NCAR Ice workshop
Rapporteur, Will Cantrell
These notes are intended as a supplement to the presentations, most of which are available on the Ice Workshop page, so most of these notes will reflect comments that the presenter made which might not be in the material on the web.

Monday

Larry Winter: Welcome
Just returned from an NCAR Director's retreat, where the subject of microphysics came up over and over. It's an area that needs to be addressed because it feeds into our understanding of larger scales.

Strategic Initiatives at NCAR:
~ 10% of money that NCAR currently gets goes into these;
identify areas of science tat will benefit from attention of interdisciplinary team
e.g. Biogeoscience; water cycle initiative (focus on development of precipitation; role of soil moisture); wildfire initiative

Andy Heymsfield: Workshop goals
Self contained. See presentation posted on the web.

Gabor Vali: Ice Observations in the Atmosphere: 6 stories and a status report
The slide right after the January 2002 picture of clouds over Boulder highlighted the fact that significant challenges still remain for theory, laboratory work, and field measurements.

What do instruments really measure? They work on different physical principles. Which one is the right one(s) for the atmosphere?

Compilation of data from all over the world (primary) of ice concentration vs. T (Cooper 1986) showed that they tended to fall in the same range. (Almost the same curve.) Is this a hint of some simplification that is possible?

Other issues: Forward links from aerosol to ice formation are tenuous.

Challenges and Responses: Radar images (airborne), reveal fine structure, very fine filaments visible in both wave cloud and cirrus. The radar shows that even wave clouds are not the perfectly controlled lab conditions (in nature) that we would hope. Is the aerosol that finely structured? The dynamics observed by the aircraft in many of the cases he talked about were rather simple.
What causes this fine scale variability?

Cumulus also show (not surprisingly) very complex structure.

Paul DeMott: Laboratory studies
Koop's theory doesn't seem to work for solutions of ammonium sulfate. (See the slide presented in the talk.)
Do organics affect the kinetics of homogeneous freezing?

Archuleta et al., 2004 shows that heterogeneous nucleation can be parameterized in a manner similar to Koop et al., 2000.

Bill Cotton: Ice formation processes in cloud-scale to global scale models and current needs
CRYSTAL-FACE: varying aerosol properties leads to 30% variation. With increasing increasing aerosol concentration, the maximum updraft velocity from 10 to 22 m/s. (There was quite a bit of discussion of the specific numbers on this point.)

Arctic: IFN have a bigger impact than do CCN.

How can we obtain initial concentrations of CCN, GCCN, IFN? - an aerosol source model with estimates of direct emissions for CCN and GCCN. Those values can then be fed into a model like RAMS.

How to get CCN? Aerosol chemistry. GCCN? Emissions of dust, sea salt, biogenic particles, industrial particles...
IFN? Presumably dust acts as IFN, but the specific fraction/type must be determined.
IFN sources as a function of climate zone are needed, especially for biogenic IFN.

Major uncertainties in the models include: riming collection efficiency, aggregation collection efficiency, secondary production (a la Hobbs and Rangno), and ice crystal production during evaporation.

Bernd Kärcher: European studies
Self contained. See presentation posted on the web.

George Isaac: Mixed phase clouds
Self contained. See presentation posted on the web.

John Hallett: Mixed phase clouds (and other things)
There are discontinuities in the atmosphere. What's the interface between water and ice in a mixed phase cloud? Is it uniformly mixed or is it parcels that coexist side by side (small parcels)?
(This was demonstrated by walking across the stage positing regions of all ice and all water with sharp interfaces. The point was made that the traverse of the stage just made would be seen as mixed phase by most aircraft instruments, when in fact it was uniform regions of a single phase that existed side-by-side.) This presents a challenge for designers of instruments for aeroplanes. “Whenever one designs an instrument you have to think about how that data is going to be used.”
How wide are the interfaces in reality? They show up as smeared out when you fly through a cloud because you are hurtling through it. Data from 1973 showed a cloud interface (edge of cloud) that was only 1 m.

Why is the width of the interface important? Convection: water is going up while ice is coming down; in between is graupel. Furthermore, cloud electrification depends on gradients of liquid water and ice over very small distances.

Look at the role of particles in cloud physics: Worry about the scale of the particles that are present. Instrumentation needs to have that degree of resolution.

“The concept of great big uniform regions isn't with us.”

Dave Rogers: Experiment: wave/layer clouds
Self contained. See presentation on the web.

Jeff Stith: Experiment: Convective clouds

Emphasis on first ice vs. early ice.
How do we address non-Hallett-Mossop secondary splintering mechanism?

The discussion after the two presentations on possible experiments included comments by A. Heymsfield suggesting that ice processes in hurricanes should be considered, K. Sassen advocating that layer clouds should not be restricted to wave clouds, and G. Isaac suggesting experiments in snow squalls.

Brian Tinsley: Contact ice nucleation and electroscavenging
These effects may be most important for marine stratocumulus because the cloud tops are only just below freezing. Cooling is slow and other ice formation mechanisms will be unlikely to operate.
Electroscavenging is favored on larger drops, which also favors marine stratocumulus.

Xiaohong Liu: A model look at heterogeneous nucleation on mineral dust
Self contained. See presentation on the web.

Ismail Gultepe: Ice crystal number concentration versus temperature relationships and models
Self contained. See presentation on the web.

Vadim Tsemekhman: Toward understanding homogeneous nucleation of ice
Self contained. See presentation on the web.

Eric Jensen: Large ice supersaturations measured in the tropical tropopause region
Conclusion: Vast majority of of aerosol at tropical tropopause are different than what people are using in the lab OR expressions used to calculate the saturation vapor pressure over supercooled water at low temperatures are off by about 20%.

Steve Sherwood: Satellite retrievals relevant to cloud glaciation and electrification
Frequently see small ice crystals (big burst of secondary nucleation in the updrafts?).
Small, numerous crystals tend to correspond with lightning rate.

Shane Mayor: Raman-shifted eye safe lidar
Self contained. See presentation on the web.

Charlie Knight: The use of radar in studying the first formation of precipitation in cumulus
Reasons why you need radar data from very early in a cloud's development. It would need to be ground based and S-Pol (S+K).
The radar can see the first formation of ice, while an aircraft might not. It gives you the time history needed to put aircraft measurements in context.
For a field program, you would need to find a place where you can put a fixed site, ground radar and where clouds frequently form nearby.

Alan Blyth: UK Field campaign to study the initiation and development of ice in cumulus clouds
Self contained. See presentation on the web.

Paul Lawson: Ice formation and development in wave clouds
Sees nucleation of ice as water droplets evaporate (at -26 C).

William Woodley: Where does ice in deep cumulus clouds come from?
Self contained. See presentation on the web.

Tuesday

William Cooper: Perspective from NSF
Use RICO as an example of the scale that is possible. Need to plan ahead.
The SOD provides a comprehensive view of the experiment for NSF to use in facilities request. View it as the scientific complement to the facilities request.

Develop the arguments carefully so that Physical Meteorology at NSF can try to pull in participation from other programs; In other words, pull in broader impacts; e.g. precipitation, climate prediction.
2006 would be the earliest you could go. Competition is stiff

A major field program will only happen if there is a redirection of effort.

Tom Ackerman: Ice experiments in ARM
ARM participants involved in development of parameterizations for GCMs. They haven't done direct ice nucleation for a variety of reasons, but they make inferences.

Question from A. Heymsfield: Is the possibility of synergy with TWP-ICE possible?
Answer: Yes.

Dan Cziczo: Single particle studies of atmospheric ice formation
The AMS instrument doesn't see refractory components but it is semi-quantitative; PALMS can see refractory but is only qualitative.

Most particles that include organic material don't like to freeze.

Ken Sassen: Arctic aerosol layers and ice nucleation
Sees little, thin, subvisual ice clouds embedded in dust layers.
The inference is that there is vapor deposition onto desert dust at very low supersaturations, which implies that the crystals are plates.

Dan Murphy: Nucleation to cubic ice
Self contained. See presentation on the web.

Paul Field: Ice nucleation characteristics of an isolated wave cloud
Freezing could not explained by homogeneous nucleation, parameterization of Meyers et al., contact nucleation, immersion nucleation, etc...
Evaporative freezing did work.

Alexei Korolev: Lifetime of mixed phase clouds (theoretical consideration)
Self contained. See presentation on the web.

Will Cantrell: Ice nucleation by long chain alcohols
Self contained. See presentation on the web.

Raymond Shaw: Contact nucleation inside out
The current theories of contact nucleation are not adequate to explain the contact nucleation observed in a system in which ash particles are inside a droplet and make contact with the surface from the inside. The freezing temperature increases when the particle touches the surface.

Matt Bailey: The habit transition at -40 C and its effect on in situ observations
Be careful about what's above you. It will very likely affect the type of crystal habit that you observe.

Nathan Magee: Ice crystal growth in a quadrupole levitation wind tunnel
Self contained. See presentation on the web.

Plenary
Dave Rogers: Report from Lab working group
Self contained. See presentation on the web.

Eric Jensen: Modeling group
Use a wave cloud because it is relatively simple. Concentrate on heterogeneous nucleation.
Do a closure experiment.
Quite a bit of discussion on what output of the model you compare with things you observe in the field.

Jeff Stith: Field group
Discussion of ice initiation vs. other evolutionary processes, icing (get the size distribution well enough to understand depositional growth), ice in hurricanes (structure of the storm is such that ice takes out the supercooled water), need for instrumentation (especially for small particles), variations in cloud active nuclei, orographic clouds.

Possible locations for field project are: Langmuir lab in New Mexico, front range, ARM site in OK, west coast (orographic and maritime cumulus environment)

Gabor Vali: A few closing thoughts
Keep a balance between optimism of what new instruments can bring vs. recognizing that this is long term process. The first few field experiments should be well thought out and productive so that the initiative gathers momentum.
Keep in mind that the field experiments may not (will not) do everything for everybody.

Andy Heymsfield: DONE!