Uncertainties of the Regional Terrestrial Biota Full Carbon Account: A Systems Analysis

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Only a Full Carbon Account Complies with the Ultimate Goal of the UNFCCC

"A full carbon budget encompasses all components of all ecosystems and is applied continuously in time"

Steffen et al., *Science*, Vol. 280, p. 1394

Two Major Goals of the Full Carbon Account (FCA)

- To quantify all carbon pools and fluxes included in the account
- To reliably estimate uncertainties

Major Requirements of the FCA

- Need for a systems (holistic) approach
- Use of strict definitions and formally complete classification schemes
- Accounting schemes, models and assumptions should be presented in an explicit algorithmic form
- Spatially explicit distribution of pools and fluxes
- Clearly defined temporal dimensions

Uncertainty — Major Terms

- Precision — reproducibility or a measure of random error
- Accuracy — correctness or a measure of bias
- Uncertainty — an aggregation of insufficiencies of our system output, regardless of whether these insufficiencies result from a lack of knowledge, the intricacies of the system, or other cases

Sources of Uncertainties

- Definitions and classification schemes
- Shortcomings of available data
- Unknown or insufficient precision of data
- Lack of a proper basis for upscaling
- Short time series
- Lack of knowledge of important processes
- Oversimplification of modeling approach
- Spatially and temporally insufficient observations

Need for a “certified” FCA

- Completeness of the FCA
- Uncertainties at all stages and for all modules are estimated comprehensively, transparently and verifiably
- The “certified” account should serve as guidelines for the management of uncertainties

Two Basic Practical Consequences

- Need for the systems integration of information sources, methods and models
- Need for a “multiple-constraint” approach (“bottom-up–top-down” philosophy as an important part)

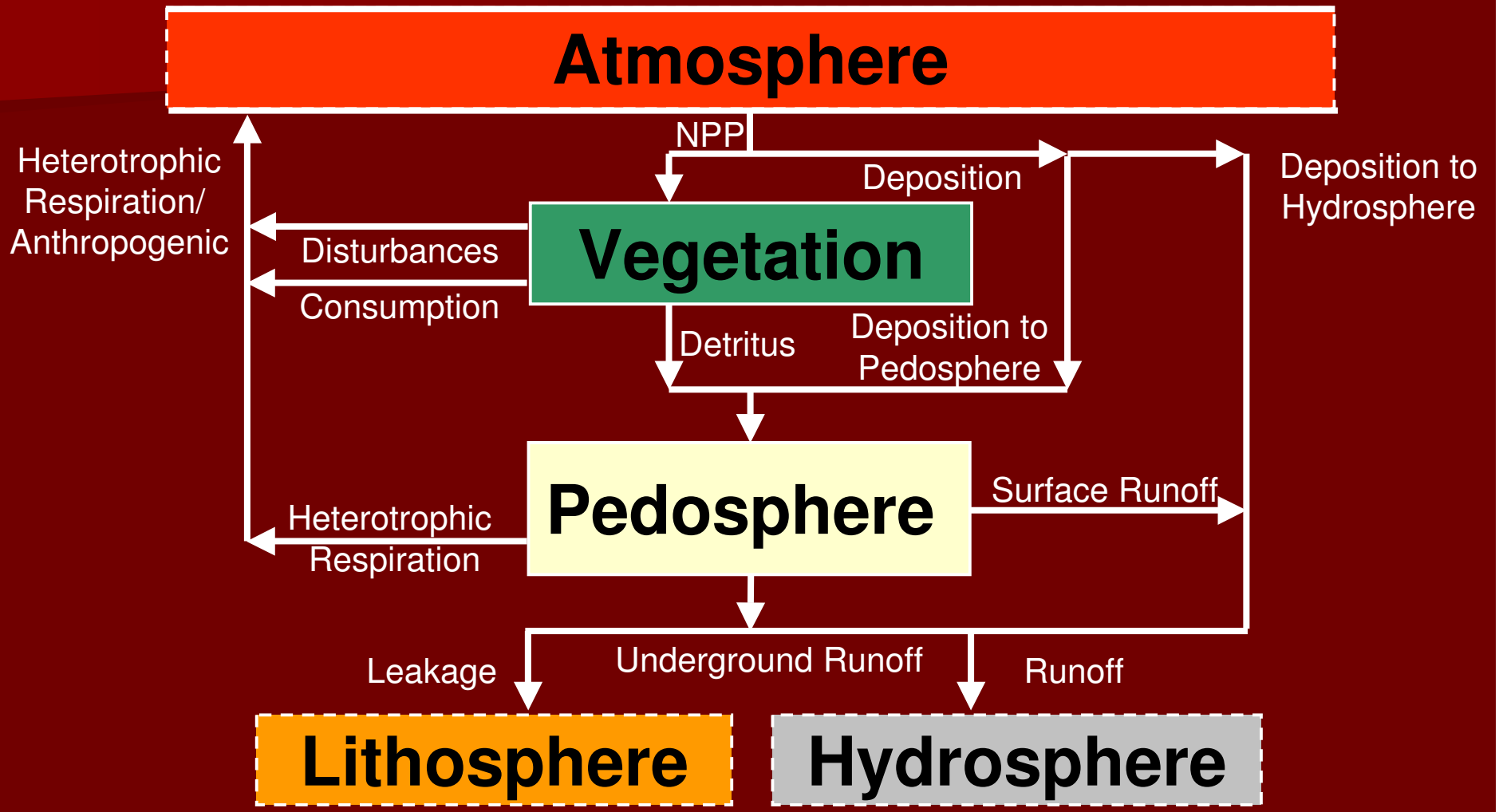
Assessing Uncertainties

(1) Estimation of precision (based on measurements and models)

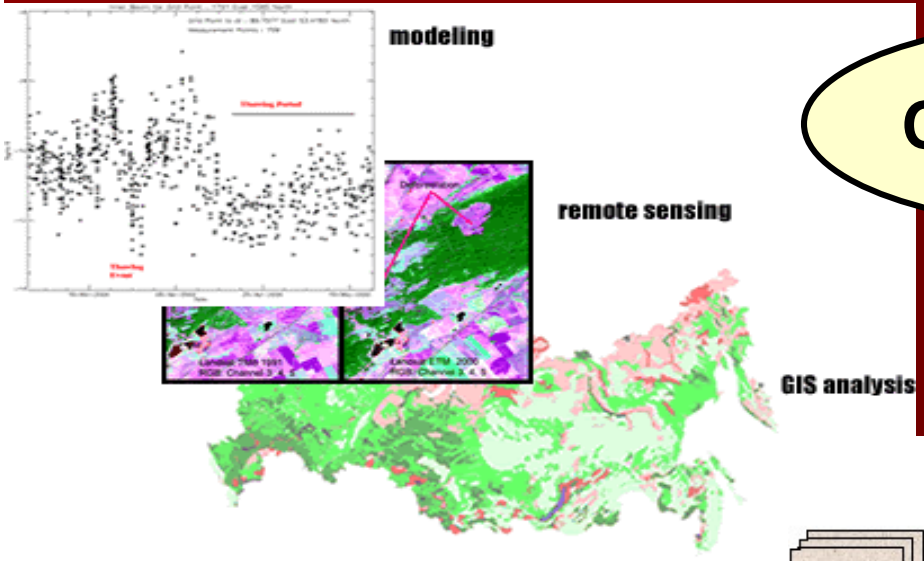
(2) Transformation of precision into uncertainties (multiple approaches)

(3) Multiple-constraint of all uncertainties (measurements, models, varying approaches)

The Full Carbon Account

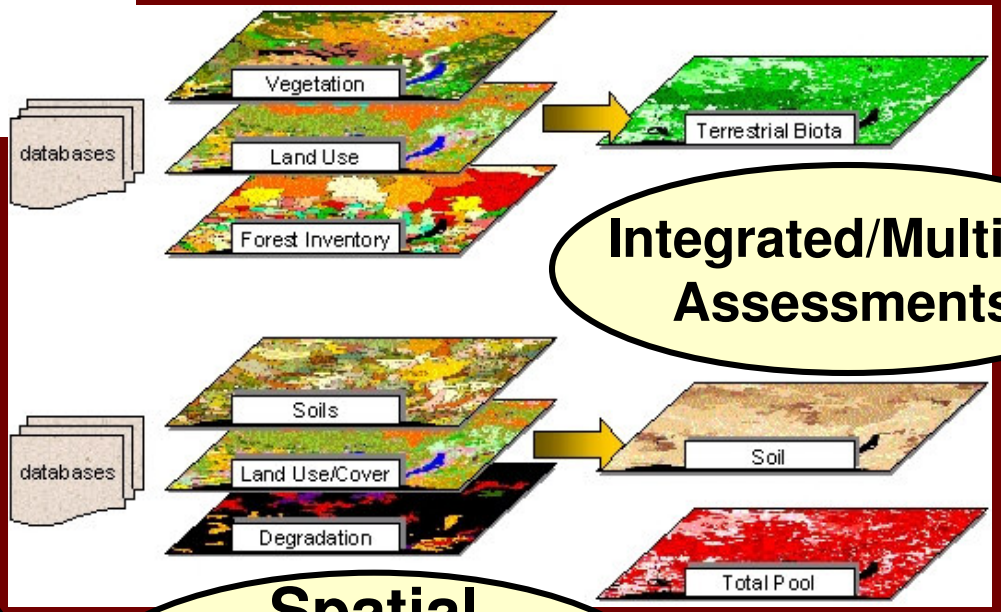


Input Datasets for and Characteristics of FCA



Consistency

Systems Approach



Integrated/Multiple Assessments

Complete Accounting

Uncertainties

Spatial and Temporal Verification

Core Model for Biogenic (CO_2, CH_4, N_2O) GHG Inventory

Forest

Wetlands

Direct Emissions

Atmosphere

Decay

Respiration

Consumption disturbances

N-fixation

Agriculture

NPP

Plant

Litter fall

N-uptake

Litter

Soil

Humification

Calculator

Grasslands

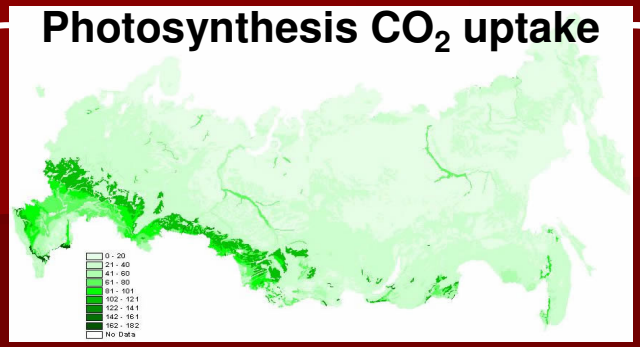
Lithosphere

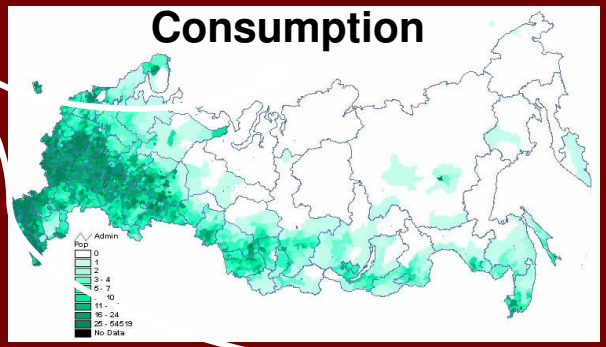
Leak

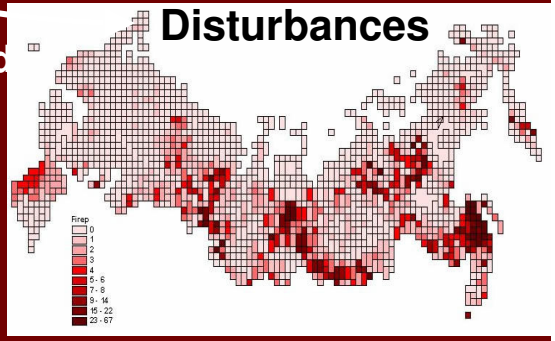
Runoff

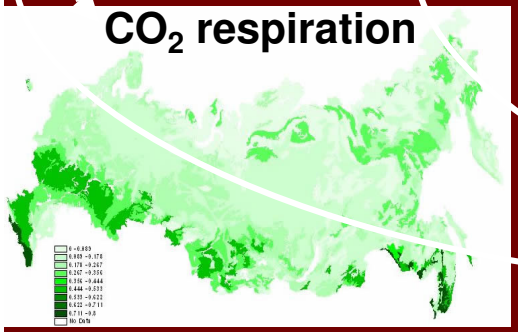
Hydrosphere

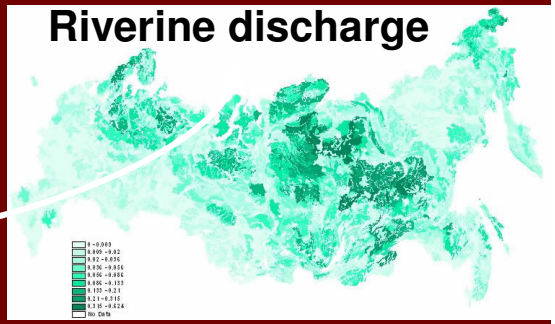
Carbon (CO_2) Cycle Module

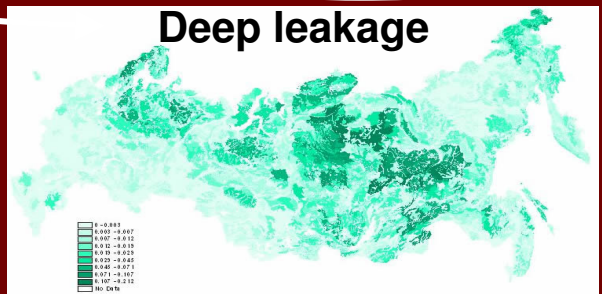


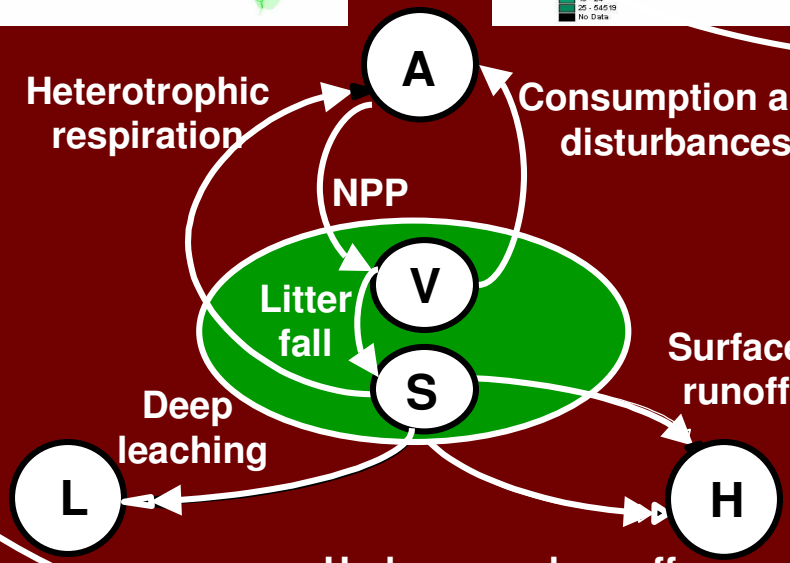












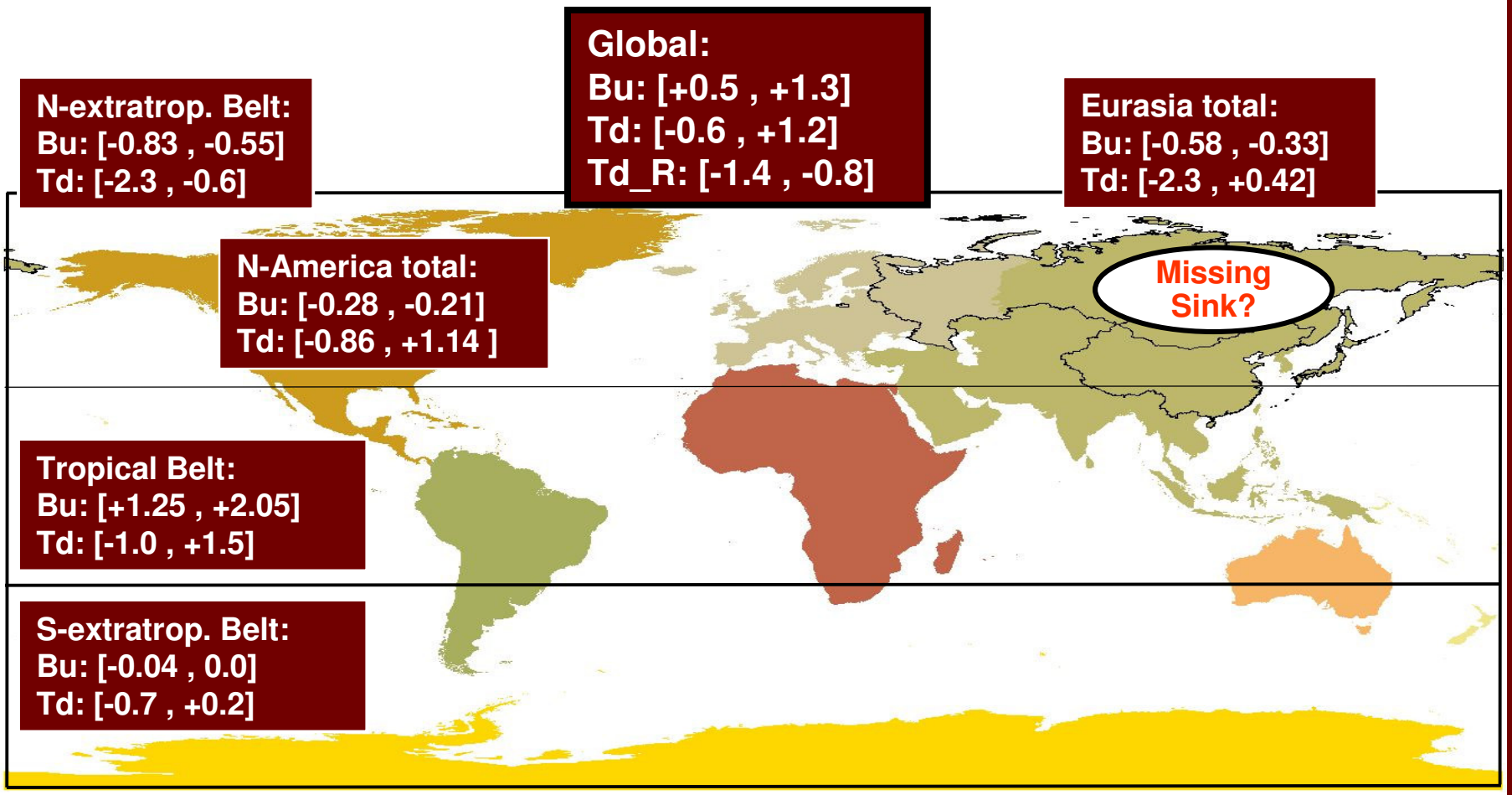
A: atmosphere; V: vegetation;
S: soil; H: hydrosphere;
L: lithosphere

Uncertainties of Major Forest Fluxes: Russia,

national scale; based on multi-sources, pool/flux based, and 5-year annual average, 1988–1992 (level of confidence probability 0.9)

Flux	Precision %	Uncertainty %	Estimate Tg C yr^{-1}
NPP	4.3	4.7	2023 ± 96
HR	5.4	7.0	1513 ± 106
Fire	7.7	9.2	84 ± 8
Net C exchange		47.7	302 ± 144
Decay of forest products		15.0	81 ± 12
Net C including decay of forest products		65.0	221 ± 144

Terrestrial Sink/Source Strength Intervals



Bottom-up (inventory/inventory-plus-models) for the 1980s and 1990s.

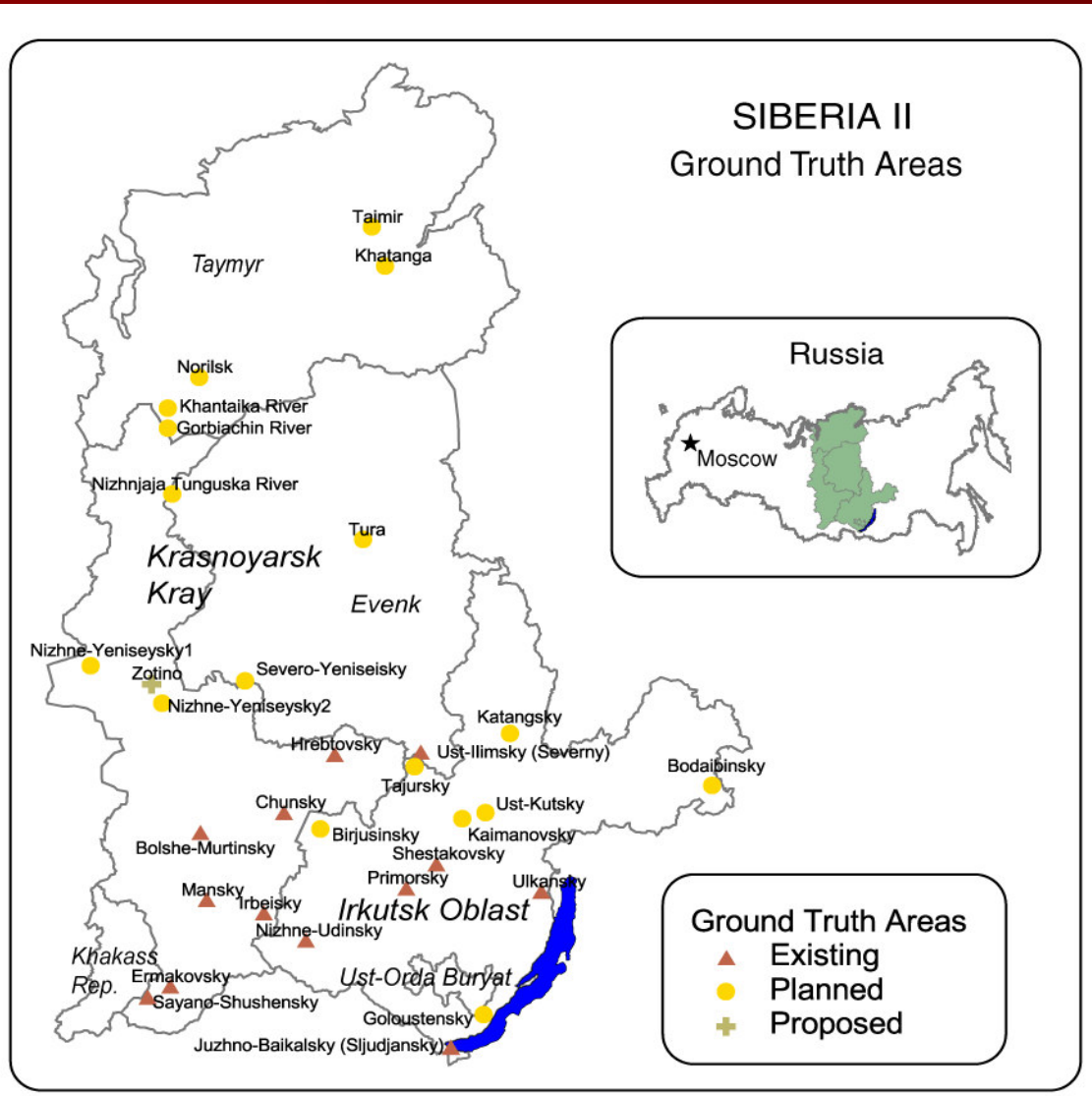
Top-down (atmospheric inversion) for the 1980s.

Russia's Terrestrial Sink Strength

FCA 1988–92 for Russia Upscaled to Eurasia and the Northern Extratropical Belt in PgC yr^{-1}		Atmospheric Inversion 1980–89 (House *et al.*, 2003; centered view) in PgC yr^{-1}	
Eurasia	Northern Extratropics	Eurasia	Northern Extratropics
-0.77	-1.22	-0.94	-1.45

- The good correspondence leads to the assumption that the "Missing sink issue" is reduced to an issue of relevant accounting

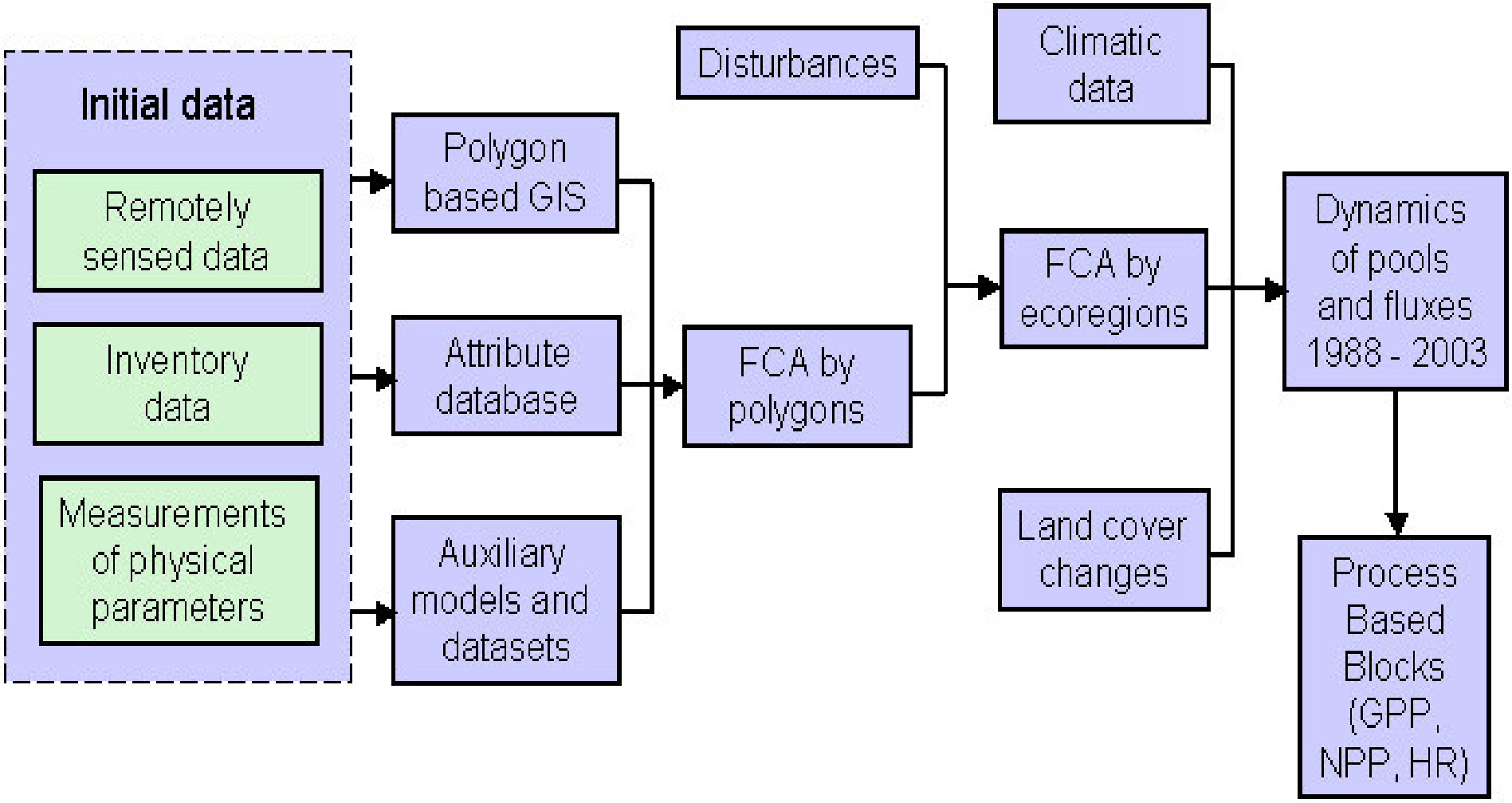
SIBERIA-II: Multi-sensor Concept for Full GHG Account (FGGA)



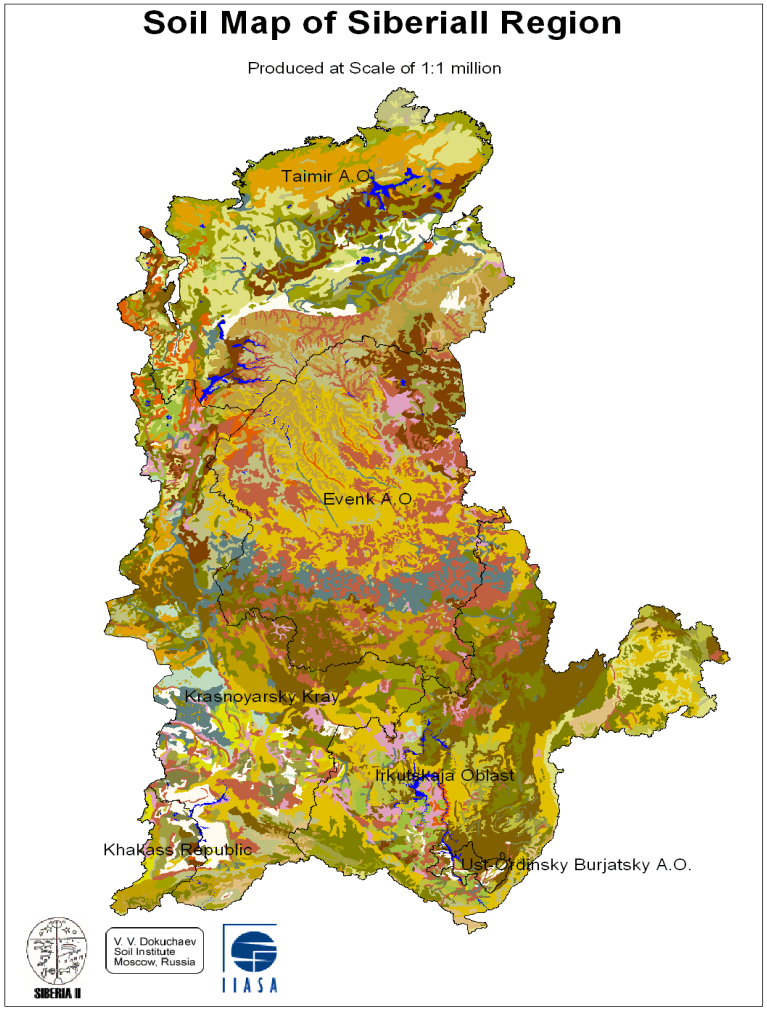
SIBERIA-II: Multiple Measurements by Remote Sensing

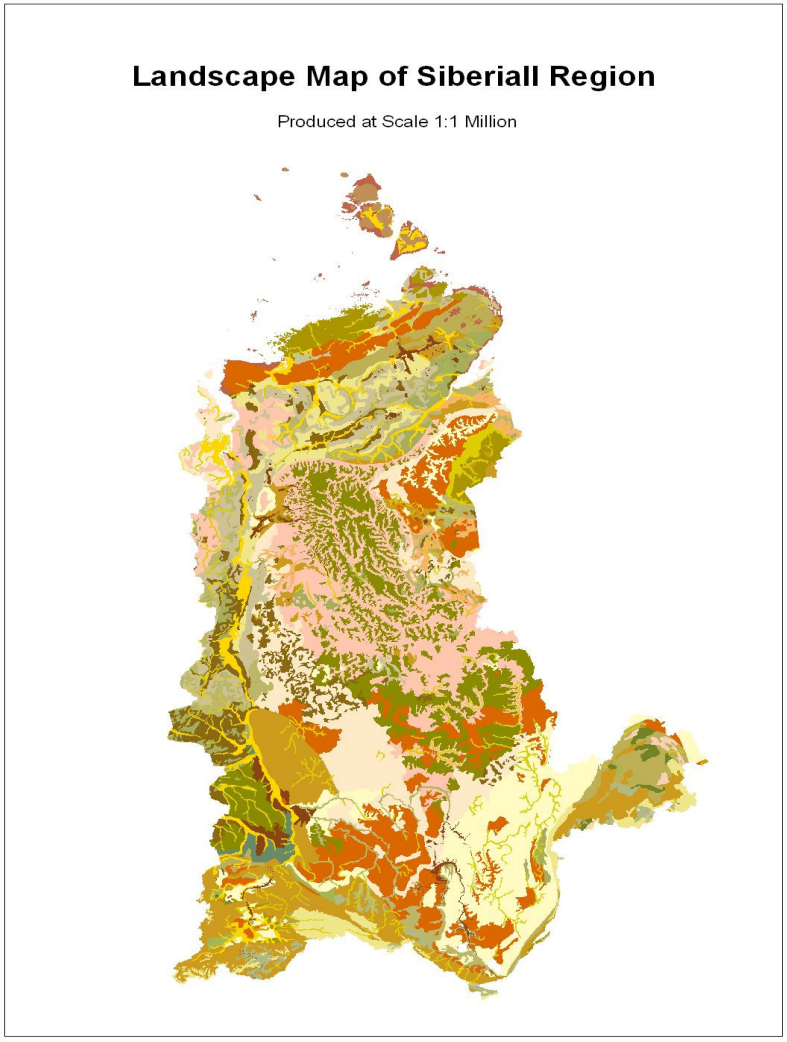
Passive Optical Sensors		NOAA AVHRR ENVISAT AATSR ENVISAT MERIS TERRA MISR ERS ATSR-2 TERRA MODIS TERRA ASTER LANDSAT TM-5 LANDSAT ETM SPOT Vegetation DMSP OLS DMSP SSM/1 Resurs-01 (MSU-SK, MSU-E)
Active Optical Sensors (Laser)		Experimental use of Russian aircraft lidars
Active Microwave Sensors	**SAR**	ENVISAT ASAR ERS-2 SAR ERS-1 SAR JERS-1
	Scatterometer	QuikScat Sea Winds ERS AMI-SCAT
Passive Microwave Sensors		SMMR, ADEOS-II AMSR

Structure of FGGA — Multi-methods Approach



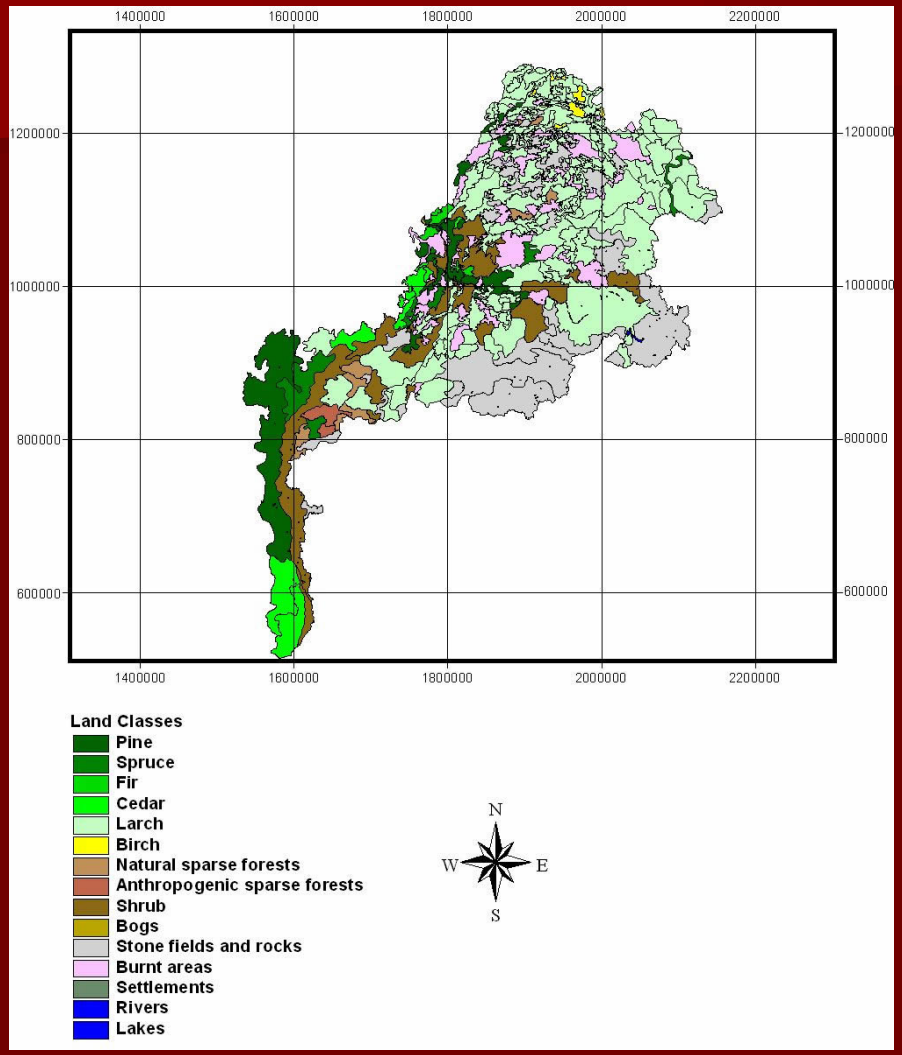
GIS Input – New Detailed Information



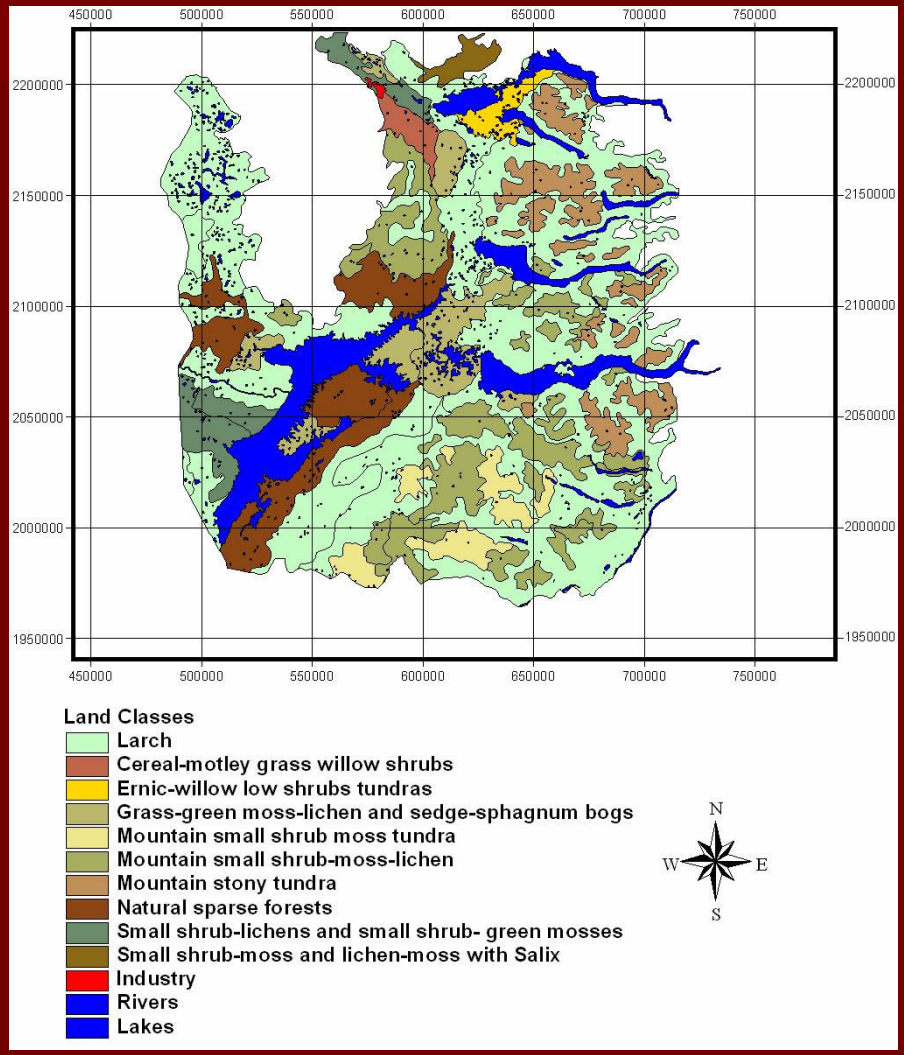


FCA Land Cover – New Detailed Information

Forest Ecoregion



Tundra Ecoregion



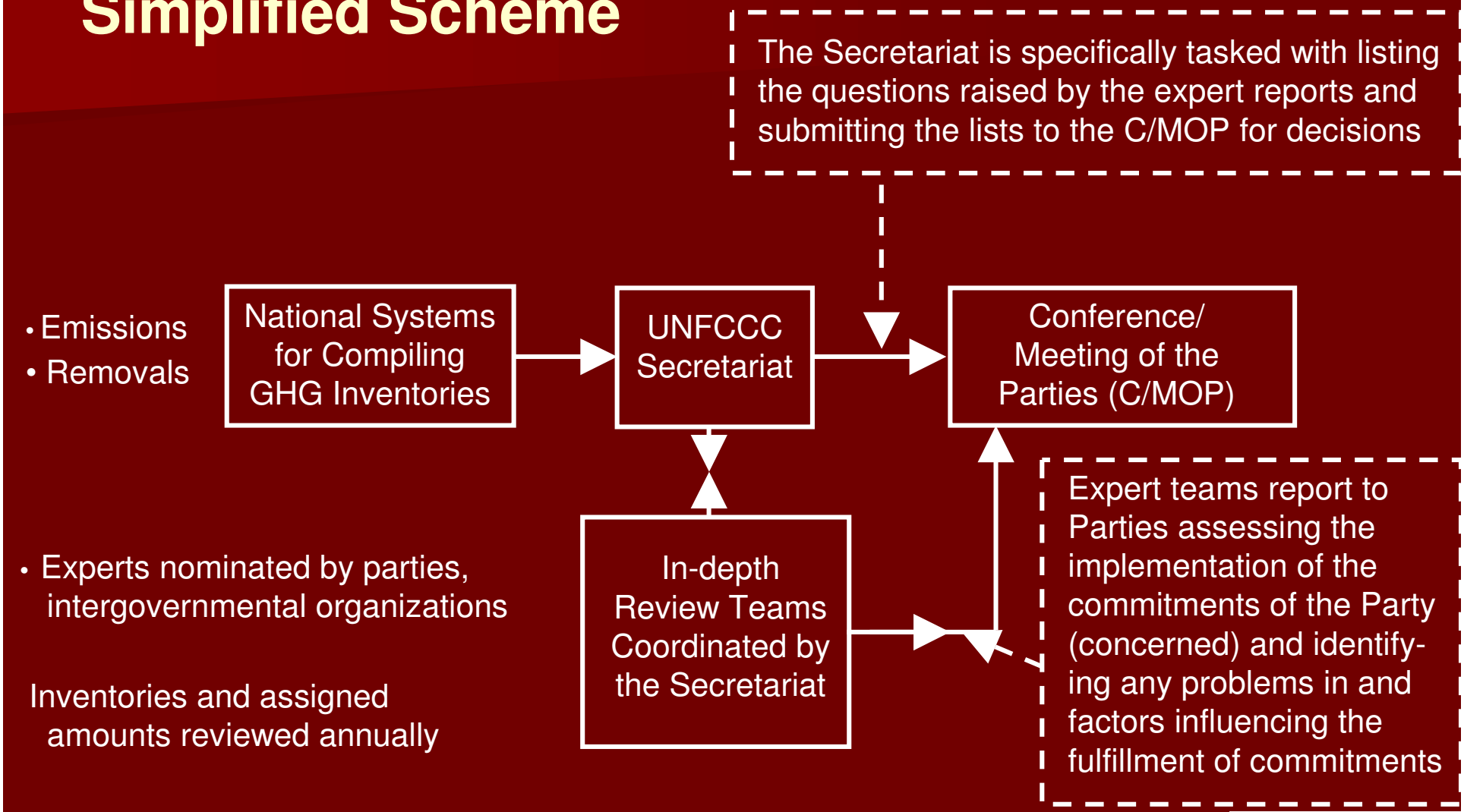
Tentative Uncertainties SIBERIA-II

By this detailed regional analysis we are reducing the national uncertainty numbers by about a factor of 2

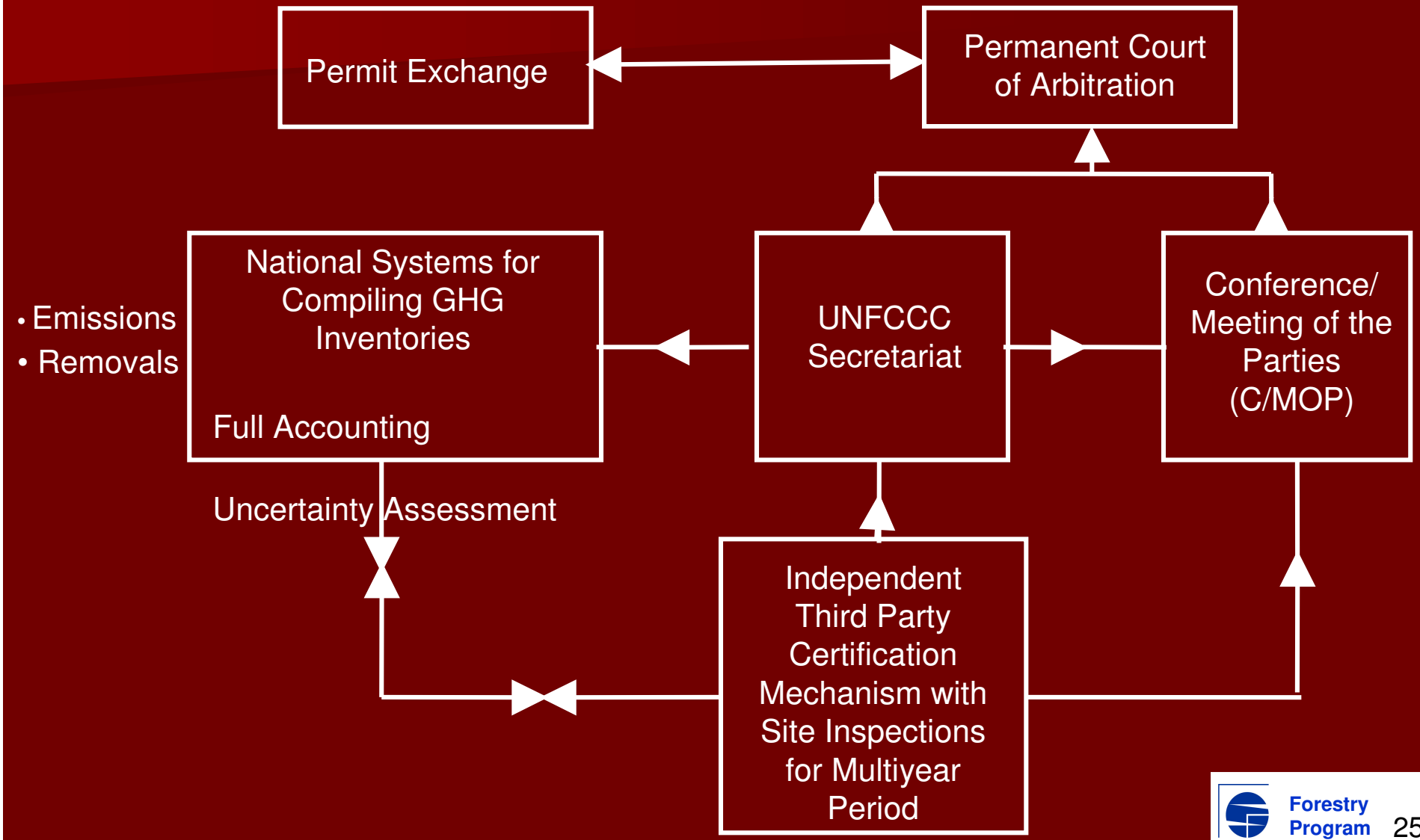
Wood Biomass (above- and below-ground) Carbon Fluxes (uptake) Before Harvests on Exploitable Forests in some European Countries Around 1990, million tC yr^{-1}

Country \ Assessment	UNFCCC and EU Monitoring Mechanisms based on JRC (2000) and Löwe et al. (2000)	TBFRA-2000 (UN, 2000a)	Schelhaas and Nabuurs (2001)
Belgium	1.94	1.35	1.23
Denmark	1.36	1.09	1.18
Finland	27.31	24.12	22.76
France	36.90	27.30	21.11
Ireland	1.87	1.02	1.36
Italy	9.85	6.03	9.94
Portugal	4.16	5.22	2.79
Spain	10.98	9.04	10.63
UK	4.23	4.42	4.76
Total	***98.60***	***79.59***	***75.76***

Institutional Framework for Verification and Compliance According to the Kyoto Protocol Simplified Scheme



Modified Institutional Framework for Verification and Compliance of Greenhouse Gas Accounting



Conclusions

- Need for an Integrated Observing System
- Improvement of the FCA methodology
- Transition to a Full Greenhouse Gas Account
- Improvement of theory and practice of uncertainties' assessment
- Development of institutions