PROPOSAL ON

Real Time Air Pollution Modeling and Dissemination of Location Based Information Using Mobile Devices

FOR CONSIDERATION UNDER

Research Grant in Geospatial Information Science and Engineering (GISE)

NRDMS/ NSDI Divisions, Department of Science and Technology
Government of India

SUBMITTED BY

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101. Project Title: *Real time air pollution modeling and dissemination of location based information using mobile devices*

102. Broad Subject: Earth Science and Atmospheric Science

103. Sub Area: Earth and Atmospheric Science

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107. Project Category: Applied Research

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Project Title: ***Real time air pollution modeling and dissemination of location based information using mobile devices***

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191. Project summary

We are proposing a web based geo-processing application which can be queried location-specifically from mobile devices using GeoSMS specification. Our objective is to implement air pollution modeling Web Processing Services (WPS) utilizing real time data from Sensor Observation Service (SOS) of distributed air quality sensors and data aggregation script on available ambient air quality website. The aim is to reach the model results to end users' queries from their mobile devices. The WPS involves Comprehensive Air Quality Modeling (CAMx) carried out on real time ambient air quality data on particulate emission and relevant meteorological parameters. The information thus created on air quality specifically on particulate pollution will be disseminated to the end users upon their location-specific queries using GeoSMS based RESTful API. Technically by doing so it is expected to create basic architecture and demonstrate the same for implementing SOS for community based sensor networks, public websites and querying web processing service on mobile devices and generating awareness about a common environmental concern.

192. Key words

Sensor Observation Service (SOS), Web Processing Services (WPS), RESTful API, CAMx, Mobile devices, Data aggregation, Spatial Data Infrastructure (SDI)

193. Budget estimates: summary

	Item	**Budget (In Rupees)**
A.	Rescurring	
	1.Salaries/wages	2,30,400
	2. Consumables	60,000
	3. Travel	50,000
	4. Other costs	4,30,120
B.	Equipment	4,30,204
	Grand total (A+B) Total FEC*	12,00,724

2. Extended Proposal

200. Technical details

The works in the proposed program involves various steps / processes as discussed below;

Air Quality Egg:

It is an open, community led, and community funded project LINK aiming to setup distributed real time air quality sensor networks. By adopting the open source, community led funding development model it intends to develop low cost, high resolution, user friendly air quality sensing devices, that would strengthen the communities' to develop awareness and negotiations on the air quality of their immediate surroundings. Currently, the developed sensing system is capable of sensing air pollutants such as Particulates, Nitrogen dioxide, Carbon monoxide, Ozone, Radiation, and Volatile Organic Carbon. The Air Quality Egg comprised of outdoor sensor board which comprises of the relevant air pollution sensors, one separate egg shaped wireless router (indoor usage) to receive the acquired data from the sensor board and transmit to the 'Internet of things' web service "Cosm.com" through Ethernet/ wireless modem.

Cosm.com LINK*:*

Cosm.com is a web service to build 'Internet of things'. By using this service users can connect their sensors, energy or intelligent environment data to a centralized database for real time feed and visualization. It provides extensive Application Programming Interface (API) to build application using the collected data. By this it instigates the merger of remote physical and virtual environments. It is based on Extended Environmental Markup Language (EEML) and use EEML processing library for easy client deployment.

Web Data Extraction: Extracting information from available web sites for use in other contexts is a worldwide practice. Web data Extraction is a set of application frameworks which can be automatised for crawling through various web sites and extracting structured data that can be re-used for a wider range of other applications, like data mining, information / knowledge generation and processing or for historical archival. It involves defining the set of items for data extraction such as URL, field, size etc and a script to extract that respective data, channeling it and transforming into usable forms such as database, XML etc. Several open source and commercial application frameworks such as Scrappy, Screen Scrapper are available for web data extraction.

Sensor Observation Services (SOS): It is an important sensor web enablement specification which acts as data aggregation from live, in-situ and remote sensors. It provides an accessible interoperable web based interface for sensors and sensor data archives. The core profile OGC SOS specification comprised of three mandatory operations; i) GetCapabilities (for requesting a self-description of the service), ii) GetObservation [for requesting the sensor data encoded in Observation & Measurements (O&M)], iii) DescribeSensor [for requesting information about the sensor itself, encoded in a Sensor Model Language (SensorML)]. '52 North', an open source company specializing in sensor web enablement, provides installable OGC compliant core profile sensor observation services. It comprised four service layers. The first layer is a Data layer that accesses the sensor databases. It uses PostGIS database to store each observation record / value and corresponding metadata such as observation and Sensor model language (ML). The second layer is the Business Logic Layer that oversees the RequestOperator, a part of the same layer. The RequestOperator receives requests from the client Layer (the topmost layer, the frontend), validates the request and forwards it to the appropriate OperationListener, a component of the second layer. The third layer is the Web-tier Servlet, which handles HTTP requests and responses. The fourth layer is a link across the client and the web processing services (WPS).

Web Processing Services (WPS): Geo-processing, the process of analyzing geospatially related data helps in extracting / generating meaning in data. OGC's WPS provides a set of standards for geo-processing. It also gives capability for modeling, simulation, analysis and transforming the geographic sensor observation data. It is considered as an important element in retrieving the information from Spatial Data Infrastructure (SDI). WPS involve three operations namely GET capabilities, DESCRIBE process and EXECUTE. Thus it can be considered as a 'brain' for 'eyes' established in SDI.

REST: Representation State Transfer (REST) is a web service design style which takes care of the addressability, statelessness (dynamic), connectedness and a uniform interface, which can act as an open gateway for web clients to communicate with GIS servers and geo-processing web applications. It uses normal HTTP semantics such as GET, POST, PUT and DELETE to extract data from web pages. ESRI GeoServices REST Specification provides OGC specification compliant way to query GIS servers by web clients.

CAMx: Comprehensive Air quality Model with extension (CAMx) is an Eulerian class of mathematical models that calculates mass balance and chemical transformations within a cell grid having specified boundary at a given time period. Objectivity of this model is to establish the relationships among meteorological factors, chemical transformations, emissions and removal processes of chemical species of atmospheric pollutants. For simulation it requires emissions, meteorological processes and definition of initial and boundary conditions. These modules prepare and provide input to the photochemical dispersion model which generated final modeling output.

GeoSMS: It is a set of standard format for Short Message Services to represent the geographical location in it. Its major application is uniform encoding for sending and receiving the geotagged location information through handheld devices. There are two vairent of GeoSMS, Open GeoSMS and GeoSMS developed by Matthew Kwan. In which Open GeoSMS is OGC complaint and another was not. Each specification provides applications ('I am here' and OpenGeoSMSescan be used in mobile devices such as Android smart phones or iPhones.

210. Introduction

211. Origin of the proposal

We have initiated the work on Sensor Web Enablement as a tool to obtain the data inputs from environmental observations on a real time basis. As a low cost alternative to sensor networks we concentrate on personal sensing observations and Human Sensor Web connectivity through mobile devices. Later, it was changed into crowd sourcing platform Ushahidi while considering the 'human' part in the indented citizen science initiative. A platform named “envirocloud” is currently running in the crowd sourcing platform (www.envirocloud.crowdmap.com). Its objective is to procure the crowd sourced environmental observations from volunteers as well as Sensors. Through the current proposal we are expecting to achieve the sensor observation service objective of the “envirocloud”, exploit the potentials of Human Sensor Web and to act as a web processing service.

212. Definition of the Problem

Modeling provides the tools for understanding the ground situation and the dynamic regulatory and mitigation measure to be implemented. End user definition and providing contextual information is important for SDIs. It offers service-oriented information management, access to it, processing geospatial data and disseminating it using the Web. It requires publishing the sensor observations as linked data, and enabling the applications that combine these observations with other domain information (e.g. modeling results, landuse, and transport) that can be retrieved from the linked data web to RESTfully publish sensor observations to clients though widely used media such as mobile phones. This requires data aggregation from a sort of information repositories to mask their intrinsic incompatibility. Standardization of procedures in sensor web enablement specification can satisfy the requirements such as masking the data incompatibility and processing those data through OGC’s compliant web processing services.

213. Objectives

a) Develop Sensor Observation Service (SOS) for spatially distributed air quality sensors (Air Quality Egg) and real time meteorological data website.
b) Develop Real time air quality modeling (CAMx) web processing service using the SOS, validate and compare it with similar other models.
c) Develop a Geo-SMS based android application to disseminate the modeling result.

220. Review of status of Research and Development in the subject

221. International status

In recent review Bröring et al (2011) on next generation sensor web highlights the significance of improved specifications for sensor web enablement (SWE). In sensor information model, observation & measurement (O&M) specification with profiling of the observed phenomenon would increase the reliability and relevance of SWE. The inclusion of SWE service as a new specification reduces the redundancy in service requests as it is more in line with widely applied web specifications. The review conclude with recommendation for improving the interoperability, facilitating the integration of sensors and services, extending sensor web eventing Concepts to a common event architecture, assessing data quality, enabling the semantic sensor web and linked sensor data. Multifaceted advantages in integrating the sensor webs, citizen sensing and 'human-in-the-loop sensing' for public and environmental health surveillance and crisis management was reviewed by Maged (2011). This review points out increasing importance of sensor web enablement in the scenario of information explosion and social networks. It points out the importance of credible and relevant information availability and its dissemination in a context specific manner. Ongoing projects such as “EO2HEAVEN” (www.eo2heaven.org), EPA funded "Near Real time modeling of weather, air pollution, and health outcome indicators in New York city for environmental health" LINK shows the application of sensor web enablement in environmental health. EO2HEAVEN (Earth Observation and Environmental Modeling for the Mitigation of Health Risks) is an end user oriented research project intended to contribute to better understanding of the complex relationships between environmental changes and its impact on human health. By utilizing OGC compliant spatial information infrastructure it encourages integration of sensor observation from different domains of environmental health hazards to human exposure. By utilizing the power of flexibility in specifications of SOS and O& M it demonstrate the validation of health hazard model derived from various sensor observations to increase its reliability for the end user.

References:

Bröring, A., Echterhoff, J., Jirka, S., Simonis, I., Everding, T., Stasch, C., Liang, S., et al. (2011) New generation Sensor Web Enablement. Sensors (Basel, Switzerland) (Vol. 11, pp. 2652-99). doi:10.3390/s110302652

Maged, N. K. B., Bernd, R., David, N. C., John, G. B., Gunho, S., Russ, B., William, A. P., et al. (2011) Crowdsourcing, citizen sensing and Sensor Web technologies for public and environmental health surveillance and crisis management: trends, OGC standards and application examples. International Journal of Health Geographics, 10(67). doi:10.1186/1476-072X-10-67.

222. National status

In India, New Delhi region has a real time air quality forecasting system. It was implemented by Indo-French collaboration (Central Pollution Control Board, India, and ARIA Technologies and Leosphere; LINK). This system comprise of web based real time animation of hourly maps for pollutants such as particulate matter and Carbon monoxide, and Air Quality Index (AQI), time series of pollutant concentrations at select locations and a Google map interface for visualization. The air pollution data are retrieved from the air quality sensors installed by Central Pollution Control Committee. The system is running based on '*CHIMERE'* chemistry-transport multi-scale model for air quality forecasting and simulation.

223. Importance of the proposed project in the context of current status

Data aggregation from sensor networks provides an infrastructure for uprating the wireless sensor networks into web enabled sensor network accessible to a wider audience. This involves converting data aggregation as a proxy sensor observation service; a process of making OGC (Open Geospational consortium) Sensor Web Enablement Specification compliant. It makes way for a large potential to develop further applications of the standardized sensor observations. Capability to search the sensors, deploy, plan, task and get notified on sensor observations from time to time are some of the applications. It also can be considered as important initial measure to apprehend the disparity among the sensor networks operating in the country. Setting up a modeling layer above the sensor observation service as a web processing services would help derivation of knowledge on the observations or underlying phenomenon. The RESTful (Representation State Transfer application) query to the sensor web through mobile phone would act as important stimuli to achieve the aims of SDI (Spatial Data Infrastructure) of reaching out to large proportion of mobile phone users. Better understanding of the functionality of environment through improving and intensifying observations, and facilitating people to make informed choices towards sustainability are two important recommendations of the UN Secretary-General's Global Sustainability Panel report "Resilient People, Resilient Planet: A future worth choosing" (2011). These recommendations justify the need for improved sensor networks, observations and their interpretation (Geo-processing) for better understanding and assuring sustainability. Since sustainability is about creating opportunity for social ecosystem to make it adaptable to forces of change, it requires better understanding of functionality and uncertainty in the ecosystem. For that it needs to have as much observations as possible on functioning of social ecosystem for generating dynamic perceptions, social consensus and adaptive strategy. Creation of widely accessible spatial data infrastructure of local environment will be an important way around for this. By making a web of various sensors and sensor networks deployed to monitor the environment with different objectives and specifications, it could be possible to achieve. The current proposal looks for implementing the basic infrastructure for that understanding by creating standardized sensor observation services, and web processing services for real time ambient air quality information.

Localized contextual knowledge is essential for co-adaptive management, important ingredient for sustainability. It requires the essential need of grouping diverse source of spatial data about a locality to make it interoperable and to provide holistic understanding of the ecosystem dynamics. Modeling is the best way to derive the knowledge from a series of spatio-temporal observations on an array of relevant parameters. In the current proposal the aim of the Air quality model is to integrate our understandings of the complex processes in a relatively more holistic manner. It facilitates knowing about the relationships among meteorology, chemical transformations, emissions of chemical species, and pollutant removal processes in the specified area. It would also aid in reasoning out the dynamic health impact of the air pollution and to identify and execute befitting environmental regulatory measures.

The information thus generated has to be shared in such a way to aid in decision making, create awareness and alliances between scales and in the organization of social ecological system. It would be enriching and educating that the citizens of a particular environment get to know about the level of their immediate surrounding atmosphere pollution. Here in the case study scenario of the present proposal commuters while querying from the bus stop to the information service, a group of end users for SDI is being identified and formed. The information required by these group of people on issues such as pollution level in the particular locations like bus stop, health hazardous due to the level of air pollution, safety measures required and some complementary estimations such as the reduction of pollution if one use public transportation system would persuade for a informed choice for sustainable life style among the users. Large-scale development in mobile computation technology provides immense potential for disseminating location-specific as well as general information. This has also added implied benefits; satiating basic information needs, creating the need for further information and developing comprehensive understanding of the same. In brief, the expected result from this proposed work is a step forward for implementing the objective of SDI for sustainability making use of the widely available user-friendly devices and applications.

224. Review of expertise available with proposed investigating group/institution in the subject of the project So far we had conducted several studies on various environmental aspects in various parts of the country. Regarding studies related with meteorological and atmospheric aspects, air pollution studies in Coimbatore and other cities of south India and had published research articles in international peer reviewed journals. The Principal Investigators (PAA) has also guided doctoral works in related aspects. The Co-investigators are also well experienced in atmospheric and other pollution studies.

30 Work Plan

231. Methodology

Objective A

The case study scenario:

The real time air pollution modeling system will be applied to investigate the dispersion of respirable particulate matter $PM_{2.5-10}$ concentrations over Coimbatore City, Tamil Nadu. Coimbatore is one of the fast growing cities in south with a strong industrial base, and fast rising urban population, and burgeoning automobile population. The district of Coimbatore has thirteen real time weather monitoring stations named as Tamil Nadu Agricultural Weather Network maintained by The Agro Climate Research Centre (ACRC), Tamil Nadu Agricultural University (TNAU), Coimbatore in collaboration with Department of Agriculture, Tamil Nadu. The network feeds its data to a common website of http://tawn.tnau.ac.in/ at a regular interval of 60 minutes. The data feed comprises real time data of air temperature and important meteorological parameters. The figure 1 given below shows the location of weather stations. The Coimbatore city doesn't have an real time automatised air pollution monitoring stations with real time access of the data for public.

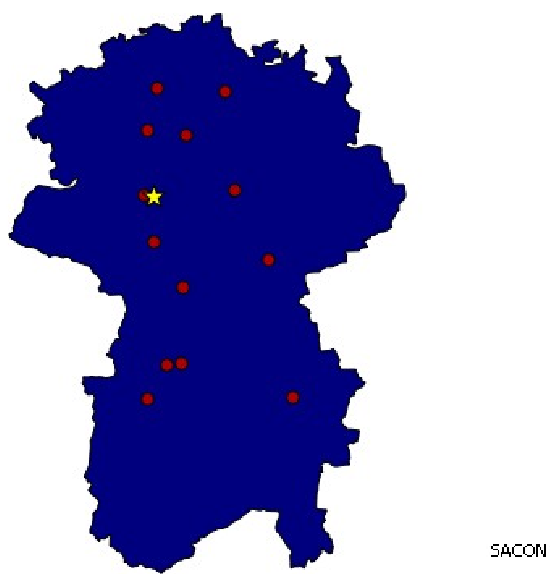

Figure-1: The locations of Automatic Weather Station in Coimbatore district (red dots), Coimbatore city is marked as yellow star

Air quality data generation

The air quality data will be collected using Air quality egg sensor board. The sensed information principally about the particulate matter pollution will be collated into '*Pachube'* Internet of things database server. The figure -2 depicts the working mode of data generation using 'air quality egg'. The two mode of distributed deployment of air quality egg sensing system will be followed, first one will be based on volunteered or sponsored deployment in which each volunteer organization or individual, shops or industry will be provided with air quality egg sensing system. The recipients have to take care of the responsibility for its safe mounting supported by uninterrupted power supply and Internet connectivity. As a reward, the recipient will be acknowledged for the deployment of the system and its operation. The second mode deployment will be remote deployment, as an experimental setup for remote area air quality sensing, the air quality egg sensing system will be deployed with up-gradation of solar power supply and GPRS based modem for data transfer; about 25 % of air quality sensing system will be deployed based on this mode. Using the Cosm.com Application Programming Interface (API) the real time database of air quality of the study area will be created in 'postGIS'.

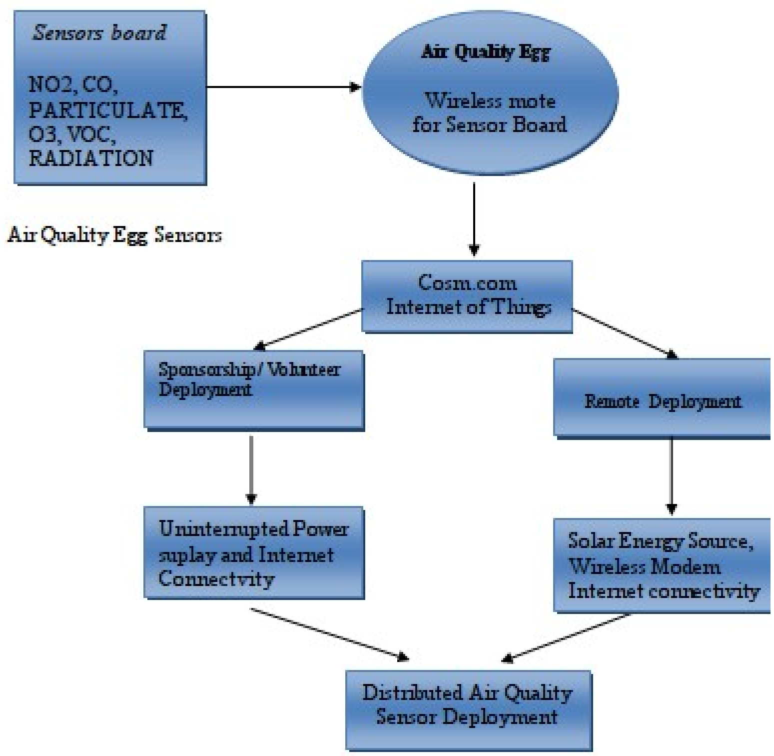

Figure 2: The work plan of air quality egg sensing system deployment

Web Data Extraction: The server side script programming provided by screen scrapper software automatically extract and append the data from different pages of the website http://tawn.tnau.ac.in/ corresponding to locality of each monitoring stations. The API of weather underground www.wunderground.com will be used to collate the hourly weather report taken in air port area of Coimbatore. The extracted data will be stored in 'PostGIS' geospatial database to feed the Sensor observation service database. The PHP based script will be running on apache web-server and will help in automatic data extraction from the website.

Sensor Observation Service (SOS): The installable '52 North' sensor observation service will be used in the present case. It requires Java Run Time Environment or Development Kit, Apache Jakarta Tomcat or PostgreSQL with PostGIS extension. The SOS database schema will be created using SQL file provided in installation directory using phpadmin of PostgreSQL. The table elements for describing the SOS such as feature of interest geometry, observation phenomenon etc will be further added. The SOS configuration and capabilities skeleton will be edited for database credentials, service identification and provisions such as time ranges, list of procedure and phenomenon. SensorML instance XML document for each sensor will be created referring the air quality egg sensor specifications. The sensor ML will be based on OGC's SensorML specification version 1.0.1. SOS Feeder framework will be used to connect with real time ambient air quality database and SOS sensor database.

Objective B

Real time air pollution modeling: The figure 3 depicts the schema involved in real time air pollution modeling using the Comprehensive Air Quality Modeling with extension (CAMx). Broadly it involves emission inventory, meteorology and photochemical model.

Emissions Inventory: It includes temporally and spatially resolved emissions from point sources (large, medium and small scale industry), mobile sources, biogenic emissions and area sources. Point source emissions from large and medium industry will be calculated from stack emission data using US EPA AP-42. On-road mobile source emissions will be estimated using EPA's MOBILE6 models. Area sources and Biogenic sources will be considered cumulatively and calculated using Biogenic Emissions Inventory System (BEIS) Modeling (BEIS 3.12) provided by US EPA.

Meteorology: The Pennsylvania State University / National Center for Atmospheric Research mesoscale meteorological model, MM5, will be used to generate gridded prognostic meteorological fields. MM5 is initially run for a larger domain with a grid resolution of 15 km, and then nested to 3 km and then to 1 km over the Coimbatore urban area.

Photochemical model: The modeling domain for the present case study (Coimbatore city area) will be of 32 km by 25 km horizontally and 4 km vertically. It will be e effectively a three dimensional array of 1 km by 1 km grid cells in the horizontal with varying vertical cell depth. CAMx calculates pollutant concentrations at the centre of each cell, as well as the meteorological state variables supplied to the model where they represent grid cell average conditions. Mean hourly concentrations of particulate matter will be used to run the model as initial condition and time invariant boundary condition will be used as boundary conditions.

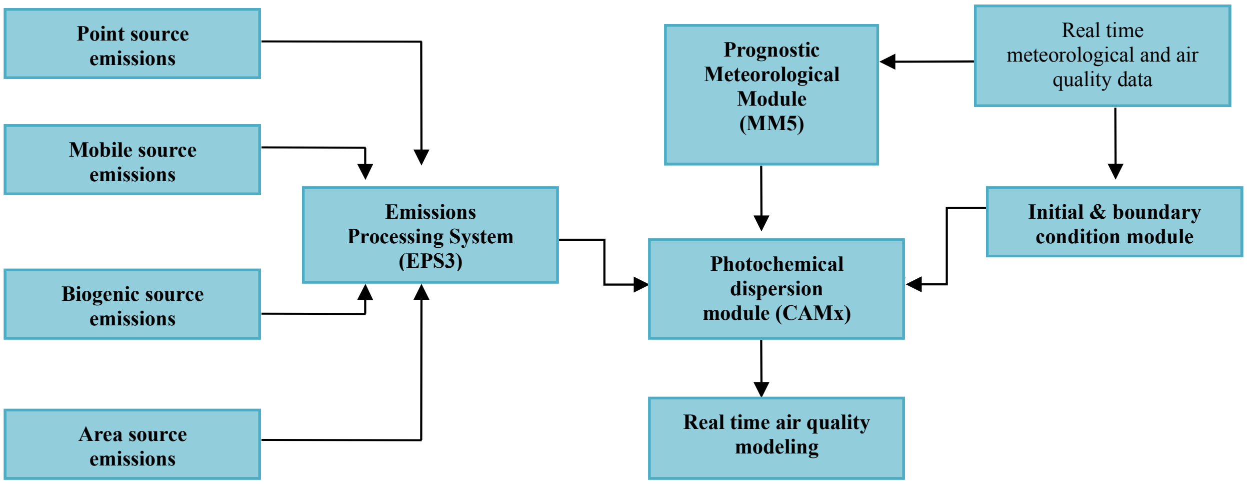

Figure 3. Schematic real time air quality modeling system

Visualization: The CAMx provides its end result in network common data format (netCDF), a machine-independent and multi-language accessible format for scientific data. Visualization Environment for Rich Data Interpretation (VERDI) will be used to visualize the CAMx modeling product in the netCDF format. The installable GUI based VERDI, overlaid with various shape file format map layers of Coimbatore area, will be used to visualize. Java script will be used to store the visualized product in postGIS database and would be accessible via the Web Processing Service.

Web Processing Services (WPS): The installable 52 North Web Processing Service compliant with OGC's WPS 2.0 will be used in the present study. It will be used as a standardized way to query the services from the CAMx and thus expands its capabilities and utility of the model. As similar to SOS it requires the Apachje Tomcat Server with run time capabilities. The linkage capabilities for ArcGIS server will be used to link with open source and freely available PostGIS server and thus to link with RESTful API.

Validation and model comparisons study:

Two tier of validation will be carried out; first tier for validation of air quality egg sensors and second tier will be for CAMx air pollution modeling. The ambient air quality monitors based on high volume air samplers will be used for validation of the air quality sensors. The continuous monitoring data of air quality using high volume air samplers will be used for air quality egg sensing system validation and calibration if requires. This data along with Tamil Nadu Pollution Control Board air quality data of Coimbatore city will be used for CAMx model validation.

Model comparison study for widely applied air quality models such as for CMAQ and CHIMERE will be carried out using the same data sets of emission, meteorology and photochemical data sets used in CMAx. The high volume air samplers will be used for validation of the different models as receptor data and average agreement value for the each model will be computed to get the prediction accuracy percentage of the each model to compare between the model and select the best suitable model for the study area.

Objective C

The web application will be developed in accordance with OGC compliant ESRI's GeoService REST Specifications. Installable Java servlet based '52 North' Web Notification Service will be used for the notification service for WPS. It will execute and manage message notification dialogues between client and web processing services.

GeoSMS based "Air quality here!" android application:
Open source GeoSMS based android mobile application "I am here" developed by Matthew Kwan will be used to develop application "air quality here". This application will act as the mobile front for disseminating the air quality modeling results to the end user. Normally the GeoSMS format will be for example "***I'm here at Gandhipuram:11.01652,76.9692;u=5"***in which "I am here at Gandhipuram" is the message, first decimal point is latitude and second longitude, and u is for uncertainty, which here is 5 meter from the location. By "I am here" application the above message will be automatically generated using mobile inbuilt GPS or Internet connectivity and it is made into either email or SMS form to be send.

The intended "Air quality here" application will be developed using the "I am here' application and instead of the normal specification of "I am here" it will be query based. It would be as follows;

"What is the air quality here?:11.01652,76.9692;u=5".

The application will automatically query the REST based modeling web application server, by means of email or SMS as per the wish of the user. The result will be riposted to the user through REST query specification, taking the latitude and longitude in the message omitting the uncertainty value will serve as a the location / point of inquiry.

232. Work Element:

1. Infrastructure creation: Creation of the basic infrastructure of the project, Air quality egg sensing system, its deployment, procuring Server work station and open source server based operating system Ubuntu Server has to be installed along with other necessary server software.

2. Recruitment of Research Fellow

3. Real time air quality Database creation: Is achieved using data aggregation software and Pachube API on air quality egg sensing system real time feed.

4. Sensor Observation Service Implementation: It involves tutorial based training and testing of the service

5. Web Processing Service Implementation: It also involves tutorial based training and testing of the service

6. CAMx modeling: It involves tutorial based training and validation of the model result. This work element comprised of 4 sub components i) Emission inventory, ii) Meteorological modeling, iii) Photochemical modeling and iv) Model validation and multi model comparison.

7. Implementation of Mobile web application and REST queries in geo-coded bus waiting stations and case study demonstration

8. Conducting the workshops, symposia and mobile based query gaming events

233. Time schedule of activities giving milestones (also append to bar diagram and mark it as Section 410)

S.No	Activities	Duration (Months)
1	Administrative tasks (Work element 1 & 2)	1
2	Database creation (Work element 3)	1
3	Sensor Observation Service (Work element 4)	1
4	Web Processing Service (Work element 5)	1
5	Emission inventory (Work element 6.1)	1.5
6	Meteorological modeling (Work element 6.2)	1.5
7	Photochemical modeling (Work element 6.3)	1.5
8	Model validation and multi-model comparison(Work element 6.4)	1.5
9	Mobile web application and REST query	1
10	Utilization of research results	1
11	Total Duration (Months)	12

234. Suggested plan of action for utilization of research outcome expected from the project.

The deliverables from the program are:

1. Sensor Observation service for air quality egg sensing system and weather monitoring public website
2. Air quality modeling based web processing service.
3. Web application based animation of hourly particulate air pollution level.
4. Mobile GeoSMS based web query of particulate air pollution and automatic Notification services with android applications.

The outcomes of this research program would be

a) Technical report, documenting the work
b) Workshop: On development methodology for system will be conducted for academic personals and stakeholders. Various methodological procedures of sensor web enablement as well as air pollution modeling will be discussed as learning modules in the workshop.
c) Mobile based gaming query events: For developing awareness on environment / air pollution popularization of RESTful query, popular mobile gaming events will be conducted in collaboration with other interested organizations.

Budget and Project Administration

300. Budget estimates: summary

	Item	Budget (In Rupees)
A.	Rescurring	
	1.Salaries/wages	2,30,400
	2. Consumables	60,000
	3. Travel	50,000
	4. Other costs	4,30,120
B.	Equipment	4,30,204
	Grand total (A+B) Total FEC*	12,00,724

*FEC- Foreign Exchange Component: Foreign Exchange component (in US$) equivalent of rupee amount at the prevailing rates may be furnished.
N.B. Entries here should match with those given in section 310 to 350; justification for each item is to be given in Section following it that is section 311, 321, 331, 341 and 351.

310. Budget for salaries/wages

Budget (In Rupees)

Designation & number of persons	Monthly Emoluments	Total (m.m.)
Senior Research Fellow, 1	16000+20%HRA	12
Total	19200	230400

*m.m: man months to be given within brackets before the budget amount

311. Justification for the manpower requirement.

Only one Senior Research fellow is proposed for the study, which is the minimum requirement.

320. Budget for consumable materials

S.No	Item	Budget (in Rupees)
1	Office stationary	37,176
2	SMS tariffs	5000
3	Expert consultation on Ubuntu Server (US$ 320)***	17,824
	Total	60,000

*Q: Quantity or number, ** Budget, ***F: Foreign Exchange Component in US$, Taken 1 US$ = 55.7 Indian Rupees-

321. Justification for consumable (if not provided for in Section 231 i.e. Methodology)

The expenditure mentioned above is towards essential consumable items and stationeries required for the project of 12 month duration. The consumables include the GSM SIM cards and tariffs for SMS for mobile based model result dissemination. This head also includes charges towards expert consultation on open source Ubuntu server maintenance for the operating system of the project server that would cost about US$ 320/-.

330. Budget for travel

Items	Budget (in Rupees)
Travel (Only inland travel)	50,000
Total	50,000

331. Justification for intensive travel, if any.

The project involves travel of the researchers essential for deployment and maintenance of air quality sensing devices in various parts of the study area, and also to other places in the country to collect research materials or technical guidance. The budget head includes the petrol cost for two /four wheeler vehicle going to be used in this connection and train / bus fare.

340. Budget for other costs/contingencies

S.No	Other costs/Contingency costs	Budget (in Rupees)
1	Institutional charges	2,00,120
2	Expenditure for remote deployment and model validation	80,000
3	Expenditure for Server Room	1,50,000
	Total	4,30,120

341. Justification for specific costs under other costs, if any.

The other cost mentioned above involves

1. The institutional charges, it is 20% of the total project budget (i.e 20% of total project budget Rs 10,00,604/-).
2. Expenditure for remote deployment of air quality sensing devices and the validation of model and multi model comparison. It involves Rs 50,000/- for solar power source for 5 air quality sensing devices (5 x Rs 5,000=25,000) and 5 pieces of wireless modem for Internet connectivity (5 x Rs 5,000=25,000). This also involves the internet connectivity tariff. The remaining Rs 30,000/- is for model validation using high volume air sampler. Air quality in at least 6 points is required for data and model validation. The HVAS available with the study group will be used for this purpose. This would involve air sampling for 5 days at each of the six identified locations. Taking the coats for each sampling day @ Rs 1000/- for each sampling day this would come to Rs 30,000/- (i.e 5 x 6 =30). This Rs 1000/- is towards the cost of Micro glass fiber filter paper for 24 hours air sampling, the charges for transport of the HVAS and electricity charges for the sampler.
3. Expenditure towards setting up and maintenance of the server room. For the server room, Rs 150000/- is required for PVC room partitioning, uninterrupted power supply, furniture and air

conditioning.

350. Budget for equipment

Sl. No.	Generic name of the Equipment along with make & model	Imported/Indigenous	Estimated Costs in Rupees(in Foreign Currency also)*
1	IBM Server X series	Indigenous	80,000
2	Dell Desktop	Indigenous	50,000
3	Dell Laptop	Indigenous	50,000
4	Amazon Elastic Compute cloud	Imported	1,10,954 (US$ 1992/-)
5	Air quality Egg Sensing Devices	Imported	1,39,250 (US$ 2,500/-)
	Total		4,30,204

* includes transport, insurance and installation charges.

351. Justification for the proposed equipment.

1. The project requires intensive computation and SMS based query and dissemination of the end products. This requires one server computer, one desktop and a laptop computer. The requirement is bare minimum. The computers will be acts as a data repository and SMS gateway. The server computer will acts as a server for the modeling web application and computation clouds.
2. For increased computational capabilities the cloud computation service of Amazon web services will be used. The budget estimate is for six months of Linux based 'Heavy utilization instances', which includes standard reserved instances (US$ 780/- for Upfront and US$ 0.1/- hourly usage which is equal to US$ 1656/- for 4368 hours = 6 months) and High CPU reserved instances (US$ 500/- for Upfront and US$ 0.063/- hourly usage which is equal to US$ 1051/- for 4368 hours= 6 months).
    1. It is essential while considering the high memory and CPU requirements for CAMx modeling and its three components such as emission inventory, photochemical model, and meteorological model.
    2. It is observed that the project, involving air pollution modeling and simulation, carried out in New Delhi region uses around 22 Central Processing Unit for the daily real time simulation of air quality in New Delhi region. Reference Link
    3. Similar kind of computation requirement is suggested by CMAQ based air quality modeling
    4. While considering the remote locality of the server in SACON campus, some 25 km from main city the computation cloud with uninterrupted band width and computational resource will be very much useful for maintaining the web application.
3. The air quality egg sensing system will be used as the primary source of data in the project. The sensing system is currently under manufacture and marketing discussions. It is estimated that the cost will be around 2,500 US$ for medium scale deployment with 30 units of air quality sensing systems. The amount includes both the import charges and consultation of experts for assembling the sensing system locally.