NOAA Scientific Publications Report
December 21, 2015

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Complex interactions in Lake Michigan's rapidly changing ecosystem
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HIGHLIGHTED ARTICLES

Does El Niño intensity matter for California precipitation?
Geophysical Research Letters (4.196)
A. Hoell, M. Hoerling, J. Eischeid, K. Wolter, **R. Dole, J. Perlwitz,** T. Xu, and L. Cheng **(OAR/ESRL)**

- Above average California winter precipitation was observed during 16 events between 1896-2014, including two of the three wettest seasons, which occurred during strong El Niño events
- Below average California winter precipitation was observed during 11 El Niño events, including the second driest season on record, which occurred during a weak El Niño
- Emerging conditions of the 2015-16 El Niño show an increased probability for above-average precipitation statewide in California

The sensitivity of California precipitation to El Niño intensity is investigated by applying a multi-model ensemble of historical climate simulations to estimate how November-April precipitation probability distributions vary across three categorizations of El Niño intensity. Weak and moderate El Niño events fail to appreciably alter wet or dry risks across northern and central California, though odds for wet conditions increase across southern California during moderate El

Niño. Significant increases in wet probabilities occur during strong El Niño events across the entire state. In California's main northern watershed regions, simulations indicate an 85% chance of greater than normal precipitation, and a 50% probability of at least 125% of normal. Our results indicate both the statewide average and the spatial distribution of California precipitation are sensitive to El Niño intensity. Forecasts of El Niño intensity would thus contribute to improved situational awareness for California water planning and related water resource impacts.
Published online: 15 December 2015
Available online: http://onlinelibrary.wiley.com/doi/10.1002/2015GL067102/full

Warming ocean conditions relate to increased trophic requirements of threatened and endangered salmon
PLoS One (3.534)
E. A. Daly and **R. D. Brodeur (NMFS/NWFSC)**

- The authors examined the trophic habits, size and condition of yearling Chinook salmon (*Oncorhynchus tshawytscha*) over 19 survey years.
- Chinook salmon had a significant increase in foraging during warm ocean regimes - they consumed 30% more food and the total prey energy density consumed during warmer regimes was significantly higher than in cold.
- Despite increased foraging, Chinook salmon had lower condition and were smaller during the warm ocean regime. They were longer and heavier for their size during the cold ocean regime.
- Adult return rates of juvenile Chinook salmon entering the ocean during a warm ocean regime were lower.
- This long term data set contradicts the long held assertion that the observed low growth and survival in juvenile salmon in a warm ocean regime is because they eat less.

The trophic habits, size and condition of yearling Chinook salmon (*Oncorhynchus tshawytscha*) caught early in their marine residence were examined during 19 survey years (1981-1985; 1998-2011). Juvenile salmon consumed distinct highly piscivorous diets in cold and warm ocean regimes with major differences between ocean regimes driven by changes in consumption of juvenile rockfishes, followed

by several other fish prey, adult euphausiids and decapod larvae. Notable, Chinook salmon consumed 30% more food in the warm versus cold ocean regime in both May and June. Additionally, there were about 30% fewer empty stomachs in the warm ocean regime in May, and 10% fewer in warm June periods. The total prey energy density consumed during the warmer ocean regime was also significantly higher than in cold. Chinook salmon had lower condition factor and were smaller in fork length during the warm ocean regime, and were longer and heavier for their size during the cold ocean regime. The significant increase in foraging during the warm ocean regime occurred concurrently with lower available prey biomass. Adult return rates of juvenile Chinook salmon that entered the ocean during a warm ocean regime were lower. Notably, our long term data set contradicts the long held assertion that juvenile salmon eat less in a warm ocean regime when low growth and survival is observed, and when available prey are reduced. Comparing diet changes between decades under variable ocean conditions may assist us in understanding the effects of projected warming ocean regimes on juvenile Chinook salmon and their survival in the ocean environment. Bioenergetically, the salmon appear to require more food resources during warm ocean regimes.
Acceptance date: 19 November 2015
Publication date: Winter 2016

Corresponding morphological and molecular indicators of crude oil toxicity to the developing hearts of mahi mahi
Scientific Reports (5.578)
R. C. Edmunds, **A. Gill**, **D. H. Baldwin**, **T. L. Linbo**, **B. L. French**, T. L. Brown, A. Esbaugh, E. Mager, J. Stieglitz, R. Hoenig, D. Benetti, M. Grosell, **N. L. Scholz**, and **J. P. Incardona (NMFS/NWFSC)**

- The authors adapted diagnostic tools developed in part for heart disease screening in humans to refine understanding of the crude oil cardiotoxicity syndrome in a wild fish species potentially impacted by the 2010 Deepwater Horizon spill.
- The findings suggest that 1) morphometric analyses of cardiac function are more sensitive to the proximal and partially reversible effects of crude

oil-derived chemicals on the heart, and 2) molecular indicators reveal a longer-term adverse shift in the trajectory of heart formation and developmental modification.

Background. Crude oils from distinct geological sources worldwide are toxic to the developing hearts of fish. When oil spills occur in fish spawning habitats, natural resource injury assessments often rely on conventional morphometric analyses of heart form and function in embryos and larvae. The extent to which these visible indicators correspond to more subtle molecular markers for cardiovascular stress is not known. A mechanistic understanding of the crude oil cardiotoxicity syndrome at the molecular level could greatly improve the resolving power and throughput of future impact assessments. Here we exposed the embryos of mahi mahi (*Coryphaena hippurus*), a top pelagic predator from the Gulf of Mexico, to field-collected crude oil samples from the 2010 Deepwater Horizon disaster. We compared visible heart defects (edema, abnormal looping, reduced contractility) to changes in the expression of cardiac-specific genes that are diagnostic of heart failure in humans, or are associated with loss-of-function cardiac mutants in zebrafish.

Results. As anticipated, mahi mahi exposed to crude oil during embryogenesis displayed the typical symptoms of the cardiogenic syndrome as larvae. Contractility, looping, and circulatory defects were evident, but larval mahi mahi did not exhibit the craniofacial and body axis abnormalities that are downstream of severe heart failure in other wild fish species examined to date. A gradation of oil exposures yielded concentration-responsive changes in the expression patterns of several cardiac-specific genes. The relative sensitivity of the two categories of markers was influenced by age, with morphological and molecular indicators showing more responsiveness during early and later larval development, respectively.

Conclusion. We have adapted diagnostic tools developed, in part, for heart disease screening in humans to refine our understanding of the crude oil cardiotoxicity syndrome in a wild fish species potentially impacted by the 2010 Deepwater Horizon spill. Our findings suggest that 1) morphometric analyses of cardiac function are more sensitive to the proximal and partially reversible effects of crude

oil-derived chemicals on the heart, and 2) molecular indicators reveal a longer-term adverse shift in the trajectory of heart formation and developmental modification.
Published online: 10 December 2015
Available online: http://www.nature.com/articles/srep17326

ADDITIONAL ARTICLES

Cross-Line Office Publications

Aerosol effects on cloud cover as evidenced by ground-based and space-based observations at five rural sites in the United States
Geophysical Research Letters (4.456)
J. E. Ten Hoeve (NWS/HQ) and **J. Augustine (OAR/ESRL)**

- By using collocated space-based and ground-based observations, the authors are able to better control for satellite-based artifacts in the assessment of the 2nd indirect aerosol effect.
- Artifacts could overestimate the 2nd indirect aerosol effect by nearly 100%.
- Collocated surface radiation data shows that over daytime hours, the total aerosol effect (direct + indirect effects) results in cooling at the surface but when averaged over all hours including night time, the total aerosol effect results in a net warming at the surface due to infrared forcing.

Previous studies of the second aerosol indirect (lifetime) effect on cloud cover have estimated the strength of the effect without correcting for near-cloud contamination and other confounding factors. Here, we combine satellite-based observations with a multi-year ground-based dataset across five rural locations in the United States to more accurately constrain the second indirect aerosol effect and quantify aerosol effects on radiative forcing. Results show that near-cloud contamination accounts for approximately 40% of the satellite-derived aerosol-cloud relationship. When contamination is removed and the effect of meteorological co-variation is minimized, a strong physical aerosol effect on cloud cover remains. Averaged over all stations, and after correcting for contamination, the daytime solar and total (solar+IR) radiative forcing is -52 W/m^2 and -19 W/m^2, respectively, due to both

direct and indirect aerosol effects for aerosol optical depths (τ) between 0 and 0.3. Averaged diurnally, the average total radiative forcing is +16 W/m^2.

Online Publication date: 1 December 2015
Available online:
http://onlinelibrary.wiley.com/doi/10.1002/2015GL066873/abstract

Cloudy with a chance of sardines: forecasting sardine distributions using regional climate models

Fisheries Oceanography (2.543)

I. C. Kaplan (NMFS/NWFSC), **G. D. Williams (NMFS/NWFSC)**, **N. A. Bond (OAR/CPO)**, **A. J. Hermann (OAR/CPO)**, and S. A. Siedlecki

- Provides seasonal forecasts of ocean conditions (i.e. temperature, salinity) relevant to fish distributions.
- Can be used by managers to prepare for changes in sardine distribution

Despite the significant advances in making monthly or seasonal forecasts of weather, ocean hypoxia, harmful algal blooms, and marine pathogens, few such forecasting efforts have extended to the ecology of upper trophic level marine species. Here, we test our ability to use short-term (up to nine month) predictions of ocean conditions to create a novel forecast of the spatial distribution of Pacific sardine, *Sardinops sagax*. Predictions of ocean conditions are derived using output from the Climate Forecast System (CFS) model downscaled through the Regional Ocean Modeling System (ROMS). Using generalized additive models, we estimated significant relationships between sardine presence in a test year (2009) and salinity, temperature, chlorophyll concentration, and dissolved oxygen levels. The top five models had moderate skill (AUC >= 0.8) in predicting sardine distributions, five to eight months in advance. The approach could be used to provide fishery managers with an early warning of distributional shifts of this species, which migrates from the US-Mexico border to as far north as British Columbia, Canada, in summers with warm water and other favorable ocean conditions. We expect seasonal and monthly forecasts of ocean conditions to be broadly useful for predicting spatial distributions of other pelagic and midwater species.

Acceptance date: 15 October 2015

NMFS Publications

Spatial delay-difference models for estimating spatiotemporal variation in juvenile production and population abundance
Canadian Journal of Fisheries and Aquatic Sciences (2.287)
J. T. Thorson (NMFS/NWFSC), J. N. Ianelli (NMFS/AKFSC), S. Munch (NMFS/SWFSC), K. Ono (NMFS/AKFSC), and **P. Spencer (NMFS/AKFSC)**

- Uses a novel modeling technique to suggest that recruitment may vary spatially as well as temporally, using an example in the Gulf of Alaska.
- Suggests new methods that can be used to capture spatial variation in fish demographics.

Many important ecological questions require accounting for spatial variation in demographic rates (e.g., survival) and population variables (e.g., abundance per unit area). However, ecologists have few spatial modelling approaches that (*i*) fit directly to spatially referenced data, (*ii*) represent population dynamics explicitly and mechanistically, and (*iii*) estimate parameters using rigorous statistical methods. We therefore demonstrate a new and computationally efficient approach to spatial modelling that uses random fields in place of the random variables typically used in spatially aggregated models. We adapt this approach to delay-difference dynamics to estimate the impact of fishing and natural mortality, recruitment, and individual growth on spatial population dynamics for a fish population. In particular, we develop this approach to estimate spatial variation in average production of juvenile fishes (termed recruitment), as well as annual variation in the spatial distribution of recruitment. We first use a simulation experiment to demonstrate that the spatial delay-difference model can, in some cases, explain over 50% of spatial variance in recruitment. We also apply the spatial delay-difference model to data for rex sole (*Glyptocephalus zachirus*) in the Gulf of Alaska and show that average recruitment (across all years) is greatest near Kodiak Island but that some years show greatest recruitment in Southeast Alaska or the western Gulf of Alaska. Using model developments and software advances

presented here, we argue that future research can develop models to approximate adult movement, incorporate spatial covariates to explain annual variation in recruitment, and evaluate management procedures that use spatially explicit estimates of population abundance.
Publication date: 23 June 2015
Avaliable online:
http://www.nrcresearchpress.com/doi/abs/10.1139/cjfas-2014-0543#.VnLYJVUrJpg

Evaluating the performance of data-moderate and catch-only assessment methods for US west coast groundfish
Fisheries Research (1.843)
C. R. Wetzel (NMFS/NWFSC) and A. E. Punt

- The performance of assessment methods for data-limited and data-moderate fish stocks is life-history dependent.
- Catch-only and index-based models perform best for slow growing species.
- Caution should be taken when attempting to interpret the resulting prior distributions for data-moderate methods.

Estimating sustainable harvest limits for stocks that have never been assessed and have limited data available is challenging. Harvest limits for previously un-assessed U.S. west coast groundfish have been set using catch-only methods (Depletion Corrected Average Catch [DCAC] and Depletion-Based Stock Reduction Analysis [DB-SRA]) for data-limited stocks, as well as catch and index based methods (Extended Depletion-Based Stock Reduction Analysis [XDB-SRA] and Extended Simple Stock Synthesis [XSSS]) for data-moderate stocks. To account for uncertainty and to prevent overfishing the harvest levels for U.S. west coast groundfish are reduced based upon the estimation method and the amount of data used. A management strategy evaluation (MSE) was applied to evaluate the performance of each estimation method to provide benchmark harvest levels for two life-history types (U.S. west coast flatfish and rockfish) under varying misspecifications of the parameter distributions used by these methods. Both data-moderate and catch-only (data-limited) methods resulted in overfishing more than half the time when the simulated stock was below the relative biomass target

for both life-histories. Each of the data-moderate methods (XDB-SRA and XSSS) that applied biomass index data failed to estimate the correct stock status in the first assessment when an overly optimistic prior distribution about the stock status was assumed. However, as the biomass index lengthened, the estimates of current stock size improved for both of these estimation methods, reducing the probability of overfishing to <0.50 (except XSSS for one scenario). The ability to incorporate index data by the data-moderate methods resulted in improved estimates, as the data became more informative, for stock status and the subsequent harvest limits, that when reduced to account for uncertainty resulted in population stock sizes that either remain stable or rebuild toward the biomass targets for both life-histories.
Acceptance date: 1 April 2015
Available online:
http://www.sciencedirect.com/science/article/pii/S016578361500185X

*Regional diving behavior of Pacific Arctic beluga whales (*Delphinapterus leucas*) and presumed associations with prey*
Marine Ecology Progress Series (2.64)
D. D. W. Hauser, K. L. Laidre, **S. L. Parker-Stetter (NMFS/NWFSC)**, J. K. Horne, R. S. Suydam, and P. R. Richard

- Explains offshore distribution of foraging belugas and provides evidence for observed diving depths of foraging belugas.
- The results are consistent with a hypothesis that Arctic cod are a primary prey item for Pacific Arctic belugas and that foraging belugas dive to depths that maximize prey encounters.
- Important differences were found between Chukchi and Beaufort beluga populations, suggesting these groups forage differently.

Two populations of beluga whales (*Delphinapterus leucas*) make extensive seasonal migrations in the Pacific Arctic to several regions characterized by diverse bathymetry and hydrography, yet there is limited information on behavior and foraging across regions. The authors used satellite tags equipped with time-depth recorders, attached to 30 belugas from two populations from 1997-2012, to infer the depths at which belugas forage regionally. Also an acoustic

survey conducted in the western Beaufort Sea was used to estimate vertically integrated densities of a prey species, Arctic cod (*Boreogadus saida*), to examine the correspondence between patterns of beluga diving in the survey area and Arctic cod abundance at depth. A suite of regional diving metrics showed that beluga dive behavior varied among regions and sometimes between populations. Occupancy time at depth as well as maximum and modal dive depths for 6-h periods suggested that Eastern Chukchi Sea (ECS) and Eastern Beaufort Sea (BS) belugas were regularly diving to the seafloor in the shallow shelf regions while specific portions of the water column were more frequently targeted along slope margins, and in the deep Canada Basin (>3,000 m). The greatest maximum daily depths were >900 m in Canada Basin. Arctic cod were most abundant at 200-300 m in the western Beaufort Sea, and dives located within the survey area also most frequently targeted these depths. These results are consistent with a hypothesis that Arctic cod are a primary prey item for Pacific Arctic belugas and that foraging belugas dive to depths that maximize prey encounters.
Acceptance date: 26 October 2015

Qualitative network models in support of ecosystem approaches to bivalve aquaculture
ICES Journal of Marine Science (2.525)
J. C. P. Reum, P. S. McDonald, **B. Ferriss**, D. Farrell, **C. J. Harvey,** and **P. S. Levin (NMFS/NWFSC)**

- Identifying potential trade-offs between increased aquaculture and shifts in the abundance of community members is critical for appropriate assessment of the possible effects of different management actions.
- Qualitative network models (QNMs) that require only qualitative understandings of systemic variables were used to evaluate responses of bivalve aquaculture scenarios in Puget Sound.
- QNMs are mathematically robust and highly flexible, but remain underutilized.

Predicting the effects of aquaculture development for coastal ecosystems remains challenging, particularly for data-limited systems, and tools that account for

complex ecological interactions are needed to support ecosystem approaches to aquaculture. Here, the authors used qualitative network models (QNMs) to examine the potential community effects of increasing bivalve aquaculture in South Puget Sound, a large estuarine system in Washington, United States. QNMs are formalized conceptual models that require only a qualitative understanding of how variables composing a system interact (that is, the sign of interactions: +, –, and 0) and are therefore well-suited to data-limited systems. Specifically examined were community-wide responses to scenarios in which bivalve cultivation effort increased for three different bivalve species (Manila clam *Venerupis philippinarum*, Pacific oyster *Crassostrea gigas*, and geoduck *Panopea generosa*). Further, community-wide responses to the removal of benthic bivalve predators, future increase in nutrient loadings, and combinations of these scenarios acting simultaneously were examined. The scenarios enabled identification of potential trade-offs between increased aquaculture and shifts in the abundance of community members and assessment of the possible effects of different management actions. The QNM enabled the authors to identify key interactions that influence the sign outcome of community responses to press perturbations, highlighting potential points for management intervention and linkages deserving of more focused quantitative study. QNMs are mathematically robust and highly flexible, but remain underutilized, and the authors suggest that QNMs may serve as valuable tools for supporting ecosystem approaches to aquaculture.
Acceptance date: 12 June 2015
Available online: http://icesjms.oxfordjournals.org/content/72/8/2278

Cross-shelf variability in hydrography, zooplankton and juvenile salmon diets across a coastal riverine plume
Estuaries and Coasts (2.245)
R. D. Brodeur and **C. A. Morgan (NMFS/NWFSC)**

- Columbia River Plume represents a unique environment in terms of physics and plankton. Salmon inhabit the plume but do not show similarity between their diets and what is in the plume.

The Columbia River plume is a dynamic coastal feature influenced by variable river flow, wind forcing, and tidal forcing. Enhanced production and accumulation of prey within the plume may increase availability of food during a critical period of salmon ocean survival and hence serve as a nursery area for these juveniles. Physical and biological sampling was conducted along a cross-shelf transect through the plume during May 1999. Based on cluster analyses of 11 physical variables, stations considered to be within the core of the plume, at 24-40 km from shore, were distinct from inshore (6.4-16 km) and offshore (48-80 km) stations. Five variables (temperature at 10 m, salinity at 3 and 10 m, silicate and chlorophyll) accounted for 92% of this difference. Both surface neuston and subsurface plankton tows revealed differences in plankton composition at the plume core stations compared to non-plume stations. However, stomach contents of juvenile Chinook salmon were not significantly different inside and outside the plume. Comparison of similarity indices showed that the stomach composition was more similar to the catch composition in the neuston (Spearman $\rho = 0.572$) than the meter net ($\rho = 0.331$). Fishes, decapod larvae, and hyperiid amphipods occurred in greater proportions and copepods and euphausiids in lesser proportions in the stomachs than in the plankton. There appeared to be a distinctive plume signal, evident in both the physical environment and zooplankton resources sampled inside and outside the plume, but the plume signature was not as evident in the salmon diets, possibly due to their higher mobility and shorter residence within the plume.

Acceptance date: 2 November 2015

*Organochlorine contaminant concentrations in multiple tissues of live Steller sea lions (*Eumetopias jubatus*) in Alaska*

Science of the Total Environment (3.163)

K. B. Beckmen, M. J. Keogh, K. A. Burek-Huntington**, G. M. Ylitalo (NMFS/NWFSC)**, **B. S. Fadely (NFMS/AKFSC)**, and K. W. Pitcher

- We examined the relationships of organochlorine (OC) contaminants between multiple tissues of young, free-ranging Steller sea lions (*Eumetopias jubatus*).

- The findings of the study indicate that alternative tissues may be obtained less-invasively and used as indicators of relative contaminant exposure in lieu of surgical blubber biopsy.

We examined the relationships of organochlorine (OC) contaminants between multiple tissues of young, live captured Steller sea lions (*Eumetopias jubatus*). Blubber (N=48), blood (N=13), feces (N=34), and milk (N=21) were collected from free-ranging Steller sea lions in Alaska over 6 years (1998-2003) to assess exposure of selected OC contaminants (e.g., dioxin-like PCBs, DDTs). Both between and within each matrix there was considerable individual variation. In spite of the individual variation, similar patterns were observed across the matrices for most of the selected PCB congeners. In all four matrices, the major PCB congeners were -101, -118, -138, and -153. The most prominent congener, both as a weight (ng/g l.w.) and as a percentage of summed PCBs (SPCB) was PCB-153. Comparisons between paired matrices showed that SDDT in blubber samples were related to concentrations in blood, feces, and milk. Whereas SPCB in blubber was related to concentrations in paired milk and fecal samples, this relationship was extremely weak in feces (r^2=0.143). These findings indicate that alternative tissues may be obtained less-invasively and used as indicators of relative contaminant exposure in lieu of surgical blubber biopsy. In particular, milk samples were related to paired blubber samples for SDDT, SPCB, and summed PCB toxic equivalents (SPCB TEQ) highlighting the potential utility of orogastric collected milk samples eliminating the need to handle adult female SSL. Feces may be used as a population-level screen or monitoring tool of relative OC exposure without handling of animals for sample collection, but should be used with caution as samples are not attributable to individuals.

Expected Publication date: Winter 2015/2016

Harmful algal blooms (HABs) and climate change: what do we know and where do we go from here?

Harmful Algae (3.34)

M. L. Wells, **V. L. Trainer (NMFS/NWFSC)**, T. J. Smayda, B. Karlson, C. G. Trick, R. Kudela, A. Ishikawa, S. Bernard, A. Wulff, D. M. Anderson, and W. P. Cochlan

- The article details the proposed impacts of HABs due to climate change.
- The authors recommend a series of observer sites important for assessment of impacts, and propose the need for a best practices manual.

Climate change pressures are anticipated to substantially influence marine planktonic systems globally, and it is conceivable that harmful algal blooms may increase in frequency and severity. However, this coupling of climate with HAB outbreaks is based on few and sometimes conflicting data, frustrating hopes for developing consensus forecasts of HABs in the future ocean. Moreover, it is not clear that many of our current research strategies are best suited to inform on the essential fundamental linkages. We report here the outcome of a 4-day workshop aimed at summarizing key aspects of what currently is known and not known about the general environmental conditions that favor initiation and maintenance of different types of HAB events. Using the anticipated changes in ocean acidification, nutrient flux, temperature, light, and grazing in the future ocean, we review the known and unknown consequences of climate change on these factors that can impact the intensity, type and duration of future HABs. The goal is to provide a starting point to identify a list of keystone research directions and infrastructure that would best serve to begin testing the purported coupling of HABs and climate change.

Expected Publication date: Spring 2016

OAR Publications

Surface ocean-lower atmosphere study
Anthropocene (0.580)
E. H. G. Brévière, D. C. E. Bakker, H. W. Bange, **T. S. Bates**, T. G. Bell, P. W. Boyd, R. A. Duce, V. Garçon, M. T. Johnson, C. S. Law, C. A. Marandino, A. Olsen, B. Quack, **P. K. Quinn, C. L. Sabine,** and **E. S. Saltzman (OAR/PMEL)**

- Describes a new study initiative: the Surface Ocean-Lower Atmosphere Study

The domain of the surface ocean and lower atmosphere is a complex, highly dynamic component of the Earth system. Better understanding of the physics and biogeochemistry of the air-sea interface and the processes that control the exchange of mass and energy across that boundary define the scope of the Surface Ocean-Lower Atmosphere Study (SOLAS) project. The scientific questions driving SOLAS research, as laid out in the SOLAS Science Plan and Implementation Strategy for the period 2004-2014, are highly challenging, inherently multidisciplinary and broad. During that decade, SOLAS has significantly advanced our knowledge. Discoveries related to the physics of exchange, global trace gas budgets and atmospheric chemistry, the CLAW hypothesis (named after its authors, Charlson, Lovelock, Andreae and Warren), and the influence of nutrients and ocean productivity on important biogeochemical cycles, have substantially changed our views of how the Earth system works and revealed knowledge gaps in our understanding. As such SOLAS has been instrumental in contributing to the International Geosphere Biosphere Programme (IGBP) mission of identification and assessment of risks posed to society and ecosystems by major changes in the Earth's biological, chemical and physical cycles and processes during the Anthropocene epoch. SOLAS is a bottom-up organization, whose scientific priorities evolve in response to scientific developments and community needs, which has led to the launch of a new 10-year phase. SOLAS (2015–2025) will focus on five core science themes that will provide a scientific basis for understanding and projecting future environmental change and for developing tools to inform societal decision-making.

Influence of post-Tehuano oceanographic processes in the dynamics of the CO2 system in the Gulf of Tehuantepec, Mexico

Journal of Geophysical Research: Oceans (3.44)

C. Chapa-Balcorta, J. M. Hernandez-Ayon, R. Durazo, E. Beier, **S. R. Alin (OAR/PMEL),** and A. Lopez-Perez

- The oceanographic structures observed during post-Tehuano conditions promote the rise of water rich in dissolved inorganic carbon near the coast in the Gulf of Tehuantepec, located in the Mexican tropical Pacific.
- Reported air-sea CO_2 fluxes are the largest observed to date in the Mexican Pacific, and suggest that the Gulf of Tehuantepec is a major source of CO_2 into the atmosphere.

This investigation reports, for the first time, results of CO_2 system variables in the Gulf of Tehuantepec, located in the Mexican tropical Pacific. The authors quantified the post-Tehuano concentration of dissolved inorganic carbon (DIC) and pH from April 2013. These values were then used to calculate pCO2, aragonite saturation (ΩAr) and air-sea CO2 fluxes (FCO2) for the region. Intense vertical stratification was found to contribute to the biogeochemical processes in surface waters (< 70 m). However, in post-Tehuano conditions, high pCO2 (~1000 µatm) and DIC concentrations (2200 µmol kg−1), as well as low ΩAr (~1.1) and pH (~7.5) remained in surface waters for a few days after Tehuano winds weakened. Four oceanographic areas were identified: 1) a highly mixed region due to previous Tehuano events; 2) coastal upwelling in the western region; 3) mesoscale eddies; and 4) a poleward surface coastal current. The first three promoted the influence of Subtropical Subsurface Water in the chemistry of surface waters, whereas the coastal current contributed to the horizontal advection of DIC. The calculated CO_2 fluxes ranged from -2.3 mmol m−2 d−1 in areas with stratified waters, to over 25 mmol m−2 d−1 for mixed areas. Positive values indicate an ocean-to-atmosphere flux. These findings suggest that the Gulf of Tehuantepec is a major source of CO_2 into the atmosphere.

Acceptance date: 11 November 2015

Complex interactions in Lake Michigan's rapidly changing ecosystem
Journal of Great Lakes Research (1.748)

- Special Section on Lake Michigan Interactions

H. A. Vanderploeg (OAR/GLERL), B. Bunnell, H. Carrick, and T. Hook

- This introductory manuscript summarizes the findings of the special issue of the Journal of Great Lakes Research that documents rapid changes in Lake Michigan ecosystem and reasons for these changes.

Over the past 30 years, Lake Michigan's food web has been in a constant state of transition. It is likely that this emerging system has not yet reached a steady state. The proliferation of invasive species at multiple trophic levels (zooplankton, mussels, fish) coupled with the success of the nutrient abatement program that have delivered long-term reductions in nutrient inputs have together contributed to a series of systemic changes to the Lake Michigan ecosystem (e.g., novel trophic interactions, reengineered nutrient cycling, altered physical habitat, shift from pelagic productivity to enhanced benthic production, and nuisance algal blooms nearshore). Our current understanding and potential future forecasting of ecosystem-wide consequences of such transitions are dependent on describing and understanding changes in the food web in time and space (i.e., horizontal and vertical), variation of key food web components and linkages with physical habitat, and nutrient cycling. Given that other Laurentian Great Lakes share kay members of the Lake Michigan food web as well as changing nutrient and climate dynamics, understanding gleaned from this special issue is highly relevant across the basin, especially in Lakes Huron and Ontario.
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New approaches to quantifying aerosol influence on the cloud radiative effect
Proceedings of the National Academy of Sciences (9.674)
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- Atmospheric general circulation models represent aerosol-cloud interactions at ever-increasing levels of detail, but these models lack the resolution to represent clouds and aerosol-cloud interactions adequately.
- The authors developed a conceptual approach to systematically constrain the aerosol-cloud radiative effect in shallow clouds through a combination of routine process modeling and satellite and surface-based shortwave radiation measurements.
- This paper gives a conceptual approach for providing much stronger observational constraints on the aerosol-induced cloud radiative effect.

The influence of atmospheric particles (aerosol) on clouds is one of the most uncertain pieces in the climate puzzle as there are many unknowns about both the aerosol and the clouds. Aerosols have a wide variation in composition, how particles affect light, how effective they are at initiating the formation of water droplets or ice particles, and in their distribution and movement in the global atmosphere. And clouds are the atmosphere's ultimate shape-shifters: turbulent, ephemeral, and largely unpredictable.

In trying to understand how the aerosol/cloud interaction affects climate, the authors found that the meteorological conditions that drive cloud formation are co-varying along with the aerosol amount. The authors focused on modeling how the aerosol affects the clouds' reflection and absorption of sunlight, using a set of inputs that describe both the aerosol and meteorology. They first illustrated the problem by making use of two different approaches that differed only in the co-variability between the meteorological conditions and aerosols. They got different outcomes for the role of the aerosols, even though both approaches used the same inputs. This perplexing outcome motivated them to look further into how to model the complex system of clouds, aerosol, meteorology, and radiation. To quantify the aerosol-cloud radiative effect the authors argue for studies that consider how the system would respond to inputs that are allowed to co-vary in a

natural way, more accurately representing real-world conditions. They call for routine process model simulations in which the initial inputs for aerosol and meteorology are derived from observations—and hence are varying simultaneously in space and time. With a large volume of observations and successful model simulations of this kind, the authors argue that this approach could advance the study of aerosol-cloud interactions and their implications for the warming or cooling effects of clouds.
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Evolution of tsunami warning systems and products
Philosophical Transactions of the Royal Society A (2.192)
E. Bernard and **V. Titov (OAR/PMEL)**

- Coastal communities would be well served by receiving three *standardized, accurate*, real-time tsunami warning products, namely (i) tsunami energy estimate, (ii) flooding maps and (iii) tsunami-induced harbour current maps to minimize the impact of tsunamis.
- The advantage of global standardized flooding products delivered in a common format is efficiency and accuracy, which leads to effectiveness in promoting tsunami resilience at the community level.

Each year, about 60 000 people and $4 billion (US$) in assets are exposed to the global tsunami hazard. Accurate and reliable tsunami warning systems have been shown to provide a significant defence for this flooding hazard. However, the evolution of warning systems has been influenced by two processes: deadly tsunamis and available technology. In this paper, we explore the evolution of science and technology used in tsunami warning systems, the evolution of their products using warning technologies, and offer suggestions for a new generation of warning products, aimed at the flooding nature of the hazard, to reduce future tsunami impacts on society. We conclude that coastal communities would be well served by receiving three *standardized, accurate*, real-time tsunami warning products, namely (i) tsunami energy estimate, (ii) flooding maps and (iii) tsunami-induced harbour current maps to minimize the impact of tsunamis. Such information would arm communities with vital flooding guidance for evacuations

and port operations. The advantage of global standardized flooding products delivered in a common format is efficiency and accuracy, which leads to effectiveness in promoting tsunami resilience at the community level.
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Winds, waves, and fronts: Frictional effects in a generalized Ekman model
Journal of Physical Oceanography (2.856)
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- The solutions, and estimates of the global distribution of the relative influence of surface waves and baroclinic pressure gradients on near-surface ocean currents, emphasize the broad importance of considering ocean sources of shear and physically realistic parameters in the Ekman problem.

Ocean currents in the surface boundary layer are sensitive to a variety of parameters not included in classic Ekman theory, including the vertical structure of eddy viscosity, finite boundary layer depth, baroclinic pressure gradients, and surface waves. These parameters can modify the horizontal and vertical flow in the near-surface ocean, making them of first-order significance to a wide range of phenomenon of broad practical and scientific import. In this work, an approximate Green's function solution is found for a model of the frictional ocean surface boundary layer, termed the generalized Ekman (or Turbulent Thermal Wind) balance. The solution admits consideration of general, more physically realistic, forms of parameters than previously possible, offering improved physical insight into the underlying dynamics. Closed form solutions are given for the wind-driven flow in the presence of Coriolis-Stokes shear, a result of the surface wave field, and thermal wind shear, arising from a baroclinic pressure gradient, revealing the common underlying physical mechanisms through which they modify currents in the ocean boundary layer. These dynamics are further illustrated by a case study of an idealized two-dimensional front. The solutions, and estimates of the global distribution of the relative influence of surface waves and baroclinic pressure gradients on near-surface ocean currents, emphasize the broad importance of

considering ocean sources of shear and physically realistic parameters in the Ekman problem.

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