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GLOBAL NEWS (GLOBAL NUTRIENT EXPORT FROM WATERSHEDS): MEDITERRANEAN FOCUS

UNEP/MAP
Athens, 2005

Preface

The diffuse transport of substances to the coastal waters of the Mediterranean was included in the scope of MED POL during Phase III for the proper implementation of the LBS Protocol and the Strategic Action Programme. Attempts were made to understand the importance of transported material from these sources to the Mediterranean coastal waters, and in this context MED POL has been involved in some international initiatives. The Global-NEWS was one of those dealing with nutrient export from watersheds at a global level and in 2002 the scientific group of Global-NEWS initiative was asked by IOC to apply the developed models to the Mediterranean, and to further improve them for the region after a data search. This report presents the results of the overall work and its focus on the Mediterranean by August 2004.

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Overview

Global NEWS (**Global** Nutrient **E**xport from **W**atersheds) is an international, interdisciplinary scientific task-force with the goal of developing and implementing the next generation of global river nutrient-export models. Global NEWS was initiated in the Spring of 2002 as an Intergovernmental Oceanographic Commission (IOC-UNESCO) workgroup (with co-sponsorship by UNEP-MAP, US-National Oceanic and Atmospheric Administration (NOAA), and US National Science Foundation (NSF)). Global NEWS is headed by Dr. Sybil Seitzinger, and is currently comprised of individuals from over 15 institutions in 8 countries (See Appendix A for participants.).

Since its inception just over two years ago, Global NEWS has made substantial progress. In this time, we have identified project participants, held three major workshops, hired personnel, initiated Global NEWS-related graduate student projects, accumulated necessary databases, moved forward with model formulation, and developed strategic partnerships with other institutions with parallel goals.

In order to better understand how global approaches can be applied to regional problems, we have also developed a specific focus on the Mediterranean (Global NEWS-Med), supported by the UNEP-MAP program. In the following report, we describe the Global NEWS project, present some preliminary findings, and discuss our recent accomplishments and future goals.

Background

Humans have dramatically altered the earth's nitrogen (N), phosphorus (P), silica (Si), and carbon (C) cycles, resulting in considerable environmental degradation. For example, nitrogen inputs to terrestrial ecosystems have more than doubled since pre-industrial times due to the fixation of N_2 gas into synthetic fertilizers and to the combustion of fossil fuels. A portion of this excess N applied/deposited in terrestrial ecosystems enters rivers and is transported to downstream coastal ecosystems. Humans have also altered the natural P cycle through widespread use of inorganic P-fertilizer, P-based detergents, and through direct discharge of P-rich sewage into surface waters. As a result, coastal ecosystems worldwide are receiving increased nutrient inputs originating from human activities. This nutrient enrichment in coastal ecosystems contributes to a host of environmental problems including increased algal growth, alteration and loss of seagrass habitats, increase in extent and duration of anoxic and hypoxic water, harmful algal blooms, and coral reef degradation, among other effects.

Nutrient inputs to coastal ecosystems are not evenly distributed globally (Fig. 1). Uneven spatial distribution of nutrient inputs results from an uneven spatial distribution of human population and the activities associated with the production of food and energy.

Human population is predicted to increase markedly over the next 50 years in certain world regions, notably Southern and Eastern Asia, South America, and Africa. Industrialization is also predicted to increase in many of these same regions. Growing food to feed the expanding world population will require increased use of nitrogen and phosphorus fertilizers. Increased industrialization, with the associated combustion of fossil fuels and NO_y production, will result in increased atmospheric deposition of N. All of these activities will lead to increased export of N and P to coastal ecosystems, resulting in water quality degradation, unless policy and/or technological advances reverse current trends.

For example, past modeling efforts have suggested that inorganic N export to coastal systems will increase 3-fold by the year 2050 from Africa and South America (Fig. 2).

Substantial increases are also predicted for Europe and N. America. Alarmingly large absolute increases are predicted for eastern and southern Asia; almost half of the total global increased N

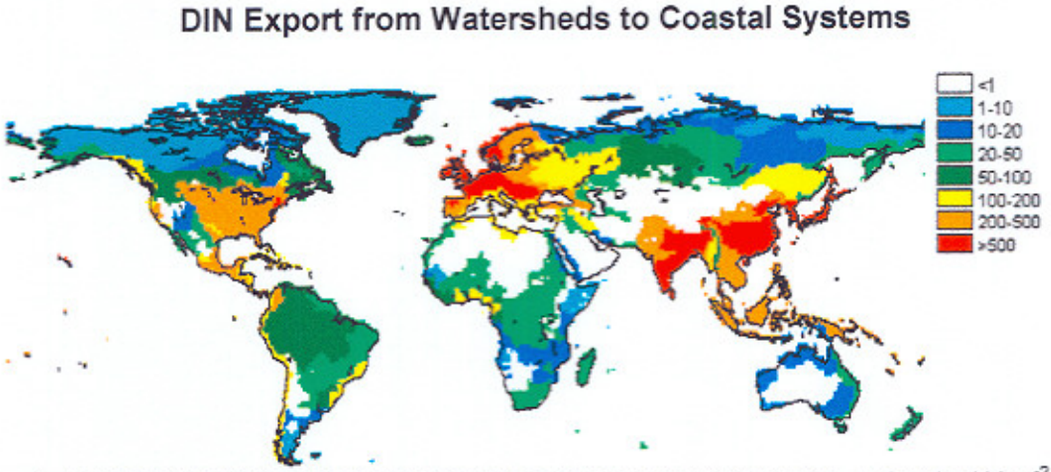

Figure 1. Nitrogen (inorganic N) export from watersheds to coastal systems. units: kg N km^{-2} watershed y^{-1}. Figure from S.P. Seitzinger and C. Kroeze (1998).

export is predicted for those regions alone.

Current and future impacts of increased nutrient mobilization on human and environmental well-being warrant further development of spatially explicit global models to hindcast, nowcast and forecast the export of N, P, Si, and C to coastal ecosystems as a function of land-use, human activities and natural processes in watersheds.

Goals of Global NEWS

- Develop the next generation of spatially explicit, multi-element (N, P, Si, and C), multi-form (particulate and dissolved, organic and inorganic) models to predict nutrient transport to coastal systems as a function of natural processes and human activities in watersheds
- Use new models to advance understanding of the relationships between human activities and natural processes in watersheds and nutrient inputs to coastal systems
- Analyze past, current and hypothetical future scenarios
- Disseminate results through peer-reviewed publications, through the internet via the IOC website, and through direct interaction and ties with other programs and the governments of developing nations
- Career development for postdoctoral fellows and training for undergraduate and graduate students

Possible Applications for Global NEWS Model Output

- Identification of sources of nutrient enrichment within watersheds
- Quantification of the relative importance of human activities as sources of coastal nutrient enrichment
- Identification of areas prone to nutrient over-enrichment
- Quantification of the types of nutrients likely to impact particular regions

- Prediction of effects of coastal nutrient enrichment (e.g. harmful algal blooms, anoxia and hypoxia leading to fish kills, and changes in ecosystem function)
- Interaction with social/policy/economic modeling efforts under consideration by other groups

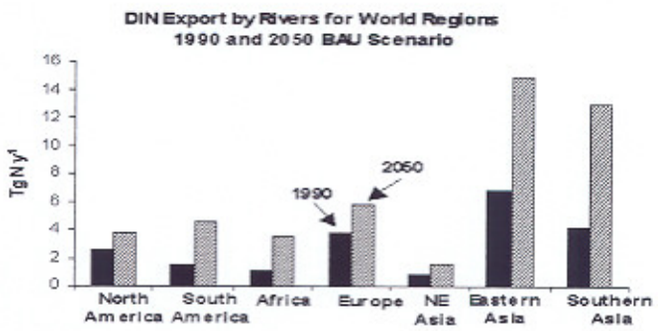

Figure 2. Predicted increases in N export to coastal systems by the year 2050 according to a Business As Usual (BAU) projection. Model predictions from C. Kroeze and S. P. Seitzinger. (1998).

Global NEWS Accomplishments 2002-2004

1. Workshops and Accumulation of Databases

Since Global NEWS was started in the spring of 2002, we have held three major, international workshops. We have made decisions about model formulations, spatial and temporal resolution of input datasets and modeling efforts, and the eventual aims of the Global NEWS project, and moved ahead with model development

At these meetings and during intervening months, we have also attained multiple databases relevant to river nutrient export at a global scale (Table 1). We have established a link with the Land Ocean Interactions in the Coastal Zone (LOICZ) group and with UNEP-MAP. We have also discussed the relevance of global nutrient export models to the regional-scale planning effort occurring in the Mediterranean.

Table 1. Some of the datasets that Global NEWS has accumulated for use in analysis of nutrient export.

Dataset	*Brief Description*
River nutrient and water discharge data	River data from multiple sources, including GEMS-GLORI, European Environmental Agency, US Geological Survey, LOICZ, MedHycos, and many individual research papers. Coverages for individual constituents are shown in Figs. 6, 8, 11, 13
STN30-p	0.5 map of drainage networks worldwide
0.5° gridded human population density	Population density by decade (1700-1990)
0.5° gridded N and P fertilizer application	Fertilizer application by crop type for 1970, 1995, and 2030
0.5° gridded N and P manure application	Manure application by land-use type for 1970, 1995, and 2030
1° gridded NHx and NO_y deposition	NHx and NOy deposition by decade (1860-2000) and projected N deposition (2025 and 2050) (Fig. 3)
Large Dams (>15m height)	Locations, volumes, and surface areas of 2000+ of the largest reservoirs globally
0.5° gridded water runoff	Modeled monthly and annual runoff (average climatology for 1960-1995)
Country-level Human N and P Excretion	Modeled N and P excretion by country for 1975,1995, and 2030
Country-level Sanitation Data	Percent connection to sanitation by country for 1975,1995, & 2030
Country-level Sewage Treatment Data	N and P removal efficiency of sewage treatment by country for 1975,1995, & 2030
0.5° Digital Elevation and Slope Maps	Elevation and average slope
0.5° gridded soils data	Data on soil derived characteristics including pH, organic C content, texture, bulk density, moisture, cation exchange capacity, anion exchange capacity, P deficiency, and others from the International Soil Reference Information Centre
0.5° gridded irrigation	% of land irrigated

2. Hydrology

Currently, Global NEWS models use a 0.5° representation of global hydrology called STN30 (Fekete et al., 2002) to delineate river basins and to define river networks discharging to coastal regions (Figs. 3 and 4). The NEWS models also require runoff estimates, which are generated by a water balance model (Vorosmarty et al., 2000, Fig. 3). Finally, several of the global NEWS models include a reservoir retention component, which requires accurate information about reservoir locations, sizes, and input and output flow volumes.

The Global NEWS workgroup is utilizing a substantially improved representation of global hydrology (STN30 Version 6.0 rather than the publicly available STN30 Version 5.1.2), which includes major corrections in river flowpaths and basin extents. The NEWS workgroup is also currently working to create a fully georeferenced dam database with the world's largest 2000 reservoirs. This database is complete for all continents except Asia, and when finished will constitute a major improvement over the best global dam database available currently, which includes approximately 700 of the world's largest reservoirs (Fig. 4).

The water balance model used by Global NEWS nutrient export models explains 87% of the variability in measured discharge and is free from bias (Fig. 5).

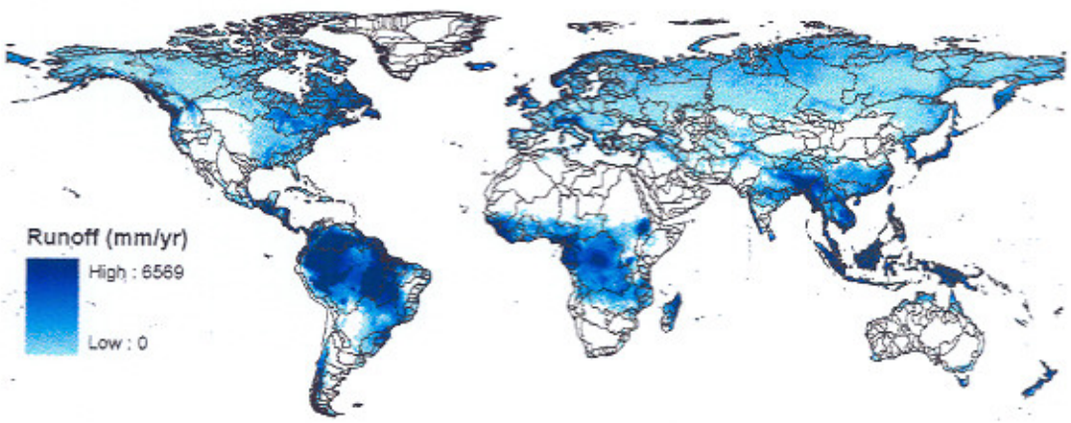

Figure 3. Modeled mean annual runoff in mm/yr for river basins is shown in varying shades of blue, with darker blue representing higher runoff values. STN30-p drainage networks are also shown.

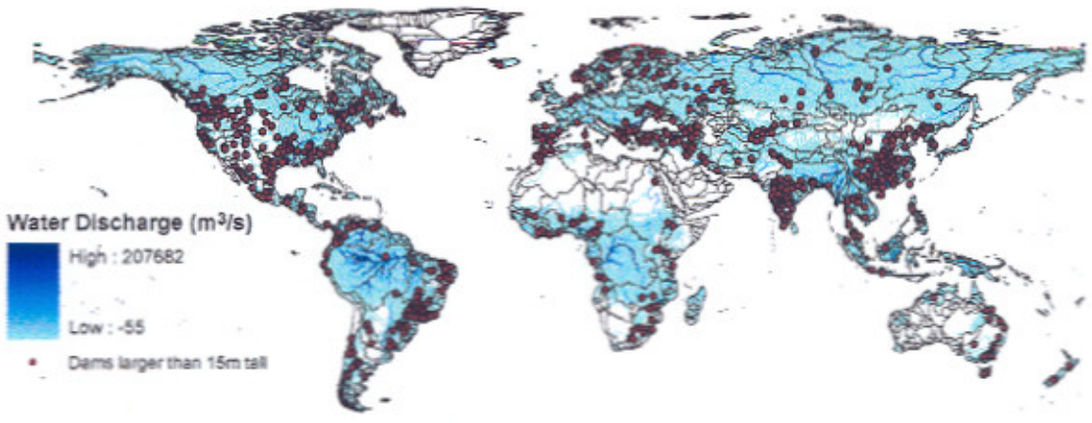

Figure 4. Modeled mean annual discharge (m^3/yr) for global river networks in varying shades of blue, with darker blue representing higher discharge values. Locations of large dams (>15 m high) are also shown (Fekete et al., 2002).

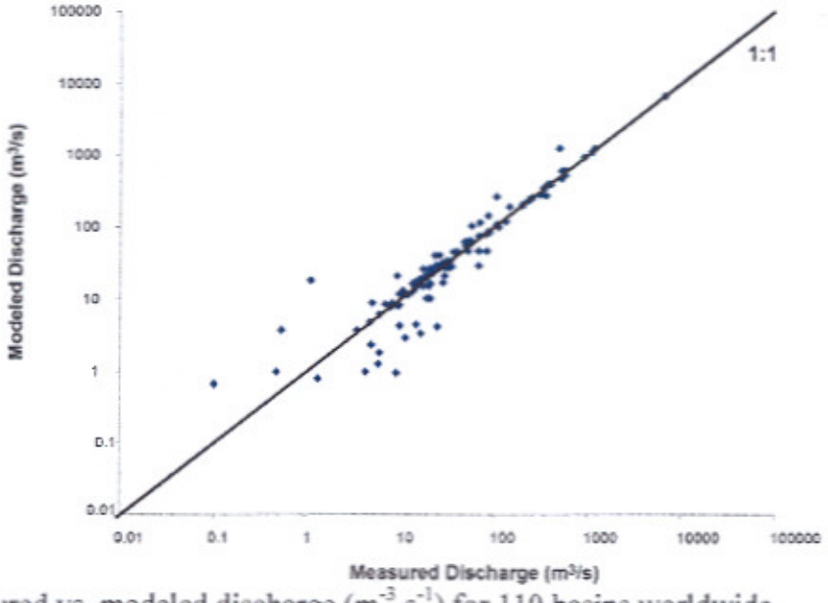

Figure 5. Measured vs. modeled discharge (m^{-3} s^{-1}) for 110 basins worldwide.

3. Dissolved Inorganic Nitrogen

The Global NEWS workgroup has created a new, improved DIN export model called NEWS-DIN. NEWS-DIN includes several enhancements over previous global DIN export models such as: improved calculation of human sewage N inputs, improved calculation of diffuse N sources, inclusion of water consumption, inclusion of dam related N retention, incorporation of enhanced-resolution datasets (calibration and validation with 0.5° grid maps of the world). NEWS-DIN also utilizes more recent data for model calibration and validation than past studies; all of the calibration and validation data used in NEWS-DIN are from measurements made after 1990. Finally, the DIN model was validated using data independent of the calibration dataset.

NEWS-DIN works fairly well, explaining 74% of the variability in measured DIN yield, and the slope of the regression for measured vs. modeled DIN export is not significantly different from unity ($P>0.05$) (Fig. 7).

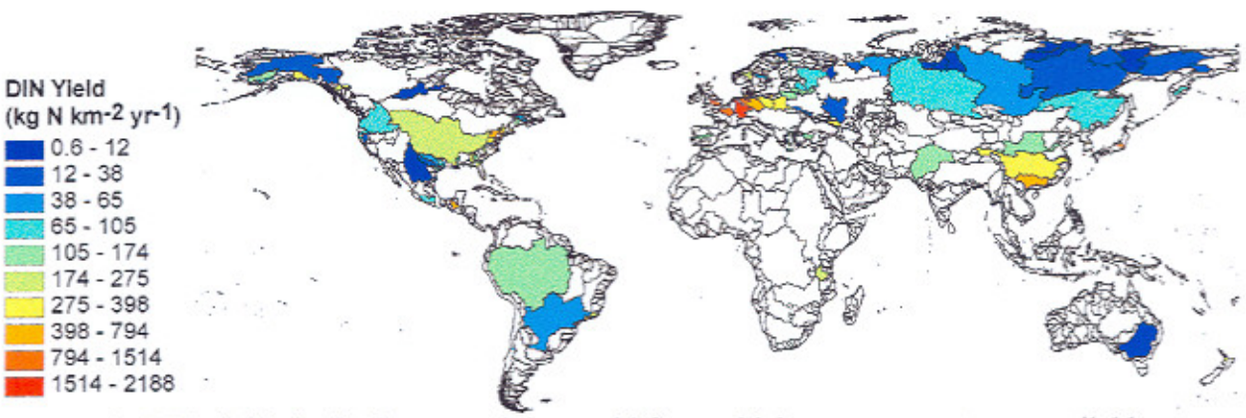

Figure 6. DIN yields for basins around the world from which measurements are available.

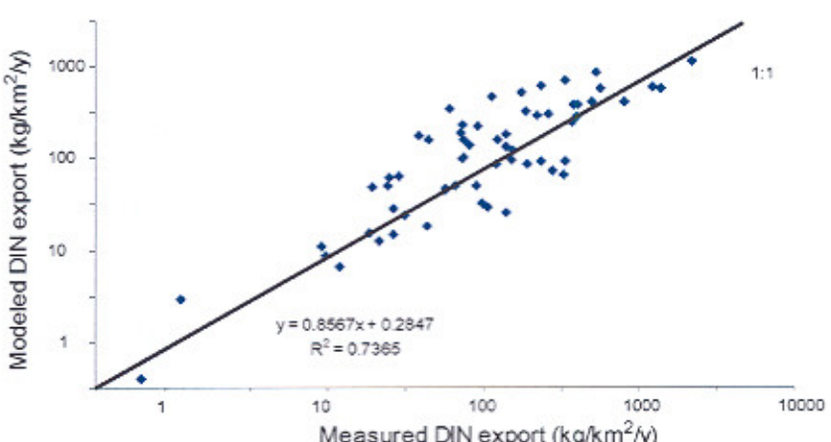

Figure 7. A comparison of measured versus modeled DIN yield (kg N/km^2/yr). Dark line is the 1:1 line.

5. Dissolved Inorganic Phosphorus

The Global NEWS working group has created a new, improved, global DIP-export model called NEWS-DIP. NEWS-DIP includes several innovations and advantages over previous global DIP export models, including increased spatial resolution (0.5 x 0.5°) of global input datasets and watershed delineations, explicit treatment of sewage, fertilizer, manure, and weathering P sources, and inclusion of reservoir retention and consumptive water use terms.

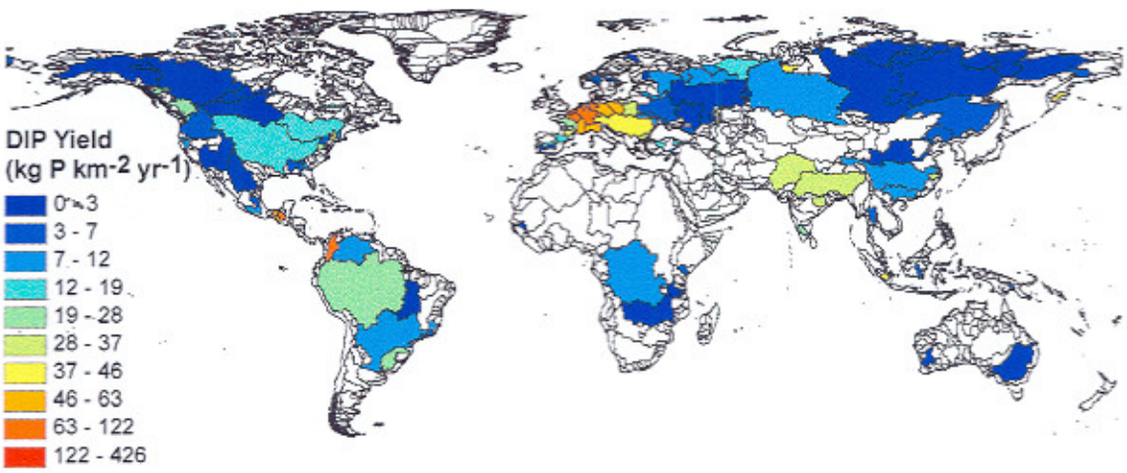

Figure 8. DIP yield for basins from which DIP export measurements are available.

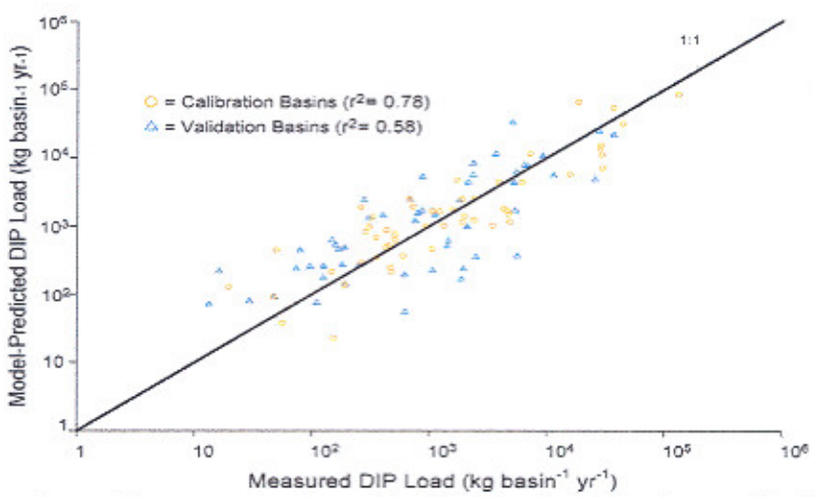

Figure 9. A comparison of measured and modeled DIP loads for basins worldwide (kg P/basin/yr). Dark line is the 1:1 line.

NEWS-DIP explains 72% and 56% of the variability in per-area DIP export (DIP-yield) in calibration and validation basins, respectively, substantially more than previous global models of DIP export. Slopes of regressions for measured versus modeled DIP yield are not significantly different from unity for calibration or validation basins ($P > 0.05$). Using modeled (i.e. STN30) rather than measured runoff values for basins with measured DIP has very little

effect on the predictive capacity of the model (r^2 using modeled runoff for measured versus predicted DIP yield = 0.72 and 0.54 for the calibration and validation datasets, respectively).

This level of uncertainty is comparable to (or less than) uncertainty associated with other continental and global scale nutrient export models [e.g. *Ludwig and Probst,* 1996; *Seitzinger and Kroeze,* 1998; *Smith et al.,* 2003; *Green et al.,* 2004]. In fact, the error associated with NEWS-DIP predictions is similar in magnitude to the inter-annual variability of DIP yields in several U.S. rivers. For example, the difference between minimum and maximum DIP export years is 5-fold for the Mississippi River and over an order of magnitude for the Potomac River [data from *Alexander et al.*, 1996]. This suggests that NEWS-DIP predictions are likely to fall within the range of inter-annual variability for any given river.

Predicted DIP yields ranged over five orders of magnitude, from less than 0.01 to 1153 kg P km^{-2} yr^{-1} (Fig. 10). Highest predicted DIP yields tend to cluster in Japan, Korea, Indonesia, and Europe. There are also predicted hot-spots for DIP yield in portions of the Northeast United States, Central and South America, and West Africa. The highest predicted yield occurs in Japan's Kiso basin. The lowest predicted yield occurs in Northern Australia. In general, low predicted DIP yields tend to occur in areas with low levels of anthropogenic influence or in relatively dry regions.

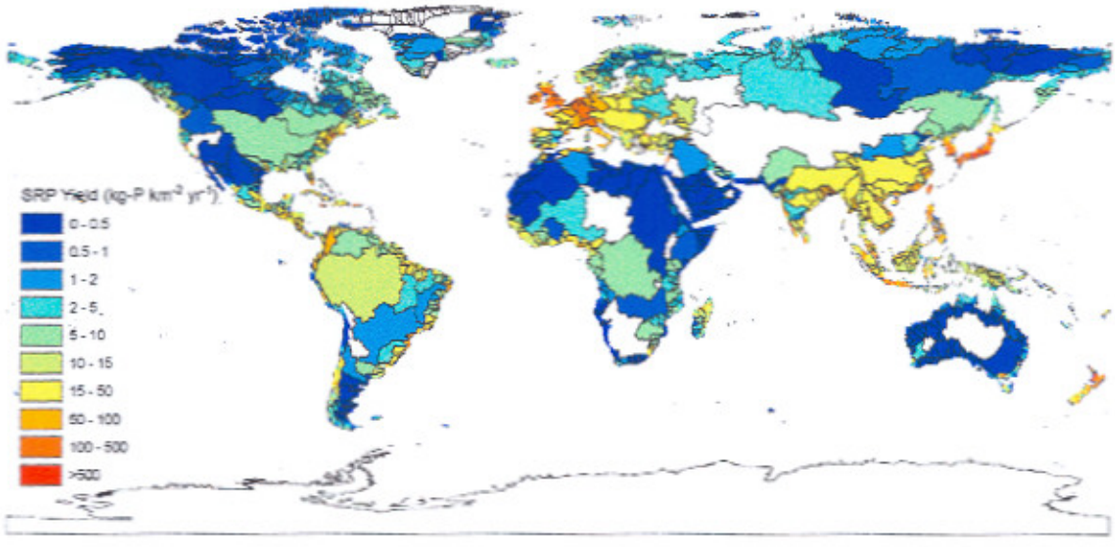

Figure 10. Model-predicted DIP yields for basins worldwide.

4. Dissolved Organic Material

Before Global NEWS, there was no spatially explicit, global model for predicting DON or DOP export from watersheds. We have determined that it is possible to use runoff as an effective predictor of DON and DOP yield (Fig. 12), and are in the process of developing a global model to predict export of these constituents. Using runoff alone, we are able to explain 92%, 91%, and 86% of the variability in the DOC, DON, and DOP yield, respectively (Fig. 12).

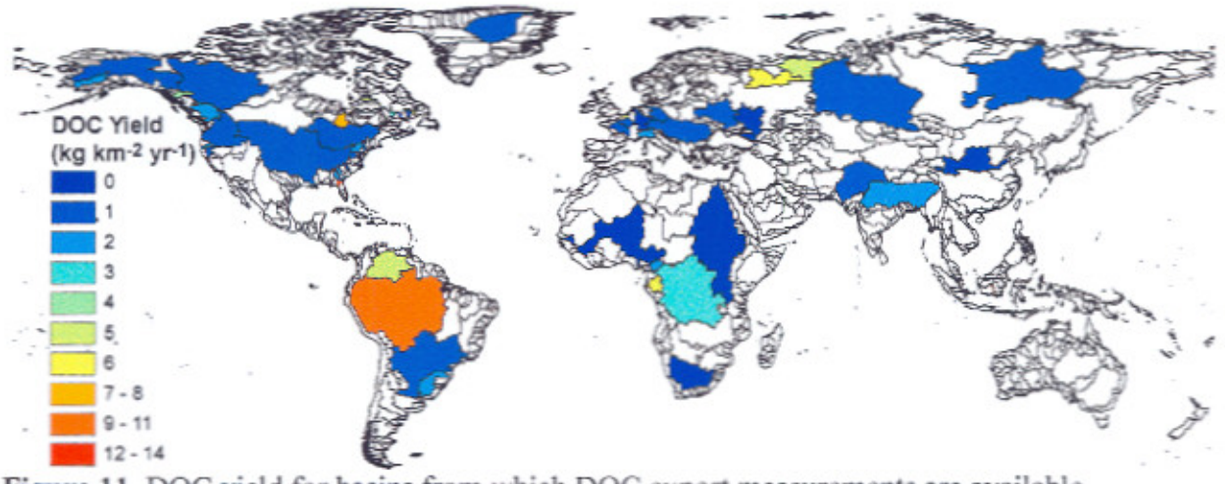

Figure 11. DOC yield for basins from which DOC export measurements are available.

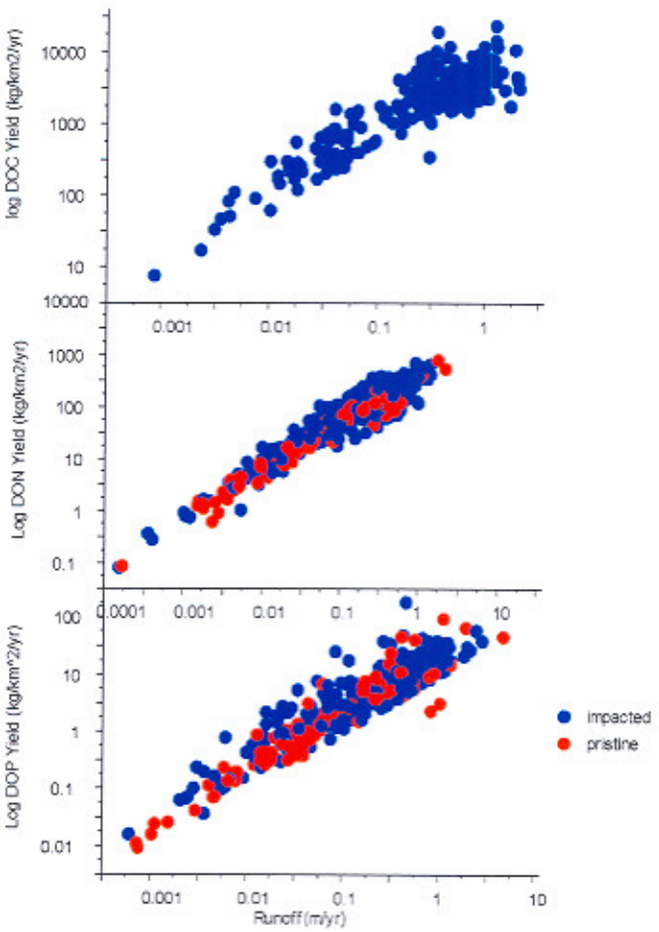

Figure 12. DOC, DON, and DOP yields ($kg/km^2/yr$) from US river basins as a function of runoff alone. In the case of DOP and DON, results have been split according to the degree of human influence.

5. Particulates

After trying several different approaches, the Global NEWS workgroup has developed a TSS model that uses 12 parameters (basin characteristics) to predict total suspended solid (TSS) export from watersheds. The multiple R^2 for the regression between modeled and measured TSS load is 0.79, its slope is not significantly different from unity, and all coefficients are significant.

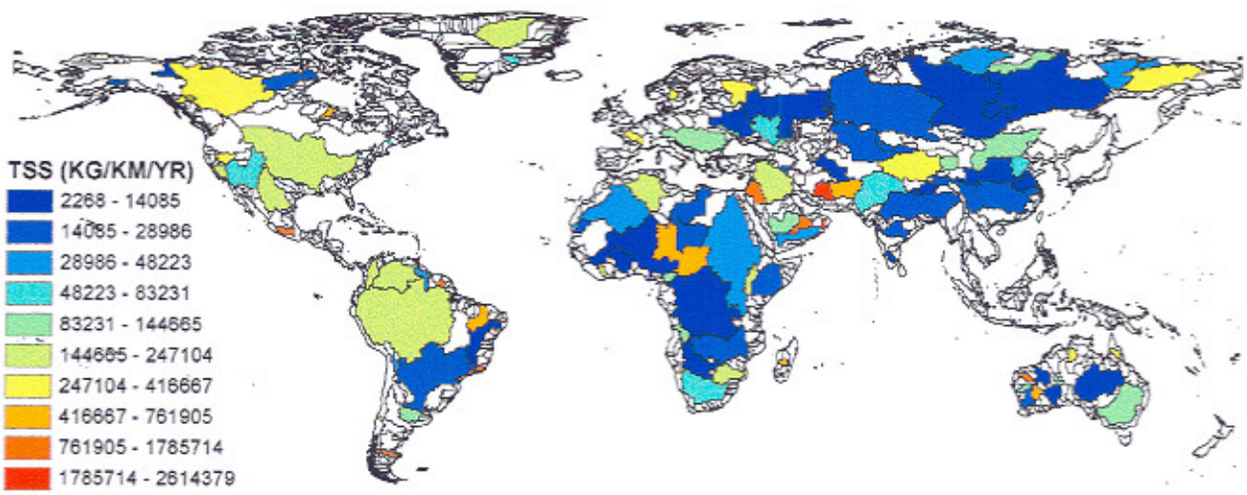

Figure 13. TSS yields (kg/km^2/yr) for basins around the world from which measurements are available.

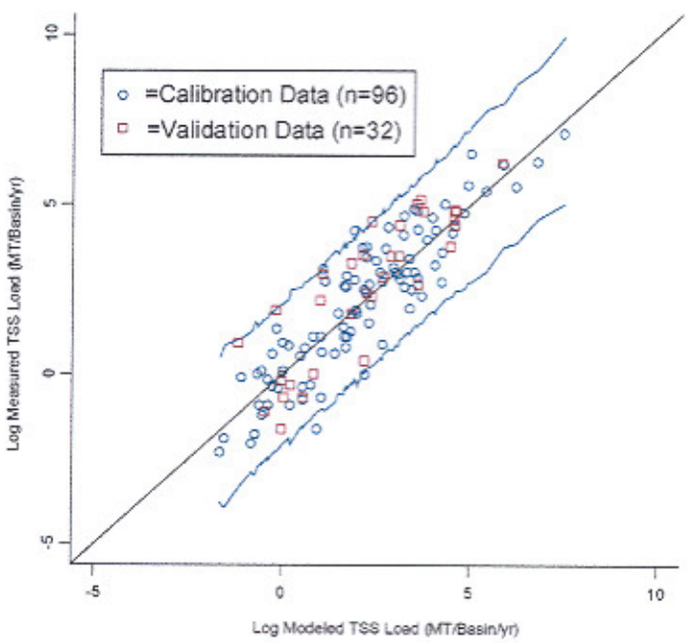

Figure 13. Modeled vs. measured TSS loads from basins worldwide

6. Focus on Mediterranean

Mediterranean Context

Eutrophication due to nutrient inputs from land-based pollution sources is a major environmental problem in the Mediterranean. The stated goals of UNEP-Mediterranean Action Plan (MAP) are to curb pollution, safeguard natural and cultural resources, manage coastal areas, and integrate environment with development. Achieving these goals will require knowledge of current and future rates of nutrient inputs to the coastal zone, as well as an understanding of the sources of those nutrients from various regions/subregions within the Mediterranean basin watershed. To help provide this understanding, we have developed Global NEWS-Med, a sub-project within Global NEWS, focused on understanding regional nutrient export to the Mediterranean Sea. The following is a brief summary of our progress to date.

In order to model nutrient export from individual basins within the Mediterranean Region, we first had to define watersheds for the region. Using a topography-generated map of water drainage, we defined 244 individual basins feeding directly into the Mediterranean Sea (Fig. 14). We then applied our old DIN model (Seitzinger & Kroeze 1998) to the Mediterranean Region, using new, higher resolution basin delineations and enhanced input datasets (Fig. 15). The DIN model performed well, explaining 81% of the variability in DIN export from Mediterranean river basins when compared with river export data (Fig. 15).

In an attempt to look at potential impacts of DIN loading on coastal primary productivity, we examined whether there was a relationship between DIN export and coastal Chlorophyll a (Chl a) concentrations, as measured from space by the SeaWiFS satellite (Fig. 16). When the southwestern portion of the Mediterranean was excluded from the analysis, there was a very strong relationship between predicted river DIN export and mean annual Chl a concentrations at the regional scale over a five year period ($r^2 = 0.91$, Fig. 17). In the southwestern region Chl a concentrations were anomalously high, a condition that might be explained by the high dust inputs that occur there. The correlation we observed between DIN inputs and Chl a has a number of potential explanations, including the fact that DIN and DIP inputs both tend to vary as a function of human population density. It may be that Chl a dynamics are more strongly driven by P inputs and availability than by N. We hope to explore this possibility in future studies of the region.

We also examined the relative importance of different N sources to coastal DIN loading to the Mediterranean by region. This analysis suggested that N-fertilizers are the largest source of DIN to coastal zones throughout the Mediterranean Region, comprising 75-85% of the total river DIN load. It also indicated that atmospheric deposition (NO_y) and point sources are relatively small sources of coastal DIN loading, contributing 11-19% and 2-9% of coastal DIN, respectively. There was some geographic variation, with the highest relative contribution of atmospheric deposition occurring in the Southwest region and the highest relative contribution of point sources occurring in the North Central region (Fig. 18).

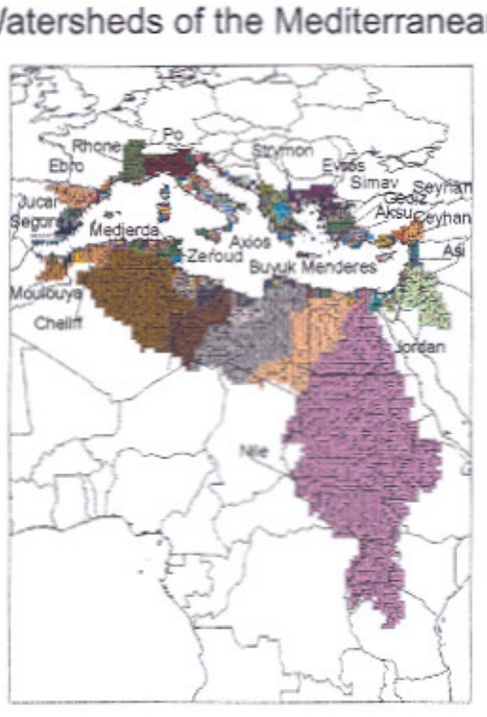

Figure 14. The drainage basins and potential networks of rivers flowing into the Mediterranean Sea as delineated by STN30-p, one of the elevation-based drainage distribution maps we are using in our Global NEWS-Med study.

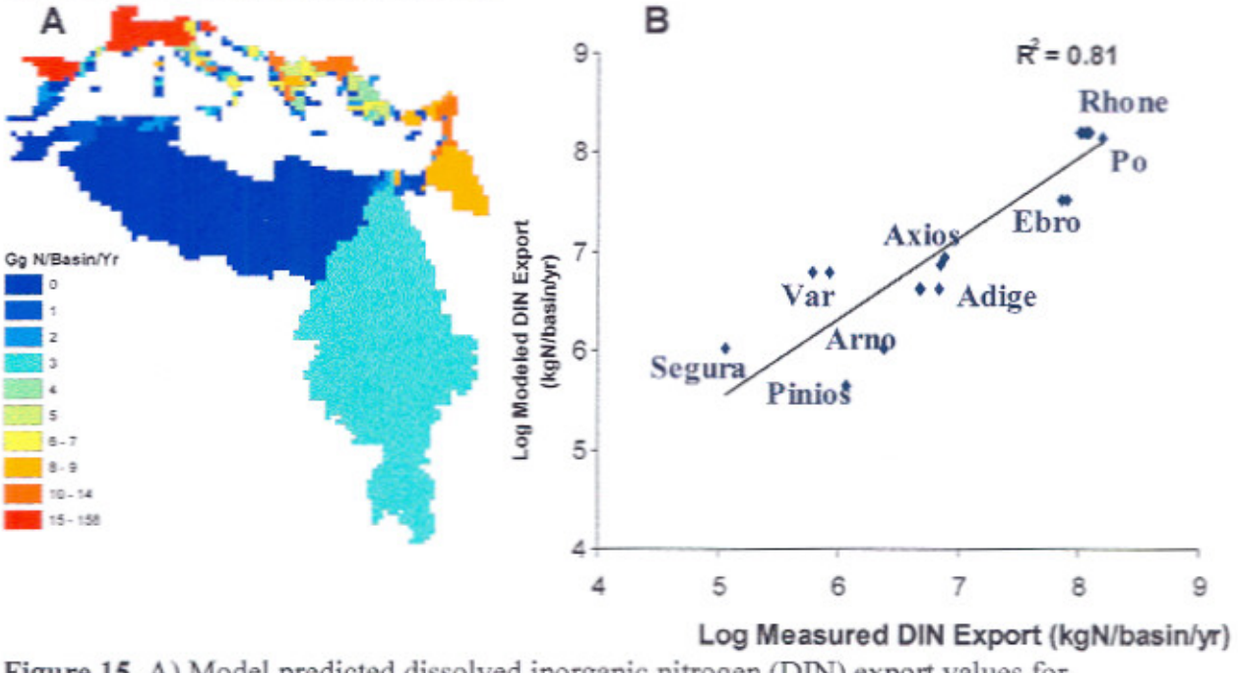

Figure 15. A) Model predicted dissolved inorganic nitrogen (DIN) export values for Mediterranean river basins (Gg N/basin/year) (Gg = 10^9g). B) Comparison of modeled and measured DIN export.

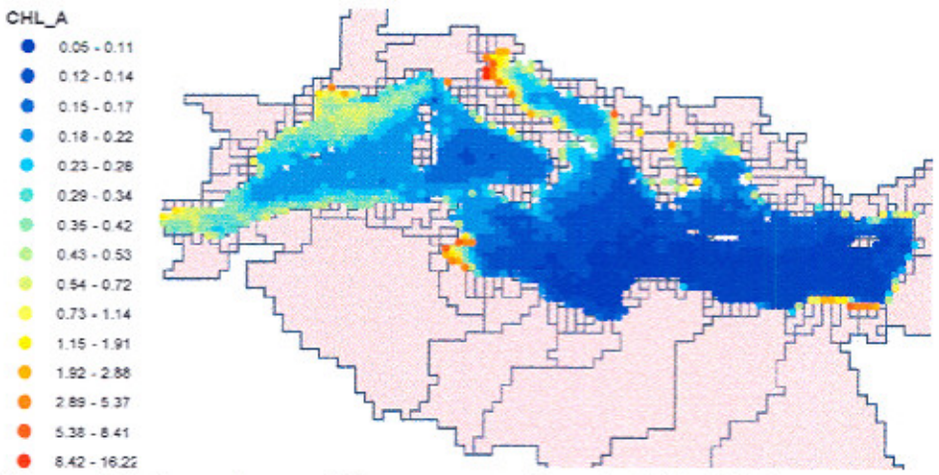

Figure 16. Annual mean Chl a concentrations (ug/L) in Mediterranean coastal waters (from SeaWiFS data). Note that high Chl a concentrations tend to coincide with regions predicted to discharge large amounts of DIN.

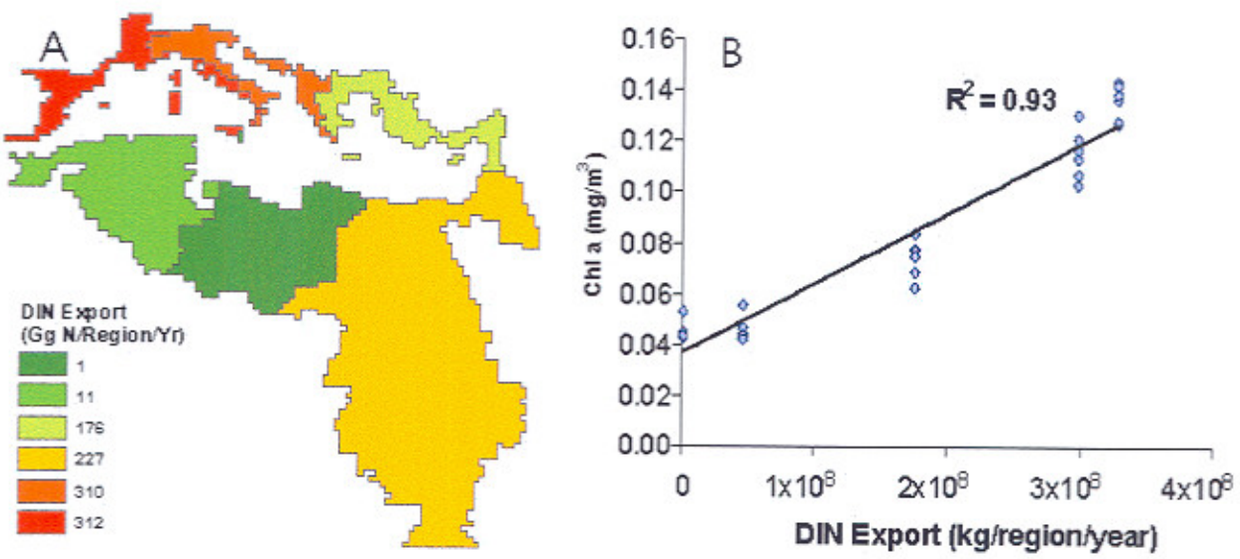

Figure 17. A) DIN export to the Mediterranean sea by geographical region, and B) the relationship between regional, mean-annual Chl a concentrations and regional DIN inputs by rivers over the period between 1997 and 2002. Southwestern region excluded from regression due to potentially confounding influence of dust inputs.

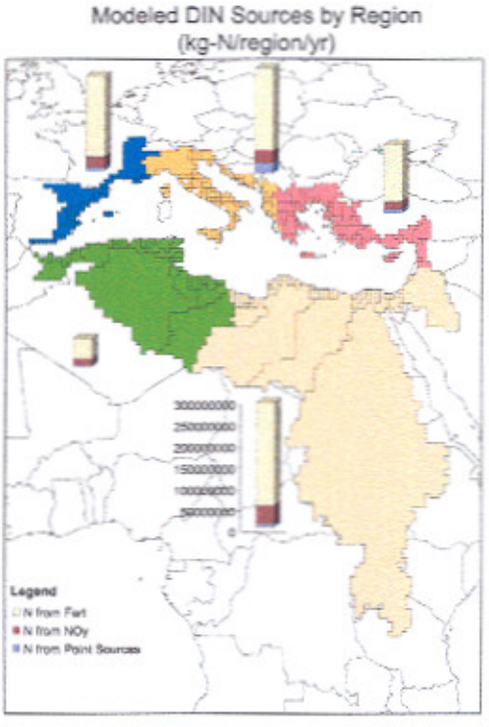

Figure 18. Model-derived dissolved inorganic nitrogen (DIN) sources by region of the Mediterranean. Bars represent the amount (kg N) of exported DIN derived from various sources in five Mediterranean Regions.

Summary of Achievements to Date:

Over the past two years, the Global NEWS project has made substantial progress. We have identified project participants, held three major workshops, and established cooperative interactions with other projects and institutions sharing similar spheres of interest. We have hired and trained a postdoc, initiated several NEWS-related graduate student projects. We have accumulated databases necessary for model formulation (Table 1), and developed global nutrient export models for several nutrients and forms. In this report we have presented preliminary output from two of the sub-models (DIN and DIP sub-models) currently in development. We are currently moving ahead with improvements to existing DOM and TSS export models as well as with development of models to predict river export of Si, and particulate forms of N, P, and C. Several manuscripts are also in preparation (Appendix C).

Goals for Remainder of Year (by 1-05)

Global NEWS

- Implement and evaluate final versions of NEWS-DIN and NEWS-DIP to quantify current global patterns, magnitudes, and sources of DIN and DIP export in a spatially explicit manner.
- Continue development of NEWS-DOM, NEWS-TSS, and NEWS-Si models
- Begin model integration: Integrate individual sub-models to examine ratios of elements and elemental forms (dissolved/particulate, organic/inorganic) of exported river waters and how they are affected by human activities.

Global NEWS-MED

- Run and evaluate final NEWS-DIN and NEWS-DIP nutrient export models specifically for Mediterranean Region. Doing this will provide insight into patterns, magnitudes and sources of nutrient inputs to Mediterranean coastal waters.
- Work with Wolfgang Ludwig and UNEP-MAP to develop a more comprehensive understanding of patterns of nutrient loading, export by river and coastal productivity within the Mediterranean Region (manuscript in preparation, Appendix C).
- Continue to compile river data for use in regional model validation: Though it represents a good start, our current river chemistry database only allows us to compare model output with data from a few of the larger rivers in the Mediterranean. Further collaboration with groups such as the IGBP Land Ocean Interactions in the Coastal Zone (LOICZ) project, the European Environmental Agency (EEA), and others should help us to test and further refine our models.

***Funding-contingent* Goals for Global NEWS (Year 3 and beyond)**

Global NEWS

- Use NEWS-DIN and NEWS-DIP export models to hindcast and forecast river DIN and DIP export using global change projections (e.g. population growth, fertilizer use) for the years 1970, 1995, and 2030. This effort will help identify sensitive coastal regions
- Use NEWS-DIN and NEWS-DIP export models to estimate the relative contributions of natural and anthropogenic nutrient sources to coastal waters. This effort would inform efforts to reduce coastal nutrient pollution by identifying dominant sources of exported nutrients.
- Apply NEWS-DOM model to predict rates of DOC, DON, and DOP export from
- Apply NEWS-DOM model to predict rates of DOC, DON, and DOP export from watersheds worldwide. Compare model predictions with NEWS-DIP and NEWS-DIN predictions in order to improve understanding of spatial distribution of export of different N and P forms to coastal waters.
- Apply the NEWS-TSS model to predict rates of TSS export as well as rates of particulate C, N, and P. Compare NEWS-TSS predictions with NEWS-DIP and NEWS-DIN predictions (as well as NEWS-DOM predictions) in order to improve understanding of spatial distribution of export of different C, N, and P forms to coastal waters.
- Develop, apply, and evaluate a NEWS-Si model. Compare predicted Si export with predictions of inputs of other nutrients and forms in order to determine what regions are likely to be Si-limited.

Global NEWS-MED

- Use NEWS models to explore impacts of different potential regional change scenarios (e.g. climate change, population growth, fertilizer use) on nutrient inputs to Mediterranean coastal waters: Such an analysis will help the Mediterranean Region plan for, and respond to, future increases in coastal nutrient loading that will likely accompany population growth and economic development in coming decades.
- Use NEWS-DOM, NEWS-TSS, and NEWS-Si export models to estimate DOC, DON, DOP, PON, POC, and Si inputs to Mediterranean coastal waters. Combine output from these models with output from NEWS-DIN and NEWS-DIP to better understand nutrient loading to Mediterranean coastal waters and to identify sensitive coastal regions.
- Run higher spatial resolution (finer than 0.5°) version of the NEWS models for the Mediterranean Region. The highest resolution dataset that we are currently using is a 0.5 degree grid, or ~50 km x 50 km. Though these datasets allow us to see some of the more distinct patterns in land use at the regional scale, access to finer-scale land-use, population, and topographic data would greatly enhance our ability to model nutrient transfer at the regional scale.

References

Caraco, N.F. Influence of human populations on P transfers to aquatic systems: A regional scale study using large rivers. Chapter in *Phosphorus in the Global Environment* H. Tiessen Ed., John Wiley & Sons Ltd. 1995.

Fekete, B. M., C. J. Vorosmarty, and W. Grabs. 2002. High-resolution fields of global runoff combining observed river discharge and simulated water balances. Global Biogeochemical Cycles **16(3)**:art-1042, Jul-Aug.

Green, P. A., C. J. Vorosmarty, M. Meybeck, J. N. Galloway, B. J. Peterson, and E. W. Boyer. Pre-industrial and contemporary fluxes of nitrogen through rivers: a global assessment based on typology. *Biogeochemistry* 68, 71-105, 2004.

Kroeze, C. and S. P. Seitzinger. 1998. Nitrogen inputs to rivers, estuaries and continental shelves and related nitrous oxide emissions in 1990 and 2050: A global model. Nutrient Cycling in Agroecosystems **52**: 195-212.

Ludwig, W., J. L. Probst, and S. Kempe. Predicting the oceanic input of organic carbon by continental erosion. *Global Biogeochemical Cycles* 10 (1):23-41, 1996.

Seitzinger, S. P., and C. Kroeze. 1998. Global distribution of nitrous oxide production and N inputs in freshwater and coastal marine ecosystems. Global Biogeochemical Cycles **12(1)**: 93-113.

Smith, S. V., D. P. Swaney, L. Talaue-Mcmanus, J. D. Bartley, P. T. Sandhei, C. J. McLaughlin, V. C. Dupra, C. J. Crossland, R. W. Buddemeier, B. A. Maxwell, and F. Wulff. Humans, hydrology, and the distribution of inorganic nutrient loading to the ocean. *Bioscience* 53 (3):235-245, 2003.

Vörösmarty, C.J., B.M. Fekete, M. Meybeck, and R. Lammers. 2000. A simulated topological network representing the global system of rivers at 30-minute spatial resolution (STN-30). *Global Biogeochemical Cycles* 14:2 599-621.

Appendix A: Global NEWS participants and their respective institutions

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Appendix B: Model Equations

DIN Model

$$DIN_{exp} = (1 - D_{DIN}) \cdot Q_{act} / Q_{nat} \cdot R_{DIN} \cdot (SewN + 0.0653 \cdot R^{0.137} \cdot DiffN)$$

Variable	Definition
DIN_{exp}	DIN export (kg km^{-2} y^{-1})
D_{DIN}	Reservoir DIN retention
Q_{act}	Measured discharge after dam construction (km^3 H_2O yr^{-1})
Q_{nat}	Measured discharge prior to dam construction (km^3 H_2O yr^{-1})
R_{DIN}	River DIN retention: 0.833 based on R_{NO3} and average ratio between river NO_3 and DIN
$SewN$	Sewage N input to river as a function of population density, per-capita N excretion, sanitation connectivity, and N removal via treatment
R	Runoff (m H_2O yr^{-1})
$DiffN$	Diffuse N inputs to basin soil surface, including inorganic N fertilizer and manure

DIP Model

$$P = (Q_{act} / Q_{nat}) \cdot (1 - D) \cdot (H \cdot E_{cap} + (1/(1+(R/a)^{-b})) \cdot (W_{max} + L_{max} \cdot (P_{fert} + P_{am})))$$

Variable	Definition
P	DIP yield (kg P km^{-2} yr^{-1})
Q_{act}	Measured discharge after dam construction (km^3 H_2O yr^{-1})
Q_{nat}	Measured discharge prior to dam construction (km^3 H_2O yr^{-1})
D	Fraction DIP retained in reservoirs (0-1)
H	Human population density (individuals km^{-2})
E_{cap}	Per capita DIP yield (kg P $individual^{-1}$ yr^{-1})
R	Runoff (m H_2O yr^{-1})
a	Unit-less coefficient defining how non-point DIP and weathered DIP respond to runoff; for NEWS-DIP set equal to 0.6
b	Unit-less coefficient defining how non-point DIP and weathered DIP respond to runoff; for NEWS-DIP set equal to 2
W_{max}	Maximum DIP yield due to weathering alone (kg P km^{-2} yr^{-1}); for NEWS-DIP set equal to 12
L_{max}	Maximum fraction of applied manure and fertilizer P lost to coastal zone as DIP; for NEWS-DIP set equal to 0.07
P_{fert}	P applied to watersheds as inorganic fertilizer (kg P km^{-2} yr^{-1})
P_{am}	P applied to watersheds as manure (kg P km^{-2} yr^{-1})

DOM Models

$log\ DOC\ yield = c + d \cdot\ Log\ R$
$log\ DON\ yield = e + f \cdot\ Log\ R$
$log\ DOP\ yield = g + h \cdot\ Log\ R$

Variable	Definition
c, d, e, f, g, and h	Fitted coefficients
DOC yield	DOC yield (kg C km^{-2} yr^{-1})
DON yield	DON yield (kg N km^{-2} yr^{-1})
DOP yield	DOP yield (kg P km^{-2} yr^{-1})

TSS Model

log(TSS) = ext.crop + height + max.runoff + MAXSLP50 + CLAY + bulkdens + basinarea + arable.slope + grass.slope + irrigation

Variable	Definition
TSS	Total Suspended Solid load (Megatons/basin/yr)
ext.crop	Extensive cropland
height	Elevation above sea level
max.runoff	Runoff in the month with maximum runoff
MAXSLP50	Maximum slope within a basin
CLAY	Clay content
bulkdens	Bulk density
basinarea	Basin area
arable.slope	% Arable land x slope
grass.slope	% Grassland x slope
irrigation	% irrigated land

Appendix C: Manuscripts in Preparation or Submitted

During the May 2003 meeting, Global NEWS participants committed to write the following manuscripts, to be submitted as a special issue of the journal *Global Biogeochemical Cycles*, the premiere journal in our field. One of these, *Soluble Reactive Phosphorus Export to the Coastal Zone: Results From a New Spatially Explicit Global Model*, has already been submitted.

1. **Global Patterns and Magnitudes of C, N, and P Export by Rivers**
(synthesis paper)

S.P. Seitzinger, J.A. Harrison, M. Meybeck, E. Dumont, C. Kroeze, A.F. Bouwman, A.H.W. Beusen, N. Caraco, C. Vörösmarty, W. Ludwig, A. Sferatorre, etc…

2. **An Improved Model for Estimating Global Distribution of Dissolved Inorganic** Nitrogen Export to Coastal Ecosystems

E. Dumont, C. Kroeze, E. J. Bakker, J.A. Harrison, A.F. Bouwman, and S.P. Seitzinger

3. **Soluble Reactive Phosphorus Export to the Coastal Zone: Results From a New Spatially Explicit Global Model**

J.A. Harrison, S.P. Seitzinger, N. Caraco, A.F. Bouwman, A.H.W. Beusen, C. Vörösmarty

4. **Estimation of Global River Transport of Particulate Matter**

A.H.W. Beusen, A.F. Bouwman, J.A. Harrison, A.L.M. Dekkers, H. Visser, etc.

5. **Global Distribution of DOM Concentration, Element Ratios, and Export to the Coastal Zone**

N.F. Caraco, J.A. Harrison, S.P. Seitzinger, etc.

6. **Global N and P Point Sources**

A.F. Bouwman, G. VanDrecht, etc…

7. **Patterns of N and P Export and Coastal Productivity in the Mediterranean: a Regional Application of Global Nutrient Export Models.**

W. Ludwig, J.A. Harrison, W.H. Chang, S.P. Seitzinger, etc.

8. **Global Patterns and Magnitudes of Nitrogen Deposition, a Revised Approach**

F. Dentener, etc.

9. **An Inter-comparison of the River Strahler and Global NEWS Models in the Seine and Mississippi River Basins**

A. Sferatorre, J. Garnier, G. Billen, etc.

Appendix D: Global-NEWS-related Presentations and Posters at International Scientific Meetings by John Harrison and Sybil Seitzinger

Harrison, J.A., S.P. Seitzinger, N. Caraco, A.F. Bouwman, A. Beusen, and C.J. Vörösmarty. Dissolved Inorganic Phosphorus Export to the Coastal Zone: Results from NEWS-DIP, Ecological Society of America, Portland, OR: August 2004.

Harrison, J.A., S.P. Seitzinger, C. Kroeze, N.F Caraco, and E. Dumont. Dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach at the regional scale, American Geophysical Union-Ocean Sciences, Portland, OR: January 2004.

Harrison, J.A., S.P. Seitzinger, C. Kroeze, N.F Caraco, and E. Dumont. Dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach at the regional scale, Estuarine Research Federation, Seattle, WA: September 2003.

Seitzinger, S.P., W.H. Chan, and J.A. Harrison. Linking patterns of nutrient export to effects in coastal ecosystems: the Mediterranean Basin, Estuarine Research Federation, Seattle, WA: September 2003.

Harrison, J.A., S.P. Seitzinger, C. Kroeze, N.F Caraco, and E. Dumont. Dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach, Gordon Conference, New London, NH: July 2003.