UNIDATA COMMUNITY EQUIPMENT AWARD PROPOSAL

Submitted to

Unidata Program Center,
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FL4-1240, 3090 Center Green Drive
Boulder, CO 80301

TITLE: **Pacific THREDDS Data Server**

EFFECTIVE DATES: 6/1/2017-5/31/2018
REQUESTED AMOUNT: $12,700

[redacted]

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1. Project Summary

This proposal seeks resources to expand the University of Hawaii at Manoa (UHM) VisionLab to bring state-of-the-art THREDDS Data Server (TDS) technology to the Department of Atmospheric Sciences in the School of Ocean and Earth, Science and Technology (SOEST) of which it is part. VisionLab utilizes operational data streams from Unidata and NOAA NWS, and custom data from UHM research programs to bring real-time and archived weather observations and products to UHM students and staff. In addition VisionLab weather servers provide access to a broad range of operational and custom products via the Internet. Staff responsible for construction and maintenance of VisionLab will interact with Unidata's support environment to develop new software capabilities and data resources for the central North Pacific Region. The goals of this proposal are to acquire necessary hardware resources to

(i) Enhance the Internet Data Delivery (IDD) system at UHM and the NOAAport data exchange with the Honolulu National Weather Service Forecast Office, which is collocated in our building on the UHM campus. The added capacity will allow UHM Atmospheric Sciences to become a relay node in the IDD for additional users in the Pacific region.

(ii) Construct a THREDDS Data Server (TDS) to significantly expand and enhance archive and historical data serving capacity that facilitates automated remote access to custom and operational Pacific data sets for research and education, and

(iii) Keep pace with the demand on computational resources of an increasing data stream, resulting from GOES-R and hyperspectral polar orbiting satellite instruments (e.g., CrIS on the Suomi VIIRS satellite).

2. Project Description

VisionLab is housed in the Meteorology Department and takes advantage of the Unidata program's data stream and other data resources from NOAA and NASA via the Internet and NOAAport to bring real-time weather data to UH. VisionLab was developed and upgraded in four phases with support from NSF equipment grants (ATM-9419433 in 1995, ATM-9815959 in 1998, and ATM-0562842 in 2005), and in 2012 SOEST invested in 16 Dell OptiPlex 790 Workstations with monitors. During the course of the VisionLab project, ongoing interaction has taken place with Unidata's support environment to develop new software capabilities directed at the tropical Pacific Region. Mr. Michael Gonsalves is the full-time IT specialist in our department and oversees VisionLab, with the help of three of Dr. Businger's staff, Dr. Tiziana Cherubini, Dr. Lacey Holland, and Mr. Ryan Lyman. The VisionLab project represents a core resource for the Atmospheric Sciences Program at UH. It is utilized to varying degrees in most academic courses offered. The greatest academic impact of VisionLab has been upper-division synoptic lab classes and introductory level classes. In introductory courses access to real time data and imagery and high resolution digital video projection systems has formed a engaging combination to bring the visual power of science to the lecture hall. In the upper division courses visualization tools such as AWIPS and IDV provide the ability to manipulate real time data sets, as part of a sophisticated hands-on learning environment.

The current equipment request will facilitate both real-time data delivery and access, while greatly expanding our ability to store and serve large geosciences data sets. Given Hawaii's remote location and historical problems with data delivery across the Internet,

requested hardware resources will allow UHM to more fully contribute to and participate in Unidata activities. Pacific TDS will increase community access to a broad range of operational and custom data products available at UHM Atmospheric Sciences.

SOEST is a world-class (top 15) environmental science and technology institution focused on informing solutions to some of the most important global issues through an integrated, comprehensive, and sustained system of Earth and planetary observations, research, education, service, and extension. In Atmospheric Sciences, we focus on the physics of tropical storms, monsoons, and decadal processes such as El Niño, particularly in the Aust-Asia/Pacific area, and their impact on winds, rainfall, droughts, and floods. We develop and maintain a wide range of climate, weather, and atmospheric forecast models to advance understanding of climate variability; assist the National Weather Service with providing accurate extended range weather forecasts; and assist emergency managers with assessing brush/forest fire risk, health impacts of volcanic gas, and the hazard potential (winds & floods) from monsoons and storms. In climate research, we manage large spatial data sets and run robust numerical models that capture the interplay between the world's oceans, atmosphere, polar-regions, ecosystems, and landmasses. The distinguished history within Atmospheric Sciences in measuring and modeling climate variability has led to greater understanding of trade wind and rainfall trends, and the occurrence of extreme events such as monsoons, tropical cyclones, storms, droughts and floods.

The overarching goal of this proposal is to develop a dynamic TDS to serve SOEST researchers and students and the community at large, by making climate and weather data streams available with the most advanced diagnostic and visualization tools available.

We will continue to develop and make available tools to analyze large data sets in a modern efficient framework. In particular, EarthCube building blocks can be used to perform a combination of geographic subsetting, regridding and statistical calculations—performed as pre-retrieval operations—to support a dynamic downsizing endeavor or other scientific projects that will be detailed below. A well-designed set of operations that may be invoked in close proximity to our data sources will lower transfer volumes sufficiently to enable a range of new studies in a world where increasingly remote data usage meets rapidly growing data volumes.

Besides large climate and weather model output archives, here are examples of some of the unique data sets that are currently stored on disks off line in Hawaii, i) a decade of gridded and empirically validated wind and solar insolation data for Oahu important for electric grid balancing models, ii) seven years of volcanic emission dispersion model output, iii) several decades of high resolution output over Hawaii from WRF model studies to downscale climate models solutions, iv) nearly a decade of global long-range lightning data.

Following hardware and software installation, we will stage a local workshop at UHM to publicize the new TDS and data capabilities that will be available and to train researchers and students on use of both. Dr. Businger will host an invited Unidata staff at his house to reduce travel costs to the cost of an airline ticket only.

2.1 Details of the Equipment Request

To achieve the goals outlined in the previous section and to remain a vibrant contributor to the Unidata community, we propose to upgrade our existing facilities with the

following hardware. The requested equipment will be integrated with our existing equipment and will serve many purposes that benefit UHM and the broader community.

(1) Silicon Mechanics Storform R518.v6 "ZOL Storage (R518)" CPU: 2 x Intel Xeon E5-2623v4, 2.6GHz (4-Core, HT, 10MB Cache, 85W) 14nm RAM: 128GB (8 x 16GB DDR4-2400 ECC Registered 2R 1.2V DIMMs) Operating at 2400 MT/s Max.
(2) Silicon Mechanics StorX ZFS Capacity Device - vdev "FileStore" ZFS Virtual Device (VDEV) - Selection: 32.0TB usable [RAID Z3, 11 x 4TB, 73% Utilization] ZFS Virtual Device (VDEV) - Device: 11 x Seagate.

SOEST's computer network provides high-speed connections and data transfer capabilities. It connects to the UHM Manoa campus FDDI campus backbone network, and through that to PACOM wide-area network services, which link Hawaii directly with the Far East and the US mainland. Network switches in the Hawaii Institute for Geophysics Building (HIG) that houses VisionLab have recently been upgraded to one GB capacity. The proposed hardware will allow us to take advantage of the enhanced SOEST network bandwidth.

VisionLab comprises ~1200 square feet of space, which contains five Ethernet outlets and 27 electrical outlets. Sufficient space is available in VisionLab for the proposed computing resources. Once the hardware arrives, SOEST research computing facility (RCF) staff and Mike Gonsalves will work with the PI to integrate and maintain the Pacific TDS and VisionLab. Appropriate software for the project is currently available for transfer through a limited area network to the workstations. Existing full-time technical personnel that are currently employed in SOEST will maintain hardware purchased for VisionLab. Ongoing network support for data delivery from Unidata via Internet will be provided through departmental resources.

2.2 Benefits to Research, Education, and Unidata Community at Large

A primary research objective of VisionLab and this TDS proposal is to mitigate the impact of natural hazards on society and industry through improvements in our ability to observe and predict the evolution of these events over the central and eastern North Pacific Ocean. Hardware requested in this proposal will allow a number of data streams and products not routinely available through Unidata to be accessed and archived for research and educational purposes. A sample of these multidisciplinary data sets for the central and eastern Pacific region is listed in Table 1, and select visual examples are shown in Figs. 1 and 2. Publications in the reference section represent a partial list of research that directly benefited from VisionLab. The research objectives outlined in this section will greatly benefit from enhanced access to real-time and archived gridded data made possible by this proposal.

In the data-sparse central Pacific, remote-sensed data sets are of critical importance for numerical weather prediction (NWP) and development of operational tools to assist forecasters (Businger et al. 2001). Improvements in the prediction of local weather and volcanic emission modeling have been achieved through a combination of i) synthesis of custom and operational data sets (see Table 1), ii) operational application of mesoscale primitive equation models for NWP with data assimilation, iii) case studies of outstanding events that result in the formulation and/or refinement of conceptual models (e.g., Businger *et al,* 1998; Morrison and Businger 2001), and iv) development and testing of forecast tools with special attention to remote-sensed sources (e.g., Mazany et al. 2002, Antonelli et al.

2017). The data storage and staging capabilities that an enhanced VisionLab will bring to the Atmospheric Sciences Department and SOEST will significantly facilitate our continued research progress, and will provide an expanded resource for the Honolulu Forecast Office of the NWS and the Joint Typhoon Warning Center (located in Honolulu).

Table 1 Data Streams for the Central and Eastern North Pacific. Note the cross-disciplinary nature of a number of the data streams. This is not a comprehensive list.

Project Name	Data Stream	Project URL
1. Vog (volcanic smog) Dispersion Model Output		http://weather.hawaii.edu/
2. Skynet	GPS precipitable water	http://imina.soest.hawaii.edu/pgf/public/SkyNet/
3. Central Pacific Products from Polar Meteorological Satellites from Direct Broadcast Station located at Hawaii Community College and operated by UHM and UW.		http://mkwc.ifa.hawaii.edu/satellite/polar/
4. UHM LAPS	Objective Analyses	http://weather.hawaii.edu/
5. UHM WRF	Custom NWP Output	http://weather.hawaii.edu/
6. GOES Satellite	GOES/GMS for Pacific	http://weather.hawaii.edu/
7. UHM Earth Observing Station (downlink site for NASA satellite data over the Pacific)	NASA & NOAA data	http://www.eos.hawaii.edu/
8. UHM Infrasound Lab	Infrasound data	http://www.isla.hawaii.edu/
9. UHM Sea-level Center	Sea-level data	http://ilikai.soest.hawaii.edu/uhslc/data.html
10. UHM SWAN	Wave model output	http://www.soest.hawaii.edu/~buoy/model.html#oahu_uh
11. Hawaii Center for Volcanism	Volcanic emissions	http://www.soest.hawaii.edu/GG/hcv.html
12. PacNet	Long-range lightning data	http://www.soest.hawaii.edu/met/Faculty/businger/projects/pacnet/lightning/lightning.pl

VisionLab has facilitated a number of cross-disciplinary research efforts. A prime example is the Mauna Kea Weather Center (MKWC), which provides custom forecast support for the astronomical observatories at Mauna Kea (Businger et al., 2001). The MKWC staff undertakes research in data assimilation and modeling of turbulence and seeing above the summit of Mauna Kea. In particular, assimilation of CIMMS atmospheric motion vectors and long-range lightning data has enhanced regional objective analyses and improved mesoscale model predictive skill (Cherubini, et al. 2004). The Infrasound Lab monitors the source regions of infrasound signals in the atmosphere. Research shows that these low-frequency sound waves are generated through interference of storm generated ocean swell trains, which may provide a novel means to remotely track tropical cyclones (Willis et al. 2004). An effort to model the dispersion of volcanic smog (vog) emanating from the Kilauea volcano complex (Businger et al. 2016) has led to the development of an operational vog dispersion forecast system. The ensemble dispersion model helps mitigate the adverse impacts of vog on general aviation and health. GPS data from Skynet monitor Mauna Loa's flanks for swelling (Brooks et al. 2004), providing lead-time for predictions of an eruption of the summit caldera, and increasing the value of the vog forecast capability.

Requests to UHM Meteorology weather server pages (http://weather.hawaii.edu and http://mkwc.ifa.hawaii.edu) are exceeding 35,000 hits per day. During the hurricane season (Jun-Nov) requests sometimes reach 80,000 per day, especially when there are tropical cyclones in the Atlantic, Eastern Pacific or Central Pacific regions. Tropical storm-centered GOES10 satellite images and combined GMS/GOES10 images overlaid with plots synoptic observations or model output are especially popular web addresses in our tropical weather section. Roughly 20% of the requests are from sites that make 75 or more requests per week.

Results from our research initiatives are currently utilized in VisionLab to train meteorology students. The proposed resources will also allow utilization of greater bandwidth made available in our building through the installation of faster (1 GB) switches in anticipation of the availability of GOES-R data.

It is important for today's undergraduate and graduate students to be educated in the use of modern analysis and displays systems. Equipment purchased with previous cost-matching grants has been successfully incorporated into VisionLab and the Meteorology curriculum and laboratories during the past decade. The analysis and display of real-time data distributed by the IDD is now a daily activity in UHM Synoptic Meteorology and Weather Analysis and Forecasting courses using IDV and AWIPS software. Significant use of Unidata products also occurs in the general-education (100-200 level) courses and the dynamics courses. As the suite of IDD and custom products expands and our generation of graphical products becomes more automated and interactive, we envision increased usage of Unidata products in additional SOEST courses.

Applications are being developed with the aid of a large body of existing public domain software (e.g., Python), including educational applications developed by Dr. Businger's group, that have been adapted to VisionLab. The development of four-dimensional visualization software at Unidata (IDV and AWIPS) has opened special educational possibilities given the robust nature of the data stream available to VisionLab (Table 1). During the next five years in our VisionLab program, we will incorporate continuous improvements in the meteorology curriculum and augment our transition to a multidisciplinary web-based learning environment. These capabilities open new possibilities in teaching the fundamentals of science, while enhancing the ability for users to explore previously intractable combinations of data display and manipulation.

There is a continuing need for the development of training and education curricula for the modernized NWS, for both current and future employees. This need is particularly acute for the Pacific Region since it encompasses such a vast geographic area and includes tropical mesoscale weather regimes that have had significantly less scientific attention than their midlatitude counter parts in the past. Forecast problems specific to the Pacific Region, some of which are touched on in this proposal, will be the focus of a NWS-UHM Collaborative Workshop in Tropical Meteorology to be held on the UHM campus in 2018. Results of climatological and case study investigations, and numerical model simulations developed on VisionLab will be incorporated in the Workshop curriculum. Data and imagery from Himawari and GOES-R (as available) will play an important role in the case studies. Data from numerous research projects (Table 1) will also be utilized on VisionLab to provide participants with computer driven case studies and exercises. The faculty at UHM and the staff at the WSFO HNL are working together to develop the curriculum for a Tropical Weather Workshop that is tentatively scheduled for the winter of 2018. The Workshop

organizers will work with COMET to explore the possibility of transitioning appropriate tropical case studies to COMET for distribution to the broader community.

The UHM Atmospheric Sciences Department has been an active participant in the Unidata program. The PI's long-standing experience and interaction with the Unidata program played a role in his selection to serve as chairman of the review panel for Unidata's NSF proposal for a 5-year renewal in 1998 and as Chair of the Strategic Planning Committee (formerly known as the Policy Committee) from 2007-2014. During the course of the VisionLab project ongoing interaction has taken place with Unidata's support environment to develop new software capabilities directed at the tropical Pacific region. We aspire to contribute more to the Unidata community in future. We are particularly interested in improving our online archival facility, supporting and promoting other sites in the Pacific, and participating in testing of future data diagnostic, transfer, and archiving technologies (e.g., EarthCube building blocks).

2.3 Relationship of Requested to Current Computer Resources

The proposed TDS addition to VisionLab fulfills the projected hardware needs in the area of data access, synoptic instruction, and geosciences data display for the next 5 years. The UHM SOEST and the Meteorology Department are committed to strengthening such mutually beneficial activities. Our commitment to maintaining a state-of-the-art research and instructional facility is readily documented. Excluding salaries for support staff, the UHM and SOEST have collectively contributed more than $100K in real dollars over the past ten years through grant-matching funds, software, maintenance, and hardware upgrades. Given the growth in the data streams available through research, Unidata and the NWSFO, the hardware requested in this proposal will allow the UH/SOEST to contribute to and participate fully in Unidata's future efforts.

a) Current VisionLab Computing Resource

In addition to the 16 VisionLab workstations, the Atmospheric Sciences Department "computing commons" consists of two home directory servers, 2 PC workstations, and two printers with specifications given in Table 2. Individual faculty now tend to buy into the UHM Information Technology Services condominium super computer on campus, which has ~3000 nodes. In addition, faculty utilize computer resources off campus, including supercomputer facilities at the Subaru center in Hilo, the Maui High-Performance Computing Center, NCAR (Yellowstone), and the Earth Simulator in Japan.

Table 2 The Atmospheric Sciences Department "computing commons" consists of two home directory servers, 18 PC workstations, and two printers with specifications as follows:

Host Name	Description	Role	CPUs	Memory	Storage	Qty
uila	Dell PowerEdge 2950 acquired October 2008	Home directory server.	Quad Core Xeon 3.1GHz	16GB	5TB	1
kahi	Advanced HPC Mercury RM206 acquired December 2011	Home directory server.	Quad Core Opteron, 1.15GHz	8GB	19TB	1
vision01 to vision15,	Dell OptiPlex 790 acquired in May 2012	Computer lab workstation.	Quad Core i7	8GB	250GB	16
m1	Lenovo ThinkStation S20	Open computing workstation, dual-boot Windows and linux	Quad Core Xeon 2.66GHz	10GB	380GB	1
timothy	Dell OptiPlex 980	Open computing workstation, Windows 10	Quad Core i7, 2.8GHz	12GB	921GB	1
metphaser 4600	Xerox Phaser 4600 B&W printer	Departmental printer	n/a	n/a	n/a	1
metphaser 6700	Xerox Phaser 6700 color printer	Departmental printer	n/a	n/a	n/a	1

3. Description of the Budget for Pacific TDS 2017

Please refer to Section 2.1 for a detailed justification of the hardware listed in this section.

Silicon Mechanics Storform R518.v6 "ZOL Storage (R518)"
CPU: 2 x Intel Xeon E5-2623v4, 2.6GHz (4-Core, HT, 10MB Cache, 85W) 14nm RAM: 128GB (8 x 16GB DDR4-2400 ECC Registered 2R 1.2V DIMMs) Operating at 2400 MT/s Max. $8,950.

Silicon Mechanics StorX ZFS Capacity Device - vdev "FileStore"
ZFS Virtual Device (VDEV) - Selection: 32.0TB usable [RAID Z3, 11 x 4TB, 73% Utilization]. ZFS Virtual Device (VDEV) - Device: 11 x Seagate 4TB Enterprise Capacity 3.5 HDD V.5(12Gb/s, 7.2K RPM, 128MB Cache, 4Kn) 3.5" SAS. $3,750.

The quoted prices include shipping to Honolulu, Hawaii.

Total Request to Unidata Community Equipment Program $12,700

4. Project Milestones

Since the physical space and networking for VisionLab and the personnel involved with maintaining VisionLab are already in place, we foresee no contingency to delay the timetable below.

Timetable for Pacific TDS 2017

Summer 2017 – Equipment will be purchased and installed so that the updated VisionLab facility will be fully functional for fall 2017 classes that start at the end of August.

Fall 2017 – Himawari, GOES-R, and polar orbiting satellite data and imagery will be added to the new LDM and archive facility and additional products will be made available online via Mauna Kea Weather Center weather servers. See: http://weather.hawaii.edu

Winter - Spring 2018 – Added archive capacity will be functional as a TDS on-line resource for imagery and data in NetCDF format.
Winter Workshop in Tropical Meteorology will be held at UHM to demonstrate and teach about the new TDS facility and the EarthCube building blocks that can be used to perform a combination of geographic subsetting, regridding and statistical calculations on large geosciences data sets.

Summer 2018 onward – A fully implemented Pacific TDS facility will provide enhanced research and educational opportunities for students, researchers, the Unidata community and the broader community.

5. References

The following is a partial list of publications that directly benefited from the development of VisionLab and the increased interaction between the WSFO-HNL and the UHM Department of Atmospheric Sciences.

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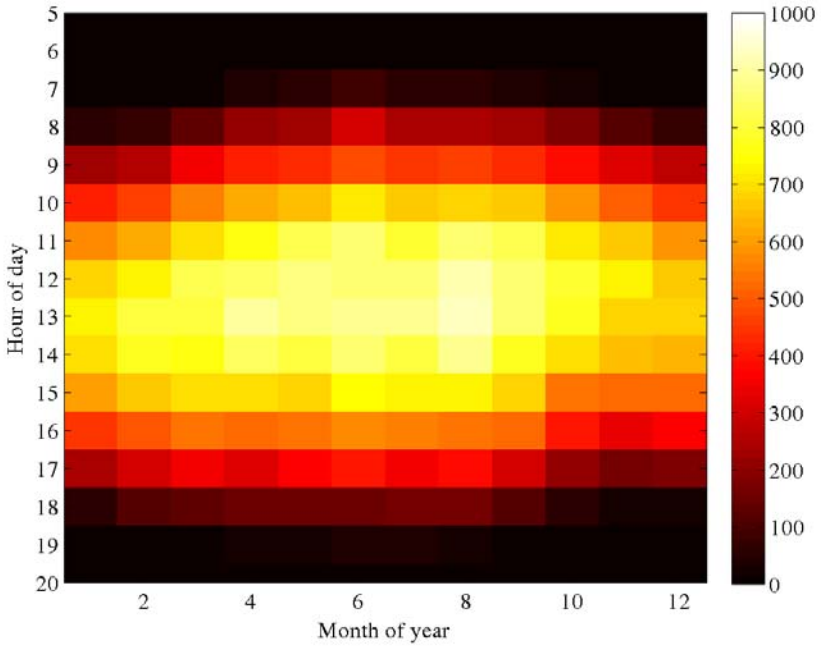


Fig. 1 Heat map showing solar radiation data (W/m^2) for the Ewa Plain on Oahu in 2014. The solar radiation data was modeled based on satellite cloud brightness and clear sky irradiance binned as a function of time of day and month of year. For each month, the data was binned by hour and the mean of each bin was calculated. These data exist every 15 minutes from 2006 to 2016 with a 1 km resolution over the Island of Oahu and are of significant value for solar resource estimation (from Williamson and Businger 2017).

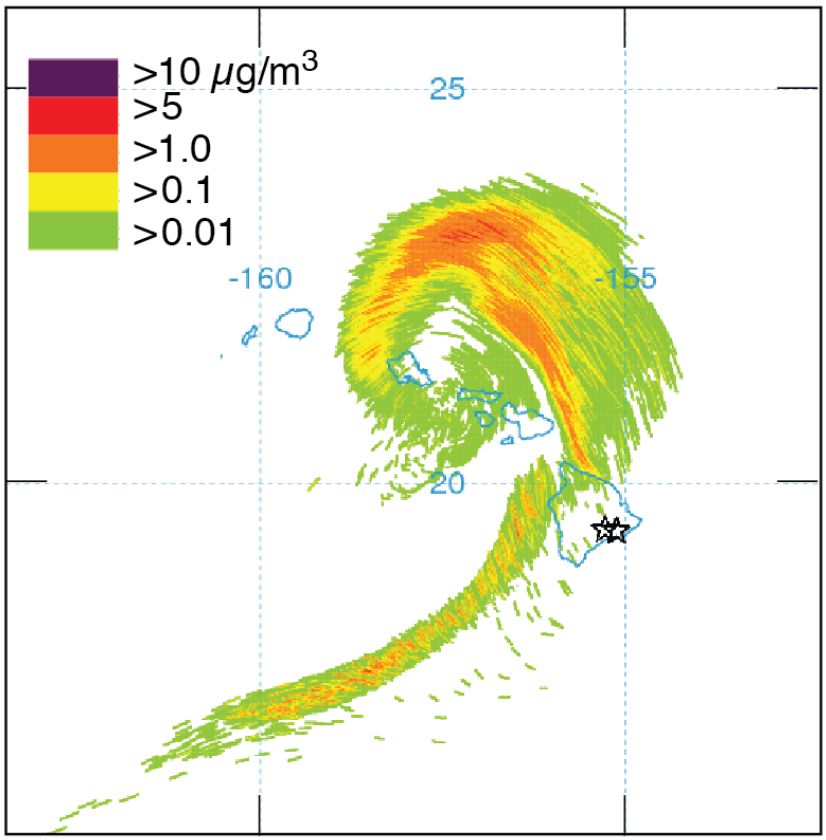


Fig. 2 Vog model layer-averaged (from 3,000 to 5,000 m) sulfate aerosol (SO_4) concentration. Forecasts valid at 06 UTC 30 July, at the time when tropical cyclone Flossie was passing just north of the Hawaiian Islands (from Pattantyus and Businger 2014).