**COOPERATIVE INSTITUTE FOR MODELING THE EARTH SYSTEM (CIMES)**

**Federal Award Number: NA18OAR4320123**
**Annual Progress Report for the period April 1, 2019 – March 31, 2020**
**Director and Principal Investigator: Gabriel A. Vecchi**

## ACCOMPLISHMENTS

### 24. What were the major goals and objectives of this project?

i. To develop the world leading earth system model, in collaboration with NOAA-GFDL, by providing expertise in key processes, physical and biological components, and software development.
ii. To apply this model to the problem of prediction across time and space scales, from high resolution simulations of extreme events, to prediction of climate phenomena from seasons to centuries.
iii. To apply this model to understand impacts of a changing climate on societally-relevant problems, including marine ecosystems, weather extremes, droughts and air quality.
iv. To train the next generation of leaders in earth system science, through the world-leading graduate Atmospheric and Oceanic Sciences program at Princeton University, and the AOS postdoctoral program.
v. To develop a more diverse workforce by broadening participation in earth system science training, through summer internships, visiting faculty exchange fellowships and increasing research collaborations with diverse institutions.

### 25. What was accomplished under these goals?

Goal i. To develop the world leading earth system model, in collaboration with NOAA-GFDL, by providing expertise in key processes, physical and biological components, and software development.

Cooperative Institute researchers have contributed to the development of GFDL's earth system model through investigations into physical and biological processes in the ocean, atmosphere, cryosphere, and land-surface; development of parameterizations of these processes implemented in the ocean, atmosphere, and land components of the GFDL earth system models; development of dynamical core algorithms for the MOM6 ocean model and FV3 atmospheric model; and development of the software infrastructure required to efficiently run the climate models and examine their results. Here we highlight only a small subset of the exciting advances in earth system model development achieved in the past year.

A major achievement of the past year was the release and documentation of the new climate model suite, CM4.0, the fully coupled climate model developed for the Coupled Model Intercomparison Project CMIP6, described in Held et al, 2020, and OM4, the MOM6 ocean model configuration described in Adcroft et al, 2019. In total 6 Cooperative Institute researchers contributed to the two multi-author publications describing these landmark models, contributing in particular to ocean model algorithm development, stratospheric dynamics, cloud representation, and software development. CM4.0 represents the state-of-the art in climate modeling, with particularly good representation of the El Nino-Southern Oscillation and Madden-Julian Oscillation. OM4 uses a hybrid vertical coordinate which leads to a reduction in the model ocean drift, providing a better model for long-term climate simulations.

Members of the Cooperative Institute have contributed to the development of the GFDL Finite-Volume Cubed Sphere Dynamical Core, documented in the technical memorandum Harris et al, 2020. This dynamical core development team is also contributing to the Dynamics of the Atmospheric general circulation modeled on non-hydrostatic domains (DYAMOND) project, a multi-institutional project to compare global storm-resolving models, described in the recent publication Stevens et al, 2019.

Cooperative institute researchers have conducted studies of fundamental physical processes in the ocean, atmosphere and cryosphere, and their parameterization, including: mixing by symmetric instability in oceanic gravity currents, cloud microphysics, anvil cloud physics, tropical convection, and tabular ice-bergs. The representation of biological processes such as mangroves and tropical forests in climate models has been explored. An example of improved process representation resulting from these studies is the new parameterization of gas transfer to the ocean described in Reichl and Deike (2020). This model uses understanding obtained from theoretical simulations (Mostert and Deike, 2020; Berny, Deike et al, 2020) together with the WaveWatchIII model incorporating the effect of both wind and waves, and finds the bubble mediated gas transfer contributes to about 40% of the total CO2 flux into the ocean.

Goal ii. To apply this earth system model to the problem of prediction across time and space scales, from high resolution simulations of extreme events, to prediction of climate phenomena from seasons to centuries.

The model components developed under Goal i have been configured as forecasting systems to tackle high resolution simulations of extreme events and the prediction of climate phenomena on seasonal and longer timescales. A major effort of the past year has been the development of the System for High-resolution prediction on Earth-to-

Local Domain (SHiELD), combining the FV3 dynamical core with the GFDL cloud microphysics scheme for convective scale prediction (Zhou et al, 2019), which has been applied to prediction of continental scale convection (Harris et al, 2019) and tropical cyclones (Chen et al, 2019a,b). This high-resolution global convection-resolving model has been applied to skillful prediction of Atlantic Hurricanes using two-way nesting (Gao et al, 2019).

For seasonal to multidecadal prediction and projection, the new “Seamless system for Prediction and EArth system Research” (SPEAR) has been developed (Delworth et al, 2020) with significant input from CIMES researcher Feiyu Lu in the development of the coupled data assimilation. An ensemble-based ocean data assimilation system newly built for MOM6 ocean model provides the ocean initial conditions for seasonal predictions. An innovative bias-reduction scheme called Ocean Tendency Adjustment (OTA) is developed to reduce model drift. OTA reduces model drift in coupled predictions and improves seasonal prediction skill for applications such as El Niño-Southern Oscillation (ENSO). In future, SPEAR will be the main Princeton/GFDL tool for examining predictability on seasonal timescales, including for phenomena such as hydrological extremes.

Several CIMES researchers have employed GFDL’s earlier prediction model FLOR for seasonal predictability research, including North American precipitation biases (Johnson et al, 2020), and improvement of seasonal tropical cyclone predictions (Zhang et al, 2019). In Pu et al (2019) FLOR is used to examine the potential for seasonal forecasts of dust in the U.S. The method shows a forecast skill of about three months in advance for spring dustiness, and the model can capture about 71% of the dust event frequency variance over the Great Plains and 62% of the variance in the southwestern U.S.

Goal iii. To apply this earth system model to understand impacts of a changing climate on societally-relevant problems, including marine ecosystems, weather extremes, droughts and air quality.

GFDL earth system models are being applied by CIMES researchers to understand the impacts of a changing climate on a wide variety of societally-relevant problems, including marine ecosystems, air quality, weather extremes and infectious disease. Here, we highlight a few of the major accomplishments of the Cooperative Institute in the past year.

The coastal environment is increasingly threatened in a high CO2, urbanized world. Multiple stressors, including harmful algal blooms and oxygen deprivation, are projected to intensify owing to the combined effects of eutrophication and climate warming. As a

major terrestrial source of nitrogen to the ocean, rivers play a critical yet poorly quantified role in shaping both coastal ecosystems and global biogeochemical cycles. Examination of the historical terrestrial-freshwater Nitrogen budgets using the GFDL Land Model LM3-TAN shows that the tropics dominates the recent rise in nitrogen pollution, despite the tropics covering only 34% of global land area and receiving far lower amounts of fertilizers than the extratropics (Lee et al., 2019). The response of the global coastal ecosystem to long-term historical changes in river nitrogen loads was investigated by combining an enhanced-resolution (1/4°) global ocean-biogeochemical simulation (MOM6-COBALTv2) with dynamically changing river inputs from LM3-TAN. Elevated river nitrogen loads resulted in a 5.5% increase in the global coastal nitrogen inventory over the past half-century, accompanied by increases in net primary productivity (+4.8%) and carbon export flux to the seafloor (+6.8%) indicative of a higher benthic oxygen demand (Liu et al, 2020). GFDL-Princeton models are also being applied to seasonal forecasts of estuarine systems and to explore the role of small scale ocean circulation features on ocean oxygen content and on the distribution and future evolution of oxygen minimum zones (OMZ) (Busecke et al, 2019).

Air quality is strongly impacted by surface ozone and fine particulate air pollution. Both quantities are exacerbated by vegetation feedbacks during drought (Lin et al., 2019; Lin et al., 2020). Under drought stress, plants close their stomata to conserve water, consequently limiting the ozone uptake by vegetation (a component of dry deposition) and increasing surface ozone concentrations. Drought also increases the risk of fires and the resulting fine particulate air pollution. Such land-biosphere feed-backs are often overlooked in air quality projections, owing to a lack of process-based model formulations and observational constraints. New earth system model simulations developed at GFDL/CIMES show that reduced ozone removal by water-stressed vegetation can explain why European ozone pollution episodes have not decreased in recent decades, despite marked reductions in regional emissions of ozone precursors due to regulatory changes.

GFDL-Princeton models have been applied to examine several different aspects of extreme weather in a changing climate, including the impact of urbanization on compound heatwaves, extreme fire seasons in Alaska, and the slowing of tropical cyclone propagation speeds (and hence increasing societal risk) due to anthropogenically-induced changes in extra-tropical weather (Zhang et al, 2020).
An exciting new application of earth system models has been to understand the influence of climate on respiratory disease, including dengue, influenza and respiratory syncytial virus (Baker et al, 2019). Most recently the possible role of climate in the COVID-19 pandemic has been examined (Baker et al, 2020).

Goals iv and v accomplishments are described in the next section, on training and professional development/dissemination.

**26. What opportunities for training and professional development has the project provided?**

CIMES provides excellent training to both students and early career scientists in the Princeton Atmospheric and Oceanic Sciences Program. CIMES-funded students and postdocs receive scientific guidance from GFDL scientists, and have access to all education and career-development resources at Princeton University. During the past year, the project has provided support to 13 graduate students in the AOS graduate program, of whom 3 have obtained their PhDs during this reporting period. In addition to funding their research, the students' travel to professional meetings was also supported by this project. 40 postdoctoral and early career researchers were trained through participation in this project during the past year, of whom 4 transitioned to federal employment at GFDL during the reporting period.

The CIMES summer internship program is a corner-stone of our activities to broaden participation in earth system science. In summer 2019, seven undergraduate students spent 8-10 weeks at Princeton, working in collaboration with hosts based in GFDL (some of whom were also CIMES-funded researchers). The students, their home institutions, and their projects are as follows:

- Nana Yaa Takyia Afreh (Bronx Community College)- Spatial Distribution and Emission of Carbon Monoxide in the Atmosphere
- Nkeh Boh (Bronx Community College)- The Pangeo Project: A New and Better Approach for Working with Big Data
- Ana Bolivar (Florida International University) - Simulated Changes of North Atlantic Air-Sea Heat Flux Feedback in a Warm Climate
- Alex Chang (University of California, Berkeley) - An Analysis of Atmospheric Rivers Simulated in GFDL 50km Resolution AM4/CM4
- Maurizia De Palma (Kean University) - Assessing Ocean Acidification in Earth System Models
- Mariela de jesus Arceo Madriz (University of California, Merced) - Representation of Marine Organic Aerosols in the GFDL Earth System Model
- Alexandra Matthews (Rutgers, The State University of New Jersey) - Evaluating the Biological Carbon Pump in a Water Mass Framework

Six of seven of these interns are under-represented minorities. While in Princeton, the students also attended tutorials on computational skills, and a discussion on applying to graduate school, and gave a final presentation on their research to the GFDL/CIMES

community. Maurizia De Palma presented her research at the 2019 fall AGU meeting (funded by CIMES) and received an Outstanding Student Presentation award.

The CIMES Visiting Faculty Exchange Fellow program brings a faculty member from a minority serving institution to work with scientists at GFDL/Princeton. While no appointment was made under this program in 2019, 2018 Visiting Faculty Exchange Fellow, Dr. Monika Sikand, assistant professor at Bronx Community College, spent a several additional weeks at Princeton in 2019. Links between Bronx Community College (a minority serving institution) and Princeton continue through seminars presented to the BCC STEM club 2-3X per semester, by CIMES researchers, and through the continuing recruitment of BCC students to the CIMES internship program.

Additional educational and training activities undertaken through CIMES include: mentoring a high-school student Alex DiNovi by Nathaniel Johnson, guest lectures by Gan Zhang in the Princeton Geoscience Junior research colloquium, and lecturer participation at two international summer schools by Sonya Legg. CIMES funded researchers and students attended a large number of conferences and workshops, presenting their scientific results and benefiting from professional development activities on offer.

**27. How were the results disseminated to communities of interest?**
Participated as either the lead author (129 papers) or contributing author (57 papers) in the publication of 186 papers, 68 of which were in the peer reviewed literature. Participated in 94 talks and 20 poster sessions, of which 17 were host-paid invited presentations, at scientific conferences, workshops, and other exchanges of scientific ideas.

Several CIMES-funded researchers and students participated in the New Jersey Ocean Fun Days, a free annual event organized by the New Jersey Sea Grant on May 18th/19th 2019, providing hands-on demonstrations of ice-berg melting and ocean acidification to New Jersey families. Regular seminars by CIMES researchers and students at the Bronx Community College STEM club serve to communicate earth system science results to undergraduate students from historically under-served communities.

Other community outreach activities include: Science Fair Volunteer Judge at Brooks Crossing and Deans Elementary School (Feiyu Lu); extensive public outreach on general climate science as part of Climate Up Close, including 10 town halls on climate science in August in central Pennsylvania and 4 town halls in January in Greater Philadelphia (Nadir Jeevanjee); a public lecture on air-sea interactions at Princeton

Public Library in June 2019 (Luc Deike); participation in the 2019 Spring Forecasting Experiment held by the NOAA Hazardous Weather Testbed from May 20th through May 24st at the National Weather Center in Norman, Oklahoma (Kai-Yuan Cheng); volunteer engagement at the Independence Seaport Museum in Philadelphia (Tsung-Lin Hsieh); writing for the NOAA climate.gov ENSO Blog (https://www.climate.gov/news-features/department/enso-blog) (Nathaniel Johnson).

**28. What do you plan to do during the next reporting period to accomplish the goals and objectives?**

In the next year, CIMES researchers will continue to i. contribute to the development of NOAA-GFDL's earth system models, ii. apply these models to problems of prediction across time and space scales, from extreme events to climate phenomena, and iii. apply these models to understand the impacts of a changing climate on societally-relevant problems. Additionally, CIMES will continue to iv. train the next generation of leaders in earth system science and v. develop a more diverse workforce by broadening participation in earth system science.

Specific plans for the next year are as follows:

Goal i: CIMES researchers will continue to contribute to the development of the MOM6 ocean model, the FV3 atmospheric model, the LM4 land surface model, the COBALT ocean biogeochemistry model, the development of a coupled ice-shelf/ocean capability, and models of atmospheric chemistry. A major effort of the next year will be CIMES participation in several multi-institutional Climate Process Teams, designed to translate understanding of fundamental processes into improved climate model parameterization and representation. This round of climate process teams is focused on: Land energy and moisture exchanges; the atmospheric boundary layer and convection; ocean transport and eddy energy. Several CIMES researchers have recently been appointed to work on these climate process teams and they will be contributing to improved parameterizations in GFDL ocean, atmospheric and land-surface models. An additional new area of process research funded by CIMES is coastal microscale dynamics, driven by surface temperature differences between land and ocean.

A developing area of CIMES research is machine learning, which is currently being applied to the detection of oceanic dynamical regimes, by applying clustering methods to climate model output. Several CIMES researchers will be exploring the use of machine learning for improvement of GFDL models in the coming year.

Goal ii: Development of the high-resolution global prediction system SHiELD will continue, including examining the impact of newly-developed cloud microphysics,

applying the model to real-time hurricane predictions and severe weather events, and to subseasonal forecasts of phenomena such as MJO teleconnections, the extratropical transition of tropical cyclones, and atmospheric rivers. The SPEAR forecasting system for subseasonal to decadal prediction will continue to be improved and used to examine predictability of a range of climate phenomena.

Goal iii. The newly-completed ESM4 earth system model will be applied to a wide variety of societally-relevant problems in earth system science, including: land-biosphere feedbacks on air pollution extremes under future climate scenarios; projections of particulate matter air quality in the Western USA under climate warming; dependence of temperature extremes on urbanization; fish habitat suitability in the North Atlantic; dynamic management of living marine resources; extreme rainfall and flooding in a changing climate.

Goal iv: CIMES will continue to train the next generation of researchers in earth system science. Specifically, we expect to continue to fund about 8-10 PhD students per year in the Atmospheric and Oceanic Sciences program, and will continue with an annual open search for postdoctoral researchers through the AOS program, as well as hiring postdoctoral researchers and associate research scholars regularly through the year on CIMES funds targeted for specific projects.

Goal v: CIMES will continue to broaden participation in earth system science. The primary mechanism for this is the CIMES student internship program. This year 6 students were selected for the 2020 summer program; however, due to the COVID-19 crisis, 3 students have elected to postpone until 2021, while 3 students will conduct their internships remotely this summer. We will not have a Visiting Faculty Exchange this summer, but should funds permit, intend to advertise for next year during fall 2020. CIMES researchers will be encouraged to participate in outreach activities, such as the New Jersey Ocean Fun Days, which have been postponed to fall 2020.

## PRODUCTS

### 29. Publications, conference papers, and presentations

The CIMES Publications Report, attached, has been submitted to NOAA's Institutional Repository. (see attached)

Conferences, Posters and other presentations (see attached)

Luc Deike chaired a session at ocean sciences on the role of wave breaking in ocean-atmosphere interaction.

Luc Deike participated in the fall 2019 SOLAS working group and workshop.

Xi Chen: MS19 - Developments of Climate and Weather Models on Modern Supercomputers, The Platform for Advanced Scientific Computing (PASC) Conference, Jun. 2019 (co-chair)

Khaled Ghannam: A workshop for the Climate process team (CPT) including teams from NASA-GEOS, DOE -E3SM, and GFDL was conducted as part of this project on March 30, 2020. He is leading the parametrization group of this project.

**Publication Request Template for CI's**

FY20 Research Performance Progress Report Request

| CI Name | PI Name / Author Names | Publication Date | Publication Title | Published In (Journal Name, volume and page number) | Type of Publication | Citation No. (Digital Object Identifier) | Research Support Award No. | CI Lead Author | NOAA Lead Author | Other Lead Author |
|---|---|---|---|---|---|---|---|---|---|---|
| CIMES | Adcroft, A., Anderson, W., Balaji, V., Blanton, C., et al. | October 2019 | The GFDL Global Ocean and Sea Ice Model OM4.0: Model Description and Simulation Features | Journal of Advances in Modeling Earth Systems, 11(10), 3167-3211 | Journal Article | doi:10.1029/2019MS001726 | NA18OAR4320123 | X | | |
| CIMES | Ayarzagüena, B., Charlton-Perez, A. J., Butler, A. H., Hitchcock, P., Simpson, I.R., Polvani, L. M., et al. | March 2020 | Uncertainty in the response of sudden stratospheric warmings and stratosphere-troposphere coupling to quadrupled CO2 concentrations in CMIP6 models | Journal of Geophysical Research: Atmospheres, 125, e2019JD032345 | Journal Article | doi:10.1029/2019JD032345 | NA18OAR4320123 | | | X |
| CIMES | Baker, R.E., Mahmud, A.S., Wagner, C.E. et al. | Dec. 2019 | Epidemic dynamics of respiratory syncytial virus in current and future climates | Nat Commun 10, 5512 | Journal Article | doi:10.1038/s41467-019-13562-y | NA18OAR4320123 | X | | |
| CIMES | Baker, R.E., Yang, Wenchang, Vecchi, Gabriel A., Metcalf, CJE, Grenfell, Bryan T. | April 2020 | Susceptible supply limits the role of climate in the COVID-19 pandemic | medRxiv 2020.04.03.20052787; doi: https://doi.org/10.1101/2020.04.03.20052787 | Journal Article | doi:10.1101/2020.04.03.20052787 | NA18OAR4320123 | X | | |
| CIMES | Bender, Morris A., Timothy Marchok, Robert E Tuleya, I Ginis, V Tallapragada, and S J Lord | Sept. 2019 | Hurricane Model Development at GFDL: A Collaborative Success Story from an Historical Perspective | Bulletin of the American Meteorological Society, 100(9), 1725-1736 | Journal Article | doi:10.1175/BAMS-D-18-0197.1 | NA18OAR4320123 | X | | |
| CIMES | Berny, A., Deike, L., Seon, T., and Popinet, S. | March 2020 | Role of all jet drops in mass transfer from bursting bubbles | Phys. Rev. Fluids, 5(3), 033605 | Journal Article | doi:10.1103/PhysRevFluids.5.033605 | NA18OAR4320123 | | | X |
| CIMES | Busecke, J.J.M., Resplandy, L., Dunne, J.P | June 2019 | The Equatorial Undercurrent and the Oxygen Minimum Zone in the Pacific | Geophysical Research Letters 46(12), 6716–6725 | Journal Article | doi:10.1029/2019GL082692 | NA18OAR4320123 | X | | |
| CIMES | Chen, Jan-Huey, et al., Linjiong Zhou | April 2019 | Advancements in Hurricane Prediction With NOAA's Next-Generation Forecast System | Geophysical Research Letters, 46(8), 4495-4501 | Journal Article | doi:10.1029/2019GL082410 | NA18OAR4320123 | | | X |
| CIMES | Chen, Jan-Huey, Shian-Jiann Lin, Linjiong Zhou, et al. | Sept. 2019 | Evaluation of Tropical Cyclone Forecasts in the Next Generation Global Prediction System | Mon. Wea. Rev.. 147, 3409-3428 | Journal Article | doi:10.1175/MWR-D-18-0227.1 | NA18OAR4320123 | | | X |
| CIMES | Clark SK, Ming Y, Adames AF | March 2020 | Monsoon Low Pressure System–Like Variability in an Idealized Moist Model | Journal of Climate, 33(6), 2051-2074 | Journal Article | doi: 10.1175/JCLI-D-19-0289.1 | NA18OAR4320123 | X | | |
| CIMES | Delworth, T. L., Cooke, W. F., Adcroft, A., Bushuk, M., Chen, J.-H., Dunne, K. A., et al. | March 2020 | SPEAR: The next generation GFDL modeling system for seasonal to multidecadal prediction and projection | Journal of Advances in Modeling Earth Systems, 12(3), e2019MS001895 | Journal Article | doi:10.1029/2019MS001895 | NA18OAR4320123 | | X | |
| CIMES | Fan, S., P. Ginoux, C.J. Semen, L.G. Silvers, and M. Zhao | Novembr 2019 | Towards improved cloud-phase simulation with a mineral dust and temperature-dependent parameterization for ice nucleation in mixed-phase clouds | J. Atmos. Sci, 76(11), 3655–3667 | Journal Article | doi:10.1175/JAS-D-18-0287.1 | NA18OAR4320123 | | X | |
| CIMES | Fu, Q., R. H. White, M. Wang, B. Alexander, S. Solomon, A. Gettelman, D. S. Battisti, and P. Lin | March 2020 | The Brewer-Dobson circulation during the Last Glacial Maximum | Geophys. Res. Lett., 47(5), e2019GL086271 | Journal Article | doi:10.1029/2019GL086271 | NA18OAR4320123 | | | X |
| CIMES | Fu, Q., S. Solomon, H. A. Pahlavan and P. Lin | Novembr 2019 | Observed changes in BrewerDobson circulation for 1980-2018 | Environ. Res. Lett., 14, 114026 | Journal Article | doi:10.1088/1748-9326/ab4de7 | NA18OAR4320123 | | | X |
| CIMES | Gao, K., J.-H. Chen, L. Harris, Y. Sun and S.-J. Lin | August 2019 | Skillful Prediction of Monthly Major Hurricane Activity in the North Atlantic with Two-way Nesting | Geophysical Research Letters, 46(15), 9222-9230 | Journal Article | doi:10.1029/2019GL083526 | NA18OAR4320123 | X | | |
| CIMES | Gliatto MT, Held IM | March 2020 | Overtransmission of Rossby Waves at a Lower-Layer Critical Latitude in the Two-Layer Model | Journal of the Atmospheric Sciences, 77(3), 859-870 | Journal Article | doi:10.1175/JAS-D-19-0055.1 | NA18OAR4320123 | X | | |
| CIMES | Harris, Lucas, et al., Linjiong Zhou, et al. | June 2019 | Explicit prediction of continental convection in a skillful variable-resolution global model | J. Adv. Model. Earth Syst.. 11(6), 1847-1869 | Journal Article | doi:10.1029/2018MS001542 | NA18OAR4320123 | | X | |
| CIMES | He, Bian, et al., Linjiong Zhou, et al. | July 2019 | CAS FGOALS-f3-L Model datasets for CMIP6 Historical Atmospheric Model Intercomparison Project Simulation | Adv. Atmos. Sci.. 36, 771–778 | Journal Article | doi:10.1007/s00376-019-9027-8 | NA18OAR4320123 | | | X |
| CIMES | Held, I. M., Guo, H., Adcroft, A., Dunne, J. P., et al. | Novembr 2019 | Structure and Performance of GFDL's CM4.0 Climate Model | Journal of Advances in Modeling Earth Systems, 11(11), 3691-3727 | Journal Article | doi:10.1029/2019MS001829 | NA18OAR4320123 | | | X |
| CIMES | Heming, J T., F Prates, and Morris A Bender, et al. | Dec. 2019 | Review of Recent Progress in Tropical Cyclone Track Forecasting and Expression of Uncertainties | Tropical Cyclone Research and Review, 8(4), 181-218 | Journal Article | doi:10.1016/j.tcrr.2020.01.001 | NA18OAR4320123 | | | X |
| CIMES | Hsieh, T.-L., S. T. Garner, and I. M. Held | April 2020 | Hypohydrostatic simulation of a quasi-steady baroclinic cyclone | Journal of the Atmsopheric Sciences, 77(4), 1415–1428 | Journal Article | doi:10.1175/JAS-D-19-0300.1 | NA18OAR4320123 | X | | |
| CIMES | Jansen, M. F., Adcroft, A., Khani, S., Kong, H. | August 2019 | Toward an Energetically Consistent, Resolution Aware Parameterization of Ocean Mesoscale Eddies | Journal of Advances in Modeling Earth Systems, 11(8), 2844–2860 | Journal Article | doi:10.1029/2019MS001750 | NA18OAR4320123 | | | X |
| CIMES | Jeevanjee, Nadir, and Stephan Fueglistaler | February 2020 | Simple spectral models for atmospheric radiative cooling | Journal of the Atmospheric Sciences 77(2), 479-497 | Journal Article | doi:10.1175/JAS-D-18-0347.1 | NA18OAR4320123 | X | | |
| CIMES | Jeevanjee, Nadir, and Stephan Fueglistaler | February 2020 | On the cooling-to-space approximation. | Journal of the Atmospheric Sciences 77(2), 465-478 | Journal Article | doi:10.1175/JAS-D-18-0352.1 | NA18OAR4320123 | X | | |
| CIMES | Johnson, N. C., D. J. Amaya, Q. Ding, Y. Kosaka, H. Tokinaga, and S.-P. Xie | May 2020 | Multidecadal modulations of key metrics of global climate change | Global and Planetary Change, 188, 103149 | Journal Article | doi:10.1016/j.gloplacha.2020.103149 | NA18OAR4320123 | X | | |
| CIMES | Johnson, N. C., L. Krishnamurthy, A. T. Wittenberg, B. Xiang, G. A. Vecchi, S. Kapnick, and S. Pascale | March 2020 | The impact of sea surface temperature biases on North American precipitation in a high-resolution climate model | Journal of Climate, 33(6), 2427-2447 | Journal Article | doi:10.1175/JCLI-D-19-0417.1 | NA18OAR4320123 | X | | |
| CIMES | Johnson, N. C., M. L'Heureux, C.-H. Chang, and Z.-Z. Hu | October 2019 | On the delayed coupling between ocean and atmosphere in recent weak El Niño episodes | Geophysical Research Letters, 46(20), 11,416-11,425 | Journal Article | doi:10.1029/2019GL084021 | NA18OAR4320123 | X | | |
| CIMES | Khani, S., Jansen, M. F., Adcroft, A. | Dec. 2019 | Diagnosing subgrid mesoscale eddy fluxes with and without topography | Journal of Advances in Modeling Earth Systems, 11(12), 3995-4015 | Journal Article | doi:10.1029/2019MS001721 | NA18OAR4320123 | | | X |
| CIMES | Lecoanet, Daniel, and Nadir Jeevanjee | Dec. 2019 | Entrainment in Resolved, Dry Thermals | Journal of the Atmospheric Sciences 76(12), 3785-3801. | Journal Article | doi:10.1175/JAS-D-18-0320.1 | NA18OAR4320123 | | | X |
| CIMES | Lee M, Shevliakova E, Stock C, Malyshev, S., Milly P C D | March 2019 | Prominence of the tropics in the recent rise of global nitrogen pollution | Nature Communications, 10, 1437 | Journal Article | doi:10.1038/s41467-019-09468-4 | NA18OAR4320123 | X | | |

| CI Name | PI Name / Author Names | Publication Date | Publication Title | Published In (Journal Name, volume and page number) | Type of Publication | Citation No. (Digital Object Identifier) | Research Support Award No. | CI Lead Author | NOAA Lead Author | Other Lead Author |
|---|---|---|---|---|---|---|---|---|---|---|
| CIMES | Lees, A., and Aluie, H. | May 2019 | Baropycnal Work: A Mechanism for Energy Transfer Across Scales | Fluids, 4(2), 92 | Journal Article | doi:10.3390/fluids4020092 | NA18OAR4320123 | | | X |
| CIMES | Li, Q., Reichl, B. G., Fox-Kemper, B., Adcroft, A. J. | Novembr 2019 | Comparing Ocean Surface Boundary Vertical Mixing Schemes Including Langmuir Turbulence | Journal of Advances in Modeling Earth Systems, 11(11), 3545-3592 | Journal Article | doi:10.1029/2019MS001810 | NA18OAR4320123 | | | X |
| CIMES | Lin, Meiyun, Larry W Horowitz, Yuanyu Xie, Fabien Paulot, Sergey Malyshev, Elena Shevliakova et al. | In-Press | Vegetation feedbacks during drought exacerbate ozone air pollution extremes in Europe | Nature Climate Change | Journal Article | doi:10.1038/s41558-020-0743-y | NA18OAR4320123 | X | | |
| CIMES | Lin, Meiyun, Sergey Malyshev, Elena Shevliakova, Fabien Paulot, Larry W Horowitz S Fares, T N Mikkelsen, and L Zhang | October 2019 | Sensitivity of ozone dry deposition to ecosystem-atmosphere interactions: A critical appraisal of observations and simulations | Global Biogeochemical Cycles, 33(10), 1264-1288 | Journal Article | doi:10.1029/2018GB006157 | NA18OAR4320123 | X | | |
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