

## HIAPER-TOGA (Trace Organic Gas Analyzer)

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### Instrument Description and Background:

TOGA will measure volatile organic compounds (VOCs), providing insights into key SEAC<sup>4</sup>RS and DC3 themes. Specific data will be obtained for radical precursors, tracers of anthropogenic and biogenic activities, tracers of urban and biomass combustion emissions, products of oxidative processing, precursors to aerosol formation, and compounds important for aerosol modification and transformation. TOGA measures a wide range of VOCs with high sensitivity (ppt or lower), frequency (2.0 min.), accuracy (15% or better), and precision (<3%). Over 30 species are routinely measured (Table 1) throughout the full HIAPER altitude range.

### Hardware, Instrument Control, Data Acquisition

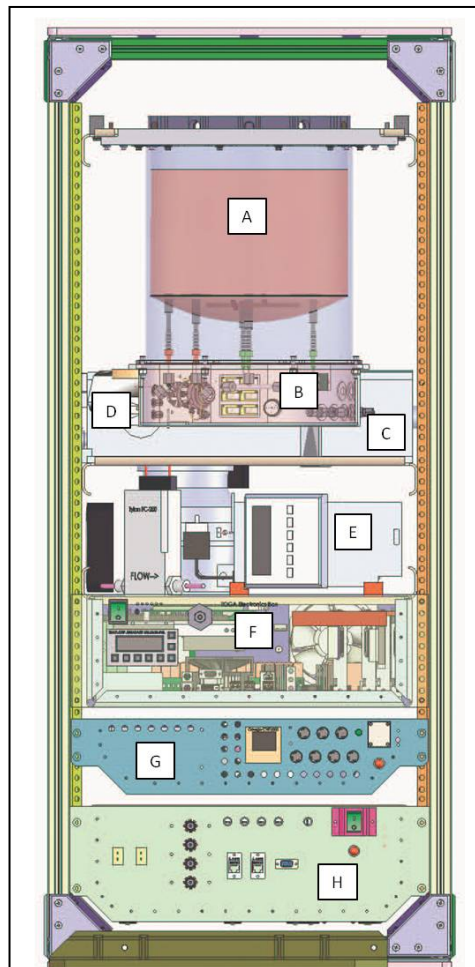
TOGA is contained in a standard HIAPER rack, weighs less than 200 kg and consumes ~1 kW of power (Figure 1). The major components of the instrument are the inlet, cryogenic preconcentrator, gas chromatograph, mass spectrometer detector, zero air/calibration system, and the control/data acquisition system. All processes and data acquisition are computer controlled.

The inlet is a constant mass flow design which mitigates the intrusion of aerosols and allows for calibrations and system blanks through the inlet.

The cryogenic preconcentrator consists of a custom-built dewar that allows rapid cooling and heating of traps used for water removal, sample enrichment and cryofocusing. Flow switching between traps is done via a heated (50°C) Valco 10-port valve.

A quadrupole mass spectrometer in selected ion monitoring mode is used to quantify individual compounds. High speed electronics allow the simultaneous measurement of several peaks with ~ 1 second peak width.

A custom gas chromatograph exhibiting rapid temperature control and a Restek MXT-624, 8 meter, 0.18 mm i.d. column is used for chromatography.



**Figure 1.** Diagram of the HIAPER/TOGA showing the major instrument components: (A) LN<sub>2</sub> dewar, (B) Heated space holding cryogenic enrichment traps and switching valves, (C) Mass spectrometer vacuum chamber, (D) Gas chromatograph, (E) Mass spectrometer, (F) Electronics box, (G) Zero air generator/dilution system, (H) Power box and UPS.

System blanks and calibrations are made using a catalytic-clean air generator/dynamic dilution system with accurate ( $\pm 1\%$ ) and precise ( $\pm 1\%$ ) calibration gas delivery. The system operates continuously, allowing for frequent calibrations and zeros during the flight.

Instrument control and data acquisition software are LabVIEW-based (National Instruments), and provide comprehensive control of all TOGA-HIAPER functions. Gas flows, temperatures, pressures, logic states, and the aircraft serial stream constitute the parameter set which is displayed on the GUI and archived. The code performs the intricate time sequencing necessary for air sampling, preconcentration (water removal, organic compound pre-concentration, cryofocusing), GC injection and oven temperature programming.

**Table 1.** Compound list and measurement rationale

|                               | <u>Compound</u>                                       |   | <u>Measurement Rationale</u>   |
|-------------------------------|---|---|--|
| Hydrocarbons                  | Propane   | Isoprene  | Biogenic compounds (e.g., isoprene and terpenes) represent the largest source of VOCs to the atmosphere. Aromatics are sources of aerosols and also indicators of anthropogenic activity. Shorter and longer-lived compounds are well suited as tracers of convective activity over continental areas. Compounds with differing reaction rates allow estimations of transport times and air mass ages. Oxidation processes result in measurable oxidation products for several of the lower molecular weight hydrocarbons, allowing for better understanding of oxidative progression. |
|                               | 1-Butene  | <i>t</i> -2-Pentene   |  |
|                               | <i>i</i> -Butene                                      | <i>c</i> -2-Pentene   |  |
|                               | Butane  | <i>i</i> -Pentane   |  |
|                               | <i>i</i> -Butane                                      | <i>o</i> -Xylene  |  |
|                               | Benzene   | <i>m/p</i> -Xylene  |  |
|                               | Toluene   | 1,3,5-Trimethylbenzene  |  |
|                               | Ethyl Benzene   | 1,2,4-Trimethylbenzene  |  |
|                               | <i>t</i> -2-Butene                                    | $\alpha$ -Pinene  |  |
|                               | <i>c</i> -2-Butene                                    | $\beta$ -Pinene   |  |
|                               | Pentane   | Camphene  |  |
|                               | 1,3-Butadiene   | Myrcene   |  |
|                               | Limonene  |   |  |
| Oxygenates                    | Acetaldehyde  | Methanol  | Many oxygenates are both direct vegetative emissions and anthropogenic emissions. There are strong biomass burning sources of certain oxygenates. Some oxygenates are direct oxidation products of precursor hydrocarbons. Many oxygenates are important participants in HO <sub>x</sub> cycling in the UT/LS.   |
|                               | Propanal  | Ethanol   |  |
|                               | Butanal   | Acetone   |  |
|                               | Pentanal  | Butanone  |  |
|                               | Methacrolein  | 2-Pentanone   |  |
|                               | Methyl Vinyl Ketone                                   | 3-Pentanone   |  |
|                               | Methyl Butenol  | Methyl <i>t</i> -Butyl Ether  |  |
| Halocarbons                   | Chloroform (CHCl <sub>3</sub> )                       | Tetrachloromethane (CCl <sub>4</sub> )                              | Halocarbons consist of CFCs and HCFCs with purely anthropogenic sources and other compounds with distinct biogenic and biomass burning sources, such as the halomethanes. Others are predominantly oceanic. Consequently, halocarbons are excellent tracer compounds for specific regional urban emissions, convection over marine regions, and biomass burning.   |
|                               | Methylene chloride (CH <sub>2</sub> Cl <sub>2</sub> ) | CFC-113   |  |
|                               | Methyl chloride (CH <sub>3</sub> Cl)                  | HCFC-141b   |  |
|                               | Methyl bromide (CH <sub>3</sub> Br)                   | HCFC-134a   |  |
|                               | Tetrachloroethane (CH <sub>2</sub> Cl <sub>4</sub> )  | 1,2-Dichloroethane (C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub> ) |  |
|                               | Tetrachloroethylene (C <sub>2</sub> Cl <sub>4</sub> ) | Methyl Iodide (CH <sub>3</sub> I)                                   |  |
|                               | Others are possible.                                  |   |  |
| Nitrogen and Sulfur Compounds | Acetonitrile  |   | Acetonitrile is an indicator of biomass burning. In combination with methyl chloride, it offers a stronger confirmation of air impacted by biomass burning than does methyl chloride alone. DMS is an excellent tracer of marine air and specifically marine biogenic activity.  |
|                               | Dimethyl Sulfide (DMS)                                |   |  |