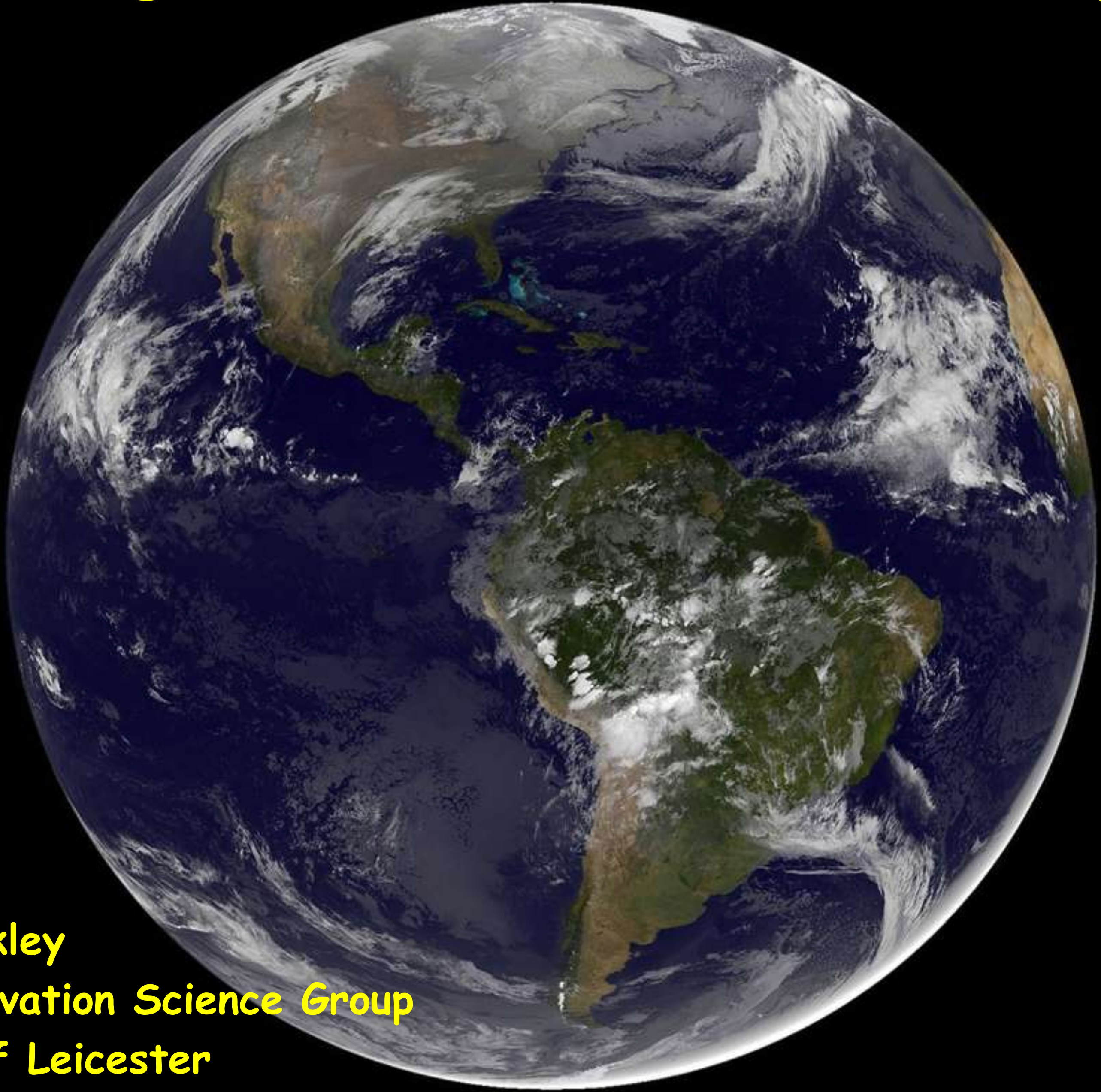
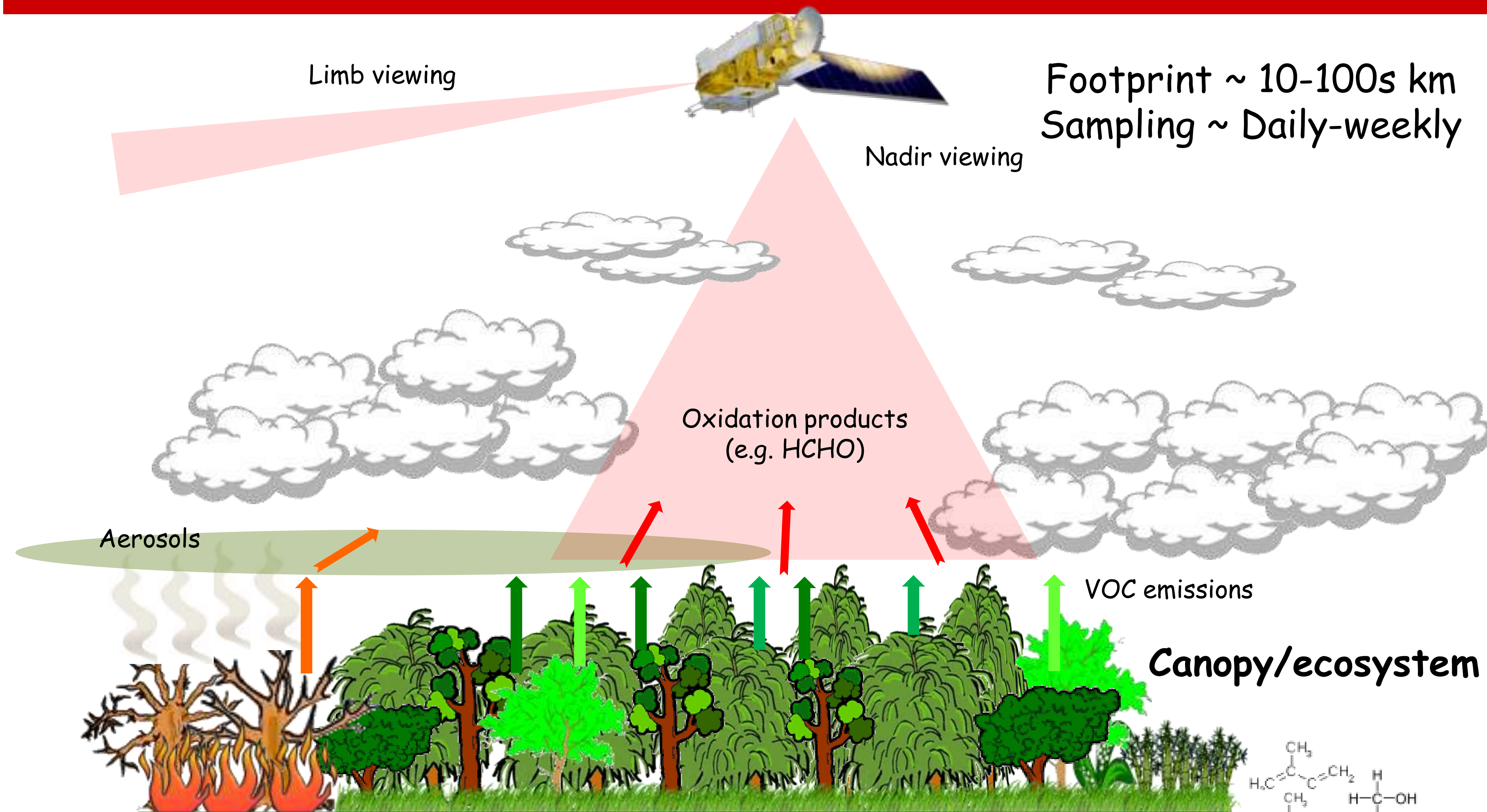
Observing the Amazon from Space

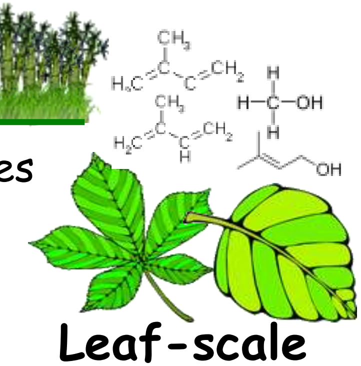


Michael Barkley
Earth Observation Science Group
University of Leicester

Atmospheric remote sensing over rainforests



- Information on ecosystem/regional/continental photochemistry and fluxes
- Specific localized events (e.g., fire)
- Long-range transport (influx and outflow)
- Vertical transport/mixing



UK trace-gas/aerosol/cloud retrievals

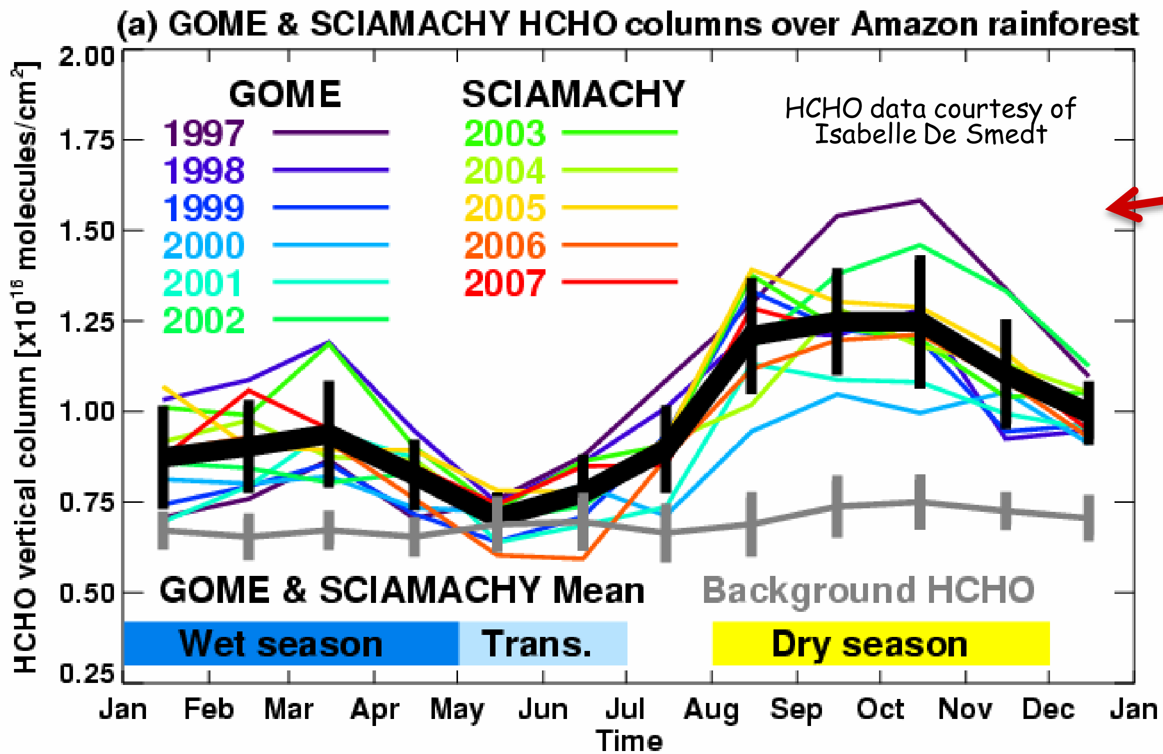
- National Centre for Earth Observation – Atmosphere Theme
  - List not exhaustive; other non-NCEO/international retrievals exist

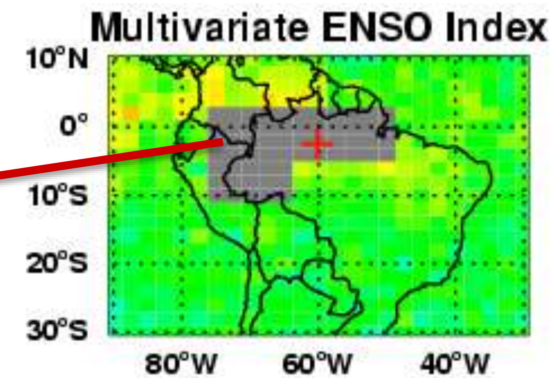
Group	Satellite(s)	Product	Profile/Column
U. Leicester	GOSAT/SCIAMACHY	CO_2, CH_4	Total Columns
	GOME-2	HCHO CHOCHO	Tropospheric columns
	IASI	CO/organics	Columns
	MIPAS	Organics (e.g., PAN, acetone, formic acid)	Profiles (UT/LS)
RAL	GOME-2	Ozone	Tropospheric / total columns
	IASI	SO2, CH_4	Total columns
U. Oxford	MIPAS	p & T, H_2O, O_3, HNO_3, CH_4, N_2O, NO_2 CFC-11, CFC-12, $ClONO_2$, N_2O_5 and CO.	Profiles (UT/LS)
	AATSR (ORAC) (with RAL)	Aerosol (AOD, R_{EFF}, type) Surface albedo (550,660,870,1600 nm)	-
		Cloud (top-height & pressure, optical depth, T, ice/water path, phase, R_{EFF})	-
U. York	ACE	+18 species plus, T & P	Profiles (UT/LS)

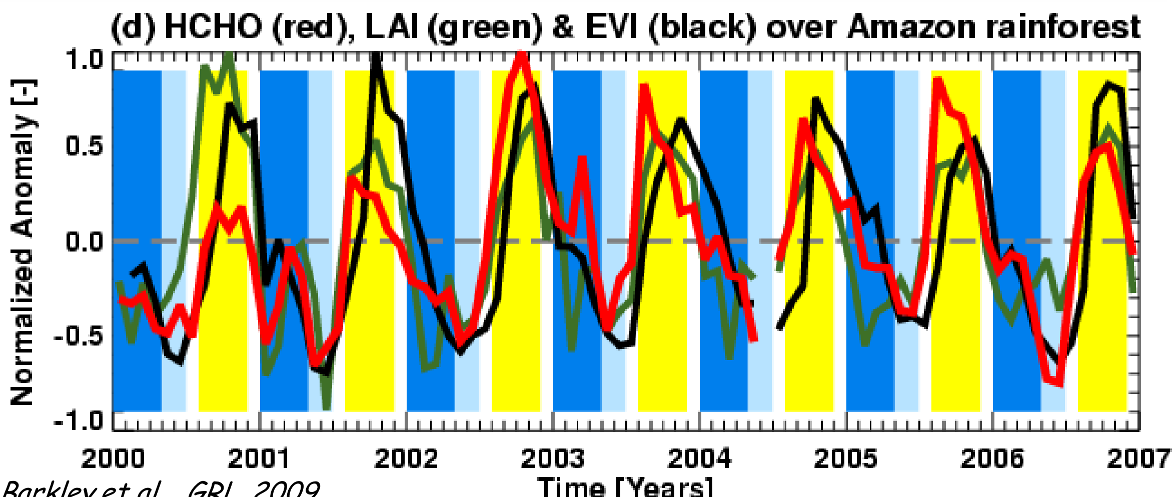
Linking ground to satellite

- Some areas of current research
  - Mapping isoprene emissions from space (me!)
  - Leaf phenology (U. Edin.)
  - Pyroconvection (U. Edin)
  - GHGs (U. Leic/Edin)
  - Air Quality over Amazon (U. Leic)
  - Hydrocarbon spill + leaf damage (U. Leic)
  - Land surface temperature (or ~ leaf T over rainforest)
  - ….
  - ….

Unusual seasonal variation of HCHO columns

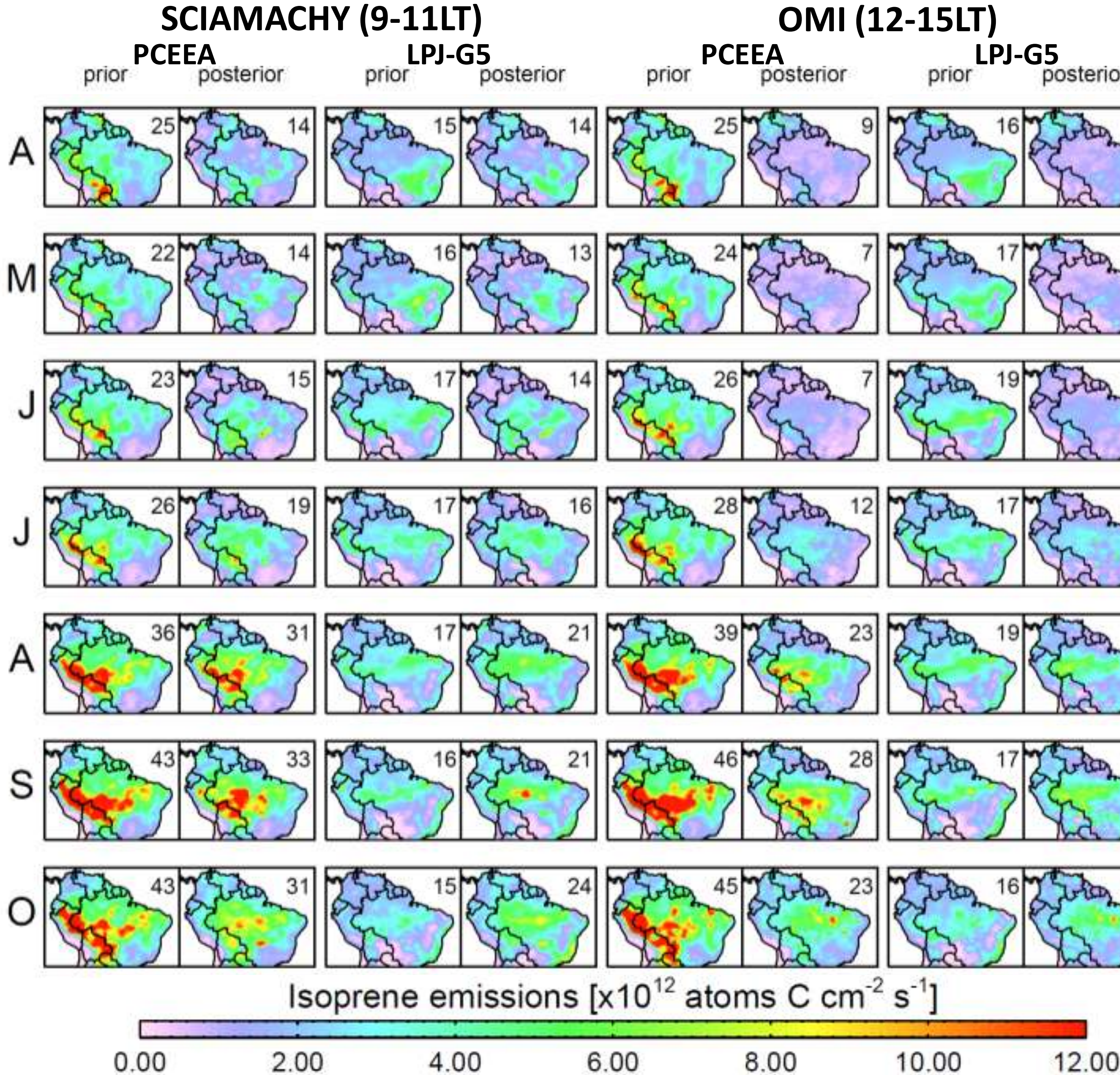






Barkley et al. , GRL, 2009

- Long-term HCHO seasonal cycle shows unexpected low columns during wet-to-dry transitional period
  - Fire scenes are excluded using firecounts & NO_2 columns
- HCHO oscillates in phase with vegetation
  - Majority of isoprene emitting species undergo leaf flushing (new leaf growth) prior to dry season in anticipation of light-rich conditions



SCIAMACHY (9-11LT)
OMI (12-15LT)
PCEEA
LPJ-G5
prior
posterior
A
M
J
J
A
S
O
25
14
15
14
25
9
16
9
22
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16
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36
31
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39
23
19
17
43
33
16
21
46
28
17
21
43
31
15
24
45
23
16
20
Isoprene emissions [x10^12 atoms C cm^-2 s^-1]
0.00
2.00
4.00
6.00
8.00
10.00
12.00

2006 annual emissions

- Local time emissions

SCIAMACHY (9-11 LT)
Prior = 355 ± 65 Tg C (194 - 403 Tg C)
Posterior = 261 ± 18 Tg C (217 - 292 Tg C)

OMI (12-15 LT)
Prior = 387 ± 73 Tg C (205 - 443 Tg C)
Posterior = 171 ± 13 Tg C (149 - 197 Tg C)

- Scaled to monthly mean emissions

SCIAMACHY
Prior = 126 ± 21 Tg C (73 - 148 Tg C)
Posterior = 93 ± 5 Tg C (82 - 102 Tg C)

OMI
Prior = 126 ± 21 Tg C (73 - 148 Tg C)
Posterior = 56 ± 3 Tg C (51 - 63 Tg C)

INSENSITIVE to boundary layer mixing, slow/fast dry deposition, time step, or hydroperoxy-aldehydes

MORE SENSITIVE TO

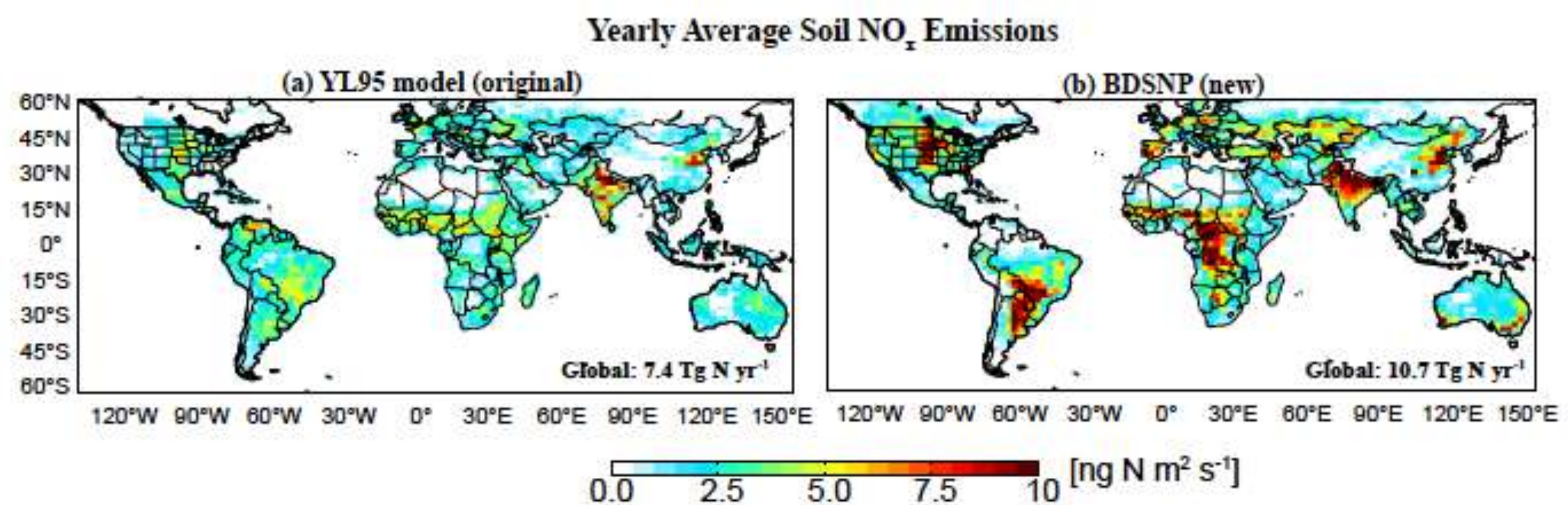
Chemical solver -> 10-15%

Uncertainty in cloud fraction and top-pressure -> up to 10%

Use of LPJ-GUESS or MULLER emissions -> 10-20%

Soil NO_x in tropical forests

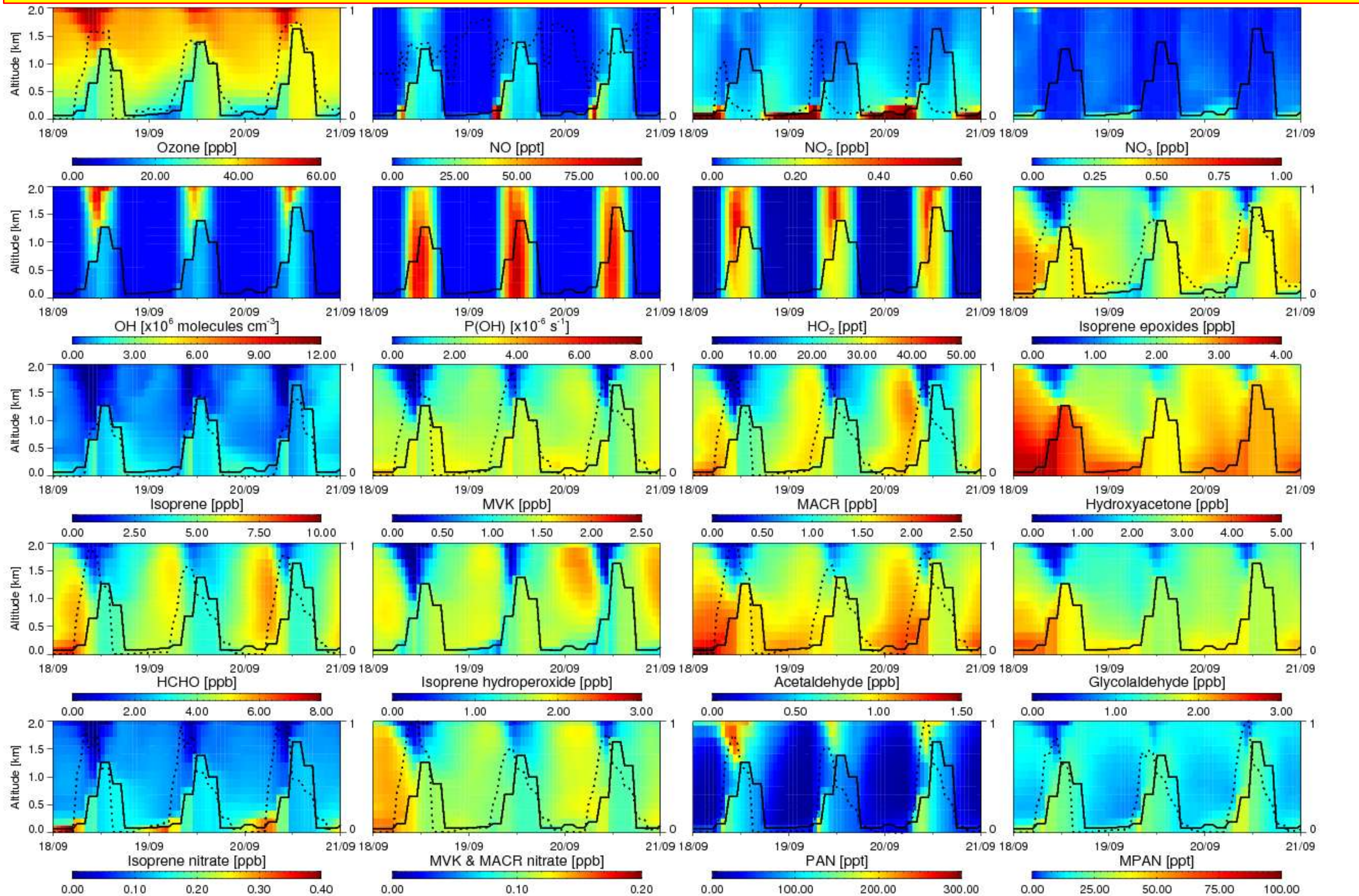
- Satellite observations of NO_2 may provide useful constrain for soil NO_x or canopy NO_x
  - Possible to infer surface NO_x from space (e.g. Lamsal et al 2008)
  - Use model surface to tropospheric column relationship
- Can we link ground based observations to satellite?
  - Few in situ soil NO_x measurements exist



What would be useful?

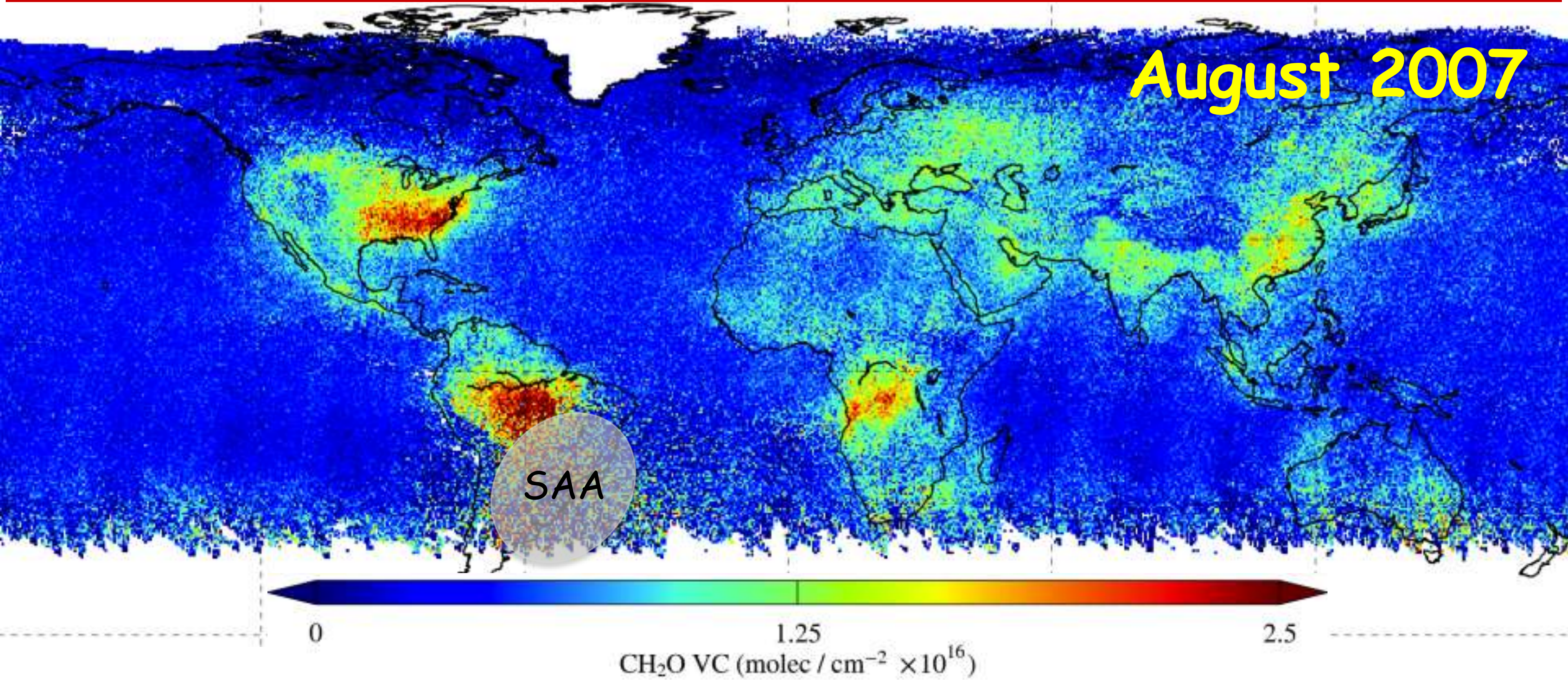
- Long term measurements sampling full diurnal cycle
  - Isoprene / monoterpene fluxes
  - Isoprene + OVOCs concentrations (in and above canopy, BL)
  - Concentrations of standard tracers (O_3, CO, NO_x, etc.)
  - OH/HO_2 would be great :0)
  - Soil NO_x emissions
  - Micro-meteorological conditions
  - LAI and leaf fall
- Coordinated integration of ground-aircraft-satellite observations
  - Satellite observations provide whole-ecosystem indirect monitoring of biogeochemical cycling
- DOAS instrument for satellite validation (permanent/temporary)

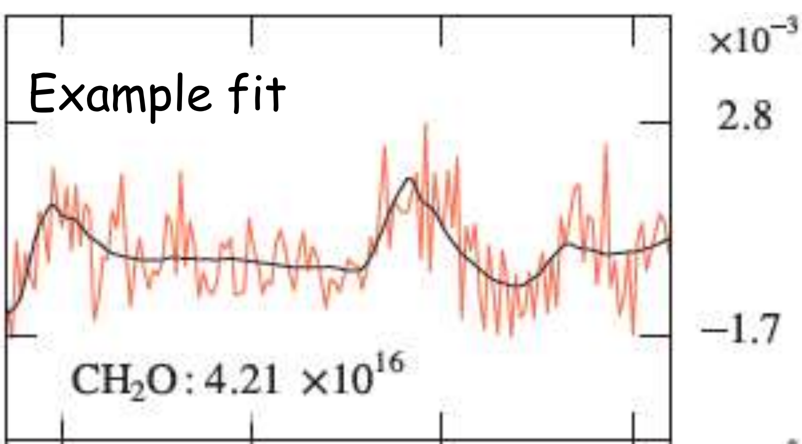
In situ observations are needed to understand diurnal photochemistry



Chemistry: Caltech **BVOC Emissions:** MEGAN PCEEA **Dry deposition:** Old ('slow') scheme **BL mixing:** full-mixing

GOME-2 HCHO retrievals at U. Leicester





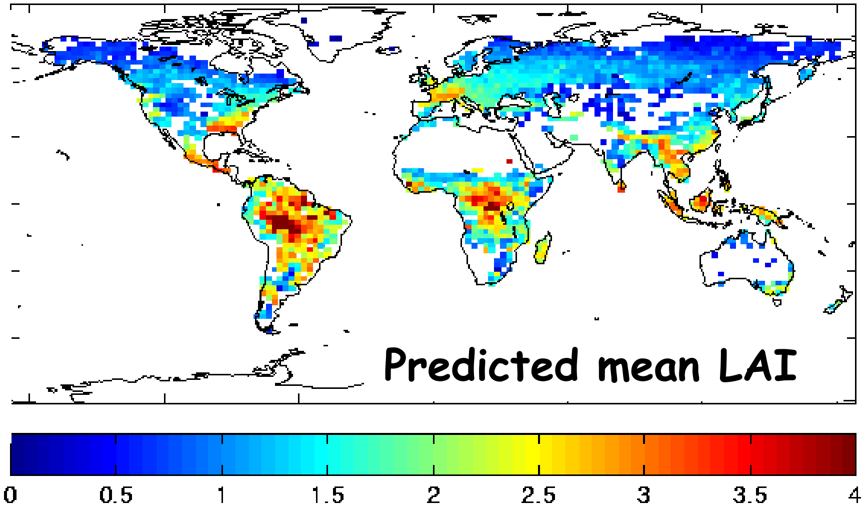
- To include a detailed examination of air-mass factors (= slant/vertical)
- Data will need <u>validating</u>
  - (MAX)-DOAS

Tropical leaf phenology inferred from MODIS LAI

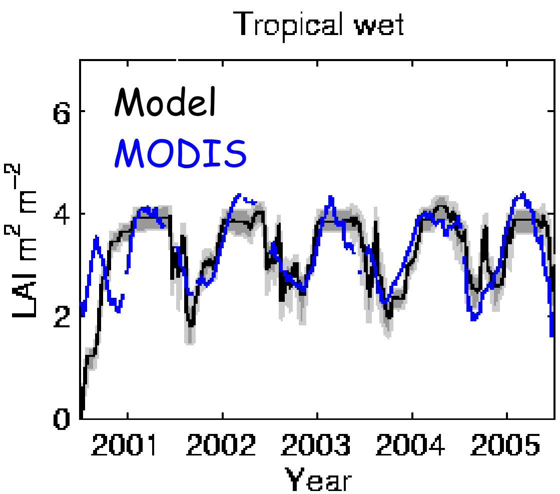
Process based model which predicts phenology as an optimal strategy for carbon gain.

Model fitted to 5 years of MODIS LAI data using a Bayesian algorithm

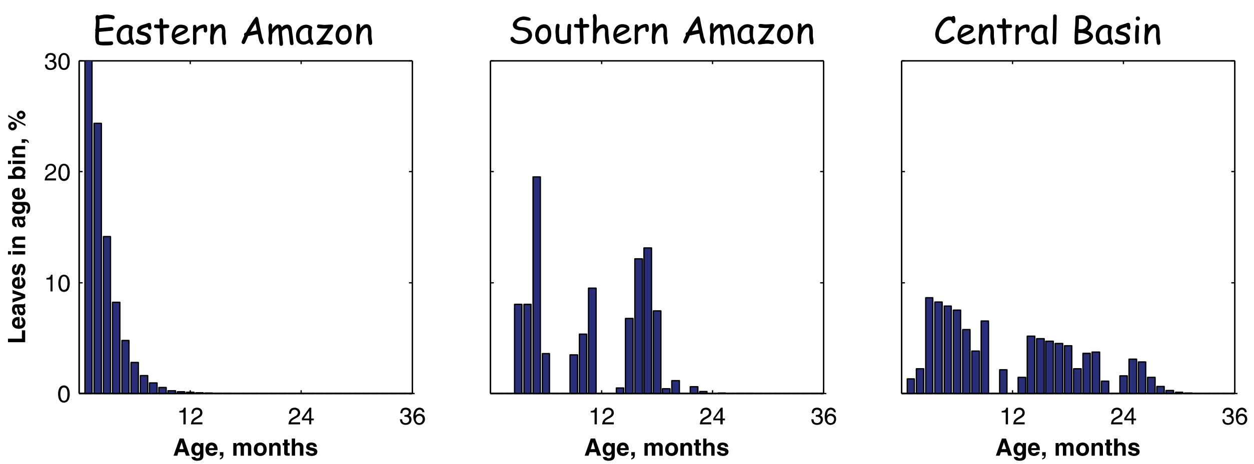
In wet tropical forests we predict an increase in LAI in response to light during the dry season



Model performance



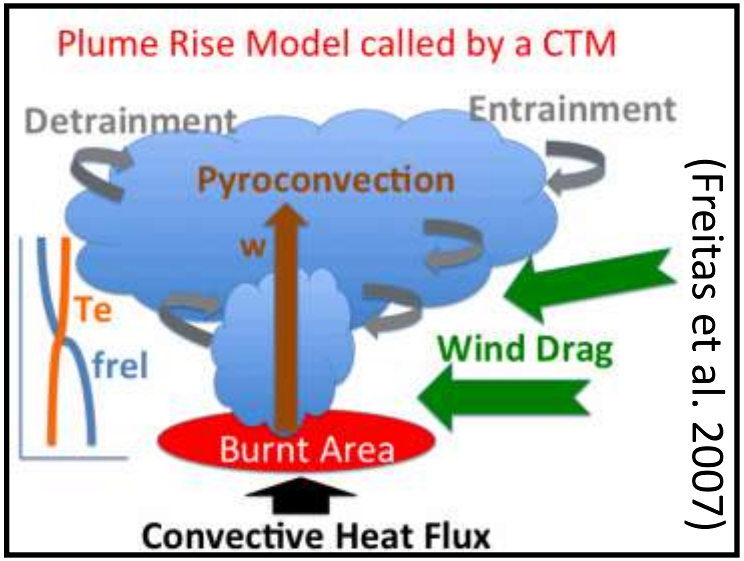
The model estimates the frequency distribution of leaf ages (months) over the Amazon basin.



Contact: Silvia Caldararu of U. Edinburgh

Caldararu et al, BGD, 2012

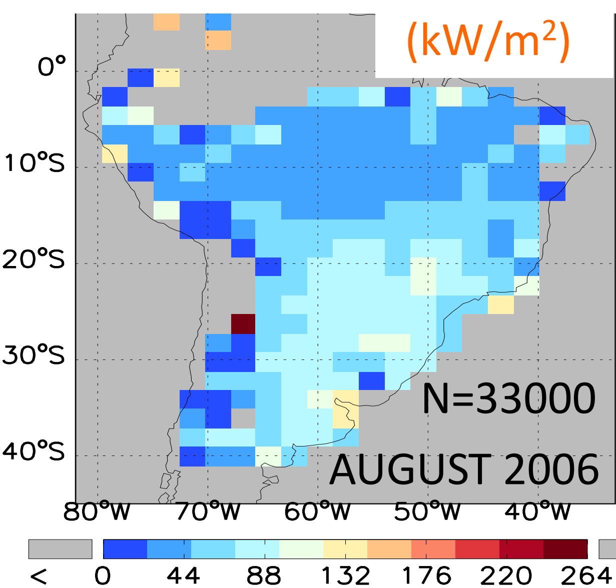
Estimating pyroconvection from fire radiative power



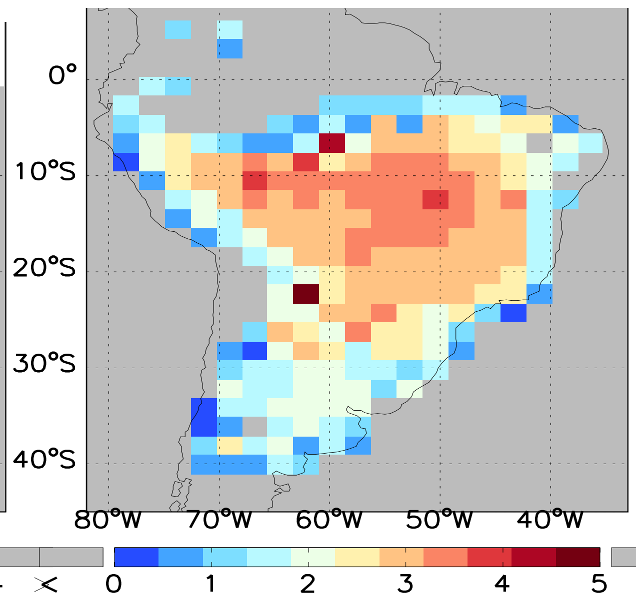
- ½ million global FRP and fire area observations in 2006 from MODIS (Wooster et al. 2005) .
- Over South America CHF is typically 1--80 kW/m^2 and fire size is <5 ha
- Pyroconvection injection heights are typically < 3 km.
- We now assess the impact of pyroconvection on biomass burning emission estimates inferred from MOPITT CO column measurements.

Contact: Sigfried Gonzi of U. Edinburgh

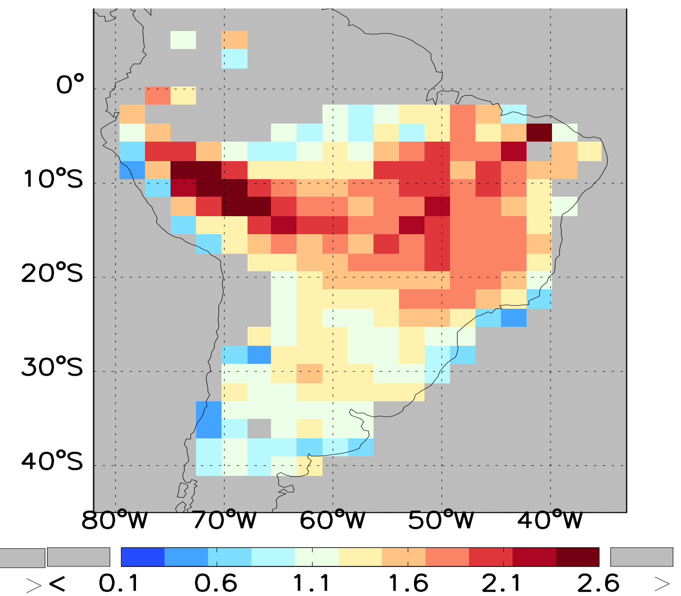
Mean Heatflux (CHF = 5xFRP) (kW/m^2)



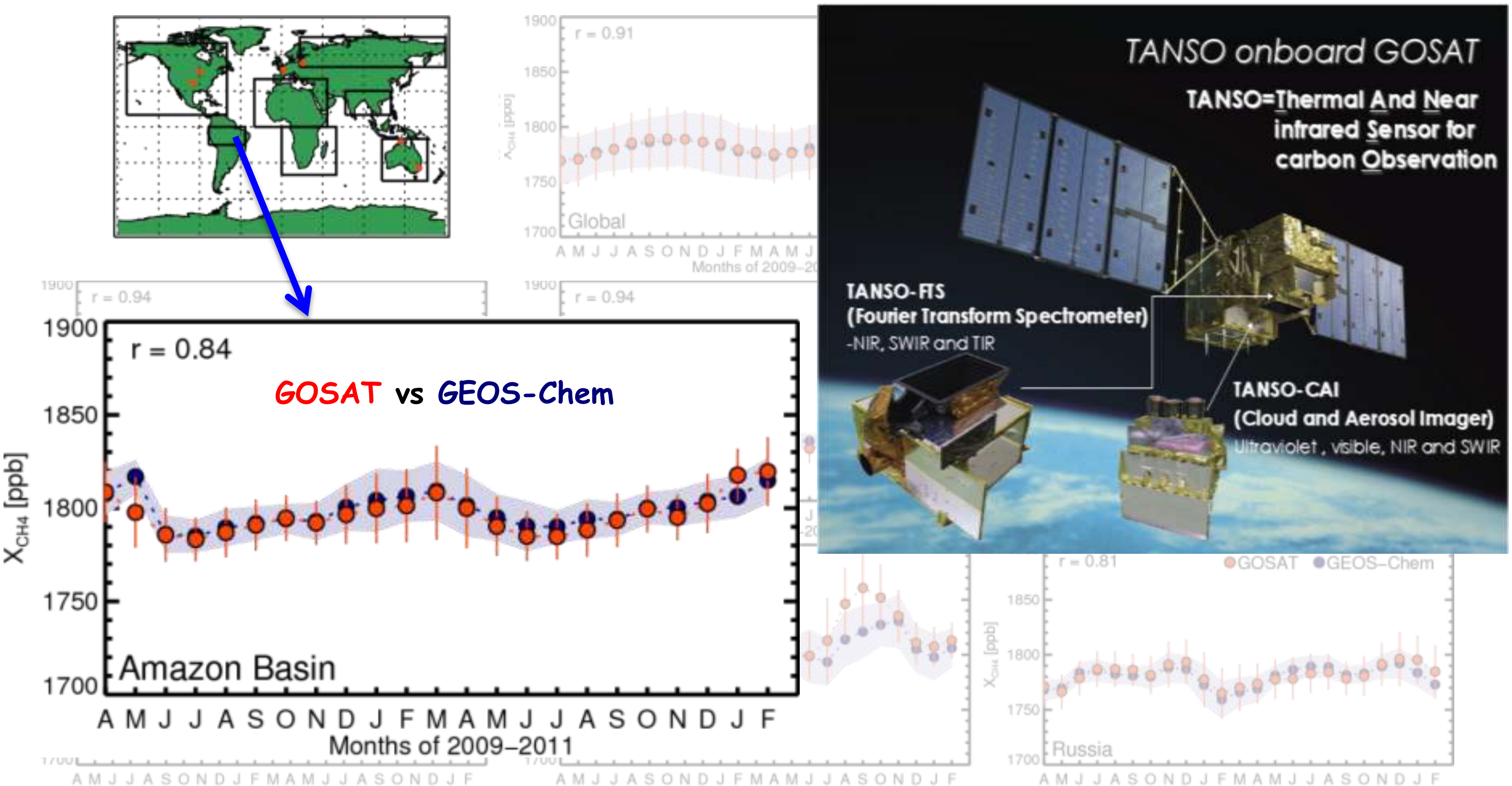
Max. Injection Height (km)



Mean Injection Height (km)



Observing atmospheric CH_4 using GOSAT



Next generation: **Tropical Carbon Mission (TCM)**

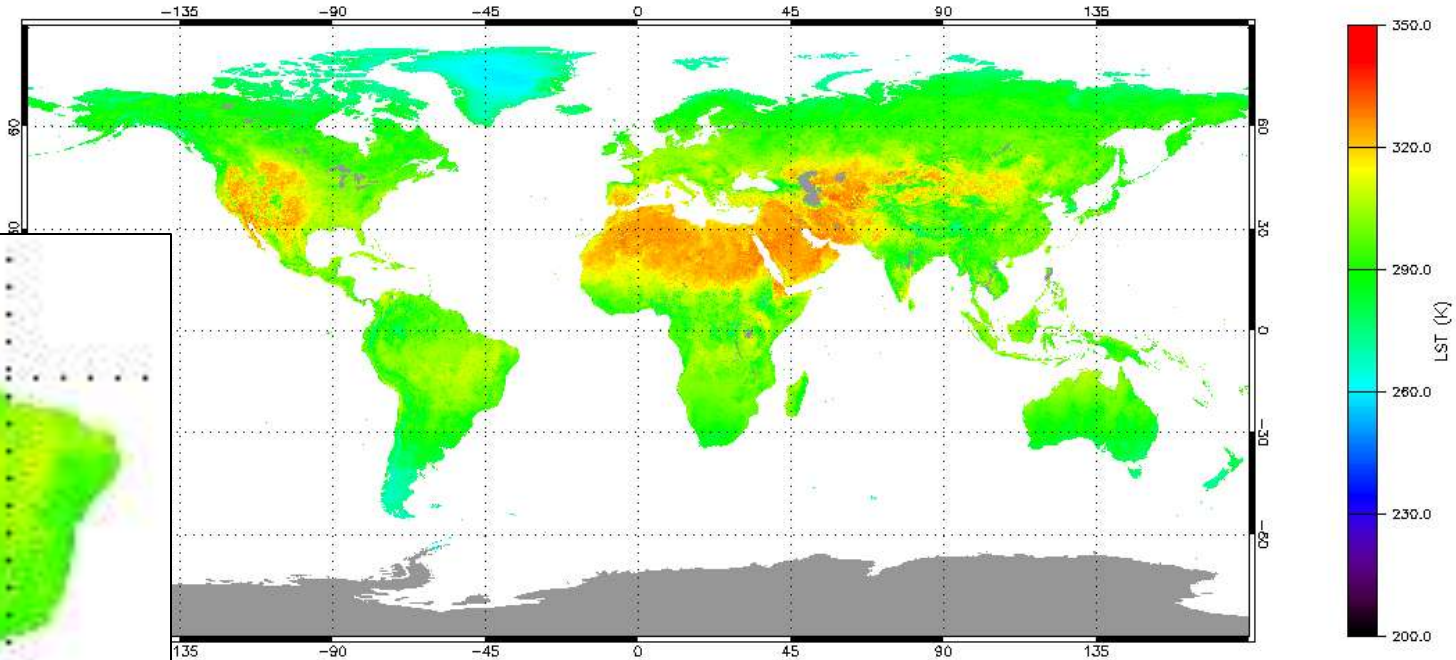
A proposed bilateral mission between the UK (Edinburgh, Leicester, SSTL) and JPL/NASA

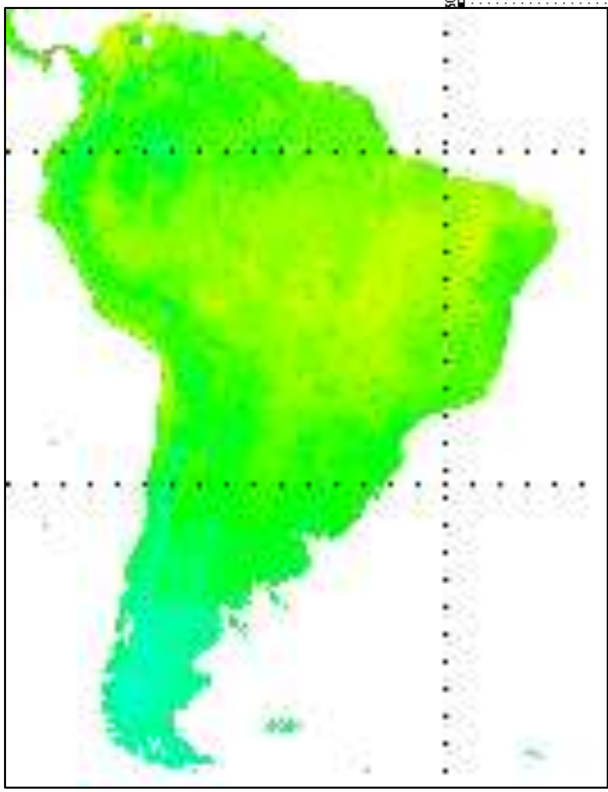
Primary objectives: Measure densely-sampled CO_2, CH_4 and CO columns over Tropics to improve understanding of tropical carbon cycle

Contact: Hartmut Boesch of U.Leciester

AATSR Land Surface Temperature (LST)

Level 3 data:
Daytime July 2006

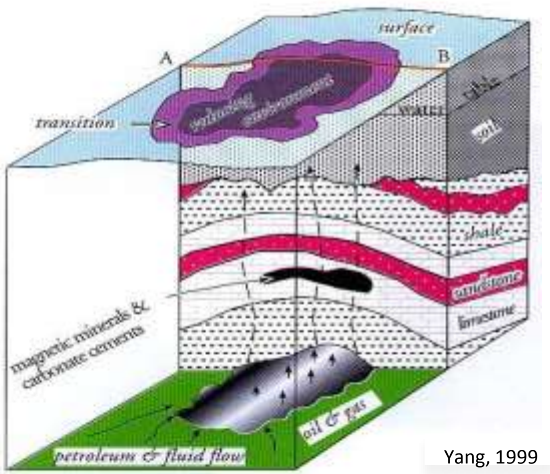




- Land surface temperature (LST) is the radiative skin temperature (~20µm) of the land
  - It determines the emission of surface-to-atmosphere long-wave radiation and exerts control over the partitioning of energy into latent and sensible heat fluxes, and heat flux into the ground
- Derived from Advanced Along Track Scanning Radiometer (ENVISAT) thermal IR measurements using an algorithm that corrects the atmospheric effects based on the differential absorption in adjacent channels
- LST can be used to drive/constrain land-surface models (e.g., UK Met Office's JULES model)

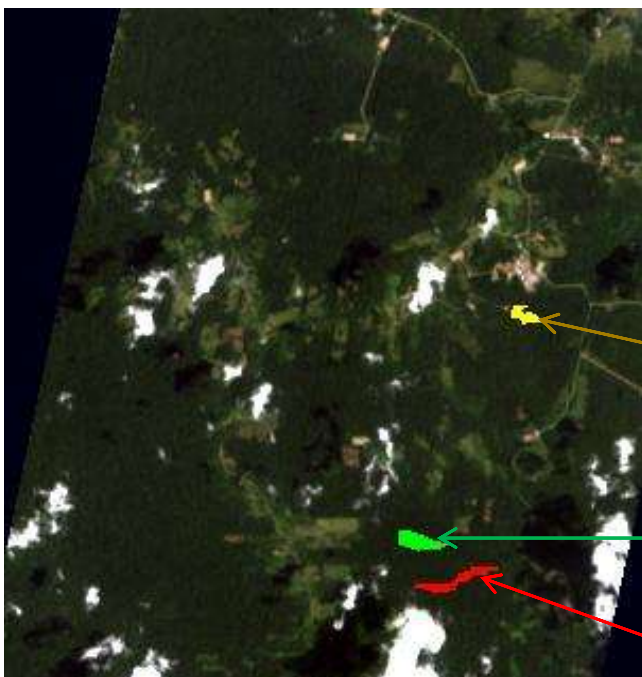
Contact:
John Remedios
of U.Leciester

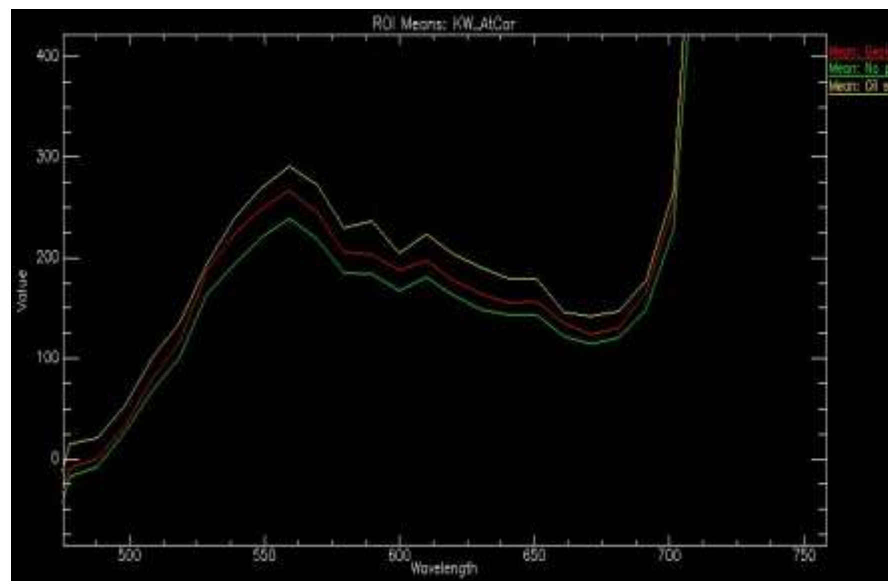
Detection of vegetation stress arising from hydrocarbon seepage in the Amazon rainforest



Yang, 1999

- Hydrocarbon seepage from geological reservoirs to the surface can cause vegetation stress – can this be detected from space?
- Preliminary results show a high reflectance response in areas influenced by hydrocarbons (spill and geological fault).
  - A reduction in the vegetation pigments (chlorophyll) is an indicator of vegetation stress correlates well with affected areas
- Field campaign to collect bio-physical/chemical parameters.
  - Scaling-up process to obtain reflectance at top-of-canopy using leaf/canopy RTMs.
- Use modelled reflectances to determine seepage areas from hyperspectral satellite images (Hyperion, EO-1)



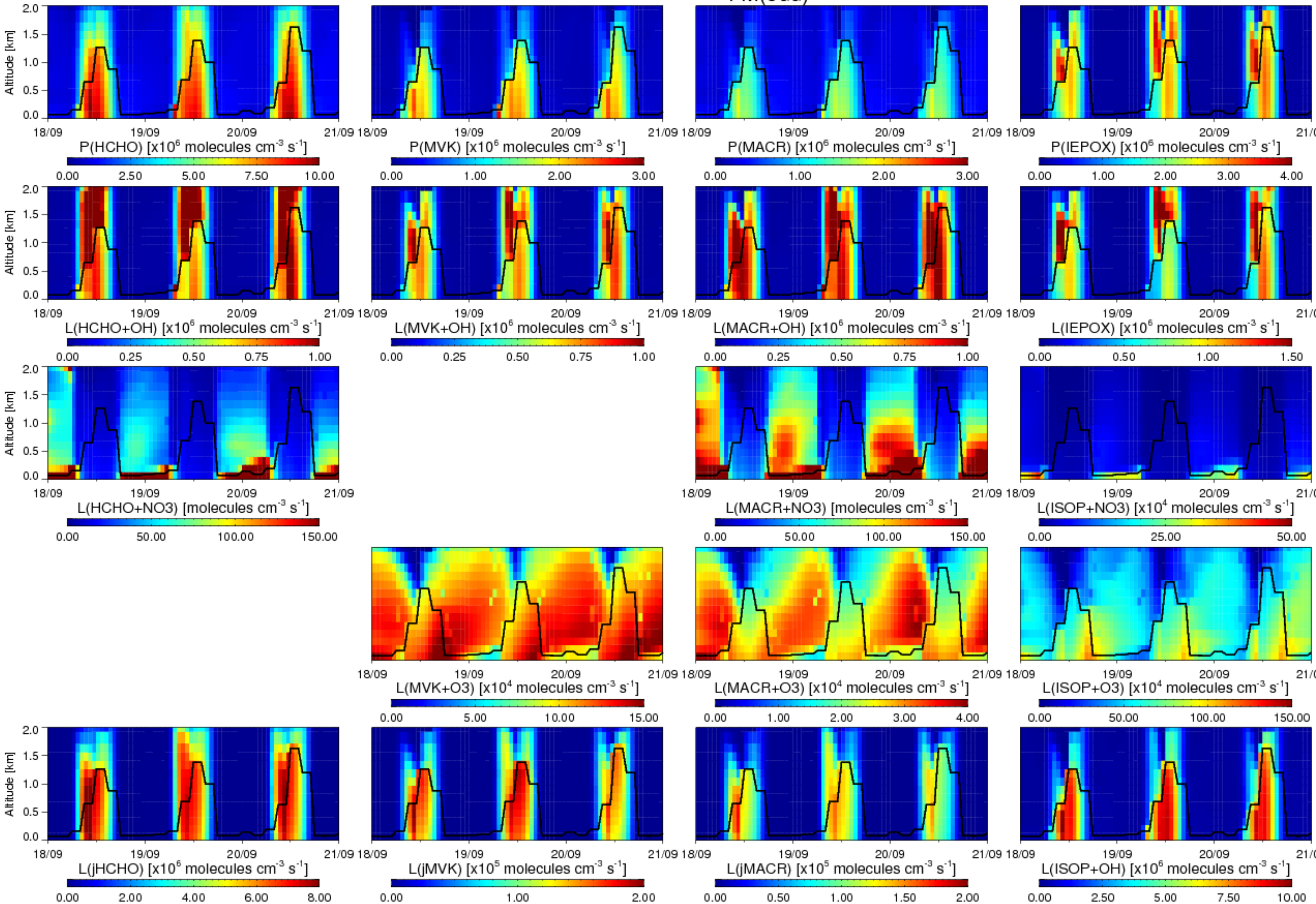


Contact: Paul Arellano / Kevin Tansey of U. Leciester

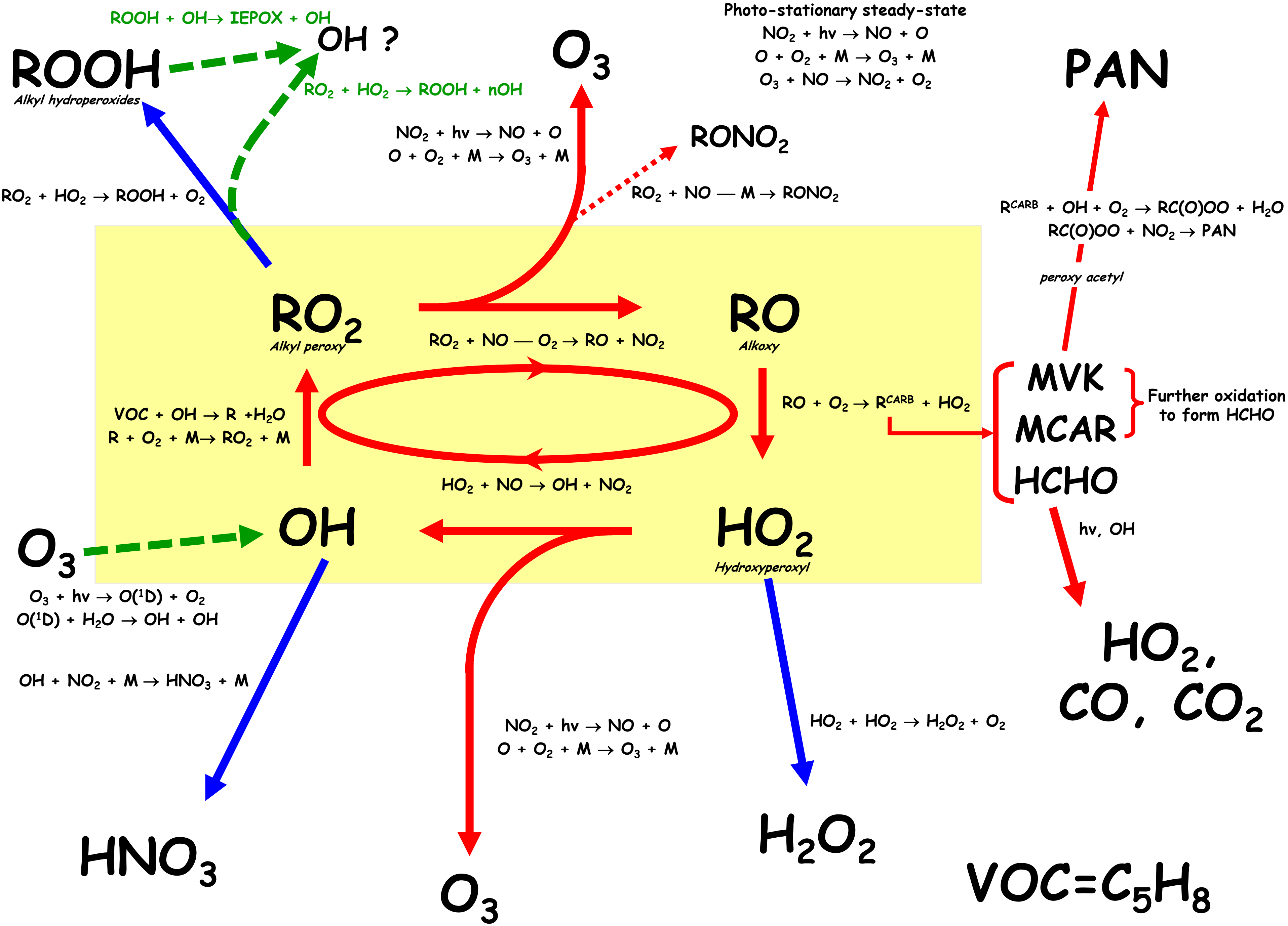
Thank you for listening.
Any questions?

Production and loss rates of key species

Scenario: $C_{FM(odd)}$



Chemistry: Caltech **BVOC Emissions:** MEGAN PCEEA **Dry deposition:** Old ('slow') scheme **BL mixing:** full-mixing



ROOH + OH → IEPOX + OH
OH ?
ROOH
Alkyl hydroperoxides
RO2 + HO2 → ROOH + nOH
RO2 + HO2 → ROOH + O2
O3
Photo-stationary steady-state
NO2 + hv → NO + O
O + O2 + M → O3 + M
O3 + NO → NO2 + O2
PAN
NO2 + hv → NO + O
O + O2 + M → O3 + M
RONO2
RO2 + NO — M → RONO2
RCARB + OH + O2 → RC(O)OO + H2O
RC(O)OO + NO2 → PAN
peroxy acetyl
RO2
Alkyl peroxy
RO2 + NO — O2 → RO + NO2
RO
Alkoxy
MVK
MCAR
HCHO
Further oxidation to form HCHO
RO + O2 → RCARB + HO2
VOC + OH → R +H2O
R + O2 + M→ RO2 + M
HO2 + NO → OH + NO2
O3
OH
HO2
Hydroxyperoxyl
hv, OH
O3 + hv → O(1D) + O2
O(1D) + H2O → OH + OH
OH + NO2 + M → HNO3 + M
HO2,
CO, CO2
NO2 + hv → NO + O
O + O2 + M → O3 + M
HO2 + HO2 → H2O2 + O2
HNO3
O3
H2O2
VOC=C5H8

Top-down estimates from an ensemble of scenarios

Scenario	Description
PCEEA	* DEFAULT SCENARIO* Parameterized PCEEA algorithm [Guenther et al. 2006]
HYBRID	5-layer canopy model [Guenther et al. 1999, 2006]
MULLER	HYBRID emissions x 0.635 to match Muller et al. [2008]
LPJ-G5	LPJ-GUESS using GEOS-5 meteorology
LPJ-CRU	LPJ-GUESS using CRU meteorology
BL	As default but with non-local boundary layer mixing scheme
SLOWDEP	As default but with standard OVOC deposition rates
HPALD	As default but assume fast photolysis of hydroperoxy aldehydes (HPALDs)
LIMO	As default but formation of HPALDs explicitly included [Peeters et al. 2009 etc]
KPP	As default but using KPP (Rosenbrock Rodas 3) chemical solver
CHEMT	As default but emissions, chemistry and dynamics all at 10 min time steps
ALB	As default but using TOMS surface reflectance in AMF [Herman and Celarier 1997]
CF +	As default but assume a +0.1 error in cloud fraction in AMF calculation
CF -	As default but assume a -0.1 error in cloud fraction in AMF calculation
CTP +	As default but assume a +60 hPa error in cloud-top pressure in AMF calculation
CTP -	As default but assume a -60 hPa error in cloud-top pressure in AMF calculation

An integrated observing/modelling system