Written Public Comments on the *Strategic Plan for the U.S. Climate Change Science Program*
Appendix I: Supplemental Submission from NIST
Comments Submitted 11 November 2002 through 18 January 2003
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NIST Measurement and Standards Programs to Support Climate Change Research

Measurement and monitoring of a wide range of chemical and physical variables is crucial to effective global climate change research. According to a recent National Research Council (NRC) report[1], "the importance of accuracy, continuity, calibration, documentation and technological innovation in observations for long-term trend analysis of global climate change cannot be overemphasized". The report emphasizes the need for high-quality long-term monitoring: "The need for comparability of measurements made at different times and places requires that high priority be given to thorough instrument calibration and measurement system validation, including the inevitable changes in technology and observing networks".

NIST does not conduct global climate change research, but does provide U.S. national standards for measurements that support accurate climate observations in several ways. NIST measurements, standards, data, and modeling tools are used extensively by the climate change research community. These NIST products and services enable researchers to more accurately monitor the Earth's atmosphere, oceans, and climate for a wide range of physical and chemical parameters including temperature, chemical composition, concentration of key chemical species, size and chemical composition of atmospheric particles, absorption and emission of radiation, and other parameters crucial to understanding climate and monitoring climatic trends. NIST metrology, data, and modeling tools also provide key support to developers and users of complex climate prediction models. These tools are used to address issues that are key to accurate assessment of global climate change including but not limited to:

- **Temporal stability:** Many key measurements of climate are technically challenging and require accurate measurement of small changes over long periods. NIST standards are needed to ensure that observational changes are real and not artifacts of changes in instrument performance or use of new measurement technologies.
- **Measurement Comparability:** NIST standards (reference materials and data) ensure that data from measurements conducted by researchers around the world using different technologies are mutually recognized and can be used to make valid decisions.
- **Uncertainties in predictive models:** Climate predictions can be very sensitive to small variations in key parameters. NIST standards and data are needed to set the

[1] National Research Council (NRC), Committee on Global Change Research. 1999. *Global Environmental Change: Research Pathways for the Next Decade.* National Academy Press, Washington, D.C.

uncertainty ranges on key measurements, defining the limits for predictive models.

- **Development and evaluation of new measurement technologies:** NIST standards are internationally recognized and accepted anchor points that will enable the development of new measurement instruments and observation technologies of known accuracy.

Measurements and Standards for Greenhouse Gases

The "greenhouse effect" has operated in our planet's atmosphere for billions of years due to naturally occurring levels of water vapor, carbon dioxide, ozone, methane, and nitrous oxide. However, there is also evidence to suggest that levels of these, as well as other, greenhouse gases are increasing in the atmosphere due to human activities. The following gaseous species come from both natural and anthropogenic sources:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)

The atmospheric contributions of the following species are primarily from human activities:

- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur Hexafluoride (SF6)
- Reactive Nitrogen Species (NO_x)
- Carbon Monoxide (CO)
- Volatile Organic Compounds (VOCs)

NIST has developed a wide range of Standard Reference Materials (SRMs) for atmospheric monitoring and global warming to ensure the accuracy of measurements worldwide. NIST SRMs for carbon monoxide, carbon dioxide (with requisite sample-to-sample isotopic reproducibility, covering the natural ranges of carbon-13 and oxygen-18.), sulfur and nitrogen oxides have been used worldwide to quality assure measurements for nearly two decades. More recently, NIST has developed primary standards for methane, nitrous oxide, CFC-11, CFC-12, and a multicomponent mixture of VOCs in an air matrix at concentrations that span normal atmospheric concentrations (= 360 µmol/mol; CH_4 = 1.7 µmol/mol; N_2O = 312 nmol/mol; CFC-12 = 530 pmol/mol; CFC-11 = 270 pmol/mol; and VOCs at nmol/mol concentration levels).

NIST SRMs and **N**IST **T**raceable **R**eference **M**aterials (NTRMs) produced by Specialty Gas Companies with NIST oversight are currently used for assuring equity in SO_2 emissions trading. Since its inception, 11 specialty gas companies have worked with NIST to certify over 8500 NTRM cylinders of gas mixtures that have been used to produce more than 500,000 NIST-traceable gas standards. According to Stephen Miller, Technical Director, Scott Specialty Gases, "the NTRM program has served as an excellent vehicle for production of the high quality standards - of known pedigree - required by both industry and the regulatory community in the implementation of Title IV [SO2 emissions trading] of the 1990 Clean Air Act." NTRMs for greenhouse gases such as CO_2 and CH_4 are already in place to underpin carbon trading activities and assure the accuracy and reliability of data for stewardship of U.S. carbon emissions.

NIST also provides exhaust gas mixture standards to ensure the accuracy of measurements performed by the automotive industry and the regulatory agencies. In addition, NIST has developed a unique High Temperature Gas Flow Calibration Facility that accurately simulates the composition range, flow rate, and temperature of vehicle exhaust streams.

Other GCC-Related Measurements and Standards

NIST performs calibrations and special tests of a wide range of instruments and measurement techniques for accurate measurement of absorption and emission spectra from the x-ray through the microwave region, measurement of absolute radiation flux, concentrations of atmospheric constituents, and the paleorecords that provide century-long records of climate and atmospheric variations that are the baseline for understanding natural variability. NIST calibrations and special tests give the end users a direct and accurate indication of instrument performance. In addition to Standard Reference Materials (SRMs) for gas mixtures, NIST provides standards covering a wide range of chemical and physical properties, enabling users to make their measurements traceable to NIST -- and thus to internationally-recognized standards. Some specific examples include:

- Calibrations for Surface and Atmospheric Temperature Measurement Systems

Absolute radiometric flux measurements for accurate global climate monitoring satellite systems. Direct calibration support for numerous systems including NASA Earth Observing System, SeaWiFS, NOAA/GOES, Scripps-NISTAR instrument on Triana.

- Development and Calibration of Ozone Monitoring Instruments

The NIST developed Standard Reference Photometer (SRP) is a standard instrument for ozone measurements used at NIST, EPA, and an increasing number of other National Laboratories worldwide. There are over 25 NIST-built SRPs in use around the World. NIST is currently collaborating with the International Bureau of Weights and Measures (BIPM) in the design and construction a new Primary Reference Photometer to further enhance the accuracy and worldwide comparability of ozone measurements.

- Absolute Humidity Standards

NIST develops and maintains primary humidity standards and offers calibration services for humidity monitoring instrumentation.

- FTIR Database to Support Open-Path Sensing for VOCs

NIST has developed a database that is used for calibrating open-path Fourier-Transform Infrared Spectroscopic Sensing devices, which increasingly are being used for real-time monitoring of gases of environmental and GCC interest. NIST has completed work on 40 of the approximately 100 species initially targeted by US EPA. These spectra and absorption coefficient data are obtained directly from NIST primary gas standards, and thus facilitate traceability of field measurements to internationally recognized standards.

- Standards for Aerosol Measurements

NIST has programs in PM metrology involving particle-size calibration, morphological and compositional mapping, Standard Reference Material (SRM) development and certification for organic and inorganic compounds, metals, black carbon, and isotopic species. We have recently developed a series of particles on filter standards that are will facilitate accurate identification and quantification of atmospheric particulate contaminants needed by U.S. industry and government.

GCC-Related Measurement Science and Data

These activities contribute to the science base for understanding the behavior of industrial chemicals in the environment, evaluation of environmentally benign chemical alternatives, and measurement techniques for key environmental species in the atmosphere. Some research projects include:

- Alternative Refrigerants

CFCs and related compounds have had a significant impact on global climate change and ozone depletion. NIST has a comprehensive program on the physical and chemical properties of pure compounds and mixtures that has been used for identification of alternative refrigerants by industry. Components of this program include: industrial consultation on exploratory materials and new commercial fluids; thermophysical measurements and critical data evaluation; theoretical modeling; establishment and promulgation of international standards; and dissemination to industry via databases.

- Atmospheric Chemistry

NIST has an array of measurement programs aimed at furthering the understanding of the chemistry of the atmosphere and the environmental lifetime and global warming potential of industrially important chemicals. NIST conducts measurements of isotopic compositions of atmospheric compounds, develops spectral databases in support of optical-based measurements of chemical emissions, hazardous air pollutants, and greenhouse gases, conducts studies of ozone chemistry and fundamental chemical reactions of atmospheric constituents, develops new sensing technologies for monitoring atmospheric compounds, and provides analytical measurements capability is maintained for providing measurements and standards for the chemical composition and size distributions of aerosols, dust, and soot. The NIST Chemical Kinetics Database is the most thorough and comprehensive collection of gas phase kinetic data in the world and provides key inputs for models of atmospheric chemistry.

- Fluid Standard Reference Data

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NIST has developed several standard reference databases that describe the basic thermophysical properties of atmospheric gases as a function of pressure, temperature, and composition.

- Database to Support CO_2 Sequestration Technologies

NIST is developing thermophysical properties data for CO_2 sequestration, including reference quality thermodynamic surfaces for water-carbon dioxide systems. These data are needed to understand global CO_2 budget cycles.

Infrastructure for International Measurement Comparability

NIST collaborates with the National Metrology Institutes (NMIs) of other countries/economies to carry out international comparisons to assure that international measurements relevant to global climate change have a firm basis for intercomparability. For almost a decade, NIST has collaborated with the Netherlands Measurement Institute (NMi) and the National Physical Laboratory (NPL) of the United Kingdom in the development and value assignment of gas mixture standards. In October 1999, NIST was one of forty NMIs to sign a Mutual Recognition Arrangement (MRA) developed by the International Committee on Weights and Measures (CIPM) for assessing the comparability of national measurement standards and providing a basis for mutual recognition of the calibration and measurement certificates that they provide. Ten additional economies have become signatories to the MRA over the past two years.

NIST has taken a leadership role in the CIPM Consultative Committee on the Quantity of Material (CCQM) in order to assure the effective, fair and metrologically sound implementation of this MRA. Gas Analysis is one of the six working groups within the CCQM. Under the auspices of this working group, international Key Comparisons have been completed for carbon monoxide, carbon dioxide, nitrogen monoxide, natural gas, automotive emission gases and VOCs -- all in nitrogen at concentrations used for instrument calibration. Key Comparisons for carbon dioxide, methane and VOCs in air at atmospheric concentrations are planned for the coming year.

As an example of the type of information provided through these Key Comparisons, see below both graphical and tabular data reflective of the degree of equivalence among national standards for carbon dioxide in nitrogen (surrogate air) at the 100 parts-per-million level from the following ten NMIs:

- NIST (United States)
- BAM (Germany)
- BNM-LNE (France)
- KRISS (Republic of Korea)
- NMi (Netherlands)
- NPL (United Kingdom)
- NRCCRM (China)
- NRLM (Japan)
- OHM (Hungary)

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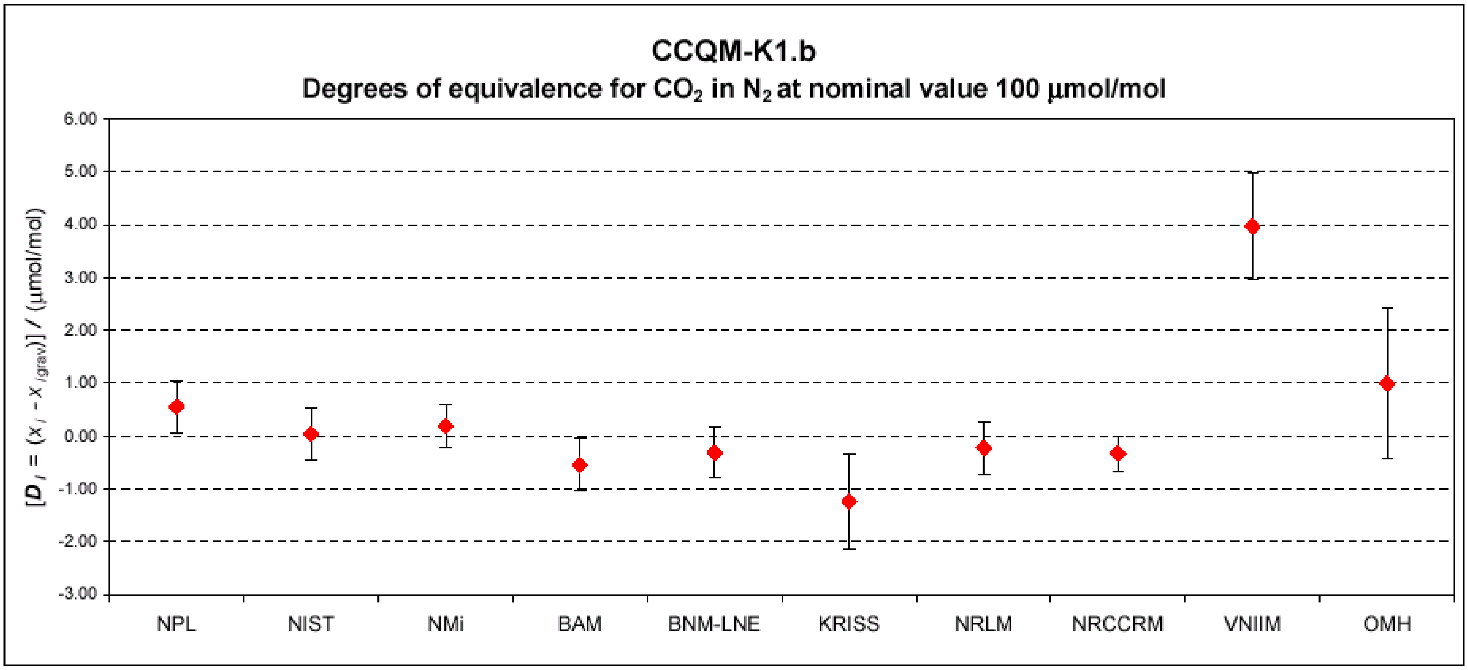
- VNIIM (Russian Federation)



Lab *i* ⇩	D_i	U_i	NPL		NIST		NMi		BAM		BNM-LNE		KRISS		NRLM		NRCCRM		VNIIM		OMH	
	µmol/mol		D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}	D_{ij} µmol/mol	U_{ij}
NPL	0.55	0.50			0.53	0.71	0.37	0.64	1.10	0.71	0.87	0.69	1.80	1.04	0.78	0.71	0.88	0.60	-3.41	1.12	-0.44	1.52
NIST	0.03	0.50	-0.53	0.71			-0.15	0.64	0.57	0.70	0.34	0.69	1.27	1.04	0.26	0.71	0.36	0.60	-3.94	1.12	-0.96	1.52
NMi	0.18	0.40	-0.37	0.64	0.15	0.64			0.73	0.64	0.50	0.62	1.43	0.99	0.41	0.64	0.51	0.52	-3.79	1.08	-0.81	1.49
BAM	-0.55	0.50	-1.10	0.71	-0.57	0.70	-0.73	0.64			-0.23	0.69	0.70	1.04	-0.32	0.70	-0.22	0.60	-4.51	1.12	-1.54	1.52
BNM-LNE	-0.32	0.48	-0.87	0.69	-0.34	0.69	-0.50	0.62	0.23	0.69			0.93	1.03	-0.09	0.69	0.01	0.58	-4.28	1.11	-1.31	1.51
KRISS	-1.24	0.91	-1.80	1.04	-1.27	1.04	-1.43	0.99	-0.70	1.04	-0.93	1.03			-1.01	1.04	-0.91	0.97	-5.21	1.35	-2.23	1.70
NRLM	-0.23	0.50	-0.78	0.71	-0.26	0.71	-0.41	0.64	0.32	0.70	0.09	0.69	1.01	1.04			0.10	0.60	-4.20	1.12	-1.22	1.52
NRCCRM	-0.33	0.33	-0.88	0.60	-0.36	0.60	-0.51	0.52	0.22	0.60	-0.01	0.58	0.91	0.97	-0.10	0.60			-4.30	1.05	-1.32	1.47
VNIIM	3.97	1.00	3.41	1.12	3.94	1.12	3.79	1.08	4.51	1.12	4.28	1.11	5.21	1.35	4.20	1.12	4.30	1.05			2.98	1.75
OMH	0.99	1.43	0.44	1.52	0.96	1.52	0.81	1.49	1.54	1.52	1.31	1.51	2.23	1.70	1.22	1.52	1.32	1.47	-2.98	1.75		

Data from CCQM Key Comparisons that have been completed in these areas can be viewed from: http://icdb.nist.gov/process_search/search_results.asp