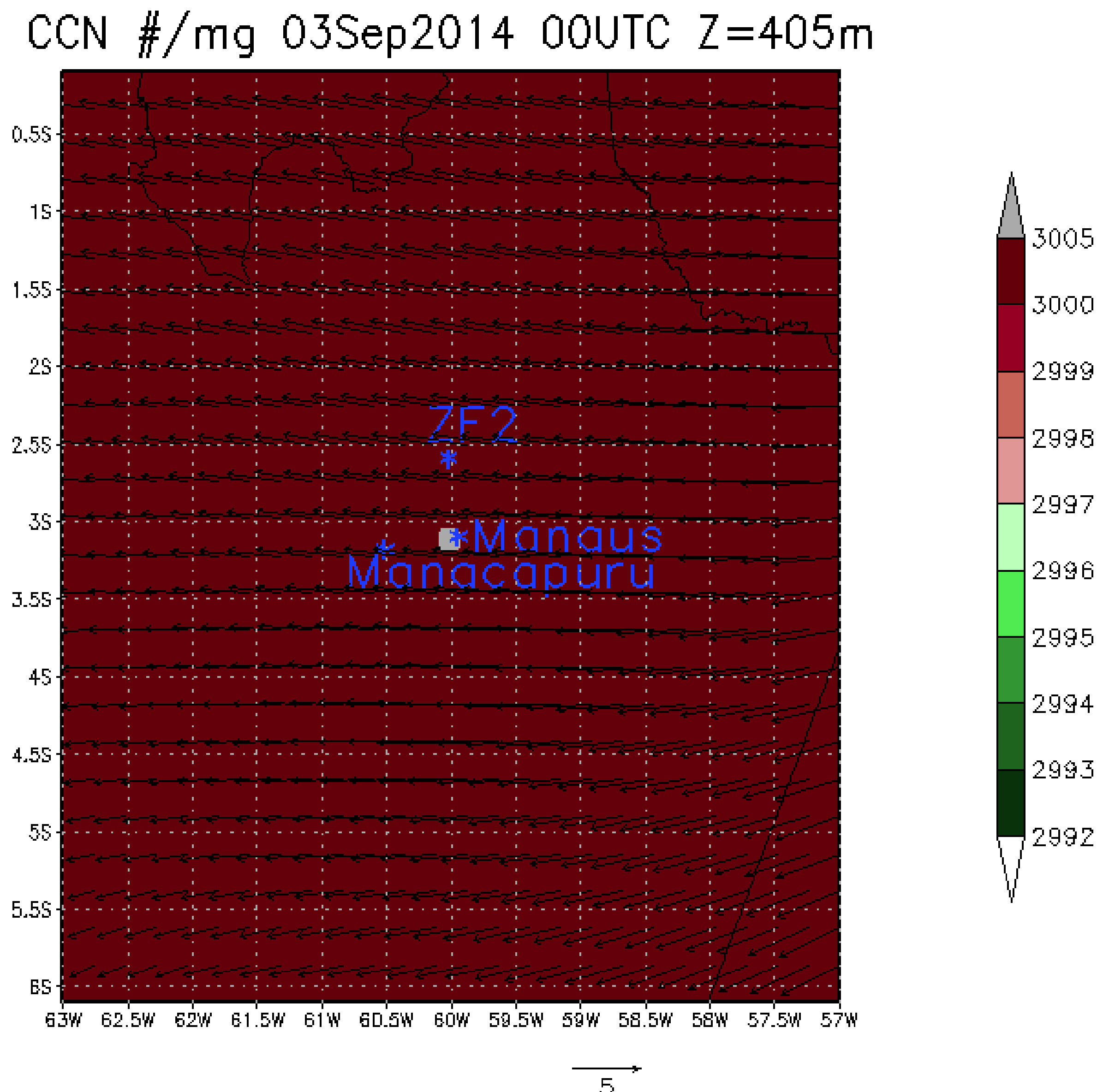




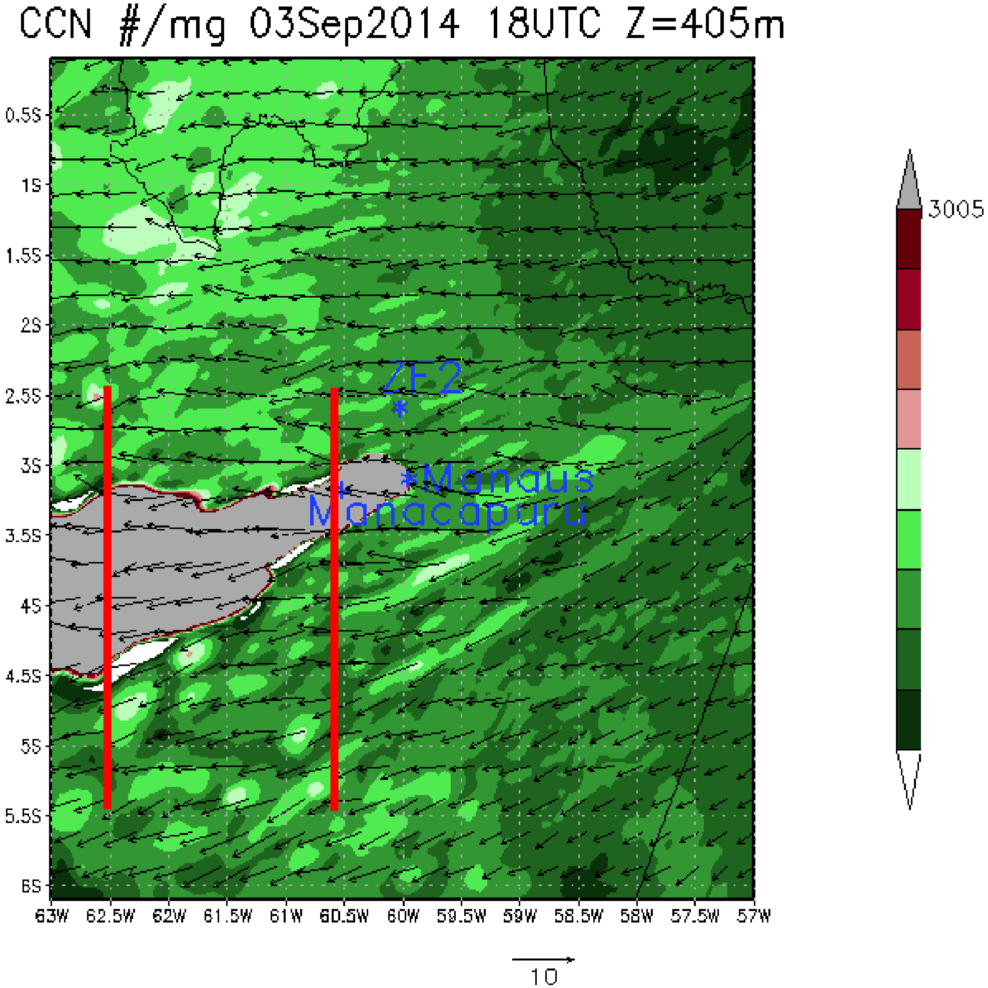
Aerosol (CCN) Bins

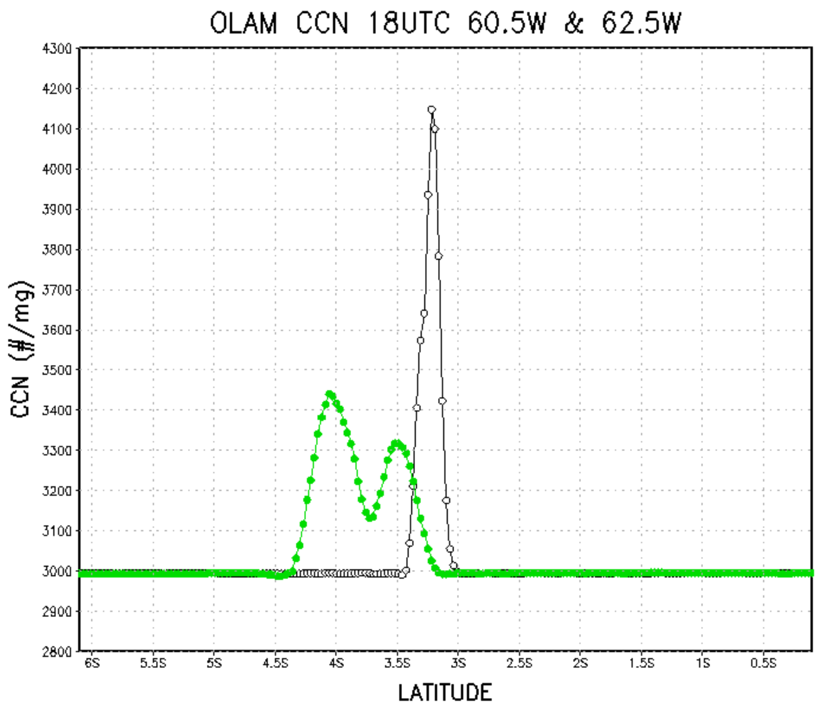
100 bins used

OLAM – Model simulation of the CCN plume dynamics from Manaus – continuous emission

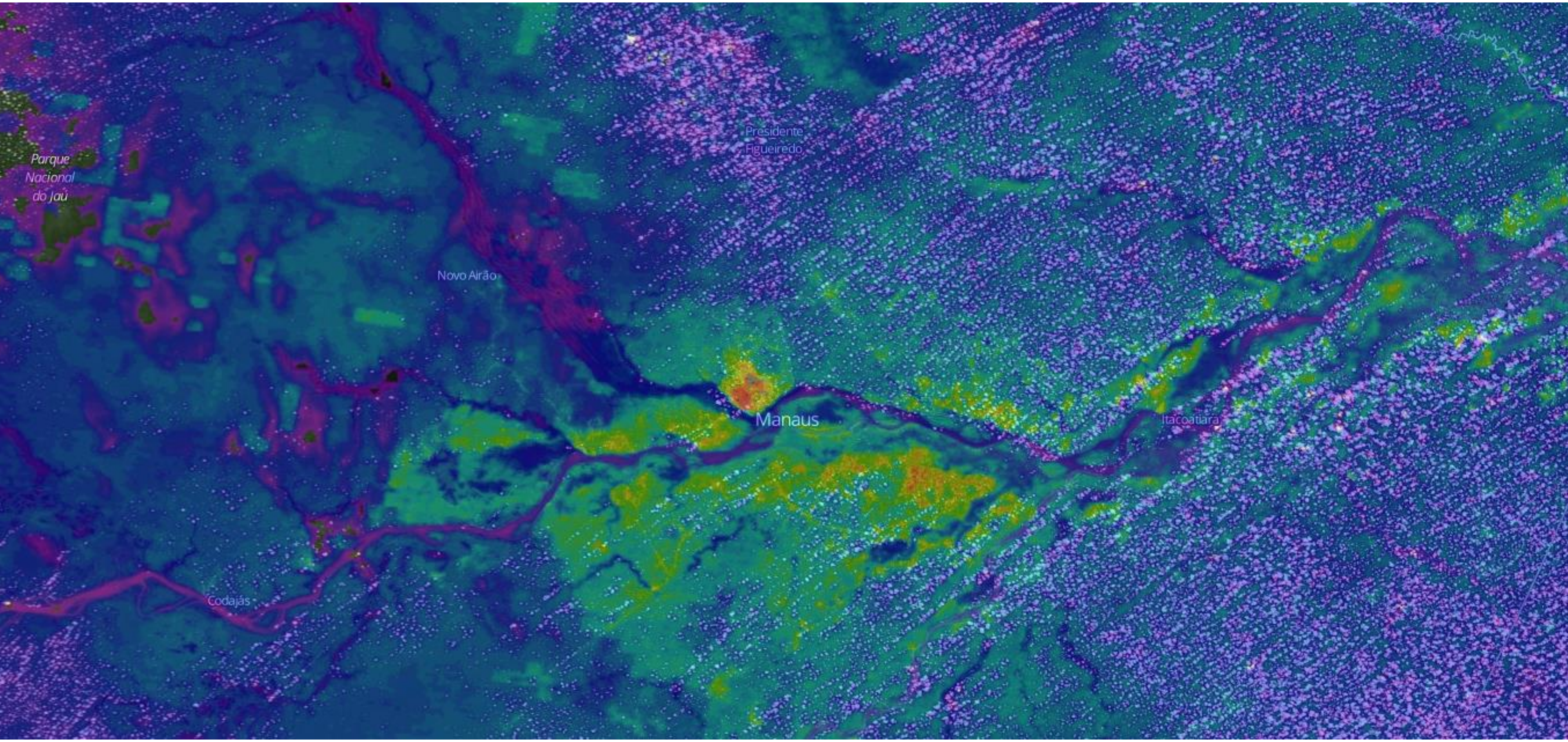


OLAM - MODEL


CCN #/mg 03Sep2014 18UTC Z=405m
0.5S
1S
1.5S
2S
2.5S
3S
3.5S
4S
4.5S
5S
5.5S
6S
63W 62.5W 62W 61.5W 61W 60.5W 60W 59.5W 59W 58.5W 58W 57.5W 57W
ZF2
Manaus
Manacapuru
10
3005

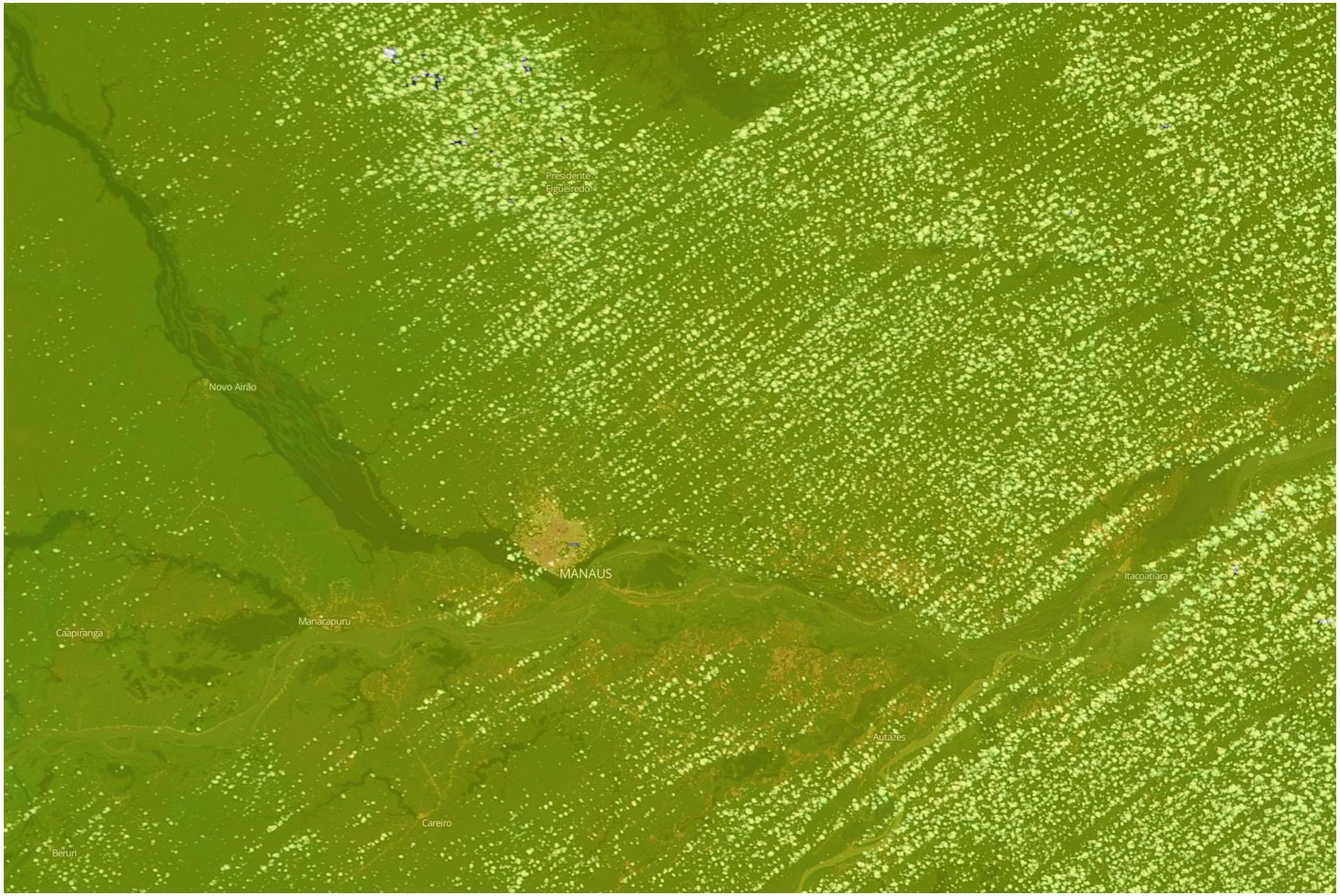

OLAM CCN 18UTC 60.5W & 62.5W
CCN (#/mg)
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200
3100
3000
2900
2800
6S 5.5S 5S 4.5S 4S 3.5S 3S 2.5S 2S 1.5S 1S 0.5S
LATITUDE

Surface Temperature estimated from Terra Satellite at daytime: City of Manaus (~ 39 °C); Rivers (~27-28 °C)



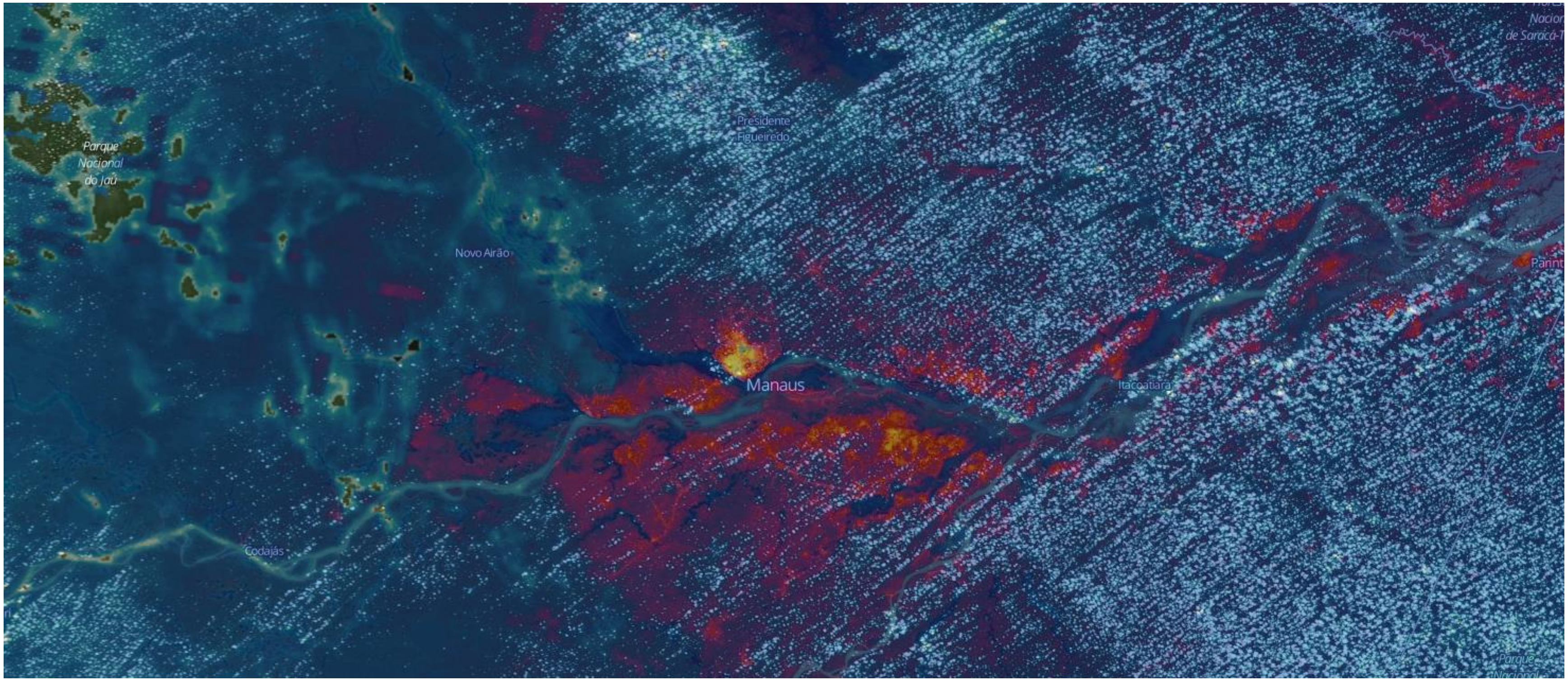
Terra Satellite - MODIS Sensor – 02 September 2014

Surface Temperature estimated from Terra Satellite at daytime: City of Manaus (~ 39 ^oC); Rivers (~27-28 ^oC)



MODIS Sensor – 02 September 2014

Surface Temperature estimated from Terra Satellite at daytime: City of Manaus (~ 39 oC); Rivers (~27-28 ^{o}C)

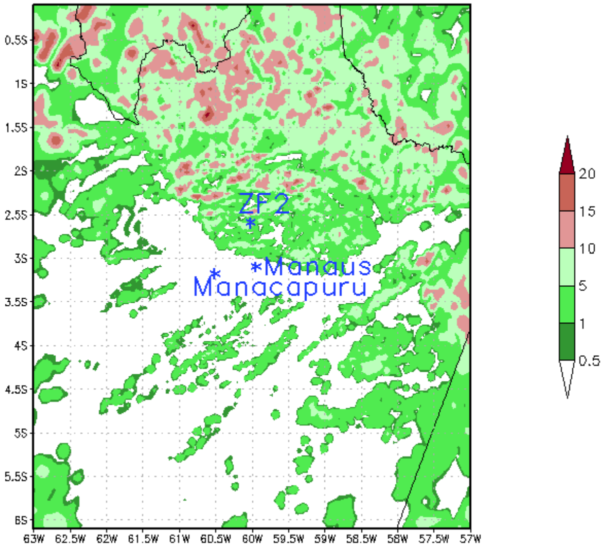


MODIS Sensor – 02 September 2014

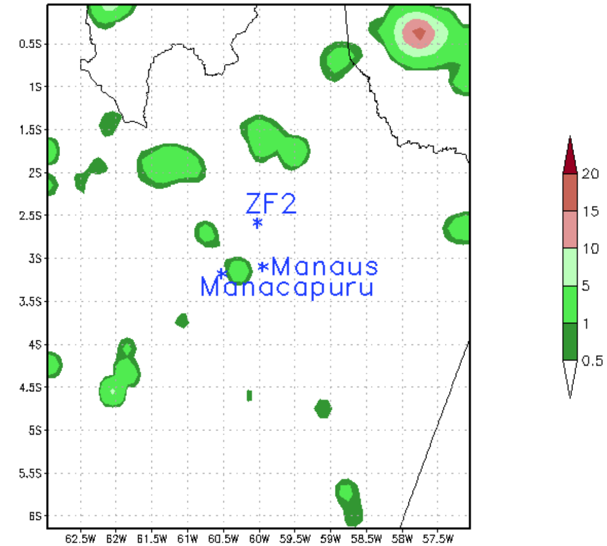
OLAM - MODEL

GPM - OBS

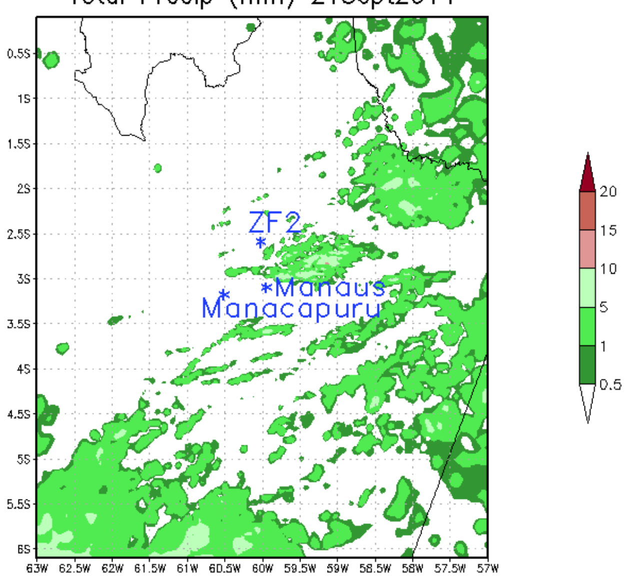
Total Precip (mm) 11Sept2014



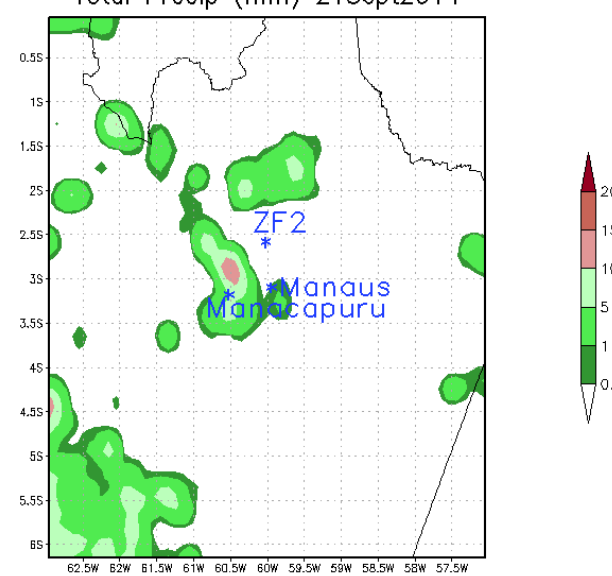
Total Precip (mm) 11Sept2014



Total Precip (mm) 21Sept2014

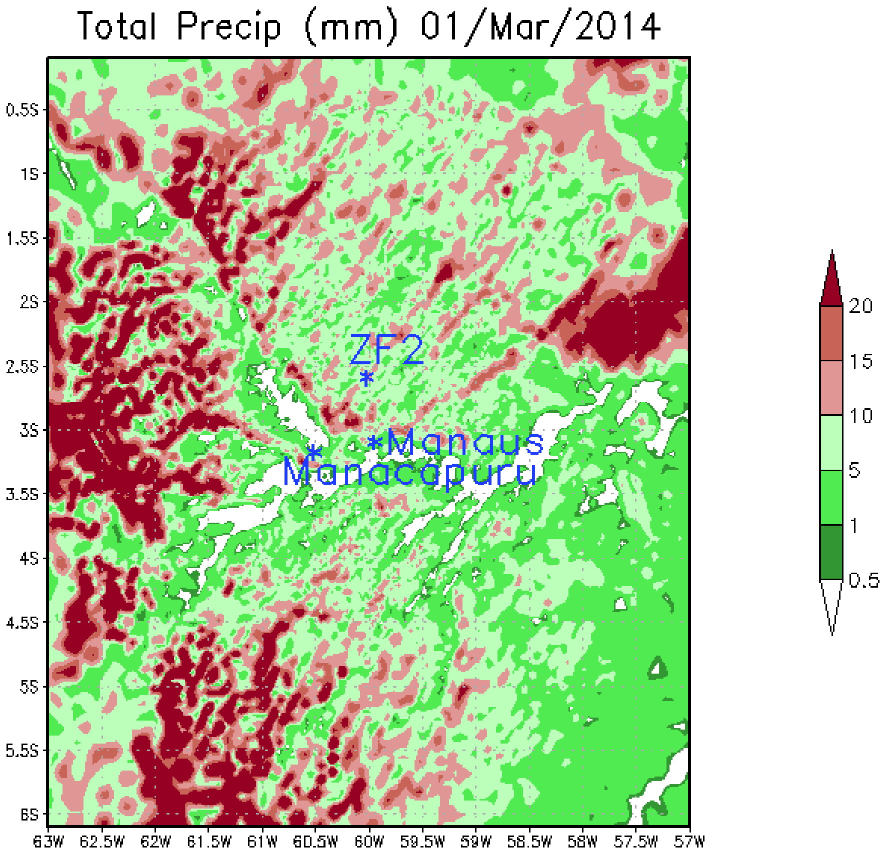


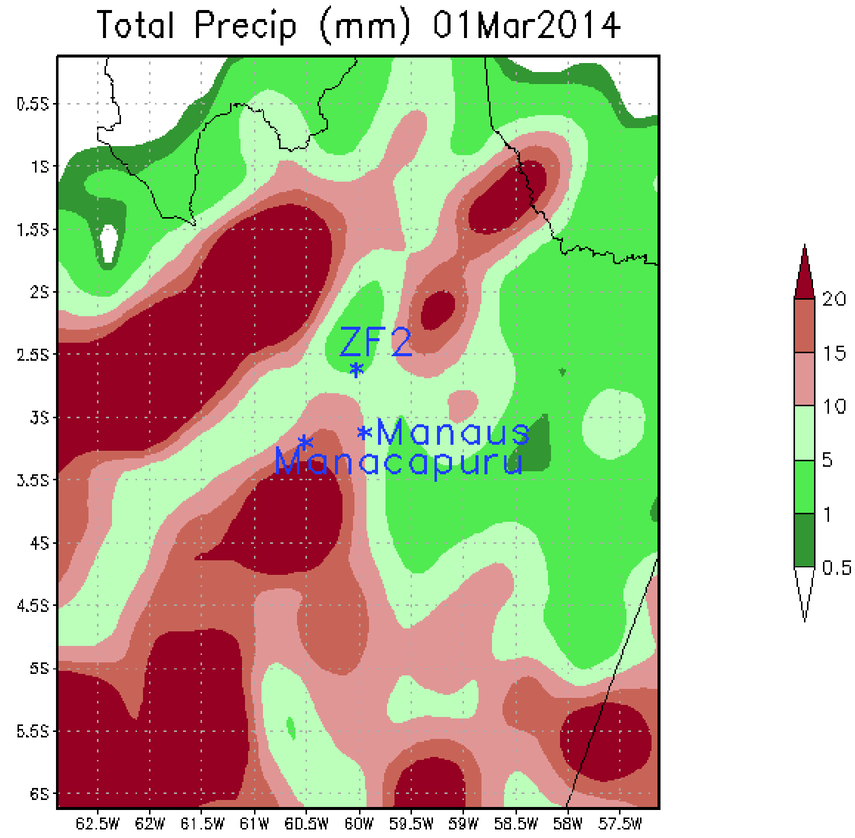
Total Precip (mm) 21Sept2014



OLAM - MODEL

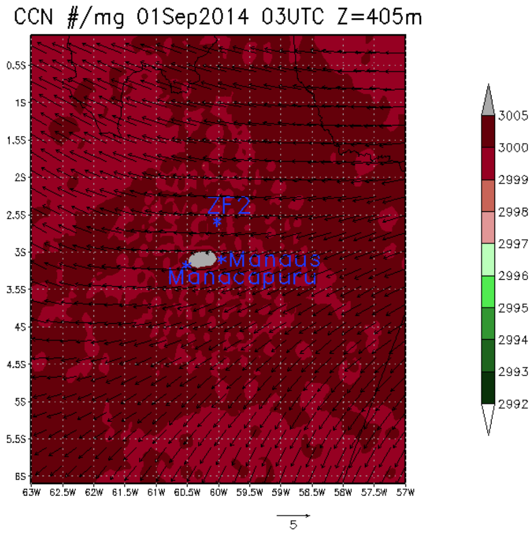
GPM - OBS

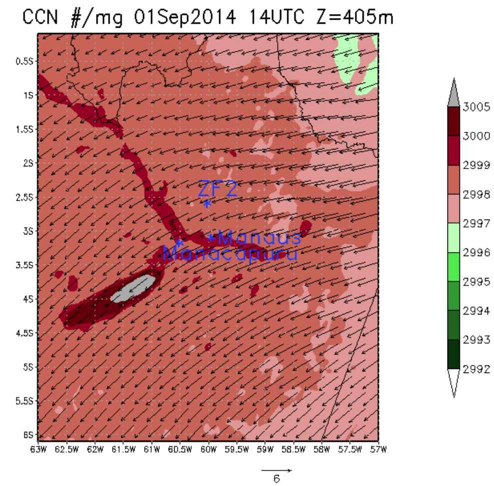




OLAM results for the accumulated rainfall (mm) for the 1st March. For this run the model was set with initial condition from the 1st march at 00 UTC. The results shows that the land heterogeneity has important impact on the rainfall distribution and that the main precipitation has the same northeast-southwest alignment shape.

OLAM - MODEL


CCN #/mg 01Sep2014 03UTC Z=405m
ZF2
*Manaus
Manacapuru
3005
3000
2999
2998
2997
2996
2995
2994
2993
2992
5


CCN #/mg 01Sep2014 14UTC Z=405m
ZF2
*Manaus
Manacapuru
3005
3000
2999
2998
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2996
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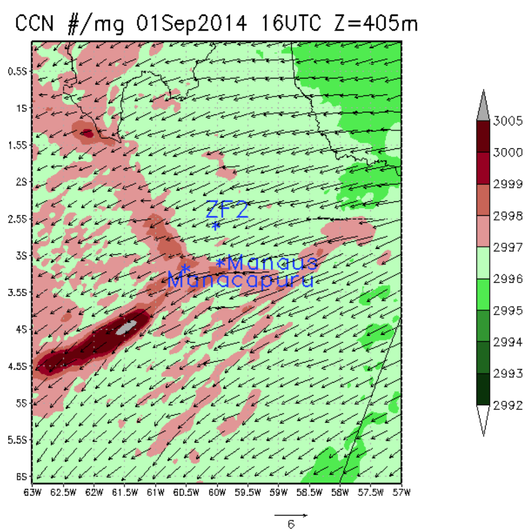
2993
2992
6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ZF2
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Manacapuru
3005
3000
2999
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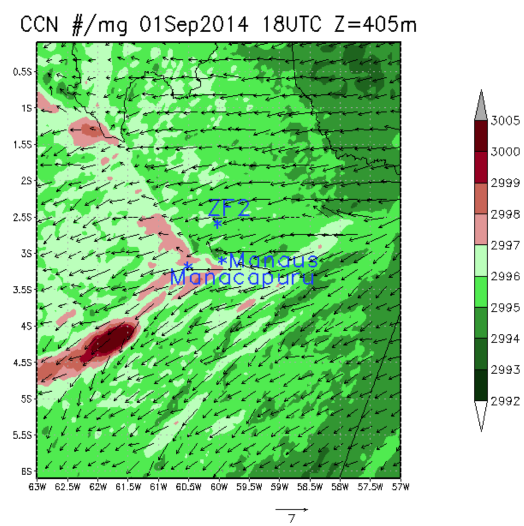
2992
6


CCN #/mg 01Sep2014 18UTC Z=405m
ZF2
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Manacapuru
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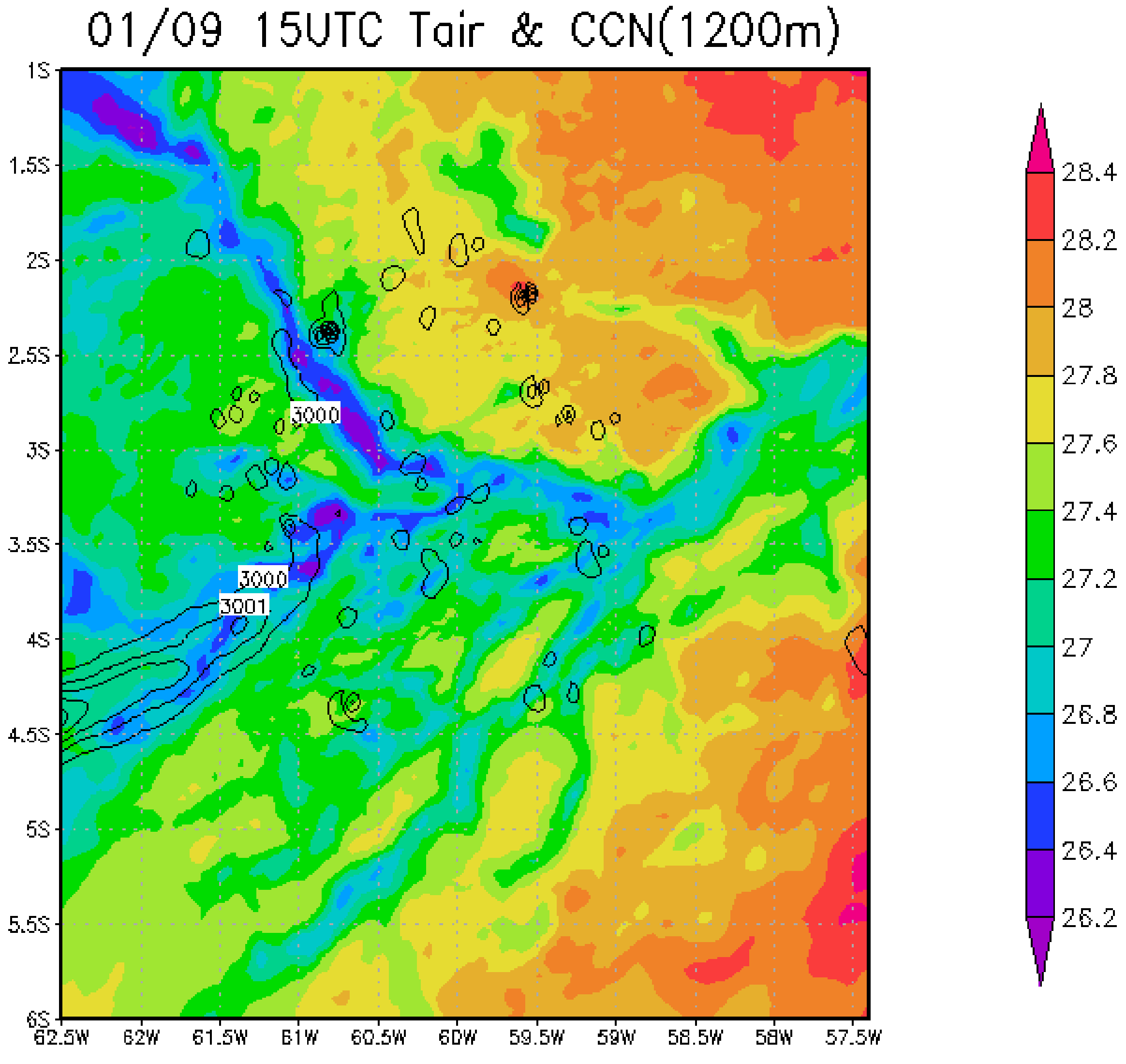
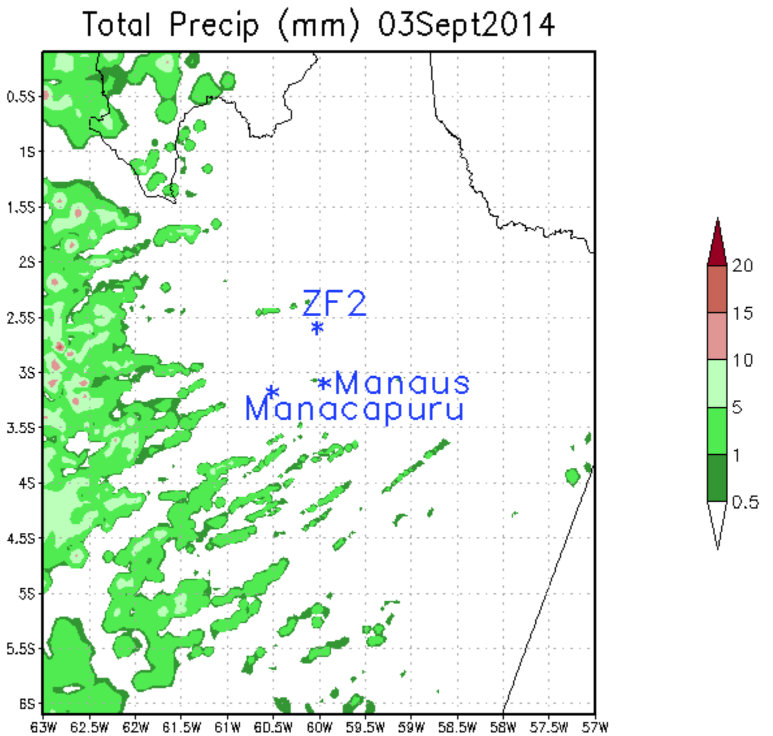
7

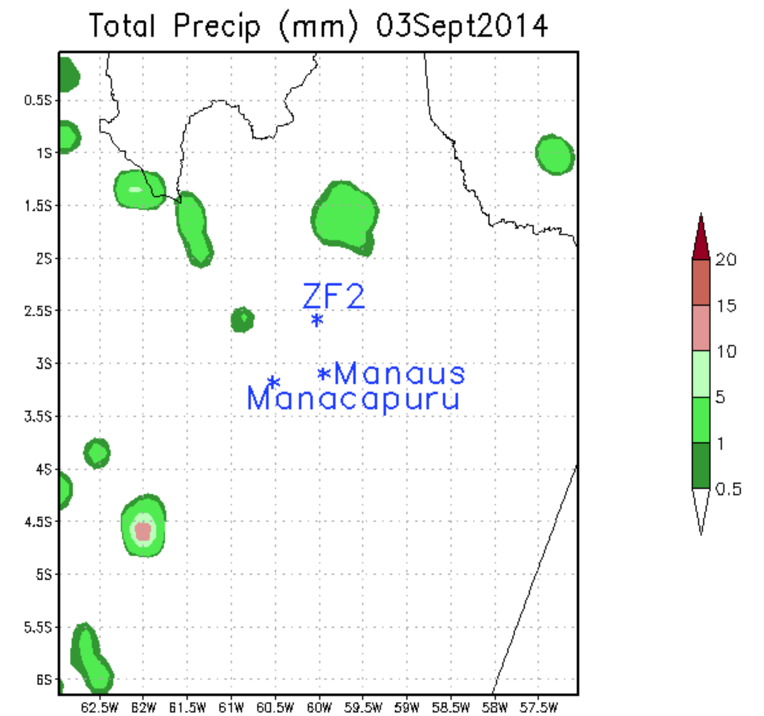


Model results for CCN & near surface Air Temperature suggest that the high load CCN plume moves along the wind over cooler surfaces.

OLAM - MODEL

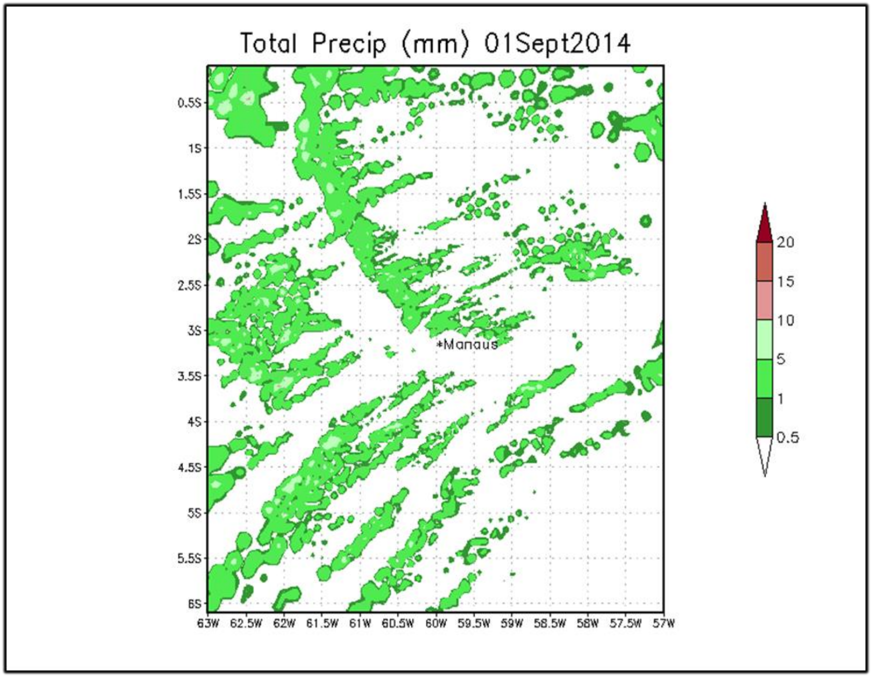
GPM - OBS





- OLAM Total precipitation (mm) for September 03rd

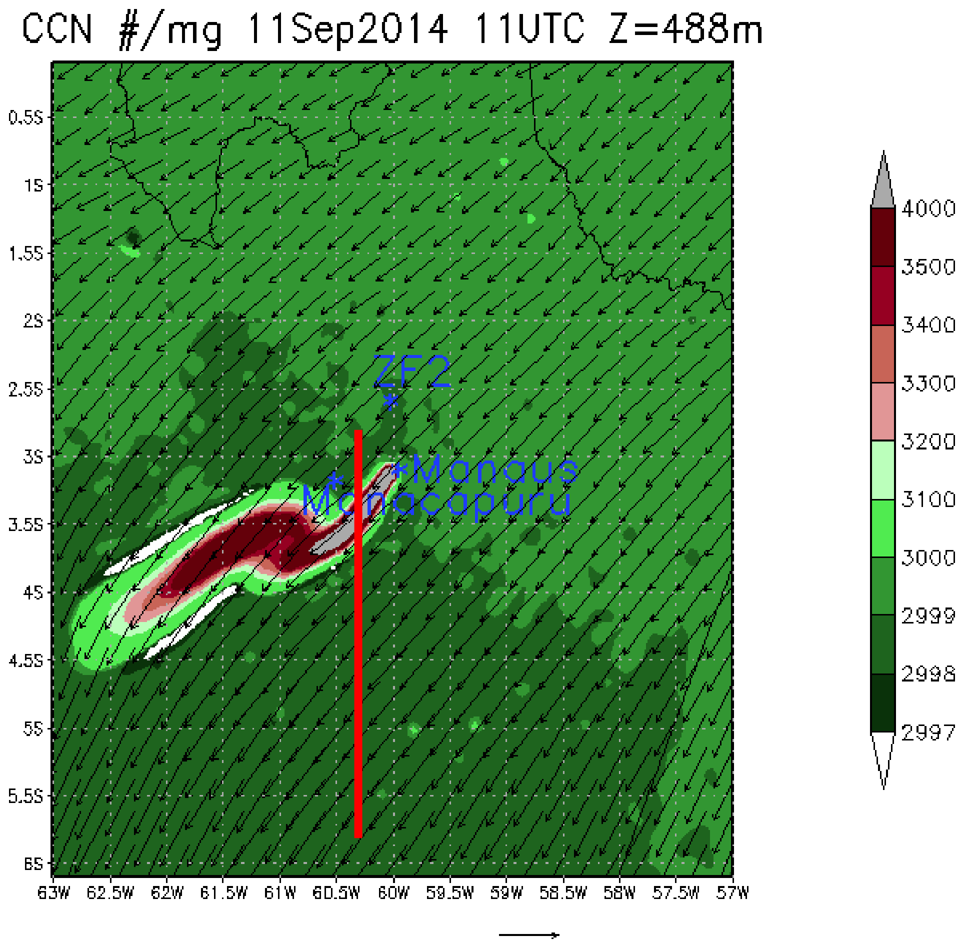
OLAM - MODEL

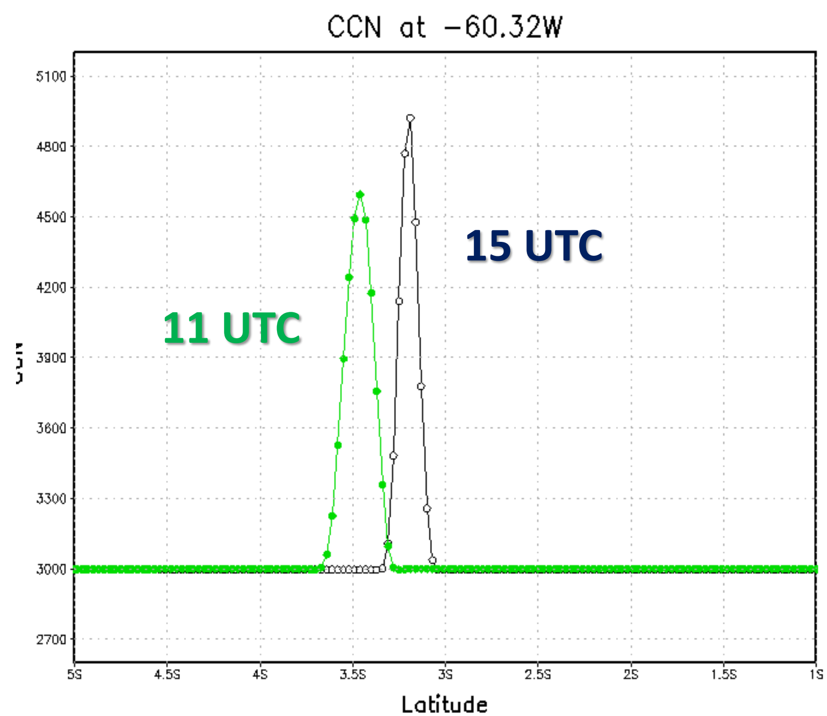


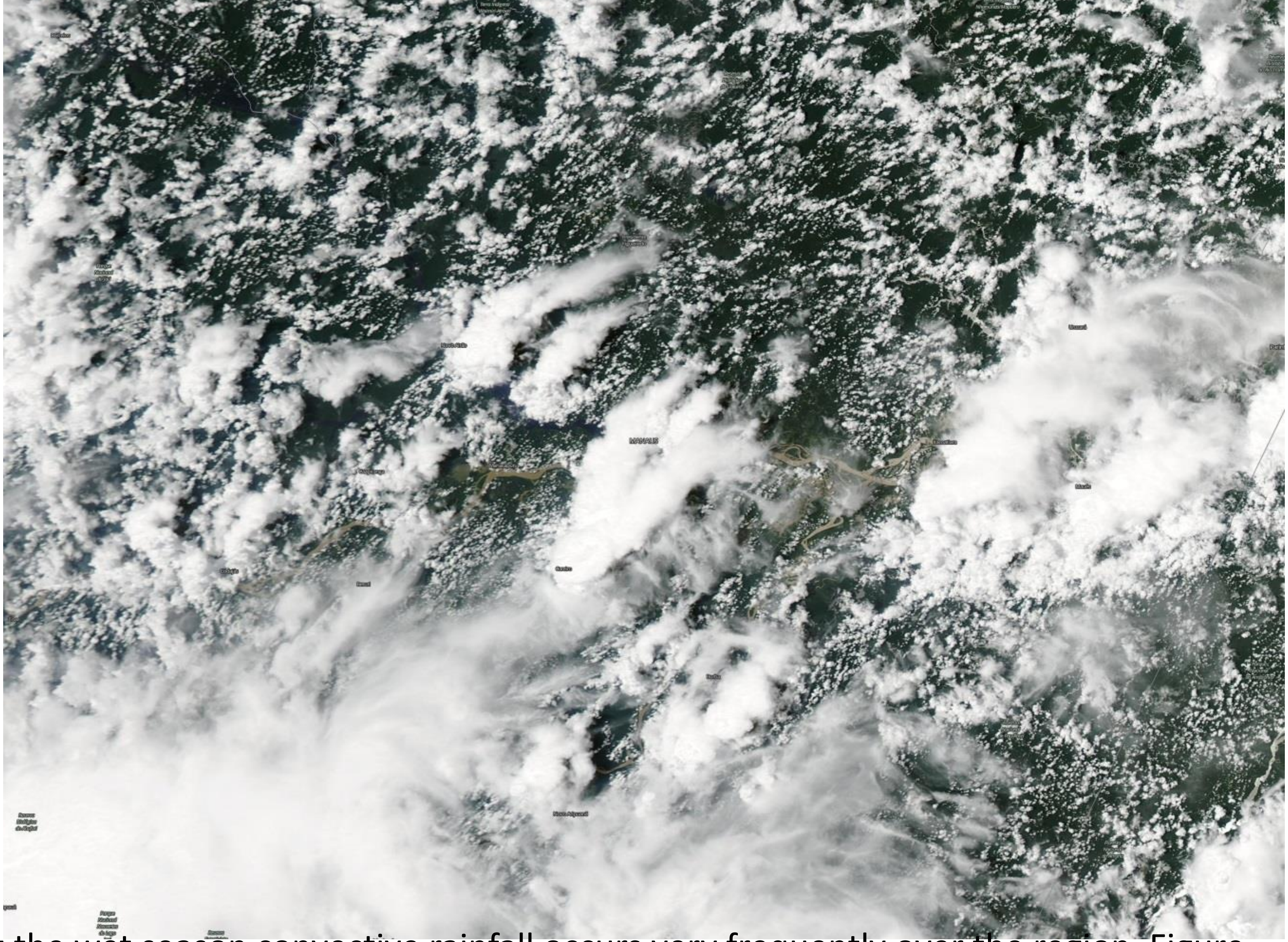
- OLAM Total precipitation (mm) for September 1st

OLAM Model
CCN & perfil at 11UTC & 15UTC

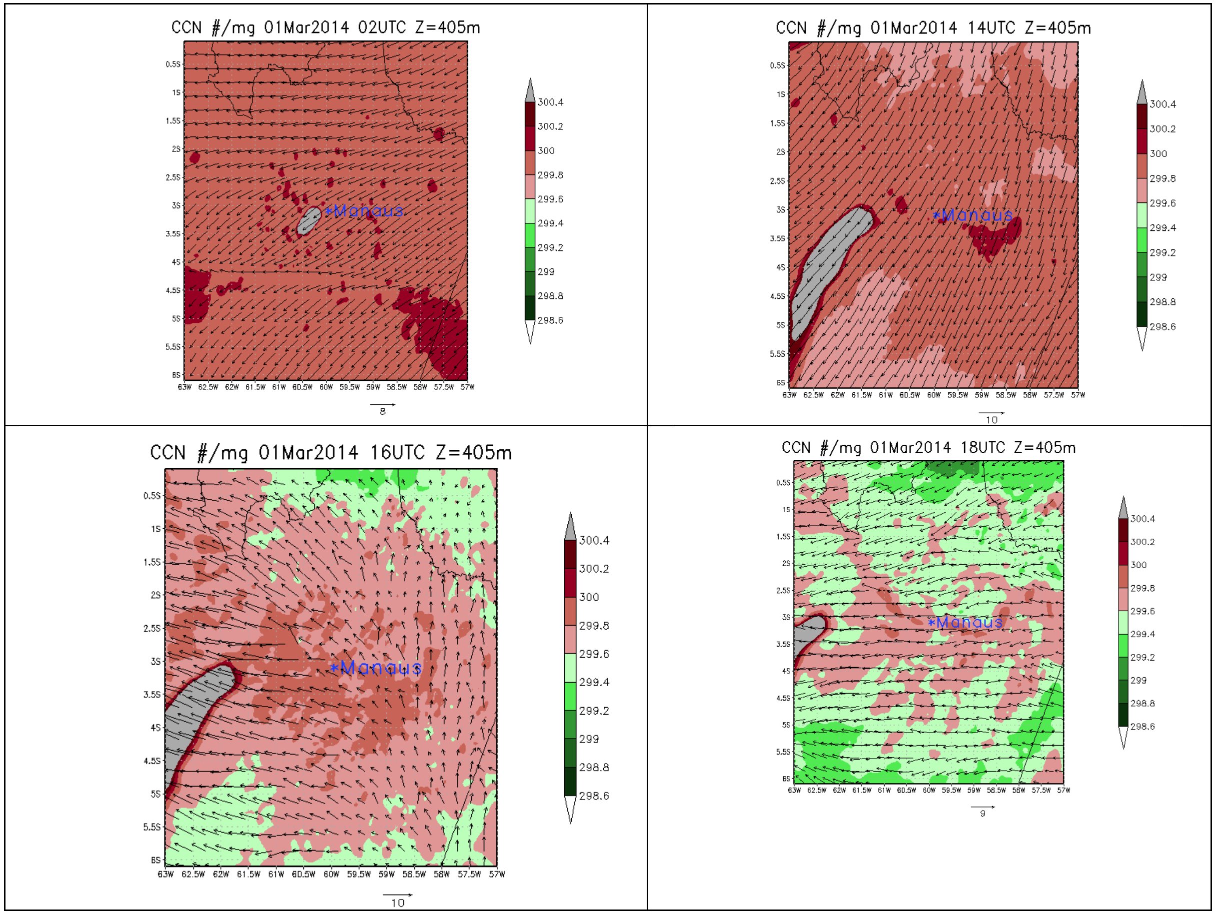
- **The CCN plume at ~500m height shows a maximum at about latitude 3.5S (11 UTC) and 3.2S (15 UTC)**
-







During the wet season convective rainfall occurs very frequently over the region. Figure shows a snapshot satellite image for 1st March near the Manaus regions. The image shows a series of convective clouds near Manaus aligned with northeast-southwest direction.



For the rainy event the model was set with atmospheric initial condition for 1st March 2014 with the same configuration of the dry case (i.e. September) but with a background CCN concentration of 300/mg and a heavy CCN load at Manaus of 3000/mg. The atmospheric dynamics for this period shows that the winds were more zonal (i.e. easterly).

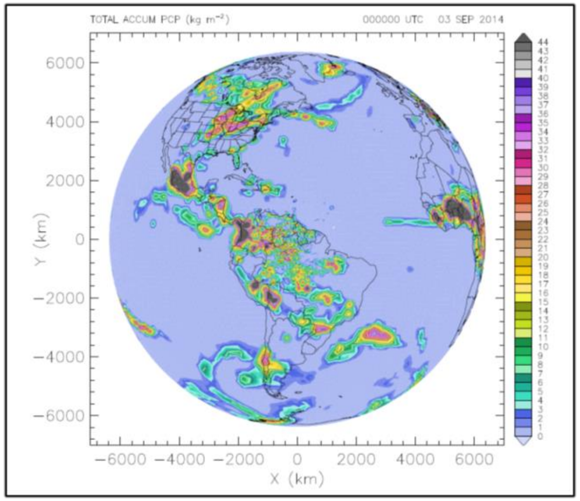
Hydrometeors in the atmosphere occur in a wide range of sizes, shapes, densities, and liquid versus ice content.

Each of these properties has an important influence on the behavior of the hydrometeor and its interaction with other hydrometeors and the environment. For example:

1. **Large hydrometeors fall faster than small ones**
2. **Liquid droplets fall faster than ice crystals of the same mass**
3. **Hydrometeors that contain ice remain at or below 0 degrees C, but liquid hydrometeors may be above or below this temperature**
4. **Ice crystals may have different shapes (dendrites, columns, needles, rosettes, plates) and each has different radiative properties and fall speeds.**
5. **An ice crystal that accumulates many small cloud droplets in a cold environment will be much less dense than an ice crystal that collides with a single supercooled rain drop.**

The main goal of the microphysics parameterization is to represent as many of these properties as possible as accurately as possible without requiring an unreasonable amount of computing effort.

OLAM – MODEL – Microphysics parametrization



OLAM accumulated precipitation for 01-02 September 2014.

- Cloud droplet nucleation
- Ice nucleation
- Vapor diffusional growth
- Evaporation/sublimation
- Heat diffusion
- Freezing/melting
- Shedding
- Sedimentation
- Collisions between hydrometeors
- Secondary ice production