Introducing FrAMES: A Framework for Studying Land-to-Ocean Linkages

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GWSP/LOICZ/CSDMS Workshop
Dynamics and Vulnerability of River Delta Systems
Boulder, CO 25 September 2007

UNIVERSITY of NEW HAMPSHIRE

CSDMS-Community Surface Dynamics Modeling System: New NSF National Center @UCBoulder

(NSF Cyberinfrastructure Directorate)

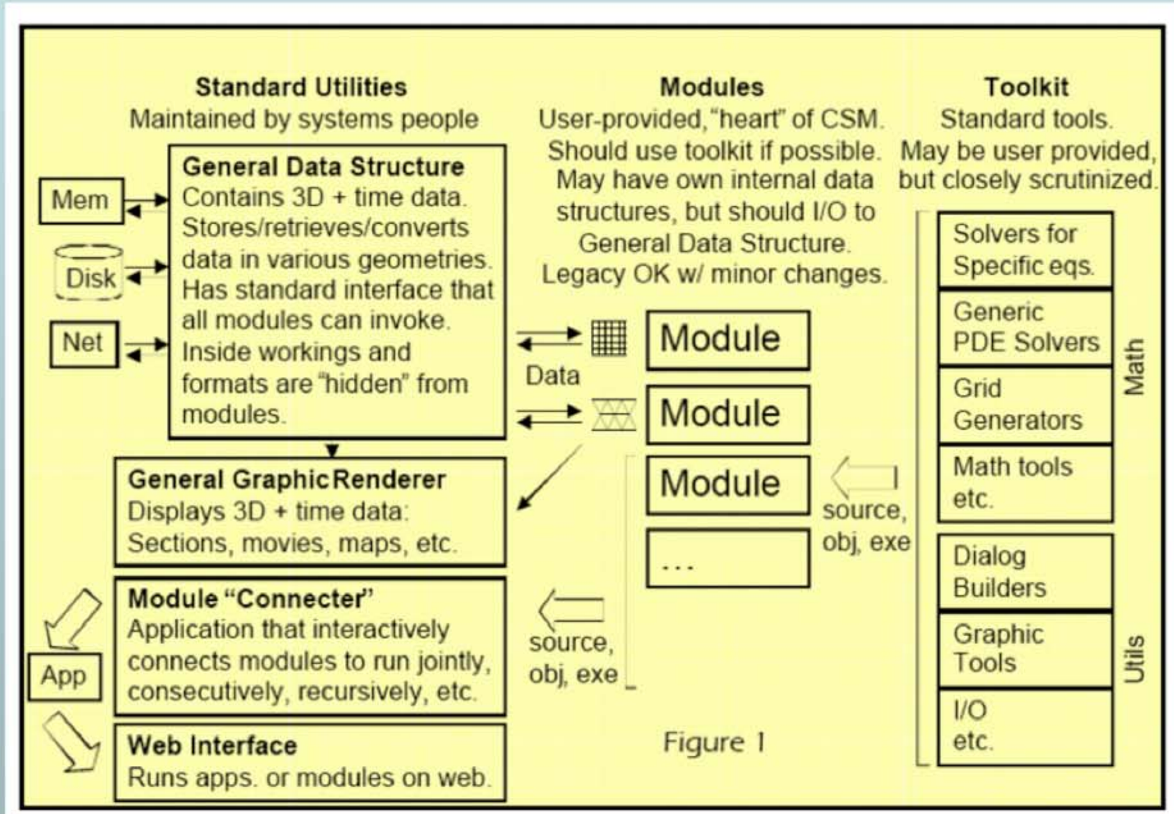
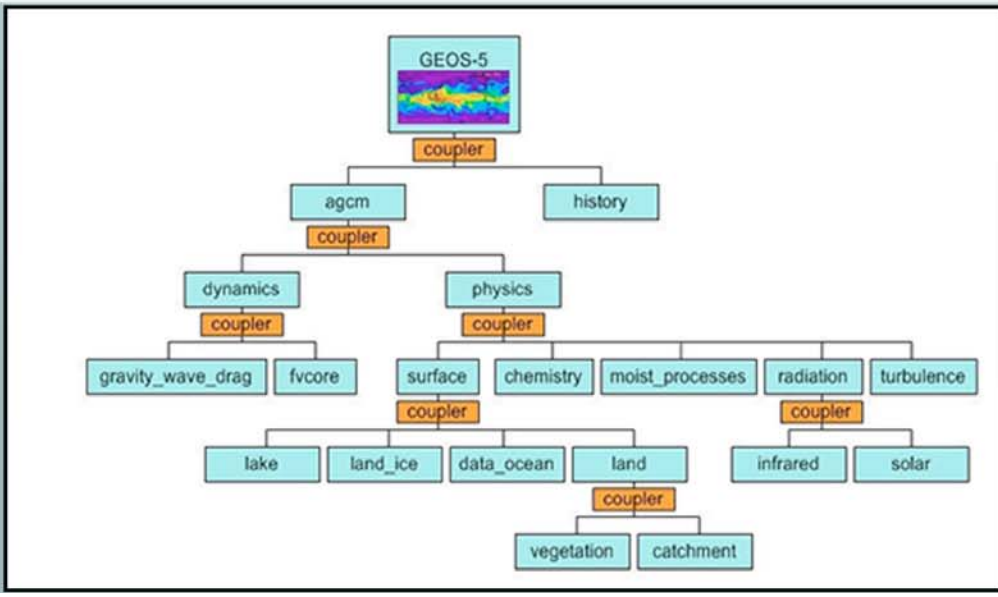


Figure 1

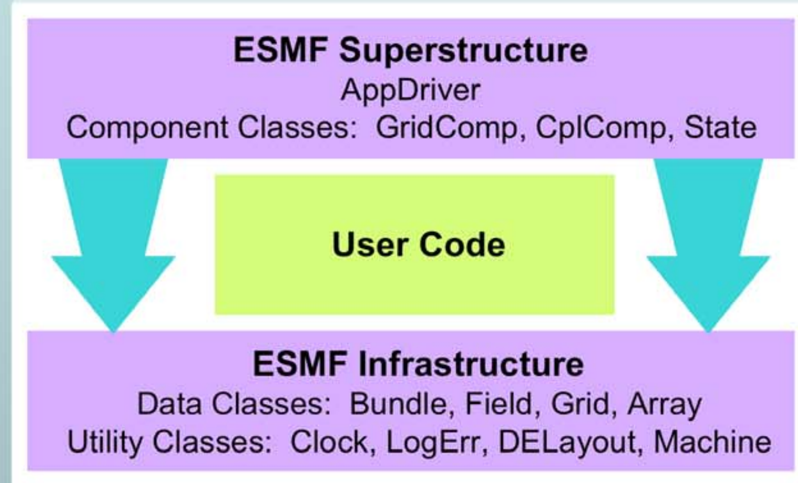
Module-based software architecture to foster community model development and synthesis studies

Framework Functions

- *Domain management*
- *Variable management*
- *Variable input/output*
- *Interfacing between domains (couplers)*
- *Time management*
- *Module management*
- *Model parallelization and execution*
- *Integrated post-processing and visualization*



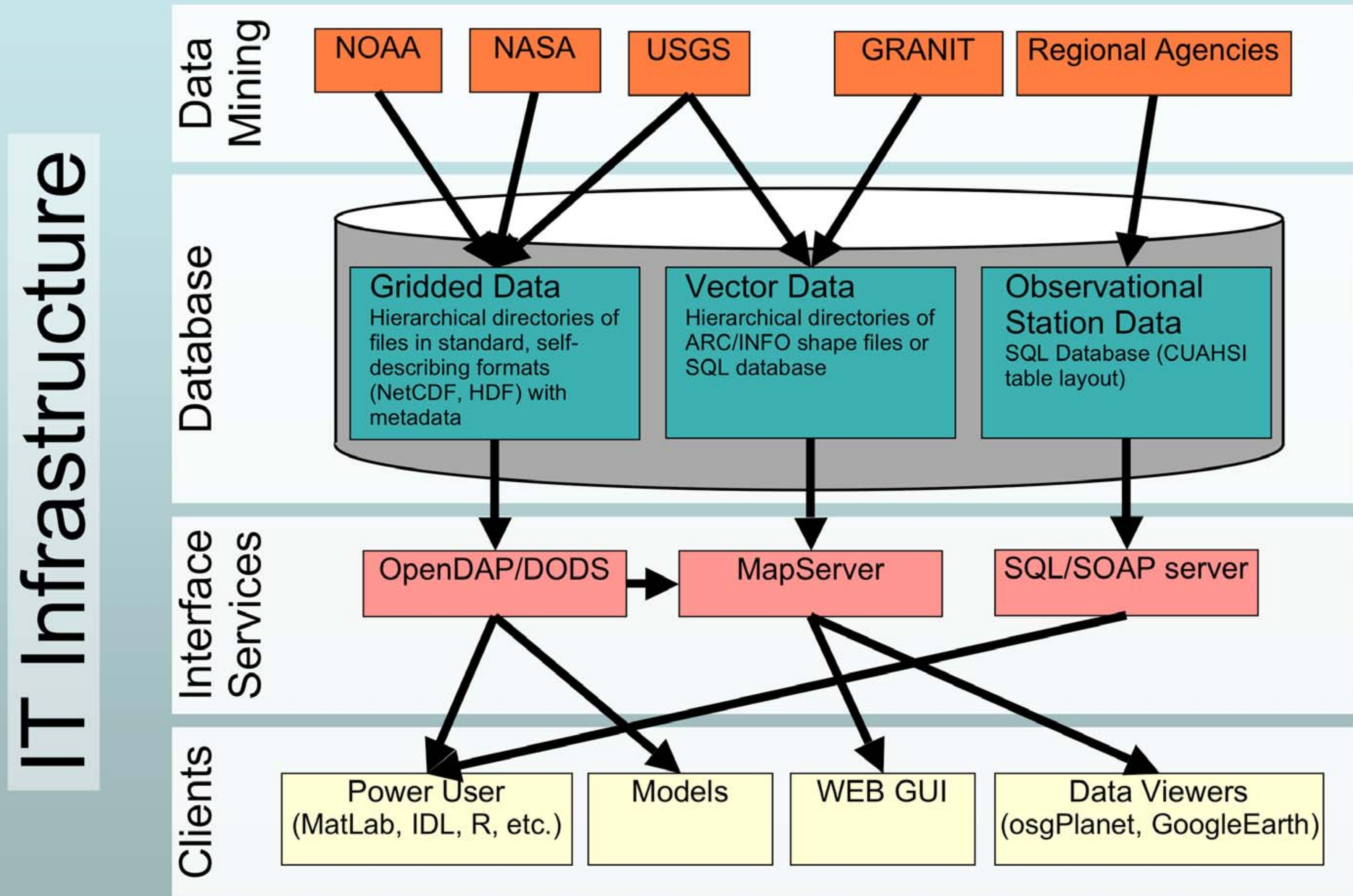
Patterned after Earth System Modeling Framework



Community-based effort (UCAR w/ several partners to develop modular, interconnected, open source modeling environments (e.g. NSF Earth System Curator)

WaterNET and IDS

New GHAAS Modeling Framework



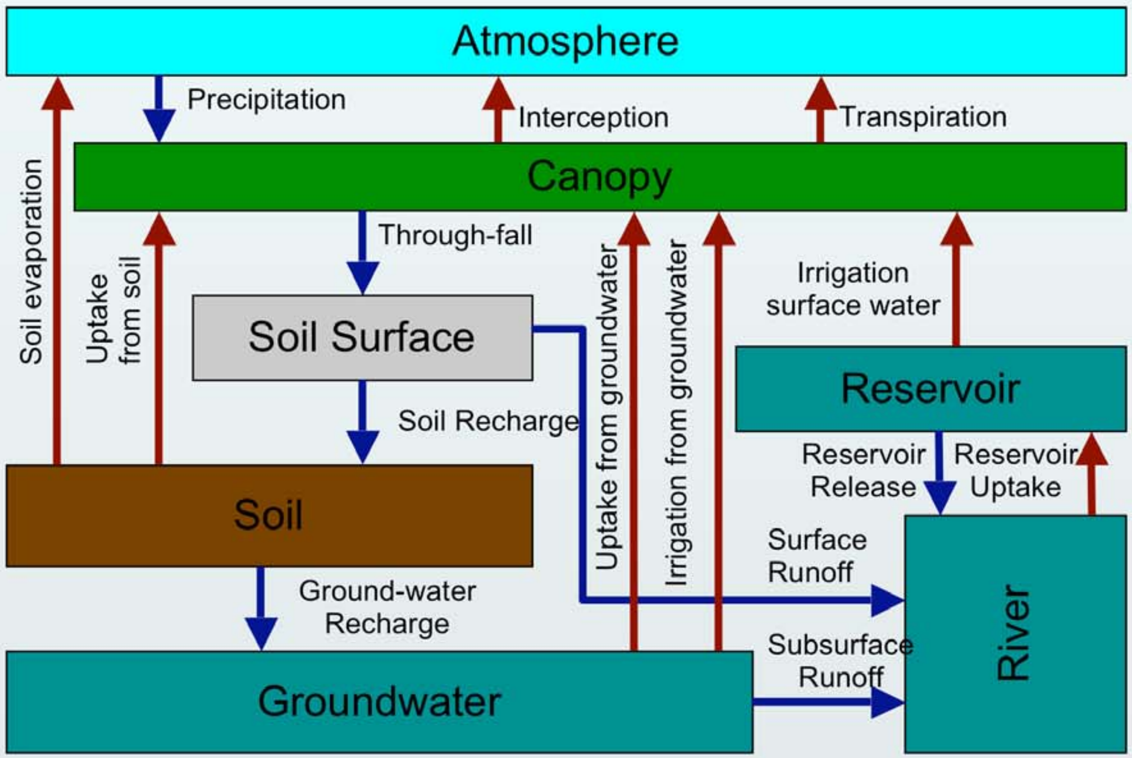
WaterNET and IDS

Model Tree Build Up

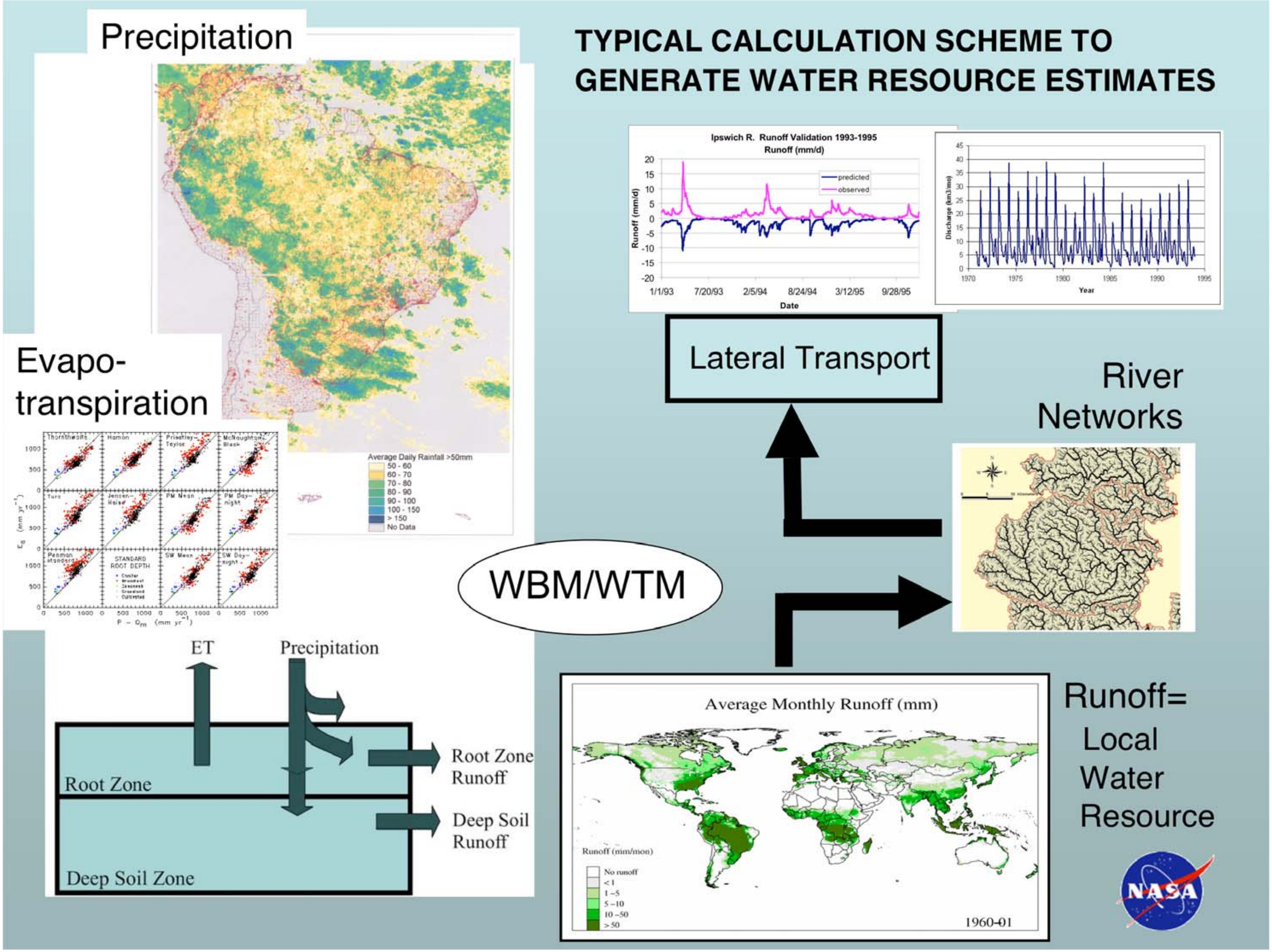
```
Entering: Discharge
  Entering: Discharge Muskingum
     Entering: Runoff
        Entering: WaterBalance
           Entering: Base flow
              Entering: Infiltration
                 Entering: Water Surplus
                    Entering: Snow Pack Change
                     Leaving: Snow Pack Change
                    Entering: Soil Moisture
                       Entering: PotET Hamon
                          Entering: Day length
                           Leaving: Day length
                        Leaving: PotET Hamon
                       Entering: Intercept
                        Leaving: Intercept
                     Leaving: Soil Moisture
                  Leaving: Water Surplus
               Leaving: Infiltration
              Entering: Irrigation
               Leaving: Irrigation
            Leaving: Base flow
         Leaving: WaterBalance
      Leaving: Runoff
     Entering: Reference Discharge
        Entering: Average NSteps
         Leaving: Average NSteps
        Entering: Accumulate Runoff
         Leaving: Accumulate Runoff
      Leaving: Reference Discharge
   Leaving: Discharge Muskingum
```

ID	Start_Date	Variable[	Unit]	Type	TStep	NStep	Set	Flux	Boundary	Output
0	XXXX	TEMVegCover[	]	int	year	365	yes	no	no	no
1	XXXX	RootingDepth[	mm]	float	year	365	yes	no	no	no
2	2000-01	AirTemperature[	degC]	float	month	31	yes	no	no	no
3	2000-01-01	DailyPrecip[	mm/d]	float	day	1	yes	yes	no	no
4	XXXX	IrrigationIntensity[	-]	float	year	365	yes	no	no	no
5	XXXX	FieldCapacity[	mm/m]	float	year	365	yes	no	no	no
6	XXXX	WiltingPoint[	mm/m]	float	year	365	yes	no	no	no
7	XXXX	IrrigatedArea Fraction[	-]	float	year	365	yes	no	yes	no

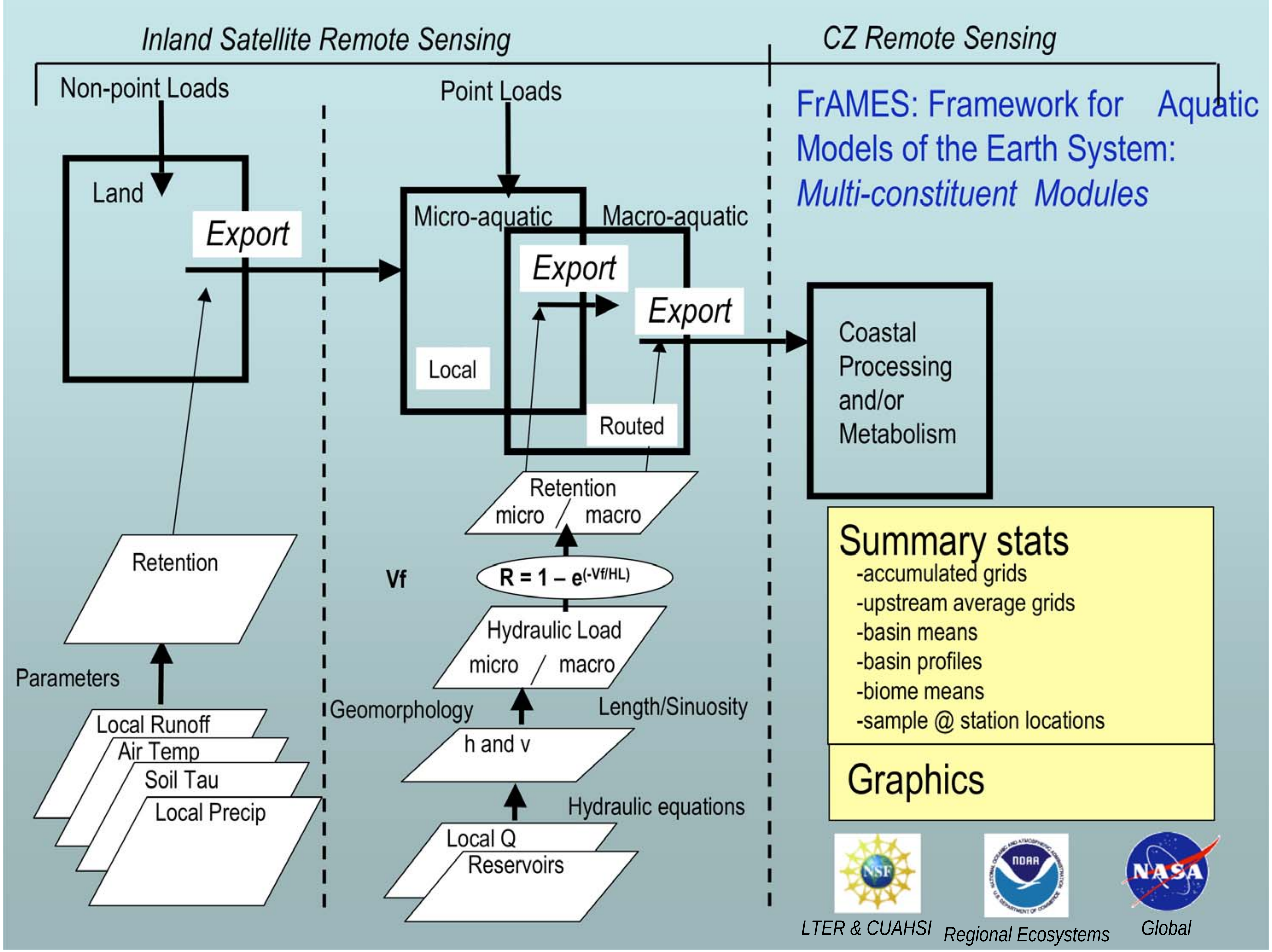
Water Resources



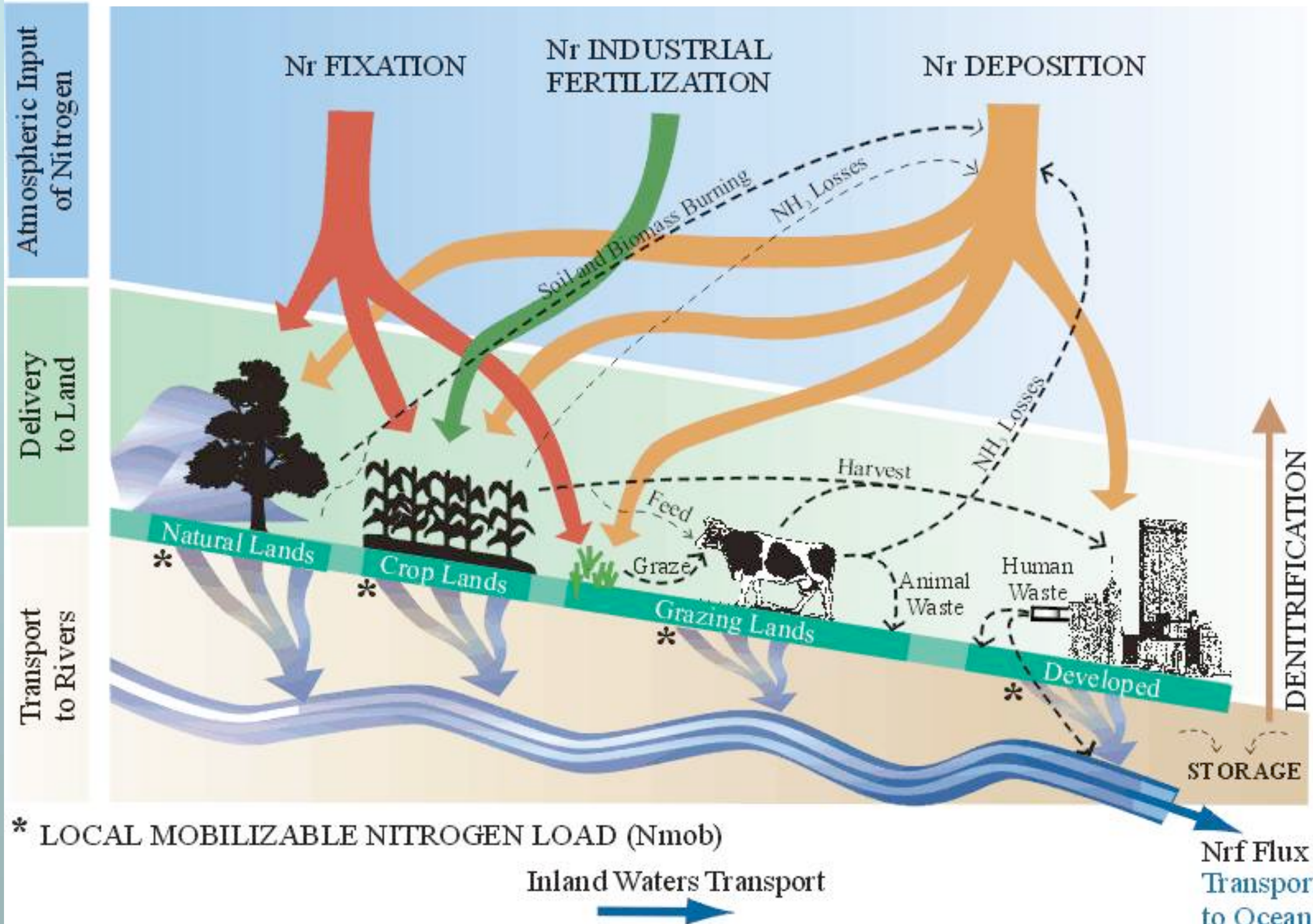
WaterNET and IDS



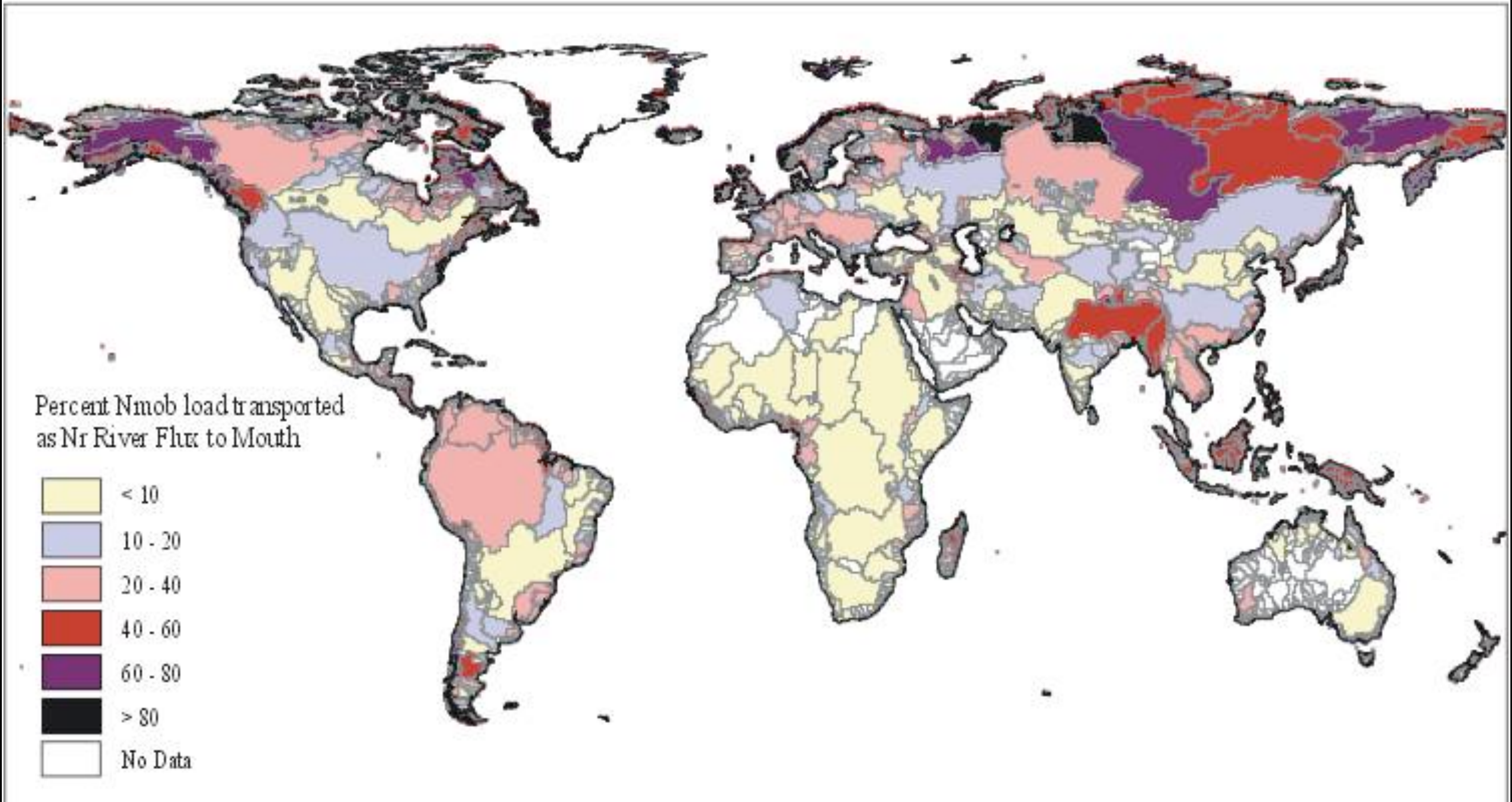
TYPICAL CALCULATION SCHEME TO GENERATE WATER RESOURCE ESTIMATES
Precipitation
Average Daily Rainfall >50mm
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 150
> 150
No Data
Evapo-transpiration
ET
Precipitation
Root Zone Runoff
Deep Soil Runoff
Root Zone
Deep Soil Zone
WBM/WTM
Ipswich R. Runoff Validation 1993-1995
Runoff (mm/d)
predicted
observed
Date
Year
Lateral Transport
River Networks
Average Monthly Runoff (mm)
Runoff (mm/mon)
No runoff
< 1
1 – 5
5 – 10
10 – 50
> 50
1960-01
Runoff=
Local
Water
Resource


Inland Satellite Remote Sensing
CZ Remote Sensing
Non-point Loads
Point Loads
FrAMES: Framework for Aquatic Models of the Earth System: Multi-constituent Modules
Land
Export
Micro-aquatic
Macro-aquatic
Export
Export
Local
Routed
Coastal Processing and/or Metabolism
Retention micro / macro
Vf
R = 1 – e^(-Vf/HL)
Hydraulic Load micro / macro
Retention
Parameters
Geomorphology
Length/Sinuosity
h and v
Hydraulic equations
Local Runoff
Air Temp
Soil Tau
Local Precip
Local Q
Reservoirs
Summary stats
-accumulated grids
-upstream average grids
-basin means
-basin profiles
-biome means
-sample @ station locations
Graphics
LTER & CUAHSI
Regional Ecosystems
Global

Green et al. (2004), Nitrogen Mass Balance Approach



Nitrogen Transport Efficiency (Nr Flux/Nmob Load)



- Mean 18% transport in basin -- similar to Howarth et al. (1996) for N. Atlantic
- Wide range of transport efficiencies in individual basins -- 0 to 100%

MODEL -- Non-linear statistical model; flux is function of mass-balanced loads, temperature and hydraulic residency time

River Flux of N

$$= E_{riv} * E_{res} * E_{lake} * (PtS + NonPtS_{org} * E_{soil\text{-}org} + NPtS_{inorg} * E_{soil\text{-}inorg})$$

where

PtS = Nmob Load from Sewered Urban Population

$NonPtS_{org}$ = (Nmob Fixation + Nmob Livestock Load + Nmob NPS Human Load) *(Runoff / Precipitation)

$NonPtS_{inorg}$ = (Nmob Deposition + Nmob Fertilizer) * (Runoff / Precipitation)

The delivery coefficients take the form of:

$E_{riv} = e^{(-\tau\ riv\ *\ Tadj\ *\ ariv)}$

$E_{res} = e^{(-\tau\ res\ *\ Tadj\ *\ ares)}$

$E_{lake} = e^{(-\tau\ lake\ *\ Tadj\ *\ alake)}$

$E_{soil\text{-}org} = e^{(-\tau\ soil\ *\ Tadj\ *\ asoil\text{-}org)}$

$E_{soil\text{-}inorg} = e^{(-\tau\ soil\ *\ Tadj\ *\ asoil\text{-}inorg)}$

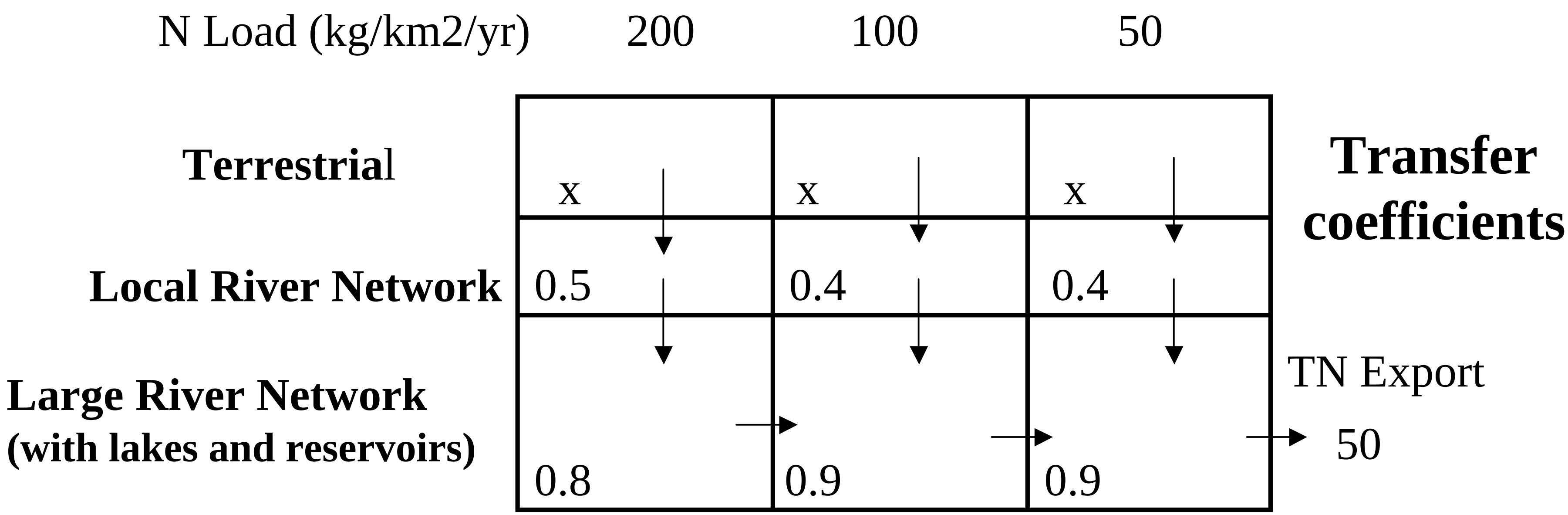
$$E_{riv} = e^{(-\tau\ riv\ *\ Tadj\ *\ ariv)}$$

TNflux---> r^2=0.88 Slope P/O=0.99 n=58

DIN Flux ---> r^2=0.68 Slope P/O=0.94 n=281

Applying an Aquatic N Processing Constraint on Terrestrial Processing Potential
--Inverse Calculation--

Three Grid Cell Example



((((200x * 0.5 * 0.8) + (100x * 0.4)) * 0.9) + (50x * 0.4)) * 0.9 = 50

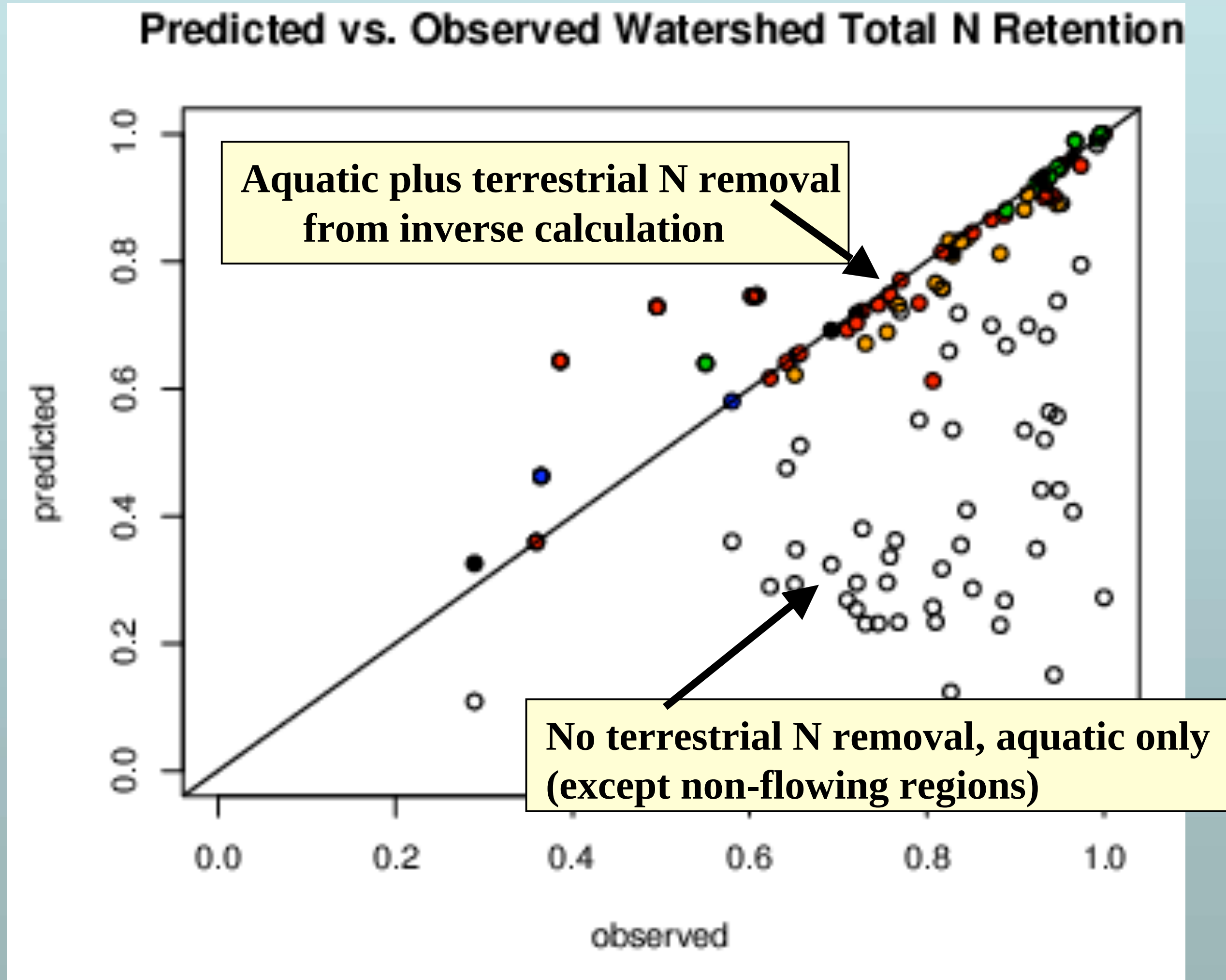
((80x + 40x) * 0.9) + 20x) * 0.9 = 50

128x * 0.9 = 50

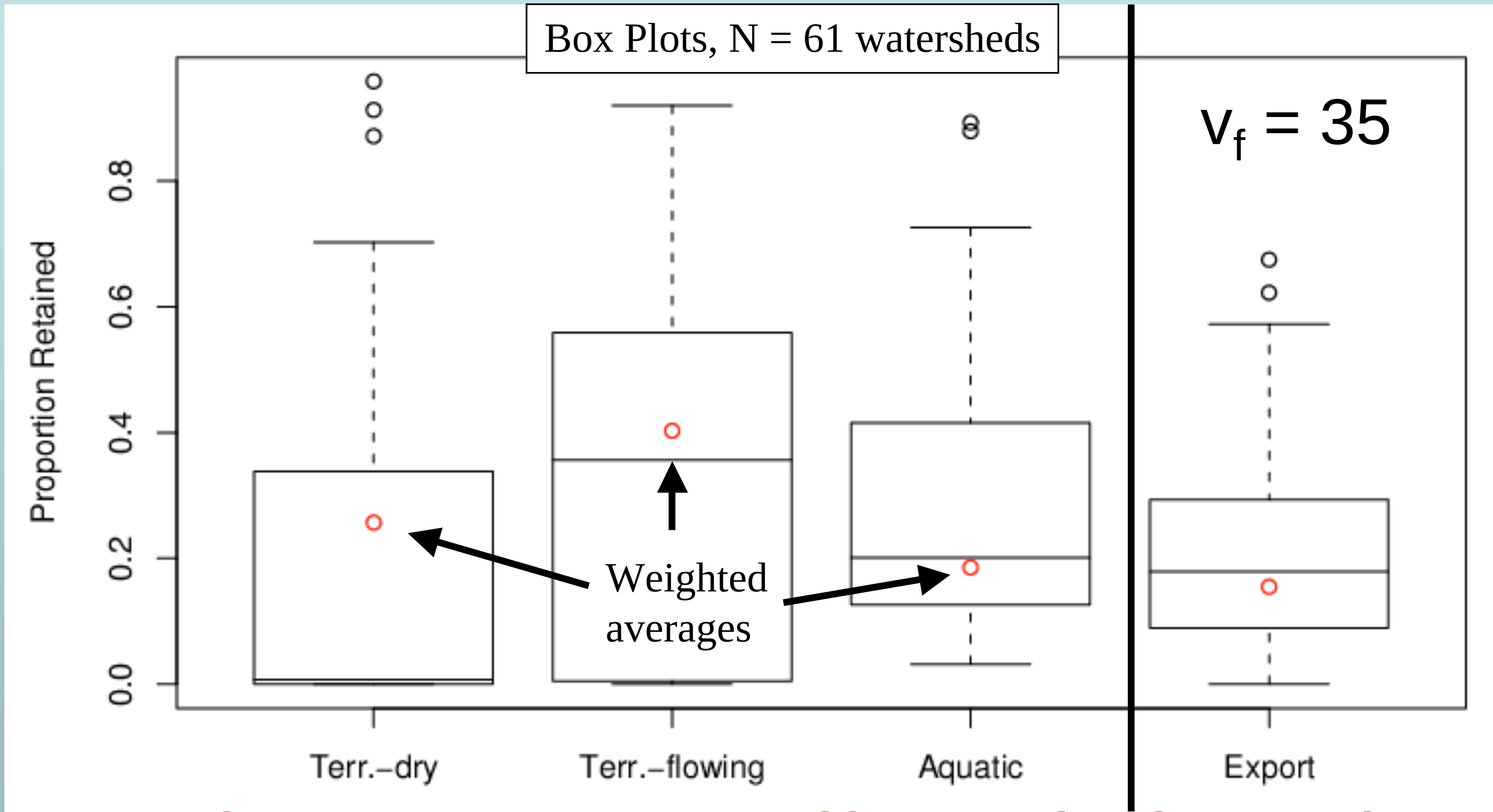
x = 0.43 = Terrestrial transfer coefficient = 1 - R

Example – inverse calculation, with aquatic v_f = 35 m yr^{-1}

N = 61 large watersheds distributed globally (GEMS-Glori [Meybeck] mean annual TN data set)



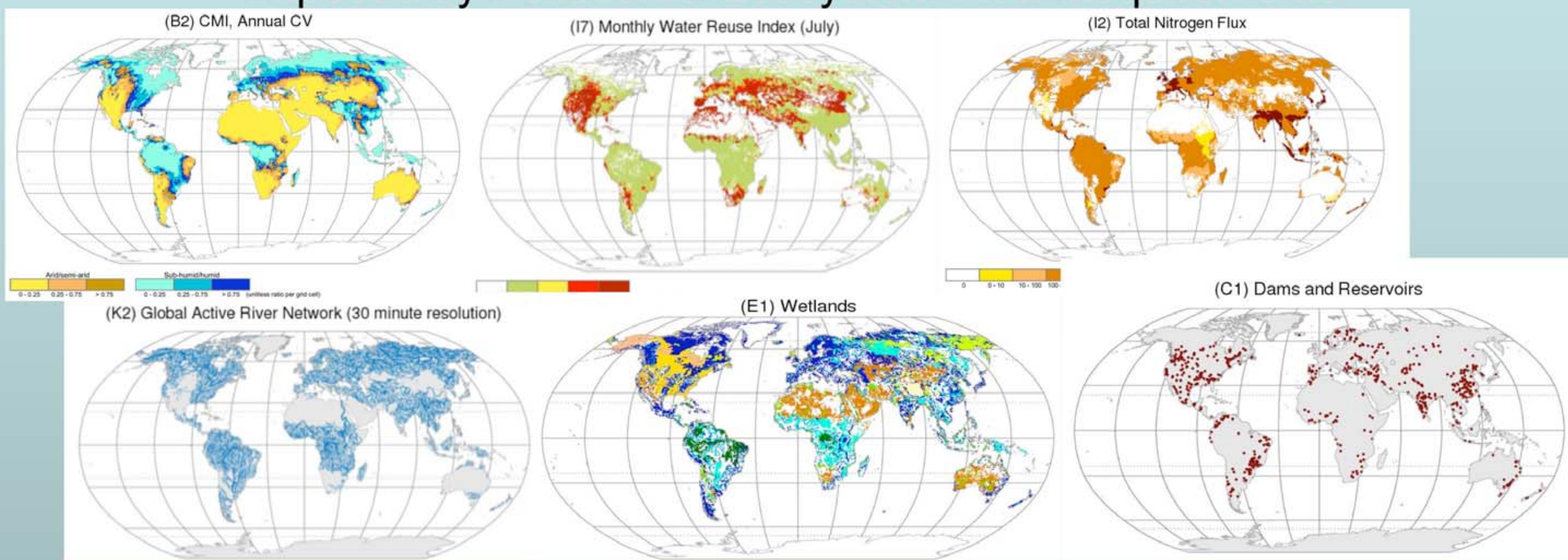
Locating the watershed N sinks
(Where does that 80% go?)

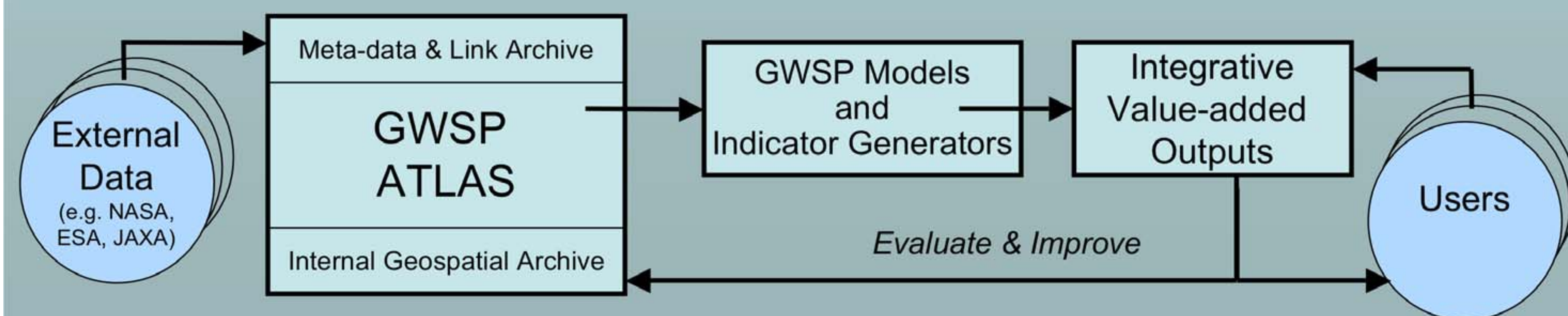


Total N load removed: **66%** **18%** **16%**

Integrated Approaches to Global Water Resource Assessment and Global Change Studies

Links Geophysics of Water, Governance, Vulnerability, Supply Limitations Imposed by Pollution & Ecosystem Flow Requirements



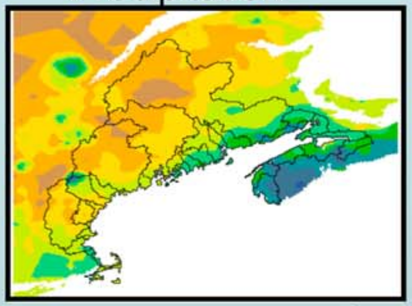


EARTH SYSTEMS DATA COLLABORATIVE

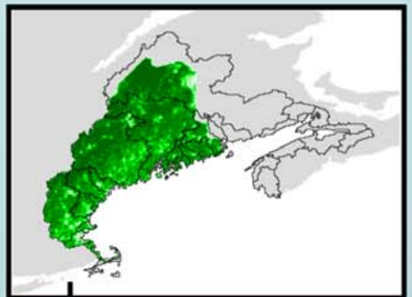
A Regional Prototype System of Systems for Environmental Surviellance

e.g. INPUTS

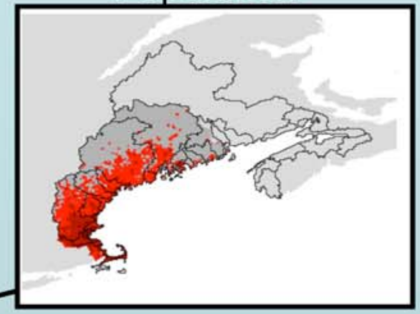
Precipitation



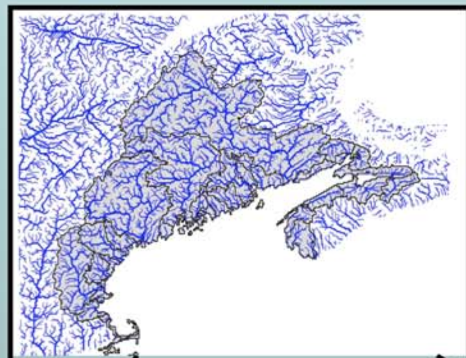
Land Cover

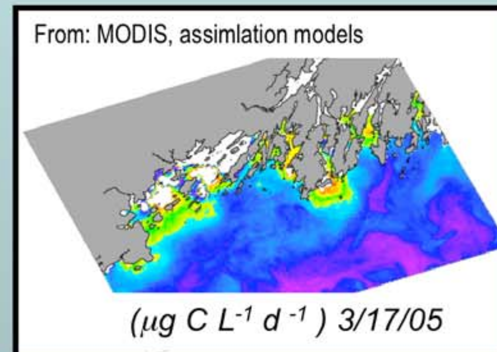


Population



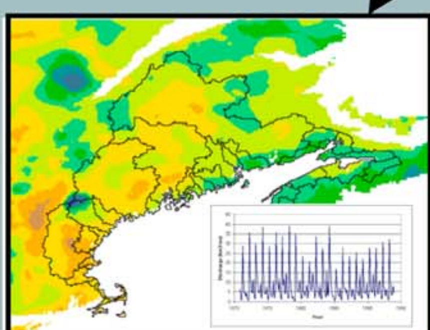
High Resolution River Networks (GM-WICS)



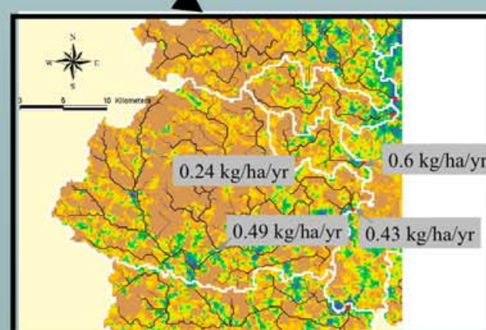


River Plumes & Coastal Zone Metabolism

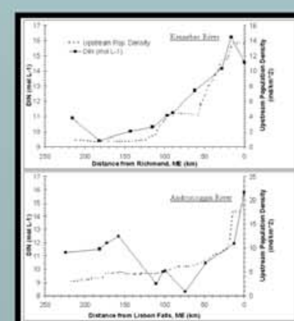
e.g. OUTPUTS



Runoff, Streamflow, Habitat Mapping



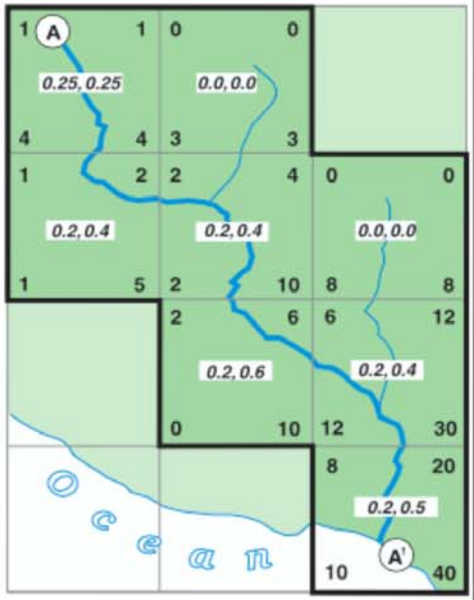
N Fluxes

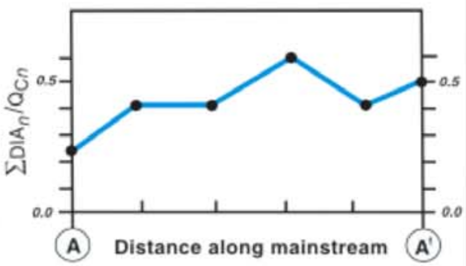


Regional Summaries, Report Cards, Alerts, & Indicaors

GWSP Indicators

CALCULATION OF KEY WATER INDICATORS





DIA_n = domestic, industrial, agricultural water use ($km^3\ yr^{-1}$) in cell n

ΣDIA_n = DIA in cell n plus all upstream cells ($km^3\ yr^{-1}$) $= \sum_{i=1}^{n} DIA_i$

R_n = locally-generated runoff (mm/yr)

A_n = area of cell n (km^2)

$Q_{Ln} = 10^6 * R_n * A_n$ = locally generated discharge ($km^3\ yr^{-1}$)

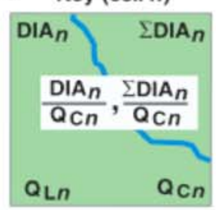
$Q_{Cn} = \sum_{i=1}^{n} Q_{L_i}$ = river corridor discharge ($km^3\ yr^{-1}$)

DIA_n/Q_{Cn} = local relative water use (unitless)

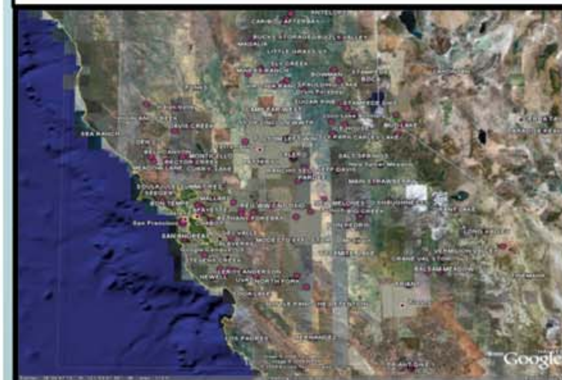
$\Sigma DIA_n/Q_{Cn}$ = water reuse index (unitless)

n = position of cell in river network
= total number of upstream cells plus cell in question

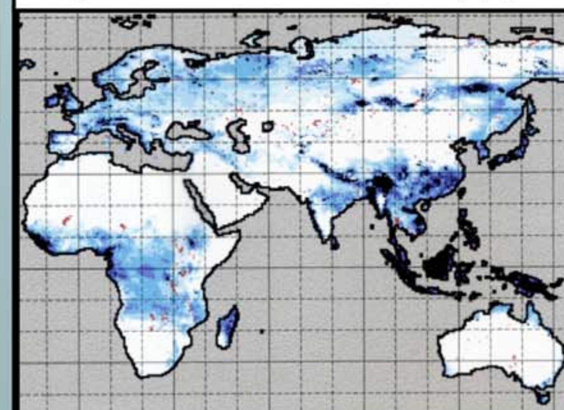
Key (cell n)



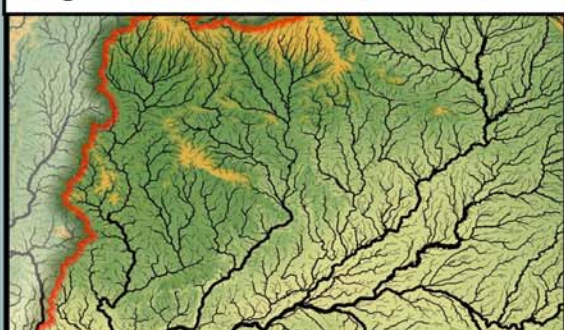
High Resolution Geo-Referenced Dams/Reservoirs



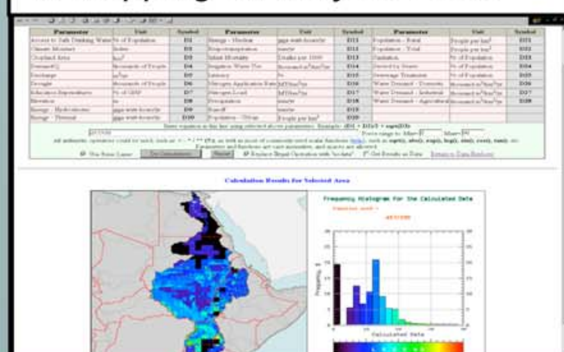
High Resolution Water Supply



High Resolution River Networks



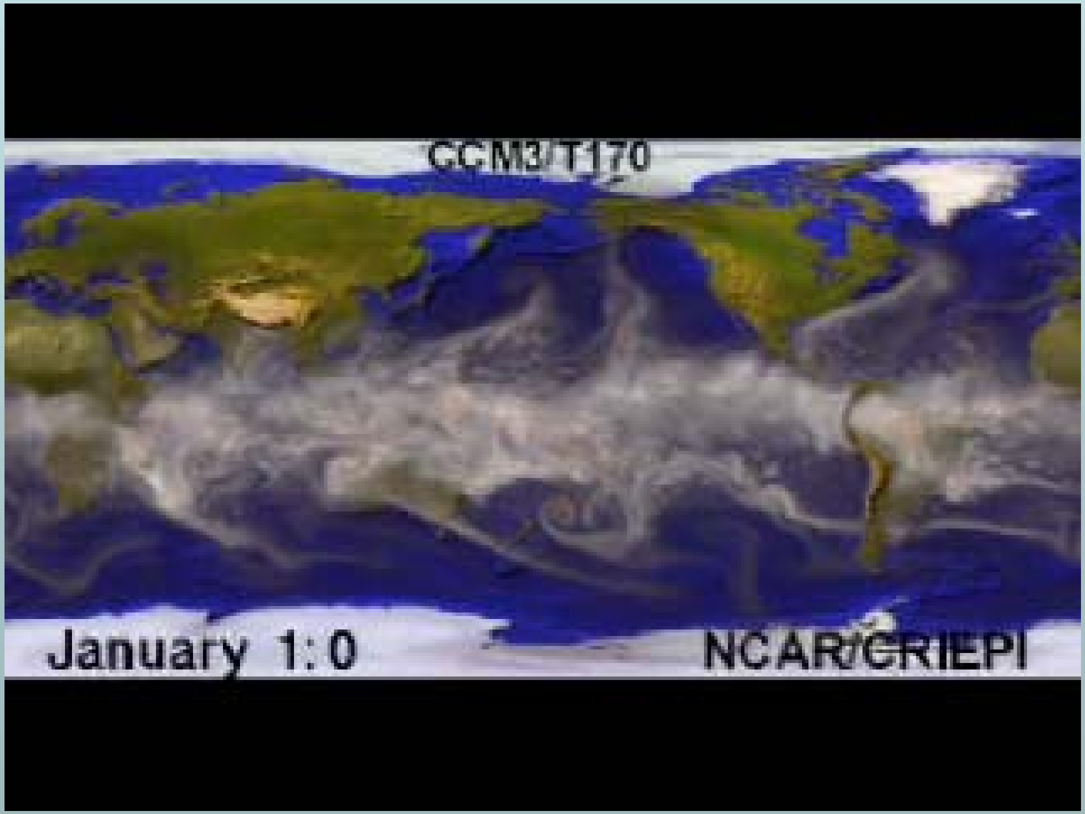
IT Mapping & Analysis Tools



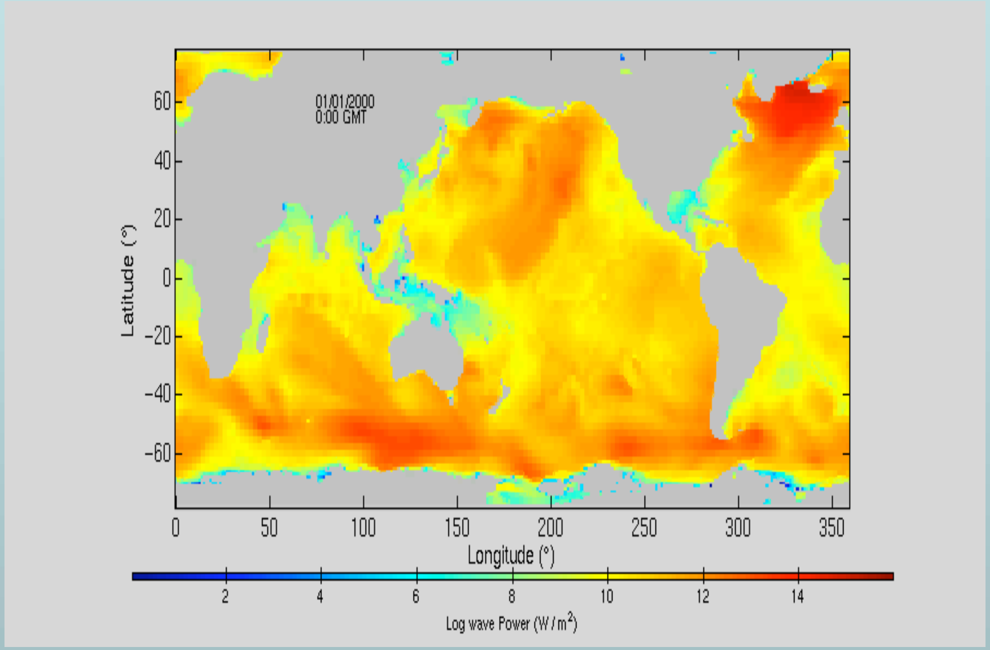
Earth System Science Partnership

GWSP Global Water System Project

1970's LAVA LAMP? No…Unprecedented Opportunities to Monitor the State of the Hydrosphere Using Observations, Data Assimilation, and Modeling Tools

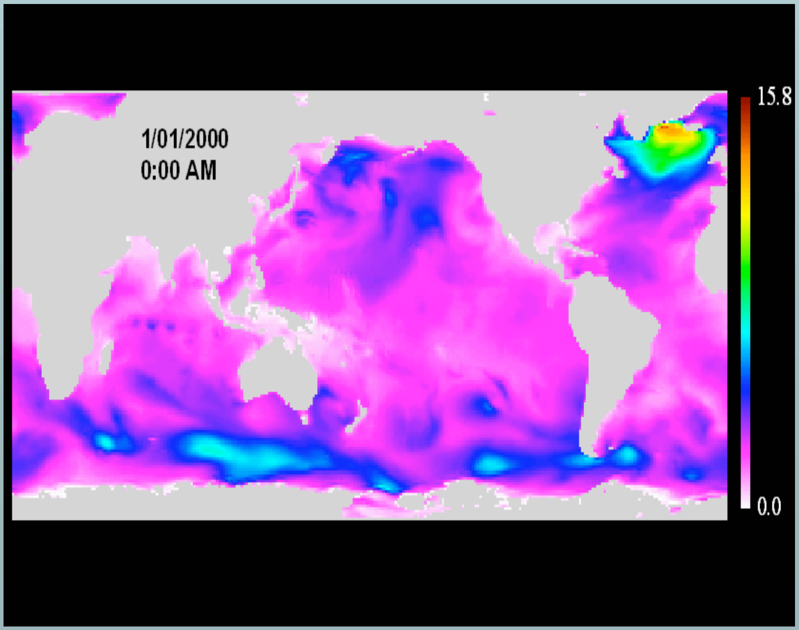


Unprecedented Opportunities to Monitor the State of the Planet Using Observations, Data Assimilation, and Modeling Tools



3-hourly Wave Power

Ocean Elements As Well



3-hourly Wave Heights

What to Scope at This Scoping Workshop?

- Develop ideas for interdisciplinary & integrative science to better understand diverse processes affecting deltas
  - Not just SLR …. upland engineering, gw and hydrocarbon abstraction, land use/cover change
  - Not just sediment ….H_2O, nutrients
  - Not just long-term, chronic change … events critical

- Tangible products:
  1. Curiousity-based science:

     - Process-based models including physics, humans, biology
  2. Service to the policy and management communities:

     - Digital map of river-coastal delta complexes

     - Geographies of long-term vulnerability and of upland/ocean events

     - Now-cast/forecast systems & scenarios

- Raise awareness through these tangible products around which the policy & management communities can take action