

lower (29). We found that pure CoO hollow nanocrystals were inactive for ethylene hydrogenation (30), even after a 1-hour H₂ prereduction at 373 K. Only on reduction at 473 K for 1 hour was ethane detected at temperatures >300 K. Samples containing platinum without pretreatment were active for C₂H₄ hydrogenation at temperatures as low as 208 K. The steady-state turnover frequency for ethane formation at 227 K was 8.3 × 10⁻³ s⁻¹ (31), which is comparable to the rates of 3.5 × 10⁻² s⁻¹ measured on a 0.04% Pt/SiO₂ catalyst (32) and 1.7 × 10⁻² s⁻¹ measured on pure platinum powders (0.2 to 1.6 μm in diameter). These observations indicate that the reaction is catalyzed by platinum particles, not the CoO shell. This also confirms that a route exists for ethylene and hydrogen entry into the CoO shell interior. The grain boundaries on the shell are the most probable entry points for ethylene and hydrogen diffusion into as well as ethane diffusion out of the shell.

In comparison to catalysts supported on other mesoporous materials, the isolation of catalyst nanoparticles within solid shells should minimize secondary reaction of the products that degrade selectivity and product distribution. Furthermore, any synergistic interactions between catalyst and support can be more efficiently used when each catalyst particle is in contact with a shell of the support material.

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31. Rates were measured on a per-gram basis. They were normalized per mole of surface platinum species (Pt_s) to obtain a turnover frequency (molecule Pt_s⁻¹ s⁻¹). Moles of Pt_s was determined by $D = 1.13/d$, where D is the platinum dispersion [the ratio of Pt_s to the total platinum content (Pt_t)] and d is the particle size in nm. The platinum particle size was determined from number average TEM measurements.
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Supporting Online Material

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Fig. S1

9 February 2004; accepted 16 March 2004

Population-Level HIV Declines and Behavioral Risk Avoidance in Uganda

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Uganda provides the clearest example that human immunodeficiency virus (HIV) is preventable if populations are mobilized to avoid risk. Despite limited resources, Uganda has shown a 70% decline in HIV prevalence since the early 1990s, linked to a 60% reduction in casual sex. The response in Uganda appears to be distinctively associated with communication about acquired immunodeficiency syndrome (AIDS) through social networks. Despite substantial condom use and promotion of biomedical approaches, other African countries have shown neither similar behavioral responses nor HIV prevalence declines of the same scale. The Ugandan success is equivalent to a vaccine of 80% effectiveness. Its replication will require changes in global HIV/AIDS intervention policies and their evaluation.

Projections of the HIV pandemic paint a bleak picture for global health (1, 2). Nevertheless, because most cases of HIV occur through consensual sexual intercourse, it is avoidable if populations are warned and mobilized to change risk-taking behaviors. Despite successes from this approach, the apparently unrelenting expansion of the pandemic has served to emphasize a need for the promotion of more effective responses (3–5).

HIV risk behaviors and infection rates dropped substantially among homosexual males in North America and Europe in the early to mid-1980s (6–8). The next widely acknowledged success was in heterosexuals

in Thailand, a result that has been unequivocally accepted since the early 1990s (9). Then, in 1994–1995, came data from resource-poor Uganda of declines in HIV prevalence among younger pregnant women, coupled with indications of preceding behavior change and reductions in HIV incidence (10–15). The Ugandan evidence is still viewed with caution, and confusion persists in its evaluation (16–19).

We reviewed population-level HIV and behavioral data in Uganda and in neighboring countries to evaluate the validity and determinants of HIV declines and to explore possible influences of preventive interventions (20, 21).

Our initial analysis indicated that HIV incidence was declining in Uganda by the late 1980s (22–24). By 1995, Ugandan surveillance of HIV prevalence in pregnant women

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showed statistically significant declines, particularly in younger cohorts (10). These nascent trends suggested that the rate of HIV incidence (new infections) in the population, particularly in younger cohorts, had decreased below the rate of removal of prevalent infections by mortality. This trend could be explained by several hypotheses, including recent changes in sexual behavior that reduced exposure and transmission, a natural decline in HIV incidence related to epidemic maturity and mortality, or biases related to the influences of HIV on fertility and problems of interpretation of antenatal data and its generalization to populations.

To evaluate this phenomenon, we examined other sources of HIV data in Uganda and performed a comparative analysis of HIV surveillance and behavioral data in neighboring countries with similar epidemic dynamics (Kenya, Zambia, and Malawi) (12, 14, 24). It became clear that the timing and scale of HIV prevalence declines in Uganda were distinct. HIV prevalence nationally among pregnant women peaked in 1991 at 21.1% and by 1998 declined to 9.7%, a decline of 54% apparent in both rural and urban settings (Fig. 1A). By 2000, prevalence had declined further to 6%. In Kampala and other urban sites, where age-specific data were available, HIV declined most in younger age groups, best reflecting recent incidence, with declines of 75% in 15- to 19-year-olds and 60% in 20- to 24-year-olds. We expected to see a similar HIV pattern in neighboring countries, but statistically significant HIV declines were absent in similar data in Kenya, Malawi, and Zambia overall or in the 15 to 24 age cohorts. Epidemic maturity in Uganda did not explain the differential dynamics, because a comparison of HIV antenatal trends from urban areas of Uganda, Malawi, and Zambia from 1985 to 2001 shows that the epidemic curves in respective neighboring countries were similar to, or no more than a couple of years later than, that in Uganda (Fig. 1B). Declines overall, and in the age group 15 to 24, were unique to Uganda. Furthermore, HIV declines from 1991 in younger pregnant women suggested an antecedent process in 1990 or earlier that reduced incidence.

A comparative analysis of 1995 and 1989 Ugandan population-based surveys of HIV behavioral risk indicators offered evidence of important changes since 1989, including an increase in the age of sexual debut, a decrease in indicators of casual or nonregular partners, and an increase in the use of condoms, both overall and in casual partnerships (10, 12, 25, 26). The subsequent report, led by the Joint United Nations Programme on HIV/AIDS (UNAIDS), emphasized the relative importance of sexual debut and condom use (13). An important and perhaps overlooked measure of behavior change in Uganda between 1989 and

1995 was a 60% reduction in persons reporting casual sexual partnerships in the past year, evident in urban and rural populations (Fig. 2A).

The proportions of persons reporting casual partnerships are much higher in Malawi and Zambia in 1996, and Kenya in 1998, than in Uganda in 1995, similar to that reported in Uganda in 1989 (Fig. 2B). Condom use in casual partnerships, although it had increased in Uganda from 1989, was not substantially different in 1995 than it was in the other countries. While the proportions of 15- to 19-year-olds never having sex increased substantially in Uganda between 1989 and 1995, only sexual abstinence in males distinguishes Uganda from comparison countries (fig. S1). These findings suggest that reduction in sexual partners and abstinence among unmarried sexually inexperienced youth (particularly in urban areas and in males), rather than condom use, are the relevant factors in reducing HIV incidence. A reduction of casual sex across the whole population, not in a particular segment or age group or only in

those exposed to a specific intervention, reduced the size of high-risk sexual networks and the efficiency of HIV transmission. There are some limitations to the data, including definitions of indicators, their interaction, survey sampling, and response bias, but when stratified and analyzed correctly, comparability is high (27) (SOM Text). Supporting evidence in Uganda comes from the proportion of never-married males aged 15 to 24 who reported a decrease in premarital sex from 60% in 1989 to 23% in 1995 and of never-married females who reported a decrease from 53% to 16% (27). In addition, according to the 1995 Uganda Demographic and Health survey (21), when asked to corroborate this behavior change, 53% and 55% of sexually experienced Ugandan women and men, respectively, reported that they "stuck to one partner," 7% and 10% "stopped all sex," and 2% and 11% "started using condoms." But why would population-level risk avoidance occur in Uganda and not elsewhere, even a decade later?

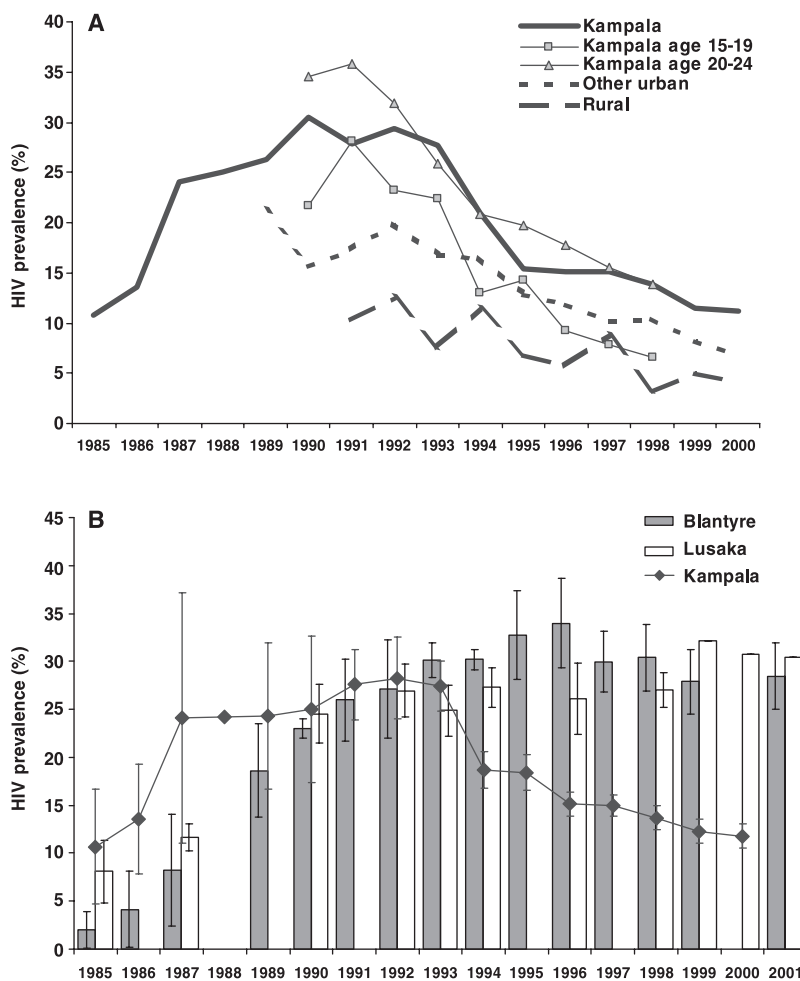


Fig. 1. (A) HIV prevalence rates (%) in pregnant women surveyed at antenatal sentinel surveillance sites in Uganda in urban Kampala, other urban sentinel sites, and rural sites from 1985 to 2001. **(B)** A comparison of HIV prevalence rates (%) in pregnant women surveyed at antenatal sentinel surveillance sites between 1985 and 2001 in urban Kampala, Uganda; Lusaka, Zambia; and Blantyre, Malawi. Error bars represent 95% CI around the sample mean.

In Uganda, knowledge indicators, such as “ever having heard of AIDS,” were similar to those in other countries; however, personal channels predominated in communicating about AIDS. Eighty-two percent of women had heard of AIDS from this source, compared with 40 to 65% in other countries. Personal networks are also dominant when stratified by urban (74%) and rural (84%) areas, and among men (70%). A second distinction in Uganda was the personal knowledge of someone with AIDS or who had died of AIDS. By 1995, 91.5% of men and 86.4% of women knew someone with AIDS. In Zambia, Kenya, and Malawi, the proportion was lower—68 to 71%—and in Zimbabwe and South Africa, it was below 50% even by 2002 (28). This suggests that a credible communication of alarm and advice had taken root in discussions in social networks to a greater extent in Uganda. Furthermore, the communication process may have provided greater personal exposure to the fear-evoking consequences of the epidemic and thus catalyzed the process of behavior change, similar to findings among homosexual males in the mid-1980s (7, 29, 30). Our modeling suggests that communication networks are multiplicative and have a stronger influence than the stage of the epidemic on the prevalence of knowing someone with AIDS (fig. S2).

The interpretation of HIV declines in Uganda has been and remains confounded by speculation that it related more to the effects of HIV on mortality and fertility, inaccuracies of surveillance systems, urban bias, migration, civil war, or natural HIV dynamics rather than to reductions in HIV incidence linked to interventions (31–33). Yet, there was evidence to counter these arguments, including relatively stable HIV mortality rates since the early 1990s (12, 34, 35). In addition, HIV prevalence rates in male military conscripts ages 19 to 22 declined from 18.6% [95% confidence intervals (CI) 14.1% to 22.9%] in 1991, to 8% (95% CI 6.3% to 9.7%) in 1996, and to 4% by 2002 (36). Similar trends in prevalence were evident in male and female clients of sexually transmitted disease (STD) clinics, in blood donors, and in other groups, including population cohort studies (12, 16). There is a wide range of supporting data on the epidemiological and behavioral changes in Uganda (11, 13, 14, 18, 37–39) (table S1).

Furthermore, there has been considerable confusion regarding behavioral change and its measure. Initial presentations and an official report on behavioral findings in 1995–1996 indicated 60% declines in indicators of casual sex (nonregular sexual partners) between 1989 and 1995 (10, 12, 25). However, later UNAIDS

analysis and reports indicated only a 9% decline in casual sex among men and increases among women, which upon re-examination was inaccurate (13, 32, 40) (SOM Text) (table S4). This has confounded the understanding of HIV dynamics in Uganda. (3, 5, 31, 41).

Since the early 1990s, other sources of data in Uganda and the region have come from population-based cohort studies (18, 42). These studies have largely focused on HIV natural history, cofactors of infection, and biomedical interventions, often employing randomized controlled trial methods. Despite international research and evaluation resources, a 60% decline in a primary indicator of sexual behavior apparent in the data was not clearly identified and associated with the interruption of HIV incidence (43). The designs of narrowly targeted epidemiological investigations and clinical trials need to consider the impact of population behaviors, particularly when such behaviors may be more powerful than the experimental intervention

(44) (SOM Text). Hence, an epidemiological model to simulate HIV dynamics in Kampala indicates a preceding reduction in risk and incidence similar to the impact of a vaccine of 80% effectiveness (21, 24, 43) (Fig. 3A).

A better understanding of social elements that triggered the Ugandan response, and that may be hindering its evolution elsewhere, is important. The Ugandan approach to HIV control was practical but based on limited information, financial resources, and precedent for success. The government communicated a clear warning and prevention recommendation: AIDS, or “slim,” was fatal and required an immediate population response based on “zero grazing,” that is, faithfulness to one partner. Condoms were a minor component of the original strategy. AIDS reporting meant communities openly acknowledged morbidity; this was perhaps a more meaningful measure for catalyzing community action than was anonymous HIV seroprevalence

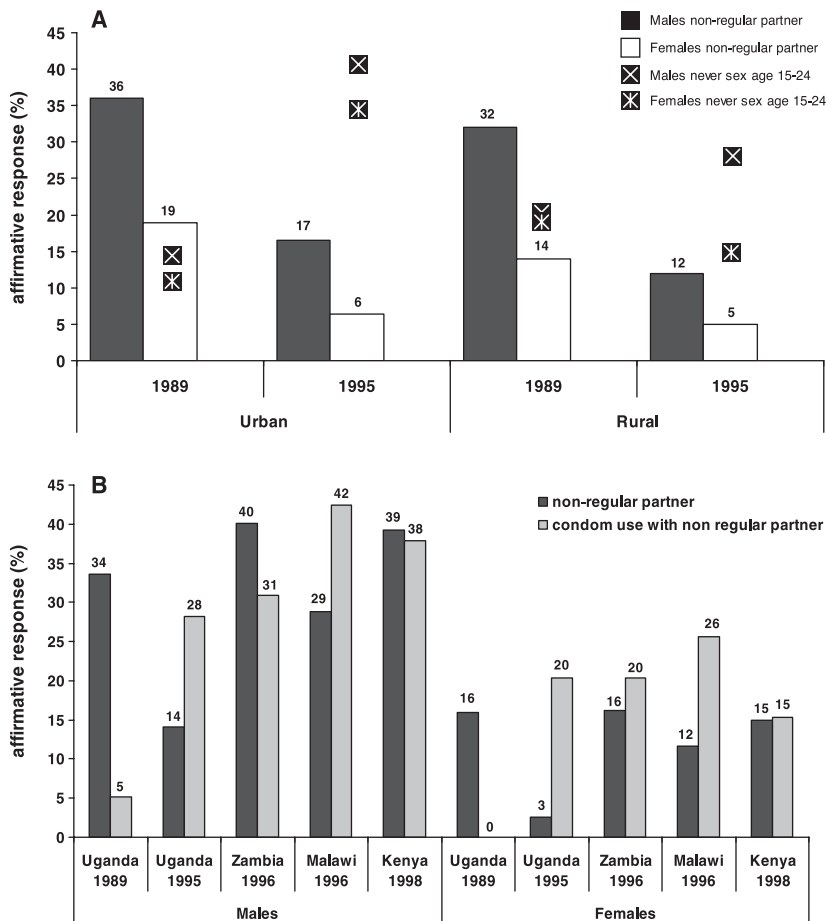


Fig. 2. (A) Changes in the proportion of persons reporting sex with a nonregular partner in the previous 12 months and persons aged 15 to 24 reporting never having sex in Uganda among adult populations, measured by population-based behavioral surveys performed in 1989 and in 1995, by sex and population characteristics. **(B)** A comparison of the proportion of persons reporting sexual contact with a nonregular partner during the past 12 months and use of condom with that last nonregular sexual partner, by sex. The data are derived from population-based survey data of persons between the ages of 15 and 55 from the following countries and years: Uganda in 1989, Uganda in 1995, Zambia in 1996, Malawi in 1996, and Kenya in 1998.

in sentinel groups, the international surveillance indicator of choice after 1995, which largely replaced AIDS reporting in Africa.

The Uganda approach clearly communicated the reality of the AIDS epidemic in terms of a rational fear of the risks of casual sex, which drew on and mobilized indigenous responses at the community level (14, 16) (SOM Text). Our findings indicate that substantial HIV reductions in Uganda resulted from public-health interventions that triggered a social process of risk avoidance manifested by radical changes in sexual behaviors. The outcome was equivalent to a highly effective vaccine. Widespread support for condom distribution using social marketing (i.e., commercial techniques to achieve social goals), voluntary testing and counseling, and improved treatment of sex-

ually transmitted infections largely came after the initial declines in HIV incidence and prevalence (Fig. 3B) (14). In contrast, some countries have failed in their leadership to communicate a credible message of alarm and advice—for example, in South Africa there is still confusion about the cause of AIDS and its threat, which contributes to denial and inaction. Although modest declines in risk behaviors have been associated with declines in HIV prevalence in Zambia, these prevalence changes have been small, restricted geographically, and transient relative to those in Uganda (45).

Questions about Uganda's success in HIV control and its measure will persist; however, the reproducibility of biological and behavioral findings and continuing declines in HIV prevalence provide support.

The behavioral changes in the data have been evident since 1996 (SOM Text).

Perhaps the population-level behavioral response to HIV in Uganda will not be transferable with the same effect or appropriate for all situations; however, similar tactics of community mobilization and population risk avoidance have characterized other intervention successes in Thailand and among homosexual men in the United States. Potential access to what are believed to be curative therapies may shift perceptions of risk from avoidance to reduction, or coexistence, as the fear and visibility of AIDS diminishes. The current practice of scaling up biomedical and risk-reduction HIV prevention elements may not reduce sexual transmission at the population level. To ensure that these lessons are replicated, we need a shift in strategic thinking on health policy and HIV/AIDS, with greater attention to epidemiological intelligence and communications to mobilize risk avoidance.

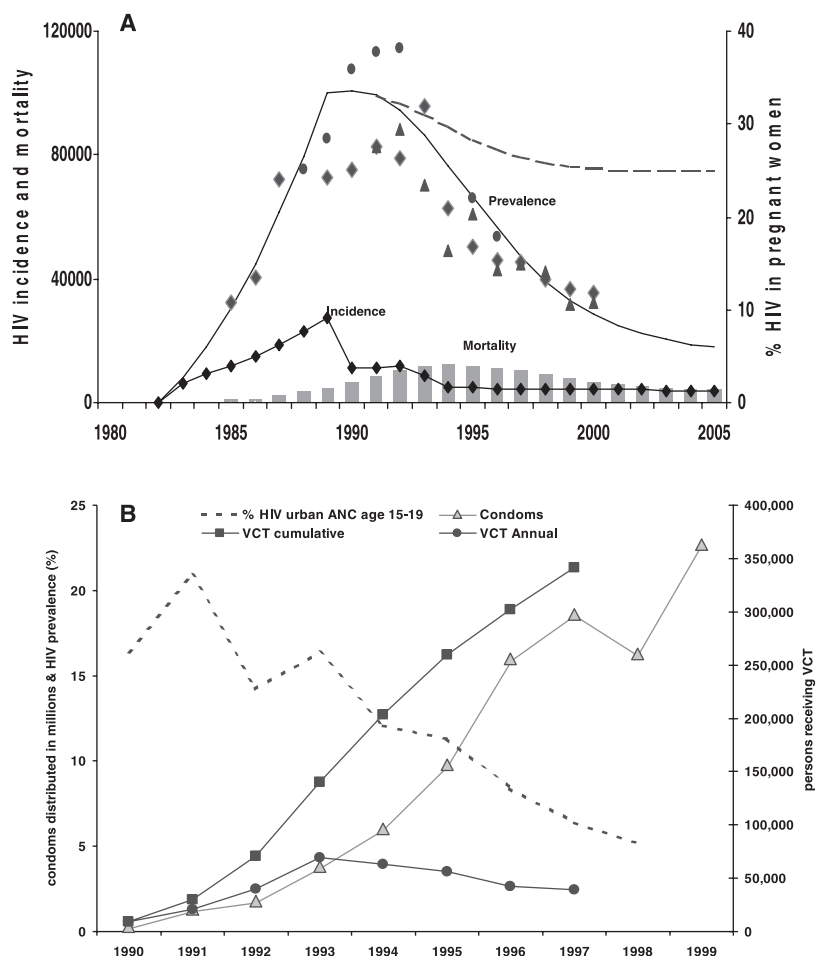


Fig. 3. (A) Simulations of HIV incidence and prevalence in pregnant women, and mortality in the population aged 15 to 59 of Kampala, Uganda, from 1981 to 2005, showing simulated HIV prevalence under HIV incidence "intervention" (solid line) and "baseline" (broken line) scenarios compared with empirical HIV data from antenatal clinic sentinel surveillance sites in Nsambya (diamond shapes), Mulago (circles), and Rubaga (triangles). The intervention scenario, in which incidence rates are reduced by 80% over a 2-year period among 15- to 24-year-olds beginning in 1992–1993, produces declines in HIV prevalence consistent with empirical data. In the baseline scenario, incidence rates remained unchanged after 1990 and prevalence remains stable. **(B)** Comparison of HIV prevalence rates in pregnant women 15 to 19 in Ugandan urban antenatal sentinel surveillance sites from 1990 to 2000 compared with the cumulative number of persons seeking voluntary testing and counseling services and the annual number of socially marketed condoms (16).

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Evidence for the Predominance of Mid-Tropospheric Aerosols as Subtropical Anvil Cloud Nuclei

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NASA's recent Cirrus Regional Study of Tropical Anvils and Cirrus Layers–Florida Area Cirrus Experiment focused on anvil cirrus clouds, an important but poorly understood element of our climate system. The data obtained included the first comprehensive measurements of aerosols and cloud particles throughout the atmospheric column during the evolution of multiple deep convective storm systems. Coupling these new measurements with detailed cloud simulations that resolve the size distributions of aerosols and cloud particles, we found several lines of evidence indicating that most anvil crystals form on mid-tropospheric rather than boundary-layer aerosols. This result defies conventional wisdom and suggests that distant pollution sources may have a greater effect on anvil clouds than do local sources.

It is well understood that cloud drops form on existing atmospheric aerosols, such as sulfuric acid particles and dust. Thus, changes in aerosol number can lead to changes in drop number during cloud formation. Complex subsequent effects on cloud microphysical development vary depending on cloud type and environmental conditions (1). The overall impact of increasing anthropogenic aerosols on low clouds such as stratocumulus may be great, generally resulting in smaller, more numerous drops and leading to brighter, longer-lived clouds that reflect more sunlight (2, 3). Because stratocumulus clouds persistently cover large global areas, it has been recognized that this aerosol-induced cooling effect partially offsets the warming effect of accumulating greenhouse gas concentrations (4).

Whereas low clouds such as stratocumulus alter the global solar radiative budget with little influence on the infrared budget, high clouds such as cirrus reduce both solar incoming and infrared outgoing radiative fluxes by comparable amounts. Whether the overall impact is warming or cooling depends in a sensitive manner on cloud optical depth and ice crystal effective radius (5), among other factors. Although cirrus clouds have a much lesser influence on the net radiative budget per unit area than stratocumulus, the area covered by tropical anvil clouds may respond strongly to increasing sea surface temperatures, thereby playing a major role in global climate sensitivity (6–8). However, the properties and evolution of anvil cirrus clouds remain poorly understood and weakly constrained in models (9). Recent observations also suggest that tropical cloud cov-

erage may be rapidly changing in a manner not captured by current general circulation model simulations (10), which serves as further motivation to seek a better understanding of anvil-forming cumulonimbus clouds.

The Cirrus Regional Study of Tropical Anvils and Cirrus Layers–Florida Area Cirrus Experiment (CRYSTAL-FACE) was coordinated by NASA with the primary goal of fully characterizing subtropical cumulonimbus anvil formation and evolution. The experiment took place throughout July 2002 over southern Florida, where simultaneous measurements were made from six aircraft and three ground stations, as well as satellite platforms, over the lifetimes of many storm systems. The data gathered included simultaneous measurements of the number and size distribution of aerosols and cloud particles throughout the full depth of developing cumulonimbus columns. Whereas a handful of previous modeling studies and data analyses have addressed the potential impact of boundary-layer aerosol loading on the microphysical properties of clouds associated with deep convection (11–14), here we incorporate these extensive new measurements into a detailed three-dimensional (3D) modeling analysis with appropriate vertical variation of the aerosol field.

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