HYPXIM: a second generation high spatial resolution hyperspectral satellite for the assessment of plant biodiversity

S. Jacquemoud [1], D. Sheeren [2], X. Briottet [3], V. Carrère [4], R. Marion [5] & the HYPXIM Science Study Group

(1) IPGP, Sorbonne Paris Cité, Université Paris Diderot, UMR CNRS 7154, 35 rue Hélène Brion, 75013 Paris, France
(2) DYNAFOR « Dynamique & Ecologie des Paysages Agriforestiers » , UMR 1201 INRA, Av. de l'Agrobiopôle,
31326 Castanet-Tolosan, France
(3) ONERA, 2 avenue Edouard Belin, BP 74025, 31055 Toulouse, France
(4) Université de Nantes, UMR-CNRS 6112, 2 rue de la Houssinière BP 92208, 44322 Nantes, France
(5) CEA/DAM/DIF, 91297 Arpajon, France

Vegetation:

Provides foundations for life on Earth through ecological functions: regulation of climate and water, habitat for animals, supply of food and good

Biodiversity:

Degree of variation in the composition and functioning of life at scales ranging from genes to entire biomes

Plant biodiversity:

Important because it may boost ecosystem productivity, but also for conservation research, management and policy development, etc.

Multi-dimensional in character, i.e., it involves multiple species and physiological processes (photosynthesis, evapotranspiration, carbon storage, decomposition of organic matter) that interact and proceed at multiple scales

Measured by different criteria: taxonomic distribution of plants, leaf chemical composition, functional traits, number of trees, architecture of plants, etc.

GLOBAL BIODIVERSITY: SPECIES NUMBERS OF VASCULAR PLANTS

© W. Barthlott 1996,1997
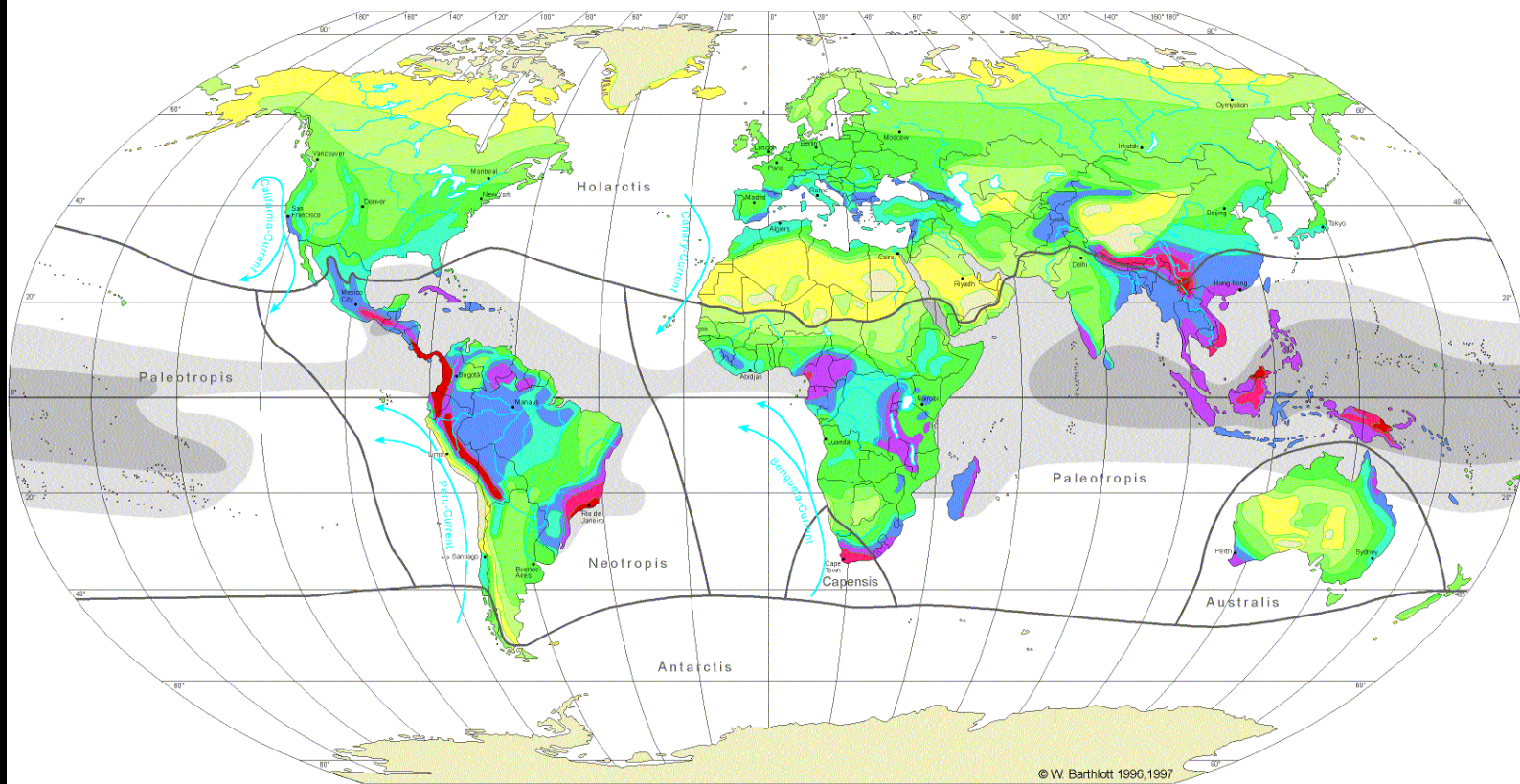
Robinson Projection
Standard Parallels 38°N und 38°S
Scale 1: 130 000 000

Diversity Zones (DZ): Number of species per 10.000km^2

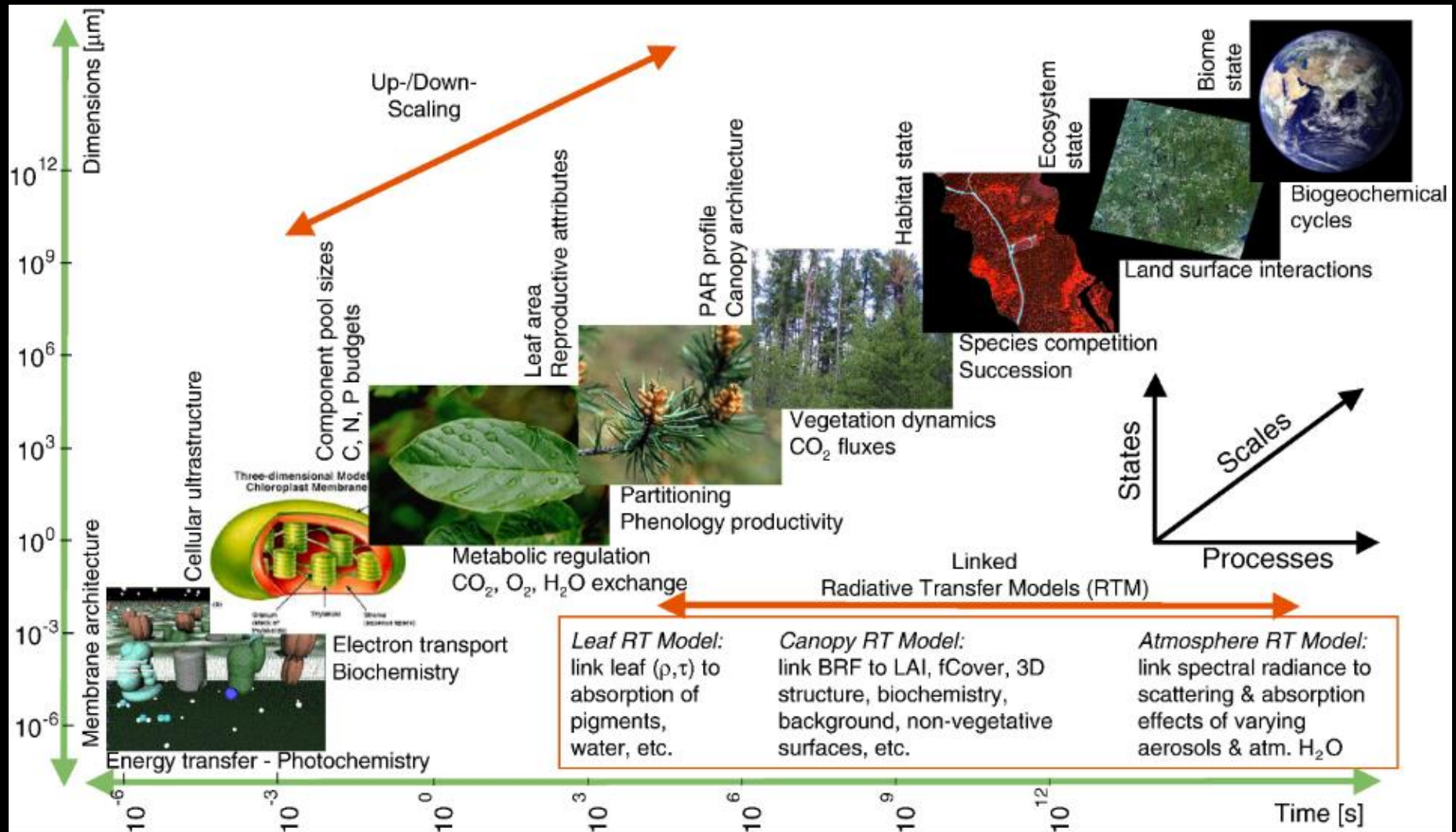|		
DZ 1 (<100)	DZ 5 (1000 - 1500)	DZ 9 (4000 - 5000)
DZ 2 (100 - 200)	DZ 6 (1500 - 2000)	DZ 10 (≥5000)
DZ 3 (200 - 500)	DZ 7 (2000 - 3000)	
DZ 4 (500 - 1000)	DZ 8 (3000 - 4000)	

Capensis   floristic regions

sea surface temperature
>29°C
>27°C

cold currents

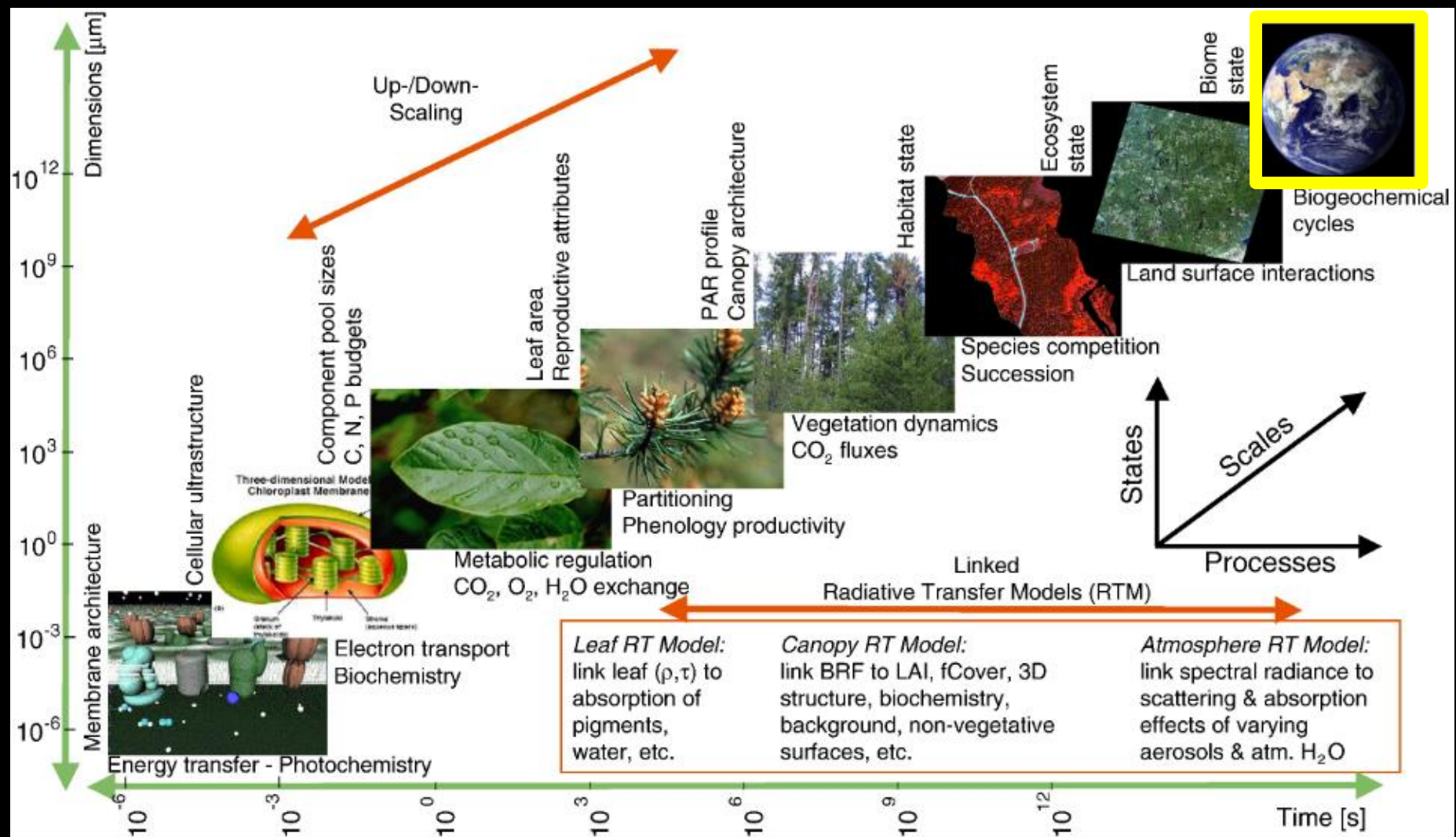W. Barthlott, N. Biedinger, G. Braun
F. Feig, G.Kier, W. Lauer & J. Mutke 1997
modified after
W. Barthlott, W. Lauer & A. Placke1996
Department of Botany and Geography
University of Bonn
German Aerospace Research Establishment, Cologne

Cartography: M. Gref
Department of Geography
University of Bonn

Barthlott et al. (1999), *Acta Botanica Fennica*, 162:103-110.

Vegetation studies: coupled states, processes and scales

Schaepman et al. (2009), *Remote Sensing of Environment*, 113:S123-S137.

Vegetation studies: hyperspectral instruments

GOME-2

~5km

Schaepman et al. (2009), *Remote Sensing of Environment*, 113:S123-S137.

Vegetation studies: hyperspectral instruments

Schaepman et al. (2009), *Remote Sensing of Environment*, 113:S123-S137.
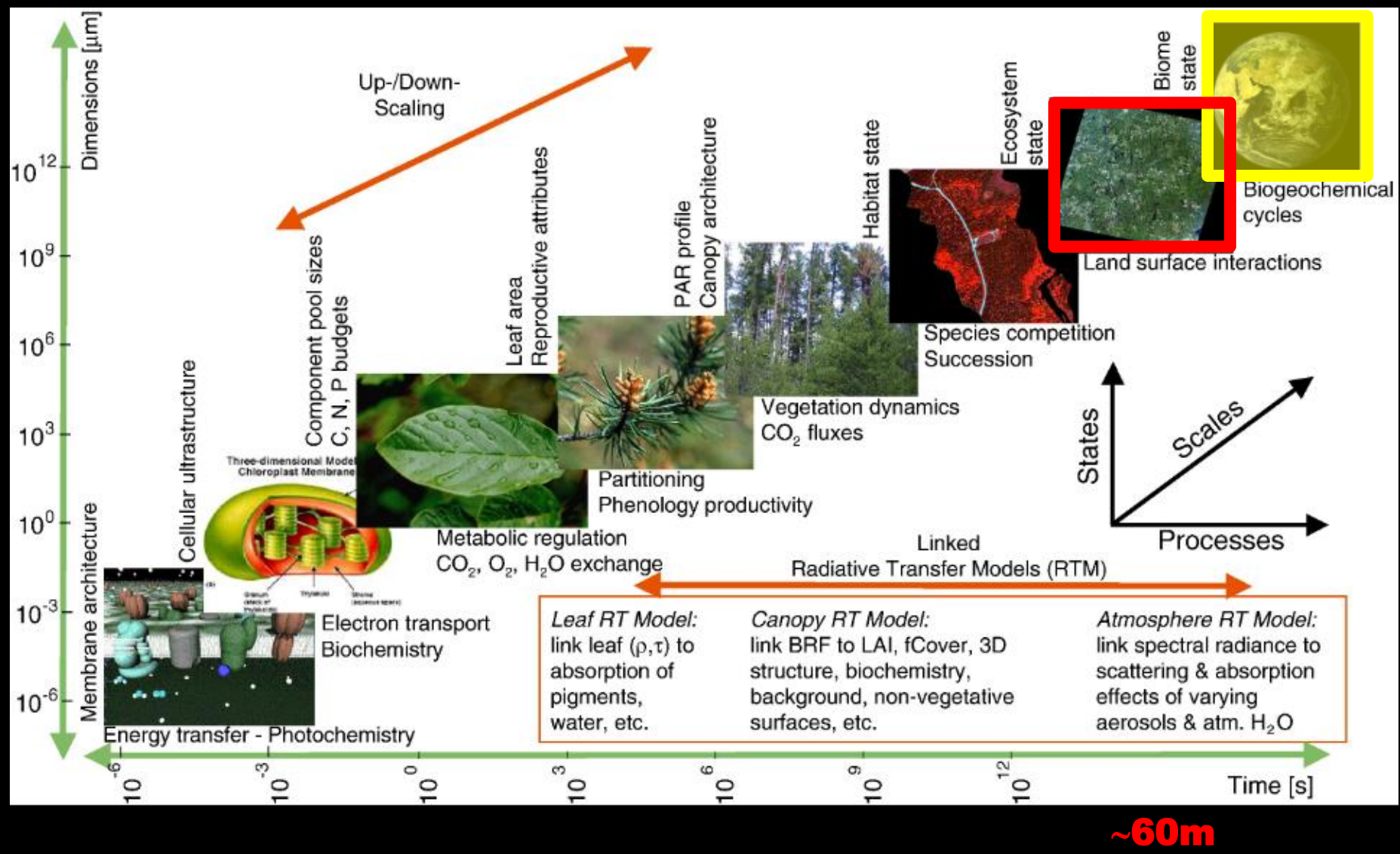
Vegetation studies: hyperspectral instruments

EnMAP **HyspIRI** **GOME-2**

~30m

Schaepman et al. (2009), *Remote Sensing of Environment*, 113:S123-S137.
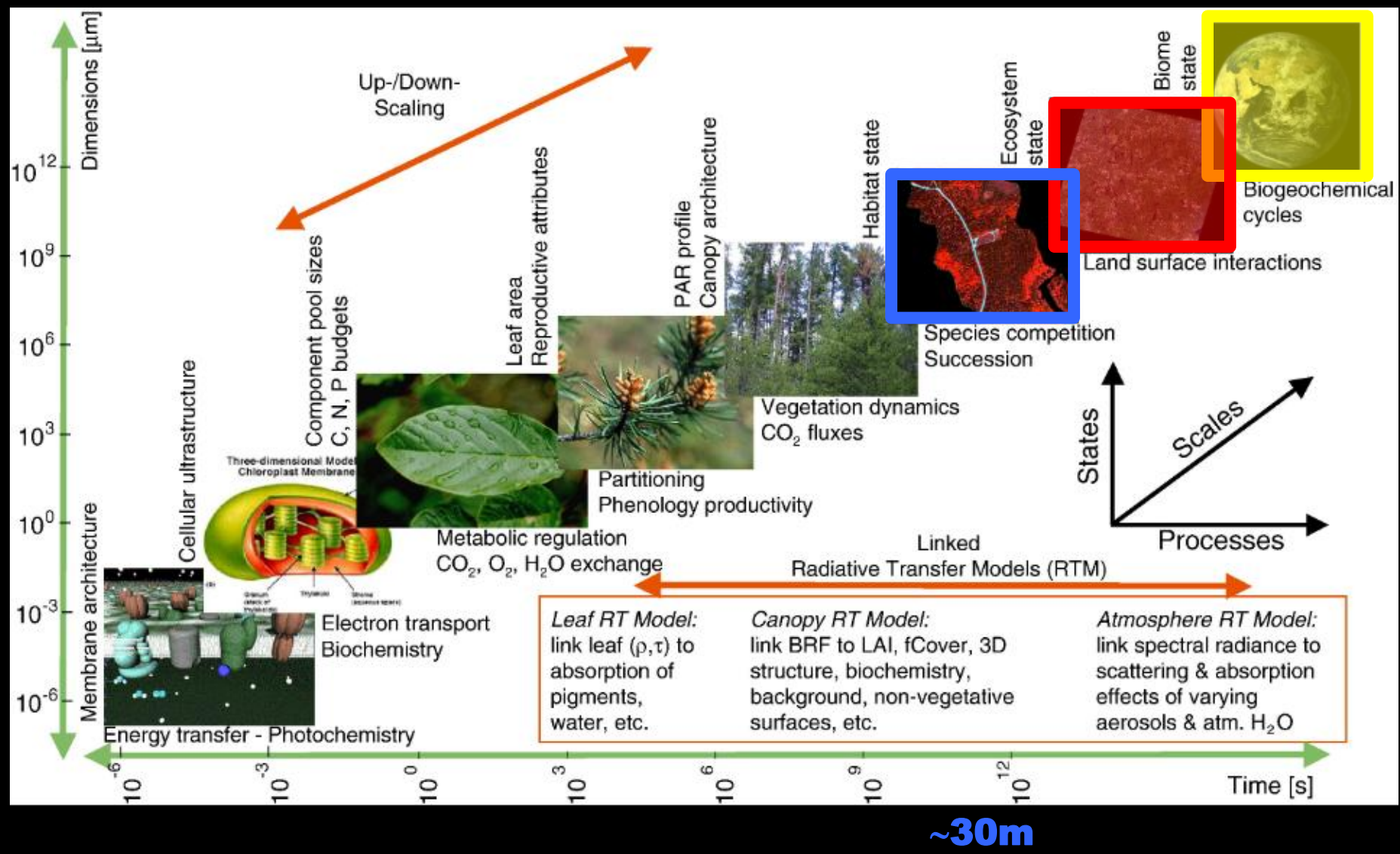
Vegetation studies: hyperspectral instruments

ASD   **EnMAP HysplRI GOME-2**

~1m

Schaepman et al. (2009), *Remote Sensing of Environment*, 113:S123-S137.
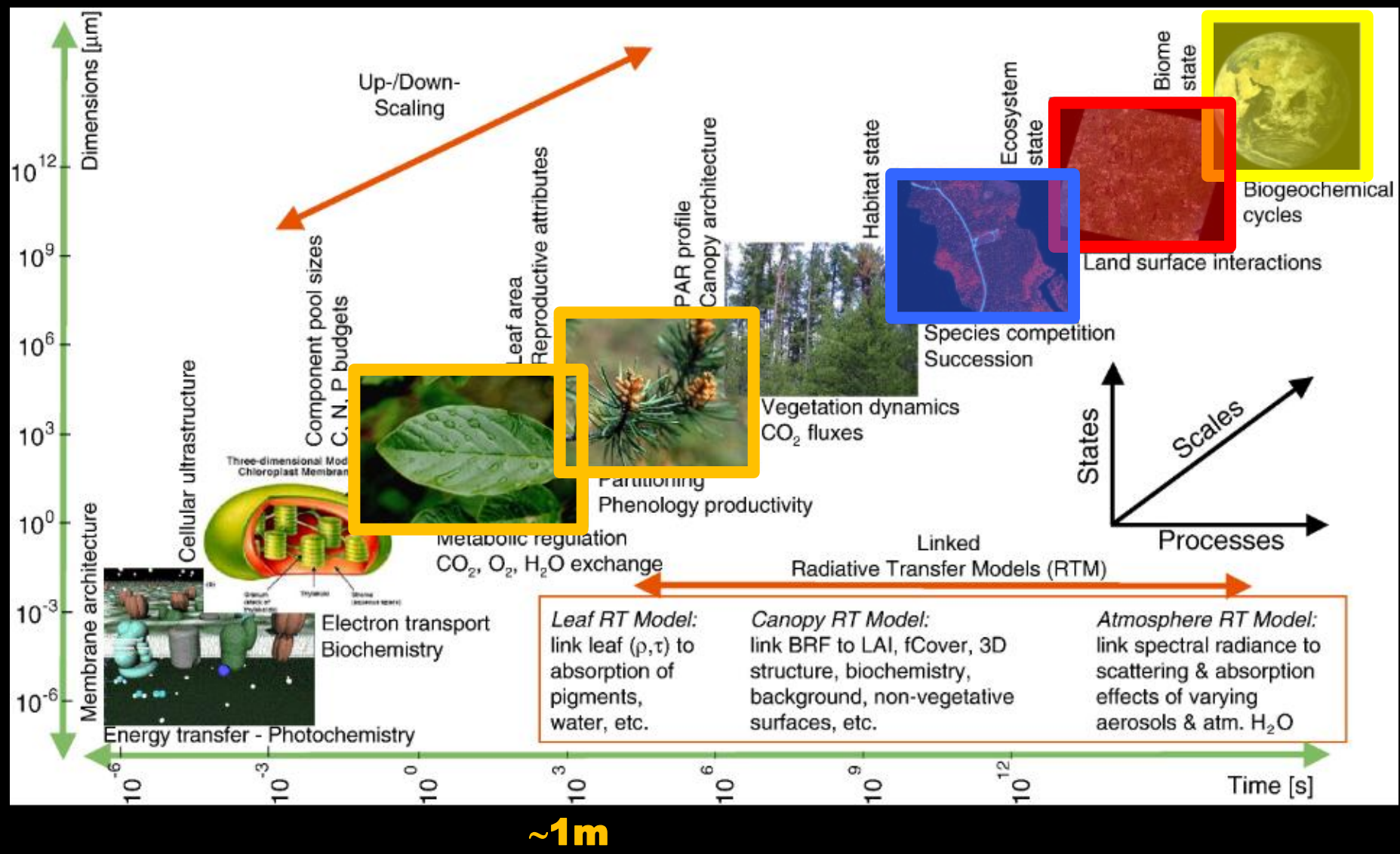
Vegetation studies: hyperspectral instruments

ASD **HYPXIM** **EnMAP** **HyspIRI** **GOME-2**

~1m **~30m** **~60m** **~5km**

Schaepman et al. (2009), *Remote Sensing of Environment*, 113:S123-S137.
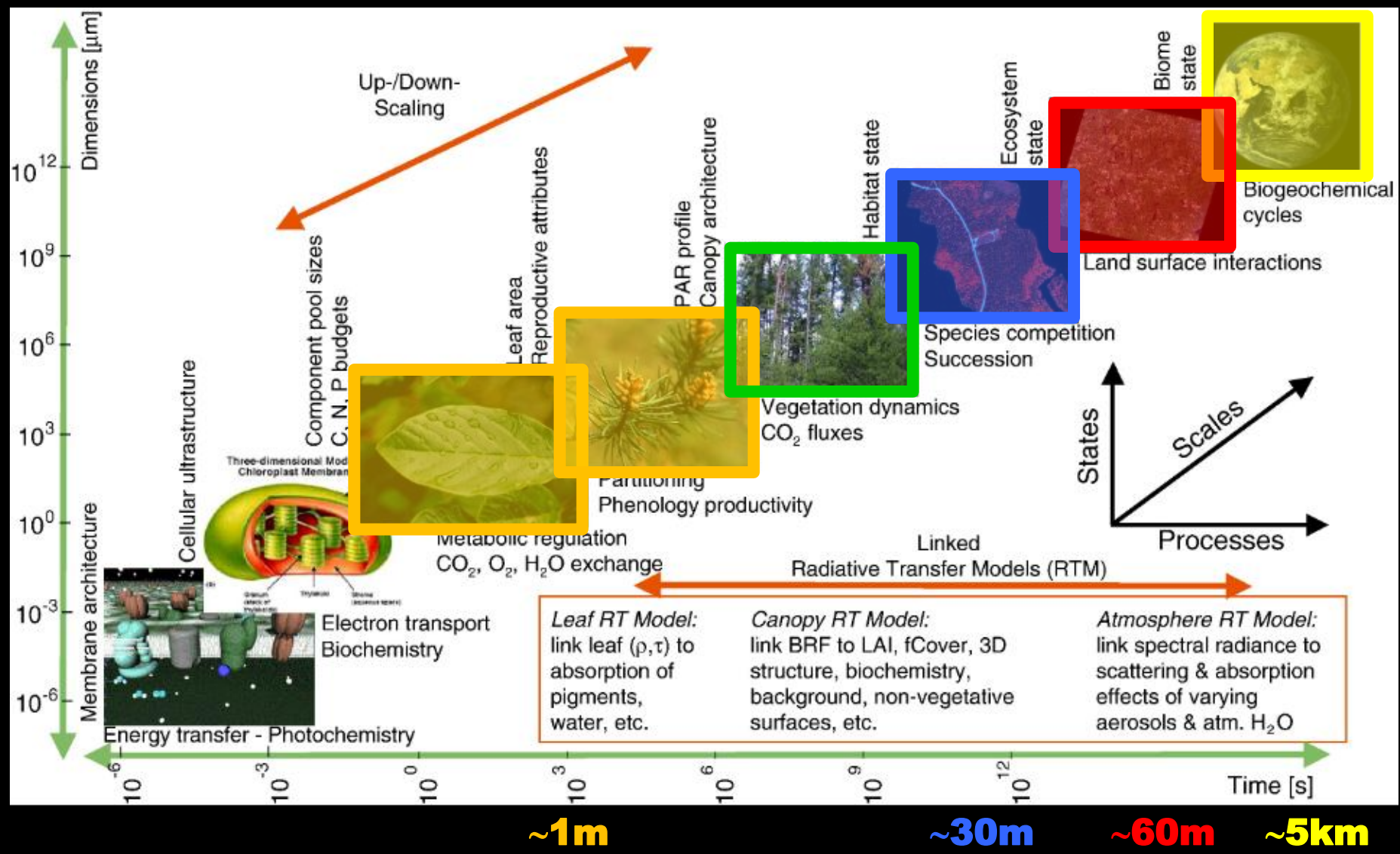
What is HYPXIM?

⇒ Altitude: 660 km
⇒ Swath: 16 km
⇒ Global access
⇒ Revisit period: from 3 days (pointing capability) to 19 days (nadir)
⇒ Payload budget: mass ~115 kg, power < 150 W (imaging), minisatellite

Domain	Wavelength range (nm)	Spectral resolution $\delta\lambda$ (nm)	Pixel size (m)	SNR
VIS	400-700	10	≤ 8 m	≥ 250:1
VNIR	700-1100	10	≤ 8 m	≥ 200:1
SWIR	1100-2500	10	≤ 8 m	≥ 100:1
PAN	400-800	400	≤ 2 m	≥ 90:1

⇒ The spectral continuum is required from VIS to SWIR optical domain with a spectral resolution of 10 nm
⇒ The panchromatic image can be combined with the hyperspectral image so as to enhance spatial resolution
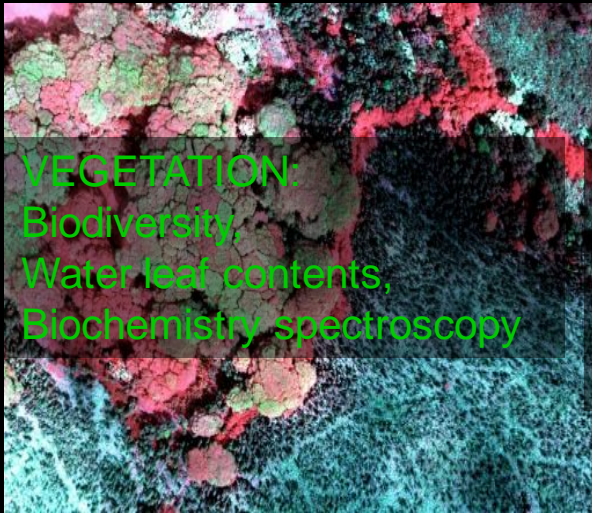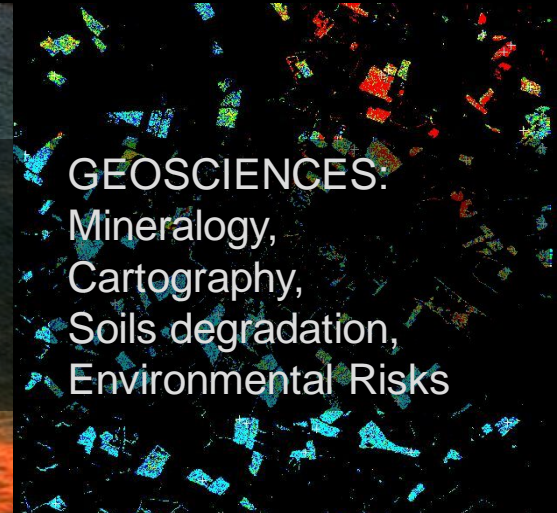⇒ Launch: 2021
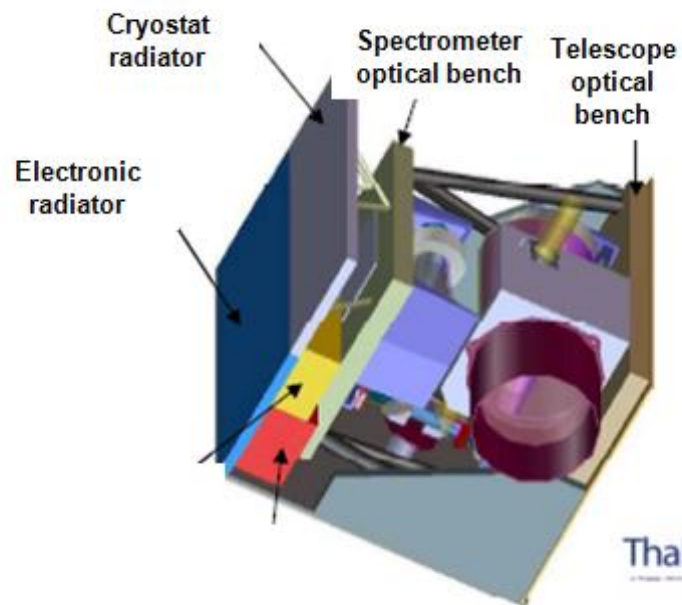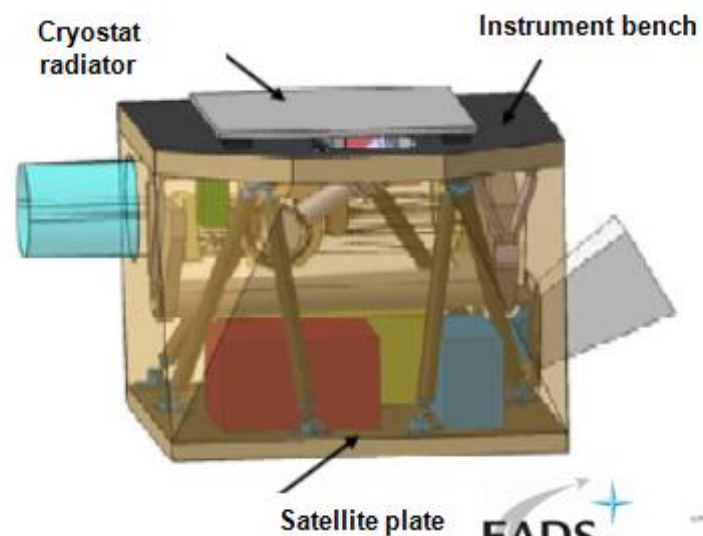
HYPXIM: five main applications

VEGETATION:
Biodiversity,
Water leaf contents,
Biochemistry spectroscopy

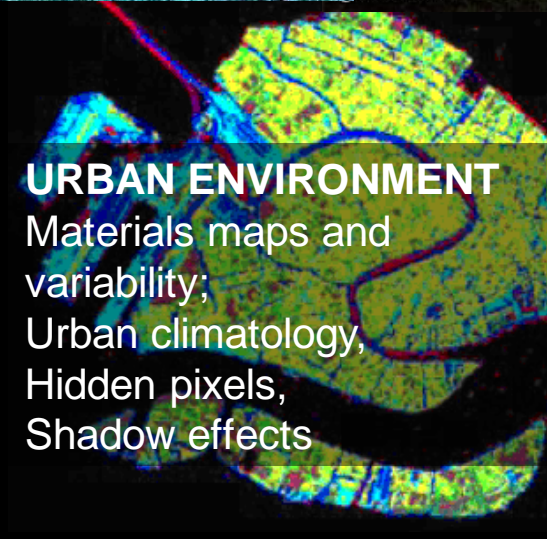COASTAL ECOSYSTEMS:
Biometry, red tide blooming,
Bathymetry, sedimentology
Effluents, water quality,
Intertidal cartography

PJS Franks

GEOSCIENCES:
Mineralogy,
Cartography,
Soils degradation,
Environmental Risks

URBAN ENVIRONMENT
Materials maps and
variability;
Urban climatology,
Hidden pixels,
Shadow effects
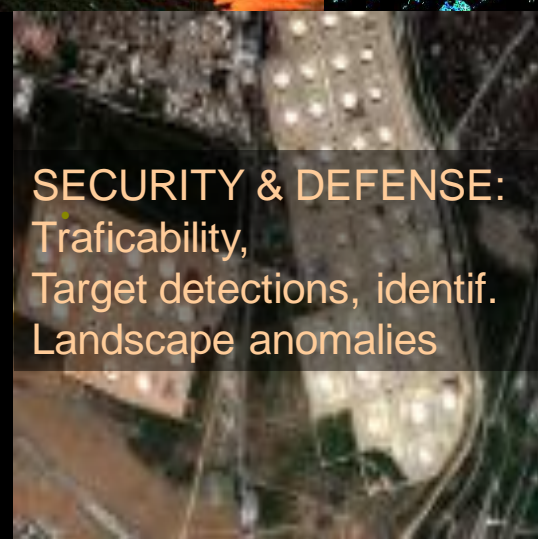
SECURITY & DEFENSE:
Traficability,
Target detections, identif.
Landscape anomalies

Vegetation: main variables of interest

But also LAI, light use efficiency, C:N, etc.

Asner et al. (2011), *Global Terrestrial Ecosystem Observatory (GTEO)*, NASA Earth Venture-2 Announcement of Opportunity, 216 pp.

Species mapping using support vector machine (SVM) classifier
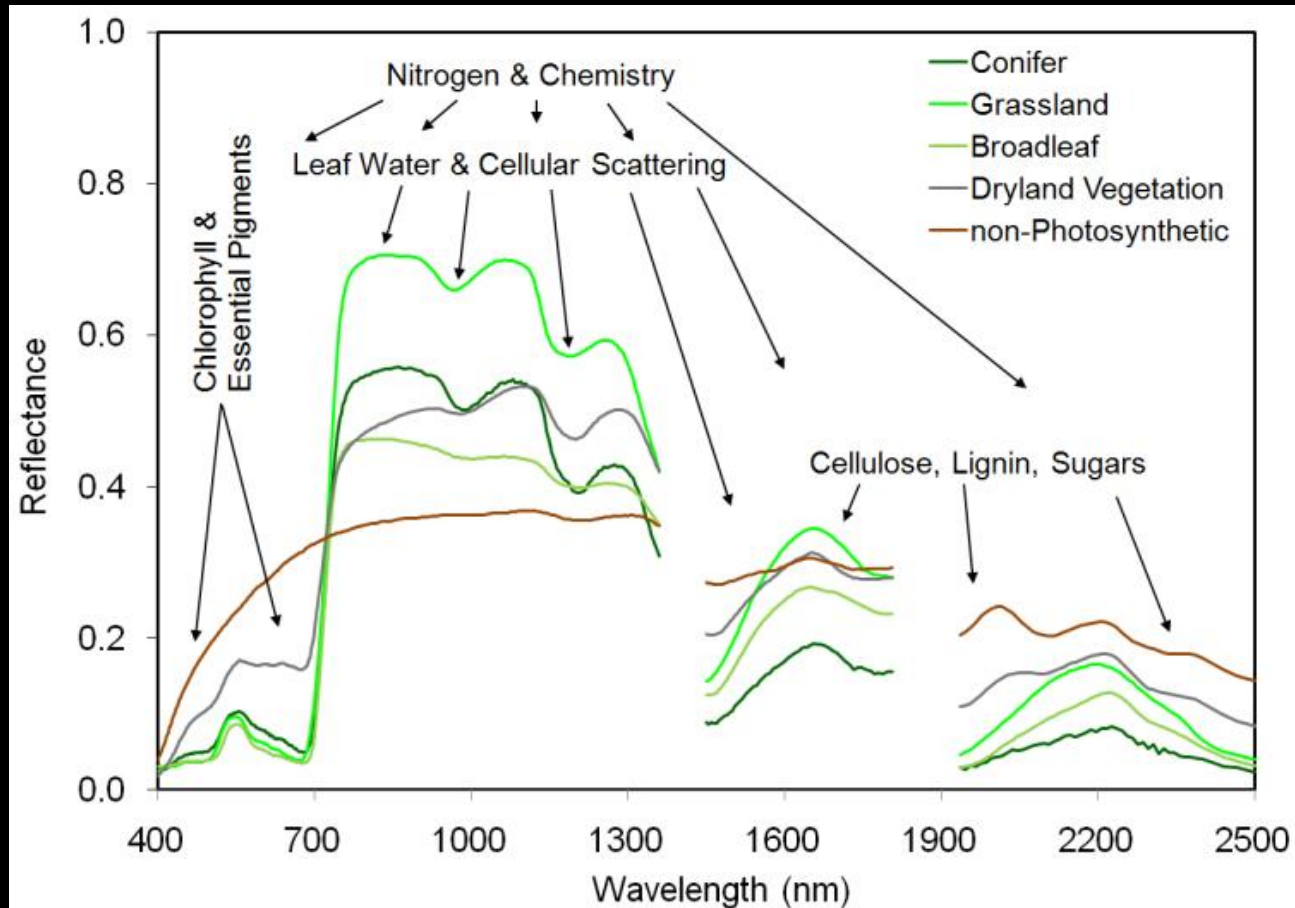
Villelongue (France)

Elyakime et al. (2011), *Journal of Alpine Research*, http://dx.doi.org/10.4000/rga.1585.
Sheeren et al. (2011), *IEEE International Geoscience and Remote Sensing Symposium*, pp. 3672-3675.
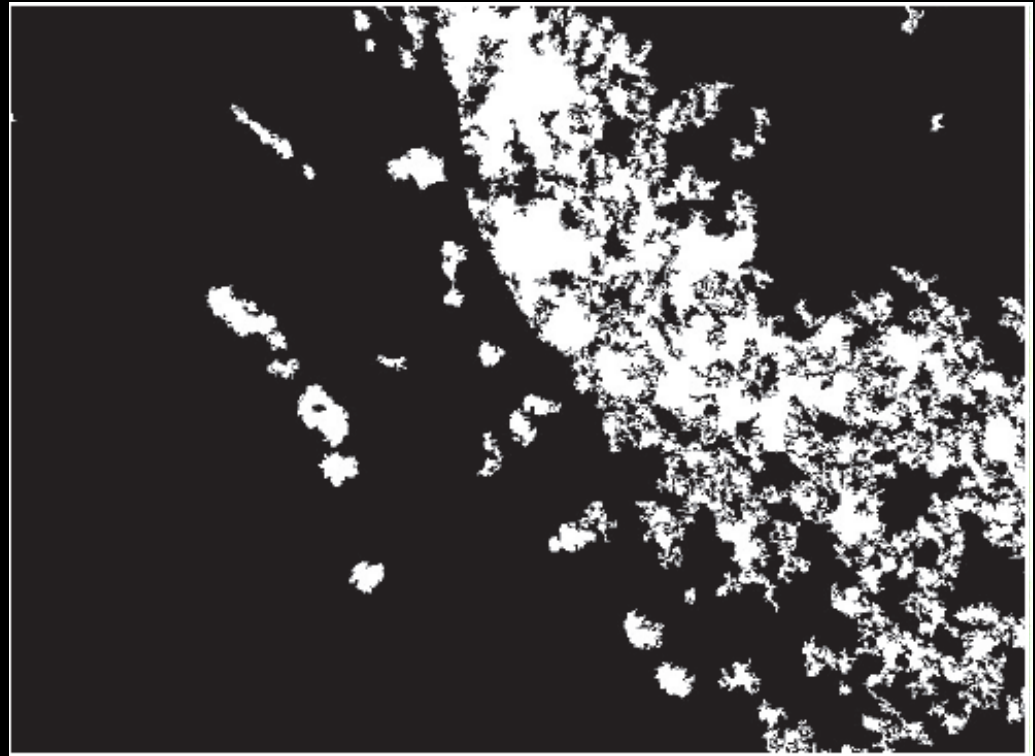
Species mapping using regularized discriminant analysis (RDA)

CAO- Alpha

Nanawale Forest Reserve (HI)

200 m

■ *Aleurites moluccana*	■ *Cananga orodata*	■ *Cecropia peltata*	■ *Cocos nucifera*	■ *Eucalyptus robusta*	■ *Flindersia brayleyana*
■ *Mangifera indica L.*	□ *Melochia umbellata*	■ *Metrosideros polymorpha*	■ *Pandanus tectorius*	■ *Persea americana*	■ *Pithecellobium saman*
■ *Psidium cattleianum*	■ *Psidium guajava*	■ *Syzygium jambos*	■ *Trema orientalis*	■ *Zingiber zerumbet*	

Féret & Asner (2013), *IEEE Transactions on Geoscience and Remote Sensing*, 51:73-84.
http://cao.stanford.edu/

Biodiversity assessment

Los Amigos Biological Station (Peru)

2 km
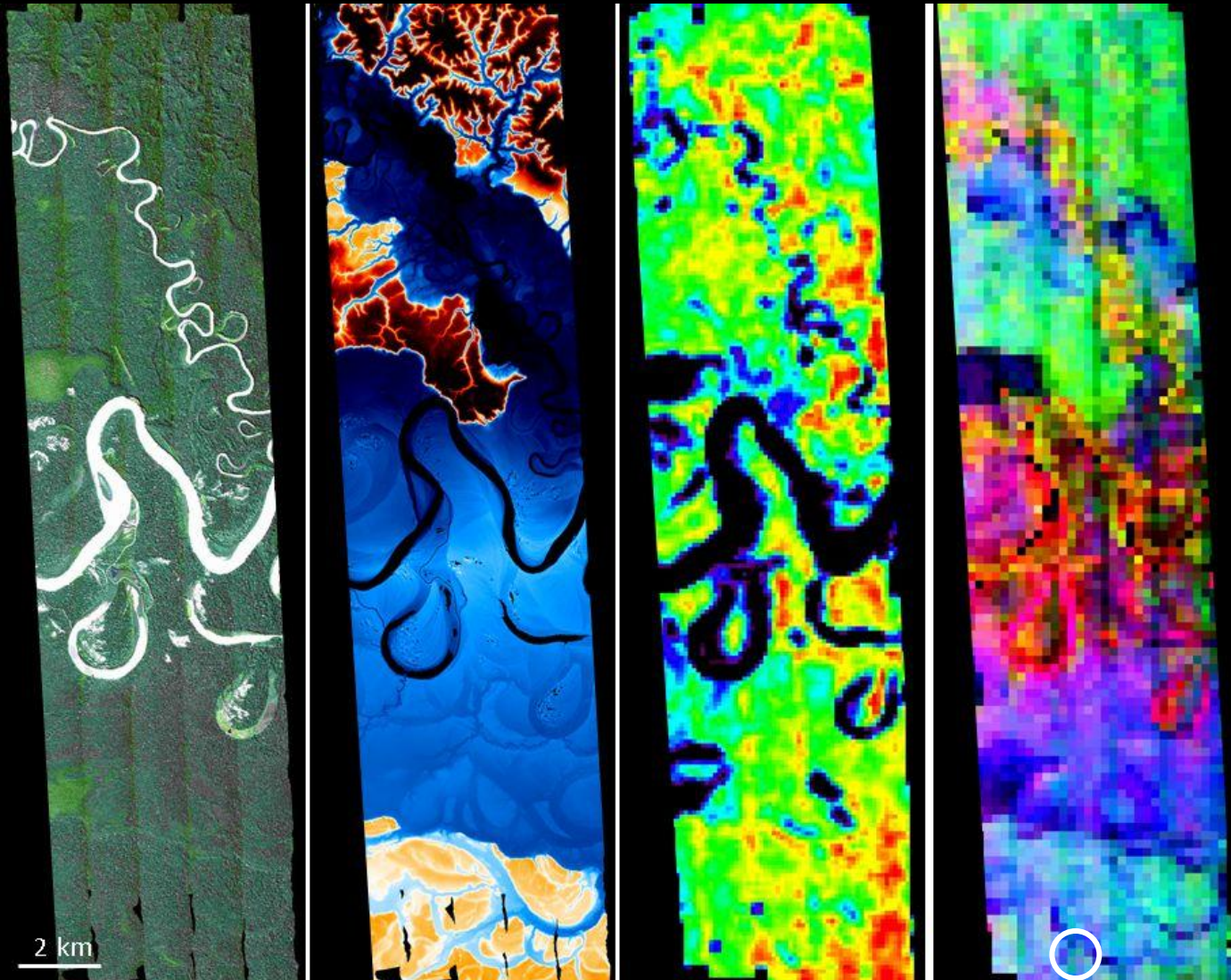
Detection of invasive species

Iceplant (*Carpobrotus edulis*)

Jubata grass (*Cortaderia jubata*)

Vandenberg Air Force Base (CA)

N   2 kilometers

Intact scrub	Iceplant 51-75%	Intact chaparral
Iceplant 91-100%	Iceplant 0-50%	Chaparral & Jubata grass
Iceplant 76-90%	Chaparral & Iceplant	Masked

Underwood et al. (2003), *Remote Sensing of Environment*, 86:150-161.
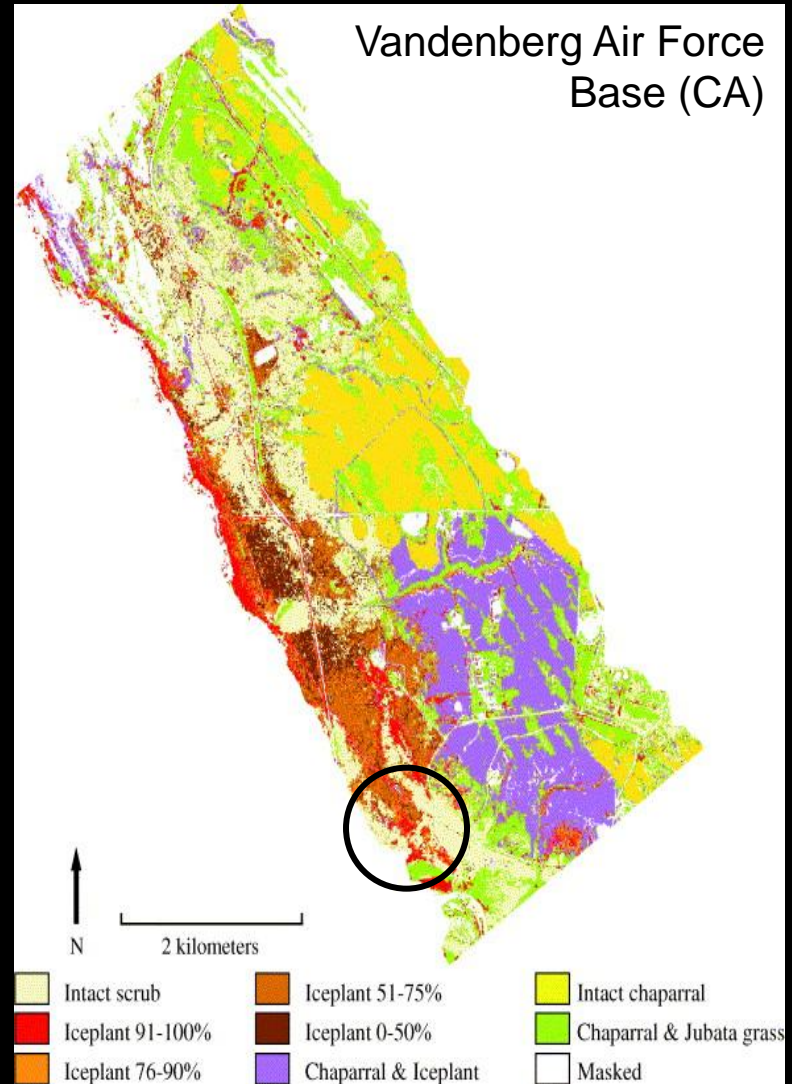
Conclusion

⇒ Pixel size of most present or future hyperspectral instruments not suited for some applications

HYPXIM

⇒ Data characteristics close to *in situ* or airborne measurements

⇒ Accurate measurement of vegetation biophysical variables poorly retrieved at lower resolution

⇒ Better estimate of human impact on the environment at a local scale

Situation

⇒ A phase 0 study conducted by CNES from 2009 to 2012 proved the mission's feasibility

⇒ A phase A started in January 2013

But…

⇒ It was frozen in June 2013 due to budget cut

⇒ It may restart in 2014 thanks to a growing scientific community