2D flux Fields sent from AGCM to Coupler

- **Any flux/tendency field sent from the AGCM to the coupler can in general be be one of 4 types:**

$F^{(1)}$ – values are relative to an area that covers the whole grid cell.

Example: Land Fraction ($LF^{(1)}$), Non-Land Fraction ($NLF^{(1)} = 1\text{-}LF^{(1)}$)

$F^{(2)}$ – values are relative to an area that covers the non-land portion of the whole grid cell.

Example: sea-ice fraction ($SICN^{(2)}$)

$F^{(3)}$ – values are relative to an area that covers the open-water portion of the non-land portion of the whole grid cell.

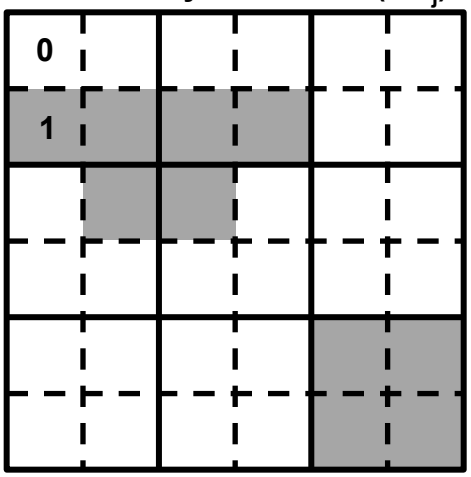
Example: fresh-water flux over ocean

$F^{(4)}$ – values are relative to an area that covers the ice covered portion of the non-land portion of the whole grid cell.

Example: snow flux over ice

Initial Test Setup

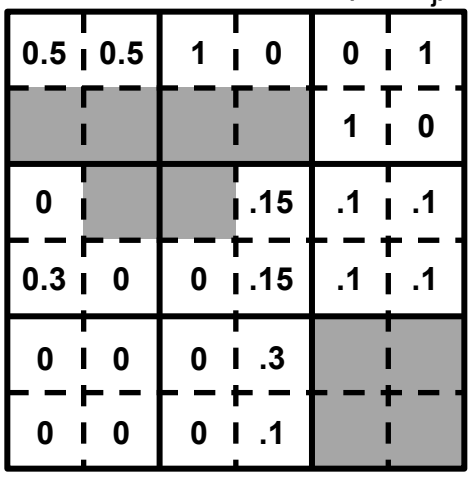
Nemo binary land mask (LM_j)



AGCM land fraction (LF_i)

0.5	0.5	0
0.25	0.25	0
0	0	1

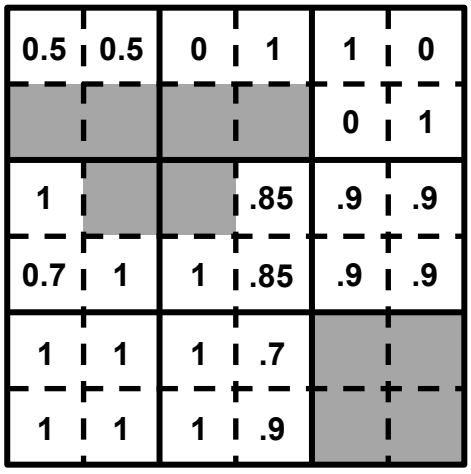
Nemo sea-ice fraction ($SICN_j$)



AGCM sea-ice fraction ($SICN_i$)

0.5	0.5	0.5
0.1	0.1	0.1
0	0.1	N/A

Nemo open-water fraction (1-$SICN_j$)



AGCM open-water fraction (1-$SICN_i$)

0.5	0.5	0.5
0.9	0.9	0.9
1	0.9	N/A

Regridding Tests

- Given the setup on the previous page, for each type of field (3 and 4) consider the conservative regridding of some AGCM flux, $F^{(i)}$, [kg/(m^2s)]) to the equivalent flux on the OGCM grid, $G^{(i)}$,
- consider $F^{(i)}$ with the following values:

1	10	1
10	1	10
1	10	N/A

- because the grids are overlapping, global conservation is equivalent to conservation over the area of each AGCM grid cell - call this A_j

A_1	A_2	A_3
A_4	A_5	A_6
A_7	A_8	A_9

- For each A_j there are the 4 underlying Nemo grid cells $N_1 \ldots N_4$:

N_1	N_2
N_3	N_4

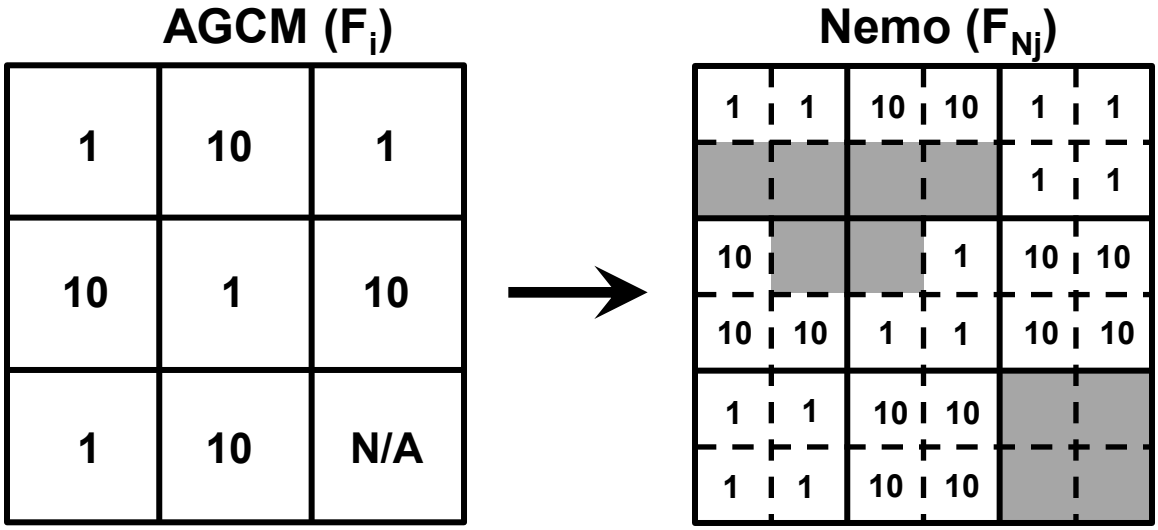
- Take the total domain area to be equal to unity. We then have:

AGCM: $A_i = 1/9$

Nemo: $A_{Ni} = 1/36$

Regridding Tests

- For each type, 3 and 4, conservative remapping puts identical values on the NEMO 4 grid boxes under each A_j

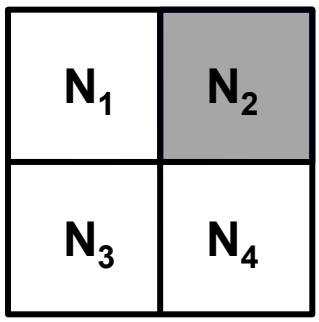


- This is true because, Nemo expects fluxes from the AGCM that are over open water (type 3) or over ice (type 4). It can handle a mixed flux over non-land (type 2) but it also requires one of the other two types as well so that it can back out the third and use just type 3 and 4.

  Here we shall assume that the AGCM sends only types 3 and 4 to the coupler

  - For type 3, Nemo multiplies the flux on its grid by its local open-water fraction (1-SICN) before its use
  - For type 4, Nemo multiplies the flux on its grid by its local sea-ice fraction (SICN) before its use

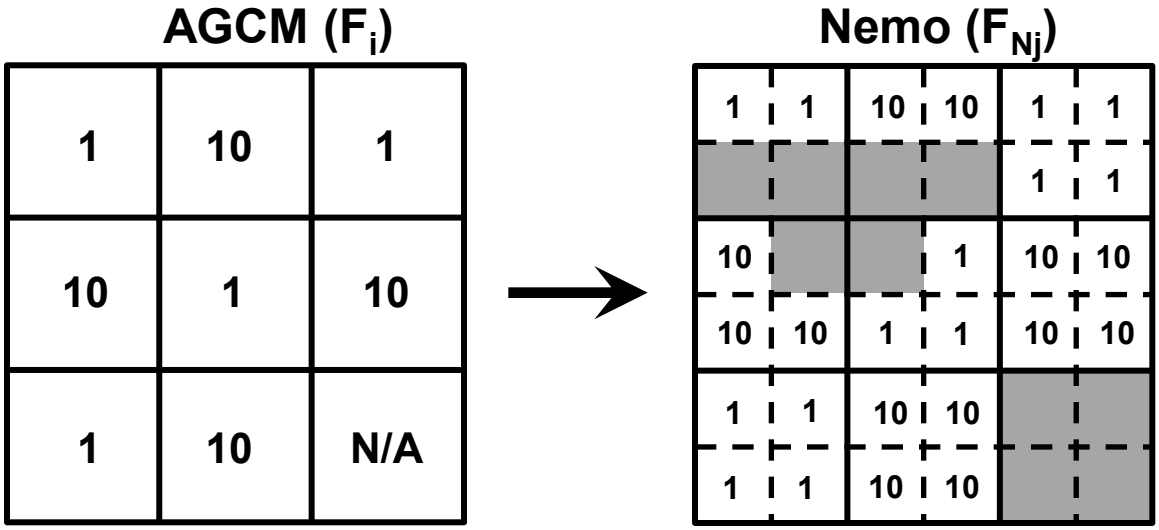
- consider conservation for AGCM grid box A_4 with non-land area $0.75A_4$



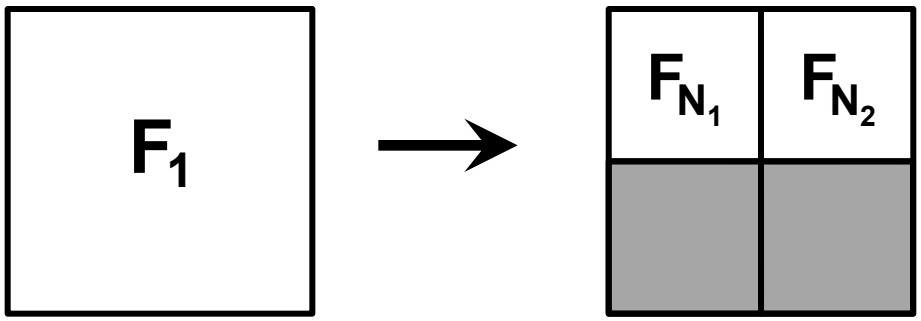
- from AGCM, total mass rate over this AGCM box is:
  for type 3 – $10*(1\text{-}SICN_4)*0.75A_4 = 6.75/9$ [kg/s]
  for type 4 – $10*\ (SICN_4)*0.75A_4 = 0.75/9$ [kg/s]
- from Nemo, total mass rate over 4 NEMO tiles, each with area 1/36 (= $0.25*A_4$) is:
  for type 3 – $10*\{2*(1) + 0.7\}*0.25A_4 = 6.75/9$ [kg/s]
  for type 4 – $10*\{2*(0) + 0.3\}*0.25A_4 = 0.75/9$ [kg/s]

Coupler Setup for Conservative Remapping A to O

- For each type, 3 and 4, we desire settings for the conservative remapping that results in:

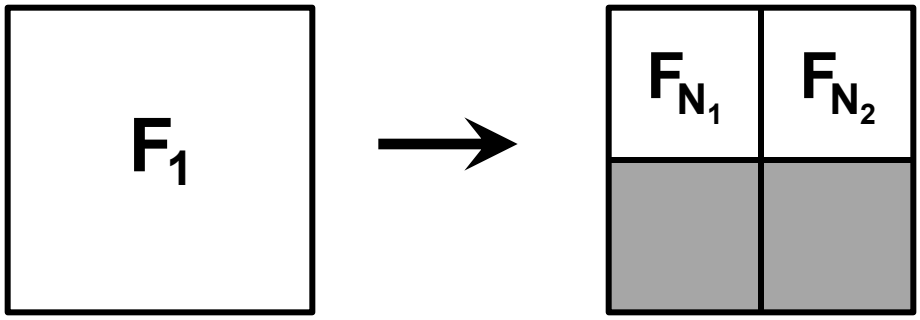


- That is, even for the case when the grids do not overlap, what are the general settings for the conservative remapping (eg fractarea vs destarea, should the remapping be forced to respect a binary land mask on source/target grid etc.) that results in this behaviour when going from the coarse AGCM grid to the fine Nemo grid. Some things to consider:
  - the remapper knows only about the location of grid centers and corners on each grid and the area of the grid boxes on each grid.
  - the remapper knows nothing about, and cannot handle, the fractional land mask on the coarse (AGCM) grid
- Consider AGCM box A_1, the remapper knows only the areas A_1 and A_{Nj}



Coupler Setup for Conservative Remapping A to O Type 3

- AGCM grid box has area A_i=1/9, underlying Nemo grid boxes have A_{Nj} = 1/36 (=0.25A_i in this example). For first AGCM grid box A_1:



- consider type 3 where F_1 represents a flux over the open water portion of the AGCM grid box. The area of the open water portion of the grid cell is the non-land fraction times the non-ice fraction of the A_1:

AGCM

$$A_{OW} = (1\text{-}LF)*(1\text{-}SICN)*A_1$$

$$[F_1] = kg/(m^2s);\ [A_{OW}] = m^2;\ [F_1 * A_{OW}] = kg/s$$

Nemo

$$A_{NOW} = \Sigma_j A_{NOWj} = \Sigma_j (1\text{-}SICN_j)*A_{Nj} = 0.25*A_1 \Sigma_j (1\text{-}SICN_j)$$

$$[F_{Nj}] = kg/(m^2s);\ [A_{NOWj}] = m^2;\ [F_{Nj} * A_{OWj}] = kg/s$$

Conservation implies

$$\Sigma_j F_{Nj}*(1\text{-}SICN_j)*A_{Nj} = F_1 * (1\text{-}LF)*(1\text{-}SICN)*A_1$$

- But, since Nemo itself performs the (1-$SICN_j$) scaling, we require that the remapper satisfies:

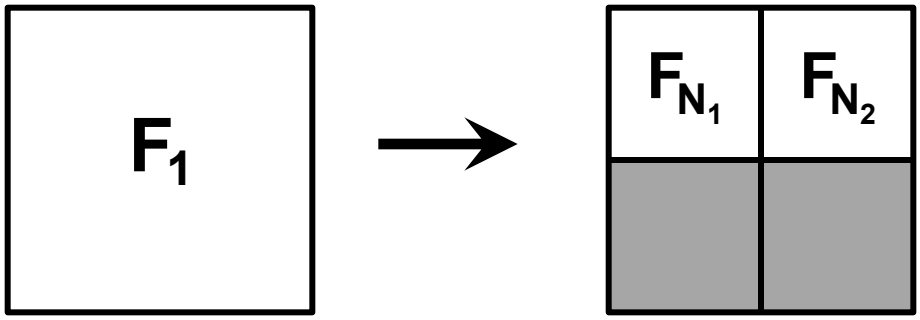
$$\Sigma_j F_{Nj}*A_{Nj} = F_1 * (1\text{-}LF)*A_1$$

$$1*1/36 + 1*1/36 = 1/18 = 1*(1\text{-}0.5)*1/9 = 18$$

- this works because: $(1\text{-}SICN) = \Sigma_j (1\text{-}SICN_j)$

Coupler Setup for Conservative Remapping A to O Type 3 cont

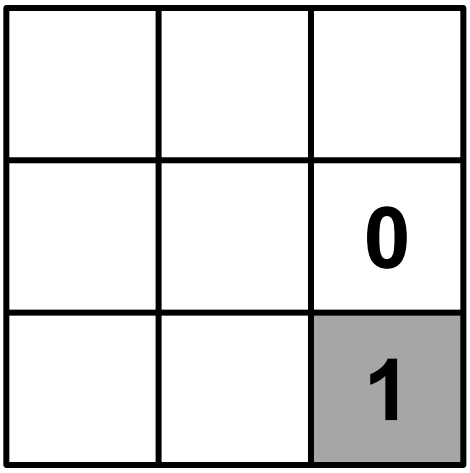
- AGCM grid box has area A_i=1/9, underlying Nemo grid boxes have A_{Nj} = 1/36 (=0.25A_i in this example). For first AGCM grid box A_1:



- remapper satisfies: $\Sigma_j F_{Nj} * A_{Nj} = F_1 * (1\text{-}LF) * A_1$

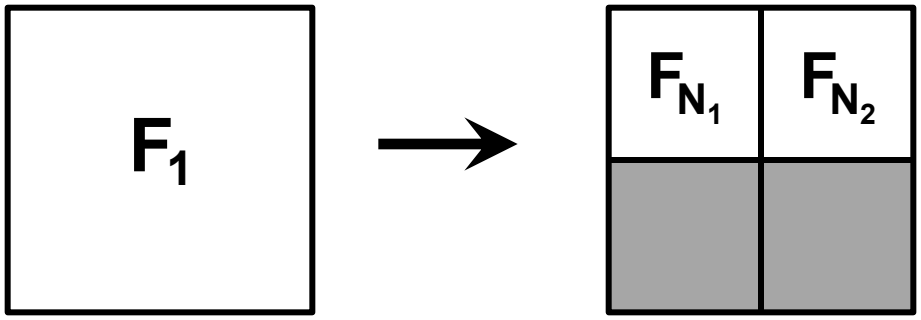
Some considerations:

- we do not want to put information in Nemo cells that are designated land. This would suggest that we use "fractarea" and respect the destination binary land mask on the Nemo grid when performing the remapping.
- for AGCM grid cells that are all land (ie land fraction is 1) we do not want any values participating in the remapping. This will not be a problem for the coincident grids here but we need to see if offset grids might violate this condition. If so, we can think about having the remapper also respect a "conservative" AGCM binary land mask define by a land fraction of 1 on the AGCM grid. For this example it look like:



Coupler Setup for Conservative Remapping A to O Type 4

- AGCM grid box has area A_i=1/9, underlying Nemo grid boxes have A_{Nj} = 1/36 (=0.25A_i in this example). For first AGCM grid box A_1:



- consider type 4 where F_1 represents a flux over the sea-ice portion of the AGCM grid box. The area of the sea-ice portion of the grid cell is the non-land fraction times the sea-ice fraction of the A_1:

AGCM

$$A_{SI} = (1\text{-}LF)*SICN*A_1$$

$$[F_1] = kg/(m^2s);\ [A_{SI}] = m^2;\ [F_1 * A_{SI}] = kg/s$$

Nemo

$$A_{NSI} = \sum_j A_{NSIj} = \sum_j SICN_j*A_{Nj} = 0.25*A_1 \sum_j SICN_j$$

$$[F_{Nj}] = kg/(m^2s);\ [A_{NSIj}] = m^2;\ [F_{Nj} * A_{NSIj}] = kg/s$$

Conservation implies

$$\sum_j F_{Nj}*SICN_j*A_{Nj} = F_1 * (1\text{-}LF)*SICN*A_1$$

- But, since Nemo itself performs the $SICN_j$ scaling, we require that the remapper satisfies:

$$\sum_j F_{Nj}*A_{Nj} = F_1 * (1\text{-}LF)*A_1$$

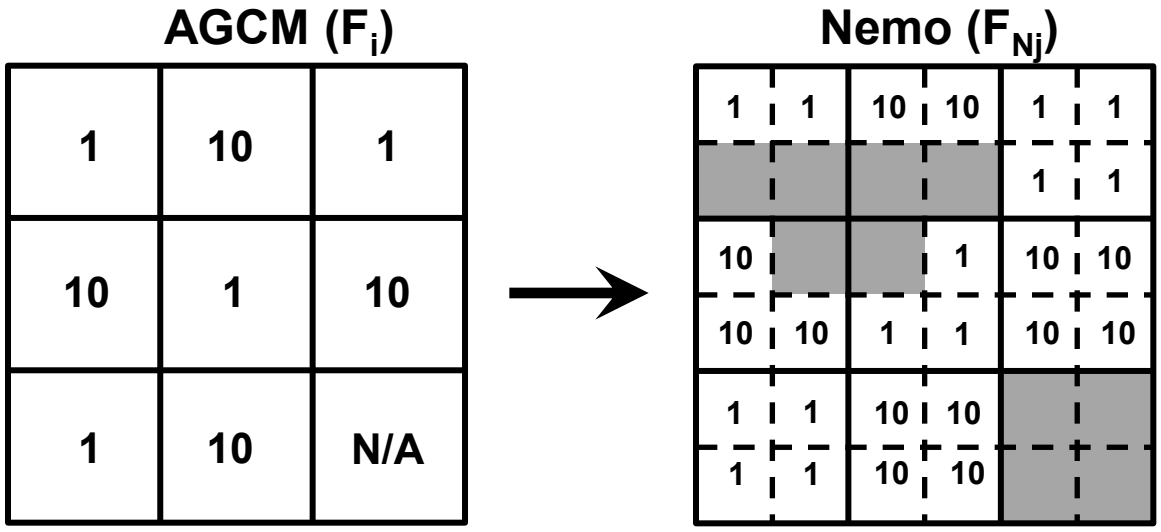
$$1*1/36 + 1*1/36 = 1/18 = 1*(1\text{-}0.5)*1/9 = 18$$

- this works because:

$$SICN = \sum_j SICN_j$$

Remapping Tests

TEST# 1 For the example here and each type 3 and 4, perform the remapping of the following AGCM data to get the following values in the NEMO grid



- From the preceding discussion, if we get these values then conservation will be enforced globally and over each AGCM grid cell
- Get the code to put out the globally integrated values:

AGCM

$\Sigma_i F_i * (1-LF_i)*(1-SICN_i)*A_i$ (type 3)

$\Sigma_i F_i * (1-LF_i)*SICN_i*A_i$ (type 4)

Nemo

$\Sigma_j F_{Nj}*(1-SICN_j)*A_{Nj}$ (type 3)

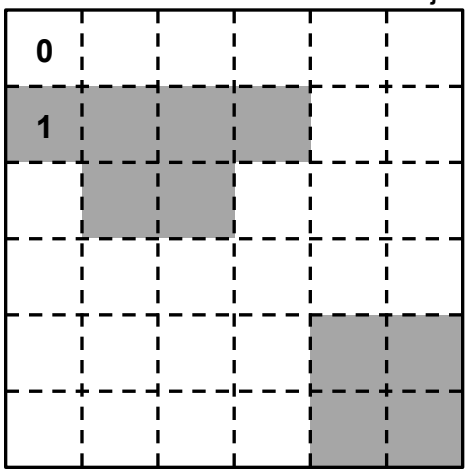
$\Sigma_j F_{Nj}*SICN_j*A_{Nj}$ (type 4)

➔ matching the global values for non-overlapping grids will be the true test to ensure that we have everything correct

non-overlapping grid tests

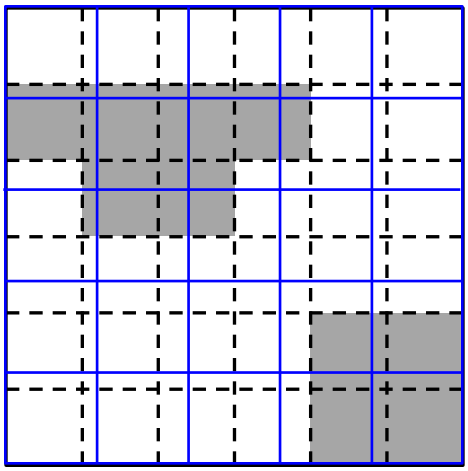
- consider the same set-up on the nemo grid but a different resolution AGCM:

Nemo binary land mask (LM_j)



AGCM land fraction (LF_i)

1/6	1/6	1/6	1/18	0
13/18	1	5/6	2/9	0
1/12	1/2	1/4	0	0
0	0	0	4/9	2/3
0	0	0	2/3	1



- aside test: derive land fractions on AGCM 5x5 grid to obtain the above.

- global conservation:
  - take total area to be 1.
  - each Nemo grid box has A_{Nj}=1/36
  - each AGCM grid box has A_i=1/25
- global land fraction:

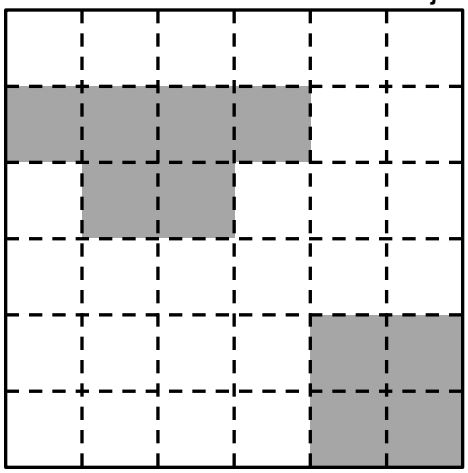
$$\Sigma_j \, LM_j A_{Nj} = 10/36 = \Sigma_i \, LF_i A_i = 10/36$$

Nemo AGCM

non-overlapping grid tests

- consider the same set-up on the nemo grid but a different resolution AGCM:

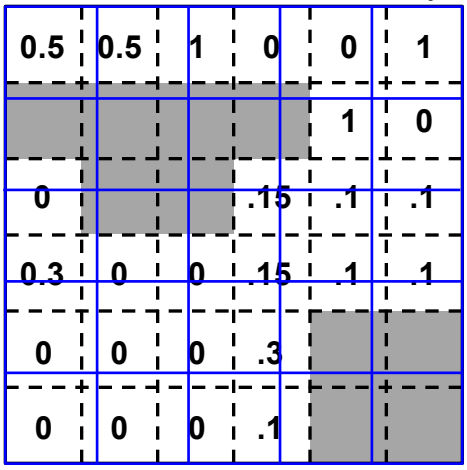
Nemo binary land mask (LM_j)



AGCM land fraction (LF_i)

1/6	1/6	1/6	1/18	0
13/18	1	5/6	2/9	0
1/12	1/2	1/4	0	0
0	0	0	4/9	2/3
0	0	0	2/3	1

Nemo sea-ice fraction ($SICN_j$)



AGCM sea-ice fraction ($SICN_i$)

1/2	2/3	1/2	2/17	13/18
0	N/A	0.15	87/140	13/90
3/22	0	1/10	7/60	1/10
1/12	0	1/8	19/100	1/10
0	0	1/15	2/15	N/A

- global sea-ice fraction fraction:

$$\Sigma_j\,(1\text{-}LM_j)(SICN_j)\,A_{Nj} = 0.15 = \Sigma_i\,(1\text{-}LF_i)(SICN_i)A_i = 0.15$$

Nemo AGCM

- the derivation of LF_i from LM_j and that of $SICN_i$ from $SICN_j$ requires a remapping from the Nemo fine grid to the AGCM coarse grid. This can be save as an exercise once we have the AGCM to NEMO remapping sorted. For now, just take the above as given

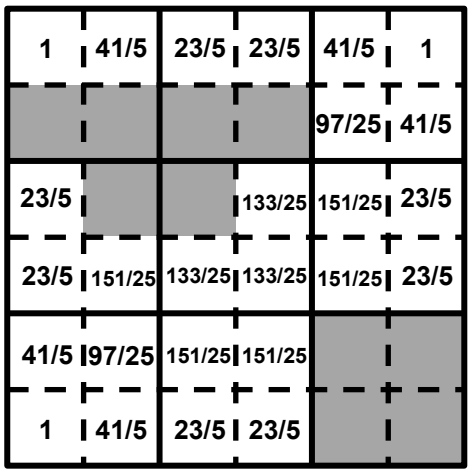
Regridding Tests

TEST#2 For each type, 3 and 4, perform conservative remapping to put AGCM flux on Nemo grid

AGCM (F_i)

1	10	1	10	1
10	1	10	1	10
1	10	1	10	1
10	1	10	1	10
1	10	1	10	1

Nemo (F_{Nj})



- check conservation by comparing the global integrals:

AGCM

$$\Sigma_i F_i * (1-LF_i)*(1-SICN_i)*A_i \quad \text{(type 3)}$$

$$\Sigma_i F_i * (1-LF_i)*SICN_i*A_i \quad \text{(type 4)}$$

Nemo

$$\Sigma_j F_{Nj}*(1-SICN_j)*A_{Nj} \quad \text{(type 3)}$$

$$\Sigma_j F_{Nj}*SICN_j*A_{Nj} \quad \text{(type 4)}$$

- check conservation by comparing the global integrals. For the above example we have:

$$\Sigma_i F_i * (1-LF_i)*(1-SICN_i)*A_i = \Sigma_j F_{Nj}*(1-SICN_j)*A_{Nj} = 3.14622164 \quad \text{(type 3)}$$

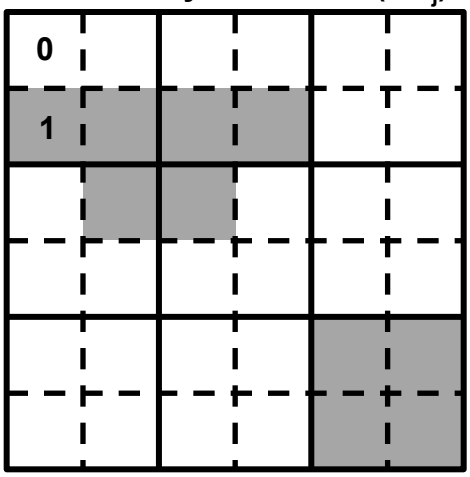
$$\Sigma_i F_i * (1-LF_i)*SICN_i*A_i = \Sigma_j F_{Nj}*SICN_j*A_{Nj} = 0.596000016 \quad \text{(type 4)}$$

NEMO to AGCM Regridding Tests

- once we have sorted the AGCM to Nemo setting for the remapping, do Nemo to AGCM mapping tests

TEST#3 For binary land mask (1/0) on the Nemo grid, derive the fractional land mask on the two AGCM grids by a conservative remapping:

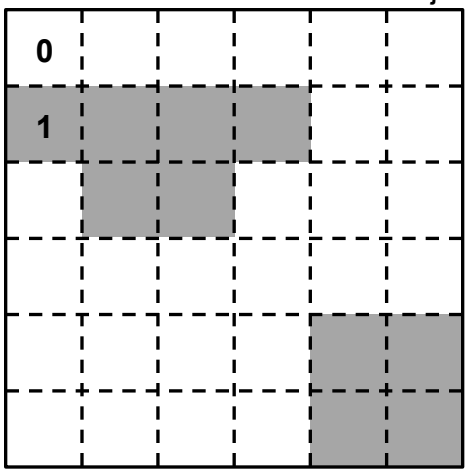
Nemo binary land mask (LM_j)



AGCM land fraction (LF_i)

0.5	0.5	0
0.25	0.25	0
0	0	1

Nemo binary land mask (LM_j)



AGCM land fraction (LF_i)

1/6	1/6	1/6	1/18	0
13/18	1	5/6	2/9	0
1/12	1/2	1/4	0	0
0	0	0	4/9	2/3
0	0	0	2/3	1

NEMO to AGCM Regridding Tests

- once we have sorted the AGCM to Nemo setting for the remapping, do Nemo to AGCM mapping tests

TEST#4 For SICN on the Nemo grid, derive the corresponding SICN on the two AGCM grids by a conservative remapping:

Nemo sea-ice fraction ($SICN_j$)

0.5	0.5	1	0	0	1
				1	0
0			.15	.1	.1
0.3	0	0	.15	.1	.1
0	0	0	.3		
0	0	0	.1		

AGCM sea-ice fraction ($SICN_i$)

0.5	0.5	0.5
0.1	0.1	0.1
0	0.1	N/A

Nemo sea-ice fraction ($SICN_j$)

0.5	0.5	1	0	0	1
				1	0
0			.15	.1	.1
0.3	0	0	.15	.1	.1
0	0	0	.3		
0	0	0	.1		

AGCM sea-ice fraction ($SICN_i$)

1/2	2/3	1/2	2/17	13/18
0	N/A	0.15	$\frac{87}{140}$	13/90
3/22	0	1/10	7/60	1/10
1/12	0	1/8	$\frac{19}{100}$	1/10
0	0	1/15	2/15	N/A