Update on mixed-phase cloud results

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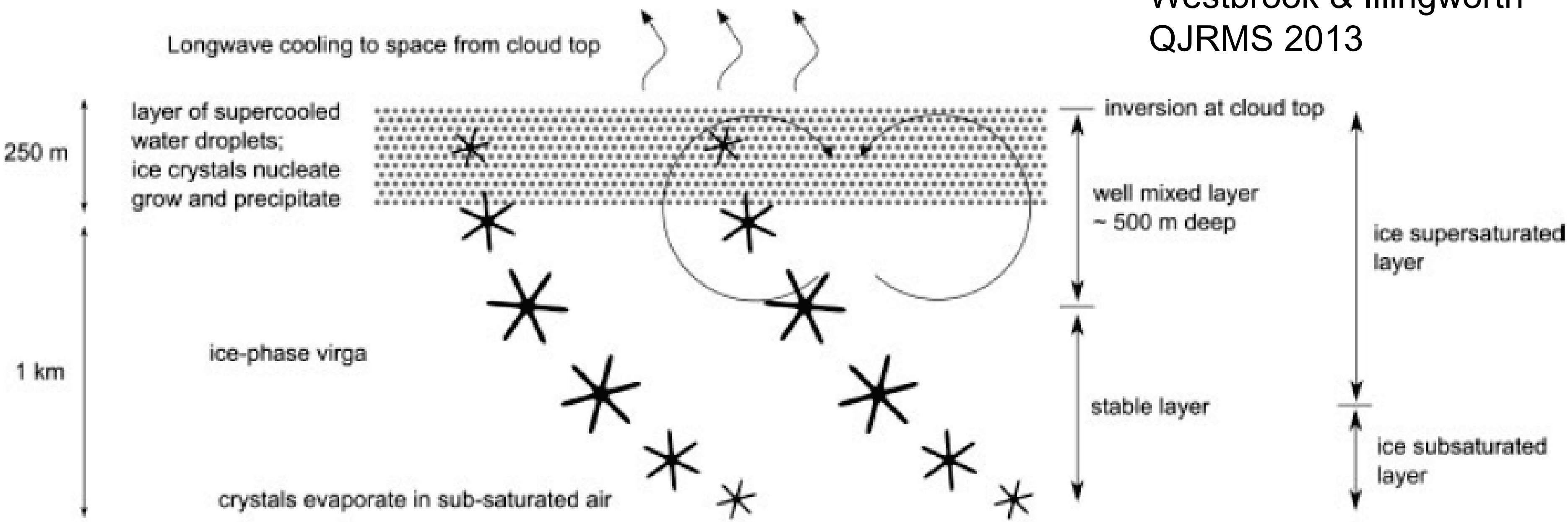
Theory and calculations: F. Yang and M. Ovchinnikov

Cloud Chamber: W. Cantrell, K. Chandrakar, K. Chang, D. Ciochetto, N. Desai, G. Kinney, D. Niedermeier

Acknowledgements: DOE ASR

Mixed-phase stratiform clouds...

Figure adapted from Westbrook & Illingworth QJRMS 2013



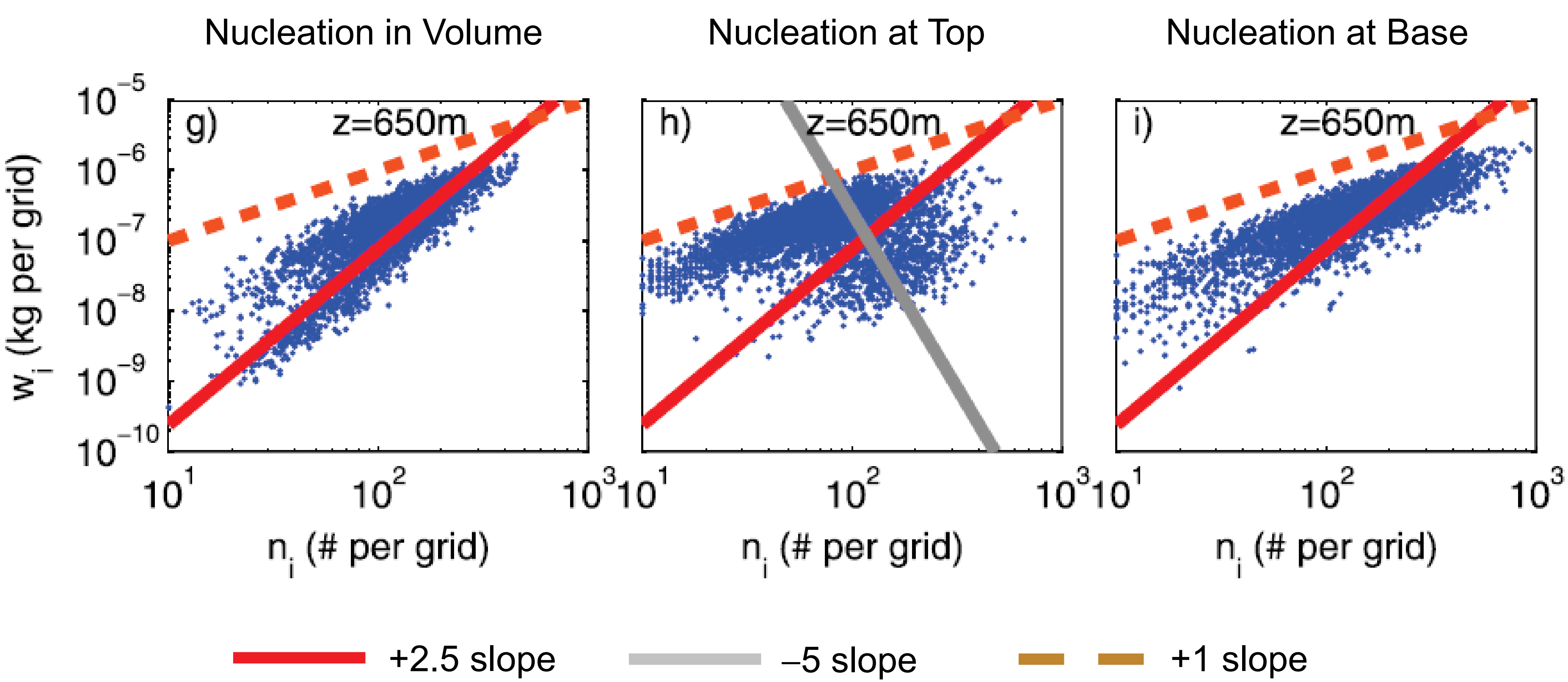
Arctic stratus & altocumulus clouds tend to be thin, long-lived, weakly precipitating ice, and radiatively important…

Questions: How can "metastable" clouds exist for so long? Where do all the ice nuclei come from? How do the ice crystals get so big in such thin clouds?

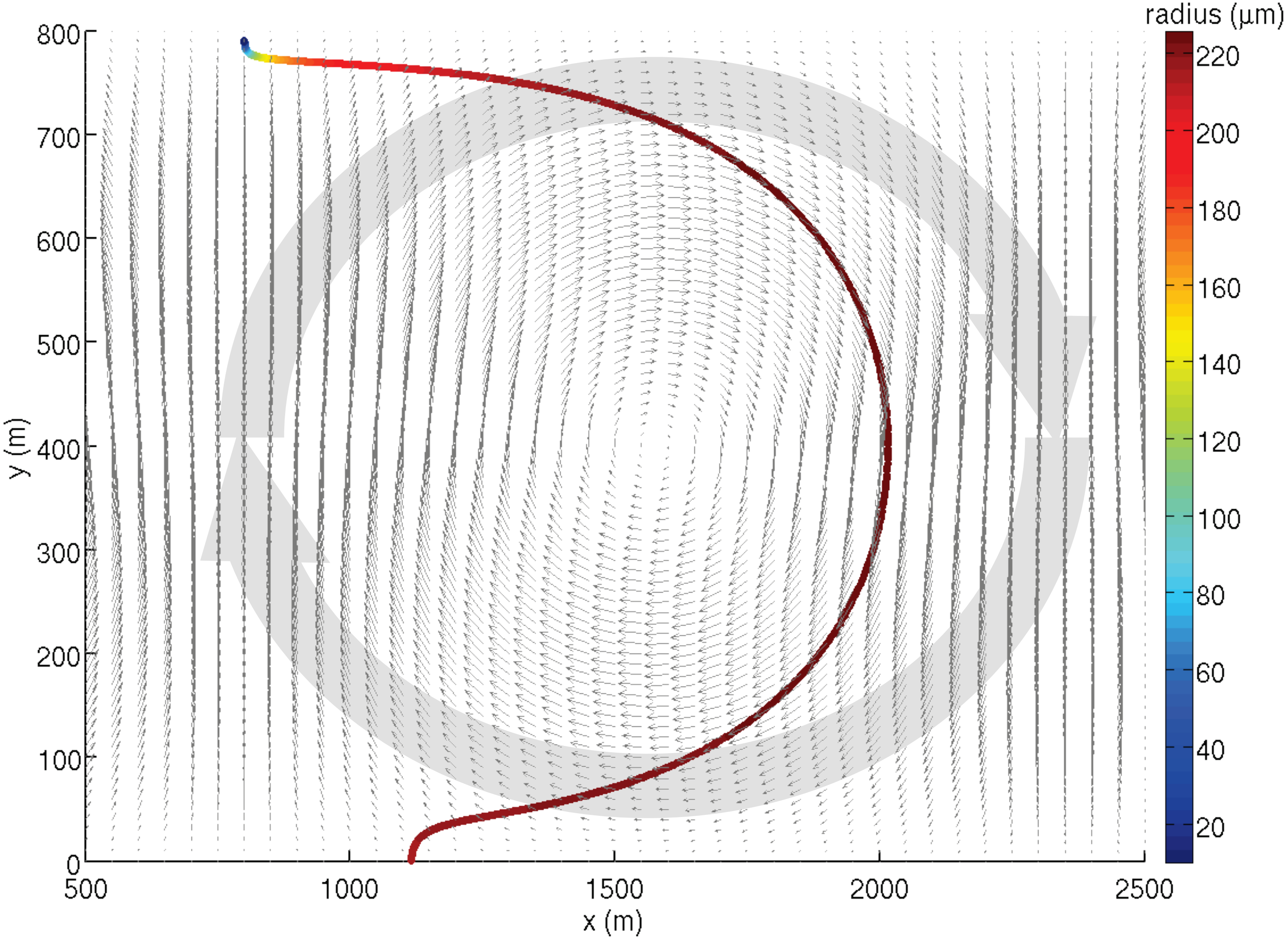

MODIS image from
blogs.woodtv.com

Power laws of Ice water content vs ice number...

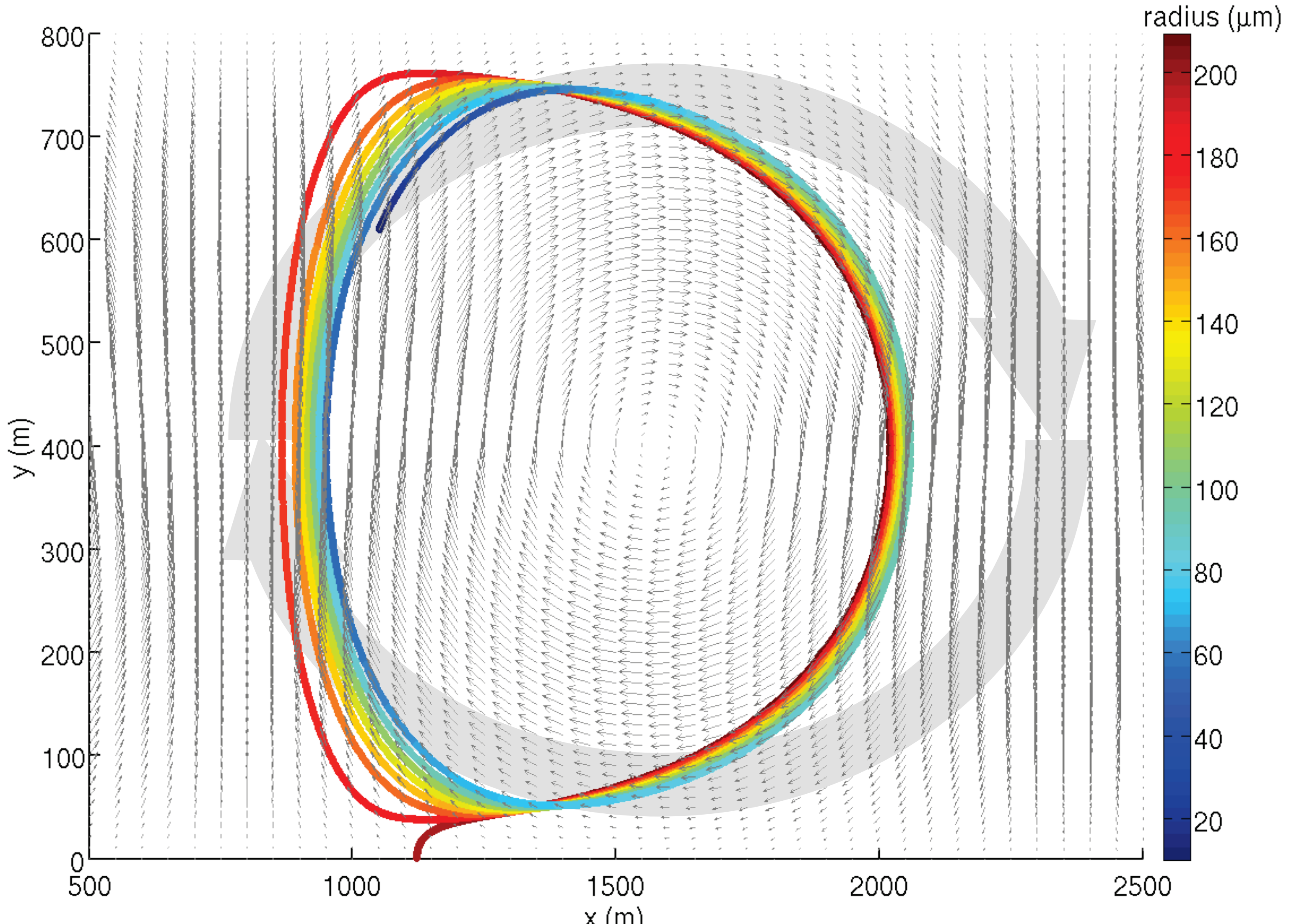
$$w_i = G_{\text{vol}} \frac{n_i^{2.5}}{\dot{n}_i^{1.5}} \qquad w_i = G_{\text{top}} \frac{\dot{n}_{i,a}^{6}}{n_i^{5}} \qquad w_i \propto n_i$$



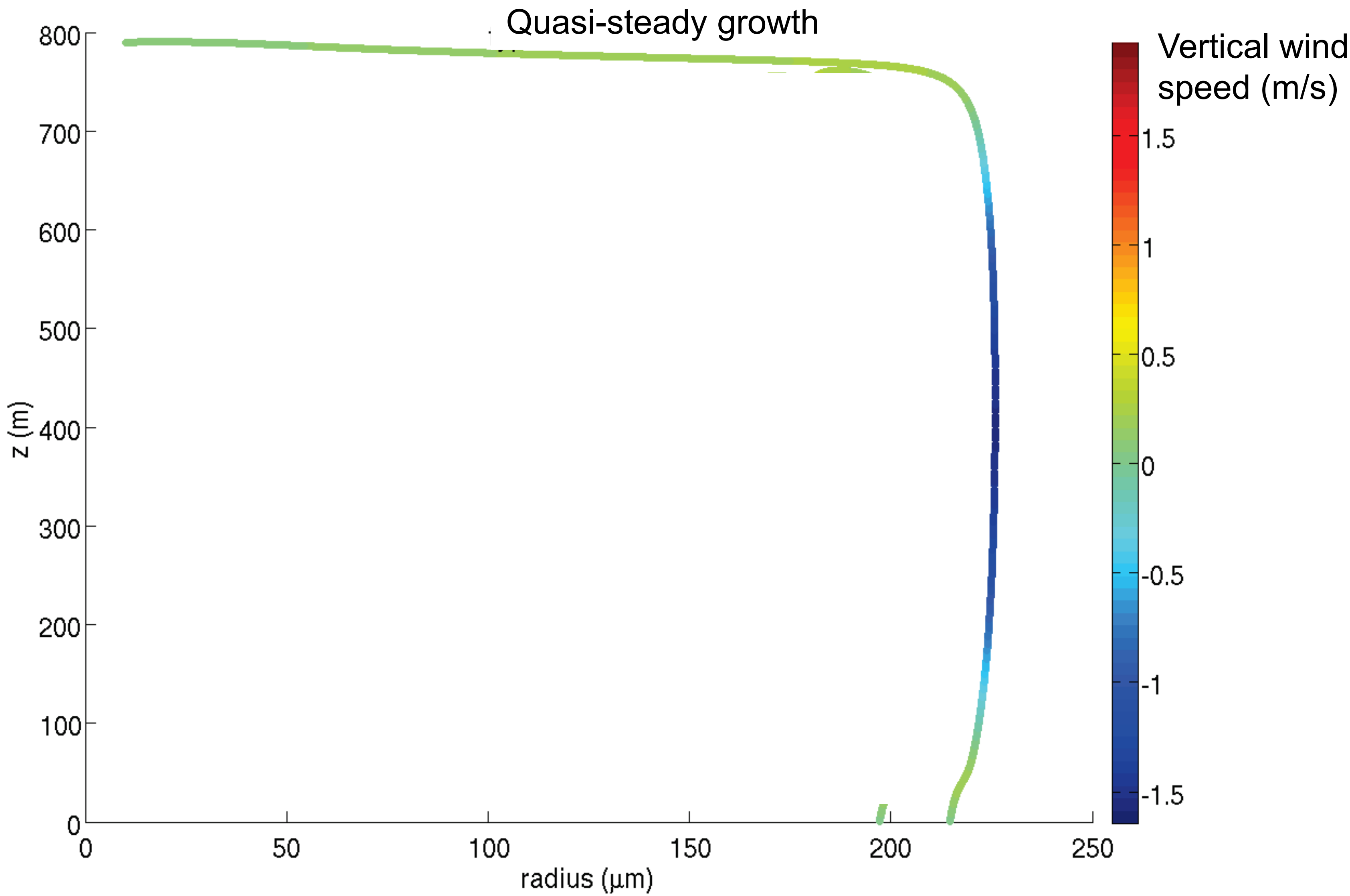
Lagrangian trajectories: quasi-steady growth...



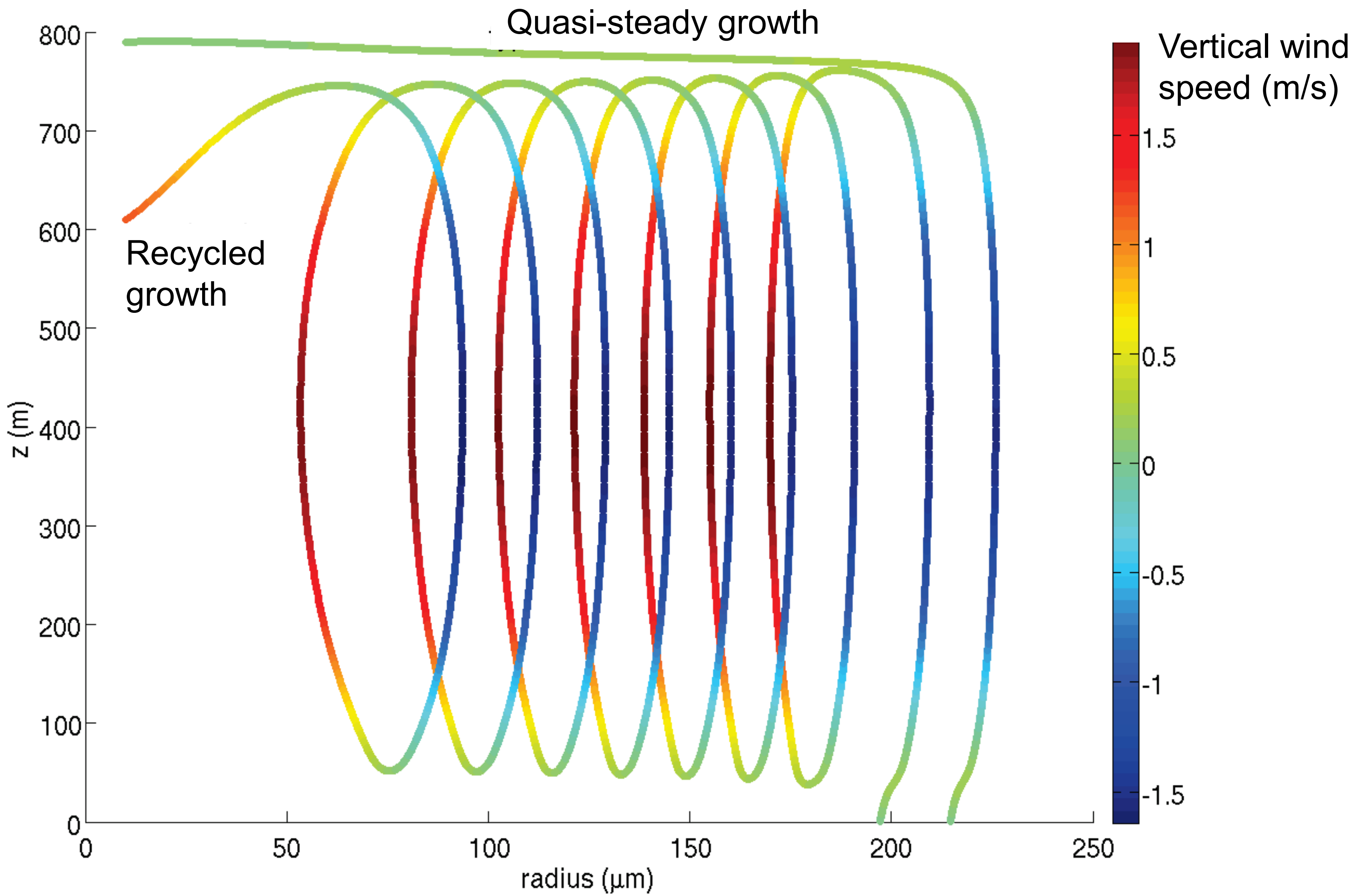
Lagrangian trajectories: recycled particles...



Trajectories in (r, z) coordinates...



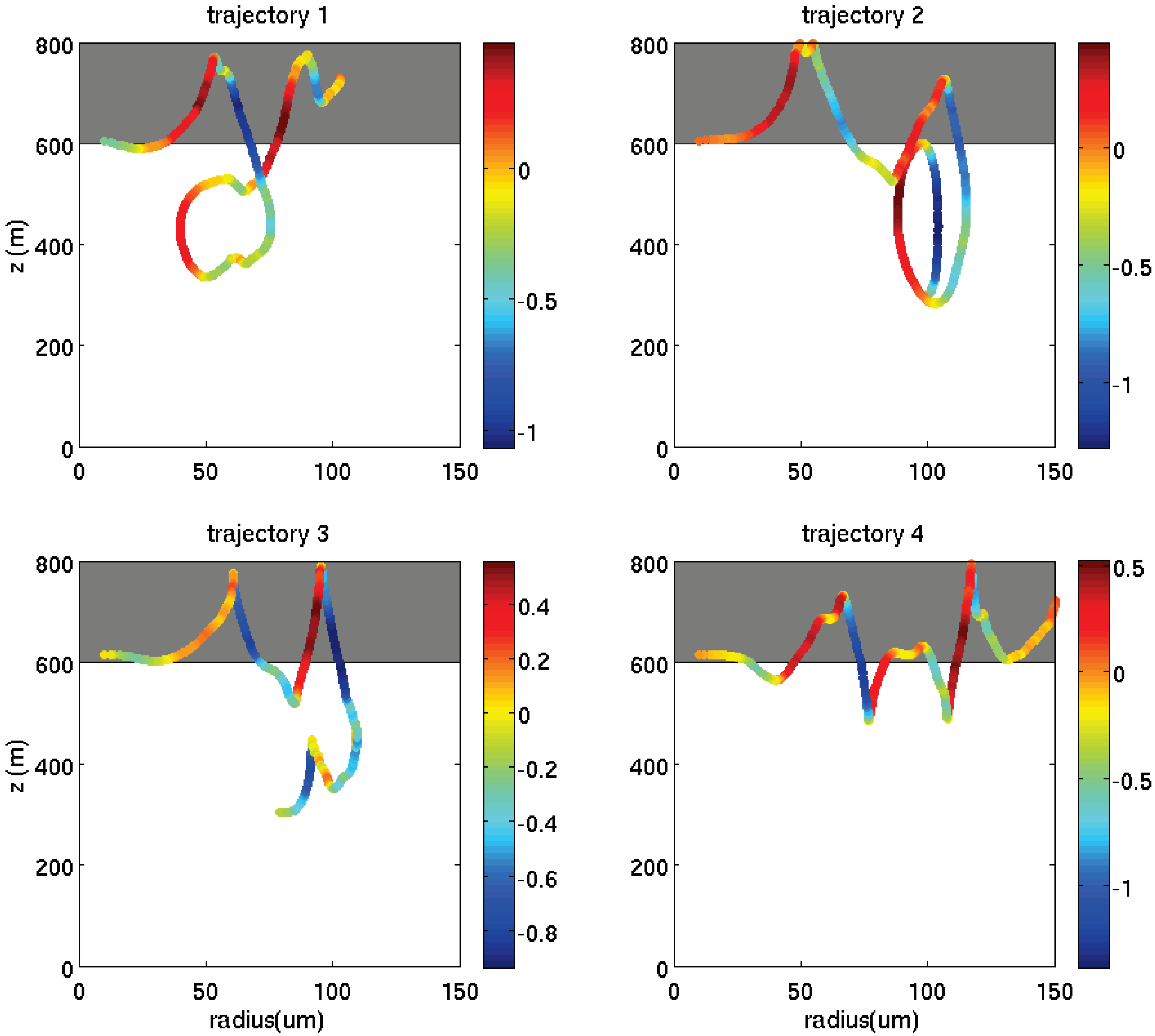
Trajectories in (r, z) coordinates...



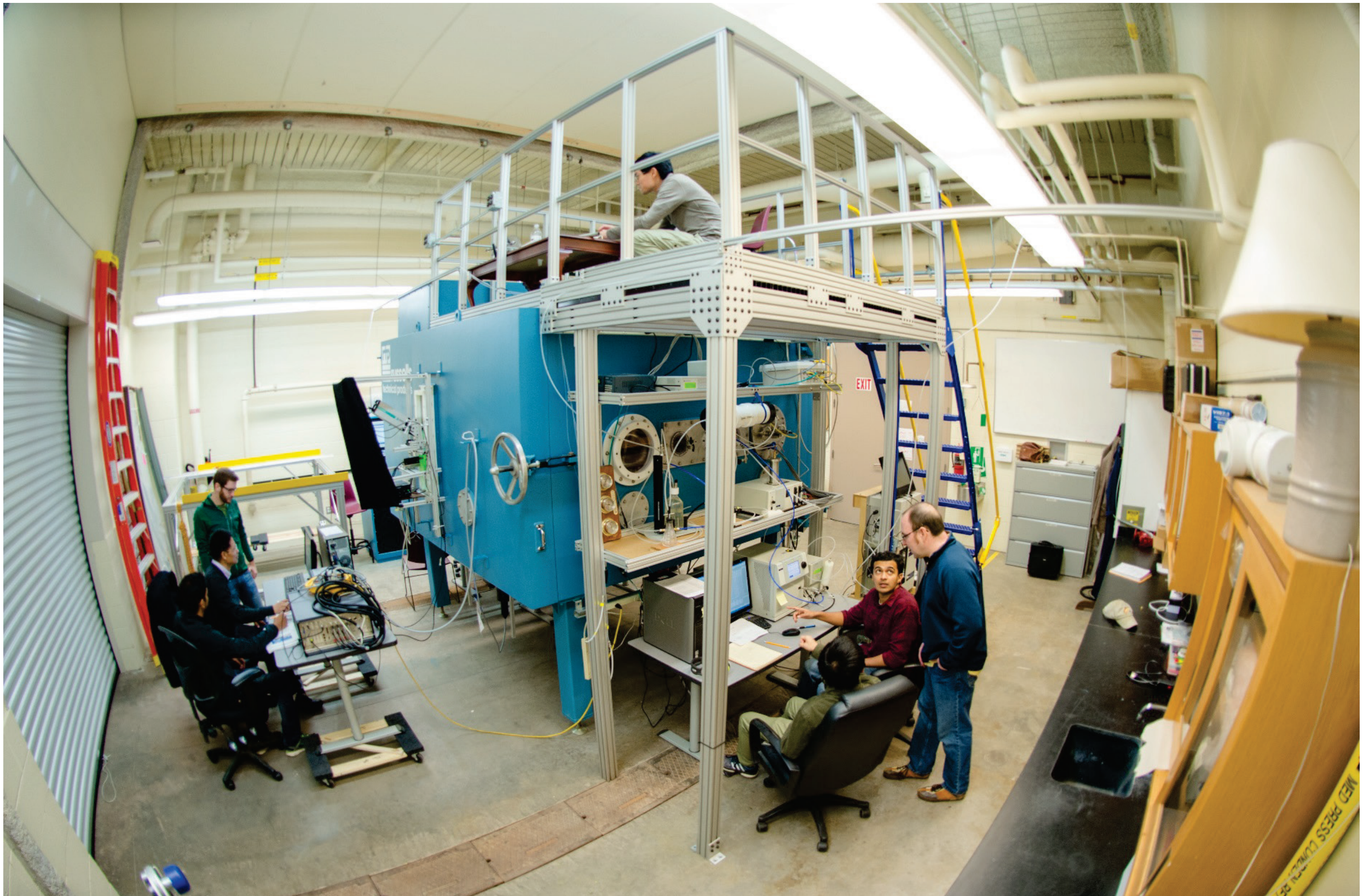
(r, z) trajectories in the LES…

Shaded area: Supercooled liquid cloud

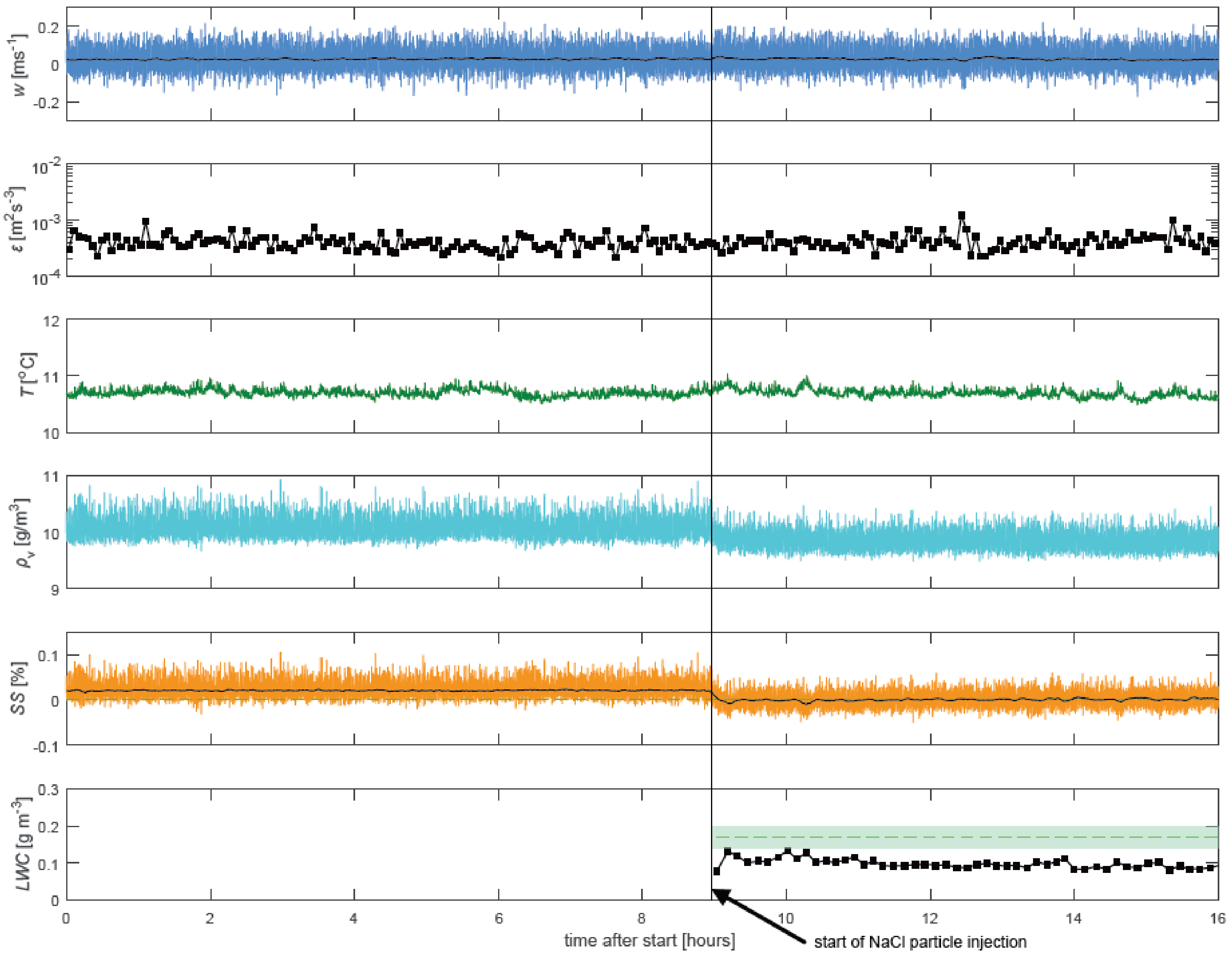
Vertical wind speed (m/s)



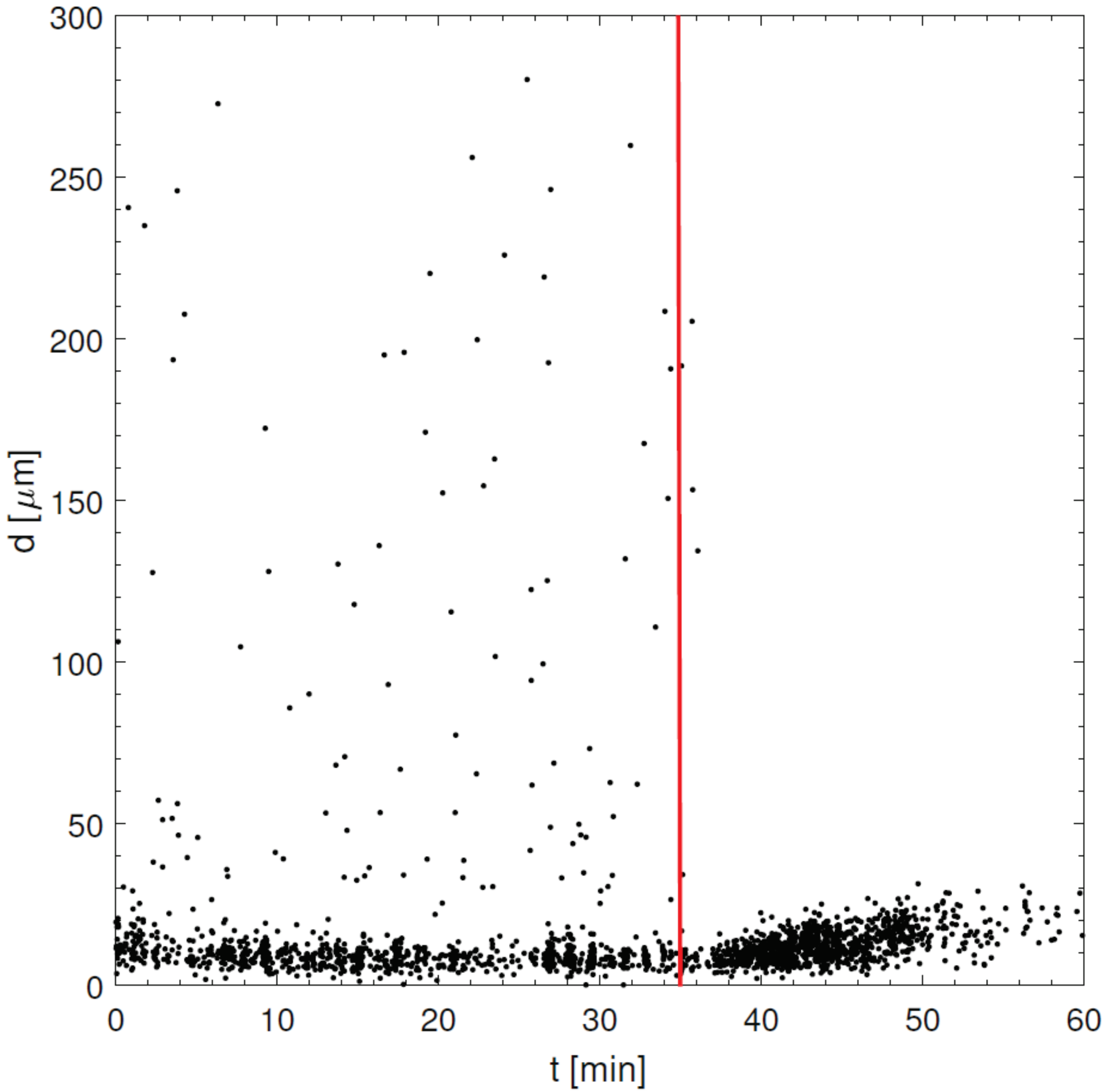
Mixed-phase clouds in the Pi Chamber...



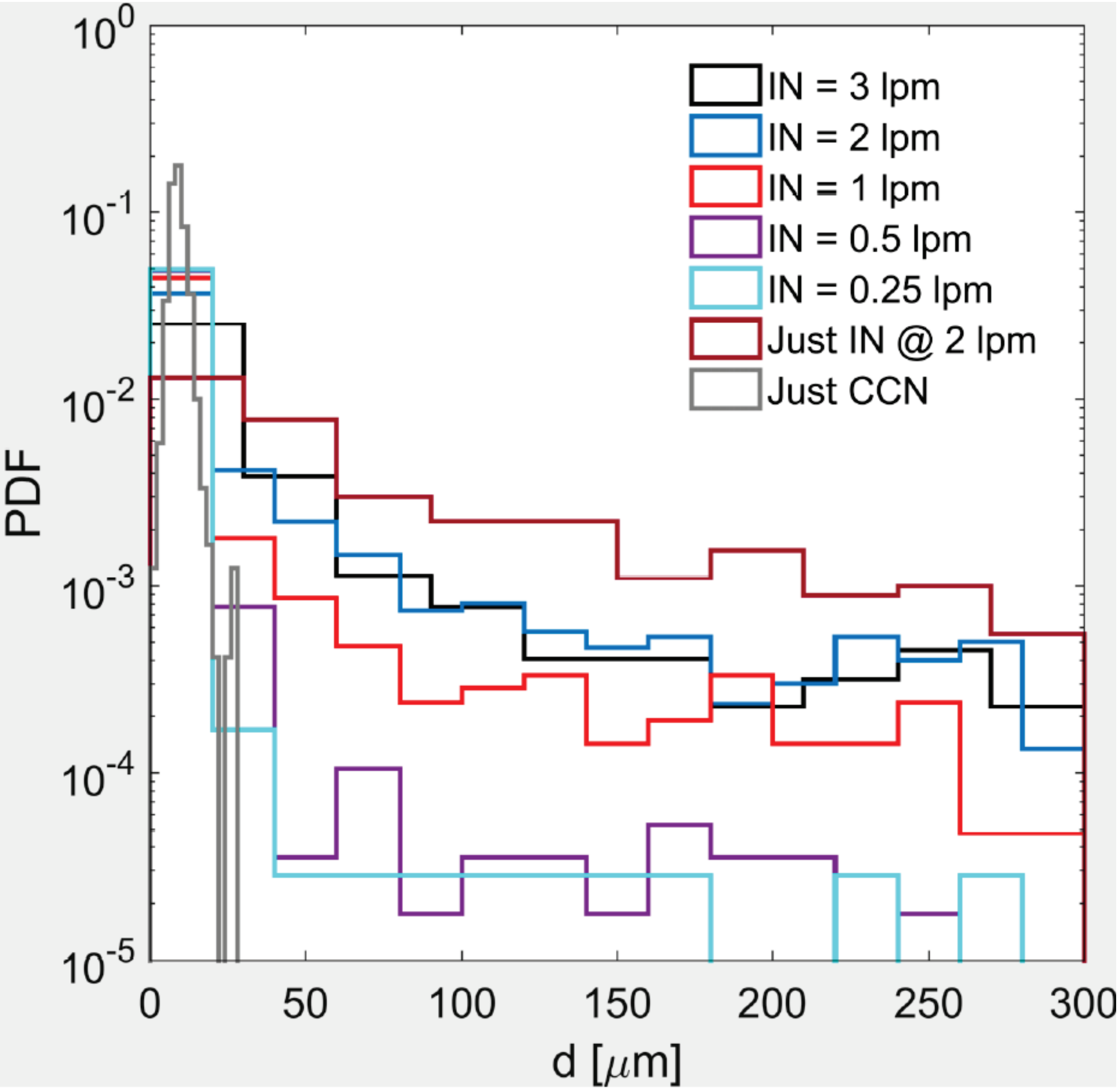
$T_0 = 10°C, \Delta T = 8K$



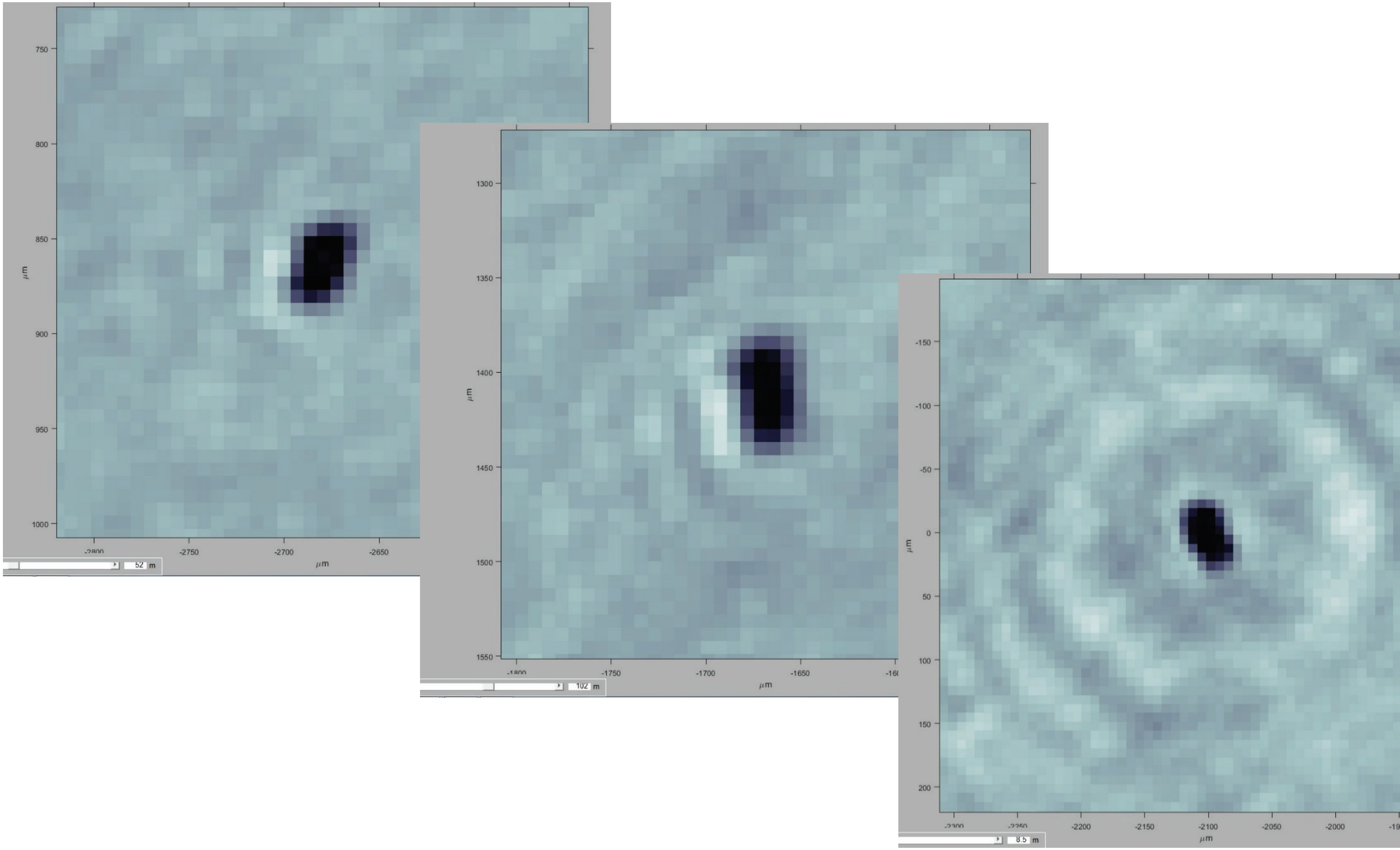
Mixed-phase clouds in the Pi Chamber...



Mixed-phase clouds in the Pi Chamber...



Mixed-phase clouds in the Pi Chamber...



Summary…

A simple model including stochastic ice nucleation and ice growth

- Steady flux scenario in which crystals nucleated within the cloud volume fall from the cloud as they grow by deposition
- Power-law relationship between ice mass and number with slope 2.5… could be an indirect, but sensitive measure of ice origin

Interpretation of model results and observations:

- LES with IN source within liquid cloud shows the predicted power law
- Lagrangian trajectories show quasi-steady growth
- Lagrangian trajectories also show importance of “recycled” ice crystals

Exploring the feasibility of steady-state mixed-phase experiments in the Pi Chamber

For more details, see: Yang, Ovchinnikov, and Shaw, GRL 2014 and JGR 2015
and, for the cloud chamber, Chang et al. BAMS 2016 and Chandrakar et al. PNAS 2016