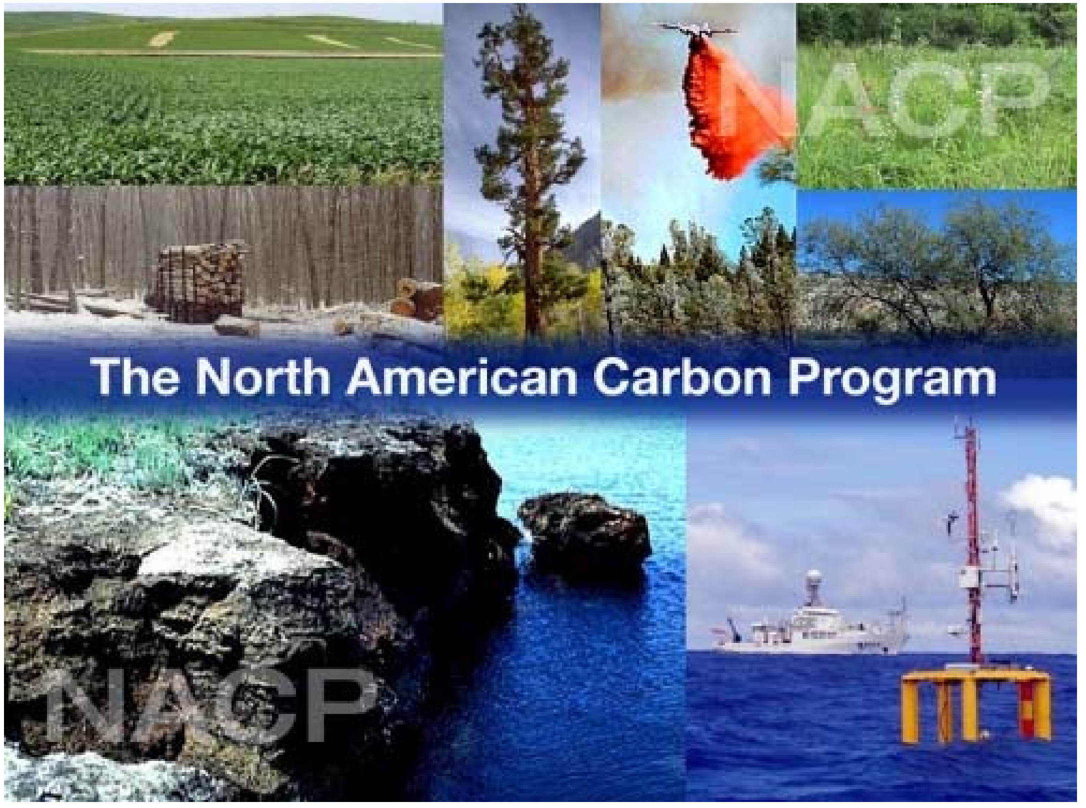
Aircraft considerations for NACP

Remote Sensing in the
North American Carbon Program
Workshop
University of Montana
20 & 21 August 2004

Jeff Morisette[1]
Forrest Hall[2]
Fred Huemmrich[2]
with input from
Bill Emanuel,
Diane Wickland, &
Piers Sellers

1 NASA
2 GSFC/JCET



OUTLINE

- Scientific Data requirements implications for aircraft data
  - Implications from the NACP Implementation strategy
  - In situ vs remote sensing
  - Aircraft vs Satellite data
- Advanced planning and experiment execution for aircraft campaigns

OUTLINE

- Scientific Data requirements implications for aircraft data
  - Implications from the NACP Implementation strategy
  - In situ vs remote sensing
  - Aircraft vs Satellite data
- Advanced planning and experiment execution for aircraft campaigns

COORDINATED LAND AIRCRAFT/SPACECRAFT EXPERIMENTS: POTENTIAL ROLES

- TOP-DOWN
  - Develop & test trace gas methodologies for inferring surface flux at regional and continental scales
  - Model parameterization (from satellite products)
- BOTTOM UP
  - Addressing "…scaling issues inherent in applying data over areas that were not measured."
  - Will require abundant data to test the models' ability and evaluate them against independent observations (both models and existing remote sensing algorithms).

NACP Science Implementation Strategy

"gridded estimates will be compared in detail to independent estimates made from observations of atmospheric trace gas concentrations and trajectories" (p. 2)
implies an emphasis on NOAA's in situ aircraft data

"NACP will involve systematic observations, intensive field campaigns, manipulative experiments, diagnostic numerical modeling of carbon sources and sinks, and synthesis of existing data sets

…and that observations will be made of the parameters and variables that are most uncertain in the models" (p. 6)
implies NASA assets should be considering in light of error budget from models

OUTLINE

- Scientific Data requirements implications for aircraft data
  - Implications from the NACP Implementation strategy
  - In situ vs remote sensing
  - Aircraft vs Satellite data
- Advanced planning and experiment execution for aircraft campaigns

IN SITU MEASUREMENTS: ATMOSPHERIC TRACE GAS

- AIRCRAFT: VERTICAL PROFILES (Surface to 8 km) FROM LIGHT AC (P26)
  - EVERY OTHER DAY @ 30 NA SITES
  - TWICE WEEKLY OVER WISCONSIN TOWER
  - Regional to continental missions (e.g. COBRA)
- Orbiting Carbon Observatory (OCO) (launch date 2007)

Roles for Land Remote Sensing: Spatially extensive information

- Extending site-specific *in situ* and field measurements to regional and continental scale
  - e.g. Forest Inventory Plots (p14)
- Multi-scale imagery can be used to assess heterogeneity
- Site selection, sampling design: "reconnaissance" from existing imagery
- Ultimately, data assimilation framework for ecological/climate forecasting will utilize remote sensing products in conjunction with other data and modeling streams

Land Remote Sensing Instruments

- Standard Multi-spectral
  - Many airborne packages
  - ETM+, ASTER, MODIS, MERIS, SPOT VEG, GOES
- Multi-angular
  - AirMISR(?)
  - MISR, AATSR
- Active laser
  - LVIS
- Hyperspectral
  - AVIRIS, EO-1
- Radar
  - RADARSAT, ENVISAT's ASAR

Blue = satellite

Roles for Land Remote Sensing: Spatially extensive information

- Current and historical remote sensing data to identify land cover status and disturbance/changes (every 2-5 years) (p15,16,17 & 18)
  - Fire history/burned areas & intensity
    insect mortality, hurricane damage
  - vegetation state, life forms and growth forms)
  - Physiological and structural properties
  - Lateral extent of surface vegetation
  - Live and senescent vegetation
  - Surface heterogeneity
  - Desertification, woody encroachment
  - Forest thickening, thinning and dieback

Specific Products/Parameters existing or "operatation" from Land Remote Sensing

- landcover/land cover change/percent cover
- topography (from Shuttle RADAR topography mission)
- snowcover
- albedo/BRDF
- surface reflectance
- land surface temperature
- vegetation index
- surface evaporation resistance
- LAI, FPAR & GPP
- Active fire & burn scar
- (not "land", but MODIS Aerosol/Ocean products should be mentioned)

Any planned or potential validation activities for these products could contribute to NACP intensive campaigns

OUTLINE

- Scientific Data requirements implications for aircraft data
  - Implications from the NACP Implementation strategy
  - In situ vs remote sensing
  - Aircraft vs Satellite data
- Advanced planning and experiment execution for aircraft campaigns

NACP Science Implementation Strategy: Aircraft considerations

- In situ sampling vs remote sensing "imagery"
  - Assume *in situ* sampling needs will be addressed by current and planned NOAA aircraft programs (including both profiles and transects)
  - Here, aircraft considerations are focused on remote sensing instruments (such as LIDAR and hyperspectral)
- Remote sensing aircraft data could likely contribute to NACP by improving
  - offer high quality spatially explicit data, but should be considered in light of satellite resources or interpolation of point data
  - Aircraft data offer some opportunities and challenges for timing and planning
  - Previously collected airborne data should be considered, but certain research objectives may require new/coincident aircraft remote sensing

Aircraft vs Satellite

Aircraft data can offer high quality spatially explicit data, but should be considered in light of satellite resources or interpolation of point data

- Spectral resolution
  - if hyperspectral is needed, AVIRIS has improved Signal/Noise over EO-1 data, for multi-spectral there are several satellite options
- Spatial resolution
  - cost, timing, and spatial coverage consideration for Quickbird or Ikonos
  - Different altitudes can allow multiple resolution from same airborne sensor/same campaign
- Canopy profile through LIDAR
  - currently not available from satellites

Aircraft vs Satellite

Aircraft data offer some opportunities and challenges for timing and planning:

- Satellite acquisition schedule is fixed (available every X days) and may require scheduling (e.g. ASTER, EO-1)
- Aircraft campaigns require extensive, thorough planning and experiment plan
- Aircraft campaign can be scheduled for a given date range and flights flown when conditions are right and over a more specific area

Aircraft vs Commerical imagery: Cost

MODIS Land validation team found:

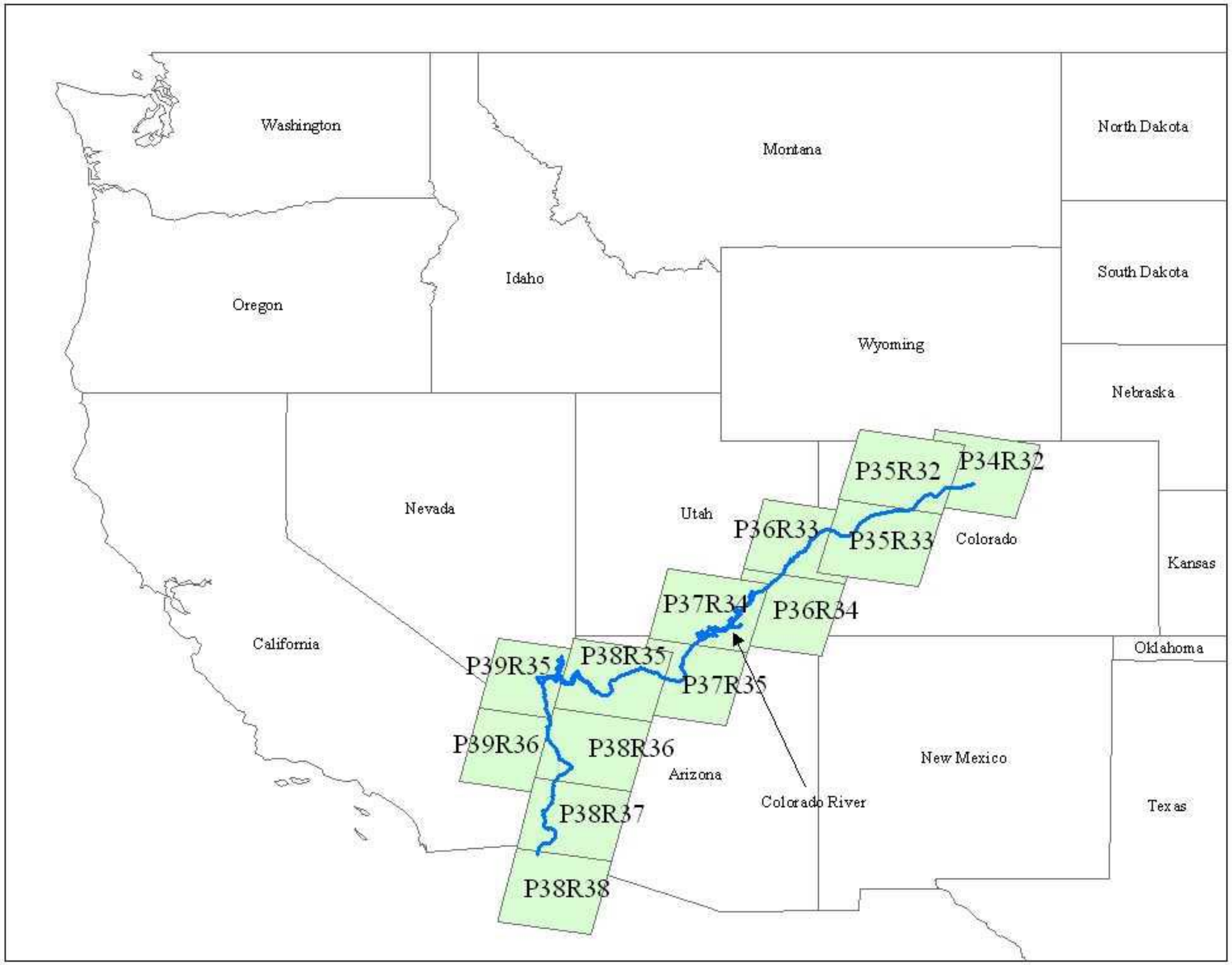
The 11 x 11 km^2 area of an IKONOS acquisitions could cost over $20,000 for Color IR orthorectified airborne digital imagery

IKONOS/Quickbird data are available for ~$5000

- assumes the study area is within the range covered by an aerial survey company

Morisette, J.T., J. E. Nickeson, et al., High spatial resolution satellite observations for validation of MODIS land products: IKONOS observations acquired under the NASA Scientific Data Purchase, *Remote Sensing of Environment*, *88* (1-2) 100-110, 2003.

Aircraft vs Commerical imagery: coverage area/timing

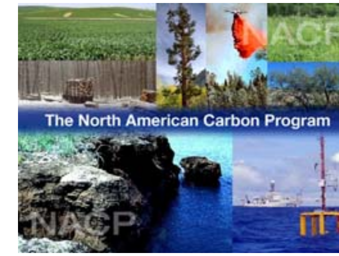


Green:
13 Landsat images covering the Colorado River

Blue:
250m buffer on either side of the Colorado River

AREA
Green: 354,000 sq km
Blue: 3,000 sq km

Coincident coverage impossible with current ~30m resolution satellite data



OUTLINE

- Scientific Data requirements implications for aircraft data
  - Implications from the NACP Implementation strategy
  - In situ vs remote sensing
  - Aircraft vs Satellite data
- Advanced planning and experiment execution for aircraft campaigns

Advance Planning

- EXPERIMENT DESIGN
  - COORDINATED MISSION PLAN OPTIONS (science objectives, Aircraft campaigns, satellite tasking and coverage)
  - COORDINATED AC EXPS (Trace Gas, Land Remote Sensing)
- WEATHER FORECASTING FOR MISSION OPERATIONS
- FAA FLIGHT REGULATIONS
- AIRCRAFT REQUESTS
- DATA PROCESSING, STAGING, AND ACCESS

Experiment Execution

"During the experiments, the theory teams should be involved in real-time operations ranging from flight planning to model-data comparisons." (p42)

- DECISION MAKING
- OPS STAFF AND PROCEDURES
- COMMUNICATIONS INFRASTRUCTURE - OPS STAFF, PIs, PILOTS, OTHER TRAFFIC
- TRACK EXPERIMENT STATUS AND RESOURCE CONSUMPTION

All of these are required to make sure that a multi-team campaign is properly coordinated and its objectives are met.

DECISION MAKING

– DECISION MAKING PROCEDURES WITHIN THE EXPERIMENT MANAGEMENT STRUCTURE FOR
  - LONGER TERM (RESOURCES)
  - SHORTER TERM (PRIORIZATION)
  - REAL TIME (MISSION LAUNCH)

Summary

- First step is to decide if/what aircraft data are needed
  - Agencies may have sensor/aircraft resources to offer but these should be considered in light of cost/benefit to the NACP and other resources
- A successful experiment will require
  - Advance planning
  - A detailed experiment plan
  - An operations staff from beginning to end of intensive
  - Multi-agency approach imposes an extra component of coordination between operations of each agency's activities
- Long term planning may be required
  - BOREAS took 2 years from where NACP is now to the first IFC
  - First NACP intensive Planned for 2005 is very aggressive. Simple design might help, additional complexity could be added in subsequent campaigns.

Possible scenario for Mid-continent 2005 intensive

- Get ASTER and EO-1 allocation for flux towers within the intensive (start around January, 2005, EO-1 may require funds)
- Get Quickbird or IKONOS data over flux tower within the intensive (Stennis)
- Consider an moderate altitude AVIRIS and LVIS flight (need funds?) in coordination with MODIS Land Validation activities (BigFoot, Warner)

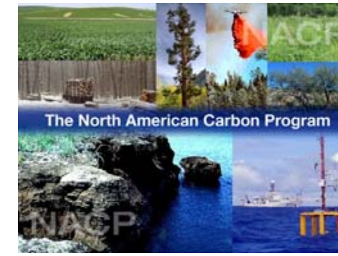
Back-up slides

EXPERIMENT DESIGN

- ANALYSIS FRAMEWORK DRIVES MEASUREMENT REQUIREMENTS AND SCALING STRATEGY.
- WHICH ALONG WITH VALIDATION PLAN & AVAILABLE RESOURCES DRIVES EXPERIMENT DESIGN.
  - SIZE AND LOCATION OF TIER 1 THROUGH 4 STUDY AREAS
  - REQUIRED ACCURACY OF MEASUREMENTS AT IN ALL TIERS
- EXPERIMENT DESIGN DETERMINES NATURE OF AC AND SATELLITE DATA MISSION OPTIONS.
  - TYPES OF MISSIONS (TRACE GAS FLUX, LAND REMOTE SENSING, COORDINATED MISSIONS)
  - REVISIT INTERVALS AND MISSION DURATIONS (DIURNAL, WEEKLY, SEASONALLY)
  - NUMBERS OF MISSION TYPES (TIER 1, 2, 3 OR 4 SITES)
- MISSION PLANS MUST CONFORM TO FAA REGS

FOR EACH AC MISSION TYPE, DEFINE A SPECIFIC MISSION PLAN (FLIGHT LINES, ALTITUDES, DURATION, REQD SAT OVERFLIGHTS), AND DETERMINE REQUIRED RESOURCES TO EXECUTE.

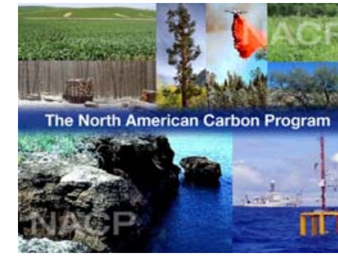
WEATHER FORECASTING



- Weather forecasts for each mission are essential
  - Long-term (2 or 3 days in advance)
  - The night before (Science Planning Meeting)
  - Early Next Morning for real-time decision making and throughout the day.
  - Cloud cover forecasts emphasized for land remote sensing
  - Winds for Trace Gas aircraft
- Essential Local Resources
  - GOES Imagery
  - Radiosonde
  - Dedicated Meteorologist

FAA FLIGHT REGS

- MUST DETERMINE AND CONFORM TO FAA FLIGHT REGS (OBTAIN WAIVERS)
- DETERMINE REQUIRED INTERACTIONS AND COMMUNICATIONS WITH LOCAL AIPORTS



OPS STAFF AND PROCEDURES

- DURING INTENSIVE PERIODS
  – DAILY OPS COORDINATION
  – RECORD KEEPING
  – NIGHTLY MEETINGS
    - REPORTS FROM DAY’S ACTIVITIES
    - WEATHER FORECAST
    - PLAN NEXT DAY’S ACTIVITIES
  – PERIODIC SCIENCE BRIEFINGS
- BETWEEN PERIODS
  – CONSOLIDATE AND REVIEW EXPERIMENT OBJECTIVES
  – PLAN NEXT INTENSIVE PERIOD

COMMUNICATIONS INFRASTRUCTURE

- RADIO COMMUNICATIONS AMONG PILOTS, PIs, STAFF ESSENTIAL FOR REAL-TIME DECISION MAKING
  - VHF -- MISSION MANAGER TO PILOT
  - FM -- PI TO PI AND TO MM
  - CELL PHONES WHERE THEY WORK
  - TELEPHONE LINKS AMONG SITES
    - NIGHTLY MEETINGS
    - COORDINATING MULTI-SITE MISSIONS