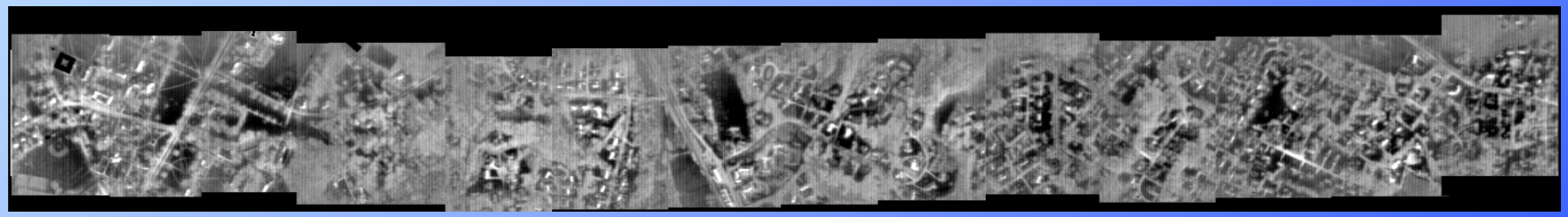
JUSTSAP FORUM 2009

Development of the Thermal Infrared Sensor (TIRS) for the Landsat Data Continuity Mission (LDCM)

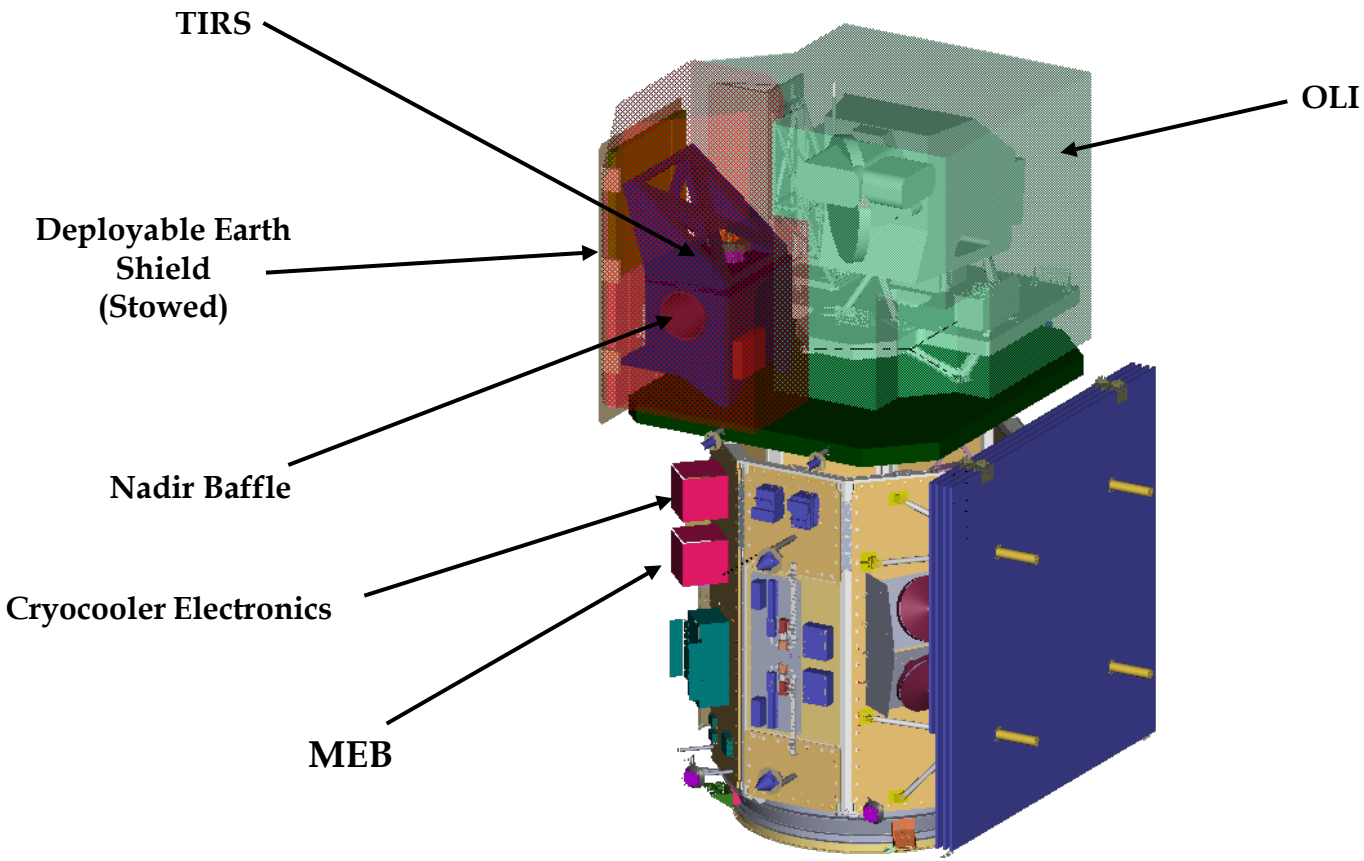


Peter Shu/Fran Stetina
NASA/GSFC

TIRS Project Overview

- TIRS will produce radiometrically calibrated, geo-located thermal image data
  - TIRS will deliver produce algorithms and parameters necessary to evaluate data and produce required outputs
  - Final scene data generated as part of the Data Processing and Archive Segment at the United States Geological Survey/ Earth Resources Observation and Science (EROS) facility in Sioux Falls, South Dakota
  - USGS responsible for operational algorithms
- TIRS will fly on the LandSat Data Continuity Mission
  - TIRS operates in concert with but independently of the Operational Land Imager (OLI)
- TIRS Level 1 - 3 requirements flow from LDCM

Instrument Configuration on Spacecraft



TIRS Spatial Coverage Requirements

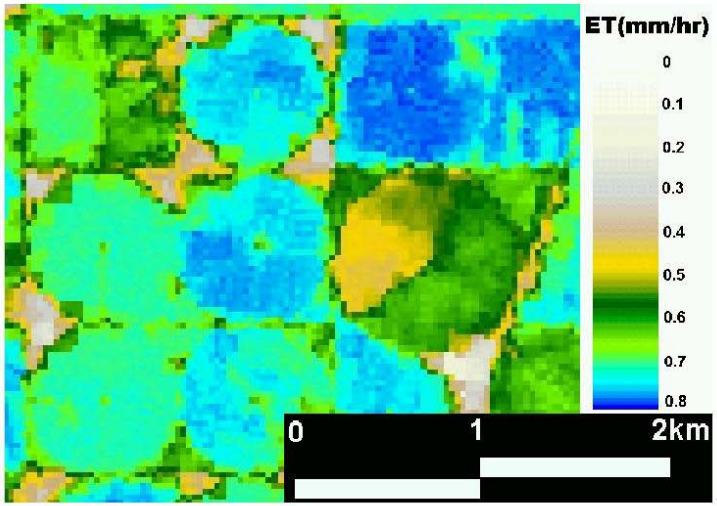
- Defined in terms of Worldwide Reference System-2 (WRS-2) Scenes
  - 185 km (cross-track) x 180 km (along-track) scene
- Spatial resolution < 120 m
  - < 0.1% dead or inoperable detectors
  - < 0.25% out of spec detectors
  - No adjacent cross-track dead or inoperable detectors
- Pushbroom implementation chosen
  - Similar in concept to OLI
  - Allow single row of data to be generated from 2 rows of detectors in each channel
- Use existing Indigo 9803 640 x 512 pixel ROIC to minimize schedule risk
  - Covers required 185 km swath in 3 arrays
    - 35 pixel overlap between arrays allows 100 m GSD (image margin) and tilt measurement
  - 25 mm pixel allows reasonable f/# @ 12.5 mm
  - Windowing and read-while-integrate capability maximizes flexibility
  - GSFC has experience with these arrays

TIRS Science Overview

- Landsat satellites have acquired single-band thermal images since 1978
  - Landsat 3 (1978 -1983) afforded 240 m spatial resolution in the thermal band
  - Landsat 4 (1982 - 1989) and Landsat 5 (1984 - present) afford 120 m resolution
  - Landsat 7 (1999 - present) affords 60 m resolution
- Landsat thermal data are now used operationally to monitor water consumption on a field-by-field basis in the U.S. West and internationally
  - Evapotranspiration cools vegetation
  - 120 meter resolution (or better) sufficient
  - Allowed by development of operational energy balanced-based evapotranspiration models
    - SEBAL, METRIC

Evapotranspiration at time of Landsat overpass

Oakley Fan, Idaho, July 7, 1989

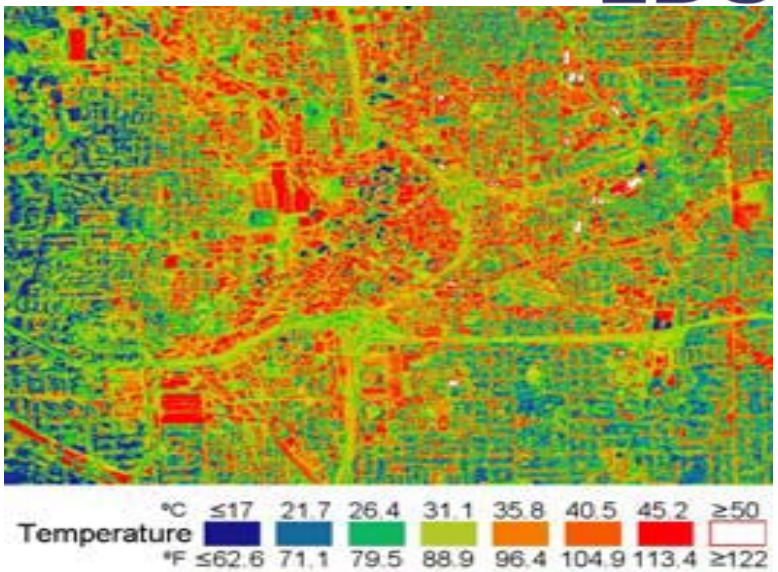


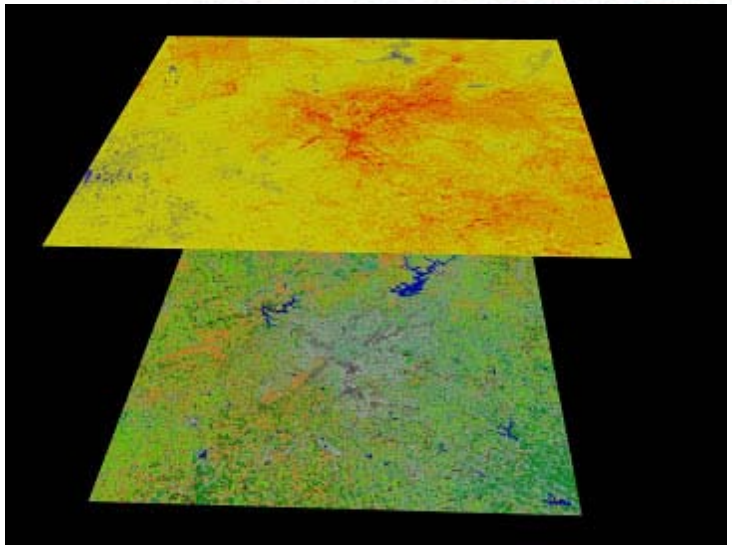
Using 120 m Landsat 5 Thermal Data
Courtesy of Richard Allen, Kimberly Research and Extension Center, University of Idaho

Additional TIRS Science

Landsat thermal data are used for:

- Mapping urban heat fluxes for air quality modeling (urban heat island)
- Volcanic hazard assessment, monitoring, and recovery
- Cloud detection and screening
- Mapping lake thermal plumes from power plants
- Burnt area mapping / Wildfire risk assessment
- Tracking material transport in lakes and coastal regions
- Identifying mosquito breeding areas and vector-borne illness potential



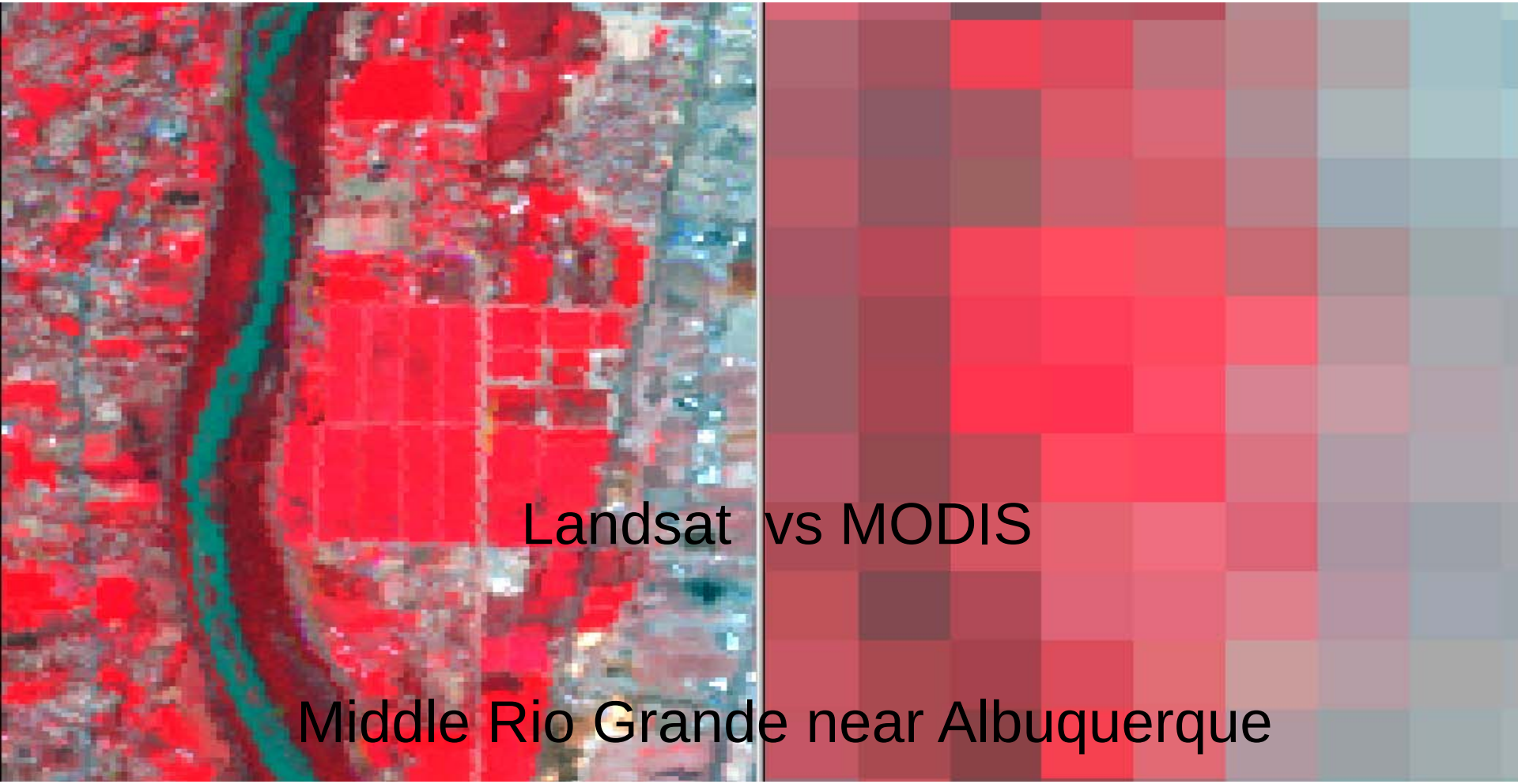


TIRS 2-Channel split window improves fidelity of thermal model

(Images from D. Quattrochi)

Why use High Resolution Imagery?

TIRS
LDCM

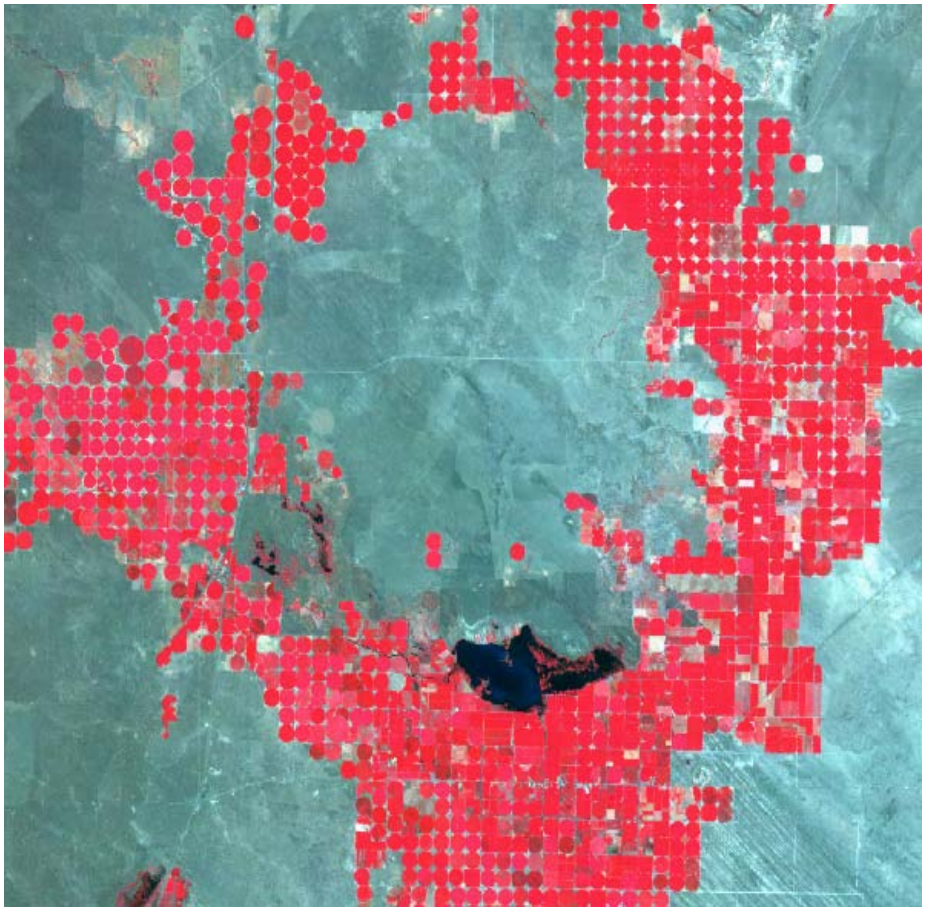


Landsat False Color
8/26/2002 10:33am

MODIS False Color
8/26/2002 11:02am

Priority Water Information Needs

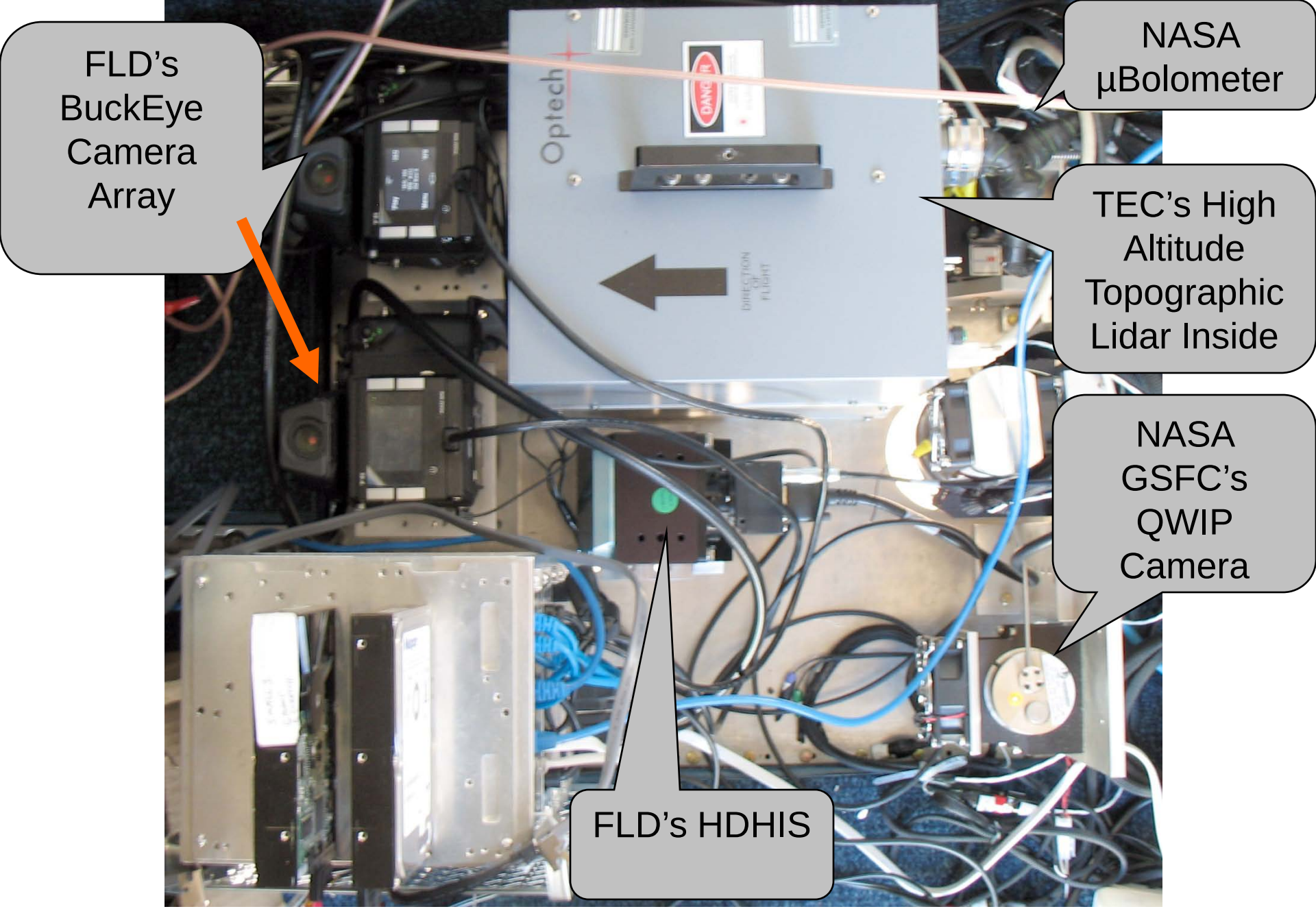
- Available Surface & Ground Water Supplies
- Present Water Uses
- Snowpack (NRCS)
- Streamflow (USGS)
- Evapotranspiration (NASA Landsat 8)
- Climate Change Impacts & Adaptation



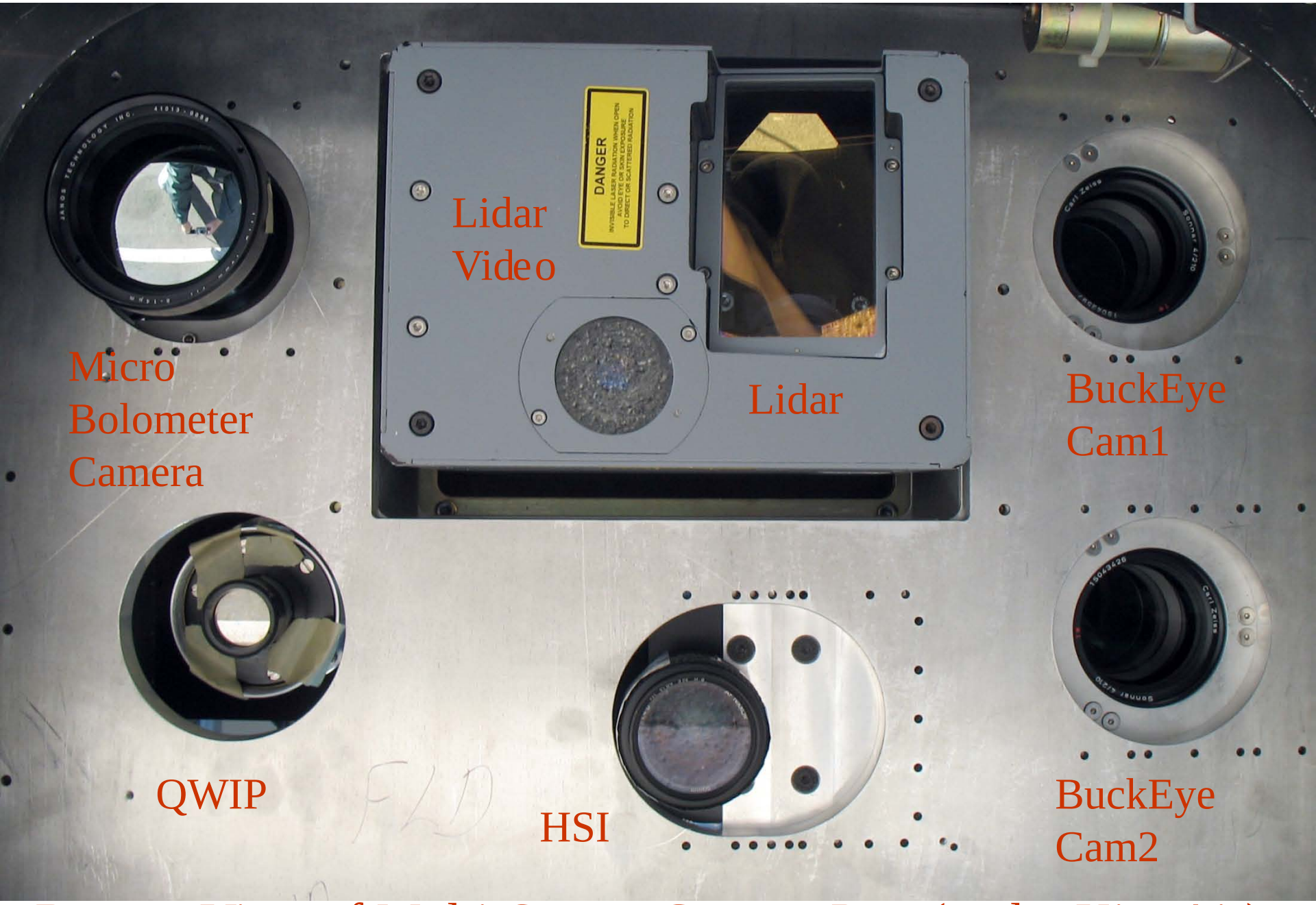
KingAir200 used for West Coast Multi-sensor Airborne Experiments

Experimental Airborne Multi-sensor Platform

- FLD’s BuckEye High Resolution Camera Array
- FLD’s Hyperspectral Instruments
- TEC’s High Altitude Topographic Lidar
- GSFC’s Long Wave InfraRed (LWIR) Camera

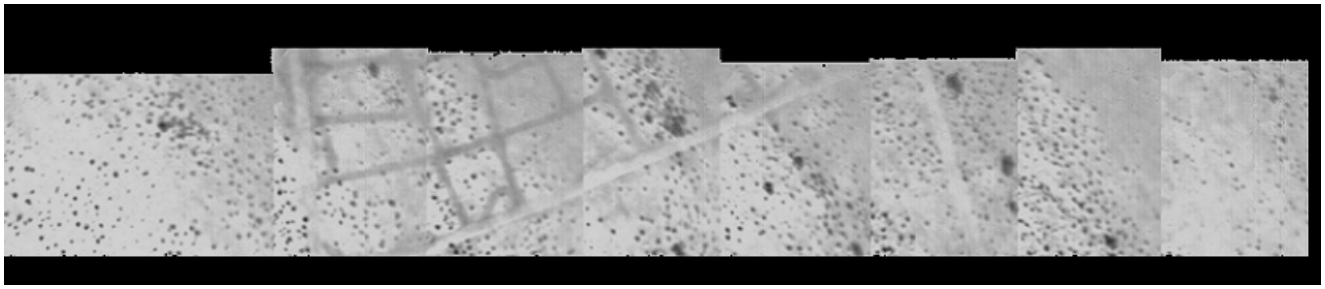


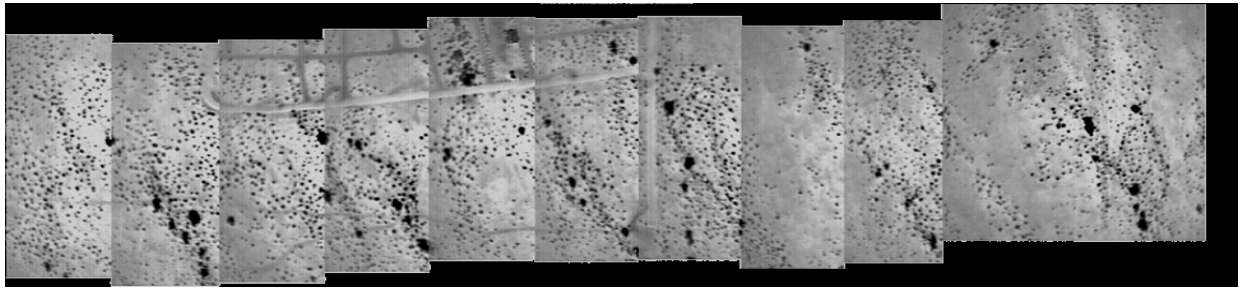
Top View of Multi-Sensor Setup (Inside the KingAir)

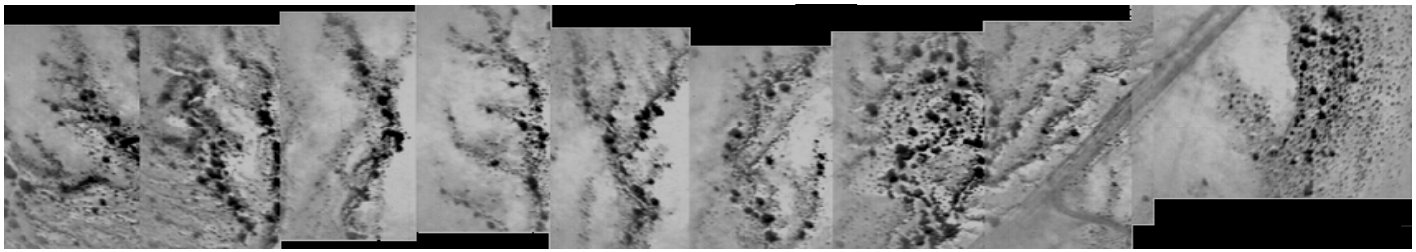


Bottom View of Multi-Sensor Camera Port (under KingAir)

Thermal Images from Yuma Proving Ground







BASE-ASIA

NASA

GSFC

soest university of hawai'i

UNIVERSITY OF MARYLAND 1856

CU

MOAC

BRRAA

Southeast Asia START Regional Center IHDP · IGBP · WCRP

ICT

IPST

Are Smoke Aerosols responsible for changing Cloud Life-Cycle and redistributing Fresh Water?

NASA

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ICT

IPST

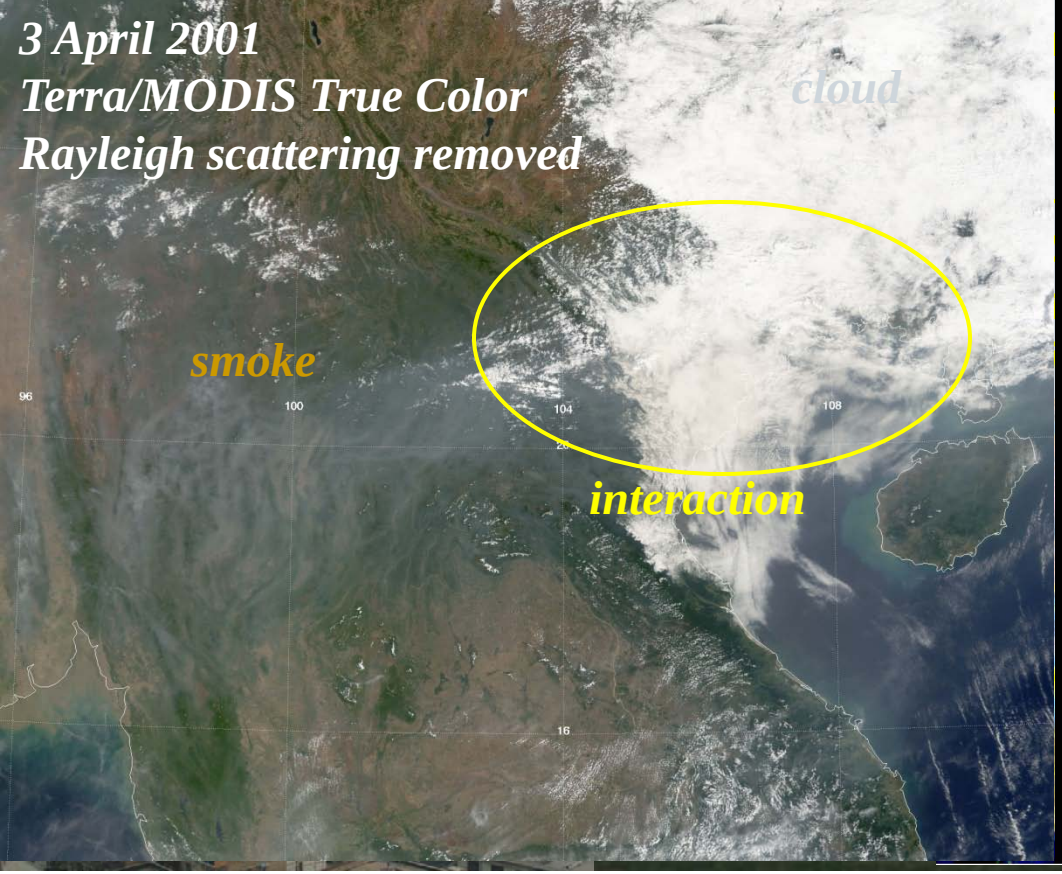
BASE-ASIA Science Team

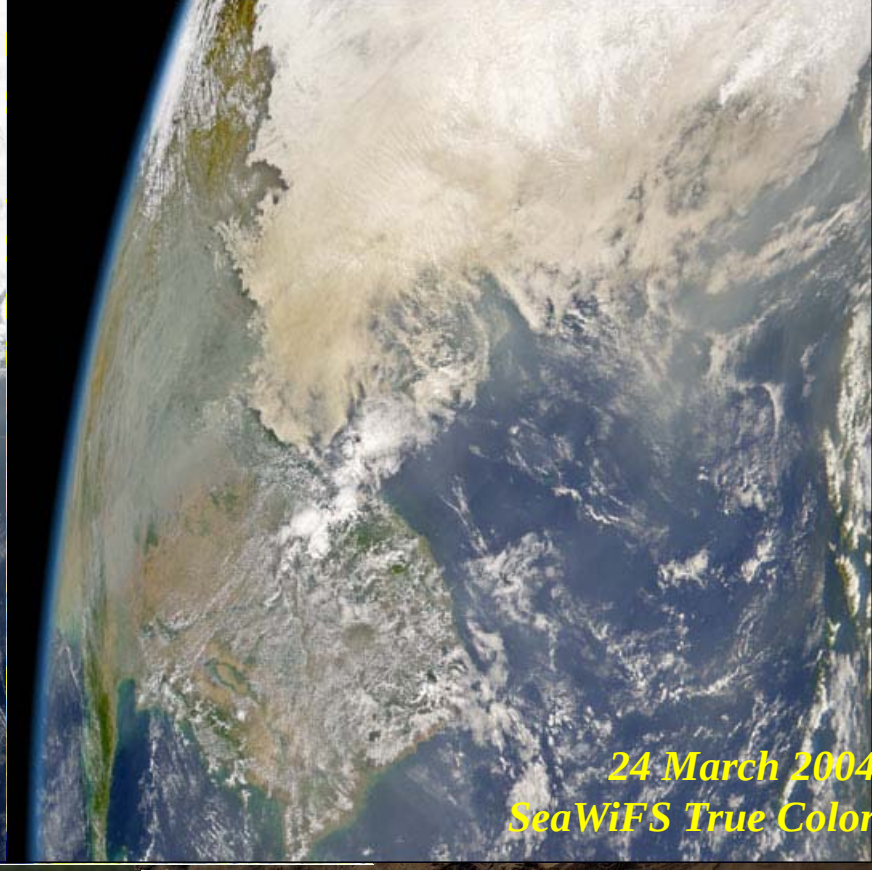
Humankind's activities have altered

our Planet Earth in many ways …

Rationale:

- *About 60% of world population reside in Asia*
  - *Southeast Asia portrays one of the fastest growing regions ...*
  - *Sheer population density presents major environmental stresses*
- *Economic expansion in this region is, in fact, accompanied by increases in coal & biomass burning, industrial pollution, and land cover & land use changes (i.e., anthropogenic and natural aerosols) …*
- *This regional change (e.g., aerosol, cloud, precipitation, etc.) will constitute a vital part of the global change in the 21st century.*





ACE-Asia: Aerosol Characterization Experiment - Asia, 2001, Huebert et al.; and follow-ups 2002-2003

APEX: Asian Atmospheric Particle Environment Change Studies, 1999-2003, Nakajima et al.

EAST-AIRE: East Asian Study of Tropospheric Aerosols - International Regional Experiment, Li et al.

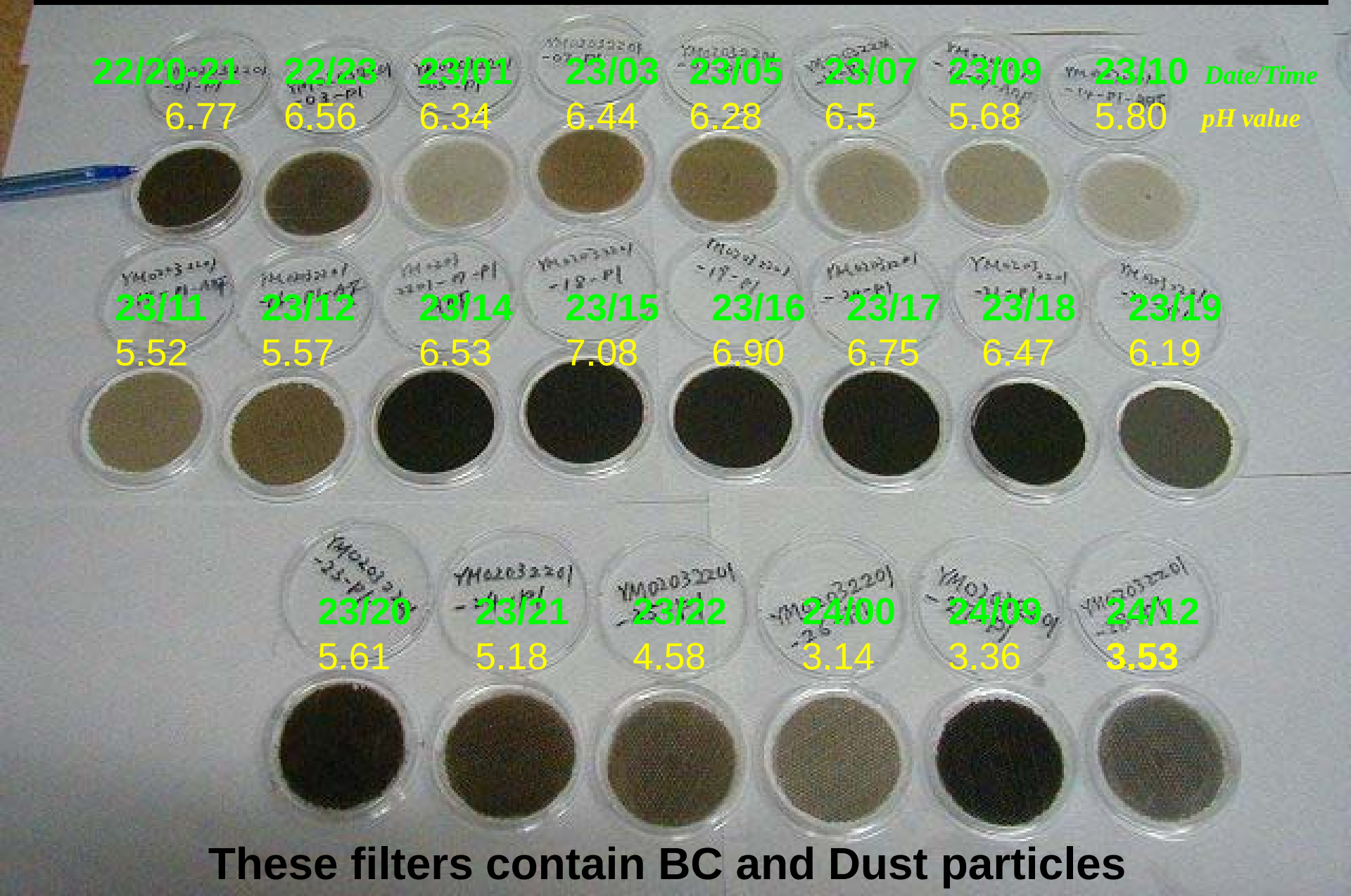
UAE2: Unified Aerosol Experiment in United Arab Emirates, 2004, Reid et al.

INDOEX: INDian Ocean EXperiment, 1999, Ramanathan et al.
ABC: Atmospheric Brown Clouds, Ramanathan et al.

RAJO-MEGHA: Radiation, Aerosol Joint Observations - Monsoon Experiment in Gangetic-Himalayan Area, Tsay et al.

BASE-ASIA: Biomass-burning Aerosols in South East Asia: Smoke Impact Assessment, Tsay et al.

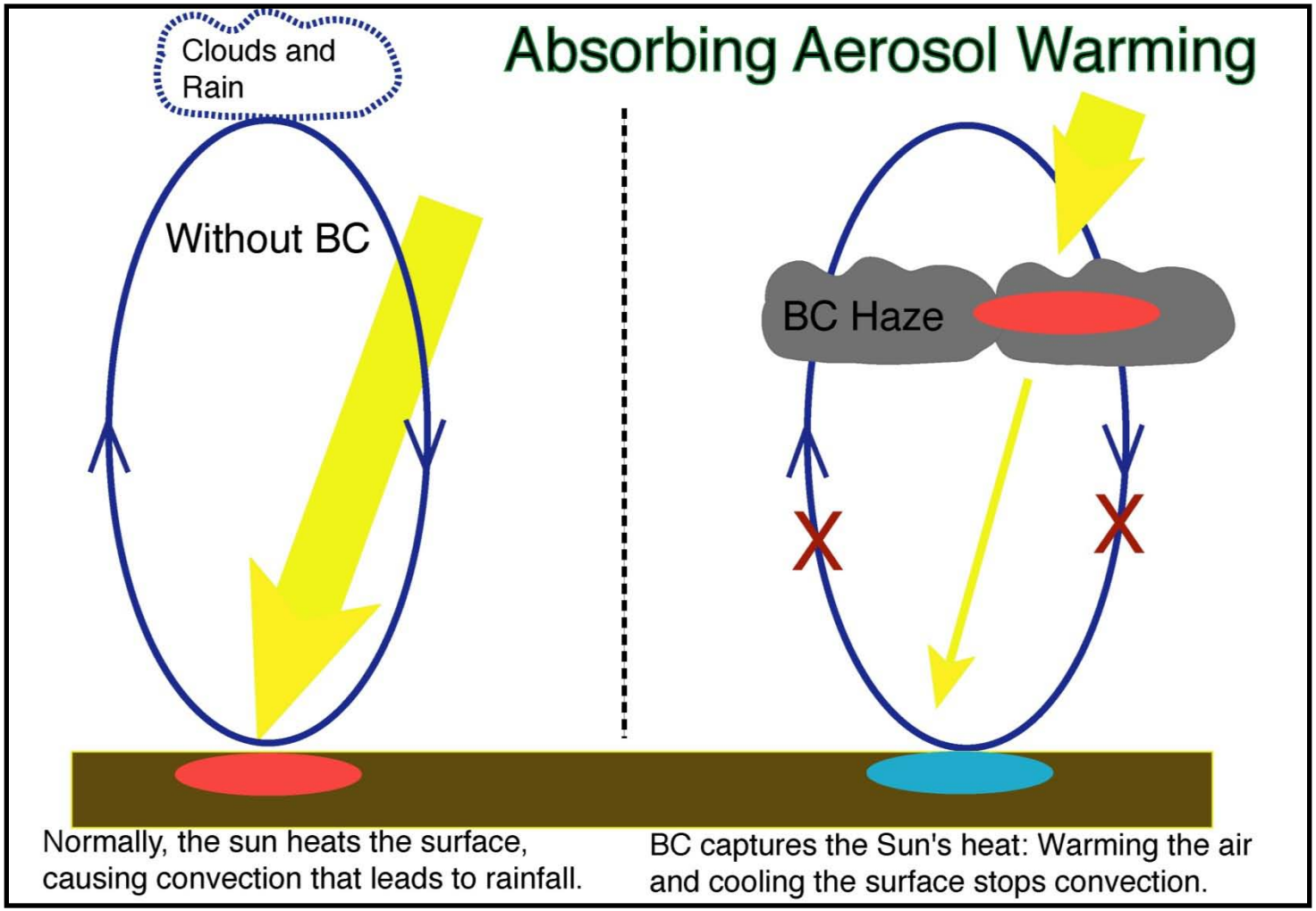
BC particles are so dark that they absorb light and convert it into heat, warming the air and cooling the surface.



These filters contain BC and Dust particles

Atmospheric aerosols *can* reduce rainfall:

Light-absorbing particles (smoke, soot, Black Carbon: “BC”) warm the upper layers of the atmosphere, reducing surface evaporation and cutting off convection that is an essential part of the hydrological cycle†.



†Ramanathan, et al., Aerosols, climate, and the hydrological cycle, *Science*, *294*, 2119-2124, 2001.

How can we determine how serious a hydrological problem absorbing particles cause for Thailand?

Numerical models of atmospheric radiation and hydrological models are the tools used for assessing such impacts.

Unfortunately, these models are no more accurate than the numbers put into them to describe the detailed light-absorbing properties of each type of particles:

Field-burning smoke
Diesel exhaust
Smokestack plumes
Soil dust particles

The Primary Goal of BASE-ASIA is to accurately *measure* the impact of light-absorbing aerosols, especially for biomass-burning smoke.

Scientific Objectives

- *Determine the physical, chemical, and radiative properties of the major aerosol types in this region for use in numerical radiative-transfer and hydrological models; investigate their interactions with clouds and vegetation;*
- *Quantify the physical and chemical processes controlling the evolution of the major aerosol types;*
- *Develop procedures to extrapolate aerosol properties and processes from local to regional/global scales (using satellites), and assess their hydrological and climatic impacts; and*
- *Improve remote-sensing approaches that policymakers can use to monitor and manage agricultural practices.*

The Primary Goal of BASE-ASIA is to accurately measure the impact of light-absorbing aerosols, especially biomass-burning smoke.

We propose to use three approaches:

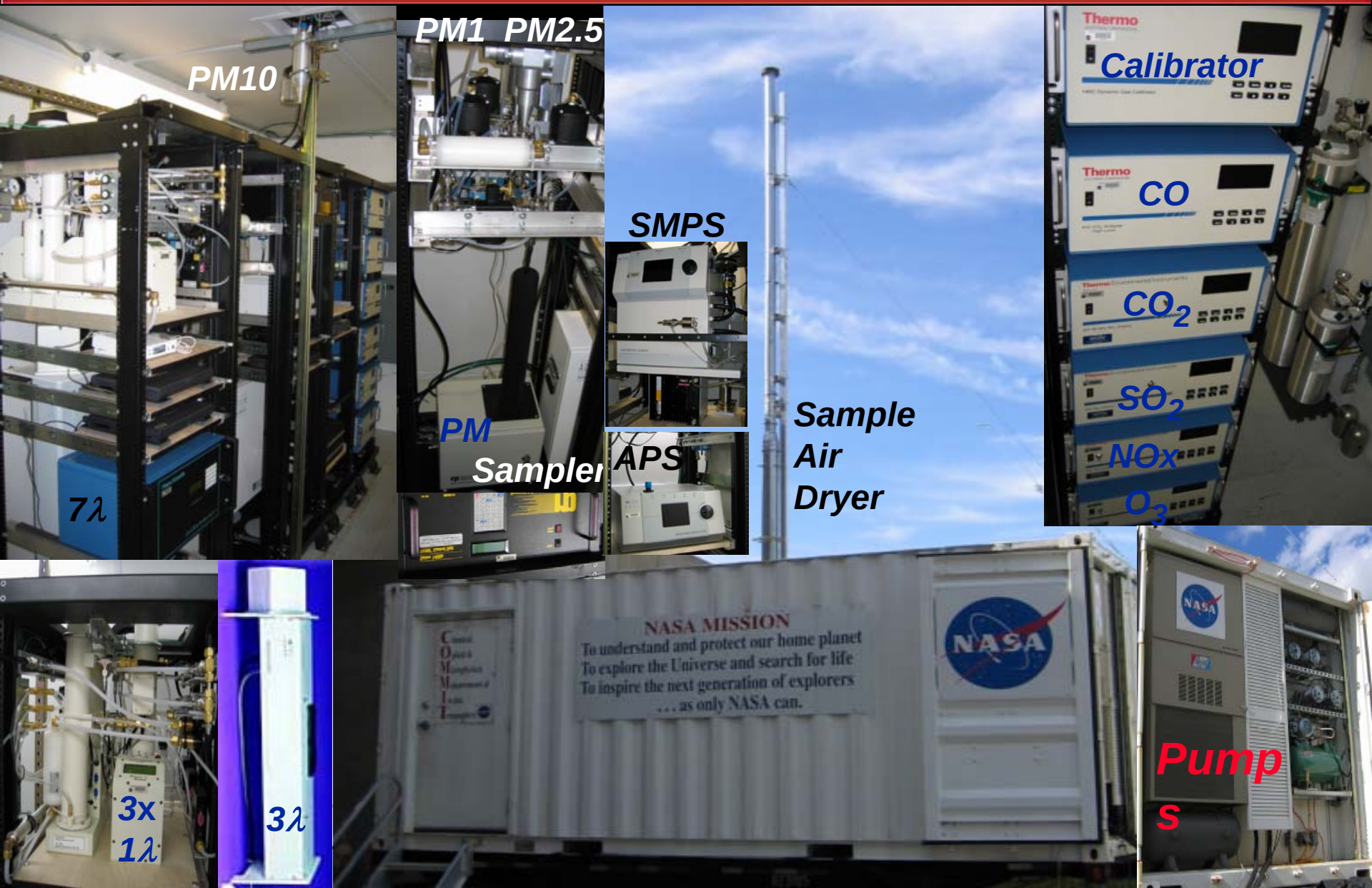
1. ***In-situ (direct) measurements of aerosol properties***
2. ***Remote sensing of the net impact of these particles.***
3. ***Capacity-building through SEA-START RC.***

- ✓ The first gives us accurate values to put into models.
- ✓ The second tests the models and gives managers a tool for monitoring the success of their management approaches.
- ✓ The third ensures that local and regional scientists are trained in the most up-to-date methods for continuing this work

SMART: *Surface-sensing Measurements for Atmospheric Radiative Transfer*

http://smart-commit.gsfc.nasa.gov/

COMMIT: Chemical, Optical & Microphysical Measurements of In-situ Troposphere



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Summary

- **Need to Conduct Future Field Experiment in Asia**
- **Long and Difficult Process for International Letter of Agreement**
- **JUSTSAP Could Become a Facilitor**