PAPER	SPECIFICS OF STUDY	DATA/PARAMETERIZATIONS	FINDINGS
Ghan et al. 2011	Excellent review of Kohler theory/droplet nucleation; evaluation of droplet nucleation parameterizations to more quickly measure aerosol number size dist'n, hygroscopicity, and cooling rate (goal: cut down on expense to enable global & decadal-centurial runs); parameterizations were initially limited (Jones et al. 1994, e.g.) and evolved to account for important cloud physics and dynamics (e.g. supersaturation in updrafts, interstitial vs. cloud-borne aerosols, etc)	Table 1 summarizes various parameterizations; Used Abdul-Rezzek et al. 1998 numerical model to evaluate several of them (more details later); ARG and Nenes parameterization schemes used in CAM5	ARG scheme consistently and credibly characterizes functional relationship between several nucleation parameters (updraft velocity, number concentrations, maximum supersaturation, etc); 10% difference in droplet number and effect of anthropogenic aerosol on shortwave cloud forcing between ARG and Nenes schemes (pretty close!)
Jones et al. 1994	Estimate aerosol indirect effect for liquid stratiform clouds in a global climate model; one of the first attempts to represent droplet nucleation in a global climate model, relying on empirical relationship between droplet number and aerosol number	SO_4 aerosol data derived from 3D chemical transport model, fed into a global climate model to estimate radiative forcing	Global annual indirect effect at top of the atmosphere due to liquid stratiform clouds is -1.3 W/m^2
Ghan et al. 1997	Attempted to predict cloud droplet number in both a cloud-resolving model ("single column model") and a global climate model	SCM uses bulk cloud microphysics parameterization from Colorado State University Regional Atmospheric Modeling System (CSU RAMS); GCM – NCAR CCM2	Predicted droplet number significantly less than observations without sufficient vertical resolution; diagnostic droplet concentrations consistently > prognostic droplet concentrations
Abdul-Razzak et al. 1998	Presents both a parameterization of the fraction of activated aerosols that form cloud droplets and a Lagrangian parcel model used to evaluate governing parameters in droplet nucleation (e.g. updraft velocity, particle radius, etc.)	Lagrangian model based on general Kohler theory; Some important specs: a) aerosol size dist'n binned (100); b) For multiple modes, 100 bins for each mode; c) Several assumptions made for simulation initialization (Temp, relative humidity, etc);	Differences between model and analytic results are "<10% for most conditions, <25% for extreme but realistic conditions"; to date, most realistic parameterization of fraction of droplet activation
Nenes et al. 2001	Examined possible limitations on growth of CCN due to mass transfer ("kinetic effects"); these included a) inertial mechanism (particles with critical supersaturations less than	1D Cloud parcel model with variable aerosol size and updraft velocity distributions	Aerosol # concentration key parameter controlling kinetic effects; assumption (via Kohler?) that particles remain in equilibrium until activated

	threshold value do not grow to r_{crit} thus and do not activate), b) deactivation mechanism (evaporation of activated droplets, forming interstitial aerosol when parcel supersaturation drops below droplet equilibrium saturation ratio), c) evaporation mechanism (particles evaporate before activation because cannot reach r_{crit})		leads to overprediction of droplet number for both marine/urban aerosols (particularly important when overprediction >10%); cloud albedo change due to kinetic limitations >0.1 in polluted environments

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Nenes and Seinfeld 2003	Development of new droplet nucleation parameterization scheme intended explicitly for use in GCMs based on “population splitting” – CCNs that form droplets are treated as two separate populations: 1) $d \sim d_{crit}$, 2) $d \neq d_{crit}$ (and not close); introduction of droplet growth limitation due to kinetic effects (see Nenes et al. 2001) – advantageous because parameterization is free from any empirical information or numerically derived correlations between parameters	New parameterization introduced; cloud parcel simulations used to compare predictions of paramterizations (Nenes and Seinfeld vs. ARG for droplet concentration and activation ratio)	Parameterization tracks model simulations “closely and robustly”; parameterization 3 times less expensive than cloud model itself; decreased reliance on empirical input enhances robustness of parameterization; parameterization can treat all types of aerosols that obey Kohler theory
Kumar et al. 2009	Developed new parameterization to consider cloud droplet formation within an ascending air parcel containing insoluble particles. This differed from previous studies of its kind, which only considered soluble fraction of particles like dust and black carbon. Wide range of parameters considered, including cloud updraft conditions, $H2O_v$ condensation coefficient, etc	Parameterization tested against numerical cloud model	Excellent agreement between parameterization and cloud parcel model (average error 10% and $R^2 \sim 0.98$)
Lohmann and Hoose 2009	Investigate several different aerosol effects on mixed-phase clouds: a) glaciation effect (more frequent glaciations due to anthropogenic aerosols) and b) deactivation effect (ice nuclei become less effective because of anthropogenic SO_4 coating)	Used GCM (ECHAM5-HAM); varied parameterization for Bergeron-Findeisen process and threshold coating of thickness for SO_4	Glaciation effect can partially offset indirect aerosol effect on warm clouds → total anthropogenic effect smaller; Up to 0.5 W/m^2 differences in net TOA radiation due to anthropogenic aerosols between different sensitivity

			studies → mixed-phase processes important
Meritanko et al. 2009	Attempt to separate CCN sources into a) primary emissions (particles emitted directly into atmosphere) and b) growth of nanometer sized particles nucleated in atmosphere; focused specifically on primary emissions of sea spray, SO_4, carbonaceous particles and nucleation processes appropriate for MBL and free troposphere	Use global aerosol microphysics model to quantify contribution of primary and nucleated particles to global CCN	55% of global low-level cloud CCN (at 0.2% supersaturation) are from source a); 35% of CCN in low-level clouds were created above MBL in troposphere; Primary and nucleated CCN are non-linearly coupled
Chen et al. 2010	Investigated whether or not black carbon mitigation would dampen aerosol indirect forcing ('reverse cloud albedo effect' – BC both heats thru absorption and cools thru scattering/reflection; mitigation of BC leads to reduction in TOA direct radiative forcing); aerosols considered include sea salt, mineral dust, SO_4, organic carbon (OC)	NASA GISS III Global Climate Middle Atmosphere Model used to evaluate aerosol forcings associated with reduction in BC emissions	50% reduction of primary BC/OC mass & number emissions from fossil fuel combustion → 0.13 ± 0.33 W/m^2 TOA global avg change; 50% reduction of primary BC/OC mass & number emissions from ALL primary carbonaceous sources (fossil fuel, domestic biofuel, biomass burning) → 0.31 ± 0.33 W/m^2 TOA global avg change; So cutting BC emissions does dampen indirect effect!