Oslo is used to further reconstruct the 3-D intrusions in terms of isentropic potential vorticity and ozone distributions. In addition to intrusion events due to mid-latitude cyclogenesis, intrusion events due to stationary Rossby waves propagating into westerly ducts in the tropics are also investigated. A quantitative relationship between TOMS column filaments and the stratospheric influx of ozone is sought.

A11B MCC: 3016 Monday 0800h

Tropical Cirrus Anvils: Properties and Processes I *(joint with SA, AE)*

Presiding: **E Jensen,** NASA Ames Research Center**; D E Anderson,** NASA Headquarters

A11B-01 0800h

Tropical Anvil Cirrus Microphysics

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This study synthesizes data collected during a number of field campaigns by in-situ aircraft to characterize the microphysical properties of tropical, convectively-generated cirrus. The field campaigns include the Tropical Rain Measuring Mission KWAJEX campaign near Kwajalein, M. I., KAMP (the Keys Area Microphysics Project) and the Cirrus Regional Study of Tropical Anvils and Cirrus Layers (CRYSTAL) Florida Area Cirrus Experiment (FACE), both over southern Florida, and CAMEX-4 (the fourth convection and moisture experiment), studying hurricanes off the east coast of Florida. The measurements include particle size distribution and particle shape information, direct measurements of the condensed water content (CRYSTAL-FACE), and radar imagery. We examine the temperature dependence and vertical variability of the ice water content (IWC), extinction, and effective radii, and deduce the ensemble-mean ice particle densities. Data obtained in quiescent regions outside of convection are compared to observations within convective cells. The relationship between the properties of the particle size distributions and proximity to convection are examined. The IWCs show a strong temperature dependence and dependence on distance below cloud top. The IWCs are larger in the convective regions than in the quiescent regions, and the particle size distributions are markedly broader. Ensemble-mean ice particle densities are a strong function of the breadth of the particle size distributions.

A11B-02 0815h

Small, Highly Reflective Ice Crystals in CRYSTAL-FACE Anvil Cirrus

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Aircraft measurements, obtained during CRYSTAL-FACE using new instruments, indicate that ice crystals within cirrus anvils have smaller sizes and are more reflective than is assumed in most current climate models. Cloud mass, scattering cross section and number concentration were highly correlated within any given temperature range. Consequently, values of effective radius r_e were primarily a function of temperature, increasingly exponentially from approximately 5 μm at -75 °C to 30 μm at freezing. Values of the asymmetry parameter g were 0.75±0.01 between freezing and -55 °C. For a given model prediction of cloud mass, these results suggest low-latitude cirrus anvils should have greatly higher values of cloud albedo and emissivity than is usually assumed in climate model representations of these clouds.

URL: http://www.met.utah.edu/tgarrett/ Publications/Icescattering/GRL2003.pdf

A11B-03 0830h

Summer African Dust and Florida Thunder Storms: Are CRYSTAL-FACE Anvils Typical of the Subtropics?

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The Florida peninsula can be viewed as an outdoor laboratory for the study of the indirect effects of aerosols on the properties of deep convective clouds, and the possible subsequent impact on precipitation. Depending on the seasonal weather patters affecting the area, sources of aerosols can be continental, smoke-produced, oceanic, and, as long known, of Saharan Desert origin. During the recent CRYSTAL-FACE field campaign, a variety of in situ and remote sensing evidence shows that after transport across the mid-Atlantic Ocean, episodes of African dust were widespread in the region. This is a well-known summertime phenomenon. In one study using aircraft ice nuclei (IN) data and ground-based polarization lidar measurements, the dust was observed to induce the glaciation of a slightly (about -5.0 to -8.0 degrees C) supercooled altocumulus cloud. Extrapolating the finding that African dust particles are especially active IN, it follows that the ingestion of boundary-layer Saharan aerosol could have a strong potential for modifying the microphysical content, dynamics and precipitation of summer thunderstorms in southern Florida. In the current study, we will attempt to identify connections between the characteristics of the intensively-studied thunderstorms and the nature of the dominant aerosols involved in cloud particle formation. As a first step, the near-continuous data record from the Micropulse Lidar, supplemented by Polarization Diversity Lidar data, will be used to monitor aerosol conditions. Backtrack and satellite analyzes, along with the University of Miami surface aerosol sampling record, will identify their source and likely cloud particle forming characteristics. The final stage of this research will search for correlations in in situ-derived cloud microphysical properties such as ice crystal concentration and type. If such connections are found, it must be recognized that the CRYSTAL-FACE dataset may not be representative of subtropical thunderstorms and the anvils derived from them.

A11B-04 0845h

CRYSTAL-FACE Convective Drafts

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Dual-Doppler data from 4 different days of the CRYSTAL-FACE experiment were analyzed. These days represented three different regime types - maritime convection, typical Florida peninsula convection, and peninsula convection influenced by Saharan dust. These days exhibited differences in convective organization, ranging from mostly short-lived cells embedded in larger convective clusters to larger more coherent, longer-lasting mesoscale organization. We will present and contrast draft (up and down) statistics for all days. Mass and water fluxes were calculated for all cases.

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A11B-05 0900h

In Situ Measurements of Microphysical and Radiative Properties of Cirrus and Anvil Clouds

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In situ microphysical and radiative properties of mid-latitude cirrus, anvil and tropical anvil clouds, based on research flights conducted with the SPEC Learjet, the NASA WB-57 and DC-8, and the University of North Dakota Citation research aircraft, are presented. The measurements were collected in Colorado, Utah, Oklahoma, Florida and Kwajalein. All of the research aircraft were equipped with a standard complement of microphysical sensors and optical probes, plus a cloud particle imager (CPI), which produces high-definition (2.3 micron pixel) digital images of ice particles. The CPI data provide improved measurements of particle shape and size, facilitating better calculations of radiative properties of cirrus and anvil clouds. Based on the measurements, average mid-latitude cirrus, and mid-latitude and tropical cirrus microphysical properties of particle size distribution, crystal habit, ice water content, extinction coefficient, effective radius and optical depth are derived. The data show a distinct difference between particle characteristics in mid-latitude cirrus and anvil clouds. In cirrus, the predominate crystal type (weighted by area or mass) is the bullet rosette, a polycrystalline structure typical of crystal formation at temperatures colder than -30 C. Conversely, although anvils occur at temperatures similar to cirrus, bullet rosettes are very rare in anvils. Instead crystal types in anvils are typical of those formed at temperatures warmer than - 30 C. There is also a notable difference in microphysical and radiative characteristics between mid-latitude, Florida, and tropical (Kwajalein) anvils. Tropical anvils are comprised mainly of single crystals, mostly irregular blocky-shapes. In mid-latitude and Florida anvils, there are more aggregates and often chains of small particles that may be formed as a result of the higher electric fields in continental clouds. The impact of crystal type on calculations of radiative transfer are also considered.

URL: http://www.specinc.com

A11B-06 0915h

The Microphysical and Radiative Evolution of a Cirrus Anvil During CRYSTAL-FACE

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A case study of the evolution of a thunderstorm cirrus anvil measured during the Cirrus Regional Study of Tropical Anvils and Cirrus Layers-Florida Area Cirrus Experiment (CRYSTAL-FACE) is presented. In situ measurements of cloud bulk properties and size spectra were obtained using the NASA WB-57F and the University of North Dakota Citation aircraft. The cirrus anvil contained bulk ice water contents up to 0.30 g m^{-3} at one hour age, diminishing to 0.018 g m^{-3} at 2.5 hours of age. Ice crystal size distributions were bi-modal, with the largest crystals and effective radii near the base of the anvil. At one hour age, the optical depth calculated from in situ bulk visible extinction coefficient measurements was ∼21.7. Ice water content, total ice crystal concentration, relative humidity with respect to ice, and effective radius all decreased with increasing distance from the upwind edge of the anvil. The effective radius was dominated primarily by small ice crystals with a mode size of 25 μm. The anvil's microphysical evolution depended primarily on dilution by entrainment, and to a lesser degree on sedimentation of large ice crystals. A second, thinner cloud, with an optical depth of 0.4, existed about 1.5 km above the anvil at the tropopause at an altitude of about 13.0 to 14.5 km and at temperatures as cold as -70°C. The cloud appears to be a remnant of the initial convective impulse of the anvil, which then maintained itself through internal circulations as the anvil dissipated beneath it. Size distributions in this cloud were monomodal with bulk ice water content values generally below 0.0015 g m^{-3}. The stability of this cloud suggests a possible production mechanism for the subvisible cirrus widespread over tropical regions.

A11B-07 0930h

Relationship Between Cirrus Anvil ice Crystal Properties and Aerosol Concentration, Ambient Relative Humidity and Vertical Velocity During CRYSTAL FACE

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The coverage of cirrus in the tropics and their radiative effects depend on anvil lifetimes and spreading in the upper troposphere (UT). One of the goals of the CRYSTAL FACE (CF) experiment is to understand the cirrus anvil evolution processes. Cirrus anvil properties can be linked to intensity of convection in the generating cumulonimbus and on UT ambient conditions. This work uses CF measurements to document the dependence of cirrus anvil ice crystal concentration and effective size on aerosol concentration, ambient relative humidity and vertical velocity. It is shown that the presence of significant ice crystal concentration (diameter larger than 50 micrometers) in cirrus anvil is linked to ambient water vapor supersaturated with respect to ice, predominant mesoscale updraft motion and large number concentration of aerosol particles (with diameter less than 1 micrometer). The study presents cases with time evolution of anvil characteristics and a discussion of factors that affect aerosol and ice crystal concentration during cirrus anvil aging. With the aim of diagnosing the dependence of ice crystal concentration on vertical motion in the cumulonimbus core, and possible dependence on atmospheric aerosol loading, an explicit microphysical model is applied.

A11B-08 0945h

Retrieval of Cirrus Properties from Solar Spectral Irradiance During CRYSTAL-FACE

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We examine spectrally resolved solar irradiance measured from above (NASA ER-2) and below (CIRPAS Twin Otter) tropical anvils during CRYSTAL-FACE in order to derive relationships between the scattered (reflected and transmitted) radiation and cirrus microphysical properties. Retrieved parameters are interpreted with respect to other remote sensing methods and to microphysical quantities obtained in situ. In particular we compare with simultaneous MODIS Airborne Simulator (MAS) and MODIS retrievals, which provide a directional inference of cloud properties, compared to the hemispherically integrated spectral irradiance. For both the spectral irradiance and MAS/MODIS retrievals identical ice crystal single-scattering models (twelve size distributions, four crystal habits) are used. This analysis is useful to determine if a directional bias exists between the directly measured spectral irradiance and the computed irradiance using cloud parameters derived from MAS/MODIS. We also show the relationship between infrared forcing and visible optical thickness for thin cirrus over the CRYSTAL-FACE domain.

A11C MCC: 3010 Monday 0800h

Effects of Biomass Burning Plumes on the Troposphere and Stratosphere I

(joint with B, AE)

Presiding: **K Drdla,** NASA Ames Research Center**; D Jaffe,** University of Washington, Bothell

A11C-01 0800h

Layers with biomass burning signature observed at 15.8 km in the stratosphere

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We present evidence that boreal forest fires represent a major source of soot in the stratosphere, affecting stratospheric temperature and chemistry and global radiative forcing. Polluted air unambiguously attributable to forest fires in North America was observed at altitudes up to 15.8 km, demonstrating direct transport of heavy smoke from the surface deep into the stratosphere which is not captured by atmospheric transport models. Stratospheric soot may not be due primarily to aircraft exhaust, as currently believed, but may be sensitive to changes in forest burning associated with climatic warming.

A11C-02 0815h

The Physical Mechanism of Injecting Biomass Burning Materials into the Stratosphere During Fire-induced Thunderstorms

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Recent satellite observations indicate that biomass burning debris can be injected into the lower stratosphere due to the fire-caused thunderstorms. This study uses a 3-D non-hydrostatic thunderstorm model to investigate the mechanism responsible for the injection. A typical thunderstorm occurred in the US High Plains is chosen as the model storm for the study. An inert tracer is assumed to be uniformly distributed in the lowest two kilometers initially and is carried upward by the storm circulation. The simulated storm is then analyzed in detail to reveal its thermodynamic and dynamic structure and the mechanism responsible for the cross-tropopause is identified. It will be shown that the diabetic process of cloud top gravity wave breaking is the mechanism of such transport. Local Richardson numbers (LRN) are computed and the animation of the LRN field indicates that the wave breaking is intimately related to the high convective instability at the cloud top region. Implications of such injections will also be discussed.

A11C-03 0830h

Pyro-Cumulonimbus: Strongly suppressed precipitation by smoke-induced extremely small cloud drops up to the homogeneous freezing level

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Pyro-cumulonimbus (Pyro-CB) is defined here as a convective cloud that feeds directly on the heat and smoke of a major fire, with its top exceeding the -40C isotherm level. The microstructure and precipitation of Pyro-CBs that were formed over large forest fires were observed by in situ measurements at the Amazon, by