

# Picarro CO<sub>2</sub>/CH<sub>4</sub> Flux Analyzers

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## For Ship and Met City Installations

### Plumbing and inlet flow control on the ship

The Picarro CO<sub>2</sub>/CH<sub>4</sub> flux analyzer is sampling from a dedicated 1/2" teflon inlet running to the top of the ship's bow tower. Inlet flow is controlled by a ball valve on the top of the APIMS instrument rack to ~40 LPM and the flow rate is monitored with the large Alicat mass flow controller. The Picarro and APIMS DMS inlets are using the same GAST pump (in the pump cabinet), connected to the green ballast tank on the high shelf next to the rack.

The Picarro seems very sensitive to pressure fluctuations in the sample inlet, which is one cause of the 0.2-0.4 ppm oscillations observed in the CO<sub>2</sub> and CH<sub>4</sub> signals. The mass flow controller was used to set the flow but it seemed a bit unstable, so the ball valve was added and the MFC is set to >40 LPM, so it just remains open and measures the flow. Flow and pressure seem a bit less variable with this setup, but a high frequency oscillation remains in the trace gas signals.

Sample flow in the Picarro, APIMS and fast O<sub>3</sub> inlets is subject to wind speed/direction sector-control via the RM Young 2D sonic and Wind Tracker display. Currently, the Wind Tracker allows sampling when the wind is within +/- 130° of the bow and the wind speed is > 1 m/s. See the Wind Tracker manual for details on adjusting the alarm limits and averaging time. It is configured so alarm ON equates to 'good relative wind direction'.

When the relative wind conditions are out-of-sector or too low, the GAST sampling pump is shut down, halting flow in both the DMS and CO<sub>2</sub>/CH<sub>4</sub> inlets. Sample inlets to the Picarro analyzer and DMS mass spec are also shut off with pneumatically-actuated valves. Zero air is flushed out the inlet lines at ~ 300 ml/min, regulated by a critical orifice. The inlet flow is controlled by pneumatic ball valves mounted on the van ceiling, above the rack.

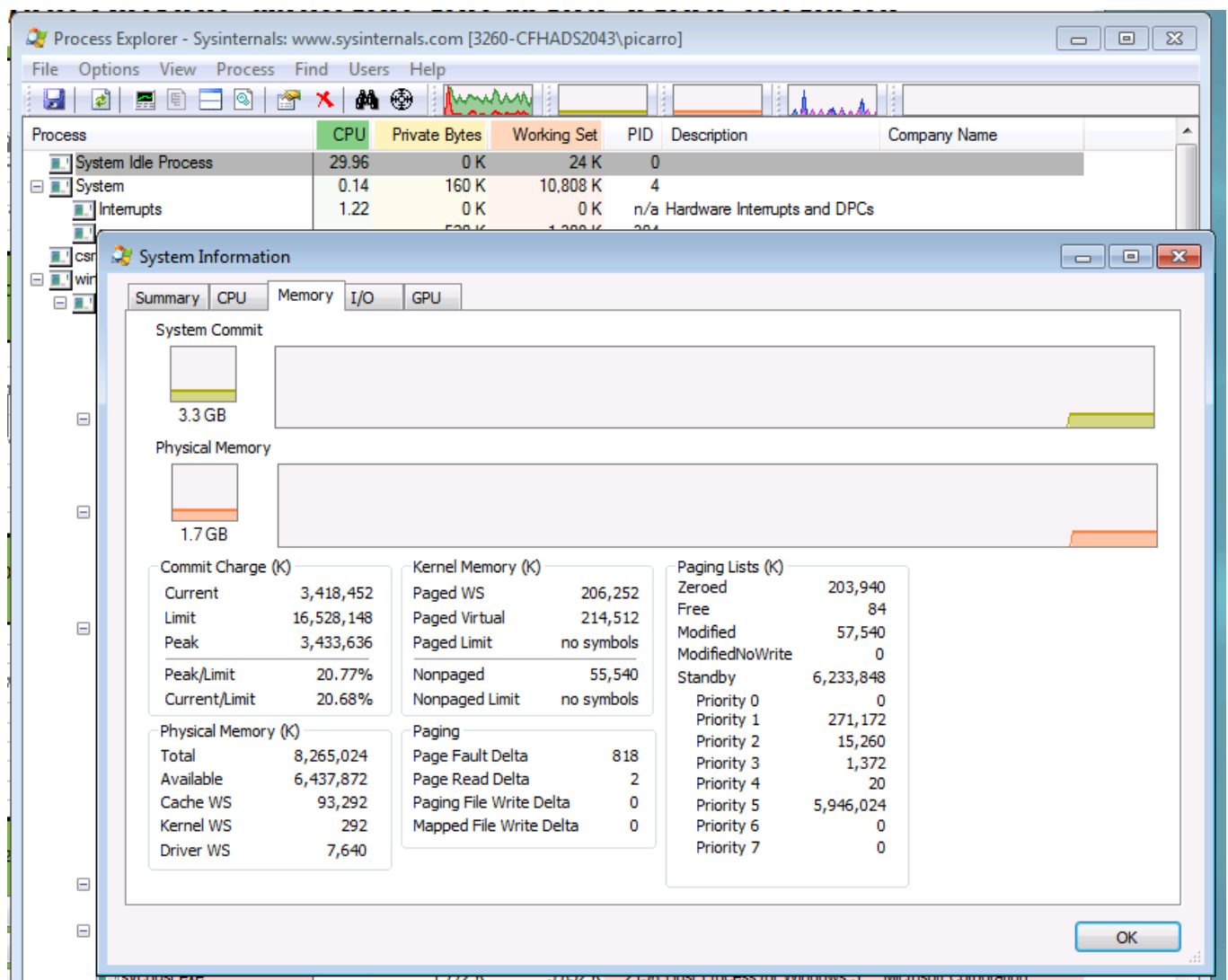
**KEEP A CLOSE EYE ON THE RELATIVE WIND DIRECTION. IT SHOULD BE WITHIN +/- 130 DEG OF THE SHIP BOW. WIND FORECASTS FOR MOSIAC HAVE BEEN ACCURATE SO FAR. ON LEG 1 THE SHIP HEADING IS ~ 203° (SSW), SO WIND FROM NE-N-NW IS IN THE BAD SECTOR. IF POOR WIND DIRECTION CONDITIONS ARE INDICATED FOR AN EXTENDED PERIOD OF TIME (A DAY OR MORE), IT IS BEST TO SHUT DOWN THE TRACE GAS ANALYZERS FOR THE DURATION AND RESTART AGAIN WHEN WIND CONDITIONS IMPROVE. THE PICARRO SHOULD NOT BE LEFT RUNNING FOR A LONG TIME WITH THE INLET SEALED OFF. SEE SHUTDOWN INSTRUCTIONS BELOW.**

# Memory Leak - IMPORTANT!!

Software running both Picarros has a memory leak issue which the manufacturer has not been able to fix. Over several days the amount of memory committed increases slowly until it reaches the max limit of 16 Gb. At that point the analyzer software freezes in a system crash.

You can check the status of memory usage with the Windows **Task Manager** program (search for Task Manager in the Windows search field in the lower left corner of the desktop). Click on the second little graph pane at the top of the TM window to open the memory usage summary.

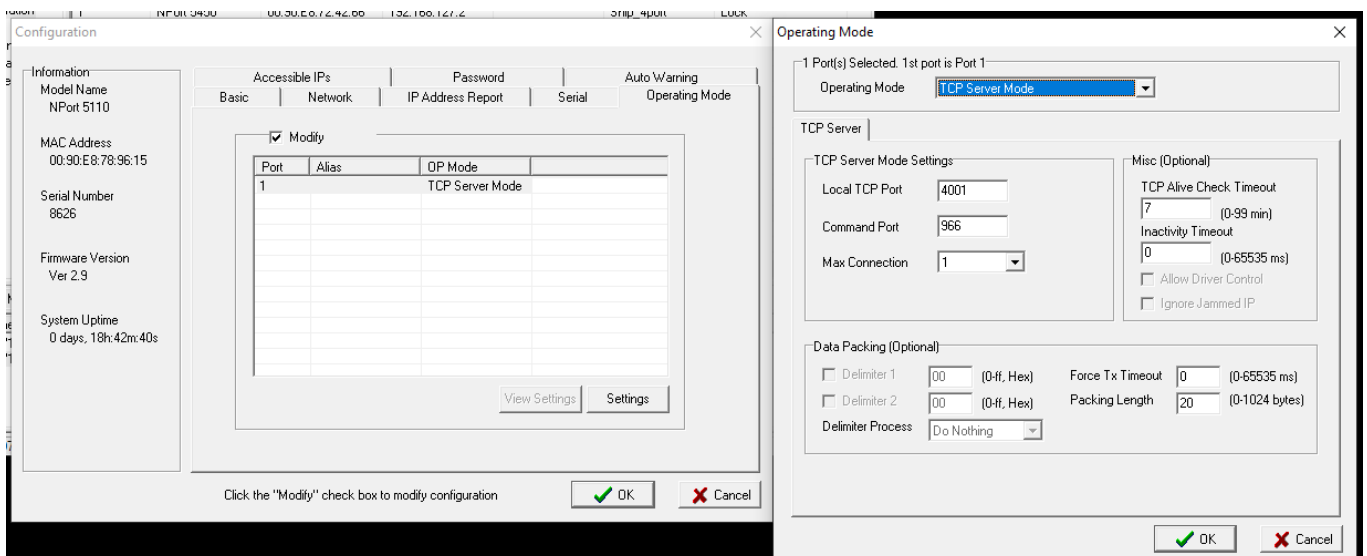
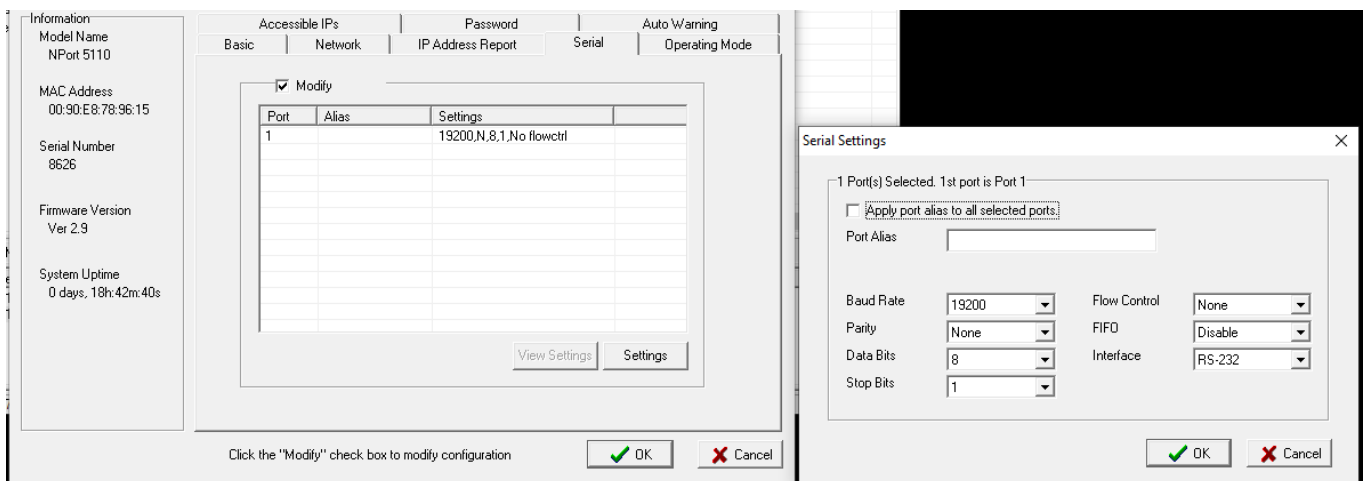
When **System Commit** grows too large you should 1) **shut down the analyzer**, 2) **reboot Windows**, 3) **cycle power on the MOXA**, and 4) **restart the analyzer software** to clear the problem. When the system first starts, System Commit is about equal to Physical Memory. Might need to do this once a week.

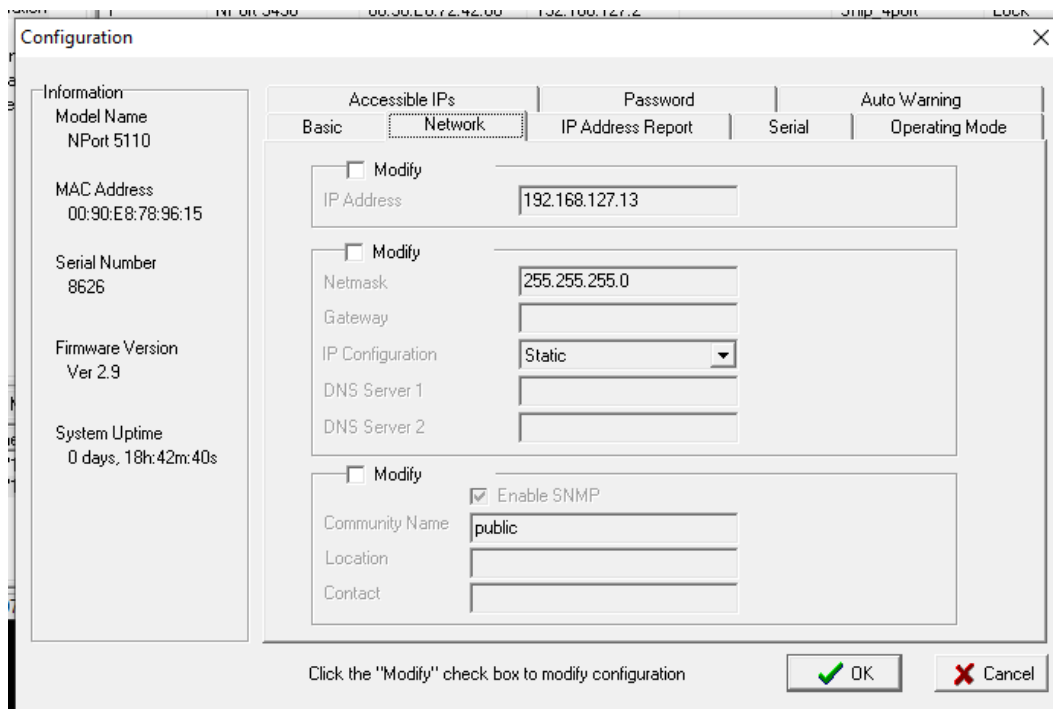


# Data Cabling and Monitor / Keyboard for Ship

The DAS100 and Picarro computers share the same keyboard, mouse and monitor, connected through a KVM switch on the back of the rack. The keyboard pulls out under the APIMS laptop shelf. Double-tap the **Scroll-Lock** key to switch the monitor and keyboard between systems.

The Picarro saves data files on an internal SSD drive. To synchronize with the wind measurements, a serial data stream is also fed to the DAS100 computer on the back of the APIMS rack. The serial cable (null modem) is connected from the upper (COM2) DB-9 output on the rear of the Picarro analyzer to the small single-channel MOXA N-Port 5110 on the side of the rack. Picarro RS-232 serial output is 19200 baud, 8,N,1. The MOXA is configured in TCP server mode, converting the RS-232 stream into a TCP-IP feed that is more efficient for the DAS100 system to log. The following screenshots show the network, serial and operating mode setup panels for the MOXA. A description of the DAS100 system and the MOXA NPort Admin app is in a separate instruction sheet.





IT'S NECESSARY TO CYCLE POWER ON THE MOXA INTERFACE EVERY TIME THE PICARRO ANALYZERS ARE STOPPED AND REBOOTED. OTHERWISE, THE MOXA DOES NOT CONNECT PROPERLY WITH DAS100 AND THE SERIAL DATA WILL NOT BE TRANSMITTED AND SAVED. WE CAN ONLY COMPUTE FLUXES FROM DATA SAVED ON THE DAS, SO DOUBLE CHECK EACH TIME TO BE SURE THE DAS IS RECORDING PICARRO DATA.

The Picarro MOXA configuration can be viewed and edited using the N-Port Administrator utility on DAS100. Open the utility and **Scan** for connected devices. You will see the 4-port 5450 which is mounted to the side of the rack, the two P5150A units that are in the flux box at the base of the tower, and the single 5110 device for the Picarro. Unlock any device by right-clicking and choosing **unlock** (user name **admin**, password **moxa**). To actually adjust any settings you need to first check the **Modify** box. Otherwise it's view only.

## System setup for MOSAiC flux measurements

For both analyzers the login is **User Name: picarro**, **Password: Extreme\_Science!** (this is the default user& password on Picarro analyzers). Auto-boot on power-up and auto start of the analyzer software are disabled on our Picarrros. Start up and shut down are manually controlled by the operator. The analyzer boots with the power button on the left front corner of the analyzer faceplate. This gets you to the Windows 7 desktop.

The ship analyzer is networked through the ethernet port to the ship's network on the Univ. Colorado VLAN with the IP address **192.168.202.66**. You can use **Microsoft Remote Desktop** to login to this IP address from any PC on the ship's network. The iMac computer in the Winch Control Room (D deck aft) has **Remote Desktop** configured for login to both

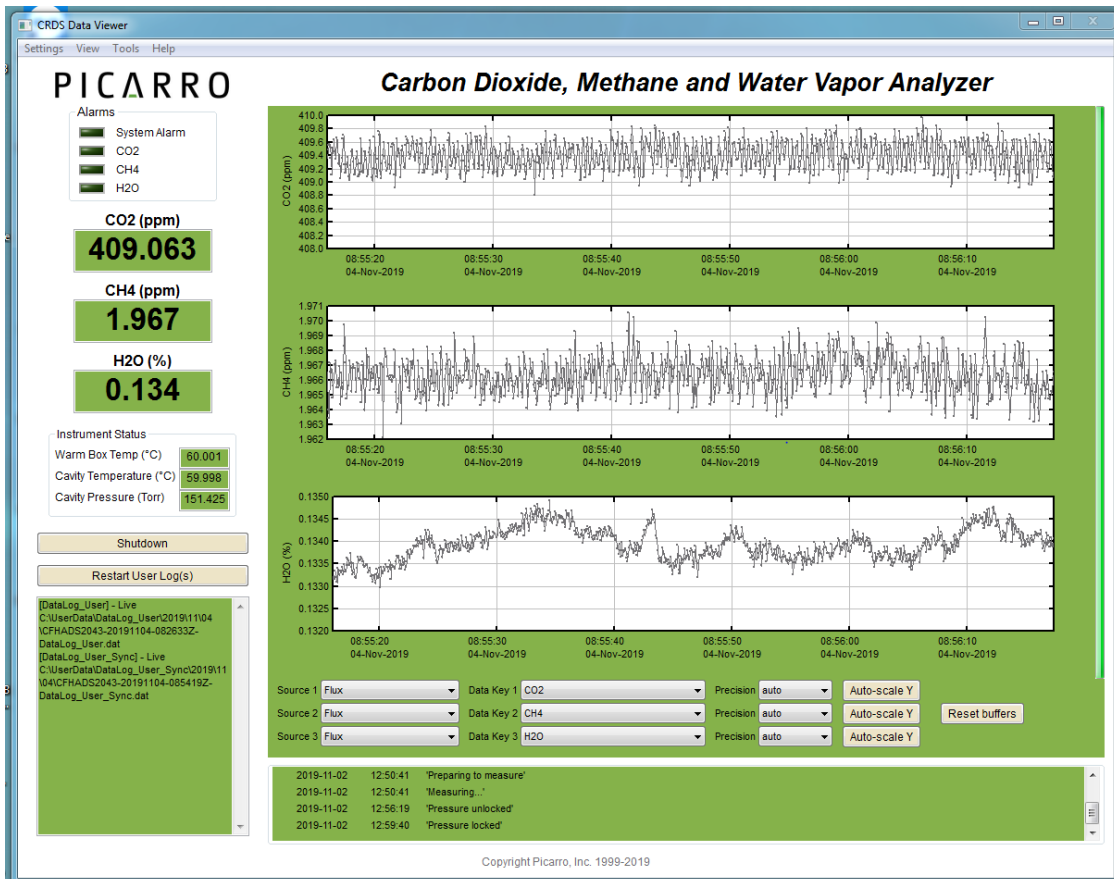
Picarro analyzers, the DAS100 computer, and Matt Shupe's DAS at the Met City tower. You can use MS Remote Desktop to view the remote system and control apps, but unfortunately you can't download data files.

The Windows 7 Date/Time on both analyzers is configured to update the system clock from one of the ship's NTP servers at 192.168.20.3 or 192.168.20.12.

## Startup

The first step is to **turn on the vacuum pump** and **boot the analyzer** with the power button on the front panel. The analyzer has several operating modes, but the only ones we use are 'flux' and 'high precision' modes. The latter is only used for calibration checks with the compressed gas standard. Sample flow rate is ~ 3 L/min in flux mode and 250 ml/min in high precision mode.

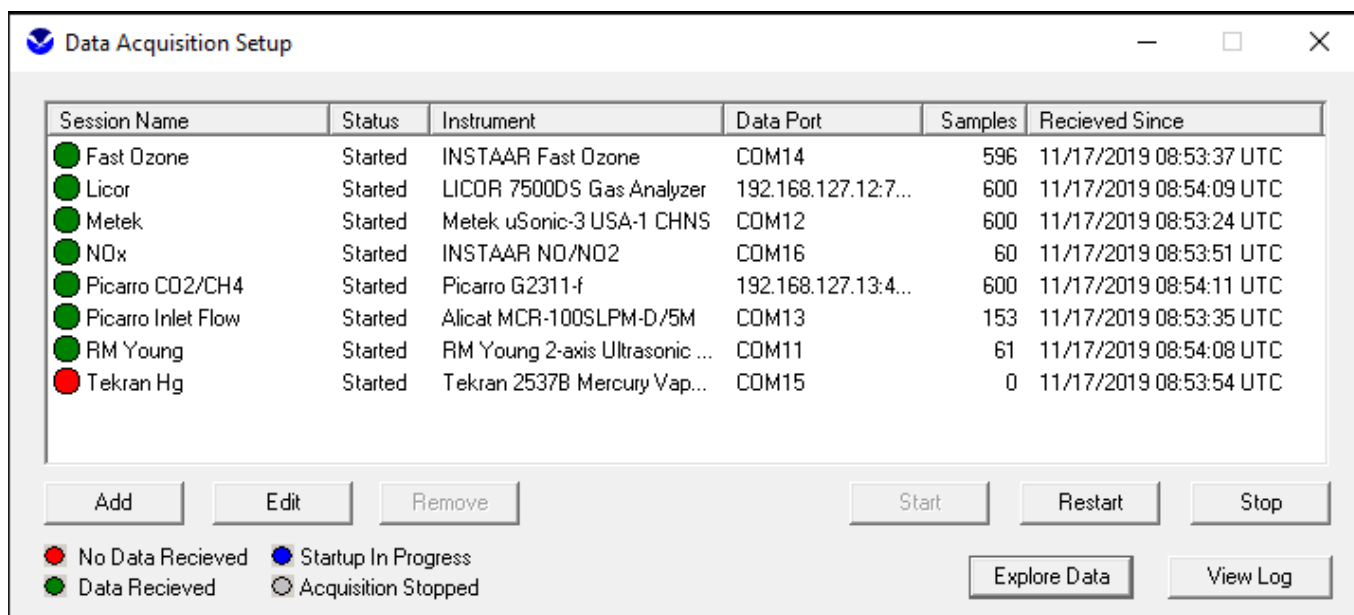
To start the analyzer, open the 'mode switcher' app with the desktop shortcut and choose 'flux' or 'high precision' modes as necessary. The analyzer will then go through an automated warm up procedure and begin collecting data without further input from the operator. The analyzer remembers the last operating mode, so if you are just stopping flux mode for a brief period and then restarting, you can click on the 'start instrument' shortcut and skip the mode switcher menu.



During warmup the cavity is pumped to low pressure (~ 4 torr) and then regulated to ~151 torr when sample flow is established. The cavity and warm box are heated to 60 °C. This can take some time when the instrument is cold. For convenience, I usually enlarge the analyzer window a bit and choose the `View>Show Instrument Status` menu option to see a continual readout of cavity pressure and temperatures on the front panel, as shown above.

When warmup is complete (pressure and temperatures locked), the display will switch to a scrolling plot of CO<sub>2</sub>, CH<sub>4</sub> and H<sub>2</sub>O concentrations in mole fraction (ppm or %), as shown above. Serial data output should begin at this time and you will begin to see Picarro CO<sub>2</sub>/CH<sub>4</sub> data appear on the DAS100 (or Met City DAS) in the NOAA Data Acquisition Setup window. See DAS100 instructions for more details.

The Picarro data rate is 10 Hz, so the Acquisition window shows ~600 data points received from the Picarro each minute and the acquisition indicator should be green. Note, the Acquisition window only updates once a minute, so if you don't see data immediately, have patience. A red indicator means no data received. If it stays red for several minutes try cycling power on the MOXA interface and check the serial cable and connections. A gray indicator means the acquisition has not been started on the DAS, so highlight the Picarro line and click the `Start` button.



When the Picarro display shows that pressure and temperatures are locked (green in the instrument status panel) and the trace gas data streams look OK, and the NOAA DAS is recording, then all is well. On MOSAiC the CO<sub>2</sub> and CH<sub>4</sub> concentrations have been at background levels (408-411 ppm and 1.96 ppm respectively). The air is very dry, with H<sub>2</sub>O concentrations at 0.2% or less most of the time. Frost point is typically a couple degrees lower than the air temperature.

Because of the very dry air, the Nation drier on both the Picarro and DMS APIMS have been bypassed, which improves signal response. In this configuration the Picarro is making a humidity measurement which we might use to compute the latent heat flux. If outside

temperatures become very warm (above -5°C) it may be advisable to hook up the Nation drier again to eliminate possible interferences.

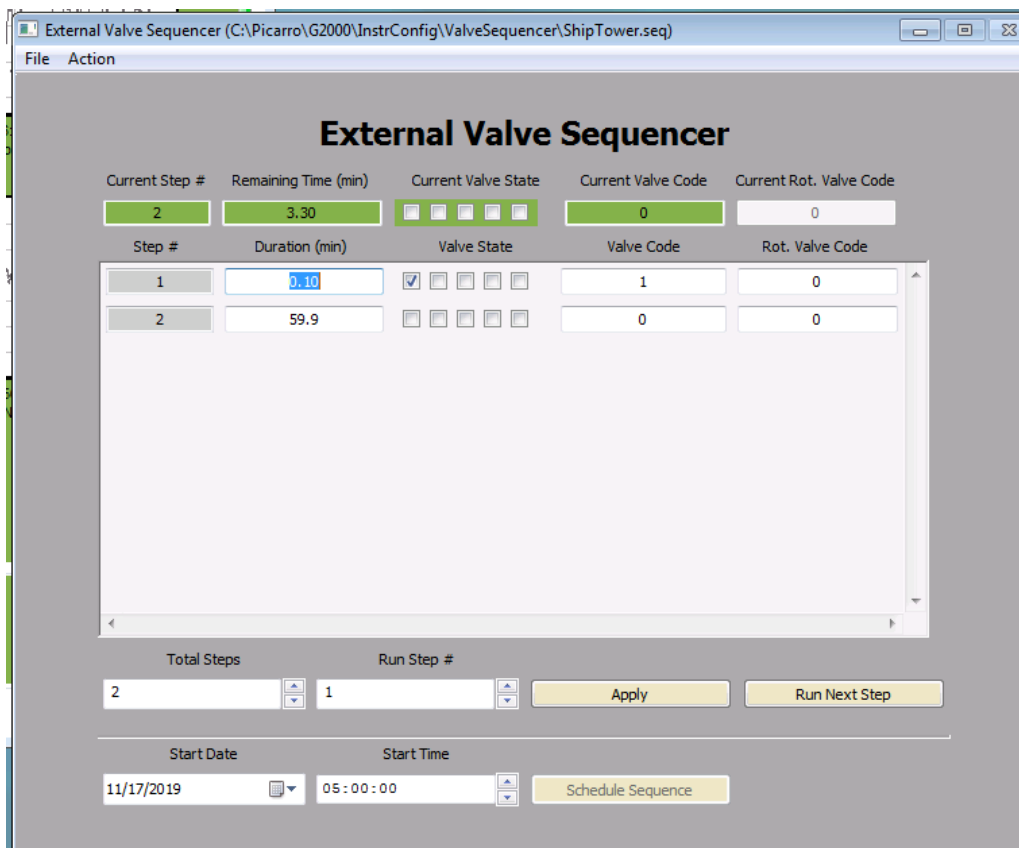
## Controlling the Nitrogen Pulse

At both the ship and Met City installations, the Picarro analyzer controls the nitrogen lag 'puff' to the inlet(s). **So, if the Picarro isn't running, there won't be a lag pulse injection to the DMS or fast ozone inlets.**

To program the lag pulse valve, choose the **Tools>Show Valve Sequencer GUI** from the analyzer window. This brings up a new window with the valve GUI. It usually appears behind the main Picarro analyzer window, so you might need to minimize or move the Picarro window to see it. The following screen shot shows the correct setup for the valve sequencer.

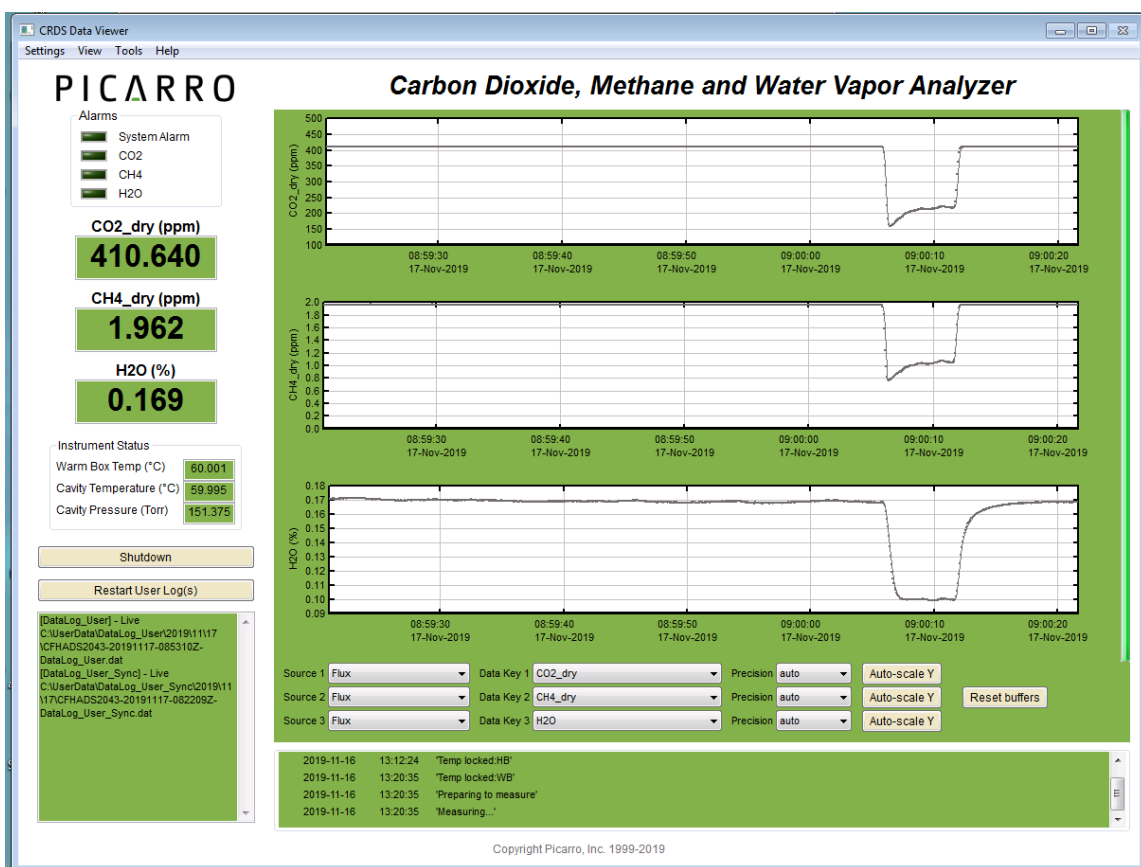
This valve sequence has been saved as **ShipTower.seq**, and you can load it from the sequencer **File** menu. It's programmed to open valve 1 for 0.1 min (6 sec) at the start of each hour. We set step# 1 for 0.1 min and put a check in the box for V1. Step# 2 is set to 59.9 min and no valves are checked. This sequence repeats indefinitely until you choose the **'Action:Stop Sequencer'** menu item.

Use the scheduler at the bottom of the window to begin the sequence exactly at the top of an hour. First, execute **'Stop Sequencer'**, **'Reset All Valves'**, and **'Go To First Step'** from the **Action** menu (I'm not sure all that is necessary, but I do it to be thorough). Then, set



the scheduler at the bottom of the window to start at exactly the beginning of the next hour. You need to enter today's date and the time of the next full hour. Click the 'Schedule Sequence' button to initiate the scheduler. The valve should fire at the top of the next hour and then every hour after until manually stopped.

When the valve fires you will see a delayed response in all the trace gas signals, as below. The concentrations will drop quickly and overshoot a bit, then stabilize at a lower value, then abruptly return to the ambient level. The response for water vapor is a bit slower than for the other two gases. Keep an eye on the nitrogen tank pressure and replace the cylinder when pressure drops below 200 psi. The N<sub>2</sub> regulator on the ship is set to an outlet pressure of ~ 90 psi to give a gas pulse large enough to flood three inlets. The Met City regulator on the small N<sub>2</sub> tank is set to ~ 60 psi. If we start to run low on nitrogen, the puff can be set to run every 2 hours instead of every hour.



Because the sequencer runs on intervals and cannot be set to exact times, the puff can drift a bit and over time may not occur at exactly the top of each hour. Every few days it's a good idea to stop the valve sequencer, reset it, and restart the scheduler at the beginning of the next hour to get things back in sync.

The solenoid valve state is transmitted in the serial data to the DAS computers, and this allows us to determine the exact inlet lag time and to synchronize clocks between the flux analyzer and wind measurements.



# Shutdown

For a quick shutdown, if you want to have the instrument off for a few minutes and then restart, you can use the 'Stop Instrument' shortcut on the desktop. This terminates all Picarro software and returns you to the Windows 7 desktop.

Otherwise, it's best to use the Shutdown button on the Picarro analyzer window. This stops the analyzer in a more graceful manner and shuts down the Windows OS. If you want to copy data files or work with other apps OS functions, simply reboot the computer.

**Be sure to shut off the vacuum pump** when you shut off the analyzer for an extended period of time.

## Met City flux system

In most cases, everything mentioned above also applies to the Met City Picarro, with the following exceptions:

- 1) There is no inlet back flush or sector control for the Met City system. The inlet and analyzer run continuously. Inlet flow rate is controlled by the ball valve on the pump inlet. There is no flow meter. Instead, we set the vacuum at the pump inlet to ~ 5 psi.
- 2) The IP address on the ship network is 192.168.202.66 and the analyzer can be accessed with MS Remote Desktop at that address. The analyzer's ethernet jack is connected to the network switch on the wall of the Met City hut.
- 3) The MOXA setup for serial streaming to the tower DAS is similar to the ship, but with a unique IP address on the network tab for the tower DAS subnet: 192.168.2.20. The MOXA is connected directly to the tower DAS with an ethernet cable running out to the tower. **Be sure to cycle power on the MOXA every time the Picarro is rebooted.**

## Calibration Checks

At least once monthly, the analyzer calibration for CO<sub>2</sub> and CH<sub>4</sub> should be checked using the small tank standards. We have eight small aluminum cylinders for these gases. Seven tanks have roughly the same concentration and one is a bit lower, to use as a span check if necessary. Save this one if possible.

**DO NOT COMPLETELY EMPTY THESE CYLINDERS. USE ONE UNTIL PRESSURE IS ~ 200 PSI, THEN LABEL IT AS EMPTY AND RETAIN FOR LATER ANALYSIS AT NOAA. WHEN YOU FINISH ONE CYLINDER, RUN A SECOND CALIBRATION WITH THE NEW CYLINDER AT THE**

## SAME TIME SO WE HAVE OVERLAPPING RECORDS OF THE INSTRUMENT RESPONSE TO BOTH CYLINDERS AT THE SAME POINT IN TIME.

The calibration cylinders have nominal CO<sub>2</sub> and CH<sub>4</sub> concentrations from the manufacturer, but we will not necessarily trust these. They will be reanalyzed by NOAA GMD after the field project to get more precise values – so be sure to save at least 100 psi in each used cylinder.

The calibration check is fairly simple. Basically, you want to run calibration gas into the analyzer in low flow mode and record the response for about 10 min. We will not do an actual recalibration of the analyzer because we do know the exact concentrations of the standards. We just want a record of the analyzer response to the standards over time so we can make later adjustments to the measured concentrations based on a high precision analysis of the standards.

- 1) First, shut down the analyzer and reboot.
- 2) Disconnect the sample air inlet line and install the low-flow restrictor on the inlet. Don't remove the inlet filter. The low-flow restrictor is in a box with other Picarro parts in the computer supplies drawer of the lab van, and there's another in the black Action Packer box out at Met City. See the Picarro manual for more information about low-flow mode.
- 3) Using a few pieces of 1/4" teflon tubing and one 1/4" Swagelok tee, plumb the calibration gas to run through the tee with the analyzer inlet connected to one branch fitting and a dump line open to room air on the other branch.
- 4) Start the analyzer software in 'high precision' mode using **Mode Switcher** and wait for the warmup period to complete and data acquisition to begin. At this point you should be sampling room air at a flow of ~ 250 ml/min and you'll probably see large and variable CO<sub>2</sub> concentrations from local sources in the room (like people).
- 5) Open the calibration cylinder valve and set the regulator so a very small excess flow comes out the dump line of the tee into the room air and the analyzer samples pure standard gas from the tee. Let the analyzer run for 10 minutes to get a stable value for CO<sub>2</sub> and CH<sub>4</sub>.
- 6) Shut down the analyzer, remove the inlet flow restrictor and reattach the sample air inlet line, restart inlet flow, reboot the analyzer and cycle power on the MOXA interface, then restart the analyzer in flux mode as described above.
- 7) Make a note in the logbook of the date, time and calibration gas cylinder serial number used for the calibration check and the concentrations observed. Also, take a copy of the DataLog\_User file generated from this test and save it in the calibrations folder for the analyzer:

`/MOSAIC_2019/crds_ghg_ship_bow/_DataLog_User/calibrations`

It's often convenient to do a calibration check on the ship Picarro and the Licor dynamic chamber trace gas analyzers simultaneously by plumbing them to tees on the cal gas line.

## Data files

The Picarro saves two types of data files internally, in addition to the serial stream data which is saved on the DAS computers using the NOAA DAS utility service. These are stored in the `C:\UserData` folder as `DataLog_User` and `DataLog_User_Sync`. The former files are ~ 15 Hz and contain additional variables on system performance. The `Sync` files are resampled to exactly 10 Hz and are identical to the serial feed data saved on the DAS.

In most cases we will use serial data saved on the DAS for flux calculations, which is saved in daily subfolders on the DAS100 computer in `D:\Data\Picarro`. Daily folders follow the naming convention `YYDDD`, where `YY` is the year and `DDD` is the Julian day-of-year. Files for the current day are not in a daily folder but instead are in the root `D:\Data\Picarro` directory. They are transferred to a daily folder after 0000 hrs, when a new day's files begin. When you copy data from the DAS100, simply copy all the daily folders since the last download to the USB drive directory `/MOSAIC_2019/crds_ghg_ship_bow`. Don't copy files for the current day since they are still in progress.

In addition to the DAS files, we want to archive `DataLog_User` files from the Picarro analyzer. These are in the analyzer `C:\UserData\DataLog_User` directory, in a rather inconvenient nested folder structure `...\YY\MM\DD`. You want to copy over all the daily `DD` folders since the last download, but don't include the current day. I've been renaming these daily folders in a more convenient way as `YYYYMMDD` and then compressing since they are more than 1 Gb. To compress a file or folder on the iMac, right click (click on the right side of the wireless mouse) and choose `compress`. Save the compressed folder on the SSD drive and on the iMac in `/MOSAIC_2019/crds_ghg_ship_bow/_DataLog_User/outbox`.

The `DataLog_User` files are inconvenient since they don't start at the top of the hour. The `/_DataLog_User/inbox` folder has a python script to parse the raw `DataLog_User` files into exact hourly files that correspond to the format of other files we use. You needn't bother with this on a regular basis, but if you want to parse out the raw files, copy as many of the `DataLog_User` files as you want to the `inbox` folder, `cd` to that folder in the `Terminal` app, and execute the following line at the `fluxuser$` prompt.

```
python parseDatalogUserFiles_Ship.py
```

This generates a series of hourly parsed files in the `inbox` folder following the naming convention `ghg0YYDDDDHH_raw.txt`. These can be moved to daily folders in the `/_DataLog_User/parsed` folder. There's a Matlab function to read these files. You can delete the raw `DataLog_User` file copies from `inbox` when done.

For the Met City Picarro, serial output files are saved on the Univ. Colorado met tower DAS and archived in the `Workstation` computer in the NOAA/CIRES white container out on the foredeck. Their acquisition system is just like DAS100 and you can remote login to check if the Picarro data is being recorded properly. The Met City 10m sonic anemometer files are also on `Workstation`. See someone from Matt Shupe's group about getting these files for our archives. We need both the Picarro and sonic data files, but only copy the Picarro files to the MCS archive.

Unfortunately, data file names from the Met City tower DAS all begin with the same root, `msc0`, and they are not saved in daily folders. I've been renaming the MetCity Picarro files as `pic1YYDDDHH_raw.txt`, to follow the naming convention of our other files. `pic0` is the ship, so `pic1` is Met City. There's an app on the iMac desktop to do this renaming automatically: `msc0_to_pic1.app`. Select a group of Picarro `msc0` files in the Finder and drag/drop them on the app icon. They will all be renamed. There's another Automator app on the desktop for renaming the 10m sonic anemometer files: `msc0_to_son2.app`. Archive the renamed Met City Picarro files in daily folders in `/MOSAIC_2019/crds_ghg_ice_station_tower`.

## Submission to MCS archive

When you have the files backed up and arranged on the USB SSD drive and on the iMac, transferring them to the MOSAiC MCS system is fairly easy. I do all this about once a week. Open the MCS archive as a network drive on the iMac or on your own computer. On the iMac just choose `Go:Connect to Server...` from the Finder menus and connect to the `smb://mcs.fs-polarstern.de/platforms` server.

The ship Picarro data goes in

```
/platforms/vessel/polarstern/bow_tower/crds_ghg_ship_bow/exdata
```

In a subfolder specific for each cruise leg. This folder is generated at the start of each leg when you enter a DShip Action Log 'Station Start' event for the `crds_ghg_ship_bow` device. The folder will be named something like `PS122-1_1-70`, where the `PS122-1` refers to the cruise leg and the other numbers mean something else. Not sure what. We are archiving the daily folders of serial data from DAS100 and the zipped `DataLog_User` files. You will see where they go.

For the Met City Picarro, data is similarly saved on MCS at:

```
/platforms/pack_ice/ice_ps/flux_tower_12m_uch/  
crds_ghg_ice_station_tower/exdata
```