

Getting Started with ACLIM Bering10K ROMSNPZ Level3 indices (FOR INTERNAL ACLIM USE ONLY)

Kirstin Holsman

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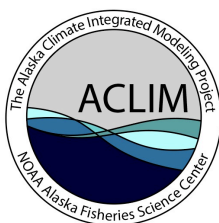


Figure 1: .

Getting Started with ACLIM Bering10K ROMSNPZ Level3 indices
(FOR INTERNAL ACLIM USE ONLY)

ACLIM Repo: github.com/kholsman/ACLIM2

Repo maintained by:

Kirstin Holsman
 Alaska Fisheries Science Center
 NOAA Fisheries, Seattle WA
kirstin.holsman@noaa.gov
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1. ACLIM data and code Overview

This is an overview of ACLIM plotting code and “canned” Rdata files generated from the downscaled ROM-SNPZ modeling work ACLIM modelers Drs. Hermann, Cheng, Kearney, Pilcher, and Aydin. Dr. Kelly Kearney has recently dedicated significant time and energy towards organizing and documenting the ROM-SNPZ output, especially as it pertains to the ACLIM project. We strongly recommend reviewing this **documentation** before using the data in order to understand the origin of the indices and their present level of skill and validation, which varies considerably across indices and in space and time.

The Bering10K ROMSNPZ documentation can be accessed on the main **documentation** webpage. The webpage is maintained by Kelly Kearney and regularly updated with new documentation, including the following core documents (also linked in the **00_ACLIM_shared/02_Data** folder):

The Bering10K Dataset documentation: A pdf describing the dataset, including:

1. A description of the various simulations (base model versions, parent model forcing datasets, and biological modules) and the output naming scheme for each.
2. A tutorial on working with the curvilinear, sigma-coordinate ROMS spatial grid, aimed at those who will be working with data on the native grid.
3. An overview of the ACLIM index dataset; this is a set of time series derived from the Bering10K output and intended for Alaska Climate Integrated Modeling (ACIM) collaborators.

Bering10K Simulaton Variables: A spreadsheet listing all simulations and the archived output variables associated with each, updated periodically as new simulations are run or new variables are made available. Note that this includes both data available on both public and private servers (see below). Please also see the Literature page for a list scientific publications related to the model, including model description and skill assessment.

1.1. Downscaled models and carbon scenarios

The full ACLIM “suite” of models include are summarized in the following table of downscaled models based on boundary conditions forced by General Circulation Models (GCM) run under Coupled Model Intercomparison Project (CMIP) phase 5 (5th IPCC Assessment Report) or phase 6 (6th IPCC Assessment Report; “AR”) global carbon mitigation scenarios. For full details see the Kearney 2021 Tech. Memo.

Table 1: Summary of ROMSNPZ downscaled model runs

CMIP	GCM	Scenario	Def	Years	Model	Status	Source
5	GFDL	RCP 4.5	Med. mitigation	2006 - 2099	H16	ACLIM/FATE	Public
5	GFDL	RCP 8.5	High baseline	2006 - 2099	H16	ACLIM/FATE	Public
5	GFDL	RCP 8.5bio*	High baseline	2006 - 2099	H16	ACLIM/FATE	Public
5	MIROC	RCP 4.5	Med. mitigation	2006 - 2099	H16	ACLIM/FATE	Public
5	MIROC	RCP 8.5	High baseline	2006 - 2099	H16	ACLIM/FATE	Public
5	CESM	RCP 4.5	Med. mitigation	2006 - 2099	H16	ACLIM/FATE	Public
5	CESM	RCP 8.5	High baseline	2006 - 2080	H16	ACLIM/FATE	Public

CMIP	GCM	Scenario	Def	Years	Model	Status	Source
5	CESM	RCP 8.5bio*	High baseline	2006 - 2099	H16	ACLIM/FATE	Public
	CORECFS	Reanalysis	Hindcast	1970 - 2018	H16	ACLIM	Public
	CORECFS	Reanalysis	Hindcast	1970 - 2020	K20	ACLIM2/RTAP	Public
6	CESM	SSP585	High baseline	2014 - 2099	K20P19	ACLIM2/RTAP	Embargo
6	CESM	SSP126	High Mitigation	2014 - 2099	K20P19	ACLIM2/RTAP	Embargo
6	CESM	Historical	Historical	1980 - 2014	K20P19	ACLIM2/RTAP	Embargo
6	GFDL	SSP585	High baseline	2014 - 2099	K20P19	ACLIM2/RTAP	Embargo
6	GFDL	SSP126	High Mitigation	2014 - 2099	K20P19	ACLIM2/RTAP	Embargo
6	GFDL	Historical	Historical	1980 - 2014	K20P19	ACLIM2/RTAP	Embargo
6	MIROC	SSP585	High baseline	2014 - 2099	K20P19	ACLIM2/RTAP	Embargo
6	MIROC	SSP126	High Mitigation	2014 - 2099	K20P19	ACLIM2/RTAP	Embargo
6	MIROC	Historical	Historical	1980 - 2014	K20P19	ACLIM2/RTAP	Embargo

*“bio” = nutrient forcing on boundary conditions

1.2. Guildlines for use and citation of the data

It is strongly recommended that you include at least one (ideally multiple) authors from the ROMSNPZ team (Drs. Hermann, Cheng, Kearney, Pilcher) as co-author on your paper if you are linking to this data, this is especially the case for the CMIP6 data. There are multiple spatial and temporal caveats that are best described in discussions with the authors of these data and inclusion as co-authors will facilitate appropriate application and interpretation of the ROMSNPZ data.

1.2.1. The Bering 10K Model (v. H16) with 10 depth layers:

The H16 model is the original BSIERP era 10 depth layer model with a 10 Km grid. This version was used in ACLIM1.0 to dynamically downscaled 3 global circulation models (GCMs) under two CMIP5 representative carbon pathways (RCP): RCP 4.5 or “moderate global carbon mitigation” and RCP 8.5 “high baseline global carbon emissions”. Details of the model and projections can be found in:

- **Hindcast (1979-2012; updated to 2018 during ACLIM 1.0):**

Hermann, A. J., G. A. Gibson, N. A. Bond, E. N. Curchitser, K. Hedstrom, W. Cheng, M. Wang, E. D. Cokelet, P. J. Stabeno, and K. Aydin. 2016. Projected future biophysical states of the Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography 134:30–47.doi:10.1016/j.dsr2.2015.11.001

- **Projections of the H16 10 layer model using CMIP5 scenarios:**

Hermann, A. J., G. A. Gibson, W. Cheng, I. Ortiz, K. Aydin, M. Wang, A. B. Hollowed, K. K. Holsman, and S. Sathyendranath. 2019. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES Journal of Marine Science 76:1280–1304.doi:10.1093/icesjms/fsz043)

1.2.2. The Bering 10K Model (v. K20) with 30 depth layers and other advancements:

The Bering10K model was subsequently updated by Kearney et al. 2020 (30 layer and other NPZ updates) and Pilcher et al.2019 (OA and O2 dynamics) and this version is used for the projections in ACLIM2.0 under CMIP6.

- **Hindcast (1979-2020 hindcast with OA dynamics used in ACLIM 2.0):**

Kearney, K., A. Hermann, W. Cheng, I. Ortiz, and K. Aydin. 2020. A coupled pelagic-benthic-sympagic biogeochemical model for the Bering Sea: documentation and validation of the BESTNPZ

model (v2019.08.23) within a high-resolution regional ocean model. Geoscientific Model Development 13:597–650.

Pilcher, D. J., D. M. Naiman, J. N. Cross, A. J. Hermann, S. A. Siedlecki, G. A. Gibson, and J. T. Mathis. 2019. Modeled Effect of Coastal Biogeochemical Processes, Climate Variability, and Ocean Acidification on Aragonite Saturation State in the Bering Sea. *Frontiers in Marine Science* 5:1–18.

- **Projections of the K20 30 layer model using CMIP6 scenarios:**

Hermann et al. in prep

Cheng et al. in prep

Kearney et al. in prep

Pilcher et al. in prep (CMIP5 K20 projections) (ACLIM indices avail by permission only)

2. Get ACLIM code (Step 1)

IMPORTANT

The ACLIM indices and ROMSNPZ simulations are stored as netcdf files (.nc) format in the Data folder of the ACLIM shared google drive (section 2.3) or available on the new PMEL web-based portal (see section 2.2 below). Please note that while the CMIP5 set is now public (Hermann et al. 2019) **the CMIP6 suite is under embargo for QAQC and should not be shared outside of the ACLIM group**. Al, Wei, Kelly, Darren, and Kerim are in the process of synthesizing and publishing the CMIP6 data (goal is spring 2021 for submission), following those publications the data will be made accessible to the public via the PMEL data portal, as is the case for the CMIP5 data and public hindcasts.

First clone the **ACLIM ROMSNPZ Repo: github.com/kholsman/ACLIM2**. This code will load and explore the netcdf (.nc) files in R and produce plots and standardized outputs for ACLIM analyses. Some standardized tools are included as functions in this repo including spatial averaging for seasonal, monthly and annual indices (e.g., Fall zooplankton biomass), as well as bias correction for projections (see Holsman et al. 2020 and Reum et al. 2020 for ACLIM 1.0 bias correction methods). The repo also includes a Rshiny interactive exploratory graphing tool which can be viewed online **at this link**.

2.1 Option 1: Use R to download from ACLIM2 github repo:

```
# Specify the download directory
main_nm      <- "ACLIM2"
download_path <- path.expand("~/desktop")
dest_fldr    <- file.path(download_path,main_nm)

url          <- "https://github.com/kholsman/ACLIM2/archive/main.zip"
dest_file    <- file.path(download_path,paste0(main_nm,".zip"))
download.file(url=url, destfile=dest_file)

# unzip the .zip file
setwd(download_path)
unzip (dest_file, exdir = "./",overwrite = T)

#rename the unzipped folder from ACLIM2-main to ACLIM2
file.rename(paste0(main_nm,"-main"), main_nm)
setwd(main_nm)
```

If you have Rstudio installed you can double click on the ACLIM2.Rproj and use Rstudio to manage your plotting and files (recommended).

2.2 Option 2: Manually download from ACLIM2 github repo

Select **Download ZIP** from the upper right hand side of the repo page :github.com/kholsman/ACLIM2 and save it to your local directory: ~[YOURPATH]/ACLIM2.

The screenshot shows the GitHub repository page for `kholsman/ACLIM2`. At the top, there are navigation links: Projects, Wiki, Security, Insights, and Settings. Below these, there are buttons for 'Go to file', 'Add file', and 'Code'. A 'Clone' modal window is open, showing options to clone the repository using HTTPS, SSH, or GitHub CLI. A message in the modal states: 'You don't have any public SSH keys in your GitHub account. You can [add a new public key](#), or try cloning this repository via HTTPS.' Below this, there is a text input field containing 'git@github.com:kholsman/ACLIM2.0.g' and a 'Use a password-protected SSH key.' checkbox. There are also buttons for 'Open with GitHub Desktop' and 'Download ZIP'. On the right side of the page, there are sections for 'About', 'Releases', 'Packages', and 'Languages'. The 'About' section has a 'No description provided' message. The 'Releases' section has a 'No releases published' message. The 'Packages' section has a 'No packages published' message. The 'Languages' section shows a bar chart for 'Text' (100%).

File/Folder	Action	Time
in Holsman update readme		
ij.user	update readme	
	setup repo	
	setup repo	
Store	setup repo	
tributes	setup repo	
nore	update readme	
M2.0.Rproj	setup repo	
M_data_Overview.Rmd	update readme	
M_data_Overview.aux	update readme	1 minute ago
M_data_Overview.log	update readme	1 minute ago
M_data_Overview.md	update readme	1 minute ago

3. Get Data (Step 2)

The naming convention of the folders is: `B10K-[ROMSNPZ version]_[CMIP]_[GCM]_[carbon scenario]`. For example, the CMIP5 set of indices was downscaled using the H16 (Hermann et al. 2016) version of the ROMSNPZ. Three models were used to force boundary conditions(MIROC, CESM, and GFDL) under 2 carbon scenarios RCP 8.5 and RCP 4.5. So to see an individual trajectory we might look in the level3 (timeseries indices) folder under `B10K-H16_CMIP5_CESM_rcp45`, which would be the B10K version H16 of the CMIP5 CESM model under RCP4.5.

3.2 Public web-based ACLIM data (hindcasts & CMIP5 projections)

The naming convention of the folders is: `B10K-[ROMSNPZ version]_[CMIP]_[GCM]_[carbon scenario]`. For example, the CMIP5 set of indices was downscaled using the H16 (Hermann et al. 2016) version of the ROMSNPZ. Three models were used to force boundary conditions(MIROC, CESM, and GFDL) under 2 carbon scenarios RCP 8.5 and RCP 4.5. So to see an individual trajectory we might look in the level3 (timeseries indices) folder under `B10K-H16_CMIP5_CESM_rcp45`, which would be the B10K version H16 of the CMIP5 CESM model under RCP4.5.

This option is available for Level3 and Level 2 CMIP5 public data, it is not yet available for the embargoed CMIP6 data but eventually will be used to host that as well.

The ROMSNPZ team has been working with Roland Schweitzer and Peggy Sullivan to develop the ACLIM Live Access Server (LAS) to publicly host the published CMIP5 hindcasts and downscaled projections. This server is in beta testing phase and can be accessed at the following links:

- LAS custom ROMSNPZ data exploration, query, mapping, and plotting tool
- ERDAPP ACLIM data access tool
- THREDDS ACLIM direct access to Level 2 and 3 netcdf files

2.2.1. Grab L2 and L3 data from ACLIM Thredds server

The code below will step through downloading L3 data from the Thredds server as well as quering the L2 (large files) on the server and saving a subset of the data to your local ~/ACLIM2/Data/out folder.

First let's get the workspace set up, will we step through an example downloading the hindcast and a single projection (CMIP5 MIROC rcp8.5) but you can loop the code below to download the full set of CMIP5 projections.

```
# first load packages and setup:
tmstp <- format(Sys.time(), "%Y_%m_%d")
main <- getwd() # should be your local path e.g., "~/GitHub_new/ACLIM2"

# loads packages, data, and setup:
source("R/make.R")

# create a directory for our new indices
if(!dir.exists("Data/in/Newest/Rdata")) dir.create("Data/in/Newest/Rdata")

# specify the root URL:
ACLIM_data_url <- "https://data.pmel.noaa.gov/aclim/thredds/"

# define the thredds url
aclim_thredds <- "https://data.pmel.noaa.gov/aclim/thredds/"
```

Let's take a look at the available datasets:

```
# preview the datasets on the server:
url_list <- tds_list_datasets(thredds_url = ACLIM_data_url)

#display the full set of datasets:
cat(paste(url_list$dataset, "\n"))
```

```
## Constants/
## B10K-H16_CMIP5_CESM_BIO_rcp85/
## B10K-H16_CMIP5_CESM_rcp45/
## B10K-H16_CMIP5_CESM_rcp85/
## B10K-H16_CMIP5_GFDL_BIO_rcp85/
## B10K-H16_CMIP5_GFDL_rcp45/
## B10K-H16_CMIP5_GFDL_rcp85/
## B10K-H16_CMIP5_MIROC_rcp45/
## B10K-H16_CMIP5_MIROC_rcp85/
## B10K-H16_CORECFS/
## B10K-K20_CORECFS/
```

```
## files/
```

First we will explore the Level 2 bottom temperature data on the ACLIM Thredds server using the H16 hindcast and the H16 (CMIP5) projection for MIROC under rcp8.5. The first step is to get the data urls:

```
# define the simulation to download:
cmip <- "CMIP5"      # Coupled Model Intercomparison Phase
GCM  <- "MIROC"      # Global Circulation Model
rcp  <- "rcp85"      # future carbon scenario
mod  <- "B10K-H16"   # ROMSNPZ model
hind <- "CORECFS"    # Hindcast

# define the projection simulation:
proj <- paste0(mod,"_",cmip,"_",GCM,"_",rcp)
hind <- paste0(mod,"_",hind)

# get the url for the projection and hindcast datasets:
proj_url    <- url_list[url_list$dataset == paste0(proj,"/"),]$path
hind_url    <- url_list[url_list$dataset == paste0(hind,"/"),]$path

# preview the projection and hindcast data and data catalogs (Level 1, 2, and 3):
proj_datasets <- tds_list_datasets(thredds_url = proj_url)
hind_datasets <- tds_list_datasets(thredds_url = hind_url)

# get url for the projection and hindcast Level 2 and Level 3 catalogs
proj_l2_cat <- proj_datasets[proj_datasets$dataset == "Level 2/",$path]
proj_l3_cat <- proj_datasets[proj_datasets$dataset == "Level 3/",$path]
hind_l2_cat <- hind_datasets[hind_datasets$dataset == "Level 2/",$path]
hind_l3_cat <- hind_datasets[hind_datasets$dataset == "Level 3/",$path]
hind_l2_cat
```

```
## [1] "https://data.pmel.noaa.gov/aclim/thredds/B10K-H16_CORECFS/Level2.html"
```

Now that we have the URLs let's take a look at the available Level2 datasets (currently temperature only, other variables available by request to Kelly Kearney:

- Bottom 5m : bottom water temperature at 5 meters
- Surface 5m : surface water temperature in the first 5 meters
- Integrated : Integrated water column averages for various NPZ variables

```
# preview the projection and hindcast Level 2 datasets:
proj_l2_datasets <- tds_list_datasets(proj_l2_cat)
hind_l2_datasets <- tds_list_datasets(hind_l2_cat)
proj_l2_datasets$dataset
```

```
## [1] "Bottom 5m" "Surface 5m" "Integrated"
```

```
# get url for bottom temperature:
proj_l2_BT_url <- proj_l2_datasets[proj_l2_datasets$dataset == "Bottom 5m",$path]
hind_l2_BT_url <- hind_l2_datasets[hind_l2_datasets$dataset == "Bottom 5m",$path]
proj_l2_BT_url
```

```
## [1] "https://data.pmel.noaa.gov/aclim/thredds/B10K-H16_CMIP5_MIROC_rcp85/Level2.html?dataset=B10K-H16"
```

We can't preview the Level 3 datasets in the same way but they are identical to those in the google drive and include two datasets

- ACLIMsurveyrep_B10K-H16_CMIP5_CESM_BIO_rcp85.nc : NMFS Groundfish summer NBS and EBS survey replicated values for 60+ variables

- ACLIMregion_B10K-H16_CMIP5_CESM_BIO_rcp85.nc : weekly strata averages for 60+ variables

weekly_vars # list of possible variables in the ACLIMregion_files

```
## [1] "region_area"          "Ben"                "DetBen"
## [4] "Hsbl"                 "IceNH4"              "IceN03"
## [7] "IcePhL"               "aice"                "hice"
## [10] "shflux"               "ssflux"              "Cop_integrated"
## [13] "Cop_surface5m"        "Eup0_integrated"     "Eup0_surface5m"
## [16] "EupS_integrated"      "EupS_surface5m"      "Iron_bottom5m"
## [19] "Iron_integrated"      "Iron_surface5m"      "Jel_integrated"
## [22] "Jel_surface5m"        "MZL_integrated"      "MZL_surface5m"
## [25] "NCa0_integrated"      "NCa0_surface5m"      "NCaS_integrated"
## [28] "NCaS_surface5m"       "NH4_bottom5m"        "NH4_integrated"
## [31] "NH4_surface5m"        "N03_bottom5m"        "N03_integrated"
## [34] "N03_surface5m"        "PhL_integrated"      "PhL_surface5m"
## [37] "PhS_integrated"       "PhS_surface5m"       "prod_Cop_integrated"
## [40] "prod_Eup0_integrated" "prod_EupS_integrated" "prod_Eup_integrated"
## [43] "prod_Jel_integrated"  "prod_MZL_integrated"  "prod_NCa0_integrated"
## [46] "prod_NCaS_integrated" "prod_NCa_integrated"  "prod_PhL_integrated"
## [49] "prod_PhS_integrated"  "salt_surface5m"       "temp_bottom5m"
## [52] "temp_integrated"      "temp_surface5m"       "uEast_bottom5m"
## [55] "uEast_surface5m"      "vNorth_bottom5m"      "vNorth_surface5m"
## [58] "fracbelow0"           "fracbelow1"           "fracbelow2"
```

Now let's grab some of the Level 3 and Level 2 data and store it in the Data/in/Newest/Rdata folder. We'll start with Level 3 since those files are already post-processed to be in the ACLIM indices format and are relatively small:

```
# define the dataset sub names:
weekly_flm      <- "ACLIMregion"
survey_rep_flm  <- "ACLIMsurveyrep"

# Tinker:add additional projection scenarios here
proj_list       <- proj

# Tinker:add additional variables to varlist
varlist         <- c(
  "temp_bottom5m",    # bottom temperature,
  "NCaS_integrated",  # Large Cop
  "Cop_integrated",    # Small Cop
  "EupS_integrated")  # Shelf euphausiids

# now grab dattat for the hindcast and projection sets:
for(m in c(hind, proj)){

  TYPE <- 1

  # create the simulation Level3 folder (and overwrite it if overwrite is set to T)
  if(!dir.exists(paste0("Data/in/Newest/Rdata/",m)))
    dir.create((paste0("Data/in/Newest/Rdata/",m)))
  if(!dir.exists(paste0("Data/in/Newest/Rdata/",m,"/Level3")))
    dir.create((paste0("Data/in/Newest/Rdata/",m,"/Level3")))
```



```

for(d in c(weekly_flg, survey_rep_flg)){

  # create filename:
  tmp_fl <- paste0(d, "_", m)

  # create the temporary URL
  tmpURL <- paste0(paste0(ACLIM_data_url, "dodsC/", m, "/Level3/"), d, "_", m, ".nc")

  # open the netcdf file remotely
  nc <- nc_open(tmpURL)

  # convert the nc files into a long data.frame for each variable
  i <- 0
  for(v in varlist){
    i <- i + 1
    tmp_var0 <- convert2df(ncIN = nc, type = TYPE, varIN = v)
    tmp_var0$sim <- tmp_fl
    if(i == 1)
      tmp_var <- tmp_var0
    if(i != 1)
      tmp_var <- rbind(tmp_var, tmp_var0)
    rm(tmp_var0)
  }

  # close the nc file
  nc_close(nc)

  # rename the object
  eval(parse(text = paste0(d, "<-tmp_var") ))

  # save the nc file in the Data/in/Newest/Rdata/ [ simulation]/Level3 folder
  tmp_path <- file.path( paste0("Data/in/Newest/Rdata/", m, "/Level3"),
                        paste0(tmp_fl, ".Rdata"))
  eval(parse(text = paste0("save(", d, ", file=tmp_path)")))
  TYPE <- TYPE + 1
}
}

```

Now we can do the same thing and download a subset of the Level2 data (full 10KM Lat Lon re-gridded data), here with an example of sampling on Aug 1 of each year:

```

# Tinker: add additional projection scenarios here
proj_list <- proj

# Currently available Level 2 variables
ds_list <- proj_l2_datasets$dataset # datasets
sub_varlist <- list(
  "temp",
  "temp",
  c("EupS", "Cop", "NCaS") ) # variables to pull from each data set
# Tinker: try subbing in other Integrated variables (3rd in the list)

# Let's sample the model years as close to Aug 1 as the model timesteps run:
tr <- c("-08-1 12:00:00 GMT")

```

```

# now grab dattat for the hindcast and projection sets:
for(m in c(hind, proj)){

  # create the simulation Level3 folder (and overwrite it if overwrite is set to T)
  if(!dir.exists(paste0("Data/in/Newest/Rdata/",m)))
    dir.create((paste0("Data/in/Newest/Rdata/",m)))
  if(!dir.exists(paste0("Data/in/Newest/Rdata/",m,"/Level2")))
    dir.create((paste0("Data/in/Newest/Rdata/",m,"/Level2")))

  for(d in 1:length(ds_list)){

    # create filename:
    tmp_fl <- paste0(d,"_",m)

    # get the url for the simulation
    m_url <- url_list[url_list$dataset == paste0(m,"/"),]$path

    # preview the projection and hindcast data and data catalogs (Level 1, 2, and 3):
    m_datasets <- tds_list_datasets(thredds_url = m_url)

    # get Level 2 .nc file URL
    m_l2_cat <- m_datasets[m_datasets$dataset == "Level 2/",$path]
    m_l2_datasets <- tds_list_datasets(m_l2_cat)
    m_l2_vT_url <- m_l2_datasets[m_l2_datasets$dataset == ds_list[d],]$path
    m_flnm <- strsplit(m_l2_vT_url,split="dataset=")[[1]][2]
    m_flnm <- stringr::str_replace(m_flnm,"Level2_", "")
    if(ds_list[d] == "Surface 5m") m_flnm <- stringr::str_replace(m_flnm,"surface_5m", "s")
    tmpURL <- paste0(paste0(ACLIM_data_url,"dodsC/Level2/"),m_flnm,".nc")

    # open the netcdf file remotely
    nc <- nc_open(tmpURL)

    # available variables:
    names(nc$var)

    time_steps <- as.POSIXct(
      nc$var[[ sub_varlist[[d]][1] ]]$dim[[3]]$vals,
      origin = substr(ncIN$var[["temp"]]$dim[[3]]$units,15,36),
      tz = "GMT")

    # get years in simulation
    yrs <- sort(unique(substr(time_steps,1,4)))
    tmp_tr <- paste0(yrs,tr)

    # subset the lat and lon values
    lat <- ncvar_get(nc, varid = "lat_rho")
    lon <- ncvar_get(nc, varid = "lon_rho")
    #M2 <- (56.87°N, -164.06°W)

    for(var_get in sub_varlist[[d]]){
      # convert the nc files into a long data.frame for each variable
      tmp_var <- get_level2(
        ncIN = nc,

```

```

varIN = var_get,
# Tinker: try extracting other vars like "NO3", or "uEast"
xi_range = 1:182,
eta_range = 1:258,
time_range = tmp_tr)

# rename the object
eval(parse(text =paste0(var_get,"<-tmp_var") ))

# save the nc file in the Data/in/Newest/Rdata/ [ simulation]/Level3 folder
tmp_path <- file.path( paste0("Data/in/Newest/Rdata/",m,"/Level2"),paste0(m_flnm,"_",var_
eval(parse(text =paste0("save(",var_get," , file=tmp_path)"))
eval(parse(text =paste0("rm(",var_get,")") ))
}
# close the nc file
nc_close(nc)
}
}

```

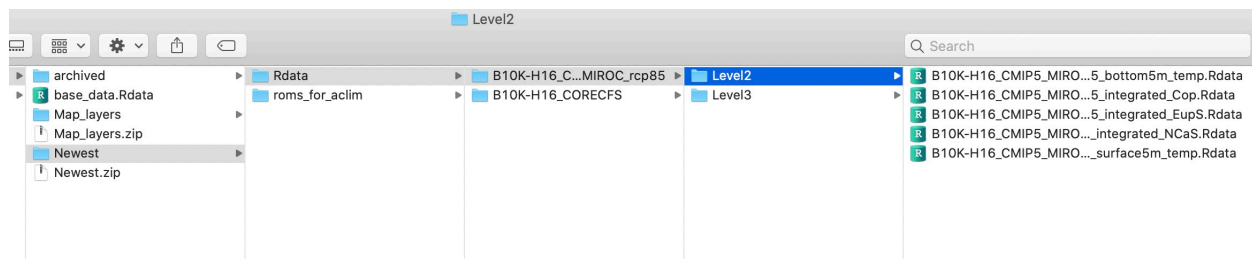


Figure 2: The final folder structure on your local drive in `Data/in/Newest` should look something like this.

3.2. (ACLIM members Only) Access CMIP6 (embargoed) L3 data

Public CMIP5 and embargoed CMIP6 Level 3 netcdf (.nc) files are saved in the shared ACLIM data folder (note: Level 2 files are too large for the google drive but are available by request from Kelly Kearney).

IMPORTANT Please note that while the CMIP5 set is now public (Hermann et al. 2019; section 2.2) **the CMIP6 suite is under embargo for QAQC and should not be shared outside of the ACLIM group.** The ROMSNPZ team (Drs. Hermann, Cheng, Kearney, Pilcher, Adyin) are in the process of synthesizing and publishing the CMIP6 data (goal is spring 2021 for submission), following those publications the data will be made accessible to the public via the PMEL data portal, as is the case for the CMIP5 data and public hindcasts. The ROMSNPZ team has made these runs available to ACLIM2 members in order to accelerate coupling to biological and social and economic models, thus out of professional courtesy please do not publish the data without permission from **all** ROMSNPZ team members, it is strongly advised that some or multiple ROMSNPZ team members be included as co-authors to ensure proper application and use of the ROMSNPZ data.

For most applications you can use the ACLIM level3 post-processed indices available on the shared ACLIM drive in the root google drive data folder: `00_ACLIM_shared>02_DATA`.

The `Newest` folder is organized by Bering10K version, General Circulation Model (GCM) and carbon scenario, e.g. `B10K-H16_CMIP5_CESM_rcp45`. Within each folder the following subfolders are:

- Level1: (Empty; not copied from Mox)
- Level2: (Empty; not copied from Mox)
- Level3: 2 files (ACLIMsurveyrep_B10K-x.nc and ACLIMregion_B10K-x.nc)

- 1) ACLIMsurveyrep_B10K-x.nc contains summer groundfish trawl “survey replicated” indices (using mean date and lat lon) *(Note that the resampling stations need to be removed before creating bottom temperature maps)*
- 2) ACLIMregion_B10K-x.nc: contains weekly “strata” values *(Note that area weighting should be used to combine values across multiple strata)*

There are two folders that need to be copied into the ACLIM2 folder on your computer under `~[YOURPATH]/ACLIM2/Data/in/`:

- 1) **00_ACLIM_shared>02_DATA>Newest**. This folder contains a folder called **roms_for_aclim** with all the ACLIM Level3 indices for model simulations available to ACLIM members.
- 2) **00_ACLIM_shared>02_DATA>Map_layers.zip**. This file needs to be unzipped after you download it to your local folder. It contains (large) base maps for the code below including **shp_files** and **geo_tif** folders.

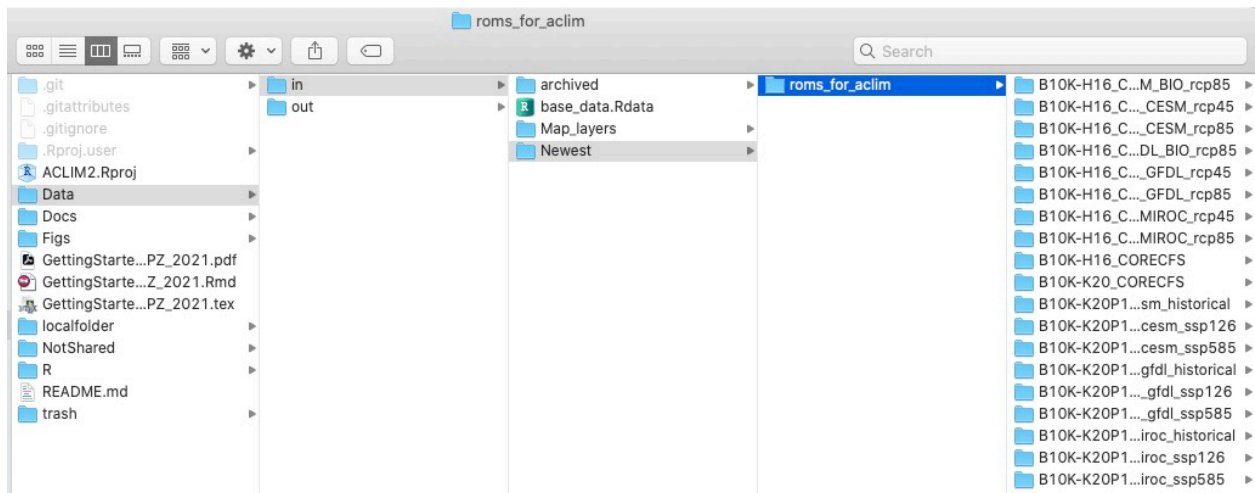


Figure 3: Your local ACLIM2/Data directory should look something like this when you are done downloading the data and unzipping it.

Now let’s convert these to level3 rdata files (as in section 2.2)

```
# first load packages and setup:
tmstp <- format(Sys.time(), "%Y_%m_%d")
main <- getwd() # should be your local path e.g., "~/GitHub_new/ACLIM2"

# loads packages, data, and setup:
source("R/make.R")

# create a directory for our new indices
if(!dir.exists("Data/in/Newest/Rdata")) dir.create("Data/in/Newest/Rdata")

# define the simulation to download:
cmip <- "CMIP6" # Coupled Model Intercomparison Phase
GCM <- "MIROC" # Global Circulation Model
```

```

rcp <- "ssp585"      # future carbon scenario
mod_h <- "B10K-K20"  # ROMSNPZ model
mod_p <- "B10K-K20P19" # ROMSNPZ model
hind <- "CORECFS"    # Hindcast

# define the projection simulation:
proj <- paste0(mod_p,"_",cmip,"_",GCM,"_",rcp)
hind <- paste0(mod_h,"_",hind)

# define the dataset sub names:
weekly_flnm <- "ACLIMregion"
survey_rep_flnm <- "ACLIMsurveyrep"

# Tinker:add additional projection scenarios here
proj_list <- proj

# Tinker:add additional variables to varlist
varlist <- c(
  "temp_bottom5m",    # bottom temperature,
  "NCaS_integrated",  # Large Cop
  "Cop_integrated",    # Small Cop
  "EupS_integrated")  # Shelf euphausiids

# now grab data for the hindcast and projection sets:
for(m in c(hind, proj)){

  TYPE <- 1

  # create the simulation Level3 folder (and overwrite it if overwrite is set to T)
  if(!dir.exists(paste0("Data/in/Newest/Rdata/",m)))
    dir.create((paste0("Data/in/Newest/Rdata/",m)))
  if(!dir.exists(paste0("Data/in/Newest/Rdata/",m,"/Level3")))
    dir.create((paste0("Data/in/Newest/Rdata/",m,"/Level3")))

  for(d in c(weekly_flnm,survey_rep_flnm)){

    # create filename:
    tmp_fl <- paste0(d,"_",m)

    # create the temporary URL
    tmppath <- paste0(paste0("Data/in/Newest/roms_for_aclim/",m,"/Level3/"),d,"_",m,".nc")

    # open the netcdf file remotely
    nc <- nc_open(tmppath)

    # convert the nc files into a long data.frame for each variable
    i <- 0
    for(v in varlist){
      i <- i + 1
      tmp_var0 <- convert2df(ncIN = nc, type = TYPE, varIN = v)
      tmp_var0$sim <- tmp_fl
    }
  }
}

```

```

    if(i == 1)
      tmp_var      <- tmp_var0
    if(i != 1)
      tmp_var      <- rbind(tmp_var,tmp_var0)
    rm(tmp_var0)
  }

  # close the nc file
  nc_close(nc)

  # rename the object
  eval(parse(text =paste0(d,"<-tmp_var") ))

  # save the nc file in the Data/in/Newest/Rdata/ [ simulation]/Level3 folder
  tmp_path <- file.path( paste0("Data/in/Newest/Rdata/",m,"/Level3"),
                        paste0(tmp_fl,".Rdata"))
  eval(parse(text =paste0("save(",d," , file=tmp_path)")))
  TYPE      <-  TYPE + 1
}
}

```

4. Derive indices & plot data

4.1 Level 3 indices:

Level 3 indices can be used to generate seasonal, monthly, and annual indices (like those reported in Reum et al. 2020), Holsman et al. 2020). In section 3 below we explore these indices in more detail using R, including using (2) above to generate weekly, monthly, and seasonal indices (e.g. Fall Zooplankton) for use in biological models. In section 3 below we explore these indices in more detail using R, including using (2) above to generate weekly, monthly, and seasonal indices (e.g. Fall Zooplankton) for use in biological models.

Please be sure to coordinate with ROMSNPZ modeling team members to ensure data is applied appropriately. If you need access to the raw ROMSNPZ files (netcdf, non-regridded large files located on MOX). Please contact **Al Hermann** or **Kelly Kearney**.

The following examples show how to analyze and plot the ACLIM indices from their stored netcdf (.nc) format in the Data folder of the ACLIM shared google drive. Please note that while the CMIP5 set is now public (Hermann et al. 2019) **the CMIP6 suite is under embargo for QAQC and should not be shared outside of the ACLIM group**. Al, Wei, Kelly, Darren, and Kerim are in the process of synthesizing and publishing the CMIP6 data (goal is spring 2021 for submission), following those publications the data will be made accessible to the public via the PMEL data portal, as is the case for the CMIP5 data and public hindcasts. It is strongly recommended that you include at least one (ideally multiple) authors from the ROMSNPZ team as co-author on your paper if you are linking to this data, this is especially the case for the CMIP6 data. There are multiple spatial and temporal caveats that are best described in discussions with the authors of these data and inclusion as co-authors will facilitate appropriate application and interpretation of the ROMSNPZ data.

4.1.1 Explore Level 3 data catalog

Once the base files and setup are loaded you can explore the index types. Recall that in each scenario folder there are two indices saved within the **Level3** subfolders:

- 1) ACLIMsurveyrep_B10K-x.nc contains summer groundfish trawl “survey replicated” indices (using mean date and lat lon) *(Note that the resampling stations need to be removed before creating bottom temperature maps)*
- 2) ACLIMregion_B10K-x.nc: contains weekly “strata” values *(Note that area weighting should be used to combine values across multiple strata)*

First run the below set of code to set up the workspace:

```
tmstp <- format(Sys.time(), "%Y_%m_%d")
main  <- getwd()  #"~/GitHub_new/ACLIM2"

# loads packages, data, setup, etc.
source("R/make.R")

# list of the scenario x GCM downscaled ACLIM indices
for(k in aclim)
  cat(paste(k, "\n"))

embargoed # not yet public or published
public    # published runs (CMIP5)

# get some info about a scenario:

all_info1 <- info(model_list=aclim,type=1)
all_info2 <- info(model_list=aclim,type=2)
all_info1
all_info2

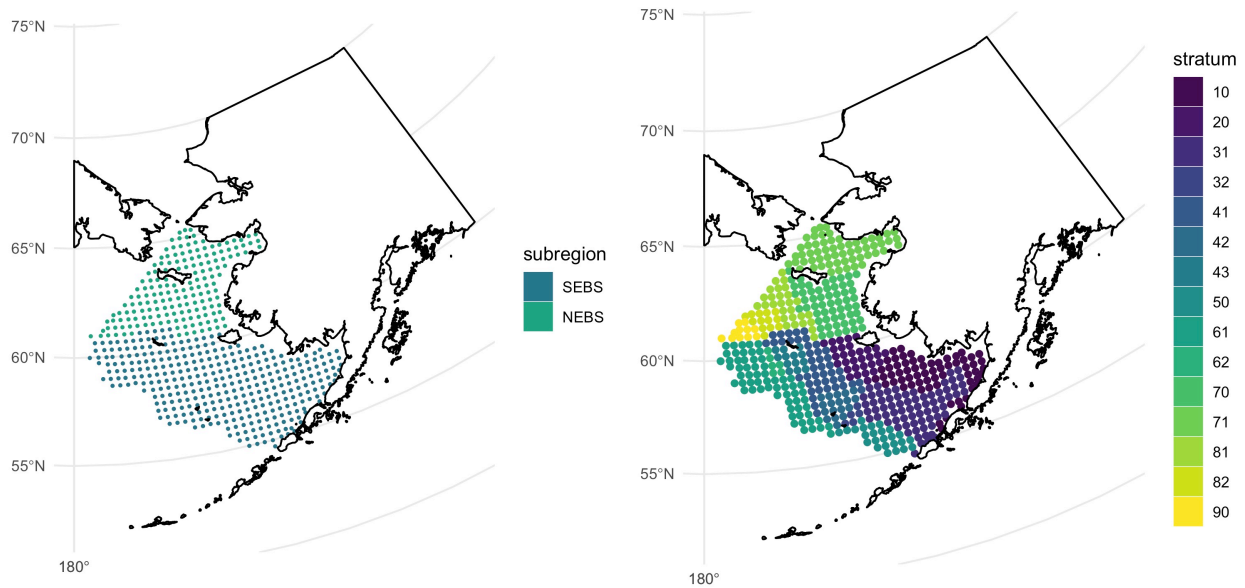
# variables in each of the two files:
srvy_vars
weekly_vars

#summary tables for variables
srvy_var_def
weekly_var_def

# explore stations in the survey replicated data:
head(station_info)
```

4.1.2 Spatial indices (survey replicated)

Let's start by exploring the survey replicated values for each variable. Steps 2 and 3 generated the Rdata files that are stored in the ACLIMsurveyrep_B10K-[version_CMIPx_GCM_RCP].Rdata in each corresponding simulation folder.



The code segment below will recreate the above figures.

```
# first convert the station_info object into a shapefile for mapping:
station_sf      <- convert2shp(station_info)
station_sf$stratum <- factor(station_sf$stratum)

# plot the stations:
p <- plot_stations_basemap(sfIN = station_sf, fillIN = "subregion", colorIN = "subregion") +
  scale_color_viridis_d(begin = .4, end = .6) +
  scale_fill_viridis_d(begin = .4, end = .6)

if(update.figs){
  p
  ggsave(file="Figs/stations_NS.jpg", width=5, height=5)}

p2 <- plot_stations_basemap(sfIN = station_sf, fillIN = "stratum", colorIN = "stratum") +
  scale_color_viridis_d() +
  scale_fill_viridis_d()

if(update.figs){
  p2
  ggsave(file="Figs/stations.jpg", width=5, height=5)}
```

Now let's explore the survey replicated data in more detail and use it to create a cold pool index for each simulation and hindcast scenario x model x CMIP combination.

```
# now create plots of average BT during four time periods
time_seg <- list('2010-2020' = c(2010:2020),
                 '2021-2040' = c(2021:2040),
                 '2041-2060' = c(2041:2060),
                 '2061-2080' = c(2061:2080),
                 '2081-2099' = c(2081:2099))

# View an individual variable (e.g., Bottom Temp)
# -----
```



```

srvy_vars
aclim
sim <-"B10K-K20P19_CMIP6_miroc_ssp585"
Rdata_path <- "/Users/kholsman/GitHub_new/ACLIM2/Data/in/Newest/Rdata"

# open a "region" or strata specific nc file
fl      <- file.path(sim,paste0(srvy_txt,sim,".Rdata"))

# load object 'ACLIMsurveyrep'
load(file.path(Rdata_path,fl))

# Collate mean values across timeperiods and simulations
# -----
m_set    <- c(18,19)
ms       <- aclim[m_set]
ms       <- c("B10K-H16_CMIP5_miroc_rcp85","B10K-K20P19_CMIP6_miroc_ssp585")

# get the mean values for the time blocks
mn_var_all <- get_mn_rd(modset = ms ,varUSE="temp_bottom5m")

# convert results to a shapefile
mn_var_sf  <- convert2shp(mn_var_all%>%filter(!is.na(mnval)))
lab_t      <- ms[1]%>%stringr::str_remove("(^[^-])")

p3         <- plot_stations_basemap(sfIN = mn_var_sf,
                                   fillIN = "mnval",
                                   colorIN = "mnval",
                                   sizeIN=.3) +
  facet_grid(simulation~time_period)+
  scale_color_viridis_c()+
  scale_fill_viridis_c()+
  guides(
    color = guide_legend(title="Bottom T (degC)",
    fill  = guide_legend(title="Bottom T (degC)")) +
  ggtitle(lab_t)

# This is slow but it works (repeat dev.new() twice if in Rstudio)...
dev.new()
p3

if(update.figs) ggsave(file="Figs/mn_BT.jpg",width=8,height=5)

graphics.off()

```

4.1.3 Temporal indices (Weekly strata averages)

The next set of indices to will explore are the weekly strata-specific values for each variable. These are stored in the ACLIMregion_B10K-[version_CMIPx_GCM_RCP].nc in each scenario folder.

```

# list of the scenario x GCM downscaled ACLIM indices
for(k in aclim)
  cat(paste(k,"\n"))

```

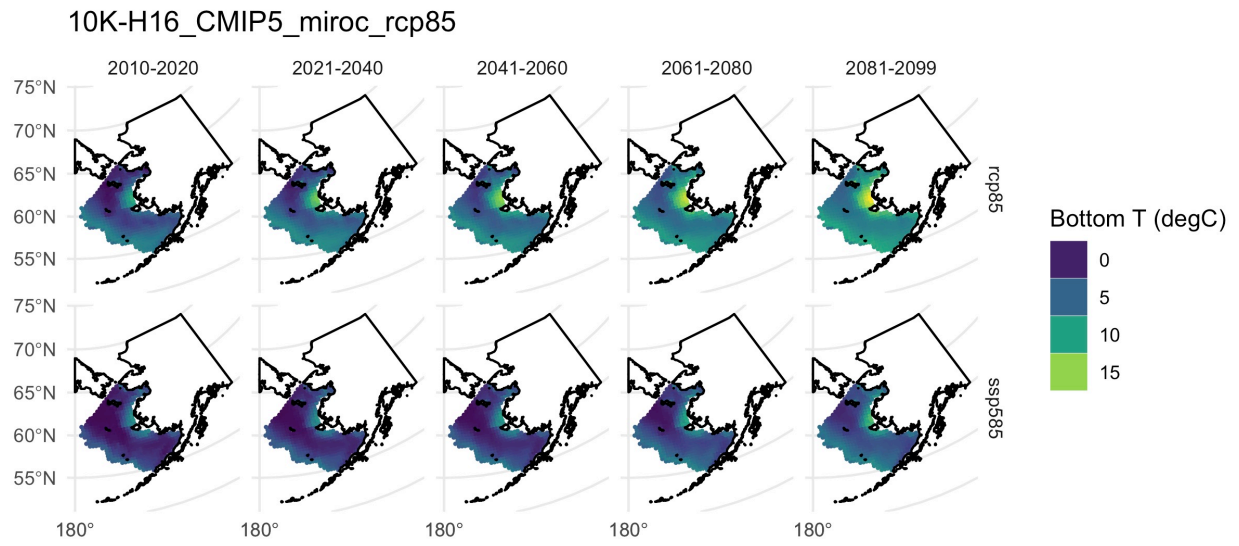


Figure 4: Bottom temperature projections under differing SSP126 (top row) and SSP585 (bottom row)

```

# View an individual variable (e.g., Bottom Temp)
# -----
weekly_vars
aclim
sim <- "B10K-K20P19_CMIP6_miroc_ssp585"
Rdata_path <- "/Users/kholsman/GitHub_new/ACLIM2/Data/in/Newest/Rdata"

# open a "region" or strata specific nc file
fl <- file.path(sim,paste0(reg_txt,sim,".Rdata"))

# load object 'ACLIMregion'
load(file.path(Rdata_path,fl))
tmp_var <- ACLIMregion

# now plot the data:

p4 <- ggplot(data = tmp_var) +
  geom_line(aes(x=time,y=val,color= strata),alpha=.8)+
  facet_grid(basin~.)+
  ylab(tmp_var$units[1])+
  ggtitle( sim%>%stringr::str_remove("[^-]") )+
  theme_minimal()
p4

# To get the average value for a set of strata, weight the val by the area:
mn_NEBS <- getAVGnSUM(strataIN = NEBS_strata, dataIN = tmp_var)
mn_NEBS$basin = "NEBS"
mn_SEBS <-getAVGnSUM(strataIN = SEBS_strata, dataIN = tmp_var)
mn_SEBS$basin = "SEBS"

p5 <- ggplot(data = rbind(mn_NEBS,mn_SEBS)) +
  geom_line(aes(x=time,y=mn_val,color=basin),alpha=.8)+
  geom_smooth(aes(x=time,y=mn_val,color=basin),
    formula = y ~ x, se = T)+
  facet_grid(basin~.)+
  scale_color_viridis_d(begin=.4,end=.8)+
  ylab(tmp_var$units[1])+
  ggtitle( paste(aclim[2],mn_NEBS$var[1]))+
  theme_minimal()
p5
if(update.figs) ggsave(file="Figs/weekly_byreg.jpg",width=8,height=5)

```

4.1.4 Create seasonal averages

Now using a similar approach get the monthly mean values for a variable:

```

sim <- "B10K-K20P19_CMIP6_miroc_ssp585"

# Set up seasons (this follows Holsman et al. 2020)
seasons <- data.frame(mo = 1:12,
  season =factor("",
    levels=c("Winter","Spring","Summer","Fall"))
seasons$season[1:3] <- "Winter"

```

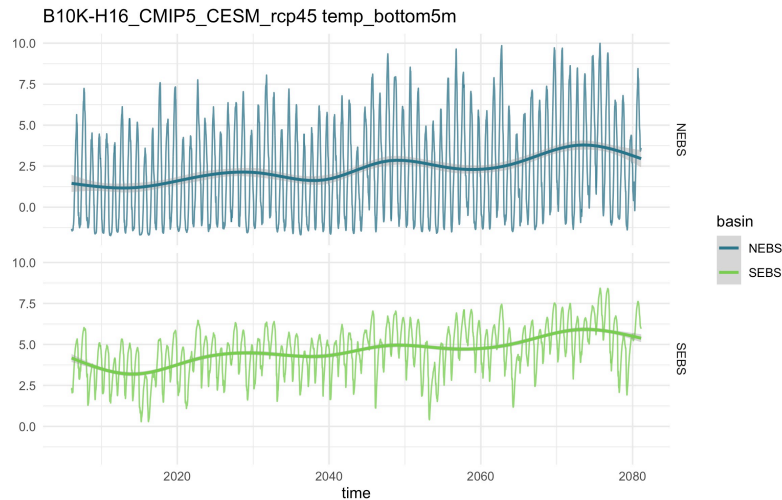


Figure 5: Weekly indices by sub-region

```

seasons$season[4:6] <- "Spring"
seasons$season[7:9] <- "Summer"
seasons$season[10:12] <- "Fall"

varlist <- c(
  "temp_bottom5m",
  "NCaS_integrated", # Large Cop
  "Cop_integrated", # Small Cop
  "EupS_integrated") # Euphausiids

# open a "region" or strata specific file
fl <- file.path(sim,paste0(reg_txt,sim,".Rdata"))
load(file.path(Rdata_path,fl))

tmp_var1 <- ACLIMregion%>%
  filter(var%in%varlist[1])%>%
  group_by(time,strata,strata_area_km2,basin)

tmp_var3 <- ACLIMregion%>%
  filter(var%in%varlist[3])%>%
  group_by(time,strata,strata_area_km2,basin)

tmp_var <-merge(tmp_var1,tmp_var3,
  by=c("strata",
      "strata_area_km2",
      "time","basin"))

tmp_var <-tmp_var%>%
  mutate(val = val.x + val.y ,units = units.x,
  var = "Zoop_integrated",
  long_name ="Total On-shelf
  large zooplankton concentration,
  integrated over depth (NCa, Eup)")%>%
  select(time,

```

```

        strata,
        strata_area_km2,
        basin,
        var,
        val,
        units,
        long_name)
rm(ACLIMregion)
head(tmp_var)

tmp_var$yr      <- strptime(as.Date(tmp_var$time),
                           format="%Y-%m-%d")$year + 1900
tmp_var$mo      <- strptime(as.Date(tmp_var$time),
                           format="%Y-%m-%d")$mon  + 1
tmp_var$jday    <- strptime(as.Date(tmp_var$time),
                           format="%Y-%m-%d")$yday + 1
tmp_var$season  <- seasons[tmp_var$mo,2]

# To get the average value for a set of strata, weight the val by the area: (slow...)
mn_NEBS_season <- getAVGnSUM(
  strataIN = NEBS_strata,
  dataIN = tmp_var,
  tblock=c("yr", "season"))
mn_NEBS_season$basin = "NEBS"
mn_SEBS_season <- getAVGnSUM(
  strataIN = SEBS_strata,
  dataIN = tmp_var,
  tblock=c("yr", "season"))
mn_SEBS_season$basin = "SEBS"

plot_data      <- rbind(mn_NEBS_season, mn_SEBS_season)

# plot Fall values:
p6 <- ggplot(data = plot_data%>%filter(season=="Fall")) +
  geom_line( aes(x = yr, y = mn_val, color=basin), alpha=.8) +
  geom_smooth( aes(x = yr, y = mn_val, color=basin),
              formula = y ~ x, se = T) +
  facet_grid(basin~.) +
  scale_color_viridis_d(begin=.4, end=.8) +
  ylab(tmp_var$units[1]) +
  ggtitle( paste(sim, "Fall", mn_NEBS_season$var[1])) +
  theme_minimal()
p6

if(update.figs)
  ggsave(file="Figs/Fall_large_Zoop.jpg", width=8, height=5)

```

4.1.5 Create monthly averages

Using the same approach we can get monthly averages for a given variable:

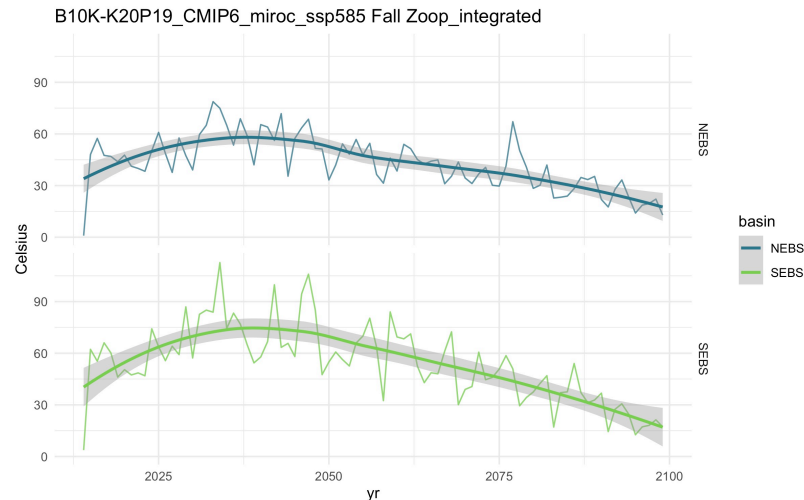


Figure 6: Large fall zooplankton integrated concentration

```
# To get the average value for a set of strata, weight the val by the area: (slow...)
mn_NEBS_season <- getAVGnSUM(
  strataIN = NEBS_strata,
  dataIN = tmp_var,
  tblock=c("yr", "mo"))
mn_NEBS_season$basin = "NEBS"
mn_SEBS_season <- getAVGnSUM(
  strataIN = SEBS_strata,
  dataIN = tmp_var,
  tblock=c("yr", "mo"))
mn_SEBS_season$basin = "SEBS"

plot_data      <- rbind(mn_NEBS_season, mn_SEBS_season)

# plot Fall values:
p7 <- ggplot(data = plot_data %>% filter(mo==9) ) +
  geom_line( aes(x = yr, y = mn_val, color=basin), alpha=.8) +
  geom_smooth( aes(x = yr, y = mn_val, color=basin),
    formula = y ~ x, se = T) +
  facet_grid(basin~.) +
  scale_color_viridis_d(begin=.4, end=.8) +
  ylab(tmp_var$units[1]) +
  ggtitle( paste(aclim[2], "Sept.", mn_NEBS_season$var[1])) +
  theme_minimal()

p7

if(update.figs)
  ggsave(file="Figs/Sept_large_Zoop.jpg", width=8, height=5)
```

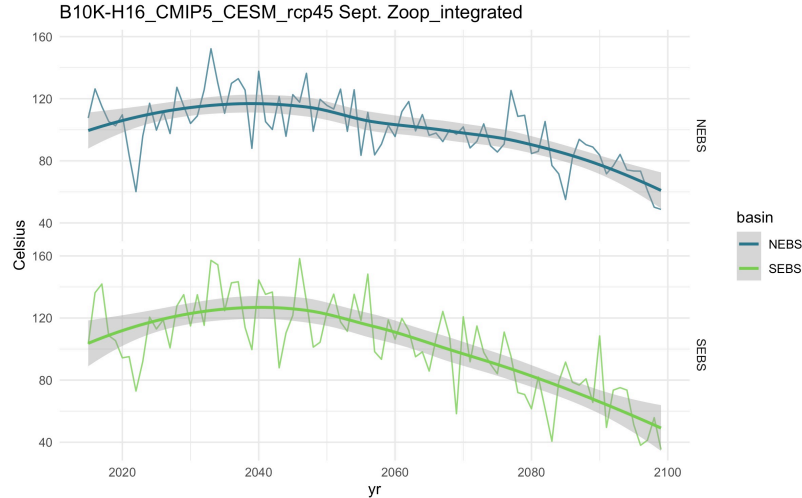


Figure 7: September large zooplankton integrated concentration

4.2 Level 2:

3.2.1 Explore Level 2 data catalog

3.2.2 Custom temporal indices

3.2.3 Custom spatial indices

5. Tinker: example applications

5.1 Recruitment $\sim f(\text{ACLIM indices})$

5.2 Spatial overlap $\sim f(\text{spp dist, aclim indices})$

6. Funding and acknowledgments (needs updating):

PLEASE Include a statement like the following one in your acknowledgements section:

This study is part of NOAA's Alaska Climate Integrated Modeling project (ACLIM) and FATE project XXXX. We would like to thank the entire ACLIM team including [add specific names] for feedback and discussions on the broader application of this work. Multiple NOAA National Marine Fisheries programs provided support for ACLIM including Fisheries and the Environment (FATE), Stock Assessment Analytical Methods (SAAM) Science and Technology North Pacific Climate Regimes and Ecosystem Productivity, the Integrated Ecosystem Assessment Program (IEA), the NOAA Economics and Social Analysis Division, NOAA Research Transition Acceleration Program (RTAP), the Alaska Fisheries Science Center (ASFC), the Office of Oceanic and Atmospheric Research (OAR) and the National Marine Fisheries Service (NMFS). The scientific views, opinions, and conclusions expressed herein are solely those of the authors and do not represent the views, opinions, or conclusions of NOAA or the Department of Commerce.

For some of the integrated papers the following maybe should also be added:

Additionally, the International Council for the Exploration of the Sea (ICES) and the North Pacific Marine Science Organization (PICES) provided support for Strategic Initiative for the Study of Climate Impacts on Marine Ecosystems (SI-CCME) workshops, which facilitated development of the ideas presented in this paper. The scientific views, opinions, and conclusions expressed herein are solely those of the authors and do not represent the views, opinions, or conclusions of NOAA, the Department of Commerce, ICES, or PICES.

7. Helpful links and further reading:

7.1 Citations for GCMs and carbon scenarios:

CMIP3 (BSIERP global climate model runs):

Meehl, G. A., C. Covey, T. Delworth, M. Latif, B. McAvaney, J. F. B. Mitchell, R. J. Stouffer, and K. E. Taylor, 2007: The WCRP CMIP3 multimodel dataset: A new era in climate change research. *Bull. Amer. Meteor. Soc.*, 88, 1383–1394.

CMIP5 (ACLIM global climate model runs):

Taylor, K. E., R. J. Stouffer, and G. A. Meehl, 2012: An overview of CMIP5 and the experiment design. *Bull. Amer. Meteor. Soc.*, 93, 485–498.

CMIP6 and SSPs (ACLIM2 global climate model runs):

ONeill, B. C., C. Tebaldi, D. P. van Vuuren, V. Eyring, P. Friedlingstein, G. Hurtt, R. Knutti, E. Kriegler, J.-F. Lamarque, J. Lowe, G. A. Meehl, R. Moss, K. Riahi, and B. M. Sanderson. 2016. The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6. *Geoscientific Model Development* 9:3461–3482.

7.2 Weblinks for further reading:

- Explore annual indices of downscaled projections for the EBS: **ACLIM indices**
- To view climate change projections from CMIP5 (eventually CMIP6): **ESRL climate change portal**

7.3 Additional information on Hindcast and Projection Models (needs updating)

CORE-CFSR (1976-2012)

This is the hindcast for the Bering Sea and is a combination of the reconstructed climatology from the **CLIVAR** Co-ordinated Ocean-Ice Reference Experiments (CORE) Climate Model (1969-2006) the **NCEP** Climate Forecast System Reanalysis is a set of re-forecasts carried out by NOAA's National Center for Environmental Prediction (NCEP). See **CFS-R** for more info.

CCCMA(2006-2039; AR4 SRES A1B)

Developed by the Canadian Centre for Climate Modelling and Analysis, this is also known as the CGCM3/T47 model. This model showed the greatest warming over time compared to other models tested by PMEL. See more data the **AOOS:CCCMA portal**.

ECHOG(2006-2039; AR4 SRES A1B)

The ECHO-G model from the Max Planck Institute in Germany This model showed the least warming over time compared to other models tested by PMEL. See more data the **AOOS:ECHO-G portal**.

GFDL (2006-2100; AR5 RCP 4.5, 8.5, SSP126,SSP585)

The NOAA Geophysical Fluid Dynamics Laboratory **GFDL** has lead development of the first Earth System Models (ESMs), which like physical climate models, are based on an atmospheric circulation model coupled with an oceanic circulation model, with representations of land, sea ice and iceberg dynamics; ESMs additionally incorporate interactive biogeochemistry, including the carbon cycle. The ESM2M model used in this project is an evolution of the prototype EMS2.1 model, where pressure-based vertical coordinates are used along the developmental path of GFDL's Modular Ocean Model version 4.1 and where the land model is more adavanced (LM3) than in the previous ESM2.1

MIROC(2006-2039; AR4 SRES A1B; 2006-2100 RCP4.5, RCP8.5, SSP585, SSP126)

The Model for Interdisciplinary Research on Climate (MIROC)-M model developed by a consortium of agencies in Japan []. Compared to other models tested by PMEL, MIROC-M was intermediate in degree of warming over the Bering Sea shelf for the first half of the 21st century. See more data the **AOOS:MIROC portal**.