Statement of Career Achievements
Rachel Schwartz Clemesha, May 2017

I have contributed to research on coastal climate and meteorology, weather extremes, impacts of low clouds, and atmospheric chemistry. Additionally, I have taught a university course and have engaged in public and stakeholder outreach. Below is a summary of my work.

A. Research
1. Coastal climate and meteorology

Low coastal stratiform clouds (stratus, stratocumulus, and fog) impact an array of systems with applications ranging from solar resource forecasting to growth of endemic species. My research has significantly contributed to the literature and improved our understanding of U.S. West Coast, and in particular California, coastal low clouds. My work has described low cloud variability, and its drivers, over a wide range of spatial and temporal scales from broad-scale climate (**Schwartz et al. 2014**), to seasonal (**Clemesha et al. 2016**), to local weather scales (**Clemesha et al. 2017**). A novel and key achievement of my research has been the development of a 20 year satellite derived low cloud record. This high resolution record has, and will continue to play, a critical role in the description of low clouds at finer spatial resolution (1-4 km) and shorter timescales (half hourly). Furthermore, since low clouds are of interest to researchers in other disciplines, my retrieval and analyses remotely sensed metrics of low clouds have lead to my involvement in interdisciplinary research (as described in section A3).

In 2012, I was awarded the NASA Earth and Space Science Fellowship. My fellowship work has led to, and contributed to, the following publications and research findings. **Schwartz et al. (2014),** bridged the gap between research on broad-scale cloudiness over the oceans and research on regional coastal cloudiness/fog. We focused on the terrestrial coastal margin in particular, using records from 20 coastal airports, yet did so over a very broad West Coast region, from San Diego all the way to the Aleutian Islands. We found that summertime coastal low cloudiness (CLC) since 1950 varies quite coherently over this broad coastal region and is organized seasonally by eastern Pacific sea surface temperature (SST) variability. We also found a modest, but statistically significant, decreasing trend in the leading mode of West Coast CLC variability, although the mode also exhibits considerable interannual and interdecadal variability. As reported in the 15 March 2015 issue of *Science* in the “California fogs are thinning” news feature, the trends reported by us in Schwartz et al. (2014) spurred collaborative research with others (see **Williams et al. 2015**) to further dissect and understand the trends in CLC in southern California. *Geophysical Research Letters* dedicated their cover to Williams et al. (2015), in which we revealed substantial declines in early morning fog (the lowest category of stratus) and identify urban warming as a cause.

To address research questions relating to finer scale variability of low clouds, I created and validated a new 20 year, 4 km, half-hour resolution, NASA/NOAA Geostationary Operational Environmental Satellite (GOES) -derived record of low clouds. I tested and optimized the satellite retrieval algorithms using coastal California airport observations. As reported in **Clemesha et al. (2016),** this record reveals in unprecedented detail that rather than a simple seasonal peak in CLC, the California coastal region exhibits a northward migration of maximum CLC along the coast. CLC peaks in June along southern California and in late July/early August along northern California. This north-south timing difference in CLC is impactful because it indicates that the heat-modulating influence of CLC differs in northern versus southern California. Similar to that of CLC, we observe a northward migration of lower troposperhic stability (LTS) along the California coast. While both CLC and LTS progress northward during the first half of summer and reach their northward extent at a similar time, the LTS maximum core remains farther northward than the CLC core. The spatial offset shown in these seasonal cycles reappears in the relationship between daily stability and CLC anomalies examined and described in **Clemesha et al. (2017**). In this work, we show for two sub-regions of California, that daily low cloud variability is linked to daily fluctuations of stability and temperatures ~865 km ± 225 km to the north. We use reanalysis variables and radiosonde measurements of inversion characteristics to uncover a new mechanism that may function in addition to advection in explaining the off-set nature of the cloud stability relationship. We show evidence that the pattern is a result of the balancing act that affects low cloudiness wherein subsidence drives increased stability, which promotes cloudiness, but too much subsidence limits cloudiness through reducing vertical space for the low cloud in the marine boundary layer.

Clemesha, R. E. S., A. Gershunov, S. F. Iacobellis, and D. R. Cayan (2017), Daily variability of California coastal low cloudiness: A balancing act between stability and subsidence, Geophys. Res. Lett., 44, doi:10.1002/2017GL073075.

Clemesha, R. E. S., A. Gershunov, S. F. Iacobellis, A. P. Williams, and D. R. Cayan (2016), The northward march of summer low cloudiness along the California coast, Geophys. Res. Lett., 43, doi:10.1002/2015GL067081.

Schwartz, R. E., A. Gershunov, S. F. Iacobellis, and D. R. Cayan (2014), North American west coast summer low cloudiness: Broadscale variability associated with sea surface temperature, Geophys. Res. Lett., 41, 3307 – 3314 doi:10.1002/2014GL059825.

Williams, A. P., **R. E. Schwartz**, S. Iacobellis, R. Seager, B. I. Cook, C. J. Still, G. Husak, and J. Michaelsen (2015), Urbanization causes increased cloud base height and decreased fog in coastal Southern California, Geophys. Res. Lett., 42, doi:10.1002/2015GL063266.

Carswell, C. (2015). California fogs are thinning. *Science*, *347*(6227), 1184-1185. *I was interviewed for this "In Depth News" article which highlights the findings of Williams et al. (2015).*

2. Weather extremes

I began research on California heat waves as a postdoctoral scholar on the NOAA Coastal and Ocean Climate Applications (COCA) grant that I helped write. I have presented my research findings and collaborated with operational meteorologists at the National Weather Service (NWS) on this work. As described by (**Clemesha et al. submitted),** we examined spatial and temporal movement of individual heat wave events and their interplay with low-level clouds. This event-centered framework uncovered features of California heat waves that would be lost if examined in an aggregate method. We quantified the different spatial footprints of heat wave events across coastal and inland regions. For those heat wave events with a strong impact across regions, we find that extreme heat starts at the coast, proceeds inland, and weakens at the coast before letting up inland. There is also an associated evolution in coastal low cloudiness (CLC), in which the beginning of coastal heat waves are associated with a loss of CLC, followed by a strong rebound of CLC starting close to the peak in heat wave intensity. We also demonstrated that during inland heat waves, the height of the inversion base which caps the marine boundary layer, is a key factor determining coastal cloudiness, and thus, coastal heat expression.

Previously, I conducted research on both warm and cold temperature extremes in the Northern Hemisphere as a part of the SPHEAR (Scripps Partnership for Environmental Hazards and Environmental Applied Research) project. The interest of the project stakeholders (industry meteorologists) was "weather regimes", anomalous temperature events with explicit emphasis on event persistence. I developed algorithms to categorize and track the movement of these weather regimes across the Northern Hemisphere and relate their likelihood to different climate indices. In 2011 I presented my research to stakeholders in Chicago, and in 2012 I wrote a white paper including an analysis of the impacts of weather regimes and extremes on natural gas markets. During this time, I also contributed to work analyzing extremes of recent winters (2009-2010 and 2010-2011) in a historical context **(Guirguis et al. 2011)** by validating daily temperature anomalies from reanalysis against station observations in station-sparse Eurasia. We found that although there were some record cold extremes during these winters, warm extremes dominated in the Northern Hemisphere. Lastly, I reviewed relevant literature for inclusion in a book chapter on projected weather extremes in the Southwest (**Gershunov et al. 2013**). This report contributed to the U.S. National Climate Assessment.

More recently, I have contributed through research discussions with collaborators to describing different flavors of Atmospheric Rivers (ARs) making landfall in Northern California **(Guirguis et al. in prep.)**. The results reveal that different climate states produce ARs with varying characteristics, including landfall orientation and subsequent precipitation patterns. Atmospheric rivers and precipitation extremes in the West are new areas of research for me, and in the future I plan to pursue more projects on this highly important and relevant topic.

Clemesha, R. E. S., K. Guriguis, A. Gershunov, I. J. Small, and A. Tardy, California heat waves: their spatial evolution, variation, and coastal modulation by low clouds, Climate Dynamics, submitted

Guirguis, K., A. Gershunov, T. Shulgina, **R. E. S. Clemesha**, and F. Martin Ralph, Flavors of Atmospheric Rivers making landfall in Northern California, in prep.

Guirguis, K., A. Gershunov, **R. Schwartz**, and S. Bennett (2011), Recent warm and cold daily winter temperature extremes in the Northern Hemisphere, Geophys. Res. Lett., 38, L17701, doi:10.1029/2011GL048762.

Gershunov, A., B. Rajagopalan, J. Overpeck, K. Guirguis, D. Cayan, M. Hughes, M. Dettinger, C. Castro, **R. E. Schwartz**, M. Anderson, A. J. Ray, J. Barsugli, T. Cavazos, and M. Alexander (2013), Chapter 7: Future Climate: Projected Extremes. In: Garfin, G., Jardine, A., Merideth, R., Black, M., & LeRoy, S. (Eds.), Assessment of Climate Change in the Southwest United States: a Report Prepared for the National Climate Assessment. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

3. Impacts of low clouds on ecology and agriculture

Catalyzed by my expertise and ability to generate a satellite derived record of low clouds, I have been contacted by a number of researchers and have contributed to interdisciplinary research collaborations. Currently two of these collaborations have resulted in journal manuscripts described below. Additionally, I have been writing proposals with ecologists associated with the US Navy to explore the influence of low clouds and fog on local coastal sage shrub communities and the reproduction of local birds. I am also a part of a new collaborative effort pairing local climatologists and ecologist for a San Diego state of the science report. I am very interested in maintaining these collaborative projects with ecologists and fostering new connections to ensure our climate work is relevant to and informs ecological conservation.

I created a record of low clouds to overlap with the location and sampling times of underwater recording instruments used by **Simonis et al. (under review)**. I also compared the cloudiness during field sampling times to longer term cloud climatology in the Southern California Bight and advised on how cloud cover can dampen lunar illumination. As described by Simonis et al. (under review), common Dolphins (*Delphinus delphis*) echolocate more frequently when there is less lunar illumination, during the darkest periods of the night and month. Furthermore, while the diurnal and lunar cycles follow predictable light level cycles, common Dolphins also show increased echolocation activity on nights close to the full moon when low clouds were present. This suggests a behavioral response by the dolphins, and also possibly their prey, to light levels.

I also contributed to research on the impact of low clouds and fog on California agricultural systems. I analyzed the spatial and temporal patterns of low clouds in Salinas Valley, California to assist with the site selection of two strawberry farms along a cloudiness gradient. During summer 2015, field work was carried out at these sites to measure canopy and leaf-level physiology and local meteorology. I contributed a remote sensed record of fog during this time and conducted a comparison with field observations, and analysis of cloud variability over different time scales. My contribution allowed plant physiology to be stratified by sky conditions and in turn, we found that water use efficiency of strawberry plants is significantly increased during foggy conditions versus clear conditions (**Baguskas et al. in prep).**

Simonis, A. E., M. A. Roch, B. Baily, J. Barlow, **R. E. S. Clemesha,** S. Iacobellis, J. A. Hildebrand, and S. Baumann-Pickering, Lunar cycles affect common dolphin (*Delphinus delphis)* foraging in the Southern California Bight, Marine Ecology Progress Series, under review

Baguskas S. A., **R. E. S. Clemesha**, M.E. Loik, Coastal fog enhances crop water use efficiency in a California agricultural system, Agriculture and Forest Meteorology, in prep.

4. Atmospheric chemistry

The radiative effect of aerosols is depended on both particle size and chemistry. In an effort to better characterize aerosol chemistry and the contribution of forest emissions to the global aerosol burden, a team of researchers conduced field work in Whistler, British Columbia (**Leaitch et al., 2011**). As a part of this team, I set-up instrumentation to collect aerosol particles at a mid-mountain site in spring 2008 and a peak site in spring and summer 2009. I then measured the organic functional group composition of the collected aerosol by Fourier transform infrared (FTIR) spectroscopy as reported in **Schwartz et al. (2010)** and **Takahama et al. (2011).** We measured an organic mass (OM) project mean of 1.3 ± 1.0 μg m^{-3} and 3.2 ± 3.3 μg m^{-3} at the mid-mountain site and mountain peak site, respectively. Through a factorization technique, we attributed 65% of the mid-mountain campaign OM to biogenic sources. At the mountain peak site OM reached a maximum of 13.6 μg m^{-3} during severe wildfires.

Schwartz, R. E., Russell, L. M., Sjostedt, S. J., Vlasenko, A., Slowik, J. G., Abbatt, J. P. D., ... & Leaitch, W. R. (2010), Biogenic Oxidized Organic Functional Groups in Aerosol Particles from a Mountain Forest Site and their Similarities to Laboratory Chamber Products, Atmos. Chem. Phys., 10, 5075–5088.

Takahama, S., **R. E. Schwartz**, L. M. Russell, A. M. MacDonald, S. Sharma, and W. R. Leaitch (2011), Organic functional groups in aerosol particles from burning and non-burning forest emissions at a high-elevation mountain site, *Atmos. Chem. Phys.*, doi:10.5194/acp-11-6367-2011.

Leaitch, W. R. ... **R. E. Schwartz** ... et al., (2011), Temperature Response of Organic Aerosol from Temperate Forests, Atmos. Environ., 45, 6696–6704. doi:10.1016/j.atmosenv.2011.08.047

B. Other professional activities

1. Teaching

In 2016, I taught MARS 220: **"Introduction to Atmospheric and Ocean Sciences" at the University of San Diego (USD)**. I was the primary instructor for the lecture portion of the semester long undergraduate course in the department of Environmental and Ocean Sciences. The course content was designed for Marine Science majors and covered the basics of atmospheric circulation and physical oceanography. The next year, USD invited me back to teach the corresponding laboratory portion of the course. I declined, deciding to focus on research.

Previously, in winter 2014 I worked as a **teaching assistant for the UCSD undergraduate course SIO 20: "The Atmosphere"** and in 2015 I guest lectured in the same course. I also completed the course "The College Classroom" at the UCSD Center for Teaching Development and I now hold the Associate level distinction from the Center for the Integration of Research, Teaching and Learning (CIRTL). Lastly, my research on local coastal climate and low clouds has contributed to the NSF funded Climate Education Partners project which aims to provide locally relevant climate science to San Diego's leaders.

2. Outreach, Presentations & Stakeholder Involvement

I first began my research on low-level clouds during summer internships in 2011 and 2012 with our local utility, **San Diego Gas and Electric (SDG&E)** and consulting firm **Green Power Labs**. I collaborated with engineers and engineering students, to create an algorithm to identify the leading edge of the marine layer from satellite observations and to explore meteorological controls of its movement. SDG&E is an important regional stakeholder and I have continued to communicate and share research findings with meteorologists at SDG&E. For example, in 2014 I presented my findings on the anomalously sunny summer. In addition to presenting this work at SDG&E, I also presented at the **National Weather Service (NWS)**. This talk at the NWS represents just one in ongoing communication and collaboration with our local meteorological community. I have also presented at a Marine Weather Workshop in 2013, and at a **local American Meteorological Society (AMS)** meeting in 2015.

In 2012, I attended the Pacific Coastal Fog Workshop at the USGS Western Geographic Science Center in Menlo Park, CA. At this three day working session I was introduced to the broader research community. This has resulted in ongoing research collaborations with other Pacific Coastal Fog Workshop attendees (e.g. Baguskas et al. in prep.). I have continued to interact with this international group of fog and low cloud researchers through webinars and by presenting my research five times over the years during the American Geophysical Union (AGU) Fall meeting session "Coastal Fog: Atmosphere, Biosphere, Ocean, and Land Interactions". I was **awarded the 2014 AGU Outstanding Student Paper Award** in the atmospheric science section for my oral presentation. This honor is awarded to the top 3 – 5 % of presenters in each section.

I have also presented my research internationally to our neighbors at Centro de Investigación Científica y de Educación Superior de Ensenada, **CICESE**, in Ensenada, Baja California, Mexico. Lastly, I have engaged in a number of public outreach activities including radio interviews, a blog post on a NASA educational website, and a write-up in SIO's *Explorations Now.* Most recently, I volunteered with Climate Science Alliance at the 2017 Balboa park Earth Fair.

Future Research

My research interests broadly include regional climate variability and change, weather-climate connections, and weather extremes and impacts. Much of my work thus far has been focused on the US West Coast. The coastal swath, where air, sea, and land interact, is a challenging and exciting zone to study. Beyond these physical interactions, the dense coastal human population and unique biodiversity have also driven my interest in this region. I am excited to connect physical science research to these underlying motivators through interdisciplinary collaborations. I have begun to work on and pursue projects that unite our understanding of regional climate dynamics to human health and ecological impacts. Looking forward, I am interested in broadening my research to other weather-climate topics that are highly relevant to society and biodiversity such as water resources and precipitation extremes. I am also excited to explore unexpected connections between different regional climate phenomena such as the link between coastal low clouds and the North American Monsoon.