RHUBC Operations Plan (Draft)

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Introduction. The ideal weather conditions needed to accomplish the RHUBC science objectives (see below) are low precipitable water vapor (PWV) with either clear skies or cirrus overhead. Analysis of several years of ARM data collected at NSA suggests that the median PWV in Feb-Mar is roughly 2 mm, but there are cases when the PWV is less than 1 mm. We will explicitly target the days that have PWV less than 2 mm. RHUBC has an additional 48 new Vaisala RS-92 radiosondes to launch during the campaign. These radiosondes will be launched by the IOP participants during periods with low PWV that are deemed to be good conditions to accomplish the RHUBC objectives. The on-site PI, with input from the NSA site scientist team and other RHUBC investigators, will determine when these sondes should be launched. These extra launches should not interfere with the routine twice-daily ARM launches, and will have to be coordinated accordingly. Special operations for RHUBC will not be performed on days with low liquid water clouds or complicated multi-level cloud scenes.

Modes of operation. To achieve the IOP's objectives, we desire cases where the PWV is as low as possible for both clear and cirrus cases. Three distinct operational modes are anticipated for the campaign, one for each of three PWV ranges:

a) 1.5 mm < PWV < 2 mm: A dataset of 2-3 hours will be taken corresponding to the launch of a single radiosonde.

b) 1.0 mm < PWV < 1.5 mm: At least three radiosondes will be launched in succession (see below) and a multi-hour dataset will be collected.

c) PWV < 1.0 mm: Radiosondes will be launched in succession and data will be collected for as long as personal limitations and the status of the TAFTS allow.

These graduated modes apply separately for clear and cirrus conditions and will be modified as necessary throughout the campaign to account for the datasets already collected during RHUBC, radiosonde inventory, etc.

Cases where the PWV is between 2 and 3 mm are still acceptable to IOP objectives; however, the far-infrared window is not as transparent and many of the microwindows beyond 25 μm start closing. Therefore, at the beginning of the IOP, the upper limit of acceptable PWV will be relaxed in order to obtain a first set of measurements: if the PWV < 3 mm then we will collect at least a single dataset of several hours for both cirrus and clear sky scenes. After at least one dataset for both cirrus and clear sky are "in the bag" then we will become more selective and only collect data when PWV < 2 mm.

Daily schedule and decision making. Since the IOP's focus is on dry clear-sky or cirrus conditions and some lead time is required before operations for radiosondes and TAFTS, the PIs will hold regular meetings to discuss and plan the operations for the next 48 hours based upon the weather forecasts. This **daily planning meeting will occur at 9:00 am AST** (1:00 pm EST) in the ARM Duplex. IOP participants who are not on-site can join the meeting via conference call. During this meeting, the day's events will be outlined, the forecast for the next 48 hours discussed, the status of the instruments and consumables (e.g., radiosondes, cryogens) will be given, and preliminary results presented and discussed. IOP participants will be encouraged to analyze their data in near real-time so that any instrument issues can be identified early during the experiment and rectified, if possible. If this morning meeting suggests that conditions may be good for RHUBC operations the following night, then **an additional (short) meeting at 9:00 pm AST may be held** in the Duplex to quickly review the weather conditions to decide if the operations should be conducted as planned.

Accurate weather forecasts will be critical for daily IOP planning. The NSA site scientist team (SST) has developed a webpage that includes links to the NWS forecasts for the Barrow region, output from the CIMSS Regional Assimilation System (CRAS) model for the North Slope region, and a specialized climatology forecast system developed by the NSA SST. The CRAS model updates every 12 hours at approximately 4:45 and 16:45 UTC (7:45 am and pm AST); these update times are what drive the 9:00 meeting times. If the forecast is for low (liquid-bearing) clouds or for PWV larger than 5 mm, then the day will be a stand-down day.

Radiosondes. Since we desire to maximize the number of model comparisons, we will launch radiosondes quite frequently if the PWV is less than 1.5 mm. To first order, the downwelling infrared and microwave radiance at the surface is driven by the water vapor and temperature structure of the troposphere (stratospheric ozone does contribute to the infrared radiance at the surface, but our radiosondes do not measure ozone concentration). Thus, we only require that the radiosonde profiles through the troposphere; after it crosses the tropopause the sounding can be terminated. While ARM has two radiosonde ground-stations that can be used simultaneously to track two individual radiosondes, ARM infrastructure has requested that we utilize only the digiCORA-III ground station, if possible. Thus, when we enter an 'intensive launch period' we will launch a radiosonde and track it with the digiCORA-III. When the sonde crosses the tropopause (this takes about 60 min, depending on the ascent rate of the sonde and the height of the tropopause), the sounding will be manually terminated and a new radiosonde launched shortly thereafter. The new radiosonde will have to be tuned to use a different transmit frequency (by at least 1 MHz) than the first radiosonde so that there is no "cross-talk" between the two soundings. If the second radiosonde is (mostly) prepared before the first crosses the tropopause, it should be possible to launch the second sonde within 15 min after the completion of the first. These "extra" RHUBC sondes will have to be coordinated with the usual ARM twice daily radiosonde launches; however, if we are in a "intensive launch period" we have received permission to truncate the normal ARM launch after it crosses the tropopause also. One note: the radiosonde instrument mentor has noted that occasionally the RS-92 humidity sensor is not fully acclimated to the ambient environment before launch at the NSA during very cold conditions. The IOP participants launching radiosondes should take care to make sure the sonde is acclimated before launching. Fortunately, the PTU sensors on the nearby 40 m tower can be used in the analysis if this occurs during the IOP.

Other considerations.

TAFTS: The only instrument that requires routine manual support for "long-term" operations is the TAFTS. The ARM instruments (AERI-ER, GVR, MPL, MMCR) operate autonomously, as does the R183 and the GSR. [IOP participants will monitor all instruments in real-time to ensure that the instruments are operating correctly.] The TAFTS uses cryogens to cool its detectors, and thus its dewars need to be filled at periodic (approximately 8 hour) intervals if continuous data collection is to be maintained. If its dewars run dry, the instrument's detectors will heat up and the data collected will be worthless. Furthermore, it takes approximately 1 hour for the instrument to return from this warm (no cryogen) state to operational readiness after its dewars have been refilled. In conditions of low overcast clouds or high PWV, we will not collect data and thus will conserve cryogens (and staff effort) by allowing the TAFTS dewars to run dry. However, during good conditions, we may desire to collect data for up to 72 hours continuously, which will require regular visits to the TAFTS at least every 8 hours to refill the dewars.

Instrument calibration: Since the intercomparison of the different instruments (both far-IR interferometers and 183 GHz microwave radiometers) is an objective of the IOP, special calibration datasets will be collected during the experiment. The best test will be to compare the data collected by the instruments in very dry, clear-sky scenes, and the investigators plan to take advantage of these opportunities. However, the use of characterized targets will also aid in the comparison of the different instruments. The AERI team at the U. Wisconsin Space Science and Engineering Center (SSEC) use a third "traveling" blackbody run at 40ºC (an intermediate temperature between the temperatures used for the two blackbodies used on the AERI-ER) to characterize the calibration accuracy of the AERI-ER each time it is deployed. The AERI-ER at NSA was recently tested in summer 2006, and the second AERI-ER (which will be installed before RHUBC begins) will be tested during the installation. We plan on using this same blackbody to evaluate the TAFTS; this will likely only be performed once during the IOP. We will also be using external calibration targets to evaluate the accuracy of the GVR and the R183. The GVR will utilize a special warm target developed by ProSensing, while the R183 view a liquid nitrogen (LN2) target. The configuration of the GVR does not allow it to easily view a LN2 target like the R183. The GSR utilizes two different calibration approaches (views at two blackbodies at different temperatures, tip-curve scans) regularly for most channels. The configuration of the GSR does not allow it to view a LN2 target.

Scientific Objectives of RHUBC

Radiative cooling and heating in the mid-to-upper troposphere contribute significantly to the dynamical processes and radiative balance that regulate Earth's climate. In the longwave, the dominant agent of this radiative cooling is water vapor. Due to the much greater abundances of this gas at lower levels of the atmosphere, the spectral regions in which the mid-to-upper tropospheric cooling occurs are opaque when viewed from the vast majority of surface locations. The opacity of the lower atmosphere is a formidable obstacle in evaluating radiative processes important in the mid-to-upper troposphere from the surface; however, an even more substantial obstacle has been the lack of radiometric instrumentation in the most critical spectral region for these processes, the far-infrared ($\lambda > 15$ μm). The recent development of a new generation of instruments for the measurement of spectral radiation in the far-infrared has provided the capability to rectify this state of affairs. These instruments will allow the evaluation of radiatively important processes in the mid-to-upper troposphere. This presents ARM with a terrific opportunity to contribute substantially to the improvement of the parameterization of these crucial radiative processes in climate simulations.

The Radiative Heating in Underexplored Bands Campaign (RHUBC) will be conducted at the ARM NSA site in Barrow, Alaska from 22 Feb – 14 Mar 2007. This experiment will make detailed observations of the downwelling infrared radiation in the 17-100 μm (100-600 cm^{-1}) rotational and 6.7 μm (1350-1850 cm^{-1}) υ_2 water vapor bands. Both of these spectral bands are underexplored because they are normally opaque at the surface due to strong absorption by water vapor, and hence the radiative heating in these bands is uncertain. Additionally, detailed observations in the spectral region of the 183.31 GHz water vapor line will be made. This band, which is also normally opaque from the surface due to strong water vapor absorption, will be used to constrain the total amount of water vapor in the column for the infrared calculations. Data in the infrared will be collected by three interferometers of two different designs: two (2) AERI-ERs (400-3000 cm^{-1}) and the TAFTS instrument from Imperial College (80-650 cm^{-1}). Data at 183 GHz will be collected by three unique microwave radiometers: the ProSensing GVR (developed under DOE SBIR and is currently at NSA site), Radiometrics R183 (developed under DOE SBIR and will be collecting its first measurements for the ARM program), and the NOAA GSR (which was deployed to the NSA site in previous campaigns).

There are three primary objectives for the RHUBC experiment:

a) To conduct clear-sky radiative closure studies in order to reduce the key uncertainties in the water vapor spectroscopy, including the foreign-broadened water vapor continuum and water vapor absorption line parameters. This campaign would allow a robust set of measurements corresponding to low PWV and cold temperatures to be collected; this is unobtainable in the laboratory.

b) Instrument cross-calibration and validation. TAFTS and the AERI-ER are state-of-the-art instruments that operate in far-IR for the purpose of atmospheric radiative transfer studies. Neither of these instruments has been validated in an operational environment against a complementary interferometer from a different manufacturer. The inter-comparison will allow a higher confidence in the results from these instruments. Similarly, this is the first time that three distinctly different 183 GHz microwave radiometers will be co-located and operated simultaneously, and thus provides an excellent opportunity to evaluate the accuracy of these observations (especially for the new SBIR instruments).

c) The investigation of the radiative properties of sub-arctic cirrus. The combination of the AERI-ER and TAFTS will allow simultaneous high-resolution measurements of Arctic cirrus emission in the far-IR for the first time. The additional instrumentation

(MPL, MMCR) at the ARM site will provide a comprehensive array of auxiliary data, maximizing the scientific value of this data set.