Organics, Mercury and NOx, oh my!

C130 aircraft operations during NOMADSS

Dan Jaffe

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NAAMEX

- **Mercury is an important environmental toxin. New rules on coal fired pp will cost ~2 billion $US per year when fully implemented. Yet there are large uncertainties in our understanding of the global sources and cycling of Hg.**
- **In past 10 years we have extensive observations of Asian Hg outflow, but almost none from US source region.**
- **NAAMEX follows on the successful WAMO project, which was a much smaller effort focused on validation of our airborne Hg measurement capabilities.**

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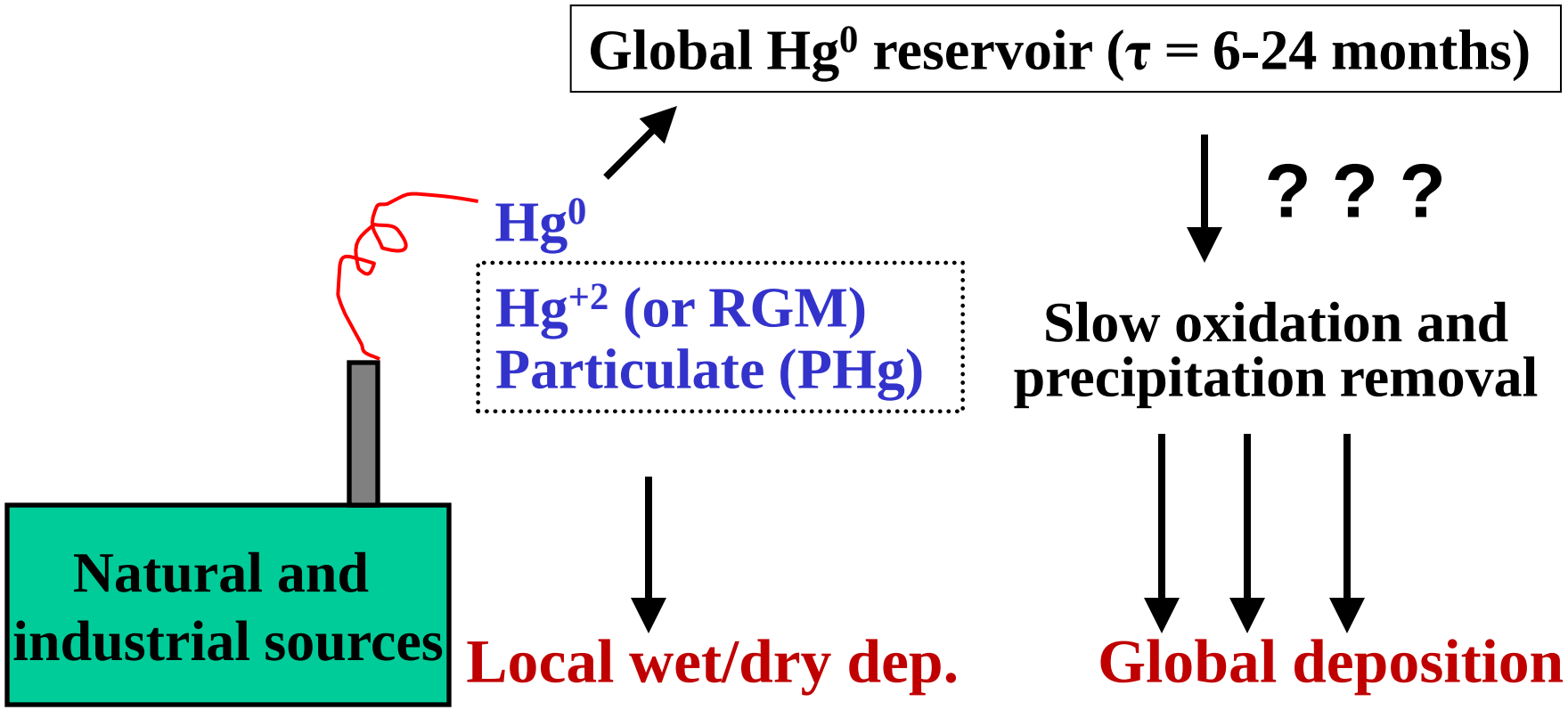
Basic Atmospheric Mercury Cycle



Whether the Hg is emitted as Hg^0, Hg^{+2} (RGM) or particulate Hg (PHg) is critical. RGM and PHg will deposit locally, whereas Hg^0 will enter the global Hg cycle due to its long lifetime.

Hg(II) compounds = Reactive Gaseous Mercury = RGM

Particulate Mercury = PHg

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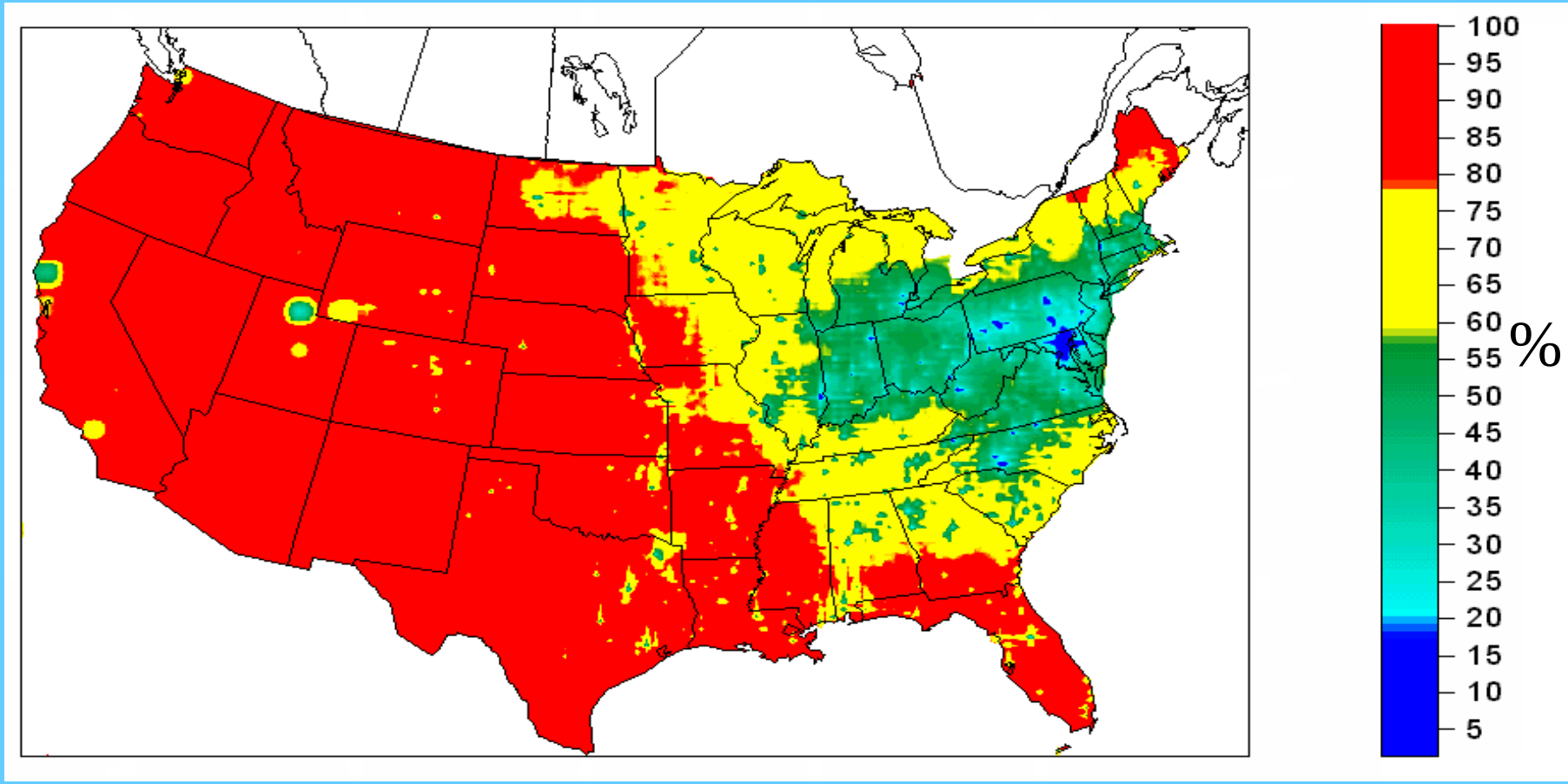
Model calculated contribution of non-US sources to Hg deposition (%)



Seigneur et al., 2004. (Similar results in Selin et al 2007 and Strode and Jaffe 2008 using GEOS-CHEM model.)

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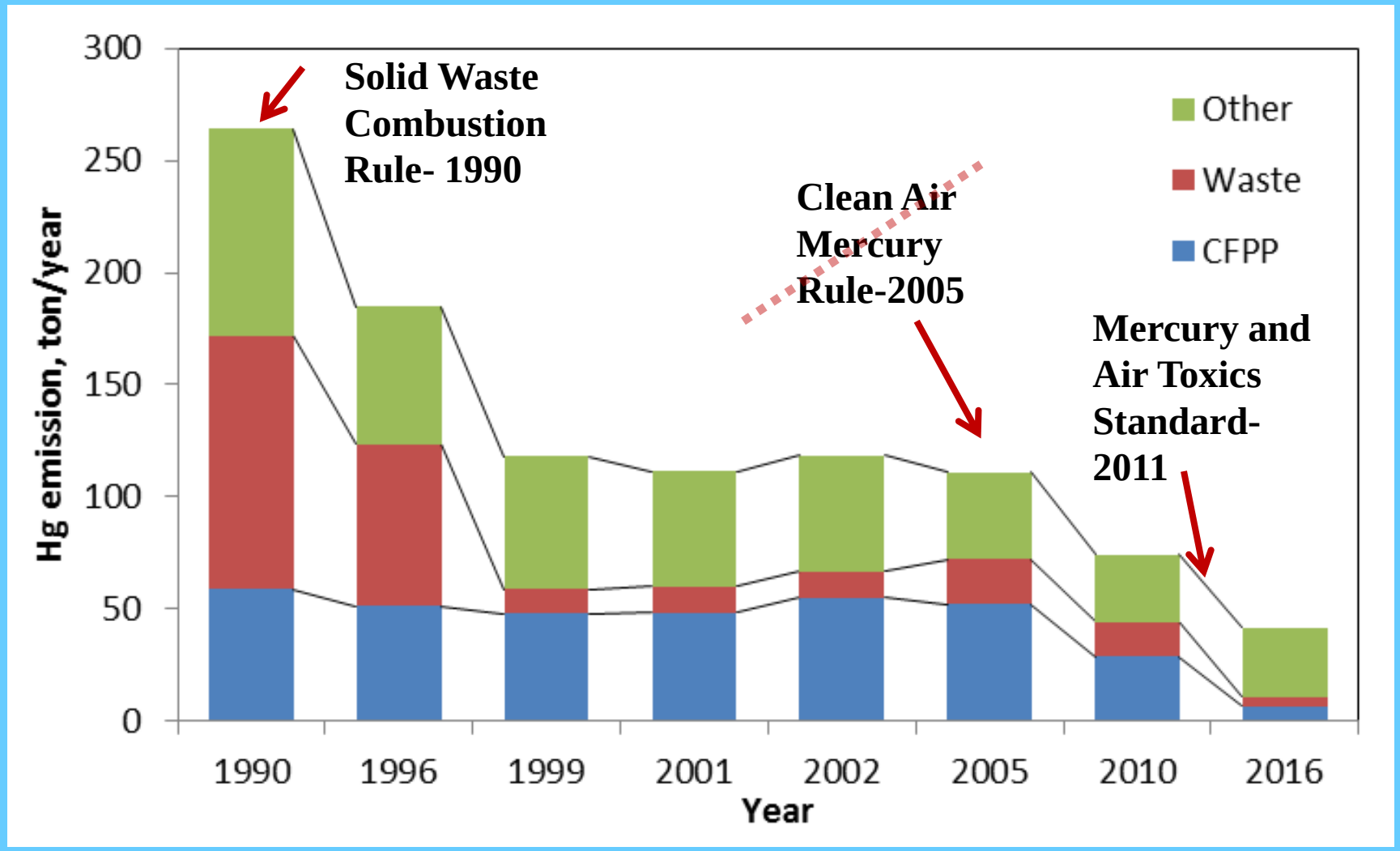
Trend in U.S. anthropogenic Hg emission



Slide from Yanxu Zhang.

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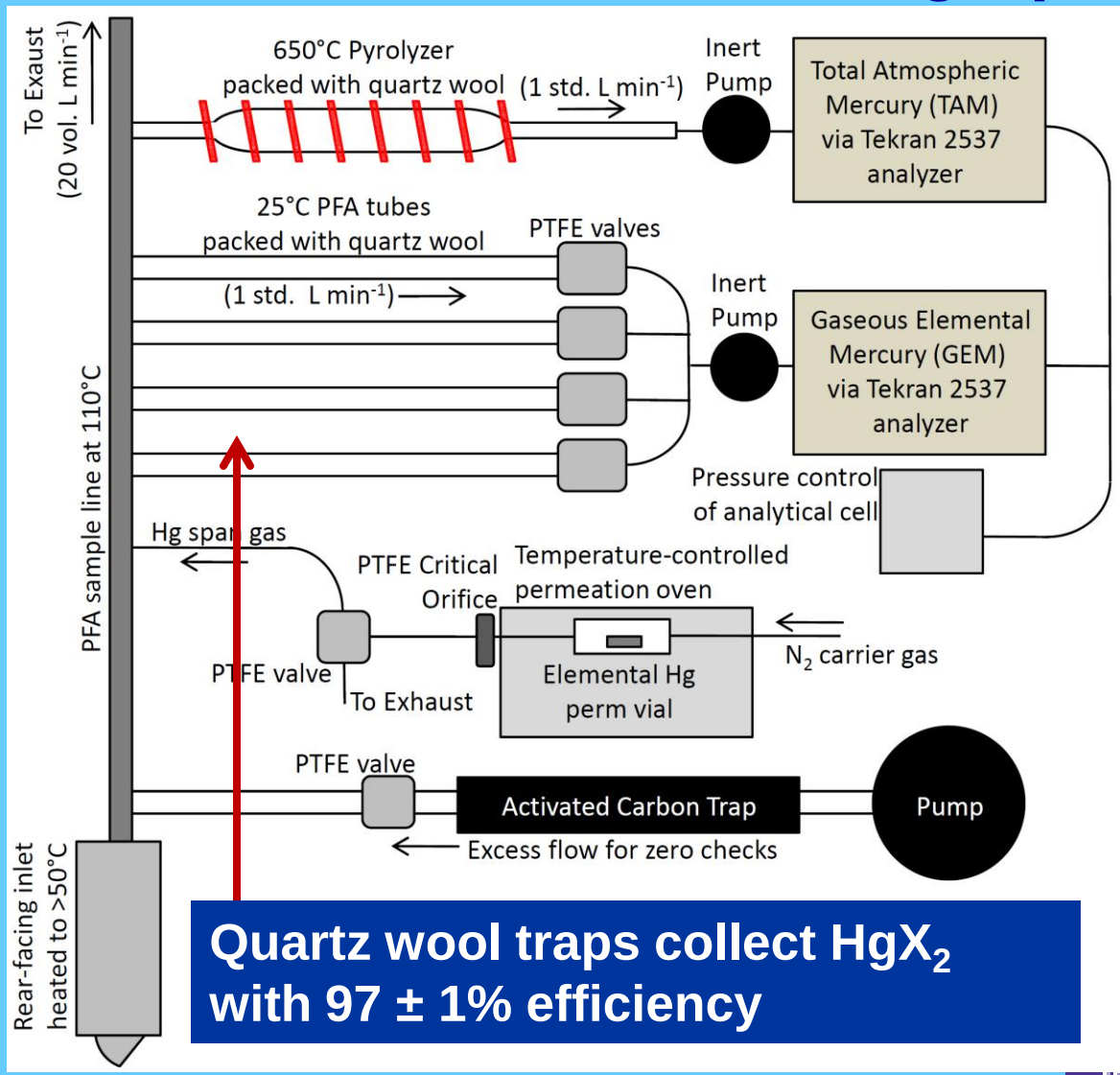
A new tool to understand atmospheric Hg: UW-Detector of Oxidized Hg Species (UW-DOHGS)



Quartz wool traps collect HgX_2 with 97 ± 1% efficiency

Lyman and Jaffe 2011

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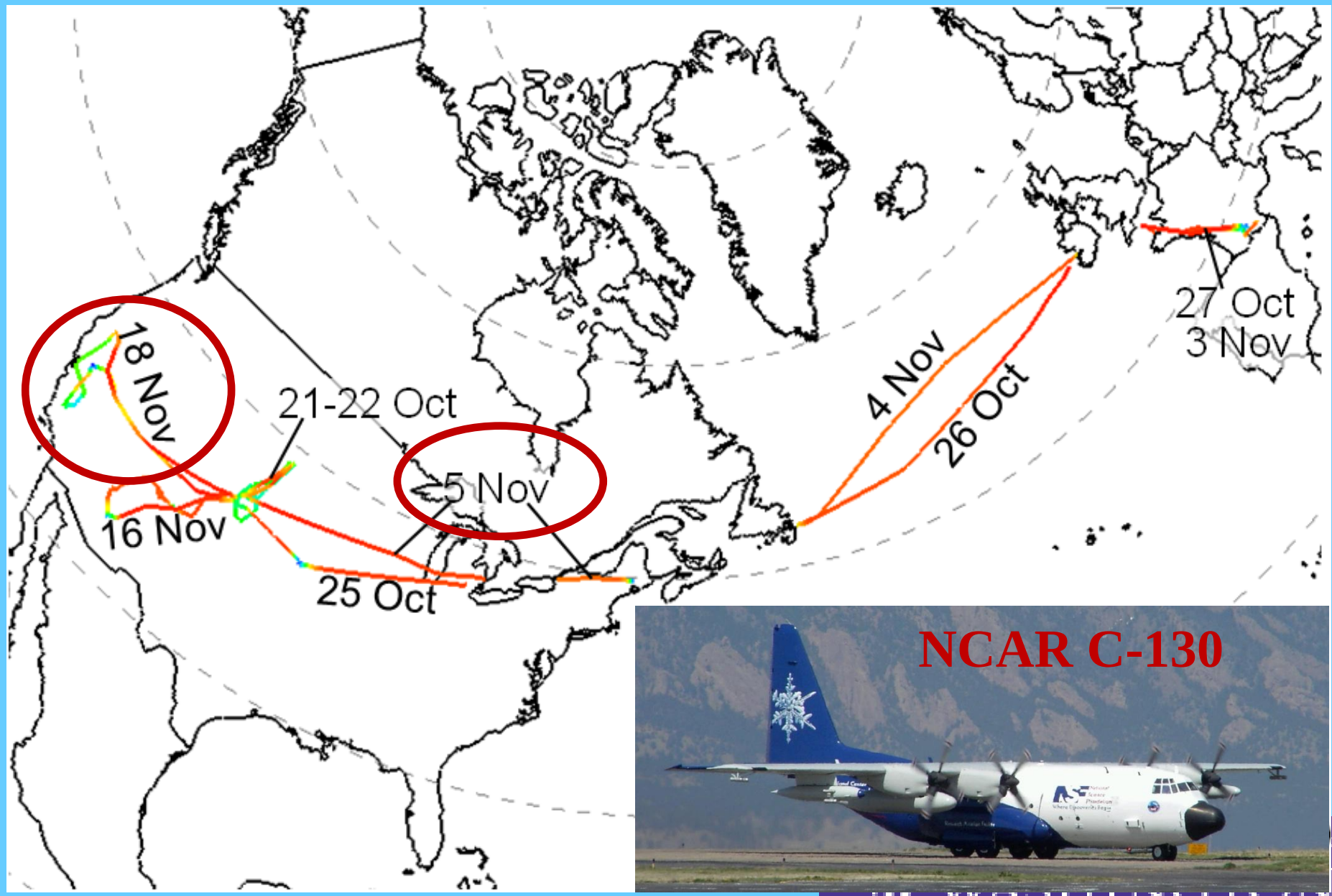
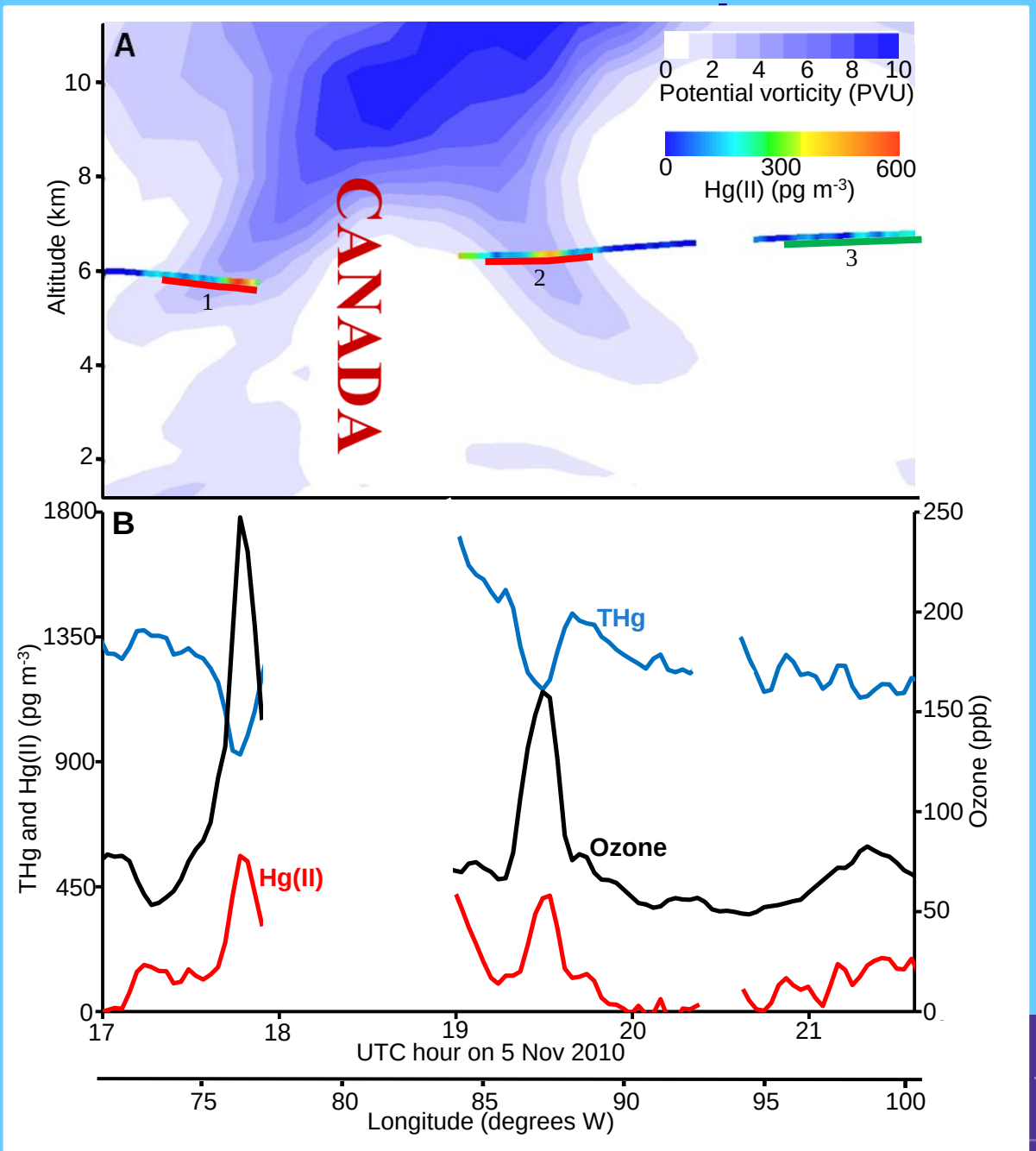
WAMO measurements, Fall 2010



Nov 5th flight: First direct observations of Hg^{2+} in UT/LS



Lyman and Jaffe, Nature Geosciences (2011)

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Key uncertainties in global Hg cycle

- Industrial emissions (at least +/-30%);
- Speciation of industrial emissions;
- Natural emissions (+/- 100%);
- Wet/dry deposition over most of the globe;
- Ability to measure Hg^{+2} in the atmosphere;
- Atmospheric chemistry of Hg;
- Cause of recent declines in global Hg.

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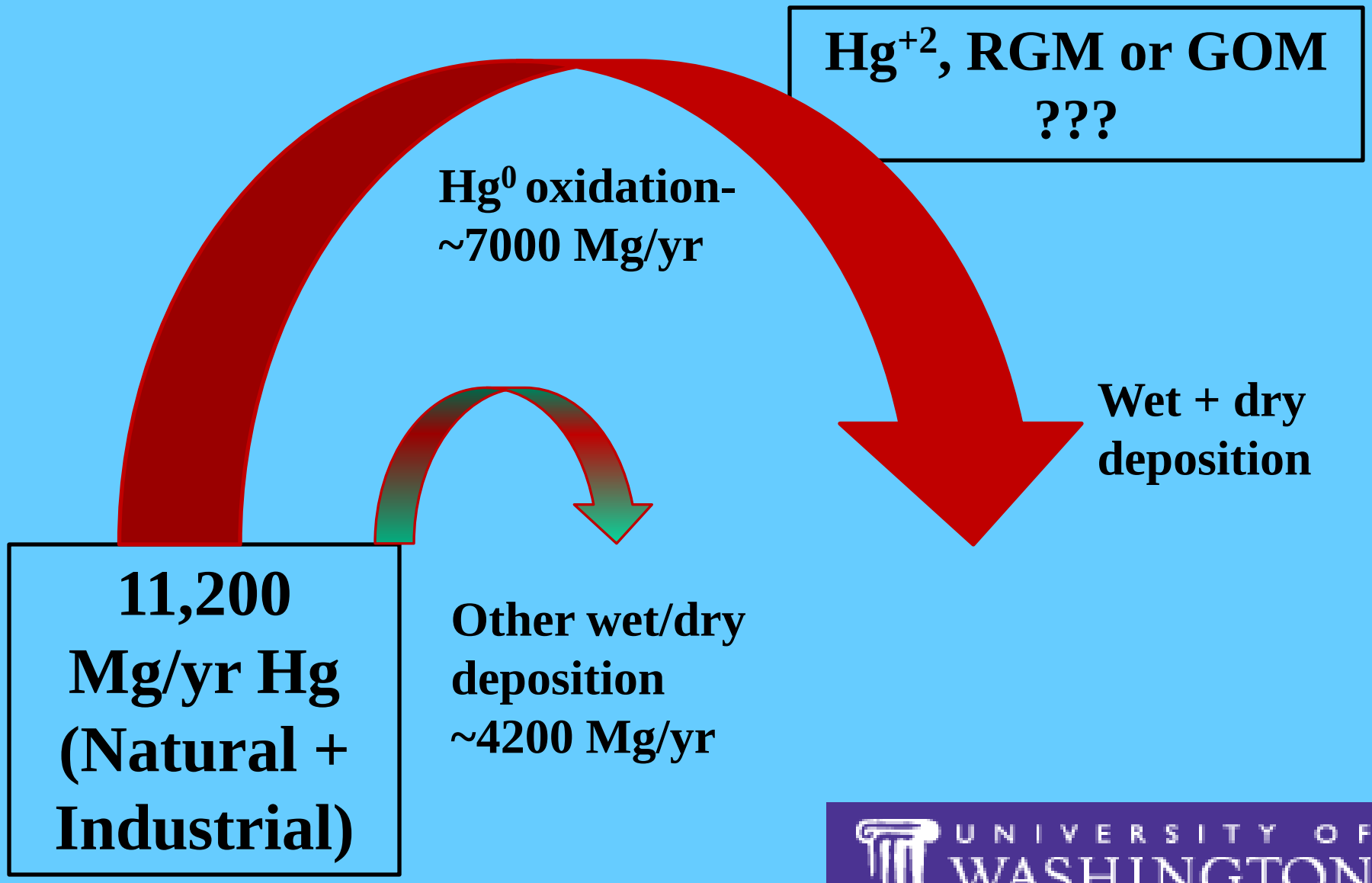
Global Hg budget (based on Selin et al 2008)



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Mt. Bachelor, Oregon, 2.8 km above sea level

Photo by Randy Hopfer

- The only free tropospheric research site on the west coast of the U.S.
- Continuous observations of CO, O_3, aerosols and Hg since 2004.
- Frequent detection of Asian pollution plumes (Jaffe et al., 2005; Weiss-Penzias et al., 2006; 2007; NAS/NRC 2009; UNEP/HTAP 2009);
- Supported by NSF and EPRI.

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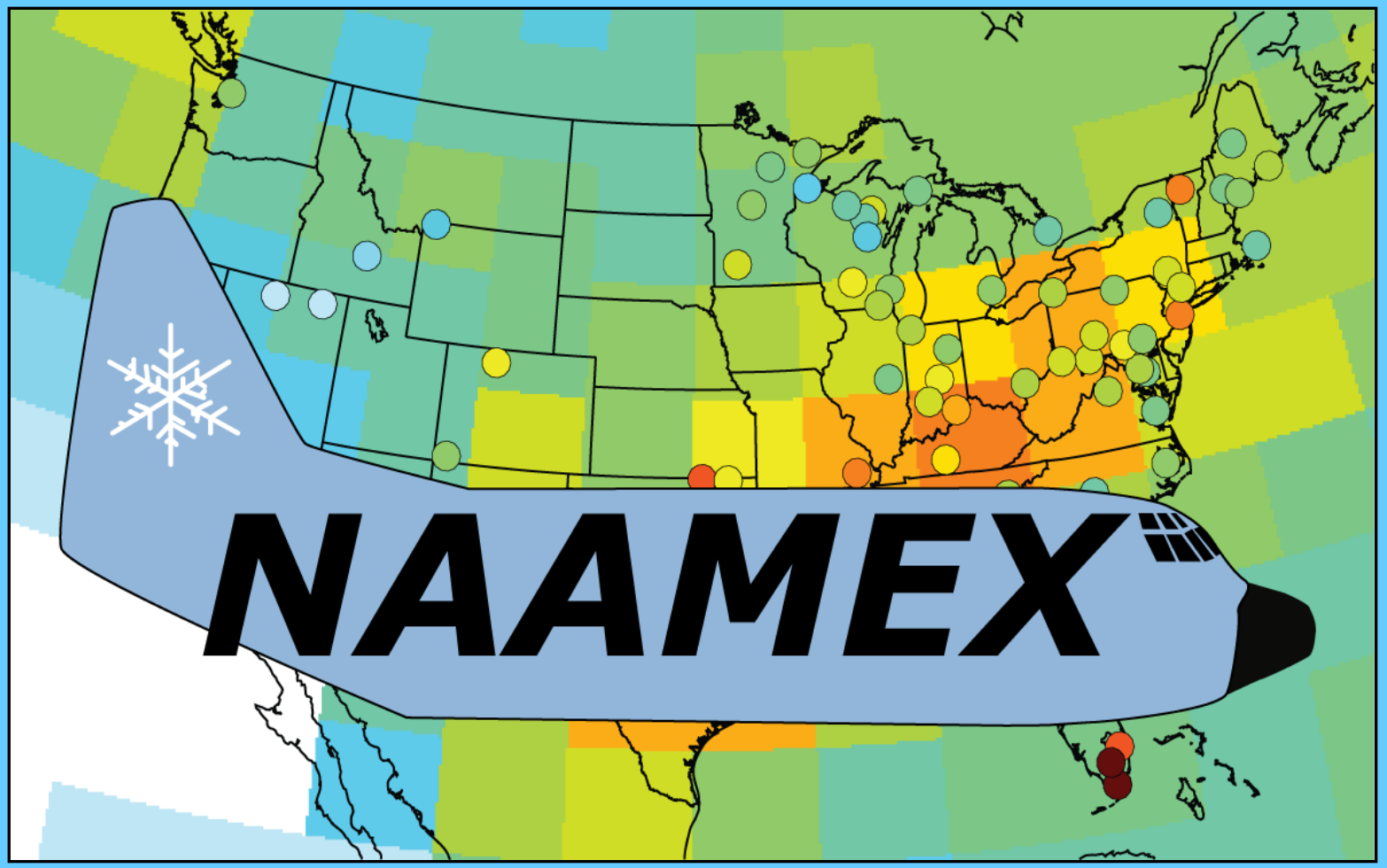
North American Airborne Mercury Experiment (NAAMEX)
Southern Oxidant and Aerosol Study (SOAS)
Re-NOx-ification Pathway in the Troposphere (TROPHONO)



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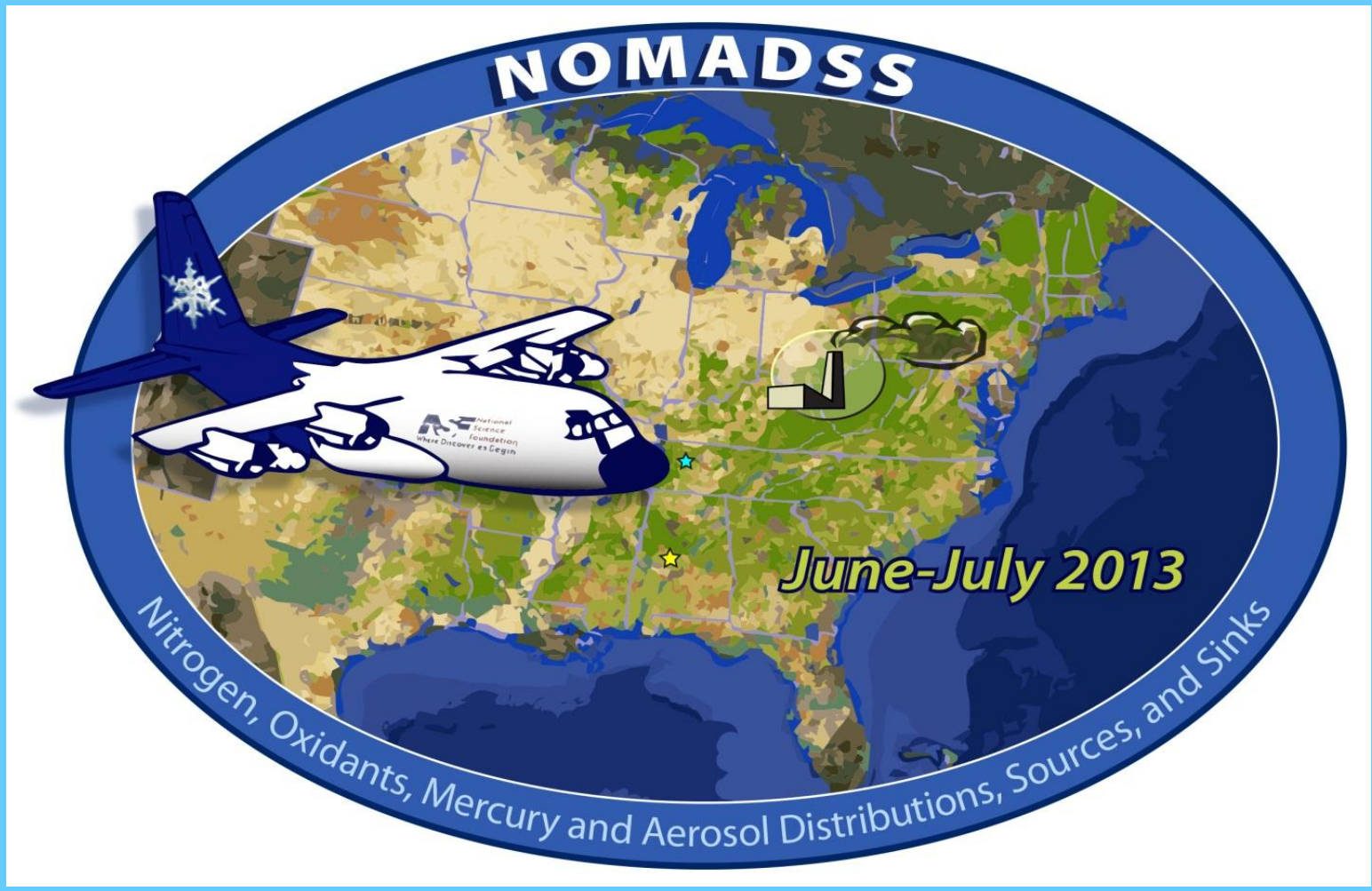
NOMADSS Flight tracks and science goals

Dan Jaffe



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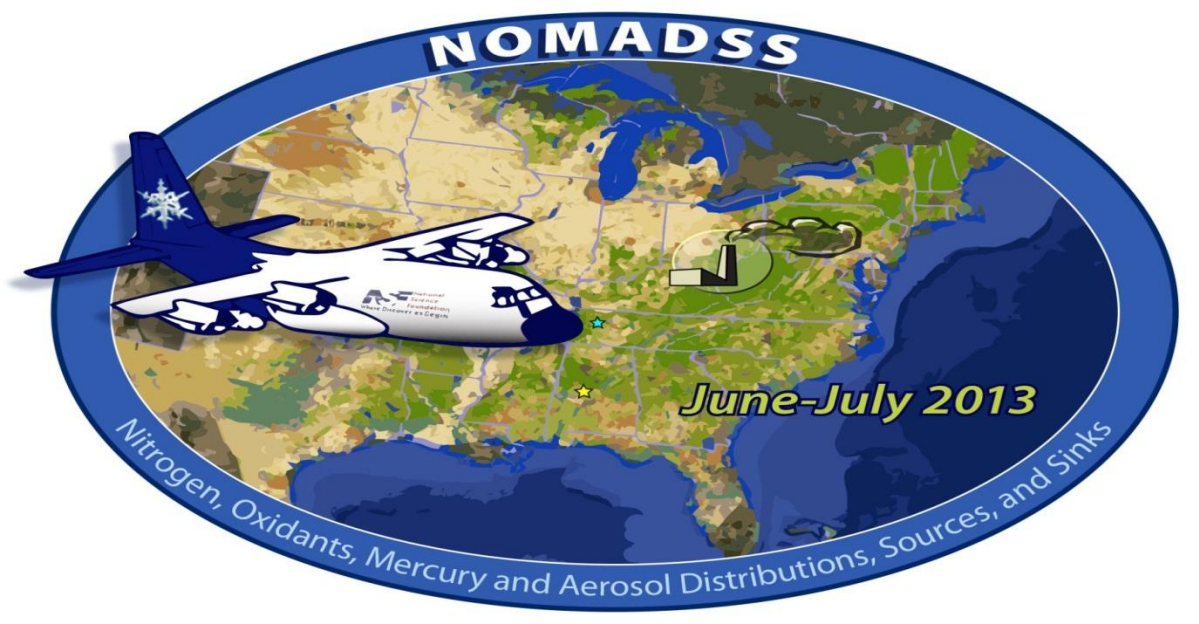
NOMADSS

- 18 Research fights, 150 hours
- 7 different flight patterns
- A variety of models run in forecast and NRT mode for fight planning



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Science goals combine goals from SOAS, NAAMEX and TROPHONO

SOAS: Quantify biogenic emissions and their interactions with anthropogenic pollutants and to understand the implications for atmospheric chemistry, air quality and climate.

NAAMEX: Constrain emissions of mercury from major source regions in the Eastern United States and quantify the distribution and chemical transformations of speciated mercury in the troposphere.

TROPHONO: Investigate the role of particulate nitrate photolysis in the cycling of reactive nitrogen species in the troposphere, focusing on HONO as an intermediate product.

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C-130 instrument package

Instrument	Lead	Location
RAF CDP Cloud Probe	Rogers	wing pod
RAF PCASP Aerosol Probe	Rogers	wing pod
RAF SPP-300 Aerosol Probe	Jensen	wing pod
RAF UHSAS Aerosol Probe	Rogers	wing pod
RAF King Probe Liquid Water	Schanot	wing
RAF OPHIR-III In Cloud Temperatu	Beaton	wing pod
RAF Cloud Base Temperature	Schanot	fuselage
RAF Radiometric Surface Tempera	Schanot	fuselage
RAF Up/Down IR Irradiance	Haggerty	fuselage
CARI NO-NO2	Weinheimer	cabin / HIMIL (1
CARI Fast Ozone	Campos	cabin / HIMIL (1
CARI Carbon Monoxide	Campos	cabin / HIMIL (1
CARI Picarro Carbon Dioxide	Flocke	cabin / HIMIL (1
EOL / HAIS GT-CIMS (2 units)	Huey	cabin / HIMIL (2
EOL / HAIS TOGA	Apel	cabin / HIMIL (3
NCAR/ACD PTRMS	Karl	cabin / inlet
UW GEM Mercury	Jaffe	cabin /Special ir
UW GOM Mercury	Jaffe	cabin /Special ir
UW GOM / PHG	Jaffe	cabin /Special ir
CU HOx / H2SO4	Cantrell	cabin / Special i
SUNY HONO / HNO3	Zhou	cabin / HIMIL (4
SUNY pNO3 / pOrganics	Zhou	cabin / SDI inlet
SUNY Bulk Aerosol	Zhou	cabin / SDI inlet
UCLA Mini - DOAS	Stutz	cabin / window
Up/Down Vis & UV Irradiance	Haggerty	fuselage

Flight pattern 1

Horizontal and vertical profiles over rural Eastern U.S. regions with various vegetation types, daytime, eight flights (types 1a, 1b,1c,1d).	**SOAS objectives: direct quantification of VOC, ozone and NO_x surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of HO_x/NO_x/ozone/ organics/aerosol distributions, sources and sinks.** **NAAMEX objectives: Characterization of major Hg source region, examination of vertical profile of Hg^0 and Hg^{+2}.** **TROPHONO objectives: Examination of horizontal and vertical distributions of HONO, HNO_3, pNO_3 and NO_x in the continental background air masses; collection of bulk aerosol samples for photochemical experiments in laboratory.**

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Flight pattern 2

Horizontal and vertical profiles over rural Eastern U.S. regions with various vegetation types, early afternoon/night, one flight.	**<u>SOAS objectives</u>: direct quantification of VOC, ozone and NO_x surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of HO_x/NO_x/ozone/organics/aerosol distributions, sources and sinks.** **<u>NAAMEX objectives</u>: Characterization of major Hg source region, examination of vertical profile of Hg^0 and Hg^{+2}.** **<u>TROPHONO objectives</u>:Examination of horizontal and vertical distributions of HONO, HNO_3, pNO_3 and NO_x in the continental background air masses; examination of nighttime HONO formation and accumulation in the PBL and FT.**

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Flight pattern 3

Horizontal and vertical profiles over rural Eastern U.S. regions with various vegetation types, early-late morning, one flight.	**<u>SOAS objectives</u>: direct quantification of VOC, ozone and NO_x surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of HO_x/NO_x/ozone/organics/aerosol distributions, sources and sinks.** **<u>NAAMEX objectives</u>: Characterization of major Hg source region, examination of vertical profile of Hg^0 and Hg^{+2}.** **<u>TROPHONO objectives</u>:Examination of horizontal and vertical distributions of HONO, HNO_3, pNO_3 and NO_x in the continental background air masses; examination of maximal HONO nighttime accumulation and its morning photolytic decay in the PBL and in the FT**

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Flight pattern 4

Ohio Valley transect and profiling , daytime, two flights	**<u>SOAS objectives</u>: direct quantification of VOC, ozone and NO_x surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of HO_x/NO_x/ozone/organics/aerosol distributions, sources and sinks.** **<u>NAAMEX objectives</u>: Characterization of most concentrated Hg source region in North America, examination of vertical profile of Hg^0 and Hg^{+2}.** **<u>TROPHONO objectives</u>: Examination of horizontal and vertical distributions of HONO, HNO_3, pNO_3 and NO_x in the continental background air masses;; evaluation of relative HONO source strengths from photo-enhanced NO_x reaction on aerosol surface *vs* p-NO_3 photolysis in urban and industrial plumes.**

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Flight pattern 5

High elevation transect to west and profiling, daytime, two flights.	**SOAS objectives: Direct quantification of VOC, ozone and NOx surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of HOx/NOx/ozone/organics/aerosol distributions, sources and sinks.** **NAAMEX objectives: Examination of vertical profile of Hg^0 and Hg^{+2} in region where models predict high Hg^{+2}.** **TROPHONO objectives: Examination of horizontal and vertical distributions of HONO, HNO_3, pNO_3 and NO_x in the continental and oceanic air masses; collection of bulk aerosol samples for photochemical experiments in the laboratory.**

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Flight pattern 6

Florida/North Atlantic transect and profiling , daytime, two flights	**SOAS objectives: Direct quantification of VOC, ozone and NOx surface fluxes and reconcile differences with "top-down" emission estimates; better understanding of HOx/NOx/ozone/organics/aerosol distributions, sources and sinks.** **NAAMEX objectives: Characterization of outflow from major Hg source region, examination of vertical profile of Hg^0 and Hg^{+2}, verification of model predicted gradients in Hg.** **TROPHONO objectives: Examination of horizontal and vertical distributions of HONO, HNO_3, pNO_3 and NO_x in the continental and oceanic air masses;**

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Flight pattern 7

Offshore outflow flight: daytime, two 9-hr flights requested, early to late July	**SOAS objectives: N.A.** **NAAMEX objectives: Characterization of outflow from major Hg source region, examination of vertical profile of Hg^0 and Hg^{+2}, verification of model predicted gradients in Hg.** **TROPHONO objectives: Examination of distributions of HONO, HNO_3, pNO_3 and NO_x in the continental and oceanic air masses; Collection of bulk aerosol samples for photochemical experiments in the laboratory.**

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P.I. Schedule

Dates	Who	Flight pattern
June 1-15	Alex Guenther	1,2
June 15-30	Dan Jaffe	4,5,7
July 1-5	Xianlaing Zhou	3,6,7

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Key Challenges/Coordination issues

- Coordination between P.I.s to achieve all NOMADSS goals;
- Coordination between C-130, NOAA P-3, and other aircraft??
- Coordination with SOAS ground sites.

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