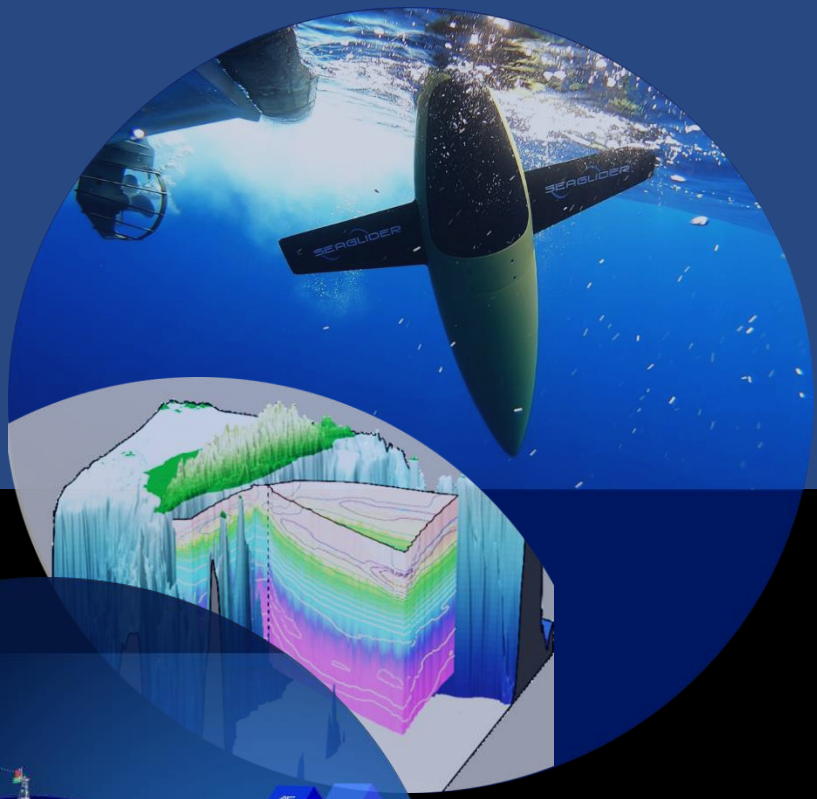
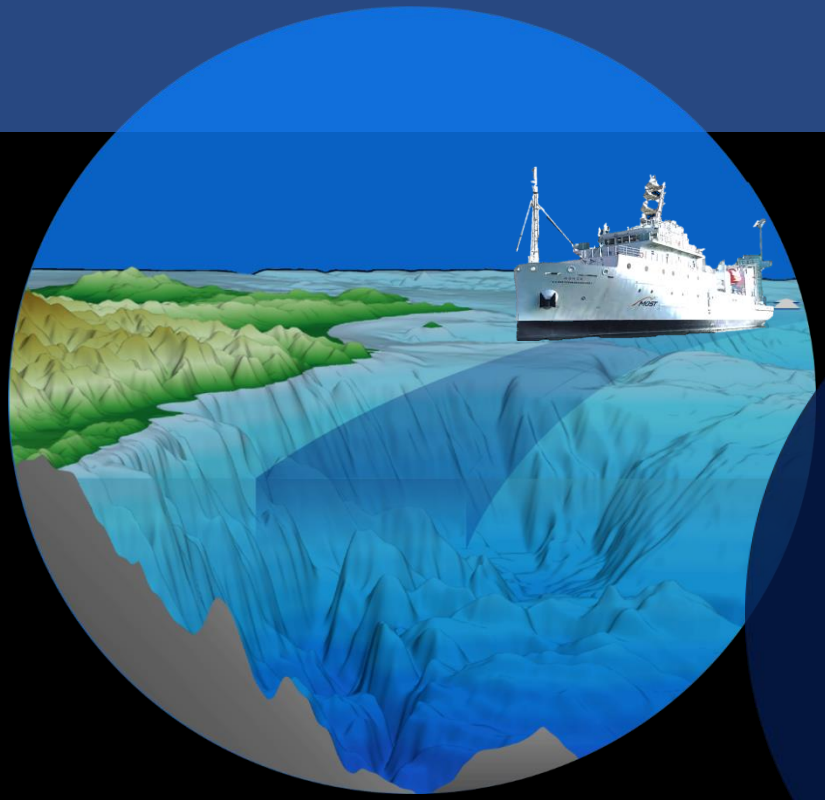
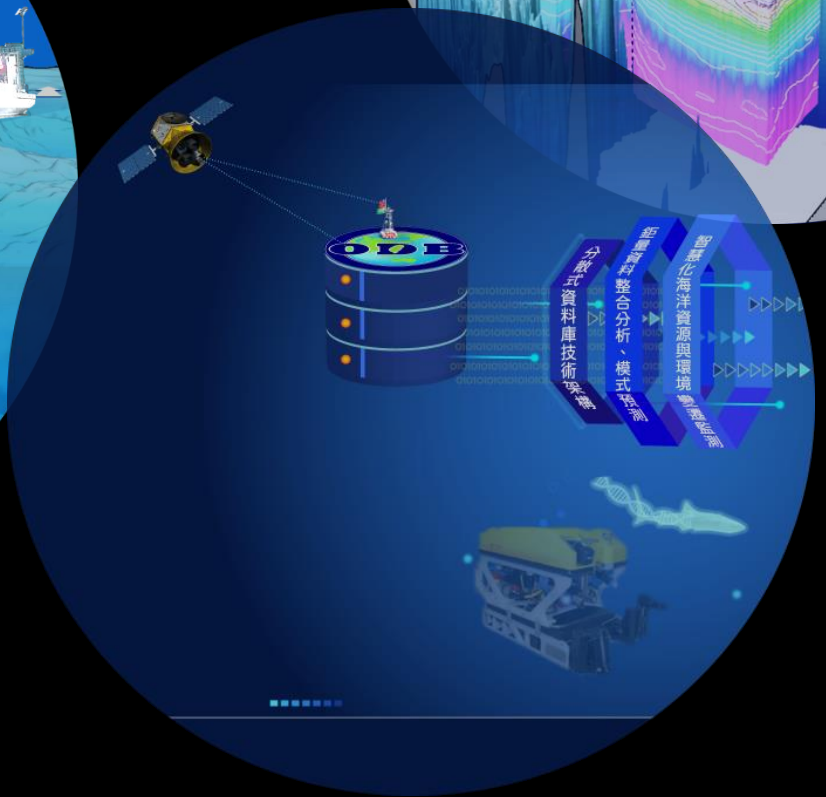
# 海洋資料庫的科學探索

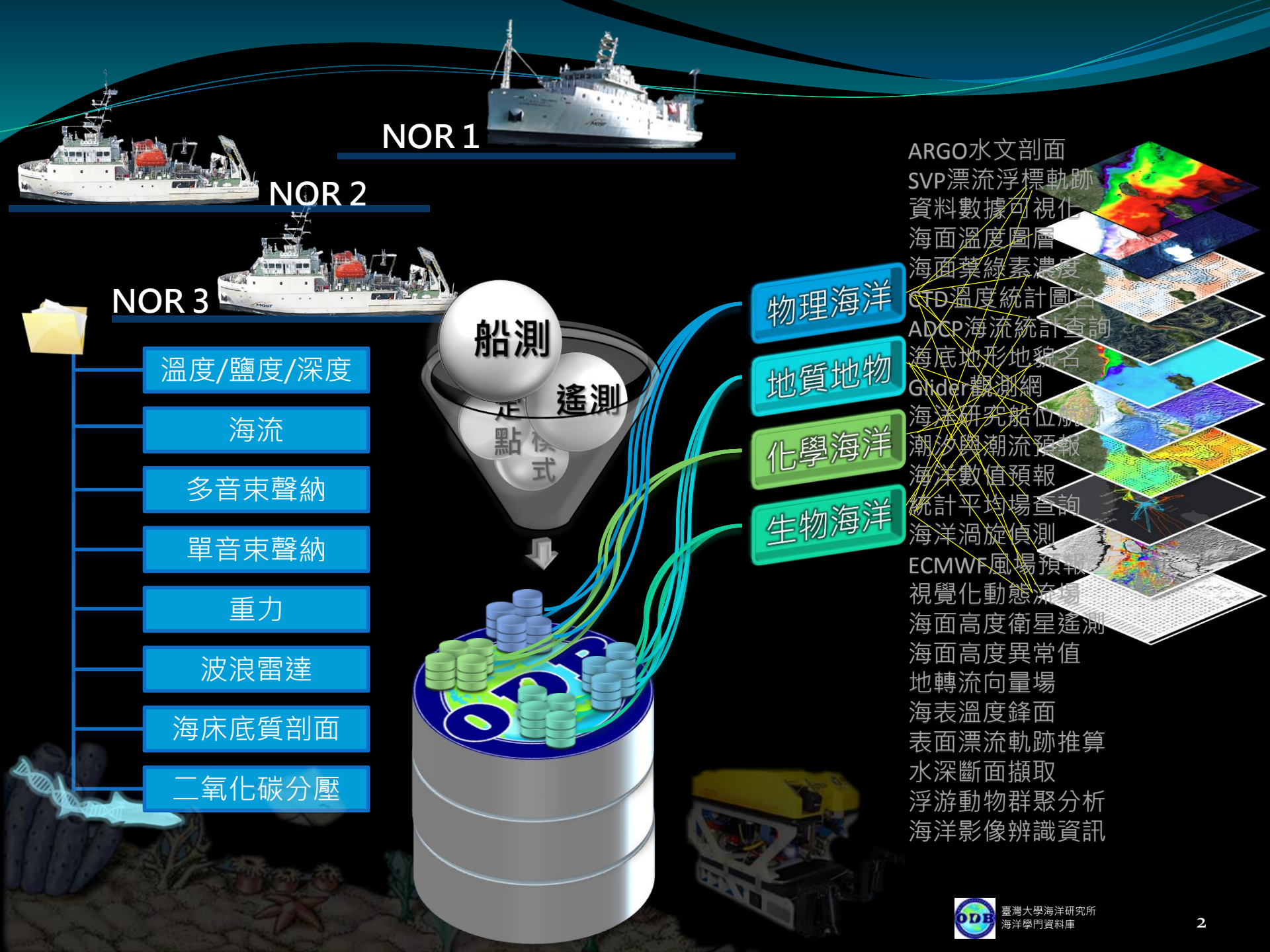
## 動手"做"海洋資料

海洋學門資料庫 (ODB)
翁其羽

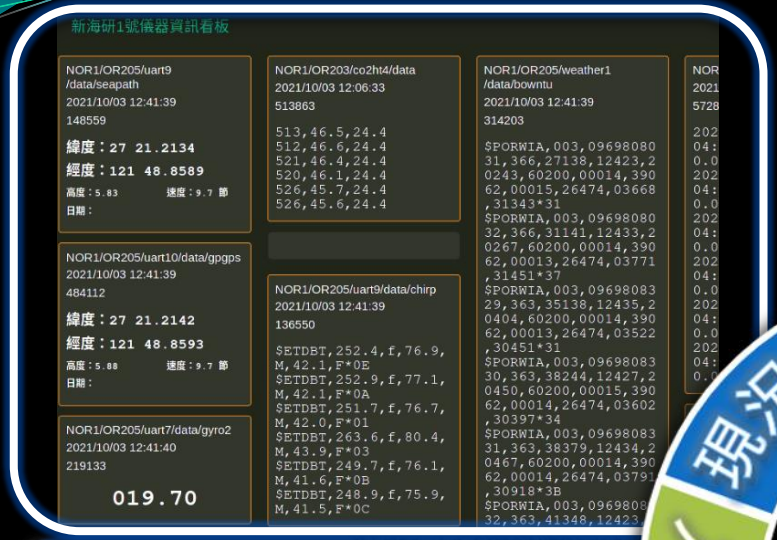




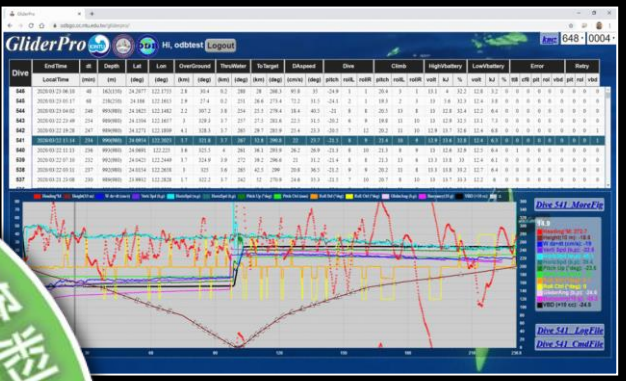

NOR 1
NOR 2
NOR 3
船測
遙測
定點模式
溫度/鹽度/深度
海流
多音束聲納
單音束聲納
重力
波浪雷達
海床底質剖面
二氧化碳分壓
物理海洋
地質地物
化學海洋
生物海洋
ARGO水文剖面
SVP漂流浮標軌跡
資料數據可視化
海面溫度圖層
海面葉綠素濃度
CTD溫度統計圖台
ADCP海流統計查詢
海底地形地貌名
Glider觀測網
海洋研究船位觀測
潮汐與潮流預報
海洋數值預報
統計平均場查詢
海洋渦旋偵測
ECMWF風場預報
視覺化動態流場
海面高度衛星遙測
海面高度異常值
地轉流向量場
海表溫度鋒面
表面漂流軌跡推算
水深斷面擷取
浮游動物群聚分析
海洋影像辨識資訊

# www.odb.ntu.edu.tw

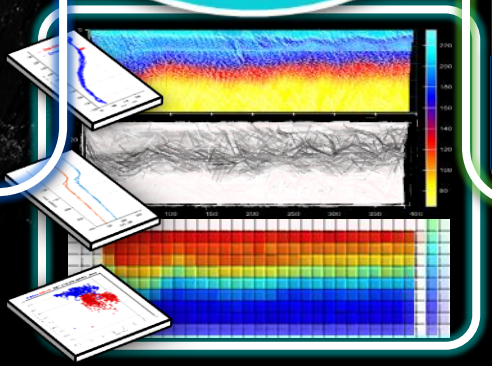


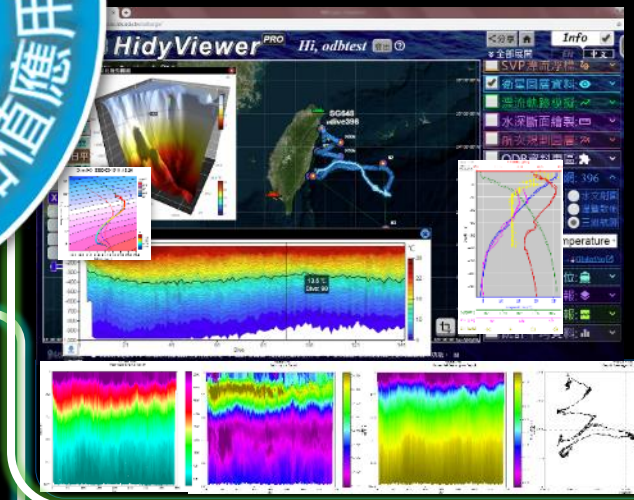

## ODB Glider Pro

駕駛專用平台








整合與展示

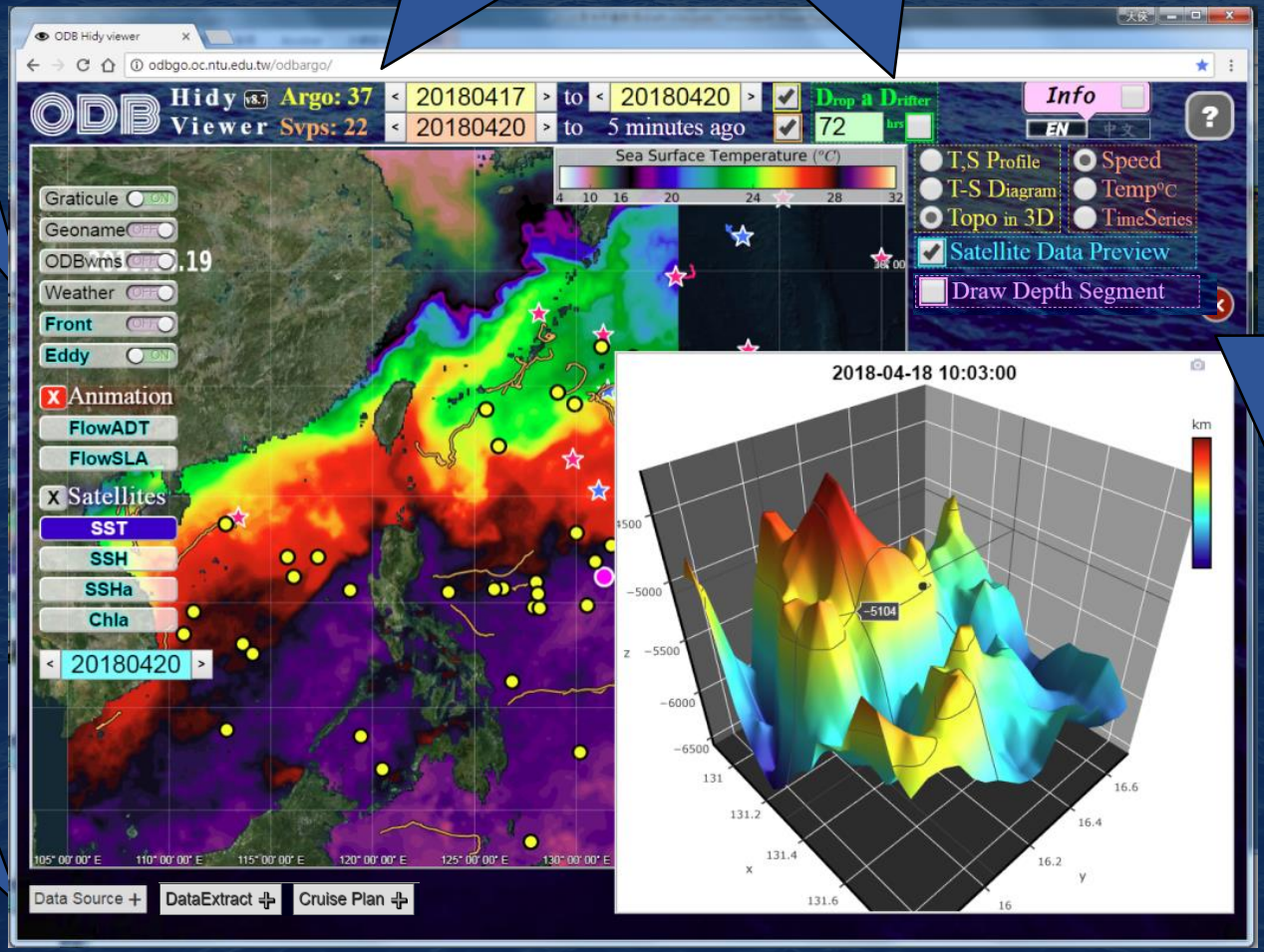
# ODB *Hidy* viewer –「海的」資料展示網頁

(http://odbgo.oc.ntu.edu.tw/odbargo/)

臺灣周遭海域Argo、 SVP 數量與時間顯示／控制

表層平均場漂流軌跡模擬

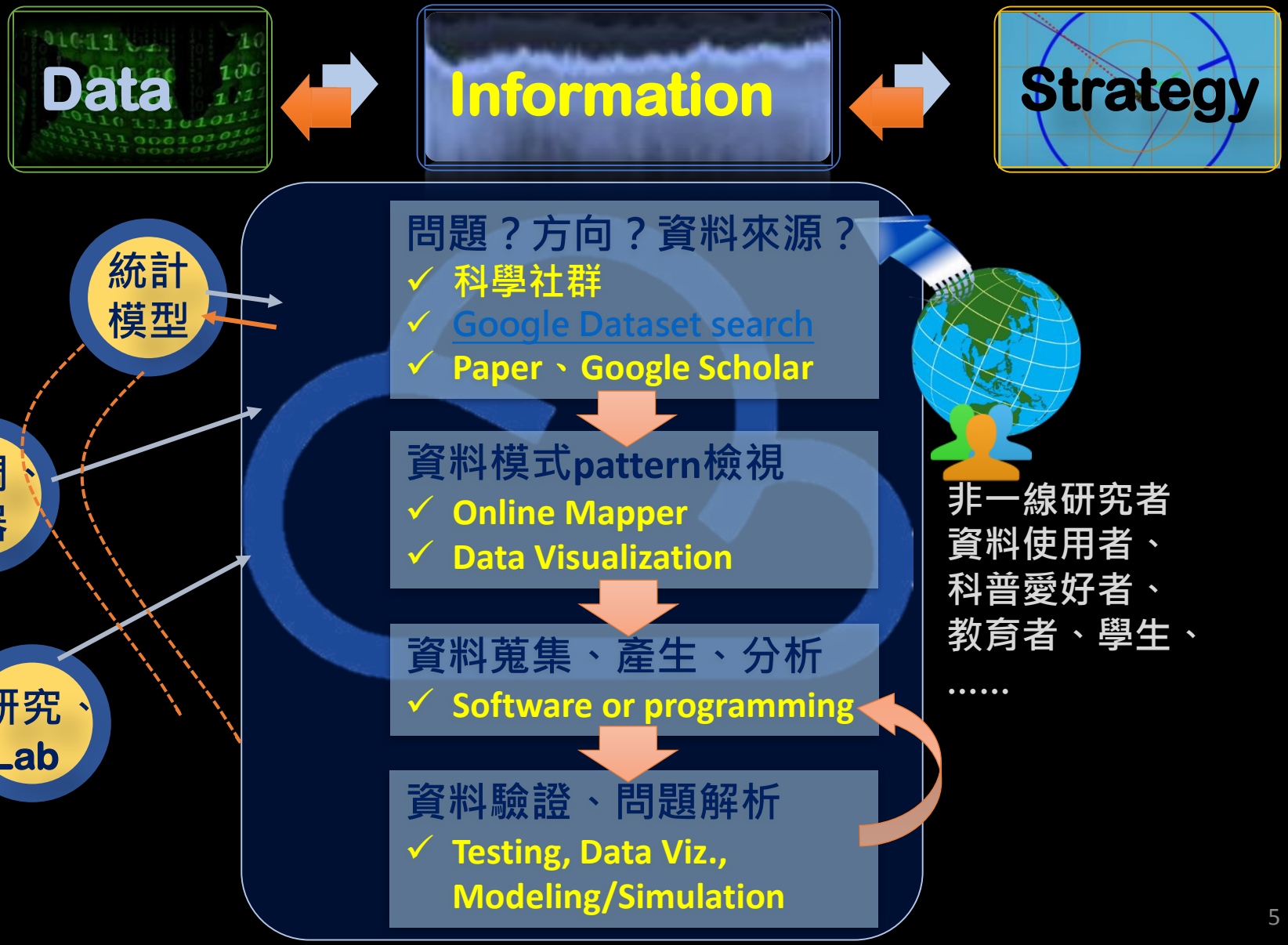
海洋地名圖層、物理環境疊圖，如海表溫度SST、溫度鋒面、渦旋、海流等

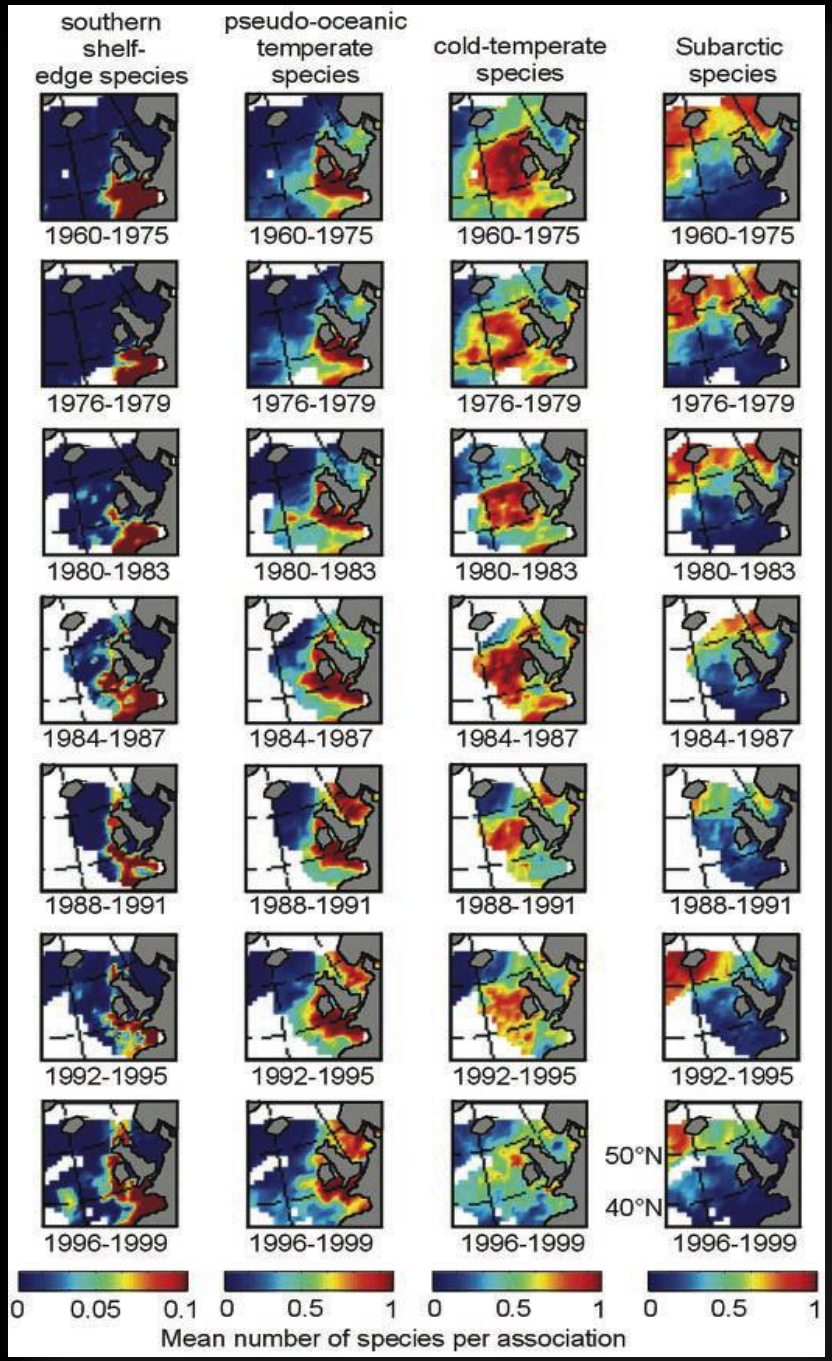



Argo水文溫鹽深度剖面、溫鹽密度分布、附近3D地形、SVP漂流速度、其軌跡海水溫度、時間序列等圖資

資料來源、資料匯出、航次規劃工具

# Information Application Pipeline






Beaugrand et al, 2002, Science 296: 1692-1694

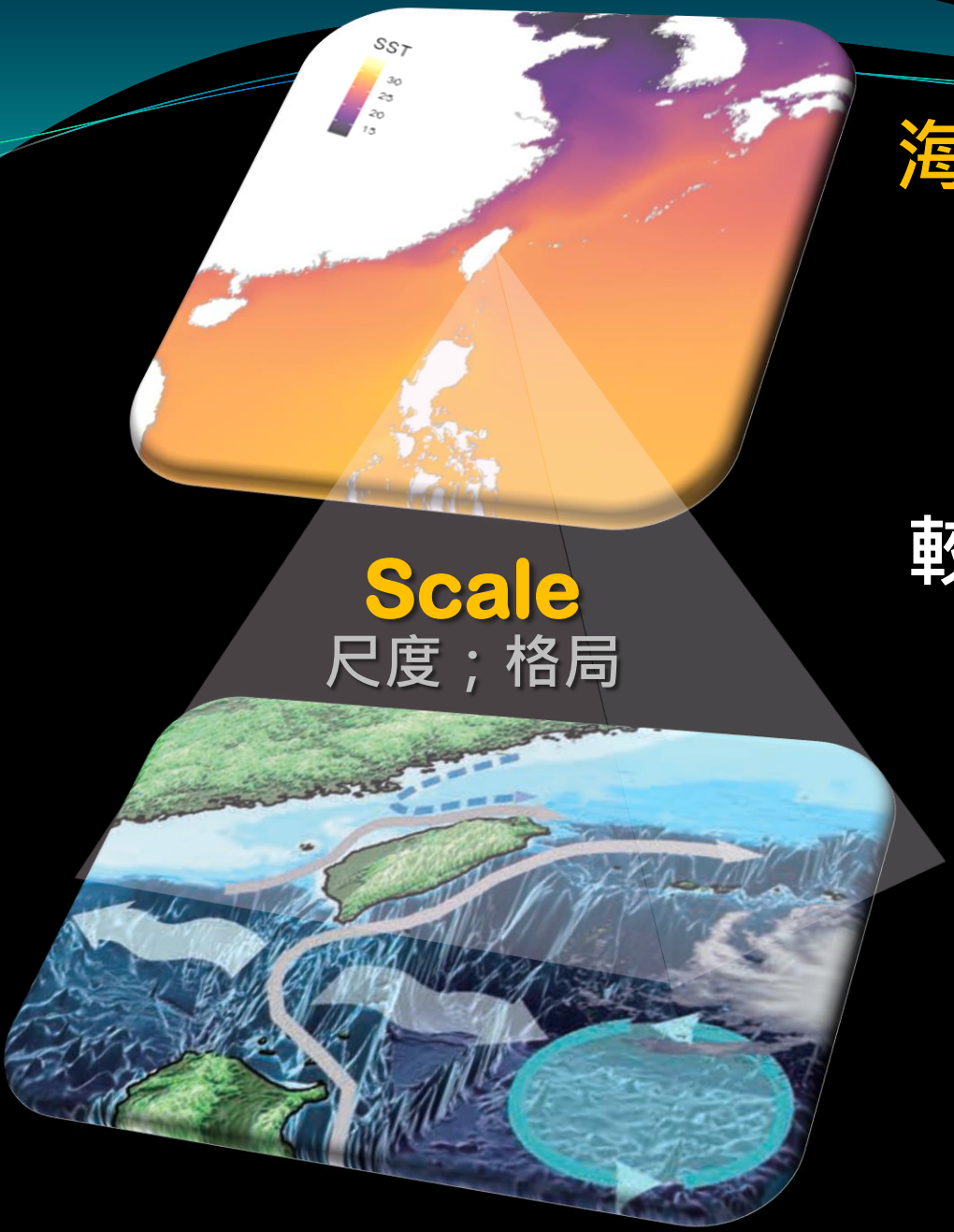
# Biogeographical shifts

## 生物地理遷移

- ✓ warm-water species northward 10°
- ✓ cold-water species decrease

# Strongly affected by SST Anomaly

## 異常海表溫（海表面溫度距平值）




# 在較大時空規模下
# 海溫 常是海洋生態機制的主要驅動因子之一

## 較大尺度的海表溫增溫 / 異常事件

**Global warming**

**El Niño / La Niña**

**Marine Heatwaves**

# 以全球尺度、持續性海洋熱浪(MHWs)考慮異常海表溫可能造成生物分布變動的量化指標

**The author's github:**

**(in Matlab)**

github.com/mjacox/Thermal_Displacement

**My working github:**

**(in R)**

github.com/cywhale/marineheatwave

nature

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nature > articles > article

Article | Published: 05 August 2020

## Thermal displacement by marine heatwaves

Michael G. Jacox, Michael A. Alexander, Steven J. Bograd & James D. Scott

*Nature* **584**, 82–86 (2020) | Cite this article

**7426** Accesses | **37** Citations | **714** Altmetric | Metrics

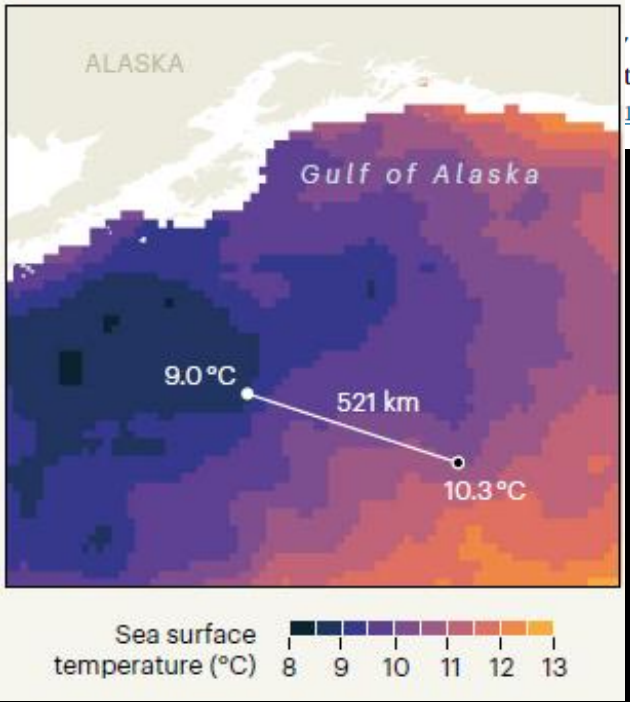
### Abstract

Marine heatwaves (MHWs)—discrete but prolonged periods of anomalously

, with profound ecolog

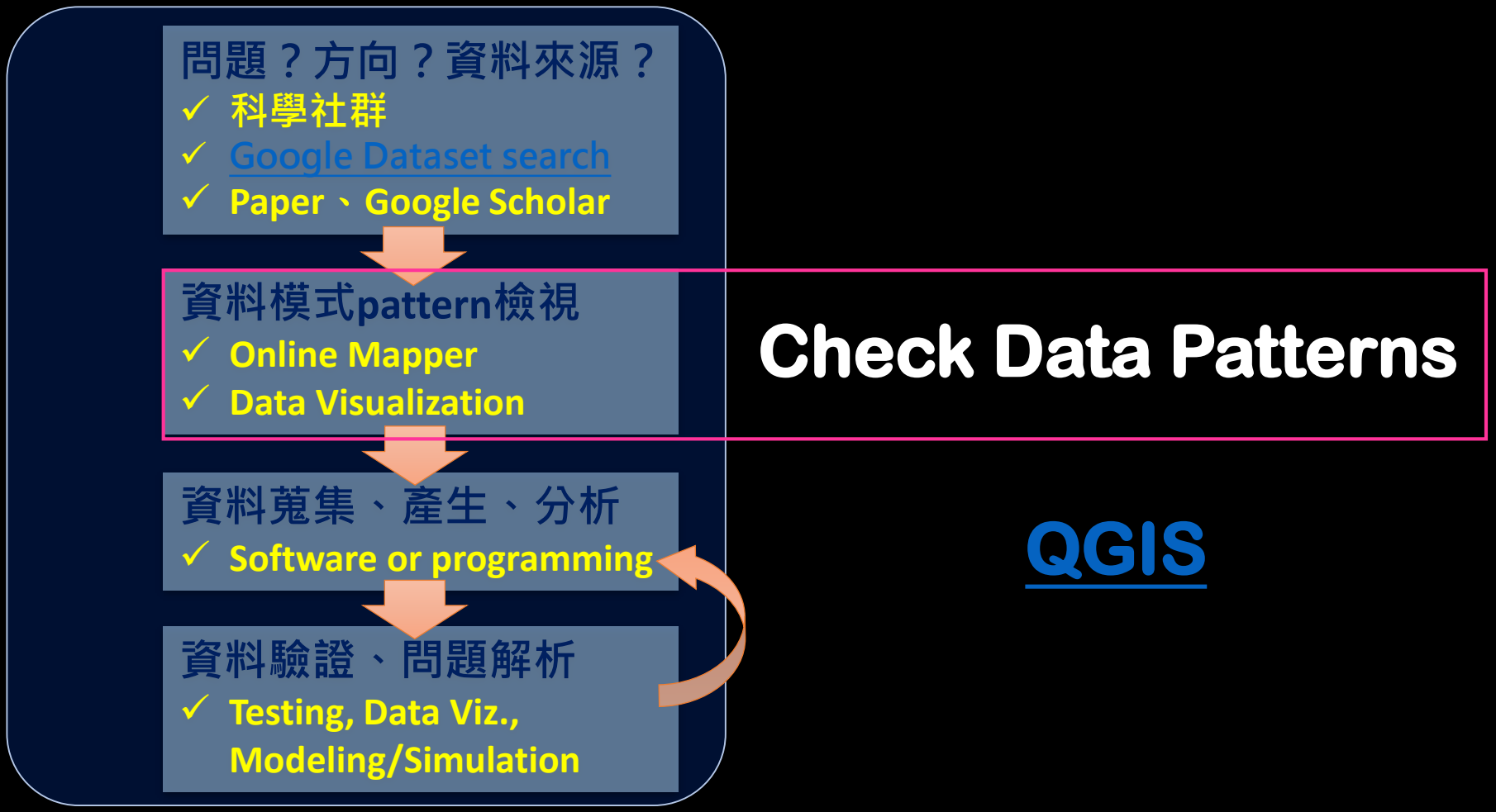
t has been directed at

. Typically, MHWs are

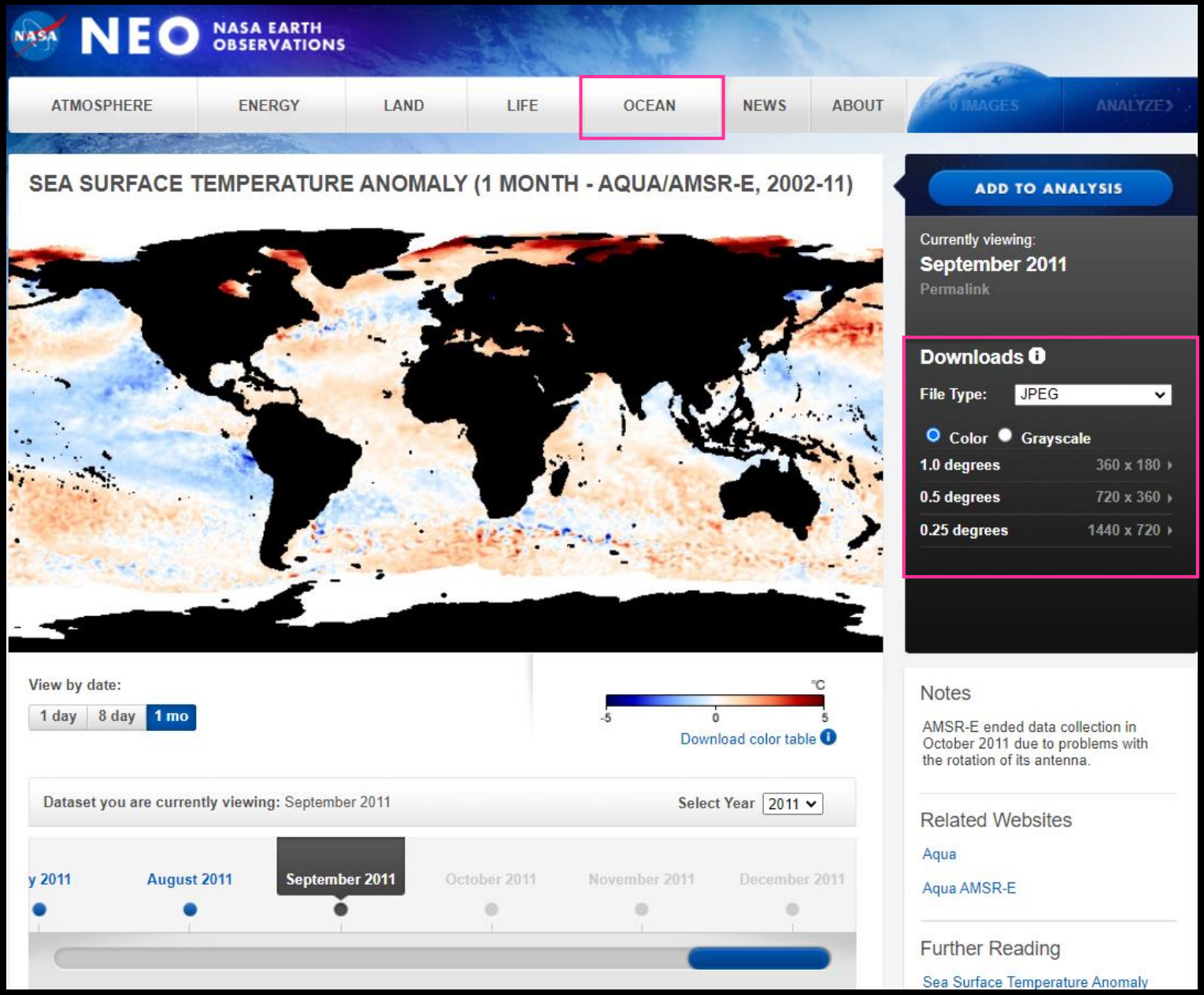



JACOX, Michael G., et al. Thermal displacement by marine heatwaves. *Nature*, 2020, 584.7819: 82-86. www.nature.com/articles/s41586-020-2534-z

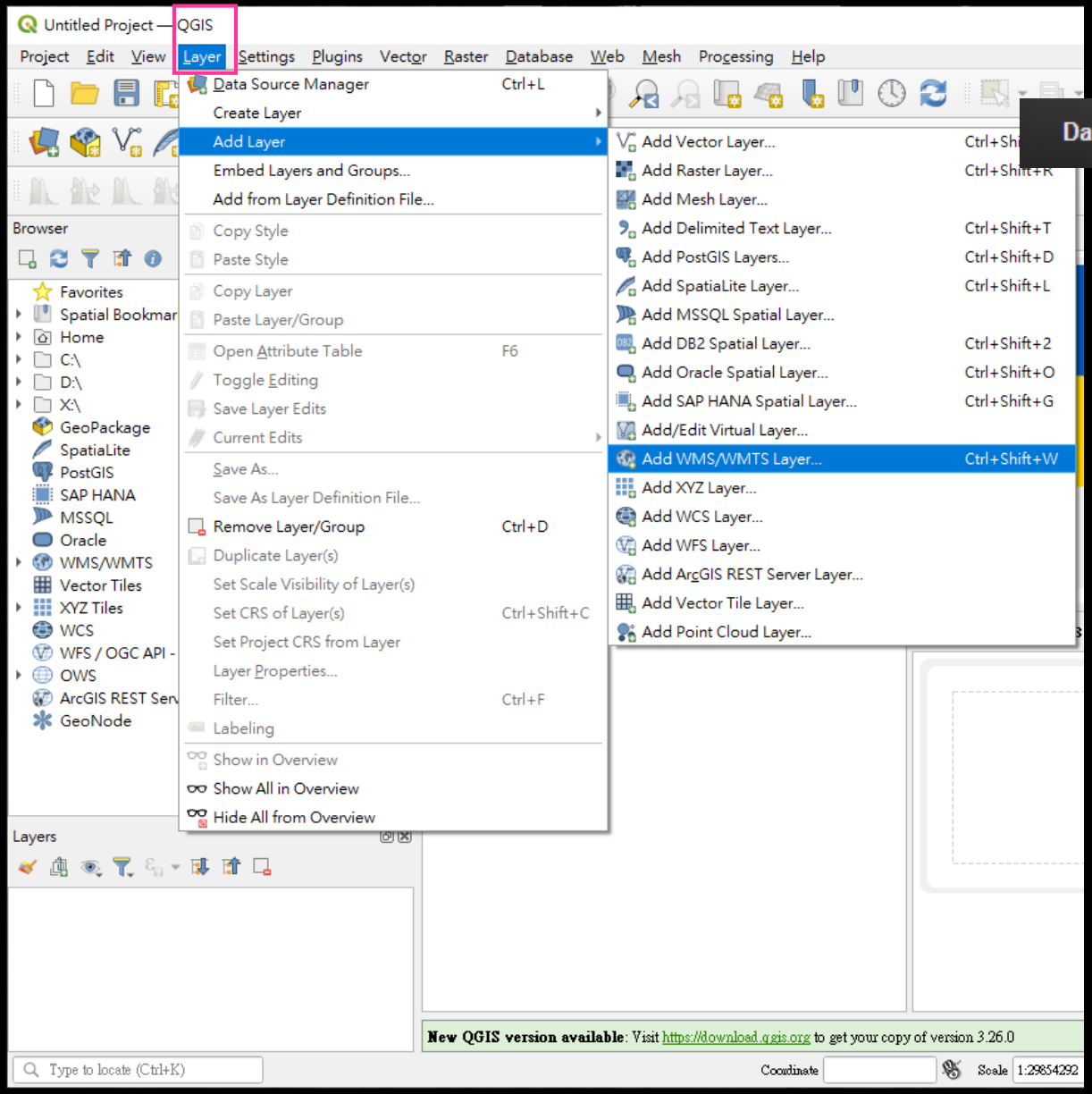
Figure redrawn by PAYNE, Mark R. Marine heatwaves put into context. *Nature*, 2020, 584.7819: 43-44.


問題？方向？資料來源？
✓ 科學社群
✓ Google Dataset search
✓ Paper、Google Scholar
資料模式pattern檢視
✓ Online Mapper
✓ Data Visualization
資料蒐集、產生、分析
✓ Software or programming
資料驗證、問題解析
✓ Testing, Data Viz., Modeling/Simulation
Check Data Patterns
QGIS

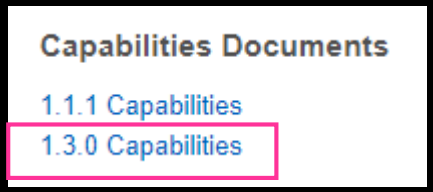
# NASA Earth Observations NEO



# 利用QGIS下載NEO資料 QGIS




**WMS:** NEO 頁面下拉到底


https://neo.gsfc.nasa.gov/wms/wms

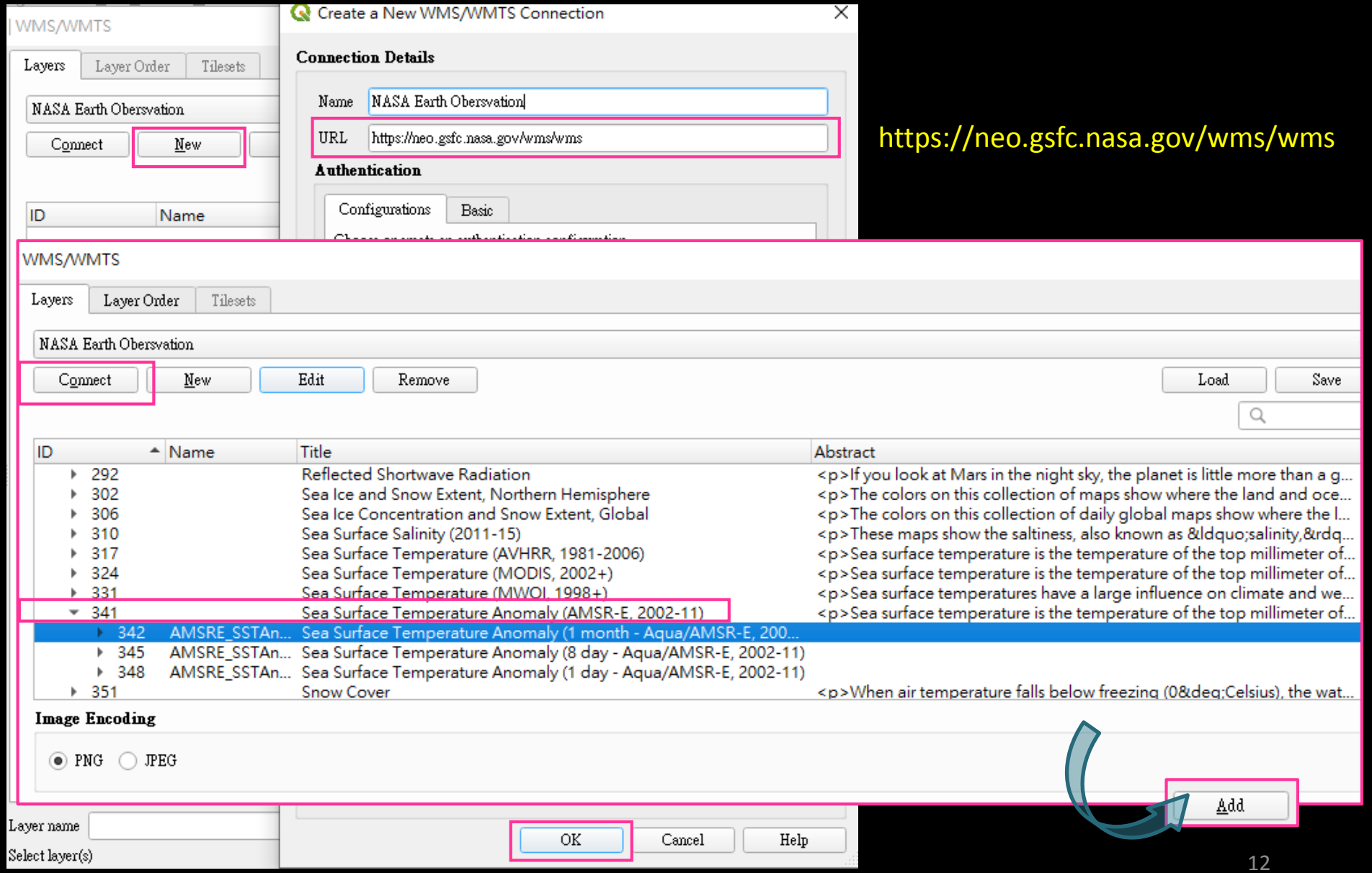
Web地圖服務

Web Map Service, **WMS**

將伺服器上的地理圖層資訊，透過網路協定傳輸的網路服務規範

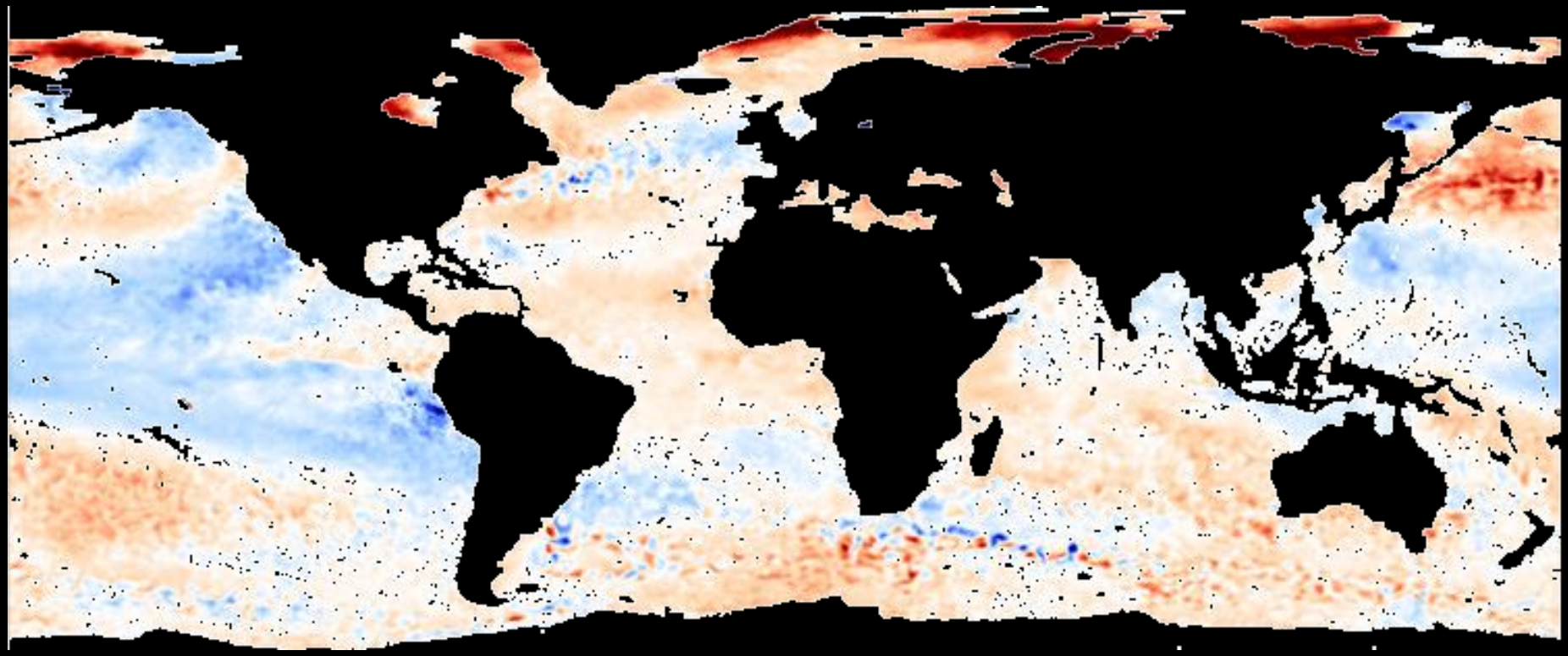
- GetCapabilities
- GetMap

# 在QGIS中設定NEO WMS

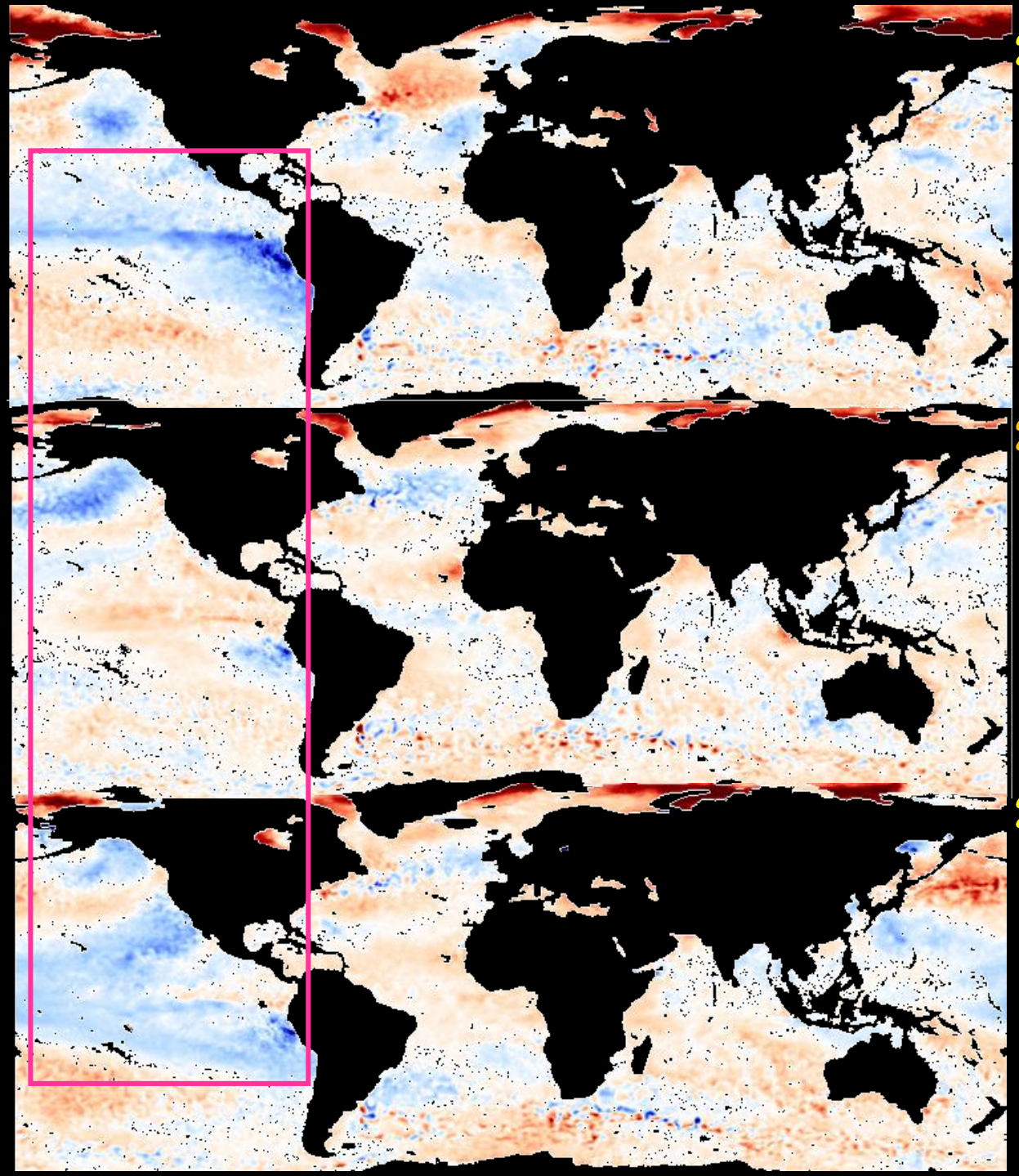



https://neo.gsfc.nasa.gov/wms/wms

# 在QGIS中檢視 SST Anomaly 資料模式



201109

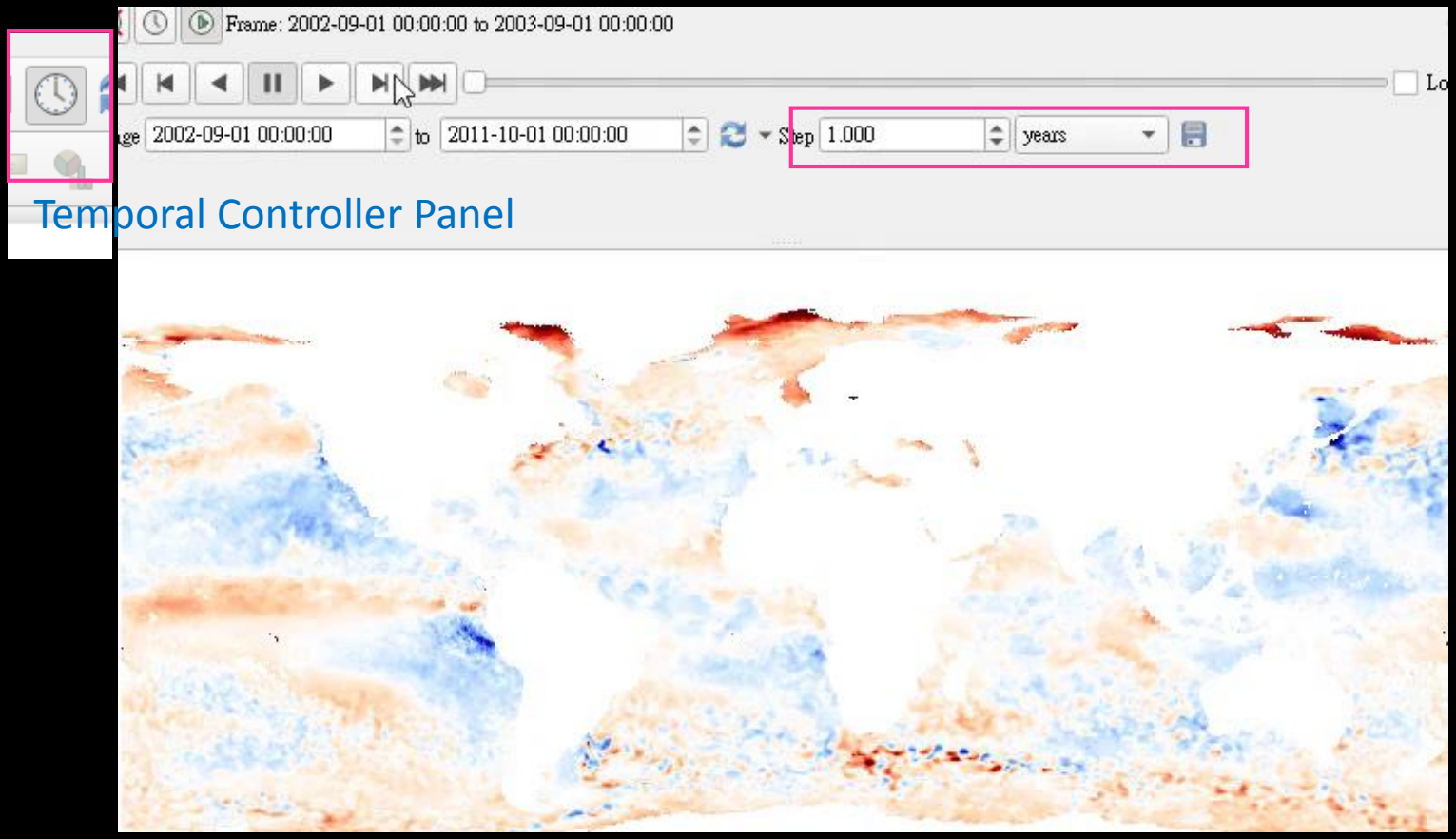



# 在QGIS中檢視 SST Anomalies 資料模式

- ✓ 2007(強), 2011(中) 反聖嬰
  2009 聖嬰(弱)

see: ggweather.com/enso/oni.htm

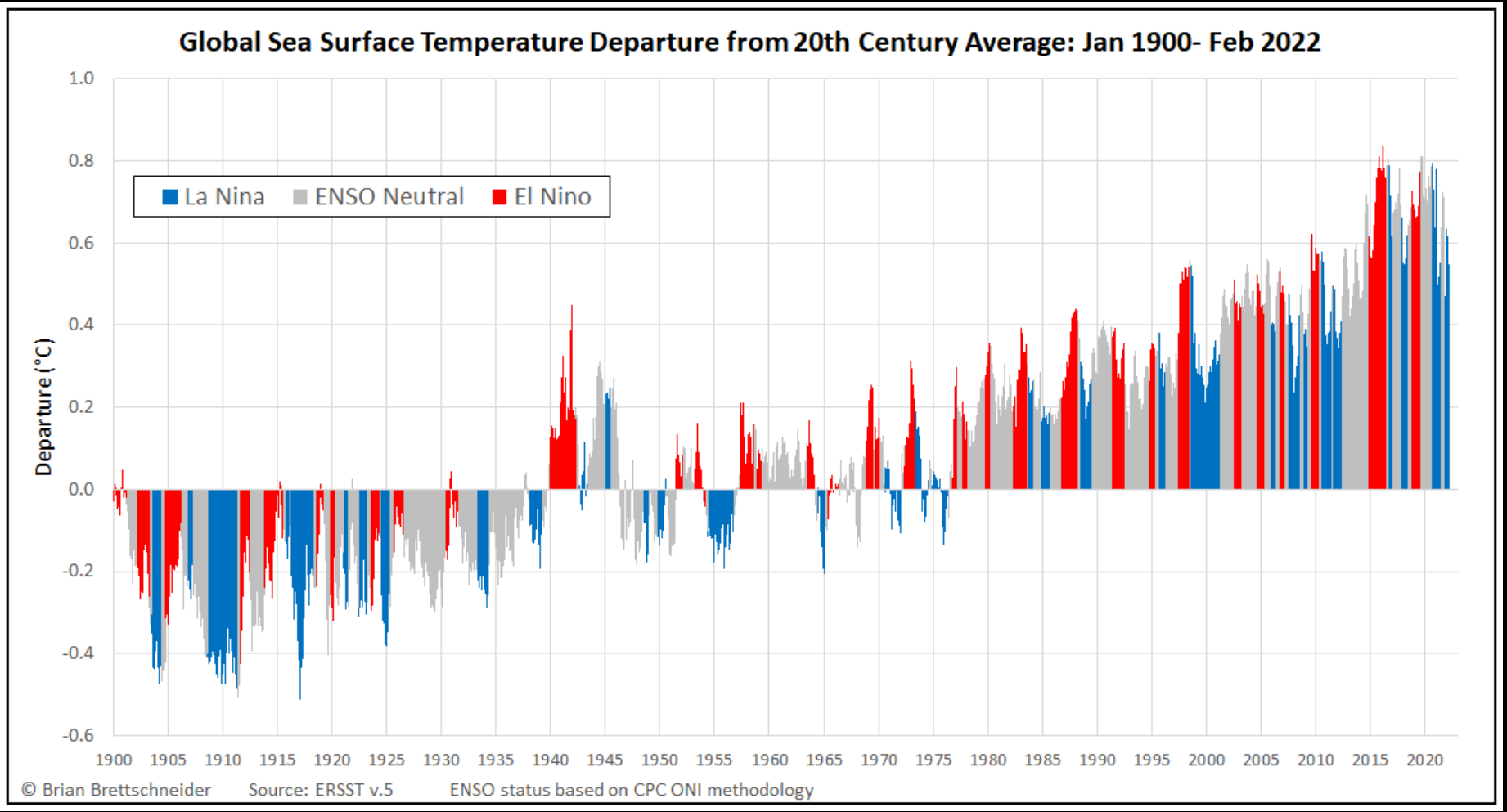
# 在QGIS中利用時間動態檢視資料模式




- ✓ WMS適合呈現，快速瀏覽資料模式
- ✓ NEO raster 有經過處理，非原始資料，作為資料分析，建議參考其blog說明與原始資料下載
- ✓ QGIS 亦提供許多Raster analysis tools，可參考其線上手冊

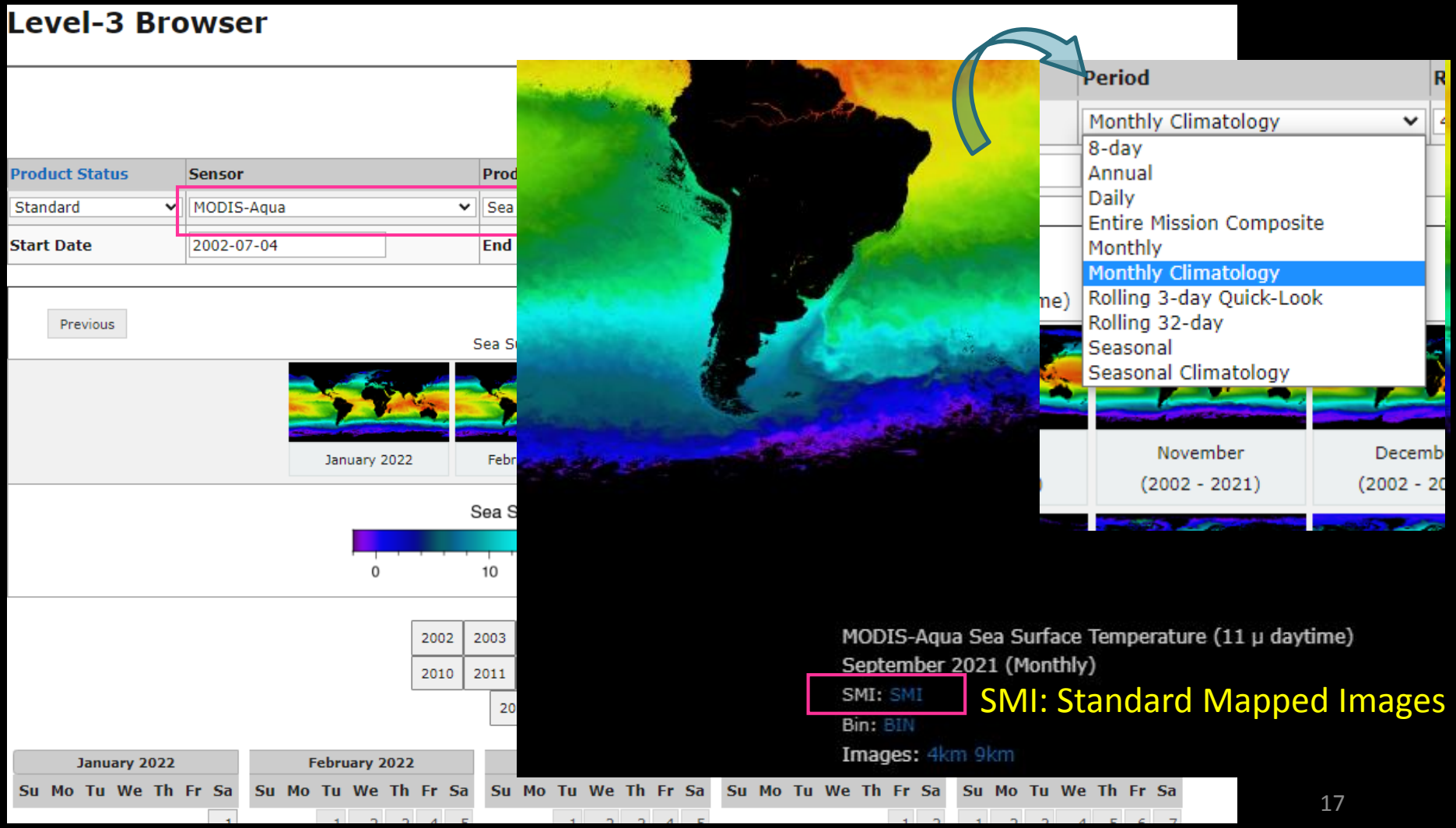
# Global SST anomaly average

by Brian Brettschneider



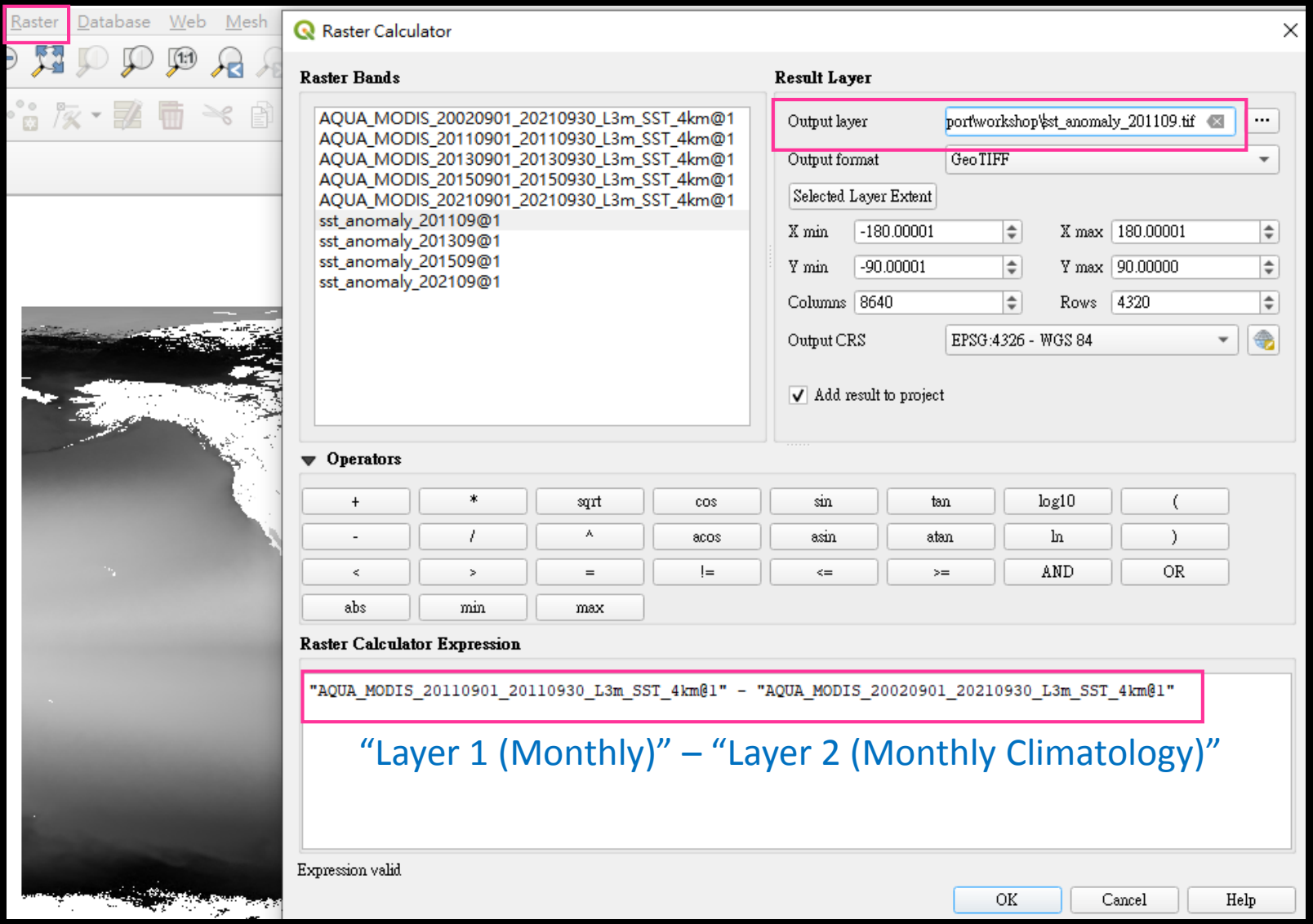

Cited from: twitter.com/Climatologist49/status/1499491799521390592

# NEO的資料有其限制，試試其他資料來源？
# NASA EARTHDATA Ocean Color
# L3 browser

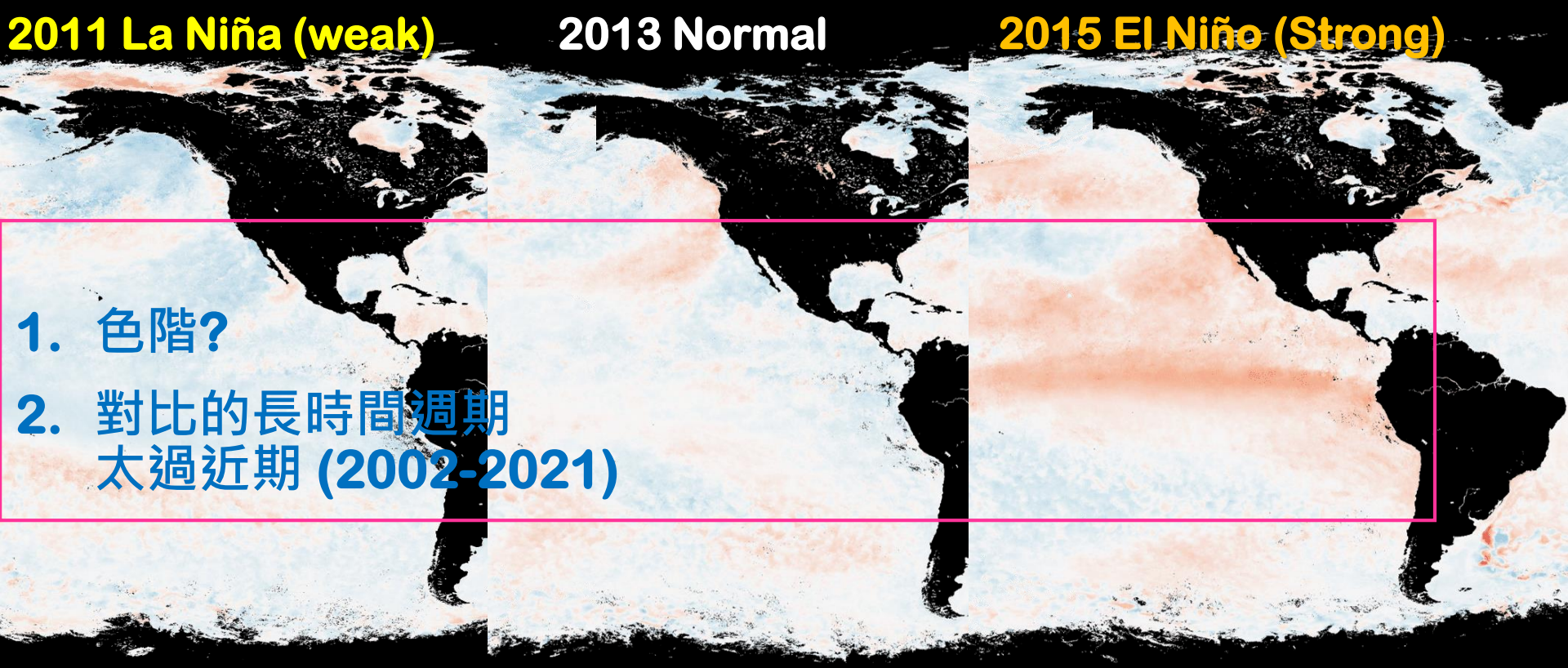


# QGIS Raster Calculator

1. Drag & Drop your NetCDF(.nc) files into QGIS, set Layer CRS
2. Raster -> Raster Calculator

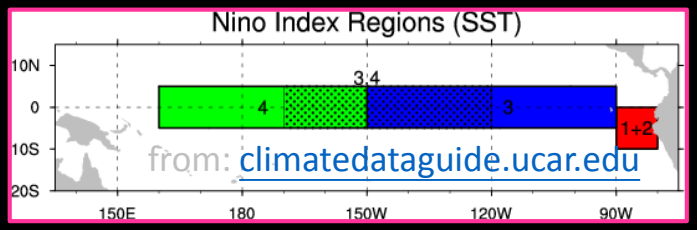


# 比較 SST Anomalies 呈現的資料模式 (vs. NEO WMS pattern)



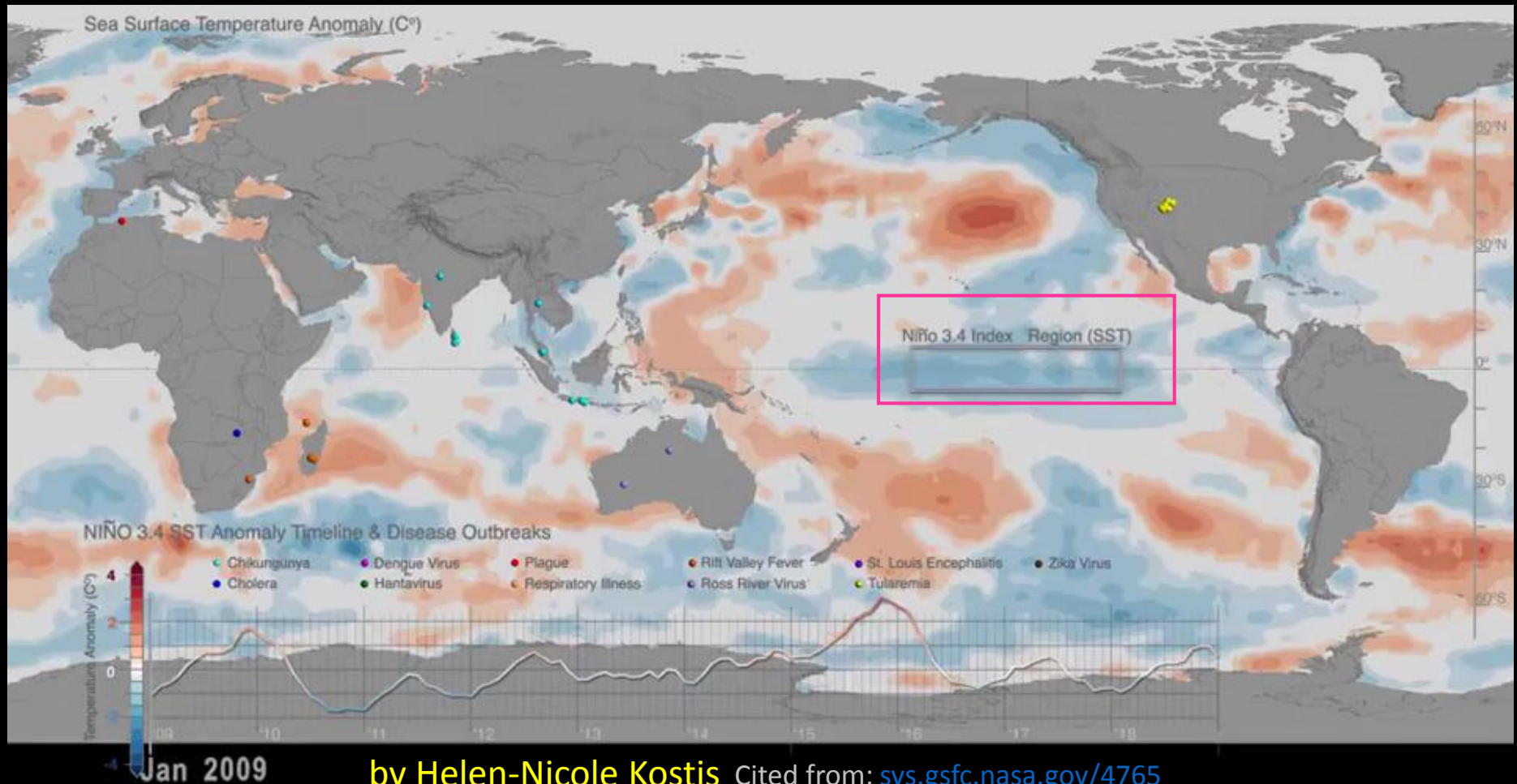

1. 色階?
2. 對比的長時間週期太過近期 (2002-2021)

# Oceanic Niño Index (ONI)



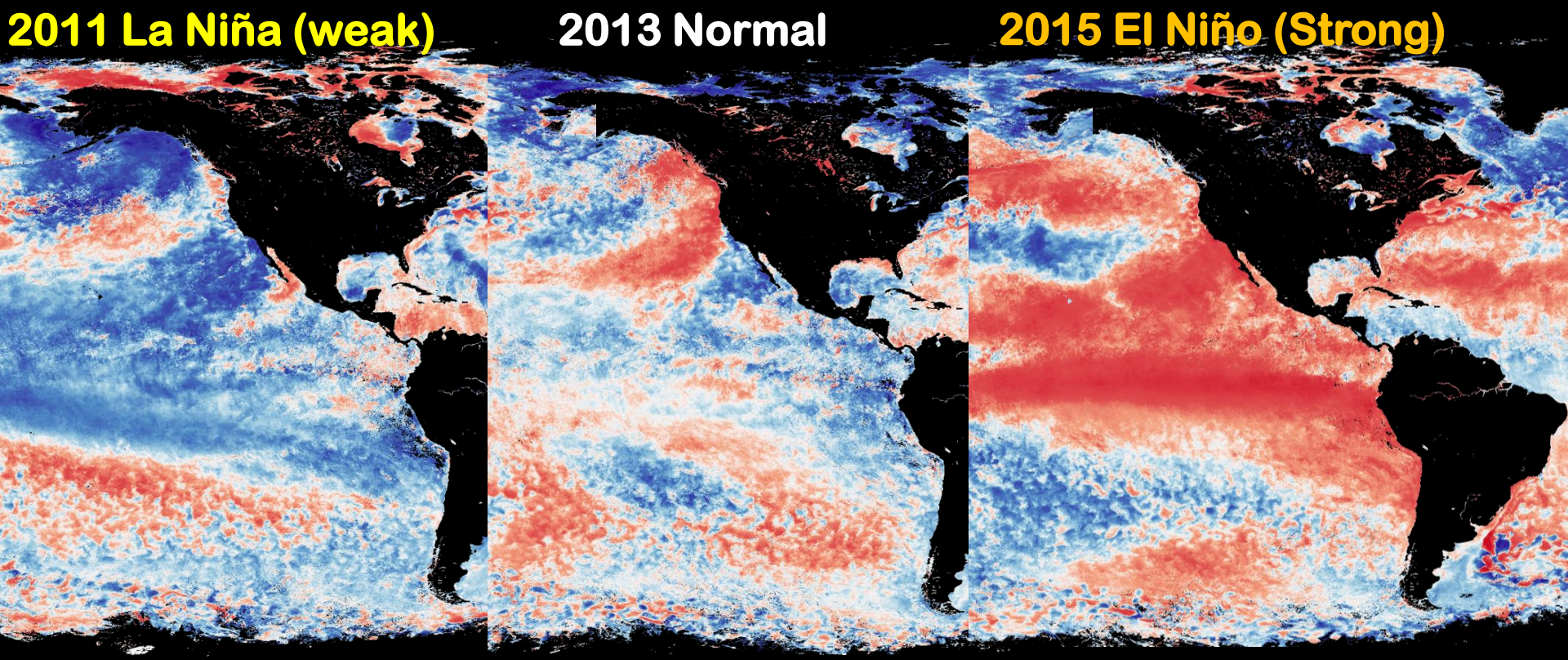

The Oceanic Niño Index (ONI)…running 3-month mean SST anomaly for the Niño 3.4 region (5ºN-5ºS, 120º-170ºW)… 5 consecutive overlapping 3-month periods >/< +-0.5ºC

see: ggweather.com/enso/oni.htm




by Helen-Nicole Kostis Cited from: svs.gsfc.nasa.gov/4765

# 比較 SST Anomalies 呈現的資料模式 (vs. NEO WMS pattern)




這也反映了在”產生資料”過程中的問題：
1. 客製化、2. 自動化的需求

# R
# RStudio

問題？方向？資料來源？
- ✓ 科學社群
- ✓ Google Dataset search
- ✓ Paper、Google Scholar

資料模式pattern檢視
- ✓ Online Mapper
- ✓ Data Visualization

資料蒐集、產生、分析
- ✓ Software or programming

資料驗證、問題解析
- ✓ Testing, Data Viz., Modeling/Simulation

## My working github (in R)

github.com/cywhale/marineheatwave

https://htmlpreview.github.io/?https://github.com/cywhale/marineheatwave/blob/main/R/01_OISST_data.html

```
ga <- ga +
    ggExtra::removeGrid(x=TRUE, y=TRUE) +
    theme(
      panel.background = element_blank(),
      panel.border = element_rect(colour = "black", fill=NA, size=0.75),
      panel.grid.major.x = element_blank(),
      panel.grid.major.y = element_blank(),
      panel.grid.minor = element_blank(),
      plot.margin = unit(c(0,0,0,0), "cm"),
      panel.spacing = unit(0,"cm"),
      strip.background = element_blank(),
      strip.text.y = element_text(angle = 0),
      axis.text.x  = element_text(family = "sans"),
      axis.title.x = element_text(family = "sans"),
      axis.title.y = element_text(family = "sans"),
      axis.text.y = element_text(family = "sans"),
      legend.key = element_blank(),
      legend.key.size = unit(0.6,"line"),
      legend.box.background = element_blank(),
      legend.title = element_text(size=10),
      legend.text =  element_text(family = "sans", size=6),
      legend.background = element_rect(fill = "transparent", colour = "transparent"),
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      legend.key.width = unit(1.5, 'cm'),
      legend.position = "bottom"
    )
ga
```
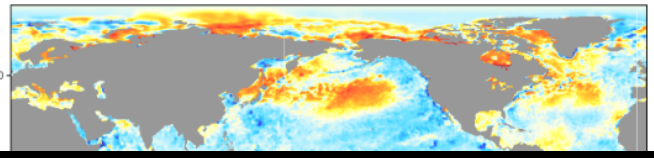
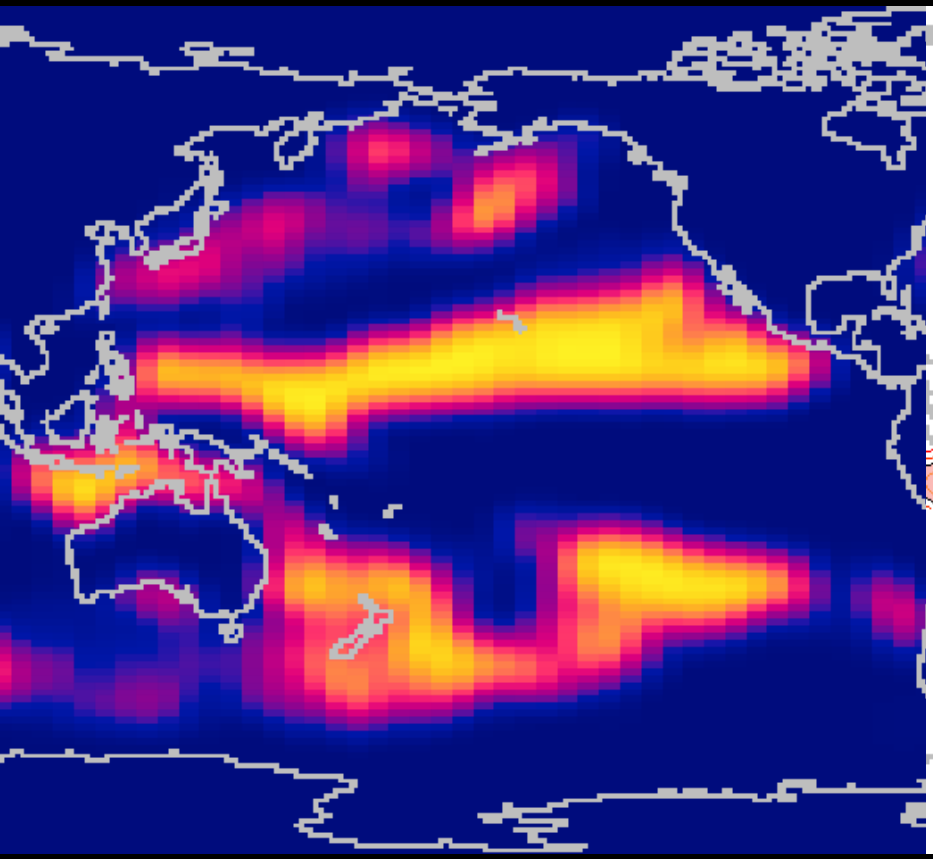
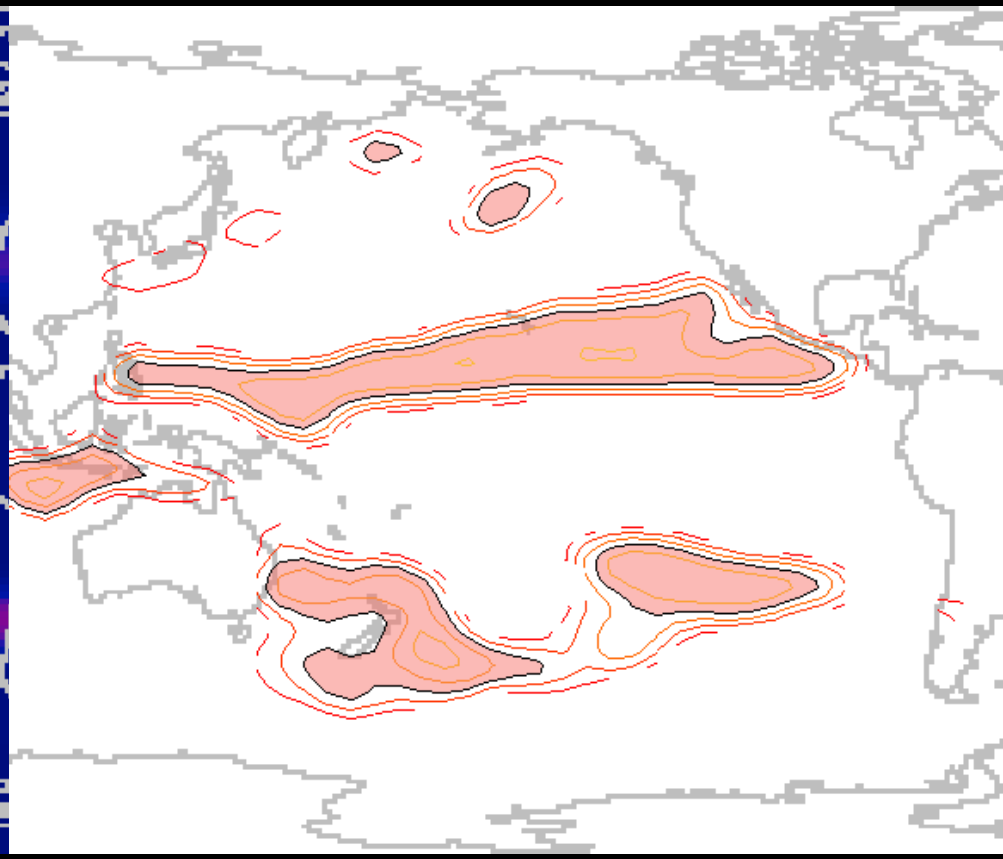



# 地理資訊圖層資料

**Raster**



**Vector**



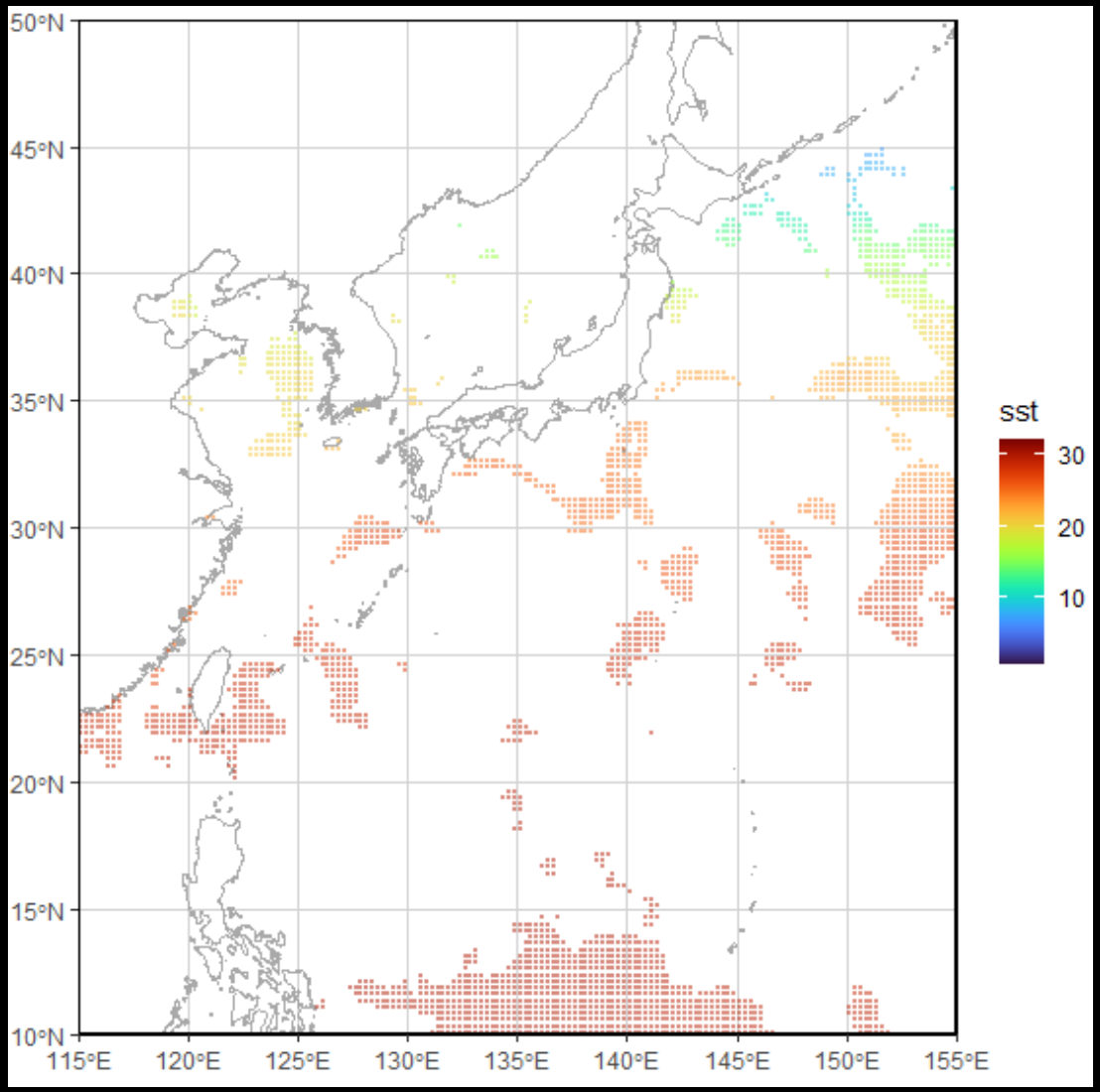
# Vector “data” in GIS

| | SST | geometry |
|---|---|---|
| 1: | 28.5453 | POINT (115.125 21.125) |
| 2: | 28.6900 | POINT (115.125 21.375) |
| 3: | 29.0320 | POINT (115.125 21.875) |
| 4: | 29.0117 | POINT (115.125 22.125) |
| 5: | 28.8973 | POINT (115.125 22.375) |
| --- | | |
| 996: | 29.9647 | POINT (136.625 13.625) |
| 997: | 29.9457 | POINT (136.625 13.875) |
| 998: | 29.8937 | POINT (136.625 14.125) |
| 999: | 29.9597 | POINT (136.625 16.375) |
| 1000: | 29.9243 | POINT (136.625 16.625) |

帶有地理空間訊息的
幾何元素 ”**feature**”

**Spatial geometry +**
**ISO 19125-1:2004:**

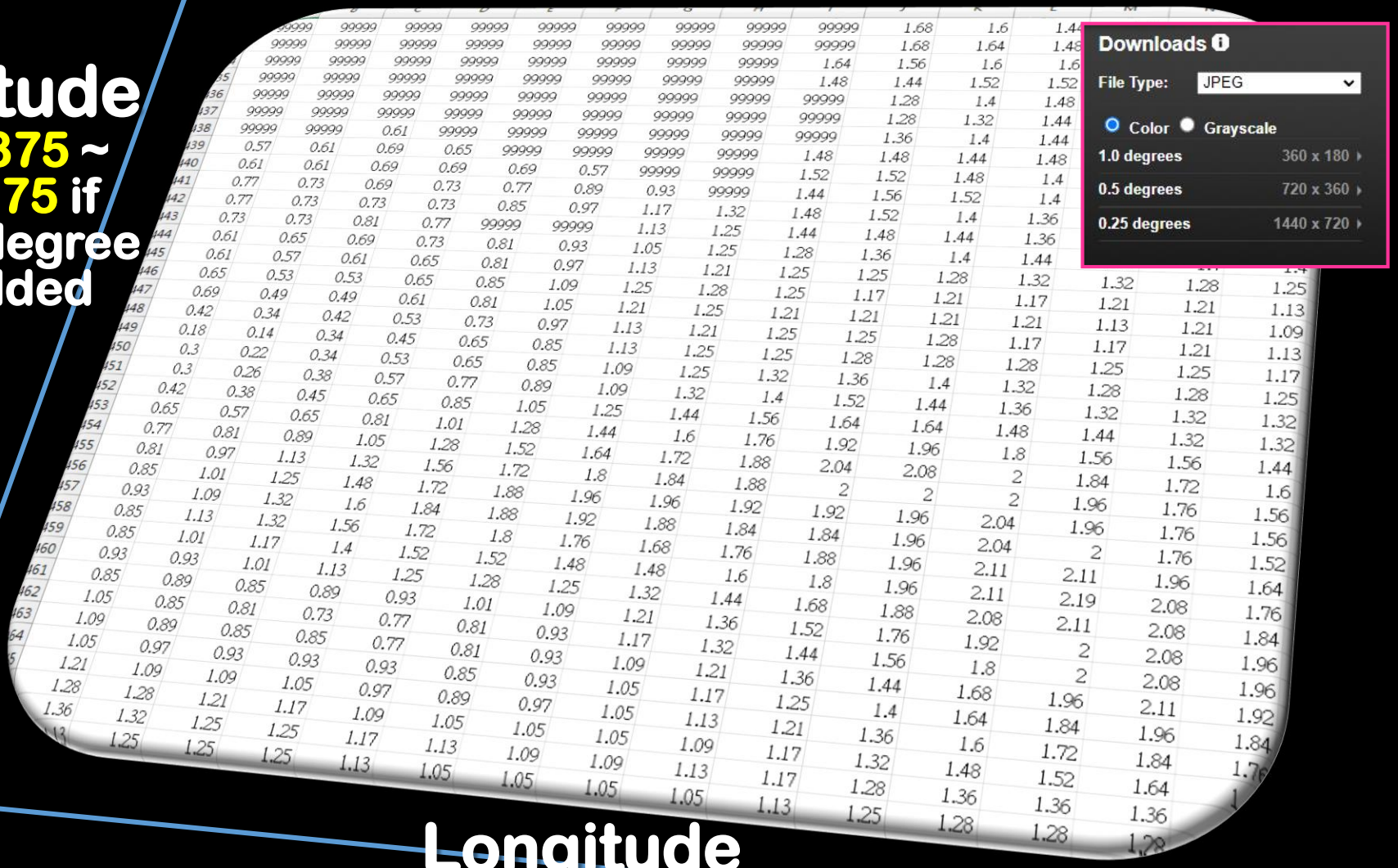
**Simple features (sf)**



# NEO csv

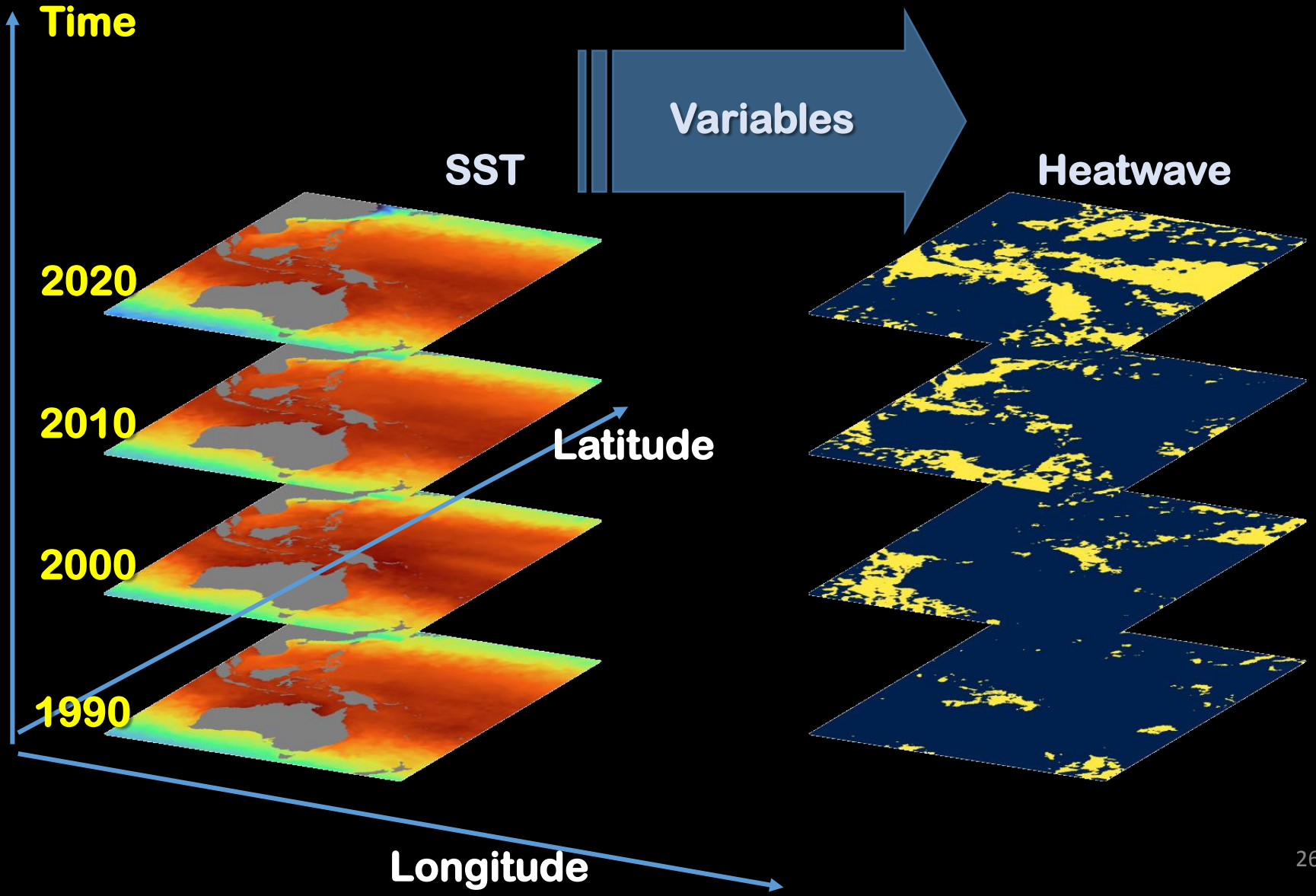
**1440 x 720**
**2-dimension matrix**

**Latitude**
**-89.875 ~ 89.875 if 0.25 degree gridded**




**Longitude**
**-179.875 ~ 179.875 or 0 ~ 359.875 if 0.25 degree gridded**

# NetCDF nc file



# NOAA OISST Data

## Optimum Interpolation SST

The NOAA 1/4° Daily Optimum Interpolation Sea Surface Temperature (OISST) is a long term Climate Data Record that incorporates observations from different platforms (satellites, ships, buoys and Argo floats) into a regular global grid. The dataset is interpolated to fill gaps on the grid and create a spatially complete map of sea surface temperature. Satellite and ship observations are referenced to buoys to compensate for platform differences and sensor biases.

Optional User Registration

Product Details | About | Help

https://www.ncei.noaa.gov/data/sea-surface-temperature-optimum-interpolation/v2.1/access/avhrr/

### Data Access

#### Additional Data

Three other maps at the same 1/4° spatial resolution complement the daily OISST:

- Anomalies (i.e., the daily OISST minus a 30-year climatological mean) represent departures from "n conditions. Computation of several climate indices, such as the El Niño index, utilize SST anomalies
- The error field provides a measure of confidence or quality, allowing users to exclude (using a thres (using weights) the impact of daily OISST values with greater interpolation errors.
- The seven-day median of daily sea ice concentrations serves as the basis for proxy SSTs in the marg observations are lacking. The proxy SST allows interpolation of temperatures from the open ocean margin.

NetCDF

**Index of /data/sea**

| Name | Last modified |
|---|---|
| Parent Directory | |
| 198109/ | 2020-05-15 17:08 |
| 198110/ | 2020-05-15 17:08 |
| 198111/ | 2020-05-15 17:08 |
| 198112/ | 2020-05-15 17:08 |
| 198201/ | 2020-05-15 17:08 |
| 198202/ | 2020-05-15 17:08 |
| 198203/ | 2020-05-15 17:08 |
| 198204/ | 2020-05-15 17:08 |
| 198205/ | 2020-05-15 17:08 |
| 198206/ | 2020-05-15 17:08 |
| 198207/ | 2020-05-15 17:08 |
| 198208/ | 2020-05-15 17:08 |
| 198209/ | 2020-05-15 17:08 |
| 198210/ | 2020-05-15 17:08 |
| 198211/ | 2020-05-15 17:08 |
| 198212/ | 2020-05-15 17:08 |
| 198301/ | 2020-05-15 17:08 |
| 198302/ | 2020-05-15 17:08 |
| 198303/ | 2020-05-15 17:08 |
| 198304/ | 2020-05-15 17:08 |
| 198305/ | 2020-05-15 17:08 |
| 198306/ | 2020-05-15 17:08 |
| 198307/ | 2020-05-15 17:08 |
| 198308/ | 2020-05-15 17:08 |
| 198309/ | 2020-05-15 17:08 |
| 198310/ | 2020-05-15 17:08 |
| 198311/ | 2020-05-15 17:08 |
| 198312/ | 2020-05-15 17:08 |

# Download OISST

```
library(curl) #呼叫函式庫

# 變數 <- 賦值 (比如給予網址字串)
oisstfile <- "https://www.ncei.noaa.gov/data/sea-surface-temperature-optimum-interpolation/v2.1/access/avhrr/201109/oisst-avhrr-v02r01.20110901.nc"

# curl: 網路傳輸、下載的開源工具
# (函式庫::)呼叫功能 function(傳遞參數)
curl::curl_download(oisstfile, destfile = outputfile)


for (i in years) {
  for (j in 1:12) {
    days <- month_dayx(i, j)
    file_list <- lapply(1:days, function(k) {
      #OISST_url <- paste0(..., i, j, days...)
      curl_download(OISST_url, destfile = outputfile)
      return(fileo)
    })
    #.....
```

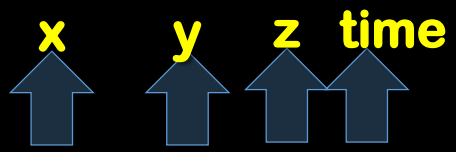
下載每日資料，傳回月檔案列表

Index of /data/sea

| Name | Last modified |
|---|---|
| Parent Directory | |
| 198109/ | 2020-05-15 17:08 |
| 198110/ | 2020-05-15 17:08 |
| 198111/ | 2020-05-15 17:08 |
| 198112/ | 2020-05-15 17:08 |
| 198201/ | 2020-05-15 17:08 |
| 198202/ | 2020-05-15 17:08 |
| 198203/ | 2020-05-15 17:08 |
| 198204/ | 2020-05-15 17:08 |
| 198205/ | 2020-05-15 17:08 |
| 198206/ | 2020-05-15 17:08 |
| 198207/ | 2020-05-15 17:08 |
| 198208/ | 2020-05-15 17:08 |
| 198209/ | 2020-05-15 17:08 |
| 198210/ | 2020-05-15 17:08 |
| 198211/ | 2020-05-15 17:08 |
| 198212/ | 2020-05-15 17:08 |
| 198301/ | 2020-05-15 17:08 |
| 198302/ | 2020-05-15 17:08 |
| 198303/ | 2020-05-15 17:08 |
| 198304/ | 2020-05-15 17:08 |
| 198305/ | 2020-05-15 17:08 |
| 198306/ | 2020-05-15 17:08 |
| 198307/ | 2020-05-15 17:08 |
| 198308/ | 2020-05-15 17:08 |
| 198309/ | 2020-05-15 17:08 |
| 198310/ | 2020-05-15 17:08 |
| 198311/ | 2020-05-15 17:08 |
| 198312/ | 2020-05-15 17:08 |

# 讀取Daily OISST NetCDF (.nc) file

```
library(stars)
sts <- read_stars(outputfile) #讀取NetCDF檔案
str(sts) # str：查看變數結構
```




>List of 4
$ anom: Units: [degree_Celsius] num [1:1440, 1:720, 1, 1] 0.05 ...
$ err : Units: [degree_Celsius] num [1:1440, 1:720, 1, 1] 0.36 ...
$ ice : Units: [%] num [1:1440, 1:720, 1, 1] NA ...
$ sst : Units: [degree_Celsius] num [1:1440, 1:720, 1, 1] -1.75 ...

```
> sts$sst[1:10, 1:10, 1, 1]
Units: [degree_Celsius]
       [,1]  [,2]  [,3]  [,4]  [,5]  [,6]  [,7]  [,8]  [,9] [,10]
 [1,] -1.75 -1.75 -1.75 -1.75 -1.74 -1.74 -1.74 -1.73 -1.72 -1.72
 [2,] -1.75 -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.73 -1.72 -1.71
 [3,] -1.75 -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.73 -1.72 -1.71
 [4,] -1.75 -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.72 -1.72 -1.71
 [5,] -1.75 -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.72 -1.71 -1.70
 [6,] -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.73 -1.72 -1.71 -1.70
 [7,] -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.73 -1.72 -1.71 -1.70
 [8,] -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.72 -1.71 -1.70 -1.69
 [9,] -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.72 -1.71 -1.70 -1.69
[10,] -1.75 -1.75 -1.75 -1.74 -1.74 -1.73 -1.72 -1.71 -1.70 -1.68
```

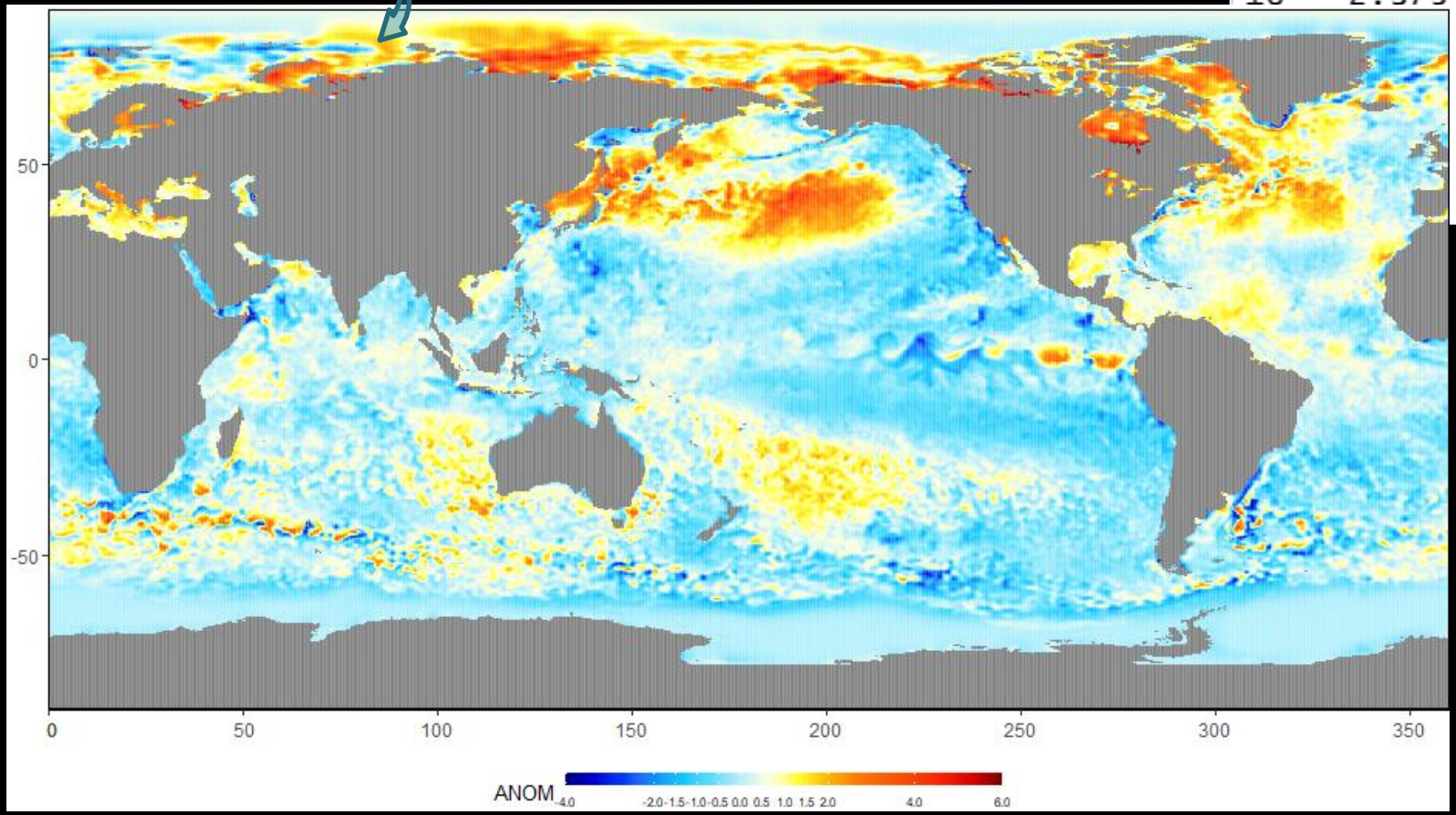
# 取出 SST and SST anomaly

```
var <- "sst"
z <- sts %>% dplyr::select(var) %>% abind::adrop
# adrop: 選擇 (select) SST 丟棄其他維度
df <- as.data.frame(z) #轉換為欄位變數之資料
```

anom

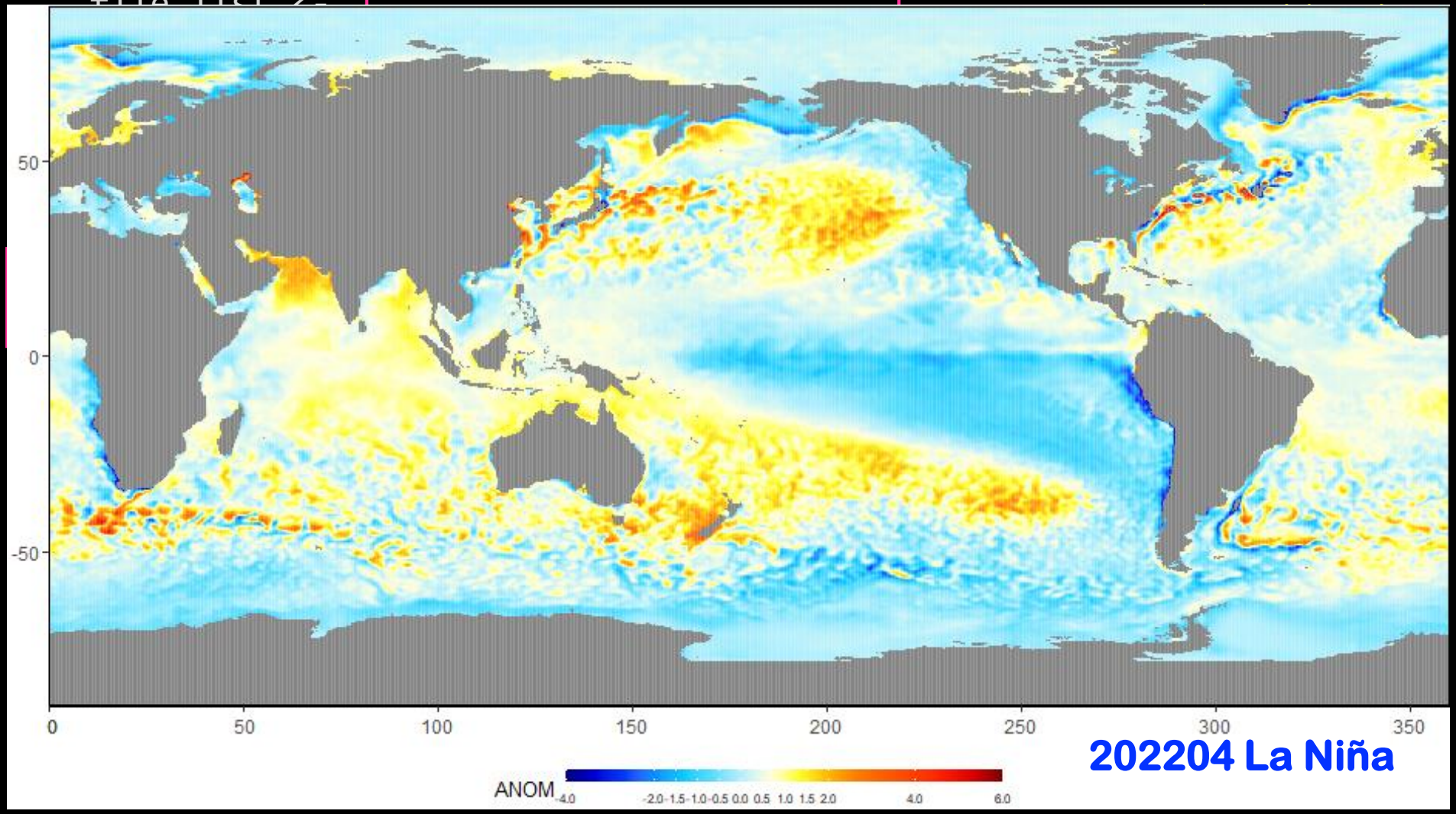
Note: it's daily data, not average

```
> df
          x      y   sst
1     0.125 89.875 -1.75
2     0.375 89.875 -1.75
3     0.625 89.875 -1.75
4     0.875 89.875 -1.75
5     1.125 89.875 -1.75
6     1.375 89.875 -1.75
7     1.625 89.875 -1.75
8     1.875 89.875 -1.75
9     2.125 89.875 -1.75
10    2.375 89.875 -1.75
      ...    ...   ...
      ...    ...   ...
      ...    ...   ...
      ...    ...   ...
      ...    ...   ...
      ...    ...   ...
```



# 計算月平均 Monthly SST & anomaly

```
for (i in years) {
  for (j in 1:12) {
    days <- month_dayx(i, j)
    file_list <-
```



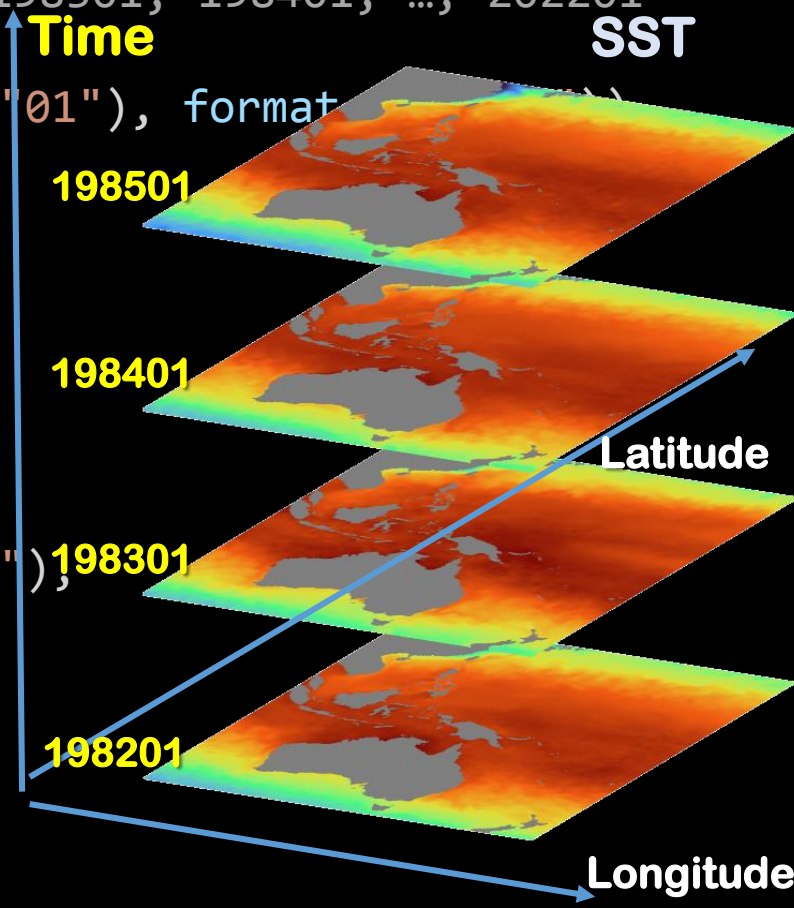
# Climatology of 30yrs monthly SST

```
sstm <- lapply(1:12, function(j) {
  for (i in 1982:2011) { #Years for climatology, 30yrs (climyrs)
    x <- read_stars("Monthly_SST_file.nc by i, j")
    #連接30年中的單一月分，比如依序 198201, 198301, 198401, …, 202201
    stmx <- c(stmx, x) #總共會有30個
    datex<- c(datex, as.Date(paste0(i, j, "01"), format
  }

  sstx <- merge(stmx) %>%
    st_set_dimensions(3, values=
      as.POSIXct(datex), names="time") %>%
      aggregate(by=paste0(climyrs, " years"),
        FUN=mean, na.rm=TRUE)

  names(sstx)[1] <- jstr
  return (sstx)
})
```

先月再年，讀出月平均檔案

串接 SST 月平均檔案

求30年平均，並為變數取名為Jan, Feb, Mar,...



# SST 減去30yrs平均，並去除線性趨勢

```
anomy <- read_stars("Monthly_SST_file.nc by I, j")
anomy[[1]] <- anomy[[1]] - sstm[[j]][[1]]
```

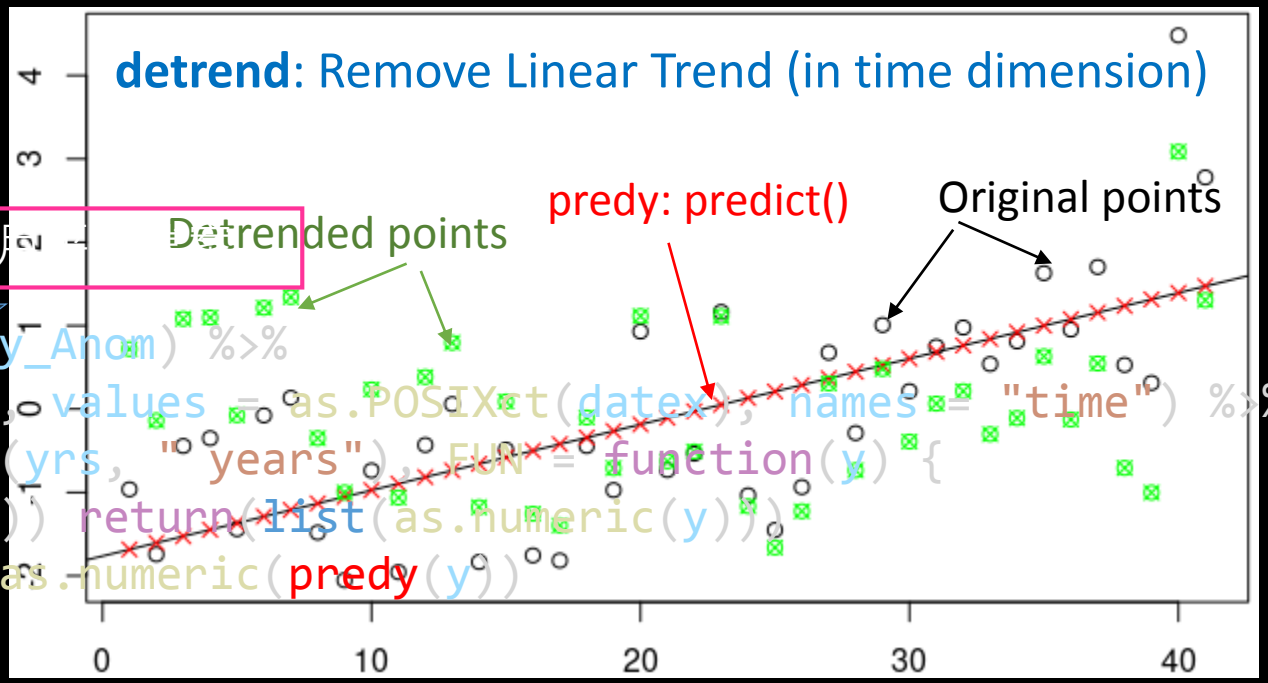
依序讀出月平均檔案，扣除當月30yrs平均

```
predy <- function(y) { return (
  stats::predict(lm(y ~ seq_along(datex)))
)}
```

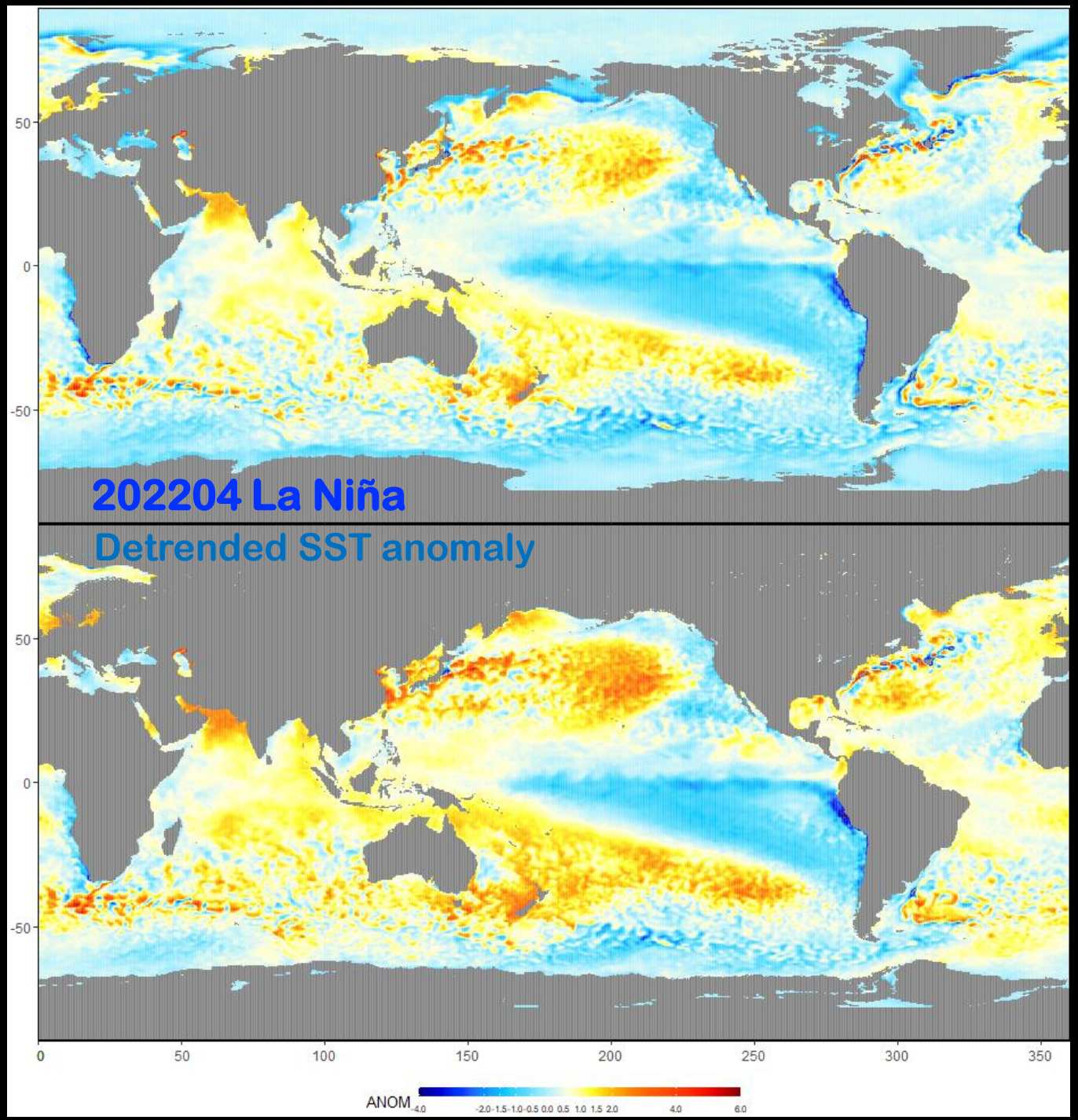
```
for (j in 1:12) {
  for (i in years) {
```

串接 Anomalies 成

```
  trend <- merge(Monthly_Anom) %>%
    st_set_dimensions(3, values = as.POSIXct(datex), names = "time") %>%
    aggregate(by=paste0(yrs, "years"), FUN = function(y) {
      if (all(is.na(y))) return(list(as.numeric(y)))
      y[!is.na(y)] <- as.numeric(predy(y))
      return(y)
    })
```




```
anomy <- read_stars("Monthly_Anomaly_file.nc by i, j")
anomy[[1]] <- anomy[[1]]- trend[[1]]
```



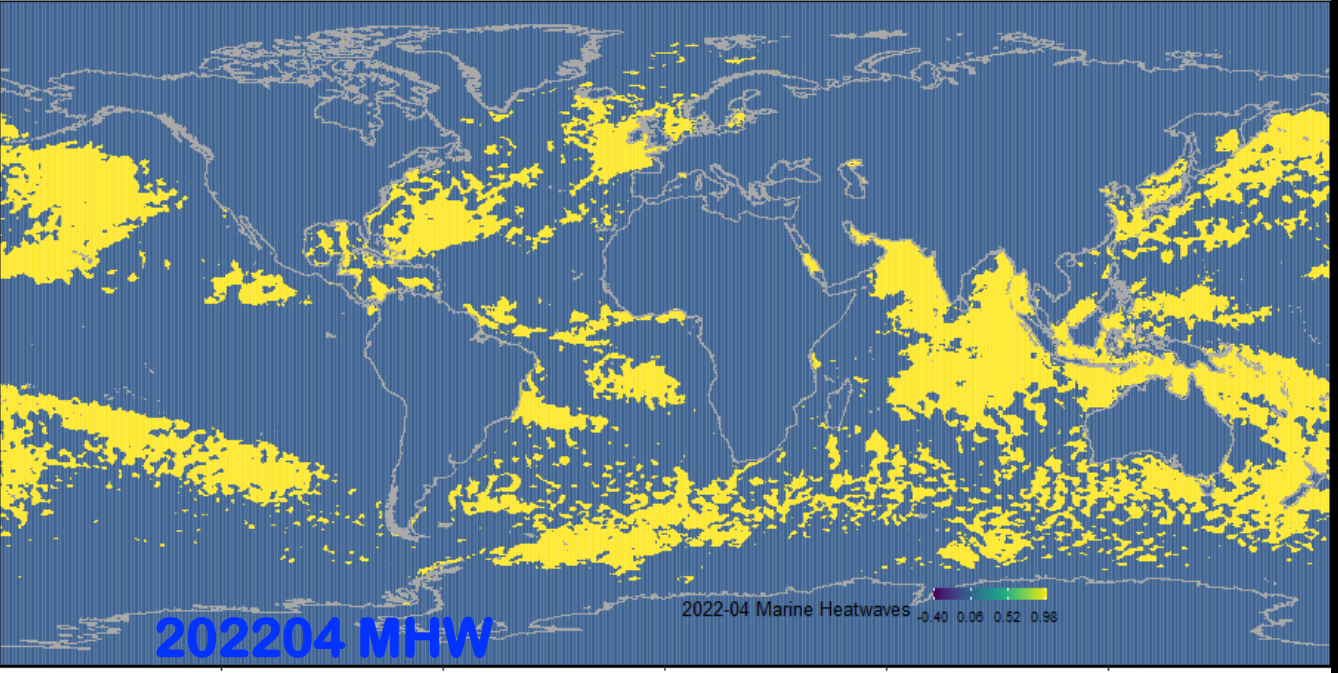

# Monthly SST Anomaly vs Detrended Monthly SST anomaly

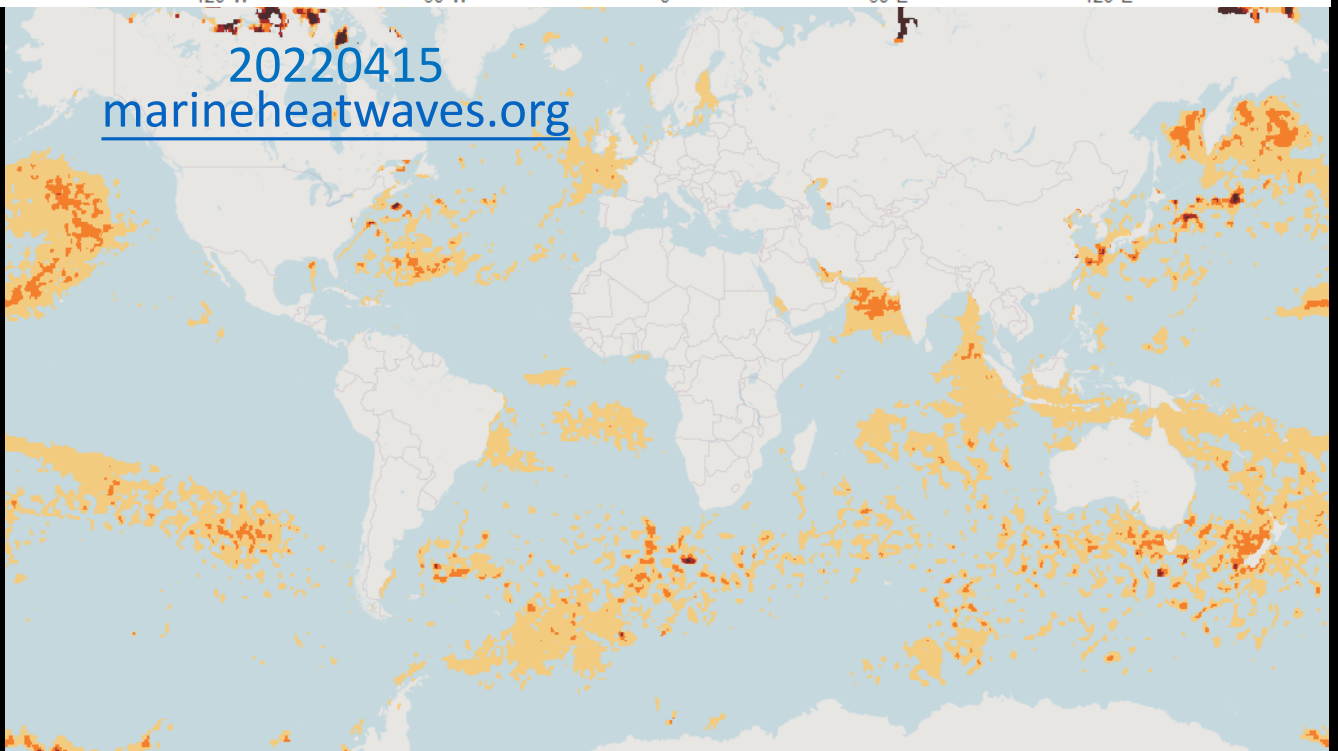
JACOX, Michael G., et al. Thermal displacement by marine heatwaves. *Nature*, 2020, 584.7819: 82-86. www.nature.com/articles/s41586-020-2534-z

# 定義 Marine Heatwaves (MHW)

tology and classified MHWs as periods with SST anomalies above a seasonally varying 90th-percentile threshold (Extended Data Fig. 5). Our analysis differs from those used in some other studies in that we used monthly averaged SST rather than daily data, and we detrended the SST anomalies to distinguish discrete, transient MHWs from the long-term warming signal[31]. Although we believe that the choices to use

```
sty <- future_lapply(1:12, function(j) {
  winj = c(j-1, j , j+1)
  for (i in clim_years) {
    x <- c(read_stars("Monthly_Anomaly_file.nc by i, winj[1]"),
           read_stars("Monthly_Anomaly_file.nc by i, winj[2]"),
           read_stars("Monthly_Anomaly_file.nc by i, winj[3]"))
    datex <- c(as.Date(paste0(i, monj[1], "01"), format="%Y%m%d"),
               as.Date(paste0(i, monj[2], "01"), format="%Y%m%d"),
               as.Date(paste0(i, monj[3], "01"), format="%Y%m%d"))
    styx <- c(styx, x)
    datey<- c(datey, datex)
  }
  styx <- merge(styx) %>%
    st_set_dimensions(3, values=as.POSIXct(datey), names="time") %>%
    aggregate(by=paste0(climyrs, " years"), FUN=quantile, probs=0.9, …)
  return (styx)
})
```

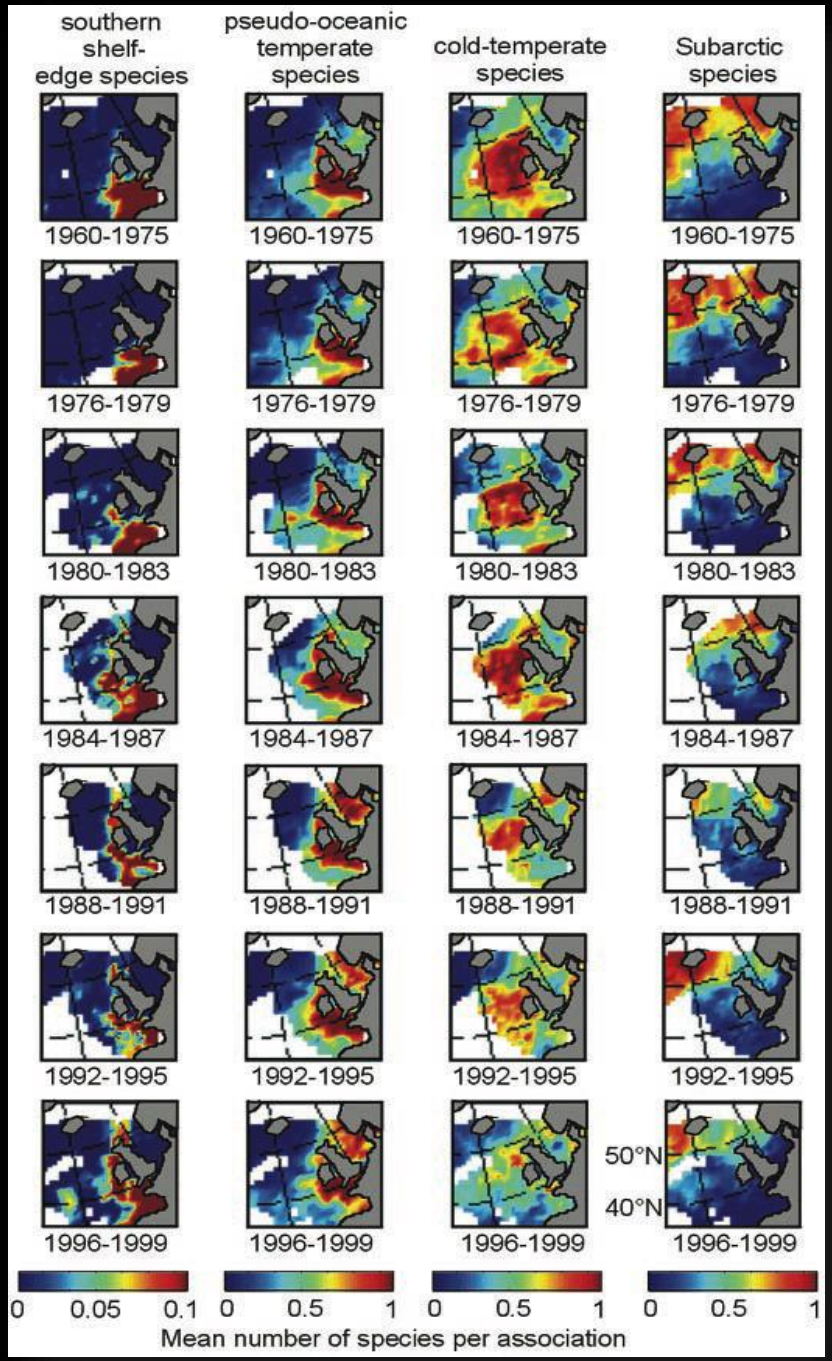


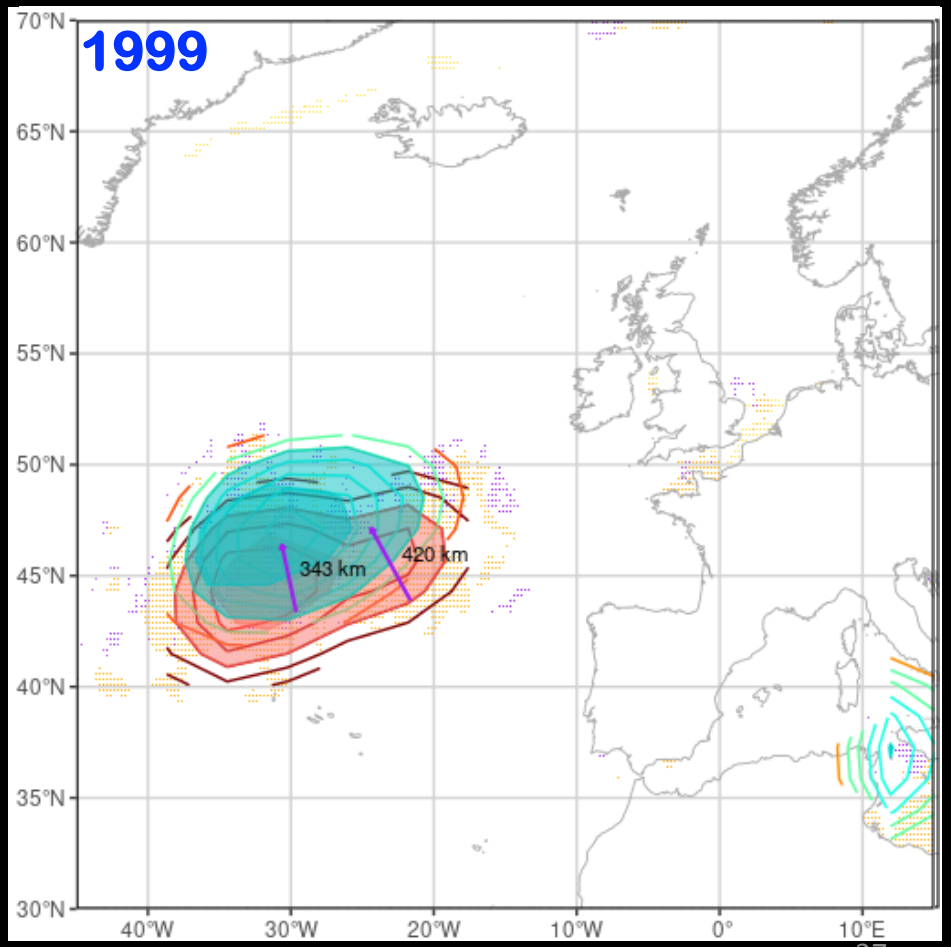




# Marine heatwaves vs Daily MHW from marineheatwaves.org

MHW: SST in the top 10% of temperatures ever recorded during that time of year for at least 5 straight days. Hobday et al. 2016

# MHW-driven Thermal Displacement since 1982




Beaugrand et al, 2002, Science 296: 1692-1694

# Take home message

- ✓ **Definition matters**：例中作者對MHWs採取了不同的"操作型定義" Why? 這也是操作資料前必須釐清
- ✓ **不只是產生資料**：資料可發展成實務性解決問題的資訊應用，關鍵在於能否進一步轉化問題成為**可量化指標**
  - 但量化後的 Thermal Displacement 不等於 Biogeographical shifts 量化指標的適用性必須慎思
- ✓ **站在巨人肩上**： 一篇好的 paper 惠我輩良多！

## 謝謝聆聽

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