Cloud Formation and Stratospheric Dehydration During ATTREX

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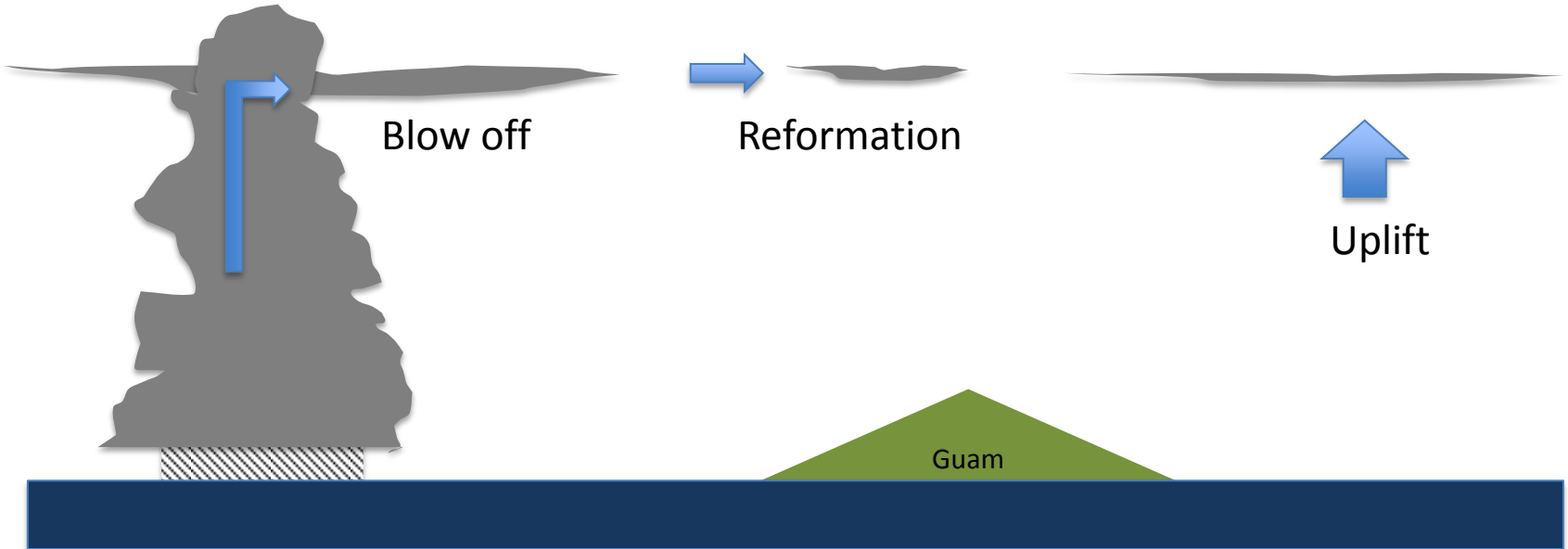
Outline

- Science Questions
- A look at satellite obs.
- Trajectory model experiments
- Model comparisons with obs.
- Conclusions

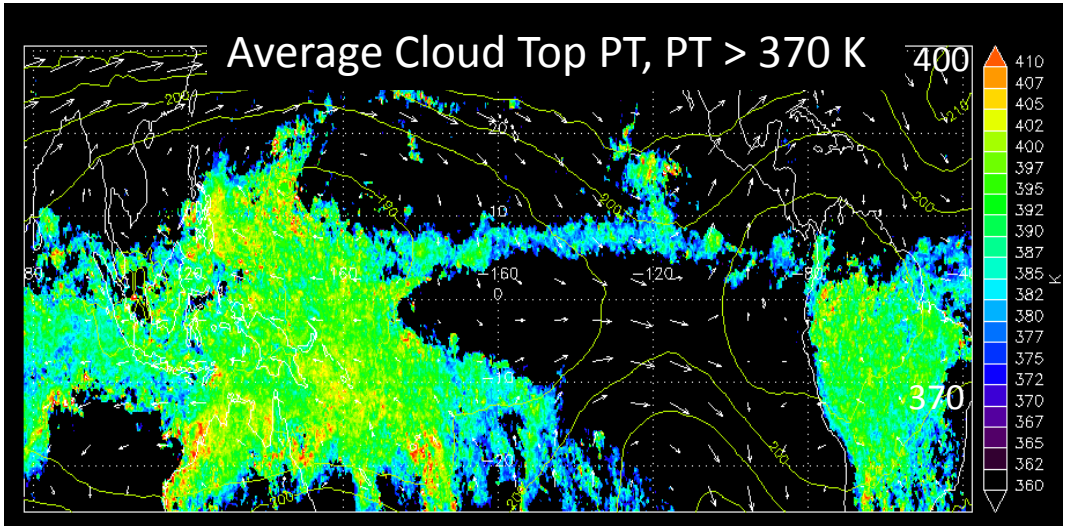
A work in progress

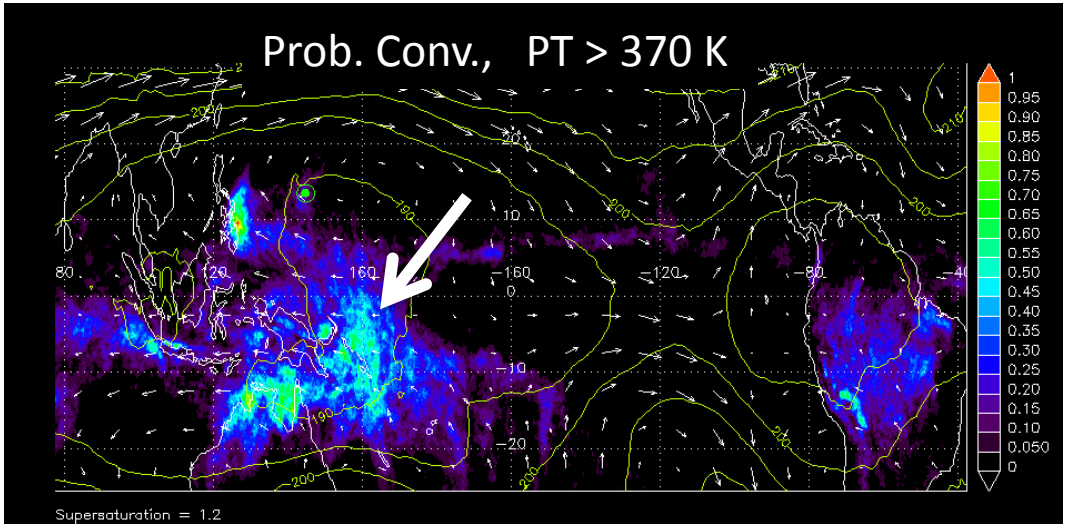
Science Questions

- Where does dehydration actually take place in the Tropical West Pacific?
- How important is convection in remoistening air parcels that have been dehydrated?
- Can we predict locus of cloud formation?
- How well do we match ATTREX and CALIOP data?



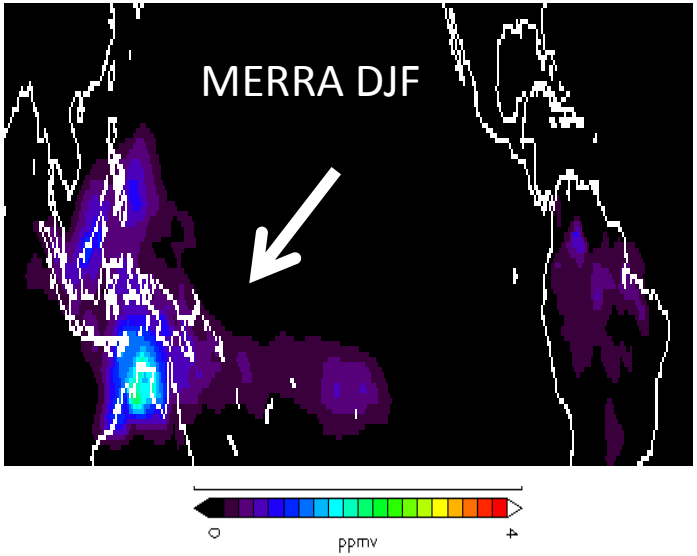
Pfister Convective Events



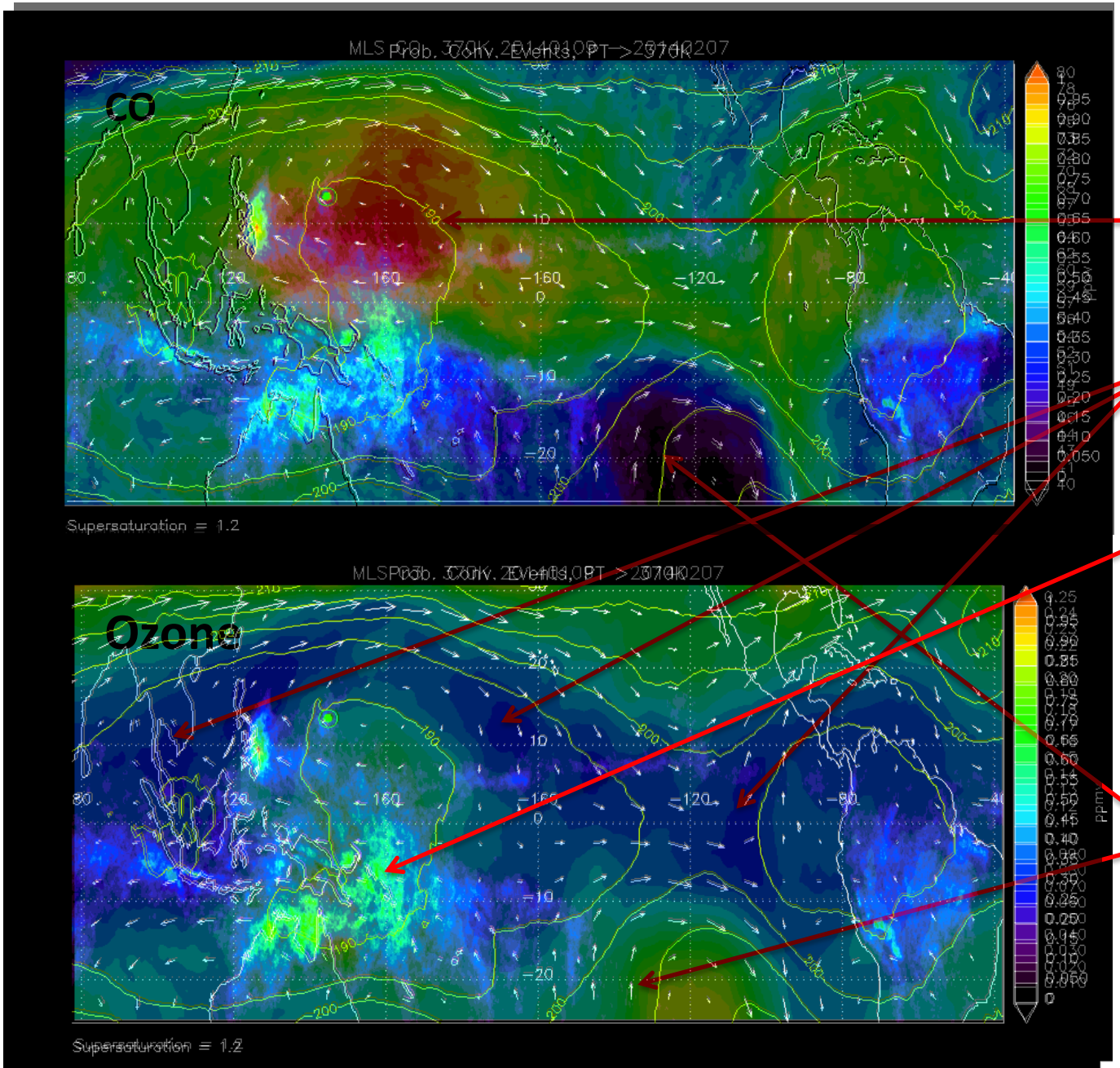


Convective Events, Jan. avg.

- Most localized over South West Pacific
- Highest probability over N. Australia and Solomon Islands
- MERRA convection too weak over Solomon islands.



Ozone and CO 370K



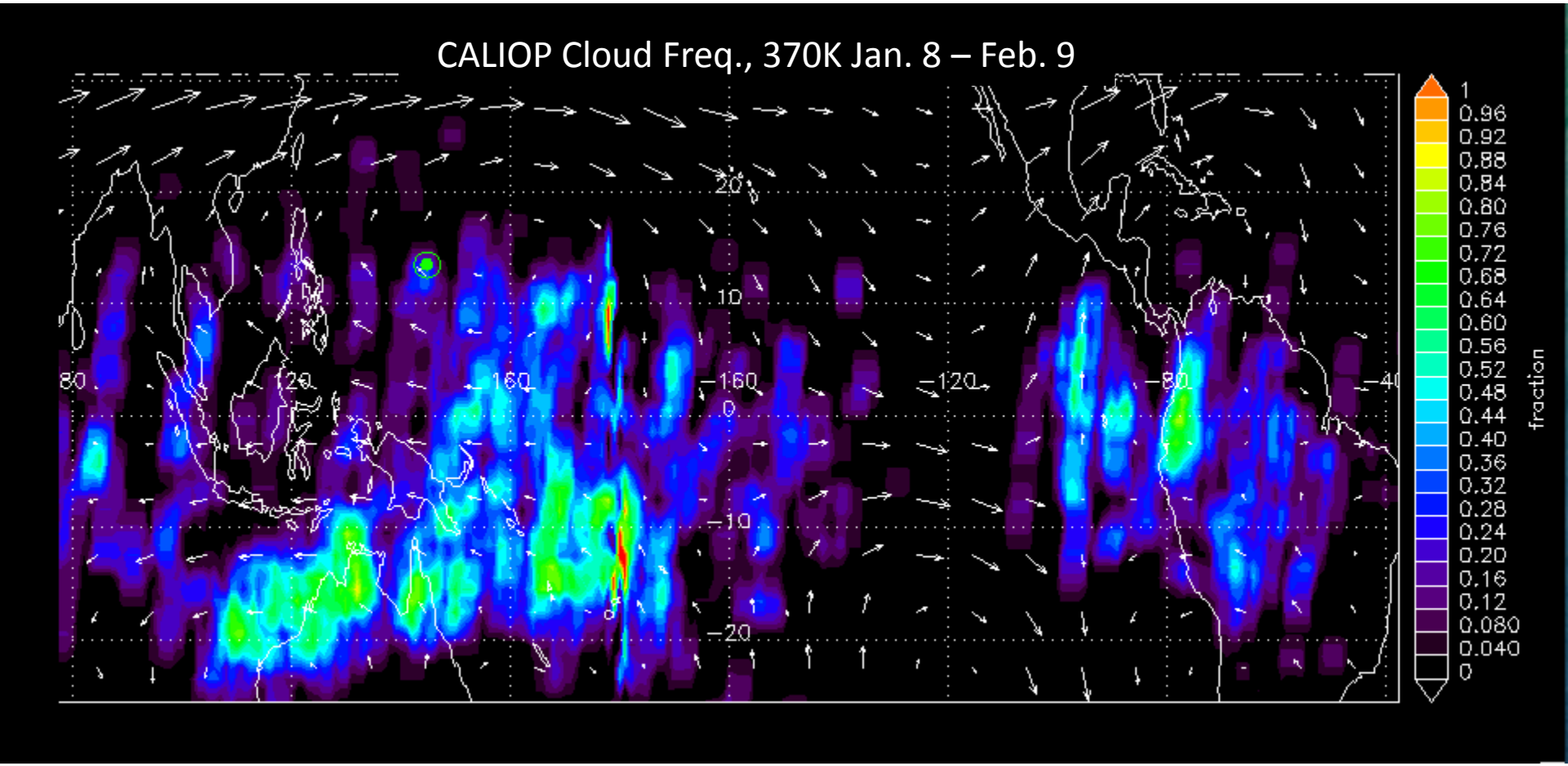
CO Trapped in center of High

Low ozone flows around High

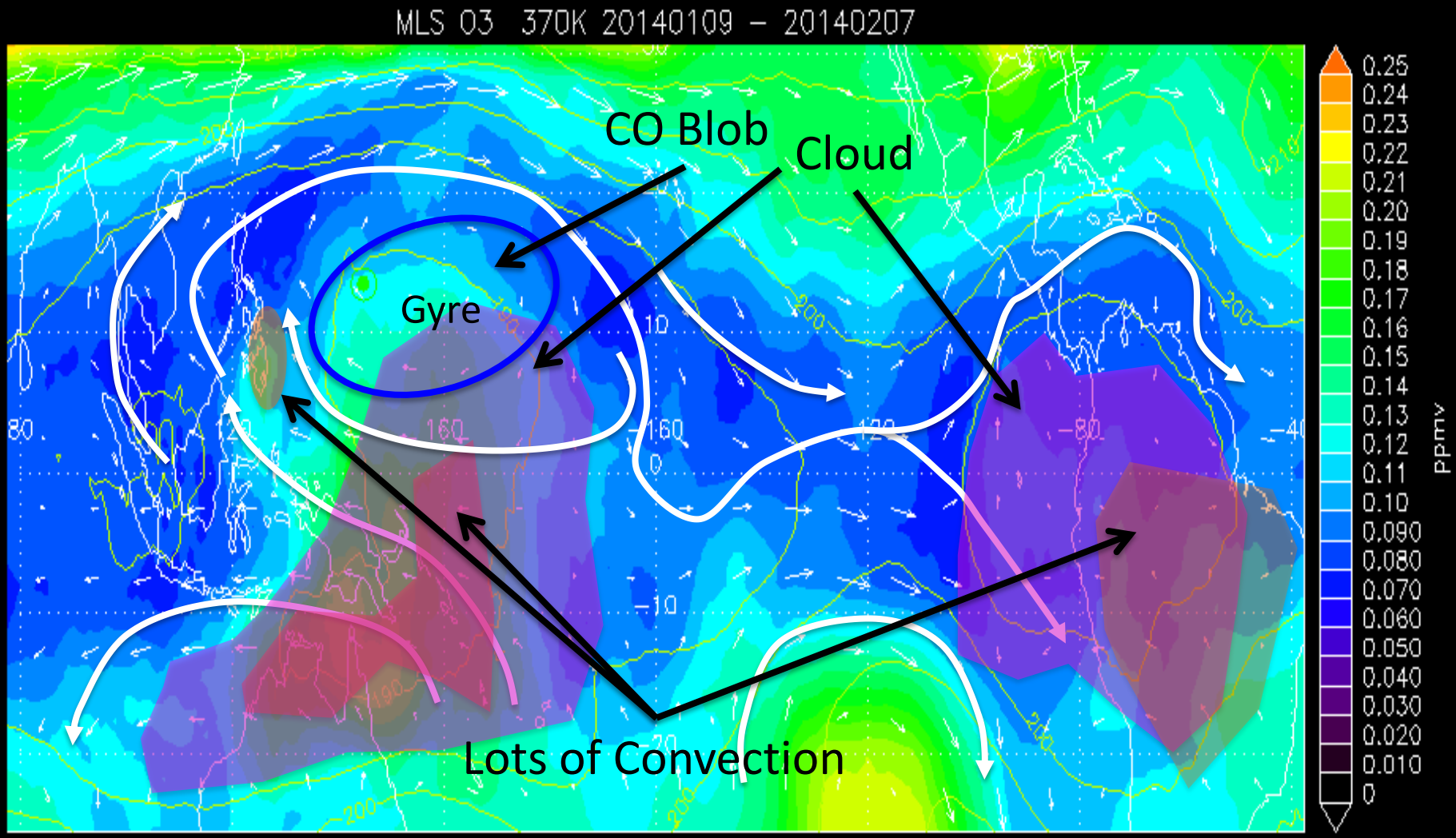
Ozone production via lightning?

Stratospheric air

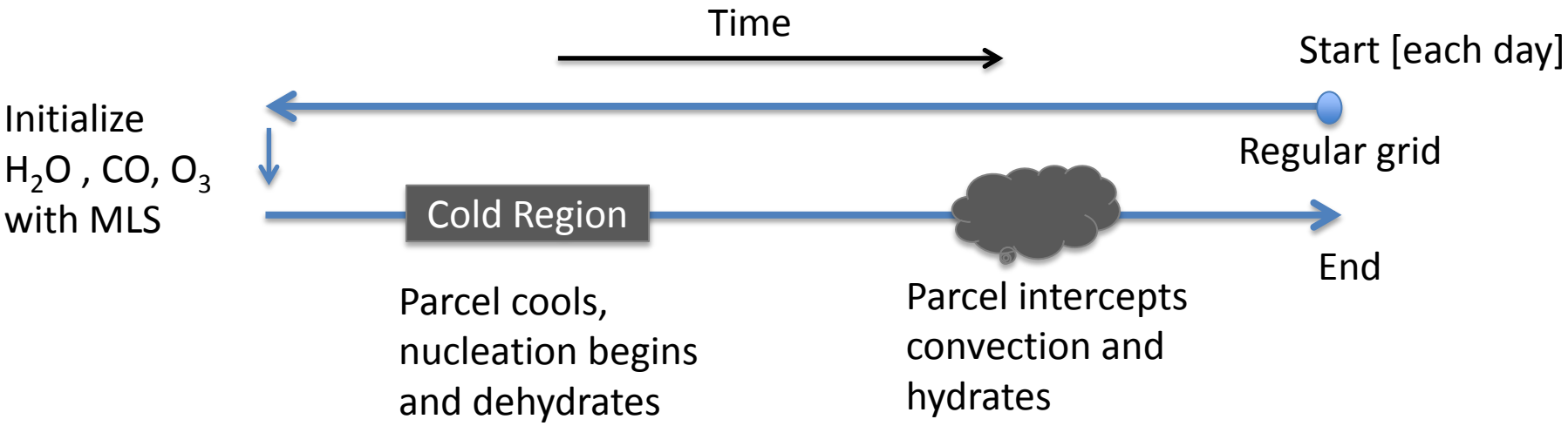
UTLS Clouds


CALIOP Cloud Freq., 370K Jan. 8 – Feb. 9
20
10
0
−10
−20
80
120
160
−160
−120
−80
1
0.96
0.92
0.88
0.84
0.80
0.76
0.72
0.68
0.64
0.60
0.56
0.52
0.48
0.44
0.40
0.36
0.32
0.28
0.24
0.20
0.16
0.12
0.080
0.040
0
fraction

Overall Picture at 370K



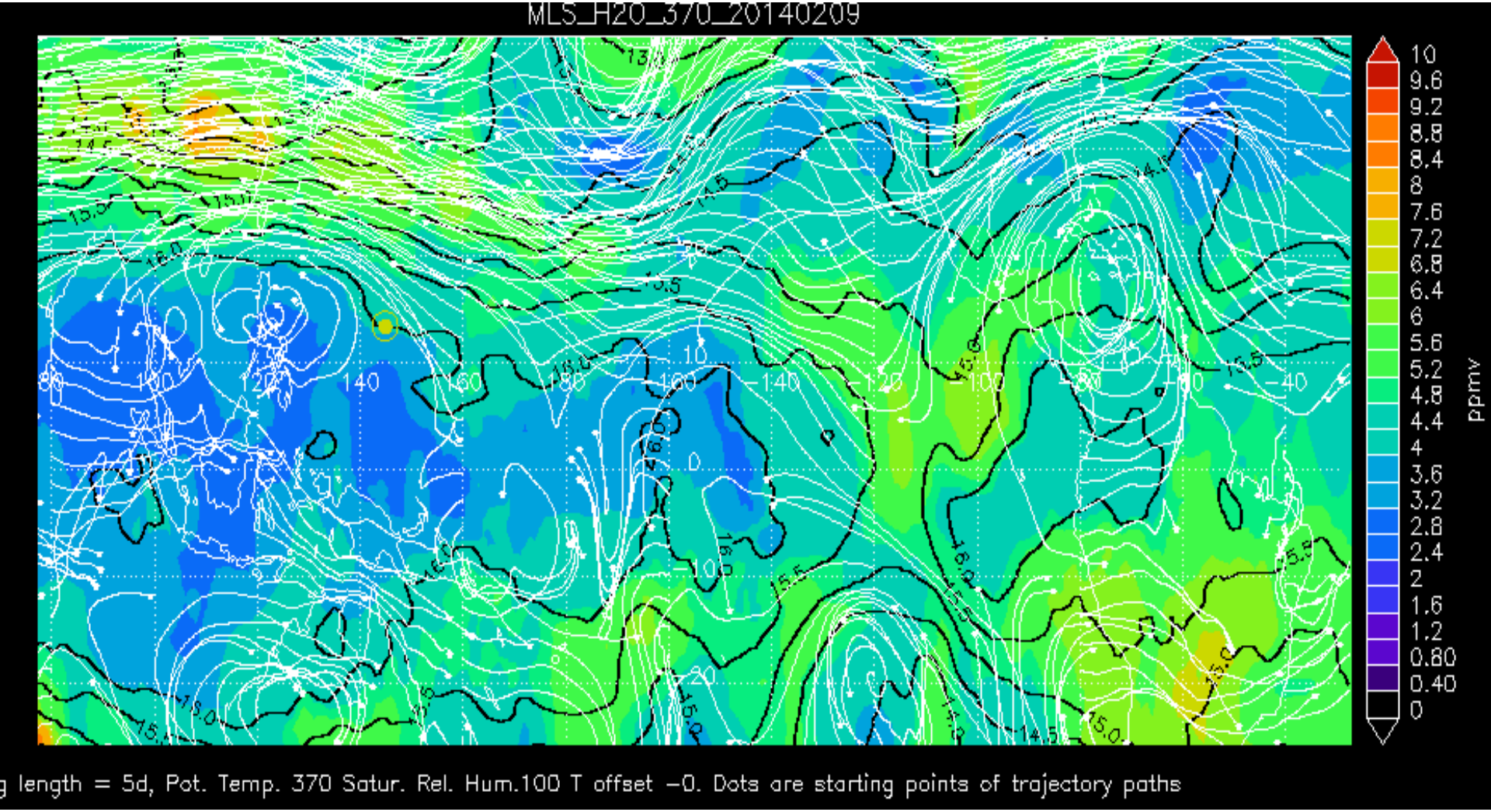
Model Experiments



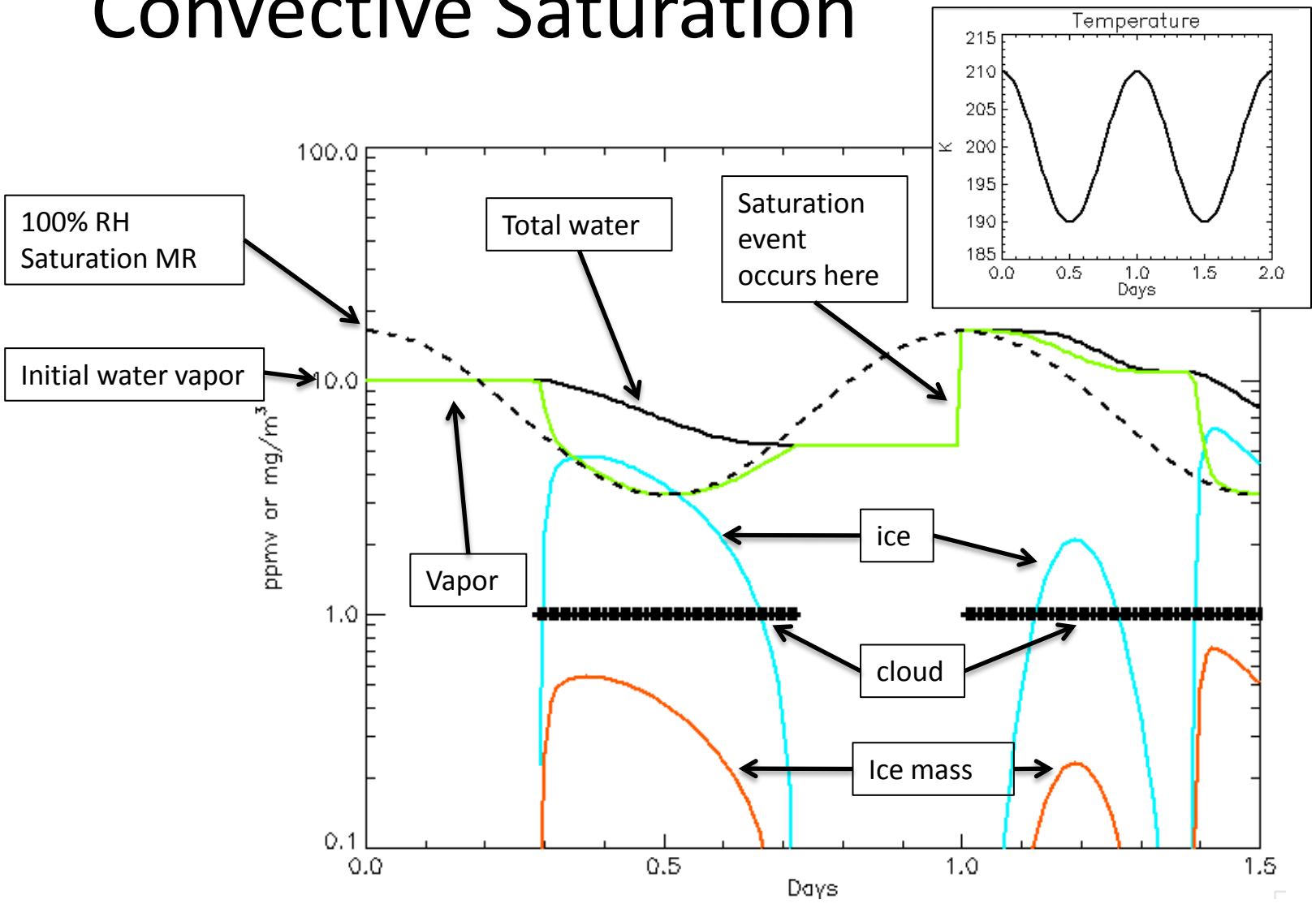
- Create 5 day RDF back trajectories, GFS analysis with constant offset temperature.
- Initialize with MLS H_2O 5 days back, add convective moistening (Pfister), then use a cloud model to dehydrate and predict cloud formation*
- Two Main Convection Cases: No convection (NC); Saturation by convection (SC)
- Three super saturation cases, 100%, 120%, 160%
- Offset cooling, 0, -1, -2, -3
- Average results Jan 8 – Feb 7 2014

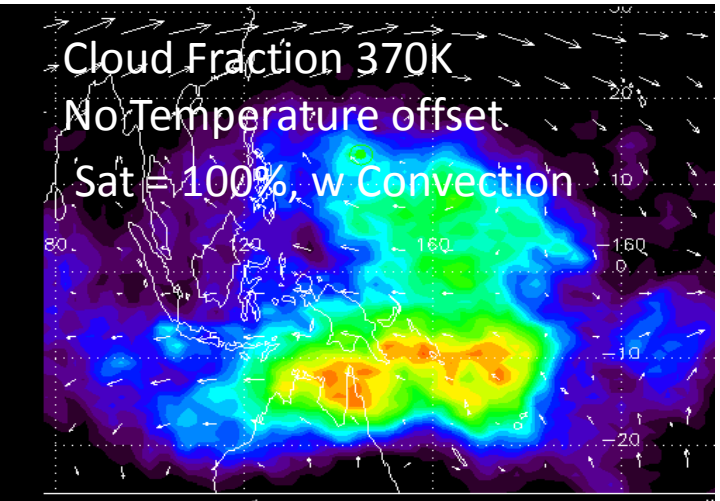
*Cloud model based on Fueglistaler and Baker [2006]

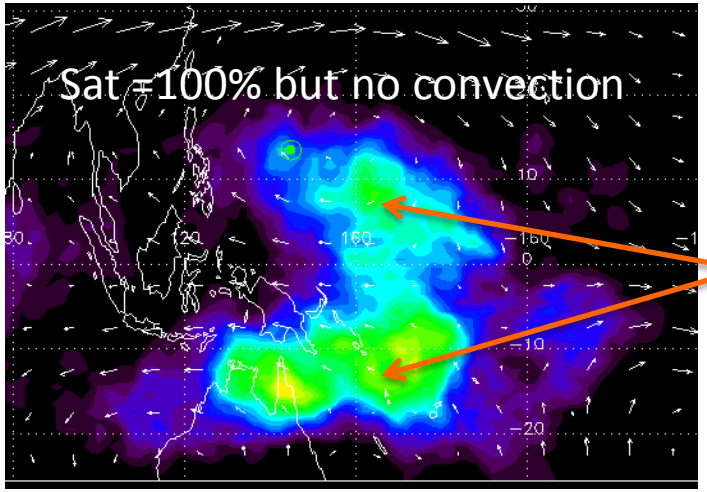
Sample Output



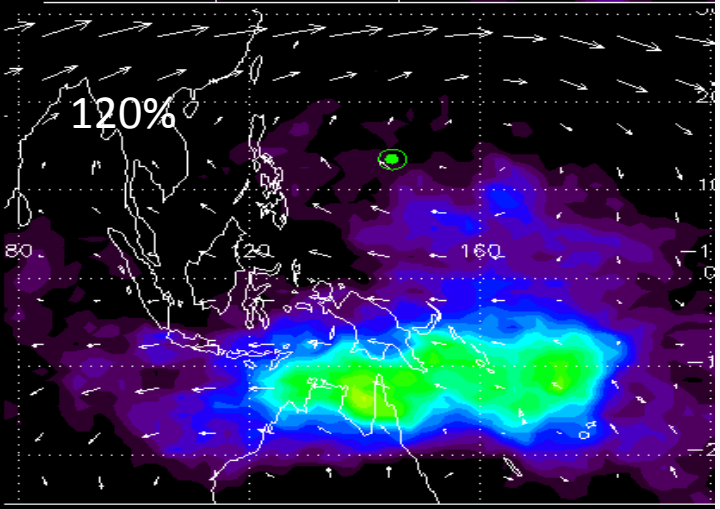
Convective Saturation

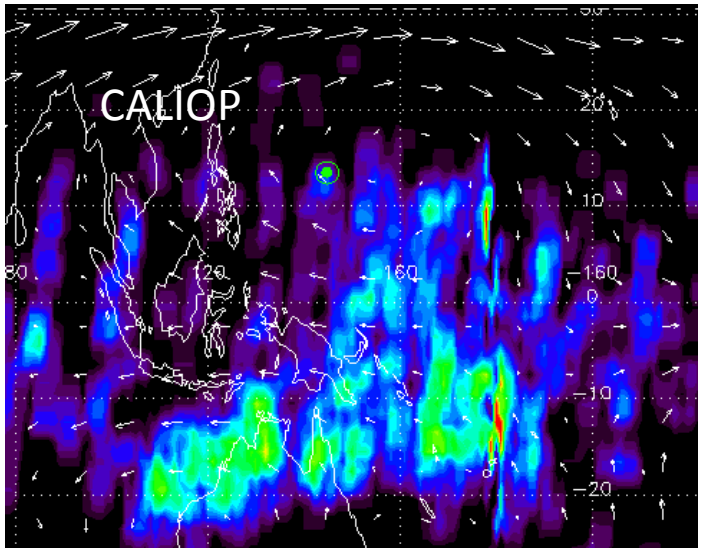


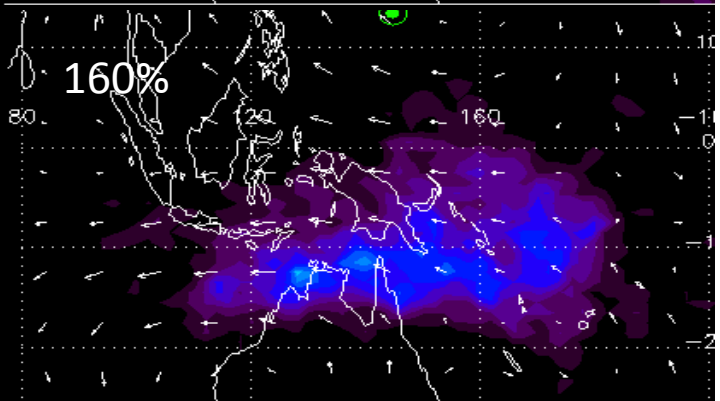




Dehydration zones

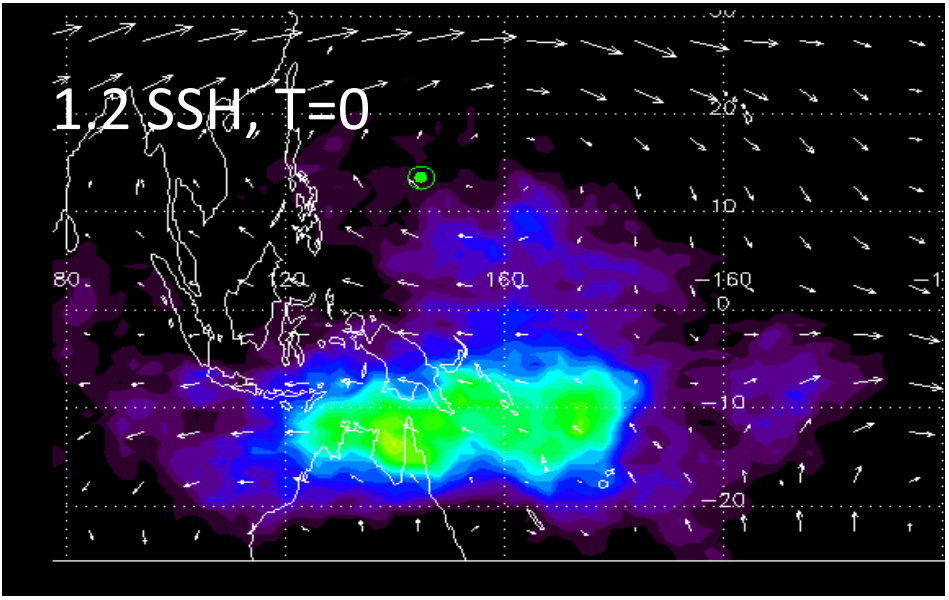


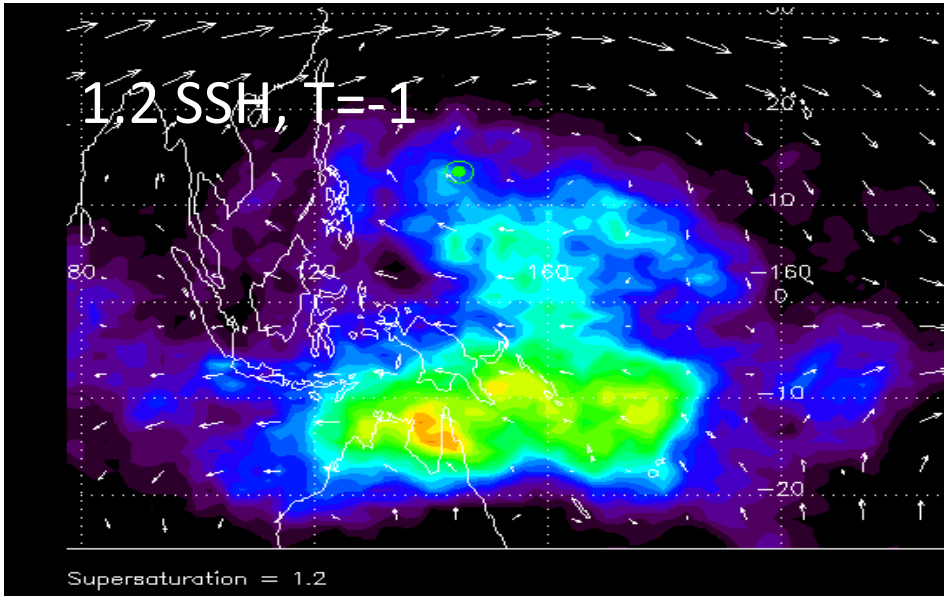


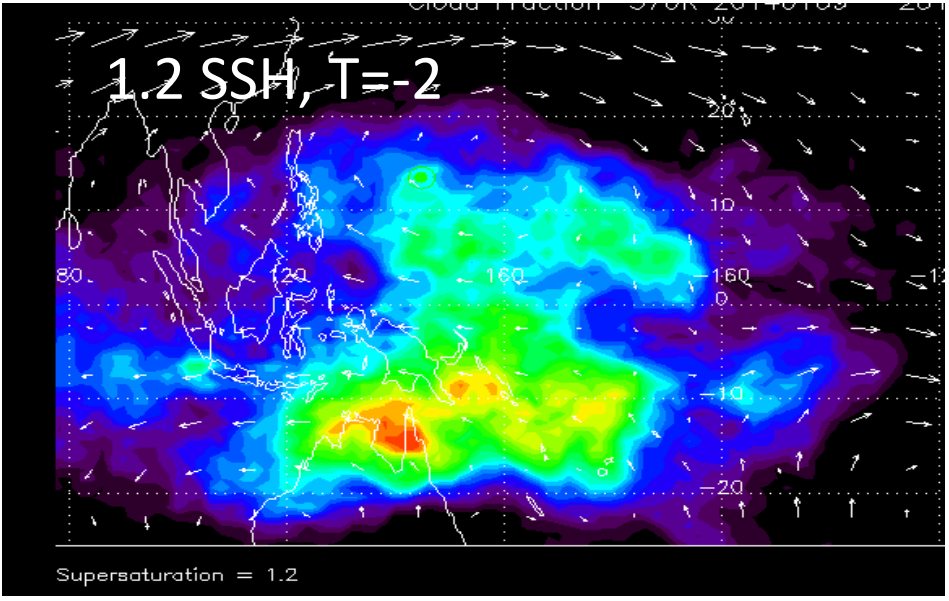


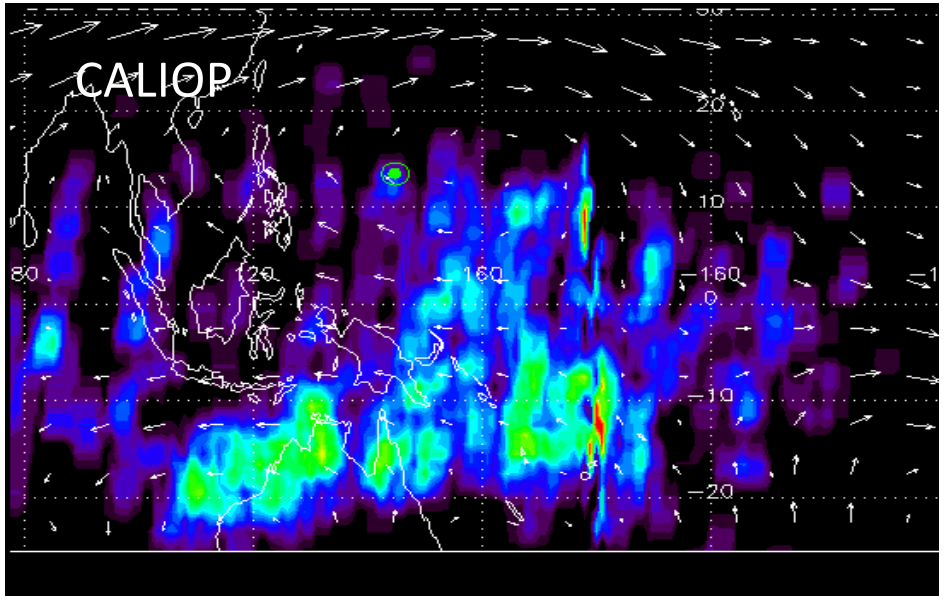
Cloud fraction is very sensitive to the RH nucleation trigger.

Cloud Fraction Sensitivity to Offset Temperature

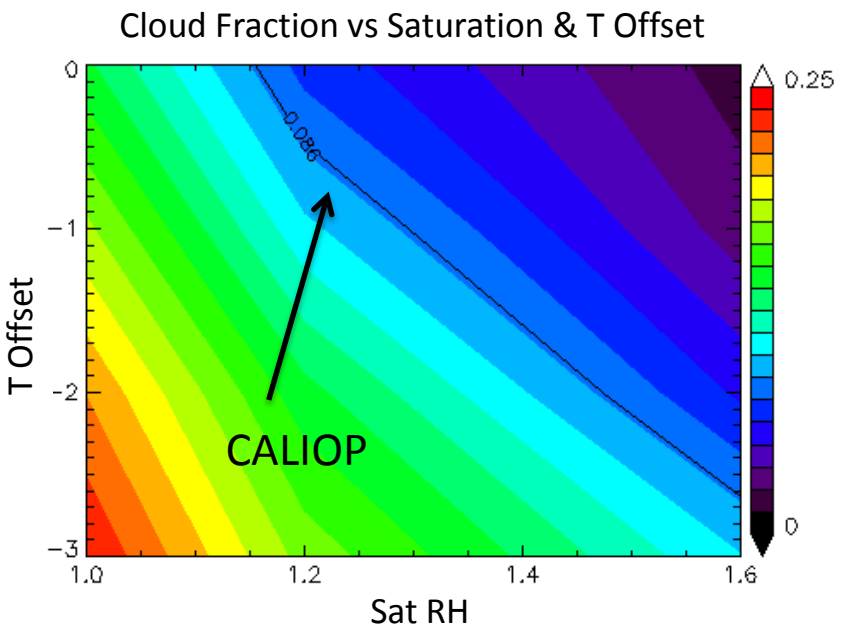


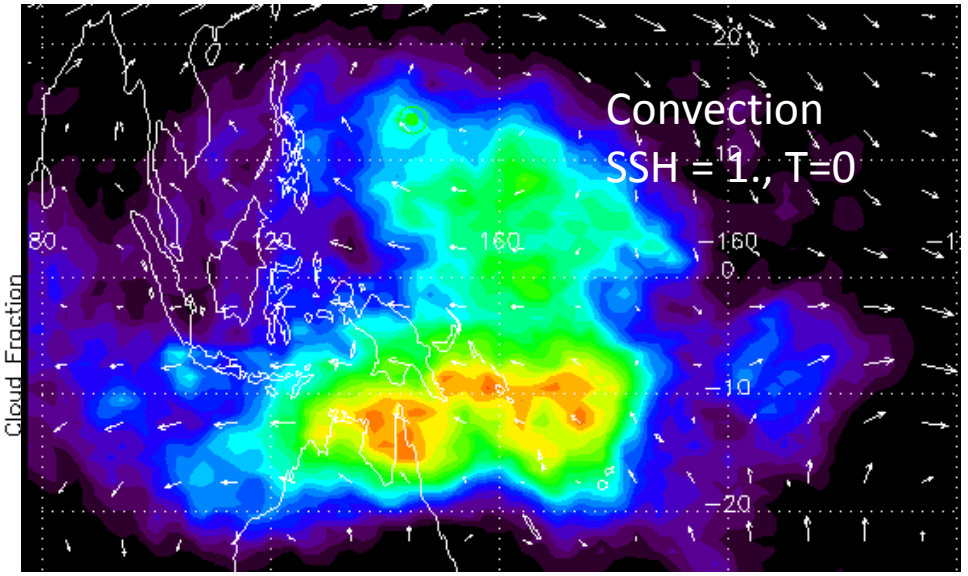


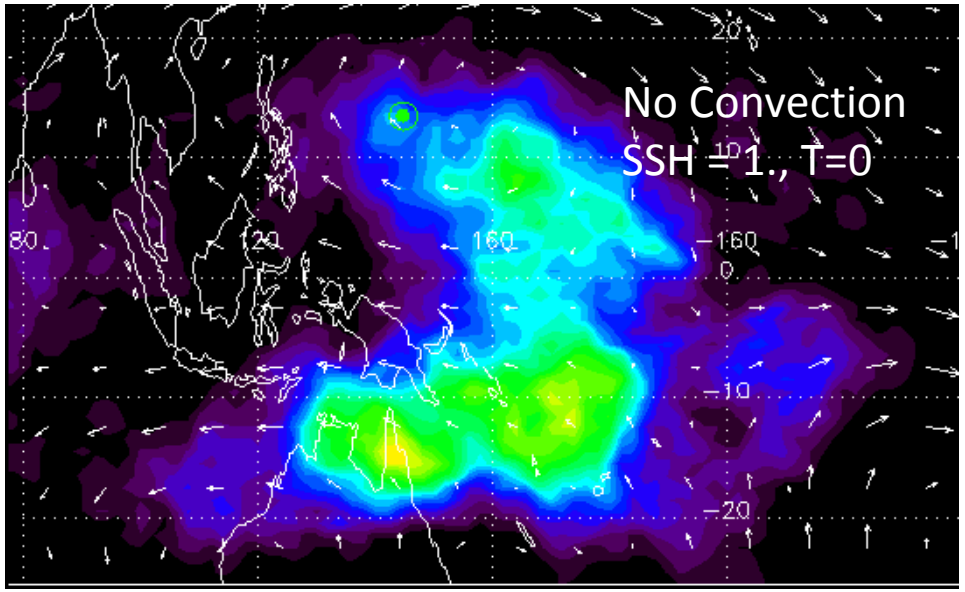




Cloud Amount: Nucleation & Convection



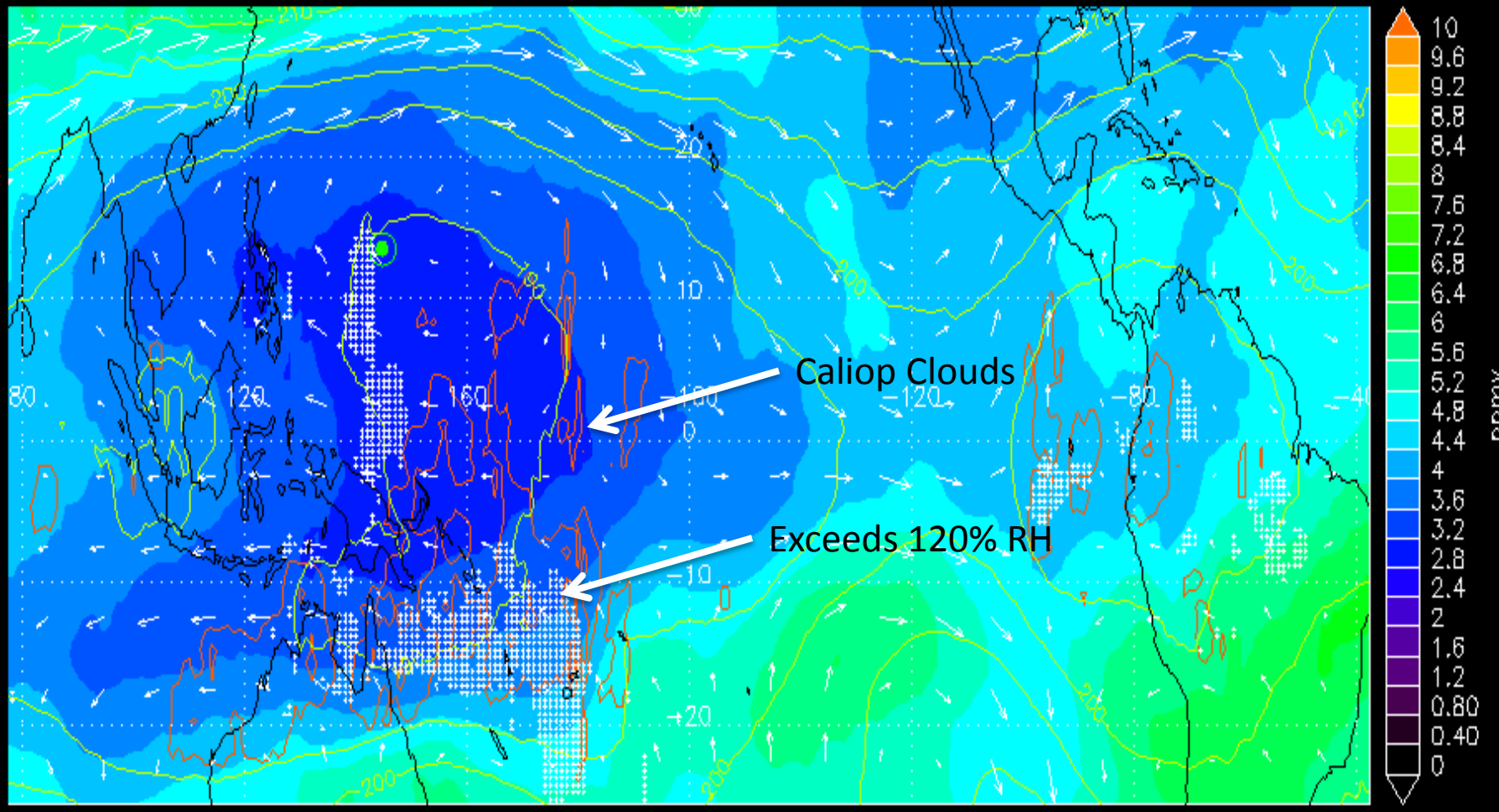




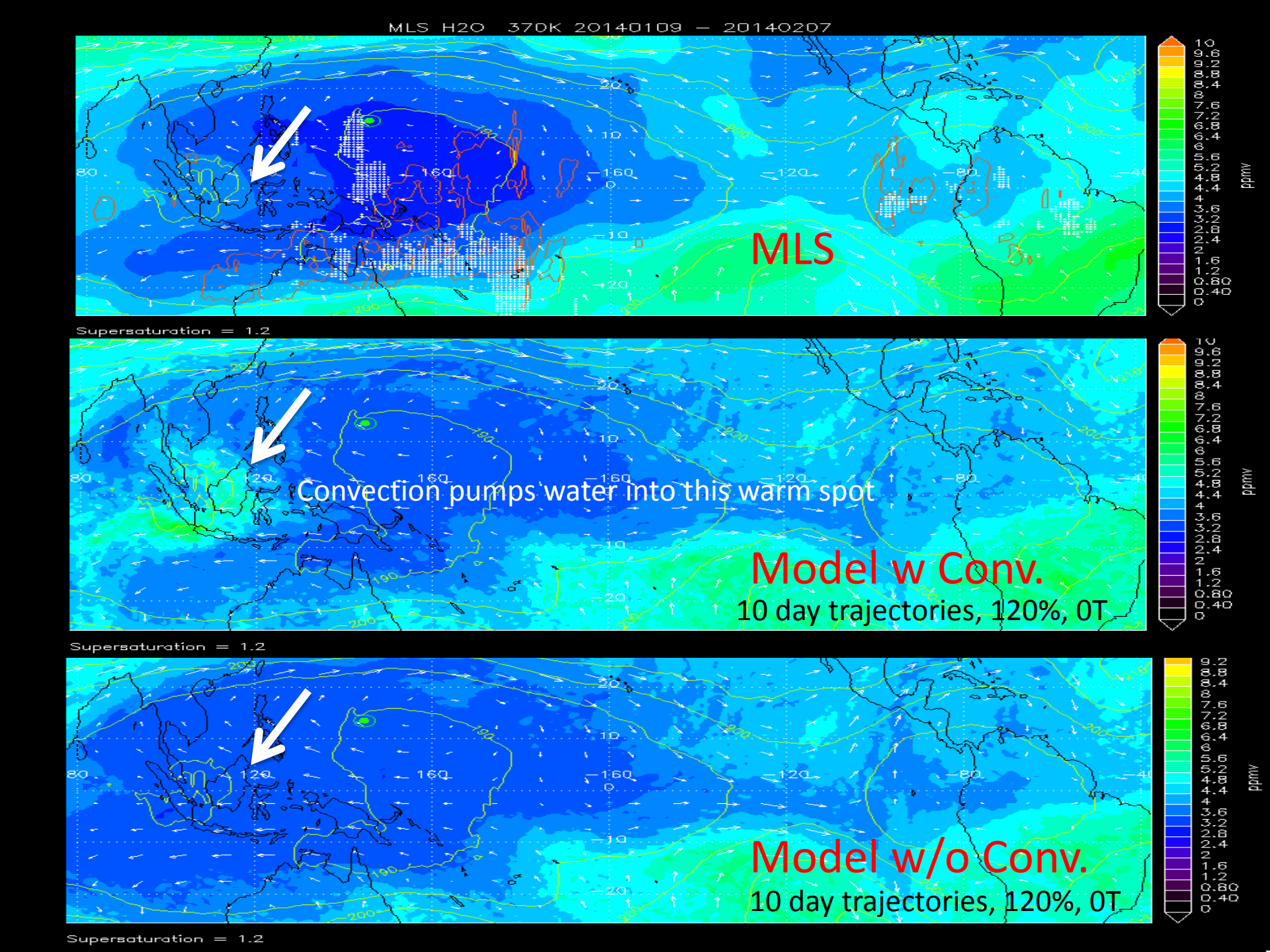
- Between SSH and T Offset there are a range of values that roughly match CALIOP
- Adding convection increases cloud everywhere, but mostly in the convective region. Convective fraction of total is 30-40%

Water vapor

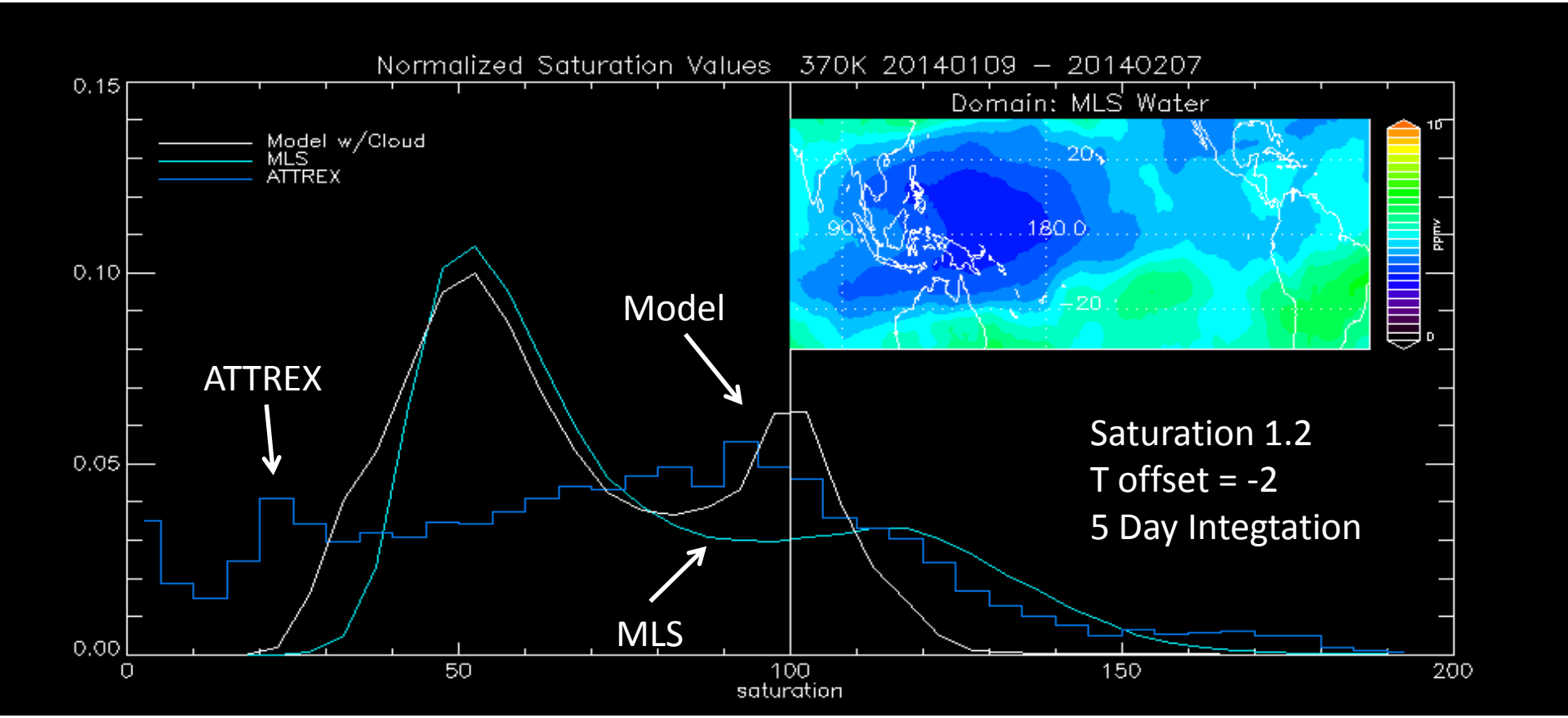
MLS 370K Average 140109-140207



Supersaturation = 1.2


MLS H2O 370K 20140109 – 20140207
MLS
ppmv
Supersaturation = 1.2
Convection pumps water into this warm spot
Model w Conv.
10 day trajectories, 120%, 0T
Supersaturation = 1.2
Model w/o Conv.
10 day trajectories, 120%, 0T
Supersaturation = 1.2

Water Vapor Statistics: Saturation

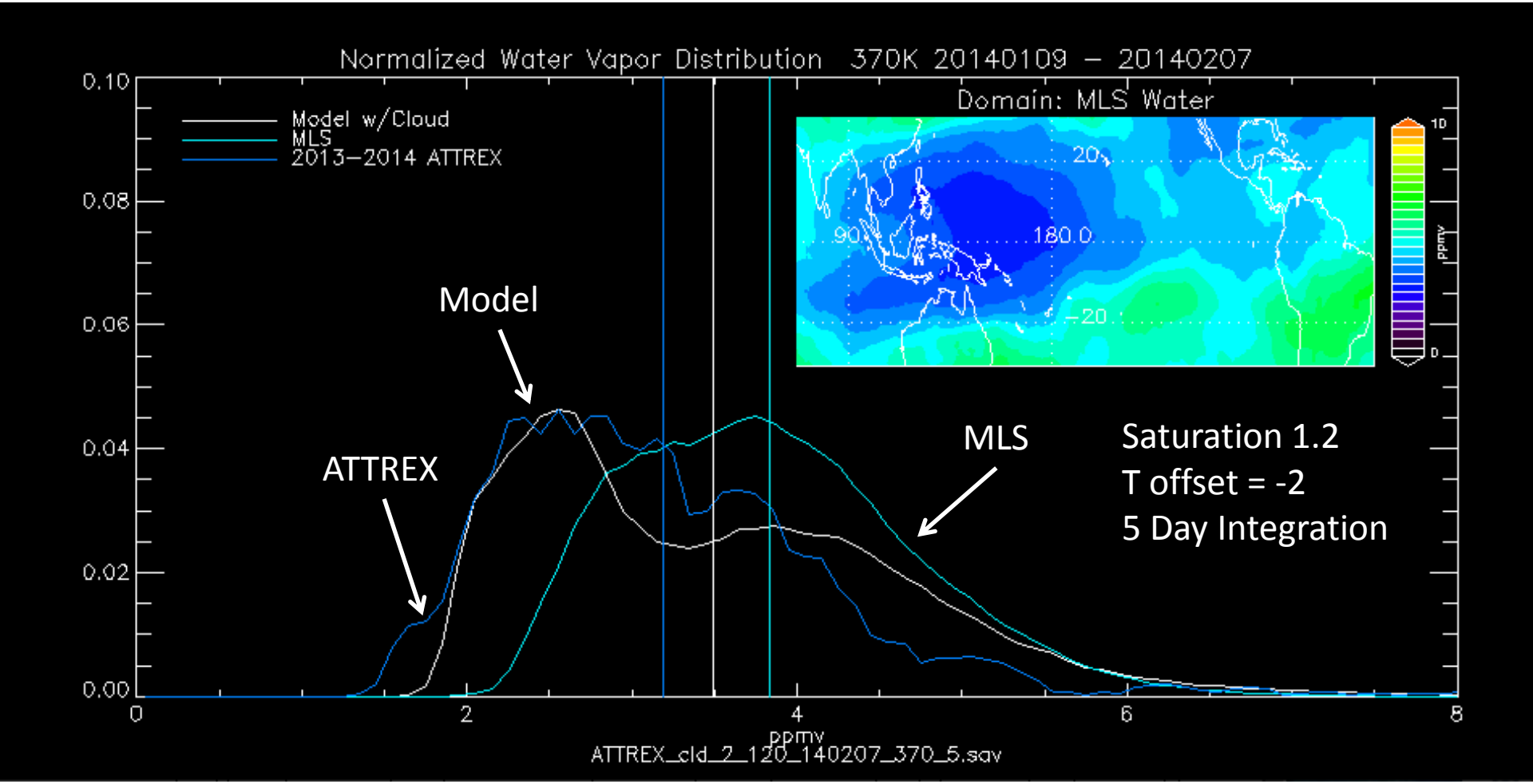


Used all 2013, 2014 ATTREX data

Peak in saturated parcels near 100%RH – peak decreases if saturation RH increased

No ATTREX peak near 50% - sampling issues?

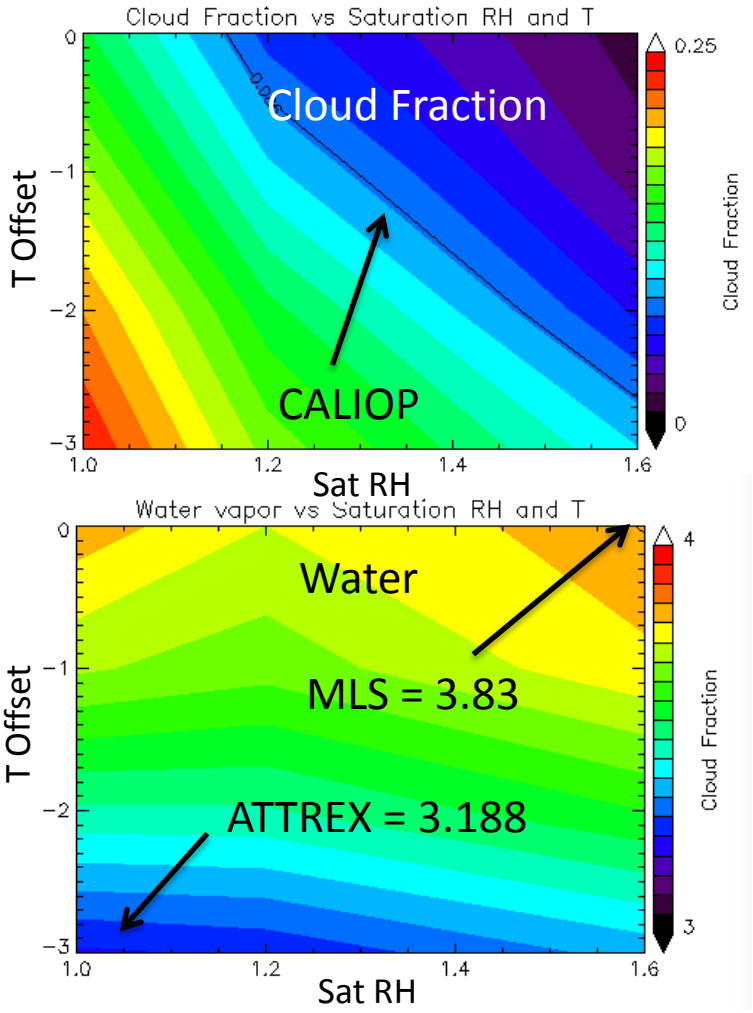
Water Vapor Statistics: Water



- Water vapor PDF shifted significantly from initial state
- ATTREX data is ~0.25 ppmv drier than model on average

Conclusions

- Cloud model does a pretty good job of simulating cirrus observations – at least the location.
- Convective processes are responsible for 30-40% of cirrus clouds
- Cloud Fraction a strong function of both temperature and Sat RH
- Water vapor is a weak function of Sat RH
- Significant difference between MLS and ATTREX water observations
- Interesting structures in CO and O_3
  - CO anomaly caught in upper troposphere gyre, origin?
  - O_3 enhanced south of gyre, why?



Acknowledgements

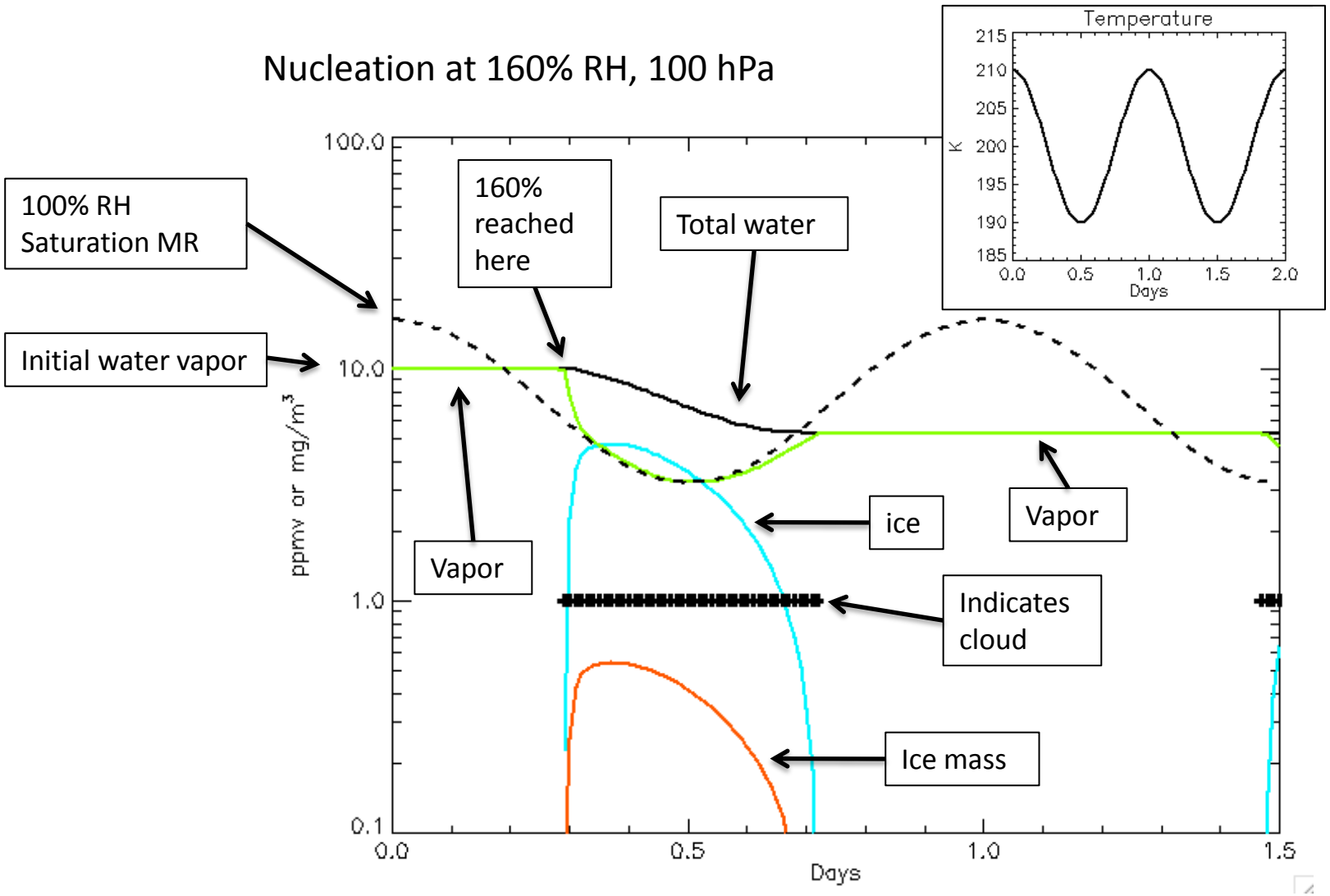
- ATTREX and CALIPSO Projects
- NASA Grants NNX13AK25G & NNX14AF15G
- Stephan Fueglistaler for prototype cloud model

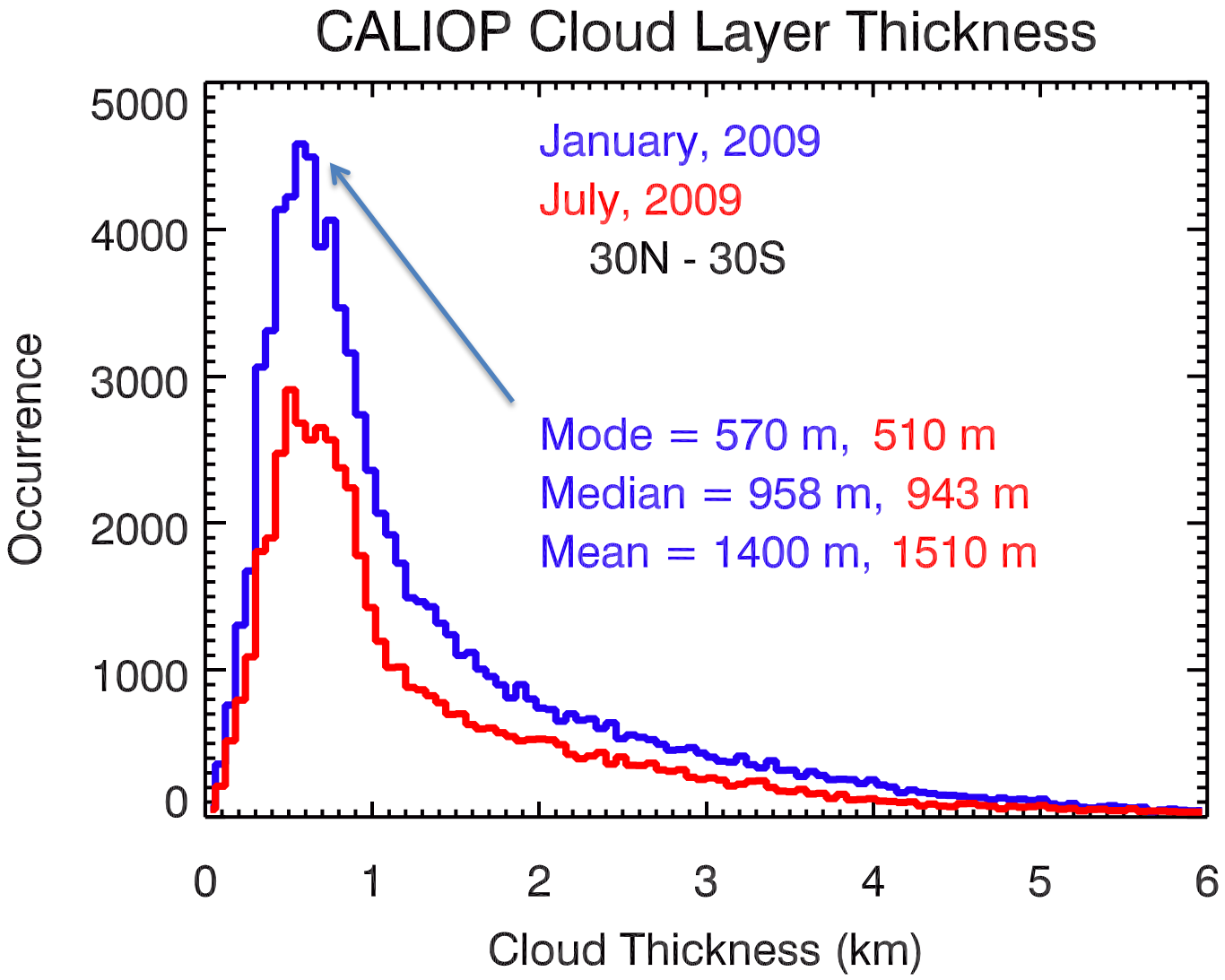
Additional Slides

More Details on Cloud Model

- Cloud model assumes a single equivalent mode.
- Ice particles are initiated at saturation according to Kårcher et al. [2006].
- Processes include deposition, sublimation, and gravitational sedimentation.
- When particle density is < 1 /m^3 the cloud is terminated.
- Clouds are assumed to be 500m thick – the mode cloud thickness from CALIOP

Cloud Model


Nucleation at 160% RH, 100 hPa
100% RH
Saturation MR
Initial water vapor
160%
reached
here
Total water
Vapor
Vapor
ice
Indicates
cloud
Ice mass
ppmv or mg/m³
100.0
10.0
1.0
0.1
0.0
0.5
1.0
1.5
Days
Temperature
K
215
210
205
200
195
190
185
0.0
0.5
1.0
1.5
2.0
Days


CALIOP Cloud Layer Thickness
January, 2009
July, 2009
30N - 30S
Mode = 570 m, 510 m
Median = 958 m, 943 m
Mean = 1400 m, 1510 m
Occurrence
5000
4000
3000
2000
1000
0
0
1
2
3
4
5
6
Cloud Thickness (km)