Suborbital Measurement Program Using the MEOS Spectrometer (MEOSuB)

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Workshop on Suborbital Platforms and Nanosatellites

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University of Waterloo
Dalhousie University
University of Toronto
University of Winnipeg
Smithsonian Astrophysical Observatory
Agriculture Canada
Environment Canada
NRCan: CCRS/CFS
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MEOS (LEO version)

- MEOS is designed for climate change studies
- Goal: to understand climate-related interactions between the atmosphere and the terrestrial biosphere.
  - to improve our knowledge of terrestrial GHG fluxes
  - To provide information on ecosystem health
  - to quantify the effects of anthropogenic pollutants on terrestrial ecosystems.
  - to provide data for forest and agricultural management, GHG emissions policy and numerical weather prediction

Context for MEOS Concept

- Anthropogenic GHG emissions affect climate. Natural ecosystems regulate climate. Both must be considered in climate change assessments.
- Carbon in natural reservoirs
  - Terrestrial & Ocean biospheres ~ 1470 GtC*
  - Atmosphere ~760 (mostly CO_2)
  - Total turnover ~220 GtC/yr (*e.g.* ~ 16% of atmospheric CO_2)
- Anthropogenic contributions ~ 9.5 GtC/yr.
- Net fluxes (GtC yr–1)
  - Ocean ~ 2.2 ± 0.5; Land biosphere ~ 0.3 - 1.0 ± ~ 300%

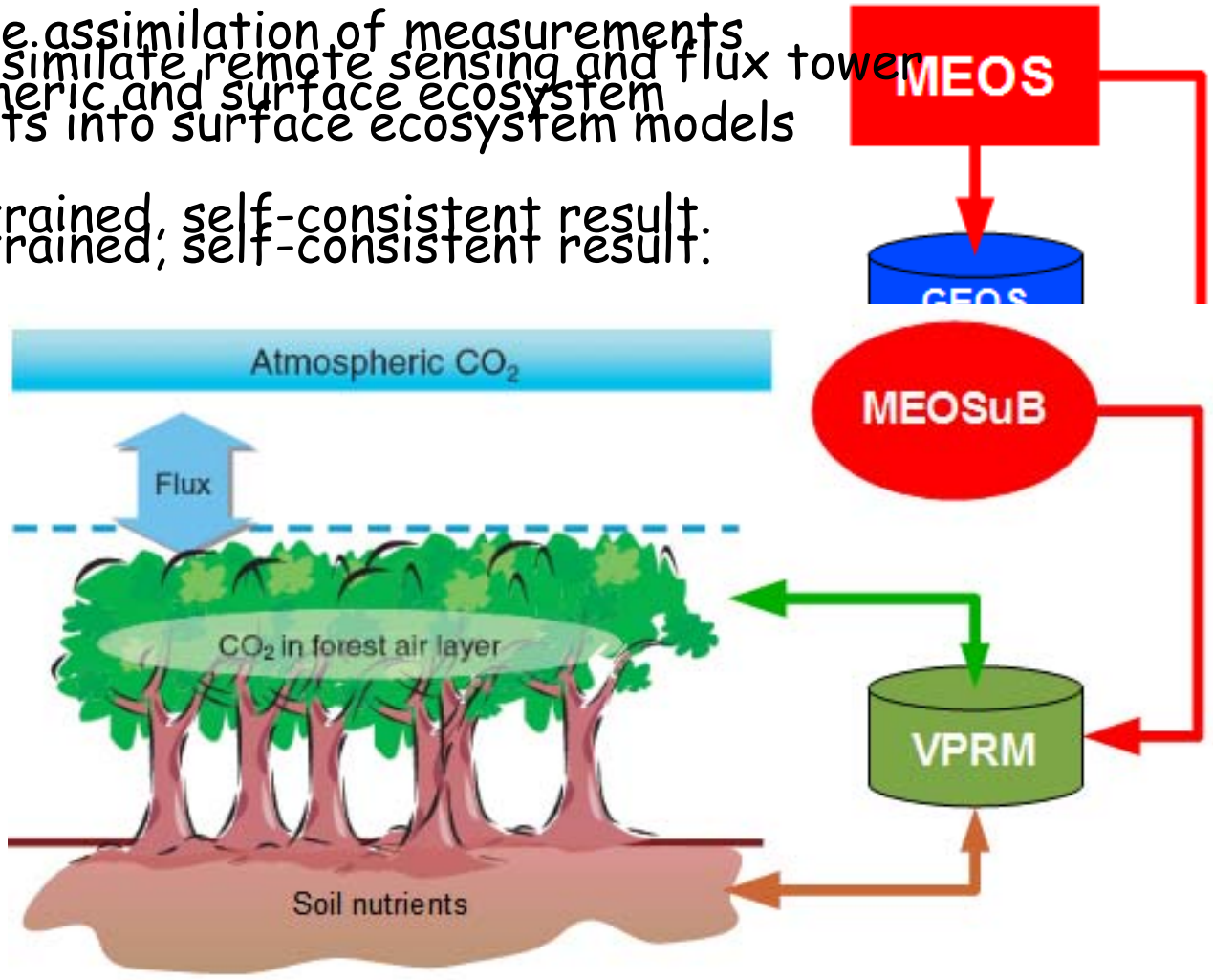
*GtC = 10^9 tonnes = 10^{15} gm of carbon

MEOS and MEOSuB Goals and Methods

- Quantify carbon fluxes
  - Measure lower tropospheric GHGs (CO_2, CH_4, N_2O, CO and H_2O) and assimilate into atmospheric and ecosystem models
- Assess effects of air pollutants on GHG fluxes
  - Measure lower tropospheric AQGs (O_3, SO_2, NO_2, H_2CO, $C_2H_2O_2$) and aerosols; correlate with GHG flux data.
- Provide fluxes, mixing ratios and derived products to the scientific community and the public in convenient formats
  - *e.g.* contour maps, NetCDF, etc.

Model-measurement Integration

- MEOS: online assimilation of measurements
- MEOSuB: assimilate remote sensing and flux tower measurements into surface ecosystem models
- Highly constrained, self-consistent result.

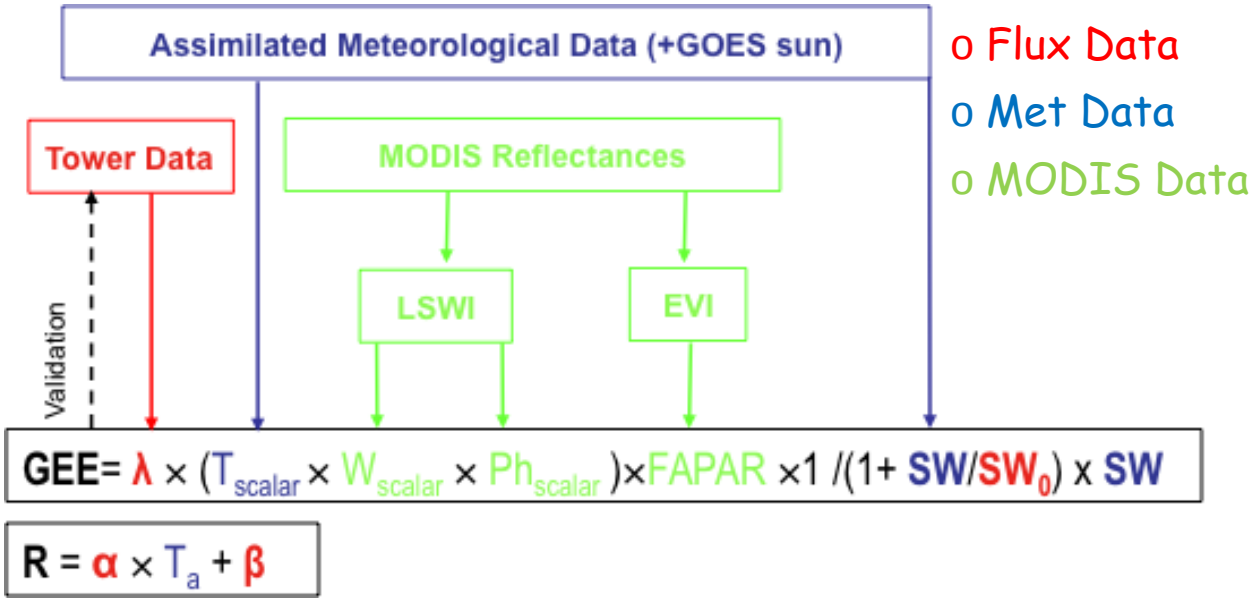


MEOSuB Experiment

- MEOSuB instrument on a tethered balloon near Flux Tower
- STILT Lagrangian transport model
  - Provides the footprint for the air sampled at the receptor
  - Identifies sources, interprets variability and provides meteorological context.
- VPRM surface ecosystem model
  - Assimilates MEOSuB observations and flux tower measurements
  - Gives Ecosystem Exchange (flux) information

Vegetation Photosynthesis and Respiration Model (VPRM)

- Three parameters (λ,α,β) x 11 vegetation classes
- Temporal and spatial carbon fluxes captured with remote sensing data and parameters (λ,α,β) fitted to Fluxnet eddy covariance data



Mahadevan, P., J.C. Lin, et al., *A Satellite-Based Biosphere Parameterization for Net Ecosystem CO_2 Exchange: Vegetation Photosynthesis and Respiration Model (VPRM)*, *Global Biogeochemical Cycles*, 22, *2008*

(J. Lin)

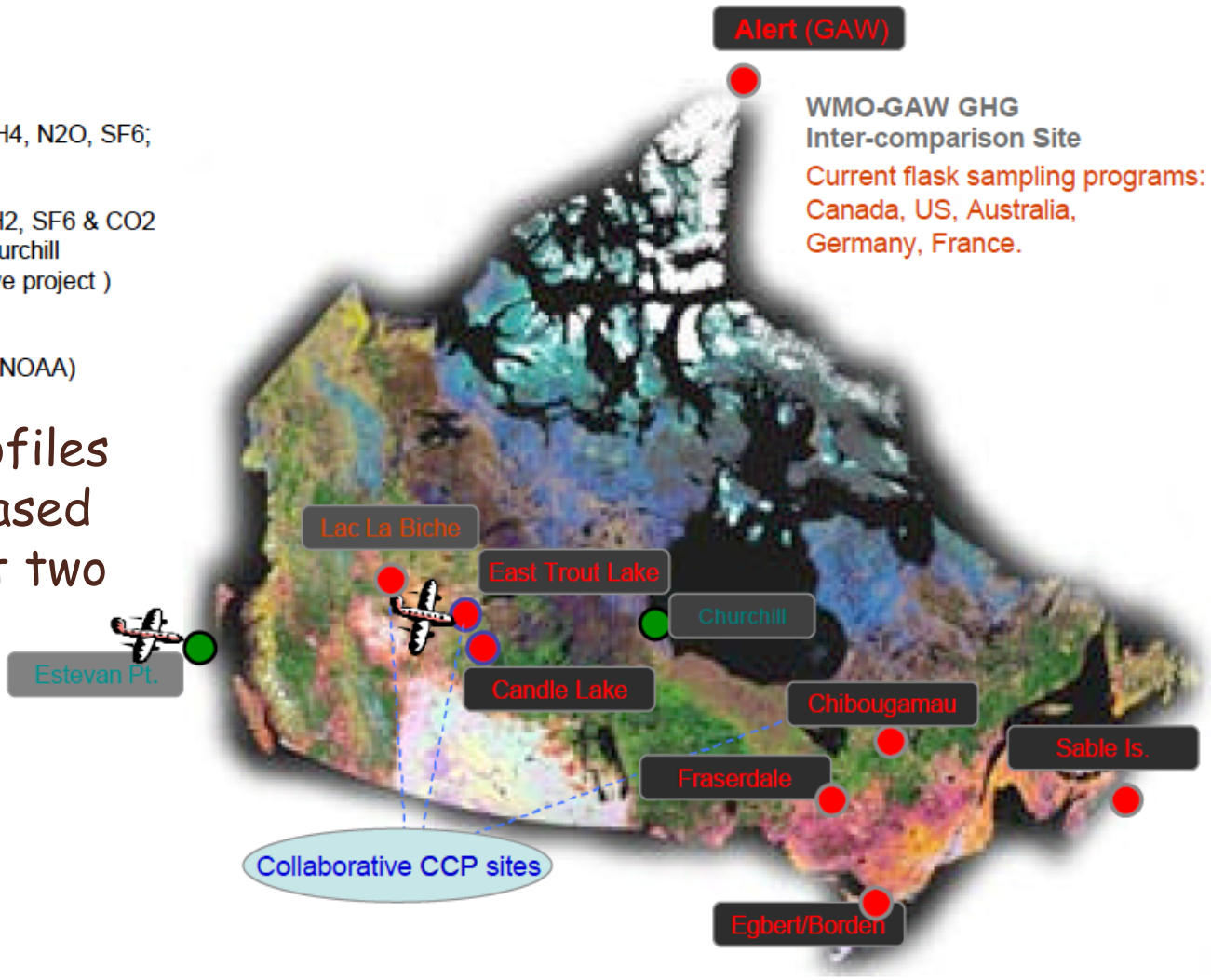
Locations for MEOSuB Deployment (EC GHG Measurements)

In situ and flask CO, CO2, CH4, N2O, SF6; Flask H2, and CO2 isotopes

Flask CO, CO2, CH4, N2O, H2, SF6 & CO2 isotopes only at E. Pt and Churchill (EC/NIPR, Japan collaborative project)

Regular vertical profiles (EC/NOAA)

Weekly GHG profiles from aircraft-based flask sampling at two stations



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MEOSuB Measurements

- Tethered blimp, launched from a mobile trailer
- Individual flights > 9 hours long
- Measurements conducted during ascent and descent, providing *e.g.* 64 vertical points at 25 m intervals near surface and 50 m above 200 m
- Measurements throughout the day to follow photosynthetic activity
  - CO_2, CH_4, CO, H_2O, aerosol vertical and temporal distributions

(K. Strong)

Another Possible Platform

The University of Guelph uses one of our 21 ft Tethered Blimps to monitor their test crops.

Digital imagery of landscapes is being processed using PCI Geomatica software. Classified imagery is exported to ESRI ArcGIS for integration with ancillary landscape data and subsequent analyses

http://www.blimpguys.com/

High-resolution and time sequence field imagery is acquired from a tethered helium blimp equipped with a gyroscopically-stabilized, remotely-controllable camera mounting platform (Skyview Technologies).

(K. Strong)

Instructions (a review)

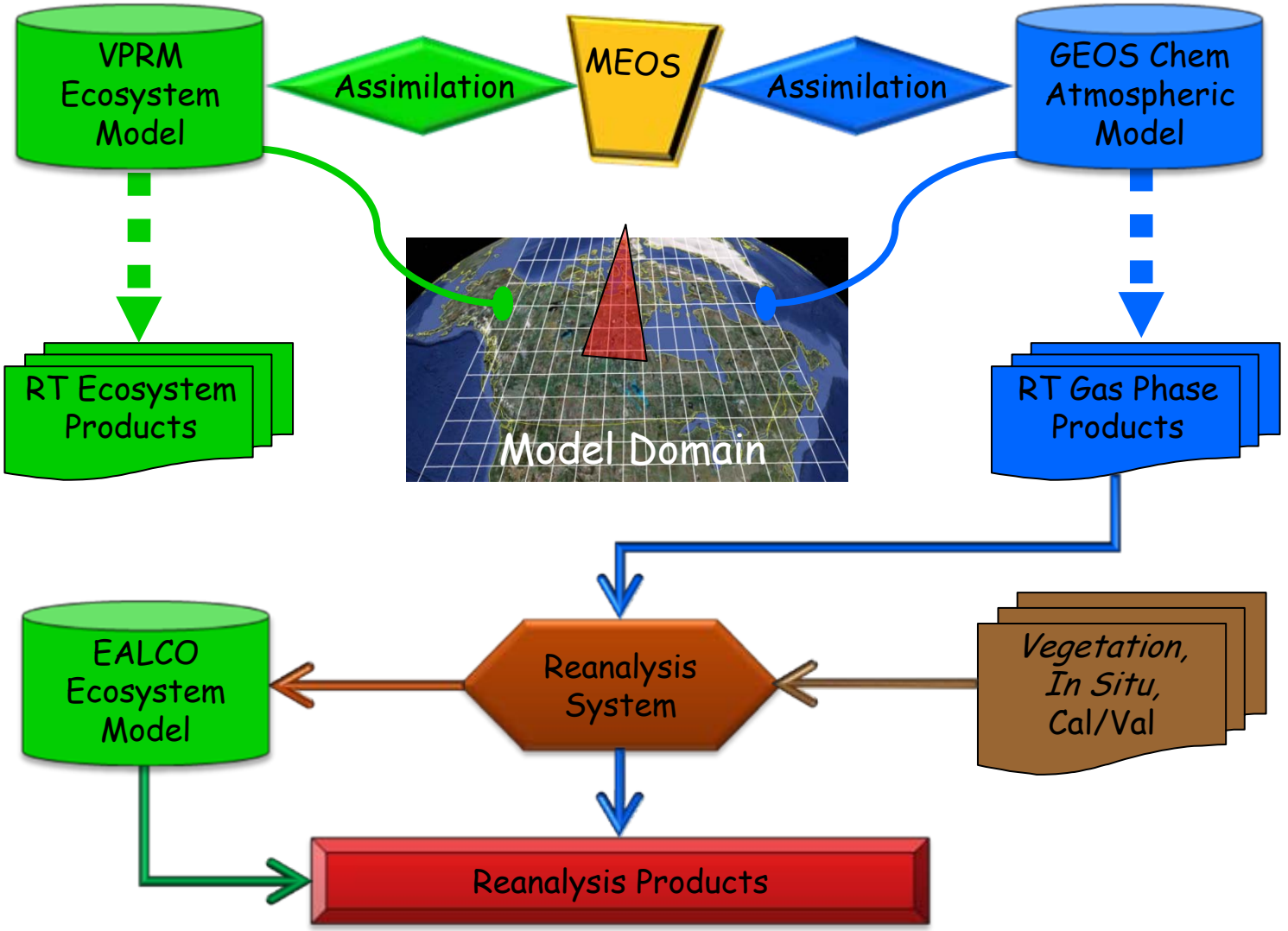
1. The scientific goals for your project. ✓
2. The nature of any collaborations. If your collaboration includes foreign partners with launch access, this should be mentioned.
   - MEOS: Chinese Research Academy for Environmental Studies (CRAES) and Chinese Academy for Space Technology (CAST)
3. An estimated schedule. MEOSuB: Summer 2011
4. Funding issues. Yes.
5. Launch requirements, including payload mass, altitude, duration and location requirements, if any. ✓ (mass ~ 12kg)
6. The level and nature of student involvement in the project.
   - See #4. One Ph.D. student currently doing preliminary studies

MEOS Observations

- Simultaneous co-located vertical profiles of GHGs and AQGs
  - Nadir; "pushbroom"; LEO; ascending node 14:00 LST
  - For GHGs (CO_2, CH_4, N_2O, H_2O): 5x10 km/pixel; 160 km swath
  - For AQGs ($O_3, SO_2, NO_2, H_2CO, C_2H_2O_2$): 5x2 km/pixel; 180 km swath
  - Cloud imaging and O_2 @ 5x2 km
  - Vegetation and land surface properties @ 30x30 m
- Observations assimilated in real time* into models
  - Chemical transport model (GEOS/Chem)
    - ✓ GHGs and AQGs
  - Surface ecosystem models (EALCO, VPRM)
    - ✓ CO_2, CH_4, and vegetation properties

* limited by downlink latency

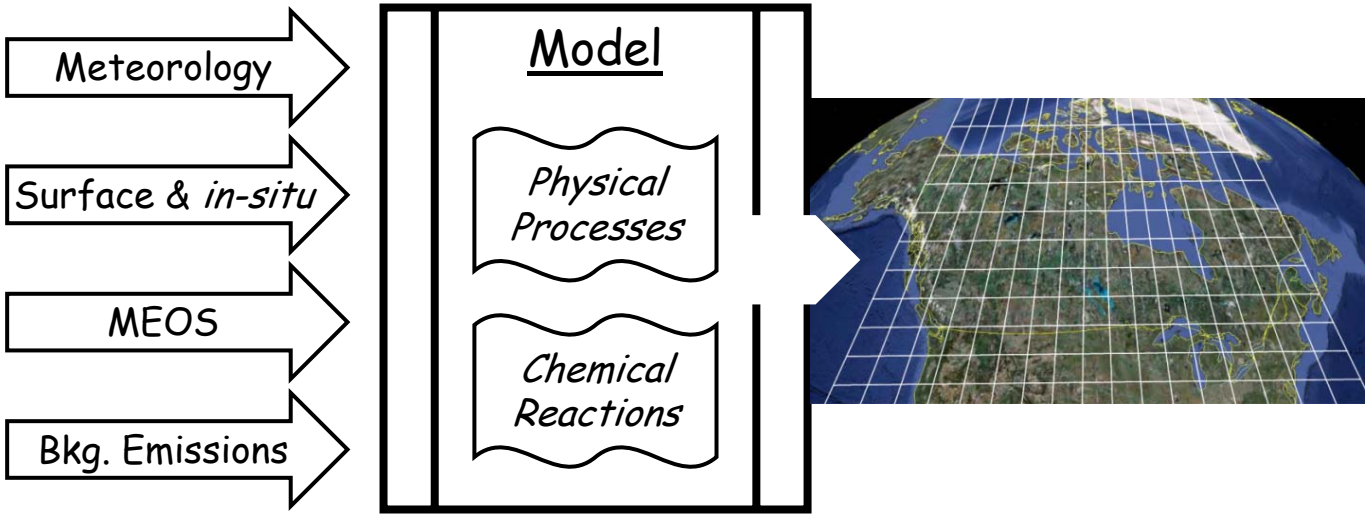
MEOS System Operation



MEOS Product Dataset

- Products are (a) Raw measurements
  (b) Model output*

* Model output integrates over many input data sources



Output is improved most if all inputs are simultaneous and co-located

hence necessity for RT operation

Anticipated Use of MEOS Dataset

- Canadian Government departments
  - Environment Canada: (GHGs and aerosols)
    - ✓ Assimilation of GHGs and aerosols for NWP. MEOS models supply background fields, do initial assimilation and facilitate subsequent processing. MEOS products are constrained by model inputs, increasing their accuracy over raw retrievals facilitating their combination with other sensors (*e.g.* AIRS, IASI)
    - ✓ Quantification of GHG fluxes negotiations of carbon credits in UNFCCC process
  - Natural Resources Canada/CCRS,CFS (Land use and vegetation parameters)
    - ✓ Surface albedo & vegetation indices; calibration of EALCO output at regional and continental scales to yield carbon flux and Ecosystem Productivity data
    - ✓ Mapping of Canadian land use/land cover at 30 m resolution; continuous updates
    - ✓ Enlarge Managed Forest and contribute to Sustainable Forest Management strategies to optimise carbon stocks vs. timber and energy exploitation
    - ✓ Identify and quantify effects of fire, pestilence and drought on forests
  - Agriculture and Agri-Food Canada (GHGs
    - ✓ Verification of biomass and growth rates in crop growth models
    - ✓ Information for crop management decisions
    - ✓ Quantification of agricultural methane emissions

Technology Development & Cal/Val

- Suborbital test program
  - Tethered blimp ⇨ Balloon ⇨ Aircraft
  - GHG measurements at CCP flux towers and AQG measurements at NAP stations.
- Pre-launch end-to-end simulation and calibration; onboard calibration for some sensors
- Validation is incorporated in the mission planning, including a description of the MEOS data products and a definition of the validation requirements
- Post-launch
  - Coincidence mapping and comparisons
  - Statistical correlations of measurements such as variances, tracer-tracer correlations, and vertical tracer profiles relative to tropopause height

Synergy with Other Data

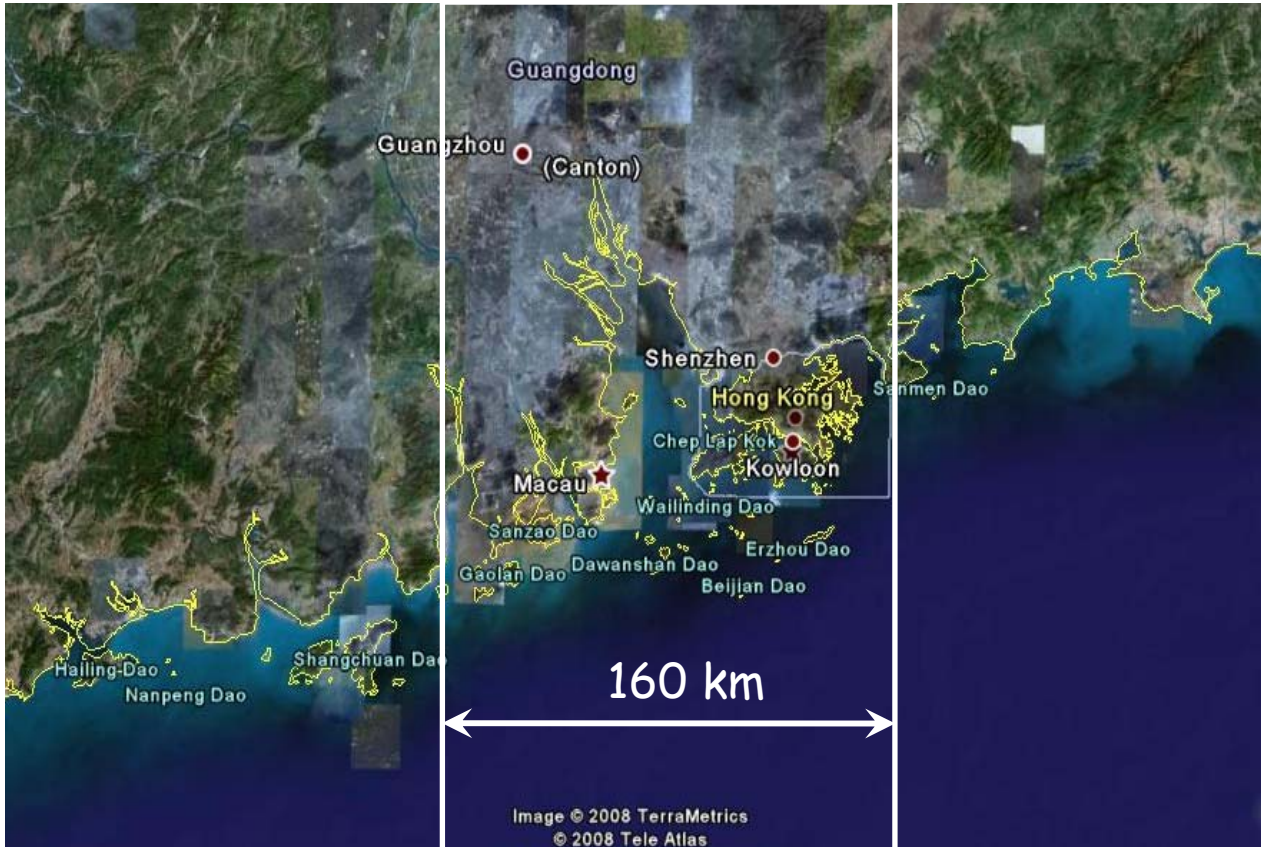
- Ground based measurements
  - Canadian Carbon Program and FluxNet data will be selectively assimilated into the MEOS model outputs
  - AERONET and AEROCAN data will be used for validation and calibration of AQ and ecosystem modelling
  - AQ measurements (NAPS, CAPMoN, SLAMS, etc.) will be either assimilated or used for validation of MEOS products
- Other EO missions overlapping MEOS dataset
  - Cal/Val: GOME-3 (O_3, NO_2, H_2CO), IASI-2 (O_3, CO, CH_4, CO_2), TROPOMI (O_3, NO_2, H_2CO, CO, CH_4, CO_2, aerosols)
  - Collaborations: Sentinel-2 (Vegetation indices)

International Context & Opportunities for Partnership

- China Ministry of Environmental Protection
  - Chinese Research Academy for Environmental Sciences (CRAES)

  - Offer of partnership in AQ studies of Beijing/Tianjin and Shenzen/Pearl River Delta regions

Example: Shenzen and Pearl River Delta



- MEOS AQ measurements: 160 km swath @ 5 km x 2 km resolution
- Assimilated by CRAES models (SMOKE/CMAQ CTM system) to improve emissions information for target domain

MEOS Science Team

ATMOSPHERIC ANALYSIS

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